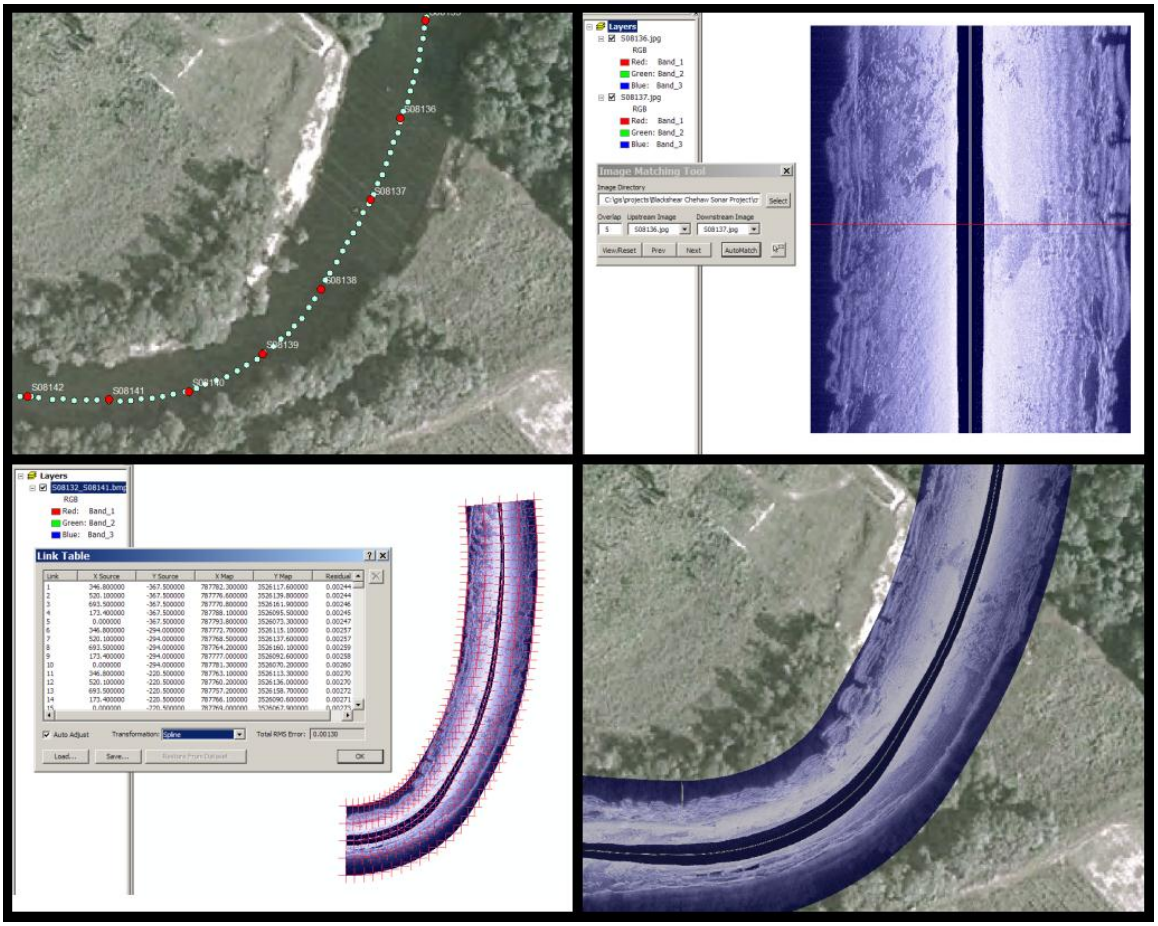
SONAR IMAGERY GEOPROCESSING WORKBOOK

An illustrated guide to geoprocessing low-cost, side scan sonar imagery obtained with the 900 or 1100 series Humminbird® Side Imaging Systems



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Introduction

Landscape level habitat data is extremely valuable to those involved with research and management of aquatic systems. The characterization of in-stream habitat at the landscape scale is, however, notably difficult and costly, especially in non-wadeable, turbid systems. In recent years a number of advanced airborne techniques, such as LIDAR and thermal infrared systems, have been demonstrated to map riparian and subsurface features. For such techniques, depth and turbidity significantly impact the quality of remotely-sensed data, while the overall cost and need for technically specialized personnel limit the number of opportunities where these techniques are feasible.

Side scan sonar (SSS), first developed in the early 1960s, provides an alternative method of remote sensing of underwater habitat. Side scan sonar transmits and receives reflected acoustic signals whose intensity is translated to produce an image of the underwater landscape. Although a variety of factors influence the operation of SSS, reliable sonar data can be obtained in deep and turbid environments.

