Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 1

Preparations for the Field Season and Equipment Needed

Version 1.09 (March 2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	11/2011	D. Witwicki	Clarified terminology for headpins / transect ends; removed species richness	Unclear in previous version; no longer sampled	1.01
1.01	04/2012	K. Lund	Added a few items to equipment list	Needed in the field	1.02
1.02	06/2012	R. Weissinger	Updated equipment list	Needed in the field	1.03
1.03	12/2012	R. Weissinger, K. Lund, & D. Witwicki	Updated equipment list	Response to peer review; remove greenline sampling, reorganize, & remove duplicates	1.04
1.04	2/2014	K. Lund	Updated equipment list	New survey equipment & other corrections	1.05
1.05	6/2014	K. Lund	Updated equipment list	Added camera battery charger	1.06
1.06	4/2015	K. Lund	Updated equipment list	Added equipment for reach overview photos	1.07
1.07	8/2016	D. Witwicki, R. Weissinger	Updated equipment list, removed equipment check out and outdated link to sat phone operating times		1.08
1.08	3/2018	D. Witwicki	Updated equipment list		1.09

This SOP describes how to prepare for the field season, including a list of field equipment and tasks that are performed before each field trip.

1. Before the Field Season

The following tasks should be completed by the project manager or field crew leader well before the arrival of seasonal field crew members.

1. Post positions for seasonal employees or student interns 3-4 months prior to scheduled field work. Riparian monitoring requires four field crew members for vegetation sampling and

three field crew members for surveying and well installation. Hiring must be completed at least six weeks prior to the beginning of the field season to allow time for federal background check procedures.

2. Review the entire protocol. Understand the goals and procedures of the monitoring program before beginning other preparations. Discuss any proposed or recent changes to the sampling design or protocol with appropriate I&M personnel. If a change has been implemented since the last field season, make sure that all field forms, databases, and relevant SOPs have been updated.
3. Compile a list of reaches that will be monitored. Discuss the season's objectives with appropriate I&M personnel to develop a field schedule.
4. Schedule field work. Use the guidelines below to develop a field schedule that meets the objectives for the field season and maintains some flexibility for unforeseen events.

   Seasonality of sampling
   Vegetation is sampled during the growing season, typically between June and September. Sampling visits should be scheduled to optimize phenology for the group of NCPN park units included in riparian monitoring. Park units should be visited at approximately the same time each year to maximize repeatability.

   Stream channels are surveyed when riparian vegetation is leafless, generally late fall or early spring. The relative timing of surveying and vegetation sampling should be scheduled to minimize the possibility of flooding between sampling events. Well installation can occur at any time the ground is not frozen, but will likely occur in spring or fall to avoid weather extremes.

   Field crew schedule
   Crew members typically work 8 consecutive 10-hour days, followed by 6 days off, especially when working at distant park units or in the backcountry. Field work that does not require travel and camping has more flexibility. Office work at the beginning and end of the field season is scheduled for 8 hour days Monday through Friday, and additional office days throughout the field season may be scheduled for trainings, field preparation, or data management.
5. Request research permits. Begin the process at least 10 weeks before the start of the field season to allow ample time for processing.
6. Coordinate with the appropriate park staff to make sure that the proper compliance is followed before installing monitoring wells and rebar. It could take several months from the time paper work is submitted until our proposed installations are cleared.
7. Plan travel logistics. Notify appropriate park personnel of the dates the riparian field crew will be in their park unit. Discuss housing availability and needs with appropriate parks, and acquire backcountry camping permits.
8. Review NCPN safety procedures and complete a risk assessment. Review the NCPN Field Safety SOP and make any necessary improvements. Complete a risk assessment (e.g., Green-Amber-Red assessment from the NPS Operational Leadership program) to identify and mitigate risks to field crew members before the field season.
9. Organize and check all equipment. Equipment is usually tested and inventoried at the end of the field season. Review this list to make sure that you have adequate supplies and that all

replacement equipment is ordered and will be available before the field season begins. Tables 1-4 list equipment needed for each SOP.

10. Review plant species lists for each park unit, and update them with new species detected in the previous field season. Print additional copies, if necessary, so that each 2-person team has a copy for the field. Review the species most likely to be encountered in each park and assemble relevant flora, keys, and field herbaria.

2. A few weeks before each field visit

The following tasks should be completed by the field crew leader in the weeks before a scheduled field visit.

1. Review existing maps for each park, and request additional maps from the GIS technician if necessary. Make sure that the locations of existing benchmarks are added to maps for surveying trips.
2. Pack and review relevant information for each reach.

All visits

Access document – contains useful information for navigating to remotes areas of park units.

Trip reports - from the previous field season. At the end of each field trip, the crew leader writes a brief report describing general field conditions, access issues, logistical challenges, safety concerns, equipment problems, and suggestions for improving efficiency.

Reference photos – photos used to help relocate each headpin, photo point, or control point for surveying.

Vegetation sampling

Revisit data sheets – provides directions to the reach, coordinates of headpins, and any other specific information from the previous visit.

Reach species list - list of species detected during previous monitoring visits.

Reach census revisit list – list of trees measured and tagged during previous monitoring visits.

Reach overview photo points – reach overview photos from previous monitoring visits and location, height, bearing, tilt angle, and recommended time from original visit.

Surveying

Field notes – a copy of notes from the previous survey.

Revisit data sheets – provides directions to the reach, coordinates of headpins, and any other specific information from the previous visit.

Hydrologic sampling

Well measurements – review distance between top and bottom of each well (TOC-BW) from Well Installation data sheet, and record these values on the Well Revisit data sheet for comparison with field measurements.

3. Print and copy the field data sheets. Print all pebble count data sheets and at least 1/4 of each of the other data sheets on Rite-in-the-Rain© paper to ensure data collection can continue in

wet conditions. Copies of each form are found at the end of the appropriate SOP. Data sheets for field measures are listed below with the minimum number needed to sample a reach.

Vegetation sampling
Reach establishment or re-visit – 1
Photos – 2
Point-intercept – 14
Canopy closure and exotic frequency - 7
5-m belt – 7
Reach census – 4
Unknown Plants – 10
Pebble count – 2
Site assessment – 1

Hydrologic sampling
Well installation or re-visit – 1

4. Coordinate with the GIS technician to reserve GPS units and load UTM coordinates for the reaches to be sampled.
5. Load data from the previous total station survey on the datalogger.
6. Contact parks and provide detailed trip information. Contact the resource staff and chief ranger and provide dates the crew will be working in the park, names of field crew members, vehicle descriptions, and approximate locations of monitoring activity. Make sure that these park personnel are familiar with the safety procedures used by NCPN crews (see the NCPN Field Safety SOP for details) and that the NCPN crew is aware of any special safety procedures required by each park.
7. Check stream flows and weather forecasts. Stream flows can be referenced at waterdata.usgs.gov. Applicable gages include:

   09404900 East Fork Virgin River near Springdale, UT for ZION
   09330000 Fremont River near Bicknell, UT, for CARE

   Storm activity should be carefully monitored for its potential impact on crew safety and sampling. Due to high flash flood potential, fieldwork should never be scheduled at NABR during an active storm period. Do not sample during flood events.

3. Immediately before each field visit

The following tasks should be completed by the field crew leader immediately before each field visit.

1. File a travel plan. The day the crew leaves for a multi-day field trip, the crew leader should fax or email a travel plan to Glen Canyon dispatch. Crew leaders should review the NCPN Field Safety SOP for specific procedures.
2. Perform a vehicle safety inspection and replace any necessary fluids.
3. Make sure that the **batteries are fully charged for all rechargeable equipment,** including cameras, GPS units, satellite phones, vehicle jump starters, lasers, total station, data logger, PDA, field laptop, and/or cordless drill.

Table 1. Equipment needed for all wadeable stream sampling.

Item	Number needed	Description	Notes
General Equipment - *Necessary for all SOPs*			
GPS with extra batteries	2	Trimble GeoXM or more accurate	main unit and backup
GPS car charger	1		
Digital camera	2		transect headpins and mid-channel, survey control points, wells
Extra battery for digital camera	2		
Camera charger	1		for charging camera batteries
Waterproof cases for cameras	2		for perennial streams (ZION & CARE)
Carabiners	2		to attach waterproof case while crossing the stream
Inverter	1	plugs into vehicle	charge electronic equipment
Permit	2 per vehicle		one on dashboard, one with crew
Maps	1 per 2 people		
Data sheets	variable		at least 25% on rite-in-the-rain paper
SOPs	1 per 2 people		
Access documents	1		Specific to park
Previous trip reports	1		
Clipboard	1 per 2 people	lightweight with interior storage	
Field notebook	variable	small, Rite-in-the-Rain©	field notes
Pencils	5 - 10		
Waders	1 per person	3 mm neoprene	optional during hot weather
Wader repair kit	1	Includes Aquaseal and patches	Fix holes in waders
Magnetic Locator	1	Metal detector in hard case	
Safety Equipment - *Necessary for all SOPs*			
First aid kit	1 per 2 people		content list in NCPN Field Safety SOP
Satellite phone	1 per 2 people		
Satellite phone charger	1 per phone		
NCPN Field Safety SOP	1 per 2 people		
NCPN Accident Log Forms	1 per 2 people		found in NCPN Field Safety SOP
NCPN Medical Information Forms	1 per person		found in NCPN Field Safety SOP
Pump sprayer	1	2- gallon herbicide pump sprayer	decontaminate equipment and personal items

Item	Number needed	Description	Notes
Protective eyewear	1		use while mixing Quat solution
Quaternary ammonium	Pre-diluted	Quat128	decontaminate equipment and personal items
Quat-Chek test paper	1		test dilution of decontamination solution
Scouring brush	1		decontaminate equipment and personal items
Rubber gloves	10		protect hands during decontamination
Group Camping Equipment – *Necessary for all field work that requires car camping*			
Stove	1-2		Include spare, if available
Propane	1-2		Ideally full containers
Kitchen box	1	Includes pots, pans, plates, bowls, silverware	
Tarp / rain shelter	1		If available. For tarp, bring ropes necessary to put it up.
Roll-a-table	1		If available when the crew is not camping in a campground
Water jugs	min. 1 gal/person/day		
Tent repair	1	Tent tape and zipper wax	
Duct tape	1		
Backpacking Equipment – *Necessary for backpacking at ZION*			
Water filters (hand pump)	2	MSR Sweetwater	
Bucket	1		For settling water
Alum	1	Spice used to help settle particles out of water	
Water bladders	2		For water storage
Backpacking stoves	2		One that attaches to canister fuel bottle; one that attaches refillable fuel bottle
Fuel	various	White gas for refillable fuel bottle or canister fuel bottles	Bring extra
Lighters	2		For stoves
Cook set	2		Includes pots of various sizes
Trowel/shovel	1		
Wag bags	1/person/day		Use if camping in main basecamp
Spare tent	1		If available. Works out well to store extra equipment and use as back-up.

Item	Number needed	Description	Notes
Transect Set-up - SOP #4, *Necessary for all visits (except hydrologic monitoring revisits) unless noted with an E = establishment or R = re-visit.*			
Permanent rebar	E -min. 18	3/8" diameter cut into 18" lengths	permanent headpins and temporary markers to secure taglines
Rebar caps	E - 15	1 1/2" pre-stamped with NCPN	label rebar and cover top for safety, includes spare
Aluminum tags	min. 16	Oval	label rebar; use as backups for rebar caps
Wire		18-20 gauge	attach tags to rebar
Wire cutters	1	small	
Stamp kit	E - 1	Letters and numbers set	label rebar caps
Leather piece	E - 1	piece of old belt or glove	protects rebar cap when pounding
100-m Kevlar taglines	7	Kevlar string with meter markings	set up transects through dense vegetation
Temporary rebar	min. 4	3/8" diameter cut into 18" lengths	secure taglines
Sledgehammer	2		drive in rebar
100-m transect tapes	5	fiberglass reel tapes	cross-section transects, includes spare; use tapes with meters on both sides
Chaining pins	min. 10	striped metal pins	secure tapes
Reference headpin photos	R - 2	reference photos taken during establishment	
Reach revisit data sheet	R - 2	Directions, headpin coordinates, specific info, etc.	
Compass	3	with declination setting	set declination, take transect bearings, includes spare
Pin flags	min. 21	narrow steel pins with flag top	mark locations
Flagging	2 rolls	brightly colored	mark locations
Orange vests	4		increase visibility of crew members in dense vegetation
2-way radios	5		crew communication, includes spare & lanyards on each radio
Extra radio batteries	min. 15	AA alkaline, 3 per radio	1.5 sets per radio per day
Prisms with padded cases	2		attaches to prism poles
Prism poles with attached levels	2		use to help line up transects in reaches with dense vegetation

Table 2. Equipment needed for riparian vegetation sampling by a four-person crew. Some equipment is used for more than one activity but is listed under the most appropriate activity in this table.

Item	Number needed	Description	Notes
Reach Establishment and Re-visits - SOP #4, ***Equipment needed for transect setup is listed in Table 1.***			
Point-Intercept Sampling - SOP #6, *Necessary for all visits.*			
Point-intercept lasers	3		includes spare
Laser monopods	2		mount lasers
Extra laser batteries	min. 6	1.5V silver oxide watch batteries	lasers take 3 per unit
Densitometer	2	periscope canopy instrument	point-intercept of tall shrub canopy
Screwdriver	1	small Phillips head	change laser batteries
Reach species list	R- 2	species previously recorded at reach	
Exotics and canopy closure - SOP #6, *Necessary for all visits.*			
Folding ruler	4		delineate exotic frequency quadrats
Spherical densiometer	2	modified concave	canopy closure
5-m Belt Transects - SOP #6, *Necessary for all visits.*			
2.5-m poles	2	made of 1.25-m PVC lengths with coupler	delineate 5-m belt boundaries
15-cm DBH calipers	2	diameter calipers in cm	measure sapling
DBH tape	2	diameter tape in cm	measure trees; also used for reach tree census
Reach Tree Census - SOP #6, *Necessary for all visits.*			
Tree tags	E - min. 200, R - min. 50	pre-stamped 1-1000 round aluminum	use different numbers for adding trees during re-visits
Nails	E - min. 200, R - min. 50	6d 2" galvanized steel	
Clawhammer	2		
Tool pouch	2		holds equipment
Reach census revisit list	R - 2		list of previously tagged trees
Plant Identification and Unknown Plants - SOP #6, *Necessary for all visits.*			
Hand lenses	2		
2-gallon resealable plastic bags	min. 6	2- gallon or larger	collect plants
Masking tape	2		label plant collections
Permanent marker	2		label plant collections
Trowel	2	small garden tool	extract specimen roots
Plant press	1	field press with card, blotter, and paper	store plant collections for identification

Item	Number needed	Description	Notes
Relevant floras and park species lists		varies by park	Utah Flora, Intermountain Flora, Field Guide to Intermountain Sedges, Field Guide to Intermountain Rushes, Grasses & Grasslike Plants of Utah
Photos - SOP #5, *Necessary for all visits.*			
Chalkboard	2	5 x 7"	label photos
Chalk	2		
Clinometer	1		used for tilt angle of reach overview photos
Reach overview photo revisit sheet	1	Location, height, bearing, tilt angle, and recommended time from establishment	needed to accurately repeat reach overview photos
Previous reach overview photos	1		used to align repeat reach overview photos
Rebar	3	3/8" diameter cut into 18" lengths	mark location of overview photo point in soil; not needed for re-visits
Chisel	1		mark location of overview photo point in bedrock (only with permission from park)
Pebble Count - SOP #7, *Necessary for all visits.*			
Metric rulers	2	stiff, with engraved or raised markings	measure pebbles
Chaining pins	10	striped metal pins	secure transect tapes
10-m transect tapes	2	fiberglass reel tapes	pebble count transects
Site Assessment - SOP #8, *Necessary for all visits.*			
Stopwatch	2		time exotic plant search

Table 3. Equipment needed for stream channel surveys by a three-person crew.

Item	Number needed	Description	Notes
Stream Channel Surveying - SOP #9, *Necessary for all visits unless noted with an I = initial survey or R = re-visit.* ****Equipment needed for transect setup is listed in Table 1.***			
Total station with 6 batteries	1		make sure batteries are fully charged before leaving; includes tribrach
Charger for total station	1		Including power cord; use when electricity is available

Item	Number needed	Description	Notes
Hand-held weather unit	1		Highgear brand, WeatherPort model. Used for calibrating temperature & pressure in total station. Stored in total station case.
Datalogger with Survey Pro software	1		make sure batteries are fully charged before leaving
Charger for datalogger	1		use when electricity is available
Datalogger holder	1	Folding metal holder	attaches to tripod leg
Battery/Generator	1	12-volt battery with inverter or Goal Zero Yeti Generator	charging equipment in the backcountry
Solar panel	1		charging equipment in the backcountry
Tripod	2	1 wooden and 1 metal with screw-mount adjustable legs	to mount total station, includes spare & carrying cases
Prism poles	3	identical	includes attached levels and both flat foot and a point on the end
Prism poles extenders	3	orange & white stripe sections	good for visibility in thick vegetation
Leveling rod	3	identical, telescoping to 5 m	with adapters to mount prisms
Levels for leveling rods	3		need to attach to rods before surveying
Bipods	2		used to turn a prism pole into a free-standing tripod
Prisms	4	identical	for rods and backsight, includes spare & padded cases for each prism
10-m engineer's tape or rolling metric tape (>5 m)	4		measure instrument and rod heights; one for each person, includes spare
Tool pouch	1		holds equipment for survey lead
Survey notebook	1		
Ear piece with microphone	1	compatible with radios	for person running total station
Survey umbrella	1		
Umbrella stand	1	separate tripod to support the umbrella	
Rebar	I - min. 12, R - 4	3/8" diameter cut in 0.5 m lengths	permanent survey markers
Survey rebar caps	I - 12	1 1/2" pre-stamped with NCPN and dot in center	label rebar and cover top for safety
Permanent bedrock marker for horizontal bedrock	I – 1 per control point	5" piece of ½"-diameter threaded rod	Cut with hacksaw or other saw borrowed from maintenance

Item	Number needed	Description	Notes
Permanent bedrock marker for vertical wall	I – 1 per control point	7" piece of ½"-diameter threaded rod	have maintenance grind down the threads on one side, so the pointed foot of the prism pole can be placed there without threads in the way
Hammer drill with extra batteries	I – 1		drill rock for permanent bedrock markers
Concrete drill bit	I – min. 1	½"-diameter	used with hammer drill
Small, flexible hose	I – 1	small diameter tube or straw that fits in ½" drill hole	blow sediment out of drilled hole
Small broom	I – 1		brush away sediment from drilled hole
Small baggie of concrete mix	I – 1	Quikrete brand	fasten metal rod to bedrock for permanent marker; pass mix through 2 mm sieve first to get larger rocks out
Small paper cup, plastic spoon, and water	I – min. 1 set per bedrock marker		mix concrete
Straw with spoon end	I – min. 1 per bedrock marker	slushie straw	put concrete slurry into and around threaded rod
Screwdriver, pliers, and allen wrench set	1 each		attach prisms, tighten rods, troubleshoot equipment
Flagging	4 rolls	brightly colored	mark locations
GPS	2	survey grade with horizontal accuracy < 0.1 m	includes spare
Field notes from previous survey			Includes files to be uploaded to datalogger and reference photos for survey control
Reference geomorphology photos	R -2	reference photos taken during survey control establishment	
Total station & Survey Pro manuals	1 each		
Pipe wrenches	2		use to tighten fittings, open and close wells; only needed for reaches with wells
Cheater bars	R - 2		assist with opening rusted well caps; only needed for reaches with wells
Personal floatation device	2-3		safety gear for surveying the thalweg or deeper channel cross-sections
Dry Suit	1-2		optional safety gear for surveying the thalweg or deeper channel cross-sections in colder weather

Table 4. Equipment needed for well installation and hydrologic monitoring.

Item	Number needed	Description	Notes
Below Ground Hydrologic Installation - SOP #10 ***Equipment needed for transect setup during well installation is listed in Table 1.**			
Well points	3	1.25” I.D. x 3’ length, 60 Gauze (Campbell)	
Galvanized pipe	min. 36 ft.	1.25” x 4’ lengths, threaded on both ends	for riparian wells
Screened riser	1	1.25” I.D. x 2.5’ length 60 Gauze well point (Campbell) without point, threaded	for instream well
Fence post driver	1	large diameter, heavy-weight	drive in wells
Drive caps	4	1.25” I.D.	
Drive couplings	12	1.25” I.D.	
Sacrifice pipe	3	1.25” x 8” length, threaded on both ends	
Teflon tape	3 rolls		protect threads while installing pipe
Ear protection	3	ear-muff style	safety
Padded gloves	3 sets		safety
Bubble level	1		level pipe during installation
Shovel	1		prepare hole for well
Rope	1	min. 15 ft.	guide casing during installation
Bentonite pellets	6 shovels worth		seal space around riparian well
Bucket	1	5-gallon	add water to purge well
Peristaltic pump	1	Geotech Geopump 2	purge well
Flexible tubing	min. 25 ft.	Masterflex	used with peristaltic pump
Metal file	1		file a notch in top of well for water level measurements
Cordless power drill	1		vent well
Drill bit	2	1/8” split point	vent well
Drill bit	1	¼”	drill cap for eyebolt
Threaded cap	1 per well	1.25”	
Eyebolt	1 per well	¼”	
¼” nut	1 per casing		keep eyebolt in place
¼” washers	2 per casing		keep eyebolt in place
¼” stopper nut	1 per casing		keep eyebolt in place
Above Ground Hydrologic Installation on Bedrock – SOP #10			
1 ¼” schedule 40 PVC slotted well casing	1 per installation	cut into 8” or longer lengths	casing for pressure transducer

1 ¼” threaded PVC sleeve	1	must fit snugly over well casing	glue to casing
1 ¼” threaded PVC cap	1		
hacksaw			cut well casing
PVC primer			prep PV surface
PVC glue			glue sleeve to casing
Disposable gloves			protect hands while gluing
Drill with ¼” drill bit			drill cap for eyebolt
Spray paint		to match native rock	reduce visibility of installation
Cardboard			cover ground while spray painting
Hammer drill	1	fully charged	bring extra batteries
Drill bit	5	¼” concrete	drill into rock for mounting
Level	1		level casing prior to drilling holes
Permanent marker	1	dark-colored	mark locations of holes for drilling
Expansion bolt	4 per installation	2 ¼” with washer and nut	bring spares
U-shaped metal bracket	2 per installation	to fit around 1 ¼” casing	hold casing to rock
Extra washers		to fit expansion bolts	make sure casing is snug against rock
Hammer	1		deploy expansion bolts
Above Ground Hydrologic Installation in Channel – SOP #10			
Galvanized pipe or well casing	1 per installation	1 ½” diameter	cut to 8” length and threaded on both ends at hardware store
Teflon tape	1 roll		prep threads for couplers
Threaded coupler	2 per installation	1 ½” diameter	attach to casing
Drill	1		drill holes in casing unless well casing is used
Drill bit	1	1/8”	drill holes in casing unless well casing is used
Drill bit	1	¼”	drill hole in cap for eyebolt
Metal file	1		mark measuring point on top coupler
Threaded cap	1 per installation	1 ½”	
Angle iron	2 per installation	1 ½” x 1 ½”	drive into channel, at least 3 feet in length
Sledge hammer	1		drive in angle iron
Level	1		level angle iron
Hacksaw	1		trim mangled angle iron
Ziptie	2	Large, heavy duty	attach casing to angle iron

Hose clamp	2	1 ½” heavy duty	attach casing to angle iron
All Hydrologic Installations			
Pressure transducer	1 per installation	non-vented (Solinst)	records water stage
Barometric pressure logger	1 per reach	Solinst Barologger	records atmospheric pressure
Kevlar rope	min. 45 ft.	1/8” braided (U.S. Rope & Cable)	install pressure transducers
Knife or scissors	1		cut Kevlar rope
Eye bolt	1 per casing	1/4” x 2” threaded	install pressure transducers
Nut	1 per casing	¼”	keep eyebolt in place
Washers	2 per casing	¼”	keep eyebolt in place
Stopper nut	1 per casing	¼”	keep eyebolt in place
Carabiner	1 per casing	2”	attach Kevlar rope to eyebolt
Ring Terminals	2 per casing		connect Kevlar rope to eyebolt carabiner and pressure transducer
Crimping tool or pliers	1		clamp ring terminals to Kevlar rope
Hydrological monitoring *(all visits)* - SOP #10 *Necessary for all visits unless noted with an R = re-visit.*			
Pipe wrenches	2		tighten fittings, open and close wells
Cheater bars	R - 2		assist with opening rusted well caps
Plumber’s grease	R - 1		grease well threads
Water level meter	1	Solinst	measure depth to water in wells
Flow measuring equipment	1	Current meter, 10-m transect tape, 2 chaining pins	measure stream flow > 1 cfs
		Flume, level, trowel	measure stream flow 0.25 – 1 cfs
		Weir, level, trowel	measure stream flow <0.25 cfs
Inertial lift pump	1	semi-rigid tubing (HDPE) with footvalve (Waterra)	remove fine sediments
Folding ruler	1		measure to ground surface
PDA and interface cable	R - 1	Solinst Leveloader and cable specific to the PDA	download pressure transducer and barometric logger data
Field laptop and cable	1	with Solinst software and optical interface USB cable is specific to pressure transducer /barometric logger	download pressure transducer and barometric logger data; reprogram instruments
Laptop access card	1	DOI Access Card	log in to laptop

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 2

Hiring and Training Field Technicians

Version 1.03 (March 2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	12/2012	R. Weissinger, D. Witwicki, K. Lund	Added detail to safety section, added data management to training, clarified wording	Response to protocol review, clarification needed	1.01
1.01	8/2016	D. Witwicki	Changed SPOT to personal locator beacon	Looking to purchase text-compatible device	1.02
1.02	3/2018	D. Witwicki	Changed title and references to “observers”	Edits for publication	1.03

This SOP explains the qualifications needed for permanent and seasonal field personnel and procedures for training vegetation sampling technicians. Accurate, consistent data collection begins with the hiring process, followed by a rigorous training program. Technicians must also be prepared, both mentally and physically, for the extreme weather and difficult terrain of NCPN parks.

Hiring Field Technicians

Staffing requirements

Riparian monitoring of wadeable streams requires hydrologic, geomorphic, and vegetation expertise. A permanent or term subject-to-furlough hydrologic technician (minimum GS-6) works independently to install and maintain all hydrologic equipment and coordinate collection of hydrologic data. A permanent or term subject-to-furlough biological or physical science technician (minimum GS-6) leads a crew responsible for vegetation and geomorphology sampling. The riparian vegetation crew comprises three seasonal crew members (NPS, volunteer, intern, or cooperator) in addition to the crew leader. Two of these seasonal technicians also assist with geomorphology sampling.

Qualifications and attributes

In addition to the technical skills, experience, and knowledge listed below, certain qualities are necessary for all NCPN field personnel. To maintain data quality, all staff should have the ability to successfully engage in repetitive, detail-oriented work. Technicians must be in excellent physical condition and able to thrive in difficult field conditions. Certification in Wilderness First

Responder (or Wilderness First Aid) and CPR is also an asset. Employees should expect to travel to remote parks and work away from home for periods of up to 8 consecutive days and, in many instances, to camp in backcountry situations.

Technical Skills, Experience, and Knowledge

The Riparian Crew Leader can be either a Biological or Physical Science Technician. Since it is unlikely that NCPN will be able to recruit a candidate with the technical expertise needed for both vegetation and geomorphology sampling, NCPN is committed to train the selected candidate in the skill that they are lacking. In addition, all permanent technicians are trained as Wilderness First Responders if they do not already have this or a more rigorous wilderness medical certification. The technical skills, experience, and knowledge required for all wadeable stream field positions are detailed below.

Lead Biological Science Technician (Crew Leader)

- Ability to identify common riparian genera and species.
- Ability to key plants to species using floras and technical keys.
- Experience leading a field crew to collect biological data in remote field settings.

Lead Physical Science Technician (Crew Leader)

- Experience using a total station and post processing total station data.
- Ability to identify bankfull and channel thalweg.
- Experience leading a field crew to collect physical data in remote field settings.

Hydrological Technician

- Experience installing and maintaining shallow monitoring wells.
- Ability to identify channel thalweg.
- Ability to work independently in remote field settings.

Seasonal Biological Science Technicians (or interns or volunteers)

The most essential element for the collection of quality data is well-trained, experienced field crews. Given the variability of plant community types across NCPN parks, it is necessary to hire highly skilled botanists with experience working throughout the region. The importance of hiring and training well-qualified field crew members cannot be overemphasized. In order to accurately detect trend across sampling periods, it is imperative that field technicians record vegetation and geomorphology data using the same methods and level of precision year after year. While not imperative, experience conducting quantitative vegetation sampling is a valuable skill in any employee. During the applicant review process, it will be important to give priority to those candidates with considerable experience conducting vegetation surveys and, secondly, to candidates with (1) experience conducting any type of field work that involves data collection, (2) extensive experience in the backcountry camping, hiking, and backpacking and/or (3) an academic degree related to vegetation or ecology. Particular attention should be paid to the experience of the observer, his/her ability to learn new plants, physical abilities to withstand difficult field conditions, and overall attitude. NCPN will train biological science technicians in geomorphology survey techniques.

Training Seasonal Vegetation Field Crew Members

To promote accuracy and consistency in data collection among data collectors, training should be designed to calibrate data collectors so that they have comparable skills in identifying species and are recording data in a consistent format. For data collectors who are already competent at identifying plants by sight and taxonomic keying, the need for training in plant identification may be minimal. If the program is fortunate enough to hire all experienced personnel for a season, then the proposed training program will improve their skills. No data collector is exempt from the training program.

1. Prepare for the training program. The project manager or crew leader acts as the primary instructor; however, experts in various aspects of the protocol (such as First Aid/CPR) should be scheduled to assist in training as necessary. The instructor must prepare training materials, itineraries, and field gear before the training program begins.

2. Issue field gear before training begins. See SOP #1 for a list of field equipment. Provide a copy of this protocol to all trainees, along with a list of recommended personal field and camping equipment, before training begins. Ensure that field crew members examine the list of necessary personal gear (see SOP #1) and that they have all the appropriate equipment by the time field work starts. Make sure that trainees are informed and prepared for the training and survey events. Have the field technicians read the relevant riparian SOPs prior to field training.

3. Train all crew members how to navigate, establish reaches, and sample riparian vegetation. The project manager and field crew leader provide several days of instruction covering all field-based procedures. All field SOPs should be thoroughly reviewed prior to field exercises so they can be used as references during training. Crew members practice navigation techniques, plant identification skills, and data collection methods on a test transect before sampling a real transect. Navigation training should include general techniques using traditional maps and compass, as well as handheld GPS units. All technicians should practice recording spatial data using a GPS unit. All field sampling procedures will be exercised to the full extent, including actual recording of observations on data sheets.

It is important that all crew members calibrate their measurement techniques with each other before collecting data at monitoring reaches. This will ensure that measurements are as consistent as possible among crew members. Crew members should rotate partners often during training so that they can identify discrepancies in data collection techniques and remedy any issues before actual data collection.

Crew members from previous seasons normally do not need as much training as new crew members; however, all data collectors must attend the entire training each year. For returning crew members, it is especially important to point out changes to the protocol, review any issues with data quality from the previous year, and recommend methods for improving data quality, if necessary. Experienced crew members can assist with training less-experienced field crew members.

4. Emphasize field safety procedures and issues. The NCPN approach to safety requires that the crew 1) keeps NCPN and park staff informed of its activities and 2) is prepared to handle

emergency situations. Training includes a minimum of NCPN safety procedures (outlined in detail in the NCPN's programmatic Field Safety SOP, available separately), First Aid/CPR instruction, Job Hazard Analysis (JHA), and review of safety equipment, safety issues specific to the Colorado Plateau, and vehicle safety.

Field Safety SOP
The NCPN Field Safety SOP applies to all NCPN monitoring protocols and outlines the minimum procedures that the NCPN must take to ensure safety for all employees working in the field. This SOP is updated annually and provides detailed safety communication procedures and other important safety information that is summarized below. At the beginning of the field season, each crew member reviews the SOP, and safety procedures are reviewed in detail.

First Aid/CPR
All crew members must have up-to-date certifications in first aid and CPR. The minimum requirement is a one-day CPR/First Aid course. The NCPN will provide this training for all crew members that do not have current certifications. In addition, the crew leader will be trained as a Wilderness First Responder before field work begins.

Job Hazard Analysis
Crew members participate in developing the appropriate JHAs for their position that identify potential hazards and ways to minimize risks (see Appendices A and B for example JHAs). JHAs need to be completed and signed before fieldwork begins.

Safety Equipment
When in the field, each crew carries a well-stocked first aid kit and a satellite phone and/or a personal locator beacon. During training crew members review the items in their first aid kits and are trained on how to use these items. Crew members are also trained on how to use the satellite phone and personal locator beacon. Crew members must know where all emergency equipment is located during field work.

Safety issues specific to the Colorado Plateau region
During training, important safety issues for the NCPN region are discussed, most notably, flooding, heat/cold exposure, hiking safety, and fatigue. Specific issues should be revisited in the field any time they are relevant to the area where the field crew is working. Some potential risks of riparian field work and ways to minimize these risks are outlined below:

- ***Wading and standing in flowing water****:* Sampling perennial streams requires wading across and standing in streams at base flow. Water may be cold and swift.

  Mitigation of risk*:* Only sample waters that follow the <10 rule: depth (ft) * velocity (ft/sec) < 10. When walking in water, use a walking stick or other support to improve balance. Test your footing before committing to a step. Waders and personal flotation devices are available to all crew members for any riparian monitoring field work.

- ***Long road trips:*** Travel between parks requires long road trips under varied weather and road conditions.

  Mitigation of risk: Trade off driving duties with other crew members to reduce fatigue. Stop and rest if needed. Drive defensively and with a level of caution relevant to driving conditions.

- ***Backcountry travel:*** Accessing riparian monitoring sites requires travel on secondary roads that are gravel or dirt, and some sites require hikes of up to three hours each way. Dirt roads can become impassible during wet weather, and may remain muddy for several days after precipitation. Hiking may be on or off trail through steep, rocky, sandy, or muddy conditions. Hiking often occurs in washes that have flash flood potential.

  Mitigation of risk: Be aware of potential hazards and continuously assess risks. Respond prudently.

- ***Varied weather conditions:*** The Colorado Plateau region is characterized by weather conditions that vary considerably through the seasons, day-to-day, and hour-by-hour. Snow, wind, and temperatures below 0°F occur in the winter, and summer temperatures are often well above 100°F. Lightning is common during the summer monsoon storms. Hypothermia and heat-related injury are possible, and occasional discomfort is certain. Successful field work requires preparation for this wide range of conditions.

  Mitigation of risk: Be prepared with water, food, sun-protective clothing, sunscreen, and warm layers and a hat. Be aware of potential hazards and continuously assess risks. Keep open communication with all crew members. Respond prudently.

Vehicle Safety and Care
Review proper use and care of government vehicles, vehicle inspection, tire changing, defensive driving, and safety on 4WD roads.

The NCPN is dedicated to providing training and equipment to maximize the safety of its employees in the field; however, it is ultimately the responsibility of each crew member to be prepared and make good decisions while in the field. Crew members must be prepared to ensure personal safety and survival for up to twenty-four hours in the backcountry. Crew members should use good judgment in the field to determine whether working conditions are acceptable. If a crew member feels that a situation is unsafe, s/he should take action to remove herself or himself from the situation. Safety should always be the first priority of every NCPN crew member.

5. Examine dominant plant species and introduce methods of collecting and documenting unknown plants. Training consists of field-based identification of plants likely to be observed during the field season, with emphasis on difficult-to-identify species. Additionally, field crews are instructed on the use of available taxonomic keys and reference materials. The field crew leader provides tips for making quality plant collections, documenting unknown species, and vouchering new species. Since the northern Colorado Plateau is ecologically diverse, the field crew leader also provides plant species training throughout the field season at each new park unit, including guided plant walks and a review of field herbaria.

6. Review data management. The data manager gives an overview of NCPN data management, emphasizing procedures relevant to the riparian protocol and collecting high-quality field data. Crew members are introduced to the riparian database and the Riparian Database User's Guide. Methods for recording data in the field, annotating paper data sheets, and entering and verifying data in the database are reviewed in detail. Attention to detail and quality checking are emphasized during all aspects of data collection and management. Recurring issues from the

previous field season are also discussed, and extra emphasis is placed on the correct procedures for completing these tasks.

7. Conduct additional training at reaches that are easily accessible. Training continues throughout the 1st field trip to actual reaches. Sampling should occur in a park that is easily accessible to account for slower data collection while new crew members are learning. Field partners should also be rotated frequently to continue calibration of field measurement techniques.

Suggested topics for training:

Program overview – introduction to NCPN goals and projects

Administrative responsibilities and policies – timesheets, travel, work hours, leave policies, and equipment care

Safety – NCPN Field Safety SOP, Job Hazard Analysis, first aid kits, satellite phone use, specific safety concerns

Government vehicles – proper use and care, vehicle inspection, tire changing, defensive driving, 4-wheel-drive safety

Park etiquette – biological soil crust, visitor interactions, low impact practices

GPS – navigation, logging points, data dictionaries

Reach establishment – measuring active riparian zone width, identifying the channel thalweg, taking bearings using a compass, transect set up

Vegetation measures – Includes all methods in SOP #6. Pay particular attention to training field technicians on tagging trees and measuring DBH.

Pebble count – identifying scoured channel, measuring b-axis

Photos – taking good reference photos, appropriate camera orientations for monitoring photos, checking time and date settings

Plant identification – making plant collections, using available plant references, review of common species with particular attention to difficult groups including grasses, sedges, rushes and willows, plant walks in the field

Data management – overview of data management, collecting high-quality data, annotating paper data sheets, entering and verifying field data in the database

Geomorphology surveys – proper extension of the rod and positioning of the prism, identifying geomorphic surface breaks, identifying bankfull and channel thalweg

Appendix A. Example Job Hazard Analysis for NCPN riparian monitoring fieldwork.

JOB HAZARD ANALYSIS (CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133) **U.S. National Park Service**	**JOB ACTIVITY: Monitoring Field Work** **DATE: 2/9/09** **PREPARED BY: Rebecca Weissinger** **CERTIFIED BY:**	
PERSONAL PROTECTIVE EQUIPMENT REQUIRED: Sun and rain protection, insect repellent, boots, water, communication equipment, shovel, and jack.		**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:** Basic backcountry competence
BASIC JOB STEPS	**HAZARDS**	**SAFE JOB PROCEDURE**
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Highway driving	a) Varied road conditions and road hazards such as animals and other obstructions b) Fatigue c) Behavior of other drivers d) Phone / mobile device use	Be well rested before road trips and constantly alert to obstructions and behavior of other drivers. Sleep if over tired on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. It is against government policy to use your mobile device while driving.
2. Dirt road driving	a) Rough and rutted roads, high-clearance driving b) Muddy roads c) Narrow roads with short sight distances d) Animals and other obstructions e) Oncoming traffic	Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s). Always wear seatbelt. Both hands on steering wheel at all times. Be wary of washboards and blind corners. Maximum speed on unimproved roads is 30 mph, slower depending on conditions.
3. Inclement weather driving	a) Slippery roads and poor visibility	Drive slowly. Watch for snow, ice, ruts, washed-out roads, washboard surfaces, loose gravel, and flash floods. Be well-rested before road trips and constantly alert to obstructions and behavior of other drivers. If overtired, stop to sleep on the way home after long days. Trade driving with passenger(s).
4. Hiking	a) Steep, loose terrain b) Uneven footing c) Long distances	Wear sturdy shoes and don't rush on uneven terrain. Distribute weight low and close to back in backpack. Rest frequently and drink lots of water and hydrating liquids. Be wary of dangerous animals (domestic or wild).
5. Stream access	a) Swift currents, deep water b) Flood flows c) Cold water and ice d) Contaminated water	Approach streams cautiously. Don't enter stream if visual estimate of product of depth and velocity is >10 (depth in ft and velocity in ft/s). Be wary of slippery and loose stream beds and dangerous animals. Be prepared to self-rescue if you fall in.
6. Deal with environmental conditions	a) Temperature and sun exposure b) Adverse weather (rain, snow, lightning, and wind) c) Bushwhacking through thick vegetation.	Wear sunscreen. Have appropriate extra clothing for weather changes. Keep to low areas during lightning. Watch for flash floods. Be prepared to spend the night out. Wear eye protection when walking through thick vegetation.

7. Surveying	a) Holding conductive rod in lightning storms or near power lines can be fatal b) Carrying heavy survey equipment over rough terrain c) Directly looking at laser beam from the total station can cause eye injury	Survey when the weather is good and avoid surveying in lightning storms. Wear sturdy shoes and don't rush on uneven terrain. Distribute weight low and close to back in backpack. Avoid looking directly at the total station laser beam when running rod.

Appendix B. Example Job Hazard Analysis for NCPN riparian monitoring office activities.

JOB HAZARD ANALYSIS (CERTIFICATION OF HAZARD ASSESSMENT - 29 CFR 1910.133) **U.S. National Park Service**	**JOB ACTIVITY: Office activities** **DATE: 2/9/09** **PREPARED BY: Rebecca Weissinger** **CERTIFIED BY:**	
PERSONAL PROTECTIVE EQUIPMENT REQUIRED:		**QUALIFICATIONS, EXPERIENCE, OR TRAINING REQUIRED:**
BASIC JOB STEPS	**HAZARDS**	**SAFE JOB PROCEDURE**
Break work down to basic elements (such as remove, lift, carry, stop, start, apply, return, squeeze, weld, saw, walk, hold, grind, place, etc.). Describe **what** is done, not how it is done.	For each job step, state what accident could occur and/or what hazard is present. To determine this, ask yourself if the person could fall; overexert; be exposed to burns, fumes, rays, gas, etc.; hit against, be struck by, come in contact with, be caught in, on, or between something?	State how each element of work should be performed to prevent the accident or avoid the hazard. What should the person do or not do? Be specific. What precautions should be taken? Ask yourself what you can do to eliminate, modify, guard, identify, or protect against the potential hazard or accident, including such things as how the worker stands, holds, uses, carries, dresses, etc.
1. Enter data	a) Repetitive motions b) Sitting in one place for long periods of time	Take frequent breaks and switch tasks with other crew members when possible.
2. Move field equipment	d) Back strain from lifting heavy objects	Lift with legs, not back. Ask for assistance when needed.

Riparian Monitoring of Wadeable Streams Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 3

Using Global Positioning System (GPS) Units

Version 1.05 (August 2016)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	12/2010	A. Wight	Added instructions for recording census trees and unmonumented transect ends	Protocol change; clarification	1.01
1.01	6/9/2011	A. Wight	Added instructions for offsetting a feature and adding UTMs	Clarification	1.02
1.02	1/13/2012	K. Lund, D. Witwicki, A. Wight	Clarified terminology, updated TerraSync screen captures	Confusion between headpins and transect end points	1.03
1.03	5/16/2012	A. Wight	Added instructions for dealing with Terrasync files older than 1 week	New error message with software update	1.04
1.04	8/22/2016	A. Wight, H. Thomas	Added total station, well, and barometric pressure logger point features to data dictionary; updated screen captures and wording; updated definitions & acronyms	Lacking features; software updates; to match current data management terminology	1.05

This SOP explains the procedures and considerations that all observers should follow when navigating to and/or collecting geospatial data at wadeable stream monitoring reaches. It assumes that each observer is familiar with the operation and function of the GPS unit to be used for this project. This SOP is intended to complement, not replace, the operations manual accompanying the GPS unit.

This SOP is divided into two main sections: 1) Riparian Site Characterization and Riparian Reach Establishment, and 2) Riparian Site Revisit. Each main section contains minimum GPS receiver requirements, followed by brand-specific instructions. The intent is to maintain a high quality of GPS spatial accuracy and collection capabilities. This SOP does not require the use of a specific brand of GPS unit; however, the unit must meet the minimum standards listed below.

Definitions and Acronyms

Accepted data	Data that have undergone all QA and QC procedures as defined in the published

	protocol and associated SOPs.
Coordinate system	Any three-dimensional reference frame that locates objects in space.
Data dictionary	Information (data) that describes features that will be located in the field.
Feature	A physical object or location of an event. A feature can be a point, line, or polygon (area).
FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
GIS	Geographic Information Systems. A computerized system used to input, manage, manipulate, analyze and display geographic data in digital form.
GPS	Global Positioning System (unit/receiver/datalogger). A three part system of 1) 25+ Department of Defense satellites, 2) Control segment, 3) Users with receivers.
I&M	Inventory & Monitoring Program of the National Park Service
Master database	Project-specific database that stores the full project dataset and is used for viewing, summarizing, and analysis. Contains only accepted data.
NCPN	Northern Colorado Plateau Network
NPS	National Park Service
Quality assurance (QA) procedures	Procedures used to ensure collection of data with minimal errors.
Quality control (QC) procedures	Procedures used to flag or modify data to ensure that data meet established data quality standards.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
SOP	Standard Operating Procedure
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by MS Excel, MS Access, database, or statistical software, and managed as text, spreadsheet, or relational databases.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time).

1. Site Verification and Reach Establishment

The project manager predetermines the centroids of riparian monitoring reaches (specific XY coordinates in UTM NAD83). NCPN requires the use of a mapping grade GPS unit to record any locations in a reach.

1.1 Minimum GPS Receiver Requirements

- Capable of uploading pre-determined riparian monitoring locations
- Capable of utilizing data dictionary utilities (NCPN Riparian Data Dictionary, see section 2.3)
- Capable of utilizing park-specific background GIS data layers
- Capable of navigation
- Capable of maintaining 4 or more satellites
- Capable of maintaining horizontal errors of less than 5 meters (PDOP (or equivalent error reading) of less than 6)
- Capable of post data collection correction (differential correction)
- Capable of storing date, time, elevation, and coordinates of features collected (in addition to data dictionary items)
- Capable of exporting features collected to a GIS data format

1.2 GPS Unit Setup

The NCPN currently uses the Trimble line of mapping grade GPS units and TerraSync software to capture the spatial data for the riparian monitoring reach locations. The requirements should be transferable to other mapping grade GPS receivers (such as Leica, etc.).

Positional accuracy can be affected by several factors which mapping-grade GPS units can track and to some extent, compensate for. Table 1 lists these functions, their definitions, and the standard settings.

Table 1. Minimum GPS receiver settings standards.

Name	Definition	Standard
Almanac	GPS unit collects data containing estimated position of satellites, time corrections, and atmospheric delay parameters.	The unit will automatically collect the almanac. Acquire within 10 days prior to data collection or navigating, download to computer.
Altitude reference	Ellipsoid model	Height Above Ellipsoid (HAE)
Antenna heights	GPS unit height above the ground (average).	1.0 meter
Coordinate System	A reference system consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions.	Universal Transverse Mercator (UTM)
Datum	Geodetic model designed to fit a point on the earth's surface to the ellipsoid.	NAD 1983 (Conus)
Elevation mask	The minimum angle at which a	15 degrees

Name	Definition	Standard
	GPS receiver will track satellite vehicles.	
Logging intervals	Time interval between positions gathered.	Point: 1 second Line and Polygon: 5 seconds
Minimum number of positions for a point feature	Number of positions received then averaged to create a point feature.	10
Mode	2-Dimensional or 3-Dimensional	3-Dimensional (4 satellites)
PDOP Mask	Positional Dilution of Precision is a measurement of the geometry of the satellites.	6.0 or less
Satellite vehicles	Number of satellites, currently a constellation of 28 DOD satellites.	4
SNR Mask	Signal-to-Noise Ratio is a measure of the strength of the satellite signal relative to background noise.	4.0
Unit of Measure	Units of measure	Meters
Zone	In UTM coordinate system, the globe is divided into 60 north-south zones.	Zone 12 North (N)* *Black Canyon & Curecanti are Zone 13 N

1.3 Data Dictionary

A data dictionary should be utilized to facilitate field data collection as well as to assure necessary data items are correctly collected. The minimum elements necessary for the riparian data dictionary are shown below. Once the project manager has given the GIS technician all potential riparian points for a given park in a given year, those points are then imported with the Riparian data dictionary (using Pathfinder Office), creating a data file for Reach Establishment (*PARK*_Riparian). All point features in the Riparian Data Dictionary should have the default feature settings of:

Logging Interval	Time = 1 second
Minimum Positions	3
Accuracy	Code
Label 1	ReachID

The following data dictionary digital file (.ddf) can be obtained by contacting the NCPN Data Management staff.

<u>Reach Establishment Center Point Feature</u>

The reach establishment point should be used to locate the center point of the riparian monitoring reach. Once the location has been evaluated as an acceptable or rejected riparian monitoring reach (see SOP #4), fill in the S_Action as “Accept” or “Reject.”

EstPlotCenter Attributes	Attribute Explanation	Entry	Type

ReachID	Numeric unique ID from Project Manager	Entry **not** permitted in the field	Numeric
S_Action*	• Accept – decision to accept the site as an acceptable riparian monitoring location • Reject – decision to reject the site as an acceptable riparian monitoring location	Entry permitted in the field	Menu
Comments	Any comments regarding the reach	Entry permitted in the field	Text – Optional

*will only be included in the data dictionary during years of initial riparian set up, this will not be needed after reaches have been established.

Total Station Point Feature

The TS (Total Station) point feature should be used to GPS the various types of points that the surveyor sets up in the field. These points will later be used to rotate and translate the whole survey into a real world coordinate system.

TS_Control Attributes	Attribute Explanation	Entry	Type
ReachID	Numeric unique ID from Project Manager	Entry permitted in the field	Numeric
Type	• Control • Reference Marker • Temporary TS Site • Occupy • Backsite • Well • Transect Rebar • Traverse • Foresight • Other	Entry permitted in the field	Menu
TS_Code	Unique ID (name) of the point, ex: “CP-7”	Entry permitted in the field	Text
Comments	Any comments regarding the tree(s).	Entry permitted in the field	Text – Optional
Notes	Any notes regarding the control point	Entry permitted in the field	Text – Optional

Headpin Point Feature

A riparian monitoring reach has seven transects, and each transect is monumented with two headpins. When possible, headpins are located at transect end points. Often a headpin cannot be located precisely at the beginning or end of a transect because it falls on bedrock, in the channel, or in some other unstable situation. In such cases, the headpin is placed at a stable point along the transect in the general vicinity of the transect end (see SOP #4). Identify and GPS the location of each headpin. Record the location of the headpin along the transect to the nearest 0.1 m in the “Headpin_m” attribute in the data dictionary.

Headpin Attributes	Attribute Explanation	Entry	Type
ReachID	Numeric unique ID from Project Manager	Entry permitted in the field	Numeric
HeadpinPt	• T1_Left (Transect 1, river Left headpin) • T1_Right (Transect 1, river Right headpin) • T2_Left (Transect 2, river Left headpin) • T2_Right (Transect 2, river Right headpin) • T3_Left (Transect 3, river Left headpin) • T3_Right (Transect 3, river Right headpin) • T4_Left (Transect 4, river Left headpin) • T4_Right (Transect 4, river Right headpin) • T5_Left (Transect 5, river Left headpin) • T5_Right (Transect 5, river Right headpin) • T6_Left (Transect 6, river Left headpin) • T6_Right (Transect 6, river Right headpin) • T7_Left (Transect 7, river Left headpin) • T7_Right (Transect 7, river Right headpin)	Entry **required** in the field	Menu
Headpin_m	Distance, in meters, along the transect where the headpin is located. Normally Right = 0 and Left = transect end, but often shifted due to bedrock or unstable surfaces.	Entry permitted in the field	Numeric
Question Headpin = transect end?	• Yes • No (GPS a 'transect' pt)	Entry permitted in the field	Menu
Comments	Any comments regarding the headpin location ("under TAMCHI" or "beside boulder", for example).	Entry permitted in the field	Text – Optional

Transect Start or End Point Feature

GPS the location of each transect beginning or end point. Record a right and left end point for each transect, even if you already recorded the same point under the headpin point feature. GPSing transect start and end points is a lower priority than GPSing headpins, but should be completed whenever possible.

Transect Attributes	Attribute Explanation	Entry	Type
ReachID	Numeric unique ID from Project Manager	Entry permitted in the field	Numeric
TransPoint	• T1_Left (Transect 1, river Left) • T1_Right (Transect 1, river Right) • T2_Left (Transect 2, river Left) • T2_Right (Transect 2, river Right) • T3_Left (Transect 3, river Left) • T3_Right (Transect 3, river Right) • T4_Left (Transect 4, river Left) • T4_Right (Transect 4, river Right) • T5_Left (Transect 5, river Left) • T5_Right (Transect 5, river Right) • T6_Left (Transect 6, river Left) • T6_Right (Transect 6, river Right) • T7_Left (Transect 7, river Left) • T7_Right (Transect 7, river Right)	Entry **required** in the field	Menu

Transect Attributes	Attribute Explanation	Entry	Type
Location	Distance, meters, along the transect where the start or end occurs. Right = 0 and Left = transect end.	Entry permitted in the field	Numeric
Comments	Any comments regarding the transect location ends (for example "on slickrock").	Entry permitted in the field	Text – Optional

Tree Census Point Feature

Individual or small groups of trees may be mapped during the reach census (see SOP #6) in order to help future crews relocate trees. For each tree/tree group that is GPSed, record the tree tag number(s) and ReachID in the data dictionary.

CensusTree Attributes	Attribute Explanation	Entry	Type
TreeTagNum	Tree tag number(s)	Entry **required** in the field	Text
ReachID	Numeric unique ID from Project Manager	Entry permitted in the field	Numeric
Comments	Any comments regarding the tree(s).	Entry permitted in the field	Text – Optional

Photo Point Feature

The photo point feature marks the location where repeat photos of the reach are to be taken each year the reach is monitored.

PhotoPt Attributes	Attribute Explanation	Entry	Type
ReachID	Numeric unique ID from Project Manager	Entry permitted in the field	Numeric
PhotoNum	Photo number	Entry permitted in the field	Text
Comments	Any comments regarding the tree(s).	Entry permitted in the field	Text – Optional

Monitoring Well Point Feature

The monitoring well feature marks the location where monitoring wells are located within the reach.

MonWell Attributes	Attribute Explanation	Entry	Type
Comments	Any comments regarding well (instream, behind ATRCAN)	Entry permitted in the field	Text - Optional
NewNotes	Any further comments regarding well/location	Entry permitted in the field	Text – Optional

BaroLogger Point Feature

The BaroLogger feature marks the location where barometric pressure loggers are placed within the reach.

BaroLogger Attributes	Attribute Explanation	Entry	Type
Comments	Any comments regarding barometric pressure logger (e.g., in cottonwood on lowest branch)	Entry permitted in the field	Text - Optional
NewNotes	Any further comments regarding barometric pressure logger/location	Entry permitted in the field	Text – Optional

Cultural Feature Point

This point feature is available for your use should you encounter a cultural site of some type.

CulturalSite Attributes	Attribute Explanation	Entry	Type
Type	• Structure • Lithic Scatter • Potsherds • Cowboy camp • Fence • Pictograph • Petroglyph • Other	Entry permitted in the field	Menu
Comment	Incidental site observation comment	Entry permitted in the field	Text – Optional
Comment2	Incidental site observation comment	Entry permitted in the field	Text – Optional

Other Optional Point Feature

This point feature is for incidental observations the crews may encounter. For example, you may find invasive plants or want to mark where you parked your car or left a trail. You can mark that location with this point feature, briefly commenting why you marked the location.

OtherPt Attributes	Attribute Explanation	Entry	Type
Comment	Incidental observation comment	Entry permitted in the field	Text – Optional
Comment2	Incidental observation comment	Entry permitted in the field	Text – Optional

Routes to Reaches line feature

This line feature is for mapping routes to riparian monitoring reaches that seem somewhat difficult to locate and/or navigate to. Once all data collection is complete, on the hike out from the reach, this feature can create a route or trail for future field crews to easily locate the monitoring reach.

Route Attributes	Attribute Explanation	Entry	Type
ReachID	unique ReachID	Entry permitted in the field	Text – Optional
Comments	Incidental observation comment	Entry permitted in the field	Text – Optional

NOTE: If the file on the GPS unit is too old to allow the locational information to be updated (i.e., the error message "Unable to append to a file over one week old" appears on the screen), close the file and open the duplicate file on the GPS unit or create a new file using the Riparian Monitoring data dictionary (see the Appendix of this SOP for detailed instructions).

1.4 Uploading possible monitoring locations

Mapping grade GPS units have the ability to upload data points to be used in concert with the data dictionary. The riparian monitoring reach locations are imported with the Riparian Data Dictionary by the NCPN GIS technician. Importing points (then uploading) to the GPS unit eliminates possible reach mis-identification in the field and allows the user to navigate more easily to a riparian reach and headpins.

Also, background data layers can be used to assist with navigation. The three GIS data layers found to be most useful as background layers are 1) Roads, 2) Trails, and 3) Drainages, along with the park boundary.

1.5 Collecting data

Once you've navigated to the reach (or potential reach), it's time to collect the necessary GPS locations. Appendix A contains detailed instructions for using the Riparian data dictionary and various files. Open the necessary file, and begin logging the point and any required data. Each point collected should be allowed to receive 10 positions before ending data collection and moving onto collecting another type of point. Given the challenging terrain of many of the riparian monitoring reaches (e.g., transect end points under an overhanging wall, next to a cliff, under trees, etc.), many locations may need to be GPSed using the offset feature (see pg. 18 for detailed instructions).

1.6 Downloading

When data collection is finished, the GPS data need to be downloaded. The NCPN GIS technician downloads the data from the GPS unit(s) after each field excursion, and then differentially corrects the data, using the appropriate (closest) base station. The corrected GPS files are then exported to a GIS data format. Table 2 indicates the attributes to capture while exporting the corrected GPS data into a GIS data format (i.e., "turn on" in Pathfinder Office).

Table 2. GPS Auto-generated attributes to capture.

PDOP	Update Status	Height
Correction Status	Data File Name	Vertical Precision
Receiver Type	Total Positions	Horizontal Precision
Date Recorded	Filtered Positions	Standard Deviation
Time Recorded	Data Dictionary Name	Position

Data should be exported using the same coordinate system used in the field (i.e., UTM, NAD83 Conus, Zone 12, meters). Any notes from the field crew pertaining to the GPS data will be corrected/fixed/edited at this time.

1.7 Uploading to the master Riparian Database

Once the GPS field data are validated and verified (GPS points given a visual review, compared to Generalized Random Tessellation Stratified (GRTS) coordinates, transect plot ID attributes verified) in ArcMap, the data are ready to be uploaded into the working Riparian Database. The GPS data are exported from ArcMap into an Excel spreadsheet for importing into the Riparian Database (see SOP #13, section 4.1).

2. Riparian Reach Revisit

Once reaches are established, GPS units will be used primarily for relocation of and navigation to the riparian reaches and transects. This allows for the use of recreational grade GPS units (Garmins, Magellans, etc.) rather than the sometimes heavier and larger mapping grade GPS units. The use of mapping grade units is encouraged for navigation to plots ready to be revisited; however, the following steps allow for the use of a recreational GPS unit. Appendix B contains detailed instructions on using a Garmin 76 GPS unit.

If it becomes necessary to replace a headpin that has washed away or become buried, the field crew should relocate the headpin following instructions in SOP #4. GPS the location of the new headpin and transect end points with the GPS unit. The GIS technician will download the updated coordinates for the reach and forward them to the Data Manager to incorporate into the Riparian database.

2.1 Minimum GPS Receiver Requirements

- Capable of uploading previously visited riparian monitoring transect locations (XY points)
- Capable of storing date and coordinates of features collected.
- Capable of exporting features collected to a format that can be used by GIS
- Capable of maintaining an EHE (Estimate of Horizontal Error) of less than or equal to 12 meters. Maintaining an EHE (or EPE – Estimate of Positional Error) of 12 meters or less meets the National Map Accuracy Standard.
- Capable of tracking a minimum of 4 satellites
- Capable of collecting real-time differentially-corrected positions (DGPS)

2.2 GPS Unit Setup

The riparian monitoring reach transects which are to be revisited in a given year will be given to the NCPN GIS technician. These locations (XYs of the plot centroid as well as all fourteen headpin and transect locations) will then be uploaded into a GPS unit for relocation purposes. If using a Garmin GPS, data transfer is enhanced by utilizing the freeware DNRGarmin (http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions.html). Background maps of the area(s) to be visited should be uploaded from Map Source as well. Once the data are transferred to the GPS unit, the GPS unit is ready for field use.

The GPS unit should be configured with the settings in Table 3.

Table 3. Minimum GPS receiver settings.

Name	**Standard**
Projection (displayed coordinates)	UTM
Datum	NAD 83
WAAS	Enabled (on)

Appendix A

File explanations:

Existing Data Files on GPSes:

- *PARK_Rip1/2* – (Park Reach Establishment) This file will contain the reach center points and headpins as well as the transect end points. This file may also contain potential center points of riparian monitoring reaches that have not been established. If Control Points and/or Monitoring Well locations are necessary, they will be included.

Background Layers (Files):

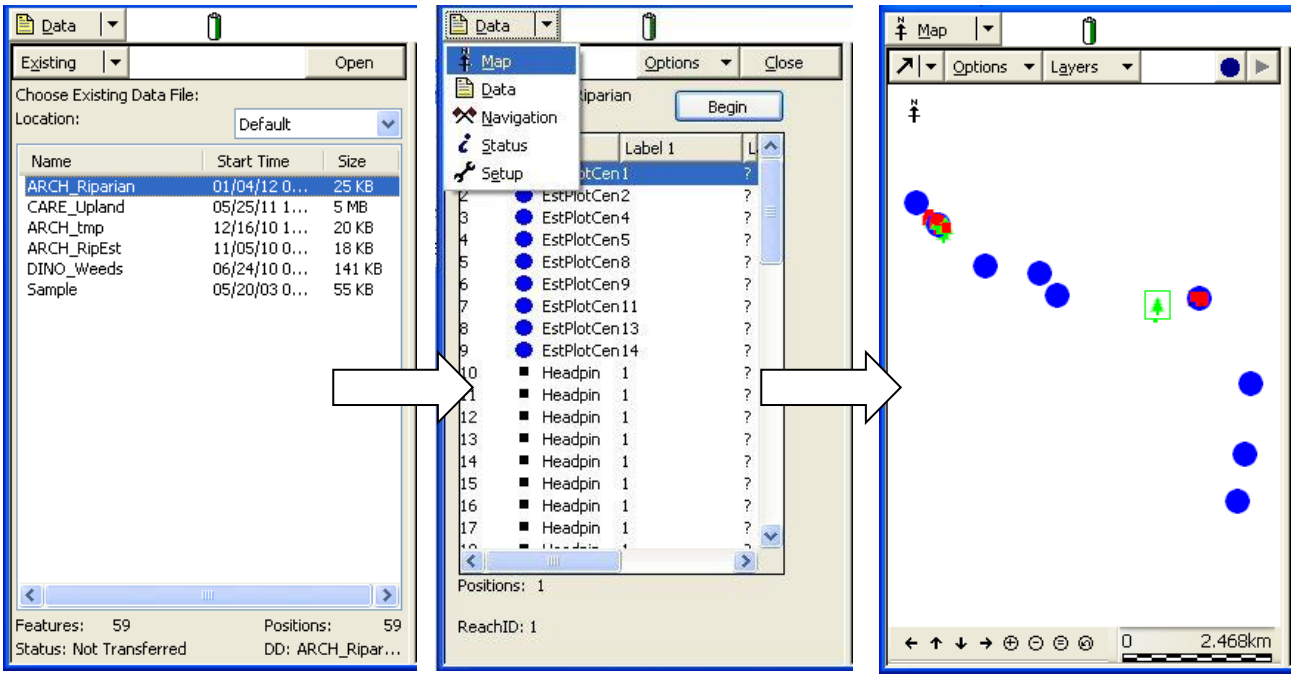
- *PARK*_RoadsTrls – This file contains the roads for [park]
- *PARK*_Trails – This file contains the trails for [park]
- *PARK*_Drainages – This file contains the drainages (hydrography) for [park]
- *PARK*_bnd - This file contains the [park] boundary.

Basic instructions:

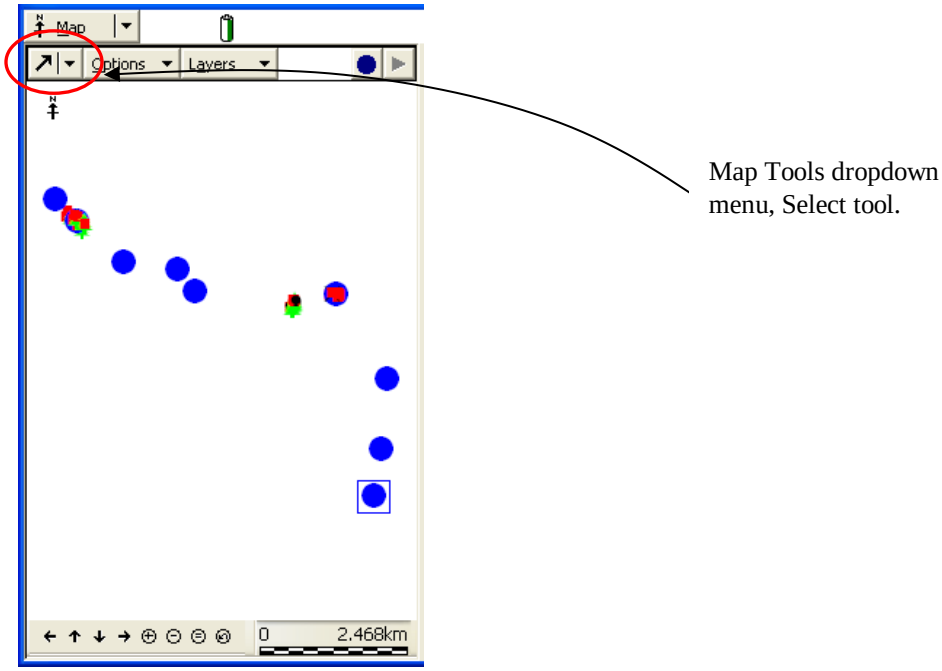
The following instructions are based on using a Trimble GPS unit with TerraSync Professional GPS software loaded. The directions below demonstrate one way of recording and navigating through the screens and options in TerraSync, not the only way to GPS the data needed for riparian monitoring points.

Navigation:

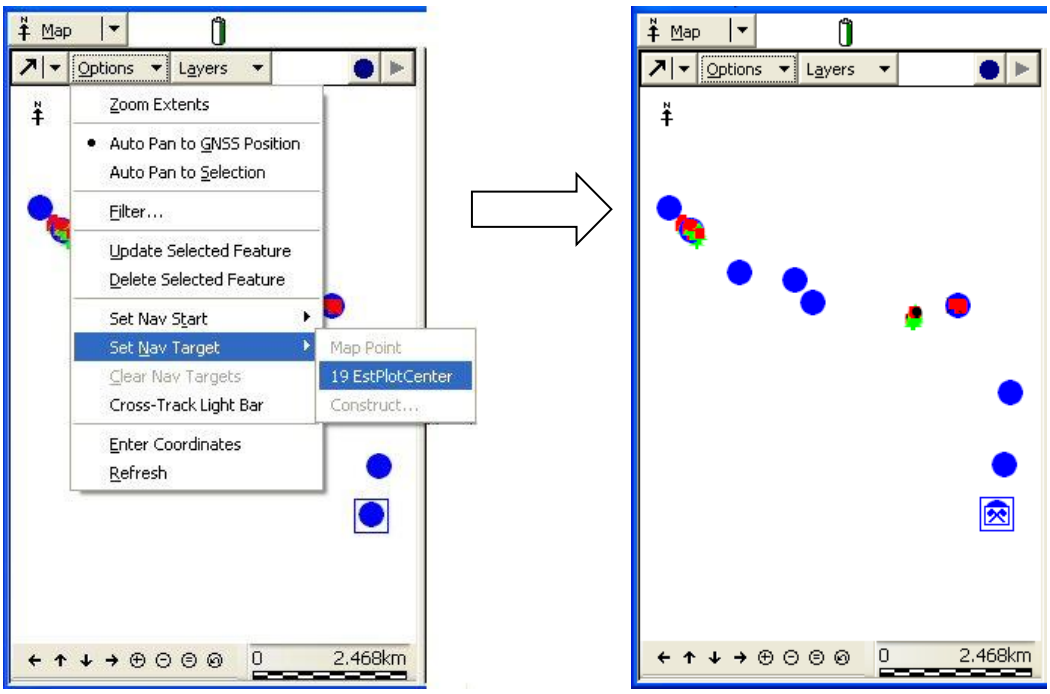
To navigate to a point, open the file which contains the point you want to update. Change the screen to the Map View (tap on the Data drop down, and choose Map).



Using the Map Tools (the drop down menu directly underneath Map), use the Select tool to select the point to which you wish to navigate. A box will display around the point.

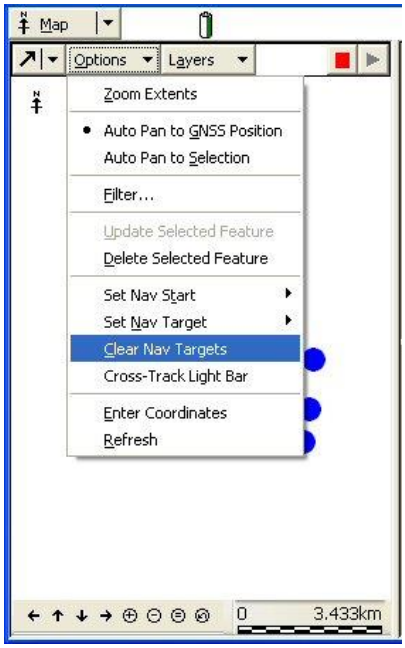


Click on the Options button, then Set Nav Target, then the point/file name. The selected point will then be displayed with the target icon (crossed flags).

