

Riparian Monitoring Protocol Implementation Plan for Park Units in the Southern Colorado Plateau Network

Standard Operating Procedure (SOP) #6

Stream Channel Surveying

Version SCPN_Riparian_SOP6_20180930

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP is adopted from the Northern Colorado Plateau Network's SOP #6 Measuring Vegetation, Version 1.14 (March 2018) in Weissinger, R., D. Witwicki, H. Thomas, A. Wight, K. Lund, and M. Van Grinsven. 2018. Riparian monitoring of wadeable streams protocol for park units in the Northern Colorado Plateau Network: Version 1.05. Natural Resource Report NPS/NCPN/NRR—2018/1636. National Park Service, Fort Collins, Colorado, and the Northern Colorado Plateau Network's SOP #16 Trimble RTK Basic Operating Instructions in the Field, Version 1.00 (April 2017) in Perkins, D. W., M. Scott, G. Auble, M. Wondzell, C. Holmquist-Johnson, E. Wahlig, H. Thomas, and A. Wight. 2018. Big rivers monitoring protocol for park units in the Northern Colorado Plateau Network: Version 1.01. Natural Resource Report NPS/NCPN/NRR—2018/1707. National Park Service, Fort Collins, Colorado.

This SOP gives detailed instructions for surveying the stream channel using a total station or RTK 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 and RTK 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. If surveying with RTK, there must be one person with in-depth knowledge of base station set-up and operation of rovers.

This SOP starts with total station information on page 1, followed by RTK operation (Section 3) on page 17. Once the total station and RTK is set up then the actual surveying procedures are outlined in Section 12 on page 71.

1. Total Station 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 SCPN currently uses a Topcon GTS239 total station instrument, Trimble Recon data collector with SurveyPro software, and Microsoft Excel software for data post-processing in the office. Terramodel software is sometimes used for initial data checking and rectification. Refer to the Topcon Total Station and SurveyPro 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 prism rod can be swapped out as a rover rod when using RTK.
- 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 cases. 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 bottom section (the largest rod), followed by the next-to-top section and so forth, unless otherwise directed at the beginning of the survey. 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. When using the leveling rod, be sure that each rod extension has snapped fully into place before the shot is taken.

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 it is 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 – When a tagline is being used, 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. During a stake-to-line transect line survey, use flagged points on the line and the position of the person at the previous shot to roughly position yourself on the transect line. Square the prism to the total station and allow the total station operator to take a shot; the operator will communicate to you the direction (upstream or downstream) and distance to the line. Reposition for the next shot attempt. It is better to move efficiently to the next approximate shot position and let the total station “do the work” than to spend a lot of time gauging the precise transect line location.

Timing of prism direction – It is crucial that 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. Alternatively, take a copy of the Topcon atmospheric correction chart (p. 12-4 of Topcon manual) into the field.
- B. In the field, locate headpins for all transects at the reach, and mark with pin flags and flagging. Positioning and driving headpins may be completed during the initial site survey.
- 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 at least 4 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 SCPN, 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 SCPN; 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 not 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.

- A. Set up the total station. The survey lead will set up the total station at the initial occupied point, using standard leveling procedures:
- 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 Topcon Total Station manual for more details). Ideally, be within $\pm 10''$. 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.
 - 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 immediately 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).

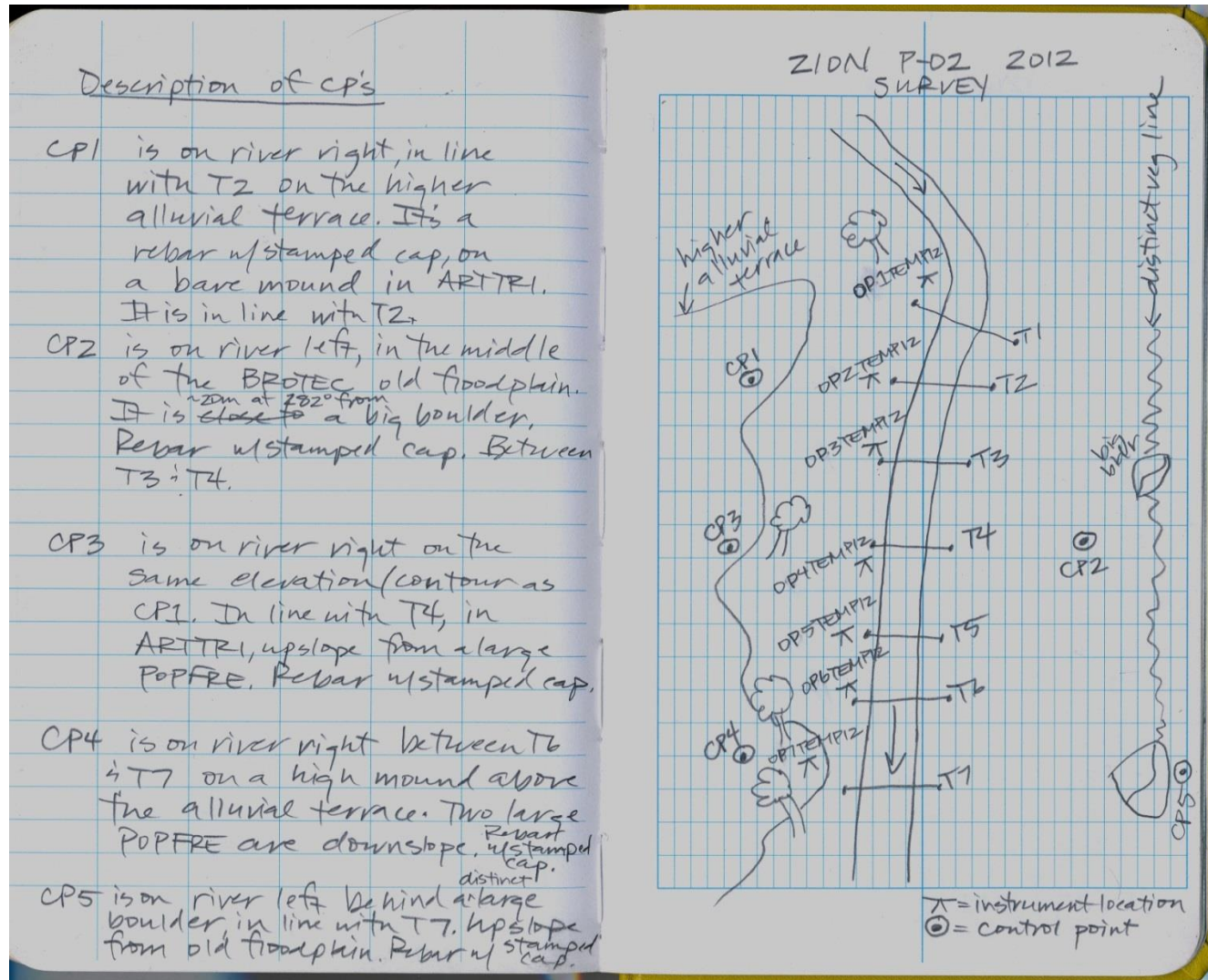


Figure 4. Example of survey field notes that describe the location of each control point and include a sketched map of transects, headpins, control points, and other distinguishing features of the reach. Codes are defined in Table 1.

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
EW	0.003	VD 0.006

3/6/12 ZION P-02

Establishing survey.
Surveyor: K. Lund
Rod persons: 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.
Leaf buds 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.

BSing to CP1.

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
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

Survey terminology	Code	Definition
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 SCPN. 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 not 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.

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 - 0.050 m (5 cm).

Ideally, it is best to have < 0.030 m (2 cm) error.

Vertical (includes elevation): 0.000-0.030 m (3 cm).

Ideally, it is best to have <0.01 m (1.0 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.

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.

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\corrPARK_Reach_YEAR

Original folder = X:\Active_Monitoring_Projects\Riparian\Data\Geomorphology\PARK\PARK_Reach_YEAR\origPARK_Reach_YEAR

Field Crews folder = X:\Active_Monitoring_Projects\Riparian\Field_Crews\PARK

Riparian monitoring spatial data folder = G:\GIS\Data\Parks\PARK\Monitoring\SCPN_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. 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. Overview of Trimble GNSS survey system

This document describes setup and operation of the Trimble R6 GNSS survey system used by Northern Colorado Plateau Network (NCPN). The equipment is configured for single-base radio-broadcast RTK method.

This system depends on using a coordinated point for setting up the base receiver.

- If you are starting a new survey at a new site and have no known coordinated points then you need to first select a base station location. See *Base Station Selection (section 1.2)*.
- If you are re-surveying a known site then you may need to find the base point using the controller as a hand-held personal GPS device. See *Using the controller as a “stand-alone” GPS device (section 2.5)*.

3.1 The Gear: Trimble R6 Model-4 system using one rover.

The equipment shown is configured primarily for a single base radio broadcast RTK survey method with one rover, however, additional rovers may be used as equipment and personnel allow. Figure 6 provides a general idea of what a minimal setup might look like when packed for transport. We often have an additional Pelican case and base battery as well as an additional solar charger setup to charge spare batteries, computers, I-pad, etc. at camp. This is the minimal setup we use for an RTK system using one rover. Typically, we are in remote areas in difficult terrain making a return trip to the base for any reason during a survey, other than to turn it on or off, very time consuming and inefficient. We minimize two common problems (power failure and wind tip-over of the radio antenna) by using a solar battery charger and mounting the base receiver and radio antenna on high quality solidly built tripods.



a)

b)



Figure 6 – Trimble R6 Model 4 GPS surveying equipment. a) equipment packed up in Pelican cases and bags b) GPS equipment completely unpacked.

3.2 Base Station Selection:

This topic is often overlooked in the rush to get the base set up and get surveying so others who need the survey data can also get to work. However, base station selection can have a very strong impact on how efficiently, or inefficiently, this survey system functions. Because we are using single base radio broadcast RTK survey method, any wireless communication problems involving satellite signal and/or radio broadcast issues can cause extensive time consuming delays. Following are some helpful guidelines when deciding on where to set the base point (in order of importance):

1. Pick a site that will allow for the best radio coverage to the sites it serves. Generally this will be an elevated prominent spot if available.
2. Stay away from potential multi-pathing obstructions like chain link fence, canyon walls, large monoliths, etc.
3. The site needs to have adequate sky visibility. Look for a spot that has the least amount of tall obstructions like tall trees or canyon walls nearby. Better visibility to the South is preferred if you have to make a choice.
4. What kind of permanent monument can you use (or are allowed to use) to mark the point?
5. Reasonable accessibility to haul the gear in and out?

Example Base station setup:

Figure 7 shows a typical base station setup showing the base receiver over a survey mark (X engraved into rock, Figure 9), the broadcast radio mounted on one of the legs of the base receiver tripod, broadcast/transmit antenna (relatively short -- about 3m tall mounted on the other tripod), and the power system (base battery and solar charger).

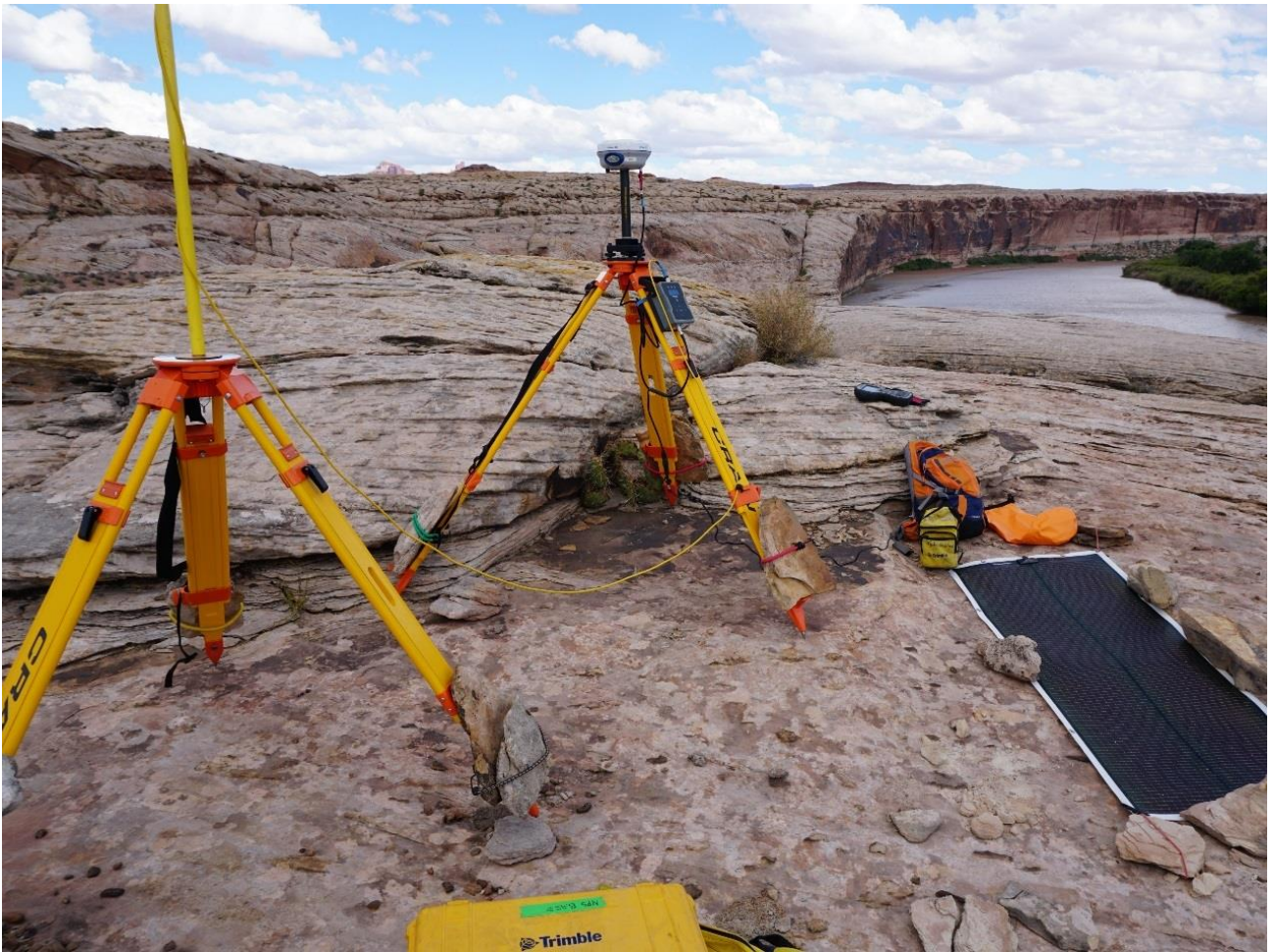


Figure 7 – Example of base station setup with base receiver, radio antenna, battery and solar panel

Notice the rocks bungeed onto the tripod legs to help prevent wind topple and the solar panel is weighted down also. The tripod legs are spread out relatively wide and the height is kept relatively short.

This base point was chosen to provide the best radio broadcast to the three sites it serves (Millard Canyon, Queen Anne, and Bonita Bend in Canyonlands NP) while maintaining good sky visibility for the base receiver and acceptable accessibility to haul the equipment in and out. This setup has slightly different looking components but function identically to what is pictured in the equipment layout photo. For instance, the radio coax cable here is yellow, not black and the stubby rod is black, not yellow.

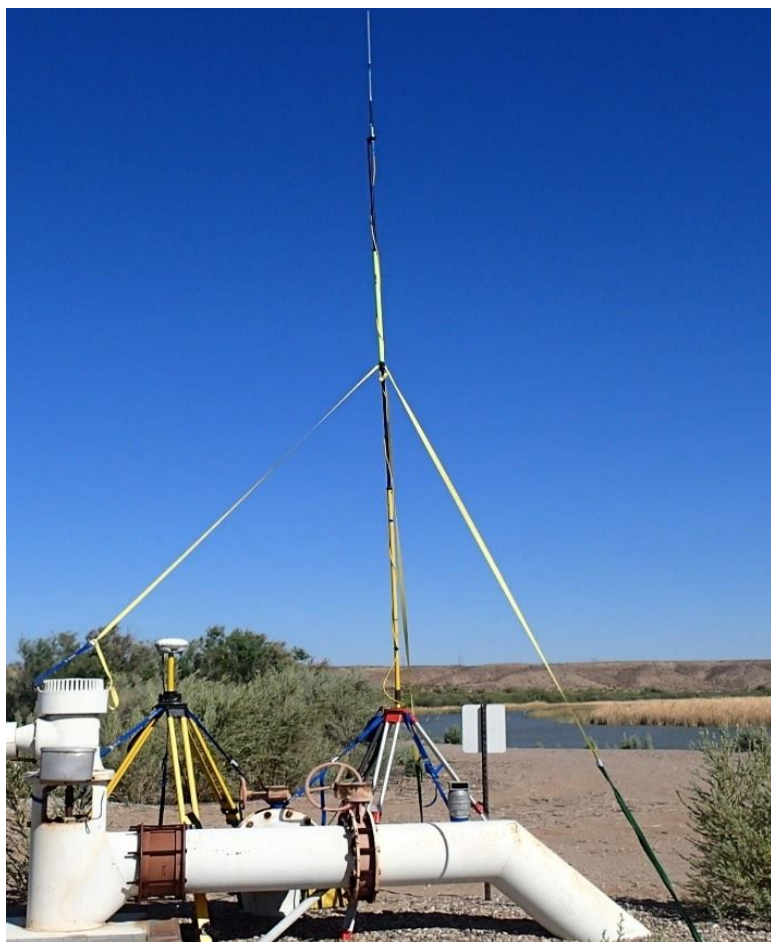


Figure shows an example of where there was no higher ground within reasonable proximity to the survey site to locate the Base radio and antenna. As a result, the surveyor chose the base point based on the other criteria listed above but had to rely on a tall radio broadcast antenna (approximately 20 feet tall) and high transmit power (35 Watts) to make the RTK survey system work effectively throughout the entire area of interest. Rover receivers still experienced radio reception drop-out in some places where dense vegetation was present. In this situation, a repeater radio could be utilized if one is available to re-broadcast the base radio signal further. Currently the NPS NCPN group does not have a repeater radio setup.