Side scan sonar has traditionally been used to locate sunken vessels, for charting navigational channels, and for characterizing benthic substrates, primarily in marine or otherwise open, deep water systems. In such environments, a transducer is towed at depth by a moving vessel during data capture. This configuration limits the use of SSS in shallow and otherwise hazardous aquatic systems where rocks or debris could damage the towfish apparatus. In addition, traditional SSS systems are expensive, require specialized personnel to operate, and require specialized software to interpret sonar data and generate georeferenced images. These factors have presumably limited access to and application of SSS in inland aquatic systems.

Although geospatial mapping and landscape ecology have flourished with advances in Geographic Information Systems (GIS) and remote sensing, the ability to map and study underwater landscapes remains largely out of reach. In short, aquatic resource professionals need an inexpensive and rapid method for mapping habitat at the landscape scale- a flexible technique that uses readily available software and requires a modest amount of training.

In 2005 the Humminbird® Company (Eufaula, AL) released the 900-series Side Imaging system, an inexpensive (~$2,000) SSS device that operates at high frequencies (455 or 800 kHz) to produce very-high resolution (10-cm pixel) imagery of underwater features. On the water experience with the SI system demonstrated that features such as large woody debris, substrates, and bank boundaries were clearly evident in sonar images. We hypothesized that instream habitat features could be reliably mapped if these images could be geoprocessed and interpreted in a GIS environment.

We have worked to develop and critically evaluate methods for achieving these objectives. As part of this effort we developed a workshop on sonar mapping. This workbook represents an important contribution to this initiative by providing a step-by-step guide to techniques we have developed for geoprocessing sonar survey data. Geoprocessing is, however, only one step in the sonar mapping process. Information on other critical aspects of sonar mapping such as gear set-up, mission planning, sonar image interpretation, and GIS mapping are not fully addressed in this workbook but are covered in other workshop materials we have developed. Mapping habitat features in GIS is a topic that might be best covered by developing another technical workbook.

What is Geoprocessing?

"Geoprocessing is the methodological execution of a sequence of operations on geographic data to create new information"- ESRI Desktop Help Manual.

All side scan systems produce image data that must be geoprocessed to be correctly displayed (i.e. geospatially projected) on a map. The same is true for image data captured with the Humminbird® Side Imaging system. In fact, sonar images captured as screen snapshots are dimensionally distorted in their raw form (x and y dimensions of each square pixel represent unequal, variable distances); raw images cannot simply be "draped" over a position on the stream channel from which they were obtained. Our task in this workbook is to geoprocess raw image and coordinate data obtained during a sonar survey to create what we call sonar image maps (or SIMs). These SIMs are raster layers, each representing a mosaic of individual images that have been georeferenced and rectified into geographic space.

Evolution of the Technique

Although Humminbird® markets the Side Imaging system to fisherman as a tool for locating fish habitat, the device was quickly adopted for alternative purposes. We were introduced to the SI system by loggers during our work on a 2-year state program established to permit and monitor the removal of submerged, pre-cut timber (a.k.a. deadhead logs) in 2 South Georgia rivers. To assess the distribution and abundance of deadhead logs prior to the issuance of recovery permits, we acquired a 981c SI system and surveyed both rivers. A few days on the water suggested great potential of this device for habitat mapping.

Sonar image data can be acquired either as bitmap (.bmp) images (the screen snapshot approach) or as sonar (.son) recording files (the streaming video approach). It is not possible to capture both types of image data at the same time with the SI system. For many reasons, foremost being that .son files where undocumented, proprietary, and only viewable on the Humminbird control head, we decided at the onset to develop techniques that use raw sonar images (screen snapshot approach) instead of the .son files.

Our first approach to mapping was simply to plot the waypoints obtained for each image and establish a "hotlink" connection to the raw images. Although hotlinking provided a satisfactory way of organizing and retrieving raw images, our aspirations quickly turned to the idea of generating a seamless mosaic of sonar images fitted to the stream channel. Given the high resolution of images and our experience ground-truthing deadhead logs, we believed that a sonar image map (SIM) could be interpreted to digitize and classify bank boundaries, major substrate classes, and large woody debris with high accuracy and complete spatial coverage. In the absence of any software available to view or geoprocess Humminbird® snapshot images, we set out to develop our own techniques and software tools that would be rapid, flexible, and accessible to most aquatic resource professionals in terms of software requirements, cost, and training needs.