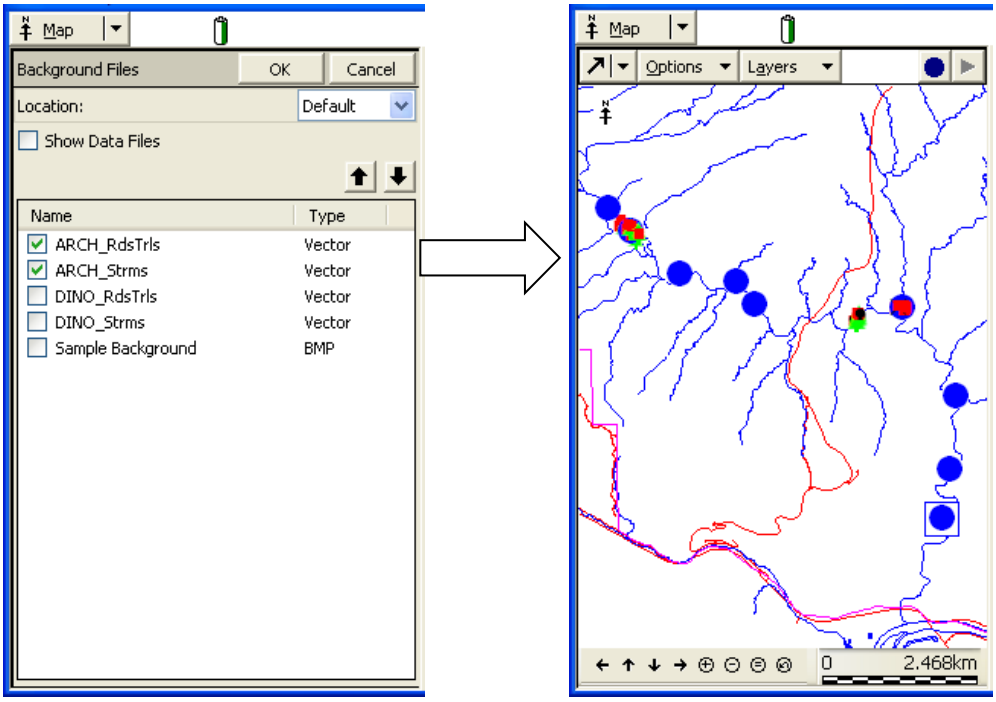


Open the Navigation section (click on Map and choose Navigation). This will open the navigation screen. As you move, this screen will display the information needed to navigate to the point.

When you've reached your point and/or no longer need to navigate, select the Map screen, then go to Options and select Clear Nav Targets.



To display background layers, tap the Layers button, then choose Background Files. You can select one or more to display on the Map view (be aware that background files may display as one color). Tap OK. Also on the Layers button, make sure that Background is checked so the layers will display on the map.

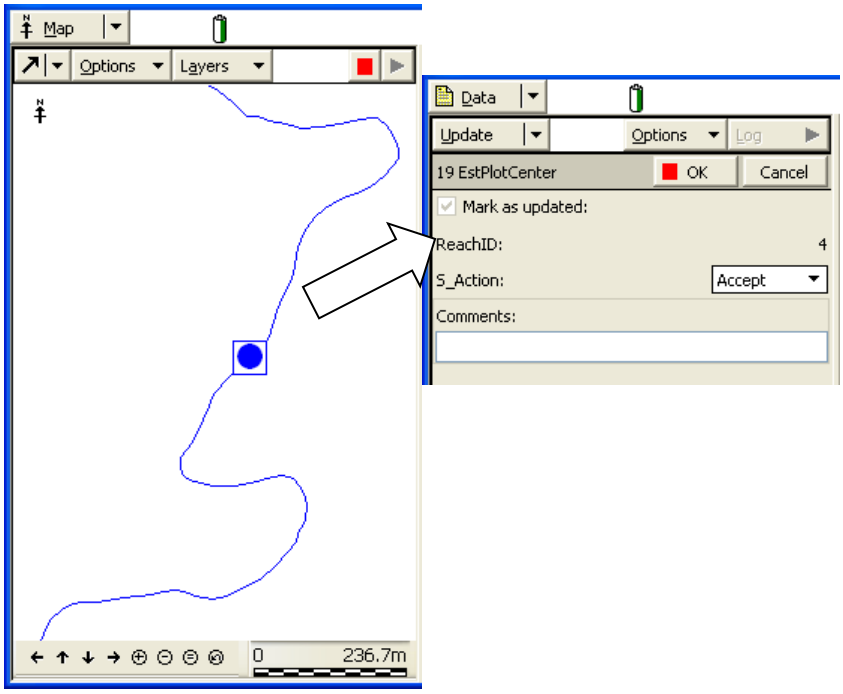


Tip – When navigating to a reach, use the reach centroid to navigate until you get fairly close to the plot, then switch to using one of the headpins or transect end points so you won't trample the transects getting to the reach.

Once you've found your riparian reach, if it hasn't previously been established, you'll need to GPS the centroid, each headpin, and each transect end point.

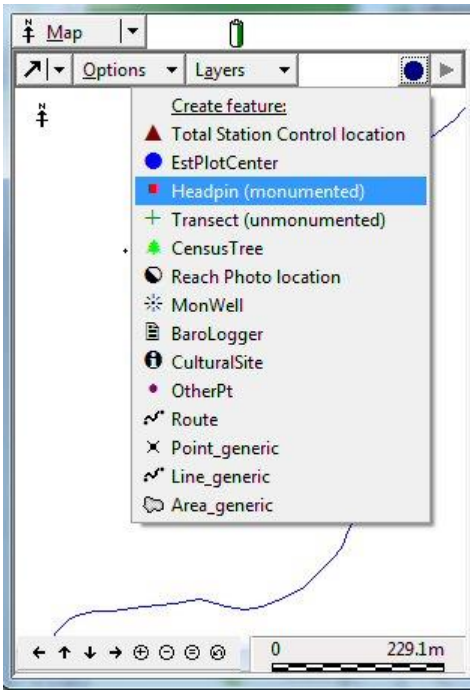
Log Data

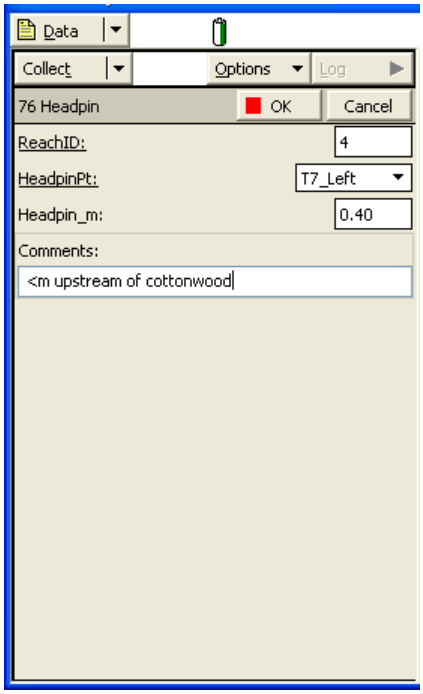
To GPS (locationally update) the reach centroid (between T4_Left and T4_Right), double tap the reach center icon from the map screen, and the data dictionary fields for the point will open (EstPlotCenter). The only item needed for a reach center is the ReachID, which is already there, so just let the GPS unit obtain 10 or so "hits" from the satellites, and tap OK.



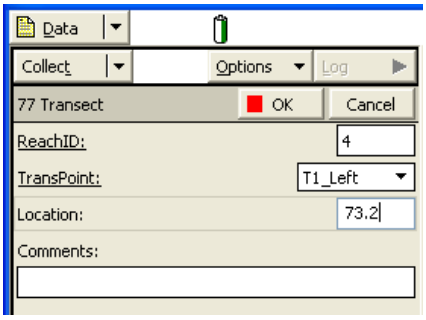
NOTE: If the file on the GPS unit is too old to allow the locational information to be updated (i.e., you get the error message "Unable to append to a file over one week old"), close the file. Two identical files are on the GPS unit, open the one that you have not been using (usually named "*Park*_Rip2". If both files are timed out, go to Data/Create new, and choose the riparian monitoring data dictionary, and create a new file. Unfortunately, none of the plot centers or transects, etc. will be displayed, but at least you can log new point locations using the choices in the data dictionary. Hopefully, this will only be necessary on the last day(s) of your field hitch.

To GPS the headpins, select the blue dot at the top and right of the map screen, and choose Headpin. Fill in the ReachID and HeadpinPt at a minimum, Headpin_m, and any comments, if needed.

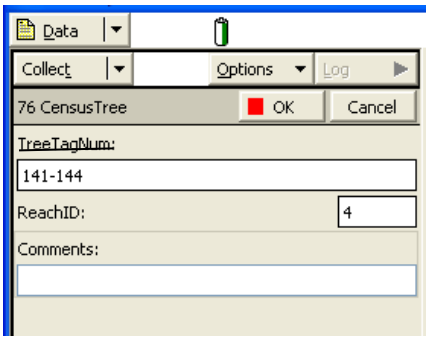




GPSing the Transect end points is nearly identical to GPSing the headpins; fill in the ReachID and TransPoint at a minimum, and Location and Comments if necessary. You may need to utilize the Offset feature, explained later on in this appendix.



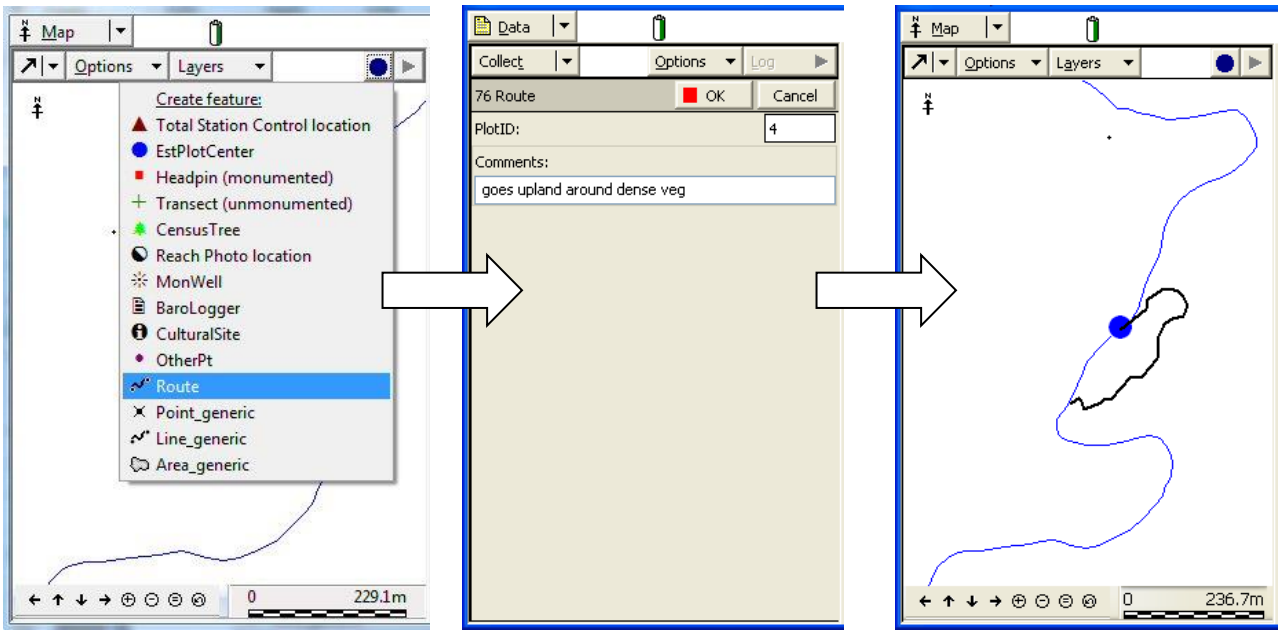
If there are a fair number of trees/tree clumps, and locations of those trees would be helpful in finding those trees in future years, use the CensusTree feature in the data dictionary, and include the tree tag number(s) and ReachID.



There are a few other point features that can be logged: PhotoPt, MonWell, BaroLogger, CulturalPt, and Other (see section 2.3).

Creating Trails/Routes:
If you feel that the reach you've visited is difficult to navigate to, you may want to GPS the route on the way out. This route can then be used by future field crews to get to the reach efficiently.

To map the route from the reach, click on Data/Collect and click on Route, which will bring up a field to fill in the ReachID and any brief comments you'd like to add.

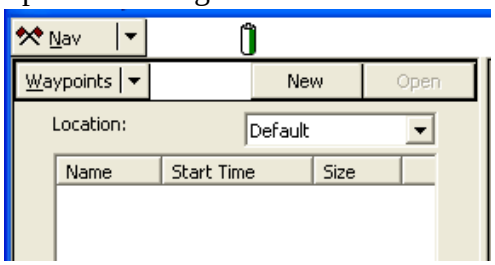


As you walk, the GPS unit will collect a point every 3 seconds. You don't need to do anything until you get to the end of the route (i.e., back to the paved road or trail). At that point, just click OK to end, close, and save the feature.

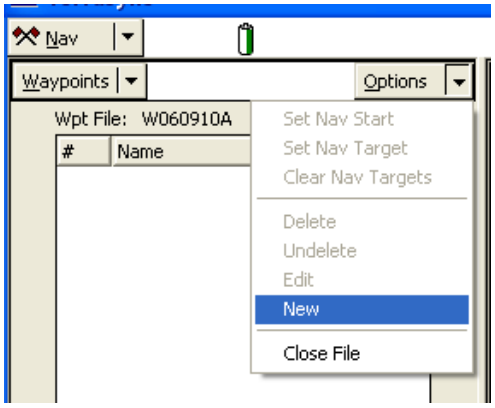
Creating a Waypoint from Coordinates

There may be times when you have a coordinate you need to get to that is not already loaded into the GPS unit. If you have the coordinates, you can create a waypoint, which then you can navigate to.

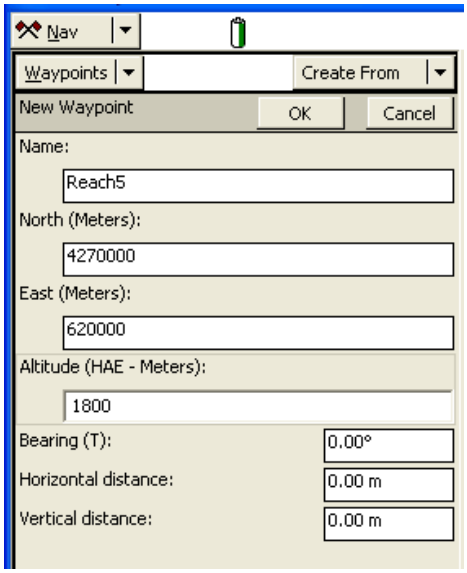
1. Go to the top left pulldown menu and select Navigation
2. Tap on the Navigate button and select Waypoints



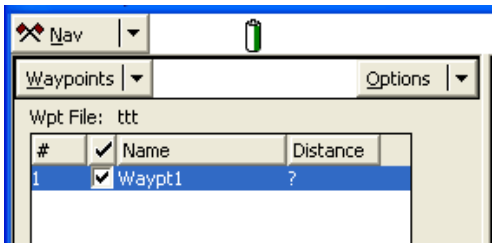
3. Create a new waypoint file by tapping the New button
4. You have the opportunity to name the file or use the default. Tap OK.
5. From the Options button, select New



6. Fill in the Name, North, East, and Altitude fields (for elevation, enter a reasonable guess). Filling in the Bearing or Distance fields is not necessary. Tap OK.



7. Double click the point you just created, and it will automatically set it as the navigation target (note the checkmark).

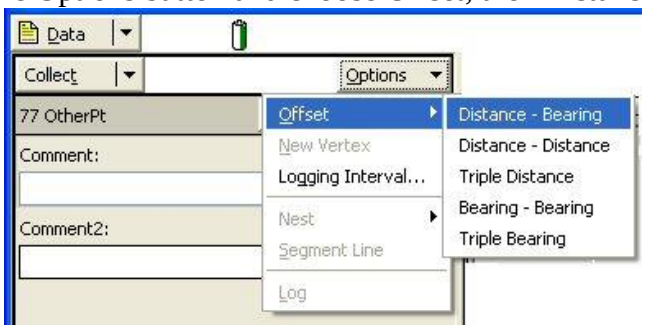


8. Tap on Waypoints dropdown menu, and choose Navigate. The Navigation screen will open, displaying the bearing and distance to the point you just entered. Now you are able to navigate to the location you just entered. The waypoint will also be displayed on the Map screen with the crossed flags icon.

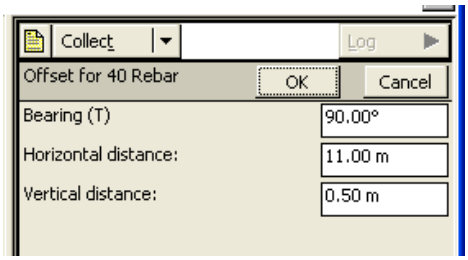
Offsetting a Point

If a location is next to a cliff or tree or something that is blocking satellite reception, you can still collect the location by using the Offset feature.

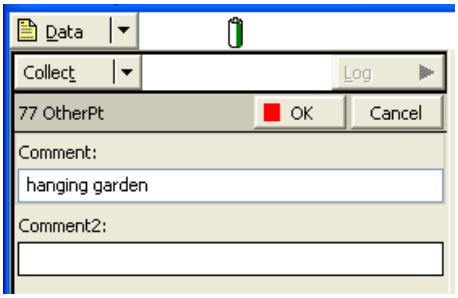
1. Select the feature to GPS from the data dictionary. Once the Data screen has opened, tap the Options button and choose Offset, then Distance – Bearing.



2. The Offset screen will appear. Fill in your bearing and horizontal distance (Vertical distance is optional) describing where the point is in relation to you, then tap OK.

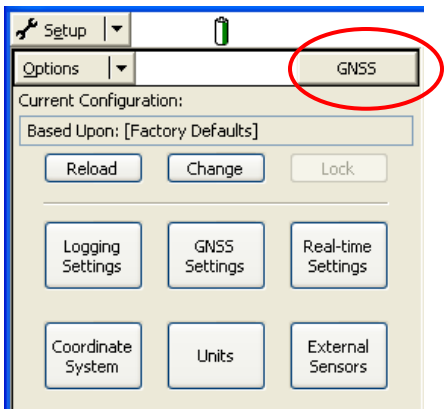


3. The data dictionary for that point feature will appear, allowing you to fill in the information necessary to collect the location. Tap OK when finished.



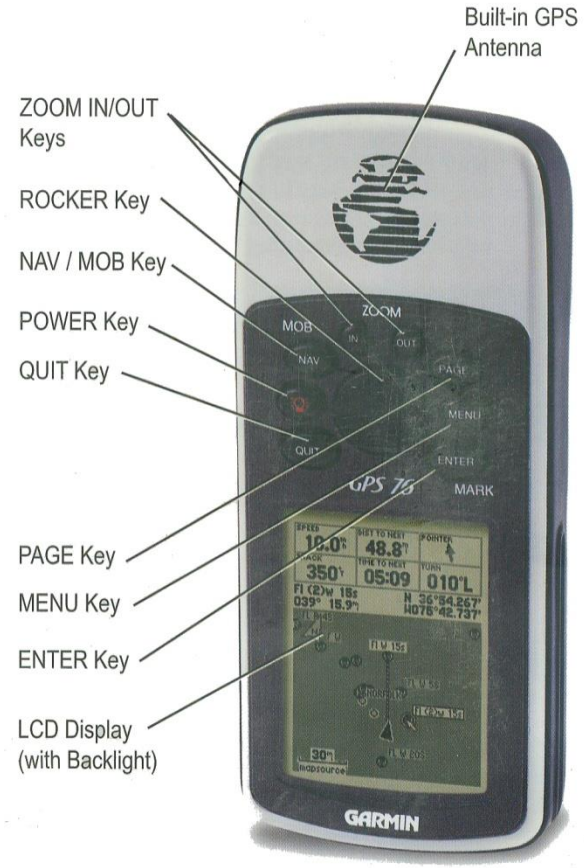
Hints for Trimble units:

- Log a point for a minimum of 10 (to 20) "hits" (about 10 – 20 seconds).
- At the end of the day (or end of needing the GPS), close the file in TerraSync (on the Data screen, Close is at the bottom right). Then close TerraSync (Data/Exit).
- Holding the power button down for 30 seconds will soft re-boot the XT GPS. Holding the power and reset button down for approximately 60 seconds will hard re-boot the XT GPS. Neither of these re-boots will lose any data, but you should recheck the coordinate system. You may need to reboot if the screen freezes or if TerraSync does not load.
- To re-boot the Junos, there is a little hole on the bottom left side (nestled in with the various buttons). Push that with the tip of the stylus to re-boot the Juno.
- To conserve on battery life, turn the unit off if you aren't using it to navigate. It is recommended that TerraSync be closed *prior* to turning off the unit.
- If the GPS gets disconnected, go to the Setup screen and tap the GNSS button on the upper right side. A little connecting icon will appear as the unit reconnects to the GPS. A satellite icon will replace the connecting icon when TerraSync is reconnected to the GPS.



- As a general rule, if the battery life goes below 20% on the Junos, it's time to replace the battery. Close all files and exit TerraSync before switching batteries.
- The NCPN has a copy of the TerraSync Users Guide, which goes into more detail about the many functions of TerraSync. Please contact the GIS technician if you would like to take a look at it.
- Report any idiosyncrasies with the Trimble GPSes to the NCPN data management staff.

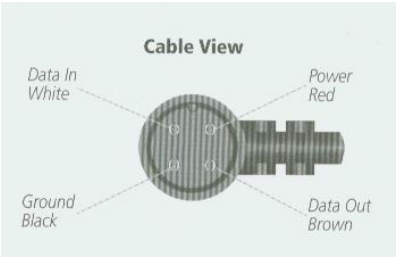
Appendix B



This graphic demonstrates the keys of a Garmin 76 GPS unit, and their functions. These keys are referred to in the following instructions.

1. To Connect GPS to Computer

- Either a serial or USB port cable will accompany the GPS unit. This is the cable that connects the GPS receiver to your workstation computer, allowing the uploading and downloading of waypoints.
- The serial or USB end of the cable attaches to your workstation computer. The other cable end (below) inserts into the Garmin GPS unit (lift bottom of black flap on the back of the GPS unit).



2. To change the displayed map projection:

- Turn on the unit by depressing the POWER key
- Set Projection
    1. Access the Main Menu (press the MENU key twice).
    2. Using the rocker key, scroll down to Setup and press the ENTER key
    3. There are several tabs listed (General, Time, Units, Location, Alarms & Interface) – using the rocker key, scroll over to the Location tab. Scroll down with the rocker key to Location Format and press the ENTER key.
    4. Scroll down the list of formats to UTM UPS, make sure this choice is highlighted, and press the ENTER key.
    5. Scroll down to Map Datum, press the ENTER key. Scroll down through the Map Datum choices, press the ENTER key when NAD 83 is highlighted.
    6. Press the PAGE key to get back to the "GPS Information" screen. (If the GPS Information screen is not showing, press the PAGE key; it will cycle through the screens). The bottom of the screen should now be displaying coordinates as UTM.

3. Set GPS to log differentially correct data

- If not already on, power up the GPS
- Enable WAAS
    1. Access the Main Menu (press the MENU key twice).
    2. Using the key, scroll down to Setup and press the ENTER key.
    3. There are several tabs listed (General, Time, Units, Location, Alarms & Interface) – using the rocker key, scroll over to the Location tab. Scroll down with the rocker key to General and press the ENTER key.
    4. Scroll down to WAAS, press ENTER, highlight Enabled, and press ENTER.
    5. Press the PAGE key to exit Setup.

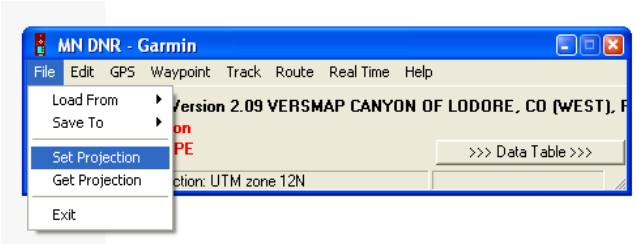
4. In the Field - optional

- Collect (or mark) a waypoint
    1. When at the observation location, check the GPS Information page for number of satellites (4 or more needed) and accuracy (12 meters or less).
    2. Press and hold the ENTER/MARK key until the Mark Waypoint Page is displayed.
    3. Using the Rocker key, change the waypoint ID.
    4. Using the Rocker key, highlight "OK" and press ENTER.
- Navigation
    1. Press the NAV key.
    2. Select 'Go To Point' then press the ENTER key.
    3. Select 'Waypoints' then press the ENTER key.
    4. Select 'your point' then press the ENTER key.
    5. Highlight the 'GoTo' button, press ENTER.
    6. As you start walking, the Pointer will point to your destination.

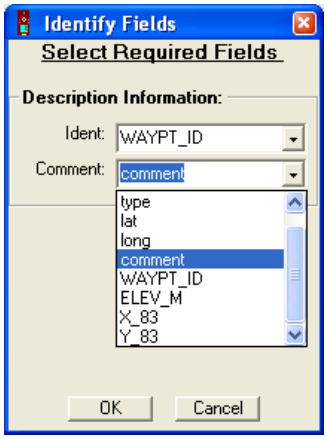
5. Upload Background Data

- Upload background maps from MapSource (proprietary software) if needed.

- Upload waypoints using MN DNR Garmin freeware.
    1. Connect GPS to the computer.
    2. Turn GPS on, then open DNR Garmin, it will connect to the computer.
    3. When the MN DNR – Garmin window opens, make sure that the projection is set to UTM, NAD 83, zone 12N (unless at CURE or BLCA, which are zone 13N). Go to File, then Set Projection to change projection.

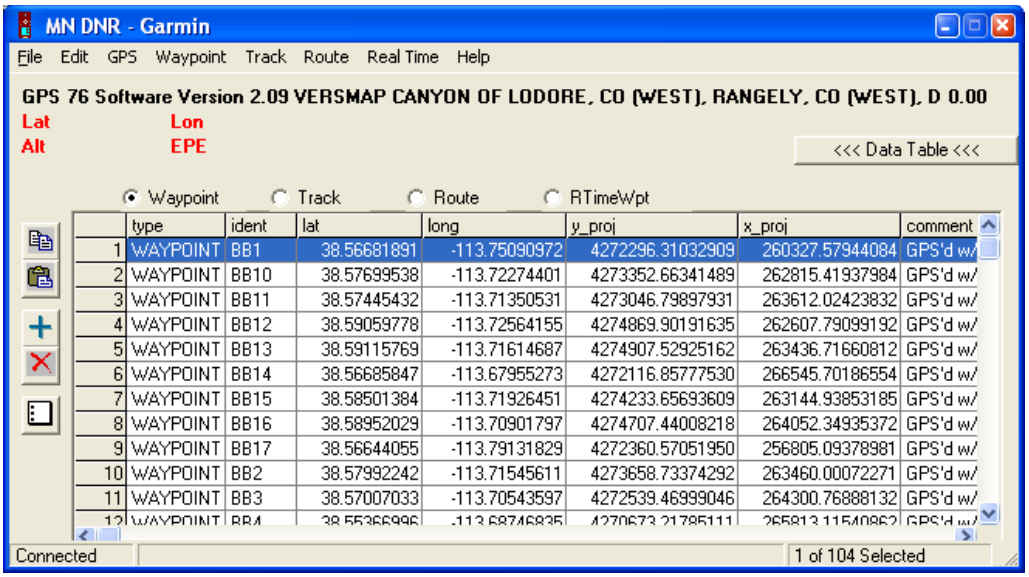


    4. Click on File, then Load From. You can upload a .txt file, .dbf file, or a shapefile. Navigate to the file you wish to upload and click Open.
    5. A window will open prompting you select description information. Choose appropriate fields for Ident (ID) and Comment and click OK.



    6. A window will open stating "File was loaded successfully from….". Click OK.

7. Points will be displayed in the MN DNR – Garmin window.

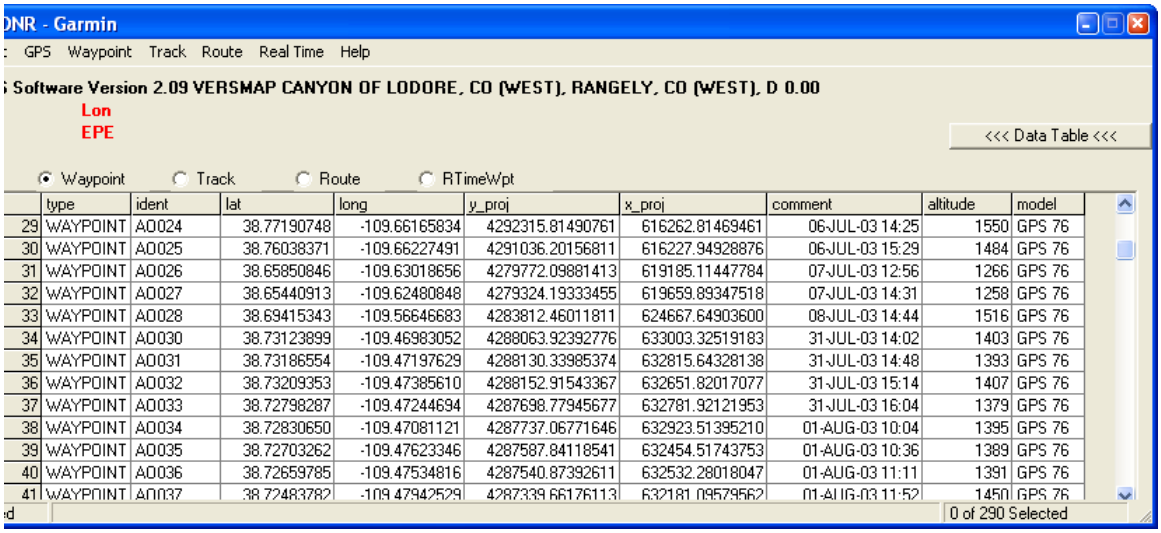


	type	ident	lat	long	y_proj	x_proj	comment
1	WAYPOINT	BB1	38.56681891	-113.75090972	4272296.31032909	260327.57944084	GPS'd w/
2	WAYPOINT	BB10	38.57699538	-113.72274401	4273352.66341489	262815.41937984	GPS'd w/
3	WAYPOINT	BB11	38.57445432	-113.71350531	4273046.79897931	263612.02423832	GPS'd w/
4	WAYPOINT	BB12	38.59059778	-113.72564155	4274869.90191635	262607.79099192	GPS'd w/
5	WAYPOINT	BB13	38.59115769	-113.71614687	4274907.52925162	263436.71660812	GPS'd w/
6	WAYPOINT	BB14	38.56685847	-113.67955273	4272116.85777530	266545.70186554	GPS'd w/
7	WAYPOINT	BB15	38.58501384	-113.71926451	4274233.65693609	263144.93853185	GPS'd w/
8	WAYPOINT	BB16	38.58952029	-113.70901797	4274707.44008218	264052.34935372	GPS'd w/
9	WAYPOINT	BB17	38.56644055	-113.79131829	4272360.57051950	256805.09378981	GPS'd w/
10	WAYPOINT	BB2	38.57992242	-113.71545611	4273658.73374292	263460.00072271	GPS'd w/
11	WAYPOINT	BB3	38.57007033	-113.70543597	4272539.46999046	264300.76888132	GPS'd w/
12	WAYPOINT	BB4	38.55366996	-113.68746835	4270673.21785111	265813.11540862	GPS'd w/

8. If the points are correct, click on WAYPOINT on the top menu, then Upload.
9. A window will pop up stating "Transfer Complete. _#_ points uploaded".

6. Downloading Waypoints

- Download waypoints using MN DNR Garmin.
  1. Connect the GPS to the computer and turn on the GPS unit, then open the program DNR Garmin on the computer.
  2. From the DNR Garmin main menu, click on Waypoint, then Download. Your data will appear in the MN DNR Garmin window. Elements to be included in the downloading process are: type, ident, lat, long, y_proj, x_proj, comment, altitude & model. These fields can be chosen by choosing Waypoint from the main menu, then Waypoint Properties and checking only those fields.



	type	ident	lat	long	y_proj	x_proj	comment	altitude	model
29	WAYPOINT	A0024	38.77190748	-109.66165834	4292315.81490761	616262.81469461	06-JUL-03 14:25	1550	GPS 76
30	WAYPOINT	A0025	38.76038371	-109.66227491	4291036.20156811	616227.94928876	06-JUL-03 15:29	1484	GPS 76
31	WAYPOINT	A0026	38.65850846	-109.63018656	4279772.09881413	619185.11447784	07-JUL-03 12:56	1266	GPS 76
32	WAYPOINT	A0027	38.65440913	-109.62480848	4279324.19333455	619659.89347518	07-JUL-03 14:31	1258	GPS 76
33	WAYPOINT	A0028	38.69415343	-109.56646683	4283812.46011811	624667.64903600	08-JUL-03 14:44	1516	GPS 76
34	WAYPOINT	A0030	38.73123899	-109.46983052	4288063.92392776	633003.32519183	31-JUL-03 14:02	1403	GPS 76
35	WAYPOINT	A0031	38.73186554	-109.47197629	4288130.33985374	632815.64328138	31-JUL-03 14:48	1393	GPS 76
36	WAYPOINT	A0032	38.73209353	-109.47385610	4288152.91543367	632651.82017077	31-JUL-03 15:14	1407	GPS 76
37	WAYPOINT	A0033	38.72798287	-109.47244694	4287698.77945677	632781.92121953	31-JUL-03 16:04	1379	GPS 76
38	WAYPOINT	A0034	38.72830650	-109.47081121	4287737.06771646	632923.51395210	01-AUG-03 10:04	1395	GPS 76
39	WAYPOINT	A0035	38.72703262	-109.47623346	4287587.84118541	632454.51743753	01-AUG-03 10:36	1389	GPS 76
40	WAYPOINT	A0036	38.72659785	-109.47534816	4287540.87392611	632532.28018047	01-AUG-03 11:11	1391	GPS 76
41	WAYPOINT	A0037	38.72483782	-109.47942529	4287339.66176113	632181.09579562	01-AUG-03 11:52	1450	GPS 76

3. Click on File, and then Save To. Navigate to the proper folder on the computer where GPS files are stored.
4. There are several file types which you can save the file as. The NCPN recommends saving the data as a projected shapefile (*.shp) file.
5. Name the file with the date of download in the file name (e.g., Riparian_June10_09.shp) and click the Save button. A window will display "File successfully written to …" .

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 4

Establishing the Reach and Setting up Transects

Version 1.05 (August 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	04/2012	K. Lund & D. Witwicki	Clarify wording; improve data sheet	Confusion between headpins and transect end points	1.01
1.01	5/2013	R. Weissinger, K. Lund, D. Witwicki	Grammatical corrections; example data sheets; clarify instructions	Response to protocol review	1.02
1.02	2/2014	D. Witwicki	Added Actual Reach Length	Actual Reach Length can be different than Estimated Reach Length	1.03
1.03	4/2015	K. Lund, D. Witwicki	Clarified instructions for when to adjust transect length during a revisit and changed error for this from 0.25 m to 0.5 m	Transect length varies more than expected at revisits	1.04
1.04	8/2016	D. Witwicki	Minor edits to wording		1.05

This SOP describes the methods for (1) assessing the suitability of a new monitoring reach, (2) establishing a sampling reach, and (3) setting up and relocating transects for vegetation monitoring and surveying. A list of necessary equipment for these procedures can be found in SOP #1.

A minimum of a three-person team is needed to establish and set up the monitoring transects.

1. Reach Establishment

1.1 Assessing suitability of a new monitoring reach

Potential monitoring locations will be selected based on the length of the stream within park boundaries using GIS technology. Reaches of the stream that are confined by bedrock or colluvium, or that are affected by a major tributary, will be buffered out of the potential monitoring areas in advance whenever possible. On longer streams, multiple random, spatially-balanced points are generated using a Generalized Random

Tessellation Stratified (GRTS) design. These points are assigned sequential reach identification numbers and should be assessed in ascending order.

Locating the centroid

A. Use topographic maps, aerial photographs, and a GPS unit to navigate to the monitoring reach.

B. Mark the point with a pin flag or flagging tape. This point is the center of the reach. In perennial streams, you can mark either side of the channel.

Determining reach length

A. Use a range finder or transect tape to measure the width of the active riparian zone at the centroid, rounding to the nearest 1 m.

- The active riparian zone boundary is defined as the intersection of surfaces dominated by riparian vegetation with surfaces dominated by upland vegetation.
- Good indicator species of the active riparian zone include *Salix exigua* and *Baccharis* species.
- Legacy riparian species, especially mature cottonwood trees, may be present beyond the active riparian zone, but they will not dominate the surface or have active regeneration (i.e., seedlings or saplings) on the surface.
- In some instances, this boundary may be between a riparian surface and a bedrock valley wall or colluvial deposit.

B. Re-measure the width of the riparian zone at four additional locations, two upstream and two downstream from the centroid.

- Separate each additional width measurement using spacing equal to the width of the riparian zone at the centroid.
- Measure the spacing between additional width measurements along the thalweg or lowest point along the stream bed.

C. Average the five measurements and multiply by 6. This number is the estimated length of the monitoring reach. If the reach length falls outside of the desired range of 180 – 360 m, default to the minimum or maximum reach length.

- Minimum reach length is 180 m.
- Maximum reach length is 360 m.

D. Determine the actual reach length after establishing all of the transects. Sometimes this will be different than the estimated calculation when transects are moved, altering the distance between transects (see Transect Troubleshooting in section 1.2). Record the actual reach length on the Reach Establishment datasheet.

Evaluating the sampling reach

Walk the entire length of the reach to determine if the reach meets the acceptance criteria described below. An acceptable monitoring reach contains riparian vegetation and remains relatively homogenous throughout its entire length.

A. No more than 25% of the reach:

- Is confined by bedrock or colluvium (CARE and ZION only; Figure 1).
- Has a bedrock channel (ARCH and NABR only)
- Lies within a different stream type (perennial, intermittent, ephemeral).
- Is influenced by side canyon springs.

B. No major tributary junctions occur within the reach.

Major tributaries are indicated by either of the following:

- Perennial flow.
- Deposition areas that visibly affect the main channel, such as cobble bars or boulder deposits, even if flow is ephemeral.

C. No significant archeological sites exist within the reach.

If a reach is rejected for any of the above reasons, be sure to collect the centroid pin flag and move on to the next consecutively numbered reach for evaluation.

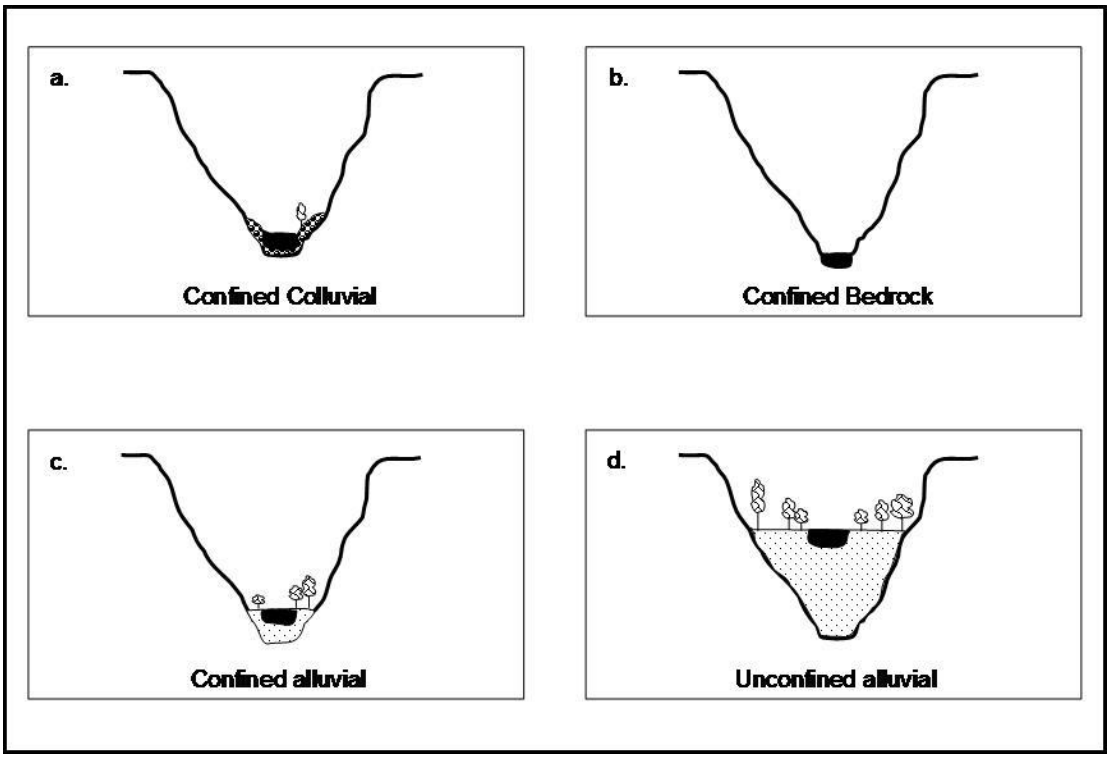


Figure 1. Idealized stream channel valley settings, including (a) colluvial, (b) bedrock, (c) confined alluvial, and (d) alluvial or unconfined alluvial. Colluvial material is typically found at the foot of a slope and is deposited as a result of gravitational action. Alluvium is material deposited by running water. The active channel is represented as solid black. Confined here refers to a channel where the valley width is less than two active channel widths. Adapted from Montgomery and Buffington (1993).

1.2 Site Establishment

Record directions to the reach

Write directions to the reach and include sufficient detail for someone who has never been there to relocate it. Begin with road travel from a designated location (such as the park's visitor center), where to park vehicles, and the route used. Describe (and photograph) landmarks used to navigate to the reach centroid. Note obstacles or hazards to be avoided at and en route to this particular site. Use specific language such as "southwest" and "downstream" rather than ambiguous terms such as "left" or "below." You may also GPS the route (see SOP #3).

Establishing a monitoring reach

A monitoring reach consists of 7 transects where the majority of sampling is conducted (Figure 2). Transects are numbered 1 through 7, in order, from upstream to downstream and have a maximum length of 100 m. Transects are spaced equally throughout the reach at a distance of the reach length divided by 6.

A. Mark the centroid flag as Transect 4.

B. From the centroid flag, walk downstream along the thalweg, or lowest part, of the channel. Use a rangefinder or transect tape to walk the distance determined above (total reach length divided by 6).

C. Mark the middle of the stream or the stream bank with a pin flag or flagging tape labeled "5."

D. Proceed downstream in the same manner, marking the location of Transects 6 and 7 along the stream.

E. Return to the centroid and walk upstream along the thalweg. Mark the locations of Transects 1-3 along the stream.

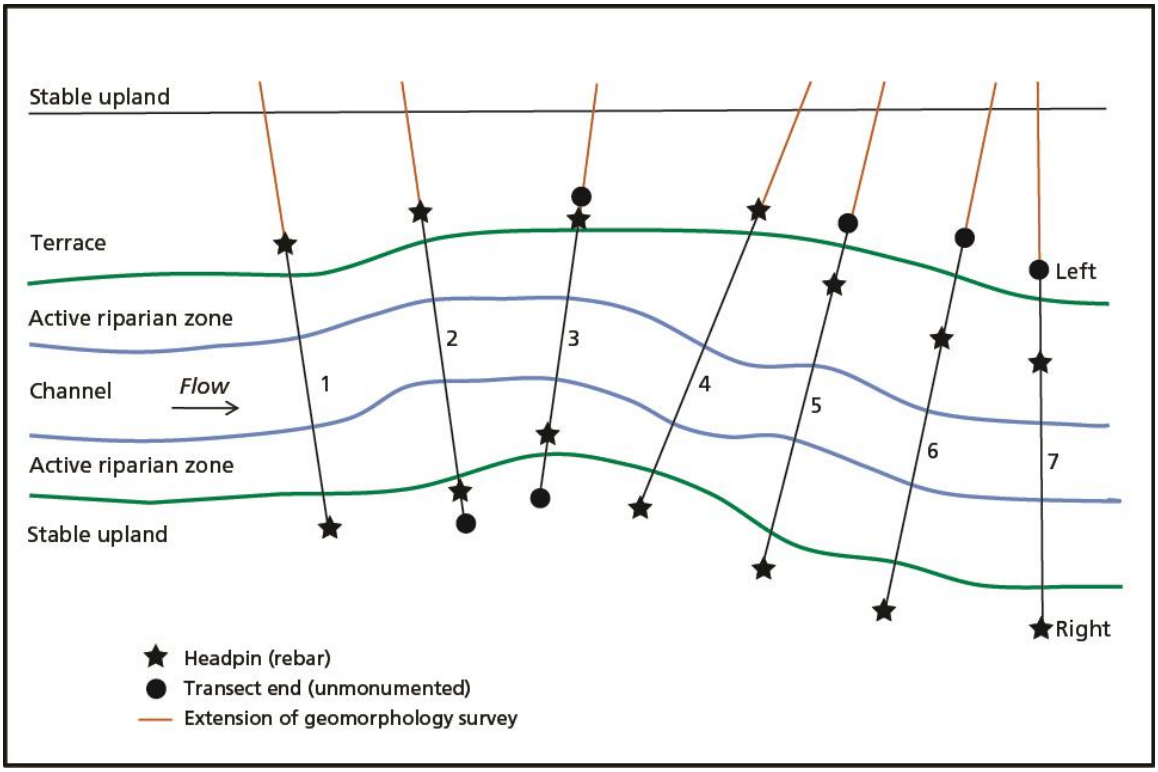


Figure 2. Features of an established sampling reach. "4" is the centroid, star symbols indicate locations of headpins, black circles indicate the locations of transect end points that cannot be monumented due to bedrock or highly unstable surfaces, and the green line represents the upland-riparian zone boundary. Geomorphology transects extend to a stable upland surface.

Establishing transects

When all transect locations have been determined, flagged mid-stream, and labeled with the appropriate transect number, you are ready to install permanent headpins.

A. Starting at the center of the transect, have two crew members walk in opposite directions perpendicular to the channel (Figure 2). In braided channels, set up transects perpendicular to the entire channel area. It is helpful to have additional crew members remain at the centroid or position themselves along the desired line to assist in lining up the transect.

B. Walk until you arrive at a stable surface, upslope of surfaces that are flooded frequently.

- The most stable surface is dominated by upland plant species and does not show active erosion such as landslides, slumps, rockfalls, gullying, etc.
- If stable surfaces are >100 m apart, headpins may be located on relatively stable surfaces such as terraces, indicated by legacy riparian species that show no recruitment (i.e., no seedlings or saplings are present, only mature trees).

- If the active riparian zone is >100 m wide, place one of the headpins in a stable area and the other in the floodplain. Document the headpin in the floodplain using witness trees (see below).

C. Mark the location with an appropriately numbered pin flag. If on bedrock, make a 2-rock cairn or stand in place.

D. Stand over the pin flag, and confirm with the other crew members that the transect line is still perpendicular to the channel.

E. Once the line has been confirmed, pound in the rebar used to mark the locations of the headpins.
   - Whenever possible, headpins are located at the ends of a transect.
   - In places where a transect end is on an unstable surface or bedrock, the headpin is installed at a different location along the transect. Select the most stable ground along the transect in the general vicinity of the transect end. The two headpins on a transect should be a minimum of 10 m apart.
   - Hammer the rebar to within 15 cm of the ground surface.

F. Inscribe the reach number, transect number, and river right or left (e.g., C-01, T4L for Reach 1, Transect 4 river left) on a rebar cap or metal tag. Right and left are determined while facing downstream. If using a rebar cap, stamp a dot or "x" in the center of the cap as well. This is used to align the point of the survey rod during geomorphic surveying (see SOP #9). Caps or tags can be prepared beforehand in the office or in camp.

G. Gently hammer the cap onto the rebar, protecting the top of the cap with a leather strip, or attach the metal tag to the rebar using galvanized wire.

H. Set up the transect following the detailed instructions in Section 2. If an unmonumented transect end is on bedrock or an unstable surface, end the transect in a location that gives you an approximately level tagline.

I. Record the locations of the headpins and transect ends using a mapping grade GPS unit (see SOP #3). Be sure to take a waypoint for each headpin and each transect end when they are located in different places. Also record UTMs of each headpin and transect end on the paper data sheet.
   - If there is no satellite coverage at the point, move to a location with coverage and offset the point.
   - If offsetting is not possible, mark the location of the headpin or transect end on an aerial photo or topographic map. This will be used to derive coordinates in the office.

J. Record the location of the headpins along the transect and the total transect length to the nearest 0.1 m. Remember to also record the location of the headpins along each

transect in the data dictionary on the GPS (see SOP #3). This is especially important when headpins are not located at the ends of the transect.

K. Record the bearing of the transect (from right headpin to left headpin) in degrees. Use true north (i.e., compass declination should be set and recorded on the data sheet).

L. Take reference photos to document locations of all headpins and any unmonumented transect ends. Include the cliff line, surrounding perennial vegetation, and/or other recognizable landmarks in the background to help the returning field crew relocate these points.
   - Label a chalkboard with the park code, reach code, transect number, river right or left, and direction facing (upstream [US], downstream [DS], right to left [R -> L], or left to right [L->R], etc.) (e.g., ZION, P-01, T3R, US).
   - Place the chalkboard in a location near the headpin or transect end where it will be easy to read in the photo.
   - Clearly mark the location of the headpin or unmonumented transect end in relation to recognizable landmarks. This location should be marked by bright-colored pin flags, placed either in the soil at the point or held above the point where they will be visible in the photo. Unlike repeat photos, you may include anything in reference photos that may assist with re-locating the point (i.e., crew members, bright-colored flagging, etc.).
   - Take a photo and check the quality. If the photo is blurry or otherwise not acceptable, delete it and take another one.
   - Record the digital file name and photographer on page 2 of the photo data sheet (see SOP #5).

M. If the headpin is located in dense vegetation or on an unstable surface, establish three witness trees.
   - Select three healthy trees within 20 m of the headpin. If possible, use different species of trees.
   - Record the diameter at breast height (DBH) and species of each tree. See SOP #6 for methods to measure DBH.
   - Align the nail so that it enters the tree at breast height (1.37 m) facing the headpin. Drive the nail into the tree at an angle, so that the tag hangs down and away from the tree. Leave several centimeters of nail exposed so the tree has ample space for growth.
   - Record the tag number, bearing in degrees from the tree to the headpin, and distance in meters from the tree to the headpin.

N. Continue throughout the reach, establishing headpins in the same manner for the remaining six transects.
   - If channel sinuosity is such that adjacent transects cross, establish the transects as described above. Sampling proceeds as usual with the exception of collecting 5-m belt data (SOP #6). Be sure to note which transects cross in the comments section of the data sheet.

Transect troubleshooting
Under certain scenarios, some transects may need to be repositioned as you are establishing the reach. The distance a transect is repositioned depends on the scale of the reach and the situation which requires it to be moved. Always slide transects away from the centroid in 10-m increments until a suitable location is reached. After repositioning or sliding a transect, each subsequent transect should be located using the original spacing between transects. For example, a reach that is 180 m long should have all transects spaced at least 30 m apart. If you need to slide transect 6 ten meters downstream due to one of the situations below, you will then measure 30 m down the thalweg from the shifted transect 6 location to determine the location of transect 7. Situations in which a transect may need to be repositioned include:

- If a transect location falls immediately upstream from a sharp, 90˚ bend in the channel and valley axis, causing the transect to run parallel to the channel and valley.
- If a transect location intersects a tributary, and as a result the transect extends up a side canyon instead of intersecting an upland terrace or colluvial surface of the main stream.
- If crew safety is endangered by a permanent, fast-flowing deep section of river or other safety concern.

Any time a transect is repositioned during reach establishment, record the distance that the transect was shifted and the reasons for doing this in the reach establishment comments. You will also need this information to calculate the actual reach length (in this case of the example above, it would be 190 m). Be sure to record this on the data sheet.

Setting up long transects and/or transects through thick brush
On many occasions, it may not be possible to align the headpins and transect center from a vantage point in the channel. One crew member may be able to direct the others by going to a higher vantage point (e.g., on top of a bedrock rim). In cases where it is impossible to see the entire transect by any means, use a compass to proceed at the proper bearing, leap-frogging with crew members in visible positions until you reach the headpin. It is helpful in these situations to tie flagging tape to properly aligned vegetation as you go.

2. Setting up transects

Relocating the transects

A. Use the site description, topographic maps, GPSed coordinates and routes, and photos to navigate to the reach.

B. Use a GPS, witness trees, azimuths, reference photos, and a metal detector to locate the transect headpins.
   - If the headpin is missing, use the information provided by the sources above to relocate the headpin as accurately as possible. Whenever possible, missing headpins will be relocated ahead of time using surveying equipment.

- If the headpin location is no longer available or has become unstable (e.g., active erosion zone, tree fall, etc.), establish a new headpin location along the same azimuth as the previous headpin. Use the guidelines in Section 1.2 above to select a headpin location.
- If a headpin has moved, remove and relocate witness tree markers as needed.
- Document the new headpin using the guidelines in Section 1.2 above.

C. Place a pin flag or flagging at the headpins and mid-stream of each transect.

Setting up a transect

A. Check the data sheet to see where the headpins are located relative to the transect ends.

B. Have one person stand at each headpin location. On transects with thick vegetation, additional people may be needed to stand in line with the headpins to provide an accurate line of sight.

C. Drive a piece of rebar into the ground at each transect end point.
   - If the headpin is located at the transect end point, place the temporary rebar behind the headpin.
   - Leave adequate space above ground on the temporary rebar for attaching the tagline and/or transect tape.
   - Use the recorded azimuth to make sure the temporary rebar is in line with the permanent transect.

D. Attach the Kevlar tagline and/or the transect tape to the temporary rebar on river right. Remember that river right and left are determined while facing downstream.
   - Attach the tagline so that one of the marked meters falls over the permanent headpin.
   - Use a chaining pin to align the transect tape such that the 0 m mark falls over the permanent headpin.
   - Do not attach the tagline or transect tape to the permanent headpins, as this may cause the headpins to move.

E. Run the tagline and/or transect tape from river right to river left.
   - To avoid trampling vegetation sampling areas, walk on the downstream side of the transect whenever possible.
   - Keep the tagline and/or transect tape as straight as possible, both vertically and horizontally. Thread through vegetation as necessary.

F. Tighten the tagline and/or transect tape.

G. Adjust the tagline and/or transect tape as needed.
   - Whenever possible, the line should not rest against any tree trunks or other obstacles such as boulders or debris (Figure 3).

- Obstructing branches can be moved or tied back with flagging.

H. Attach the tagline and/or transect tape to the temporary rebar on river left.

I. If using both a tagline and a transect tape, run the tagline first, make any necessary adjustments, and then run the transect tape. Take up any slack in the tape by tying it to the tagline with flagging at regular intervals. This step is especially important in windy conditions.

J. On a revisit, check the length of the transect at establishment to make sure you are within 0.5 m of the original length.
   - Small changes in transect length occur over time due to changing vegetation and geomorphology along the transect. It is highly unlikely that any of the headpins have been moved when there are small changes in transect length.
   - If the difference in transect length is more than 0.5 m, check to make sure that the tagline/transect tape is straight and aligned correctly with the headpins, especially in cases where headpins are not located at transect end points. If this and any additional troubleshooting does not resolve the issue, record the new transect length and document the issue in the visit comments. Do not move the headpin.

K. Begin sampling. Use the Visit Comments section of the data sheet to record any general comments relevant to the current monitoring visit.

Transect end point located on bedrock

If a transect end point is located on bedrock, you will not be able to place the temporary rebar at the transect end. Place the temporary rebar as close to the transect end as possible, and secure the tagline and/or transect tape to this point following the instructions above. To sample the transect beyond the temporary rebar, you will need to extend the transect tape using other methods. If possible, use a rock cairn to hold the transect tape in place. If this is not possible, have a crew member hold the transect tape in place while you are sampling.

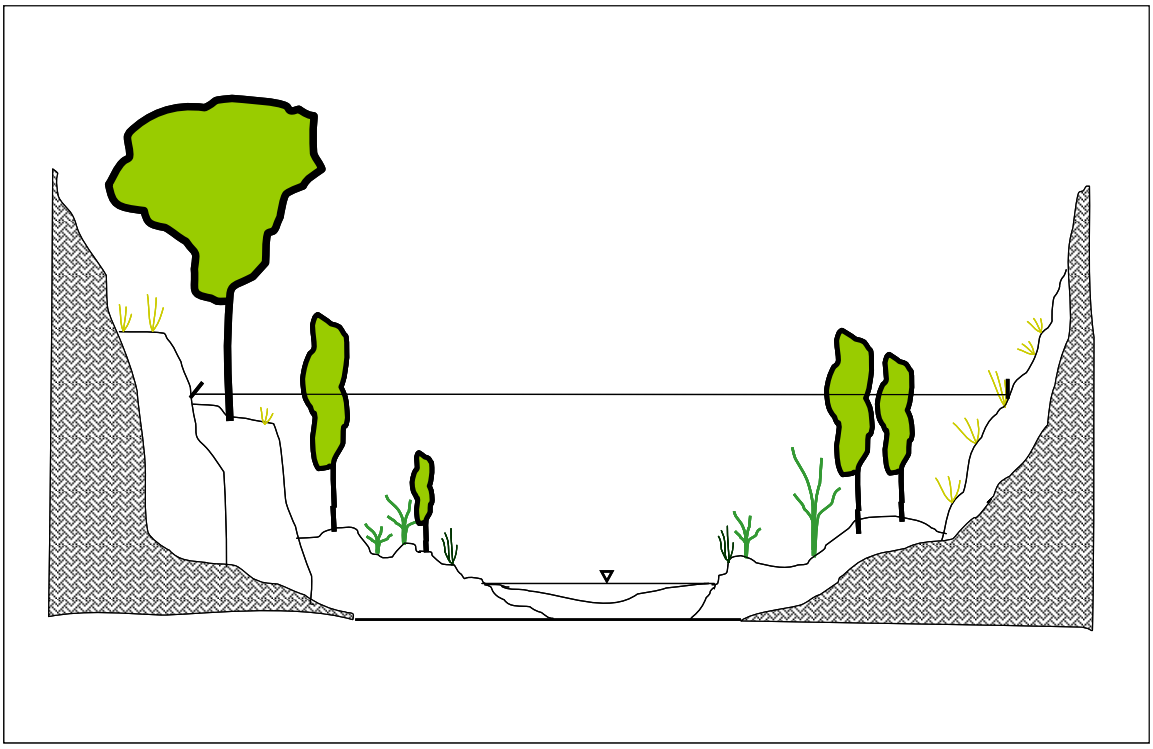


Figure 3. Diagram of Kevlar tagline established between two rebar headpins. Always establish taglines as taut as possible. If the line runs through vegetation, make sure that branches do not cause the line to bend. Vertical elevations are exaggerated in this diagram.

References

Montgomery, D.R. and J.M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Report prepared for the SHAMW committee of the Washington State Timer/ Fish/ Wildlife Agreement. Report TFW-SH10-93-002.

Reach Establishment

Data entered by: Data verified by: p.1

NCPN Riparian Monitoring

Park Code: _____ Stream Name: _____ Reach ID: _____ Accept Reject

Observers: _____ Date: _____

Rejection criteria (circle appropriate):
>25% confined
>25% different stream types
>25% spring-influenced
major tributary present
archeological site present
other (describe):

Centroid UTMs: Datum: _____ Zone _____ _____ N _____ E

Active Riparian Zone Width (m): _____ _____ _____ _____ _____

Average Reach Width (m): _____ x 6 = Est. Reach Length: _____ Min. 180m Max. 360m

% Valley Setting: Confined colluvial _____% Confined bedrock _____% Confined alluvial _____% Unconfined alluvial _____%

% Stream Type: Perennial _____% Intermittent _____% Ephemeral _____%

Actual Reach Length: _____

Reach Establishment Comments:

Directions to Reach:

Visit Comments:

Reach Establishment

Data entered by: Data verified by: p.2

NCPN Riparian Monitoring

Headpin Coordinates

Compass declination _____

Headpin	Right			Left			Transect Length (m)	Bearing (R to L)
	Easting	Northing	Location (m)	Easting	Northing	Location (m)		
T1 (upstream)								
T2								
T3								
T4								
T5								
T6								
T7 (downstream)								

Transect End Point Coordinates

Transect	Right		Left	
	Easting	Northing	Easting	Northing
1				
2				
3				
4				
5				
6				
7				

Establish transects from downstream (7) to upstream (1) and from right (R) to left (L) when facing downstream.

Witness Trees

Monu-ment*	Tag #	Species	DBH (cm)	Bearing (°)	Distance to rebar (m)

*Include the transect number, river right or left, and a letter to identify witness trees (e.g., T1-Ra, T1-Rb, T1-Rc, T1-La, etc.)

Example Data Sheet:

Reach Establishment

Data entered by: A. Jones Data verified by: C. Whitford p.1

NCPN Riparian Monitoring

Park Code: ARCH Stream Name: Courthouse Wash Reach ID: C-03 (Accept) Reject

Observers: A. Jones, C. Whitford, S. Smith, K. Spears Date: 6/5/2013

Rejection criteria (circle appropriate):
- >25% confined
- >25% different stream types
- >25% spring-influenced
- major tributary present
- archeological site present
- other (describe):

Centroid UTMs: Datum: NAD83 Zone 12 4274199.99 N 623324.80 E

Active Riparian Zone Width (m): 20 25 24 37 32 = 138

Average Reach Width (m): 28 x 6 = Est. Reach Length: 168 (Min. 180m) Max. 360m

% Valley Setting: Confined colluvial ____% Confined bedrock 5 % Confined alluvial ____% Unconfined alluvial 95 %

% Stream Type: Perennial ____% Intermittent 100 % Ephemeral ____%

Actual Reach Length: 192 m

Reach Establishment Comments: T1 was slid 10 m upstream because of a tributary on river right & safety concerns where the transect would be (i.e., a steep colluvial slope).

Directions to Reach:
Park at the Courthouse Wash trailhead on Hwy. 191. Walk south on the paved bike path to the Courthouse Wash trail. Follow the trail for about 50m then head west towards the wash.

Visit Comments:
- There are many slash piles throughout the reach (Elaegnus angustifolia & Tamarix sp.) from exotic plant removal crews. They were recorded as "other" disturbance in Point-Intercept. Beware of thorns hiding in grassy areas.
- Beware of biting ants near large Populus fremontii trees and litter near T1L.

Example Data Sheet:

Reach Establishment

Data entered by: A. Jones Data verified by: C. Whitford p.2

NCPN Riparian Monitoring

Headpin Coordinates

Compass declination 11°

Headpin	Right			Left			Transect Length (m)	Bearing (R to L)
	Easting	Northing	Location (m)	Easting	Northing	Location (m)		
T1 (upstream)	623385.54	4274276.83	0	623384.87	4274246.73	30.1	30.1	182°
T2	623336.97	4274257.33	0	623353.28	4274239.71	24.0	24.0	140°
T3	623321.32	4274227.20	0	623345.58	4274220.94	25.2	25.2	104°
T4	623305.70	4274199.14	0	623343.10	4274189.81	38.5	38.5	104°
T5	623298.79	4274174.02	0	623340.20	4274165.06	42.4	42.4	104°
T6	623291.06	4274143.24	0	623336.35	4274141.95	29.3	45.3	91°
T7 (downstream)	623297.83	4274112.46	0	623333.20	4274113.42	35.4	35.4	89°

Transect End Point Coordinates

Transect	Right		Left	
	Easting	Northing	Easting	Northing
1	623385.54	4274276.83	623384.87	4274246.73
2	623336.97	4274257.33	623353.28	4274239.71
3	623321.32	4274227.20	623345.58	4274220.94
4	623305.70	4274199.14	623343.10	4274189.81
5	623298.79	4274174.02	623340.20	4274165.06
6	623291.06	4274143.24	623336.35	4274141.95
7	623297.83	4274112.46	623333.20	4274113.42

Establish transects from downstream (7) to upstream (1) and from right (R) to left (L) when facing downstream.

Witness Trees

Monu-ment*	Tag #	Species	DBH (cm)	Bearing (°)	Distance to rebar (m)

None

*Include the transect number, river right or left, and a letter to identify witness trees (e.g., T1-Ra, T1-Rb, T1-Rc, T1-La, etc.)

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 5

Repeat Photos

Version 1.05 (August 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	11/2011	D. Witwicki & K. Lund	Clarify wording; improve data sheet	Confusion between headpins and transect end points	1.01
1.01	5/2013	R. Weissinger, K. Lund, D. Witwicki	Clarify wording; add example data sheet	Response to protocol review	1.02
1.02	11/2013	D. Witwicki	Instructions for mid-channel photo when location is not obvious	Needed clarification for consistent location	1.03
1.03	4/2015	D. Witwicki & K. Lund	Added reach overview photos and figures of example photos, revised data sheets	Needed better documentation of changes in channel and throughout reach, protocol clarification	1.04
1.04	8/2016	D. Witwicki	For reference photos, changed "Photo taken from" to "Direction facing"	Crew finds it more intuitive to record direction that photo was taken than the location of the photographer	1.05

This SOP provides instructions for taking photos at each reach. Repeat photos are taken from each transect end point and from the middle of the channel on each transect during vegetation sampling. Overview photos of the reach are taken during vegetation sampling and may be repeated at other times too. Reference photos taken during reach establishment (SOP #4) to document locations of headpins, unmonumented transect ends, reach overview photo points, and survey control points are also recorded on the photo data sheet.

Fill out the top of each data sheet:

Park Code – The four letter park code
Reach ID – The reach ID number
Date – Use the format mm/dd/yyyy
Camera date/time checked? – Make sure that the date and time displayed by the camera are accurate. Make any corrections as needed then check the box.

All photos are taken using a digital camera. Follow the guidelines below to ensure that your photos are the highest quality possible and that the Digital File Name is recorded correctly.

A. Check the quality of each photo by setting the camera to "play" mode to view the photo. If the photo is blurry or otherwise not acceptable, delete it and take another one.

B. If a chalkboard is being used (transect and reference photos), make sure it is legible in the photo.

C. Record the Digital File Name using the following procedures:

   a. While the camera is in "play" mode, you will be able to view the number assigned to the photo. *Do not record this number.* This number changes when the photos are downloaded from the camera. Instead, use the following instructions to record the digital file name on the data sheet.
   b. The last 4 digits of the number displayed on the camera (those following the dash) represent a unique photo number.
   c. The template for the number you will record is P*mdd9999*, where P = photos, *m* = month (Jan – Sept are coded 1-9, Oct = A, Nov = B, Dec = C); *dd* = day (01-31); and *9999* = the unique number of the photo. For example, photo 0300 taken on October 1 would be recorded as PA010300.

D. When recording the photographer, use the first initial and full last name.

1. Repeat Transect Photos

Take photos of each transect from both transect ends while the meter tape or tagline is stretched out along the transect. These photos are always taken from the transect end point and should not be moved for any reason (e.g., vegetation obstructing the view).

A. Label the chalkboard with the information below and place it near the transect end so that it will be visible in the photo.

   Site – Park code and Reach ID number (e.g., ZION P-01)
   Date – mm/dd/yyyy, e.g., 08/22/2010
   Transect # and side – photographer location **(**i.e., T1-L or T1-R; T = transect, L = river left, R = river right when facing downstream)

   If you are having difficulty propping up the chalkboard, use additional objects behind it rather than including field crew members or their body parts in the photos. You can also hang the chalkboard on vegetation.

B. Stand at a transect end, set the camera body on top of a fully extended laser monopod (1.5 m in height) and point the camera down the transect.

C. Orient the camera so that it is rotated 90˚ and takes a vertical format (portrait) photo.

D. Check to ensure that the chalkboard is visible at the bottom of the field of view and the tape or tagline is visible in the middle of the photo (Figure 1).

Figure 1. Example of repeat photo from the transect end.

E. Take a photo, and then check the quality using the guidelines above.

F. Record the digital file name, photographer, and location along the transect where the photo was taken on the Repeat Photos – Transect Ends & Mid-Channel section of the Photos data sheet. The location of the photo is recorded as 0 m on river right and as the location on the transect to the nearest 0.1 m on river left.

G. Repeat on the other transect end.

2. Repeat Mid-Channel Photos

Two repeat photos are taken from the middle of the channel along each transect. Because the chalkboard cannot be placed in these photos, always take the photo facing upstream first, followed by the photo facing downstream.

A. Determine the location of the mid-channel along the transect, and record this location to the nearest 0.1 m for both mid-channel photos on the Repeat Photos – Transect Ends &

Mid-Channel section of the Photos data sheet.

- For perennial streams, the mid-channel is the middle of flowing water.
- For intermittent or ephemeral streams with a single channel, take photos from the middle of the scoured channel area.
- For intermittent or ephemeral streams with braided channels or where the location of the main channel is otherwise unclear (e.g., upper Courthouse Wash), determine the main channel (i.e., typically the channel with the most water), and take the repeat photo from the middle of this channel.
    - On revisits, make sure take repeat photos in the same location as the previous visit. This information can be found on the revisit sheet.
    - If it becomes obvious that the main channel has switched locations, take photos at mid-channel of the new main channel in addition to the repeating photos at the mid-channel location from the previous visit.

B. Go to the location where you need to stand for the photo. Remember that the photo facing upstream is taken first.

- For the photo facing upstream, position yourself 3 m downstream from the tagline.
- For the photo facing downstream, position yourself 3 m upstream from the tagline.

Figure 2. Example of mid-channel photo facing upstream.

C. Set the camera body on top of a folding engineer ruler or monopod extended to 1.5 m high, and orient the camera so that it takes a horizontal format (landscape) photo.

D. Align the camera using the display (see Figure 2). Photos should be taken in the direction of the current channel with the tape included in the photo. These photos do not need to be taken perpendicular to the tape.

E. Take a photo, and then check the quality using the guidelines above.

F. Record the digital file name and photographer in the data sheet.

G. Repeat the procedure above to take the mid-channel photo facing downstream.

3. Repeat Reach Overview Photos

Photo points are established at one or more locations at each reach to get a better perspective of the entire reach. Whenever possible, at least one photo should be taken from a location that overlooks the reach, perhaps from a nearby vantage point or accessible canyon rim. These points are revisited to document change that occurs over time, so it is very important that the locations are described in detail so that they can be relocated in the future. At each photo point, one or more reach overview photos are taken. Chalkboards are not included in these photos.

Repeat photos are taken on revisits using detailed information recorded on the first visit and by matching photos from earlier visits as closely as possible.

Establishing photo points and reach overview photos

A. Select a location to establish a photo point. Ideally, this should be a location that overlooks the reach where you can view the reach in relation to the valley. The location should be relatively easy to find again (i.e., has distinctive permanent features). When choosing points, think about whether vegetation is likely to grow that would obscure the view.

B. If possible, mark the location of the photo point with a permanent monument such as a rebar or small “x” etched in bedrock. All permanent monuments must be cleared ahead of time with the park unit. Check to see what is permitted before you leave for the field.

C. Record the **Photo Point ID** on the Reach Overview – Photo Point Establishment section of the Photo Points data sheet using the code PP#, where # is the order of the photo points established at a reach (e.g., PP1, PP2).

D. Record the location of the photo point by taking a point on the **GPS**, and by recording the **UTMs (easting and northing**) on the data sheet.

E. **Describe the location** of the photo point in detail on the data sheet. Key in on site characteristics that are long-term in nature (e.g., rocks, large trees). Be VERY detailed if you cannot get a GPS reading, and mark the location of the photo point on map.

F. Take **reference photos** of the photo point to help you relocate it (see SOP #4 and section 4 below).

G. Determine the number of overview photos that will be taken from the photo point and the direction and orientation of each photo. Horizontal (landscape) or vertical (portrait)

photos may be used.

