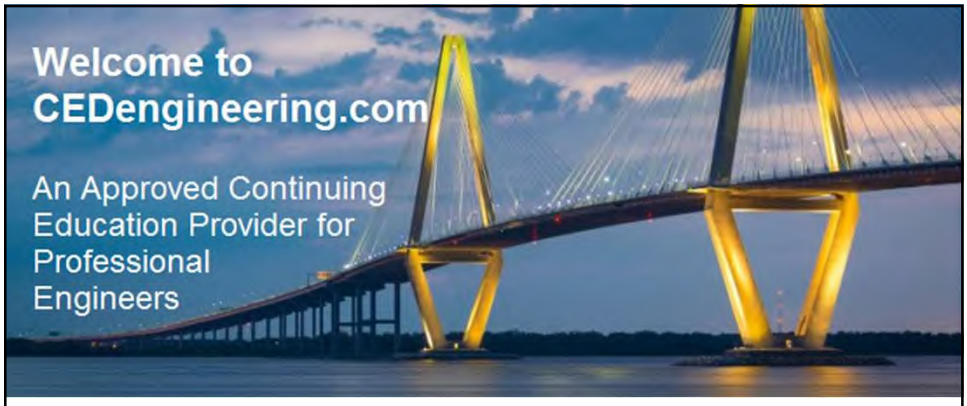

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Best Practices in Hydrographic Surveying – Part 1

Course No: L02-304 - Course Credit: 2 PDH

Prepared by:

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Best Practices in Hydrographic Surveying – Part 1
L02-304
2 PDH

LEARNING OBJECTIVES

1. To understand the purpose and scope of the equipment and procedures used in hydrographic surveying.
2. To learn how to set up and operate Real-Time Kinematic Global Positioning System base stations and rovers, including radio setup and data processing.
3. To learn how Real-Time Network surveying is planned, carried out in the field, and post-processed.
4. To know how robotic total stations are set up and used to collect topographic, scan, and panoramic data, and how the data are post-processed and exported.
5. To become familiar with single beam depth sounding using the SonarMite, including setup, quality assurance, troubleshooting, and data processing.
6. To gain an overview of multibeam surveying, including swath coverage, system components, calibration, and the data editing workflow in the MBMAX64 editor.

REAL-TIME KINEMATIC GLOBAL POSITIONING SYSTEM SURVEYING

Introduction

Real-Time Kinematic (RTK) Global Positioning System (GPS) surveying is a technique that uses carrier-based ranging and provides ranges (and therefore positions) that are orders of magnitude more precise than those available through code-based positioning. The basic concept behind RTK GPS surveying is to reduce and remove errors common to a base station and rover pair, as illustrated in Figure 1.

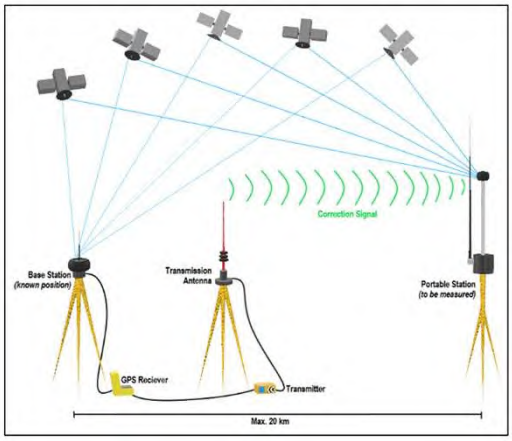


Figure 1: RTK GPS basic concept.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

RTK GPS calculates horizontal coordinates in real-time relative to a known base point and orthometric elevations based on the ellipsoid and geoid models selected. The GPS base receiver is set up over a point with known coordinates. Position corrections are transmitted to the GPS rover receiver using an external GPS radio and UHF antenna. The base station is typically powered by a 12-volt battery. Figure 2 shows a typical RTK GPS base station setup.

Figure 2: Typical RTK GPS base station setup, Thunderbird Reservoir, Oklahoma.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

The rover component consists of a second GPS receiver with internal radio and external antenna mounted on a range pole (ground survey) or survey vessel (bathymetric survey). The rover receiver, reading the same satellites at the same time as the base station, receives the corrected positions from the base receiver. This results in real-time positions with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically over relatively large survey areas.

Equipment

As of September 2019, the Sedimentation and River Hydraulics Group (SRH) in Reclamation's Technical Service Center has the following RTK GPS equipment:

- Seven R8 GPS receivers
- Three R10 GPS receivers
- Three HPB450 radios
- Three TDL450 radios
- Seven TSC3 controllers
- Six antenna kits

RTK Base Station Setup Procedure

The R8 and R10 receivers have a slightly different setup, but both base station setups follow the same general steps:

1. Put battery in base receiver.
2. Set GPS base receiver over point of interest on first tripod (e.g., rebar, stake [hub], PK nail, survey cap, etc.); accurately level with tribrach before turning on receiver.
3. Set external (base) radio and radio antenna on second tripod in close proximity to base receiver; coarse level with tripod legs.
   - R8 base receivers are typically used with HPB450 radios (yellow).
   - R10 base receivers are typically used with TDL450 radios (gray).
1. Connect radio antenna cable to external radio.
2. Connect external radio to base receiver using data end of super cable.
3. Connect base battery using power end of super cable (ALWAYS CONNECT THIS LAST!) .
   - HPB450 radios require larger (car) 12-volt batteries.

- TDL450 radios can be powered using smaller (amp/hour) 12-volt batteries.

7. Measure the Height of Instrument (HI) from the established base point to base receiver using collapsible black measurement rod.
   - For R8 base receivers, measure to the center of bumper.
   - For R10 base receivers, measure to the bottom of the lever arm extension.
8. Power on survey controller and start new job using the appropriate settings (General Survey → Jobs → New job).
9. Connect to base receiver via Bluetooth (General Survey → Instrument → GNSS functions → Bluetooth).
   - Under "Connect to GNSS base," select receiver type and serial number corresponding to base receiver using the drop-down list.
   - Once the Bluetooth setting is accepted ("Accept"), select "Base Mode" under "GNSS functions." The user can then "Esc" back to the general survey screen, which should have the job name listed at the top.

10. Start base receiver (Measure → select appropriate survey style template → Start base receiver).

- Enter pertinent base measurements and site information:
  - o Point name is point number
  - o Can "List" a pre-loaded point or "Key in" a new point by selecting menu to the right of the point name field
  - o If keying in a point, can enter known coordinates and elevation or establish an autonomous position through the "Here" button near the lower left corner of the screen
  - o Code is point descriptor
  - o "Store" the point, which will bring the user back to the "Start base" screen
- Enter the antenna height (followed by "m"), which will automatically convert the measurement into the coordinate system units.
- Enter "Measured to" from drop-down menu:
  - o Center of bumper for R8
  - o Lever of R10 extension for R10
  - o "Station index" can be any integer
  - o "Transmit Delay" should be set to 0 millisecond.

- "Start" base receiver in the lower right corner.

11. Verify the external radio is on the appropriate power setting, is transmitting ("TX" light is blinking), and is set to the appropriate channel before leaving the base station.

Field Book Notes

While in the field, the user should log the following notes for each base station setup:

- Survey team member names
- Date
- Survey job file name and datum (TSC controller)
- Estimated project height
- Receiver serial number (last three digits)
- Controller number
- Radio frequency and channel
- HI measurement (and what it is measured to)
- Base station point number and coordinates (note datum and source of base point coordinates, or if needs to be post-processed with OPUS)
- Point description
- General location
- Survey style
- Start time
- End time
- Position of base station relative to local landmarks and address, or nearby cross streets
- Photograph of the base station setup from at least two vantage points

RTK Rover Setup Procedure

While in the field, the user should log the following notes for each base station setup:

1. Put battery in rover receiver.
2. Power on survey controller and start new job using appropriate settings (General Survey → Jobs → New job).

Note: This step is not necessary if using the same controller that was used for the base station setup.

3. Connect to rover receiver via Bluetooth (General Survey → Instrument → GNSS functions → Bluetooth).
   - Under "Connect to GNSS rover," select receiver type and serial number corresponding to rover receiver using the drop-down list.
   - Once the Bluetooth setting is accepted ("Accept"), select "Rover Mode" under "GNSS functions." The user can then "Esc" back to the general survey screen, which should have the job name listed at the top.
4. Start survey (Measure → select appropriate survey style template → Measure points or Continuous topo).
   - Enter pertinent rover measurements and site information:
     - Point name is point number
     - Point code is point descriptor
     - Rod height (normally measured to "bottom of antenna mount")
     - "Station index" can be any integer
     - "Transmit Delay" should be set to 0 millisecond

Downloading and Processing Data

While in the field, the user should log the following notes for each base station setup:

1. Download the ".T02" (base) file from the base receiver to a TSC3 controller via Bluetooth.
2. Transfer both the ".T02" and ".job" files from the TSC3 controller to a flash drive (hard disk) for import into Trimble Business Center (TBC).
3. Convert ".T02" file.
   a. Install the "RINEX" utility from the Trimble "Support Products A-Z" Web page.
   b. Open the ".T02" file in the "Convert to RINEX" software (Ctrl + O).
   c. Make note of the antenna offset in meters (this antenna reference point [ARP] measurement is what will be used when submitting to OPUS).
   d. Convert the ".T02" file to RINEX (File → Convert Files).

   Note: The utility will store three output files (.XXo, .XXn, and .XXg) in the same directory as the ".T02" file:
   - XXo = observation (this is the file the user submits to OPUS)
   - XXn = navigation
   - XXg = Glonass

4. Submit to OPUS .
   a. Attach data file; use the ".XXo" file from the RINEX converter utility where XX are the last two digits of calendar year (e.g., 19o if collected in 2019).Open the ".T02" file in the "Convert to RINEX" software (Ctrl + O).
   b. Choose antenna type, e.g., TRMR8_GNSS.
   c. Enter ARP in meters, e.g., 1.783 meters.
   d. Select "Options."
      - Change standard format to standard + XML.
      - Dictate which Continuously Operating Reference Station (CORS) to use. Can pull up map of CORS stations by clicking on "—find site IDs" to see if there are better geometric solutions. Ideally, the base station should be in center of three CORS stations. If all CORS stations are in one direction, this is not a good solution as the base station will be outside of center.

e. Upload to "Static" if more than 2 hours of data are available. Upload to "Rapid-Static" if less than 2 hours of data are available, or if needing a quick solution while in the field (best static solution occurs after at least 2½ weeks from collection date).

Note: OPUS will send the user a ".xml" file via email, which can be dragged directly into TBC, with the high-quality OPUS Solution Report that contains (from OPUS Web site):

- Orbit Used = precise or rapid
- Over 90% observations used
- Over 50% ambiguities fixed
- Correct antenna and antenna height
- Static: overall RMS < 3 cm, peak to peak errors < 5 cm
- Rapid Static: no warning messages
- Quality indicators that are suspiciously low
- Normalized RMS that is suspiciously high
- Coordinate standard deviations that are suspiciously high

The user should check the OPUS solution against the "HERE" X,Y,Z values:

- Document X,Y,Z while in field, or pull from controller
- Convert OPUS solution from meters to survey datum, such as U.S. Survey Feet, using Corpscon and appropriate datum (e.g., Washington State Plane North)

Global Versus Local Coordinates

In TBC, global latitude/longitude heights are in terms of a "global coordinate datum" which, in most modern cases, is synonymous with the WGS84 datum. A global coordinate datum is an approximation of the shape of the entire globe.

Local latitude/longitude heights are in terms of a "local coordinate datum," which is a datum that is a regional best fit, rather than a global best fit.

When users import NGS datasheets or OPUS solutions to use in a site calibration, they can easily convert the Global Navigation Satellite System (GNSS) local coordinates used in those solutions to global coordinates, which are required when performing the site calibration. To do so, expand the base point node in "Project Explorer," right-click the local coordinate, and select "Change Local to Global." Another solution is to disable the grid/local coordinates or terrestrial stations for these base points.

Import Corrected Base Point Into Trimble Business Center

1. Set up a new file with a name different than field project to note post-processing.
   a. Start new project in U.S. Survey Feet (or unit of project).
   b. Import ".job" file (controller file) and choose coordinate system of imported file.

2. Import the ".xml" file from OPUS.
   a. Select File → import, then navigate to path where file is stored and double-click.