To arrive at this "end" point we have invested a great deal of time and energy to develop and verify all aspects of the sonar mapping method. This work included the execution of sonar surveys, the development and testing of processing tools, and the scientific assessment and verification of the method as a whole. We hope that by making the tools and training available, researchers and managers will consider using side scan sonar to map aquatic habitat at the landscape level. Given the alarming rate of habitat loss and modification worldwide, we hope these tools may be used to support habitat conservation and improve our ecological understanding of the complex structure and function of aquatic ecosystems.

Evolution of the Processing Tools and Geoprocessing Workbook

Since the release of the original 981c SI system, new models of the Humminbird SI system have rapidly appeared on the market, in addition to new control head firmware releases and new versions of HumminbirdPC. The current top-end model SI system is the 1197c. To support the geoprocessing of imagery from other models we have modified the processing tools and the techniques presented in this workbook. We have automated additional processing steps, and others have simply been rendered more straightforward with changes Humminbird® has made to control head operation. Wherever appropriate we have maintained older instructions that pertain to the 981c SI system, and supplemented the workbook with instructions that guide these same operations involving imagery and data from newer models.

Acknowledgements

The sonar habitat mapping initiative was made possible through funding and support provided by the Georgia Department of Natural Resources, the Fisheries Information and Technology Section of the American Fisheries Society, the Joseph W. Jones Ecological Research Center at Ichauway, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service (NOAA), and the Southeast Aquatic Resources Partnership. We wish to thank many colleagues who have provided advice and assistance in support of this initiative (in no particular order): Marquerite Madden, Tommy Jordan, and RG Brown III (University of Georgia), Jean Brock and Staff of the Joseph W. Jones Ecological Research Center at Ichauway, Bill Fisher, Andy Loftus, and Jeff Kopaska of the AFS Computer User's Section and Fisheries Information and Technology Section, Chris O'Bara (WV DNR), Scott Robinson (Southeast Aquatic Resources Partnership) and interns, technicians, and graduate students Joshua Hubbell, T. Wes Tracy, and Philip Marley, Andrea Crawford, Tanner Williamson, and Reuben Smit.

Data, Software, Semantics, Enhancements and Time Requirements

Data

The geoprocessing techniques presented in this workbook require three principal data sets:

1) Raw sonar images (.bmp/.png files)
2) Geographic coordinates for image capture locations (waypoints)
3) Geographic coordinates representing the survey route (track points)

These data sets must be acquired in an appropriate manner during the sonar survey. **Raw sonar images must be obtained such that a *small* portion of overlap exists between consecutive images.** (Please see Appendix section- How to Capture Consecutive, Overlapping Images). The SI system control head settings should be adjusted to record waypoint coordinates in decimal degrees. Track points should be recorded at frequent intervals (we use a 3-sec interval). If depth data along the mid-channel track is important to your study, we suggest setting the control head for NMEA communication with a separate GPS receiver (see **Note** below) to provide a depth observation at each track point.

Note: Although it is now possible to capture a track point file that contains depth data at each track point on the 1197c control head (and possibly some of the 900-series models), the process of exporting and accessing such track files demands more time than the approach we take. In addition, any track file captured on the 1197c control head must be saved before the unit is powered off or else the data is lost- an approach that is definitely not fail-safe. For these reasons, we recommend the use of a separate, hand-held GPS receiver (e.g. Garmin GPSMap76) that is networked to the sonar control head during surveys via a GPS-accessory connect cable (available for purchase at the Humminbird® store).

Software

Below is a list of the software products required to process sonar imagery using the procedures described in this workbook. All development and testing was performed in a Windows environment running either Windows XP or Windows 2000 operating systems while running ArcGIS 9.2 and 9.3.x. ArcGIS 10.0 was tested on Windows 7 Professional; testing of the sonar processing tools has been limited.

HumminbirdPC

Humminbird PC is required to transfer waypoints from the sonar control head, or from the removable SD/MMC card (997c/1197c SI systems), to a computer. Upon registering your sonar device with Humminbird® you are provided a link to download HumminbirdPC. If using the original 981c SI system you must also obtain a hardware kit called the PC Connect Accessory Kit ($24). This kit can be ordered from the Humminbird website. The PC Connect kit provides a cable to connect two 9-volt batteries to serve as a power source for the control head, and provides another cable that connects the output port of the control head to the 9-pin input port on a desktop computer.

ArcGIS (ArcView Level)

The sonar processing tools have been developed and tested for use in ArcGIS 9.2, 9.3.x and 10.0 geographic information system (GIS) software (with all service packs installed). Within the ArcGIS 10.0 package, Visual Basic for Applications (VBA) requires registration and you must request a free VBA license from ESRI. For more information on ArcGIS software and obtaining a VBA license for ArcGIS 10 visit www.esri.com.