H. Record the **Photo ID** on the data sheet using the code O#, where # is the order of the overview photos established at a reach (e.g., O1, O2).

I. Set the appropriate declination on the compass so that it points to true north. Record the **bearing** of the photo in degrees.

J. If the photo is angled up or down more than 5°, record the **tilt angle** in degrees using a clinometer.

K. Record the **height** of the camera to the nearest centimeter.

L. Use observations during the field visit to **recommend times** to take photos. Full shade is ideal (e.g., shade from afternoon clouds), however, when this is not possible, take photos when the reach is in full sun and is not backlit. Shadows can make rematching photos more difficult.

M. Record any **additional comments** in the space provided.

Taking reach overview photos

A. Write down the **Camera name, Model, and ID number** that you will use to take the reach overview photos on the Reach Overview – Repeat Photos section of the Photo Points data sheet.

B. Note the **weather conditions**, including cloud cover and wind, that could affect photo interpretation and matching. Whenever possible, take photos when the entire reach is shaded by clouds.

C. **Take all of the reach overview photos** at a photo point (see Figure 3 for an example), and record information for each photo on the repeat photo section of the data sheet.

D. Record the **Photo Point ID** (i.e., PP1, PP2, etc.) and **Photo ID** (i.e., O1, O2, etc.).

E. Check to make sure the photo was taken at the **correct bearing, tilt angle,** and **height**, and check these boxes on the data sheet to show that these were matched.

F. Record the **digital file name, photographer,** and the **time** each photo was taken on the data sheet. Record any relevant **comments** as well.

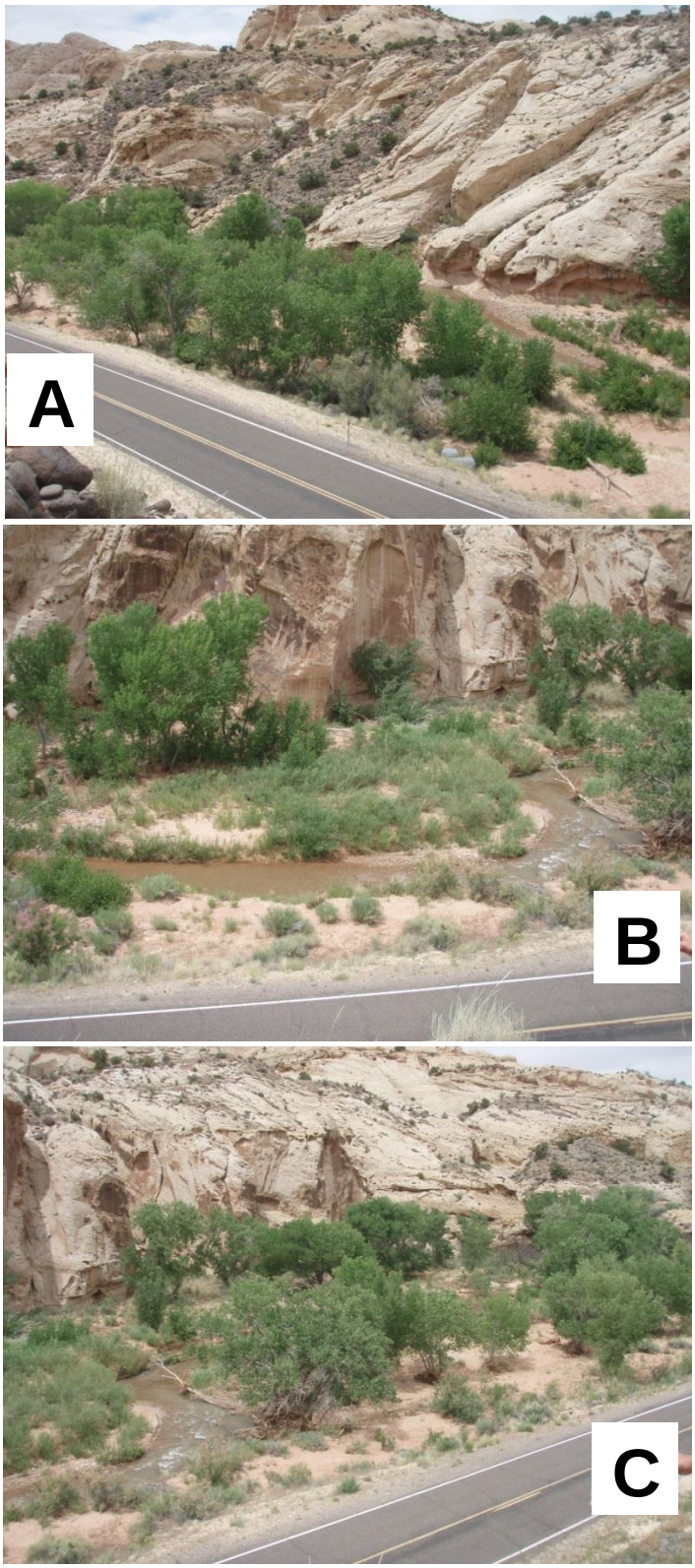


Figure 3. Three overview photos were taken from a single photo point to capture this entire reach: A) upstream end of reach, B) middle section of reach, and C) downstream end of reach.

Repeating reach overview photos:

A. Plan to take repeat photographs at the same time of year and, if possible, during the recommended time or at the same time of day as the original photos.

B. Use the GPS, site map, location description, and reference photos to accurately relocate each photo point.

C. During revisits, photos should be matched as closely as possible to photos from previous visits.
   - Bring overview photos from previous visits so that you can match up and repeat these as closely as possible. Attempt to include the same field of view.
   - Make sure that you are taking the photos from the same height and approximately the same bearing and tilt angle as the original photo.
   - Use the same camera orientation as the original photo (i.e., horizontal [landscape] or vertical [portrait]).

D. Record each repeat photo on the Reach Overview – Repeat Photos section of the Photo Points data sheet using the same name that was used for previous visits.

4. Reference Photos

Reference photos are taken during reach establishment to document the locations of headpins, unmonumented transects ends, reach overview photo points, and survey control points (see SOPs #4 and #9).

A. Include the cliff line, surrounding perennial vegetation, and/or other recognizable landmarks in the background to help the returning field crew relocate these points.

B. Clearly mark the location of the headpin, unmonumented transect end, photo point, or control point in relation to recognizable landmarks. This location should be marked by bright-colored pin flags, placed either in the soil at the point or held above the point where they will be visible in the photo. Unlike repeat photos, you may include anything in reference photos that may assist with re-locating the point (i.e., crew members, bright-colored flagging, etc.).

C. Label a chalkboard with the park code, reach code, Point ID, and any other helpful information (e.g., ZION, P-01, T3R, US). Place the chalkboard in a location where it will be easy to read in the photo.

D. Take as many reference photos as you need to relocate the point.

E. For each reference photo, record the following on the Reference Photos section of the Photos data sheet:

Type – Circle to indicate the type of reference photo: headpin (H), unmonumented transect end (U), reach overview photo point (PP), or control point (CP).
Point ID – Name of the point that you are taking a photo of (e.g., T1R, PP3, T5L-unmon, CP6).
Direction facing – Describe the direction that the photographer was facing when taking the photo (e.g., downstream). Remember that river right and left are determined while facing downstream.
Close up? – Check the box if this is a close up shot.
Replacement? – If this photo is replacing a previous reference photo, check this box.
Digital file name – Use the instructions in the first section of this SOP to record this.
Photographer – Use the instructions in the first section of this SOP to record this.
Comments – Record any relevant comments for the photo.

Other Photos

Crew members are encouraged to take other photos to document specific aspects of a reach or to provide scenic or field work photos for publications. On the Other Photos section of the Photos data sheet:

A. Circle the type of photo: animals, plants, cultural, scenic, disturbance, weather, field work, or other.

B. Record the digital file name, photographer, and any relevant comments.

Photos

Photos downloaded by: Data entered by: Data verified by:

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Park Code: **Reach ID:** **Date:** ► **Camera date / time checked?** ☐ ◄

Repeat Photos – Transect Ends & Mid-Channel

Transect	Direction	Digital file name	Photographer	Location (m)
1	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
2	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
3	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
4	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
5	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
6	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			
7	Right End			
	Facing Upstream			
	Facing Downstream			
	Left End			

Right & left transect ends- stand at transect end point
Mid-channel facing upstream- stand 3 m downstream tape
Mid-channel facing downstream - stand 3 m upstream of tape

PA010300
❶ ❷ ❸

❶ **Month:** Jan-Sep = 1-9, Oct -Dec = A - C
❷ **Day:** 01-31 ❸ 4-digit Camera Photo Sequence #

Comments:

Park Code: **Reach ID:** **Date:** **p. 2**

Reference Photos

Headpins (H), Unmonumented Transect Ends (U), Reach Overview Photo Points (PP) and Control Points (CP)

Type (circle)	**Point ID:** (T1R, PP1, T3L-unmon, CP6)	**Direction facing:** (e.g., DS)	**Close up?**	**Replacement?**	**Digital file name**	**Photo-grapher**	**Comments**
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
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H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							
H U PP CP							

US = upstream, DS = downstream

Other Photos

Type	Digital file name	Photographer	Comments
Animals Cultural Disturbance Field work Plants Scenic Weather Other			
Animals Cultural Disturbance Field work Plants Scenic Weather Other			
Animals Cultural Disturbance Field work Plants Scenic Weather Other			
Animals Cultural Disturbance Field work Plants Scenic Weather Other			

Photo Points

Photos downloaded by: Data entered by: Data verified by:

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Park Code: **Reach ID:** **Date:** **► Camera date / time checked? ☐ ◄**

Reach Overview - Photo Point Establishment

Photo Point ID: _____ **UTMs- Easting:** _____ **Northing:** _____
Location description:

Photo ID (O1, O2,…)	**Bearing** (degrees)	**Tilt angle** (degrees)	**Height** (cm)	**Recommended time**	**Comments**

Photo Point ID: _____ **UTMs- Easting:** _____ **Northing:** _____
Location description:

Photo ID (O1, O2,…)	**Bearing** (degrees)	**Tilt angle** (degrees)	**Height** (cm)	**Recommended time**	**Comments**

Photo Points

Photos downloaded by: Data entered by: Data verified by:

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Park Code: **Reach ID:** **Date:** ► **Camera date / time checked?** ☐ ◄

Reach Overview - Repeat Photos **Camera name, model, and ID:** **Weather:**

Photo Point ID (PP1, PP2…)	Photo ID (O1, O2…)	Matched?			Time	Digital file name	Photographer	Comments
		Height	Bearing	Tilt angle				

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #6

Measuring Vegetation

Version 1.17 (January 2021)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	11/2008	R. Weissinger	Remove 1-m belt and take density measures in 5-m belt; do not sample trees beyond the headpins; do not record geomorphic surface	Simplify sampling; not connected to active riparian zone; measure not repeatable between observers	1.01
1.01	4/2010	R. Weissinger	Added crown health class 6 and instructions; discontinue shrub line intercept sampling	Standardize with upland methods; redundant with point-intercept	1.02
1.02	1/2011	R. Weissinger	Added densitometer for measuring tall canopy; added species richness; deleted exotic density and added exotic frequency; changed diameter for reach census from 15 to 25 cm dbh	Tall shrub layer not captured by laser; detect more rare species; increase repeatability and detect annuals; too many small trees in the reach census	1.03
1.03	1/2012	K. Lund, D. Witwicki	Clarify when to record full species name; improve instructions for greenline sampling; remove species richness	Only needed once per reach; difficult to determine location of greenline; no longer used	1.04
1.04	2/2012	D. Witwicki	Make sure no duplicate tree tag numbers at a plot		1.05
1.05	5/2013	R. Weissinger, D. Witwicki, K. Lund	Remove greenline sampling; minor word edits; clarification of methods and figures	Not a repeatable measure; response to protocol review	1.10
1.10	5/2014	D. Witwicki, K. Lund	Clarify how to sample with laser and densitometer and record other disturbances	Needed additional clarification	1.11
1.11	6/2014	D. Witwicki, K. Lund	Add live/dead to 5-m belt data sheet	Needed additional clarification	1.12
1.12	4/2015	D. Witwicki, K. Lund	Clarify instructions for flood-trained or traumatized trees. Add fine print to data sheets. Clarified definition of	Needed additional clarification. Needed reminders on data sheets. Unclear which to call at 2.5 cm.	1.13

			litter and woody debris. Added photo of *Populus* cotyledons.	Example photo would be helpful.	
1.13	8/2016	D. Witwicki	Clarified wording on spherical densiometer figure		1.14
1.14	3/2018	D. Witwicki	Updated Fig. 1. Improved quality of text in figures 3, 5, and 6	For publication	1.15
1.15	3/2019	D. Witwicki	Changed > to ≥ for DBH of reach census trees in tree density section	Correction	1.16
1.16	1/2021	L. Gommermann	Removed cotyledons from 5-m belt seedling count	Change in protocol	1.17

This SOP describes methods used to conduct vegetation sampling in a reach. NCPN vegetation sampling includes *cover* of dominant species along cross-section transects, *frequency* of exotic plant species in 1-m^2 quadrats, canopy closure, *density* of tree species by diameter in a 5-m belt, and a census of all large diameter trees (≥25 cm at breast height) in the reach (Figure 1). A list of necessary equipment for these procedures can be found in SOP #1.

A two-person team comprised of a data recorder and an observer skilled in plant identification can efficiently complete the tasks described below. Generally, it will be easiest to record point-intercept data first, then record exotic frequency and canopy closure as you walk back along the transect. It is important to record understory measures first as they are susceptible to trampling impacts. In dense vegetation, tree density measures in the 5-m belt may require two passes along the transect.

For all vegetation sampling, record the full Latin name of each species the first time it is encountered at a reach. Any additional times the species is encountered, use the six-letter code composed of the first three letters of the genus and specific epithet.

1. Point-Intercept Cover

Point-intercept sampling is used to sample vegetation on seven cross-section transects of varying length at a 0.5 m intervals.

1.1 Cross-section transects

Fill out the top of the data sheet including:

Park Code: Use the standard 4-letter code to indicate the park unit.
Reach ID: A pre-assigned, unique code provided for each stream reach.
Transect #: 1-7, upstream to downstream.
Observer: Record the initials of the person calling out the intercept data.
Recorder: Record the initials of the person recording the data.
Date: Use the format mm/dd/yyyy

Record point-intercept data for understory species and tall shrubs.

A. Stand on the downstream side of the transect and work from river right to river left. River right and river left are determined while looking downstream.

B. Start at 0.5 m on the tape and move forward 0.5 m for each consecutive point. The final point sampled is the last half meter interval before the transect end point.

C. If there is a shrub canopy layer taller than 1.5 m from the ground surface, use a densitometer to sample the top canopy layer.

a) Position a fully extended monopod (1.5 m tall) on the downstream side of the tape at the correct point. Extend the laser out perpendicular to the tape so that you are sampling on the upstream side.
b) Use the bubble on the monopod to level the laser.
c) Position the densitometer on the monopod just above the laser.
d) Use the bubbles inside the densitometer to level it in both directions.
e) With both the monopod and the densitometer leveled, determine what species of vegetation, if any, is located at the crosshairs of the densitometer.
f) Record the species in the top canopy on your data sheet (see section F below).

Tree species taller than 1.5 m from the ground surface are not recorded with the densitometer. Trees are only recorded when hit by the laser at a height of under 1.5 m.

D. Sample vegetation less than 1.5 m tall and the ground surface.

a) Position the monopod on the downstream side of the tape at the correct point. Extend the laser out perpendicular to the tape so that you are sampling on the upstream side.
b) Use the bubble on the monopod to level the laser. With the laser leveled, push the button to sample the point. **Be careful not to point the laser at anyone's eyes. It can cause serious damage.**

E. Once you have recorded a hit, move the uppermost vegetation away so that you can take subsequent hits for lower canopy and surface layers. If it is difficult to keep the monopod level and record hits, have one person hold the monopod level while a second person reads and records hits. On a windy day, it is important to turn the laser on for just a second to record a hit.

F. With the laser leveled, record every plant species it intercepts. Record each canopy species no more than twice, a maximum of one live hit and one dead hit, even if it is intercepted several times. Record the following information for each point:

1. **Top Canopy** - Record the species of the top plant intercepted in the "Top canopy" column (Figure 2). The top canopy may be a species intercepted by the densitometer or the laser. If a plant cannot be identified to species, follow the instructions below to name and collect a specimen. If a plant is not intercepted,

leave this column blank. After the species code, write "-D" if the part of the plant intercepted by the laser is dead.

2. **Lower canopy layers** - From the top canopy species, move down the laser and record species intercepted in the order that they occur. Use the "Lower canopy" columns (Figure 2) to record all additional species intercepted by the laser. Record the plant as dead following the guidelines above. You may also intercept litter and woody debris, but it must be elevated above the soil surface to be considered a lower canopy layer (Table 1). If you hit more than two lower canopy layers, be sure to record them on the back of the data sheet under "Additional canopy layers". If you do not encounter lower canopy layers leave these columns blank.

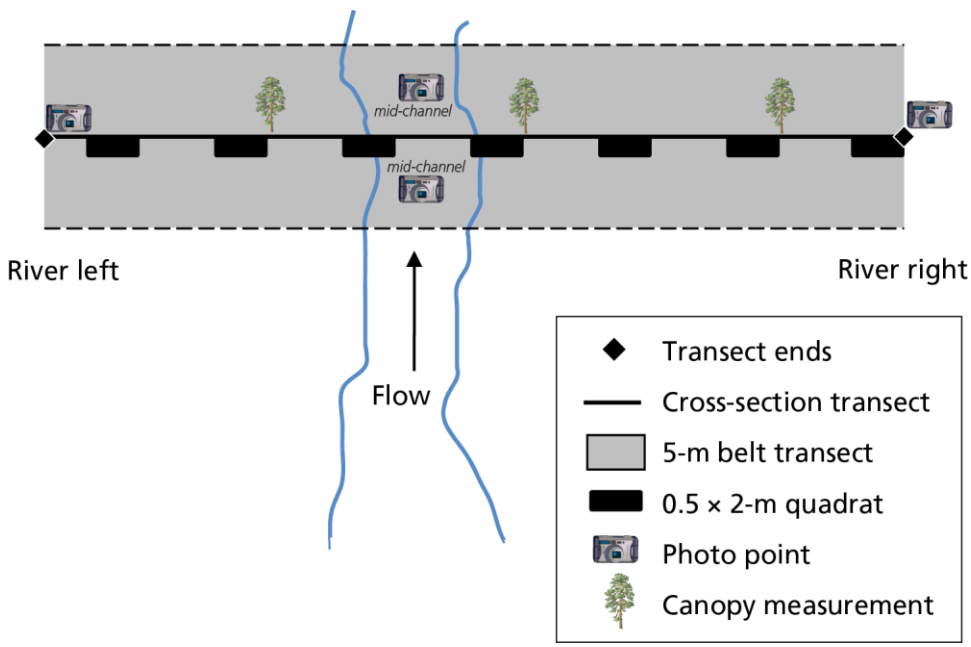
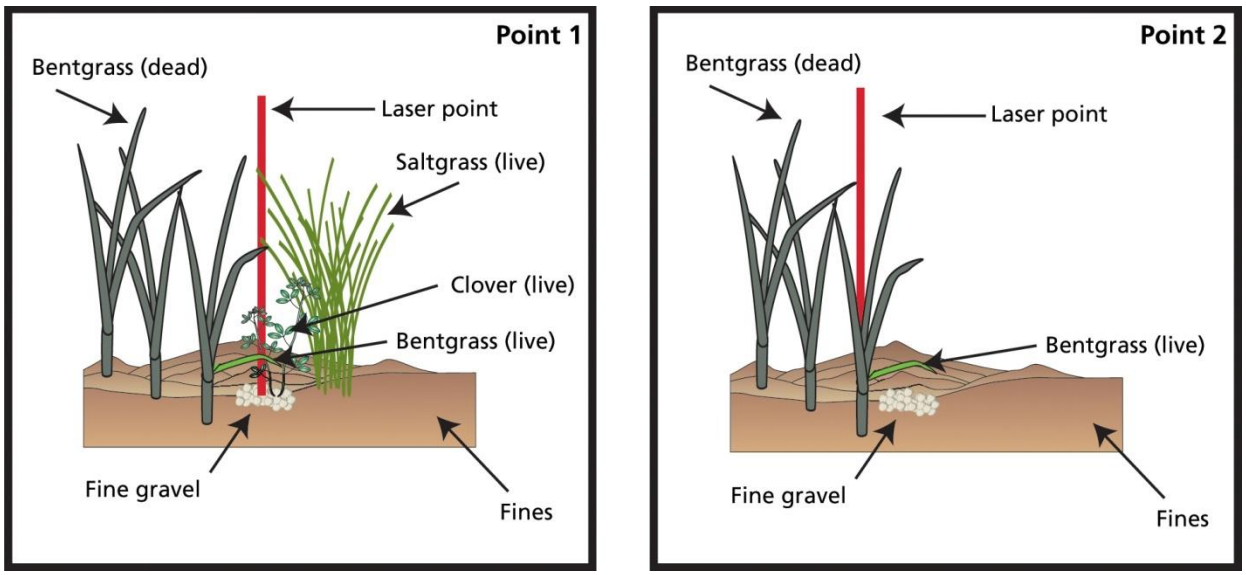


Figure 1. Locations of vegetation sampling along each permanent cross-section transect. Understory vegetation is sampled using a point-intercept method at 0.5 m intervals along the cross-section. Canopy closure is sampled at 10 m intervals on the cross-section. Seedling, sapling, and overstory tree density is recorded in a 5-m belt transect, and exotic plant frequency is sampled in 0.5 m x 2-m quadrats. A census of large diameter trees occurs at the reach scale.



Point	Top canopy	Lower canopy		Soil surface	Disturb.
		1	2		
1	disspi	agrsto - D	meloff	GF	
2	agrsto - D	L		agrsto	
3	bacsal - D	poapra	L	F	ant
etc.					

Additional canopy layers

Point	Lower Canopy		
	3	4	5
1	agrsto		

Figure 2. Point-intercept cover along a transect and sample data sheet. Points 1 and 2 show the first two points on a transect. In Point 1, the laser is touching saltgrass (*Distichlis spicata*), dead bentgrass (*Agrostis stolonifera*), clover (*Melilotus officinalis*), live bentgrass, and fine gravel. Record bentgrass twice for one dead and one live intercept. Notice that additional canopy hits are recorded in the "Additional canopy layers" section on the back of the data sheet. In Point 2, the laser touches dead bentgrass, then touches litter, and finally the bentgrass plant base. The sample data sheet above shows how to record these two points on the data sheet. Notice that all plants are recorded using six-character abbreviations. (Adapted from Herrick et al. 2005)

Table 1. Abbreviations and definitions of litter and woody debris as lower canopy layer classes for point-intercept sampling.

Code	Lower canopy cover type	Definition
L	Litter	Detached dead plant material that is less than 2.5 cm in diameter and elevated above the soil surface
WD	Woody debris	Detached woody plant material that is 2.5 cm or greater in diameter and elevated above the soil surface

3. **Surface Features** - In the "Surface" column record whether the laser intercepts a plant base (Figure 3) or a surface feature (see Figure 2). Use the abbreviations of surface features defined in Table 2 to record all other surface features.

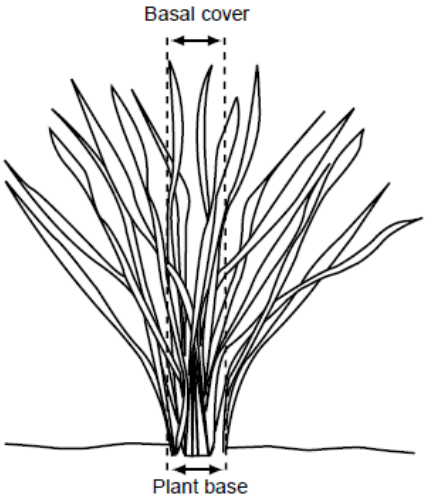


Figure 3. Area defined as plant base and included as basal cover (from Herrick et al. 2005).

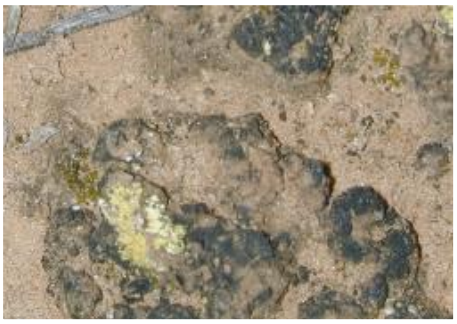


Figure 4. Photos of biological soil crust (from Belnap et al. 2008). Dark areas in the upper photo are dark cyanobacteria. The lower photo includes substantial areas of lichen (yellow and black areas) and moss (green areas) in addition to dark cyanobacteria.

Table 2. Abbreviations and definitions of surface feature classes for point-intercept sampling.

Code	Surface Feature	Definition
F	Fines	Loose mineral particles 0-2 mm in diameter
GF	Gravel, Fine	Particles >2-16 mm in size; ant to beetle-sized
GC	Gravel, Coarse	Particles >16-64 mm in size; beetle to baseball-sized
CB	Cobble	Particles >64-256 mm in size; baseball to basketball-sized
BL	Boulder	>256 mm in size; larger than a basketball
BR	Bedrock	Exposed bedrock
WA	Water	Flowing or pooled water
BSC	Biological soil crust	Biological soil crust composed of dark cyanobacteria, lichen, and/or moss (see Figure 4)
L	Litter	Detached dead plant material less that is than 2.5 cm in diameter
WD	Woody debris	Detached woody plant material that is 2.5 cm or greater in diameter and is in direct contact with soil
SL	Scat, livestock	Any type of livestock scat
SW	Scat, wildlife	Any type of wildlife scat

4. **Disturbance -** Record whether the laser intercepts a disturbance on the soil surface in the "Disturb." column (Figure 2). Use abbreviations from Table 3 to label the type of disturbance. Leave this column blank if there is no disturbance.

Table 3. Abbreviations and definitions of soil-surface disturbance classes for point-intercept sampling.

Code	Disturbance type	Definition
Ant	Ant mound	Holes and mounds created by ants
Bike	Bicycle	Disturbances caused by non-motorized bicycles
Trail	Tracks and trails	Defined tracks or trails from wildlife, livestock, or humans
Camp	Campsite	Bare ground or other disturbances caused by camping
Auto	Motor vehicle	Disturbances caused by any motorized vehicle, including two tracks and roads
Flood	Recent flooding	Recent flooding indicated by flattened vegetation, mud, and debris lines
Other	Other	Any other disturbance, such as beaver activity, old slash piles from exotic plant removal, etc. Make a note in the visit comments with the specifics of what you encountered.

1.1.1 Unknown Plants

Sometimes it may be difficult or impossible to determine the specific identity of individual plants encountered during sampling. Crews may be unfamiliar with a plant or unable to distinguish one species from other similar species at the time of sampling. Before sampling, review previously collected unknown species from the stream and use existing unknown names whenever possible.

When an unknown plant is encountered

A. Search the immediate area surrounding the point or transect, looking for specimens of the unknown plant that are more readily identifiable (i.e., due to the presence of flowers or fruits from current or previous seasons).

B. If an identifiable specimen cannot be found, create a unique name using the following code: unk + 4 letter park code + reach number + your initials + collection number for the reach (e.g., unkZION-P1-ST1). Record this code in the appropriate column on your vegetation sampling data sheet instead of the species name.

C. Take a photograph of the unknown plant.

D. As you proceed through the reach, continue to attempt to find identifiable specimens of unknowns.

E. It is permissible to identify a plant only to the genus level if no identifiable parts are present for keying, or if hybridization makes species delineation difficult. Record the full Latin name of the genus followed by "sp." (e.g., *Opuntia* sp., *Tamarix* sp., etc.).

Collecting unknown plants

Once it has become apparent that no identifiable plants can be found or that a plant with identifiable features cannot be keyed out in the field, a collection of the plant should be made.

A. Collect specimens from outside of the monitoring transects whenever possible.

B. Attempt to collect as many identifiable parts as possible, including flowers, fruits, leaves, and roots. It is especially important to collect roots of forbs and grasses. You may need to collect from more than one plant to achieve this goal.

C. If you must collect from inside a monitoring reach, remove only a minimal amount of plant material. Do not remove roots of perennial species that are collected within the transect.

D. Wrap a piece of masking tape around the plant and use a fine-point permanent marker to label it with the unknown species code.

E. Carefully place the specimen inside a resealable plastic bag labeled with the reach number, unknown species code, date, and collector.

F. Place the sample in your backpack and in a shady spot until you get back to camp. Attempt to identify the plants when you return to camp.

G. If the specimen cannot be identified right away but can still be identified within one week, preserve the bag in a cooler as soon as possible. Make sure the specimen does not get wet. If a cooler is not available or if plant identification will occur after one week, place the plant between two sheets of newspaper and store it in a press.

H. Fill out an unknown species data sheet for each specimen. It is especially important to fill out data sheets for specimens that do not have identifiable characteristics in this sampling year, but may be identified in future years.

Data sheets

When filling out the data sheet, give a detailed description of each characteristic. This allows greater potential for future identification when crews return to the site. Fill in the top of the data sheet and record the following information:

- **Unknown Code:** unk + 4 letter park code + reach number + your initials + collection number for the reach (e.g. unkZIONP01-ST1).
- **Plant Type and General Description:** Circle the appropriate categories and provide a succinct description of the overall appearance (e.g., tiny *Eleocharis*).
- **Most Salient Feature:** A unique characteristic that identifies the plant from others.
- **Leaf Characteristics (optional):** Describe the leaf type, leaf margin, leaf surface, petiole, etc.
- **Stem Characteristics (optional):** Describe the shape, pubescence, markings, and color of the stem, as well as the bud characteristics.
- **Flower Characteristics (optional):** Describe the floral formula, location (axillary or terminal), habit (indeterminate or determinate), pubescence, and color.
- **Microhabitat Characteristics:** Describe the microhabitat in which it was found if unique in the reach (e.g., wash bottom, limestone outcrop, etc.).
- **Collected:** Circle yes or no, whether a specimen was collected.
- **Best Guess:** Preliminary guess about species in field.

Annotating data sheets

When updating data sheets with identified plants, draw a line through the unknown code and write in the correct species code in the nearest available space. Initial and date the change on the data sheet.

2. Exotic Plant Frequency

Record the presence of all exotic plant species rooted in 0.5-m x 2-m quadrats placed every 5 meters along each cross-section transect.

A. The quadrat is oriented so that the long end lies on the transect tape and the upstream side of the transect is sampled beginning at 0 m (Figure 1). Use engineering rulers to delineate the quadrat starting at the 0-m mark on the transect tape and ending on the 2-m mark.

B. Record each exotic plant species rooted in the quadrat. All live annual and perennial exotic plant species, or species that were alive earlier in the growing season, are recorded. For any plant rooted underneath the sampling frame, count ones that are rooted at least 50% within the quadrat.

C. Sample exotic plant frequency in quadrats beginning at 0 m, 5 m, 10 m, 15 m, and every 5 m thereafter for the entire length of the transect. Do not sample quadrats that start on the transect and extend beyond the transect end point.

3. Canopy Closure

Canopy closure is recorded every 10 m along the transect starting at the 5-m mark (i.e., 5, 15, 25 m, etc.) using a modified concave spherical densiometer.

A. Hold the densiometer 12” in front of you at elbow height with your elbows steadied against your torso. Level the densiometer using the bubble level. Position your body so that your forehead is visible at the top of the mirror as you take the reading (Figure 5).

B. Count the number of point intersections covered by live or dead vegetation above the V (maximum is 17). Do not count canyon walls or cutbanks.

C. Four measurements are made: (1) facing downstream, (2) facing the right bank, (3) facing upstream and, (4) facing the left bank. Keep the densiometer in the same place as you rotate it and yourself for each reading. It does not matter what order you take the readings.

Occasionally, you may not be able to take the measurement at one of the standard locations because a tree trunk is blocking that location. If this occurs, move down the transect 0.5 m (i.e., move to 5.5 m) until you can hold the densiometer in the correct location. Do not move the location of the densiometer along the transect for branch obstructions. You should be able to move the densiometer up or down a centimeter or so in order to take the measurement.

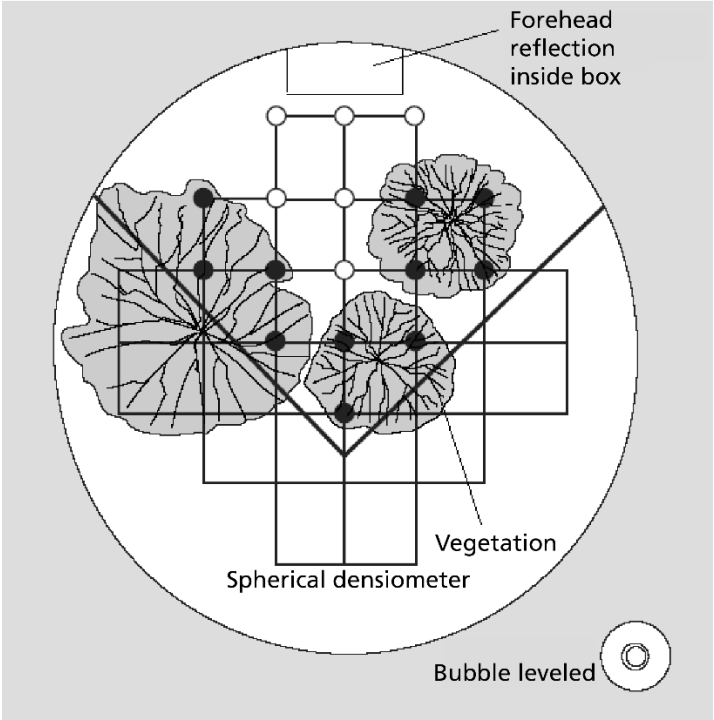


Figure 5. A modified concave spherical densiometer. Note the bubble level, the right angle marking the area sampled, and the 17 points of intersection. Closed circles represent line intersections where vegetation is present and consequently counted in measurement of canopy closure (example shows 11 out of 17 points) (from Fitzpatrick at el. 1998).

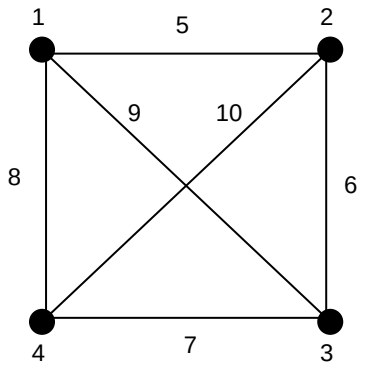
4. 5-m Belt

Tree density by size class is recorded in a 5-m belt that is centered on each cross-section transect (2.5-m upstream and 2.5-m downstream). Seedlings, saplings, and overstory trees are sampled simultaneously.

4.1 Seedling density

A. Use a 2.5 meter pole to determine the boundaries of the 5-m belt on each side of the cross-section transect.

B. Use a dot tally to record the density of all live exotic and native tree seedlings ≤1.37 m in height or ≤2.5 cm DBH. Do not include cotyledons from the current growing season. A dot tally is created by forming the following figure as you count stems:



C. Tree cotyledons are not counted in the 5-m belt. Cottonwood (*Populus* species) cotyledons are most commonly encountered (Figure 6). If observers choose to count cotyledons (cotyledons were included in seedling counts prior to 2021), they should note the cotyledon count for each transect in Visit Comments.

Figure 6. Cotyledons of *Populus* species. Look for the distinct shovel-shaped leaves.

D. *Tamarix* species and *Salix exigua* are not considered trees during this tally.

E. The goal of seedling density is to count discrete young individuals.
- Multiple "suckers" that originate from the same location and stump sprouts (including beaver-browsed stumps and/or traumatized trees broken off below DBH) are considered one seedling.
- If any of the suckers or stump sprouts are >2.5cm DBH, measure each one as a sapling and do not count any as seedlings.
- Do not count attached branches of larger trees, partially or completely covered by soil at the base, as seedlings.
- Do not count suckers originating from the exposed roots of a live tree.
- If live sprouts are arising from a dead-looking main trunk, measure only the main trunk and do not count any live sprouts as seedlings.

F. At sites with high densities, estimate density using the following categories: 100-250, 251-500, 501-1000, and >1000 individuals.

G. After completing a belt, add up the dot tally marks for each species and write in the numeric total in the "Total" row.

Sampling adjustment if two transects cross
If two transects cross, do not sample the lower numbered transect's belt area where it overlaps with the higher numbered transect. Note on the data sheet where tallying stops, and at what point it restarts if necessary. Use this rule for seedlings, saplings, and overstory trees in the 5-m belt.

4.2 Sapling and overstory tree density

Record DBH of live and dead saplings and mature trees >2.5 cm DBH in a 5-m belt.

A. Measure all individuals rooted more than 50% within the 5-m belt. If a tree is rooted near the belt transect boundary, use a tape or pole to measure the perpendicular distance between the tree and the transect line.

B. Record the tree species. Use "-D" to denote dead individuals. Record unknown species using the guidelines in Section 1 of this SOP.

C. Measure the diameter at breast height (DBH) of the stem or trunk using the guidelines below. Trees ≥25 cm DBH are also recorded in the reach census.

- If using the 15-cm plastic calipers, record to the nearest 0.5 cm.
- If using the DBH tape, record to the nearest 0.1 cm.
- Do not measure secondary stems that lean more than 45 degrees (these are considered branches).

Measuring DBH:

- Use the DBH tape to measure the diameter of the tree at 1.37 m above the ground surface (breast height; Figure 6A).
- If the tree is on a slope, stand on the uphill side of the tree to measure DBH (Figure 6B). If the ground surface on the uphill side of the tree is blocked by a debris pile, move around the tree to where you can determine the location of the ground surface and measure DBH there.

Using the DBH tape

1. Hook the end of the tape into the bark and run the tape around the trunk, ensuring that the tape is straight and pulled perpendicular to the axis of the trunk. Bowed tapes will give an overestimate of trunk diameter.

2. Wrap the tape tightly around the tree and read the number where the tape crosses the zero mark at the beginning (hook end) of the tape (see Figure 7).

3. Make sure that you are reading the correct side of the DBH tape. Often one side has standard centimeters and the other side has units calibrated to give the diameter in centimeters when wrapped around the circumference of the tree. Read the calibrated side of the tape.

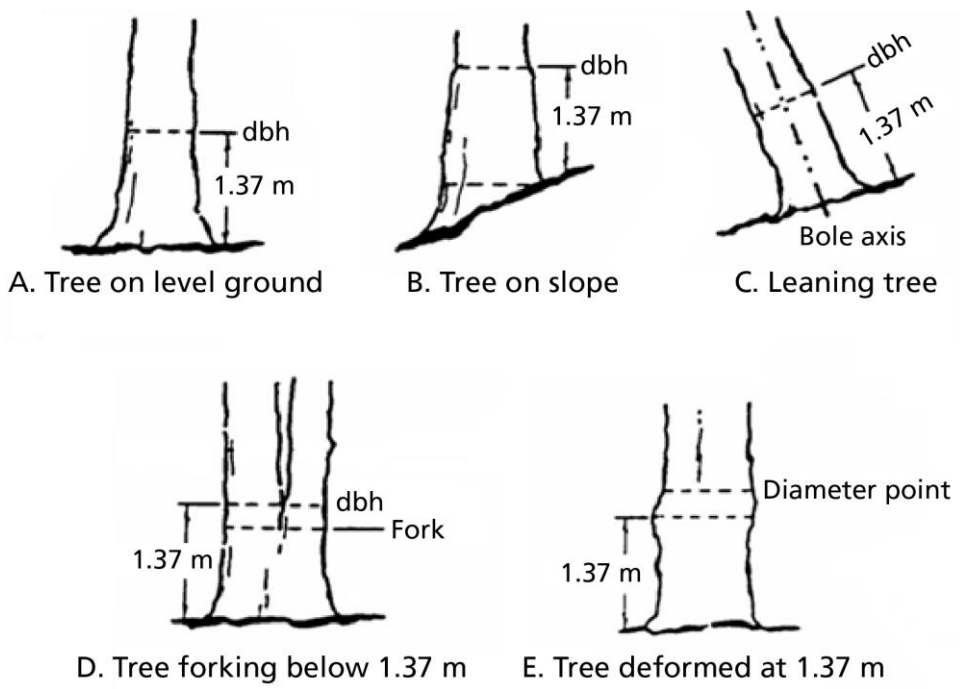


Figure 6. Locations of diameter at breast height (DBH) measurements for a variety of bole forms. DBH measurements will always be taken perpendicular to the bole axis as illustrated (modified from USDA Forest Service 2005).

Common stem irregularities (see Figure 6)

- *Trees missing bark or wood at breast height* - Record diameter of the wood and bark that is still attached to the tree.
- *Curved, leaning, or flood-trained trunks* - Find the point equivalent to breast-height (1.37 m) by measuring along the curvature of the bole on the upper surface of the main trunk. For flood-trained trees, count the main stem as live when there are live branches growing from it, even if the main stem looks dead (Figure 6C).

- *Trees that fork at breast height* - If forking influences DBH, the diameter should be measured below the fork.
- *Trees that fork below breast height* – Measure the DBH of each side of the fork (Figure 6D).
- *Trees with swellings, bumps, depressions, and branches at breast height* - Measure diameter immediately above the irregularity at the place it ceases to affect normal stem form (Figure 6E).

Figure 7. The proper method for securing a DBH tape.

5. Reach Census

All individuals of woody species within the reach with a DBH greater than or equal to 25 cm are tagged and measured. This includes large individuals of species that are considered shrubs in other parts of the protocol (e.g., *Tamarix* spp., *Salix exigua*, etc.).

A. Start at one end of the reach and work your way to the other end. It is often easiest to sample all of the woody species between two adjacent transects before taking down the tagline and setting up a new transect. The area sampled includes:

- the area between Transect 1 and Transect 7
- the active riparian zone and any surfaces in a direct line between the headpins.

B. Locate a woody species, hereafter referred to as tree, with a diameter at breast height of ≥25 cm.

C. If the tree is not tagged, affix a pre-numbered tag to the tree using a nail. *Make sure to attach a tag with a number that has not already been used at the plot*.

- When establishing a reach, tag trees in numeric order.
- When revisiting a reach, use tree tags from a different numeric series to add individuals to the census. For example, if tags 1-80 were used during establishment, use tags 100-199 during the subsequent visit for new trees.
- Align the nail so that it enters the tree at breast height (1.37 m). If the tree forks below breast height, both forks should be tagged.
- Drive the nail into the tree at an angle, so that the tag hangs down and away from the tree. Leave several centimeters of nail exposed so the tree has ample space for growth.

D. Record the tag number and species of the tree. If a tree is dead, write ("-D") after the species name. If the species is unknown, write UNKT-D.

E. Measure DBH using the notes in Section 4.2 of this SOP.

- Measure just above the nail.
- Measure to the nearest 0.1 cm, making sure to read the correct side of the DBH tape.
- Sometimes flooding will alter the ground surface so that the nail is no longer at breast height during a revisit. Leave the nail in its current location and measure diameter just above the nail.

F. Record Crown Health

Evaluate the density of each tree's crown in relation to crowns of the same species located in a similar position within the canopy, and from a similar habitat. Crown health codes are defined in Table 4 and listed at the bottom of the data sheet. Classes 1 through 4 refer to the estimated amount of the foliage that is intact, expressed as a percent. Class 5 is used to designate standing dead trees with an overall height greater than 1.37 meters that are still rooted to the ground.

Class 6 should only be used to record trees that were previously tagged and standing but have fallen down since the last reach visit. This class is used in order to not confuse fallen trees with missing data. After a tree has been recorded once as class 6, it does not need to be recorded on the data sheet on subsequent reach visits.

Standing dead trees whose diameters fall below 25 cm since the last reach visit (usually due to decay) should be recorded as class 5. A comment should also be included in the Notes/Conditions field explaining why a tree < 25 cm dbh was recorded on the data sheet. After a tree has been recorded once as class 5 and < 25 cm dbh, it does not need to be recorded on the data sheet in subsequent reach visits.

Table 4. Crown health classes for forest species

Crown Health Class	Description
1	90-100% live foliage
2	50-89% live foliage
3	16-49% live foliage
4	0.1 – 15% live foliage
5	standing dead
6	dead and down

G. Record Location

Record the location of the tree relative to the transects and/or headpins including river right or river left. For reaches with a high density of trees, you may also want to record the location of the tree in the GPS (see SOP #3 for further instructions) to help returning crews relocate them.

H. Record Conditions/Notes

Any significant damage to a living tree should be recorded. Scan each tree carefully for signs of damage, including but not limited to beaver browsing, recent fire scars, lighting strike scars, mistletoe infestation, bark beetles, cankers, stem decays, wood-boring insects, tent caterpillars, or broken or dead top.

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Point Intercept

Data entered by: Data verified by: p.1

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:** **Page _____ of _____**

Observer: **Recorder:** **Transect:** 1 2 3 4 5 6 7

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
0.5					
1					
1.5					
2					
2.5					
3					
3.5					
4					
4.5					
5					
5.5					
6					
6.5					
7					
7.5					
8					
8.5					
9					
9.5					
10					
10.5					
11					
11.5					
12					
12.5					

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
13					
13.5					
14					
14.5					
15					
15.5					
16					
16.5					
17					
17.5					
18					
18.5					
19					
19.5					
20					
20.5					
21					
21.5					
22					
22.5					
23					
23.5					
24					
24.5					
25					

Additional canopy layers can be added on other side

Top canopy
Species code*
Lower canopy layers
Species code*, litter (L), woody debris (WD)
Plant Status
*If part of plant touching laser is dead, write "-D" after species code.

Surface Feature
F = Fines
GF = Gravel, fine (ant to beetle)
GC = Gravel, coarse (beetle to baseball)
CB = Cobble (baseball to basketball)
BL = Boulder
BR = Bedrock

Surface Feature
WA = Water
BSC = Biological soil crust
L = Litter
WD = Woody debris
SL = Scat, livestock
SW = Scat, wildlife

Disturbance
Ant = Ant mound
Bike = Bicycle
Trail = Trail
Camp = Campsite
Auto = Motor vehicle
Flood = Recent flooding
Graze = Recent grazing
Oth = Other

Point Intercept p.2

Additional canopy layers

Point (m)	Lower Canopy		
	3	4	5

Point (m)	Lower Canopy		
	3	4	5

Point (m)	Top Canopy	Lower canopy		Soil surface	Disturb.
		1	2		
25.5					
26					
26.5					
27					
27.5					
28					
28.5					
29					
29.5					
30					
30.5					
31					
31.5					
32					
32.5					
33					
33.5					
34					
34.5					
35					
35.5					
36					
36.5					
37					
37.5					

Point (m)	Top Canopy	Lower canopy		Soil surface	Disturb.
		1	2		
38					
38.5					
39					
39.5					
40					
40.5					
41					
41.5					
42					
42.5					
43					
43.5					
44					
44.5					
45					
45.5					
46					
46.5					
47					
47.5					
48					
48.5					
49					
49.5					
50					

Canopy Closure and Exotic Frequency

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:**

Observer: **Recorder:** **Transect:** 1 2 3 4 5 6 7

Spherical Densiometer

5-m	_____	_____	_____	_____	35-m	_____	_____	_____	_____	65-m	_____	_____	_____	_____
15-m	_____	_____	_____	_____	45-m	_____	_____	_____	_____	75-m	_____	_____	_____	_____
25-m	_____	_____	_____	_____	55-m	_____	_____	_____	_____	85-m	_____	_____	_____	_____
										95-m	_____	_____	_____	_____

Exotic Frequency – Quadrats

- All live annual and perennial species, or species that were alive earlier in the growing season.
- Rooted at least 50% within the quadrat.

	Meter																			
Species	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95

5-m Belt Transect

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:**

Observer: **Recorder:** **Transect:** 1 2 3 4 5 6 7

Tree Seedlings (<1.37 m tall or ≤2.5 cm DBH) *live only*

Species	Tally	Total

Density Classes: 100-250, 251-500, 501-1000, >1000

Trees (>2.5 cm DBH) *live or dead*

Species	DBH

Trees (>2.5 cm DBH) *live or dead*

Species	DBH

Reach Census

Data entered by: Data verified by: Pg _____ of _____

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:** **Observer:** **Recorder:**

Tag #	Species	DBH	Crown Health	Location	Notes

Crown Health
1 = 90-100% live
2 = 50-89% live
3 = 16-49% live
4 = 0.1 - 15% live
5 = standing dead
6 = dead and down

Notes
Examples include: beaver browsing, fire scar, lightning strike, canker, tent caterpillar infestation, etc.

Unknown Plant Species

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:** **Recorder:**

Transect: 1 2 3 4 5 6 7 **Position on transect (m) / method:** **Photo #s:**

Unknown species code (e.g., unkZION-P02-KL1): _____

Plant Type & General Description: *tree* *shrub* *grass* *forb* *other*_____

Forbs and grasses: *annual* *perennial*

Perennial Grasses: *bunchgrass* *rhizomatous*

General Description:

Most salient feature:

Leaf Characteristics (optional):

Leaf Type: (compound/simple, arrangement, etc.)

Margin:

Other: (pubescence, sap, stipules, etc)

Stem Characteristics (optional): (shape, pubescence, bud)

Flower Characteristics (optional): (color, location, floral formula)

Microhabitat Characteristics:

Collected: *Yes* *No* Collected by:

Best Guess:

Confirmed to be:

Identified by: Date:

Example Data Sheet:

Point Intercept

Data entered by: S. Kast Data verified by: J. Doucette p.1

NCPN Riparian Monitoring

Park Code: CARE **Reach ID:** F-14 **Date:** 8-4-11 **Page** 1 **of** 1

Observer: J. Doucette **Recorder:** K. Lund **Transect:** 1 2 3 4 5 (6) 7

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
0.5	Tama sp.	Tama sp.-D		L	
1	Tama sp.-D	L		L	
1.5	Tama sp.	L		L	
2	Tama sp.	Chrnau-D		F	
2.5	Chrnau	L		GC	
3				F	
3.5				CB	
4		L		F	
4.5				WA	
5				WA	
5.5				WA	
6				WA	
6.5				WA	
7				WA	
7.5				WA	
8				WA	
8.5				WA	
9				WA	
9.5				~~CB~~ BL (KL 8-4-11)	
(*) 10	Melalb	Phraus-D	Ele pal	F	
10.5	Sal exi	Phraus-D	Muhasp	F	
11	Muhasp			F	
11.5	Elaang	Oxyace		F	
12	Sal exi	Oxyace	Elysmi	F	
12.5				F	

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
13		WD		Sal exi	
13.5	Elaang			F	
14	Sal exi			F	
14.5				F	
15				F	
15.5	Elaang			F	
16		L		F	
16.5				F	
17	Sal exi			F	
17.5	Chrnau	Chrnau-D		L	
18	Chrnau-D	Chrnau		L	
18.5	Sal exi			F	
19				F	
19.5	Stihym			F	
20	Chrnau-D			F	
20.5	Chrnau	Chrnau-D		L	
21	Chrnau	L		F	
21.5	Chrnau-D			F	
(*) 22	Sal exi	Chrnau-D	Stihym-D	Stihym	
22.5	Sal exi			Sal exi	
23	Chrnau-D	Psolan		L	
23.5	Chrnau	Chrnau-D		L	
24	Atrcan	Atrcan-D		L	
24.5	Psolan	Chrnau-D		F	
25	Chrnau	Chrnau-D		F	

Additional canopy layers can be added on other side

Tamarix sp.
Chrysothamnus nauseosus
Melilotus alba

Phragmites australis
Eleocharis palustris
Salix exigua

Top canopy
Species code*
Lower canopy layers
Species code*, litter (L), woody debris (WD)
Plant Status
*If part of plant touching laser is dead, write "-D" after species code.

Munkenbergia asperifolia
Eleagnus angustifolia
Oxytenia acerosa

Surface Feature
F = Fines
GF = Gravel, fine (ant to beetle)
GC = Gravel, coarse (beetle to baseball)
CB = Cobble (baseball to basketball)
BL = Boulder
BR = Bedrock

Elymus smithii
Stipa hymenoides
Psoralidium lanceolatum

Surface Feature
WA = Water
BSC = Biological soil crust
L = Litter
WD = Woody debris
SL = Scat, livestock
SW = Scat, wildlife

Disturbance
Ant = Ant mound
Bike = Bicycle
Trail = Trail
Camp = Campsite
Auto = Motor vehicle
Flood = Recent flooding
Graze = Recent grazing
Oth = Other

Atriplex canescens
Sporobolus cryptandrus
Salsola sp.

Example Data Sheet:

Point Intercept p.2

Additional canopy layers

Point (m)	Lower Canopy 3	Lower Canopy 4	Lower Canopy 5
10.0	Elepal-D		
22.0	Stihym		
25.5	Spocry-D		

Point (m)	Lower Canopy 3	Lower Canopy 4	Lower Canopy 5

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
25.5	Chrnau-D	Chrnau	L	F	
26	Chrnau-D	Spocry		Spocry	
26.5	Psolan			L	
27		L		F	
27.5				F	
28	Psolan			L	
28.5	Sals. sp-D			F	
29		L		F	
29.5	Psolan			F	
30	end of transect				
30.5					
31					
31.5					
32					
32.5					
33					
33.5					
34					
34.5					
35					
35.5					
36					
36.5					
37					
37.5					

Point (m)	Top Canopy	Lower canopy 1	Lower canopy 2	Soil surface	Disturb.
38					
38.5					
39					
39.5					
40					
40.5					
41					
41.5					
42					
42.5					
43					
43.5					
44					
44.5					
45					
45.5					
46					
46.5					
47					
47.5					
48					
48.5					
49					
49.5					
50					

Example Data Sheet:

Canopy Closure and Exotic Frequency

Data entered by: W. Plafcan Data verified by: S. Karinen

NCPN Riparian Monitoring

Park Code: NABR **Reach ID:** A-04 **Date:** 6/27/12

Observer: W. Plafcan **Recorder:** K. Lund **Transect:** 1 (2) 3 4 5 6 7

Spherical Densiometer

5-m	0	0	0	0	35-m	12	1	6	1	65-m				
15-m	0	0	0	0	45-m	13	12	10	11	75-m				
25-m	12	11	7	12	55-m	8	4	3	9	85-m				
										95-m				

Exotic Frequency – Quadrats

Species	Meter 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
BROTEC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓										
(*) ~~unk NABR A-04-KL1~~		✓	✓		✓															
BRO JAP				✓		✓		✓			Exotics		Exotics							
Meli sp.					✓															
POA PRA								✓												
MEL OFF									✓											
AGR CRI											No	✓	No							

(*) IPO ROS (native), KL 7/23/12
(Ipomopsis roseata)

Bromus tectorum
Bromus japonicus
Melilotus species
Poa pratensis
Melilotus officinalis
Agropyron cristatum

Example Data Sheet:

5-m Belt Transect

Data entered by: S. Karinen Data verified by: W. Platean

NCPN Riparian Monitoring

Park Code: NABR Reach ID: A-05 Date: 6/12/11

Observer: S. Karinen Recorder: K. Lund Transect: 1 2 3 (4) 5 6 7

Tree Seedlings (<1.37 m tall or ≤2.5 cm DBH)

Species	Tally	Total
Populus angustifolia	⊠ ⊠ ⊠ ⊠ ⊠ ⊠ ⊠ ⊠ ⊠	90
Acer negundo	⊠ ⊠ ⊠ ⊠ ⊠ 1:	55

Density Classes: 100-250, 251-500, 501-1000, >1000

Trees (>2.5 cm DBH)

Species	DBH
Ace neg	3.0
Ace neg	2.9
Ace neg	9.7
Ace neg	5.5
Ace neg -D	4.8
Ace neg	5.6
Ace neg	5.5
Ace neg	3.6
Ace neg	3.1
Ace neg	4.1
Ace neg	3.4
Pop ang	3.4

Trees (>2.5 cm DBH)

Species	DBH
Populus angustifolia	4.9
Pop ang	3.9
Pop ang	5.6
Pop ang	4.7
Pop ang	9.6
Pop ang	3.3
Pop ang	3.4
Pop ang-D	4.1
Pop ang	2.8
Pop ang	3.3
Pop ang	3.1
Pop ang	2.6
Pop ang	5.9
Pop ang	4.2
Pop ang	5.9
Pop ang	7.0
Pop ang	6.6
Pop ang	3.7
Pop ang-D	19.7
Acer negundo	2.6

Example Data Sheet:

Reach Census Data entered by: J. Doucette Data verified by: W. Plafcan Pg 1 of 1

NCPN Riparian Monitoring

Park Code: ARCH Reach ID: C-07 Date: 6/7/2011 Observer: J. Doucette Recorder: K. Lund

Tag #	Species	DBH	Crown Health	Location	Notes
301	Populus fremontii	26.2	3	River left (RL), upstream (US) of T7. Clump of 10 PopFRE's.	
302		37.3	2	"	
303		31.3	1	"	
304		40.3	1	"	
305		44.8	2	"	
306		36.9	2	RL. Between T6 & T5.	Cankers on trunk.
307		41.6	2	" Same tree as #306.	
308		36.0	1	RL. Just downstrm (DS) of T5.	
309		42.3	1	" Same tree as #308.	
310		41.2	2	RL. Between T5 & T4.	Beaver browsed.
311	Pop FRE	31.8	2	RL. DS of T4.	
312		37.0	2	Just DS of T3R.	
313		32.5	1	Just US of T3R.	
314		36.1	1	River right (RR). Between T2 & T3.	
315		27.3	2	"	
316		41.3	2	"	
317		30.0	2	RL. Between T2 & T3.	
318		29.4	2	" Same tree as #317.	

Crown Health
1 = 90-100% live
2 = 50-89% live
3 = 16-49% live
4 = 0.1 - 15% live
5 = standing dead
6 = dead and down

Notes
Examples include: beaver browsing, fire scar, lightning strike, canker, tent caterpillar infestation, etc.

Example Data Sheet:

Unknown Plant Species

Data entered by: K. Lund Data verified by: S. Karinen

NCPN Riparian Monitoring

Park Code: ARCH Reach ID: C-02 Date: 05/26/11 Recorder: K. Lund

Transect: 1 2 3 4 5 6 (7) Position on transect (m) / method: 71.9 m Point-intercept Photo #s: PS261313 – PS261316

Unknown species code (e.g., unkZION-P02-KL1): unkARCH C02-KL2

Plant Type & General Description: *tree* *shrub* *grass* (*forb*) *other*_____

Forbs and grasses: (*annual*) *perennial*

Perennial Grasses: *bunchgrass* *rhizomatous*

General Description:
Small forb, cauline leaves opposite with a slightly swollen node. Lower (basal) leaves contorted around stem. Leaves sessile.

Most salient feature: Buds, distinctly long, green w/prominent venation & ridges.

Leaf Characteristics (optional):

Leaf Type: (compound/simple, arrangement, etc.)
Linear, mostly basal

Margin:
Hyaline margin, at least on lower part of cauline leaves

Other: (pubescence, sap, stipules, etc)

Stem Characteristics (optional): (shape, pubescence, bud)
Has glands

Flower Characteristics (optional): (color, location, floral formula)
Not blooming yet!
Calyx ridged

Microhabitat Characteristics:
Growing in Salix forest
Only specimen found on transect

Collected: *Yes* (*No*) Collected by:

Best Guess: Caryophyllaceae? Silene?

Confirmed to be: Silene antirrhina

Identified by: S. Topp Date: 6/8/11

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #7

Assessing Channel Substrate Particle-size Distribution using a Pebble Count

Version 1.03 (October 2018)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	5/2013	R. Weissinger, D. Witwicki, K. Lund	Clarify wording; add example data sheet	Response to protocol review, confusion about sampling tributary side channels and beaver ponds	1.01
1.01	4/2015	D. Witwicki & K. Lund	Clarify spacing of sampling		1.02
1.02	10/2018	A. Washuta	Clarify pebble count starting location		1.03

This SOP provides instructions for conducting a pebble count along cross-section transects at each reach.

Fill out the data sheet:
Park Code: Use the standard 4-letter code to indicate the park unit.
Reach ID: A pre-assigned, unique code provided for each stream reach.
Date: Use the format mm/dd/yyyy
Observer: Record the initials of the person measuring the pebbles.
Recorder: Record the initials of the person recording the data.

Pebbles are sampled in the channel along each cross-section transect. Begin at Transect 7 (the downstream end of the reach) to minimize disturbances upstream before you sample.

A. Lay the transect across the channel perpendicular to flow.

Perennial streams - Sample the wetted width of the stream and any adjacent scoured channel.
Dry Channel - Sample the scoured channel bottom.
Braided channels - Lay the transect tape across the entire channel, but only sample pebbles from scoured areas (i.e., not from islands).

For all channel types, only sample the main channel(s) and not channels of tributaries that cross the transect.

B. Measure the channel width in meters, and record it on the data sheet.

C. Determine the sampling interval, and record this number on the data sheet.

- Divide the channel width by 60 to determine your sampling interval. The minimum sampling interval is 0.1 m (i.e., 10 cm).
- **To avoid sampling bias, it is extremely important that your samples are spread evenly across the channel.**
- If the channel width is less than 6 m, you will need to make an additional pass across the channel to collect all 60 samples. Sample the first pass at 0.1 m intervals across the channel. After finishing the first pass, calculate the number of additional pebbles needed, move upstream 0.5 m, and do a second pass parallel to the cross-section, sampling at the appropriate interval to sample equally across the channel (i.e., if only 20 pebbles are needed on the second pass, sample them at equidistant intervals such that the entire channel is sampled).
- If the channel width is greater than 6 m, it is acceptable to round the sampling interval up to the nearest 0.05 m (i.e., 5 cm; see Table 1). If this is done, a second pass across the channel will be required to collect a total of 60 samples. Move 0.5 m upstream for the second pass, and use the instructions above to sample equally across the channel for the remaining samples. *Beware of rounding down! This could cause one side of the channel to be sampled more than the other side, which is not acceptable.*

Table 1. Sampling intervals on the **first pass** for different channel widths.

If your channel width is:	Your sampling interval on the first pass is:
6 m or less	0.10 m
>6 to 9 m	0.15 m
>9 to 12 m	0.20 m
>12 to 15 m	0.25 m
>15 to 18 m	0.30 m
>18 to 21 m	0.35 m
>21 to 24 m	0.40 m
>24 to 27 m	0.45 m
>27 to 30 m	0.50 m

D. Begin sampling on one side of the channel. Move one interval down the transect from the start of the transect to take the first sample (i.e., for a 0.1 m interval, the first sample is taken at 0.1 m). Without looking at the channel bottom, plunge your index finger into the water towards the first sampling point.

E. Pick up the first pebble that you touch. If there is silt or sand on top of a rock or bedrock, record “F” for fines.

F. If there is not silt or sand on the pebble, measure the intermediate axis (not the shortest or longest) using a ruler (Figure 1). Record the length to the nearest 0.1 cm on the data

sheet. The intermediate axis corresponds to the axis that determines the sieve size through which a particle can fall.

- If a pebble is <0.2 cm, record "F" on the data sheet for fines. Enter as 0.1 in the database.
- If you touch bedrock, record "BR" on the data sheet. Enter as 1000 in the database.

G. Continue across the channel, sampling at the pre-determined interval.

H. After recording 60 pebbles, move upstream to the next transect.

Fig. 1. Measuring the intermediate axis. Note its position relative to the longest axis (the vertical axis in this image) and the shortest axis (pebble depth in this image).

Rules for Pebble Counts

- Do not count a pebble twice. If a large rock is intercepted multiple times, record the rock once and move on to the next location that intercepts a new pebble.
- If a rock is too large to pick up, measure the smaller of the two available axes.
- If water is too deep at the cross-section location (i.e., it would flow over your shoulder when picking up pebbles), move the pebble count location upstream at 0.5-m intervals until the water is shallow enough for sampling.
- If the channel is too deep to sample because of a beaver pond, record all 60 pebbles as "F" for fines.

Pebble Count

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:**

Minimum sampling interval is 0.1 m. Measure to nearest 0.1 cm.

Width T7(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Width T6(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Width T5(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Width T4(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Pebble Count p.2

Minimum sampling interval is 0.1 m. Measure to nearest 0.1 cm.

Width T3(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Width T2(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Width T1(m): **Width/60:** **Observer:** **Recorder:**

1	7	13	19	25	31	37	43	49	55
2	8	14	20	26	32	38	44	50	56
3	9	15	21	27	33	39	45	51	57
4	10	16	22	28	34	40	46	52	58
5	11	17	23	29	35	41	47	53	59
6	12	18	24	30	36	42	48	54	60

Example Data Sheet:

Pebble Count

Data entered by: J Doucette Data verified by: K. Lund

NCPN Riparian Monitoring

Park Code: ZION **Reach ID:** P-01 **Date:** 9/1/12

Minimum sampling interval is 0.1 m. Measure to nearest 0.1 cm.

Width T7(m): 5.1 **Width/60:** 0.10 **Observer:** K. Lund **Recorder:** W. Plafcan

1	F	7	F	13	0.8	19	5.3	25	13.8	31	12.2	37	2.5	43	10.6	49	8.0	55	77.0
2	F	8	F	14	18.5	20	7.6	26	6.9	32	9.3	38	1.7	44	18.5	50	12.7	56	F
3	F	9	F	15	18.0	21	10.5	27	9.0	33	8.9	39	9.3	45	11.5	51	36.5	57	F
4	F	10	F	16	2.4	22	F	28	8.0	34	2.0	40	2.0	46	11.0	52	11.2	58	F
5	F	11	0.3	17	12.2	23	0.4	29	8.3	35	3.7	41	F	47	8.5	53	10.8	59	23.0
6	F	12	0.6	18	15.5	24	F	30	20.0	36	9.1	42	F	48	12.6	54	13.5	60	3.7

Width T6(m): 4.4 **Width/60:** 0.10 **Observer:** J. Doucette **Recorder:** S. Karinen

1	F	7	7.0	13	29.2	19	F	25	16.4	31	F	37	F	43	1.9	49	5.8	55	6.8
2	F	8	3.1	14	7.4	20	F	26	2.9	32	F	38	F	44	8.3	50	7.3	56	6.4
3	F	9	14.4	15	15.3	21	7.6	27	6.4	33	F	39	F	45	2.7	51	8.6	57	F
4	3.3	10	0.9	16	6.5	22	2.7	28	4.2	34	F	40	F	46	4.4	52	8.8	58	F
5	1.3	11	22.1	17	18.1	23	5.3	29	F	35	F	41	F	47	2.8	53	16.8	59	5.3
6	F	12	4.0	18	F	24	3.3	30	F	36	F	42	F	48	8.5	54	11.1	60	17.3

Width T5(m): 3.5 **Width/60:** 0.10 **Observer:** W. Plafcan **Recorder:** K. Lund

1	F	7	14.6	13	5.5	19	3.0	25	82.5	31	F	37	11.2	43	8.5	49	2.6	55	2.1
2	F	8	2.3	14	26.5	20	0.9	26	3.6	32	F	38	2.5	44	4.8	50	35.0	56	11.3
3	12.3	9	F	15	3.2	21	3.7	27	F	33	F	39	BR	45	5.5	51	0.8	57	6.9
4	3.2	10	2.0	16	12.1	22	4.8	28	F	34	F	40	BR	46	6.1	52	F	58	F
5	6.9	11	20.5	17	7.2	23	F	29	F	35	F	41	BR	47	5.7	53	4.7	59	1.4
6	24.7	12	10.1	18	3.4	24	F	30	F	36	F	42	15.0	48	4.2	54	10.9	60	F

Width T4(m): 5.4 **Width/60:** ~~0.01~~ 0.10 JD 9/1/12 **Observer:** S. Karinen **Recorder:** J. Doucette

1	F	7	8.6	13	7.9	19	F	25	7.2	31	16.2	37	8.7	43	11.2	49	F	55	22.0
2	F	8	12.3	14	34.0	20	16.8	26	17.2	32	19.2	38	4.6	44	F	50	6.1	56	F
3	F	9	5.4	15	3.9	21	2.1	27	68.0	33	3.8	39	F	45	F	51	3.9	57	F
4	F	10	F	16	F	JD 9/1/12 22	~~25.5~~ 45.5	28	2.3	34	3.9	40	F	46	F	52	4.9	58	F
5	46.0	11	18.1	17	F	23	3.2	29	47.0	35	33.0	41	F	47	F	53	F	59	F
6	3.7	12	2.3	18	F	24	5.0	30	8.2	36	42.0	42	3.3	48	F	54	F	60	F

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Example Data Sheet:

Pebble Count p.2

Minimum sampling interval is 0.1 m. Measure to nearest 0.1 cm.

Width T3(m): 7.6 **Width/60:** 0.10 **Observer:** K. Lund **Recorder:** W. Plafcan

1 F	7 2.1	13 4.0	19 8.2	25 11.0	31 7.5	37 6.2	43 2.5	49 F	55 4.9
2 11.5	8 5.2	14 6.9	20 14.5	26 F	32 4.0	38 7.5	44 6.3	50 2.9	56 10.0
3 12.0	9 4.3	15 4.5	21 4.5	27 15.0	33 2.9	39 8.2	45 15.0	51 F	57 BR
4 1.0	10 6.0	16 6.5	22 14.0	28 2.0	34 F	40 23.0	46 4.7	52 14.5	58 BR
5 4.5	11 1.0	17 27.0	23 1.6	29 10.5	35 5.7	41 4.6	47 7.0	53 1.8	59 BR
6 3.0	12 4.0	18 9.7	24 2.9	30 2.9	36 1.7	42 1.5	48 F	54 9.0	60 BR

Width T2(m): 12.0 **Width/60:** 0.2 **Observer:** J. Doucette **Recorder:** S. Karinen

1 F	7 15.0	13 5.8	19 2.1	25 12.3	31 F	37 2.9	43 5.2	49 3.3	55 12.1
2 F	8 2.9	14 1.6	20 4.6	26 6.4	32 5.0	38 14.8	44 10.1	50 5.8	56 3.5
3 F	9 19.9	15 5.8	21 2.1	27 2.7	33 1.9	39 8.4	45 2.2	51 2.4	57 1.2
4 1.8	10 F	16 0.8	22 1.9	28 3.3	34 11.8	40 8.7	46 9.4	52 3.1	58 F
5 1.9	11 3.4	17 1.5	23 F	29 1.8	35 66.0	41 4.8	47 12.2	53 4.5	59 6.8
6 2.3	12 1.5	18 1.6	24 7.3	30 7.1	36 4.7	42 1.2	48 3.9	54 2.4	60 F

Width T1(m): 9.5 **Width/60:** 0.2 **Observer:** W. Plafcan **Recorder:** K. Lund

1 F	7 6.4	13 F	19 6.4	25 5.1	31 F	37 6.0	43 4.0	49 F	55 F
2 4.4	8 F	14 F	20 5.1	26 0.9	32 3.2	38 F	44 F	50 F	56 F
3 F	9 4.0	15 F	21 1.9	27 1.2	33 8.9	39 0.5	45 F	51 F	57 F
4 F	10 3.7	16 6.0	22 1.2	28 0.6	34 0.6	40 5.2	46 1.0	52 F	58 F
5 2.3	11 11.0	17 5.0	23 3.4	29 3.3	35 9.4	41 4.0	47 F	53 2.4	59 1.9
6 F	12 2.9	18 3.5	24 5.9	30 5.5	36 1.8	42 F	48 2.7	54 1.0	60 3.5

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #8

Site Impact Assessment

Version 1.02 (May 2013)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	11/2009	R. Weissinger	Added timed walk for presence of exotic species	More information for resource managers	1.01
1.01	5/2013	D. Witwicki	Added example data sheet	Response to protocol review	1.02

This SOP provides instructions for detecting and describing disturbances and exotic plant species at a reach. This assessment is conducted every time vegetation is sampled.