Figure 8 – Example of base radio setup with a tall antenna mast



Figure shows an example of a typical base point where permanent rebar/markers are not able to be placed. In these circumstances a 1-2 inch cross/plus is engraved into a rock surface using either a grout saw, rock chisel, or a battery operated Dremel tool. These markings are very unobtrusive and, unless you have been to the location repetitively, you will need to use the TSC3 survey controller (or similar) in the stand-alone GPS mode to navigate to the point. These crosses can fill in with a little sand/silt and become nearly invisible. Often we put a somewhat ‘suspicious looking’ rock or group of

rocks over it to mark the spot.

Figure 9 – Example of base station cross/plus etched into rock surface

4. Trimble TSC3 Hand Controller

This section describes controller operation and functionality for the Trimble Survey Controller Model-3 (TSC3) device (*Figure*). This is a Windows OS device with touch-screen capability. Although it has many features and functionality, only certain functionality is enabled on this device, namely:

- Global Navigation Satellite System (GNSS) functionality using external receivers and radios for precise survey methods. (For us that means single base, radio broadcast, RTK method and other static/semi-static methods.)
- Stand-alone GPS navigation and positioning as a hand-held unit. (Internal GPS)
- USB and Bluetooth communication standards.
- Compass, Camera and Flashlight

4.1 Controller notification and keys:

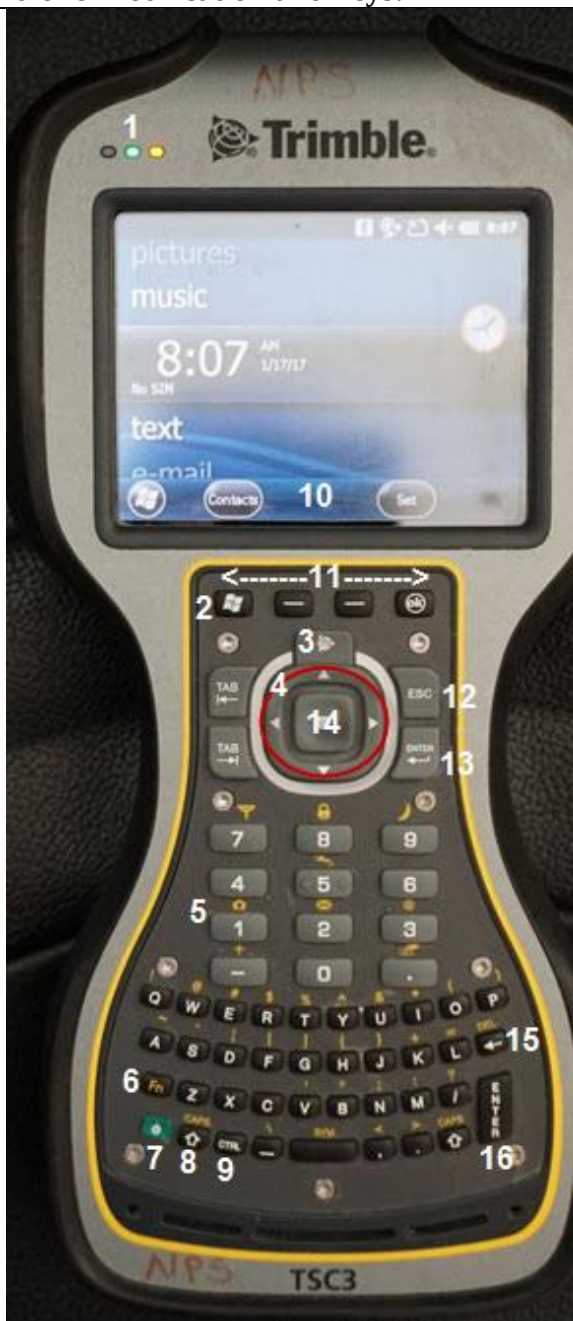


Figure 10 – Trimble TSC3 hand controller

1. LED status lights

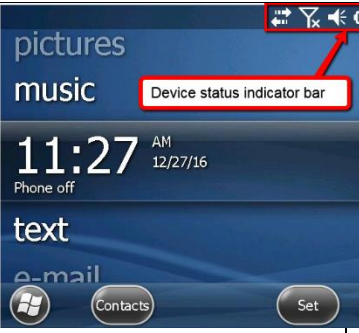
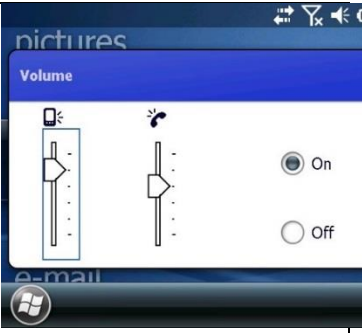
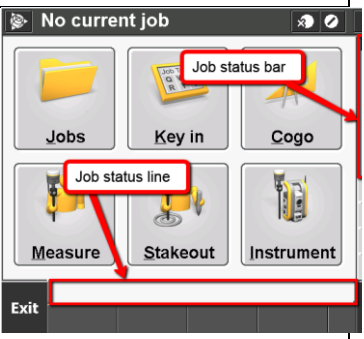
Notification LEDs

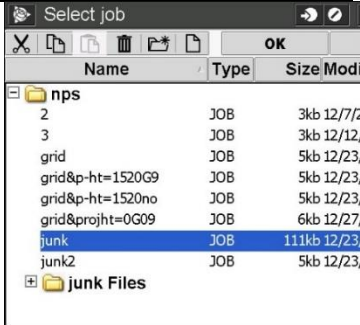
At the top of the unit are three LEDs that provide status information

Left LED 	Center LED 	Right LED 
Colors: amber, green, red	Colors: amber, green, red	Colors: amber, blue, green
Battery Status: Green: fully charged Amber: charging Red: battery error	OS Status (application dependent): Red-blinking: alarm WWAN Status: Amber-blinking: 2G connection Green-blinking: 3G connection (if OS status alarm and WWAN is on, the red will blink faster)	Bluetooth on: Blue-blinking Wi-Fi on: Amber-blinking GPS on: Green-blinking (LED will flash in a sequence if multiple features are on)

2. Windows key
3. Trimble Access key
4. Curser direction (arrow) buttons
5. Camera key (Fn > 1)
6. Function (Fn) key
7. Power key (green). Quick press for On/Off. Hold for reset (warm boot).
8. Upper case (Caps) key. One press for one-time use, Fn > Caps for continued Upper case.
9. Control (CTRL) for shortcut functions.
10. Touch screen with screen protector. Keep a spare one or two in the field with you.
11. These four black keys can control the soft key displays above them if there are any.
12. Escape (ESC) key
13. Enter key
14. Enter button
15. Backspace/Delete key (position curser past item to be deleted)
16. Enter key

4.2 Opening a Job from the Device Home screen:

		
a.) The <i>Device Home</i> screen. Notice the <i>Device Status Indicator bar</i> at the top.	b.) Tapping on the device status bar opens an icon menu for the active device functions.	c.) Tapping on the Speaker icon opens the sound options, pick the one on the left to adjust the volume and options for ON/Off.
		
e.) Tapping the <i>Clock</i> icon brings up the time and date options. For accurate records, please check/set the time correctly. This is very important for total station work as it is used for the time stamp on all measurements taken.	f.) Pressing the <i>Windows</i> key (lower left) brings up the <i>Windows Applications</i> screen. The <i>Trimble Access</i> application is currently highlighted.	g.) To create or open a survey job you need to start the <i>Trimble Access</i> application. Tap The icon or press the <i>Enter</i> key on the keypad (<i>Figure</i> item #3) and you should briefly see this message.
		
h.) This is the Trimble Access Home screen. <i>General Survey</i> is what you need to get into the survey functions. <i>Settings</i> will be discussed later and the <i>Files</i> option is the same as <i>Windows Explorer</i>.	i.) The upper bar names the root folder, in this case nps. Tap the General Survey icon or highlight it using the arrow key button and press the Enter key.	j.) This is the General Survey screen. The job's <i>Status Bar</i> is on the right side and the job's <i>Status Line</i> is along the bottom of the display. These two information boxes (and perhaps the <i>Map</i>) is where you will spend most all of your time looking at the controller screen during a

		survey.
		
k.) To open or create a job, tap on the Jobs icon or highlight the <i>Jobs</i> icon and press the <i>Enter</i> key.	l.) The Jobs options screen is displayed and you can pick an option. In this case, we have already created a job so it just needs to be opened.	m.) Pick the job you want opened. Here you can see some obscure job names. Follow the NCPN protocol for naming jobs when you create one.
		
n.) This is the main screen of the selected job. The <i>Status Bar</i> and the <i>Status Line</i> are vacant because there is no survey running in this job at this time. A main job screen is what you need to have open to start any survey session.	Note: if your job has not already been created for you as part of the field preparation procedures then you will need to create a new job in the controller. See section 3 on <i>Creating a Job</i> to get to this point of having a defined job already created/loaded in the controller as part of the pre-trip procedures.	

4.3 Camera function:

		
a.) Go to the <i>Windows</i> applications screen and open	b.) Tap on the Camera icon to open the camera	c.) The camera function is opened and is ready to take a

Pictures & Videos or use the shortcut key (Fn > 1) on the controller (<i>Figure</i> , item #5) and skip to c.)	function if not using the shortcut keys.	picture. Here the controller case laying on a desk is in view.
		
d.) Tap Menu to open and check/set the resolution. Sometimes when the controller is reset the camera resolution will be reset to the lowest value.	e.) Set the resolution to 2048x1536 to get nice sharp pictures. We have had issues with the highest setting.	f.) After taking the picture this Media file screen appears. Use the drop-down list to indicate how you want the image associated with the collected survey data. Then tap Accept or press the Enter key to store it.

4.4 File Explorer and USB flash drive access

To access *File Explorer* navigate to the Windows home screen (*Windows* key > *File Explorer* > *Trimble Data*). This directory will typically contain at least these two folders: 1) The named *Root Directory* (i.e. NPS or Rover #), and 2) The *System Files*.

- The **System Files** directory contains all the files needed to operate the controller within the general survey program (i.e. geoid models, survey styles, feature code libraries, etc.).
- The named **Root Directory** contains all the files associated with a given job (i.e. Job files, media files/photos, and any linked files like previous survey data in a csv format). The root folder is where you will copy/paste files that are needed in referencing previous data sets, previous job files, and/or job templates.

The easiest way to transfer files between controllers is to use a USB flash drive. To find the USB flash drive, insert the flash drive into the USB port. Go to: Windows home screen (*Windows* key) > *File Explorer* > *My Device* > *Hard Disk* (the USB flash drive is recognized as a hard disk).

To copy files to the flash drive:

- **Highlight** the file(s) in either the *System Files* directory or the named *root directory*. **Tap and hold** on the highlighted file. Pick **Copy** when the popup menu appears.
- Tap **Up**, and navigate to the same directory the job is in (*Trimble Data* > {*Root Directory*}).
- Tap **Menu**, scroll to *Edit*, and choose *Paste*. The file(s) will now be copied into the root directory. All data files associated with the job must be in the same directory as the job. Once your reference csv files have been copied into the *Root Directory* you will then be able to link to those files in the Job Properties screen described in section 3.1.2.

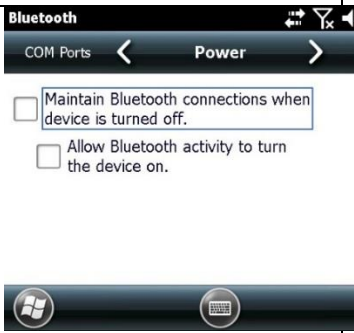
4.5 Bluetooth connectivity

There are three parts to the Bluetooth wireless system:

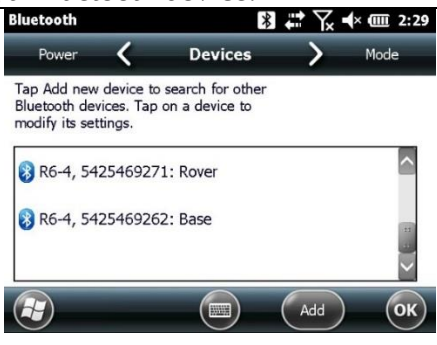
- Turning the Bluetooth function ON or OFF.
- Pairing devices in the *Windows* environment.
- Assigning survey functions of paired devices in the *Trimble Access* survey application.

First, make sure the Bluetooth functionality is turned on and then make sure the receivers are known by pairing them and finally assign the appropriate devices as either a GNSS base or GNSS rover. Press the *Windows* key again to put you back in the survey job.

Turning the Bluetooth device On or Off:

		
a.) From a job screen, press the Windows key. Scroll to Settings and tap to open.	b.) From the <i>Settings</i> screen, tap Bluetooth to open.	c.) Scroll right/left to get to the Mode screen. Tap in the Turn on Bluetooth box to place an X there then tap OK or press Enter to turn it on.
		
d.) In the <i>Power</i> screen, make sure these are turned off (unchecked) to prevent the Bluetooth device from starting unnecessarily and causing power drain.		

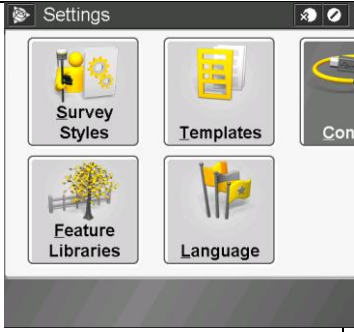
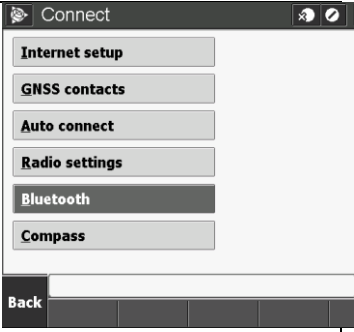
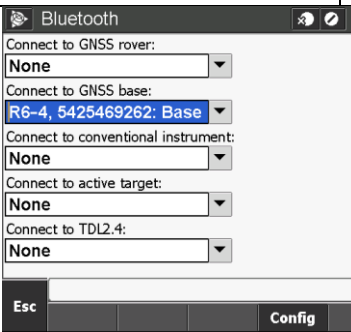
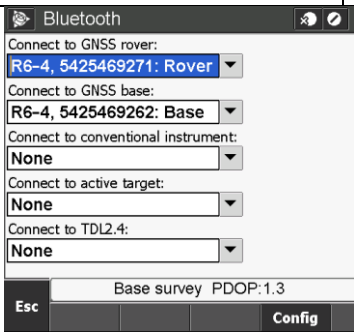
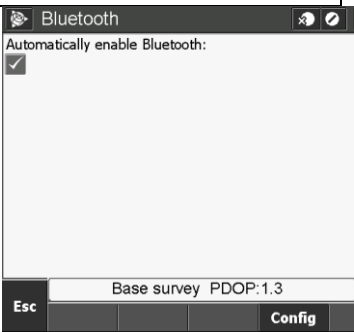
Pairing a Bluetooth device:

	
a.) See <i>Turning Bluetooth On or Off</i> to get	b.) Tap Add new device... if you need to

to the **Bluetooth** management screen. Scroll right/left to get to the **Devices** screen shown here. First check to see if your device is already paired by scrolling down to see the list of paired devices.