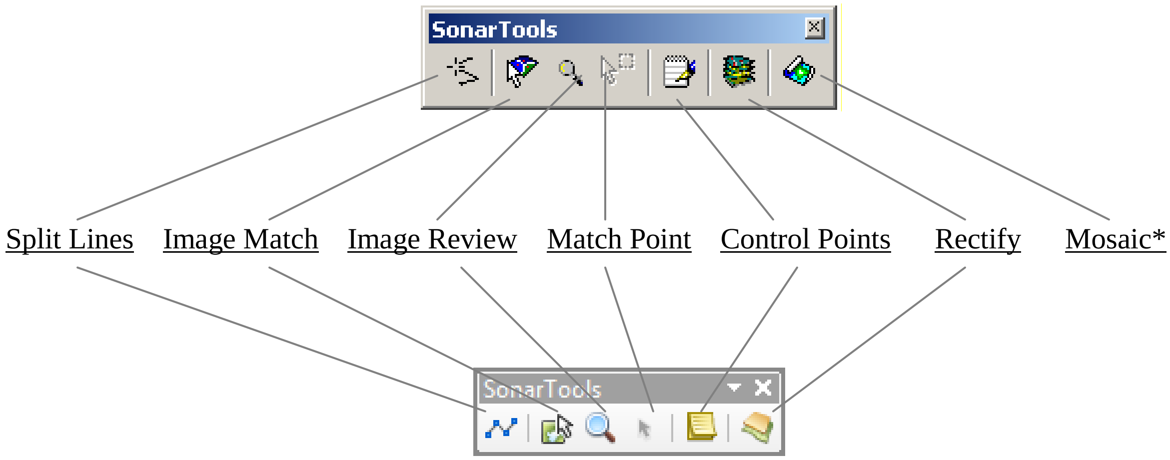
ET GeoWizards

ET GeoWizards is a set of wizard type tools that allow ArcGIS users to easily manipulate data. Most importantly, it enables ArcGIS users with an ArcView license to perform certain data processing tasks that are standard only at the ArcEditor and ArcInfo level. Though ET GeoWizards is not free, it does offer a number of free functions. Some of these free functions can only be run on datasets with less than 100 features, while others are unlimited. The procedures outlined in this workbook have been tested using ET GeoWizards version 9.8 for ArcGIS 9.2 and 9.3.x. ET GeoWizards version 10.0 is required for ArcGIS 10.0. ET GeoWizards can be downloaded at: http://www.ian-ko.com/.

Sonar Processing Tools

The sonar processing tools are a set of customizations (toolbar, forms, VBA code) developed to process sonar image snapshots. Currently, we deliver these customizations within ArcGIS projects. The project/document named **sonar_processing_tools_9x.mxd** has been tested in ArcGIS versions 9.2 and 9.3.x (ArcView level) and will only work in the aforementioned environments. The project/document named **sonar_processing_tools_10_0.mxd** will only work in ArcGIS 10.0. The SonarTools toolbar can be opened and closed as you would any other ArcGIS toolbar (i.e. Editor). The toolbar looks a bit different in ArcGIS 10 than it does in ArcGIS 9.x. Below is a quick guide to the SonarTools toolbar:

ArcGIS 9.x SonarTools



ArcGIS 10.0 Sonar Tools

*With ArcGIS 10.0 the Command Line is no longer available and the mosaic tool has been removed. An alternative method for mosaicking images in ArcGIS 10 (and ArcGIS 9.3.1) is presented in the Appendix section of this workbook.

Note: ESRI intends to discontinue VBA at the next release of ArcGIS, presumably ArcGIS 10.1. The unfortunate consequence of this change will be that the Sonar Tools, as developed, will not function in ArcGIS 10.1 or beyond. These tools may be redeployed as stand alone "Add Ins" in the .NET environment as time, interest and/or funding dictate.   For more information on ArcGIS software or obtaining VBA for ArcGIS 10 visit www.esri.com.

Irfanview
IrfanView is a fast, small, compact and innovative FREEWARE (for non-commercial use) graphic viewer for Windows 9x, ME, NT, 2000, XP, 2003 , 2008, Vista, Windows 7. It will also run on Linux with using Windows emulators, such as Wine. The software is free for private use and available for commercial use at the very modest price of $12 US. The software can be downloaded and registered at: www.irfanview.com. See Appendix for installation instructions.

Microsoft Excel
Used in waypoint and track point downloading and to create DBF IV files.