Fill out the data sheet:

Park Code: Use the standard 4-letter code to indicate the park unit.
Reach ID: A pre-assigned, unique code provided for each stream reach.
Recorder: Record the initials of the person(s) recording data.
Date: Use the format mm/dd/yyyy.

1. In-stream disturbances

Record the presence of all in-stream disturbances listed on the data sheet (see Table 1). If a significant disturbance is present but not listed on the data sheet, be sure to record it. If there is no disturbance to report, enter "none". Write a detailed description of any disturbances that you find.

Table 1. Common in-stream disturbances on the Colorado Plateau.

Disturbance Type	Description
Channel modification	Anthropogenic modification such as a dam, structure, or diversion
Road crossing	
Beaver dam	
Recent flooding	Indicated by flattened vegetation, turbidity, and debris lines. Only record flooding that appears to have occurred in the previous several days.
Crayfish	All crayfish species in this region are exotic. They look like little lobsters.

2. Terrestrial disturbances

Follow the instructions in section 1 to record terrestrial disturbances. Common terrestrial disturbances are listed in Table 2.

Table 2. Common riparian disturbances on the Colorado Plateau.

Disturbance Type	Description
Road	Paved, dirt, or two-track. Note whether it is currently open or closed.
Trail	Livestock or human trail. Note whether it is maintained or social.
Campsite	Denoted by compacted areas devoid of vegetation, fire rings, etc.
Beaver browsing	Chewed and/or felled trees.
Livestock trampling/grazing	Indicated by the presence of livestock or livestock scat.
Wildlife trampling/grazing	Significant impacts due to native ungulates.
Insect infestation	
Fire	Indicated by fire scars on trees, charred vegetation, etc. Note if fire is recent or not.
Exotic plant removal	Indicated by cut stumps, debris piles, etc.
Tamarisk beetle	Indicated by presence of eggs, larvae, adults, or extensive tamarisk defoliation.

3. Exotic plant species

Perform a timed 30-minute walk through the reach and record all annual and perennial exotic plant species present. Make sure to record any species that were not detected during vegetation sampling. Describe the number of plants detected, the size of the invasion, and the approximate location within the reach.

It is the park's responsibility to remove invasive exotics, but the crew may decide to pull exotics if only a few plants are present and if the time needed to hike to the reach is great. Record if plants were pulled by the crew and their general location.

4. Other notes

Record any other notes that may assist in interpreting data for the reach. Describe interesting features of the reach, such as amphibians or fish species seen, management activities noted, etc.

Site Assessment

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Recorder:** **Date:**

In-Stream Disturbance

Channel Modification	Yes	No
Road Crossing	Yes	No
Beaver Dam	Yes	No
Recent Flooding	Yes	No
Crayfish Present	Yes	No
Other	Yes	No

Describe all:

Terrestrial Disturbance

Road	Yes	No
Trail	Yes	No
Campsite	Yes	No
Beaver Browsing	Yes	No
Livestock Grazing	Yes	No
Wildlife Trampling/Grazing	Yes	No
Insect Infestation	Yes	No
Fire	Yes	No
Exotic Plant Removal	Yes	No
Other	Yes	No
Tamarisk Beetle	Yes	No

Describe all:

Site Assessment

Data entered by: Data verified by: p. 2

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Recorder:** **Date:**

Exotic Plant Species Present: (number of plants/size of the invasion, location, note if pulled)

Other Notes:

Example Data Sheet:

Site Assessment

Data entered by: W. Plafcan Data verified by: S. Karinen

NCPN Riparian Monitoring

Park Code: ZION **Reach ID:** P-01 **Recorder:** K. Lund **Date:** 9/3/12

In-Stream Disturbance

Channel Modification	Yes	No
Road Crossing	Yes	No
Beaver Dam	Yes	No
Recent Flooding	Yes	No
Crayfish Present	Yes	No
Other	Yes	No

Describe all:

A flood of ~900 cfs came through last week & inundated the floodplain.

Terrestrial Disturbance

Road	Yes	No
Trail	Yes	No
Campsite	Yes	No
Beaver Browsing	Yes	No
Livestock Grazing	Yes	No
Wildlife Trampling/Grazing	Yes	No
Insect Infestation	Yes	No
Fire	Yes	No
Exotic Plant Removal	Yes	No
Other	Yes	No
Tamarisk Beetle	Yes	No

Describe all:

- Beaver browsing — one Salix exigua stump near T1 recently browsed. Old evidence present throughout reach.
- Exotic plant removal — old Elaeagnus angustifolia & Tamarix sp. projects evident. New Tamarix sp. growing, but no new ELAANG.

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Example Data Sheet:

Site Assessment

Data entered by: W. Plafcan Data verified by: S. Karinen p. 2

NCPN Riparian Monitoring

Park Code: ZION **Reach ID:** P-01 **Recorder:** K. Lund **Date:** 9/3/12

Exotic Plant Species Present: (number of plants/size of the invasion, location, note if pulled)

Verbascum thapsus – one individual on T2 on river left (RL). Pulled.
Taraxacum officinalis – few individuals along greenline RL on T3.
Tamarix sp. – a few saplings on far river right.
Agrostis stolonifera – throughout greenlines on reach. Moderate cover (5-25%)
Festuca pratensis – one clump in T1 greenline, RL.
Melilotus officinalis, Melilotus sp., Melilotus alba } throughout reach. Low cover (1-5%).
Bromus tectorum – throughout uplands in reach. Mod cover.
Bromus rubens – a few individuals throughout reach.
Bromus diandrus – " " " "
Lactuca serriola – a few individuals mid-reach.

Other Notes: ~~mk ZION P01 KL2 – a few individuals on T2~~ (native, KL 9/4/12)

The flood of winter 2010/2011 has significantly changed this reach since it was established in 2008. A new cutbank exists in the upper section of the reach and a new gravel island is present.

DRAFT

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) #9

Stream Channel Surveying

Version 1.05 (September 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	5/2011	K. Lund		Update protocol based on field testing	1.01
1.01	2/2013	K. Lund, D. Witwicki	Clarified text in surveying section; edited post-processing steps.	Updated protocol based on refinements to our methods	1.02
1.02	3/2014	K. Lund, D. Witwicki, R. Weissinger	Edits to operating the total station to include more detail, updates to procedures, restructuring document	Better clarification was needed	1.03
1.03	9/2015	K. Lund	Made surveying instructions more general. Clarified hydrologic section. Added two appendices with specifics for current instruments and software.	Changed data collector and survey software.	1.04
1.04	9/2016	D. Witwicki	Cleaned up remaining comments from 9/2015 edits, added instructions for installing permanent bedrock markers, changed gradient to channel slope		1.05

This SOP gives detailed instructions for surveying the stream channel using a total station and post-processing survey data after returning from the field. A list of necessary equipment for these procedures can be found in SOP #1.

A three-person team comprised of a survey lead and two rod persons can efficiently complete the tasks described below. The survey lead should be skilled in total station operation at remote field sites and have experience with rod duties (i.e., running rod) and post-processing survey data. The rod persons should have excellent attention to detail, basic knowledge of surveying, and be skilled in running rod.

1. Surveying Basics & Equipment Operation

1.1 Survey Equipment

The survey lead is responsible for instructing the rod persons on how to handle and take care of sensitive and expensive survey equipment (see SOP #1 for complete list of survey equipment). The NCPN currently uses a Nikon Nivo 3.M total station instrument, Trimble TSC 3 data collector with Trimble Access software, and Foresight DXM, Traverse PC, and Microsoft Excel software for data post-processing in the office. Refer to the Nikon Total Station and Trimble Access manuals for more details on surveying and using this equipment.

Two different types of rods are used for surveying: prism poles and leveling rods (Fig. 1). Both types of rods hold prisms and have attached levels to ensure the rod is plumb. The level on a leveling rod is removable, and may need to be attached before you begin using it. The general term "rod" is used to refer to both types of rods.

- The prism pole is an adjustable pole with two different rod ends that can be used (Fig. 2). The pointed end will **only** be used on backsights, control points, and occasionally on headpin shots. Do not use the pointed end for generic topographic shots because it will sink into the ground causing the incorrect elevation of the shot to be recorded. The flat foot end is best for topographic shots and all other shots.
- The leveling rod has extensions that snap into place and is not adjustable beyond these settings. It has flat foot end that should only be used for topographic shots (i.e., not control points and backsight shots).

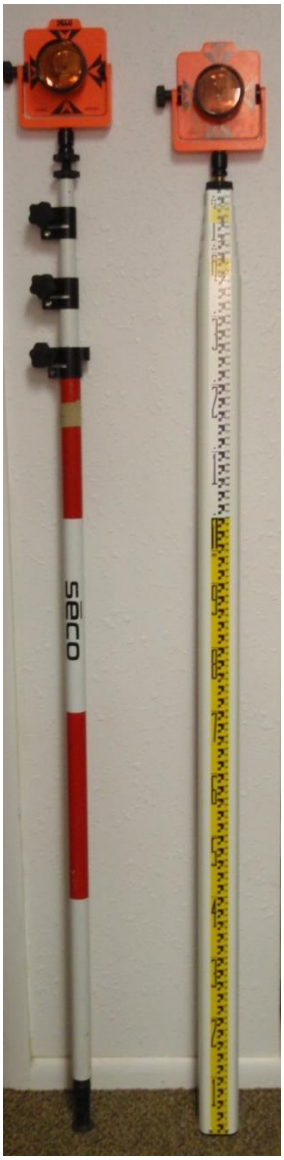


Figure 1. Prism pole (left) and leveling rod (right).

Figure 2. Options for the bottom of prism poles. The point on the left is used for control points, top of headpins, and well shots while the flat foot is on the right is used for all other shots. Leveling rods only have a flat foot.

1.2 Safety concerns while surveying

The following is a list of safety concerns that you need to be aware of while surveying. Refer to the Nikon Total Station, Trimble Access software, or other specific survey manuals for more complete lists of safety precautions.

- Do not look directly into the laser beam produced by the total station. When the survey lead is taking shots, the rod person focuses their eyes on keeping the rod level. The survey lead will let the rod person know when the shot has been completed by communicating “got it”, “okay”, etc.
- Be mindful of potential hazards during thunderstorms. Know what materials each rod is constructed of and whether they are conductive. Serious or fatal injuries may result from conductive materials being struck by lightning.
- Never look at the sun through the total station telescope. If you do, you may damage or lose your eyesight.
- Avoid recharging batteries in direct sunlight. Do not recharge the battery pack when it is wet. If you do, you may receive electric shocks or burns, or the battery pack may overheat or catch fire.
- Do not cover the battery charger when battery pack is being recharged. The charger must be able to dissipate heat adequately. Coverings such as blankets or clothing can cause the charger to overheat.
- Avoid getting the total station batteries wet. The batteries are not waterproof. Do not get the battery wet when it is removed from the instrument. If water seeps into the battery, it may cause a fire or burns.
- Do not sit, stand, or stack objects on the total station case. It is unstable and its surface is slippery. Stacking or sitting on the plastic carrying case may cause personal injury or instrument damage.

1.3 Rod technique

This section explains techniques and tips for using surveying rods (i.e., running rod). It is important that the rod persons know how to be accurate and efficient during a survey. See section 3 for additional rod techniques specific to certain parts of the survey.

Communication - Clear communication between team members is a key component of a successful survey. If people are beyond a comfortable talking range, use radios to communicate. The survey lead may use an ear piece and microphone attached to the radio to free their hands for operating the total station and data collector.

Raising the rod – Shots are generally taken at the lowest rod height unless there is an obstruction. Always raise the rod from the top section (the smallest rod), followed by the next-to-top section and so forth. If the total station does not have a clear line of sight to the prism, try raising the rod until the total station operator can see it.

Leveling the rod - Center the leveling bubble attached to the rod to make sure the rod is precisely vertical. Hold the rod steady in this position while the shot is taken. If the rod was not level, notify the survey lead immediately so that the shot is re-taken. A bipod (a piece of equipment that turns a rod into a tripod) can be very useful to minimize survey error and should be used for control shots and other important shots. All other shots typically do not need a bipod.

Squaring the prism - The rod person needs to make sure that the prism on their rod is square to (i.e., facing) the total station during each shot. When the rod person does not have a clear view of the total station, the survey lead can communicate to the rod person to rotate their prism until is it square by instructing them to rotate clockwise or counterclockwise.

Rod location and height - Know the height of your rod at all times. Rod persons should always have a measuring tape on them while surveying. **The rod person always needs to let the total station operator know the location of the rod and how many rods are up before each shot is taken (e.g., "T3R, top of headpin, one rod").** The total station operator will let the rod person know when the shot has been successfully completed. **Any shot errors (e.g., rod not raised to full height, incorrect rod height relayed to survey lead) need to be communicated to the survey lead immediately, documented, and corrected by re-taking the shot, if necessary.**

Rod positioning - Each shot should be taken with the rod flush against the downstream side of the tagline. When two crew members are running rod, they should "leapfrog" across the tagline or down the profile for the greatest efficiency.

Timing of prism direction - Only the prism of the current shot should be facing the total station operator. Crew members running rod need to make sure their prisms are facing away from the total station while setting up for their next shot.

Know what rod foot to use - For control shots, the rod persons will use the point (not the foot) of the prism pole (see Figure 2) on the exact location of the control point (i.e., the center of the X on rock or in the pre-stamped dot on a rebar cap), the top of headpins, and wells. For all other shots on topographic features, use the flat foot on the bottom of the prism pole or a leveling rod.

1.4 Establishing survey control

The following instructions are used when establishing the first survey at a reach. Revisit instructions begin in Section 2.2.

A. Before leaving the office, calibrate the Weatherport hand-held weather unit along with other pre-trip duties. See the Weatherport manual in the Total Station manual binder for details.

B. In the field, locate headpins for all transects at the reach, and mark with pin flags and flagging.

C. Identify potential survey control points, which will be used for instrument setups (i.e., occupied points), backsight locations, and maintaining control throughout the survey. The survey lead should determine these locations with the help of other crew members to check lines-of-sight. Ideally, each reach should have 4-6 control points that are all intervisible to each other and have good geometry. Among all control points, there should be good visibility of the entire reach.

D. Monument the control points. All permanent survey control must be cleared ahead of time with the park unit. Check to see what is permitted before you leave for the field. Permanent survey control are established using the following methods:

- Permanent metal cemented in bedrock (if permit allows). Use ½”-diameter threaded rod; a 5” piece works best on horizontal bedrock, while a 7” piece works best on vertical walls. On the 7” pieces, have maintenance grind down the threads on one side, but just on the part that will be sticking out of the rock. Use a hammer drill with a ½” concrete bit to drill a hole with a wider entrance. For vertical walls, make sure to align the rod so that the flat spot is facing up and enough is protruding from the rock to place the pointed foot of a leveled prism pole on it. Add water to 2-3 spoonfuls of concrete mix to make a mixture the consistency of pancake batter. Place the threaded rod in the drilled hole, making sure that the appropriate length is sticking out (½ - 1 in.), then add cement down and around the rod. After filling the hole, make a cement collar around the rod to ensure that water does not get in the hole.
- X’s etched in rocks (if permit allows)
- 0.5-m lengths of 3/8” rebar. Place an aluminum cap on top of the rebar stamped with NCPN, the ReachID, the appropriate code for the control point, and an exact mark on the cap to place the point of the prism pole (i.e., a dot pre-stamped in the center of the cap either by the manufacturer or by the NCPN; Fig. 3). It is easiest to stamp the cap first, place the cap on the rebar, and then use a piece of wood or something else to protect the cap while hammering the rebar into the ground.

Figure 3. Example of a rebar cap with a pre-stamped dot in the center.

It is important <u>not</u> to move any monuments once they have been surveyed in. Flag the areas around control points for easy visibility while surveying.

E. Document control points using photos, descriptions, and a sketch of the reach.
   a. Reference photos should include 1) a few shots with enough background topography for anyone returning to the reach to find the approximate location, and 2) at least one close-up of the precise position of the point. Try to include either the total station or a rod person in each photo.
   b. Write detailed notes describing the location of each control point in the field notebook (Fig. 4). Use permanent features rather than vegetation that will change over time. The lead surveyor is responsible for recording these in the field notes.
   c. Sketch a well-drawn location map of the reach including transects, headpins, control points, and any distinguishing features of the reach (Fig. 4).

F. Record the location of each control point using the highest grade GPS unit available. Use the highest precision possible. If satellites are hard to acquire, precision can be dropped down to the middle range, but try to avoid low precision. These coordinates will be used to translate and rotate the survey data into real-world coordinates.

G. Determine a surveying strategy including occupied points, backsights, and order of transects and longitudinal profile shots. Have as few instrument locations as possible to reduce error.

1.5 Setting up the survey equipment

This section describes steps to set up the total station (also referred to as the instrument or gun), data collector, and backsight. Most of these steps are performed by the survey lead while the rod persons attach prisms to the prism poles/leveling rods and measure the length of each. Rod persons will also typically set up the backsight too.

A. Set up the total station. The survey lead will set up the total station at the initial occupied point, using standard leveling procedures:
   a. Use the red laser plummet to center the total station over the occupied point location (e.g., pre-stamped dot in rebar cap of control point, middle of top of uncapped rebar, center of X on rock, etc.). Start with coarse leveling using the tripod legs followed by using the three adjustment screws on the total station for electronic leveling using the bubble screen (refer to Nikon Total Station manual for more details). Ideally, be within +/- 10". If you are establishing the point, it is easiest to level the instrument first, then place the capped rebar or chisel an X in the rock at the precise location.
      - To turn the laser on and off, hit the ANG button in the bubble screen.
      - To access the bubble screen, hit the 0 button on the total station.
   b. Measure the height of the instrument (HI), to the nearest millimeter, from the top of the permanent rebar or center of etched X in rock to the horizontal axis indicator mark on the side of the instrument. Document occupied point location and height of instrument (see Fig. 5).

B. Set up the rods. Attach a prism to each rod. Measure the height of each prism pole and leveling rod, to the nearest millimeter, from bottom of rod to center of prism. Make sure that prisms are set so that the heights for each type of rod are identical. Note that the heights of the prism poles will be different from the heights of the leveling rods, and there will need to be clear communication during the survey as to which type of rod is being used. Always raise the rod from the top section (the smallest rod), followed by the next-to-top section, etc. Document rod heights in the field notes (Fig. 5; e.g., 1HR = 1.768 m, 2HR = 2.987 m, 3HR = 4.151 m…6HR = 7.680 m). **If rod heights are changed during survey, the rod person must <u>immediately</u> notify the survey lead. Rod height errors are the most common source of error during a survey.**

C. Set up the backsight in the initial position. The backsight may be established using a tripod/tribrach/prism, rod/bipod/prism, or a roving rod/prism held by a rod person. If the backsight will be established using a rod and prism, make sure it can be shot at a single rod since higher rods are less precise. Set up the backsight using standard leveling methods. Measure the height, to the nearest millimeter, from top of the permanent rebar or etched X in rock to the center of the prism. Use a bipod on the rod to improve steadiness. Document the backsight location and height in field notes (Fig. 5).

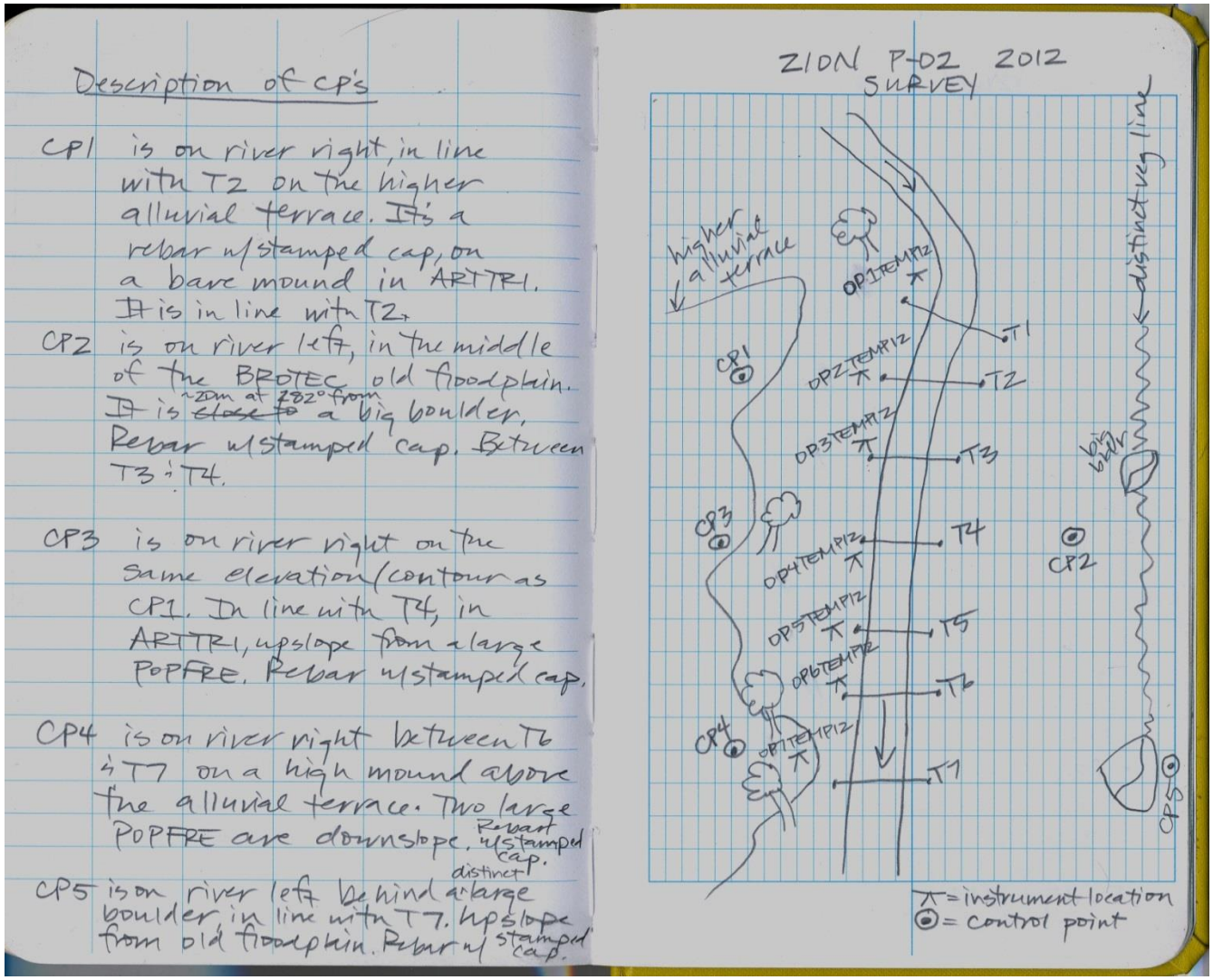
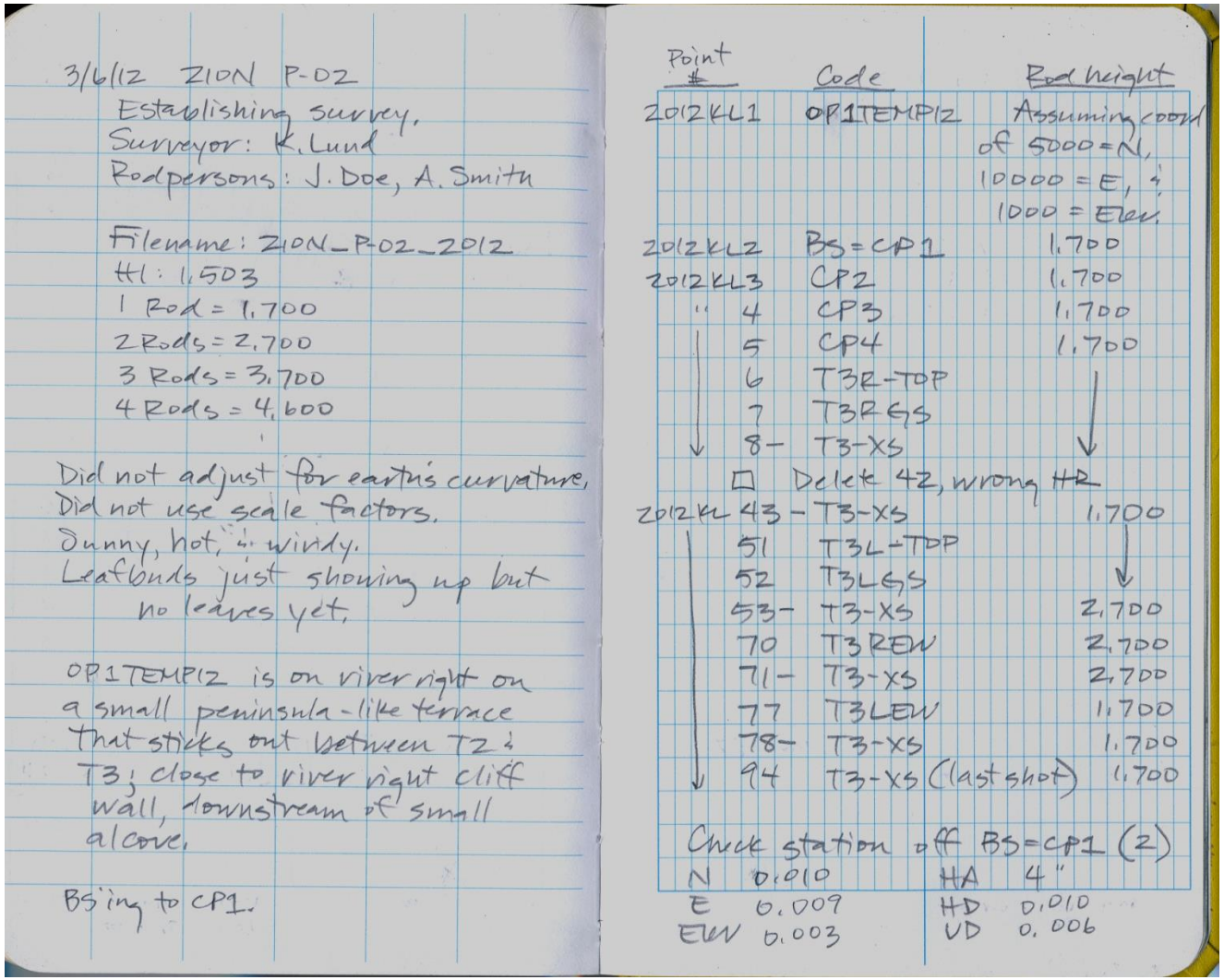


Figure 4. Example of survey field notes that describe the location of each control point and include a sketched map of transects, headpins, control points, and other distinguishing features of the reach. Codes are defined in Table 1.



3/6/12 ZION P-02
Establishing survey.
Surveyor: K. Lund
Rodpersons: J. Doe, A. Smith

Filename: ZION_P-02_2012
HI: 1.503
1 Rod = 1.700
2 Rods = 2.700
3 Rods = 3.700
4 Rods = 4.600

Did not adjust for earth's curvature.
Did not use scale factors.
Sunny, hot, & windy.
Leafbuds just showing up but no leaves yet.

OP1TEMP12 is on river right on a small peninsula-like terrace that sticks out between T2 & T3; close to river right cliff wall, downstream of small alcove.

BS'ing to CP1.

Point #	Code	Rod height
2012KL1	OP1TEMP12	Assuming coord of 5000=N, 10000=E, & 1000=Elev.
2012KL2	BS=CP1	1.700
2012KL3	CP2	1.700
" 4	CP3	1.700
5	CP4	1.700
6	T3R-TOP	↓
7	T3RGS	↓
8-	T3-XS	↓
□	Delete 42, wrong HR	
2012KL43-	T3-XS	1.700
51	T3L-TOP	↓
52	T3LGS	↓
53-	T3-XS	2.700
70	T3REW	2.700
71-	T3-XS	2.700
77	T3LEW	1.700
78-	T3-XS	1.700
94	T3-XS (last shot)	1.700

Check station off BS=CP1 (2)
N 0.010 HA 4"
E 0.009 HD 0.010
Elev 0.003 VD 0.006

Figure 5. Example of survey field notes for establishing a reach. Codes are defined in Table 1. Use an equal sign to indicate when you are set up on a known location (e.g., BS1 = CP3 or OP2 = CP1).

Table 1. Definitions and abbreviations for survey terminology. In codes, # is replaced with the number of the transect that is being surveyed; * indicates L for river left and R for river right.

Survey terminology	Code	Definition
Occupied point	OP$ or OP$TEMPYY	Monumented or unmonumented points occupied by the total station during a survey. The dollar sign corresponds with the order of the occupied points used. YY is the last two digits of the year.
Backsight	BS	A measurement taken back towards a point of known elevation (or arbitrary elevation entered in the total station), or a point previously occupied by the total station used to maintain survey control
Control point	CP	Monumented point used to maintain control in survey
Note: Use an equal's sign to indicate if you're set up on a known location (e.g., BS1=CP3 or OS2=CP1)		
Instrument height	HI	Height of the total station from the top of the rebar or the center of the X etched in rock to the horizontal axis indicator mark on instrument (to the nearest millimeter)
Rod height	HR	Height of prism pole or leveling rod from the bottom of the rod to the center of the prism (to the nearest millimeter), also includes backsight height
Top of headpin	T#L-TOP or T#R-TOP *	Shot taken with the point of the prism pole on top of the headpin
Headpin ground surface	T#LGS or T#RGS *	Shot taken with the rod on the ground surface downstream of the headpin
Unmonumented transect end	T#L-UNMON or T#R-UNMON *	Unmonumented transect end, lined up as closely as possible with vegetation transect.
Bankfull elevation	T#BFL or T#BFR *	Shot taken with the rod at bankfull elevation
Edge of water	T#LEW or T#REW *	Shot taken with the rod at the edge of flowing water
Cross-section transect points	T#-XS	All other points shot along each cross-section transect, including shots taken at 1-m intervals and at surface breaks
Thalweg length	P#	Shots of the thalweg profile (i.e., longitudinal profile) with # corresponding to the number of the transect upstream of the shot (e.g., P0 is upstream of transect 1, P2 is between transects 2 and 3, P3 is between transects 3 and 4, etc.)
Water surface at thalweg length shots	P#-REW or P#-LEW	The beginning (upstream-most) and ending (downstream-most) thalweg shots need to have a right and left water surface shots taken at the same location.
Top of well casing, instream	T#WELL-INSTRM-TOC	Shot taken at the notch filed on the top of the well casing of an instream well
Ground surface at well, instream	T#WELL-INSTRM-GS	Shot taken on the ground surface next to notch filed into the instream well casing
Water surface at well, instream	T#WELL-INSTRM-W	Shot taken at water surface next to notch filed in instream well casing

Survey terminology	Code	Definition
Top of well casing, river right or left	T#WELL-RR-TOC or T#WELL-RL-TOC *	Shot taken at the notch filed on the top of the well casing located in the riparian zone on river right or river left
Ground surface at well, river right or left	T#WELL-RR-GS or T#WELL-RL-GS *	Shot taken at the ground surface next to the notch filed into the well casing at a well located in the riparian zone on river right or river left
Confirmation shot	code.#	Check shot taken to document errors during a survey. Usually taken at the backsight or a known monumented location such as a control point or a headpin (e.g., CP1)
Traverse shot	TR=	Used when moving or traversing the instrument to the next location (e.g., TR=CP3 means that you are moving the total station to control point 3)

1.6 Recording survey notes in the field

While the survey lead is operating the data collector and total station, he/she is simultaneously recording information in a field notebook (Fig. 5), which will be important for post-processing data and documenting survey details. The information in the field notebook needs to match what is in the data collector, although some information is not recorded in the data collector. Field notebook information includes the following:

- Record the date, park unit, ReachID, field crew members and their duties (i.e., total station operator or rod crew), scale factor, and general notes (foliage present, weather conditions, etc.).
- Record the file name used in the data collector.
- Record all rod heights before the survey begins. The term “rod height” is used for both prism poles and leveling rods.
- Document each instrument and backsight height and location.
- Record all transect and stream profile points. The data collector requires a point name (which should include year, surveyor’s initials, and a unique number), code (called “description” in the data collector), and rod height for each point surveyed. Table 1 contains a list of standard codes used for surveying wadeable streams in the NCPN. Similar points may be grouped in your notes using a dash after the number to indicate that all following numbers have the same code and rod height (see Fig. 5). This information is very helpful in post-processing and should be recorded in your notes for all points. Details of every point are also stored in the data collector.
- When checking station setup and/or backsight, document errors (Northing, Easting, Elevation, Horizontal Angle, Horizontal Distance, Vertical Distance). Record what point was used as reference. Before moving the total station, shoot a check shot to document errors.
- List all mistakes or blunders made during the survey so they can be corrected later (e.g., mis-naming of points and any rod heights that were entered incorrectly in the data collector). It is <u>not</u> recommended to make these changes in the field but to keep a running list of changes to be made during post-processing. **It is very important to keep track of the rod height at all times and record any mistakes.**

- Record photos taken for documentation.
- Description of each control point (see Section 1.4, E and Fig. 4).
- Sketch the reach including relative locations of transects, reference marks, instrument setups, and the riparian corridor (Fig. 4).
- Define any codes that you use that are not defined in Table 1.
- Note anything unusual or that will potentially be helpful with data post-processing (e.g., overhanging cliff wall, secondary channels, woody debris piles, etc.).

2. Operating the data collector and total station

This portion of the SOP assumes that the survey lead is competent at surveying. Refer to Appendix A for specifics of operating the current NCPN equipment (Trimble TSC3 data collector with the Nikon Nivo 3.M total station).

2.1 Establishing a survey

Create a local, arbitrary coordinate system to establish the survey. Survey in as many control points as you can from the first instrument location before starting to survey. Be diligent and precise since this will be the baseline for all future revisits.

Acceptable Errors for Establishing a Survey:

Horizontal (includes the northing and easting): 0.000 - 0.030 m (3 cm).
Ideally, it is best to have < 0.020 m (2 cm) error.

Vertical (includes elevation): 0.000-0.010 m (1 cm).
Ideally, it is best to have <0.005 m (0.5 cm) error.

A. Dealing With Errors

There are plenty of ways for errors to occur within a survey. Errors are minimized by thoroughly training the survey lead and rod persons and by constant attention to detail throughout the survey. Survey errors can accumulate, and in the worst case scenario, the data will be unusable for scientific purposes. Some sources of error include wrong rod height, wrong instrument height, tripod or rods not level, wrong location, poor aiming, wrong Electronic Distance Measurement (EDM; also known as Measurement Mode), parallax, instrument in need of calibration, etc. If errors are encountered, double-check every element of the setup and see if the error can be addressed and minimized. If the source of the errors cannot be determined, then the survey will need to be started over from the beginning.

Surveying errors are managed by checking the backsight every hour, after about 100 shots, or after a good stopping point (e.g., after finishing T2). Take a check shot of the backsight every time you check the backsight.

Do not continue if errors are outside the acceptable range. Stop and remedy the problem.

2.2 Revisiting a survey

Before leaving for the field, be sure to gather any previous trip reports, survey notes and details of the original survey, revisit maps, headpin and control reference photos, vegetation transect lengths and calibrate the Weatherport hand-held unit before you leave the office (see Table 2 for all necessary revisit documents). Also make sure to upload all necessary baseline files of previous survey control and headpin coordinates to the data collector before leaving the office. Refer to Appendix A for more details about how to do this with our current equipment.

In addition, have the GIS technician load all control points, headpins, and other relevant locations onto GPS units before leaving for the field.

In the field, locate headpins for all transects and all survey control at the reach, and mark with pin flags and flagging. Set up the taglines and transect tapes, making sure the lengths are within 0.1 m of the original vegetation transect lengths. The lead surveyor then needs to figure out a surveying strategy for the reach.

When revisiting a site, the initial parameters of the survey will be set up differently than when establishing a survey. We recommend setting up the total station over one known control point and the backsight over another known control point to re-establish the coordinate system. Refer to Appendix A for more details.

Acceptable Errors for Revisiting a Survey:

Horizontal (includes the northing and easting): 0.000 - 0.050 (5 cm).
Ideally, it is best to have < 0.020 (2 cm) error.

Vertical (includes elevation): 0.000-0.030 (3 cm).
Ideally, it is best to have <0.010 (1.0 cm) error.

Do not continue the survey if errors are outside of the acceptable range. Stop and remedy the problem. See Section 2.1 for tips on minimizing errors. An additional factor that can create errors during a revisit is that the location of a control point may shift. The survey team can determine this through check shots on multiple control points. If there is only one control point with high errors, most likely its location has shifted. Do not attempt to move the control point. Instead, record this in the field notebook and shoot in its new position.

Table 2. Summary of all data derived from the survey or used for revisits.

Data	File type	Location*	Comments	Needed for revisit
Survey Visit Notes	Word	Corrected folder	Typed up from field notes	X
Original raw data	.JOB, .raw, .csv, and .txt	Original folder	Only one master copy!	
Metadata	Worksheet in FINAL Excel	Corrected folder		
Corrections to raw data	Worksheet in FINAL Excel spreadsheet	Corrected folder		
Final corrected data	Worksheet in FINAL Excel spreadsheet & .csv file	Corrected folder		
Cross-sections for each transect	Each transect has a worksheet in FINAL Excel spreadsheet	Corrected folder		
Longitudinal profile for thalweg	Worksheet in FINAL Excel spreadsheet	Corrected folder		
Post-processing notes	Word	Corrected folder	Tied in closely with FINAL spreadsheet	
Revisit file: Control coordinates (local & real-world)	Separate .csv and .xlsx files	Corrected folder	Uploaded to data collector for revisits	X
Revisit file: Headpin & ground surface coordinates (local & real-world)	Separate .csv and .xlsx files	Corrected folder	Uploaded to data collector for revisits	X
Plan map for revisit (or Revisit map)	PDF or JPEG file	Corrected folder	Created from real-world coordinates imported into ArcGIS	X
Survey reference photos	Powerpoint or Word	Field Crews folder	Photos of survey control points and descriptions of locations	X
Reference headpin photos	Powerpoint	Field Crews folder	Photos of headpins and descriptions of locations	X
Previous trip reports	Word	Field Crews folder		X
Spatial data for headpins, unmonumented transect ends, control points, monitoring wells, etc.	Shape files	Riparian monitoring spatial data folder		X

*Corrected folder =X:\Active_Monitoring_Projects\Riparian\Data\Geomorphology*PARK**PARK _Reach_YEAR*\corr*PARK _Reach_YEAR*
Original folder = X:\Active_Monitoring_Projects\Riparian\Data\Geomorphology*PARK**PARK _Reach_YEAR*\orig*PARK _Reach_YEAR*
Field Crews folder = X:\Active_Monitoring_Projects\Riparian\Field_Crews*PARK*
Riparian monitoring spatial data folder = G:\GIS\Data\Parks*PARK*\Monitoring\NCPN_Riparian

2.3 Establishing a new instrument setup

Make as many shots as possible from each instrument setup, including transects, stream profile, control points, and hydrologic instrumentation. Refer to Appendix A for specific instructions for our current equipment. Shoot in additional instrument setup locations as necessary to complete the survey. Make sure to document any additional instrument locations and backsights used in the field notes.

3. Surveying the reach

Set up all seven taglines and transect tapes on adjacent transects (see SOP#4 for instructions). Make sure that the length of each transect corresponds with the transect length recorded during the vegetation monitoring.

Keep a running list of points, descriptions, and rod heights in the field notebook as you survey. The survey lead needs to be diligent about making sure that all three pieces of information are correct for each shot. You can group shots that have the same description and rod height (see Fig. 5 for an example).

Different shots may require a different Electronic Distance Measurement (EDM) or Measurement Mode. This changes how precise the total station shoots the laser. Use a precise or fine EDM or measurement mode for control points, headpins, and any hydrologic equipment. Use a normal EDM or coarse measurement mode for all other shots.

Once the first occupied point and backsight have been established, you can begin surveying. All of the following will need to be surveyed (see additional instructions in the proceeding sections):

- Control points
- 7 transects including:
    - Headpins & ground surfaces next to headpins
    - Unmonumented transect end points
    - Water's edge
    - Every meter mark on the transect tape
    - Every geomorphic break along transect
- Longitudinal profile of the thalweg (from approximately 10 m upstream to 10 m downstream of the reach)
- Hydrologic equipment (only in some reaches):
    - Top of well casings (with cap off)
    - Ground surfaces next to wells
    - If instream, water surface next to hydrologic equipment
    - Transect that is closest to hydrologic equipment.

Shoot as much of the reach as is visible from the current location before moving the instrument.

3.1 Surveying control points

It is highly recommended to shoot as many control points as are visible from the occupied point as foresights or confirmation/check shots. For control shots, the rod persons will use the point

(not the foot) of the prism pole (Fig. 2) on the exact location of the control point (i.e., the center of the X on rock or in the pre-stamped dot on a rebar cap). Another way to minimize survey error is to use a bipod to keep the rod steady and level for control shots.

3.2 Surveying transects

Cross-sections of the stream are surveyed along each transect, and shots are taken at the following locations:

1) One-meter intervals marked on the tagline
2) Slope break points that provide an accurate depiction of topography (see Figure 7)
3) The top of each headpin and the ground surface downstream of the rebar
4) The ground surface at each unmonumented transect end point
5) The left and right edge of the water (note the time surveyed for each on transects with wells)
6) Bankfull elevations on both banks (if this can be determined)

Cross-sections are also extended beyond each transect end point onto a stable upland surface, and are surveyed at 2-5 m intervals and at slope break points. The best way to extend the transect and stay on the line is to use the stakeout feature in the data collector.

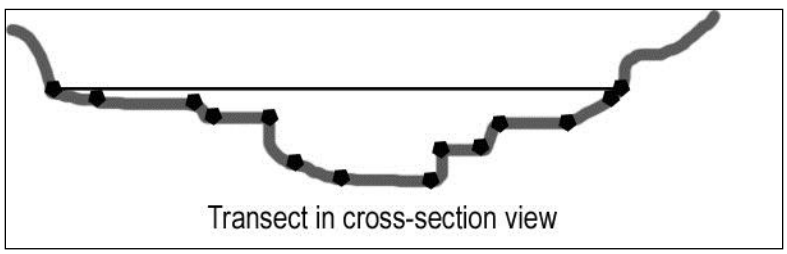


Figure 7. Example of slope breaks points surveyed in addition to 1-m intervals.

A. Begin at any location along the tagline, although it is most efficient for rod persons to leapfrog down the transect *away* from the total station. Shoot as much of the transect as possible from the initial instrument setup. Each shot should be taken with the rod flush against the downstream side of the tagline. Use codes in Table 1 to name shots in the data collector and field notes (Fig. 5). Code names for each point should include the transect number, but there is no need to distinguish between 1-m interval shots and slope break shots along the transect.

B. Rod crew members should alert the total station operator when they reach a headpin. Set the rod point (not the foot) in the center of the top of the rebar or on the stamped dot/X on the rebar cap, notifying the total station operator that the shot is “Top of Pin.” The next shot should be on the ground surface next to the rebar on the downstream side (using the rod foot). If a transect end point is not monumented, make sure to shoot the ground surface at the pin flag marking this using one of the rods with a foot end.

C. Rod crew members should also alert the total station operator when they reach the right and left edge of the water, bankfull (if this can be determined), and any debris piles. On transects with wells, note the time that right and left edges of water are recorded.

D. After surveying transects along the tagline, use the data in the total station to extend the transects beyond the transect end points onto the upland terrace. Beyond transect end points, points should be surveyed at 2-5 m intervals and all surface breaks until you reach a very stable upland surface. You may extend the tagline along the correct azimuth to help line up the shots or you can use a Stakeout feature in the data collector to designate the line. Refer to Appendix A for more details.

E. Determine when to move the total station.
- If you can shoot additional transects from the existing instrument setup, make sure to check the backsight, record any errors reported by the data collector, and take a check shot before beginning the next transect.
- If the total station must be moved to accommodate the next transect, shoot as much of the stream profile as possible before moving the instrument.
- If a transect needs to be shot from two different instrument setups, mark the location where you stopped surveying with flagging so that you can begin surveying at the correct location from the new instrument setup. Also record this location in the field notebook.

F. Tips for Difficult Surveying Situations:
- If dense vegetation is blocking the shot, move the rod slightly upstream or downstream while keeping the bottom of the rod on the same geomorphic surface. The rod person will need to estimate the distance upstream or downstream of the tagline and relay this to the total station operator to document in the field notes.
- Use an alternative rod height. The total station operator finds a section of the rod that is visible and sets the crosshairs to the elevation shown on the rod face (e.g., 1.500 m). The rod person then adjusts the rod so that the prism is at this height. The total station operator instructs the rod person to raise or lower the prism until it is centered in the pre-set crosshairs, takes the shot, and enters the appropriate rod height.
- To take a shot where it's difficult to get the rod level (e.g., a cliff wall), place the prism on the wall and use a rod height of zero.
- If the rod is too tall (e.g., at an overhanging cliff wall next to a stream), you can use a small stick instead of the rod. Place the prism on top of the stick and measure from the end of the stick to the center of the prism.
- Ground shots: It is also possible to place the prism directly on the ground (i.e., by laying the rod on its side) if that is the only way to get shot. Measure rod height from the ground to center of prism.
- Take a shot using the horizontal or vertical offset functions in the data collector (see instructions for the software).
- If dense vegetation is blocking part of the prism but some of the glass is still visible, aim the total station at the crosshairs in the center of the prism and not at the portion of visible glass. If you are unable to get a shot at any of the standard rod heights, attempt one of the alternative shots described above.

- Where large woody or other debris precludes placing the base of the rod on the ground surface, the rod person should place it on the object for the shot, and relay to the total station operator the height of the debris above the ground surface. The total station operator should document this information in the field notes in order to make later adjustments to the survey data. It is helpful if you can shoot a ground shot perpendicular to the transect that is the same height of the ground below the debris.

3.3 Surveying the stream profile

The stream's longitudinal profile is surveyed following the thalweg throughout the reach. The thalweg is a continuous line of the deepest part of the stream channel. The entire length of the reach between the transects is surveyed, as well as far enough upstream and downstream to capture important features near the ends of the reach (approximately 10 m upstream and downstream of the reach). Shots should accurately represent major slope breaks and channel features such as pools, runs, riffles, and meander bends.

- The total station operator shoots as much of the stream profile as possible from each instrument setup.
- Rod persons should leap-frog 1-m intervals, moving continuously upstream or downstream for each section.
- River right and left edge of water shots need to be taken at the beginning and end of the thalweg profile, in addition to at each transect crossing.
- Number each segment of the thalweg profile separately to organize shots for the final map. Use P# for the descriptions, with # as the number of the transect upstream of the shot (e.g., P0 for profile shots taken upstream of transect 1, P1 for profile shots taken between transects 1 and 2, P2 for profile shots taken between transects 2 and 3, etc.).
- To ensure continuity of the survey, rod persons mark the start and end of each section of profile shot with flagging. Label this flagging to differentiate it from flagging used to identify transect locations.

3.4 Surveying wells and other hydrologic monitoring equipment

NCPN has determined that the minimum requirements necessary for surveying hydrologic equipment requires a total station with an angle precision of 3 seconds, roughly +/- 0.01 cm over 500 m. The current Nikon Nivo 3.M total station fulfills this.

For the select reaches that have hydrologic equipment, survey all hydrologic monitoring equipment in and around the reach. Each of these reaches will have permanent datum coordinates, referencing permanent bedrock survey control or stable uplands rebar (see Section 1.4 D). The permanent datum will be the instrument location. You will also need another known point to backsight to use as a reference elevation. This surveying will need to be in these coordinates, which are the basis for conversion of hydrologic data and integrated analysis, and may be comprised of establishing or revisiting, depending on the reach.

Riparian/instream wells – Bring pipe wrenches to open the well cap. Survey the following using permanent datum coordinates and appropriate coding for each (see Table 1):

1. Top of the uncapped well at the measuring notch (Fig. 8)
2. Ground surface next to the measuring notch on the well casing
3. If instream, the water surface next to the hydrologic equipment
4. The entire length of the nearest cross-section transect to the wells. This can be done between the transect end points and does not need to be extended to stable uplands. Follow the methods outlined in Section 3.2.

Staff gages – Select a height on the staff gage to take a shot (e.g., 1.00 m, as read from the face of the staff gage), and record this in the field notes. If the staff gage contains more than one section (e.g., one for ≤ 1.0 m and one for 1.0-2.0 m), collect readings for both.

For the hydrologic equipment, elevations are the most important numbers. The acceptable errors for hydrologic surveying are as follows:

Acceptable Errors for Establishing a Hydrologic Survey:

Horizontal (includes the northing and easting): 0.000 - 0.030 m (3 cm).
Ideally, it is best to have < 0.020 m (2 cm) error.

Vertical (includes elevation): 0.000-0.010 m (1 cm).
Ideally, it is best to have **<0.006 m (6 mm)** error.

Acceptable Errors for Revisiting a Hydrologic Survey:

Horizontal (includes the northing and easting): 0.000 - 0.050 (5 cm).
Ideally, it is best to have < 0.020 (2 cm) error.

Vertical (includes elevation): 0.000-0.010 m (1 cm).
Ideally, it is best to have **<0.006 m (6 mm)** error.

If the elevational error is over 0.010 m, then double check all the rod heights and try to determine the source of error. Complete a final closure error by shooting back to the permanent datum (or original instrument location).

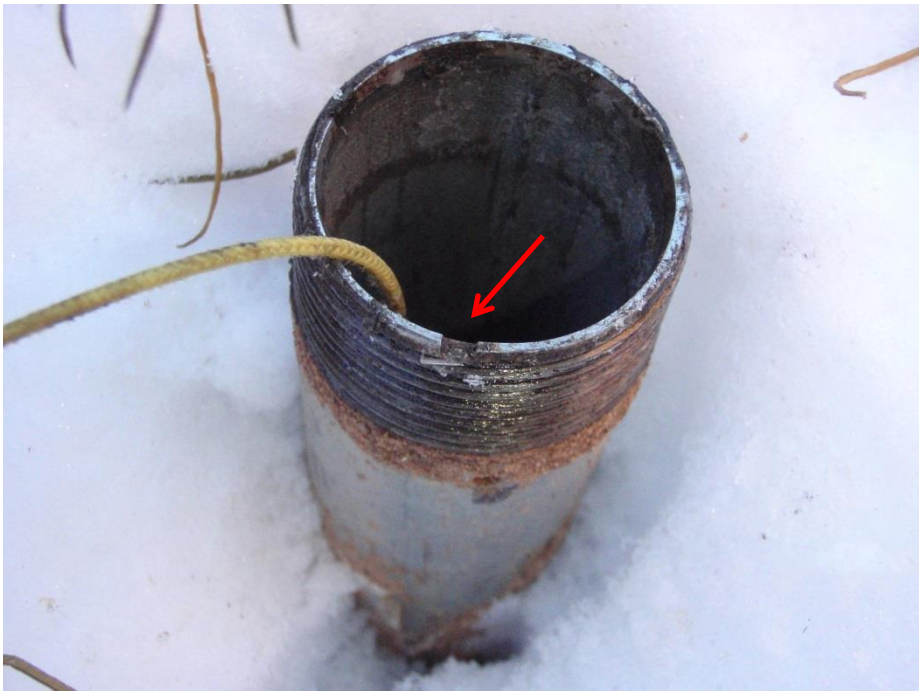


Figure 8. The measuring notch on the well casing

Tips for Surveying Hydrologic Equipment:

- Survey the hydrologic equipment in a separate job from the rest of the transect.
- Shorter distance shots will have a higher accuracy than long distance shots.
- Maintain a tight control network and check your backsight often. This will be the main source of quality checking.
- Use a precise electronic distance measurement (EDM) or fine measurement mode (see survey manual for software specifics).
- If it is a revisit, take previous measurements (level sheets) to compare elevations.
- Refer to the Hydrologic Surveying Cheatsheet (see Appendix C) to see if there are any special instructions for surveying (e.g., use the rod point in the measuring notch, etc.).

3.5 Tips for surveying

- To effectively manage surveying errors, check the backsight every hour, after about 100 shots, or after a good stopping point (e.g., after finishing transect 2). See Acceptable Errors for Establishing a Survey in Section 2.1.
- Make sure that the tripod is solid from the ground up (i.e., the feet are solidly placed so there's no chance of the tripod moving or settling). Take extra precaution on bedrock since it is easy to bump the tripod. Use a permanent marker to draw circles on the rock around the laser plummet dot and around the tripod feet.
- If the tripod becomes out of level (e.g., from being accidentally bumped or the tripod heating up), repeat the total station setup procedures, including leveling the tripod, measuring the instrument and backsight heights, setting the temperature and atmospheric pressure, and performing the backsight circle.
- Know where to easily access the list of all the points in the job in the survey software.
- There is a manual cord if the Bluetooth (wireless option) doesn't work.

- NCPN prisms have a prism constant of -30 mm. This is usually printed on the prism target facing the gun. Do **NOT** set the prism constant in total station or it doubles the value of the constant. Set the prism constant in the data collector ONLY.
- Take check/confirmation shots of the backsight or a previously shot control point, which can be helpful in post-processing (use code.#, e.g., CP1.1, CP1.2, CP1.3, etc.).
- The battery life of the data collector should last for about 24 hours of surveying (usually 3 full days of surveying). Older total station batteries last 4-5 hours while new ones last about 6 hours.
- Make sure to charge total station batteries at the end of each day and data collector batteries at the end of every 3rd day.
- Do not remove any pin flags until the very end of the survey.

4. After the Field Visit

4.1 Tasks performed immediately after returning from the field

This section contains instructions for downloading raw data from the data collector, returning GPS units, and creating a Survey Visit Notes document from the details recorded in your field notebook. Table 2 provides a summary of all data derived from the survey or used for revisits.

Download raw data from the data collector.

A. For each reach surveyed, create an Original and a Corrected folder (e.g., origZION_P-03_2012, corrZION_P-03_2012, etc.) in X:\Active_Monitoring_Projects\Riparian\Data\Geomorphology*PARK\PARK_Reach_YEAR*. It is essential to include the year in the file name.

B. Download or export the raw data from the data collector into the Original folder:

   a. Connect the data collector to the computer with a USB cord. This automatically opens Windows Mobile Device Center > Connect without setting up your device > File Management > Browse the contents of your device > drive > Trimble Data. Navigate to the job.

   b. Copy and paste or move the .JOB file to the Original folder. Leave this file on the data collector for the time being.

   c. Save a comma delimited (.csv) file. On the Trimble TSC3 data collector, open the correct job. Click on Jobs > Import / Export > Export fixed format:

      - File format: pick Comma Delimited (*.csv or *.txt)
      - File name: keep the same file name and make sure it has .csv as the file extension
      - Point name: Field1
      - Northing: Field2
      - Elevation: Field4
      - Point code: Field5
      - Easting: Field3
      - Click Accept
      - Choose All Points (or whatever is appropriate)

- Click OK on the Transfer Complete window.
- Transfer this file from the data collector into the Original folder.

These are the only files that belong in the Original folder. This data will be archived.

C. Make copies of the original data (.JOB, .csv, and .txt files) and paste them into the Corrected data folder. Once corrections have been made, rename these files by adding "corr" to the beginning of the existing names.

Download data from the GPS units.
GPS units should be given to the GIS technician as soon as you return from the field. All data should be downloaded and differentially corrected as soon as possible. The coordinates are then given to the lead surveyor for the post-processing. These data are used for relocating points and making maps.

Use survey notes to write a Survey Visit Notes document
In a Word document, create a report with the details of the survey from your field notebook, including the dates, lead surveyor, the rod crew, the type of total station and software used in survey, if scale factors were used, intrasurvey errors, prism constant, weather, etc. Add any relevant details important to the survey or for future visits.

4.2 Documenting post-processing steps

Create a Word document to record the details of survey post-processing, including the number of jobs surveyed for the reach (if more than one) and specifics of each post-processing step (i.e., what points were used for translating and rotating, what computer programs were used to accomplish the tasks (e.g., "exported file from Traverse PC and imported into ArcGIS"), etc. This document should be clear and specific enough to allow someone else to understand what you did and to repeat it, if necessary. The list of individual corrections does not need to be listed here but should be referenced in this document.

4.3 Correcting survey data and other initial processing

Create a spreadsheet for the corrected survey data.
In the Corrected folder, create an Excel spreadsheet that contains the 13 worksheets outlined in Table 3. More detailed instructions of how to complete each worksheet are provided in the remainder of this SOP and in Appendix B.

Make corrections to the survey data.
Copy the coordinates from the .csv file into the Reach Corrections worksheet. Make corrections from field notes here in a separate column. For example, where an incorrect rod height is documented in the field notes, locate the appropriate point number in the Excel file, and make the needed correction to the elevation recorded for the shot. Notes describing each correction can be made to the coordinate and raw data files in the corrected data folder. When all corrections

have been completed, save the final data as a comma-delimited file (.csv) in the Corrected folder. This is the file that is imported into the survey software used by the data collector for revisits.

Translate and rotate all jobs into the same coordinate system.
If the survey data contains more than one job, all jobs need to be converted to the same coordinate system. Import the corrected data into your survey software. Determine which job is the most accurate, and translate and rotate the remaining jobs around that. Document details of each step in your post-processing notes document (see Section 4.2).

4.4 Creating stream cross-sections for each transect

To create stream cross-sections for each transect, data are processed in the survey software then graphed in Excel (refer to Appendix B for specific instructions). Make sure that the Excel file with figures of the transect cross-sections and the longitudinal profile includes “FINAL” and a version number in the file name (e.g., ZION_P-03_2011_FINAL_1.0).

The advantage of using this method is that the survey software calculates the direct length between the headpins rather than the accumulated lengths between each surveyed point. Any variations from the line that may have occurred while surveying points along the transect are disregarded, and points are “snapped” into a straight line between the headpins so that errors do not accumulate over the length of the transect. In this section, the survey data are translated and rotated to the locations of the vegetation transects in order to graph the stream cross-sections. Note that this is different than translating and rotating the data to real-world coordinates. This method also allows locations along the transect tape to be easily correlated with vegetation data for integrated analyses.

Table 3. Worksheets in the excel file that contain the final corrected survey data.

Worksheet	**Contains**
Metadata	Explanations of survey codes and descriptions, and general project information
T1, T2, T3, etc. thru T7 (each transect has its own worksheet)	– All cross-sectional data for that transect. – One graph showing the full cross-section. – Another graph showing the close-up cross-section between the vegetation transect end points. – Relevant data needed for graphing purposes. – Comparison of vegetation transect length vs. survey transect length. – Waterline elevation.
Profile, Sinuosity, Slope	– All longitudinal profile data for the reach. – One graph showing the longitudinal profile for the reach. – Relevant data needed for graphing purposes. – Slope, including calculations. – Sinuosity index, including calculations.
Reach (e.g., P-03) Corrections	– The first 5 columns contain the original data for all shots that were taken (point name, northing, easting, elevation, and description) – The 6th column contains the corrections next to the relevant shot. Describe in detail what correction happened (e.g., corrected rod height from 1.7 to 2.0, deleted, changed description from T3L-TOP to T3R-TOP, duplicate shot deleted, etc.). – The next columns will be the corrected data.
Corr data- FINAL	The final version of the corrected data. Choose the most accurate shot for each control point and headpin, and make sure that only one point is included for each.
Comparing Pts	Shows intrasurvey errors (i.e., compares control points from different instrument locations)
Real World Coord	The corrected data after being translated and rotated to real-world coordinates. These data are used for reporting and not for survey revisits.

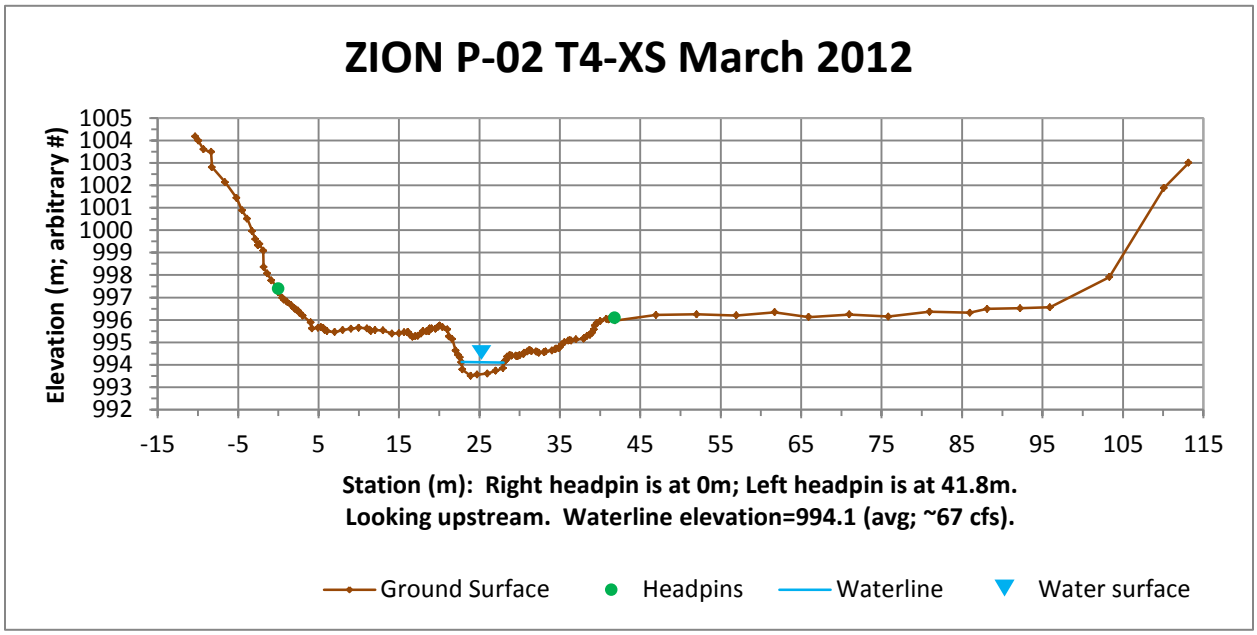


Figure 9. The full survey of a stream cross-section for a transect.

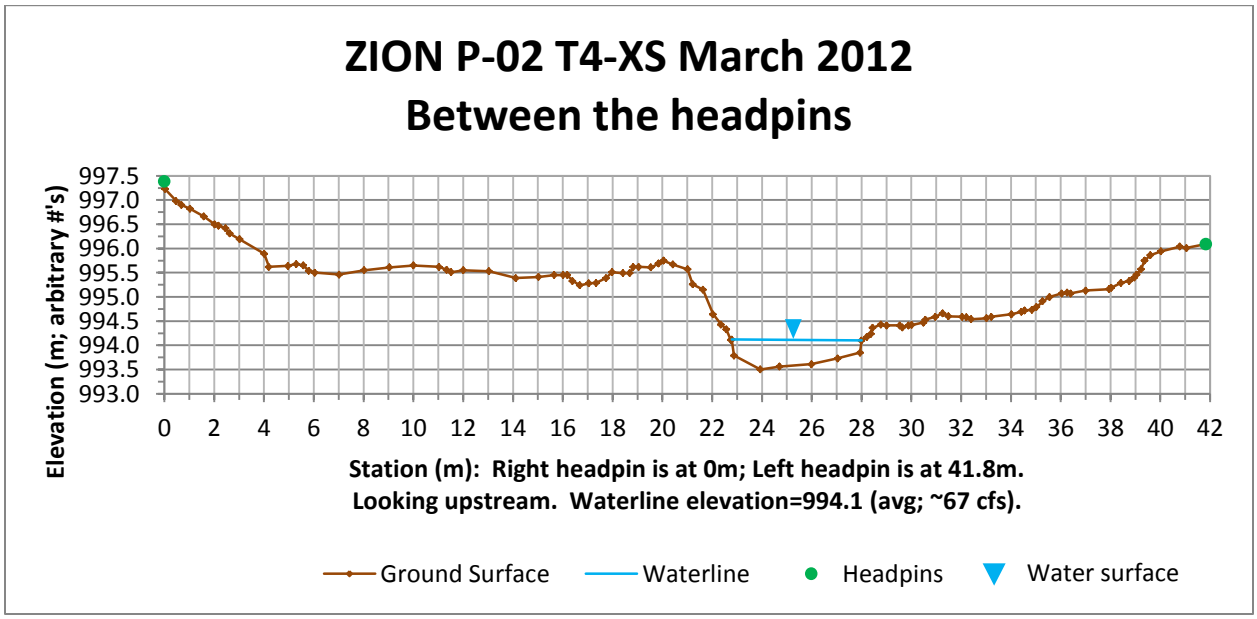


Figure 10. A stream cross-section between the end points of a vegetation transect.

4.5 Creating a longitudinal profile of the stream and calculating channel slope and sinuosity

A. To create a longitudinal profile of the stream, data are processed in the survey software then graphed in Excel. Refer to Appendix B for specific instructions.

B. Calculate the channel slope of the reach.
- Determine the highest water elevation (i.e., the most upstream waterline).
- Determine the lowest water elevation (i.e., the most downstream waterline).
- Calculate the difference between the highest and lowest water elevations.
- Calculate the stream length in meters between the stations of the points with the highest and lowest water elevations, and convert this value to kilometers: stream length (m) * 0.001 (km/m).
- Calculate the stream channel slope (m/km) = difference in water elevations (m) / stream length (km).

F. Calculate the sinuosity index.
- Determine the length of the stream in meters. This is the station of the most downstream point in the longitudinal profile.
- Determine the length of the valley in meters. Import the profile shots that have been converted to real-world coordinates into ArcGIS (see section 4.6 below), and use aerial photos to draw a line down the center of the valley. Calculate the distance along this line from the most upstream profile shot to the most downstream profile shot.
- Sinuosity index = stream length (m) / down valley length (m)
- To calculating sinuosity for a single reach, divide the total reach length by the straight-line distance between the thalweg at transects 1 and 7.

I6 =SQRT((POWER((B5-B6),2))+(POWER((C5-C6),2)))

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	*All values are in meters.*													
2	*These pts are in the relative local arbitrary coordinate system for the reach.*								*Longitudinal profile throughout reach.*					
3														
4	Point	Northing	Easting	Elevation	Description	At Transect				Station	Elevation		Graph	Waterline
5	2013KL700	4955.37	4903.12	993.347	US-RE_ICE	Upstrm				0.000	993.347	PROFILE0	991	993.34
6	2013KL701	4956.4	4902.28	993.343	US-LE_ICE				1.329	1.329	993.343	PROFILE0		
7	2013KL699	4956.08	4902.83	993.29	PROFILE0				0.638	1.967	993.29	PROFILE0		
8	2013KL698	4956.63	4903.32	993.32	PROFILE0				0.734	2.701	993.32	PROFILE0		
9	2013KL697	4957.2	4903.96	993.29	PROFILE0				0.854	3.556	993.29	PROFILE0		
10	2013KL696	4957.69	4904.58	993.29	PROFILE0				0.794	4.350	993.29	PROFILE0		
11	2013KL695	4958.25	4905.19	993.29	PROFILE0				0.830	5.180	993.29	PROFILE0		
12	2013KL694	4958.86	4905.81	993.28	PROFILE0				0.873	6.053	993.28	PROFILE0		
13	2013KL693	4959.41	4906.65	993.29	PROFILE0				1.005	7.058	993.29	PROFILE0		
14	2013KL692	4959.96	4907.42	993.26	PROFILE0				0.942	8.000	993.26	PROFILE0		
15	2013KL691	4960.46	4908.17	993.24	PROFILE0				0.901	8.901	993.24	PROFILE0		
16	2013KL690	4961.18	4908.73	993.19	PROFILE0				0.914	9.815	993.19	PROFILE0		
17	2013KL689	4961.42	4909.31	993.22	PROFILE1	T1			0.624	10.439	993.22	PROFILE1	991	993.31
18	2013KL688	4962.1	4910.41	993.2	PROFILE1				1.295	11.735	993.2	PROFILE1		
19	2013KL687	4962.54	4911.27	993.18	PROFILE1				0.962	12.697	993.18	PROFILE1		
20	2013KL686	4963.13	4912.12	993.19	PROFILE1				1.035	13.732	993.19	PROFILE1		
21	2013KL685	4963.96	4912.83	993.17	PROFILE1				1.092	14.825	993.17	PROFILE1		
22	2013KL684	4964.33	4913.86	993.19	PROFILE1				1.096	15.921	993.19	PROFILE1		
23	2013KL683	4964.6	4914.68	993.17	PROFILE1				0.859	16.780	993.17	PROFILE1		
24	2013KL682	4965.41	4915.86	993.16	PROFILE1				1.428	18.208	993.16	PROFILE1		
25	2013KL681	4966.27	4916.1	993.21	PROFILE1				0.901	19.110	993.21	PROFILE1		

Sheet1 Sheet2 Sheet3

Ready 145%

Figure 11. Longitudinal profile data for a stream in an Excel worksheet.