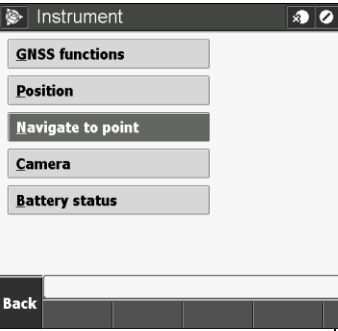
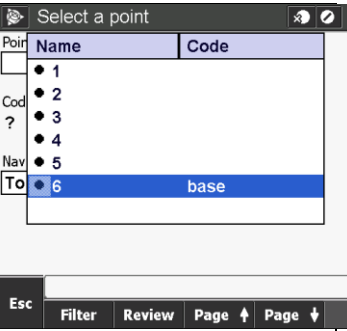
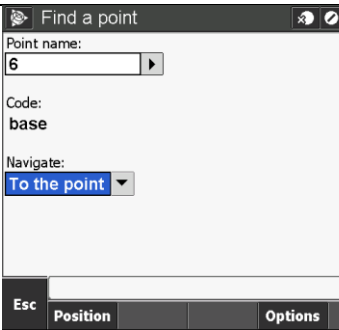
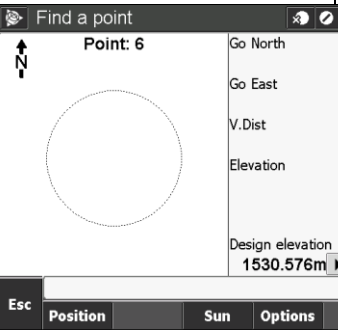
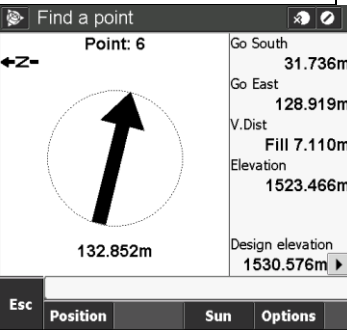
pair a device. Make sure the device you want to pair is turned on. The controller should recognize the device and you can rename it there. You don't need to create a password and it is best to just leave this blank.

Assigning Bluetooth survey devices:

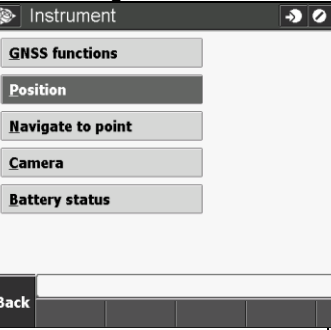
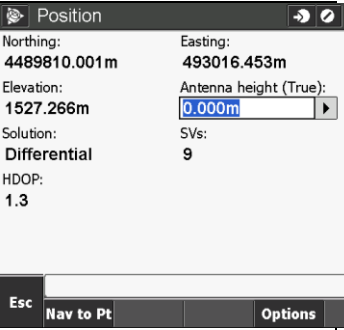
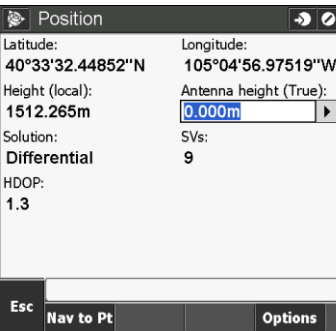
		
a.) Push the Trimble key and select Trimble Access to get to Access main page. Open the Settings menu by tapping on it.	b.) Open the Connect menu by tapping on it.	c.) Pick the Bluetooth option.
		
d.) The Bluetooth assignment settings screen. This tells the Access survey application which paired devices it should be communicating with for a specific function in the survey system. Paired devices will appear in the drop-down list next to the device function. Here, the base receiver is selected from the list of paired devices in the Connect to GNSS base drop-down list.	e.) This shows the rover receiver is selected from the paired devices in the Connect to GNSS Rover drop-down list. If there is more than one rover listed, make sure you pick the right one from the list. This is why its good practice to list the receiver's serial number in the device name (when pairing), so you can physically check the number on the bottom of your receiver unit. It can be rather confusing when your controller is paired with someone else's rover receiver. Tap Accept to set the device assignments.	f.) The last screen of the Bluetooth assignment settings in Trimble Access is this Automatically enable Bluetooth switch. If this is check-marked then the <i>Windows Bluetooth</i> device > <i>Mode</i> > <i>Turn on Bluetooth</i> option will always be on. Even if you go in and turn it off (uncheck the box in <i>Mode</i>) it will turn on again as soon as you exit. This switch means if <i>Trimble Access</i> is running the Bluetooth device will be turned on. I prefer to keep this option off (unchecked) to save power when I'm not actually surveying.

4.6 Using the controller as a “stand-alone” GPS device

The TSC3 controller can be used as a traditional hand-held personal GPS unit. It is often used to navigate to a base point monument.

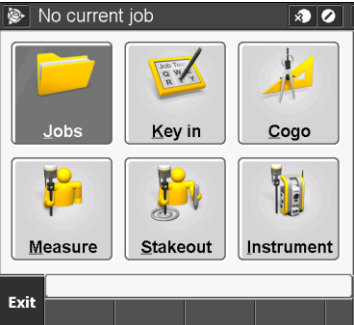
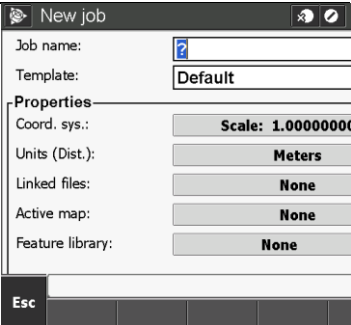
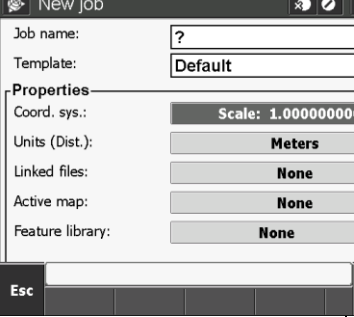
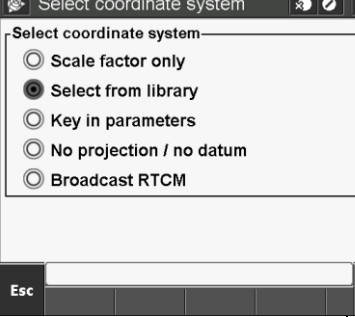
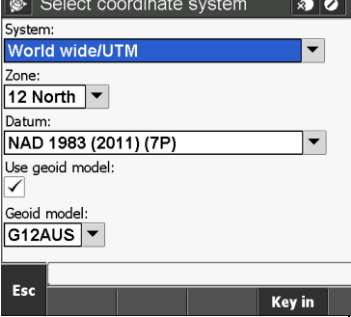
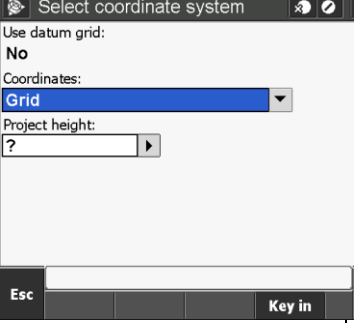
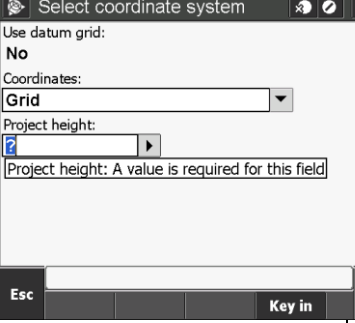
		
a.) From the main Job screen, open <i>Instrument</i>.	b.) Pick <i>Navigate to point</i>. The right LED light on the controller should start to blink green every 5 seconds, letting you know the internal GPS is functioning.	c.) You need to have a point keyed in or be linked to a file of points.
		
d.) A point has been selected. Press <i>Start</i> or the <i>Enter</i> key. You may see a message asking you to calibrate the compass.	e.) It may take a few minutes to get its current position and calculate the direction you need to go.	f.) It figured it out. The N compass needle points North. You need to go the in the direction of the large arrow relative to North. When you get near the point it will change to a + and circle diagram as shown in the <i>Stakeout a point</i> routine. Pressing <i>Esc</i> twice will close the stand-alone GPS function. When you start an RTK survey this will also close it.

You can also get the coordinates of your current position:

		
a.) From the main Job screen, open <i>Instrument</i>.	b.) Pick the <i>Position</i> option. The right LED light on the controller will start to blink every 5 seconds, letting you know the internal GPS is functioning.	c.) It may take a few minutes to generate your position. The undefined values (question marks) will populate with grid coordinate values.
		
d.) Tapping the <i>Options</i> soft key allows other display options for the position, These are the local geographic coordinates. Pressing <i>Esc</i> will close the stand-alone GPS function. When you start an RTK survey this will also close it.		

5. Creating a Job in the TSC3 Hand Controller

Trimble Access is the field surveying application software found on the TSC3 survey controller device. You need to have an **Access Job file defined and opened** to start any kind of survey. This section describes how to create an *Access Job* file. For sites that have been previously surveyed, the Job file is probably easiest and safest to create in the office before the field trip to avoid last minute surprises about missing data/missing files or incorrect project settings (i.e. datum and projections). However, for new surveys having no stakeout data, you can create the new job in the office if you know about it ahead of time or the Job can be defined at the site in the field during base startup.

		
a.) The main job screen. Notice there is <i>No Current job</i> in the title bar. Tap Jobs or highlight Jobs and press the Enter key.	b.) On the jobs options screen tap New job.	c.) The New job screen will then appear. Name the job according to the NCPN format "Project+Site+year+rover#+person" (i.e. CanyQA2014r2HoJo).
		
d.) To set the job properties, Tap on the Coord. Sys.: entry box.	e.) The Select coordinate system options screen will appear. Select from library opens up the pre-defined coordinate system library.	f.) This screen is where you define the coordinate system. Use the drop-down lists to fill in the various boxes. The values shown are the coordinate system settings that are used for all five of the NCPN Big Rivers Monitoring Sites (YAMPA, GREEN, CANY, BLCA, and CURE).
		
g.) This is page-2 of the Select coordinate system screen. The Coordinates (type) option is either <i>Grid</i> or <i>Ground</i>. Choose Grid for this setting to generate	h.) A Project height must be defined. This is the message you get when you try to store the defined coordinate system without defining the project	i.) After Storing the job's coordinate system definition you will be back at this main job screen. This example job is called <i>junk</i>.

true UTM grid coordinates. Ground elevations will be computed using the Geoid model set on the previous page. The <i>Ground</i> setting means the grid coordinates will be computed at a scaled up ground elevation. These, then, are not UTM grid coordinates as UTM is defined at the ellipsoid height.	height. For RTK-GNSS jobs this can be any value. Zero is a good option if you don't know the average elevation in the area that you are working. Note: Project height is used to compute an elevation (and thereby a grid coordinate) of 2D points, which you won't have any running a RTK-GNSS system since this allows you to measure 3D points (x,y,z) within a tolerance of a couple centimeters.	
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5.1 Adding stake-out information to the Job:

If this is a return trip to a known site then you will have coordinated points and possibly transect lines that you are looking to repeat survey measurements at. This is called “stake-out” data. This section describes various ways to add stakeout data to the job. There are basically three methods, one of which is hand entering all the data called “keying in”. As you can imagine, this is OK for a few points but is not an acceptable method for many points. The other two methods involve getting data from files. The two methods for this are **data file import** and **data file link**.

5.1.1 Importing data to a Job:

When using the data file import method, all data points that are imported into the current job are essentially copied into and made a part of the existing job's data set. Survey jobs that accumulate lots of data can be unwieldy to manage if all the stakeout data is imported/copied into the job and gets added together with the current survey topo measurements. Therefore, this method is not recommended for including previous stake-out data as a reference for the current field survey job. The other method, described below as linking, is the preferred method for accessing previous survey data from the current job.

5.1.2 Linking a data file to a Job:

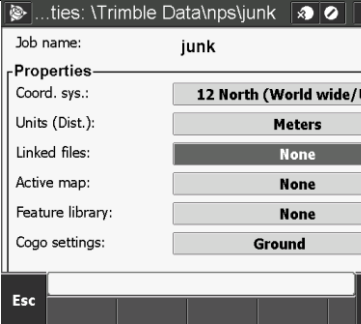
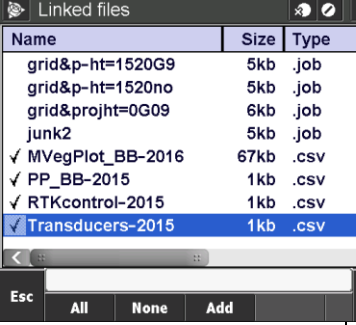
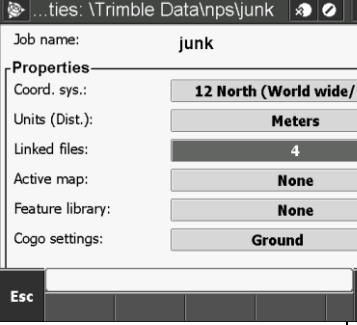
During a repeat survey there exists previous data such as control points, photo points, veg plots, transect lines, etc. These items usually need to be found by *staking out* because the purpose of the repeat survey is to gather data in the exact same horizontal location as previously done.

Terminology Note: *Stakeout* is a term used by surveyors (and the survey application software) to precisely locate a known point when performing a survey while *Navigate* is a term, generally used by everyone, when roughly locating a known point with a stand-alone GPS unit not involved in a precise surveying system.

There are two ways of accessing known (coordinated) data points in either *Stakeout* or *Navigate* mode. One is by importing the data into the job and the other is by *linking* data files. Linking files is easy to do but requires that the files be created correctly and available in the controller. This takes a bit more time and effort to set up than importing the data directly into the job but it makes the field work much more manageable by logically isolating data into subsets by type and location.

- Linking only those files having data of a certain type on your current transect or site will serve to keep the map less cluttered and the stakeout list much shorter and manageable. Linked files are usually CSV grid coordinate files and are generally created in the office and uploaded to the

controller into the same root folder as the job. Files may be linked/unlinked from a job at any time during a survey. (Menu > Jobs > Properties of job > Linked files).

		
a.) From the main job screen, open Jobs.	b.) Pick the Properties of job option.	c.) Tap on the Linked files option. Currently, there are no linked files.
		
d.) Tap in the check-mark area for each .csv file you want linked to the job. You can link to jobs also but this can cause some unexpected problems if you are loading previous versions of an Access Job file. Tap Accept. Note: CSV files must be in PNEZD format with no header, just 5 columns of data. PNEZD means Point name, Northing (Y coordinate), Easting (X coordinate), Z (elevation), and Description.	e.) You now see there are 4 linked files to this job. Tap Accept. Now when you list points you will see all the points in the job as well as those in the linked files. The points in the linked files are not imported into the job until a function needs the coordinates. This has the advantage of keeping the job free of unnecessary clutter and copies of points that you don't need.	

- Points within linked files are not imported into the current job until they are used for a job function such as *Stakeout*, or *Compute Inverse*. When a point is imported into the job from a linked file you will hear the controller make a “Chunk” sound. *Review* of the job will show the point with a small “C” icon next to it indicating it was copied into the job.
- Data in linked files can be viewed in the *Point Manager* and displayed in the *Map* view as shown in Figure 11 below. The blue colored data is from the linked file(s). The black colored data is currently in the job.

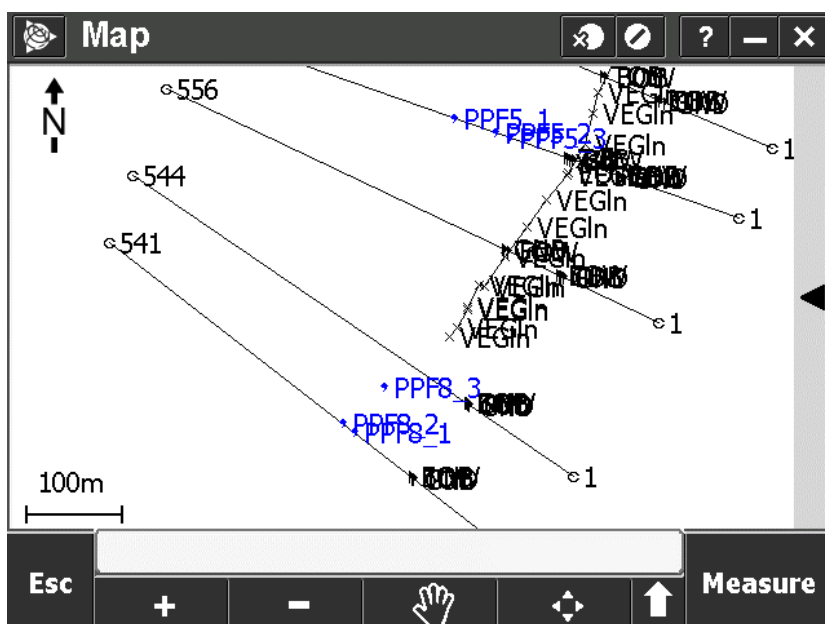


Figure 11 – General survey map view showing current surveyed data along with data from a linked file for reference.