3. Adjust quality.
   a. Zoom into control points.
   b. Select View → Project Explorer → Points → Select field base point.
      • Select "Properties" (right-click), then change elevation and latitude/longitude from control (triangle) to "unknown quality."
   c. Select View → Project Explorer → Points → Select OPUS point.
      • Select "Properties" (right-click), then change OPUS elevation and latitude/longitude to control quality (will show as local).
   d. Click red ball at bottom to recompute.
   e. Repeat for ".job" files for global and grid coordinates.

4. See how far OPUS solution and original HERE point differ.
   a. Select Survey (tab) → Measure Distance (drop-down menu) → Inverse.
   b. Use mouse to measure distance (it will show elevation and distance difference between the two points).

5. Check for red flags and investigate any major issues.

6. Merge base points.
   a. Zoom into two base points (field and OPUS solutions).
   b. Select Edit → Merge Points
   c. Select OPUS point first, then use control (Ctrl) key and select field base point (HERE point).
   d. Expand "Selected Points" box and check first and second box to include both OPUS and field base points; verify OPUS point is checked as final.
   e. Click "Apply" at bottom of right panel screen (points should be merged now and user should only see OPUS point label).

f. Reselect new merged control point (OPUS) and right-click to select "properties" and change point ID to new name, similar to "CP-OPUSdate."

g. Go to Project Explorer → Points, and then click on new merged control point.
   - Change height and horizontal (latitude/longitude) to control quality in local coordinates (user's .XML OPUS point).

f. Click red ball to recompute (watch that no red flag shows up; if it does, something is wrong).
   - Local and global coordinates should be the same.
   - Should match OPUS solution latitude/longitude and height in meters.
   - Turn ".job" back on and verify vectors are now originating from OPUS point.

Troubleshooting Common Issues

- Rover data link settings.
  - Change rover radio frequency
  - Change data string
  - Change baud rate
- R10 data cable input/output (i/o) port
  - Verify the data cable going into the R10 receiver is in the i/o port (see black arrow) and not the USB port
- Rubber ducky antenna
  - Verify the antenna is connected to the rover receiver to help with radio connection
- Antenna mast connection
  - Verify there is a good connection at the base of the antenna mast (sometimes the metal tab gets pushed up into the mast base resulting in a bad connection)

Survey Styles Nomenclature

- R8B: R8 receiver as base
- R10B: R10 receiver as base
- R8R: R8 receiver as rover
- R10R: R10 receiver as rover

Radio Setup Notes

Important information to know before getting started:

- GPS radios communicate using two different baud rates:
  - The data exchange/serial baud rate is the rate at which data are exchanged between the radio and the receiver. For SRH's GPS radios (HPB or TDL), this is always "38400." THE USER SHOULD NEVER NEED TO CHANGE THIS!
  - The radio link/over-the-air baud rate is the rate at which the GPS base radio communicates with the GPS rover receiver. This rate can be different for the TDL radios than for the HPB radios.
- SRH's HPB450 radios only operate at 4800 over-the-air baud rate. This cannot be changed on SRH's HPB radios.

- The 4800 over-the-air baud rate consumes an excessive amount of power. A full-size 12-volt battery (car-size or larger) is required to operate a base radio at 4800 over-the-air baud rate for more than 4 hours, approximately.
- An over-the-air baud rate of 4800 can only be repeated once. This means the user can only set up one base radio and one repeater radio when operating at 4800 over-the-air baud rate

• TDL radios have a variable over-the-air baud rate that can be changed directly on the face plate of the radio.

- The over-the-air baud rate of the TDL450 radios must be changed before starting a survey. If a survey has already been started, it must be ended before changing the over-the-air baud rate.

- In order for a TDL radio to communicate with one of SRH's HPB radios, the over-the-air baud rate of the TDL radio will have to be changed to 4800.
- When operating at 9600 over-the-air baud rate, the TDL radios (base or repeater) should be able to run for a full day on a smaller 12-volt battery (motorcycle or lawn mower size).
- An over-the-air baud rate of 9600 can be repeated twice. To increase range, the user can set up a base operating at 9600 baud and two repeaters (also at 9600 baud).

Channel	Frequency (MHz)
0 and 1	410.6
2	411.975
3	414.875
4	415.075
5	417.575

Table 1: List of Channel IDs and Corresponding Frequencies Programmed Into GPS Radios.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Step 1: Select base radio type.

TSC3: Select Trimble Access → Settings → Survey Styles → select style to edit → Base data link

- Set up per Table 2; accept and exit Step 2: Set up new project and "start" base receiver.

Setting	TDL450 as Base Radio	HPB450 as Base Radio
Type	Radio	Radio
Radio	Trimble TDL450	Trimble HPB450
Controller and Receiver Ports	COM1 and Port 1	COM1 and Port 1
Baud Rate and Parity	38,400 and none	38,400 and none

Table 2: TSC3 Controller Settings for TDL450 and HPB450 Radios.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Step 3: Set up TDL450 base and/or repeater radio (radio screen).

TSC3: Select Trimble Access → Settings → Survey Styles → select style to edit → Base data link

- Right and left arrows scroll through menu items; up and down arrows scroll through setting options for a given menu item
- Use center button to select and accept a new setting

Setting	Set Base TDL450 With Repeater TDL450	Set Base TDL450 With Repeater HPB450	Set Repeater TDL450 With Base TDL450	Set Repeater TDL450 With Base HPB450
Channel Frequency	410.6, etc.	410.6, etc.	Match to base	Match to base
Data Protocol	Trimark3	Trimtalk450s	Trimark3	Trimtalk450s
Radio Link Rate (Over air baud rate)	9600	4800	9600	4800
Serial Baud Rate	38,400	38,400	38,400	38,400
Operation Mode	Base/Rover	Base/Rover	Repeater 1	Repeater 1
Transmit Power	2W (1 to 2 miles) up to 16W (5 miles)	Hand select low or high switch		

Table 3: TDL450 Radio Faceplate Settings.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Step 4: Set up rover radio to match base.

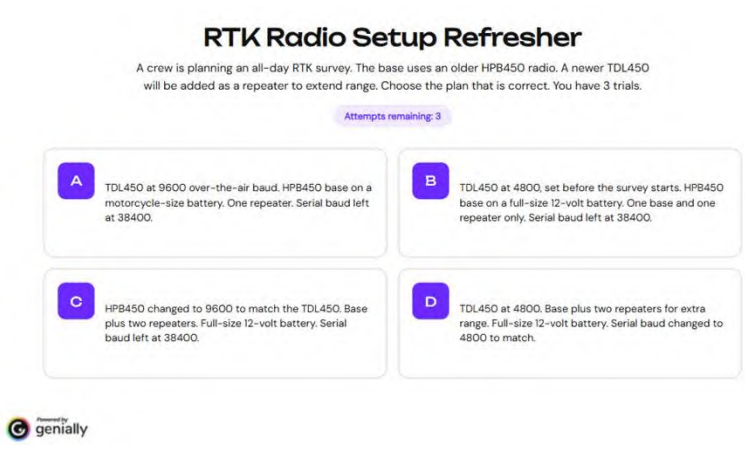
TSC3: Select Trimble Access → General Survey → Instrument → GNSS functions → Select Rover Mode → Select Data link

- Select Rover data link/Type: Radio/Radio: Receiver internal
- Click "Connect" hot key
  - Radio operating mode: Rover
  - Frequency: Match to selection at base (Table 1)
- Select Base Radio Mode
  - Older HPB450 radio at base or repeater: Trimtalkv1 at 4800 bits per second
  - Newer TDL450 radio as base and repeater: Trimtalkv1 at 9600 bits per second
- Click "Accept"

Changing HPB450 Radio to Repeater or Vice Versa

1. Connect radio to battery and laptop using grey serial port cable.
2. Connect yellow cord to battery to disperse power.
3. Open PDL configurator on laptop.
4. Click "load," then turn radio off and on.
5. Go to "Serial Interface" tab.
   - Check on repeater box (or off if changing from a repeater to an emitter).
6. Go to "Radio Link" tab.
   - Change digisquelch to "high" for repeater mode (or to "low" for non-repeater mode).
7. Go to "Program" tab.
   - Click "YES" (applies settings).

Check the next slide to explore an interactive GIF about the RTK radio link.



REAL-TIME NETWORK SURVEYING

Introduction

Real-Time Network (RTN) surveying is becoming an efficient and common method of surveying that eliminates the need for establishing base control. RTN surveying is similar in concept to Real-Time Kinematic (RTK) surveying in that corrections are sent from a base station to improve rover positional accuracy in real-time (Figure 3). The primary difference is that unlike RTK surveying, where the reference station is physically located at a permanent or semi-permanent location, RTN surveying computes a "virtual" reference station (VRS) about 1 meter (m) from the rover.

RTN is capable of operating over inter-receiver distances up to many miles with performance equivalent to a current single-base RTK system operating over much shorter baselines. With RTN surveying, a permanent network of reference stations (Virtual Reference Network or VRN) is established with typical spacing between stations of 10 to 50 miles. The reference station network continuously streams data (using LAN, Internet, or radio links) to a central location (server) established for each network. The server stores the transmitted RINEX data, performs quality assurance checks on the data, accomplishes network modeling and estimation of systematic errors, calculates and converts correction data to a user format of either Radio Technical Commission for Maritime Services (RTCM) or Compact Measurement Record (CMR+), and communicates the data to the users.

1. User's rover connects to the VRN using LAN, Internet, radio links, or a cellular modem.
2. Rover sends a NMEA[1] string (GGA[2]) to the RTN server.
3. Server uses NMEA data to establish a VRS position ±1 m from the user's rover position.
4. Using input from the closest surrounding reference stations, the RTN server computes and sends corrections back to the rover as if a real base station were broadcasting from the location of the VRS.
5. Rover receives and applies the corrections in real-time and functions like a normal RTK survey, but essentially receives data as if coming from the VRS, thereby eliminating PPM error that normally occurs.

[1] NMEA is an acronym for "National Marine Electronics Association" and, in RTN/RTK Global Positioning System (GPS), it indicates a standard data format supported by all GPS manufacturers.

[2] NMEA GGA sentence example contains information about 3D location and accuracy data.

The accuracy of RTN surveying depends on many factors, including the reference station distances, equipment and its settings, survey procedures, and the survey environment. Accuracy typically is in the range of and, in some cases, can exceed that of traditional RTK surveying.

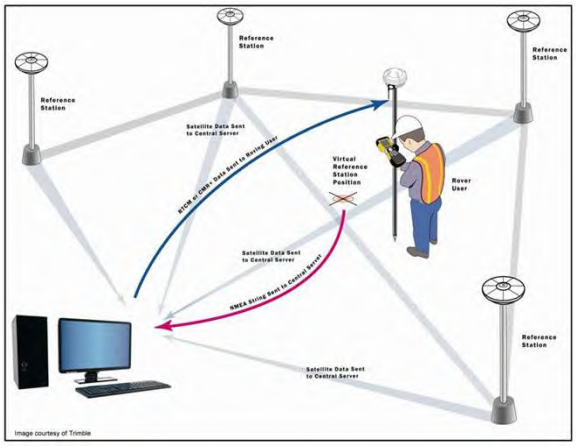


Figure 3: Configuration of a VRN.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Benefits and Limitations of RTN Surveying

The U.S. Geological Survey (USGS) lists the following benefits of RTN surveying over traditional RTK surveying:

1. "The need for a user to establish a permanent/semi-permanent base station is eliminated. This eliminates the time for initial site selection and (daily) setup, any issues of security and power supply, and the possibility of setup errors.".
2. "The RTN can monitor its own integrity and can detect if there is a problem with a particular reference station. With a single-base RTK setup it can be difficult to tell if a problem exists or occurs with a base station while conducting a survey."

3. "Since the reference stations are part of a network, a loss of one station does not result in failure of the entire network or the resulting survey. Whereas the loss of a reference station with single-base RTK setup results in the end of data collection, with RTN surveying the system accuracy degrades gradually."
4. "A sufficiently dense reference station network can result in shorter baselines. As with any other style of GPS surveying, shorter baselines result in improved accuracy because of reduced effects of atmospheric interference."
5. "The RTN reference stations allow for network atmospheric modeling resulting in improved accuracy. With RTK, atmospheric effects are computed using (usually) one location."
6. Common reference coordinate frame.

Limitations of RTN surveying include the following items as noted by USGS:

1. High cost to establish, maintain, and manage an RTN.
2. Use and accuracy of an RTN can be limited by cellular phone coverage, network extent, and network density.