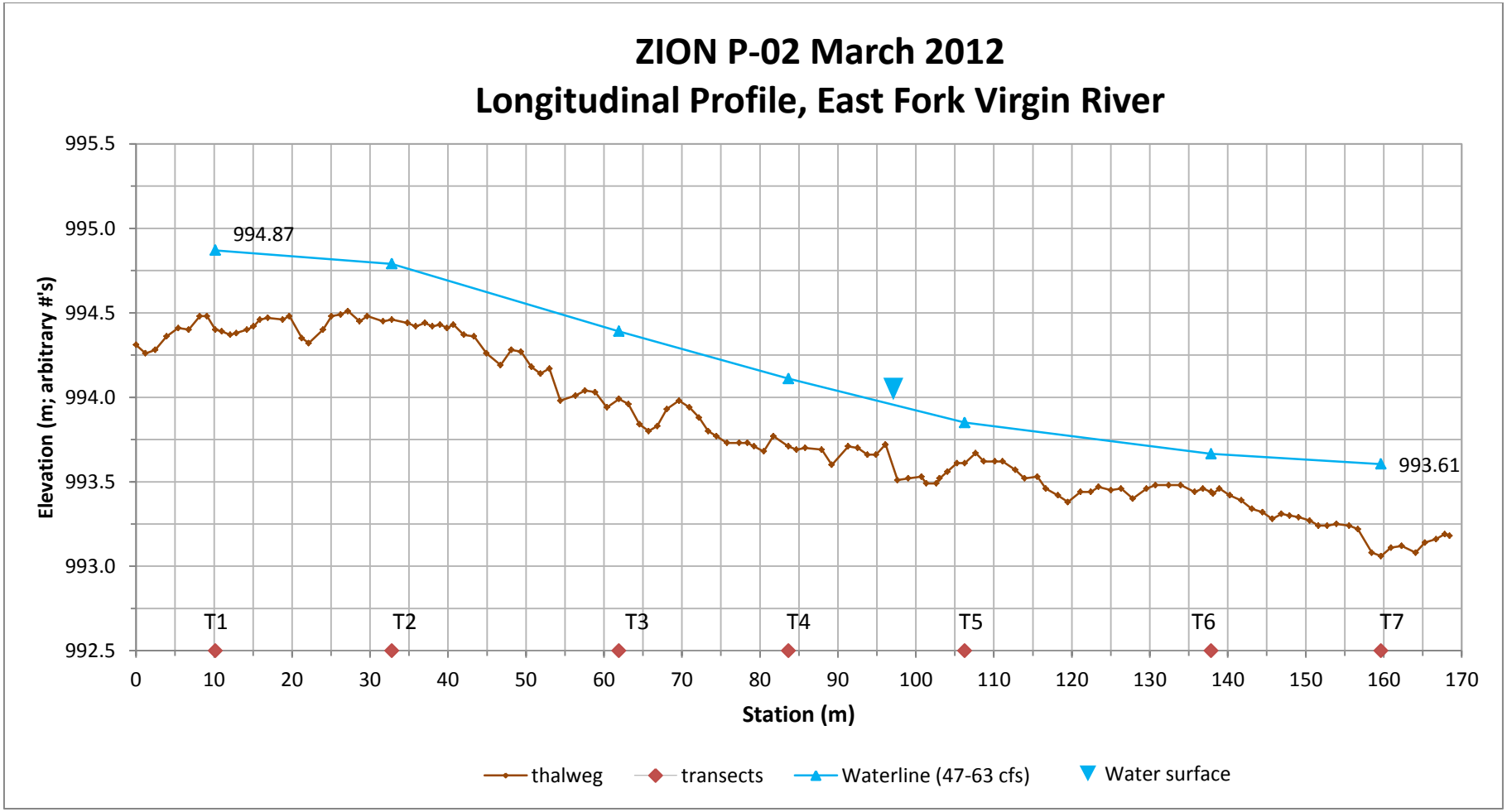


Figure 12. Longitudinal profile of a stream.

4.6 Translating and rotating survey data into real-world coordinates

Using your survey software, the data is translated and rotated to real-world coordinates and converted into UTM coordinates. Due to errors introduced from the GPS, these real-world coordinates should be used only for reporting purposes (e.g., to show the points on background imagery in ArcGIS, make revisit maps, etc.) and not in the data collector for survey revisits.

A. Import the corrected .csv file into your survey software.

B. Obtain differentially-corrected UTM coordinates for all control points, headpins, instrument setups, and backsights from the GIS technician. Examine the GPS report to identify points with the combination of the lowest Positional Dilution of Precision (PDOP) values and reported errors (horizontal and vertical precision). Select the two most accurate points.

C. Using the COGO features in the software, translate the entire survey dataset to the most accurate point recorded on the GPS unit. The coordinates of the selected point will match the coordinates of that same point in the GPS data. Rotate the dataset to the second-most accurate GPS point.

D. Compare the northing and easting coordinates for the remaining control points to make sure that they are within a few centimeters to those reported by GPS. If the error is greater than this, check all transformations and rotations to identify any errors and correct them.

E. Export these coordinates into the Real-world worksheet in the Excel file. Be sure to report the errors here as well.

4.7 Making a revisit map

Import the real-world coordinates into ArcGIS, and make a map for the next visit which clearly shows the control points, occupied points, transects, headpins, and stream profile (see Fig. 13 for an example).

4.8 Creating revisit files

In the survey software or Excel, separate the corrected local coordinates for the control points, headpins, ground surfaces at the headpins, and transect end points from the rest of the survey data and save as a .csv file. This file is uploaded to the data collector before a revisit survey (see Section 2.2 for details).

REFERENCES

Demeurichy, Kenny. CHaMP Introduction to Topographic Survey Manual. Utah State University, Ecogeomophology and Topographic Analysis Lab. Bonneville Power Administration.

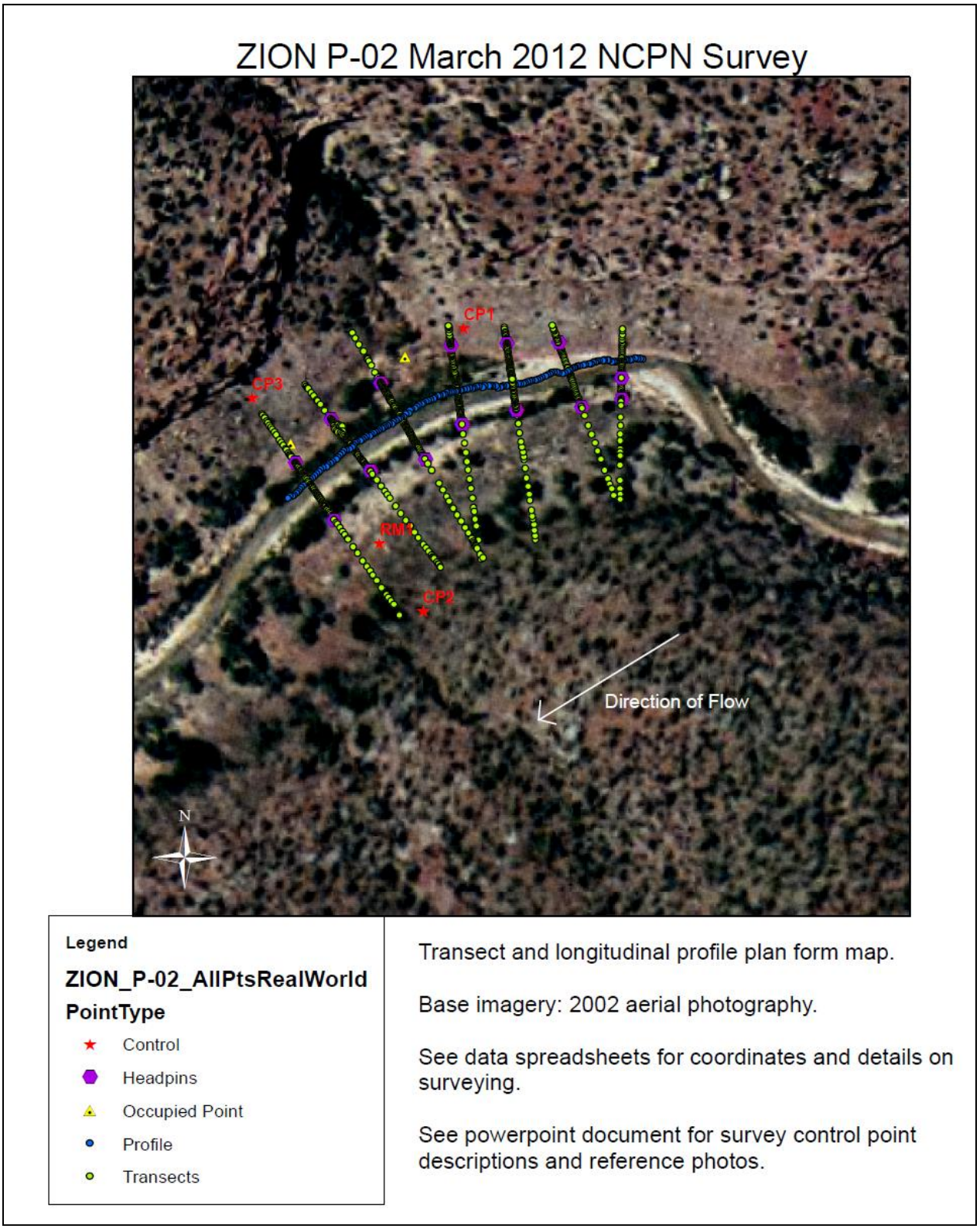


Figure 13. Revisit map containing all surveyed points at a reach.

SOP #9 Stream Channel Surveying

Appendix A

Operating the Trimble TSC3 Data Collector & Nikon Nivo 3.M Total Station

Turn on the Trimble TSC3 data collector and open Trimble Access. As of 9/1/15, you need to connect the data collector with the cord to the total station.

1.1 Establishing a survey

Set the initial parameters for the survey. Each of these details will need to be documented in the field notebook.

A. To begin a job, go to General Survey > New job. Enter the Job name. You can Browse to make sure you're in the correct folder in the data collector.
   - Record the job name using the park code, reachID, and year (e.g., ARCH_C-01_2012). This name will appear on the upper part of the screen in Trimble Access.
   - In the Properties Box:
   - Coord. Sys: Scale 1.0000 (meaning there is no scale factor applied)
   - Units: Meters
   - Linked files: None
   - Active map: None
   - Feature library: None (unless you've made a separate file of all the codes)
   - Click the 1/2 button to go to the next screen
   - Cogo settings: Ground
   - Additional settings: Off
   - Media file: Previous Point
   - Leave all the others as question marks.
   - Click Accept.

B. For station setup, go to Measure > Nikon > Station Setup (the data collector will then connect with the total station). The total station needs to not be on the bubble screen. Hit the yellow REC/ENT button to switch to the data screen.
   - Corrections: Pressure: referencing the separate High Gear Weather Port hand held unit, enter the pressure and hit the black triangle to enter the correct units.
   - Temperature: do the same as above but for the temperature (note: the High Gear Weather Port, if left in direct sunshine, will report higher than normal temperatures)
     - The hand-held weather unit will automatically shut off after 48 hours if Sleep mode is on (currently on; see manual for details). The barometer on the Weatherport unit will frequently need calibration. See the Weatherport manual for details.
   - Click Accept

- Instrument point name: since this is an establishment, enter the year, the surveyor initials and 1 (e.g., 2015KL1)
- Code: enter the control point you are occupying (e.g., CP1 or RM2, etc.)
- Instrument height: enter the height of the instrument in meters (e.g., 1.534 m)
- Northing: enter a local arbitrary number (Y coordinate; e.g., 5000.000). *Note: the initial survey at each reach establishes an arbitrary coordinate system that is translated and rotated into UTM coordinates during post-processing in the office. It is best to have the numbers be all different series (5000, 10000, 1000 rather than 5000, 5000, 5000) to help distinguish these coordinates during post-processing.*
- Easting: enter a local arbitrary number (X coordinate; e.g., 10,000.000)
- Elevation: enter a local arbitrary number (Z coordinate; e.g., 2,000.000)
- Do not click the Control point box.
- Click Enter. Make sure all information is correct.
- Click Accept.
- Backsight point name: since this is an establishment, enter the year, the surveyor initials and 2 (e.g., 2015KL2)
- Code: enter the control point the backsight is on (e.g., CP2 or RM3, etc.)
- Backsight height: enter the rod height of the backsight
- Azimuth: enter 0
- Method: Angles and Distance
- Click Enter. Make sure all information is correct.
- Click Measure. The total station will now measure the backsight.
- Click Store. You should hear a voice that says "Station Setup Completed." The gun is now set to zero degrees on the backsight.

  The Station Setup is complete. **This zero angle from the total station to the backsight is very important because it becomes the basis for all horizontal angles for all other shots taken after the Station Setup as well as any future horizontal angle errors. It is important that this is not changed in any way. When you re-check the backsight, you are re-checking this angle.** You can now begin surveying.

C. To start shooting points (or sideshots), go to Measure > Measure Topo
   - Make sure the prism constant is set to -30 mm. On the right side of the Measure Topo screen, you will see a prism icon and two numbers. The top number is the prism constant (-30) and the bottom number is the rod height. You can click on this icon to make changes.
   - Point name: enter 2015KL3 (this is the third point of the job)
   - Code: enter the description code (refer to Table 1 in SOP 9; e.g., T1R-TOP)
   - Target height: enter the rod height in meters (e.g., 1.700 m)
   - Click Measure (the gun is now shooting the target)
   - Once the numbers are on the screen, click Store to store the point. You should hear a voice that says, "Observation stored."

D. To change between Fine & Coarse measurement modes and make things more efficient so you only have to hit one button to enter and store the point:

- From the Measure Topo screen, click on the up arrow (to the right of the Measure button)
- Click on Options
- Right now you are in a Fine measurement mode (i.e., more accurate shot for control points, headpins, and hydrologic equipment). Click on the dropdown in Measurement mode to switch between Fine and Coarse
- Uncheck the View Before Storage (which will eliminate the need to hit Store for every shot)

Acceptable Errors for Establishing a Survey:

Horizontal (includes the northing and easting): 0.000 - 0.030 m (3 cm).
Ideally, it is best to have < 0.020 m (2 cm) error.

Vertical (includes elevation): 0.000-0.010 m (1 cm).
Ideally, it is best to have <0.005 m (0.5 cm) error.

Do not continue if errors are outside the acceptable range. Stop and remedy the problem.

E. Dealing With Errors

There are plenty of ways for errors to occur within a survey. Errors are minimized by thoroughly training the survey lead and rod persons and by constant attention to detail throughout the survey. Survey errors can accumulate, and in the worst case scenario, the data will be unusable for scientific purposes. Some sources of error include wrong rod height, wrong instrument height, tripod or rods not level, wrong location, poor aiming, wrong Electronic Distance Measurement (EDM), parallax, instrument in need of calibration, etc. If errors are encountered, double-check every element of the setup and see if the error can be addressed and minimized. If the source of the errors cannot be determined, then the survey will need to be started over from the beginning.

Surveying errors are managed by checking the backsight every hour, after about 100 shots, or after a good stopping point (e.g., after finishing T2).

F. Checking the Backsight

- From the Measure Topo screen, click Check (at bottom of screen)
- Click ChkBS (same button; it should automate the point name, code, and height of the backsight)
- Aim at the backsight
- Click Measure (this will bring up the change in horizontal and vertical distances. Click on the 1/2 button to see the changes in northing, easting, and elevation in the next screen).
- Make sure Action says “Store and Reorient”
- Click Store (this zeros the gun on the backsight again)

- Write down the errors (Northing, Easting, Elevation, Horizontal Angle [HA], Horizontal Distance [HD], Vertical Distance [VD]) in the field notebook along with the reference point that was used (e.g., BS1 = CP2)
- Shoot the point as a check shot. Hit ESC to get out of the Check Backsight screen
- In the Measure Topo screen, for the Code, enter the "code.#" where the # is the number of check shots for that particular code (e.g., CP1.1, CP1.2, CP1.3, etc.)
- Make sure target height is correct.
- Click Enter.
- Click Measure. This shoots the backsight as a foresight (with the code indicating that it is a check shot).

1.2 Revisiting a survey

Before leaving for the field, be sure to gather any previous trip reports, survey notes and details of the original survey, revisit maps, headpin and control reference photos, vegetation transect lengths and calibrate the Weatherport hand-held unit before you leave the office (see Table 2 for all necessary revisit documents).

Also make sure to prepare all necessary files of previous survey control and headpin coordinates to the data collector before leaving the office. In order to do this, a .csv file will need to be uploaded into the data collector or placed onto a thumb drive and taken out to the field. Please note that not all .job files are created equal and are not necessarily accepted by all survey softwares, so avoid using .job files. For the Trimble TSC3, the .csv file can contain NO headers and make sure all numbers are valid (i.e., if a formula was cut and pasted, the file will not be accepted).

We recommend using the original local coordinate system instead of real-world coordinates.

1. If a .csv file already exists, go to Steps 3.
2. If a .csv file needs to be created of the needed control point, headpin, and headpin ground surface coordinates, make 5 columns containing Point number, Northing, Easting, Elevation, and Description. No column headers or other information should be in this file.
3. Uploading this .csv by linking to the job:
   - Copy this .csv file onto a thumb drive.
   - Insert the flash drive into the data collector & press the Trimble icon key on the controller (globe on a triangle). Select: *Trimble Access* > *Files*. You will probably be in the Jobs home folder. Navigate to the NCPN surveying file folder for that job.
   - In the upper left hand corner, click on Navigate up to get to the *My Device* folder and you will see the flash drive listed as *Hard Drive.*
   - Find the .csv file and copy it (*Copy* is in the *Edit* Menu, or you can select the file and hold the stylus to pull up small menu).
   - Navigate back to the folder your Job is in and paste it in there (in the Trimble Data folder). Hold the stylus down in a blank part of the screen and the same small menu should pop up. Click paste.

- Close *File Explorer* (X in lower right hand corner) and go back into *General Survey* and you should be in your current Job.
- Now go to *Jobs* > *Properties of Job* > *Linked files* and check the file you just added.

In addition, have the GIS technician load all control points, headpins, and other relevant locations onto GPS units before leaving for the field.

In the field, locate headpins for all transects and all survey control at the reach, and mark with pin flags and flagging. Set up the taglines and transect tapes, making sure the lengths are within 0.1 m of the original vegetation transect lengths. The lead surveyor then needs to figure out a surveying strategy for the reach.

When revisiting a site, the initial parameters of the survey will be set up differently than when establishing a survey. We recommend setting up the total station over one known control point and the backsight over another known control point to re-establish the coordinate system. It is good practice to check off a third known point. The following steps are used to set up over known control points on a revisit:

A. Open Trimble Access. Click on Jobs. Click on the Open Jobs. Pick the job file you created and linked the .csv to in the previous step.

B. Click Nikon > Station Setup.
   - Enter the pressure and temperature. Click Accept.
   - Instrument point name: from the dropdown, pick List. Choose the correct point that the instrument is set up over. The code should automatically fill in.
   - Instrument height: enter in meters
   - Click Enter (should automate the coordinates)
   - Click Accept
   - Backsight point name: from the dropdown, pick List. Choose the correct point that the backsight is set up over. The code should automatically fill in.
   - Backsight height: enter in meters
   - Azimuth: should be automatically filled in
   - Methods: Angles and distances
   - Click Enter.
   - Aim at backsight. Click Measure.
   - Use the acceptable error standards below to evaluate the shot. Record the errors in the field notebook.

Acceptable Errors for Revisiting a Survey:

Horizontal (includes the northing and easting): 0.000 - 0.050 (5 cm).
Ideally, it is best to have < 0.020 (2 cm) error.

Vertical (includes elevation): 0.000-0.030 (3 cm).
Ideally, it is best to have <0.010 (1.0 cm) error.

Do not continue the survey if errors are outside of the acceptable range. Stop and remedy the problem. See the end of Section 2.1 for tips on minimizing errors. An additional factor that can create errors during a revisit is that the location of a control point may shift. The survey team can determine this by using Survey/Check Setup/By Point (or Stakeout/Stake to Point) on multiple control points. If there is only one control point with high errors, most likely its location has shifted. Do not attempt to move the control point. Instead, record this in the field notebook and shoot in its new position.

C. Before moving the total station off the backsight, choose Measure > Measure Topo. Shoot a check / confirmation shot.

D. It is good practice to check off a third known point.

- From the Measure Topo screen, click Check at the bottom.
- From the dropdown, choose list or key in to pick the previous point you want to compare to.
- Enter target height in meters.
- Click Enter, then Measure.
- The screen will show your change in horizontal and vertical distance. Click on the 1/2 button to see the change in northing, easting, and elevation.

If you are in the correct coordinate system and errors are low, begin surveying the rest of the reach.

E. If any headpins are missing, use the Stake Points feature under Stakeout to find the location, using headpin coordinates from the uploaded file.

1.3 Establishing a new instrument setup

Make as many shots as possible from each instrument setup, including transects, stream profile, control points, and hydrologic instrumentation. Before leaving an instrument location, make sure you have shot the new instrument and backsight locations. Also, take a final backsight check and shoot this as a check shot. Go to Measure > End Conv. Survey. You can then turn off the data collector and the total station.

Move to the new instrument location. Document the details of the new occupied point and backsight along with errors in the field notebook. **Do not continue if errors are outside the acceptable range.** Stop and remedy the problem.

There is no traverse function in Trimble Access software.

Shoot in additional instrument setup locations as necessary to complete the survey. Make sure to document any additional instrument locations and backsights used in the field notes.

1.4 Staking out points and lines

Go to Stakeout > Points.

- Point name: From the dropdown menu, pick List. Choose the point that needs to be staked out.
- Code: this should automate with the code
- Point increment: leave as a question mark.
- Have the rod person stand in a location, aim at the prism, and press Stakeout.
- Can use the Options button at the button to specify how the data collector should report the data (e.g., instrument perspective, target perspective, etc.).
- Have the rod person follow the directions to stake out the point. Continue until you find the point.

Go to Stakeout > Lines.
Start point: choose a starting point. If you're extending the transect, one of the headpins is a good one to use.
End point: choose an ending point. If you're extending the transect, one of the headpins is a good one to use.

SOP #9 Stream Channel Surveying

Appendix B

Creating Stream Cross-Section and Longitudinal Profile Graphs

Written by Katrina Lund, 09/09/15

A. Throughout the entire process, survey data is constantly being evaluated and analyzed for QA/QC both visually and through troubleshooting.

B. Make sure all the survey data is corrected before you do this. The corrections are made in the Excel spreadsheet, and the data is saved as a corrected .csv file.

C. Before dealing with the survey data, get the Excel spreadsheet template ready for the data. It is easiest to do this by copying a previous year's Excel file, saving it as a working document, deleting all the data, and leaving all headers and graphs.

D. Open up Traverse PC.

E. Go to New Survey.

F. In the Survey Information window:

   a. Filename: Click Browse and browse to the correct folder to store and name this project (X:\Active_Monitoring_Projects\Riparian\Data\Geomorphology\PARK\PARK_REACH_YEAR\corrPARK_REACH_YEAR.trv). This is the name of the Traverse PC project, and it will automatically save 1-2 backup projects that always accompany the current project.

   b. Survey: optional
   c. Location: optional
   d. Job ID: optional
   e. Units: Meters
   f. Client and Address: optional
   g. Click OK

G. Import the corrected .csv file into Traverse PC by going to File > Import (make sure the .csv file is NOT open):

   a. Type: ASCII
   b. Files: Click Browse. Make sure it's on All Files on lower right-hand corner. Navigate to the corrected .csv file.
   c. Click Open.
   d. Click Import. It should then say the # of points being imported. If not, then the .csv may be open, and it will not import if the .csv is open.
   e. Click Close.

H. In the Task pane, click on the Traverses tab. The file you just imported should be in there. Double-click on the filename to open it.

I. In the Traverse Window:

   a. Name: keep as the filename
   b. Increment name: leave box checked
   c. Desc: leave as file pathname
   d. Traverse View format: from dropdown, pick NCPN
   e. Traverse Drawing Settings: from dropdown, choose Topo Shots
   f. State: None
   g. Drawing Options: leave as Share current drawing.
   h. Click OK. This should open up the Traverse View and show all the points. If there is a header row, highlight & right click and choose Delete Selected Items (cannot have headers).

J. To visually see all the points, go to the Task pane and click on the Drawings tab. Click on Tools > Insert New Drawing > Append to End.

   a. In the New Drawing window, enter a New Name type (I prefer something like PARK_REACH_AllPoints…or something to that effect)
   b. Desc: optional
   c. Select template: I leave as Empty.DRT (but you could create a drawing template and save it)
   d. Mode: Plan View (sidenote: if you change this to Profile View, it will not save this setting)
   e. Clear all tags: leave unchecked
   f. Click OK. This should pull up a Drawing View Window with a blank drawing.

K. In the Task pane, go back to the Traverses tab, click on the box next to the filename. This should put the points on the drawing. In the Drawing View window, click on Zoom Extents (icon of box with 4 arrows in the corner:), which will make the points fill the whole page.

L. To change how points are displayed in the Drawing View, go back to the Task pane and Traverse tab.

   a. Right click on the file name > Traverse Drawing Settings. Here you can select the type of symbol (my preference is the Set Rebar dot at 1.0 mm) or the label next to the symbol (under Points; my preference is just the description or sometimes nothing).
   b. Click Apply to see the changes or OK to accept and exit from that window.
   c. Note: I use these traverse drawing settings a lot to see the data in different ways.
   d. In the Drawing View, you can hover the crosshairs over a point or its label and it will tell you the details.

M. Now you need to make individual traverses and drawings for each cross-section (7) and the profile (1).

a. First, create the 8 traverses. In the Task pane, go the Traverses tab > Tools > Insert New Traverse > Append to End. Name them T1XS, T2XS, T3XS, etc. and a PROFILE. Leave everything else the same.
b. Second, create a drawing for each. In the Task pane, go the Drawings tab > Tools > Insert New Drawings > Append to End. Name each one the same as the traverses you just created.

N. Split the points into the correct traverses:

a. In the Task pane, in the Traverses tab, double-click the traverse (e.g., T1XS). This will open the traverse in a Traverse View window.
b. In the Traverse View window, go to Edit > Insert Existing Points > Matching Points > OK.
c. In the Matching Points window:
    i. Find what: write something that will pull up all the necessary points (e.g. T1)
    ii. Match whole word only: leave blank
    iii. Match case: leave blank
    iv. Point label: leave blank (unless you know the exact PointID name and then you enter this here)
    v. Point description: choose this (so that it chooses all points in the job that have T1 in the code description)
    vi. Click Find Next. It will tell you the search found how many (e.g., 183 points).
    vii. Click OK.
    viii. Click Cancel to get out of the Matching Points window.

O. Double-check all the points in the traverse are correct. Scroll through and make sure they are all relevant and delete the ones that are not (highlight the row, right click, choose Delete Selected Items).

a. This is also a good QA/QC to make sure that you don't have duplicate points in your job. If so, go back and make corrections to the .csv and .xlsx files.

P. Visually see the points of the traverse (e.g., T1XS):

a. In the Task pane, go to the Drawings tab. Click on that traverse's drawing (e.g., T1XS). Make sure it's the only drawing selected in gray; double-click to select it).
b. In the Task pane, go to the Traverses tab and make sure that only that particular traverse is the only one checked (e.g., T1XS).
c. Go back to the Drawing tab and R click on the current drawing name (e.g., T1XS) > Drawing Properties > Mode: Profile View (sidenote: unfortunately, if you choose Profile before this, it won't save it as a setting). Click OK.
d. In the Drawing View, click Zoom Extents. Most likely, the line will look really wonky. This is because the points are not in the right order, which we'll fix in the next step.

Q. Order the points:

a. Refer to your survey field notes or determine from the drawing which point will be a transect end (ideally, you want the far river right transect end). Jot the Point (a.k.a. PointID, Point Name) down on a scrap piece of paper.
b. Go to the Traverse View window and select this transect end point > Tools > Sort Points.
c. In the Sort Points window, make sure the First Point is what you just determined. Source: All. Click OK. This should order the points in the correct fashion so it looks like the realistic cross-section. Again, you can change symbols and labels in the Traverse Drawing Settings (R click on traverse name in the Traverse tab).

R. On the drawing (e.g., T1XS), make sure the graph represents looking upstream so that the right headpin is on the left side of the graph and the left headpin is on the right (can hover over the label in the drawing to see the description). If this is not the case, choose the other transect end to sort the points.

a. This is another good time to QA/QC the data to make sure all the rod heights look correct, nothing looks out of the ordinary, etc.

S. Once the profile drawing looks good, export the traverse. You'll be exporting each traverse two different times; this is the first.

a. Go to File > Export (usually asks you to save first, choose Yes)

b. What: Entire Traverse (e.g., T1XS). MAKE SURE you choose only the traverse you just sorted (e.g., T1XS) and not anything else (i.e., 1 Selected Items in T1XS, Entire Survey, etc.)

c. Type: leave as ASCII

d. File: browse to the corrected folder (corrPARK_REACH_YEAR). This will only be a temp file. Name "T1XS_export1.csv". MAKE SURE you type in the .csv file extension!!

e. Click Save.

f. Click Export. It will show the # of points being exported.

T. Now open that .csv. Copy and paste the data (just the necessary data, NOT the entire columns) into the first set of columns in the appropriate transect tab in the Excel spreadsheet. These points should be in the coordinate system they were surveyed in (i.e., local arbitrary system or real-world). In Traverse PC, the export default settings for the decimal point are set to 0.001. If this is not how it is exporting, go into Traverse PC and fix these export settings to the thousandth.

U. I recommend sorting the points, making sure the graph looks good, and doing the first export for all transects. For the longitudinal profile points, you can use just a Plan View drawing because you will not need to make a cross-section (although you can in Traverse PC if you want). Make sure they are in the right order before you export them.

V. Now we will prepare the points for graphing. You will do this for all the transects, but not the profile shots. First, do a File > Save Survey As on the Traverse PC project. I call this

new survey PARK_REACH_YEAR_graphing.trv. You will now have the older one to refer to if something goes wrong.

W. Get the wadeable streams Revisit Sheet for the reach that was referred to during the survey.

X. The easiest way I have found to do this next part is to create a cheatsheet on a scrap piece of paper. It will be a table with the top of right/left headpin PointID's (a.k.a. Point, Point Names, etc), the revisit transect length (from the Revisit Sheet), and the Surveyed Transect Length (you will calculate this from the survey data). It will look something like this:

Transect	Top of Right headpin	Top of Left headpin	Revisit Transect Length	Surveyed Transect Length
T1	2015KL897	2015KL898	75.3	(you will calculate this in later steps)
T2	2015KL750	2015KL751	56.8	
T3	etc.	Etc.	etc	Etc.

Y. Now we translate the right headpin to itself to get the survey points to match up with the transect meter marks:

   a. In the Traverse View window, go to Cogo > Translate.
   b. What: Entire Traverse (e.g., T1XS). MAKE SURE this is what is selected and not any other options!!
   c. By Existing Points > From: enter the top of right headpin for the right transect that you wrote down on your cheatsheet. (e.g., 2015KL897)
   d. To: the same point (e.g., 2015KL897)
   e. X = 0.000
   f. Y = meter mark of right headpin location (refer to Revisit sheet; usually this is zero)
   g. Z = actual elevation recorded (do NOT change elevation)
   h. Click Compute. This shifts all the points to match the meter mark at the right headpin.
   i. Click Close.

Z. Now we rotate, or "snap," all the points on the transect in place between the headpins so errors along the tape are not accumulated over the length of the transect. This also helps with long-term monitoring of the same transect, ensuring the transect is the same length every time:

   a. In the Traverse View window, go to Cogo > Rotate.
   b. What: Entire Traverse (e.g., T1XS). MAKE SURE this is what is selected and not any other options!!
   c. Rotation point: enter the top of right headpin (e.g., 2015KL897)
   d. From: enter the top of right headpin again then type two periods with no spaces then the top of the left headpin (e.g., 2015KL897..2015KL767)
   e. To: leave as N0°0'0"

f. Degrees: leave as whatever it pulls up
g. Click Compute. This rotates the points toward north, "snaps" them into place, and should place the left headpin at the appropriate meter mark. After this rotation, the easting is the distance the point is offset from the transect.
h. Make sure this doesn't change anything on the drawing.

AA. Now for the second export. Go to File > Export (usually asks you to save first, choose Yes)

a. What: Entire Traverse (e.g., T1XS). MAKE SURE you choose only the traverse you just sorted (e.g., T1XS) and not anything else (i.e., 1 Selected Items in T1XS, Entire Survey, etc.)

b. Type: leave as ASCII

c. File: browse to the corrected folder (corrPARK_REACH_YEAR). This will only be a temp file. Name "T1XS_export2.csv". MAKE SURE you type in the .csv file extension!!

d. Click Save.

e. Click Export > Close.

BB. Now open that .csv and copy and paste the data into the second set of columns in appropriate transect tab in the Excel spreadsheet. These points will now be the rotated versions and the numbers will be different compared to the first exported version.

CC. You will use these numbers to create two graphs in Excel:

a. Make sure to change the northing heading to "Station".

b. One thing I did to increase graphing efficiency in Excel was to make a "For Graphing Efficiency" section close to the graph itself. The first two lines are for the headpins, then a blank row, then the waterlines. This just speeds things up for graphing and calculating.

c. On the first graph, plot station on the x-axis and elevation on the y-axis for the entire surveyed cross-section transect (Fig. 9). You will need to tweak the graphs in Excel to display the data correctly for that transect. May need to change the axis formatting to show the data if the coordinate systems are different between the previous Excel template you chose and the imported data.

d. Create another graph of the cross-section transect that only shows data between the end points of the vegetation transect (usually between the two headpins; Fig. 10). Again, you will need to tweak the graphs in Excel to display the data correctly for that transect. May need to change the axis formatting to show the data if the coordinate systems are different between the previous Excel template you chose and the imported data.

DD. Compare the transect lengths between the headpins from the survey vs the vegetation monitoring (recorded on the Reach Establishment or Reach Revisit data sheet). I like to do this for all the transects at once and record on my cheatsheet.

a. To determine the transect length from the survey data, go the Transect View window for the transect (e.g., T1XS).
b. Go to COGO > Random Inverse
c. From: enter the right headpin (e.g., 2015KL897)
d. To: enter the left headpin (e.g., 2015KL898)
e. Click Recompute.
f. Look at the Slope Dist. Record on the cheatsheet and compare this to the Revisit sheet.
g. Also record these numbers below the graph in the Excel spreadsheet.
h. These lengths should be within 0.1 m of each other. If not, find the issue and correct it, if possible.

EE. Calculating waterline elevations. In Excel, average the right and left edge of water shots (REW and LEW) for each transect. This is recorded below the graph (should already be in the Excel template), and you will use this number again on the Profile graph.

FF. For the longitudinal profile graph, you will need to do a few things in the Excel spreadsheet (this is after you've sorted in Traverse PC, exported, and copy/pasted the points into the spreadsheet):

a. On the At Transect column, make sure T1, T2, T3, etc. is on the same row as the first transect profile shot (e.g., write T1 on the first P1 shot, T2 on the first P2 shot, etc.). Write Upstrm for the very first point.
b. The distance between the stationing (northing) of every two points should already be in the Excel template. This is in the column left of Station. Use a formula based on the Pythagorean theory in Excel (and using the sample table below to illustrate): =SQRT((POWER((B5-B6),2))+(POWER((C5-C6),2))).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	*All values are in meters.*														
2	*These pts are in the relative local arbitrary coordinate system for the reach.*							*Longitudinal profile throughout reach.*							
3															
4	Point	Northing	Easting	Elevation	Description	At Transect				Station	Elevation		Graph	Waterline	
5	2013KL1286	5469.638	4951.346	985.83	PROFILE0	Upstrm				0.000	985.83	PROFILE0			
6	2013KL1287	5468.765	4950.965	985.85	PROFILE0				0.953	0.953	985.85	PROFILE0			
7	2013KL1288	5467.865	4950.698	985.8	PROFILE0				0.939	1.891	985.8	PROFILE0			
8	2013KL1289	5467.129	4949.973	985.85	PROFILE0				1.033	2.924	985.85	PROFILE0			
9	2013KL1290	5466.296	4949.409	985.87	PROFILE0				1.006	3.930	985.87	PROFILE0			
10	2013KL1291	5465.393	4948.635	985.83	PROFILE0				1.189	5.120	985.83	PROFILE0			
11	2013KL1292	5464.705	4947.64	985.83	PROFILE0				1.210	6.329	985.83	PROFILE0			
12	2013KL1293	5463.755	4947.19	985.76	PROFILE0				1.051	7.381	985.76	PROFILE0			
13	2013KL1294	5462.446	4946.847	985.78	PROFILE0				1.353	8.734	985.78	PROFILE0			
14	2013KL1295	5461.144	4946.143	985.79	PROFILE0				1.480	10.214	985.79	PROFILE0			
15	2013KL1296	5459.901	4944.734	985.65	PROFILE1	T1			1.879	12.093	985.65	PROFILE1	983	985.88	
16	2013KL1297	5458.76	4944.242	985.61	PROFILE1				1.243	13.335	985.61	PROFILE1			
17	2013KL1298	5457.812	4943.878	985.69	PROFILE1				1.015	14.351	985.69	PROFILE1			
18	2013KL1299	5456.678	4943.372	985.75	PROFILE1				1.242	15.593	985.75	PROFILE1			
19	2013KL1300	5455.637	4943.055	985.75	PROFILE1				1.088	16.681	985.75	PROFILE1			

c. In the Station column, the entire length of the longitudinal profile is accumulated by adding the numbers in the above step to the station number

(this should be set up in the Excel template). The Station starts with zero, then gets calculated with the following formula, starting on the second line: =I6+J5.

d. Copy the Elevations and Descriptions over next to the Station.
e. Display the Waterline and Transect on the graph:
    i. Determine what the x-axis number will be. This should be an elevation that displays the information on the graph with enough spacing.
    ii. On the same line that you wrote T1 in the step *FF.a* above, write the x-axis number under the Graph column. This will be where the transects are displayed on the graph.
    iii. For the waterline, use the elevation you determined in step *EE* (I like using the formula "=cell of waterline average" from each transects' tab)
    iv. Follow the longitudinal graph template to display on this information on the graph.

GG. Once all the data is in the Excel spreadsheet, delete the temporary exported files from the corrected folder.

SOP #9 Stream Channel Surveying
Appendix C

Hydrologic Surveying Cheatsheet

Written by Katrina Lund, 9/10/15

- All prism constants are -30 mm.
- Do not adjust for earth's curvature.
- Other than CARE F-01, do not use scale factors.
- For wells, take the following shots:
    1. top of casing (TOC; cap taken off and the rod foot rests nicely on the TOC),
    2. ground surface next to casing,
    3. water surface next to the hydro equipment with date and time in the code.
- Get a final closure error.
- Take past levels documents for reference.
- A rod and bipod are recommended for all important shots (backsight, control, hydro equipment, etc.).
- Use the Fine measurement mode in the Trimble TSC3 (will automatically default to this until you change it to Coarse).

PARK & REACH	YEAR ESTAB.	# GUN LOCATION(S)	GUN LOCATION	PERMANENT DATUM COORD	BS LOCATION	BACKSIGHT DATUM COORD	VISIBLE FEATURES	COMMENTS
ARCH C-01	2013	1	RM1 (permanent datum)	N 5000.000 E 5000.000 Elev 1000.008	RM2	N 5045.803 E 4956.785 Elev 995.202	• CP2 • CP5 • CP6 • Temp	– Have not been able to successfully get the TOC casing within 0.010 m. – Temporary instrument location required in order to see the wells.
		2	Temp	NA	RM1	N 5000.000 E 5000.000 Elev 1000.008	• Instrm well TOC • RL well TOC • RM2 • T2R & T2L • T2XS • RM3? • RM4? • RM5?	– Have used a temp location between T3 and T4 on the floodplain terrace. – Good to stake out unmonumented end first before stringing tagline.
CARE F-01	2009	1	CP1 (permanent datum)	N 4236769.351 E 483713.12 Elev 1579.942	RM4	N 4236747.782 E 483612.641 Elev 1581.397	• RM5 • RR well TOC • T1R-TOP & GS • T1XS (partial, RR side to water) • Temp	– Use original 2009 scale factor of 0.99960325. – Need to use 2 rod heights to see backsight prism at RM4. – Cannot see RM1, RM2, or RM3 from either of these gun locations.
		2	Temp	NA	CP1	N 4236769.351 E 483713.12 Elev 1579.942	• Instrm well TOC • RL well TOC • T1L-TOP & GS • T1XS (partial, RL side from water)	Good temp location is on river left, ~12m upstream from T1 and ~5m away from the stream.

NABR A-05	2015	1	RM1 (permanent datum)	N 5000.000 E 10,000.000 Elev 2000.00	CP1	N 5017.546 E 10000.000 Elev 2006.336	• RM2 • CP2 • CP3 • TOC-NOTCH • Temp transect	– For TOC-NOTCH, put the rod point in the notch since the casing is tilted. Do not shoot top of eyebolt. See photo below. – Temp transect ends will be need to be staked out before transect can be set up. No rebar is present at these ends. – Make sure to have the transect end coordinates in the uploaded revisit file.
ZION P-03	2011	1	CP2 (permanent datum)	N 5112.736 E 4936.461 Elev 1000.280	CP3	N 5101.428 E 5047.383 Elev 1003.942	• CP4 • RR well TOC • Instrm well TOC • RL well TOC	– Cannot see CP1. Can see wells from CP2, but they are better shots from CP4. – Not sure where transect cross-section is best seen from.
		2	CP4		CP2	N 5112.736 E 4936.461 Elev 1000.280	• RR well TOC • Instrm well TOC • RL well TOC	

NABR. The rod point in the measuring notch. This was how the “TOC-NOTCH” shot was taken in 2015.

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 10

Well Installation and Hydrologic Monitoring

Version 1.06 (August 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1.9.2012	D. Witwicki	Updated Fig. 1	Consistency with other SOPs	1.01
1.01	6/2012	R. Weissinger	Set dataloggers to standard time; added instructions for rusted well caps	Clarify for better data consistency; resolve problems encountered in the field	1.02
1.02	3/2013	R. Weissinger	Include flow measurement instructions; calculate water elevation above sensor; take multiple manual measurements; increase field visit frequency; minor word edits	Include all instructions in one document and remove reference to other protocol; conform with USGS standards; response to protocol review	1.03
1.03	8/2013	R. Weissinger	Improve flow measurement instructions; add quality guidelines for flow and depth to water measurements	Improve data quality and descriptions of data quality	1.04
1.04	3/2014	R. Weissinger	Remove elevation above sensor calculations; add additional water level measurements; change Baski flume to WRD rating table; add different installation types; remove flow msmt at most sites	Reduce calculation errors; increase data checks; Baski rating table incorrect; new installations at CARE and NABR; rating curves unstable	1.05
1.05	8/2016	D. Witwicki	Changed Barologger to barometric pressure logger	Brand name, and any brand would suffice	1.06

This SOP describes installation techniques, instrument set up, and monitoring measurements for surface and groundwater wells. An equipment list is provided in SOP #1. The initial site visit includes infrastructure installation and development, programming and installing dataloggers, and taking initial water level and discharge measurements. Monitoring revisits include water level and discharge measurements, downloading dataloggers, and infrastructure maintenance, if needed. When conducting hydrologic monitoring visits, attempt to access the wells by walking downstream of them to avoid unnecessary trampling along vegetation transects. Installation and ground surface elevations are also recorded during the reach survey (SOP #9).

A three-person team comprised of one installation specialist and two assistants is required to effectively complete the installation tasks described below. All crew members should have good physical endurance and be capable of heavy lifting. Revisits can be completed by one person.

1. Casing installation

The most appropriate type of installation depends on the type of data being collected and the stream setting. For groundwater monitoring, including riparian groundwater and instream installations at intermittent or ephemeral streams, below-ground installations such as a well or piezometer are required. For surface water monitoring, including perennial streams and instream installations that focus only on flood flows, above-ground installations may be cheaper and easier to install and maintain over time.

1.1 Groundwater monitoring assemblies

The objective of well installation is to place the well screen deep enough into the floodplain to penetrate the alluvial water table or deep enough into the channel to maintain contact with water levels as they decline during the growing season. The deepest placement possible allows for water level measurements to be obtained as groundwater levels decline during long-term drought. Wells can be installed to maximum depths of 3 to 5 meters in finer textured substrates such as sand and gravel by pounding steel pipe into the ground with a post pounder. Deeper wells or wells that must be placed in coarser substrates, such as cobble, may require the use of mechanized equipment, such as a backhoe. Only manual installation will be addressed in this SOP.

Two distinct types of installations can be used to monitor groundwater or water levels that fluctuate between surface water and groundwater: riparian wells and instream wells.

Riparian well – This type of well is used to measure groundwater elevation in the riparian zone. It typically consists of one screened well point on the bottom attached to *one or more sections of solid galvanized pipe* reaching to the surface (see Fig. 3).

Instream well – This type of well is used to measure surface water elevation in the stream channel. It typically consists of one screened well point on the bottom attached to *a screened galvanized riser* (see Fig. 3). The screened riser section must be fabricated prior to the field visit. Cut off the point of a screened well point and install threads on the remaining screened section. A rock saw will easily cut off the tip, and this equipment is often available at maintenance yards in park units. The thread will need to be installed at a local hardware store.

When referring to both types of wells, the general terms “well” and “well point assembly” are used.

1.1.1 Determining well locations

Wells should be installed in line with a monitoring transect (Figure 1), preferably in a straight section of the reach with smooth flow. Attempt to avoid placing a well downstream of side canyons, culverts, or any other source of disturbance that could increase flood risk or channel change. Wells should be co-located with other hydrologic monitoring devices such as gaging stations or existing wells if they exist anywhere in the reach.

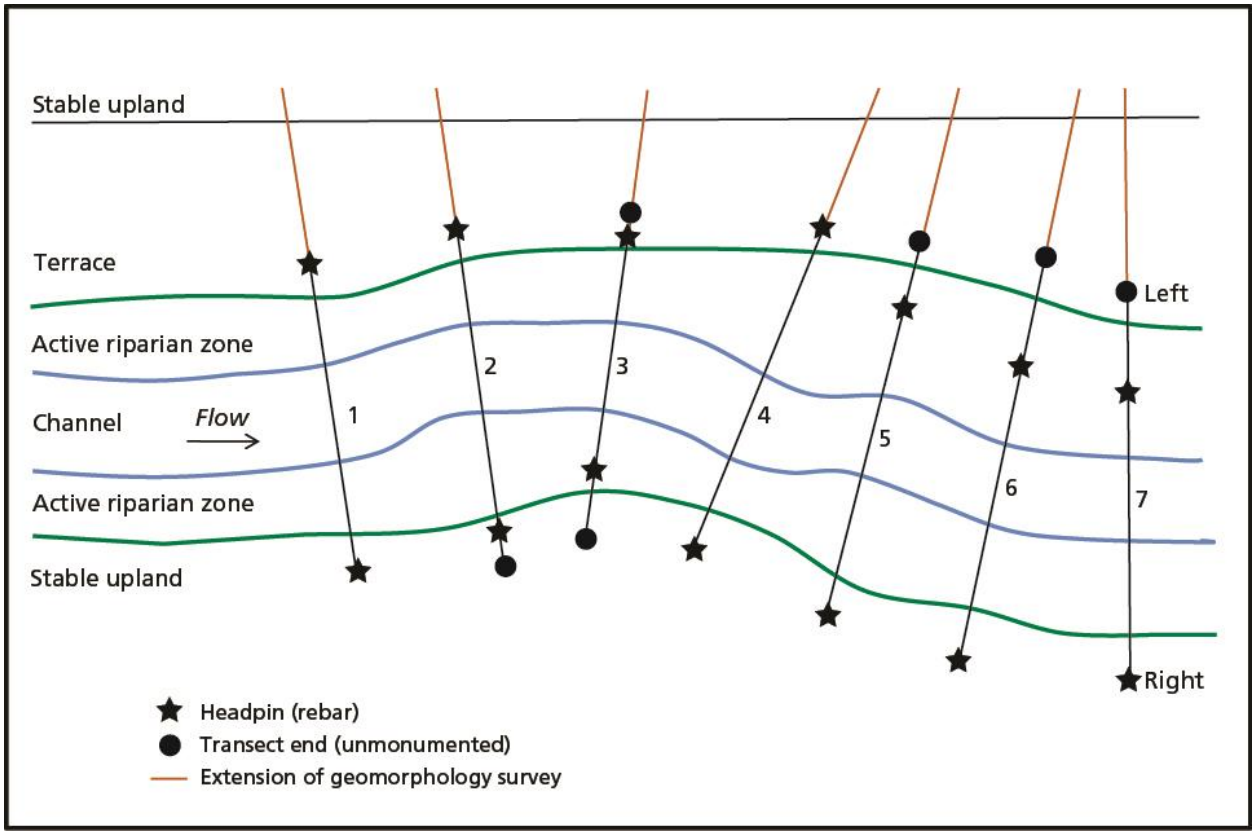


Figure 1. Example of a riparian monitoring reach with seven equidistant cross-section transects. Unmonumented transect ends may occur on bedrock or highly unstable surfaces.

Two riparian wells are installed along the transect in the active riparian zone. They are located three-quarters of the distance from the thalweg to each headpin, one on river left and one on river right (Figure 2). Some constricted reaches may not permit installation of two riparian wells due to the presence of bedrock. In this case, only one riparian well should be installed on the non-constricted side of the riparian corridor.

A. Locate both headpins within the selected transect. Follow instructions in SOP #4 to run the tagline and 100-m tape between the headpins. Confirm the length of the transect and the location of the headpins along the transect to make sure the entire sampled area is considered, including sections that are not monumented due to bedrock or highly unstable surfaces (Figure 1).

B. Determine the location of the thalweg within the stream.

C. Determine the distance between each respective headpin and the thalweg, and calculate location of riparian wells (3/4 distance from thalweg to headpin; see Figure 2). Mark riparian well locations using pin flags.

The instream well should be installed in the stream channel near the wetted edge of the stream during base flow conditions or the scoured edge of the channel in intermittent and ephemeral streams. If a depositional bank is present, install the well on this side of the stream. If no obvious depositional bank is present, locate the well on

the side of the stream that would minimize damage during flood events. For perennial streams, the instream well should be installed at a location that ensures the pressure transducer is submerged during low-flow periods.

1.1.2 Preparing the riparian surface

After the riparian locations are marked, dig the deepest hole reasonably possible with a shovel, making sure that the diameter of the hole is not greater than 3 feet. In many cases, it should be possible to dig a hole as deep as the entire shovel and no more than 2 feet in diameter. This preparation will significantly reduce total resistance between the well point assembly and the surrounding sediments during installation.

1.1.3 Assembling the well

The initial height of the well point assembly depends on the depth of the hole in the riparian surface and the height of the crew members relative to the top of the well point assembly.

A. Connect a screened well point to the appropriate galvanized riser pipe (Figure 3). Be absolutely sure that you have connected the appropriate type of riser pipe (screened for instream wells or solid for riparian wells- see section 1.1 for more details). Add enough sections of pipe so that the top of the well point assembly will be approximately shoulder height prior to pounding. Be sure to coat all of the threads with Teflon tape, and use drive couplings at each pipe junction.

B. Attach a sacrifice pipe to the top of the well point assembly, and attach a drive cap to the top of the sacrifice pipe. Make sure to use Teflon tape and drive couplings here as well.

C. Use two large pipe wrenches to tighten all of the threaded junctions as much as possible.

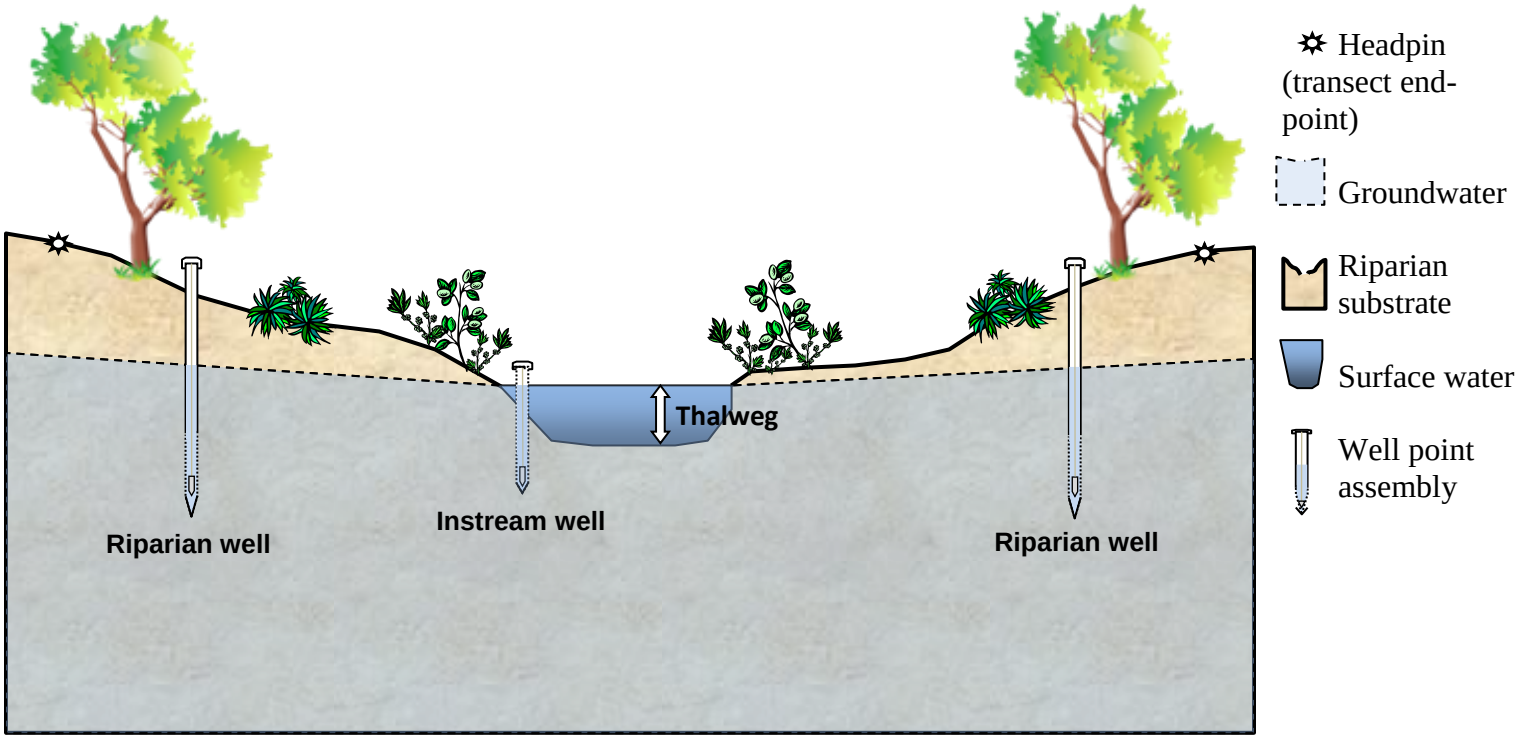


Figure 2. Cross-section of a riparian transect. Notice the riparian wells are spaced three-quarters of the distance from the thalweg to each headpin, and the instream well is placed on the depositional edge of the channel (the gradual sloped edge). The instream well is fully screened (surface and sub-surface), while the riparian wells are only screened at depth.

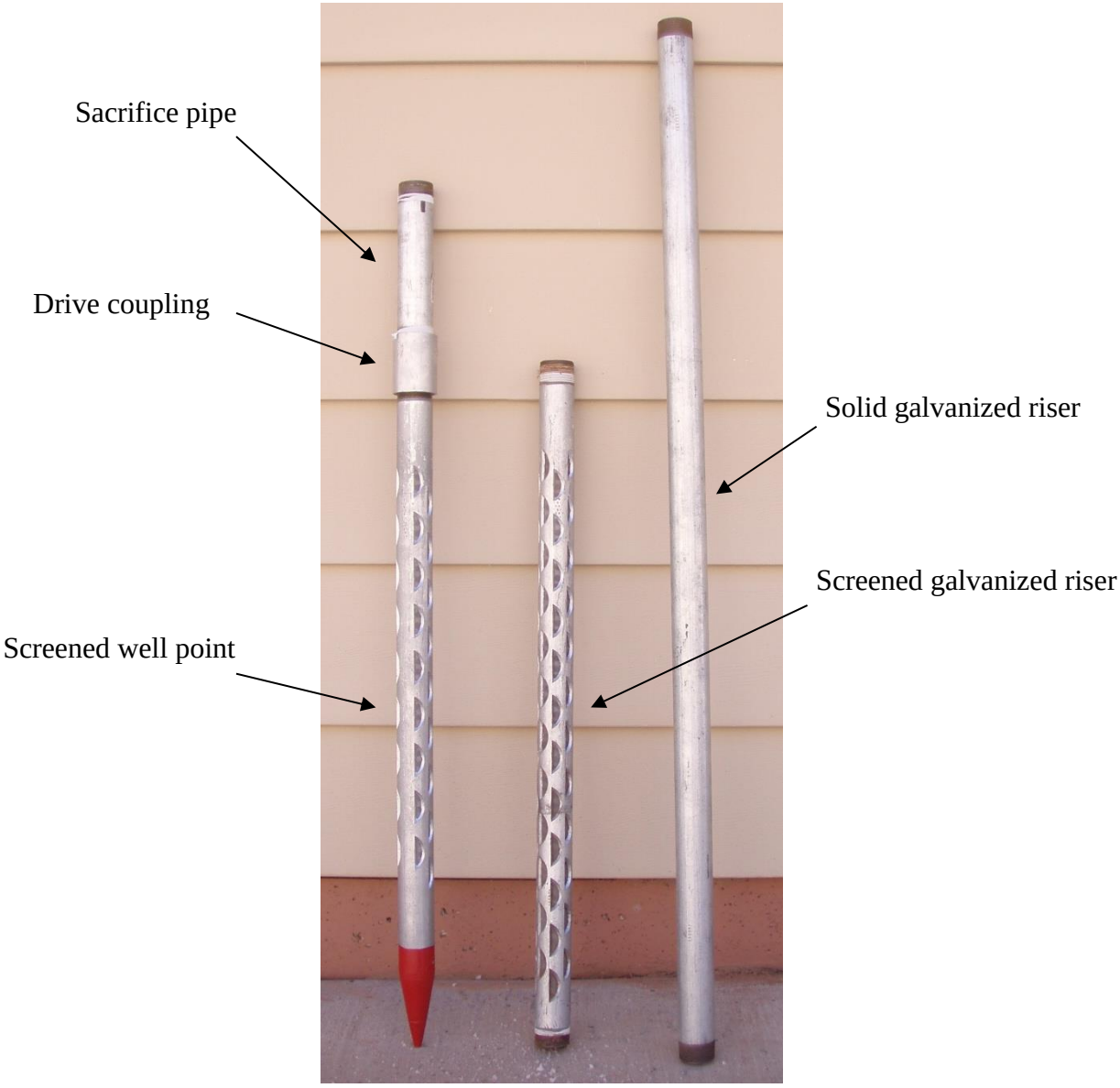


Figure 3. Components of the monitoring well assembly, including screened well point, drive coupling, sacrifice pipe, screened galvanized riser, and solid galvanized riser.

1.1.4 Driving in the well point assembly

Use a large diameter and heavy-weight fence post driver to pound the wells into place (Figure 4). Handlebar grip tape (used on road bikes) attached to the handles of the fence post driver will significantly reduce the vibration on your hands. Use thick padded gloves (or two sets of gloves) to additionally reduce vibration forces.

High decibel ear protection must be worn by all crew members at the installation location. Ear muff-type protection is recommended (versus ear-plugs) due to ease of taking them on and off.

Figure 4. Installing a riparian well at the East Fork of the Virgin River, Zion National Park.

A. Place the well point assembly at the pre-determined instream location or in the hole on the riparian surface. One person should stabilize the well point assembly, while another person levels it with the bubble level. Once level, place the fence post driver on well point assembly and two crew members can begin pounding. Determine the number of repetitions (reps) before you begin to pound (typically 7 reps).

   Make sure you don't over-drive the well. It needs to be checked and adjusted periodically during installation to ensure it is level upon completion.

   Leveling the well point assembly
   -Check the alignment of the well at two perpendicular locations along the riser section. Use a bubble level to perform this task between each set of reps of pounding.

   -At first it should be easy to level the well point assembly. The well point can be shifted to the level position with little effort in between reps.

   -Once the well point assembly attains a sufficient depth, it will no longer be easy to level. Try moving the assembly in a circular motion to loosen the adjacent sediments, and then re-level. Be careful not to torque the assembly while leveling. Too much torque can make it bend which may necessitate removal and reassembly. It is better to have the well not perfectly vertical than to bend the assembly.

   -After 3-5 feet of the well point assembly is beneath sediments, it will become extremely difficult to adjust the alignment of the well. If necessary, one crew member can use a rope or webbing to apply pressure to the well point assembly while the other two crew members initiate pounding. Loop the rope around the well point assembly near the soil surface and apply a constant pulling force.

B. After one set of reps, remove the fence post driver. Level the well and use the pipe wrenches to tighten all threaded junctions again. Tightening should be performed every time the fence post driver is removed (between 1 and 3 sets of approximately 7 reps). If threaded junctions are not regularly tightened, the

threads may suffer significant and irreparable damage. Thread damage to the well point assembly (not the sacrifice pipe), may necessitate removal and re-assembly.

If the well point assembly is bent or threads are damaged during installation
- The well point assembly should be removed and a new one should be installed. It may be necessary to dig deeper to remove the well point assembly. Removal may be difficult or impossible depending on the depth achieved before damaged occurred.

-If the well point assembly has been damaged enough that it will not function properly, and it cannot be removed, the last resort is to detach remaining riser sections and bury the stuck section. ***This should be avoided at all costs.***

C. Once the well point assembly is level and all pipe junctions are tight, begin pounding again. Do not pound too much before re-tightening and re-leveling. The number of sets (e.g., one set equals 7 reps) gradually increases to three or four sets of 7 reps once the ability to re-level the well point assembly has diminished.

D. Wells should be installed to a depth of 2-3 feet below the lowest anticipated water level. In most locations, a depth of 11-15 feet is sufficient. Once 11 feet of the well point assembly are below the surface, attempt to measure the water level in the well using the water level meter (see instructions in section 1.8). It will typically be necessary to agitate the sediments surrounding the well screen with an inertial lift pump to ensure sufficient hydraulic connectivity (see instructions in section 1.6). After agitating the sediments, allow time for the water level to equilibrate prior to measuring the water level.

E. If the depth of the well is not sufficient, continue pounding until the appropriate depth is reached. Depending on the groundwater level, you may choose to use a smaller length of riser pipe for the last section. Six to18 inches of pipe should be exposed above the surface of the completed well. You may choose to keep the exposed section shorter for aesthetic reasons (e.g. proximity to a trail or likelihood of visitor interaction) or longer to prevent burial during large flood events.

1.1.5 Developing the well

The sediments surrounding the well screen may become smeared during installation, reducing hydraulic conductivity of the sub-surface material. Pump the well with an inertial lift pump to eliminate smearing and to create a sedimentary filter pack surrounding the well screen that maintains proper hydraulic connectivity in the sub-surface environment and responds quickly to changes in water level. The amount of time it takes for water levels to respond to natural variation in the well is a function of the hydraulic conductivity of the sub-surface material and the connectivity between this material and the well screen. The plunging motion of the pump will effectively push the finest sediments (fine sand, silt and clay) further away from the well screen or suck them into the well, allowing coarser materials (coarse sand, gravel, and cobble) to remain closer to the screen. This procedure reduces or eliminates fine sediment buildup in the well over time.

All wells require plunging and pumping for development. This procedure is most effective when performed by two crew members, although the task can be completed by one person if necessary.

A. Insert the foot valve end of the inertial lift pump into the well until it reaches the bottom (Figure 5). With one person holding the opposite end of the tubing away from the well, the other person should initiate a plunging motion within the well. If there is not enough water to purge the sediment, use a bucket to pour water into the top of the well during purging.

B. The check valve in the pump allows water in the well to enter the tubing during the downward motion, and prevents water from escaping during the upward motion (see Figure 5). Water will continue to fill the tubing with each plunge and eventually will be expelled from the opposite end. The water will slowly clear as this procedure continues, typically in 5-10 minutes of pumping.

C. Once the water expelled from the well is no longer opaque and begins to clear, remove the inertial lift pump and insert the tubing attached to the Geopump 2 peristaltic pump (Figure 6). The flexible tubing should reach the bottom of the well. Turn on the peristaltic pump and allow it to continue pumping until the water being removed from the well is visibly clear.

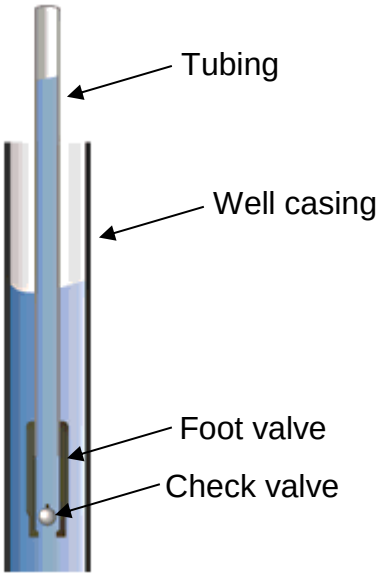


Figure 5. Diagram of inertial lift pump (image from www.waterra.com). On the actual pump, the tubing extends several meters beyond the top of the well casing so that you can direct the expelled water away from the well.

Figure 6. Pumping a well with a peristaltic pump at the East Fork of the Virgin River, Zion National Park.

1.1.6 Completing the well

Once the well is installed to a sufficient depth and pumped, a few remaining tasks are necessary to complete the installation.

Riparian wells

A. For riparian wells, it will be necessary to back-fill the sediments removed during the installation. Fill in sediments until approximately 2 feet of the hole remains below the riparian surface. Stamp the sediments down with your foot.

B. Place enough dry bentonite pellets in the bottom of the 2-foot deep hole surrounding the well to cover the surface (a few shovels worth). Arrange the pellets so that there is a thicker coat around the exposed well riser section.

C. Using a small bucket or water bottle, slowly pour water on top of the bentonite pellets. Use your hand to ensure that all of the bentonite pellets become saturated and form a smooth impermeable surface. Pay careful attention to the area around the exposed well. Once hydrated, the bentonite pellet layer will effectively seal the annular space surrounding the well and prevent preferential flow paths from forming adjacent to the well.

D. Back-fill the rest of the hole, and scatter leaves and branches to camouflage the site (Figure 7).

Figure 7. Completed riparian well in Courthouse Wash, Arches National Park.

Instream wells

A. Pour water into the instream well to ensure proper connectivity with the surface water. If proper connectivity was achieved, the level in the well should quickly equilibrate with the surface water elevation.

1.2 Surface water monitoring assemblies

The objective of surface water installations is to capture water elevations in perennial streams or to capture flood flows in intermittent and ephemeral streams. Because the installation is above the channel bottom, low flows are vulnerable to missing data.

1.2.1 Assemblies attached to bedrock or large boulders

1.2.1.1 Assemble a casing

Cut 1¼” inside diameter schedule 40 slotted PVC well casing into 8 inch or longer lengths. Prime and glue a 1¼” threaded PVC sleeve to the top and bottom of the piece of casing using PVC glue (Fig. 8). Make sure to wear gloves during this process. Allow to dry 15 minutes.

Drill a hole in a threaded PVC cap for a ¼” diameter eyebolt. Thread a nut and washer onto the eyebolt to the top of the threads. Put the eyebolt through the hole in the threaded PVC cap. Put another washer and stopper nut on the eyebolt on the outside of the cap.

Use a small 2” carabiner to attach the data logger to the eyebolt. The bottom of the logger should not be touching or extending past the bottom of the casing.

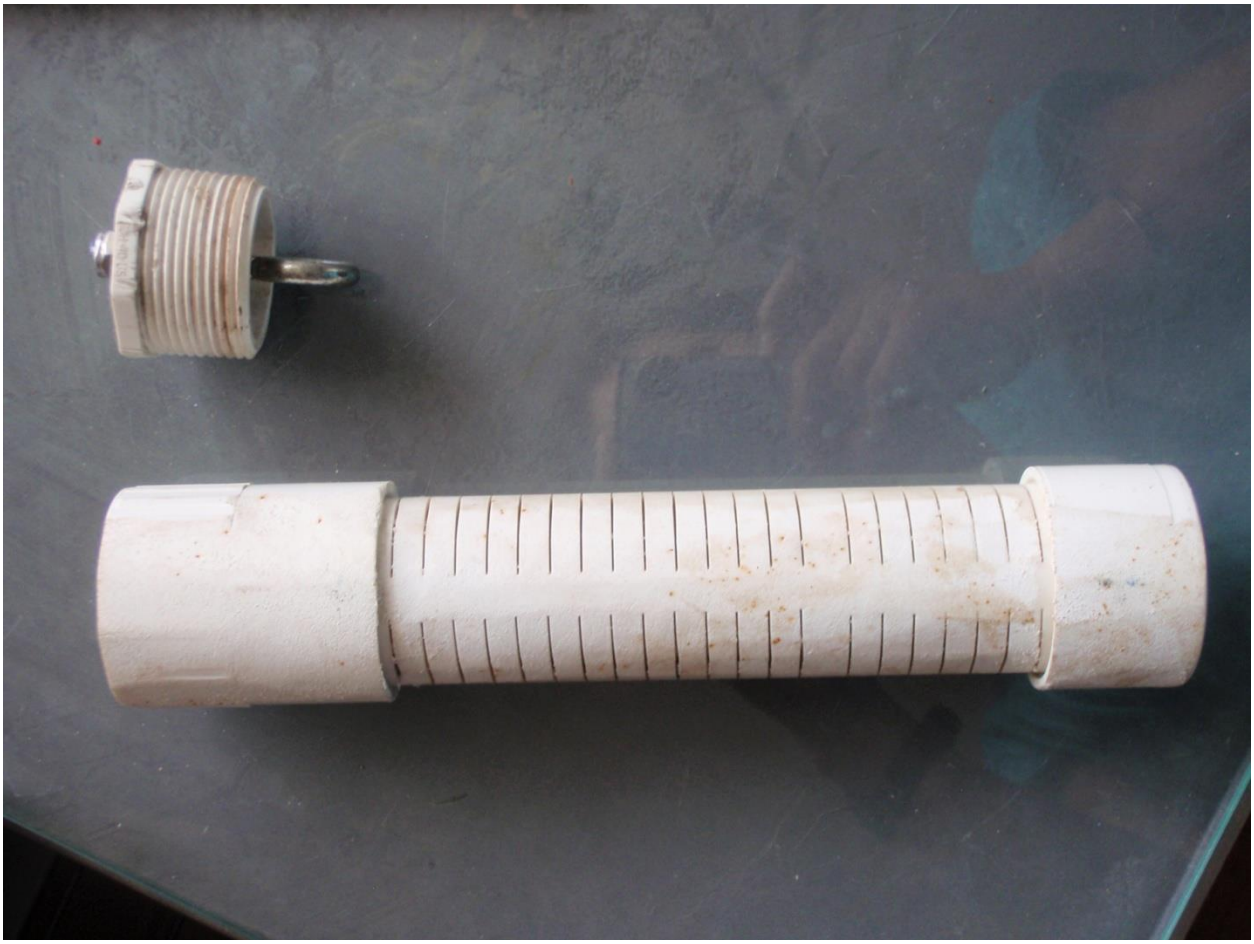


Figure 8. PVC casing for logger.

1.2.1.2 Mounting the logger

Select a portion of bedrock or large boulder that is relatively vertical and will be inundated by the desired flows (low flows in a perennial stream; flood flows in intermittent and ephemeral streams). Hold the casing up to the rock with metal brackets that will be used to affix the casing to the rock. Make sure the casing is vertical and that you will be able to open and close the threaded cap. Mark the locations of the holes in the metal brackets using a permanent marker.