5.1.3 Keying in data

As mentioned at the beginning of this section, points and certain types of data objects created by points can be hand entered by typing in the point name, coordinates, and description. It is recommended to have a paper copy of control point coordinates in case access to electronic files is lost. To key in points, go to: The *main menu* of the existing job > *Key in* > *Points*. Enter the Point name, Northing, Easting, Elevation, and Code as they appear on the printed copy. Leave the *Control Point* option unchecked even for control points. This makes it easier to manipulate in the office software later.

6. Step 1 - GNSS Base Station Setup and Assembly

Figure shows all of the base station equipment unpacked and each item identified below:



Figure 12 – RTK base station equipment unpacked

Items in figure 12:

- | | |
|--|--|
| 1. 42-watt solar panel with connecting cable | 16. Heavy duty wooden tripods for base and radio antenna |
| 2. Extension rods for radio antenna | |
| 3. Tribrach base | |
| 4. Tribrach adaptor (removable mount) | |
| 5. Flat disc for mounting radio antenna rod on tripod | |
| 6. Long whip antenna | |
| 7. Short whip antenna | |
| 8. Antenna base (connects to antenna coax cable #13 and whip antenna #6 or #7) | |
| 9. Solar panel voltage regulator/battery saver | |
| 10. R6-4 base receiver dome | |
| 11. Short extension pole for base receiver (0.2m) | |
| 12. TDL-450 broadcast radio | |
| 13. Radio antenna coax cable with fixed antenna mount | |
| 14. Power/data cable for base receiver and broadcast radio | |
| 15. Marine battery with quick connect cables for base receiver power and solar panel | |

The Basic RTK system setup connects the battery (power), broadcast radio, antenna, and GPS receiver using two cables: one is the combination power/data cable and the other is the radio antenna coax cable (alternate coax cable may be yellow in color). *Figure 13* shows the base receiver and radio setup and all cable connections without being mounted on the tripods. The following sections describe how to assemble each of the components in more detail and mount on the tripods.



Figure 13 – Example of basic RTK base station system components and connections



Figure 14 – Base tripod with tribrach base mounted

Base station tripod setup and receiver assembly

- a) Set up the base tripod over the control point (i.e. “x” in a rock or rebar) and roughly level the tripod head by eye by adjusting the legs and tighten the thumb screws firmly. Screw the tribrach base (adaptor removed) onto the base of the tripod and level over the control point:
 - Roughly center the tribrach on the tripod head as shown in *Figure* .
 - Adjust the three tribrach thumb screws to be near the mid-point of their travel range. This is represented by a groove mark in the post holding the thumb screw. The top edge of the thumb screw should be near the groove mark.
 - Adjust the eyepiece reticle (cross-hair) to your eyesight to eliminate parallax error (sharp, crisp lines).
 - Roughly adjust the focus if necessary and center the



Figure 15 – Base tripod anchored with tie-down straps

tripod over the base point.

- Using full body weight, press the tripod shoes into soft ground or verify solid setup on rock surface and finish leveling/setting up the tripod.
- Anchor the tripod using either large rocks on the tripod shoes (shown in *Figure*) or using tie-down straps connected to a strap around the tripod head and anchoring them into the ground with stakes (*Figure*).
 - Note: this anchoring process should be done for both the base station tripod and radio antenna setup to insure that neither of the tripods get blown over in high winds or disturbed by wildlife.



Figure 16 – Base station receiver setup

- b) Screw the stubby pole (0.2 meter) onto the tribrach adapter and screw the base receiver onto the stubby pole. Plug the combination power/data cable to the round port on the receiver (port#1). The connector is keyed, line up the red marks first then carefully but firmly push it in (pull the small wire loop to release the small prongs and remove it). Now attach this assembly to the tribrach base (as shown) and close the tribrach latch to lock it in place. The base receiver is now set up.



Figure 17 – Base station radio setup

Base radio and antenna assembly:

Set up another tripod within a couple meters of the base receiver. Lengthen the legs to nearly the max and spread them out pretty far to reduce the chances of the wind blowing it over. Strap it down with a tie-down kit if there is a chance of this. Roughly level the tripod head by eye by adjusting the legs and tighten the thumb screws firmly. Its only job is to support the radio mast so it doesn't need to be perfectly level and you can adjust it after you have the mast up. Note that the radio antenna can be mounted on anything (such as a pole lashed to a tree or fence post) as long as it is positioned relatively vertical and as high as is reasonable for the situation at hand. A tripod is necessary where there is no other way to mount the radio mast and always works. Other methods should be considered "make shift" or "less than optimal but it will work" approaches in case of a loss of a tripod.

In the large photo of *Figure* the radio setup is shown with no additional antenna mast (so it fits into the photo). It is recommended to use at least one telescope pole (shown mounted in the inset photo) to raise the antenna. Antenna height is a big factor in effective broadcast reception at the rover. The choice of base point location will determine how effective the radio coverage will be. Low elevation base points may mean using a very tall (unwieldy) antenna mast which will require additional strapping/tethering for support (see Figure 8). There are two whip attachments, the short whip is shown. The long whip (5dB gain) sends the same transmit power but shapes the signal pattern flatter (ie – less vertical coverage) so the transmit power is concentrated in the horizontal direction perpendicular to the antenna axis. This works best for long distances. If you are working relatively near the base station and it is up higher in elevation, use the short whip.

Figure shows an additional 42W solar panel charging system (PowerFilm product) which helps prolong the life of the base battery (12V AGM, deep cycle) when operating at higher wattage radio broadcast for a long time. At lower broadcast wattages it can keep the battery fully charged if it receives full sun (YMMV). The small square object is a voltage regulator to prevent overcharging. This setup typically provides enough charge during the day to maintain the battery well above 50% and eliminates the need for a generator or alternate power source to re-charge the base battery at night. This is especially important when having to operate in remote areas and when floating the river when transporting generators and fuel can be problematic and noisy.

Caring for the solar panel: Although these are really pretty tough they can be damaged by rolling them up improperly. The directions say to roll them up with the solar side facing out and not to be less than 4" diameter. Be careful of the wire pig-tail. When setting it up, connect the voltage regulator to the battery first. Then make the final connection between the voltage regulator and the solar panel.



Figure 18 – Base station battery and 42 watt solar panel charging system

7. Step 2 - Starting the GNSS base station

7.1 Start the base from a known point:

This section describes how to start the base survey session utilizing a control point with known coordinates.

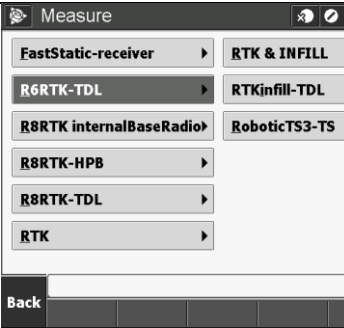
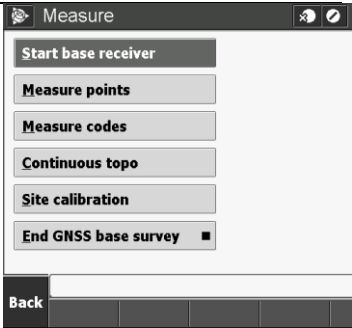
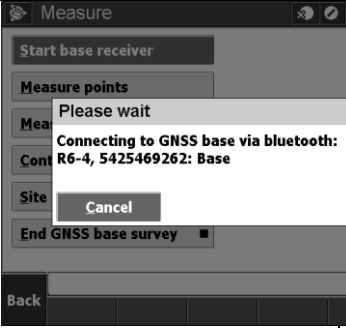
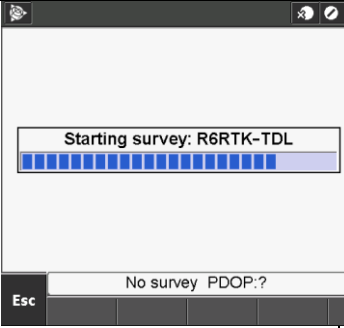
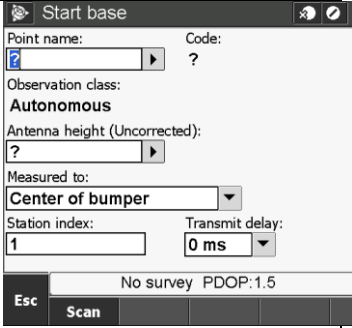
Key points:

- The base and rover receivers for this system are identical units but we have assigned one to be the base and the other to be the rover to simplify the setup process (Trimble Access > Settings > Connect > Bluetooth). Each of the receivers also have printed labels on them for easy identification.

- The base height (height of instrument) and rover height (rod height) are measured to different places on the receivers respectively. The base is measured to the center of bumper and the rover is measured to the bottom of antenna mount.
- The base is normally set to log base data based on the parameters we have set in the survey style (R6RTK-TDL). The base receiver needs to collect data for at least 2 hours to be post-processed effectively using OPUS, preferably longer, but can't exceed 24 hours continuous.

Step-by-step process for starting base station using the Trimble TSC3 hand controller:

At this point the base receiver and base radio have been powered on. There is no transmit signal (Tx) light from the radio, only the green power light is on. Similarly, the base receiver has a steady green power light and a steadily flashing orange light indicating it is receiving satellite signals. The radio transmission light is not on. The following sequence describes how to start the base survey session, after which a rover survey session may be started.

		
a.) The main job screen. Notice there is nothing in the status bar except the controller battery status and the status line is empty. Go to Measure.	b.) Pick the survey style you'll be using. R6RTK-TDL is configured to work with the NPS base receiver and broadcast radio. More on survey styles elsewhere.	c.) Pick Start base receiver. To initiate communication with the base. You need to be within Bluetooth range (generally 25ft.)
		
d.) You should briefly see this screen. • If it hangs on this screen then the Bluetooth device in the controller needs to be	e.) If the receiver is not listed in the <i>Connect to GNSS base</i>: drop-down list then it needs Bluetooth pairing (Windows > Settings > Bluetooth > Devices > Add new	f.) When you have established communication with the base receiver you will be in the Start base screen. The status bar shows it's tracking 17 satellites and the base battery is

turned on or setup (see section 2.5 Bluetooth connectivity).

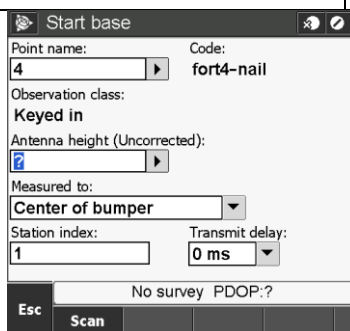
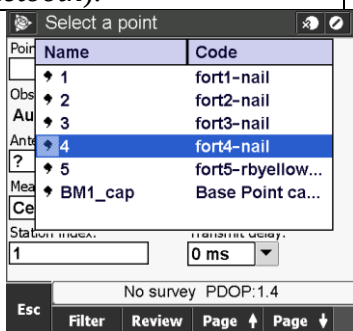
Quick check: Is the blue light on the controller flashing once every 5 seconds? If not go to *Windows > Settings > Bluetooth > Devices > Mode*.

- If it says connecting via cable then the receiver needs RTK survey device assignment (*Trimble Access > Settings > Connect > Bluetooth*).

device...).

You should also briefly see this starting base message and hear some connection sounds.

fully charged (bottom battery icon). The highlighted *Point name* box is asking you to define the base point position (default is by *Point name*). You can pick different ways to define the point by tapping on the drop-down list arrow.



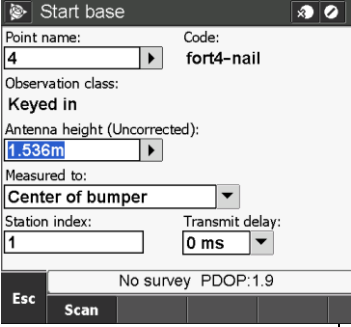
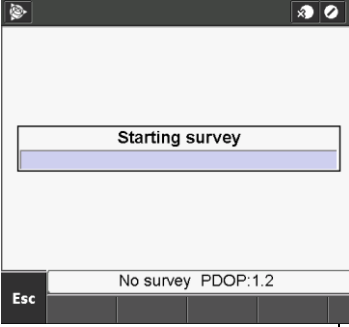
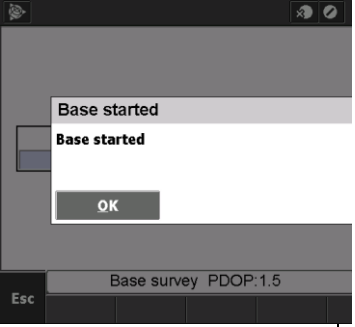
g.) **Note:** At this point, it is assumed you have a known (coordinated) base point. If you are starting from an unknown base point, refer to the part about starting from a “Here” position.

If there is a defined base point coordinate by name (from you either hand-entering it into the job via *Key in*, or from a linked or imported file) then you can pick it from the list of points. Tapping the drop-down arrow brings up a list of options on how to get a base point. Use the **List** option to bring up the list of named coordinated points.

h.) After picking the base point from a list (or keying it in), the *point name*, *code*, and *observation class* will be filled in.

Next is to measure the antenna height. **Antenna height (Uncorrected)** means you are providing a raw measurement. You don’t apply any modifications to this raw measurement. Notice the default *Measured to* point for the base receiver is **Center of bumper**. The software will correct this raw slant measurement to a vertical distance to the ARP (Antenna Reference Plane).

i.) Be sure to measure the base receiver height from the survey point (monument object) up to the **center of bumper** and enter it. In this case, it is 1.536m.

		
j.) The antenna height has been entered. Now the Start soft key becomes enabled because the required information is present. Other information on this screen: • <i>Station index</i> is the ID number assigned to this base receiver. • <i>Transmit delay</i> has to do with multiple bases operating at the same time on this radio frequency. Leave it at zero. • Verify that the information on this screen is correct and tap Start or press <i>Enter</i>.	k.) You should briefly see this message. Notice the icons in the status bar area of the screen. These represent: • Battery conditions: 1st is controller, 2nd is the device the controller is connected to, in this case the base receiver. • Satellite information icon and number tracked. • GNSS functions menu. • Active base icon with base height.	l.) Then it should halt on this message until you OK it.
		
m.) After you OK it you will be returned to the main job screen. The base has now started and the status line at the bottom indicates a base survey session is in progress. You can now start a rover survey session. At this point it's a good		

idea to check the receiver and radio. • The green power light on the base receiver will flash off briefly every five seconds. This is your confirmation that it's logging base data. • The green radio light on the receiver will start blinking every second as it computes correction information. • The red TX (transmit) light on the radio will blink once per second as it transmits the correction on the broadcast frequency.		
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NOTE: It is good practice to keep a log sheet of the base set-up (*Figure*). This includes control point used, base height measurement, start times and dates, radio transmit power, broadcast antenna height, and any other relevant issues to setting up the base station. When the survey is ended, make a note of the base file name (number) and end time. Check to see that the receiver is still centered over the base point and that the height is still the same. These notes will come in very helpful in the office if you have multiple base setups and/or base sessions as well as for future planning if you return to the same site repeatedly.

Transect Survey metadata			
General data			
Date:			
Transect ID:			
Details on getting to the transect:			
Survey Specific data			
Survey type: RTK RTK+infill RTN Fast Static Static Total Station (see other side)			
For GNSS survey method			
Base height measure up (HI):		To: Bumper ARP	
Base Start time:	Base End time:	Base File:	
Base Point Description:			
Base Radio:	HPB-450 TDL-450 Trimark-III	Transmit Power (W):	Battery: Tractor Marine
Repeater:	HPB-450 TDL-450 Trimark-III	Transmit Power (W):	Battery: Tractor Marine
On-transect Survey Start time:		End time:	
Rover/Controller:		User:	
Point range:			
Notes:			

Figure 19 – Example of survey metadata sheet

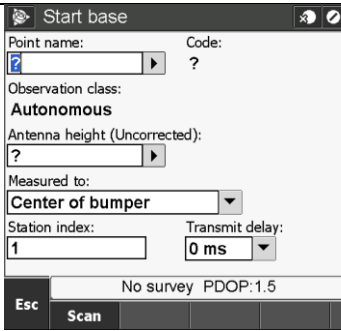
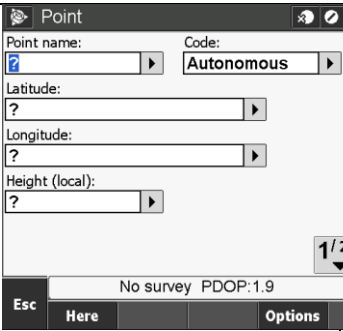
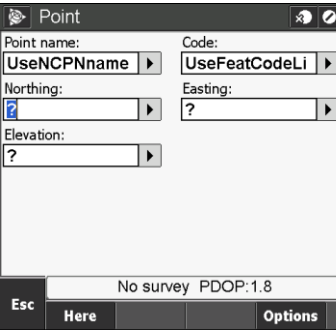
Radio transmit power:

The TDL-450H radio has several transmit power settings. These range from 2W to 35W. With good base station placement, the radio transmit power can be kept relatively low. 8W is generally more than enough to handle most sites. The transmit power can be changed by using the arrow buttons to

scroll through the menu. Current settings are marked with an asterisk. Scroll left/right to find the power setting. Scroll up/down to find the one you want. Press the power button to accept the change. The radio will last approximately a day at 8W with no solar charger.