WinZip
The demonstration dataset and processing tools are bundled and delivered in a WinZip file (*.zip). WinZip, or similar utility, is required to unzip these files.

Workbook Semantics

This document is written to process the sonar demo dataset using the Sonar Tools in the ArcGIS 9.x environment. However, the workbook can be followed to process the sonar demo dataset in ArcGIS 10.0. Efforts have been made to indicate where ArcGIS 10.0 commands deviate from ArcGIS 9.x (i.e. ArcGIS command locations). It is possible, and even likely that we missed a few of these points. Therefore, if you can't find command we've referenced in ArcGIS 10.0 environment, be assured that the command does exist – with a bit of searching you will find it.

Referenced throughout this document are folder and file names, as well as program commands, buttons, etc. For discrimination, all program commands are bound like <this>. All folders and file names appear in **bold font**.

Enhancements

We have learned much from our students and interns over the years. As a result we are able to provide information in this release that will help you to avoid or troubleshoot certain pitfalls that may be encountered during sonar processing. This information is provided as "**Notes:**" throughout the document. In addition, the Appendix contains a great deal of information including a detailed method to consistently capture overlapping imagery, time saving tips in the rectification process, alternative methods to selected processing steps, and detailed instruction on how to fix images that warp upon themselves. As always, we are available to answer questions and enjoy hearing from you. However, we are providing this information so you can be more efficient and autonomous in your endeavors.

January 2011 Enhancements to the Processing Toolkit

Major enhancements have been implemented to support the processing or automation of:

1. Use of either JPG (lossy) or PNG (lossless) image formats
2. Images captured using **left side only**, **right side only**, or both **side beams**
3. Images collected with 900 or 1100-series Humminbird side imaging systems
4. Full automation of the image matching tool for batch clipping of sonar images
5. Creation of an Image Review tool
6. Development of tools for use in ArcGIS 10.0

These enhancements and changes affect the following sonar image processing tools

1. Image Matching Tools
2. Control Point Generation Tool
3. Batch Rectification Tool
4. Batch Mosaic Generation Tool

Time

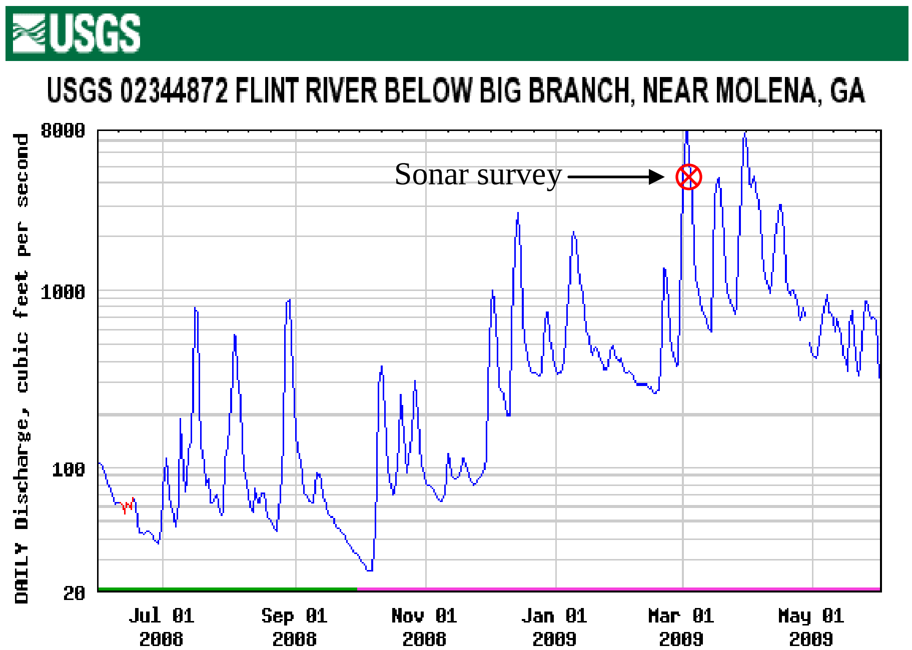
At first glance it might appear as though geoprocessing of sonar imagery is time consuming and complicated. We have intentionally included as much detail as possible in this workbook to lead a novice user through all phases of geoprocessing. Although the speed at which you are able to process data will vary according to experience both with ArcView and with the techniques presented here, we typically complete geoprocessing at a rate of 16 minutes per kilometer of survey data (estimate includes CPU image rectification and mosaicking time), or -more realistically- within **8-12 min/km** (excluding CPU rectification and mosaicking time). Other work tasks can be addressed while the computer is executing image rectification.