At a location you have marked, drill a hole big enough for a ¼ ” expansion bolt using a hammer drill. Level the logger casing against the rock, and put a U-shaped pipe mounting bracket or plumbers hanger tape snug against the lip of the threaded PVC sleeve on the casing. Work the expansion bolt through the hole in the bracket into the drilled hole in the rock, and deploy the expansion bolt by hitting the pin with a hammer. If necessary, before deploying the expansion bolt, use additional washers to make sure that the casing is held snugly to the rock. Drill another hole and mount a bracket near the bottom of the casing in a similar fashion. Add additional holes and bolts if necessary. Paint the casing to match the surrounding rock (Fig. 9).

Figure 9. PVC casing instream installation at Natural Bridges National Monument.

1.2.2 Assemblies driven into the channel

1.2.2.1 Prepare the casing

Drill a series of holes in an 8” length of 1 ½” diameter galvanized steel pipe to allow water to flow throw the casing easily. Attach a threaded coupler to the top and bottom of the pipe. Drill two holes through the pipe and coupler that will attach to a length of angle iron. Drill a series of holes in a 4’ length of 1 ½” angle iron that can be used to attach the casing. File a notch in the top coupler to mark the permanent measuring point.

Drill a hole through a threaded plug and attach a ¼” long eyebolt. Thread a nut and washer onto the eyebolt to the top of the threads. Put the eyebolt through the hole in the threaded cap. Put another washer and stopper nut on the eyebolt on the outside of the cap.

1.2.2.2 Installing the casing

Select a location in the stream that will be inundated during low flows. Place the angle iron so the angle points upstream. Drive the angle iron into the channel bottom using a sledgehammer, leveling as you go. When the angle iron is to the desired depth, use a hacksaw to cut off the top portion if it has been warped during installation. Once the top of the angle iron is straight and level, attach the casing so that the top of the casing matches the top of the angle iron and the permanent measuring mark points downstream. Secure the casing

using bolts and nuts. An additional angle iron may be placed upstream to protect the installation from flood debris (Fig. 10).

Figure 10. Angle iron installation in the Fremont River, Capitol Reef National Park.

2. Installing the pressure transducer

2.1 Program the loggers

For detailed instructions on settings, refer to the instrument's user manual (i.e., Solinst Levelogger User Manual). Depending on accessibility of the reach, you may perform these steps in the office ahead of time or in the field using a laptop loaded with Solinst Levelogger 4.0.3 software. Stage loggers should be programmed for each hydrologic installation, and a barometric logger is needed for each monitoring reach to compensate for atmospheric pressure.

A. Electronically label each pressure transducer with the stream and reach location, and any well-specific identification information, e.g. ARCH_C1_instrm, ZION_P3_left, CARE, F1_baro, etc.

B. Set the logging interval to 15 minutes.

C. For stage loggers, change the units to centimeters. For barometric pressure loggers, use the default units. Adjust the site elevation, if programmable. Elevations acquired from online mapping applications such as Google Maps are sufficient for this setting.

D. Synchronize the logger time to your computer's time. If needed, adjust the logger time to **Mountain Standard Time**, and set a future launch date and time. It is best to set the start time in the field just prior to installation so you can collect a representative water level elevation and flow measurement at the same time. If this step is completed prior to field work, make sure to provide an appropriate buffer between the anticipated time of well completion and the logger start date and time.

2.2 Install the logger

A. Cut a length of Kevlar cord approximately the same depth as the casing where the logger will be deployed. Attach one end of the Kevlar rope to the hanger on the pressure transducer with a ring terminal. Use the crimping tool to properly connect the ring terminal to the pressure transducer.

B. Stretch the logger and cord out next to a meter tape with casing cap, eyebolt, and a 2" carabiner. Make a mark where the total length is approximately 3 cm shorter than the depth of the casing. Attach the cord to the carabiner using a ring terminal and crimper. The pressure transducer sensor should be situated at least 3 cm above the bottom of the well to allow for minor sedimentation between visits.

C. Clip the carabiner to the eyebolt attached to the cap, and lower the pressure transducer into the well. For barometric pressure loggers (e.g., Solinst Barologger), tie the barometric pressure logger to a nearby tree where it will not be affected by flooding.

D. Lower the pressure transducer into the well, grease the well threads with plumber's grease, and tighten the well cap with pipe wrenches.

3. Recording location and photos

Record a waypoint for each installation and Barometric pressure logger using a mapping grade GPS unit (see SOP#3 for the details of operating a GPS). Make sure the coordinate system of the GPS unit is set to NAD 1983. Also record the northing, easting, and elevation of each well on the Well Installation data sheet.

Photos should be taken throughout the installation process to document conditions that may help interpret results, including photos of each completed installation. To help re-locate installations and the Barometric pressure logger during future site visits, take landscape photos that contain unique features, such as rock outcrops or large trees that serve as reference points. On the Installation data sheet, record the photo number, the installation ID, the photographer, and a brief description of each photo.

Installation locations and elevations are also recorded during the reach survey (SOP#9).

4. Data collection

4.1 Manual water level measurements

The water surface level is the depth of the water surface beneath the top of the installation casing. Use a Solinst water level meter and the appropriate data sheet (Well Installation or Well Revisit) to record your measurements.

A. Remove the cap and leave the pressure transducer in, if installed. Wait at least one minute to allow the water level to equilibrate.

B. Align the tape guide with the marked location on the casing (Figure 8), place the meter tape in the tape guide, and allow the water level sensor to hang from the tape guide. Lower the water level sensor into the casing, then attach the tape guide in the correct location.

C. Turn on the water level meter and adjust to maximum sensitivity.

D. Release the brake, and slowly lower the water level meter into the well.

E. When the sensor encounters water, you will hear a loud constant tone. Raise the water level meter up until the tone stops. Slowly lower the water level meter back into the well, and determine the depth of the water surface (DTW) using the notch on the tape guide once the sensor begins making the tone again. It may be necessary to raise and lower several times before getting an accurate measurement.

F. On the data sheet, record the time the measurement was taken and the number read from the notch in the "Measured" column to the nearest 0.1 cm. The number read from the notch is 6 cm above the top of the well casing (TOC).

G. Repeat steps E-G two more times at one minute intervals. If the three readings differ by more than 0.5 cm, the water has not equilibrated sufficiently. Wait five minutes and try again.

H. Record the true DTW measurement to the nearest 0.1 cm:
   Measurement – 6 (if using notch on tape guide)
   Make sure all units are the same (cm).

I. Turn off the sensor, and remove the logger, if installed.

4.2 Other manual measurements

A. Lower water level meter until it reaches the bottom of the well. The tape will go slack when you reach the bottom. It may be necessary to raise and lower the water level meter to obtain an accurate measurement.

B. Record the depth between the TOC and the bottom of the well (BW) in the "Measured" column on the data sheet to the nearest 0.1 cm. Read this value from the notch on the tape guide. If the well point assembly has just been installed, this measurement will also be used to estimate the length of Kevlar rope that will suspend the pressure transducer in the well.

C. Use a tape measure to measure (along the outside of the well casing) the distance from the measuring point (TOC) to the ground surface to the nearest 0.1 cm. Record on the data sheet.

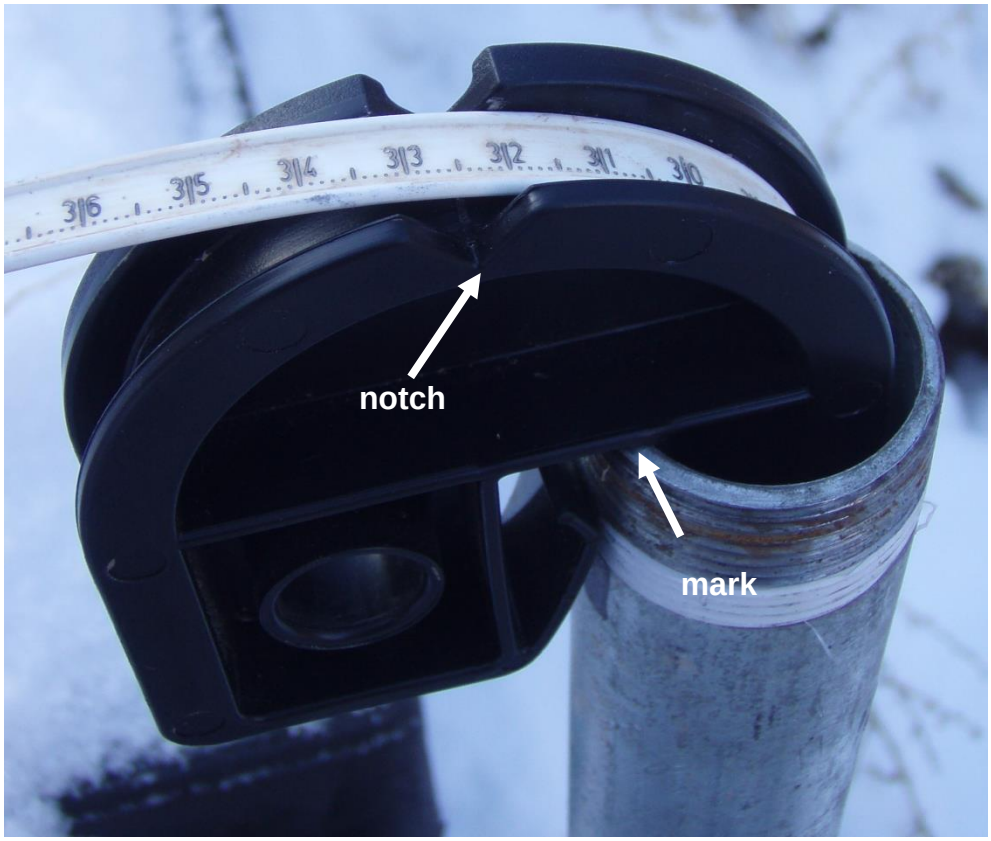


Figure 8. Aligning and reading the water level meter. Align the tape guide on the top of the well with the file/permanent marker mark. Read the water level meter at the notch and enter the value in the "Measured" column on the data sheet.

4.3 Measuring flow

4.3.1 Qualitative descriptions

Record a qualitative determination of flow severity and hydrograph limb based on the descriptions in the following two tables.

Table 1. Flow Severity

Flow Severity	Description
Dry	No visible water in stream (typical of dry period for an ephemeral/intermittent stream).
No Flow	Discrete pools of water with no apparent connecting flow (at surface).
Low	Base flow for a stream or flow within roughly 10% to 20% of base flow condition.
Normal	When stream flow is considered normal (greatest time that stream is characterized by this in terms of flow quantity, level, or general range of flow during a falling or rising hydroperiod, but above base flow).
Above Normal	Bank full flow or approaching bank full (generally within upper 20% of bank full flow condition).
Flood	Flow extends outside normal bank full condition or spreads across floodplain.

Table 2. Hydrograph Limb

Code	STORET Description

BASE	Natural groundwater flow unaffected by precipitation events
RISING	Increasing flow associated with precipitation or snowmelt.
PEAK	Highest flow associated with a precipitation event or snowmelt
FALLING	Decreasing flow associated with the return to natural groundwater flow following a precipitation event or snowmelt.

4.3.2. Discharge measurement

Currently, discharge is only being measured at CARE and ZION using a current meter.

The current meter procedure - general

A. Record the water level in the instream installation before and after the discharge measurement to ensure conditions are stable.

B. Assemble the wading rod and current meter mount. Slide the current meter mount on to the upper sections of the hexagonal wading rod and round setting rod. Screw on the bottom sections of each rod. Place the split washer into the foot of the wading rod, and screw the foot onto the hexagonal rod. Slide the current meter mount to the bottom of the rod.

C. Ensure the current meter has the correct time in **Mountain Standard Time** (-1 hour from clock time during Daylight Savings).

D. Choose a cross section in a straight reach that has the following characteristics:

- Streambed is free of large rocks, weeds, and protruding obstructions that create turbulence.
- Streambed has a flat profile to eliminate vertical components of velocity.
- All of the flow is directed downstream (i.e., there are no eddies) and lines of flow are as near parallel as possible.

E. Pull a fiberglass-reel measuring tape taut perpendicular to the channel and secure using chaining pins.

F. Divide the cross section of the channel into 20 to 30 partial sections.

- A partial section is a rectangle whose depth is equal to the measured depth at the location and whose width is equal to the sum of half the distances of the adjacent sampling locations.
- The spacing between partial sections is adjusted so that no more than 10% of the flow is in any one partial section. The ideal is to have no more than 5% of the flow in any one partial section. This means that where water is deeper and swifter measurement points are spaced closer together, while in shallow and slow water they are spaced further apart.

G. Measure the area and mean velocity of each section separately. The person wading the channel should stand downstream of the velocity meter at an arms-length distance from the current meter so as not to disturb the flow path.

H. At each vertical, the following observations are recorded on the electronic interface:

- The distance to a reference point on the bank along the tag line.
- The 0.6 tenths of depth value - The velocity should be measured at a depth which is 0.6 of the depth from the surface of water in the channel.
- The averaged 40-second velocity as indicated by the current meter.

The discharge of each partial section is calculated as the product of mean velocity times depth at the vertical times the sum of half the distances to adjacent sampling locations. The sum of the discharges of each partial section is the total discharge. All of the necessary data and calculations are performed by the electronic interface/datalogger.

The current meter procedure – specific

FlowTracker Procedure

1. Insert the flattened prong into the current meter mount attached to the bottom of the wading rod. Use a screwdriver to tighten the screw and keep the probe in place.
2. Attach the data logger to the top of the wading rod.
3. Turn on the FlowTracker by pressing the On/Off switch for 1 second until the LCD screen turns on.
4. Press Enter to display the Main Menu.
5. Press 1 for the Setup Parameters Menu and verify the following values:
    a. Units: English
    b. Avg Time: 40
    c. Mode: Discharge
6. To set date and time go to Main Menu, press 2 for the System Function Menu, then scroll through screens to select 9: Set System Clock.
7. From the Main Menu, press 3 to Start Data Run
8. Enter a file name
    a. Naming convention is 2 letter site abbreviation + 2-digit month + 2-digit day + 2-digit year.
    b. Example: FR110512 for Fremont River November 5, 2012
9. Enter site and operator name (Optional)
10. When prompted to run the automatic QC test, Press 1 to run the test and follow the on-screen instructions. The QC test must be performed at each site to ensure that the FlowTracker is working properly. If all checks say “Pass”, continue with the measurement. If a check fails, readjust the rod, and try again.
11. In the Starting Edge screen, press Set Location and enter the edge of water tag line distance.
12. Press LEW/REW to toggle the starting edge of water (Enter Right or Left *facing downstream*).
13. Press Next Station to continue.
14. Press Set Location and enter the tag line distance.
15. Place the wading rod at the target location. Use the 0.1 ft markings on the hexagonal rod to determine the water depth. Flow dynamics may cause water to rise on the upstream side of the rod and dip on the downstream side of the rod. Do your best to determine the actual depth. Press Set Depth, and enter the stream depth for the location.
16. Adjust the setting rod so that the current meter is located at 0.6 of the total water depth. For the top setting wading rod, move the line with the appropriate number of feet on the round setting rod to match the line with the appropriate tenths of feet depth printed on the wading rod handle. For example, if the water depth is 0.5 feet, slide the setting rod until the setting rod line marked “0” aligns with the handle line marked “5”. This sets the current meter at the correct depth for measuring.
17. Situate the probe so that the current meter mounting pin is perpendicular to the tag line, and the banded probe is on the downstream side. Press Measure.
18. The screen will display a countdown from 40 seconds while velocity is being measured.
19. Once the 40 second measurement is complete, a summary of velocity and quality control data is shown.
    a. Press 1 to accept the measurement and move on to the next measurement.
    b. A warning will be issued if any data are outside expected values.

i. If the warning is due to operator error, Press 2 to repeat the measurement.
ii. If a warning is due to natural elements of the stream, then accept the measurement and move on to the next.

20. Measure the velocity at 20-30 stations following the same procedure outlined above.
21. After recording the final distance at edge of water, press the End Section key.
22. Press Calculate Disch to complete discharge calculations. Press Enter to move between the different display screens.
23. Record discharge (Total Q) and velocity (V Mean) on the field form.
24. Press 0 to return to the main menu. It is important to return to the Main Menu before turning the system off to ensure all data are saved.
25. Power off the FlowTracker by holding the On/Off switch for 4 seconds.

5. Return Site Visits

Each set of monitoring wells is visited at a minimum of 8-week intervals from March through November. Visits timed to capture the greatest variation in stage and streamflow will enable computation of a robust stage-discharge relationship over time. If possible, visits should be continued throughout the winter. If there is a danger of the pressure transducer becoming encased in ice it should be removed from the installation prior to winter and reinstalled in very early spring. A lens of ice at the surface of the water can affect pressure transducer readings but does not jeopardize the equipment.

On each visit to the installations the following procedures should be performed.

A. Note on the datasheet whether the visit is in Mountain Standard Time (MST) or Mountain Daylight Time (MDT). Use your watch's time to record times for all field measurements on the datasheet. Adjustments to MST will be made during data entry.

B. Prior to removing the datalogger, measure the water level in each well following the instructions in section 4.1.

C. If the logger is partially or fully buried in sediment, make a note in the field comments including a qualitative description of the depth of sediment or debris. Clean out the sediment and rinse the logger, replace the logger, and take a water level measurement.

D. Measure the distance between the top of casing (TOC) to the ground surface at the notch filed into the well casing.

E. Measure the distance between the top of casing (TOC) and bottom of the well (BW) following the instructions in section 4.2. If the TOC-BW measurement is smaller than what was recorded during the original installation (due to sediment buildup), then well re-development is necessary. Follow the well development procedures in section 1.1.6 to remove the sediment. If there is more than 6 cm of sediment buildup, you should re-develop the well during this visit. Otherwise, you can plan on developing the well during the next site visit. Always keep well development equipment in your vehicle in case you need it.

F. Download data from pressure transducers and barometric loggers. Detailed instructions for downloading data are provided in the manufacturer's user manual for each instrument.

   A field laptop loaded with Solinst Software can be used to download data from wells that are close to the vehicle. Make sure to bring the optical interface USB cable that is compatible with the pressure

transducers and barometric logger. A field laptop may also be used to re-program instruments when necessary.

For routine visits to wells in remote locations, a smaller Solinst Leveloader PDA is recommended. Make sure to bring the correct interface cable (which is different than the cable used with a field laptop). The Leveloader does not have the ability to re-program the instruments so you will need to bring a laptop if this is necessary.

G. Record the % battery remaining, logger time, and laptop (system) time for each logger when downloaded. If the battery is below 50%, replace the logger with a new logger. If the logger time and system time are off by more than 5 minutes (accounting for the difference between Standard and Daylight Savings time), the logger should be synchronized with the laptop and re-adjusted to **Mountain Standard Time**.

H. If all loggers can be accessed on a visit, it is best to stop the programmed test after downloading the data. Simultaneously start a new test for all loggers at a site. If not all loggers can be accessed, it is best to leave the test running so that the barometric pressure logger record matches the logger records for each well.

I. After reinstalling a datalogger in a well, take an additional three water level measurements using the methods detailed in section 4.1.

J. Record flow information following the instructions in section 4.3.

K. Record detailed notes about any changes to the wells, leveloggers, or geomorphic setting (e.g., channel change due to significant flooding) noted at the site.

1. Hydrologic Data Processing

Detailed methods for data archiving and processing are provided in Appendix B. Upon returning from a field visit, the datasheet is scanned, and datalogger files are uploaded to the NCPN server. Water level data are barometrically compensated and adjusted to the manual water level measurement taken at the beginning of the test, and all data are visually reviewed for gaps or errors. Logger and manual depth to water data are uploaded to the Aquarius platform as time series datasets. Data are inspected for error or drift, and relevant corrections are applied if manual measurements (true water level) are more than 0.5 cm from the concurrent recorded logger measurement. Derived datasets convert the raw data to data referenced to a permanent datum, referenced to the ground surface, and referenced to a stage-discharge rating curve (when feasible). Finally, daily mean datasets are derived from approved data for data summary and analysis.

Well Installation

Data entered by: Data verified by:

NCPN Riparian Monitoring

Park Code: **Reach ID:** **Date:**

Observers: **Transect:** 1 2 3 4 5 6 7 **Start Time:**

Measurements for Levelogger deployment

WELL ID	Measurement description	Abbrev.	Measured	Units
Right*	Distance between top of casing (TOC) and bottom of well (BW)	**TOC- BW**	_____	(cm)
	Distance from TOC to pressure transducer sensor (PTS)	**TOC-PTS**	_____	(cm)
Left*	Distance between top of casing (TOC) and bottom of well (BW)	**TOC- BW**	_____	(cm)
	Distance from TOC to pressure transducer sensor (PTS)	**TOC-PTS**	_____	(cm)
Instream	Distance between top of casing (TOC) and bottom of well (BW)	**TOC- BW**	_____	(cm)
	Distance from TOC to pressure transducer sensor (PTS)	**TOC-PTS**	_____	(cm)

*Riparian well on right and left side when facing downstream

Water Surface Elevation Measurements

DWS = depth to surface water, Time = time of measurement (24:00)

WELL ID	Measurement description	Abbrev.	Time	Measured	Calculated	Units
Right	Distance between TOC and DWS	**DWS**	_____	_____	_____	(cm)
Left	Distance between TOC and DWS	**DWS**	_____	_____	_____	(cm)
Instream	Distance between TOC and DWS	**DWS**	_____	_____	_____	(cm)

GPS Coordinates

UTM NAD 1983

Log at least 30 points on GPS

WELL ID	Northing	Easting	Elevation	Units
Right	_____	_____	_____	(m)
Left	_____	_____	_____	(m)
Instream	_____	_____	_____	(m)
Barologger	_____	_____	_____	(m)

Photo Log

Photos taken? yes no

Reference images taken of well and general comments

Photo #	***Photo Type***	*Well ID*	*Photographer*	*Description*
_____	digital	_____	_____	_____
_____	digital	_____	_____	_____
_____	digital	_____	_____	_____
_____	digital	_____	_____	_____
_____	digital	_____	_____	_____
_____	digital	_____	_____	_____

Field Notes

Add descriptive notes and general comments below

NCPN I&M INTEGRATED RIPARIAN HYDROLOGY FIELD FORM: REVISIT								Date	
v. 1.2	12/16/2013							Start Time	
								Daylight Savings	
Park Code	ZION	**Reach #**	3	**Transect #**	7		**Sampled by**		
		Right		**Left**		**Instream**		**Baro**	
Logger Download (y/n)									
Logger Time									
System Time									
Battery Remaining			%		%		%		%

Water elevation - Top of casing at notch to water surface (nearest 0.1 cm). Measured distance includes 6cm for using notch on water me

	Prior to logger download			**Prior to logger start**					
Right	Time	Meas.	TRUE	Time	Meas.	TRUE	**Maintenance - TOC to bottom of well**		
1							Ref. 401.3		cm
2							True 395.3		cm
3							**Ground Surface - TOC at notch to ground**		
Average									cm
Left	Time	Meas.	TRUE	Time	Meas.	TRUE	**Maintenance - TOC to bottom of well**		
1							Ref. 354.8		cm
2							True. 348.8		cm
3							**Ground Surface - TOC at notch to ground**		
Average									cm
Instream	Time	Meas.	TRUE	Time	Meas.	TRUE	**Maintenance - TOC to bottom of well**		
1							Ref. 186.5		cm
2							True 180.5		cm
3							**Ground Surface - TOC at notch to ground**		
Average									cm

Photo Log		Photos taken?			Reference images taken with WELL ID and general comments				
File Name	*Photo Type*		*Description*						
Field Notes		Flow conditions, geomorphology, maintenance, weather, etc.							

Park Code	ZION	**Reach #**	3	**Transect #**	7		**Sampled by**		
Flow Measurement									
measurable		**Time of**		**hydrograph**	**flow**				
dischar. (y/n)		**Measurement**		**stage**	**severity**				
Discharge	**Meas.**		**Flow**			**Measurement type**		**Avg velocity**	**vtype**
Method	**Device**		**Value**			(M,E,blank)		(ft/s, blank)	(M,E,blank)
				cfs					
current meter file name									
current meter discharge(									
estimated discharge (cfs)			**estimate type**						
Volumetric						estimated	adjusted flow		
measurement	*vol.(mL)*	*time (s)*	*(mL/s)*	*(gpm)*	*(cfs)*	% loss	*(cfs)*		
1									
2									
3									
4									
5									
	stable flow?					***average***			
Weir		*calculated*				estimated	adjusted flow		
measurement	*stage (ft)*	*(gpm)*			*(cfs)*	% loss	*(cfs)*		
1									
2									
3									
4									
5									
	stable flow?					***average***			
Flume		*Look up*				estimated	adjusted flow		
measurement	*stage (ft)*	*(gpm)*			*(cfs)*	*% loss*	*(cfs)*		
1									
2									
3									
4									
5									
	stable flow?					***average***			
Discharge comments									

Appendix B - Hydrologic Data Processing

Hydrologic data collection methods are detailed in SOP #10. Upon returning from a field visit, the datasheet is scanned, and the scanned datasheet, datalogger files, and current meter files are uploaded to the NCPN server. Water stage data are barometrically compensated and adjusted to the manual depth to water measurement from the beginning of the logger test. Logger data are uploaded to the Aquarius platform as time series datasets. Field visit data are entered manually in Aquarius. All data are visually reviewed for gaps or errors. Data are inspected for error or drift, and relevant corrections are applied. Derived datasets convert the raw data to data referenced to the site's permanent datum and referenced to the ground surface for riparian wells. Daily mean datasets are derived from approved data for data summary and analysis.

Acronyms and Naming Conventions

For naming purposes, the following codes should be used:

Park Code	Park
ARCH	Arches National Park
CARE	Capitol Reef National Park
NABR	Natural Bridges National Monument
ZION	Zion National Park

Reach Code	Stream/Wash	Park
A	Armstrong Canyon	NABR
C	Courthouse Wash	ARCH
F	Fremont River	CARE
P	Parunuweap Canyon (East Fork Virgin River)	ZION

Dates use Year-Month-Day (YYYYMMDD) format, e.g., 20120514

Firmware and Software Deployment History

Logger	Use started	Use ended	Compatible software
Solinst Levelogger Gold	10/17/2010		Solinst Levelogger v.4.0.3
Solinst Barologger Gold	10/17/2010		Solinst Levelogger v.4.0.3
Solinst Levelogger Edge	3/30/2014		Solinst Levelogger v.4.0.3
Solinst Barologger Edge	3/30/2013		Solinst Levelogger v.4.0.3

Current Meter	Use started	Use ended	Compatible software
AquaCalc with pygmy meter	10/17/2010	9/4/2012	AquaCalc DataLink Pro v.2.1.1
SonTek Flowtracker ADV	9/4/2012		SonTek FlowTracker v.2.30

Data Management	Use started	Use ended
Aquarius 3.x	11/1/2012	
Data sheet v. 1.0	10/2010	11/31/2012
Data sheet v. 1.1	12/12/2012	12/09/2013
Data sheet v. 1.2	12/10/2013	

Temporary data storage

Upon completing a field visit, data are uploaded to the NCPN server at X:\Active_Monitoring_Projects\Riparian\Data\Hydrology (Fig. A-1).

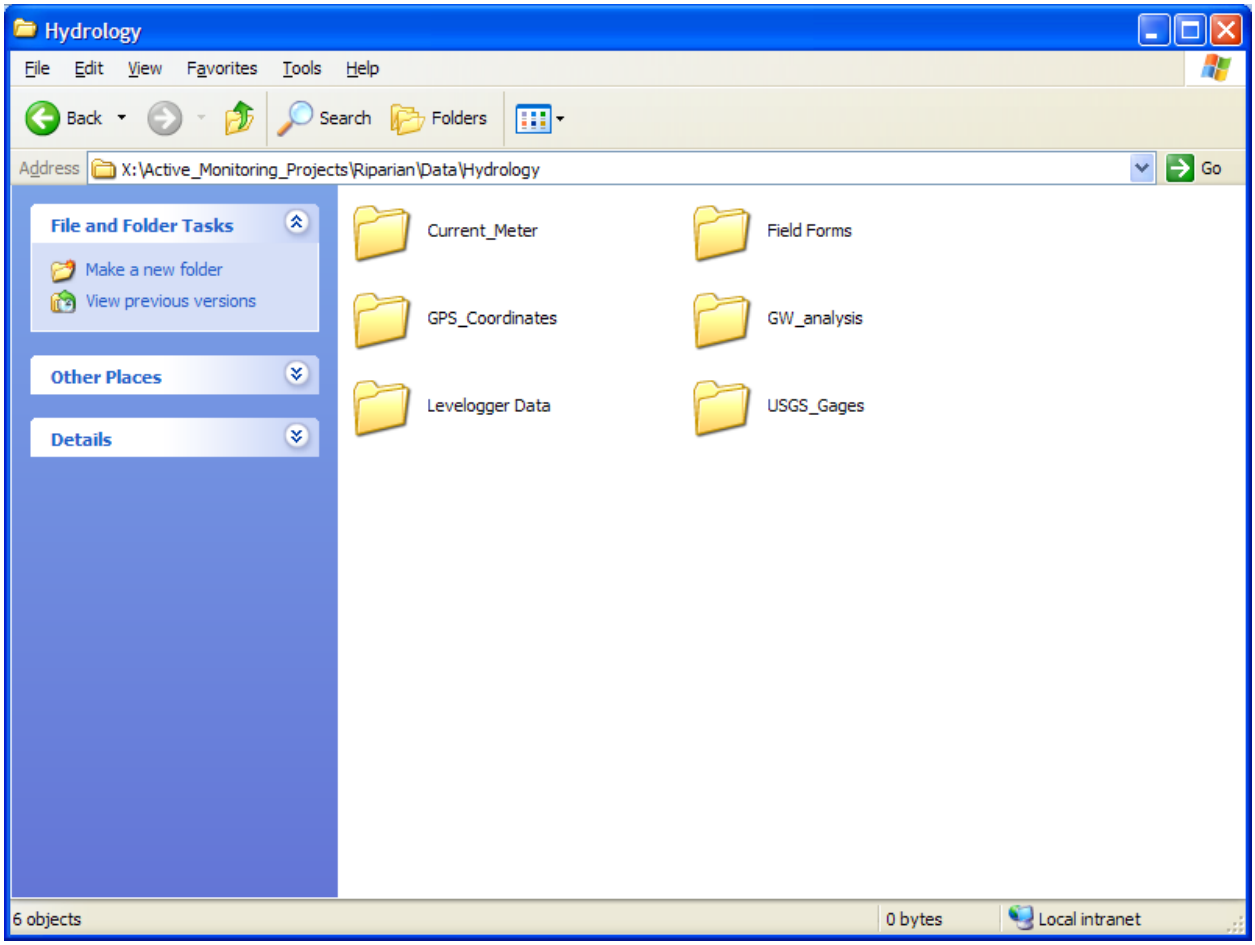


Fig. A-1. File structure for hydrology data on NCPN server.

Upon completing a field visit, upload raw logger files to the NCPN server at X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Levelogger Data into the appropriate park, reach and date folder (YYYYMMDD of site visit). Make sure the levelogger file uses the following convention:

PARK_Reach_well_date, e.g., ARCH_C1_instrm_20120514.lev, ZION_P3_left_20131008.lev, etc.

Scan the datasheet and upload to X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Field Forms in the appropriate park, stream reach and date (YYYY) folder. Name the field visit data sheet using the following convention:

PARK_Reach_Date, e.g., ZION_P3_20120514.xls

Update each well log with the site visit date, the period of record that was downloaded, the observer, and any maintenance issues pertaining to the well or notes about geomorphic change at the site. *These logs are essential for interpreting potential jumps or drifts in the logger data*.

When applicable, upload current meter files in their native format and as .csv files to X:\Active_Monitoring_Projects\Riparian\Data\Hydrology\Current_Meter in the appropriate park, stream reach and date (YYYY) folder. Name the current meter file using the following convention:

Reach_date, e.g., F1_20120514.csv

Upload photos to X:\Archive\NCPN Photos\Incoming\Monitoring\Riparian to the appropriate year and project folder. Leave photo names as produced by the camera.

Barometric Pressure Compensation of Water Level Logger Data

All water stage data must be barometrically compensated by subtracting the barometric pressure recorded by the barometric pressure logger from the water stage recorded by each well's pressure transducer. Barometric pressure compensation can be completed using Solinst Levelogger software. Compensated data are then adjusted to the manual water level measurement taken during the field visit at the beginning of the logger record using Solinst Levelogger software.

Software compensation

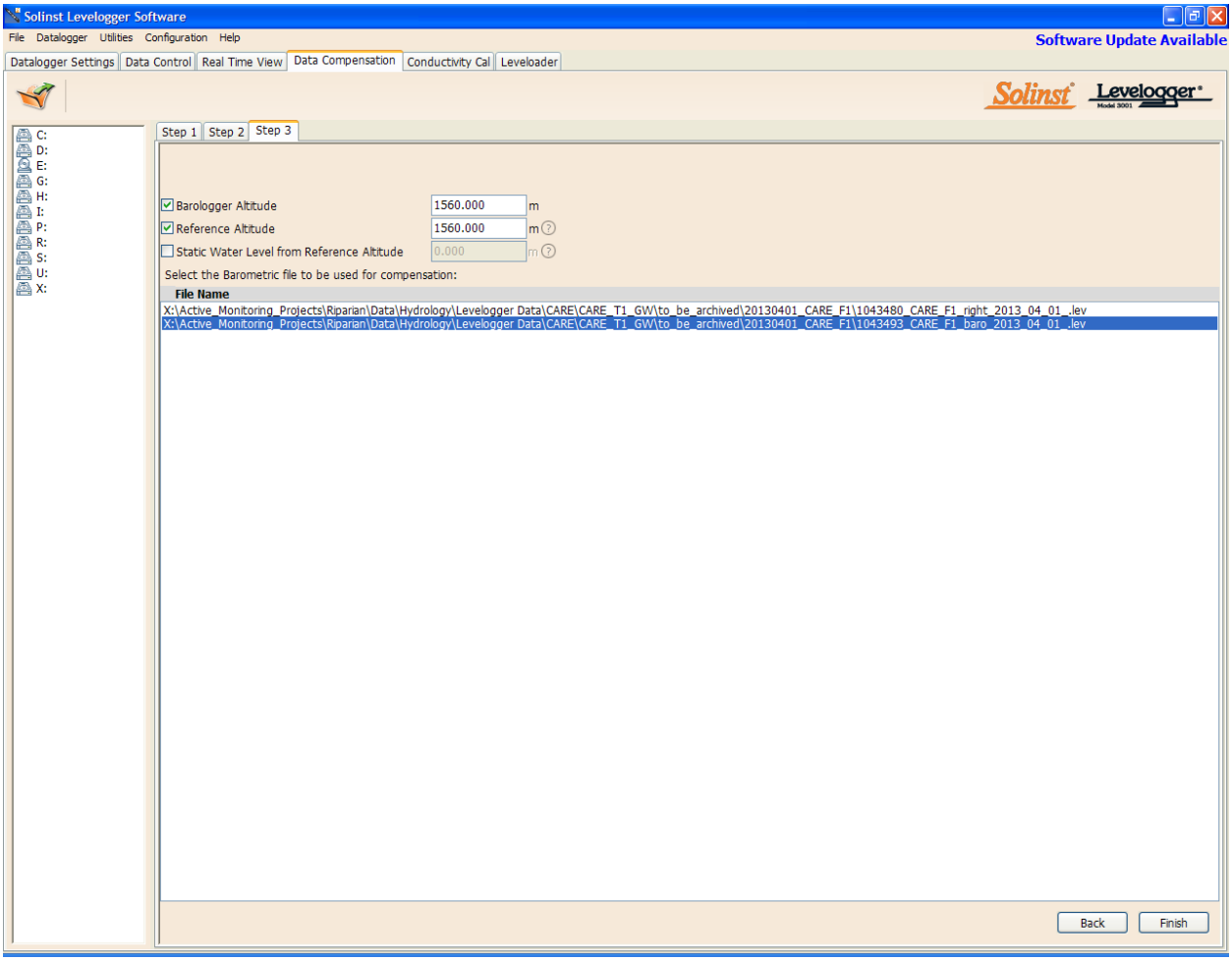
These instructions are written for Solinst Levelogger Software v. 4.0.3 for use with the Levelogger Gold and Edge series.

1. Open Solinst Levelogger Software.
2. Open groundwater or surface water data file.
3. Select Data Compensation tab.
    a. Make sure submerged levelogger file toggle is active, then click next .
    b. Check Barometric Compensation, then click next.
    c. Open and select the bfile that is associated with the levelogger file that you are compensating.
    d. Add the elevations of the submerged levelogger and the barometric pressure logger.

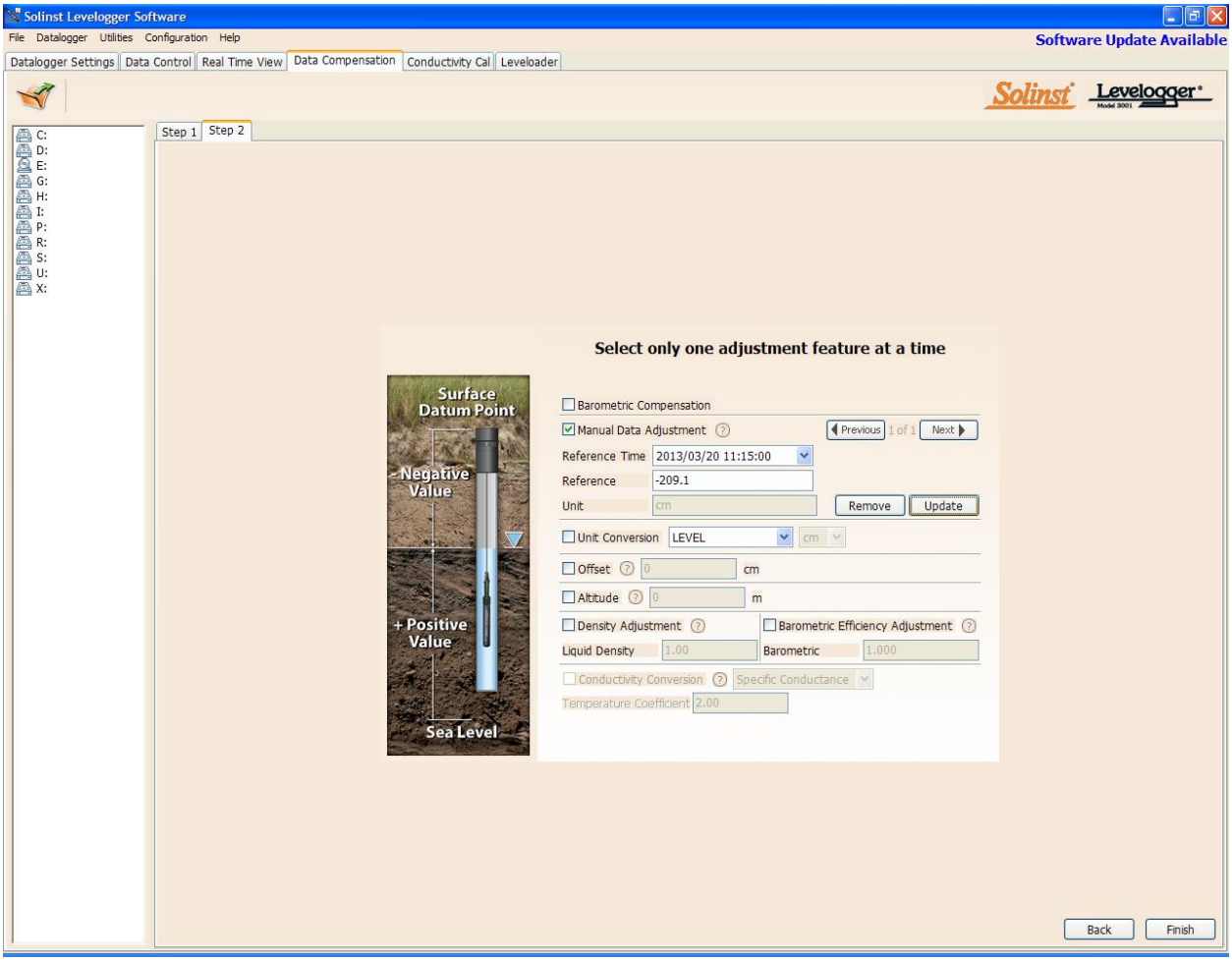
Reach	Elev. (m)
ARCH C-1	1247
CARE F-1	1560
NABR A-5	1780

ZION P-3	1200

e. Click Finish. The software will automatically add the word COMPENSATED to the original levelogger file name and save it in the same location.



4. Open the compensated levelogger file you just created.
   a. Look at the dataset to determine the earliest date and time closest to the field visit measurement time that shows the datalogger is correctly deployed in the water (look for changes in temperature and stage).
   b. Select the Data Compensation tab and the compensated dataset, then click next.
   c. Select Manual Data Adjustment. Choose the date and time corresponding to the equilibrated datapoint noted above.
   d. In the Reference cell, enter the negative value of the manual depth to water measurement (to the -0.1 cm) recorded at the field visit that corresponds to the beginning of the test. For example, if the measured depth to water on 2/14/13 at 11:45 MST was 125.3 cm from the top of the well casing, enter (-125.3) as the Reference for 2/14/13 at 12:00 MST on the logger file. Click Add, then Finish.
   e. The software will automatically add the word COMPENSATED to the original levelogger file name and save it in the same location.



5. Open the adjusted levelogger file you just created (filename_compensated_compensated.lev). Export the adjusted and compensated levelogger file as a comma separated value (filename.csv) file. All files should be saved in the same folder on X (original, compensated, and exported .csv files).
6. Open the .csv file and delete any measurements taken prior to the equilibrated measurement. Round the level measurement column to the nearest 0.1 cm and the temperature measurement column to the nearest 0.01°C.
7. Repeat steps 2-6 for each levelogger file (riparian groundwater and instream leveloggers).

Aquarius Database

The following instructions are written for Aquarius 3.x developed by Aquatic Informatics.

The Aquarius database is currently accessed through five concurrent licenses held by the Water Resources Division (WRD). Permission to use a license is arranged by contacting the data manager for WRD, Dean Tucker (Dean_Tucker@nps.gov). Each unique user must have an account created by Dean.

Once an account has been created, to access the Aquarius database, double click the Aquarius Remote Assistant icon on your desktop. Use your PIV card or NPS username and password to log in to the Ft. Collins server ('localhost' or 'inp2300fcvgett1.nps.doi.net'). Once you have logged in to the server, right click the Aquarius Assistant (Remote) icon in the notification area of the Windows Task Bar (you might have to click the double-carets to show hidden icons), and select "Launch Springboard." Log in to the Aquarius database using your NPS username and password.

When you are finished using Aquarius, close the interface (Workstation/Whiteboard or Springboard). Right click the Aquarius Assistant (Remote) icon in the notification area of the Windows Task Bar, and select "Exit" to free up the license for another person's use.

Data in the Aquarius database are organized by Organization, Project, and Location. Use the Northern Colorado Plateau Network Organization folder and Wadeable Streams Project folder. Each installation is a Location, and each parameter (i.e., levelogger depth to water, manual depth to water measurement, manual discharge measurement) is stored in a separate time series within the Location. Tutorials for getting started in Aquarius are available from WRD at:

http://nrdata.nps.gov/programs/water/aquarius/AquariusVideos.htm

and at the Aquatic Informatics support portal: http://aquaticinformatics.com/main/%3FSupport_Login.

Data in Aquarius

After all steps have been completed, you should have the following time series in Aquarius for each well:

Filename	Type	Description	Use
DepthtoWaterFromCasingTop.compensated logger@Location	Basic	15-minute barometrically compensated water stage data adjusted to manual depth to water measurement (cm)	Convert to Stage or Discharge; apply data corrections
Water Temp. logger@Location	Basic	15-minute water temperature (°C) from datalogger	Summarize and analyze approved data (optional)
DepthtoWaterFromCasingTop.Field Visits@Location	Basic	Manual depth to water (cm)	Compare to logger time series to determine drift corrections

Filename	Type	Description	Use
Stage.Datum@Location	Derived – calculated	Depth to water data converted to water elevation referenced to site's permanent Datum (m)	Summarize and analyze approved data (SOP 14; stage metrics); apply well elevation corrections; archive; compare groundwater well elevations to interpolate groundwater elevations between wells; compare to geomorphology data
Stage.Dailies@Location	Derived – statistical	Calculated daily mean stage in site datum (m)	Summarize and analyze approved data (SOP 14)
Riparian shallow groundwater wells			
DepthtoGroundFromCasingTop.Field Visits@Location	Basic	Manual depth to ground (cm)	Look for changes in ground surface elevation
DepthtoWaterFromGroundSurface.Calculated@Location	Derived – calculated	Calculated 15-minute depth to water from ground surface (m)	Convert to daily mean time series; apply ground surface elevation corrections
DepthtoWaterFromGroundSurface.Dailies@Location	Derived – statistical	Calculated daily mean depth to water from ground surface (m)	Summarize and analyze approved data (SOP 14)
Instream wells (CARE and ZION only)			
Discharge.Field Visits@Location	Basic	Manual discharge measurements (m^3/s)	Create and maintain rating curve
Stage-Discharge.rating curve@Location	Rating curve	Stage-discharge relationship based on field visit measurements	Convert 15-minute stage to 15-minute discharge time series

Filename	Type	Description	Use
Discharge.Calculated@Location	Derived – rating curve	Derived discharge (m^3/s) based on rating curve	Convert to daily mean time series
Discharge.Dailies@Location	Derived – statistical	Calculated daily mean discharge (m^3/s)	Summarize and analyze approved data (SOP 14)
Discharge.gagenumber.Discharge_(cfs)_Daily_Mean@Location	External – USGS	Daily mean discharge (cfs) at USGS gaging station	Data quality checking and interpretation; summarize and analyze data (SOP 14; optional)

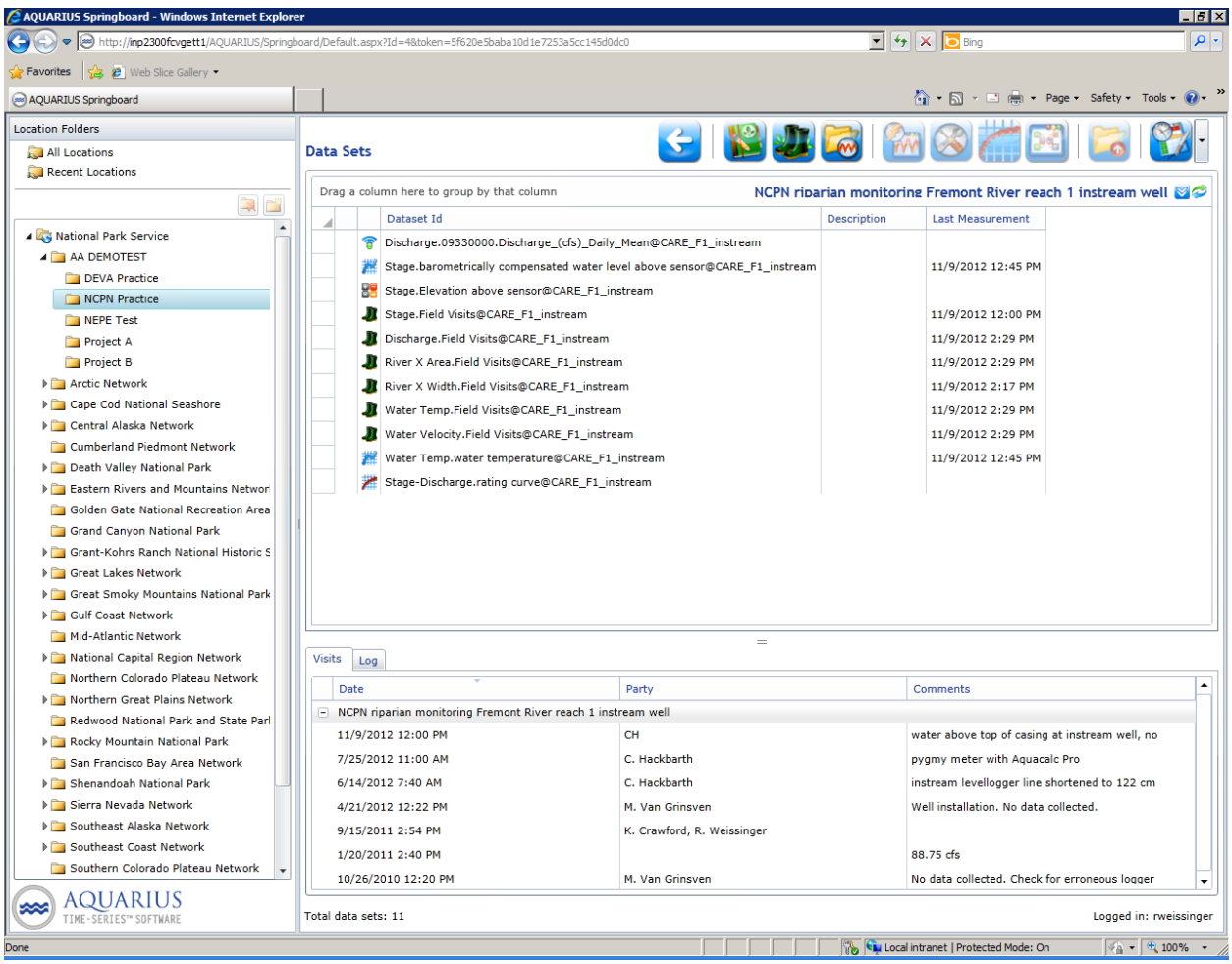


Fig. A-2. Example data set file structure for an instream well in Aquarius.

Upload Logger Data to Aquarius

1. Open the Northern Colorado Plateau Network organization folder.
2. Select the appropriate well location, e.g., CARE_F1_instrm.
3. Click on the Append Logger File icon.
4. Browse to the appropriate park and reach folder on X, and select the.csv file for upload. *Make sure you upload the compensated and adjusted data*! Use the appropriate configuration file or set up a configuration using the following steps.
5. Click on Config Settings.
    a. Select Time Series, Text File (CSV, etc), and click Next.
    b. Adjust the "Start import at row" so that the first row of data in your .csv file is shown in white in the import box in Aquarius (Solinst v.4.0.3 row 14). Adjust the "Number of headers" so only the column names are shown in gray in the import box (Solinst v.4.0.3 = 1). The "Delimiter" should default to "Comma." Click Next.

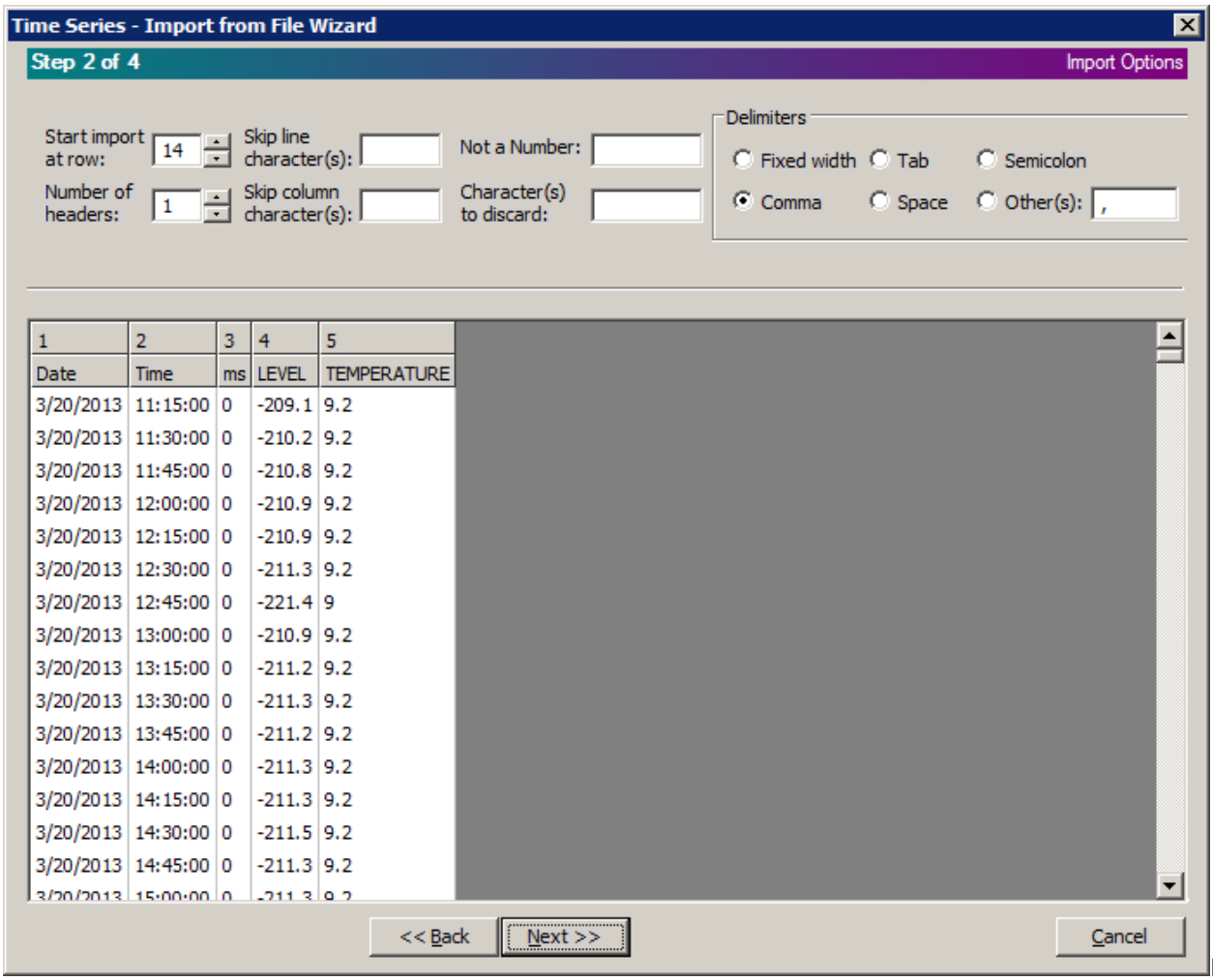


Fig. A-3. Importing logger data into Aquarius.

    c. Define upload information for each column. For Solinst v.4.0.3 logger files:
        i. For Column 1 (Date), select "Date/Time" and choose mm/yy/dddd in the 'Date/Time Format' drop down list. Select time zone UTC-07:00 (Mountain Standard Time). If for some reason the logger used a different time zone (such as daylight savings) during the period of upload, select

the time zone used by the datalogger, and Aquarius will adjust to the correct Standard time when appending the data to the existing time series.

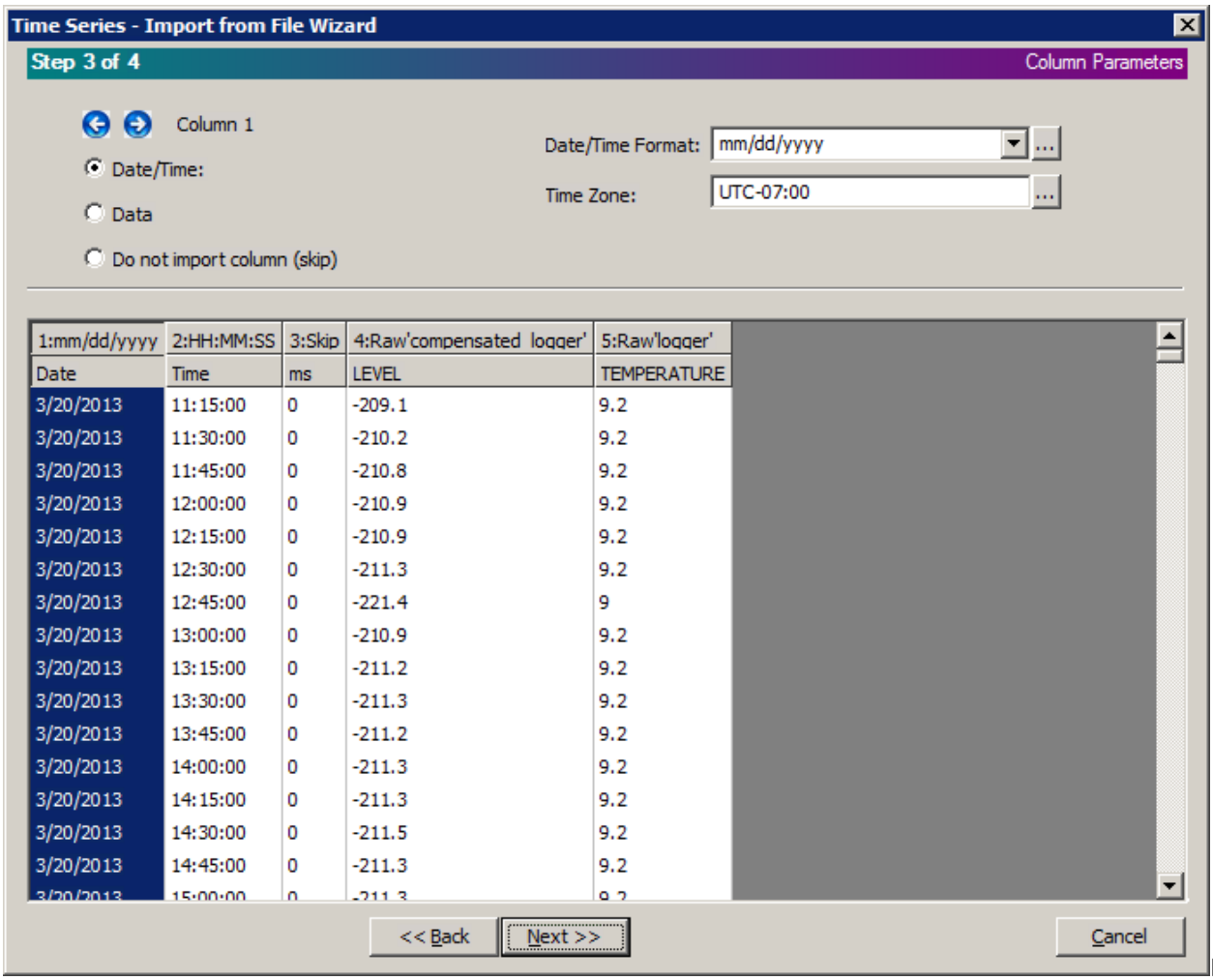


Fig. A-4. Example Date Format for logger data import in Aquarius

ii. For Column 2 (Time), select “Date/Time” and choose HH:MM:SS in the ‘Date/Time Format’ drop down list. Leave the default Time Zone value selected for Column 1.
iii. For Column 3 (ms), select “Do not import column (skip).”
iv. For Column 4 (LEVEL), select Data (Raw). For “Parameter” select DepthtoWaterFromCasingTop. For “Units”, select cm. If for some reason the logger file is not in cm, select the appropriate unit (such as m), and Aquarius will adjust to the correct unit when appending to the existing time series. For Gap Tolerance, write in the sampling interval plus one (e.g., “16” for a 15-minute sampling interval). For “Label” write “compensated logger.” The remaining selections can remain at their defaults (Int. Type = 1, Grade = unspecified, Approval = unspecified).

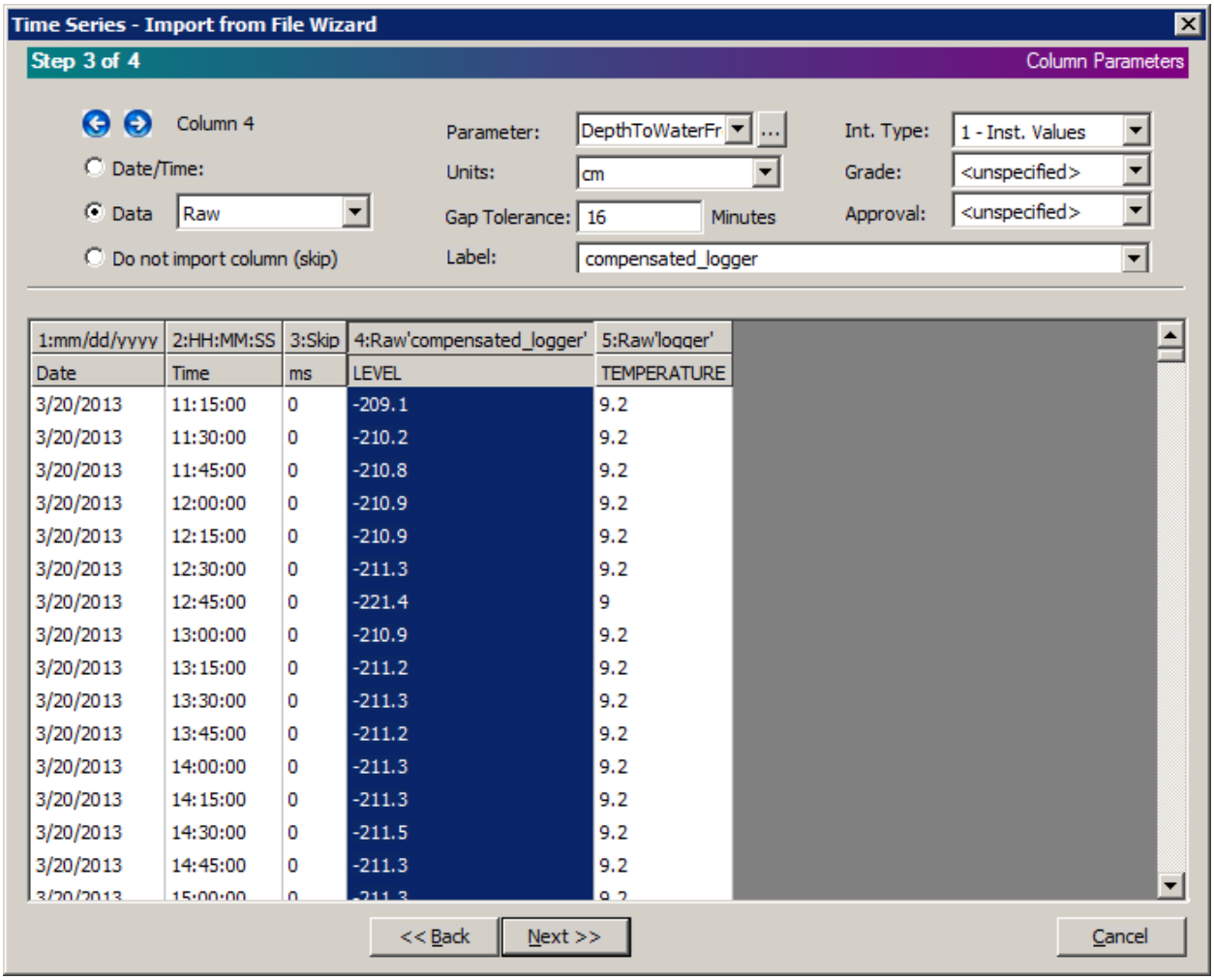


Fig. A-5. Example depth to water data format for logger data import.

v. For Column 5 (TEMPERATURE), select Data (Raw). For “Parameter” select Water Temp. For “Units”, select °C. If for some reason the logger file is not in °C, select the appropriate unit (such as °F), and Aquarius will adjust to the correct unit when appending to the existing time series. For Gap Tolerance, write in the sampling interval plus one (e.g., “16” for a 15-minute sampling interval). For “Label” write “logger.” The remaining selections can remain at their defaults (Int. Type = 1, Grade = unspecified, Approval = unspecified).

vi. Once all columns are defined, click Next.

d. On “Time Series Import Options” accept the default of “Apply Gap Processing Tolerance.” If you have not used a pre-made configuration file, you can choose to save the configuration you just created. Click Finish.

6. Select the target datasets and, in the “Append to” dropdown boxes, select the appropriate existing time series. Click Append.

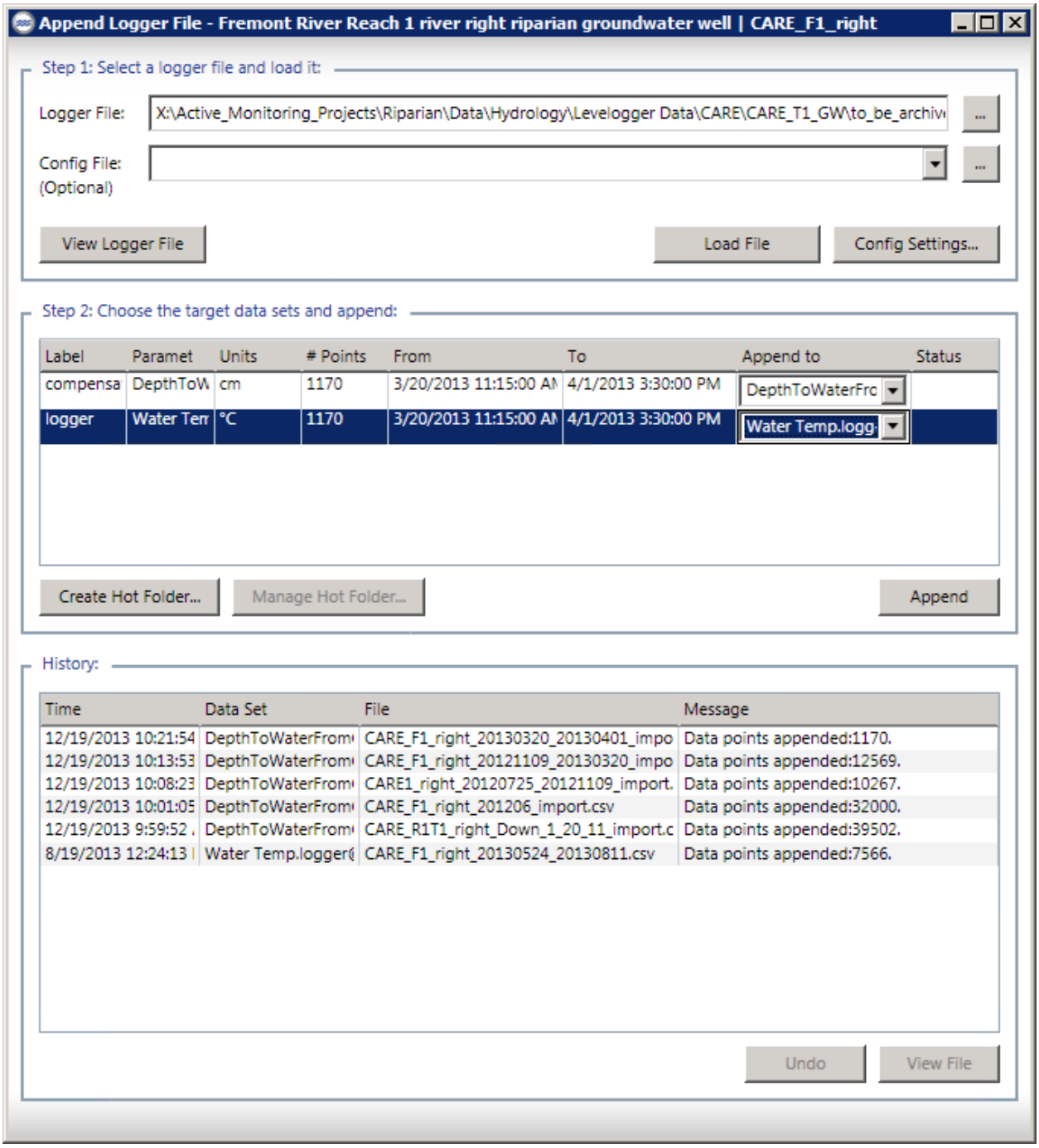


Fig. A-6. Appending data to existing datasets. Note the import history at the bottom of the screen and the ability to undo imports.

7. You can then choose to upload additional files, or exit out of the Append Logger tool by closing the window via the 'X' in the upper right corner of the window to return to the Location folder.
8. To ensure that the data have uploaded correctly, click on the large, right-pointing blue arrow to move to the location's data sets. Select a data set and then click on the Quick View icon to visually inspect the period of data just uploaded.
9. If incorrect data are uploaded (i.e., the wrong well, data that have not been barometrically compensated, etc.), select the appropriate location, and launch the Append Logger File toolbox. In the History section at the bottom

of the window, select the date/time and data set(s) that were incorrectly uploaded and click "Undo." The incorrect data will be removed from the time series.

Enter Field Visit Data in Aquarius

1. Select the appropriate well location.
2. Click on the Field Visit icon, and select New Field Visit in the field visit toolbox.
    a. Enter the date, start time (**adjusted to Mountain Standard Time**), observer (party), and relevant logger, well, or geomorphic notes in the Remarks section. Record top of casing to bottom of well (TOC-BOW) in the Remarks section.
    b. For instream wells, under Hydrometric Field Notes, upload copies of the data sheet and current meter file. Under Maintenance Notes, upload the updated well log.
    c. For all wells, under Hydrometric Field Notes, upload copies of relevant site visit photographs.
    d. If applicable, under Survey Notes, upload final copies of the survey data for the well transect (see geomorphology SOP).
    e. Click Save.

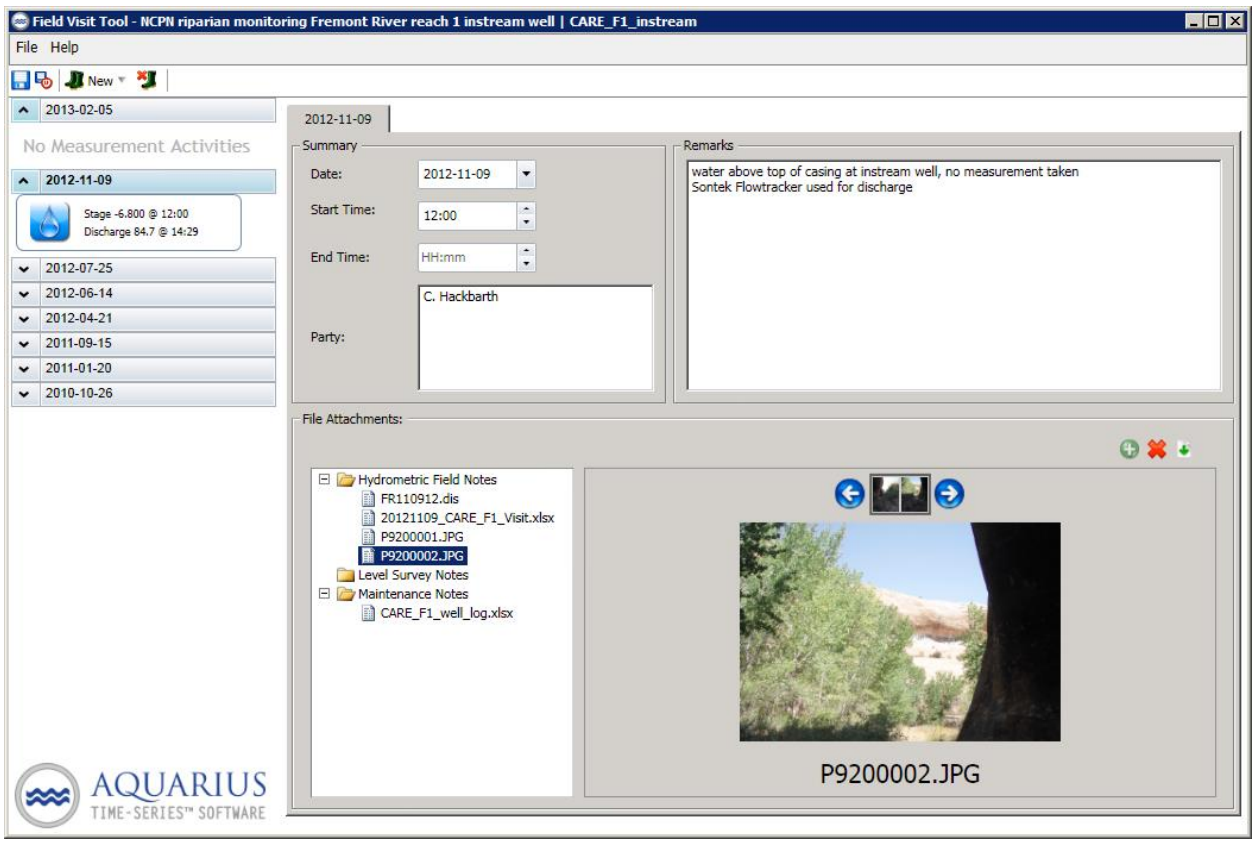


Fig. A-7. Example Field Visit in Aquarius.