7.2 Starting the base from a “Here” point:

If this is a new site and you have no known (coordinated) points then you will need to set up and start the base on an autonomous position called a ‘**Here**’ coordinate. This is basically a GPS snapshot of your position about as accurate as a personal “hand-held” GPS unit. An RTK survey needs a base coordinate to function so this will suffice to get the survey going. Later on, in the office software, you can post-process this coordinate to get a better, more truthful, position using an online processing service. Because it’s an RTK survey, all other points collected using this base session will also benefit from the post-process re-positioning of this point.

		
a.) From the Start base screen, tap the drop-down list for Point name and tap Key in.	b.) This is the Key in (point) screen. This screen enables the Here soft key at the bottom left. The Point name is undefined and the Code is Autonomous by default. The GPS satellite icon with the yellow wave symbols means the receiver is getting a SBAS position correction which improves the accuracy of the autonomous point.	c.) Naming and coding the new base point. • Name the point using the NCPN cheat-sheet to set the point naming convention for this new site. • Code the point by using the NCPN <i>Feature Code Library</i> (see Creating a Job). • Let the receiver sit running for a few minutes from when you powered it up in order for the receiver to be able to generate a reliable position/location.

--	--	--

d.) The coordinates will populate when you tap the **Here** soft key. Tapping it again will change the coordinates. Verify that the coordinates change only by a relatively small amount, say 50cm not 500m. The last **Here** position generated is what gets stored as the autonomous base coordinate.

e.) The **Options** soft key allows the 'Here' position to be displayed in geographic coordinates. These are the *Local* geographic coordinates.

f.) Page two shows the computed grid coordinates.

--	--	--

g.) Tapping **Store** or pressing **Enter** stores the last 'Here' coordinate generated and brings you back to finish the base point definition so you can start the base.

Enter the appropriate antenna height measured to the center of bumper as described in section 5.1 i and j then the **Start** soft key becomes enabled because the required information is present.

Verify that the information on this screen is correct and tap **Start** or press **Enter**.

h.) You should briefly see this message.

Notice the icons in the status bar area of the screen. These represent:

- Battery conditions: 1st is controller, 2nd is the device the controller is connected to, in this case the base receiver.
- Satellite information icon and number tracked.
- GNSS functions menu. Active base icon with base height.

i.) Then it should halt on this message until you OK it.

8. Step 3 - Assembling the rover and starting an RTK survey

8.1 Rover assembly

Figure -a shows the Trimble R6 rover survey equipment along with all the chargers and accessories packed in the pelican case for storage/transport in the field. Figure shows the minimum equipment that must be assembled to conduct a survey in the field and includes the following: adjustable rover rod, rover receiver, radio whip antenna, 2 rover batteries, two-piece controller mounting bracket, and TSC3 controller.



a)

Figure 20 – Trimble R6 rover a) pelican case containing rover survey gear and accessories b) rover survey gear unpacked

Figure shows the rover gear assembled and ready to setup an RTK survey. The connection between receiver and controller is via Bluetooth wireless. The rover receiver accepts incoming RTK correction information from the base via the whip antenna.



Figure 21 – Trimble R6 rover gear assembled

Be vigilant about rover rod heights. Make it a habit to continually compare the setting shown on the controller to what the rod height is actually set at. See the part about measuring points for more info on rod heights.

- The scale printed on the rod is for rod heights measured to the bottom of the antenna mount. In the case of the R6 receiver it's also the bottom of the receiver.
- It is recommended to pin the rod height at one of the convenient locations using the attached pin (1.8m or 2m shown in Figure). Rod height mistakes are the most common surveying

mistake made and are very difficult if not impossible to fix after the survey has ended and you've left the site.

- Fixed-height rods (2m is common) are available and go a long way toward preventing rod height mistakes, but the adjustable height rod allows us to work in places where a fixed-height rod would either make it very difficult or even prevent certain measurements.



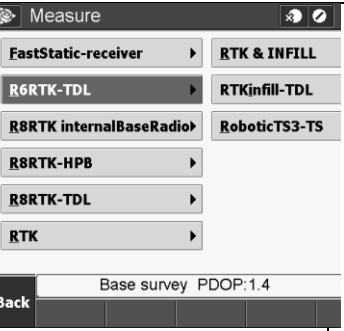
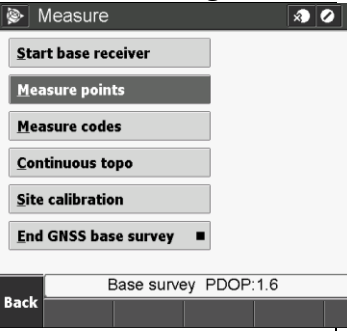
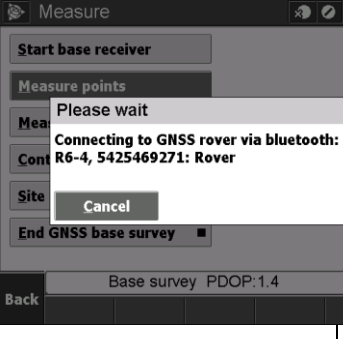
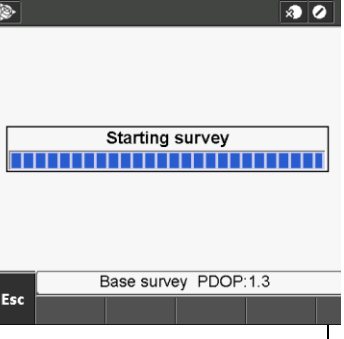
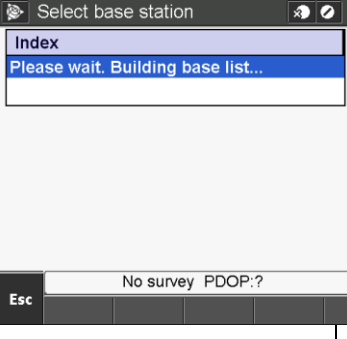
Figure 22 – adjustable height rover rod with locking pin

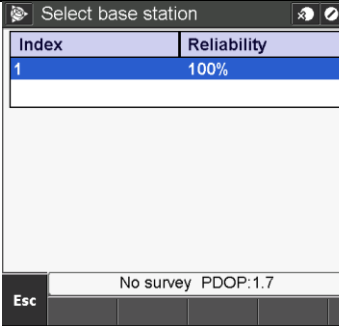
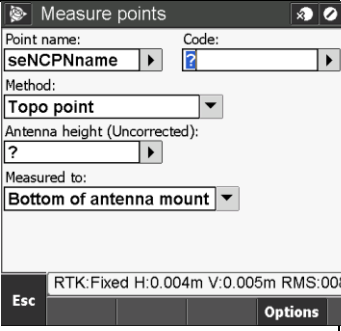
Starting the Rover session:

Once the base station is set up and started then a rover survey session can be started. This is the last step in getting the RTK survey system functioning. Collecting survey data can begin once a rover session is started. Any number of rovers can be used in an RTK survey which is what makes this method so powerful, as the work can be divided up between rover operators.

Key ideas:

- Be sure to set the rover's controller to the correct job.
- The point name will be a hold-over from the last point name entered in any job. Be sure to change it to the correct naming format.
- Entering the correct point name does not **set** the naming pattern. Take a junk/temporary shot to set the naming pattern for the job. The NCPN cheat-sheet shows how to set the naming convention.
- Be sure to stake out a known point (preferably a control point) if this is a resurvey (see *Staking-out points*). This verifies the system is working correctly and that no blunders have occurred during job creation, equipment setup, or survey startup. If it's a new site then set an additional control point and have every rover measure it and then compare coordinates.

		
a.) Main job screen showing the base station in operation. Go to Measure.	b.) Pick the survey style R6RTK-TDL (same as used for the base setup).	c.) Pick Measure points.
		
d.) You should briefly see this screen. - If it hangs on this screen then the Bluetooth device in the controller needs to be turned on or setup (see section 2.5 Bluetooth connectivity). Quick check: Is the blue light on the controller flashing once every 5 seconds? If not go to <i>Windows > Settings > Bluetooth > Devices > Mode</i>. - If it says connecting via <i>cable</i> then the receiver needs RTK survey device assignment (<i>Trimble Access > Settings > Connect > Bluetooth</i>). - If the receiver is not listed in the <i>Connect to GNSS base</i>: drop-down list then it needs Bluetooth pairing (<i>Windows > Settings > Bluetooth ></i>	e.) You should briefly see this message and hear some connection sounds.	f.) You should briefly see this message then be presented with a list of available base stations broadcasting on this radio frequency (next screen).

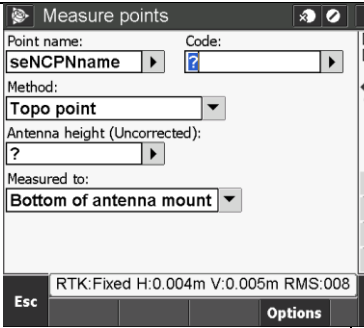
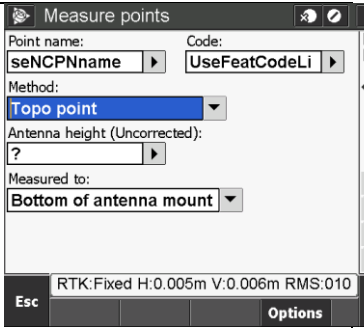
<i>Devices > Add new device...).</i>		
		
g.) This shows only one base station is detected (normally the case due to our remote sites and government radio frequency) and the radio reception is 100%. The index is the ID number assigned to the base in the survey style. If you see other base stations broadcasting on this radio frequency then you'll see them listed also. Make sure you pick the correct base ID. Tapping Accept or pressing Enter starts the rover survey session and returns you to the <i>Measure points</i> screen. You may briefly see another <i>Starting survey</i> message and hear a message saying 'waiting for information from the base' as well as some more connection sounds as base information is imported into the job.	h.) The <i>Measure points</i> screen with an Initialization message. You should see this <i>Initialization gained</i> message for about 3 seconds if the rover receiver is upright and sky view is not obstructed.	i.) This is the Measure points screen. Refer to either the next section "<i>Measure points</i>" (section 7) or "<i>Stake-out</i>" (section 8) to continue. You can now see additional information, mostly indicated by icons, in the status bar area of the screen. These represent: • Battery conditions (1st is controller, 2nd is the device the controller is connected to, in this case the rover receiver) • Satellite information icon and number tracked • Base information icon • Active radio icon • Rover receiver icon and rover rod height (currently undefined). The status bar at the bottom shows that an RTK survey is in progress and has a fixed solution with the estimated horizontal and vertical accuracies and RMS. When conducting an RTK survey these values are usually less than 0.02m.

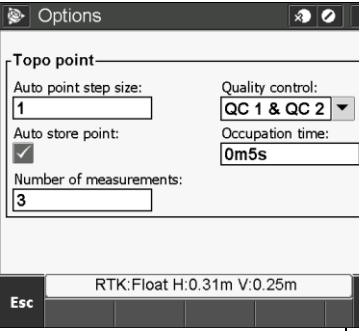
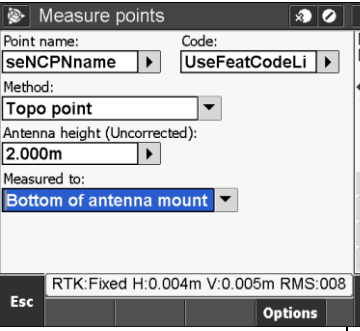
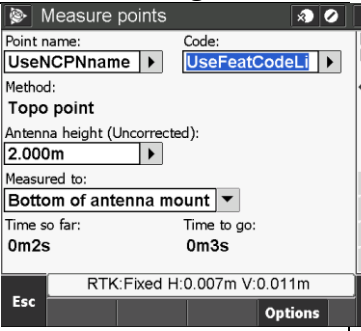
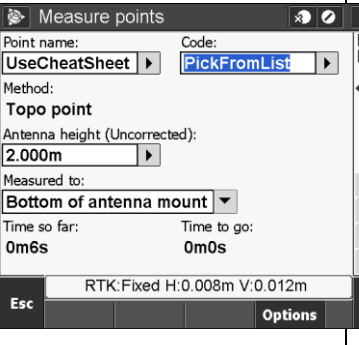
9. Step 4 - Measuring Points

This section covers an overview of how to collect survey data using an RTK setup and possible interruptions that can occur in the field. Once the base and rover receivers are set up and running, there is radio communication from the base, the rover receiver has initialized, and a fixed position solution at the rover is attained, then the actual task of measuring points can begin. The following sections describe how to measure points using the TSC3 controller and the guidelines for naming conventions for point names as well as point code descriptions.

For a detailed description of field procedures associated with RTK surveying refer to the Standard Operating Procedure (SOP) #8 - *Field Preparation and Surveying Protocols*.

9.1 Measuring points:

		
a.) From the main job screen you can see the status bar and status line show an active RTK survey is running with a fixed solution. To start measuring points select/open Measure. Note: this screenshot should have undefined rod height for the rover (not 2.000) since we haven't measured our first point yet.	b.) This is the Measure points screen. - The point name is a hold-over from the last job or point entered in this job. Use the NCPN point naming convention to set the point name correctly. - Use the <i>Feature Code Library</i> (associated with the job in Job Properties) to get the point coding correct.	c.) The Method determines only how long the shot takes before self-storing or being allowed to store manually. The default method is <i>Topo point</i>, which is commonly set at 5 seconds. You can change the amount of time required before storing a measurement by going into the <i>Options</i> soft key and changing the occupation time. I would not go less than 3 seconds, and this only if you have wide open sky, lots of satellites, excellent radio reception, very low RMS, very small residuals, etc. i.e. – perfect GNSS survey conditions.