Connection Options From Rover to RTN

A cellular connection is required to accomplish an RTN survey. Many survey equipment setups are now sold with an internal modem included. The Trimble TSC2 and TSC3 devices can be installed with SIM cards. However, they are only compatible with AT&T at this time. Thus, the user should investigate cellular phone coverage at the worksite to determine which carrier has coverage.

Note: AT&T uses General Packet Radio Service (GPRS) bandwidth and Verizon uses Code-Division Multiple Access (CDMA).

Alternatives to an internal SIM card include:

1. MiFi device (e.g., Verizon jetpack)
2. Wi-Fi from a work vehicle
3. Cellular phone that is Bluetooth compatible
4. Commercial RTK bridge or repeater
5. RTK bridge system created with a laptop that has Internet access

Planning for Virtual Reference Network Surveying

The following steps can be followed to plan for VRN survey:

1. Ensure RTK methods are applicable to site.
2. Select VRN.
   a. Check VRN coverage for survey area.
      - Will the survey be inside or within 5 miles of boundary?
      - If only part of the survey area is covered by VRN, can it be used to establish the base control network?
   b. Verify quality assurance and control of VRN
      - Who runs it?
      - How long has it been up and running?
      - How often is VRN updated?
      - What kind of technical support is provided?
      - How does VRN communicate outages and check if any are planned during field work?
   c. Sign up for an account.
      - Sometimes VRN will give discounts or free accounts to government/research efforts.
      - Note user name, password, IP address, and port.
      - Test account is active by logging into Web site.

   d. Document contact for VRN to take in the field.
   e. Look for support information on the VRN Web site that may help with setup in the field.
   f. Determine broadcast format; RTCM3 normally works well.

3. Check for cellular phone coverage relative to the provider option setup in the equipment.
   a. Be careful with carrier Web posting maps and talk to locals.
   b. Data transfer needs are less than voice transfer, but still need decent signal.
4. Select cellular connection device.
   a. Choose reliability over speed; data stream is small so speed is not as important as reliability.
   b. Consider spare batteries for cellular device as VRN is draining.
   c. Bring waterproof case if using an external modem.
5. Survey schedule.
   a. Talk with local operator of network about the application and ensure system will be running during the survey; check that no planned maintenance (downtime) of base stations is scheduled.

   b. Ensure that the base stations that encompass the survey area will be running.
   c. Plan for times of day with best satellite coverage, particularly if establishing a base station.
   d. Check the space weather forecast and use caution when working during increased ionospheric activity.
6. Determine what projection the selected RTN broadcasts in and if there is a need to post-process to a different projection.
7. Determine if RTN will be used for base control only, or the entire survey.
   a. Limited cellular coverage may warrant using VRN only for base setup.
8. Check into which base stations (single vs. network) will be selected when establishing connection.
   a. Some VRNs have multiple networks to represent specific geographic regions; for example, Washington State has five "VRNs" to choose from.
9. Document nearby published benchmarks that can be used as checks in the field.
   a. May need to convert coordinates to those used by RTN.

In the Field

The basic scenario for RTN surveying is a follows:

1. Due to difficulty in testing prior to survey, have some contingency time at beginning of survey trip to get connections set up and tested.
2. Consider a field reconnaissance along boundaries and within survey extent to test cellular coverage. This can be done during reconnaissance for establishing base control and access points.
3. Set up cellular connection and VRN survey style.
4. Verify quality assurance and control.
    a. Stay within the RTN.
    b. If a base station is set up, collect at least 2 hours of data to allow comparison to OPUS.
    c. Check accuracy of field survey results against known control points (benchmarks) that surround the work area(s) utilizing similar reference frames
    d. Perform in-field calibration of survey job if necessary, and take redundant, independent readings of a selected number of survey points.

    e. Perform normal quality assurance and control steps such as checking multipath and distance from base.
    f. Recheck same point at beginning and end of day.
    g. For important survey points, conduct two separate time-windowed observations of at least 1 minute with unique initializations.
5. Whenever the user moves a set distance (3 to 5 miles) within a set of reference stations, or moves into a new area surrounded by a different set of reference stations, a new VRS and corrections are computed. This ensures that small baseline distances are maintained. The user will notice in the output files that a new VRN base is listed. Typically, only the closest base station is listed in the output file from the controller, even when surveying in a network.

Post-Processing

1. Download job file like normal RTK survey and pull into Trimble Business Center software.
2. If a base station is set up, download the ".T02" file and also pull it into Trimble Business Center software.
3. Check solution at base station against OPUS solution (may need to convert OPUS solution to same projection and datum as VRN). Expect a small amount of discrepancy from published benchmarks or OPUS; are you within published tolerance/accuracy?
4. Review RTN Web site for any noted issues or downtimes during the survey.
5. Download RINEX files from VRS Web site and import and compare against topo solution for base point or a series of ground shots, control points, etc.

Example Applications: Elwha River, Washington

Reclamation has utilized the Washington State VRN (WSRN) to survey the Elwha River since 2012, and has an established research account that is free. Reclamation staff used the VRN with a Verizon network to establish base points for RTK surveys, including topo points and bathymetric surveys in continuous topo mode without a base control setup. Reclamation was able to Bluetooth from TSC2 and TSC3 controllers simultaneously to a depth sounder and the cellular device and R8 receiver.

Example Applications: Siletz River, Oregon

Reclamation accomplished a survey of the Siletz River using the Oregon VRN to establish base control. Reclamation staff used TSC2 controllers linked with R8 receivers and a Verizon cellular connection, and collected in the native broadcast projection of NAD83(2011) Epoch 2010. When Reclamation used the Oregon RTN in 2013, it only broadcast GPS without GLONASS capability, although this may have been updated.

Helpful Web Links

For a general explanation of RTN, see the U.S. Geological Survey's "Real-Time Network (RTN) Surveying" Web site at: https://water.usgs.gov/osw/gps/real-time_network.html.

For a general explanation of the Global Navigation Satellite System (GNSS), see the U.S. Geological Survey's "USGS Global Positioning Application and Practice" Web site at: https://water.usgs.gov/osw/gps/.

ROBOTIC TOTAL STATION SURVEYING

Introduction

Total station surveying is a technique that measures angles and distances from a known central point to compute horizontal coordinates and elevations. All measurements are made from the total station (or base station), which is an electronic/optical instrument that measures slope distances from the instrument to a particular point.

Data can be collected using a base and rover setup or by collecting point clouds, depending on the capabilities of the instrument. Surveying can be conducted in a similar manner to Real-Time Kinematic (RTK) Global Positioning System (GPS) surveying, where one base station is established and a rover (prism) is used to measure points. Robotic total stations allow the operator to control the base instrument from a distance. Many models will automatically track the rover prism, potentially eliminating the need for additional staff to help operate the total station. Newer total stations may also have scanning capabilities, which allows a single user to collect point clouds of a designated area. The scanning function is best applied to unvegetated surfaces (ground, concrete, gravel bars, etc.) and does not work well in areas with vegetation or inundated by water.

Unlike RTK GPS surveying, total station surveying does not rely on satellite coverage to operate. Therefore, this surveying technique can be very useful at locations where satellite coverage is limited (e.g., narrow canyon). The optical nature of the instrument requires:

- A direct line of sight and radio connection between the total station and prism.
- A recommended distance of approximately 1,000 feet (ft) between the total station and prism (may go further in ideal conditions). Multiple base station setups may be required to survey a large site.
- The need to re-level and adjust the temperature of the total station throughout the day. Survey accuracy is highly dependent on these two factors.

Equipment

As of September 2019, the Sedimentation and River Hydraulics Group (SRH) in Reclamation's Technical Service Center does not have any equipment for robotic total station surveying. All equipment can be rented from Vectors, Inc. (Phil Woodcock, 303-283-0343, PhilW@VectorsInc.com). Recommended equipment for this type of surveying includes:

- Trimble S7 or S5 total station (only the S7 has scanning capabilities)
- Multiple TSC3 controllers with robotic total station antennae mounts (while SRH does own TSC3 controllers, they do not have the appropriate antennae mount and cannot be used during robotic total station surveying)
- Multiple robotic prisms plus adjustable survey rods (VX/S series multitrack, equal to the number of surveyors)
- One or two backsight prisms
- All necessary batteries:
  - Total station batteries last 2 to 6 hours
  - Robotic prism batteries last 4 to 5 hours (same as R8 batteries)
- Air thermometer
- Hand-held radios
- Rebar/wooden stake and flagging for base location(s)
- Field book

Total Station Setup Procedure

The following steps detail how to set up the total station. Note that the greatest error during total station surveying is from human error. For an instructive step-by-step demonstration, see the "Station Setup for Total Stations in Trimble Access" video at:

1. Establish known control point (rebar, stake, NGS point, etc.).

   a. This coordinate should be a known point, or the user will need to survey it with a GPS rover. If that is not possible, the final survey will be in local coordinates, relative to the total station.

   b. All points of the total station survey will be tied to this point. The data can then be shifted during the post-processing to an OPUS solution obtained for the base.

   c. Record control point number and coordinates (if known).

2. Set up total station (Figure 4).

   a. Set up and level the tripod using a wide stance to increase stability. The Trimble S7 and S5 units are heavy. Dual clamp tripods are recommended.

   b. Insert battery into total station.

   c. Mount total station on tripod for further leveling.

   d. Pull out lower site knob and gently turn to coarsely focus total station over control point. Push in site knob.

   e. Continue leveling. Turn the backface of the total station (with the Trimble plate; Figure 5) and center over two of the tripod legs. Adjust the bubble laterally, moving two leveling screws. Then, adjust the last screw to move the bubble up and down.

   f. Turn on total station. Record the Radio Channel and Network ID in field book. This information is key to communicating with the TSC3.

Figure 4: Total station final setup.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Figure 5: Backface of Trimble S7 total station should be centered over two tripod legs for efficient leveling.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

3. Set up the TSC3.
   a. Start new job.
      - Name the job. SRH typically includes the location, date, and controller number in the name (e.g., SMR_20190519.C8).
      - Select coordinate system under properties. If coordinate system is unknown (local), select the "Scale factor only" radio button. Set scale factor to "1."
      - Select coordinate geometry settings ("Cogo Settings") under the "Distances:" drop-down menu, then select "Ground." Leave all other settings as default unless instructed to do otherwise.
   b. Connect to radio.
      - Go to Settings, press "Connect," and select "Radio Settings."
      - Select the "VX/S Series" from the "Model:" drop-down menu.
      - Match the Radio Channel and Network ID to total station output.
   c. Set up station and fine leveling.
      - Go to General Survey, select "Measure," and then press the "VX/S Series" button. Select "Station setup" to connect to total station.
      - Use very small adjustments to the three level screws on the tribrach to achieve a sighting of "0." Remember survey accuracy is highly dependent on level instrument.

- Measure temperature (watch units) and enter. Make sure pressure set "from instrument." Do not change pressure; it will automatically populate based on temperature. Record the time and temperature in field book. Update temperature measurement during day and reset total station if more than 10 degrees increase or decrease.
- Press "Accept."

b. Enter base coordinates (right-click arrow and select point from list if already entered, or key in new GPS point).

c. Measure antennae height of base station from control point to bottom of black notch (Figure 6). Enter antennae height in the TSC3 and record in field book. Set to "bottom notch" on the TSC3.

Figure 6: Bottom of black notch used to measure antennae height (left) and backsight prism black line used to measure prism height (right).
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

4. Set up backsight.
   a. Set up backsight over a rebar/stake. Backsight locations should be placed at a distance equal to, or longer than, the longest foresight shot (prism/rover shot). If possible, survey the location of the backsight as a means to check the survey in the office. Record point number in field book.
   b. Measure backsight prism height from control point to center of prism black line (Figure 6), or at 6-ft mark setting if using rover rod. Record in field book.
   c. Click the prism icon in the right side bar of the TSC3 screen (below total station icon). Select the correct prism type used for the backsight.

a. Enter the backsight information into the TSC3. An Azimuth angle of "0" is sufficient without known information. This can be corrected during post-processing. Under "Method:" select "Angles and distance" from the drop-down menu. If the backsight and control point from RTK GPS is known, the TSC3 will compute the Azimuth angle automatically.