For more details on time requirements by step of the mapping process we refer you to our article in the April 2010 issue of Fisheries, available for free online at:
http://www.fisheries.org/afs/publications_fisheries.html

The Demonstration Data Sets

On March 5, 2009 we conducted a single-pass sonar survey of ~22 km of the Upper Flint River, located 80 km south of Atlanta, Georgia. The goal of the survey was to gather data to produce a full coverage habitat map for an ongoing, radiotelemetry study of habitat use of three, congeneric species of bass inhabiting the study area.

The survey was conducted on the receding limb of a high discharge event, providing us with enough water to safely pass over several shoal areas. Water clarity was poor, with a few inches of visibility. Observed discharge at the nearest gauge was 3000-3500 cubic feet /second (cfs).



Water levels were critical to navigation; it was important to execute the survey at this time.

Only 2 other subsequent events would have provided safe passage.

Mean width of the Flint River in the study area was ~55 m; range settings of 110-130 feet per side were used to capture bank-to-bank sonar images. One stop, and several range setting adjustments were made during the survey. On-the-water data acquisition was completed in 2.5 hours. The demonstration data set includes the waypoint, track point, and image data acquired for one segment of the study area (images S12960-12990).

Near the downstream end of the study area we passed over a 3.5 km set of submerged shoals. The photograph (right) provides an idea of the conditions that day, and the size of the river system. It is important to note that the underwater turbulence created by these shoals did produce some image distortion- a potential limitation to effective sonar mapping in turbulent environments. Nevertheless, experience with substrate in this area during low water conditions enabled us to later classify the entire area as boulder substrate.

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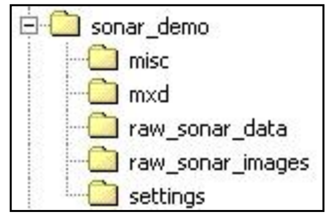
Data Structure

The data demonstration data set is bundled and compressed in a WinZip file (sonar_demo.zip). Using WinZip <Extract> the data. Navigate to the folder created to house the demo data and processing tools, be sure <Use folder names> is checked and click the <Extract> button. This will create a **sonar_demo** folder and four subfolders: **mxd**, **raw_sonar_data, raw_sonar_images**, and **settings** (see figure right).



Folder Contents

misc: This folder contains a NAIP digital aerial photograph (**sonar_demo_naip.img**) of the demo area and a copy of the workbook (**Sonar_Image_Processing_Workbook_2_0.pdf**).

mxd: This folder contains the ArcGIS projects **sonar_processing_tools_9x.mxd**, which has the customizations built in for ArcGIS 9.x. The project **sonar_processing_tools_10_0.mxd** contains customizations for use in ArcGIS 10.0. Use the appropriate project as the workspace for processing sonar imagery.

raw_sonar_data: This folder contains the raw waypoint and track files that will be used in the demo **(waypoints_030509.dbf and trackpoints_030509.dbf)**.

raw_sonar_images: This folder contains sonar images captured in the field.

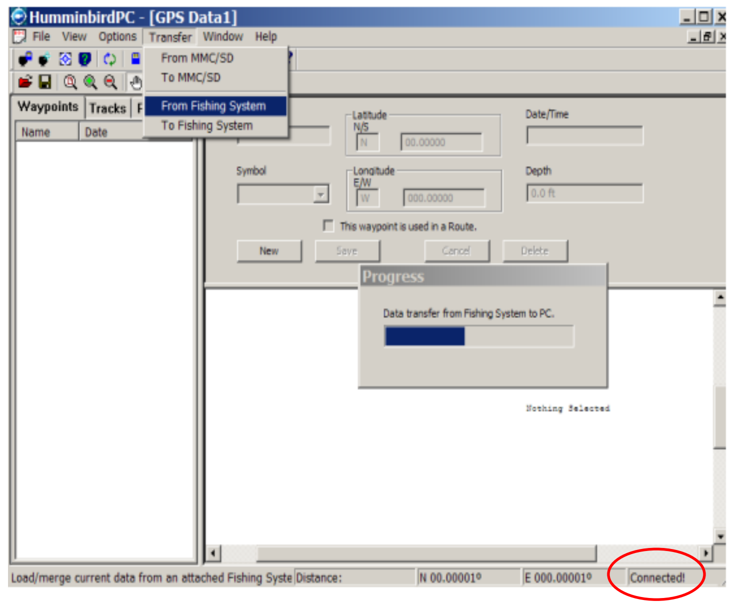
settings: This folder contains **cropsettings_900.ini** and **cropsettings_1197.ini**. These files contain crop settings to remove collar information in Irfanview from the raw sonar images collected with 900 (only tested on 981c imagery) and 1197 series Humminbird units, respectively.