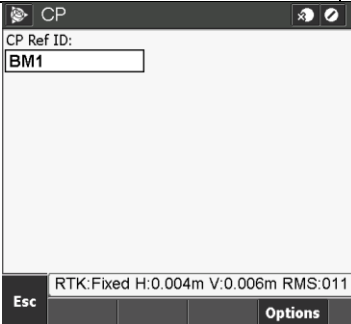
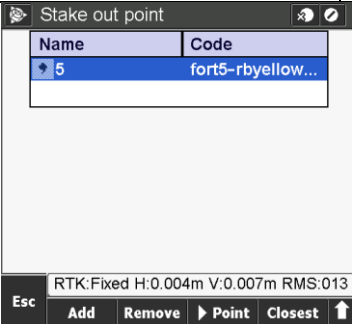
		
d.) This is the first page of the <i>Options</i> screen (Options soft key) showing settings for a <i>Topo point</i>. This is where you can enable or disable the Auto store point function. When this is check-marked and Accepted, measured points will automatically store when the countdown clock expires. This is very useful for most topo work but I find it better to disable this function when measuring points that require higher precision and accuracy such as control points.	e.) This shows the Measure Points screen correctly filled out. The operator has: 1. Defined the <i>Point Name</i> 2. Defined the <i>Point Code</i> 3. Set the <i>rod height</i> (antenna height) 4. Set the <i>measure point</i> (default is <i>Bottom of antenna mount</i> for the rover) 5. Checked that the positioning solution is fixed and that the error estimates are within acceptable limits. Now measuring points can begin.	f.) The rover is placed on a point and plumbed using the target bubble attached to the rod. The Measure soft key is tapped or the Enter key is pressed to start the measuring process. The Time to go clock counts down from 5 seconds (for a <i>Topo point</i>) while the Time so far clock counts up as the point continues to be measured. The Store function soft key is currently disabled until the countdown clock expires and the positioning solution remains fixed and within acceptable tolerances.
		
g.) As the point is being measured the countdown (<i>Time to go</i>) clock expires and the Store soft key becomes enabled unless the “auto store point” option has been checked. The <i>Time so far</i> clock shows the point is being measured for 6 seconds and	Note: if the “auto store point” has been selected/checked in the options tab then the measurement will be auto stored after the required time has expired and the user will not need to enter/tap the “Store” key. Instead you will hear “Observation Stored” once the	

continues until the Store soft key is tapped or the Enter key is pressed.	point has been measured/auto stored and you are then ready to move to the next point and take your next measurement.	
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9.2 Point Coding (Feature Coding):

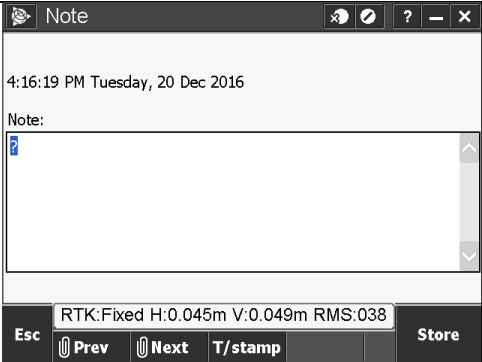
This section discusses how to use a **Feature Coding Library** which is associated with the file (Job properties). The feature code library is used to standardize the coding used by each surveyor in the field as well as simplify data processing back in the office. The feature code library allows the surveyor to enter/select a standardized code for each measurement by the type of data point that is being collected (topo points, control points, breaklines, etc.). A more detailed description of how this is utilized in the field is provided in the Standard Operating Procedure (SOP) #8 - *Field Preparation and Surveying Protocols*.

a.) This is the Stake out point screen. The cursor default location is always in the <i>Code</i> entry box and the code defaults to the listed name.	b.) If there is a Feature Code Library associated with the file then pressing any letter key associated with a code in the file will bring up a list of those feature codes. In this case the letter C was pressed. The feature code library (.fxl) file is <i>NPS point coding 09092015</i> as shown in the title bar.	c.) The operator then either taps or scrolls using the up/down arrow keys to highlight the code from the list. Then tap Select or press the Enter key to actually pick it. Codes with A inscribed in a circle are codes with attributes.
d.) The code has been selected and is displayed on the top line. Tapping Enter or pressing the Enter key will return you to the <i>Stake out point</i> screen and the code you picked will be inserted into the <i>Code</i> entry box.	e.) The code appears in the <i>Code</i> box and the point is ready to be measured. Notice the Attrib soft key is enabled because this point code has an attribute. You can enter it now by tapping the soft key or enter it after you measure when it prompts you. Tapping Measure	f.) This shows the point being measured. <i>Auto store</i> is not enabled hence the 15 seconds noted for the current observation time that has elapsed. Tapping Store or pressing the Enter key will store the point.

	or pressing the Enter key will measure the point.	
		
g.) This is the point code attribute screen. The point has been measured but it will not store until the code's attribute is defined.	h.) When you store a staked out point, it is removed from the stake out list by default. Only the point 5 remains.	

Notes function:

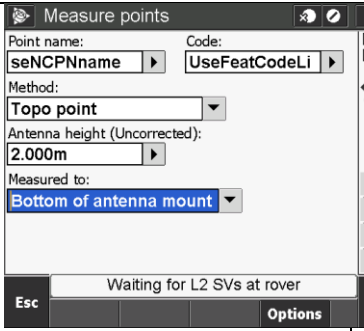
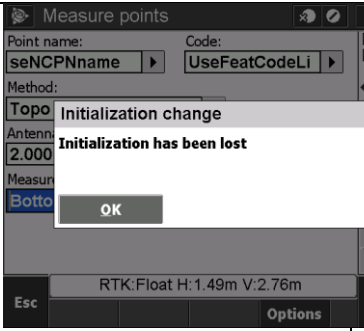
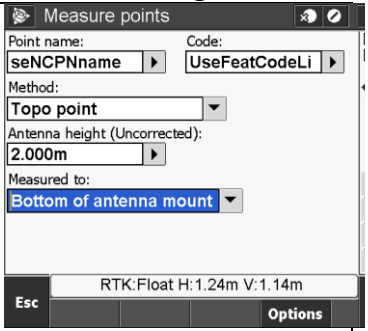
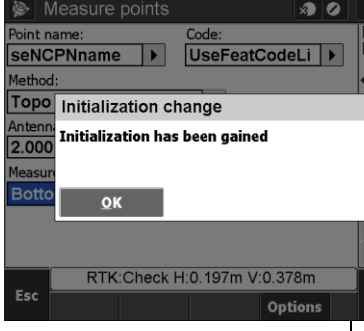
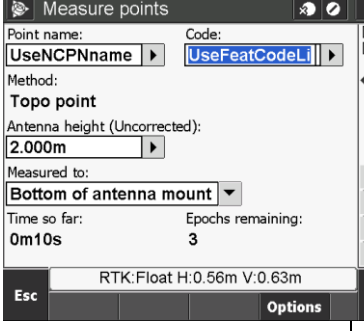
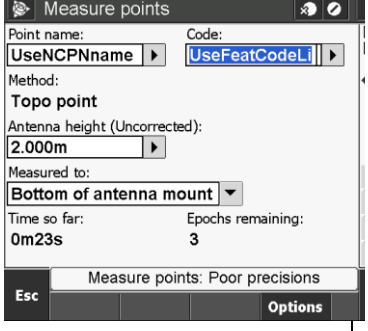
The Notes function in the controller is very convenient and easy to use.

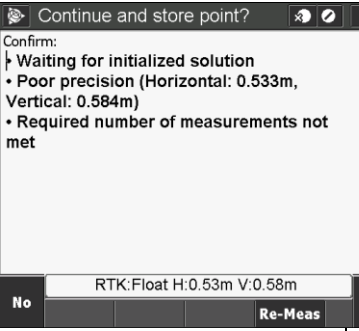
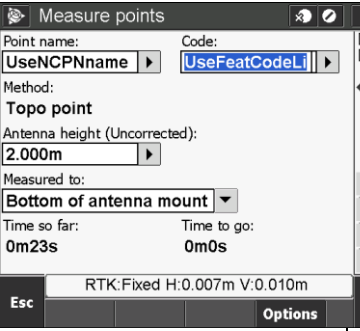
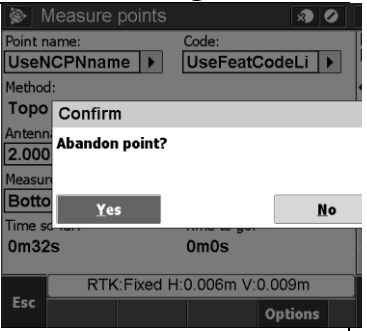
	It's very convenient to attach notes to points as you are surveying. In the status bar tap Menu > Key in > Notes or Favorites > Key in note. This opens the Note screen. After you type a note and enter it, tap or press the ESC key to close the Note function.
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9.3 Interruptions when measuring points:

These are some examples of interruptions that can occur or prevent the measuring of points during an RTK survey and how to handle them. There are basically two sources for interruption problems: one is **satellite** related and the other is **radio reception** related. If the base point has been set to provide maximum sky coverage for the base receiver (always a priority) then the following satellite related issues are unlikely to occur when surveying in open areas with the rover. If/when you take the rover into vegetation that obstructs the receiver's sky view, or severely skew its sky view window (as being next to a towering canyon wall) then you are likely to experience satellite signal reception issues which manifest themselves with a **Loss of initialization** message.

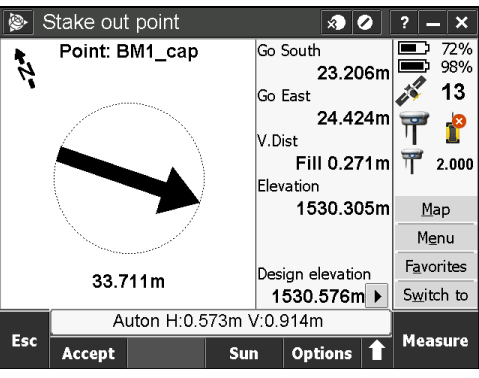
Satellite signal reception issues:

		
a.) Status line message showing a problem. The operator is not presently measuring a point but the <i>RTK: Fixed</i> solution has been replaced by this message.	b.) Loss of initialization: You will see a brief message indicating Initialization lost. The <i>Fixed</i> solution will revert to <i>Float</i>. As can be seen the horizontal and vertical precisions have grown unacceptably large. Any number of issues can cause a loss of initialization.	c.) The <i>Float</i> solution continues but the precisions are getting better.
		
d.) The receiver regains initialization and the user is notified. Audible messages also accompany the visual messages. The <i>RTK: Check</i> status will change to <i>RTK: Fixed</i> and the operator is good to measure a point provided that the precisions are acceptable.	e.) Here's an example of losing initialization after a measurement has started. The solution status has gone to Float and the <i>Store</i> soft key is not shown because of this condition. The countdown clock is removed and replaced with an <i>Epochs remaining</i> statement. An epoch is a time duration for a measurement; for RTK this is one second. The horizontal and vertical tolerances shown in the status line are far above the acceptable limits.	f.) The solution has not improved at 23 seconds of measuring. 3 epochs still remain. I can still tap the blank soft key or press the Enter key to force the point to store.

		
g.) Here I've forced the store function of a less than quality point solution. This Continue and store point? confirmation message appears describing the problem and how bad the precisions are. If these conditions are acceptable for this point then tap Yes or press Enter. If not tap No or Re-Meas.	h.) In this case the measurement has been going on for 23 seconds and it appears that it's a good measurement by the precisions shown. However, for some reason I don't want to store this point. I'm going to abandon this measurement.	i.) Tapping the Esc soft key or pressing the ESC key will generate this Abandon point? message.

Radio reception issue:

If the base and rover receivers have adequate sky visibility then the only problem you are likely to encounter is loss of radio reception.



This screen shows a **loss of base radio reception**. When this occurs you will see the radio icon has a red circle with an X inscribed in it. The positioning solution will revert to *Autonomous* as shown in the status line and the precisions will become very poor. Also, the green radio light on the rover receiver will stop blinking. The only readily available solution is to raise the rod height to the max to get the radio antenna higher up and wait for a minute or two. Sometimes the radio will drift in and out and you may still be able to get a shot.

This problem is minimized by a combination of good base station placement to start with and taking notes on how the base radio is set up to overcome this condition in repeat survey sessions. If the base station is located out of line of site or a large distance from where the rover is being used the connection issue could be related to the radio signal not being transmitted far enough. This could be due to a low output wattage set on the base broadcast radio (5W instead of 35W) or the points being measured are located around a canyon corner where the radio signal is not able to be received. In the latter case the only option to continue surveying is either to move the base station or use a repeater

radio if one is available. A repeater radio allows you to move to a location where the base radio signal is beginning to drop out and setup up an additional radio that will receive the base radio signal and re-transmit the signal using an additional broadcast radio.

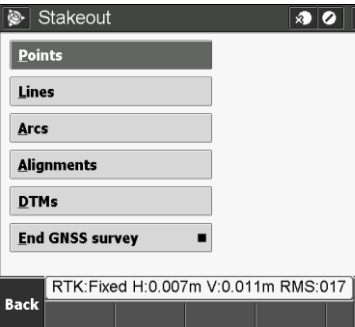
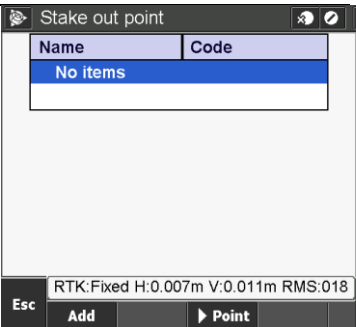
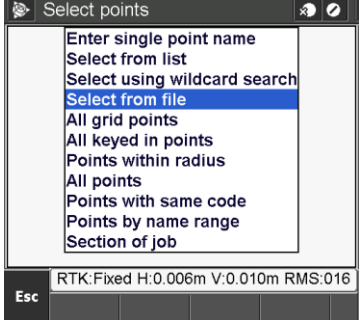
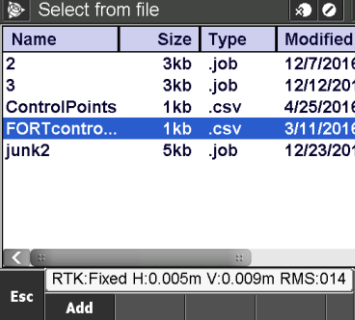
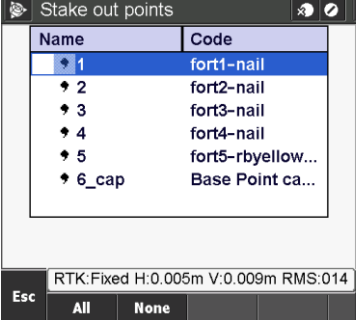
10. Staking out

“Staking out” (also called *setting out*) is the process of determining where a point or object exists in the current coordinate system and then perhaps measuring and storing an additional record at that position. This section shows how to stake out two common objects, a *point* and a *line*, in an RTK survey.

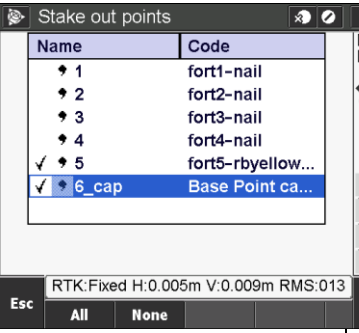
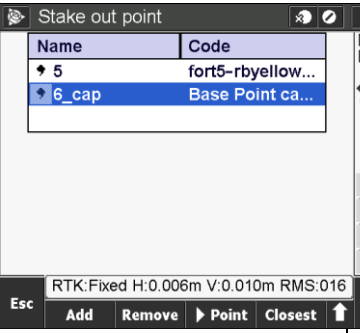
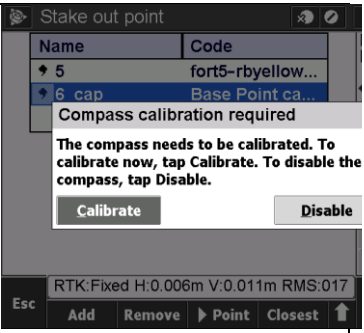
Key points:

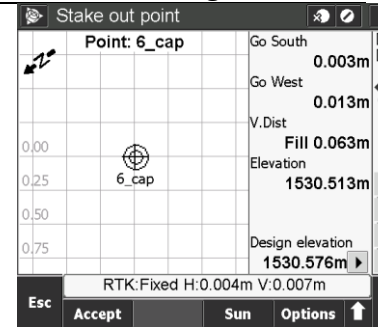
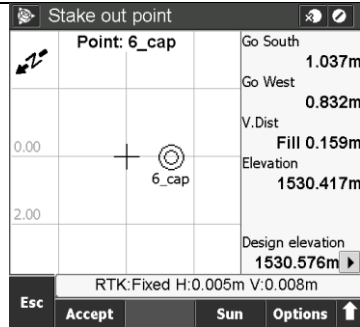
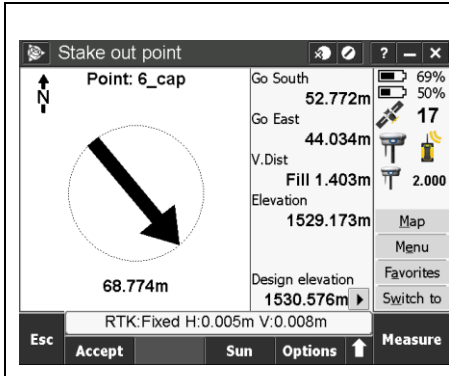
- Staking out a known point for the purpose of verifying that the RTK survey system is properly set up and functioning is vitally important and should be done as a matter of good field practice immediately after the rover survey is started. The staked point should match the known coordinates within a couple centimeters horizontally and vertically. If not figure out why not before proceeding, especially with any kind of stake out procedure. All rovers should stake out the same point independently and rover operators should compare ‘As-staked’ coordinate differences (*View before storage* option set to ON check-mark).

10.1 Staking out a point:

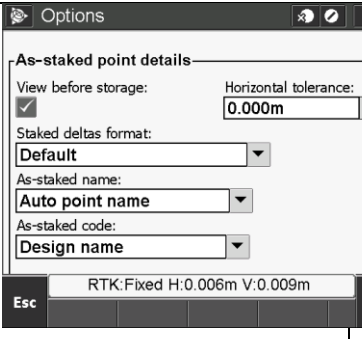
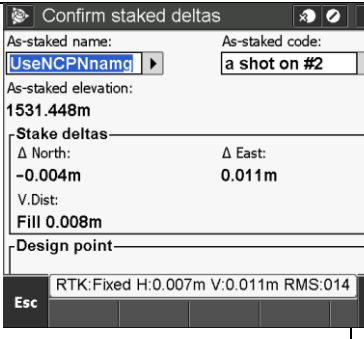
		
a.) The main job screen, pick Stakeout.	b.) Pick the Points option.	c.) This is the Stake out points screen. Notice there are no points listed. Tap the Add soft key.
		

d.) These are various methods to add points to the stake out list. Generally, we link files to the job so go to Select from file and tap Enter or press Enter key. See the part about linking files in Create a job if you need to do this.	e.) Now a list of available files is shown. Highlight the file you need and Accept.	f.) Now the points in the file you selected are shown.
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g.) Check-mark the ones you need. Optionally, you can tap the <i>All</i> soft key at the bottom, tap Add.	h.) The points you check-marked from file listing are now added to the stake out list. • Highlighting a point and tapping <i>Stakeout</i> or pressing <i>Enter</i> will start the stakeout process for that point. Tapping <i>Closest</i> will start the stakeout process for whatever point on the list is closest to your current position.	i.) The internal compass won't remain in calibration because we do survey work in locations that are quite far apart from each other. As a result, this Compass calibration message pops up as soon as you try to navigate to a point. You can either disable it or follow the calibration procedure. The calibration procedure requires you to release it from the rod, turn it 360 in the face up position, roll it 360 end-over-end, and roll it 360 through face down to face up again.