4. Set up prism/robot (rover).

a. Insert battery and turn on prism.

b. Adjust dial (1 through 7) to match prism ID displayed on the prism icon in the right side bar of the TSC3 screen.

c. Record rod height in field book (measured to the bottom of the mount; Figure 7).

d. Point the total station in the general direction of the prism (use the joystick buttons on the TSC3 to move the instrument).

e. Select the instrument icon on the right side bar of the TSC3.

Note: The user can press "Autolock" if they want the total station to automatically follow the prism.

f. Select semi-active tracking mode.

g. Select the instrument icon on the right side bar of the TSC3, then press the "Search" button. The total station should find the robot, stating "Target locked" in the lower banner.

h. Record the first measurement point number in field book

Figure 7: Robotic prism mounted on rod. End of pen is pointing to the "bottom of mount" where rod height is measured.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Field Book Notes to Record for Each Base Setup

The following steps detail how to set up the total station. Note that the greatest error during total station surveying is from human error. For an instructive step-by-step demonstration, see the "Station Setup for Total Stations in Trimble Access" video at:

- Channel
- Network ID
- Temperature and Time
- Base station point number and location
- Base station height
- Backsight point number (do not reuse the same point number) and height
- Rod height and starting point number

Measurement Procedures

The three measurement procedures outlined in this section include: topo measurements using the prism, scanning to collect a point cloud, and panoramic photographs of the site. Keep in mind that direct line of sight is required for all measurements, and the total station will need to be re-leveled and temperature adjusted throughout the day.

1. Topo measurements (using the prism).

   a. Go to General Survey and select "Measure Topo."

   b. Under the Measure Topo menu, select a starting point number under "Point name:" and type in an appropriate code and "Method." Choose "Angles and distance" from the drop-down menu. Key in target height, which equals rod height (Figure 7).

      Note: It is helpful to set it to a default fixed rod height of 6 ft when possible.

   c. If measuring a ground shot such as edge of building or rock near edge of water, the user can select "DR" at 0 ft height and 0 millimeter (e.g., reflection shot).

2. Scanning (to collect a point cloud).

   Note: This is only effective in bare earth scenarios. In areas with vegetation or tall grass, the laser will not return and data will be erroneous or non-existent.

   a. Go to General Survey and select "Measure" then "Scanning."

   b. Select "Scan method:" using the drop-down menu. The default recommendation is "HA VA interval."

   c. Use the drop-down menu under "Framing:" to select how to outline the scanning area. Click "Next" to frame the scanning area.

   - To scan a rectangle area, simply tap the upper left and lower right area to be scanned.
   - To scan a polygon area, press the polygon icon → up arrow → select polygon.

d. Define scan parameters.

- Press arrow to right of distance to update.
- Select "Method grid interval spacing:" using the drop-down menu. Recommend "HD VD interval." HD equals horizontal distance; VD equals vertical distance. Select an appropriate "Scanning mode:" using the drop-down menu.

e. Check scanning area of the photograph in the TSC3. Press "Start."

f. After each scan, the prior grid points will be visible on the photograph with a different color for each scan. Adjust scanning grid pixel size if difficult to see, using options.

3. Panoramic photographs (of the site, which helps inform post-processing).

a. Go to General Survey and select "Measure" then "Panorama" (first button in second column).

b. Select an image overlay of 10 percent, which is an appropriate default in most cases.

c. Select rectangle in video.

d. Press "Start" (it will take photographs of the framed area).

At the end of each day, download all controller files from the rover receiver (including ".job" and ".tsf" files, plus any image folders).

Post-Processing Total Station and Scanning Data (Trimble S7 Total Station)

Vectors, Inc., recommends the following computing capabilities:

- Number-crunching quadro video card
- Zion processor
- 32 gigabyte (GB) RAM
- Solid-state hard drive

Post-processing total station surveying data will be done in Trimble Business Center (TBC) software. The user will need a separate key or 30-day code from Trimble to unlock the scanning/total station module. The code will not work with SRH's hardware locks. The code will also access all of the tools needed to post-process GPS data. Vectors, Inc., includes the 30-day software code with the price of renting their equipment. Before post-processing the total station data, it is recommended to process RTK GPS survey data first.

To register the key/code, click "License Manager" under "Common tasks" on the "Welcome to Trimble Business Center!" start page (Figure 8).

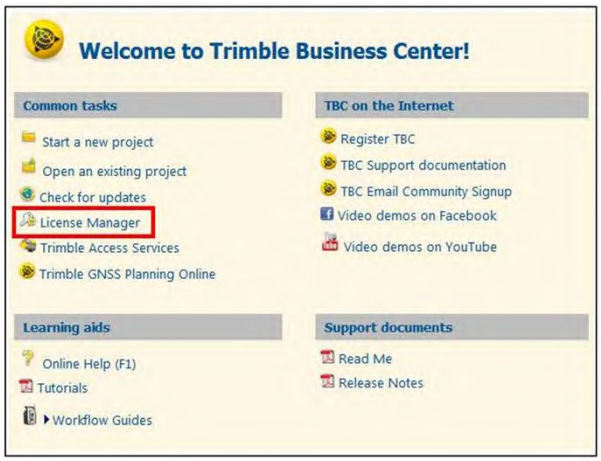


Figure 8: Trimble Business Center start page.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Then, under "License," click "Upgrade" and enter 19-digit code (Figure 9).

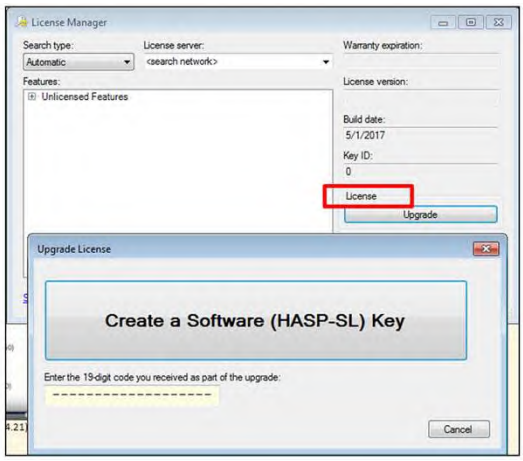


Figure 9: License registration screen.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

The following steps outline how to view, rectify, and export the total station data once the software is activated. These steps assume that the total station was set up over a known point.

1. Start and save a new project in TBC. Select the appropriate units and coordinate system. The coordinate system can be assigned using the "Coordinate System Manager" on the "Home" tab on the ribbon, within the Geodetic menu.
2. Import the ".job" file. The import button is located on the "Home" tab on the ribbon, within the "Import/Export" menu.
3. Identify base, occupation, and backsight points.

a. If the control point was measured with an RTK GPS surveying rover, post-process the RTK GPS data first. Then, open the post-processed RTK GPS survey job file (.vce). Verify the coordinate system and point elevation by comparing grid distance to ellipsoid distance (they will be the same if using a State Plane Coordinate System [SPCS]). If the control point was known, verify its location within TBC. Select occupation and backsight points in survey project file. This set of points will be referred to as "control points."1. Start and save a new project in TBC. Select the appropriate units and coordinate system. The coordinate system can be assigned using the "Coordinate System Manager" on the "Home" tab on the ribbon, within the Geodetic menu.

b. Export those points as a ".jxl" file (under the survey tab). Export the points with global coordinates (latitude, longitude, and height information). The ".jxl" file will upload the project information and accurate X,Y,Z values. The latitude, longitude, and height positions are the closest to the original data and will have the least amount of rounding.

c. Start a new project file. Import the newly created ".jxl" file. Verify that the project coordinate system changed.

d. Lock in the coordinates for the control points by exporting the points as a ".csv" file as northing and easting coordinates. (Click the "Export" button to open the export toolbar. Select the "Custom" tab, choose the appropriate format from the list, and save as ".csv".)

   Note: This seems redundant, but this is the best way to make it work. The northing and easting coordinates will set it as a higher priority, allowing the user to easily select the correct file in the next step.

e. Import the control points ".csv" file into the existing project (can drag and drop file from Windows Explorer). Select the correct definition name with "(Control Quality)." This should change all of the control points from survey quality (circles) to control quality (triangles).

4. Import scan files.

a. Verify the ".job" file is in the same folder as the scans.

b. Import the ".job" file. A conflict will arise between the control points in the existing file and the control points in the newly imported ".job" file. Merge points and keep the existing points (select "keep existing definition"). Red flags will appear on the merged points.

4. Resolve conflict.

a. Expand the "Imported Files" folder under "Project Explorer." Continue to expand the ".job" file, station view, and "Single Backsight (#)." There the user will find the two merged points (Figure 10).

b. Delete both of the field-entered single backsight points. This is the crucial step to shift all of the scanned data to the OPUS Solution.

c. Recompute and SAVE!

d. View filter manager and uncheck the box next to "total station."

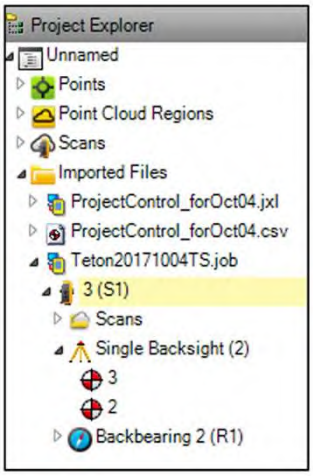


Figure 10: Project Explorer window.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

6. Three-dimensional (3D) view.
   a. SAVE AGAIN! This is the point where most projects crash.
   b. Select "3D View" under the "Home" tab (Figure 11). This will open a new window within the project where the user can scroll, pan, and rotate data.
   c. Select "Rendering" under the "Points Clouds" tab. This will provide the user with options to view their data.
      - Scan color allows the user to change the color of the points based on intensity, scan, region, elevation, etc.
      - Point size can be increased or decreased.
   d. Scan to "CAD." This allows the user to switch the scan from a scan file with multiple points to multiple individual point files. This will be used in later instructions.

Figure 11: Trimble Business Center ribbon highlighting the 3D View tool.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Data Export Options

There are three options to export the data into a useful format that can be used in either Geographic Information System (GIS) or CAD:

1. Select LAS (file type) format to export.

   a. Open the "View Filter Manager." Turn off raw data, photogrammetry, flags, and layers.

b. Select "Export" and choose "Point Cloud" and "LAS exporter." Manually select all of the data in the "3D View" window, making sure to first turn off the items previously listed. Click "Export." (The number selected will reflect the number of scan files. The ellipsis after the file name will allow the user to select the export location. The default location is in the folder with the same name as the project ".vce" file.)

Note: If the total station rover data are combined with the scanning data, it is recommended that the user keep them separate and export them as two different files.

2. Select points to export. (This option allows the user to select different hard points to export.)

Note: Corners of structures, top of banks, etc., are recommended.

a. Turn on points under View Filter Manager → Raw Data to see the points as they are delineated.

b. "Create Point" under the "CAD" tab. This setting snaps to the nearest node from the scan. In the newly opened toolbar, select point ID, layer, and feature code. It is recommended to create a new layer with the created points. It is also recommended to pick the first point ID number as one that will not overlap other project points.

c. Click inside the "Northing" box to activate the curser. The default setting is to only create points over an existing scan point. To extrapolate a point based on the existing data, select the point cloud smart picking mode . The "face of curb" is intended to extrapolate a point at a corner. "Gutter" is intended to extrapolate a flow path. (Note that these two tools are still in development.

d. Click in the "3D View" window to delineate the points.

e. Export points as a ".csv" file when complete.

3. Create breaklines to export. (This option allows the user to create breaklines to then export into GIS/CAD.)

a. Select "Linestring" under the "CAD" tab. Pick a name (optional) and layer. Again, it is recommended to create a new layer file. Click "OK.".

b. Select the segment type: straight, curved, etc.

c. Select the first point. Keep selecting points until the breakline is completed. To go back and edit the breakline, scroll through the "Current segment" in the toolbar. This allows the user to delete or move previously delineated points (Figure 12).

d. Select "new" to create next linestring.

e. Export points as a ".csv" file when Export as a ".dwg" or ".shp" file once the lines are completed.

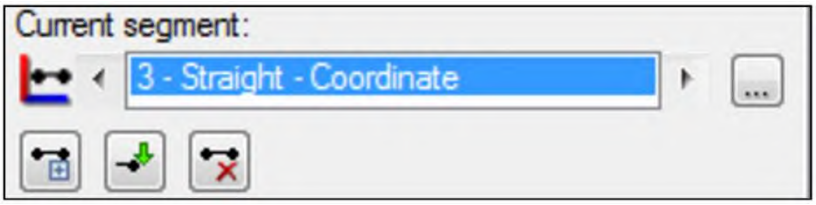


Figure 12: Toolbar allowing the user to delete or move previously delineated points in each breakline.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

If the point cloud is too dense, the user can coarsen the data by converting points to CAD. A small area, points of interest, or the entire dataset can be selected.1. Select LAS (file type) format to export.