Note: As the demo progresses, additional subfolders will be created under the **sonar_demo** folder. All folder names are flexible, except where otherwise noted. **Note: DO NOT put spaces in the names of folders or the processing tools will NOT function.**

Data Transfer to Desktop Computer

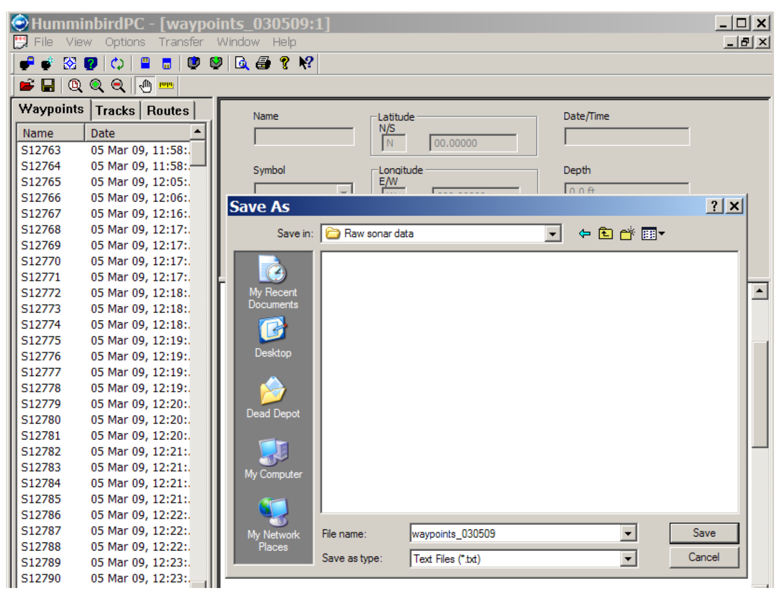
For the purposes of this demo the data transfer of raw sonar images, waypoints, and track points has been completed. <u>Thus, the processing of the demonstration data set should begin at page 12-</u> <u>*Preparing Coordinate Data*</u>. Data transfer methodologies are presented here to provide explicit instructions for transferring data collected in the field to a computer for review and processing.

Transferring Waypoint Coordinates from 981c (Image Capture Locations)



Once connected to the computer, power up the control head (981c only). Next, open HumminbirdPC and select the option <Manage Tracks Waypoints Routes>. If HumminbirdPC is communicating with the control head, a note in the lower right hand corner of the screen will read Connected! From the <Transfer> menu select <From Fishing System>. When the download succeeds, all of the waypoint data will display in the left panel under <Waypoints> tab.

Choose an appropriate file name and save the .gpx file to the folder named **raw_sonar_data**.

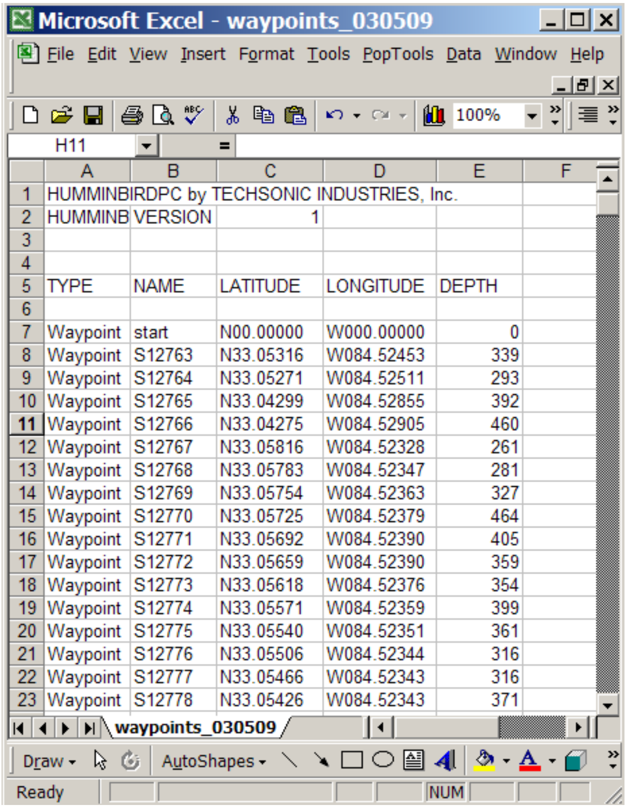


Next, under the <Options> menu, select <File> and <Export>. Change the <Save as type> to <Text Files (*.txt)> and save the exported text file to the **raw_sonar _data** folder. At this point the control head can be powered off and disconnected.