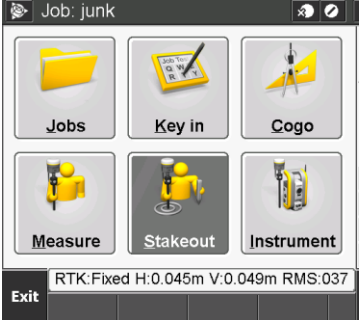
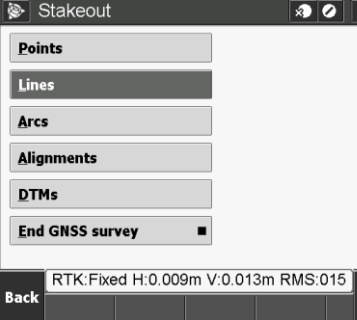
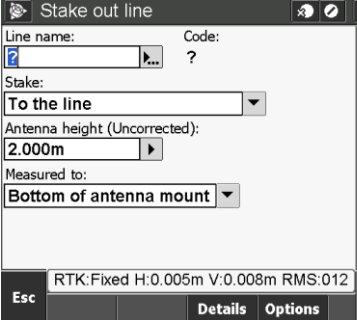
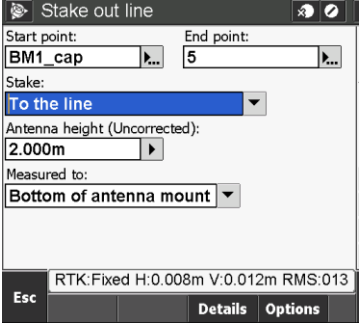
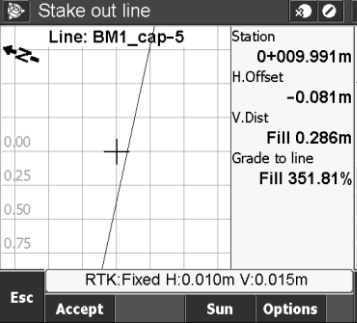
j.) If the rover is more than a few meters from the point then you'll see this big arrow display telling you how far you need to go and in what direction. Note the relationship to the North arrow.	k.) When you get close enough to the point the display will change to this. • Your location is the cross in the middle. It doesn't appear to move. This is called <i>Surveyor centered</i> (changeable in Options to <i>Target centered</i>). • The point location is the round circle object. It moves around as you do. • There is a compass direction shown in the upper left to help you know which way to move. Some operators prefer a small compass mounted on the rod. • Distances to the point are also shown to help you know how far to move in a direction. <i>Cut</i> or <i>Fill</i> are survey terms meaning 'down' or 'up' respectively. • When you have moved the tip of the rod to the stake out coordinate and plumbed it using the rod's target bubble, the distances to the point will be a few millimeters or a centimeter or so. This depends on the quality of the positioning solution shown in the bottom status bar.	l.) Here, the operator has positioned the rover rod on a survey cap monument. As can be seen, the horizontal positioning is acceptable at 3mm and 13mm. However, vertical distance is indicating a problem. It's saying I need to come up about 6cm to get to the point (Fill 0.063m). As it turns out this monument was run over by a tractor and squashed down into the ground about this much. Tapping Measure or pressing Enter will put you temporarily in the <i>Measure Points</i> screen (previously discussed) and will start measuring a point.
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m.) The <i>Options</i> screen (Stake out point Options soft key). The View before storage option lets you see the relationship between the position you just measured and the known coordinates of the point.	n.) If <i>View before storage</i> is check-marked then this Confirm staked deltas screen appears when you try to store a staked out measurement. This allows the operator to see how close the measured point is and rename, recode, or escape (abandon measurement) if necessary. Just like <i>Auto store</i> (unchecked) for measured points, this option is nice when you are wanting to see the actual details and have the option to cancel (Esc) or store the shot but for general topo work uncheck it if you don't need to see the details.	

10.2 Staking out a line:

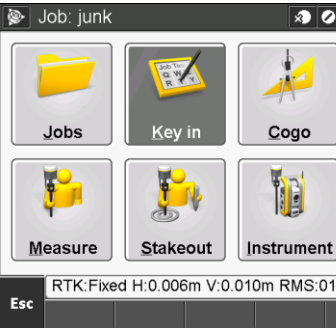
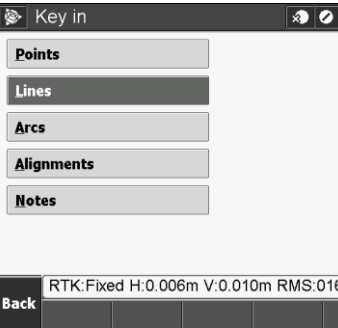
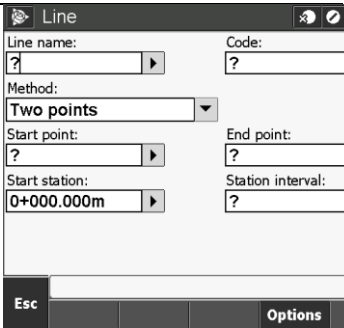
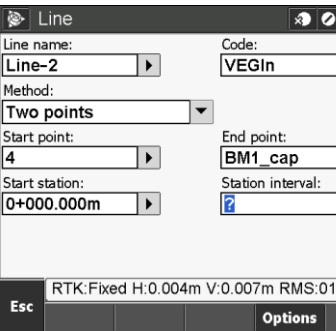
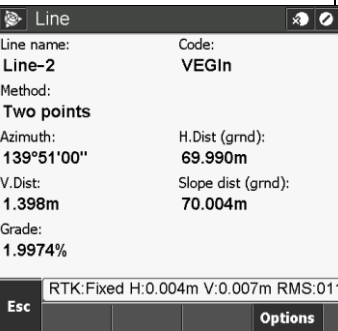
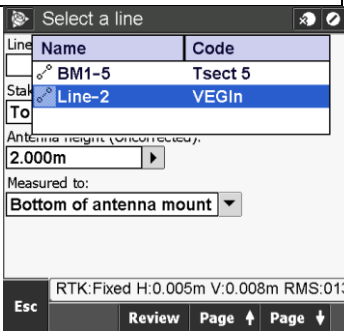
There are a few different ways to stake out a line. The two most commonly used ones are by *Line name* and by *Two points*. First we will discuss the *Two points* method.

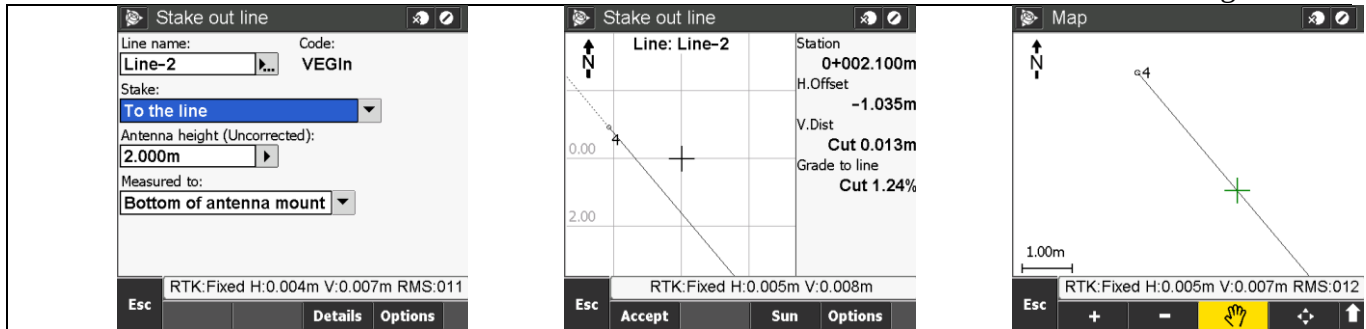
Staking a line by two points is faster to initiate but you will only be able to see the line in the stake out program. It will not be visible in the map.

		
a.) The main job screen, pick Stakeout.	b.) Pick the Lines option.	c.) This is the default Stake out line screen (by <i>Line name</i>). To stake out by two points, use the drop-down list and tap ahead of the Two points method to place a check-mark there. That will open the Stake out line by two points screen (following).
		
d.) This is the Stake out line (by two points) screen. You can pick the start and end points by opening the drop-down list for each. Tapping Start or pressing the Enter key will start the stake out process.	e.) Here you can see the line on the display. The rover's position is indicated by the cross. <i>H. Offset</i> is negative if the rover is left of the line. The left or right side is predicated on the direction the line is defined from start point to end point.	

10.3 Stake out a line by name:

This method starts with the assumption that you need to create a *named line object*. This takes slightly longer to set up but you can see the line object in the *Map* view as well as in the *Stake out line* display window.

		
a.) The main job screen. Select Key in.	b.) Select the Lines option.	c.) The Key-in Line screen. You can always stake a line by two points without defining it as a line object in this key-in screen but you won't be able to see it using the map function.
		
d.) The line object has been named and coded. The line object is defined by two points and the stationing at the start point has been set to 0 (default). If you need to measure points at set station intervals then fill in the Station interval box. Tap Calc or press the Enter key to create the line object.	e.) This shows the created line object, its direction, length, etc. Press Store to store it and you will be returned to the stake out line's <i>Select a line</i> screen.	f.) Tapping on the Line name drop-down list brings up all the known line objects. Tap on <i>Line-2</i> to select it.



g.) The selected line is entered into the Line name box. Now the **Stake method** is highlighted. In this case, for topo measurement, I'm not concerned with where on the line I am as long as I'm on the line so I'll choose **To the line** from the drop-down list. If I needed to be at a certain spot on the line I would have picked **Station on the line**. Tapping **Start** or pressing **Enter** will start the actual stake out process.

h.) Here you see the actual stake process. You can see the line in the 'window' and one of the endpoints, point 4. The cross in the middle is where you are in relation to the line. Remember how the line was defined: Start at point 4 end at point **BM1_cap**. Your current position is about 2 meters from the start point along the line and a little over 1 meter left of the line. If *H. Offset* is negative, you are left of the line. If *Station* is negative you are behind the start point. Since the line is a vector, the *V. Dist* means your current position is above or below the line. For our intent and purpose we don't really care where the line vector is vertically. If a measurement on the line is needed at this time then move right about a meter until the *H. offset* value drops to near zero.

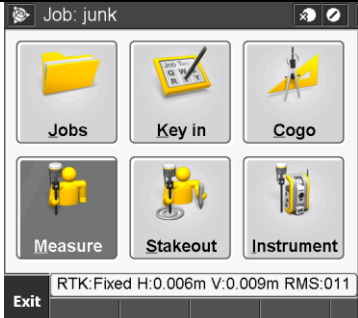
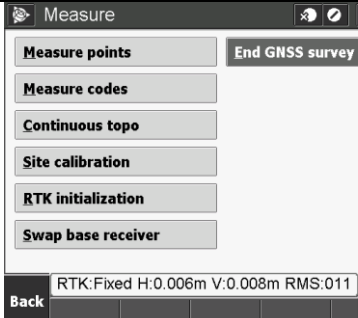
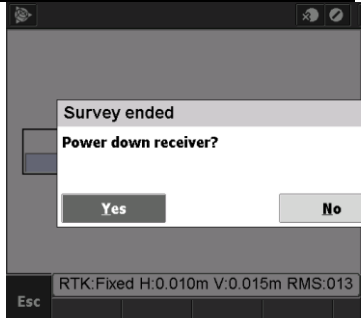
i.) This is the map function. Main job screen, **Map** from the menu bar. Since the line is a named object it will appear on the map. The map function does not give you any numerical values about your relationship position to an object. For tight tolerances along the line and stationing I would suggest using the previous method (Stake out line). For faster positioning many find the map function easier to use. However, the operator must **pay attention to the map scale** as the depictions of lines, points, position cross, etc. appear the same size at any scale. So you may be watching the line move in relation to the cross as you position yourself on the line and think you are on the line (as it appears here) only to find out later in the office that you were over a meter away because the scale was at something like 20m. I find the scale at .5m to 1.5m adequate for topo work. Here, the scale is at 1 meter and a reference bar is shown for comparison to other objects in the map window. It would appear that the rover's current position is within a couple of centimeters of the line based on comparison to the scale bar, acceptable for topo

		work. The yellow 'hand' soft key is the current enabled map operation. The map view can be dragged along the line using the touch screen. The big 'up-arrow' soft key opens up other map options.
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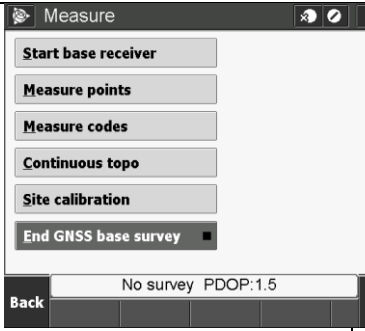
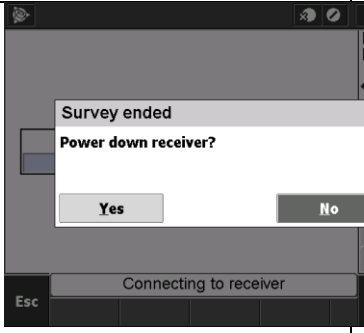
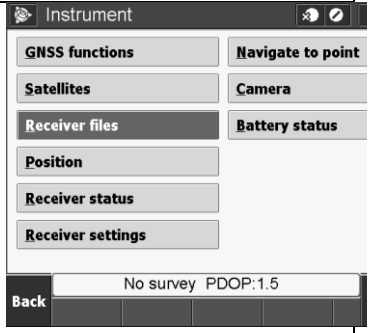
11. Step 5 - Ending the survey

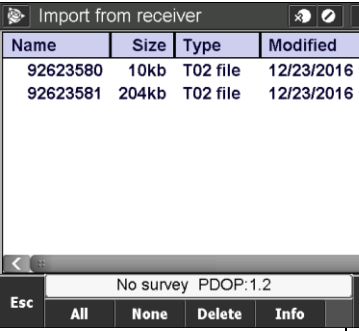
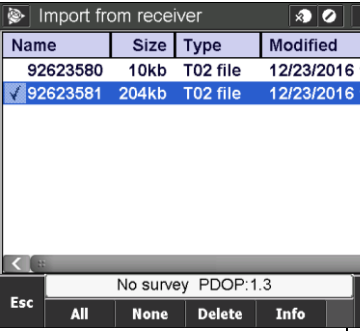
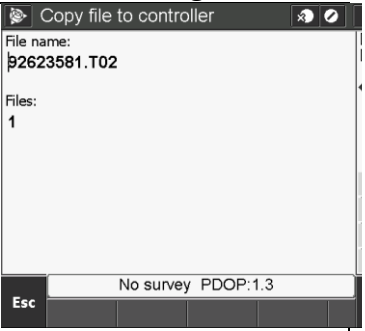
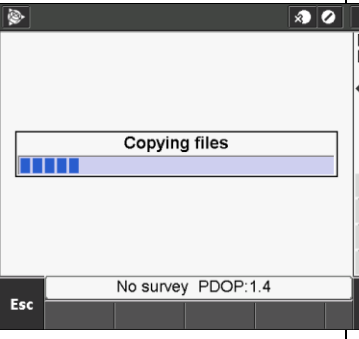
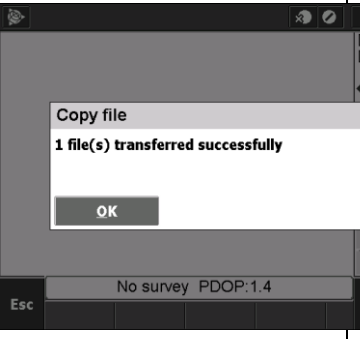
This is a two-part process. First end the rover session, then end the base session.