1. Select the scan points of interest.
2. Select "Scan to CAD" under the "Point Clouds" tab.
3. Choose between "spatial" or "random" sampling. Choose the layer. Close the "Scan to CAD" toolbar.

   Note: Vectors, Inc., recommends spatial sampling. If "spatial" is chosen, also select the "sampling distance."
4. Turn off the scan data and all other layers (uncheck "grid-only points," "survey quality," etc.). Select the new CAD points. Then, right-click and select "Convert CAD Points."
5. Check "Delete CAD points when done." Continue and choose "Survey Quality" under the "Point quality" drop-down, then assign the "Feature code" and "Starting ID for survey point" (Point ID; Figure 13).

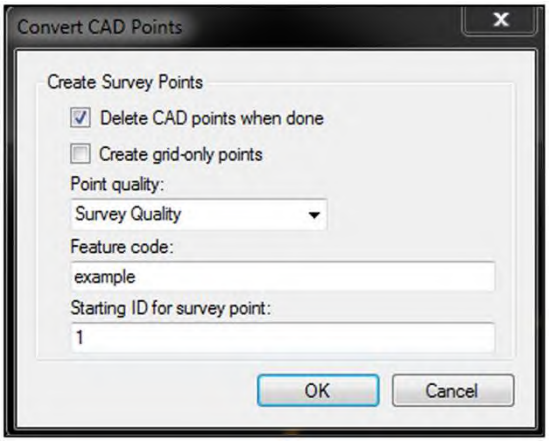


Figure 13: Convert CAD Points tool window.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Other Useful Tips and Tricks

- If any panorama photographs were taken while in the field, they can be displayed under the "Station View" button in the "Graphic Views" toolbar within the "View" tab on the ribbon (Figure 14). While it is presumed that further capabilities exist with the panoramic photographs, they are unknown at this time.
- Users can view their data in Google Earth while post-processing it (Figure 14).
- If processing large point cloud files in AutoCAD, may need to separately install the "Recap" (.rcp) tool within AutoCAD

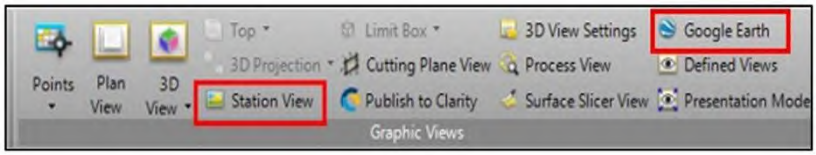
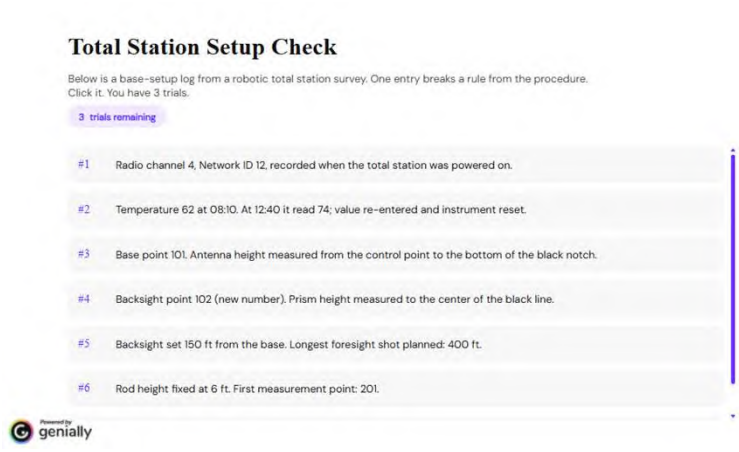


Figure 14: Graphic Views toolbar within the "View" tab on the ribbon.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Check the next slide to explore an interactive GIF about the Field Book Audit.



SINGLE BEAM MEASUREMENTS WITH SONARMITE

Introduction

The SonarMite MILSpec echosounder (SonarMite) is a single beam depth sounder designed to be ruggedized, portable, and economical (see the "Ohmex Instruments" Web site at: http://www.ohmex.com/sonarmite.html). The SonarMite was designed to have a large number of pings with as minimal processing of raw data to define the bottom in as fine of detail as possible. The sounder has a beam width of 4 degrees and a ping rate of 6 hertz that operates from 0.3 to 75 meters (m) (1 to 246 feet [ft]).

Equipment

- The SonarMite MILSpec echosounder with Bluetooth antenna (processor box SMIL120316)
- A 12-volt power supply with velcro pouch to mount on survey pole and charger (battery)
- A 200 kilohertz echosounder transducer with cable (depth sounder)
- A serial interface cable to connect to computer for changing settings or data transfer
- The HydroLite-TM (transom mount)
  - Aluminum shoe to mount on survey pole
  - Three 2-ft yellow survey poles with 5/8-inch antenna mount for Trimble receiver and one survey point (for topo shots)
  - Black transom mount to attach unit to boat
- A rugged shipping case

Figure 15: SonarMite equipment package components.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Technical Components

There are three standard configurations in which the SonarMite can be used for hydrographic surveying applications

1. As a "Dumb" sounder connected via a serial cable/Bluetooth link to a computer running data logging and display software.
2. As a "Logging" sounder in which all depths are internally time-tagged and stored.
3. Using both modes where the serial output data are processed in real-time and the stored data are post-processed.

The connecting cable to the transducer carries only low direct current (DC) voltage and digital stream data. The device has two connectors—one that connects the device to a computer port and a second return pin with cable connection pin that connects the device to the battery and powers the depth sounder.

The accuracy of the current SonarMite is 1 centimeter or approximately 0.1 percent of the measured depth.

Planning

The basis on which all data correlation is achieved is internal time base, so particularly when using the SonarMite with Global Positioning System (GPS) data the clocks should be synchronized to GPS time (UTC). SonarMite WinCE software or SonarMite WinXP software can be used to set up the depth sounder. There is a new Android app that can also be used in the field to change SonarMite settings via Bluetooth to another Bluetooth-enabled device (cellular phone, tablet, etc.)

Battery Charging

The SonarMite battery charge display on the power adapter (wall plug) is shown in Figure 16.

1. Fully charge equipment prior to use in field by plugging in to wall charger.
2. Avoid using the SonarMite until the batteries are completely charged as there will be a high risk of both data loss and permanent damage to the batteries.
3. Charger will illuminate constant red when bulk charging and flashing yellow when charged.
4. Trouble Shooting: The SonarMite is protected from reverse connection or direct short circuit by an internal 1.0 amp thermal fuse. If the fuse is tripped, then the system will need to be disconnected for 1 minute for the fuse to cool down and reset itself.
5. Should last 12 hours in field.

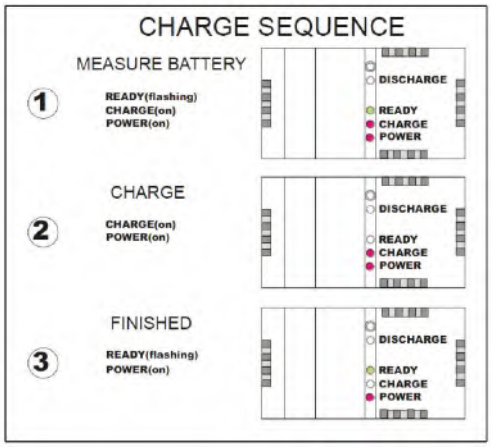


Figure 16: SonarMite battery charge display information.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Speed of Sound

1. The depth sounder computes depth based on the time it takes a pulse of ultrasound in water to travel from the transducer face to the channel bottom and back. Pulse travel time return signal is affected by the "Speed of Sound" setting.
2. The default "Speed of Sound" is set at "1500 m/s (4921 ft/s)," but can be adjusted based on water density that is affected primarily by water temperature, salinity, and turbidity.

3. The user can measure the speed of sound through the water column by collecting velocity profiles using a dedicated velocity measuring device. The speed of sound through the water column can also be calibrated using the SonarMite at a static position in a known depth over a flat, firm base. SonarMite-measured depths can be compared to the known depth and the speed of sound adjusted until the measured and known depths match.
4. To adjust the speed of sound:
   a. Connect SonarMite to computer and charger (if not charged)
   b. Press "^H" (Ctrl H) to display the following help information: "^Help, Format, Version, ID, Save,[Reset, Load, U/Dsos]."
   c. Press (^U)p
      - Increase the sound velocity setting for dense cold water (only available in the "SYS>" output mode)
      - This will change calibration values if saved
   d. Press (^D)own
      - Decrease the sound velocity setting for less dense fresh/warm water (only available in the "SYS>" output mode)
      - This will change calibration values if saved

Bluetooth Specifications

1. SonarMite uses BluWAVE PCB serial compatible with UART or RS232 interfaces.
2. Ranges up to 100 m (330 ft).
3. If the Bluetooth interface requires a password to pair devices, typically "1234" will work, or for older devices (if borrowed or rented), "0000" or "1111."
4. Supports baud rates from 2400 to 115200 baud.
5. When connected to another device, the green/blue LED illuminates continuously.

In the Field: Equipment

- SonarMite transducer, processor box, and battery (Figure 15)
- SonarMite mount
- Tools to set up mount and transducer
- Extra cam straps to secure to boat
- Tape measure to record transducer draft and GPS antenna height
- Probing rod with 0.15 m (0.5 ft) increments marked off (with permanent marker) to calibrate depth sounder
  - Can use wooden probing rod from items such as wheelbarrow handles or group leveling rods
  - Aim for about 1.8 m (6 ft) long, any shorter is not usable and any longer is too hard to manage in swift water
  - If rod has pointed end, account for that in markings
- GPS equipment (receiver, controller, radio antenna, and mounting pole)
- Writing utensil and field book

In the Field: Mount

1. Set up transducer mount on boat.
   a. Normal shoe mount has angles up to 30 degrees with 12 millimeters of vertical adjustment.
   b. Reversible wedge allows transom mounting at angles ranging from 2 to 22 degrees.
   c. Transducer cable length is approximately 3 m (10 ft).
   d. Consider mounting near center of boat and adjust so beam angle is perpendicular to channel bed.
   e. Minimum draft in slow, quiet water is around 0.2 ft, but should be increased to typically 0.5 to 1 ft in deeper more turbulent river conditions.
2. Check transducer mount on boat.
   a. Avoid mounting near turbulence field generated from motor propellers or oars.
   b. Check that mount is secure and can raise quickly if transducer hits a rock.
   c. Consider strapping on counter weight if mounted on side of boat.
3. Use aluminum rings to mark desired draft location or permanent marker in case mounting poles slip during survey.
4. Use cam straps to secure equipment.

In the Field: Power Depth Sounder

1. Connect the transducer to the TXR connector on the front panel.
2. The red LED alongside the connector will flash, indicating connection and battery charge status.

In the Field: Connecting to Trimble Equipment

1. Mount GPS receiver directly above transducer on mounting pole if possible, otherwise record the X/Y offset.
2. Consider at least two yellow mounting poles or use an extended radio antenna to increase radio antenna range or improve sky/satellite visibility of GPS receiver.
3. Open survey style on rover controller.
   a. Select depth sounder at bottom of list.
   b. Select SonarMite from drop-down menu (each SonarMite is identified by a unique serial number on processor box).
   c. Accept/store to save updated survey style.
4. Establish Bluetooth connection to SonarMite.
   a. Verify "enable Bluetooth" and "discoverable" are selected on Trimble controller.
   b. Go to Trimble Access → settings → connect → Bluetooth → config → add new or select unit if connected previously:
      - Type: SonarMite
      - Controller Port: Bluetooth
      - Latency: 0
      - Draft: Leave as "0" and post-process
5. Start survey.

a. Use continuous topo setting, which needs to be used to record depths.

b. Set data spacing typically by distance between points (e.g., X ft) depending on density of data needed.

c. Set point name (number) and code (description) as desired.