3. For instream wells, select "New Measurement Activity from File" in the field visit toolbox, and select Flowtracker DIS.
    a. Navigate to the appropriate current meter file on X and import the discharge data. Aquarius will create five parameters with default units: Discharge, River x Area, Water Velocity, River x Width, and Water Temp.

b. Click Save.
c. After the data have imported, click on the Discharge Measurement Details icon. Look at the Summary Result tab. Evaluate the Uncertainty (Stats) to determine the data quality as follows:

Uncertainty (Stats)	Grade
<2%	Excellent
2-5	Good
5-8	Fair
8-10	Poor
>10	Unusable

d. Click Save.

4. For "Conditions" include the hydrograph stage (base, rising, falling) and weather conditions during the site visit.
5. For instream wells, click the green plus icon to add observations. For riparian wells, select New Measurement Activity. Manually enter the Depth to Water measurements from the data sheet to the nearest -0.01 cm (e.g., if the depth to water was 213.1, enter -213.1). If the tape guide was used, enter 6 in the Correction cell, and the true depth to water will automatically be calculated. **Adjust the time of the measurement to Mountain Standard Time if necessary**. Grade the measurements as follows:

Range of 3 measurements	Grade
0 cm	Excellent
0.1-0.3	Very Good
0.4-0.5	Good
0.5-0.8	Fair
0.8-1.0	Poor
>1.0	Unusable

6. Enter the Depth to Ground from Top of Casing measurement to the nearest -0.01 cm (e.g., if the depth to ground was 14.5 cm, enter -14.5)
7. For instream wells, click the green plus icon to add observations. Manually enter the stages recorded before and after the discharge measurement.
8. Click Save and close. The new site visit will show up in the Visit Log on the location page, and the data will be appended to the relevant field visit data set automatically.

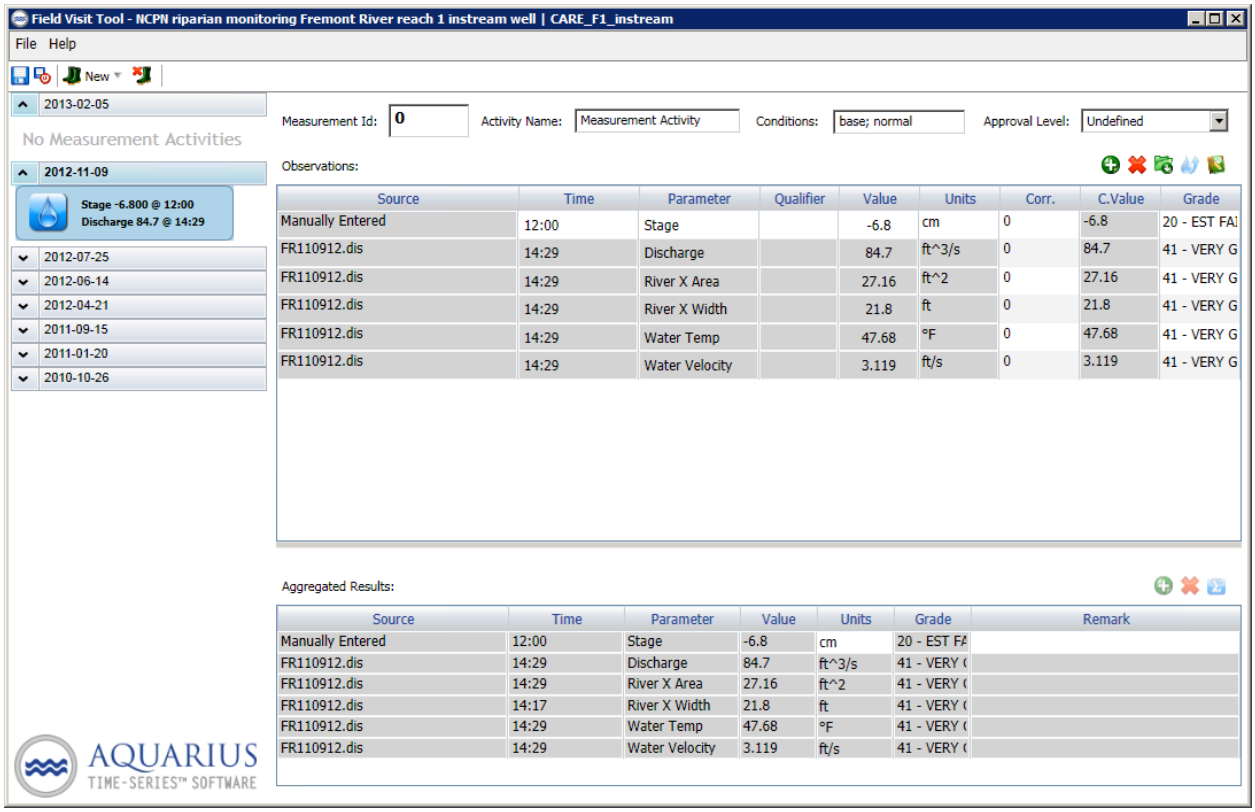


Fig. A-8. Example Measurement Activity for an instream well showing imported discharge data and manually entered stage data.

Acquire USGS gage data in Aquarius

The East Fork Virgin River and Fremont River have USGS gages with 15-minute discharge data relevant to our monitoring locations.

Gage number	Gage name	Location relative to monitoring site
09330000	Fremont River near Bicknell, UT	About 21 miles upstream of CARE-F01
09404900	East Fork Virgin River near Springdale, UT	Co-located with ZION-P03

The East Fork Virgin gage is co-located with the monitoring wells at Zion, and gage data may be used to quality check NCPN data and fill gaps in the NCPN data record for discharge. The Fremont gage is too far upstream from the monitoring wells at CARE to be used in the same way, but it can still provide a useful comparison to NCPN data for identifying some flood events, the opening and closure of irrigation diversions, etc.

1. Select the appropriate instream location, and click on the Location Manager icon. Select the Data Sets tab, and click on the New Time Series icon.
2. Under Type, select 'External'. Click on the '…' and set the Data Provider to 'USGS Water Services'.
3. Enter the gage number in the Location field or Browse to find a gage and then click 'Load'.

4. Once a gage has been selected, select the time series of interest (generally Discharge (cfs) Daily Mean).
    a. The Start date and End date will show the period of record available. You may select the entire period of record or specify an interval to extract. Click OK.
5. Specify Parameter (Discharge), Units (ft^3/s), and Gap Tolerance (1440 minutes per day).
6. Save and close. Launch the time series in Quick View to visually inspect the data.

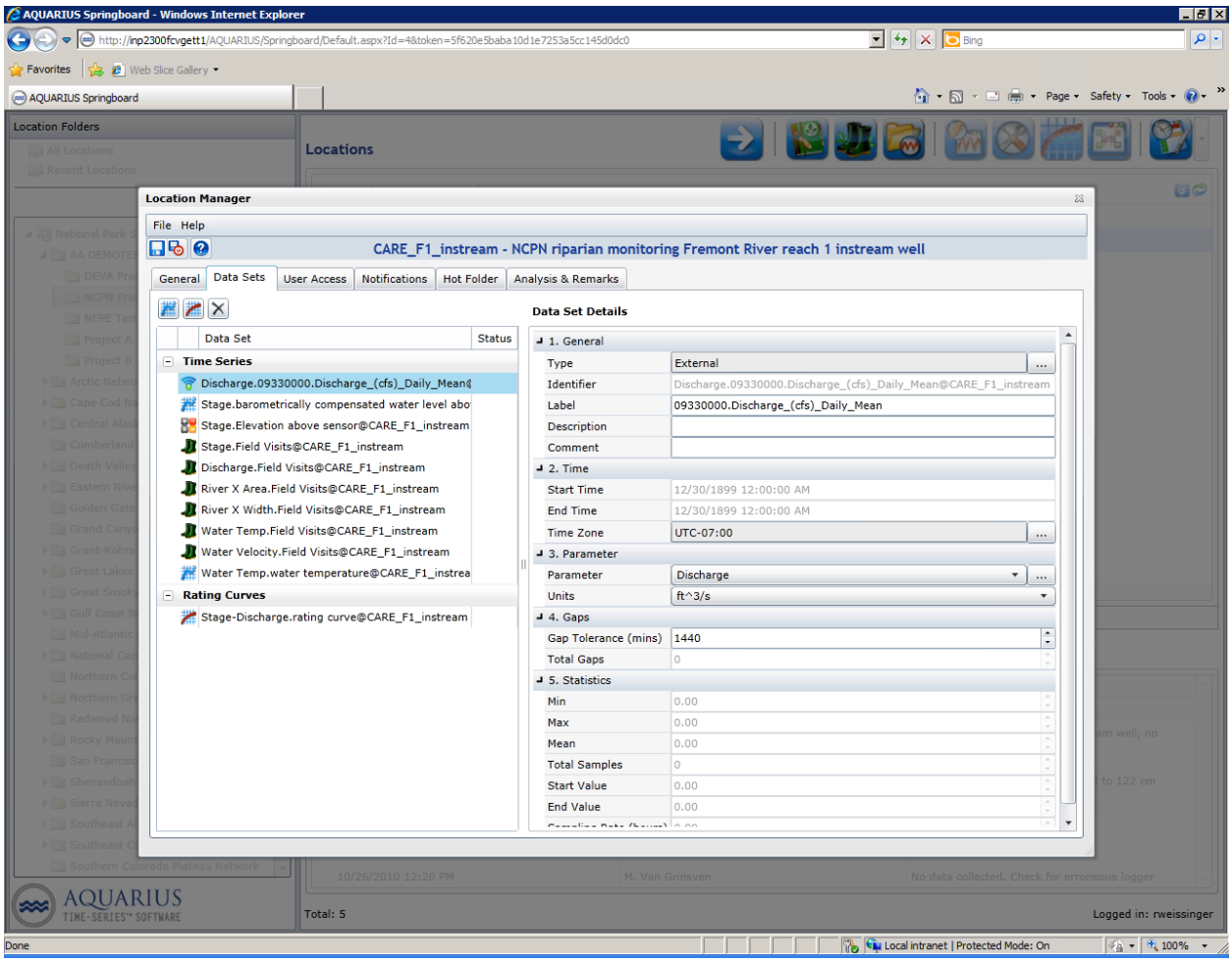


Fig. A-9. Creating an external dataset to acquire USGS gage data.

After the time series is created, Aquarius creates an active link to the USGS gage data. The data are not stored in Aquarius, but are pulled in each time the time series is needed.

Data Corrections and Edits to the compensated logger time series in Aquarius

Data corrections and edits are accomplished using the Data Corrections toolbox. The Data Corrections toolbox creates a log of each edit applied to the dataset. The underlying raw data are maintained in Aquarius as well as the corrected dataset, and each edit can be toggled on or off by selecting it in the correction log.

The goal for each well's hydrograph is to have the logger data match up with manual water level measurements taken during each field visit. Manual depth to water measurements are assumed to be the true water level, and logger data should be corrected to match the manual water level measurements. The beginning datapoint of each imported logger file is adjusted to match the manual water level measurement using Solinst Levelogger software (see Software Compensation section above).

Several types of data corrections may be needed. Faulty data are collected any time the sensor is out of water, such as during data download or sensor programming. Drift corrections occur due to the gradual degradation of the pressure transducer sensor and components and can be seen as a mismatch between the last recorded logger value and the manual water measurement taken during the field visit at the end of the logger record. Offset corrections may be needed to correct unusual jumps in the data, perhaps from sedimentation, ice, or differing sensor elevations. All of these corrections should be applied to the DepthtoWaterFromCasingTop.compensated logger@Location time series.

When evaluating a data record, look for smooth curves and reasonable agreement between wells. Investigate and attempt to explain any jagged (noisy), spike (non-event related jumps), or flat (instrument malfunction) data. Do instream peaks match known precipitation events or rises in discharge or stage at relevant gaging stations? Do Stage.Datum curves match for all wells? Detailed instructions for removing faulty data and adjusting for sensor drift are included below.

Removing faulty readings corresponding to field visits

Incorrect depth to water data that correspond to when Leveloggers are removed from wells for data downloads should be flagged in the raw dataset and removed for data summary and analysis. In Aquarius, open the logger time series for the well of interest in the Data Correction toolbox. Select the values that correspond to when the logger was out of the water, and select Delete Region. When prompted, add a note, e.g. “logger out of water.” Save.

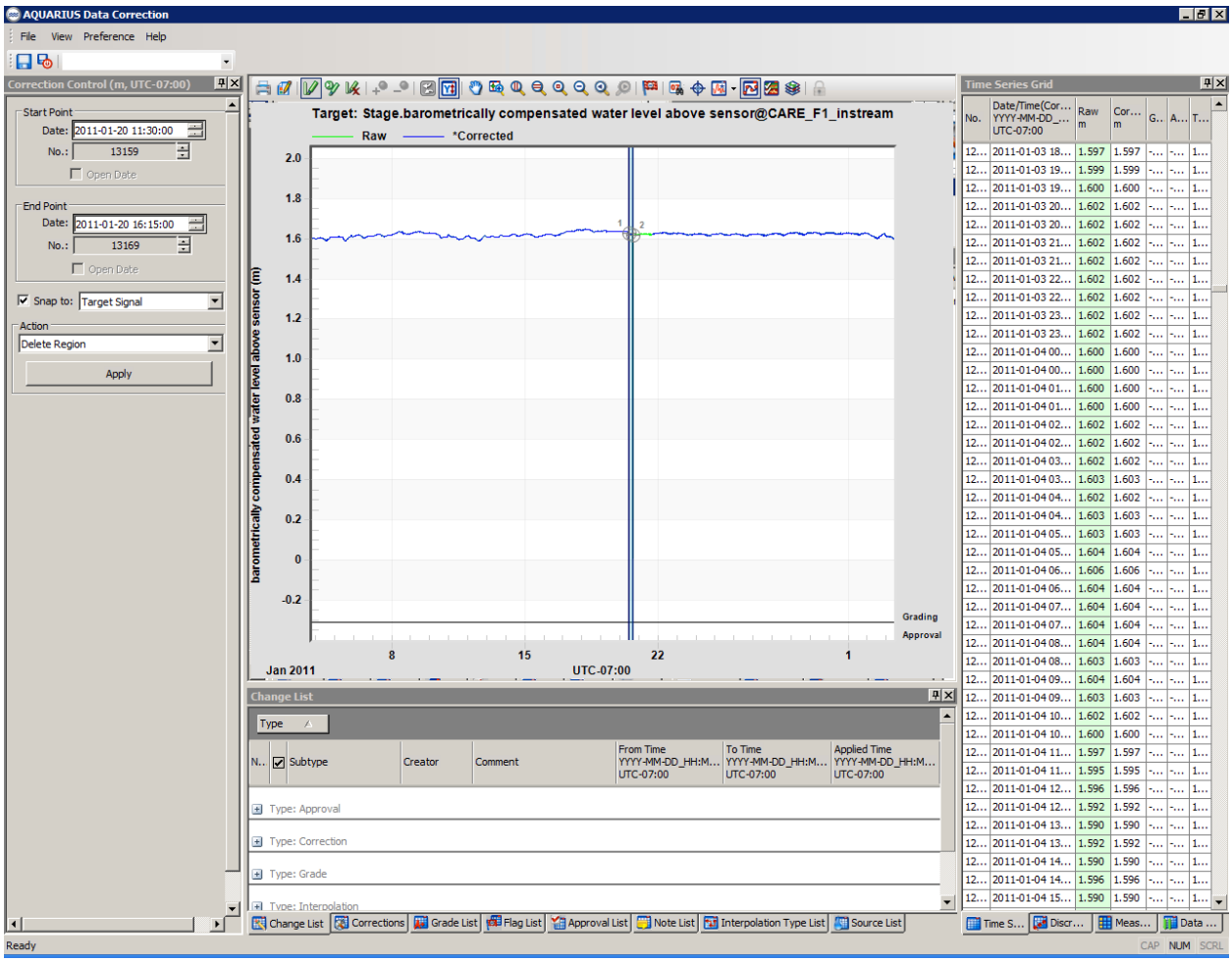


Fig. A-10. Deleting erroneous data in the Data Correction toolbox.

Adjusting for sensor drift or offsets

Compare the levelogger reading at the end of the period with the manually measured depth to water reading from the corresponding field visit. If the difference is 0.5 cm or less, no corrections are applied.

If there is more than 0.5 cm difference between the two measurements, a data correction should be applied. The quality goal for NCPN is to have less than 1.5 cm drift between site visits spaced two months apart. If there is more than 1.5 cm difference between the two measurements on a recurring basis, the logger should be serviced or replaced.

In the Data Correction toolbox, open the logger (DepthtoWaterFromCasingTop.compensated logger) time series as the Target and the field visit time series (DepthtoWaterFromCasingTop. FieldVisit) as the Surrogate. If field visit values are offset from the logger time series, check for possible user errors such as: an offset of one hour due to differences between Daylight Savings and Standard time, an offset of 6 cm due to incorrectly accounting for whether or not the tape guide was used, etc. Other specific corrections include corrections for sediment and ice effects.

Adjusting for sedimentation

If a logger sensor becomes partially or completely covered in sediment, the pressure of the sediment is added to the water pressure, and stage records can be artificially high. If the logger record is higher than the manual measurement, check the field visit information to see if sediment may have affected the record. If so, apply the relevant offset correction back to the peak flood flow since the previous field visit and record "sedimented logger" as a note on the data correction.

Adjusting for ice effects

During particularly cold periods, surface ice may accumulate on streams. When the stream warms, an ice blockage may suddenly break, causing a surge of water down the stream that is unrelated to a precipitation event. Remove the false spike using the Delete Region function, and interpolate a linear line between the stable water depth measurements using the instructions below.

Interpolating missing data

Missing data can occur due to equipment failure, staff turnover, ice, flooding, siltation or other causes. Gaps of less than two hours may be filled using linear interpolation, although caution should be used during flood events. Open the time series of interest in the Data Correction toolbox. Select the gap of interest, and choose “Fill Data Gaps” and “Linear Interpolation.” Apply and save.

Corrections when the cause is unclear

If no user errors are apparent and the data record is smooth with no apparent problematic areas, select the appropriate period of record, and select “Drift Correction”. A drift correction applies a correction incrementally over the selected time period.

Click on the hand icon and select the crosshairs at the end of the selected region. Drag the crosshairs to the manual water level reading data point. Note the calibration drift, and click Apply. When prompted, add a note indicating the

series was adjusted to the manual water level reading and the level of drift, e.g., "adjusted to manual water level reading, drift =- 1.2 cm." Save.

Other data corrections

For corrections based on changes in well elevations or ground surface elevations, see the section on correcting derived datasets below. No other routine data corrections are anticipated at this time. However, should the need for additional data corrections arise, make sure each correction is documented using an explanatory note in Aquarius.

Approving and grading the time series for data summary and analysis

Once the data have been corrected and edited and are ready for use in derived datasets, data summary and analysis, select the appropriate period of record, and select "Set Approval." Select "Approved," and apply it to the time series. For any period of data that has a beginning and ending field visit, a minimal drift correction, and no unexplained noise or jumps, set the Grade to "Good". For any period of data that has a beginning and ending field visit, but has an unusually large offset, unexplained spikes, or some other problem that can be rectified with corrections, set the Grade to "Fair." For any period of data that 1) is missing either a beginning field visit, an ending field visit, or both; or 2) has unexplained spikes or noise that cannot be reasonably corrected, set the Grade to "Poor" or "Unusable". Save and close. Only "Fair" or better graded data should be summarized and used for analyses.

Create Derived Datasets in Aquarius

Derived datasets include calculating water elevation tied to the site's permanent datum and depth from ground surface for riparian well logger data. Statistically derived datasets include daily mean depth to water, stage and discharge.

Calculate derived datasets

1. Select the appropriate location and click on the Location Manager icon. Select the Data Sets tab, and click on the New Time Series icon.
2. For type, select Derived – calculated.
3. Click on the ellipsis to select the time series from which you will derive the calculated time series.
    a. For Stage.Datum, select the DepthtoWaterFromCasingTop.compensated logger time series.
    b. For DepthtoWaterFromGroundSurface.calculated, select the Stage.Datum time series.
4. Create a formula to calculate the new time series:
    a. For Stage.Datum: calculated y = initial datum elevation of top of casing from geomorphic surveys + data x1

Reach	Right well elev (m) – Date	Instream well elev (m) – Date	Left well elev (m) - Date
ARCH C-01	N/A	993.350 – 3/1/2014	995.749 – 3/1/2014
CARE F-01	1580.555 – 3/20/2013	1578.501 – 3/20/2013	1580.603 – 3/20/2013
NABR A-05	N/A	1976.717 – 3/25/2015	N/A
ZION P-03	998.347 – 2/28/2013	996.075 – 2/28/2013	997.962 – 2/28/2013

    b. For DepthtoWaterFromGroundSurface.calculated: calculated y = -(initial datum elevation of ground surface from geomorphic surveys – data x1)

Reach	GS at right well (m) - Date	GS at left well (m) - Date
ARCH C-01	N/A	995.592 – 3/1/2014

CARE F-01	1580.244 – 11/14/2009	1580.471 – 11/14/2009
ZION P-03	997.450 – 10/27/2011	997.606 – 10/27/2011

c. Make sure all units in the formula are the same. To convert from an input in centimeters to an output of meters, write the formula so that all units are in cm. Set the dataset units to m.
d. Add a label: "Datum" for elevation referenced to the datum or "calculated" for depth to water. Select the appropriate Time Zone (UTC-07:00), Parameter (Stage or Depth to water from ground) and units (cm). Choose a Gap Tolerance of the sampling interval plus one (e.g., "16" for a 15-minute sampling interval).

5. Click Save and Exit. A new derived time series will appear in the dataset list. Visually inspect the dataset using the Quick View toolbox. After a derived time series is created, the derived dataset is updated each time data are appended to the original time series or the original time series is edited or corrected.

Daily means

1. Select the appropriate location and click on the Location Manager icon. Select the Data Sets tab, and click on click on the New Time Series icon.
2. For type, select Derived – Statistical.
3. Choose the parameter (Stage, Depth to water from ground or Discharge) and the appropriate units.
4. Click on the ellipsis to select the time series from which you will derive the daily mean time series, the 15-minute depth to water or discharge data.
5. Select Aggregate and Daily, and click OK.
6. Add a label "Dailies." Choose a Gap Tolerance of 1440 (number of minutes per day).
7. Click Save and Exit. A new derived time series will appear in the dataset list. Visually inspect the dataset using the Quick View toolbox. After a derived time series is created, the derived dataset is updated each time data are appended to the original time series or the original time series is edited or corrected.

Derived dataset corrections

Changes in well elevations

Occasionally, the top of well casing elevations may change due to flood damage, the need to deepen a well to capture extreme drought, or for other reasons. If the well casing elevation changes by more than 0.01m, an offset should be applied. In the Data Correction toolbox, open the Stage.Datum time series. Select the period affected by the change and select "Offset Correction". An offset correction applies the correction immediately and for the entire period selected, rather than incrementally. Enter the offset needed, and click Apply. When prompted, add a note indicating the well elevation changed and the level of offset, e.g., "well deepened, offset = 58 cm." Save.

Offsets to the DepthtoWaterFromGroundSurface time series should be applied if the ground surface elevation has changed more than .05 m (5 cm) based on field measurements of top of casing to the ground surface and/or geomorphic survey data. If a flood event has caused significant change, apply the new ground surface elevation as an offset correction at the flood peak. If there is no associated flood event, a drift correction can be applied between field visits.

1. Open the derived dataset using the Data Correction toolbox. Select the region to which the correction needs to be applied.
    a. If you want to apply an open-ended correction (i.e., a change that should be applied to data added to the time series in the future), check the Open box under End Date.
2. Select Offset Correction, and enter the correction that needs to be applied. You will see a preview of a corrected time series shifted to your offset. If you are satisfied with the correction, click Apply.
3. Add a note indicating the reason for and magnitude of the offset correction, e.g., "Flood reshaped groundsurface; resurvey indicates surface is +0.22m higher than earlier survey." Click save.

Create a Rating Curve in Aquarius

Once the instantaneous (15-minute) water stage data have been corrected, additional steps are needed to convert water stage data to discharge. These steps include the establishment or maintenance of the stage-discharge relationship (rating curve), and finally, computation of 15-minute and mean daily discharges. The development of the rating is one of the principal tasks in computing discharge records. Due to predominate low flows, no stable section control, and a very dynamic channel geometry it would be extremely difficult to create an accurate stage-discharge relationship at ARCH C-01. Stage-discharge relationships may be created for CARE and ZION.

A rating curve or stage-discharge relationship is developed from numerous stage and discharge measurement computations made at the site over a range in flows by plotting stage versus discharge in the Rating Development toolbox. The more points, the more precise the rating curve is likely to be. A minimum of 10 sampling events over a range of flow levels is recommended initially. However, the rating curve will shift over time, and periodic measurements are necessary throughout operation to either confirm the permanence of the rating or to apply changes/shifts in the rating. In order to be most accurate, it is important that the rating curve include measurements made at flow extremes, under both high flow and extreme low flow conditions. Because of the flashy nature of NCPN streams, it is unlikely NCPN will be able to sample high flow events for safety and access reasons. Extrapolating values for discharge outside of the range of actual stage/discharge measurements can introduce error. Because of the log relationship between stage and discharge, small errors in the rating curve can result in large errors in discharge calculations. NCPN may require expert assistance when first developing rating curves for each site.

Open the Location Manager toolbox for the appropriate instream well, select the Data Sets tab, and click on the New Rating Curve icon. Label "rating curve". Specify the Input Parameter as Stage (cm) and the Output Parameter as discharge (m^3s). Click Save and Exit. Aquarius automatically populates the rating curve with the manual stage and discharge measurements taken during field visits.

Go to Data Sets. Select the rating curve and stage time series, then open the Rating Development toolbox.

Select the points to use to develop the rating curve; for example, measurements taken during the period of record, measurements at stages that fall into the same type of control, etc.

In log-log space (Rating Zoom 1 view), use the Offset Manager tool to create Offset 1, single plotting offset. Enter offsets until the selected points begin to create a straight line in log-log space. To better visualize departures from linearity, add rating points between the lowest and highest selected points. Consult the Shift Diagram. For a good offset, the rating curve line will cross the error bars of all points. Look at the Rating Table, and check that the slope is between about 1.3 and 2.8.

Create additional offsets for stages with different control, geomorphic breaks, etc. When adding additional offsets, one of the rating points must be defined as the breakpoint.
It is highly unlikely that NCPN will have measured stage and discharge values for high flow events. Extrapolation of the rating curve is acceptable up to 2x the highest measured discharge value OR up to a stage that corresponds to a different channel geometry (e.g., when flow overtops the channel and moves onto the floodplain). To extrapolate the rating curve, use the Extend Rating in a Straight Line icon.

Open the Rating Period Measure and choose the period of record for which the rating curve applies.

Temporary shifts to the rating curve
Temporary shifts to the rating curve often apply during periods of scour (rising hydrograph) and deposition (falling hydrograph). Stage/discharge measurements from these periods may not align well with an established rating curve. In such cases, the Shift Manager can be used to shift the curve away from the underlying curve temporarily. Select the applicable points, and in Shift Diagram select Move Shift Point. In Shift Diagram, drag the rating curve to the applicable points. Set the start date and end date to which to apply the shift in the Shift Manager toolbox, and fine tune dates using Adjust Date in the Time Series View.

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 11

After each Field Visit

Version 1.03 (September 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	6/9/11	R. Weissinger	Added more detailed decontamination instructions	Clarification	1.01
1.01	12/2012	K. Lund, D. Witwicki	Minor word edits, revised wording/format of decontamination procedure	Response to protocol review	1.02
1.02	9/2016	D. Witwicki	Minor updates to match current procedures		1.03

This SOP lists procedures performed at the end of each field visit, including equipment maintenance, data management tasks, trip reports, and decontamination procedures.

Procedures

1. Follow check-out procedures with Glen Canyon dispatch detailed in the NCPN Field Safety SOP.

2. Make sure that all cameras, lasers, satellite phones, and GPS units are returned to the office as well as the total station, data logger, water level meter, and/or PDA, if used.

3. Complete data entry and verification (see SOP #13). Resolve any questions with the crew members who collected the data.

4. Organize and file data sheets.

5. Download photos into appropriate folders within X:\Archive\NCPN Photos\Incoming\Monitoring\Riparian. Organize by year, park code, reach name, and transects.

6. Charge camera, satellite phone, and vehicle jump starter batteries. Also charge batteries for the total station, data logger, PDA, and field laptop if these electronics were used.

7. Return GPS units to the GIS technician for downloading and charging.

8. Report all broken or missing equipment to the field crew coordinator. Repair equipment if possible or indicate if new equipment needs to be purchased before the next field hitch. Clean stoves and any other equipment that is dirty.

9. Remove plant collections from the press or cooler, and store them in a secure location where they will not be damaged. If possible, identify any remaining unknown plants within a day or two of returning to the office. Annotate data sheets with species information once plants have been identified.

10. Download data from total station surveys (see SOP #9) or hydrologic monitoring (see SOP #10) and perform any post-processing.

11. The crew leader should complete a trip report detailing the dates of field work, crew members participating, work completed, travel and housing availability, safety concerns and how they were accommodated, weather conditions, any equipment problems or needs, and any other pertinent information. Also note any interesting or unusual findings, observations of disturbance, human or animal activity, deviations from the SOP, or access issues.

12. Organize monitoring boxes for the next hitch.

13. Clean the insides of vehicles. Especially dirty or muddy vehicles may be washed as often as monthly when needed. Report vehicle repair needs to the field crew coordinator.

14. Decontaminate all equipment, personal items, and clothing that have come into contact with water or mud to minimize the potential for spreading of exotic aquatic invasive species between streams.

    A. **Remove all mud and debris using a scrub brush.**

    B. **Make a 5% cleaning solution of quaternary ammonium compound.** This is a common cleaning agent used in homes, swimming pools, and hospitals that is safe for gear and equipment when used at the recommended concentration. Two brands are readily available from GSA or local suppliers: *Quat128*® (by Waxie) or *Sparquat 256*® (by Spartan). Use one of these products and the appropriate amount of tap water to make the 5% cleaning solution (Table 1). Cost and effectiveness of the two brands are comparable.

    Safety

    - Use protective, unlined rubber gloves and splash goggles or a face shield when handling the cleaning solution. Take extra precautions when handling undiluted chemicals. Have an eye wash and clean water available to treat accidental exposure.

- Consult the product label and Material Safety Data Sheet for additional information before working with these products.

Table 1. Recipe for 5% cleaning solution using either *Quat128®* ***or*** *Sparquat 256®*

Volume of tap water	Volume of *Quat128®*	Volume of *Sparquat 256®*
100 mL water	4.63 mL	3.00 mL
1 gallon water	6.35 liquid oz.	4.12 liquid oz.
1 gallon water	12.7 tbsp	8.2 tbsp
1 gallon water	0.79 cups	0.51 cups
100 gallons water	4.96 gallons	3.22 gallons
1000 gallons water	49.6 gallons	32.2 gallons

C. **Test the cleaning solution before each use**. If the concentration is too weak, adjust the concentration or dispose of the used solution properly and make a new solution.

- To determine if the solution is below 5% strength use "Quat Chek 1000" Test Papers (purchase these from the supplier of the cleaning compound). The used cleaning solution needs to be diluted to about 600 parts per million (ppm) of ammonium compounds before it can be tested with these papers.
  - Take **one** cup of 5% cleaning solution made from *Sparquat 256®*, and pour it into a bucket. Add **5** cups of water and mix. **OR**
  - Take **one** cup of 5% cleaning solution made from *Quat128®*, pour it into a bucket. Add **4** cups of water and mix.
- Test the diluted solution with "Quat Chek" Test Paper. Match the color of the paper with the ppm's on the color chart. For optimal disinfection, the diluted solution should have a concentration between 600 and 800 ppm. **Do not use the diluted solution for decontamination.**

D. **Decontaminate sampling equipment**. Place the 5% cleaning solution in a backpack spray pump, and use this to apply the solution to equipment. The solution must be in contact with the surface being sanitized for at least 10 minutes.

E. **Rinse sanitized equipment with water.** When feasible, allow to dry completely before entering another body of water.

F. **Dispose of used cleaning solution properly.** Disposal of used cleaning solution must be in compliance with all local, state, and federal regulations. Do not dump cleaning solution into any stream or lake, or on areas where it can migrate into any storm drain, body of water, or sensitive habitat.

G. **Store unopened *Sparquat 256*® and *Quat128*® in a cool, dry place, out of direct sunlight.** These products will keep for up to two years at temperatures ranging from 32º to 110º F without losing effectiveness.

15. Fill out and submit any necessary administrative paperwork (i.e., travel vouchers, timesheets, extra work authorizations, leave requests).

16. Tidy the conference room before leaving for multiple days off.

Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 12

After the Field Season

Version 1.02 (September 2016)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	12/2012	K. Lund, D. Witwicki	Clarification to wording	Response to protocol review	1.01
1.01	9/2016	D. Witwicki	Minor updates to match current procedures		1.02

This SOP lists procedures performed at the end of the field season, including equipment maintenance, data management tasks, and assessment of monitoring and safety protocols.

Procedures

1. Equipment maintenance. Inspect all equipment for damage and note any missing equipment. Clean and repair all equipment.

2. Equipment inventory. Ensure that adequate supplies are on hand for the next field season and create a list of supplies that need to be ordered.

3. Complete identification of unknown plants. The field crew leader is responsible for ensuring complete resolution of all unknown plants. Plants are identified to species, family, or at least life form. Annotate the data sheets with the correct identifications and ensure that species are entered correctly in the database.

4. New species follow-up. The field crew leader is responsible for ensuring that plant species not on current park lists are submitted to the data manager for NPSpecies updates. The field crew leader is also responsible for mounting, labeling, and preparing voucher specimens for any new species collected in a park unit. Update park plant species lists and the species list in the database.

5. Field herbaria. The field crew leader mounts and labels appropriate specimens for the field herbarium.

6. Data management. The field crew leader is responsible for ensuring that all data sheets are completed properly (see SOP #13).

7. Data entry. The field crew leader is responsible for ensuring that all data are entered and verified according to procedures outlined in SOP #13. Also make sure all photographs are downloaded to the X:\ drive and correctly labeled and oriented.

8. Field season review procedures. Prior to the departure of the field crew, the crew leader has each crew member complete an end-of-season evaluation detailing issues with existing monitoring protocols, field logistics, and safety procedures and recommendations for improvements. These issues are discussed with all relevant NCPN staff, and the appropriate changes to monitoring and safety protocols are implemented.

9. Logistics. The field crew leader updates internal access documents for each park with new and updated access and logistical information, such as road closures, park personnel turnover, etc.

Riparian Monitoring of Wadeable Streams Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 13

Data Management

Version 1.05 (August 2016)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	11/2011	H. Thomas	Modified instructions for correcting field sheets	To clarify procedures	1.00
1.00	1/2012	H. Thomas	Updates due to protocol changes in 2011	To document database and data management procedure changes related to protocol changes made in 2011	1.01
1.01	11/2012	H. Thomas	Updates due to protocol changes in 2012	To document database changes related to protocol changes made in 2012	1.02
1.02	8/2013	H. Thomas	Added new section (Overview of Riparian Data Management) and made other minor edits throughout.	To expand upon the management of hydrology and geomorphology data, and to document database changes related to protocol changes made in 2013	1.03
1.03	4/2015	H. Thomas	Updated appendix A	To reflect database modifications for 2014 field season	1.04
1.04	8/2016	H. Thomas	Made minor edits throughout the document	To reflect current data management practices	1.05

This Standard Operating Procedure (SOP) describes data management procedures for all data derived from riparian monitoring in Northern Colorado Plateau Network (NCPN) park units. The procedures for data management given in this SOP follow guidelines and standards that are described in the NCPN Data Management Plan (Beer et al 2005).

Definitions and Acronyms

FGDC	Federal Geographic Data Committee. The interagency committee that promotes the coordinated development, use, sharing, and dissemination of geographic data.
GIS	Geographic Information Systems

GPS	Global Positioning System
I&M	Inventory & Monitoring Program of the National Park Service
NCPN	Northern Colorado Plateau Network
NPS	National Park Service
PDF	Portable Document Format
PDLC	Project Data Life Cycle
SOP	Standard Operating Procedure
Accepted data	Data that have undergone all QA and QC procedures as defined in the published protocol and associated SOPs.
Data products	Information that is derived from accepted project data.
Data Store	The NPS-wide repository for documents, publications, and datasets related to NPS natural and cultural resources (https://irma.nps.gov/DataStore).
Master database	Project-specific database that stores the full project dataset and is used for viewing, summarizing, and analysis. Contains only accepted data.
Primary dataset	The dataset that is the most comprehensive and representative of the data associated with a project. This dataset can normally be used independently of other project datasets and is often distributed to external users. The primary dataset can be tabular or spatial. For most NCPN monitoring projects, the primary dataset will be either a Microsoft (MS) Access database or a geodatabase.
Project level metadata	A metadata record associated with the primary project dataset that contains cross references to all project data products and is uploaded to the Data Store.
Quality assurance (QA) procedures	Procedures used to ensure collection of data with minimal errors.
Quality control (QC) procedures	Procedures used to flag or modify data to ensure that data meet established data quality standards.
Raw data	Data that have not been subjected to either quality control or documentation procedures; includes data recorded by hand on hard-copy forms, digital files from handheld devices, GPS receivers, telemetry data loggers, etc.
Spatial dataset	A dataset that is natively read by mapping software; often produced by mapping software, such as ESRI ArcMap and ArcInfo; also includes georeferenced imagery, geodatabases, as well as hardcopy aerial photographs, satellite imagery and maps.
Tabular dataset	A dataset organized in a table or group of tables where each column and row has a specific interpretation; often produced by MS Excel, MS Access, database, or statistical software, and managed as text, spreadsheet, or relational databases.
Working database	A project-specific database for entering and processing data for the current season (or other logical period of time).

1 Overview of Riparian Data Management

There are three main types of riparian monitoring data that are collected and managed: vegetation, hydrology, and geomorphology data. Vegetation data are mostly recorded on paper data sheets and then entered into a Microsoft Access database. Since this database was developed by the NCPN, it is described in more detail in Section 2. Many of the other sections in this document are focused on vegetation data management.

Hydrology data are recorded digitally using data loggers and electronic data sheets, and then uploaded to the Aquarius system hosted by the NPS Water Resources Division. Aquarius is commercial software for managing time series data. Most processing and analysis of the hydrology data is done within Aquarius. Copies of raw digital data files and derived datasets generated in Aquarius are stored on the NCPN server. For more details on hydrologic data processing, refer to SOP #10.

Geomorphology data are recorded digitally using a total station and then uploaded to the NCPN file server. The raw data files, post-processed data files, and metadata describing all post-processing are stored on the server. For more details on geomorphology data processing, refer to SOP #9.

2 Database Design

The primary dataset associated with the NCPN riparian monitoring project is a tabular dataset stored in a Microsoft (MS) Access database, referred to subsequently as the riparian database. The riparian database accommodates only the vegetation methods used in riparian monitoring. It is compatible with Access 2007 and 2010, and has a frontend/backend file structure:

- *Riparian.accdb*: This frontend file contains all queries, forms, reports, and associated Visual Basic for Applications (VBA) application code.
- *Riparian_be.accdb*: This backend file contains the database tables.

The frontend/backend file structure allows multiple users to enter data in a network environment, and allows for easy backup and transfer of the data tables. Users typically launch the frontend file, and a utility will prompt them to establish a link to the backend file.

The riparian database was developed following the NPS Natural Resource Database Template (NRDT), which is based on a location record, one or more related event

records, and observation data elements linked to each event.

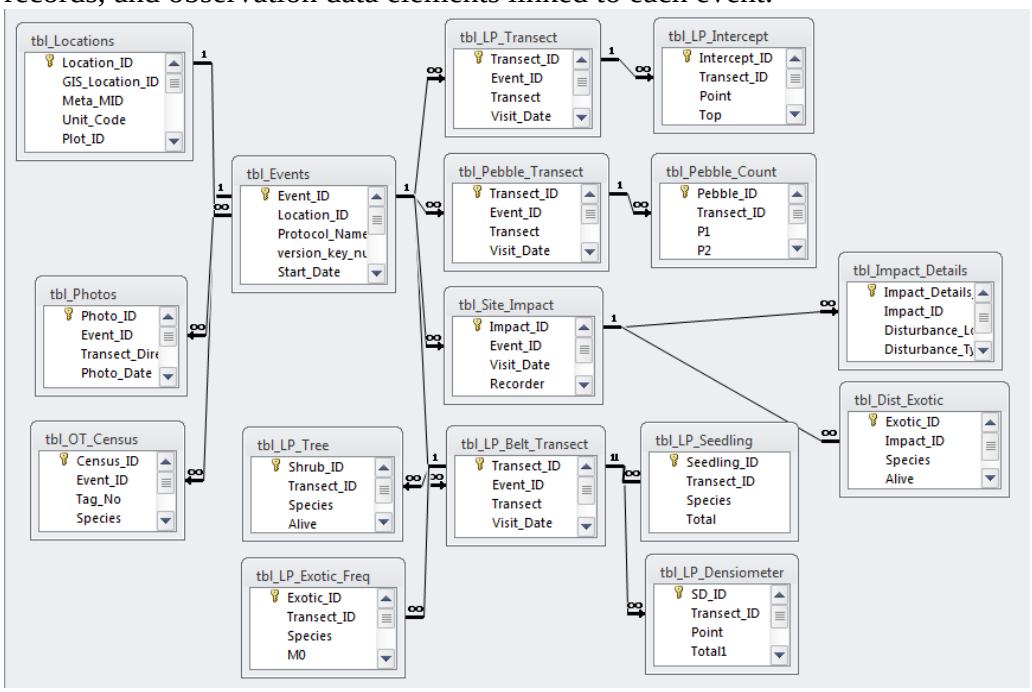


Figure 1 shows the relationships between the primary riparian database tables (all tables are not shown).

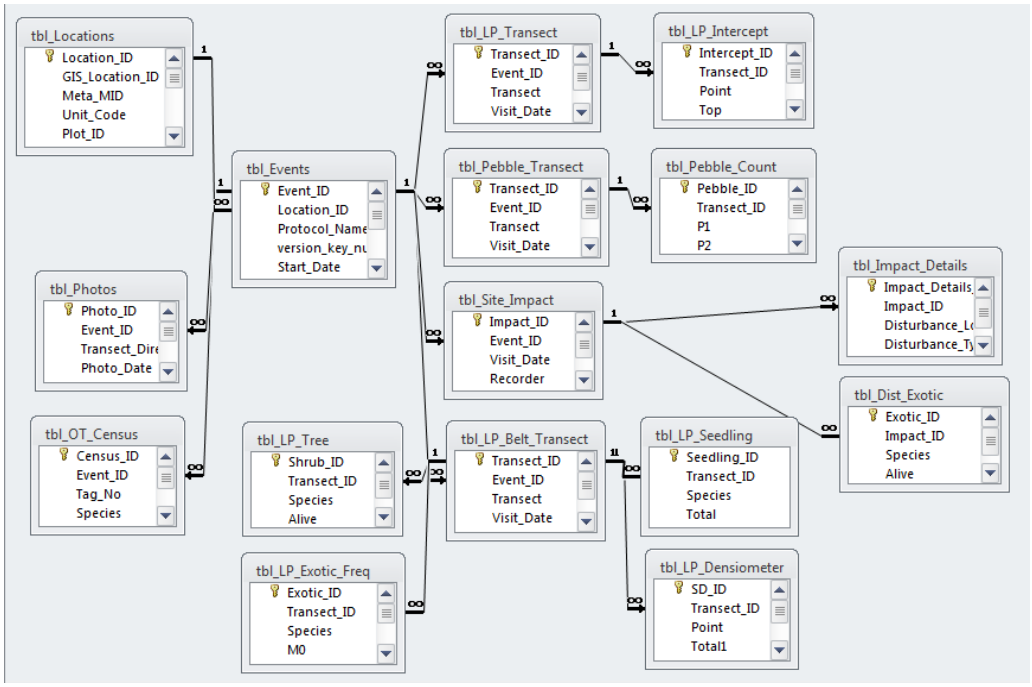


Figure 1. Data Model for Riparian Database

Each riparian monitoring site or reach has a record in *tbl_Locations*, which stores basic location information as well as other site characteristics that are recorded during reach establishment. Each reach can have many site visits, which are recorded in *tbl_Events*. During each site visit, several different types of observations are recorded. The main types of observations recorded are described briefly below:

- Understory species, surface features, and disturbance are recorded using point-intercept sampling for each of seven cross-section transects and stored in *tbl_LP_Transect* and *tbl_LP_Intercept*.
- Density of trees and tree seedlings is measured in a 5-meter belt transect for each of seven cross-section transects and recorded in tables *tbl_LP_Belt_Transect*, *tbl_LP_Tree*, and *tbl_LP_Seedling*.
- Estimates of canopy closure are recorded for each of seven cross-section transects in *tbl_LP_Densiometer*.
- Exotic species frequency is sampled in quadrats placed at regular intervals along each of seven cross-section transects and is recorded in table *tbl_LP_Exotic_Freq*.
- A pebble count is conducted at each of seven cross-section transects and recorded in *tbl_Pebble_Transect* and *tbl_Pebble_Count*.
- Transect and transect establishment photos are taken for each of seven cross-section transects and recorded in *tbl_Photos*.
- A reach census is conducted and recorded in *tbl_OT_Census*.
- Qualitative descriptions of reach disturbances are recorded in *tbl_Site_Impact* and *tbl_Impact_Details*. Exotic plant species observed during a timed plant walk are recorded in tables *tbl_Site_Impact* and *tbl_Dist_Exotic.*

Each site visit is linked to tables *tbl_master_version* and *tbl_SOP_version*, which together define the narrative and suite of SOP versions in effect at the time of the site visit. Documentation of all tables and fields in the riparian database is provided in Appendix A.

3 Populating the Riparian Database

Prior to each field season, the working database for the riparian monitoring protocol is prepared for the upcoming field season's data entry. The working database is initially an "empty" database, i.e., it contains no observation data, just populated lookup tables and certain "static" site information (e.g., location information). The working database is used for data entry, verification, and validation for a given field season. After the dataset in the working database is quality checked, it is merged into the master riparian database.

For the remainder of this document, the term "riparian database" refers to the working database. The riparian database will be populated via a combination of data import and data entry.

3.1 Data Import

Records for riparian monitoring sites can be established in the database either manually or by importing site location data collected via GPS units. It is expected that most site

records will be created manually during data entry. In such cases, the site record will subsequently be updated with the corrected GPS data. Table 1 lists the fields either imported or derived from GPS data (see Appendix A for field descriptions). Elevation will not be imported directly from the GPS data, but rather will be derived from digital elevation models. Note that the fields "T1_RLocation, T1_LLocation, …, T7_RLocation, T7_LLocation" represent the headpin locations (right and left) for the seven transects, "T1_RN, T1_RE, T1_LN, T1_LE, …, T7_RN, T7_RE, T7_LN, T7_LE" represent the headpin UTM coordinates (right and left) for the seven transects, and "T1_REndN, T1_REndE, T1_LEndN, T1_LEndE,…, T7_REndN, T7_REndE, T7_LEndN, T7_LEndE" represent the UTM coordinates (right and left) for the seven transect end points.

Table 1. Fields Imported/Derived from GPS Data into tbl_Locations

Elevation	Max_PDOP	T1_RN	T1_REndN
E_Coord	T1_RLocation	T1_RE	T1_REndE
N_Coord	T1_LLocation…	T1_LN	T1_LEndN
Coord_Units	T7_RLocation	T1_LE…	T1_LEndE…
Coord_System	T7_LLocation	T7_RN	T7_REndN
Datum		T7_RE	T7_REndE
UTM_Zone		T7_LN	T7_LEndN
Rcvr_Type		T7_LE	T7_LEndE

Site location data are expected to be relatively static over time. Thus, GPS data will normally only be imported when a reach is initially established. If the location information for a given site changes for some reason (e.g., a rebar gets lost and it's not possible to establish the new rebar at the same location), it will need to be re-imported from the GPS files. When imported, reach location data will be imported from corrected GPS files into *tbl_Locations*.

3.2 Data Entry

The majority of data in the riparian database will be populated via data entry. Data entry should occur as soon as possible after data collection is completed, before the next observation occurs, and by the person who collected the data or someone who is familiar with the project and data. The primary goal of data entry is *to record data in digital form with 100% accuracy.*

Detailed data entry instructions are provided in the Riparian Database User's Guide (NCPN-NPS 2015a). The user's guide is available as a standalone document in the same folder location as the working copy of the riparian database:

X:\Active_Monitoring_Projects\Riparian\Data\Database\Current

The project manager makes certain that persons performing data entry are familiar with the user's guide and understand how to enter data and follow the protocols. Data entry technicians are responsible for becoming familiar with the field data forms, database software, database structure, and any standard codes for data entry. The data manager, in

conjunction with the project manager, will ensure that the user's guide is kept current as new features are implemented in the database and/or as data entry procedures change.

QA/QC measures for data entry are built into the database forms to automatically validate data where possible. Data entry forms maximize the use of auto-filled fields, range limits, pick lists, and spelling checks. Error messages alert the operator to correct mistakes. Any errors or omissions that become apparent during data entry should be resolved as soon as possible. In such cases, the data entry technician should contact the person who collected the data for clarification. The appropriate modifications should then be made to the field sheets according to the instructions provided in Section 4.

4 Data Verification and Validation

To ensure that riparian monitoring data are of the highest possible quality, verification and validation of riparian monitoring data will be performed according to the procedures described in the NCPN Quality Assurance and Quality Control Guidance Document (NCPN-NPS 2008a). *Data verification* checks that data entered into a secondary (i.e., electronic) format match the source data, while *data validation* checks that the data make sense.

4.1 Data Verification

Data verification immediately follows data entry and involves checking the accuracy and completeness of the computerized records against the hard copy field records and identifying and correcting any errors. The following verification methods will be used to verify riparian data:

1. **Visual review at data entry**. The person doing data entry verifies each and every record after input and immediately corrects any errors.
2. **Visual review after data entry**. All records are compared to the original data source. Each data field on the corresponding electronic data entry form is compared with the original values from the hard copy, preferably by a second person who did not perform the data entry. Any errors that are discovered are corrected in the database as soon after data entry as possible.
3. **Summary queries and tallies**. Queries are run that detect broad errors such as duplicate or omitted records. Examples of such queries for riparian vegetation data are given below:
    a. Listing and count of the monitoring reaches established by park by year.
    b. Listing and count of the monitoring reaches visited by park by year.
    c. For each year/park/reach combination, a count of the number of photo points recorded.
4. **Visual review of spatial data**. Using GIS, riparian monitoring location data are visually inspected for accuracy. This review will take place at the end of the field season.

Detailed verification procedures are provided in Riparian Database Quality Assurance (QA)/Quality Control (QC) Procedures) (NCPN-NPS 2015b).

4.2 Data Validation

While many errors are prevented by including validation routines that function during data entry, additional review of the data by the project manager is needed to detect generic and specific errors that fall outside the scope of automated validation.

Invalid data commonly consist of slightly misspelled names, the wrong date, or out-of-range errors in parameters with well-defined limits (e.g., elevation). Other errors consist of unreasonable metrics or associations. For example, suppose a species was dominant on a reach during the current year's visit, but there was no observation recorded during the previous year's visit. Such data seem questionable and might indicate a species identification error. These types of logic errors (or potential errors) can be challenging to resolve, and in some cases it may not be possible to resolve them during the current year. Such questionable data will be flagged for future resolution.

Validation queries are of two types: one type presents tabular data in ways that allow records to be reviewed for content and context; the other type performs specific calculations or routines to detect logic or range errors. Corrections to errors detected during validation require notations in the *original paper field records* about how and why the data were changed. Modifications to the field records, whether made during data collection or subsequently, should be clear and concise while preserving the original data entries or notes. The original data entries should be crossed out with a single line and initialed - they should ***not*** be erased. Validation efforts should also include a check for the completeness of a dataset since field sheets or other sources of data could easily be overlooked.

Detailed validation procedures are provided in Riparian Database Quality Assurance (QA)/Quality Control (QC) Procedures (NCPN-NPS 2015b).

4.3 Data Quality Review and Communication

The project manager and any personnel involved in data collection or entry will meet several times during the field season to discuss data quality problems and issues. Procedures may need revision if verification and validation processes reveal an unacceptable level of data quality. Quality checks may also reveal the need to modify field or computer forms if data transcription or entry errors are frequent.

Once validation has been completed, metadata will be created for the riparian datasets. An important part of this metadata is data quality documentation, which consists of the verification and validation results. This data quality documentation, along with the data quality assessment form, will be used to notify end users and other project personnel of project data quality. For example, any questionable data that have been flagged will be identified. The data quality assessment form will be completed by the project manager to indicate that the data have undergone all QA/QC procedures and are documented and ready for archiving, posting, and distribution. The data quality assessment form can be

found in the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a). The data quality documentation and assessment form will be stored in the riparian project archive folder.

5 Version Control

Version control is the process of managing copies of changing files over the course of a project. Change includes any alteration to the structure or content of the files, which should not be made without the ability to fully recover a dataset as it existed before changes were made. NCPN uses several techniques to help ensure proper version control: data archiving (refer to Section 6 for data archiving details), directory structure conventions, backup procedures (refer to the user's guide (NCPN-NPS 2015a)), and database versioning.

5.1 Directory Structure Conventions

NCPN has adopted directory structure conventions for I&M project folders (NCPN-NPS 2007b). Based on these conventions, each project has an active folder for storing all current or working project files and an archive folder for storing archived project files. In general, the active project folder stores only the most recent project files (e.g., data and reports from current year, current protocol version). All active project folders are stored on the NCPN shared drive (X:). The active riparian project folder is in the following location:

X:\Active_Monitoring_Projects\Riparian

The structure of the active project folder is as follows (all folders are not shown):

- **Data**:
  - **Database:** Contains the working and master databases.
  - **Field_Forms**: Contains scanned field forms for current year.
  - **Geomorphology**: Contains geomorphology data files.
  - **GPS_Downloads**: Contains corrected GPS data for current year.
  - **Hydrology**: Contains hydrology data files.
  - **Reach_Summary_Data**: Contains reach data summaries.
- **Field_Crews**: Contains files used by field crews, such as plant lists and trip reports.
- **NCPN_Working_Files**: Contains miscellaneous files used internally, such as database requirements documentation.
- **Project_Life_Cycle**: Contains files related to project data life cycle tracking for current year, e.g., data quality assessment form, data quality documentation.
- **Protocol**:
  - **Native_Format**: Contains source files for current version of protocol.
  - **PDF**: Contains PDF of current version of protocol.
- **Protocol_Review**: Contains current documents associated with protocol reviews.
- **Reports**:
  - **Native_Format**: Contains source files used to create current year reports.
  - **PDF**: Contains PDF version of current annual project reports and any other reports produced during current year.

- **Sampling_Design**: Contains files related to sampling design.

For additional details on NCPN directory structure conventions, refer to the NCPN Directory Structure Guidance Document (NCPN-NPS 2007b).

5.2 Database Versioning

Database versioning refers to the process of tracking modifications to the database structure or application code, which can occur independently of modifications to the data. NCPN uses a version numbering scheme to track database modifications, in which modifications are grouped into software releases. Major releases are those involving significant changes to the database and are designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). For releases with only minor database changes (e.g., bug fixes), version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02, etc). Database version information is maintained within the database, and can be viewed by choosing the **About** tab on the riparian main menu page, and then choosing **View release history**. Whenever a database version change occurs, copies of the database files are placed in the appropriate archive location (refer to Section 6).

6 Data Archiving

Archiving is a critical step in ensuring the long-term preservation of data. Riparian data will be archived on an annual basis, after the current year data have been quality checked and analysis and reporting have been completed. Archiving of certain data may occur more frequently, e.g., if a protocol version change occurs. Archiving will be done for both digital and hard copy data.

6.1 Digital Data Archiving

All digital riparian data will be archived on the NCPN read-only shared drive (R:) in the riparian archive folder (R:\Monitoring_Archive\Riparian). Table 2 lists the riparian monitoring digital data files that require archiving, along with their respective archive folder locations. The digital files listed in Table 2 will also be burned onto an archival-standard CD or DVD and sent to the Western Archeological and Conservation Center (WACC) according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN-NPS 2010). WACC is the official archival repository for all NCPN data. This facility provides temperature and humidity-controlled storage conditions and a professional archives staff, and it meets all NPS museum standards.

Table 2. Riparian Digital Data Archiving Summary

Data Product(s)/ File(s)	Archive Location[1]	Comments
Database	Data\<*year*[2]>\Database\	• Contains archived riparian database files for a given year
Geomorph-	Data\<*year*>\Geomorphology\	• Contains archived geomorphology data

[1] Archive location is relative to R:\Monitoring_Archive\Riparian unless stated otherwise.
[2] <*year*> indicates year in yyyy format.

Data Product(s)/ File(s)	Archive Location[1]	Comments
ology		files for a given year
Hydrology	Data\<*year*>\Hydrology\	• Contains archived hydrology data files for a given year
Field forms	Data\<*year*>\Field_Forms\	• Contains archived digital field forms (PDF) for a given year
GPS data	Data\<*year*>\GIS_Data\ GPS_Data\	• Contains archived GPS data files for a given year
Field crew files	Field_Crews\<*year*>\	• Contains archived field crew files for a given year
Project data life cycle files	Project_Life_Cycle\<*year*>\	• Contains archived files related to project data life cycle tracking for a given year
Protocol	Protocol\<*version*[3]>\	• Contains archived protocol files for a given version
Protocol review	Protocol_Review\<*year*>\	• Contains archived protocol review documents for a given year
Reports	Reports\<*year*>\	• Contains archived report files for a given year
Sampling design files	Sampling_Design\<*year*>\	• Contains archived files related to sampling design for a given year
Photos	R:\NCPN_Photos_Archive\ NCPN Photos\ Riparian	• Archive location is an absolute path • Renamed photo files archived as part of NCPN photo database processing - refer to NCPN Photo Management Guidance Document (NCPN-NPS 2008b) for details
Original photos	R:\NCPN_Photos_Archive\ Raw_Photo_Data_Archive\ Monitoring\Riparian\<*year*>	• Archive location is an absolute path • Contains original, unedited (e.g., not rotated) photo files

6.2 Hard Copy Data Archiving

All hard copy riparian data will be archived at WACC according to the procedures outlined in the NCPN Archiving Guidance Document (NCPN-NPS 2010). Table 3 lists the riparian monitoring hard copy data files that require archiving, along with a summary of archiving procedures.

Table 3. Riparian Hard Copy Data Archiving Summary

Data Product(s)/File(s)	Comments
Field forms	• Original field forms stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Reports	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.
Protocol	• Archival copies stored in NCPN archives at WACC. • Hard copies retained in NCPN office.

[3] <*version*> indicates protocol version key number, e.g., Version_Key_1

Data Product(s)/File(s)	Comments
Protocol review	• Archival copies stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Photos	• Slides or selected prints stored in NCPN archives at WACC. • Digital copies retained in NCPN office.
Data/metadata Printouts	• Archival copies of project-level metadata stored in NCPN archives at WACC. • Hard copies retained in NCPN office. • Above applies to any other data/metadata printouts deemed critical to long-term riparian monitoring.
Project data life cycle files	• Archival copies stored in NCPN archives at WACC. • Digital copies retained in NCPN office.

7 Metadata

Metadata, which is defined as structured information about the content, quality, condition, and other characteristics of data, is a critical step toward ensuring that datasets are usable for their intended purposes well into the future. Metadata can take many different forms, including formal FGDC-compliant metadata, Data Store References, and protocol version information.

To comply with NPS metadata requirements, metadata for riparian datasets will be created following NCPN metadata procedures (NCPN-NPS 2007c):

- A metadata record will be created for the riparian database (since it is considered the *primary dataset* for the riparian monitoring project). The Data Store metadata record, also referred to as the project level metadata, will be updated annually.
- All other riparian datasets and data products will be documented as cross-reference citations in the project level metadata record.

Another type of metadata specific to NCPN is the Project Data Life Cycle (PDLC) checklist, which helps to ensure that all data management activities (e.g., data verification/validation, metadata, archiving) are completed each year for monitoring projects. In accordance with this requirement, a PDLC checklist will be completed each year for riparian monitoring data. For further details related to the PDLC checklist, refer to the NCPN Project Data Life Cycle Guidance Document (NCPN-NPS 2007a).

Table 4 summarizes the metadata tasks required for riparian monitoring datasets and data products, and Table 5 describes the tasks and provides references where more detailed procedures are described.

Table 4. Summary of Metadata Tasks for Riparian Monitoring Data

Dataset/ Data Product	Data Store	X-Ref Citation	PDLC Check-list	MVT	Photo DB	DB Doc
Database	X		X			X
Geomorpholgy Data		X	X			

Hydrology Data		X	X			
GIS Data		X	X			
Report(s)	X	X	X			
Protocol	X	X	X	X		
Photos		X	X		X	
Field Forms		X	X			

Table 5. Metadata Task Descriptions

Metadata Task	Metadata Task Description	Reference(s)
Data Store	A Data Store Reference is created for the riparian database and then updated annually. References are also created for each report and for the protocol. The Reference for the protocol is versioned as needed.	Metadata Guidance Document (NCPN-NPS 2007c), https://irma.nps.gov/Content/DataStore/Help/
X-Ref Citation	A cross reference citation is added to the project level metadata record.	Metadata Guidance Document (NCPN-NPS 2007c)
PDLC Checklist	The PDLC checklist is completed, which includes adding product records to the NCPN Project Tracking Database.	Project Data Life Cycle Guidance Document (NCPN-NPS 2007a)
MVT	The Master Version Table is updated as needed.	Protocol Versioning Guidance Document (NCPN-NPS 2009)
Photo DB	Photo records are added to the NCPN Photo Database.	Photo Management Guidance Document (NCPN-NPS 2008b)
DB Doc	Database table and field documentation is updated as needed.	Appendix A

The complete protocol for this project (Protocol Narrative and all SOPs) is an integral component of the project metadata. All narrative and SOP version changes are noted in a Master Version Table (MVT), which is maintained in SOP #15. Any time the narrative or an SOP version change occurs, a new Version Key number (VK#) must be created and recorded in the MVT, along with the date of the change and the versions of the narrative and SOPs in effect. The Version Key number is essential for project information to be properly interpreted and analyzed. *The protocol narrative, SOPs, and data should not be distributed independently of this table.* Refer to the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009) for detailed protocol versioning procedures.

8 Photo Management

Photos taken as part of riparian monitoring are managed following NCPN photo management procedures, which are described in detail in the NCPN Photo Management Guidance Document (NCPN-NPS 2008b). This section will focus on digital photo management, since riparian monitoring photos are taken with digital cameras.

Photos are initially uploaded to a temporary folder on the NCPN shared drive (X:). This drive is backed up regularly, with a backup rotation scheme that includes off-site storage of backups. Refer to the NCPN Disaster Recovery Guidance Document (NCPN-NPS 2007d) for detailed backup procedures. The photos are then documented (NCPN-NPS 2008b) and quality checked (NCPN-NPS 2015b). Any issues discovered are resolved. For example, duplicate photos or photos of very poor quality are usually discarded.

Photos are then uploaded to the NCPN Photo Database. As part of this process, the image files are moved to the NCPN read-only shared drive (R:). This drive is also backed up regularly, with off-site storage of backups. The read-only drive serves as the primary long-term storage location for the photos. In addition, copies of the photos are burned onto archival-standard DVDs and sent to WACC, the official archival repository for NCPN data. This is in accordance with NPS Director's Order 11D: Records and Electronic Information Management (NPS 2012), which requires that all NPS natural resource records be retained permanently and receive archival care as soon as practical.

9 References

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- NCPN-NPS 2007a. Project Data Life Cycle Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007b. Directory Structure Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2007c. Metadata Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
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- NCPN-NPS 2015a. Riparian Database User's Guide. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NCPN-NPS 2015b. Riparian Database Quality Assurance (QA)/Quality Control (QC) Procedures. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.
- NPS 2012. National Park Service. 2012. NPS Director's Order 11D: Records and Electronic Information Management. (https://www.nps.gov/policy/DOrders/DO_11D.pdf)

Appendix A Documentation of Database Tables

The table and field definitions in this appendix correspond to version 2.06 of the riparian database (the version used during the 2015 field season). The database consists of three types of tables: data tables, lookup tables, and metadata tables. Tables appear in alphabetical order within each of these three categories.

Data Tables

Table Name: tbl_Dist_Exotic
Description: Table of exotic plant species observed on reach during site assessment.

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Impact_ID	Foreign key to tbl_Site_Impact	dbText	50
Species	Exotic species code	dbText	15
Alive	Is species alive?	dbBoolean	1
Notes	Notes on species	dbMemo	0

Table Name: tbl_Events
Description: Table of sampling events.

Field Name	Field Description	Field Type	Field Width
Event_ID	Event identifier (Event_ID)	dbText	50
Location_ID	Link to tbl_Locations (Loc_ID)	dbText	50
Protocol_Name	The name or code of the protocol governing the event (Protcl_Nam)	dbText	100
version_key_number	Master protocol version key	dbLong	4
Start_Date	Starting date for the event or site visit (Start_Date)	dbDate	8
Comments	Reach revisit comments	dbMemo	0
Observer	Reach revisit observer	dbText	50
Census_Observer	Reach census observer	dbText	50
Census_Recorder	Reach census recorder	dbText	50
Census_Date	Date of census observation	dbDate	8

Table Name: tbl_GL_Intercept
Description: Table of greenline point intercept measurements [Discontinued in 2013].

Field Name	Field Description	Field Type	Field Width
Intercept_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_GL_Transect	dbText	50
Point	Intercept point - increments of 0.25m up to 10m	dbDecimal	16
Top	Top canopy species code	dbText	15
Alive	Is top canopy species alive?	dbBoolean	1
Surface	Soil surface code	dbText	15
Surface_Alive	[not used]	dbBoolean	1
LCS1	Lower canopy species 1 - Database flattened to accommodate field data entry and work around Access limitations.	dbText	15
LCA1	Lower canopy alive 1	dbBoolean	1
LCS2	Lower canopy species 2	dbText	15
LCA2	Lower canopy alive 2	dbBoolean	1
LCS3	Lower canopy species 3	dbText	15
LCA3	Lower canopy alive 3	dbBoolean	1
LCS4	Lower canopy species 4	dbText	15

Field Name	Field Description	Field Type	Field Width
LCA4	Lower canopy alive 4	dbBoolean	1
LCS5	Lower canopy species 5	dbText	15
LCA5	Lower canopy alive 5	dbBoolean	1
LCS6	Lower canopy species 6	dbText	15
LCA6	Lower canopy alive 6	dbBoolean	1
LCS7	Lower canopy species 7	dbText	15
LCA7	Lower canopy alive7	dbBoolean	1
LCS8	Lower canopy species 8	dbText	15
LCA8	Lower canopy alive 8	dbBoolean	1
LCS9	Lower canopy species 9	dbText	15
LCA9	Lower canopy alive 9	dbBoolean	1
LCS10	Lower canopy species 10	dbText	15
LCA10	Lower canopy alive 10	dbBoolean	1
D1	[not used]	dbText	15
D2	[not used]	dbText	15
D3	[not used]	dbText	15
D4	[not used]	dbText	15
D5	[not used]	dbText	15

Table Name: tbl_GL_Transect
Description: Table of transect information for greenline point intercept measurements [Discontinued in 2013].