11.1 Ending the Rover session:

		
a.) From the main job screen, pick Measure to get to the options.	b.) Pick the End GNSS survey option.	c.) You will see a brief message saying <i>Ending survey</i> and then see this <i>Survey ended</i> message. Picking Yes will turn the receiver off. Picking No will leave the receiver running and receiving radio broadcast but the survey session has ended. The screen will return to the main job screen. Whether or not you power down, if you forget to measure something simply start another survey session and reconnect to the base radio.

11.2 Ending the Base session and retrieving the base file:

		
a.) The main job screen, pick Measure to get to the options.	b.) Notice the <i>End GNSS survey</i> option (for the rover) is no longer available. Pick End GNSS base survey.	c.) You will see a brief message saying <i>Connecting to GNSS base via bluetooth</i>. It will hang on this screen if you are not within Bluetooth wireless range.
		
d.) You will then see a brief message saying <i>Ending survey</i> and then see this message. The default is Yes but you need to pick No. This will end the base session but leave the receiver powered on so you can extract the base file it created. Base files accumulate in the receiver (up to the point of reaching storage capacity) and they can be retrieved later but because they are unreadable and the names are somewhat obscure it is better practice to get it now so it's immediately available to work with.	e.) After the base session has ended it will put you back in the main job screen. Note in your base log file when the base session ended. Go to Instrument.	f.) Pick the Receiver files option.

		
g.) This is a list of all the receiver files logged base data currently in the receiver. Every time the base is started it logs a file. Some of these may not contain relevant information. Look for files by date and by size. The 8 digit file name is composed of: • First 4 digits are the last 4 digits of the receiver serial number. • Next 3 digits are the day of the year. • Last digit is sequence number of files created in a day, starts with zero.	h.) Check-mark the files you want to copy by tapping in front of the file name. Tap Import or press the Enter key.	i.) A confirmation list of the selected files you want to copy appears. Tap Start or press the Enter key to start the Bluetooth transfer. The base files will be copied to the root folder. Note the names of the base files and maybe the sizes in your base log so you know which files go with which base point.
		
j.) The selected file(s) will start to be copied to the controller. Keep the controller near the base receiver and don't unplug or turn off the base receiver until the transfer is finished. It can take several minutes for a large file.	k.) This notice will appear when the transfer is complete. Tap OK and you're done. You can now power down the base receiver by pushing the power button for about 4 seconds or from the controller by answering Yes to the power down question again.	

12. Surveying the reach

Set up all seven taglines and transect tapes on adjacent transects (see SOP#2 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.

12.1 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.

12.2 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 23)
- 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.

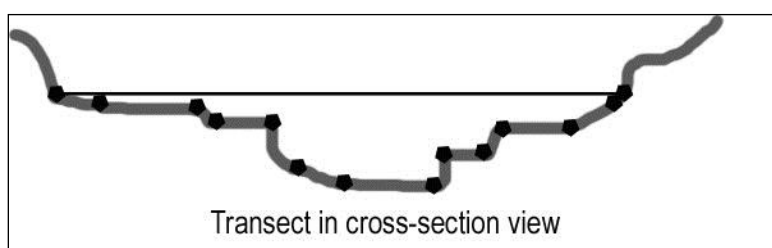


Figure 23. Example of slope breaks points surveyed in addition to 1-m intervals.

- 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.

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.

12.3 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.

12.4 Surveying wells and other hydrologic monitoring equipment

SCPN has determined that the minimum requirements necessary for surveying hydrologic equipment requires a total station with an angle precision of 9 seconds, roughly +/- 0.016 m over 500 m. The current Topcon GTS-239 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 unless re-sectioning to establish an occupied point from which all features and controls are visible. You will also need another known point to backsight to use as a reference elevation. Surveying will be conducted using pre-established coordinates for all controls, which are the basis for conversion of hydrologic data and integrated analysis. Data may be comprised of those collected during reach establishment or during revisits.

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. 24)
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 24. 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 to see if there are any special instructions for surveying (e.g., use the rod point in the measuring notch, etc.).

12.5 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.
- SCPN 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.

13. After the Field Visit**13.1 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., origPARKP-03_2012, corrPARKP-03_2012, etc.) in Z:\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:
- Create a comma delimited (.csv) file on the Recon. Open the correct job. In the File menu, click on Export. Select the CSV radio button and click Next. On the next screen, click the down arrow on the right side of the screen and click on Select All Points; click Next. On the next screen, select the Plane radio button under “Coordinates.” Units will default to meters; click Next. Select Name, Northing, Easting, Elevation, Description as the export order and click Finish.
 - 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 > Survey Data. Navigate to the job.
 - Copy and paste the 3 files from this job (.CSV, .RAW, and .JOB) to the Original folder. Leave the files on the data collector for the time being.

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 .RAW 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.

13.2 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.

13.3 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.

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).

13.4 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. Each transect output from Excel should use either 10.00 m or 100.00 m as the stationing value for the left endpin, depending on the extent of area beyond the left endpin that may be included in future surveys over the long term. This enables relocation of the left endpin farther left, if ever necessary, without introducing negative stationing values. 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., PARK_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.

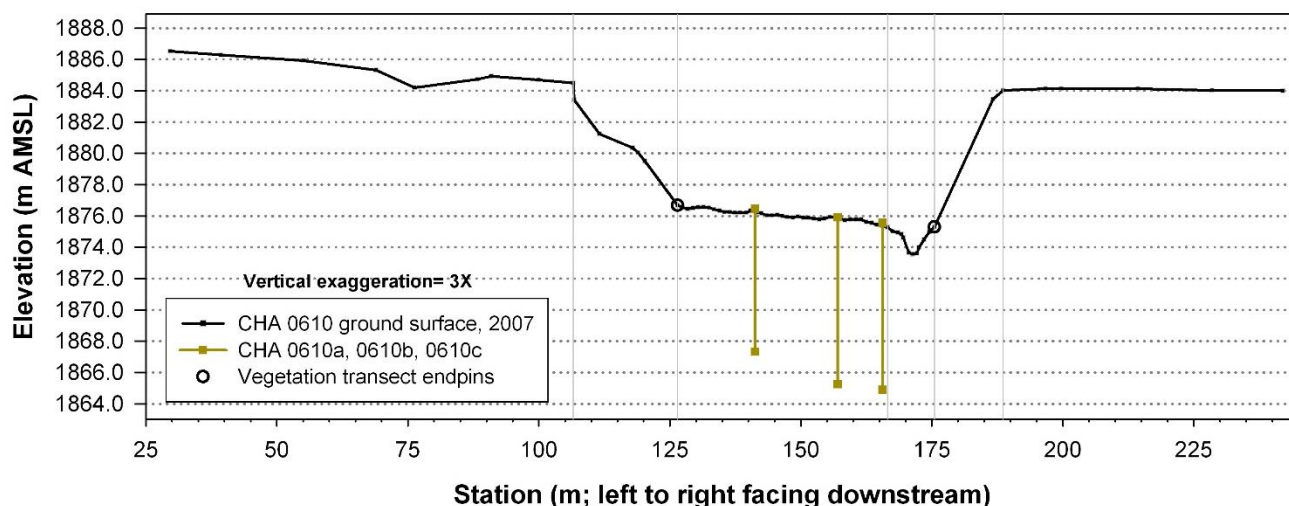


Figure 25. The full survey of a stream cross-section for a transect. In this example, three monitoring wells on the transect have also been graphed to show relative depths. The vegetation sampling transect is between the vegetation endpoints.

13.5 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.
- 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.

=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		
26	2013KL680	4967.04	4916.94	993.25	PROFILE1				0.770	20.004	993.25	PROFILE1		

Figure 26. Longitudinal profile data for a stream in an Excel worksheet.

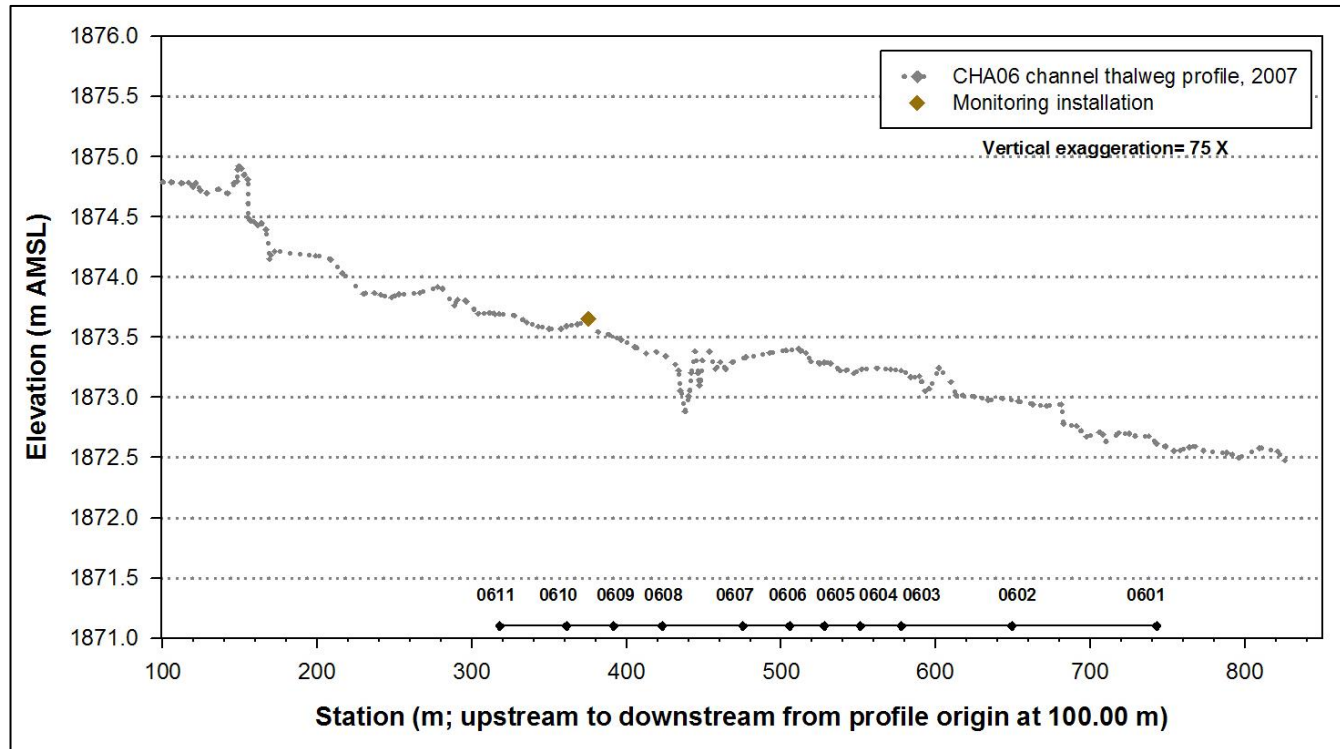


Figure 27. Longitudinal profile of a stream through a monitoring reach. Vegetation sampling transect positions are labeled above the bottom axis.

13.6 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. Unless RTK or extremely high-accuracy GPS is used to establish control point coordinates, errors introduced from the GPS make real-world coordinates usable 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.

13.7 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.

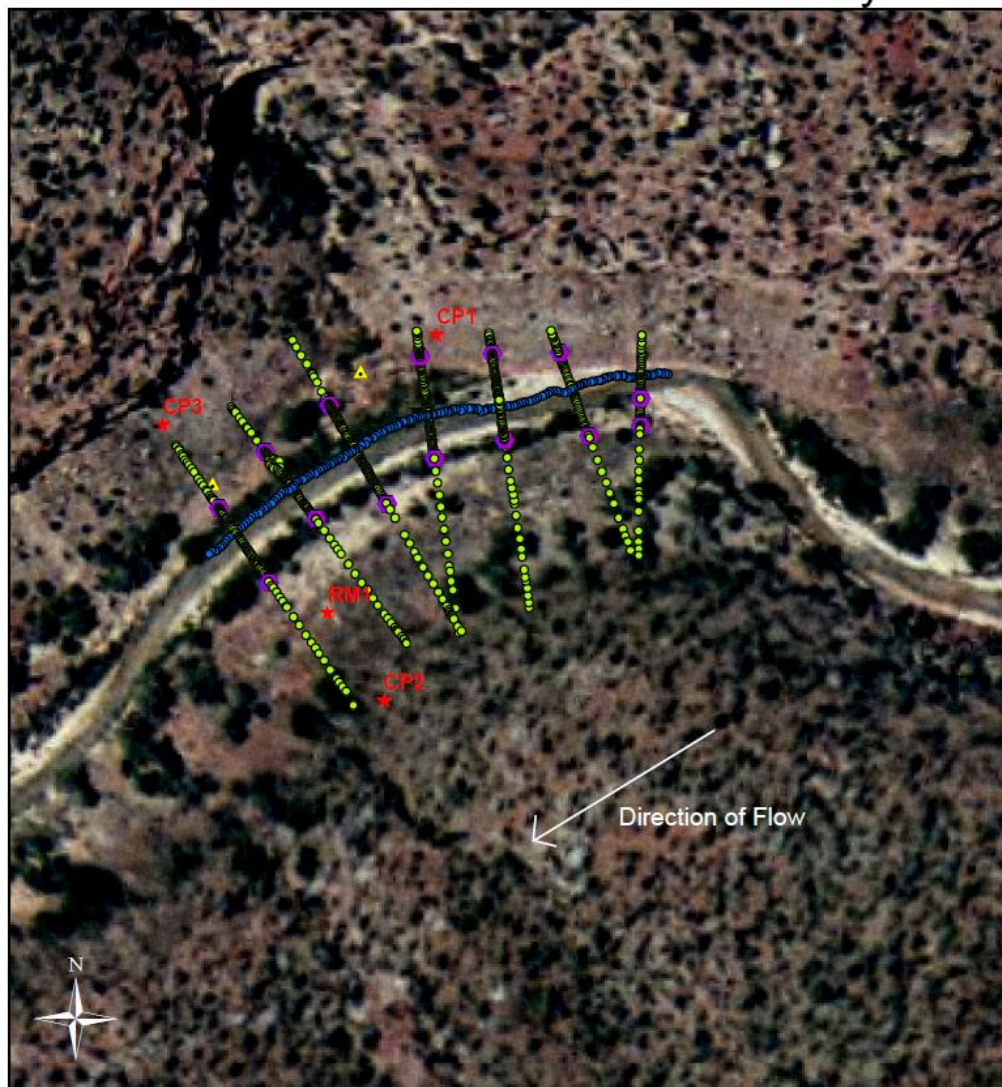
13.8 Creating revisit files

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, Ecogeomorphology and Topographic Analysis Lab. Bonneville Power Administration.

ZION P-02 March 2012 NCPN Survey



Legend

ZION_P-02_AllPtsRealWorld

PointType

- ★ Control
- Headpins
- ▲ Occupied Point
- Profile
- Transects

Transect and longitudinal profile plan form map.

Base imagery: 2002 aerial photography.

See data spreadsheets for coordinates and details on surveying.

See powerpoint document for survey control point descriptions and reference photos.

Figure 28. Revisit map containing all surveyed points at a reach, from 2018 NCPN *Riparian Monitoring of Wadeable Streams Protocol*.

Appendix A: Packing list

Base station gear:



Base station setup:

- | | |
|--|--|
| 1. 42-watt solar panel with connecting cable | 14. Power/data cable for base receiver and broadcast radio |
| 2. Extension rods for radio antenna | 15. Marine battery with quick connect cables for base receiver power and solar panel |
| 3. Tribrach base | 16. Heavy duty wooden tripods for base and radio antenna |
| 4. Tribrach adaptor (removable mount) | |
| 5. Flat disc for mounting radio antenna rod on tripod | |
| 6. Long whip antenna | |
| 7. Short whip antenna | |
| 8. Antenna base (connects to antenna coax cable #13 and whip antenna #6 or #7) | |
| 9. Solar panel voltage regulator/battery saver | |
| 10. R6-4 base receiver dome | |
| 11. Short extension pole for base receiver (0.2m) | |
| 12. TDL-450 broadcast radio | |
| 13. Radio antenna coax cable with fixed antenna mount | |

Not shown but often necessary: A means of securing the base receiver, base radio antenna, and solar charging panel from being toppled by strong winds. There are generally two methods; weigh it down or tie it down.

- In areas where there is only rock; A set of six 24” – 30” bungee cords to strap rocks to the tripod legs as ballast to help prevent wind topple and hold down the solar charger. (Photo example shown on page 3)
- In areas of sufficient soil depth; A set of six tent pegs and a tie-down kit, 3 lb. hammer, and a set of four smaller bungee cords for use in holding down the solar panel with 4 tent pegs.

Appendix A: Packing list (cont'd)

Rover gear:

5



For each rover setup:

- Rover rod (adjustable height model shown, with flat topo tip)
- Rover receiver
- Receiver radio antenna
- Receiver batteries (you'll need at least 2 per rover)
- Rod mounting bracket (2-pieces)
- Survey controller (TSC3 controller)