In the Field: Measurements Before Launching

1. Measure draft from water surface to bottom of transducer with all people and equipment in boat (Figure 17).

2. Measure distance from bottom of transducer to bottom of Trimble receiver to use as antenna height.

3. Note offset of GPS pole (X and Y) if not mounted directly on top of transducer pole.

In the Field: Quality Assurance Before Launching

Use measurement rod to take sample measurements in backwater location ideally at launch to validate initial readings before launching. Note the depth sounder has to be in the water to record depths and should be at least 0.3 m (1 ft) above channel bottom. Depth displayed on controller is distance from transducer face to river/reservoir bed (draft is incorporated during post-processing).

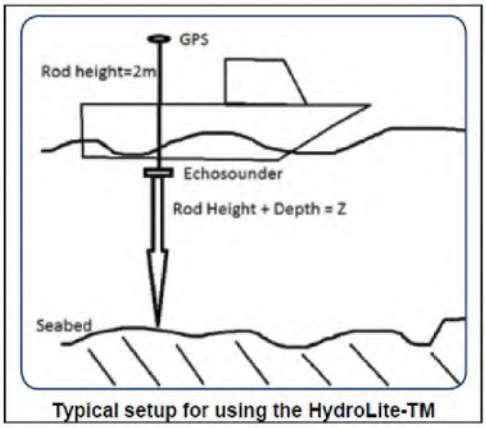


Figure 17: Measurements required for HydroLite-TM setup.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

In the Field: Quality Assurance During Launching

1. If turbulence is generated around or in front of transducer when moving, lower transducer further down into water column.

2. Raise depth sounder up when at risk of hitting bottom, typically in depths less than 0.5 m (1.5 ft).

3. During survey, have one person periodically use probing rod to measure and record depths and another to document SonarMite depth and associated GPS point number that will be used in post-processing.

4. Note in field book using probing rod:

   a. Areas of shallow depths less than 0.5 m (1.5 ft); these areas often produce depth readings that are inaccurate and can be inaccurately recorded at 2 to 3 times the actual depth.

   b. Turbulence in deep scour holes where readings may be bad such as near bedrock, bottom of rapid, or base of infrastructure (dam or low-head weirs).

   c. Portage locations or where rowing along channel edge that may temporarily read shallow and deviate from actual deeper thalweg.

   d. Depths and locations with shallow riffles; manually measure depths and record with Real-Time Kinematic (RTK) GPS point in locations with shallow riffles.

   e. Periodic Trimble depths; visually monitor depth readings in Trimble controller and manually measure periodic depths and record to allow checking accuracy in post-processing.

In the Field: Troubleshooting During Survey if Depth Sounder Stops Working

1. Check survey style. Was SonarMite option turned on and saved?
2. Ensure Bluetooth connection to SonarMite is active (blue light illuminated on processor box).
3. Verify continuous topo setting is in use.
4. Check power cord is plugged in and did not come loose.
5. Stop survey; try unplugging power to SonarMite, replugging back in, and starting new survey (sometimes it locks up and this often fixes issue).
6. Check depth sounder is still mounted securely and has not come loose causing it to make improper readings.

In the Field: Removing Depth Sounder

At the end of the survey, place mount at 45 degree angle and press firmly to release depth sounder as shown in Figure 18.

Figure 18: Removal of transducer at completion of survey.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Process Hydrolite Depth Sounder Data

1. Output depth data.
   a. Open Trimble Business Center.
   b. Start new job and save project in desired coordinates/units.
   c. Import ".job" file from Trimble controller that contains bathymetric data.
   d. Select file → tools → job report generator.
   e. Select ".job" file.
   f. Select stylesheet (comma delimited with depths.csv) with elevations and depths.
   g. Identify output location.
   h. Select draft zero (in past, draft tool has not worked).
   i. Select apply (may give code error, but ignore and should work fine).
2. Update X,Y,Z values for cases with post-processing of coordinates.
   a. If any updates are made to X,Y,Z coordinates in Trimble Business Center, such as changing projection or post-processing with OPUS data, note that the Trimble export file with depths does not apply the updated information.
   b. To apply updated X,Y,Z coordinates, export the processed X,Y,Z coordinates.
   c. Align with same point numbers of exported depth data.

d. Delete the original X,Y,Z points associated with depth data and use the updated values.

e. Use formula in spreadsheet to verify point numbers are aligned correctly before deleting duplicate point numbers associated with depth data.

3. Review and edit depth data.

a. Type in notes from field that correlate to GPS points to review depth readings indicating areas of potentially bad readings, or to validate shallow or deep locations.

b. Plot points in Geographic Information System (GIS) and pan through aerial photograph to check for erroneous values.

c. Plot points on longitudenal profile in GIS and export to spreadsheet to review.

- Generate centerline along middle of channel
- Create a route of centerline
- Use "near" function to determine distance of raw survey points to routed line
- Use "locate features along route" to compute station along centerline (be sure to type in search tolerance in tool)
- Plot in spreadsheet

d. Plot points in ArcScene and use three-dimensional view to look for outliers.

e. In spreadsheet, look for points less or equal to 0.5 m (1.5 ft) and review for legitimacy.

f. Interpolate or delete depth readings that are not valid.

g. Add draft back to depth and compute total depth.

4. Review and edit water surface elevations.

a. Compute approximate stationing between sequential points with distance formula.

b. Highlight distances greater than X to denote there may be legitimate reasons for jump in water stage reading.

c. Look for outliers by plotting in sequence in spreadsheet with approximate stationing between points.

d. Use "IF/THEN" formula to check for deviations between sequential points of more than 0.3 m (1 ft) if in turbulent water, or perhaps more than 0.5 m (1.5 ft) if in calmer water.

e. Plot in GIS and manually pan to look for outliers.

f. Consider averaging every 3 to 10 water surface elevations (amount depends on distance between recorded points, slope of river, and profile tracks).

- Do not average across gaps with large distances between recorded points, such as where satellite coverage is poor and loses RTK fix

g. Interpolate or delete bad water surface elevation data.

5. Review and edit water surface elevations.

a. Average water surface elevation minus total depth.

b. Use spatial join tool in ArcMap to merge depths to nearest water surface elevations. Compute depths in attribute table using field calculator.

6. Final check.

a. Delineate channel centerline in GIS.

b. Pull data into GIS and route along centerline.

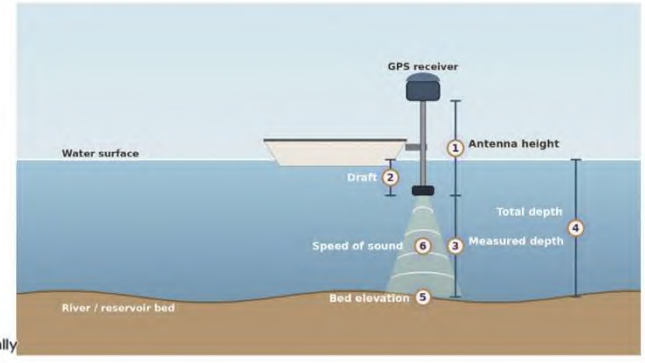
c. Export to spreadsheet and replot longitudinal profile of water surface elevation and channel bottom.

d. Look for any outliers and perform final edits as needed.

Check the next slide to explore an interactive GIF about the Anatomy of One Sounding.

Water Depth Measurement Diagram

Click each numbered marker, then press the button called Play Button to hear a short explanation. The audio keeps playing until it ends, so wait for it to finish before opening the next marker.



MULTIBEAM SURVEYING

Background

Multibeam technology was originally developed in the 1960s for deep water ocean mapping. In the 1990s, multibeam technology was further advanced for application to shallow water conditions, primarily the detection of navigational obstacles. An increasing number of companies manufacture multibeam systems and develop the software required for both data collection and processing. Numerous vendors demonstrate, sell, install, and train users on multibeam systems in the United States and around the world. Manufacturers and vendors typically provide training for users on proper data collection and processing techniques.

Multibeam Systems

Multibeam systems are fan-beam array, acoustic sounding systems comprised of multiple narrow-beam transducers mounted in close proximity, typically within a single transducer head, each emitting beams at equally spaced angles or equal distances from one location under the survey vessel (Figure 19).

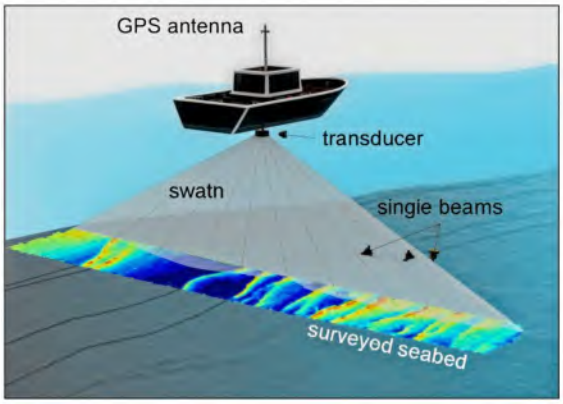


Figure 19: Typical multibeam (swath) system for bathymetric surveying.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Beam Operation and Swath Coverage

Each transducer acts as a separate acoustic-distance measuring unit, emitting beams at a given angle with respect to the transducer head mounted to the survey vessel. Real-time computations determine the depth of each beam from the slant-distance signal, adjusted to account for the orientation and motion of the survey vessel and changes in sound velocity at the transducer face and throughout the entire depth of the water column.

An integrated Motion Reference Unit (MRU) or Inertial Measurement Unit (IMU) allows multibeam systems to collect accurate data in rough water while providing full bottom coverage within the survey swath. Typical swath coverage angles for current multibeam systems range from 120 degrees to over 200 degrees. The coverage area is primarily dependent on the water depth. For example, a fan array of 120 degrees results in a bottom swath approximately 3.5 times the water depth. In water 20 feet deep, a 120-degree multibeam system will produce approximately 70 feet of swath coverage along the bottom (Figure 20). Multibeam manufacturers have recently developed transducers capable of full coverage over a swath angle of 210 degrees, providing complete coverage up to the water's edge in a single pass and eliminating the need to tilt the transducer head for mapping vertical features.

Curved transmission and receiver arrays provide the most accurate and precise distance measurement up to the water's edge and are limited only by the power of the transmission signal and the distance to the bottom, banks, or other features. Dual head multibeam systems mounted at opposite angles can achieve similar swath coverage. Figure 21 represents the relative difference in bottom coverage that surveyors might expect from the various types of bathymetric data collection methods. The figure demonstrates the additional bottom detail provided by a multibeam system while traversing similar survey patterns.

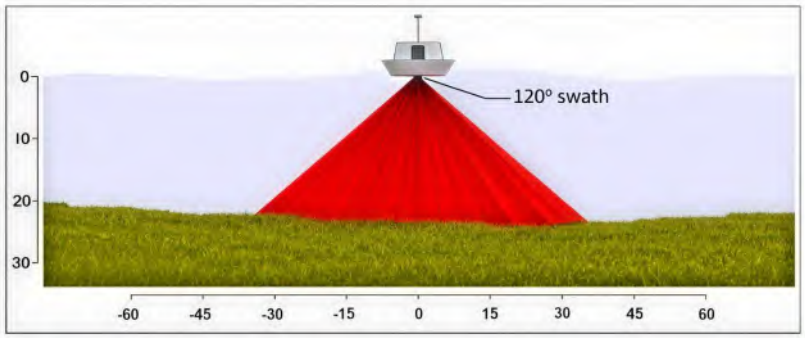


Figure 20: Multibeam swath/beam pattern emitted from typical multibeam transducer demonstrating bottom swath coverage for a 120-degree system.

(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

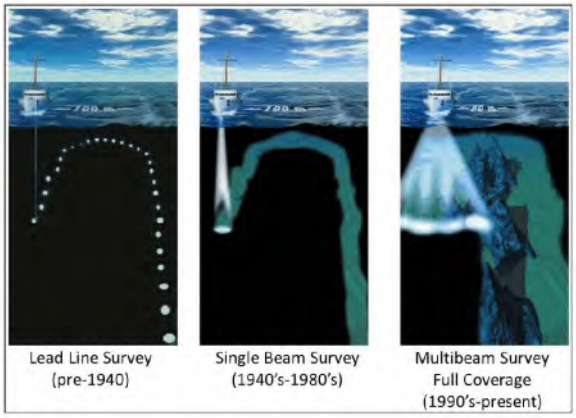


Figure 21: Relative bottom coverage provided by various bathymetric survey methods.