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number: 1 to 7.5 (right transects numbered as .5)	dbDecimal	16
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_Impact_Details
Description: Table of site impact assessment details

Field Name	Field Description	Field Type	Field Width
Impact_Details_ID	Unique record identifier - primary key	dbText	50
Impact_ID	Foreign key to tbl_Site_Impact	dbText	50
Disturbance_Location	Observation-location type: in-stream or terrestrial.	dbText	15
Disturbance_Type	Disturbance type (tlu_Disturbance).	dbText	50
Disturbance_Description	Description of disturbance including potential effects on fire or erosion processes.	dbMemo	0

Table Name: tbl_Location_History
Description: Site and reach definition history table

Field Name	Field Description	Field Type	Field Width
Location_History_ID	Location identifier (Loc_ID)	dbText	50
Location_ID	Foreign key to tbl_Location	dbText	50
Unit_Code	Park code	dbText	4
Plot_ID	Reach identifier	dbInteger	2
Modify_Date	Date of update	dbDate	8
Stream_Name	Name of stream	dbText	100
Recorder	Person recording data	dbText	50

Field Name	Field Description	Field Type	Field Width
E_Coord	UTM East of Centroid (X_Coord)	dbDouble	8
N_Coord	UTM North of Centroid (Y_Coord)	dbDouble	8
Compass_Declination	Compass declination	dbInteger	2
T1_RN	UTM northing of rebar, transect 1 right	dbDouble	8
T1_RE	UTM easting of rebar, transect 1 right	dbDouble	8
T1_RLocation	Rebar location in meters, transect 1 right	dbDecimal	16
T1_LN	UTM northing of rebar, transect 1 left	dbDouble	8
T1_LE	UTM easting of rebar, transect 1 left	dbDouble	8
T1_LLocation	Rebar location in meters, transect 1 left	dbDecimal	16
T1_Length	Length in meters (1 decimal), transect 1	dbDecimal	16
T1_Bearing	Bearing in degrees R to L, transect 1	dbInteger	2
T1_REndE	UTM easting of end point, transect 1 right	dbDouble	8
T1_REndN	UTM northing of end point, transect 1 right	dbDouble	8
T1_LEndE	UTM easting of end point, transect 1 left	dbDouble	8
T1_LEndN	UTM northing of end point, transect 1 left	dbDouble	8
T2_RN	UTM northing of rebar, transect 2 right	dbDouble	8
T2_RE	UTM easting of rebar, transect 2 right	dbDouble	8
T2_RLocation	Rebar location in meters, transect 2 right	dbDecimal	16
T2_LN	UTM northing of rebar, transect 2 left	dbDouble	8
T2_LE	UTM easting of rebar, transect 2 left	dbDouble	8
T2_LLocation	Rebar location in meters, transect 2 left	dbDecimal	16
T2_Length	Length in meters (1 decimal), transect 2	dbDecimal	16
T2_Bearing	Bearing in degrees R to L, transect 2	dbInteger	2
T2_REndE	UTM easting of end point, transect 2 right	dbDouble	8
T2_REndN	UTM northing of end point, transect 2 right	dbDouble	8
T2_LEndE	UTM easting of end point, transect 2 left	dbDouble	8
T2_LEndN	UTM northing of end point, transect 2 left	dbDouble	8
T3_RN	UTM northing of rebar, transect 3 right	dbDouble	8
T3_RE	UTM easting of rebar, transect 3 right	dbDouble	8
T3_RLocation	Rebar location in meters, transect 3 right	dbDecimal	16
T3_LN	UTM northing of rebar, transect 3 left	dbDouble	8
T3_LE	UTM easting of rebar, transect 3 left	dbDouble	8
T3_LLocation	Rebar location in meters, transect 3 left	dbDecimal	16
T3_Length	Length in meters (1 decimal), transect 3	dbDecimal	16
T3_Bearing	Bearing in degrees R to L, transect 3	dbInteger	2
T3_REndE	UTM easting of end point, transect 3 right	dbDouble	8
T3_REndN	UTM northing of end point, transect 3 right	dbDouble	8
T3_LEndE	UTM easting of end point, transect 3 left	dbDouble	8
T3_LEndN	UTM northing of end point, transect 3 left	dbDouble	8
T4_RN	UTM northing of rebar, transect 4 right	dbDouble	8
T4_RE	UTM easting of rebar, transect 4 right	dbDouble	8
T4_RLocation	Rebar location in meters, transect 4 right	dbDecimal	16
T4_LN	UTM northing of rebar, transect 4 left	dbDouble	8
T4_LE	UTM easting of rebar, transect 4 left	dbDouble	8
T4_LLocation	Rebar location in meters, transect 4 left	dbDecimal	16
T4_Length	Length in meters (1 decimal), transect 4	dbDecimal	16
T4_Bearing	Bearing in degrees R to L, transect 4	dbInteger	2
T4_REndE	UTM easting of end point, transect 4 right	dbDouble	8
T4_REndN	UTM northing of end point, transect 4 right	dbDouble	8
T4_LEndE	UTM easting of end point, transect 4 left	dbDouble	8
T4_LEndN	UTM northing of end point, transect 4 left	dbDouble	8

Field Name	Field Description	Field Type	Field Width
T5_RN	UTM northing of rebar, transect 5 right	dbDouble	8
T5_RE	UTM easting of rebar, transect 5 right	dbDouble	8
T5_RLocation	Rebar location in meters, transect 5 right	dbDecimal	16
T5_LN	UTM northing of rebar, transect 5 left	dbDouble	8
T5_LE	UTM easting of rebar, transect 5 left	dbDouble	8
T5_LLocation	Rebar location in meters, transect 5 left	dbDecimal	16
T5_Length	Length in meters (1 decimal), transect 5	dbDecimal	16
T5_Bearing	Bearing in degrees R to L, transect 5	dbInteger	2
T5_REndE	UTM easting of end point, transect 5 right	dbDouble	8
T5_REndN	UTM northing of end point, transect 5 right	dbDouble	8
T5_LEndE	UTM easting of end point, transect 5 left	dbDouble	8
T5_LEndN	UTM northing of end point, transect 5 left	dbDouble	8
T6_RN	UTM northing of rebar, transect 6 right	dbDouble	8
T6_RE	UTM easting of rebar, transect 6 right	dbDouble	8
T6_RLocation	Rebar location in meters, transect 6 right	dbDecimal	16
T6_LN	UTM northing of rebar, transect 6 left	dbDouble	8
T6_LE	UTM easting of rebar, transect 6 left	dbDouble	8
T6_LLocation	Rebar location in meters, transect 6 left	dbDecimal	16
T6_Length	Length in meters (1 decimal), transect 6	dbDecimal	16
T6_Bearing	Bearing in degrees R to L, transect 6	dbInteger	2
T6_REndE	UTM easting of end point, transect 6 right	dbDouble	8
T6_REndN	UTM northing of end point, transect 6 right	dbDouble	8
T6_LEndE	UTM easting of end point, transect 6 left	dbDouble	8
T6_LEndN	UTM northing of end point, transect 6 left	dbDouble	8
T7_RN	UTM northing of rebar, transect 7 right	dbDouble	8
T7_RE	UTM easting of rebar, transect 7 right	dbDouble	8
T7_RLocation	Rebar location in meters, transect 7 right	dbDecimal	16
T7_LN	UTM northing of rebar, transect 7 left	dbDouble	8
T7_LE	UTM easting of rebar, transect 7 left	dbDouble	8
T7_LLocation	Rebar location in meters, transect 7 left	dbDecimal	16
T7_Length	Length in meters (1 decimal), transect 7	dbDecimal	16
T7_Bearing	Bearing in degrees R to L, transect 7	dbInteger	2
T7_REndE	UTM easting of end point, transect 7 right	dbDouble	8
T7_REndN	UTM northing of end point, transect 7 right	dbDouble	8
T7_LEndE	UTM easting of end point, transect 7 left	dbDouble	8
T7_LEndN	UTM northing of end point, transect 7 left	dbDouble	8
Plot_Directions	Directions to reach	dbMemo	0

Table Name: tbl_Locations
Description: Site and reach definition table

Field Name	Field Description	Field Type	Field Width
Location_ID	Location identifier (Loc_ID)	dbText	50
GIS_Location_ID	Link to GIS feature, equivalent to NPS_Location_ID (GIS_Loc_ID)	dbText	50
Meta_MID	Link to NR-GIS Metadata Database (Meta_MID)	dbText	50
Unit_Code	Park code	dbText	4
Plot_ID	Reach identifier	dbInteger	2
Stream_Name	Name of stream	dbText	100
Av_Reach_Width	Average width of reach in meters	dbInteger	2
Est_Reach_Length	Estimated length of reach in meters	dbInteger	2
Act_Reach_Length	Actual length of reach in meters	dbInteger	2

Field Name	Field Description	Field Type	Field Width
SiteDate	Date reach established	dbDate	8
Observer	Person observing data	dbText	50
Recorder	Person recording data	dbText	50
Soil_Survey_Area	[not used]	dbMemo	0
Soil_Map_Unit	[not used]	dbText	10
GPS_File_Name	GPS file name for centroid coordinates	dbText	50
Rcvr_Type	GPS unit type	dbText	50
Elevation	Elevation of site origin in meters	dbInteger	2
E_Coord	UTM easting of centroid (X_Coord)	dbDouble	8
N_Coord	UTM northing of centroid (Y_Coord)	dbDouble	8
Coord_Units	Coordinate distance units (Coord_Unit)	dbText	50
Coord_System	Coordinate system (Coord_Syst)	dbText	50
UTM_Zone	UTM Zone (UTM_Zone)	dbInteger	2
Datum	Datum of mapping ellipsoid (Datum)	dbText	5
Max_PDOP	Horizontal accuracy	dbDouble	8
Max_HDOP	Positional accuracy	dbDouble	8
Updated_Date	Date of entry or last change (Upd_Date)	dbText	50
ARZW1	Active riparian zone width 1 in meters	dbInteger	2
ARZW2	Active riparian zone width 2 in meters	dbInteger	2
ARZW3	Active riparian zone width 3 in meters	dbInteger	2
ARZW4	Active riparian zone width 4 in meters	dbInteger	2
ARZW5	Active riparian zone width 5 in meters	dbInteger	2
Confined_Colluvial	Percentage of the reach that is confined colluvial	dbDecimal	16
Confined_Bedrock	Percentage of the reach that is confined bedrock	dbDecimal	16
Confined_Alluvial	Percentage of the reach that is confined alluvial	dbDecimal	16
Unconfined_Alluvial	Percentage of the reach that is unconfined alluvial	dbDecimal	16
Perennial_Pct	Percent perennial stream type	dbDecimal	16
Intermittent_Pct	Percent intermittent stream type	dbDecimal	16
Ephemeral_Pct	Percent ephemeral stream type	dbDecimal	16
Site_Selection	Site accepted or rejected	dbBoolean	1
Establishment_Comments	Reach establishment comments	dbMemo	0
Rejection_Criteria	Reason for rejection	dbText	50
Compass_Declination	Compass declination	dbInteger	2
T1_RN	UTM northing of rebar, transect 1 right	dbDouble	8
T1_RE	UTM easting of rebar, transect 1 right	dbDouble	8
T1_RLocation	Rebar location in meters, transect 1 right	dbDouble	8
T1_LN	UTM northing of rebar, transect 1 left	dbDouble	8
T1_LE	UTM easting of rebar, transect 1 left	dbDouble	8
T1_LLocation	Rebar location in meters, transect 1 left	dbDouble	8
T1_Length	Length in meters (1 decimal), transect 1	dbDecimal	16
T1_Bearing	Bearing in degrees R to L, transect 1	dbInteger	2
T1_REndE	UTM easting of end point, transect 1 right	dbDouble	8
T1_REndN	UTM northing of end point, transect 1 right	dbDouble	8
T1_LEndE	UTM easting of end point, transect 1 left	dbDouble	8
T1_LEndN	UTM northing of end point, transect 1 left	dbDouble	8
T2_RN	UTM northing of rebar, transect 2 right	dbDouble	8
T2_RE	UTM easting of rebar, transect 2 right	dbDouble	8
T2_RLocation	Rebar location in meters, transect 2 right	dbDouble	8
T2_LN	UTM northing of rebar, transect 2 left	dbDouble	8
T2_LE	UTM easting of rebar, transect 2 left	dbDouble	8

Field Name	Field Description	Field Type	Field Width
T2_LLocation	Rebar location in meters, transect 2 left	dbDouble	8
T2_Length	Length in meters (1 decimal), transect 2	dbDecimal	16
T2_Bearing	Bearing in degrees R to L, transect 2	dbInteger	2
T2_REndE	UTM easting of end point, transect 2 right	dbDouble	8
T2_REndN	UTM northing of end point, transect 2 right	dbDouble	8
T2_LEndE	UTM easting of end point, transect 2 left	dbDouble	8
T2_LEndN	UTM northing of end point, transect 2 left	dbDouble	8
T3_RN	UTM northing of rebar, transect 3 right	dbDouble	8
T3_RE	UTM easting of rebar, transect 3 right	dbDouble	8
T3_RLocation	Rebar location in meters, transect 3 right	dbDouble	8
T3_LN	UTM northing of rebar, transect 3 left	dbDouble	8
T3_LE	UTM easting of rebar, transect 3 left	dbDouble	8
T3_LLocation	Rebar location in meters, transect 3 left	dbDouble	8
T3_Length	Length in meters (1 decimal), transect 3	dbDecimal	16
T3_Bearing	Bearing in degrees R to L, transect 3	dbInteger	2
T3_REndE	UTM easting of end point, transect 3 right	dbDouble	8
T3_REndN	UTM northing of end point, transect 3 right	dbDouble	8
T3_LEndE	UTM easting of end point, transect 3 left	dbDouble	8
T3_LEndN	UTM northing of end point, transect 3 left	dbDouble	8
T4_RN	UTM northing of rebar, transect 4 right	dbDouble	8
T4_RE	UTM easting of rebar, transect 4 right	dbDouble	8
T4_RLocation	Rebar location in meters, transect 4 right	dbDouble	8
T4_LN	UTM northing of rebar, transect 4 left	dbDouble	8
T4_LE	UTM easting of rebar, transect 4 left	dbDouble	8
T4_LLocation	Rebar location in meters, transect 4 left	dbDouble	8
T4_Length	Length in meters (1 decimal), transect 4	dbDecimal	16
T4_Bearing	Bearing in degrees R to L, transect 4	dbInteger	2
T4_REndE	UTM easting of end point, transect 4 right	dbDouble	8
T4_REndN	UTM northing of end point, transect 4 right	dbDouble	8
T4_LEndE	UTM easting of end point, transect 4 left	dbDouble	8
T4_LEndN	UTM northing of end point, transect 4 left	dbDouble	8
T5_RN	UTM northing of rebar, transect 5 right	dbDouble	8
T5_RE	UTM easting of rebar, transect 5 right	dbDouble	8
T5_RLocation	Rebar location in meters, transect 5 right	dbDouble	8
T5_LN	UTM northing of rebar, transect 5 left	dbDouble	8
T5_LE	UTM easting of rebar, transect 5 left	dbDouble	8
T5_LLocation	Rebar location in meters, transect 5 left	dbDouble	8
T5_Length	Length in meters (1 decimal), transect 5	dbDecimal	16
T5_Bearing	Bearing in degrees R to L, transect 5	dbInteger	2
T5_REndE	UTM easting of end point, transect 5 right	dbDouble	8
T5_REndN	UTM northing of end point, transect 5 right	dbDouble	8
T5_LEndE	UTM easting of end point, transect 5 left	dbDouble	8
T5_LEndN	UTM northing of end point, transect 5 left	dbDouble	8
T6_RN	UTM northing of rebar, transect 6 right	dbDouble	8
T6_RE	UTM easting of rebar, transect 6 right	dbDouble	8
T6_RLocation	Rebar location in meters, transect 6 right	dbDouble	8
T6_LN	UTM northing of rebar, transect 6 left	dbDouble	8
T6_LE	UTM easting of rebar, transect 6 left	dbDouble	8
T6_LLocation	Rebar location in meters, transect 6 left	dbDouble	8
T6_Length	Length in meters (1 decimal), transect 6	dbDecimal	16

Field Name	Field Description	Field Type	Field Width
T6_Bearing	Bearing in degrees R to L, transect 6	dbInteger	2
T6_REndE	UTM easting of end point, transect 6 right	dbDouble	8
T6_REndN	UTM northing of end point, transect 6 right	dbDouble	8
T6_LEndE	UTM easting of end point, transect 6 left	dbDouble	8
T6_LEndN	UTM northing of end point, transect 6 left	dbDouble	8
T7_RN	UTM northing of rebar, transect 7 right	dbDouble	8
T7_RE	UTM easting of rebar, transect 7 right	dbDouble	8
T7_RLocation	Rebar location in meters, transect 7 right	dbDouble	8
T7_LN	UTM northing of rebar, transect 7 left	dbDouble	8
T7_LE	UTM easting of rebar, transect 7 left	dbDouble	8
T7_LLocation	Rebar location in meters, transect 7 left	dbDouble	8
T7_Length	Length in meters (1 decimal), transect 7	dbDecimal	16
T7_Bearing	Bearing in degrees R to L, transect 7	dbInteger	2
T7_REndE	UTM easting of end point, transect 7 right	dbDouble	8
T7_REndN	UTM northing of end point, transect 7 right	dbDouble	8
T7_LEndE	UTM easting of end point, transect 7 left	dbDouble	8
T7_LEndN	UTM northing of end point, transect 7 left	dbDouble	8
Plot_Directions	Directions to plot	dbMemo	0
Greenline_PI_Applies	Does greenline point intercept method apply to this reach	dbText	3

Table Name: tbl_LP_Belt_Transect
Description: Table of transect information for 5 meter belt transect measurements.

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number: 1 to 7	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_LP_Densiometer
Description: Table of Spherical Densiometer point intersection counts in 5 meter belt transect.

Field Name	Field Description	Field Type	Field Width
SD_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Point	Point on transect	dbText	4
Total1	Total count, measurement 1	dbInteger	2
Total2	Total count, measurement 2	dbInteger	2
Total3	Total count, measurement 3	dbInteger	2
Total4	Total count, measurement 4	dbInteger	2

Table Name: tbl_LP_Exotic
Description: Table of exotic perennial species in 5 meter belt transect [Discontinued use in 2011]

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Exotic species code	dbText	15
Alive	Is species alive?	dbBoolean	1
Total	Total count	dbInteger	2

Table Name: tbl_LP_Exotic_Freq
Description: Table of exotic frequency by quadrat [Added in 2011]

Field Name	Field Description	Field Type	Field Width
Exotic_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Exotic species observed	dbText	15
M0	Zero point quadrat species detected checkbox	dbBoolean	1
M5	5 meter quadrat species detected checkbox	dbBoolean	1
M10	10 meter quadrat species detected checkbox	dbBoolean	1
M15	15 meter quadrat species detected checkbox	dbBoolean	1
M20	20 meter quadrat species detected checkbox	dbBoolean	1
M25	25 meter quadrat species detected checkbox	dbBoolean	1
M30	30 meter quadrat species detected checkbox	dbBoolean	1
M35	35 meter quadrat species detected checkbox	dbBoolean	1
M40	40 meter quadrat species detected checkbox	dbBoolean	1
M45	45 meter quadrat species detected checkbox	dbBoolean	1
M50	50 meter quadrat species detected checkbox	dbBoolean	1
M55	55 meter quadrat species detected checkbox	dbBoolean	1
M60	60 meter quadrat species detected checkbox	dbBoolean	1
M65	65 meter quadrat species detected checkbox	dbBoolean	1
M70	70 meter quadrat species detected checkbox	dbBoolean	1
M75	75 meter quadrat species detected checkbox	dbBoolean	1
M80	80 meter quadrat species detected checkbox	dbBoolean	1
M85	85 meter quadrat species detected checkbox	dbBoolean	1
M90	90 meter quadrat species detected checkbox	dbBoolean	1
M95	95 meter quadrat species detected checkbox	dbBoolean	1

Table Name: tbl_LP_Intercept
Description: Table of cross-section point intercept measurements.

Field Name	Field Description	Field Type	Field Width
Intercept_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Transect	dbText	50
Point	Intercept point - increments of 0.5m up to length of transect	dbDecimal	16
Top	Top canopy species code	dbText	15
Alive	Is top canopy species alive?	dbBoolean	1
Surface	Soil surface code	dbText	15
Surface_Alive	If soil surface is a species, is it alive?	dbBoolean	1
LCS1	Lower canopy species 1 - Database flattened to accommodate field data entry and work around Access limitations.	dbText	15
LCA1	Lower canopy alive 1	dbBoolean	1
LCS2	Lower canopy species 2	dbText	15
LCA2	Lower canopy alive 2	dbBoolean	1
LCS3	Lower canopy species 3	dbText	15
LCA3	Lower canopy alive 3	dbBoolean	1
LCS4	Lower canopy species 4	dbText	15
LCA4	Lower canopy alive 4	dbBoolean	1
LCS5	Lower canopy species 5	dbText	15
LCA5	Lower canopy alive 5	dbBoolean	1
LCS6	Lower canopy species 6	dbText	15
LCA6	Lower canopy alive 6	dbBoolean	1

Field Name	Field Description	Field Type	Field Width
LCS7	Lower canopy species 7	dbText	15
LCA7	Lower canopy alive7	dbBoolean	1
LCS8	Lower canopy species 8	dbText	15
LCA8	Lower canopy alive 8	dbBoolean	1
LCS9	Lower canopy species 9	dbText	15
LCA9	Lower canopy alive 9	dbBoolean	1
LCS10	Lower canopy species 10	dbText	15
LCA10	Lower canopy alive 10	dbBoolean	1
D1	Disturbance code 1	dbText	15
D2	Disturbance code 2	dbText	15
D3	Disturbance code 3	dbText	15
D4	Disturbance code 4	dbText	15
D5	Disturbance code 5	dbText	15
Geomorphic_Surface	Master stratification for summaries and analysis	dbText	50

Table Name: tbl_LP_Seedling
Description: Table of tree seedlings in 5 meter belt transect.

Field Name	Field Description	Field Type	Field Width
Seedling_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Seedling species code	dbText	15
Total	Total count	dbInteger	2

Table Name: tbl_LP_Transect
Description: Table of transect information for cross-section point intercept measurements.

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number: 1 to 7	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_LP_Tree
Description: Table of mature trees in 5 meter belt transect.

Field Name	Field Description	Field Type	Field Width
Shrub_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_LP_Belt_Transect	dbText	50
Species	Tree species code	dbText	15
Alive	Is tree species alive?	dbBoolean	1
DBH	Diameter at breast height in centimeters	dbSingle	4

Table Name: tbl_Monument
Description: Table of monument tree information.

Field Name	Field Description	Field Type	Field Width
Monument_ID	Unique record identifier - primary key	dbText	50
Location_ID	Foreign key to tbl_Locations	dbText	50
Monument_Code	Corner code (tlu_Monument_Code)	dbText	5
Tag_No	Tag number of monument tree	dbInteger	2
Species	Species code of monument tree	dbText	15

Field Name	Field Description	Field Type	Field Width
DBH	Diameter at breast height in centimeters	dbSingle	4
Bearing	Bearing from monument tree to rebar in degrees	dbInteger	2
Rebar_Distance	Distance from center point of monument tree to rebar in meters	dbSingle	4

Table Name: tbl_OT_Census
Description: Table of reach tree census information.

Field Name	Field Description	Field Type	Field Width
Census_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Tag_No	Tag number	dbInteger	2
Species	Tree species code	dbText	15
DBH	Diameter at breast height in centimeters	dbSingle	4
Crown_Health	Crown health class (tlu_Crown_Health_Class)	dbInteger	2
Notes	Notes about any significant damage to a living tree	dbText	255

Table Name: tbl_OT_Location
Description: Table of reach tree census information.

Field Name	Field Description	Field Type	Field Width
Tree_Location_ID	Unique record identifier - primary key	dbText	50
Location_ID	Plot ID	dbText	50
Tag_No	Tag number	dbInteger	2
Location_Information	Tree location information	dbText	255

Table Name: tbl_Pebble_Count
Description: Table of pebble counts.

Field Name	Field Description	Field Type	Field Width
Pebble_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_Pebble_Transect	dbText	50
P1	b-axis measurement to nearest 0.1 cm, pebble 1	dbSingle	4
P2	b-axis measurement to nearest 0.1 cm, pebble 2	dbSingle	4
P3	b-axis measurement to nearest 0.1 cm, pebble 3	dbSingle	4
P4	b-axis measurement to nearest 0.1 cm, pebble 4	dbSingle	4
P5	b-axis measurement to nearest 0.1 cm, pebble 5	dbSingle	4
P6	b-axis measurement to nearest 0.1 cm, pebble 6	dbSingle	4
P7	b-axis measurement to nearest 0.1 cm, pebble 7	dbSingle	4
P8	b-axis measurement to nearest 0.1 cm, pebble 8	dbSingle	4
P9	b-axis measurement to nearest 0.1 cm, pebble 9	dbSingle	4
P10	b-axis measurement to nearest 0.1 cm, pebble 10	dbSingle	4
P11	b-axis measurement to nearest 0.1 cm, pebble 11	dbSingle	4
P12	b-axis measurement to nearest 0.1 cm, pebble 12	dbSingle	4
P13	b-axis measurement to nearest 0.1 cm, pebble 13	dbSingle	4
P14	b-axis measurement to nearest 0.1 cm, pebble 14	dbSingle	4
P15	b-axis measurement to nearest 0.1 cm, pebble 15	dbSingle	4
P16	b-axis measurement to nearest 0.1 cm, pebble 16	dbSingle	4
P17	b-axis measurement to nearest 0.1 cm, pebble 17	dbSingle	4
P18	b-axis measurement to nearest 0.1 cm, pebble 18	dbSingle	4
P19	b-axis measurement to nearest 0.1 cm, pebble 19	dbSingle	4
P20	b-axis measurement to nearest 0.1 cm, pebble 20	dbSingle	4
P21	b-axis measurement to nearest 0.1 cm, pebble 21	dbSingle	4
P22	b-axis measurement to nearest 0.1 cm, pebble 22	dbSingle	4

Field Name	Field Description	Field Type	Field Width
P23	b-axis measurement to nearest 0.1 cm, pebble 23	dbSingle	4
P24	b-axis measurement to nearest 0.1 cm, pebble 24	dbSingle	4
P25	b-axis measurement to nearest 0.1 cm, pebble 25	dbSingle	4
P26	b-axis measurement to nearest 0.1 cm, pebble 26	dbSingle	4
P27	b-axis measurement to nearest 0.1 cm, pebble 27	dbSingle	4
P28	b-axis measurement to nearest 0.1 cm, pebble 28	dbSingle	4
P29	b-axis measurement to nearest 0.1 cm, pebble 29	dbSingle	4
P30	b-axis measurement to nearest 0.1 cm, pebble 30	dbSingle	4
P31	b-axis measurement to nearest 0.1 cm, pebble 31	dbSingle	4
P32	b-axis measurement to nearest 0.1 cm, pebble 32	dbSingle	4
P33	b-axis measurement to nearest 0.1 cm, pebble 33	dbSingle	4
P34	b-axis measurement to nearest 0.1 cm, pebble 34	dbSingle	4
P35	b-axis measurement to nearest 0.1 cm, pebble 35	dbSingle	4
P36	b-axis measurement to nearest 0.1 cm, pebble 36	dbSingle	4
P37	b-axis measurement to nearest 0.1 cm, pebble 37	dbSingle	4
P38	b-axis measurement to nearest 0.1 cm, pebble 38	dbSingle	4
P39	b-axis measurement to nearest 0.1 cm, pebble 39	dbSingle	4
P40	b-axis measurement to nearest 0.1 cm, pebble 40	dbSingle	4
P41	b-axis measurement to nearest 0.1 cm, pebble 41	dbSingle	4
P42	b-axis measurement to nearest 0.1 cm, pebble 42	dbSingle	4
P43	b-axis measurement to nearest 0.1 cm, pebble 43	dbSingle	4
P44	b-axis measurement to nearest 0.1 cm, pebble 44	dbSingle	4
P45	b-axis measurement to nearest 0.1 cm, pebble 45	dbSingle	4
P46	b-axis measurement to nearest 0.1 cm, pebble 46	dbSingle	4
P47	b-axis measurement to nearest 0.1 cm, pebble 47	dbSingle	4
P48	b-axis measurement to nearest 0.1 cm, pebble 48	dbSingle	4
P49	b-axis measurement to nearest 0.1 cm, pebble 49	dbSingle	4
P50	b-axis measurement to nearest 0.1 cm, pebble 50	dbSingle	4
P51	b-axis measurement to nearest 0.1 cm, pebble 51	dbSingle	4
P52	b-axis measurement to nearest 0.1 cm, pebble 52	dbSingle	4
P53	b-axis measurement to nearest 0.1 cm, pebble 53	dbSingle	4
P54	b-axis measurement to nearest 0.1 cm, pebble 54	dbSingle	4
P55	b-axis measurement to nearest 0.1 cm, pebble 55	dbSingle	4
P56	b-axis measurement to nearest 0.1 cm, pebble 56	dbSingle	4
P57	b-axis measurement to nearest 0.1 cm, pebble 57	dbSingle	4
P58	b-axis measurement to nearest 0.1 cm, pebble 58	dbSingle	4
P59	b-axis measurement to nearest 0.1 cm, pebble 59	dbSingle	4
P60	b-axis measurement to nearest 0.1 cm, pebble 60	dbSingle	4

Table Name: tbl_Pebble_Transect
Description: Table of transect information for pebble counts.

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number: 1 to 7	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50
Wet_Width	Wetted width in meters	dbSingle	4
Sampling_Interval	Sampling interval in meters	dbSingle	4

Table Name: tbl_Photos

Description: Table of reach visit photos

Field Name	Field Description	Field Type	Field Width
Photo_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect_Direction	Transect number and direction (tlu_Photo_Location)	dbText	25
Photo_Date	Date photograph taken	dbDate	8
Photo_Type	[not used]	dbText	50
Roll	Roll for film photos	dbText	10
Frame	Frame for film photos; sequential number for digital photos	dbInteger	2
Digital_File	Digital file name	dbText	50
Photographer	Photographer	dbText	50
Location	Location of photo point along transect in meters	dbDecimal	16
Other_Type	[not used]	dbText	12
Other_Identifier	[not used]	dbText	50
Comments	Photo comments or description	dbMemo	0
NCPN_Image_ID	Digital file name in NCPN Photo Database	dbText	50

Table Name: tbl_Site_Impact
Description: Table of site impact assessment information

Field Name	Field Description	Field Type	Field Width
Impact_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Visit_Date	Date of visit	dbDate	8
Recorder	Person recording site impact information	dbText	50
Site_Sketch	[not used]	dbLongBinary	0
Other_Notes	Other disturbance notes	dbMemo	0

Table Name: tbl_SL_Transect
Description: Table of transect information for shrub line-intercept gaps [Discontinued in 2010]

Field Name	Field Description	Field Type	Field Width
Transect_ID	Unique record identifier - primary key	dbText	50
Event_ID	Foreign key to tbl_Events	dbText	50
Transect	Transect number: 1 to 7	dbByte	1
Visit_Date	Date of visit	dbDate	8
Observer	Name of person observing	dbText	50
Recorder	Name of person recording	dbText	50

Table Name: tbl_SLI_Gaps
Description: Table of shrub line-intercept gaps [Discontinued in 2010]

Field Name	Field Description	Field Type	Field Width
SLI_ID	Unique record identifier - primary key	dbText	50
Transect_ID	Foreign key to tbl_SL_Transect	dbText	50
Species	Species code	dbText	50
Shrub_Start	Start of shrub cover to nearest centimeter	dbLong	4
Shrub_End	End of shrub cover to nearest centimeter	dbInteger	2

Table Name: tbl_Unknown_Species
Description: Table of unknown plant species

Field Name	Field Description	Field Type	Field Width
Unknown_ID	Unique record identifier - primary key	dbText	50

Field Name	Field Description	Field Type	Field Width
Species_ID	[not used]	dbText	50
Unknown_Code	Temporary code for unknown species	dbText	15
Collected_by	Person collecting specimen	dbText	50
Method	Collection method	dbText	50
Transect_Number	Collection transect	dbInteger	2
Plant_Type	Plant type: herb, shrub, tree, grass, sedge, other	dbText	50
Plant_Description	General description	dbMemo	0
Salient_Feature	Most salient feature	dbText	255
Leaf_Type	Leaf type: compound/simple, arrangement	dbText	50
Margin	Leaf margin	dbText	50
Other_Characteristics	Other leaf characteristics: pubescence, sap, stipules	dbText	255
Stem_Characteristics	Stem characteristics: shape, pubescence, bud	dbText	255
Flower_Characteristics	Flower characteristics: color location floral formula	dbText	255
General_Characteristics	General and microhabitat characteristics	dbText	255
Collected	Was plant collected	dbBoolean	1
Best_Guess	Best guess species name	dbText	50
Confirmed_Code	Confirmed species code	dbText	50
Have_Photos	Are there photos?	dbBoolean	1
Forb_Grass_Type	Annual or Perennial	dbText	10
Perennial_Grasses	Perennial grass type: Bunchgrass or Rhizomatous	dbText	15
Identified_by	Person making final identification	dbText	50
Identified_Date	Date of identification	dbDate	8
Position	Position on transect (m)	dbInteger	2

Lookup Tables

Table Name: tlu_Contacts
Description: Contact data for project-related personnel.

Field Name	Field Description	Field Type	Field Width
Contact_ID	Contact identifier (Contact_ID)	dbText	50
Last_Name	Last name (Cnt_Last)	dbText	50
First_Name	First name (Cnt_First)	dbText	50
Middle_Init	Middle initial (Cnt_MI)	dbText	4
Organization	Organization or employer (cntorg)	dbText	50
Position_Title	Title or position description (cntpos)	dbText	50
Address_Type	Address (mailing, physical, both) type (addrtype)	dbText	50
Address	Street address (cntaddr)	dbText	50
Address2	Address line 2, suite, apartment number (Cnt_Addr2)	dbText	50
City	City or town (city)	dbText	50
State_Code	State or province (state)	dbText	8
Zip_Code	Zip code (postal)	dbText	50
Country	Country (country)	dbText	50
Email_Address	E-mail address (cntemail)	dbText	50
Work_Phone	Phone number (cntvoice)	dbText	50
Work_Extension	Phone extension (Work_Ext)	dbText	50
Contact_Notes	Contact notes (Cnt_Notes)	dbMemo	0

Table Name: tlu_Crown_Health_Class
Description: Lookup table of crown health classes

Field Name	Field Description	Field Type	Field Width
Crown_Health_Class	Crown health class	dbInteger	2
Class_Description	Health class description	dbText	50

Table Name: tlu_Densiometer_Point
Description: Lookup table of valid densiometer points

Field Name	Field Description	Field Type	Field Width
Point	Densiometer measurement point	dbText	4
Sort_Seq	Sort sequence	dbInteger	2

Table Name: tlu_Disturbance
Description: Lookup table of site impact disturbances

Field Name	Field Description	Field Type	Field Width
Dist_Code	Disturbance code	dbText	50
Dist_Type	Disturbance type - 1=In-stream, 2=Terrestrial	dbByte	1
Disturbance	Disturbance description	dbText	255

Table Name: tlu_LP_Disturbance
Description: Lookup table of point intercept disturbances

Field Name	Field Description	Field Type	Field Width
Dist_Code	Disturbance code	dbText	5
Disturbance	Disturbance description	dbText	50

Table Name: tlu_LP_Soil_Surface
Description: Lookup table for point intercept soil surface codes

Field Name	Field Description	Field Type	Field Width
Surface_Code	Soil surface code	dbText	5
Surface_Description	Soil surface description	dbText	50
LC_Code	Lower canopy code; 1=applies also to lower canopy	dbByte	1

Table Name: tlu_Monument_Code
Description: Lookup table of monument tree corner codes

Field Name	Field Description	Field Type	Field Width
Monument_Code	5 character monument corner code	dbText	5

Table Name: tlu_NCPN_Plants
Description: Contains all NCPN master plant species

Field Name	Field Description	Field Type	Field Width
Master_Family	Master family	dbText	50
Master_PLANT_Code	Master species code; primary key (USDA PLANTS Database)	dbText	20
Master_Species	Master species name (Integrated Taxonomic Information System)	dbText	50
UT_Family	Utah family	dbText	50
CO_Family	Colorado family	dbText	50
WY_Family	Wyoming family	dbText	50
Utah_PLANT_Code	Utah species PLANTS code	dbText	20
Utah_Species	Utah species name (Welsh et al 2003)	dbText	50
Co_PLANT_Code	Colorado species PLANTS code	dbText	20
Co_Species	Colorado species name (Weber & Wittmann 2001)	dbText	50
Wy_PLANT_code	Wyoming species PLANTS code	dbText	20
Wy_Species	Wyoming species name (Dorn 2001)	dbText	50

Field Name	Field Description	Field Type	Field Width
Add_Synonyms	Additional synonyms	dbMemo	0
Taxonomic_Notes	Taxonomic notes	dbMemo	0
Master_Common_Name	Master common name	dbText	50
ARCH	Park presence descriptor for ARCH	dbText	15
BLCA	Park presence descriptor for BLCA	dbText	15
BRCA	Park presence descriptor for BRCA	dbText	15
CANY	Park presence descriptor for CANY	dbText	15
CARE	Park presence descriptor for CARE	dbText	15
CEBR	Park presence descriptor for CEBR	dbText	15
COLM	Park presence descriptor for COLM	dbText	15
CURE	Park presence descriptor for CURE	dbText	15
DINO (UT)	Park presence descriptor for DINO - Utah	dbText	15
DINO (CO)	Park presence descriptor for DINO - Colorado	dbText	15
FOBU	Park presence descriptor for FOBU	dbText	15
GOSP	Park presence descriptor for GOSP	dbText	15
HOVE (UT)	Park presence descriptor for HOVE - Utah	dbText	15
HOVE (CO)	Park presence descriptor for HOVE - Colorado	dbText	15
NABR	Park presence descriptor for NABR	dbText	15
PISP	Park presence descriptor for PISP	dbText	15
TICA	Park presence descriptor for TICA	dbText	15
ZION	Park presence descriptor for ZION	dbText	15
Lifeform	Lifeform derived from USDA PLANTS	dbText	255
Duration	Duration derived from USDA PLANTS	dbText	255
Nativity	Nativity derived from USDA PLANTS	dbText	255
Trinomial	True if species code represents a trinomial name	dbBoolean	1
Unique_Species	True if species code represents a genus and species designation	dbBoolean	1
New_Record	Is it a new record?	dbBoolean	1
LU_Code	Shorthand (a.k.a. 6-letter) lookup code	dbText	25
Wetland_Code	Code identifying wetland designation (see http://plants.usda.gov/wetinfo.html#categories)	dbText	20
Wetland_Code_Info_Source	Information source used to determine wetland classification	dbText	50
Photosynthetic_Pathway	Photosynthetic pathway designation (source: Osborne et al. 2014, doi: 10.1111/nph.12942)	dbText	5

Table Name: tlu_Parks
Description: Look-up table of parks in the Northern Colorado Plateau Network

Field Name	Field Description	Field Type	Field Width
ParkCode	Four-letter abbreviation for park code	dbText	5
ParkName	Full name of park where data were collected	dbText	50
ParkState	State code	dbText	2

Table Name: tlu_Photo_Location
Description: Lookup table of transect/direction for photos

Field Name	Field Description	Field Type	Field Width
Sort_Sequence	Sort order	dbInteger	2
Location	Transect - Direction identifier	dbText	25

Table Name: tlu_Photo_Type
Description: Lookup table of other photo types

Field Name	Field Description	Field Type	Field Width
Other_Type	Non-transect photo type	dbText	12

Table Name: tlu_Rejection_Criteria
Description: Lookup table of reach rejection criteria

Field Name	Field Description	Field Type	Field Width
Rejection_Criteria	Site rejection criteria	dbText	50
Sort_Sequence	Sort sequencing	dbInteger	2

Table Name: tlu_Sand_Modifier
Description: Lookup table of sand modifiers

Field Name	Field Description	Field Type	Field Width
Modifier	Sand modifier	dbText	25

Table Name: tlu_Stream_Name
Description: Lookup table of stream names

Field Name	Field Description	Field Type	Field Width
Stream_Name	Stream Name	dbText	100
Unit_Code	Park Code	dbText	4

Table Name: tlu_Wetland_Code
Description: Lookup table of wetland indicator categories

Field Name	Field Description	Field Type	Field Width
Monument_Code	Wetland indicator code	dbText	5
Wetland_Type	Wetland type	dbText	20

Table Name: xref_Event_Contacts
Description: Cross-reference table between events and contacts.

Field Name	Field Description	Field Type	Field Width
Event_ID	Link to tbl_Events (Event_ID)	dbText	50
Contact_ID	Link to tlu_Contacts (Contact_ID)	dbText	50
Contact_Role	The contact's role in the protocol (Cnt_Role)	dbText	50

Metadata Tables

Table Name: tbl_master_version
Description: Table of protocol version information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
version_key_number	Protocol version key number	dbLong	4
version_key_date	Date of protocol version key number	dbDate	8
narrative_version	Version of protocol narrative	dbDecimal	16
version_comments	Comments regarding version, if any	dbMemo	0

Table Name: tbl_SOP_version
Description: Table of SOP version information

Field Name	Field Description	Field Type	Field Width
version_key_number	Protocol version key	dbLong	4
SOP_number	SOP number	dbLong	4
SOP_version_number	SOP version number	dbDecimal	16
active_flag	Yes indicates SOP is active	dbBoolean	1

Table Name: tlu_projects
Description: Table of NCPN project information

Field Name	Field Description	Field Type	Field Width
project_ID	Project ID number to ensure uniqueness across all projects	dbLong	4
project_name	Project name	dbText	50
project_linkfile	Path and file name of project database	dbText	255
project_include_flag	True indicates project is to be included in query results	dbBoolean	1
project_comments	Comments regarding project, if any	dbMemo	0

Table Name: tsys_App_Releases
Description: Application table - Application release history

Field Name	Field Description	Field Type	Field Width
Release_ID	Unique identifier for the release	dbText	50
Release_date	Date of the release	dbDate	8
Database_title	Title of the database	dbText	100
Version_number	Version control number	dbText	20
File_name	Filename, used to identify older versions of the database	dbText	50
Release_by	Person who made the release	dbText	50
Release_notes	Release notes, which may include a summary of revisions	dbMemo	0
Author_phone	Phone number of application author	dbText	50
Author_email	Email address of application author	dbText	50
Author_org	Organization (NPS Unit code) for the author's place of work	dbText	10
Author_org_name	Name of organization for author's place of work	dbText	100

Riparian Monitoring of Wadeable Streams Protocol for the Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 14

Data Analysis and Reporting

Version 1.03 (September 2016)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	1/2012	D. Witwicki	Correction to basal area calculation; update summary for species richness	Incorrect; no longer measured in 1-m belt	1.01
1.01	3/2013	D. Witwicki, R. Weissinger	Minor changes in wording, addition of hydrologic summaries	Revisions from protocol review	1.02
1.02	9/2016	D. Witwicki	Minor updates to summaries; updates to variance assessment	To match current procedures; based on initial data analyses	1.03

This SOP provides an overview of analysis and reporting procedures. After raw data from the field season are quality checked, they are then summarized to the reach level. Additional QAQC is performed comparing these data to previously collected data to catch misidentified species and values that represent unlikely amounts of change between years. Once data quality issues are resolved, analyses can be conducted. Two general types of analyses are performed: 1) summary reporting of the most recent monitoring observations (summary reports and annual briefs), and 2) comprehensive assessments of the long term data set (assessment of the overall sampling design, evaluation of status and trends, and correlations with other vital signs).

1.0 Data Summary

The sampling unit for wadeable streams analyses is the reach, and sub-samples recorded on transects are scaled to this level (see Figure 1). Summary queries in Access can be used for many of the vegetation summaries. Vegetation and geomorphology data may be integrated at the transect level, but are ultimately summarized to the reach level. Hydrology data are summarized from data taken throughout the water year. There may be cases when reaches are evaluated separately and data are summarized to the transect level, but this SOP will only focus on summary and analysis at the reach level.

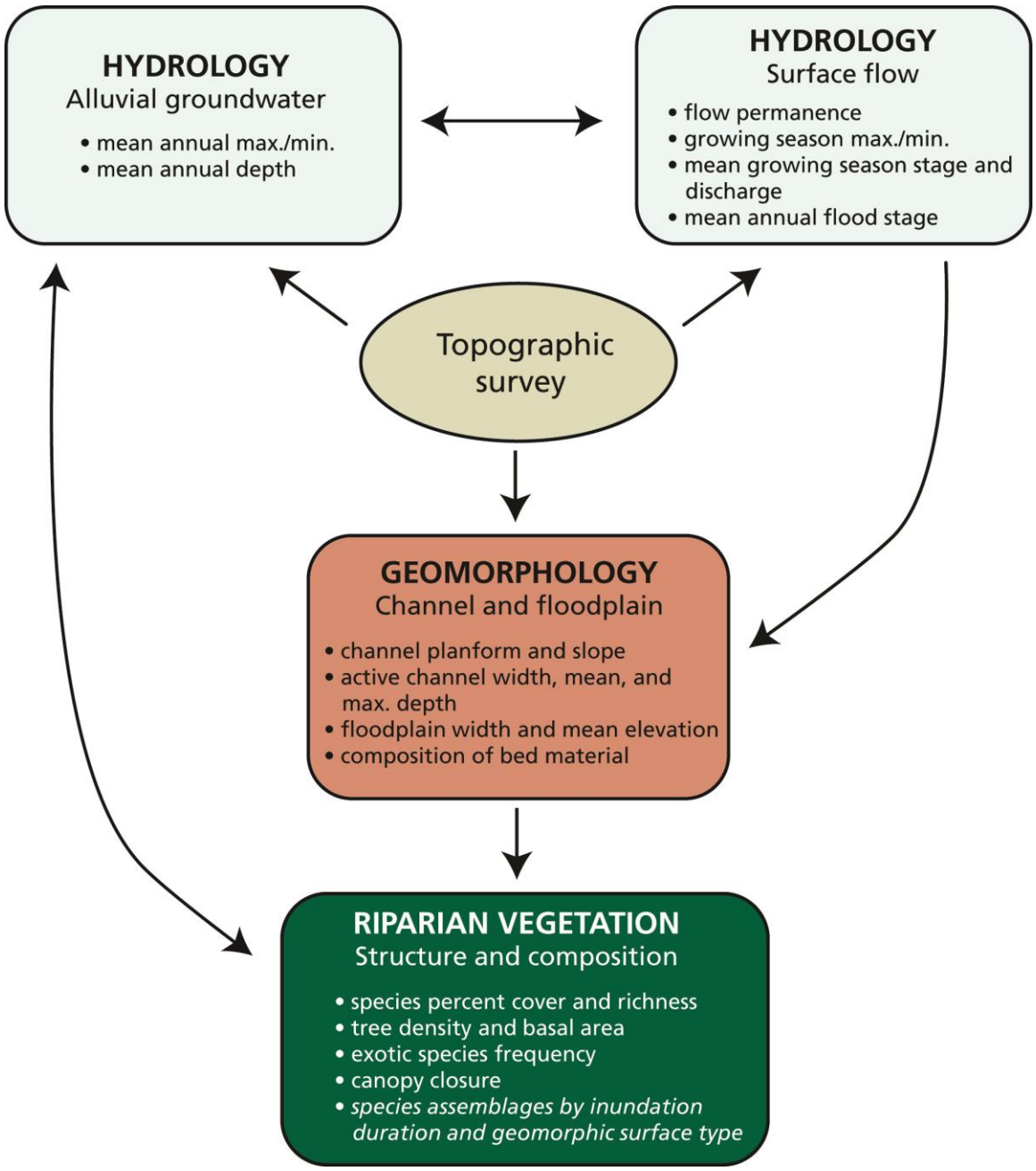

Figure 1. Conceptual model illustrating relationships among measurements for wadeable stream vital signs and their metrics. Geomorphic metrics of channel planform and slope and the vegetation metric for large trees are established at the reach scale. These are integrated with the remaining metrics, which are collected at the transect scale.

Vegetation Summaries

Richness

Species richness is the number of unique species encountered. For each reach, calculate richness of all species, nonnative species, species by life form (e.g., tree, shrub, etc.), and species by wetland status group. Richness of dominant species can be compiled from point-intercept data. It is important that species richness is derived using the same methods and area sampled for all years and reaches in an analysis. Otherwise, rarefaction methods will need to be used if the number of sub-samples changes within or among monitoring plots (e.g., Krebs 1989, Ludwig and Reynolds 1988). In addition, a species list for the reach is assembled using all vegetation measures.

Percent Cover

Percent cover is calculated for each species, life form, wetland status group, ground cover attribute, and disturbance using point-intercept data from transects. It is derived by summing the number of points where each species, etc. is hit, and dividing by the total number of point-intercept readings across all transects, times 100 (eq. 1, Table 1). Canopy closure is the average of all densiometer readings across a reach expressed as a percent (eq. 1, Table 1).

Exotic frequency

Exotic frequency is derived from the number of detections of each exotic species in the 1-m^2 quadrats, and reported as the percent of detections.

Density

Density is derived from trees in the 5-m belt. It is the number of trees counted divided by the total area of the belt transects, scaled to stems per ha (eq. 2, Table 1). This measure is calculated for each species by size class.

Basal Area

Basal area is the cross-sectional area of trees divided by the total area of the 5-m belt transects, scaled to m^2 per ha. Basal area and density are correlated and should always be considered together when reviewing data summaries of each (eq. 3, Table 1).

Census of large diameter trees

The tree census summary includes the total number of trees and the distribution of DBH and crown health classes.

Geomorphology Summaries

After total station survey post processing, relevant geomorphic surfaces are delineated by elevation or abrupt surface breaks on each transect. The data can then be integrated with other measurements or summarized to the reach-level.

Channel morphology

The mean active channel width and depth in meters (eq. 4, Table 1) and the channel slope in meters per kilometer are calculated for the reach using data from the geomorphology

survey transects. The distribution of particle sizes in the channel bed is derived from the pebble count, and the diameter of streambed particles in the 50th and 84th percentiles (d50 and d84) is determined.

Flood plain morphology
The mean flood plain width and elevation in meters is calculated for the reach using data from the geomorphology survey transects. The delineation of the flood plain will be estimated until enough hydrologic data are collected to determine this.

Hydrology Summaries

Summarize hydrologic data by the calendar year of January 1 to December 31 and for the growing season of March 1 to October 31. From the final approved data, calculate a daily mean for each day that has 90% or more observations (87 out of a possible 96 for 15-minute data), starting at midnight and including observations up to 23:59.

For each well, present a time series of all depth to water (to 0.01 m) or discharge (to 0.1 m^3 per second) data for the summary period and a time series of daily mean data for the summary period. For depth to water, reverse the y-axis so that larger values are shown at the bottom of the y-axis and the time series provides a depth profile. Include a table of all manual water depth measurements (to 0.01 m) including the date and time (to minute) each measurement was taken. Include a table of all gaps in the datasets (missing data).

Summary statistics are sensitive to the amount and type of data that are missing from the period of interest. Missing data can occur due to equipment failure, staff turnover, ice, flooding, siltation or other causes. The following metrics may be calculated when 90% or more of the daily means are available. Even then, caution must be used to investigate whether missing data are biased, such as those caused by sensor malfunction during a flood event or those that occur during a period in which the spring peak might have passed. If a metric cannot be calculated, document why.

Table 1 presents a summary of metrics that should be presented for each stream type and summary period, with additional details on calculating metrics provided below. Metrics were chosen to reflect changes in both the amount and timing of flow/stage over time. Discharge summaries can only be calculated after an acceptable rating curve is in place. Perennial streams include the Fremont River (CARE) and the East Fork of the Virgin River (ZION). Courthouse Wash (ARCH) is intermittent, and Armstrong Canyon (NABR) is ephemeral.

Table 1. Summary of stage and discharge metrics calculated for each stream type and summary period. See the text for additional information on how each metric is calculated and presented.

Metric	Perennial	Intermittent	Ephemeral	Annual	Growing Season	Monthly
Median	X	X	X	X	X	X
Minimum	X	X	X	X	X	X
Maximum daily	X	X	X	X	X	X
10th quantile	X	X	X	X		
30th quantile	X	X	X	X		
70th quantile	X	X	X	X		
90th quantile	X	X	X	X		
Absolute maximum	X	X	X	X		
Spring peak	X	X	X	X		
Center of volume	X	X	X	X		
Total volume	X	X	X	X		
Channel overflow	X	X	X	X		
Flow permanence		X	X	X		
End of flow		X	X	X		
Beginning of flow		X	X	X		

Calculate the following summary statistics for annual, growing season, and monthly datasets for each well for depth to water (to 0.01 m) or discharge (to 0.1 m^3 per second):

- Minimum daily mean ± one standard deviation, date, day of year from Jan. 1 (DOY)
- Median daily mean ± one standard deviation, date, DOY
- Maximum daily mean ± one standard deviation, date, DOY

Calculate the following summary statistics for annual daily mean datasets:

- 10th quantile daily mean ± one standard deviation
- 30th quantile daily mean ± one standard deviation
- 70th quantile daily mean ± one standard deviation
- 90th quantile daily mean ± one standard deviation

Present the following summary statistics for annual 15-minute datasets:

- Absolute maximum stage or discharge

For instream well or gage data, additional surface water summaries include:

- Spring peak - date and DOY when spring peak flow occurs, defined as the highest daily mean in the relatively smooth hydrograph corresponding to snowmelt run-off
- Center of volume - date and DOY on which half of annual mean volume has passed through the system

- Total annual volume – calculated as the sum of (daily mean * 60 seconds * 60 minutes * 24 hours) in m^3 to 4 significant digits
- Channel overflow - using the 15-minute instream well data: number of events during which surface water overflowed the channel, duration of overflow (to 0.25 hours), date of each event. The specific elevation that determines overflow is derived from the contemporary channel cross-section data for the well transect at each reach.

For intermittent and ephemeral instream wells:

- Flow permanence - annual and growing season % of days with flowing surface water, defined as daily mean water elevation (to 0.01 m) greater than or equal to the channel thalweg elevation defined by the contemporary channel cross-section survey
- End of flow - date and DOY when continuous surface flow ceases in spring or summer, defined as >1 day with daily mean water elevation (to 0.01 m) less than the channel thalweg elevation defined by the contemporary channel cross-section survey
- Beginning of flow - date and DOY when continuous surface flow resumes in fall, winter or early spring, defined as >1 day with daily mean water elevation (to 0.01 m) greater than the channel thalweg elevation defined by the contemporary channel cross-section survey
- Longest disturbance-free period – Greatest number of days bracketed by floods and/or dry periods

Integrated Summaries

Vegetation data are integrated with the geomorphology survey transects to derive mesic to xeric plant cover by surface elevation and species richness and percent cover by geomorphic surface elevation. Vegetation data are integrated with the hydrology data to derive species assemblages by inundation duration and frequency.

Inundation duration of the floodplain (% of growing season) will be determined using geomorphology surveys and hydrologic data, and will be more meaningful as additional floods are recorded. Inundation frequency of the floodplain (return frequency in years) requires multiple years of hydrologic data in addition to a survey of the flood plain.

Table 1. Formula for deriving reach-level measures.

Percent Cover

$$PC = (h / n)*100 \quad (1)$$

where PC = percent cover
h = the number of points where each species, ground cover attribute, life form, or overstory is hit
n = the total number of points per reach

Tree Density

$$D = 10{,}000 * t / (\sum_{i=1}^{q} z_i) * w \quad (2)$$

where D = density of trees in stems/ha
t = the number of trees in the 5-m belt
z_i = length of riparian transect i
q = total number of riparian transects
w = width of belt transect in m

Basal area

$$BA = (\sum_{i=1}^{y} [(DBH_i /[2*100])^2 * \pi]) / [(\sum_{i=1}^{q} z_i) * w / 10000] \quad (3)$$

where BA = basal area in m^2/ha
DBH_i = diameter at breast height in cm for tree i in the 5-m belt
y = the total number of trees with DBH measures
π = 3.142
z_i = length of riparian transect i in m
q = total number of riparian transects
w = width of belt transect in m

Mean (channel width, etc.*)

$$M = (\sum_{i=1}^{v} c_i) / v \quad (4)$$

where M = mean channel width in m
c_i = channel width in m for transect i in a reach
v = the total number of transects in the reach

* channel width shown in this example, but this formula is also used for channel depth, flood plain width and elevation, annual and growing season stream stage, annual and growing season stream discharge, annual flood stage, and depth to ground water.

2.0 Data Quality Assessment

Before data analysis and reporting, reach-level data should be additionally evaluated for reasonable levels of change based on historical conditions at each reach. For instance, a measure may appear to be valid based on the database domain, but represent an unreasonable (and unlikely) change in reach conditions since the last field visit. Summarized attributes should be compared between years, and all suspect values (large increases or decreases) should be flagged and resolved before the data are analyzed. In addition, data should be evaluated for the omission of historically dominant species or the appearance of dominant species not detected in previous years. New occurrences of a species should be compared with the park-level species list and species-range limits.

Suspect measures or species should be evaluated by field crew members and by field verification if possible. Any corrections made to the database should be recorded in the QAQC log. Suspect data that are not resolved should also be flagged in the QAQC log so that it can excluded from analyses, if appropriate. Suspect data that cannot be resolved in the office should be brought to the attention of the field crew at the next monitoring visit so that they may eventually be resolved.

3.0 Summary Reports and Annual Briefs

Summary Reports
The primary objectives of the summary report are to 1) document monitoring activities for the period of record, 2) summarize data and describe the current condition of resources, and 3) provide information to park managers in a timely manner that increases data utility and communication. A separate report is completed for each NCPN park unit with wadeable streams monitoring. Existing NCPN reports should be consulted for formatting.

Annual Briefs
Each year, information from summary reports and other analyses is further summarized in 1-2 page briefs that provide resource managers with a concise summary of issues of concern. NCPN produces two types of briefs: vital signs briefs and park briefs. The wadeable streams vital signs brief summarizes findings from wadeable streams monitoring in all NCPN parks. Park briefs are produced for each NCPN park unit and contain a section on wadeable streams monitoring. Existing vital signs briefs and park briefs should be consulted for formatting.

4.0 Comprehensive Assessments

Comprehensive analyses and reports are completed periodically on the long term data set. Comprehensive reports should be structured like typical scientific manuscripts (introduction, methods, results, discussion, and literature cited sections) and may include any of the analyses described in this section.

Sampling-Design Variance Assessment

The sampling design for riparian monitoring at each stream is documented in a separate report that outlines specific sampling objectives and in Appendix A. Periodic checking of the assumptions of the sampling design affords timely opportunities to invoke enhancements to meet the original monitoring and sampling objectives. Sampling designs are evaluated by calculating variance and power for trend, and assessments are recommended every 5-7 years.

Variance estimates are derived from all years of monitoring data, not just observations from the current field season. Where necessary, alternative survey designs are evaluated to determine appropriate enhancements, such as an increase in sample size or more frequent visits to established reaches, to achieve the original sampling objective. Power-for-trend is evaluated with alternative numbers of panels, sample sizes, and re-visit schemes. A trend may be reported as a yearly rate or a rate over a set number of years. This conversion is outlined for increasing (eq. 5, Table 2) and decreasing (eq. 6, Table 2) rates of trend. Results are then used to determine which survey designs best meet the original sampling objectives.

Preliminary assessments of riparian monitoring data suggest that inference to the stream level may be difficult due to the low number of reaches sampled on each stream, the relatively short length of each stream within the sampling frame, and the need for consistent data before and after flood events. If survey designs are abandoned in the future, this particular variance assessment would not be needed, but an assessment of the overall sampling design would continue in some form.

Table 2. Formula for converting a yearly rate of trend to a rate of trend over a set number of years.

Conversion for rate of trend

$$I = e^{rt} \quad (5)$$

$$D = 1 - e^{rt} \quad (6)$$

where;

I = % increase over t years
D =% decrease over t years
r = the yearly rate of increase or decrease
t = the total time period of increase or decrease

Status and Trend Assessments

The underlying motivation for using survey designs to monitor wadeable streams is the ability to make inferences to a finite, target population. Alternatively, model-based designs and assessments rely on modeled relationships, and thus tend to have inherent assumptions, and in some cases, limitations in terms of the scope of inference. However, model-based assessments may be useful to help explain reasons for trends observed in survey-design efforts, and information from other vital signs monitoring (e.g., climate, air quality, land use, land condition) or other sources may prove critical to interpreting observed wadeable stream trends. Bayesian methods may detect trends earlier than frequentist methods and should be developed over time.

Status and trend analyses are performed after at least 5 years of monitoring data are collected. Data are analyzed for the period of record (long-term trends), and for any period where 1) a change is expected to have occurred due to a known impact at or upstream of the site (e.g., a major flood event) or 2) a change is apparent after a graphical inspection of the data record. When significant trends are detected, reasons for these trends should be evaluated by literature reviews, comparison with similar data sets, and additional assessments using ancillary information. When unidirectional trends are not detected, correlations may help us understand system drivers.

Frequentist Methods

Frequentist trend assessments of complex survey designs are performed using a mixed-effects model (Larsen et al. 1995). Reach-scale measures are used in the model and evaluated on the basis of time. The output from this model is a measure of the intercept and slope, the significance of the slope and intercept being different from zero, and measures of the variance and covariance of the regression parameters. A significant slope indicates a significant trend at the alpha level used to assess significance or below.

Status is the condition of the attribute and is derived in two ways. If the trend slope is not significantly different from zero, mean and variance of status is simply the mean and variance of all measures of the attribute up to the current time period. If the slope is significant, then status is the solution of the regression model for the latest time period of the data used to generate the trend line (eq. 7 in Table 3). Variance measures of mean status are derived from the covariance matrix of the regression coefficients (eq. 8 in Table 3).

Table 3. Formula for deriving status and trend estimates.

Mean Status From a Trend Line

$$ST_t = b_0 + b_1 * t \qquad (7)$$

where;

ST_t = estimate of mean status at time = t
b_0 = the estimated intercept parameter
b_1 = the estimated slope parameter
t = the most recent time period of the data (in the same units used to generate b_0 and b_1)

Standard Error of Status

$$SeSTt = \sqrt{(\sigma^2_{b0} + 2t\ \sigma_{b0b1} + \sigma^2_{b1}t^2)} \qquad (8)$$

where;

$SeST_t$ = the standard error of the mean-status estimate at time = t
σ^2_{b0} = the variance of the intercept parameter
σ_{b0b1} = the covariance of the regression parameters
σ^2_{b1} = the variance of the slope parameter
t = the most recent time period of the data

Model-Based Methods

Model-selection procedures consider a range of potential factors influencing directional change in resource conditions. Even if a significant trend occurs as a function of time, the relationship between other explanatory variables and riparian measures should be evaluated to determine potential 'causal' factors of trends. These other explanatory variables can include biophysical features of the reaches as well as measures from other vital signs monitoring (e.g., climatic conditions).

Model selection methods (Burnham and Anderson 1998) evaluate the explanatory power of different models of trends in riparian measures. Multiple models are considered, each with different combinations of independent variables and interaction terms. All models should be based on hypothesized, ecologically meaningful relationships. Adjusted AIC (Akaike's Information Criterion) values generated with a mixed-effects model are used to determine the best predictive model as well as the importance of independent variables.

The primary model in this model-selection procedure is the response of interest vs. time (see frequentist methods above). Alternative models can be based on measures of climate, air quality, land use, and land condition, as well as other measures that may be considered important. When evaluating other variables, they are either included in an interaction with time or time is replaced with the variable.

The result of the model-selection procedure is the selection of the model (i.e., set of independent variables) which best predicts the trend of the response variable. This, in turn, aids in explaining reasons for the observed trend. For instance, if alternative models with one or more driver attributes (e.g., drought days) accounted for more variance than just using time, trends may be attributed to these attributes in a correlational relationship, but not necessarily a causal relationship. If alternatives to time account for less variance, other avenues of investigation should be considered to explain reasons for observed trends.

Bayesian Methods
Bayesian methods for trend assessment identify the probability of different slope-parameter values (Gelman et al. 2000, Wade 2000) given the observed data. This differs from frequentist methods which calculate the probability of observing data given a specific value for a parameter, such as the null hypothesis. Assessing the probability of different slope values is potentially important for various reasons. First, sampling designs are largely based on a few key features. The minimum detectable trend at a reasonable power level for many of the other responses will likely be much higher. Estimating the probability of slope values may be the best way to provide insight into trends for these attributes. Second, even for the key features around which sampling designs were based, Bayesian methods may reveal the potential of declining trends before rejecting the null hypothesis that the regression slope equals 0 with conventional statistics.

Bayesian methods use a likelihood distribution generated from the sample data that provides the probability of observing the data for every possible parameter value. Combining this with a prior distribution produces a posterior distribution which is used to make inference about parameters. The prior distribution reflects previous knowledge about the distribution of parameters. In the absence of such knowledge, a non-informative distribution can be used, which essentially is a uniform distribution across the range of the likelihood distribution. In subsequent analyses, the posterior distribution of previous assessments is used as the prior distribution. The posterior distribution allows assessments of the probability of user-selected parameter values. The probability of various increasing and decreasing slopes should be evaluated based on the posterior distribution and the consequences of not alerting management of a potential trend. The result of this assessment is the derivation of the probability of different levels of decline/increase. Even though conventional statistics may not reveal a significant trend, relatively high probabilities (e.g., $\geq$0.70) of trends with a Bayesian method may warrant special attention.

Correlations
There will be instances where a monitored attribute fails to exhibit a trend (i.e., a direction change), but instead may have periods of decline followed by recovery. In other words, natural variation may be more evident than a precipitous decline or increase, and it may mirror the variation in a key driver attribute. Discerning this variation and reasons for it can involve many complex procedures. As a first step, however, correlational methods can provide useful insight and are relatively simple.

For attributes that fluctuate between declines and increases, correlations with climate, air quality, land cover/use, land condition, and other potential drivers should be considered. Strong correlations between a response and driver may be sufficient to understand reasons for the observed variation over time (e.g., strong correlation between shrub cover and annual precipitation).

Another type of correlation assessment is path analysis (Lindquist 2000). This method accounts for the inter-correlated structure among factors by decomposing correlations to

direct and indirect effects. For instance, changes in grass cover in a shrub-steppe system may be influenced by shrub cover alone or by climate alone or by the influence of climate on shrub cover. A path analysis would decompose the effects of climate and of shrubs on grass cover, while considering the combined influence of climate and shrubs. The result of a path analysis is the indication of the strength of direct and indirect factors on a response, thus providing insight into reasons for the observed changes in a response. Path analysis is based on correlation values and the simultaneous solution of structural equations. Simple examples of the construction and use of path analysis are provided in Lindquist (2000) and Van Bruggen and Arneson (1986); details of path analysis are provided in Pugesek et al. (2003).

5.0 References

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Riparian Monitoring of Wadeable Streams Protocol for Park Units in the Northern Colorado Plateau Network

Standard Operating Procedure (SOP) # 15

Revising the Protocol Narrative and SOPs

Version 1.08 (November 2019)

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	4-1-2009	H. Thomas	Updated master version table (MVT)	To reflect protocol changes based on field work.	1.01
1.01	4-1-2010	H. Thomas	Updated MVT	To reflect protocol changes based on field work.	1.02
1.02	1-12-2012	H. Thomas	Updated MVT	To reflect protocol changes based on field work.	1.03
1.03	6-6-2013	H. Thomas	Updated MVT	To reflect protocol changes based on field work.	1.04
1.04	3-4-2014	H. Thomas	Updated MVT	To reflect protocol changes based on field work and finalize protocol following peer review.	1.05
1.05	4-7-2015	H. Thomas	Updated MVT	To reflect protocol changes based on field work.	1.06
1.06	9-30-2016	H. Thomas	Updated MVT	To reflect protocol changes based on field work and prepare for publication.	1.07
1.07	11-18-2019	K. Long	Updated MVT	To reflect protocol changes based on field work.	1.08

This SOP explains how to make and track changes to the protocol narrative and related SOPs. Following these guidelines ensures that data collection and processing procedures are documented and retained for use and interpretation of historical data sets. Project staff should refer to this SOP when any changes to an approved protocol document are necessary. The procedures in this SOP are based on the NCPN Protocol Versioning Guidance Document (NCPN-NPS 2009).

Procedures

1. Modifications must be reviewed for clarity and technical soundness. Small changes or additions to existing methods will be reviewed in-house by NCPN Inventory and Monitoring staff. An outside review is required for substantive changes in methods. Regional and national staff of the National Park Service and experts outside of the Park Service with familiarity in vegetation monitoring, hydrology, geomorphology, and data analysis will be used to review major changes.

2. Record all changes to a protocol document (protocol narrative or SOP) in the document's revision history log, even minor edits like fixing typos or formatting changes. It is not necessary to record the specific edits made, rather just the fact that typos were fixed or formatting changes were made. For minor edits, record the same document version number in the revision history log. For actual protocol changes (e.g., changes in methods, equipment), assign a new version number in the revision history log. Depending on the significance of the changes, it may be okay to combine multiple changes in the same entry in the revision history log. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision, author of the revision, and the reason for the changes along with the new version number (if applicable).

3. Narrative and SOP updates may occur independently. That is, a change in one SOP will not necessarily invoke changes in other SOPs; a narrative update may not require SOP modifications. The NCPN tracks the narrative and SOP version numbers in a Master Version Table (MVT), which is maintained in this document (SOP #15). Any time a narrative or an SOP version change occurs, a new record is added to the MVT.

4. New versions of the protocol narrative and SOPs must be posted on the NCPN website. Older versions of the protocol narrative and SOPs must be archived in the NCPN Riparian Protocol Library: (R:\Monitoring_Archive\Riparian\Protocol).

Master Version Table

A reorganization of the protocol occurred after the 2010 field season. As a result, some SOPs were renumbered. To simplify version tracking, two master version tables are maintained, one for the initial SOPs (2008-2010), and one for the current SOPs (2011-present).

A dash ("-") in a cell indicates that the narrative or SOP is not applicable during the corresponding time period. An "x" indicates that an SOP has been discontinued.

Riparian Monitoring of Wadeable Streams, Master Version Table, 2008-2010

Effective Date	Narrative	1-Preparations for the Field Season	2-Hiring & Training Field Technicians	3-Using GPS Units	4-Reach Establishment	5-Transect Setup	6-Point Intercept Transect	7-Line Intercept Transect	8-Belt Transect	9-Measuring Trees	10-Unknown Plants	11-Repeat Photos	12-Site Impact Assessment	13-Pebble Count	14-After the Field Season	15-Revising the Protocol
1/1/2008	-	1.00	-	-	1.00	1.00	1.00	1.00	1.00	1.00	-	1.00	1.00	-	-	1.00
1/1/2009	-	1.00	-	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.00	1.00	1.00	1.00	-	1.01
1/1/2010	-	1.00	1.00	1.00	1.00	1.00	1.00	x	1.01	1.02	1.00	1.00	1.01	1.00	1.00	1.02

Riparian Monitoring of Wadeable Streams, Master Version Table, 2011-present

Effective Date	Narrative	1-Preparations for the Field Season	2-Hiring & Training Field Technicians	3-Using GPS Units	4-Reach Establishment	5-Repeat Photos	6-Measuring Vegetation	7-Pebble Count	8-Site Impact Assessment	9-Stream Channel Surveying	10-Hydrologic Monitoring	11-After each Field Visit	12-After the Field Season	13-Data Management	14-Data Analysis & Reporting	15-Revising the Protocol
1/1/2011	1.01	1.01	1.00	1.03	1.01	1.01	1.04	1.00	1.01	1.01	1.01	1.01	1.00	1.01	1.01	1.03
1/1/2012	1.01	1.03	1.00	1.04	1.01	1.01	1.05	1.00	1.01	1.01	1.02	1.01	1.00	1.02	1.01	1.04
1/1/2013	1.03	1.04	1.01	1.04	1.02	1.02	1.10	1.01	1.02	1.02	1.04	1.02	1.01	1.03	1.02	1.05
1/1/2014	1.03	1.06	1.01	1.04	1.03	1.03	1.12	1.01	1.02	1.03	1.05	1.02	1.01	1.04	1.02	1.06
1/1/2015	1.05	1.09	1.03	1.05	1.05	1.05	1.15	1.02	1.02	1.05	1.06	1.03	1.02	1.05	1.03	1.07
1/1/2019	1.05	1.09	1.03	1.05	1.05	1.05	1.17	1.03	1.02	1.05	1.06	1.03	1.02	1.05	1.03	1.08

References

NCPN-NPS 2009. Protocol Versioning Guidance Document, Version 1.0. National Park Service, Inventory and Monitoring Program, Northern Colorado Plateau Network, Moab, UT.