(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Swath Overlap and Outer Beams

It is recommended, and must be noted for navigation-type surveys, that a 50-percent overlap of the survey swaths should be maintained for quality control. Most Reclamation surveys, though, are not performed for navigational purposes, so the percentage of swath overlap can be reduced. Overlap between successive passes should be enough to ensure complete coverage once outer beams are filtered out. The outer beams produce the most measurement error because they travel the furthest distance to and from the transducer head and strike the bottom at more of an oblique angle (referred to as the grazing angle), introducing more measurement uncertainty.

Depending on the characteristics of the multibeam system and the bathymetric survey conditions (both water and bottom conditions), a portion of the outer beam depth measurements will be eliminated to reduce errors. For example, when processing data collected using a 120-degree multibeam system, it is common to filter the outer 5 degrees from each side of the swath, eliminating the largest sources of error.

System Components

The horizontal and vertical accuracy of the collected multibeam data relies on many vital system components. These components include a computer with hydrographic surveying software; sensors to measure the heave, pitch, roll, yaw, and heading of the transducer and survey vessel; a surface sound velocity probe; a positioning system (typically, Global Positioning System [GPS]); and a vertical sound velocity profiler for calibration. Figure 22 shows some of the important multibeam system components mounted to a survey vessel belonging to the Sedimentation and River Hydraulics Group (SRH) in Reclamation's Technical Service Center.

Figure 22: Multibeam bathymetry system mounted to an SRH survey vessel.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

An MRU or IMU integrates with the other system components to measure and correct position and depth errors introduced due the heave, pitch, and roll of the transducer head. On newer systems, the MRU or IMU are often mounted to the outside or inside of the transducer head itself to provide a more accurate measurement of transducer head motion. A surface sound velocity probe (usually mounted to the transducer head) is required to compute the correct angle that each beam is received into the transducer. GPS instruments provide accurate horizontal and vertical positioning in real-time, as well as calculating the heading and yaw of the transducer head relative to the survey vessel. The vertical sound velocity profiler is separate from the integrated multibeam system, but is necessary to measure the properties of the water column that affect the speed of sound of the sonar beams (primarily water temperature and salinity).

Calibration

Multibeam systems have very high data acquisition rates, typically thousands of depth points per second. To minimize measurement errors and reduce post-processing times, an extensive calibration is necessary prior to data collection. The calibration is necessary to determine the magnitude of error sources such as the roll, pitch, and yaw mounting angles of the transducer head relative to the MRU or IMU and GPS antennas. Field calibration of multibeam systems is more critical and complicated than what is required for single beam systems. Periodic, precise calibration is essential to ensure that the multibeam positions and elevations are accurate.

The horizontal positioning accuracy is dependent upon the ability of the system to compensate for pointing errors caused by vessel roll, pitch, and yaw, where a small degree of roll can cause large errors in the outer beams. For high-accuracy surveys, restrictions are typically placed on the use of the outer beam data. Manufacturer recommendations and experience should be used to determine the appropriate use of the outer beams. Accurate and efficient multibeam system operation requires an experienced crew and good calibration practice. Multibeam calibration is achieved by performing patch tests and by collecting multiple vertical velocity profiles.

The purpose of a calibration patch test is to measure the position and orientation of the MRU or IMU relative to the acoustic center of the multibeam transducer and survey vessel heading system. A patch test should be performed after initial installation, after any system component modification, and prior to each survey to confirm previous system alignment. This comprehensive patch test includes a latency test to measure any delay between the positions and depth inputs and checks to determine the pitch, roll, and yaw or azimuth offsets.

Velocity profile corrections are required for proper calibration of any multibeam hydrographic survey system and should be performed periodically throughout the area being surveyed each day. It is recommended that the velocity profile correction be completed at least twice per day and more frequent in locations where physical changes in the water column are suspected, measured, or observed. A traditional bar test can be used to verify the settings and corrections of the measured multibeam depths. The bar test can also be used to check some of the outer beam depths and is an excellent method to confirm the draft settings of the system. Manufacturer and software vendors usually recommend patch and performance tests to ensure the quality of the survey data. The performance test may compare overlapping bathymetry collected using different survey methods, such as multibeam overlapping a single beam data.

Sound Velocity and Beam Deflection

Most multibeam sonar beams are not projected perpendicular to the water surface and encounter changes in sound velocity resulting in deflection as they travel through the water column. Increases in sound velocity deflect sonar beams upward towards the water surface. Decreases in the speed of sound deflect sonar beams downward towards the bed (Figure 23). Correction for these sounding refractions requires an actual velocity variation with depth table of values that are used in post-processing of the depth data. The outer beams travel the greatest distance through the water column at the most oblique angles and are, therefore, subject to the greatest deflection caused by changes in water properties.

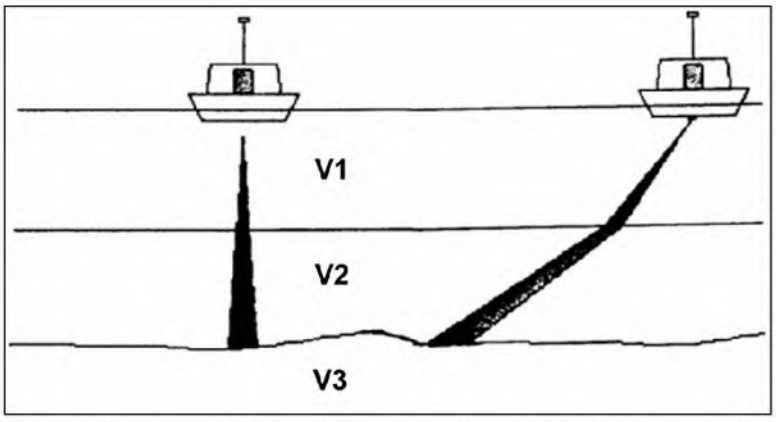


Figure 23: Sonar beam deflection due to changes in sound velocity. Note sound velocity increase in zone V2 deflecting beam upward.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Data Editing and Filtering

Raw multibeam datasets are very large, usually with many data spikes and anomalies, requiring significant filtering and editing before they can be used for final map development. Hydrographic survey software packages contain many routines for manipulating and editing large raw datasets. Filtering and editing can be conducted automatically in the software editing processes, but must be conducted with much caution to avoid accidentally eliminating useful data. During the editing process, each group of soundings (each ping) can be viewed separately and edited manually.

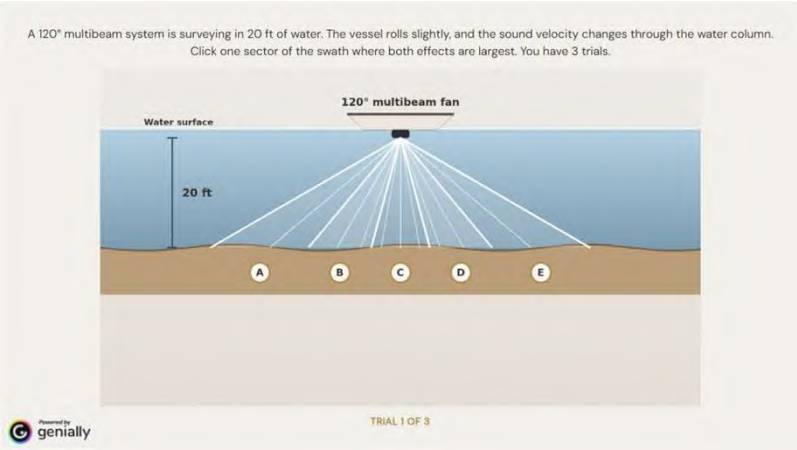
Multiple pings can be stacked together to reduce the amount of time spent during manual editing. This viewing and manual editing procedure can be very time consuming, but it should be performed on most of the datasets as a means of conducting quality control checks of the automated filtering process. A general guide on multibeam editing published by HYPACK - A Xylem Brand (HYPACK / Xylem, Inc.) is included in the next section, "Processing Multibeam Data Using the HYPACK ® MBMAX64 Multibeam Editor".

Data Reduction and Other Methods

Even after the raw datasets are edited and filtered, additional data reduction may be necessary to produce the final deliverables. Generating final Geographic Information System (GIS) surfaces and subsequent maps from massive multibeam bathymetry datasets can be time-consuming and even impossible. Filtering processes have been developed, tested, and incorporated into hydrographic software routines that allow data to be reduced without sacrificing significant quality or resolution. These filtering routines must also be used with caution to avoid eliminating important details and actual bottom features from the dataset. Filtering routines can be adjusted to identify important details such as dam faces, possible sinkholes, trashracks, and other objects of interest.

Many other viable methods for underwater mapping of reservoir and river bottoms exist. Manufacturer references and hydrographic survey manuals published by the U.S. Army Corps of Engineers (USACE) et al. should be consulted for more detail (USACE, 2004).

Check the next slide to explore an interactive GIF about the Read the Swath.



PROCESSING MULTIBEAM DATA USING THE HYPACK M-B-MAX-64 MULTIBEAM EDITOR

Multibeam Editor Guide for MBMAX64

For almost 20 years, I have been collecting and processing Multibeam data, and have done my best to find the 'best way' to process all of the billions of data points that I have collected. By the "best way", I mean the method that is the simplest, easiest, quickest way that will produce the most accurate, cleanest, and complete final dataset.

When I perform a Multibeam Training Course, and reach the 'Editing' portion of it, I always explain to the attendees, that Multibeam Editing, is, in reality, the operation of performing 'data interpretation'. If I were to provide everyone in the Course with the same RAW Multibeam dataset, and ask each attendee to 'edit' the data, it would be an extremely rare coincidence that any two or more of the attendees would produce exactly the same final XYZ dataset. This is due to the fact that each attendee would look at the data points, from their previous experience and knowledge, and use their own 'interpretation' of which points are 'bad' and which points are 'good'.

With the introduction of HYPACK's MBMAX64 Multibeam Editor, just a little over 2 years ago, multibeam processing has made significant leaps and bounds towards making this a much easier and visually understandable process.

The main focus and purpose of this "Guide" is to provide you with a good fundamental approach to processing multibeam data. I have set it up in an Outline, step-by-side walk-thru of how to 'possibly' use HYPACK's MBMAX64 Multibeam Editor. It will NOT go over EVERY aspect of the MBMAX64 Editor. From this Guide, I hope that you will be able to modify, adapt, and expand on its premise, and allow you to create a Guide of your own.

In the Outline, "The Prep Work" walks thru the loading of the data, the selection of corrections and devices, the verification of the offsets, the verification of the calibration values, and how some specific devices' data will be applied to the soundings. Continuing into Stage 1, each device's time sequential data is verified and modified for ALL of the currently loaded files.

In "The Heart of the Beast" Section, Filters will be selected and applied to individual files, groups of files, and/or ALL files. Here is where your experience and knowledge of Multibeam surveying and processing will come into play. After the Filters have been applied, the Manual Editing will clean up the remaining 'spikes' and 'bad' data points.

When you reach "The Finish Line", you will be ready to Save all of your hard work into the predefined outputs from your Scope of Work.

Again, this is just the Outline. I am working on a detailed version, with screen captures and in-depth explanations and reasoning of all the steps contained within the Outline. Until the detailed version is ready, you can get most of the details from the "MBMAX64" PowerPoint on our 2014 and 2015 Training DVDs.

Processing Outline

1. Open MBMAX64
2. Configure Settings

   Edit > Settings
3. Load Survey Data

The Prep Work

4. Read Parameters Window

4.1 Survey Tab

4.1.1 Perform Memory Test

(Don't exceed 100% of your computer's RAM)

4.1.2 Select Survey Mode (Vertical Reference)

4.1.3 Set up/Select Matrix and Cloud Sections

(Per your Scope of Work)

4.1.4 Auto-Processing

(Not applicable for this Outline)

4.1.5 TPU

(Not applicable for this Outline)

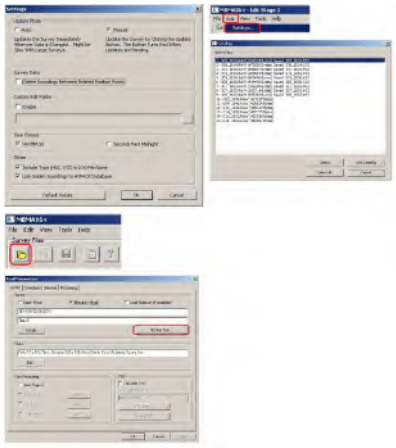


Figure 24: MBMAX64 screens for configuring settings, loading survey data, and reading parameters (Survey tab).
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

4.2 Corrections Tab
- 4.2.1 Set or Select Tide
- 4.2.2 Select Sound Velocity Profile(s)
- 4.2.3 Set Dynamic Draft

4.3 Devices Tab
- 4.3.1 Verify/Modify Device Offsets
- 4.3.2 Verify/Modify Patch Test Offsets
- 4.3.3 Save Offsets to a 'BoatOffsets.ini' file

4.4 Processing Tab
- 4.4.1 Select Heave Device
- 4.4.2 Select additional Heave Options
- 4.4.3 Select the Sonar ID for Geocoder
- 4.4.4 Select the Sound Velocity Method
- 4.4.5 Select a Presort Option

5 Proceed to Stage 1 of the MBMAX64 Editor

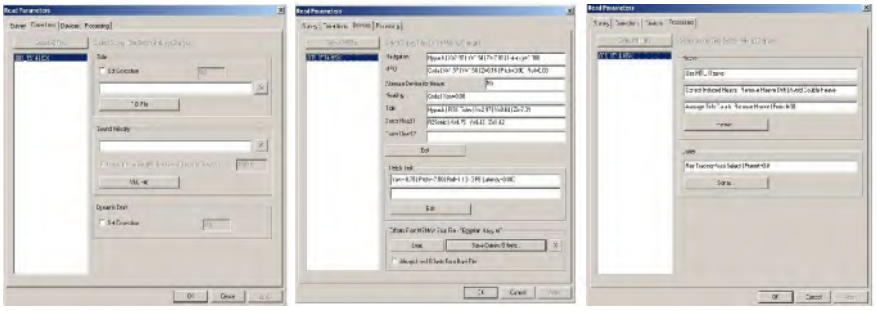


Figure 25: MBMAX64 Read Parameters window: Corrections, Devices, and Processing tabs.
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

Stage 1

6 Open the 'Speed' Window

(Verify/ Modify the Speed of each file)

7 Open the 'Heave/Tide' Window

(Verify/ Modify the Heave and Tide of each file)

8 Open the 'HPR' Window

(Verify/ Modify the Heading, Pitch, and Roll of each file)

9 Open the 'SV' Window

(Verify/ Modify the Sonar Probe's Speed of Sound for each file)

10 Proceed to Stage 2

The Heart of the Beast: Stage 2

11 Run Filters (CTRL+F)

11.1 Basic Tab

11.1.1 Select a Filter (ONLY 1 !!)

11.1.2 'Update Filter Preview'

Actions Tab

11.1.3 Apply the Filter to 'All' or 'Selected' Files

11.1.4 'Reset All' Filters

MBMAX64 Main Window

11.1.5 'Update' changes made by Filter

11.1.6 Select the next Filter from the Basic Tab

11.1.7 Repeat the above Steps until you have applied all the Filters you wish to apply from the Basic Tab (Again, 1 at a time. This allows you to visualize how each Filter affects the data.)

11.2 GPS Tab (CTRL+F)

11.2.1 Select a Filter (ONLY 1 !!)

11.2.2 'Update Filter Preview'

Actions Tab

11.2.3 Apply the Filter to 'All' or 'Selected' Files

11.2.4 'Reset All' Filters

MBMAX64 Main Window

11.2.5 'Update' changes made by Filter

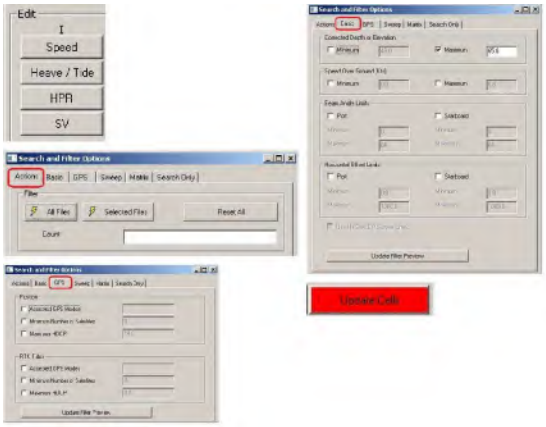


Figure 26: MBMAX64 Stage 1 window buttons and Stage 2 Search and Filter Options window (Basic, Actions, and GPS tabs).
(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

11.2.6 Select the next Filter from the GPS Tab

11.2.7 Repeat the above Steps until you have applied all the Filters you wish to apply (Again, 1 at a time. This allows you to visualize how each Filter affects the data.)

Important NOTE: In the Sweep Tab, each of its Filters may need to be run thru several times. Each time the Main Window is updated, the Filter reruns with the current selection and may find additional 'bad' points after extraneous points have been removed. 5 or more times may be common. Pay close attention to the following order of Steps.

11.3 Sweep Tab

11.3.1 Select a Filter (ONLY 1 !!)

11.3.2 'Update Filter Preview'
Actions Tab

11.3.3 Apply the Filter to 'All' or 'Selected' Files
MBMAX64 Main Window

11.3.4 'Update' changes made by Filter

11.3.5 If additional Yellow X's appear on Main Window, repeat the Actions Tab.

11.3.6 When NO additional Yellow Xs appear on the Main Window, go to next Step.
Actions Tab

11.3.7 'Reset All' Filters

11.3.8 Select the next Filter to be used from the Sweep Tab

11.3.9 Repeat the above Steps until you have applied all the Filters you wish to apply (Again, 1 at a time. This allows you to visualize how each Filter affects the data.)

Important NOTE: The Matrix Tab and its Filters can ONLY be used if you have the proper Tide, Sound Velocity Cast, Device Offsets, and Patch Test information entered. This is due to the fact that the Matrix Filter is performing the filtering on overlapping files, and not individual files, like the Filters above.

11.4 Matrix Tab

11.4.1 Select Vertical Option

11.4.2 Enable Above, Below, or Both

11.4.3 Select Vertical Tolerance

(2 Sigma = 95% Confidence)

(4 Sigma = 99.994% Confidence)

(Set Limit)

Actions Tab

11.4.4 Apply the Filter to 'All' or 'Selected' Files

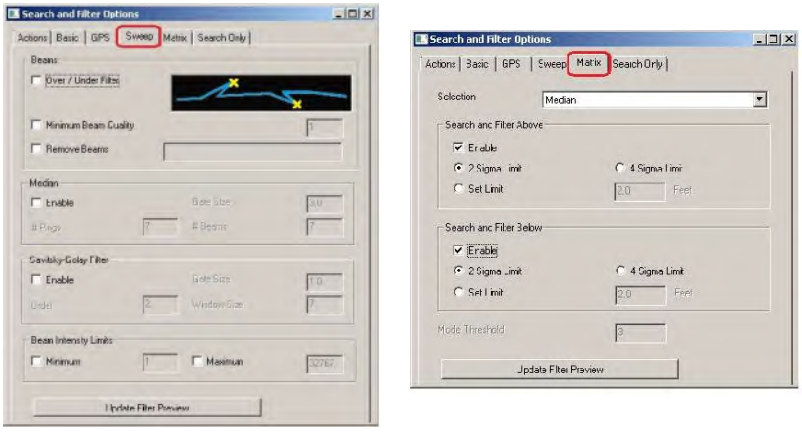


Figure 27: MBMAX64 Search and Filter Options window: Sweep and Matrix tabs.

(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

11.4.5 'Reset All' Filters

MBMAX64 Main Window

11.4.6 'Update' changes made by Filter

11.4.7 Select the next Vertical Tolerance to be used from the Matrix Tab

11.4.8 Repeat the above Steps until you have applied all the Vertical Tolerances that you wish to apply from the Matrix Tab

NOTE: Dependent upon how 'clean' your initial raw data is, using the Filters can potentially remove 80 – 90+ % of your unwanted, incorrect data, making your Manual Editing a much easier task.

12 Manual Editing

Using the Manual editing Tools (Lasso, Block, Line, Eraser, etc.):

12.1 Sweep 1 and 2 Windows

Edit remaining spikes from individual files

12.2 Cloud Sections - Edit and Mark as 'Checked'

12.3 Profile Window - Edit and Mark as 'Checked'

13 When ALL Cloud Sections and/or Profiles have been 'Checked' (verifying that ONLY 'Good' data points remain), you are ready to Save your data.

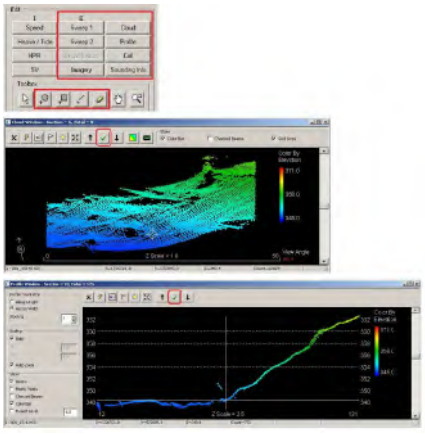


Figure 28: MBMAX64 manual editing tools, Cloud window, and Profile window.

(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

14 Save Files

14.1 Save to HS2 format

14.2 Save to HS2x format

NOTE: Saving to these 'Edited' formats ... Offsets, bad SV Profiles, incorrect Tides, incorrect Patch Test values, etc.

14.3.1 (Ability to create detailed subsets from it)

14.3.2 Save 'One Point per Cell' datasets

14.3.2.1 Save with different Cell Sizes

(Modify the Cell Size in the Read Parameters Window)

14.3.2.2 Save with different Z-value Selection

(Change the 'MTX Selection')

Examples of Selections: 1x1 Median, 1x1 Average, 1x1 Minimum, 1x1 Maximum; 3x3 Median, 3x3 Average, 3x3 Minimum, 3x3 Maximum; 5x5 Median, 5x5 Average, 5x5 Minimum, 5x5 Maximum, etc.

14.3.2.3 Save data from 'Save All Files' or 'Save Selected Files'

14.3.2.4 Name the File by its contents

Example: Boat Name_Jobsite_Date_Cell Size_Z-value.XYZ; MV Simpson_St Louis Harbor_11112014_1x1_Median.XYZ

14.4 Save to other formats as needed

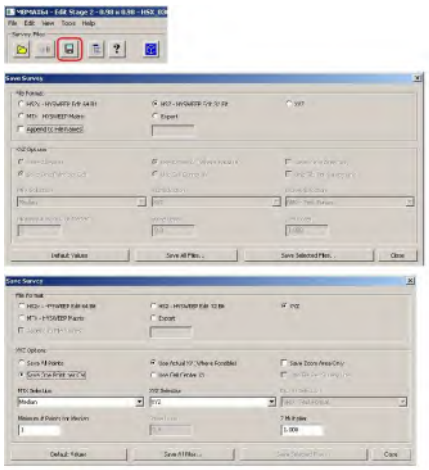


Figure 29: MBMAX64 Save Survey windows.

(Source: US Department of the Interior, Bureau of Reclamation, "Best Practices in Hydrographic Surveying," September 2019

THANK YOU FOR LISTENING!

This concludes our presentation, and we hope that you enjoyed it.

For instructions on how to receive PDH credits, please continue till the end of the presentation.

REFERENCES

This interactive presentation was adapted from the US Department of the Interior, Bureau of Reclamation, “Best Practices in Hydrographic Surveying,” September 2019

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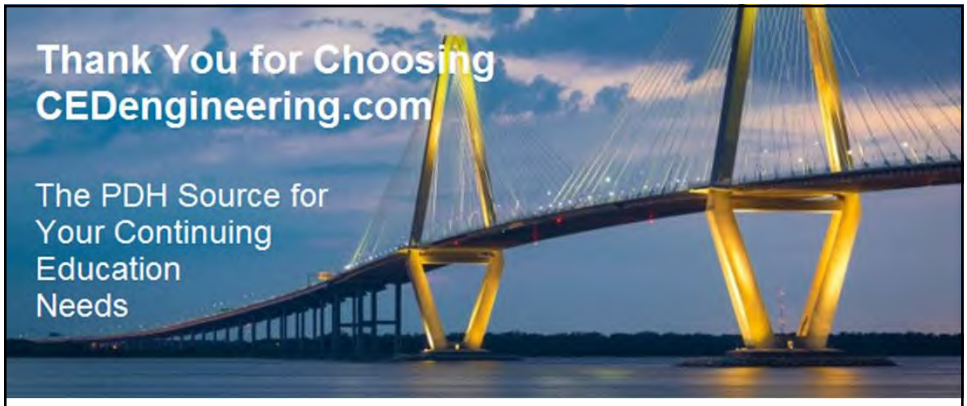

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