Note: The control head data transfer process (981c SI only) can be temperamental, sometimes requiring multiple attempts before successfully downloading the entire data set. A fresh pair of 9-volt batteries seems to be important. If the download repeatedly fails to execute, try connecting the control head directly to a marine battery for a robust power supply.

Minimize or close HumminbirdPC and open a blank Excel spreadsheet. Select <File> and <Open> and navigate to the folder containing the exported waypoint data .txt file. Within the

<Text Import Wizard >select <Delimited>for the file type, <Tab> as the delimiter, then <Finish>. A spreadsheet should be populated with the survey waypoint numbers, coordinates, and depth (in centimeters). The next step is to manipulate this spreadsheet into a format that can be imported into ArcGIS.

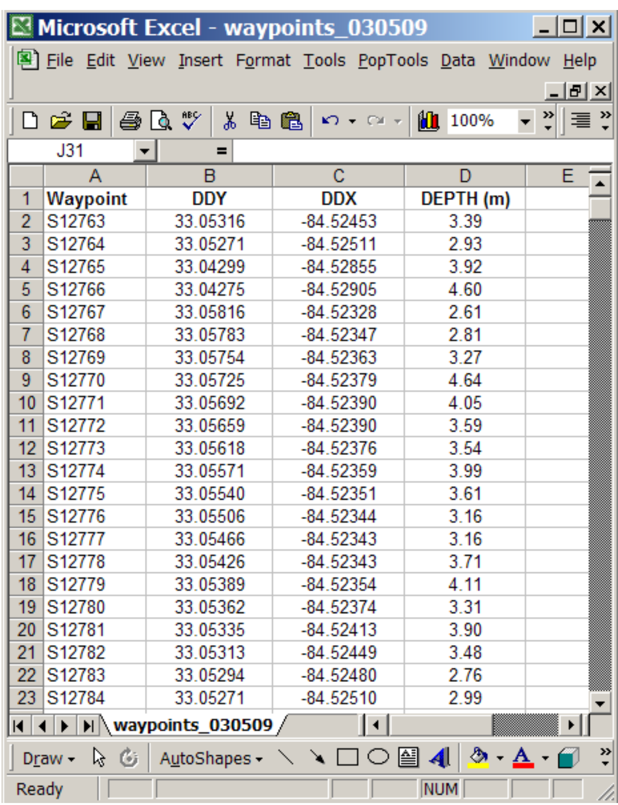


	A	B	C	D	E	F
1	HUMMINBIRDPC by TECHSONIC INDUSTRIES, Inc.					
2	HUMMINB	VERSION	1			
3						
4						
5	TYPE	NAME	LATITUDE	LONGITUDE	DEPTH	
6						
7	Waypoint	start	N00.00000	W000.00000	0	
8	Waypoint	S12763	N33.05316	W084.52453	339	
9	Waypoint	S12764	N33.05271	W084.52511	293	
10	Waypoint	S12765	N33.04299	W084.52855	392	
11	Waypoint	S12766	N33.04275	W084.52905	460	
12	Waypoint	S12767	N33.05816	W084.52328	261	
13	Waypoint	S12768	N33.05783	W084.52347	281	
14	Waypoint	S12769	N33.05754	W084.52363	327	
15	Waypoint	S12770	N33.05725	W084.52379	464	
16	Waypoint	S12771	N33.05692	W084.52390	405	
17	Waypoint	S12772	N33.05659	W084.52390	359	
18	Waypoint	S12773	N33.05618	W084.52376	354	
19	Waypoint	S12774	N33.05571	W084.52359	399	
20	Waypoint	S12775	N33.05540	W084.52351	361	
21	Waypoint	S12776	N33.05506	W084.52344	316	
22	Waypoint	S12777	N33.05466	W084.52343	316	
23	Waypoint	S12778	N33.05426	W084.52343	371	

Using the <Data - Text to Columns> spreadsheet function, rearrange the data so that the spreadsheet format is:

column 1= Waypoint
column 2= DDY (or Lat)
column 3= DDX (or Long)
column 4= Depth

You will need to strip the N from the data Latitude DDY column and replace the W0 in the DDX column with the minus sign (-) if you are working in the western hemisphere. This can easily be done using the <Find> / <Replace> tools in Excel.



	A	B	C	D	E
1	**Waypoint**	**DDY**	**DDX**	**DEPTH (m)**	
2	S12763	33.05316	-84.52453	3.39	
3	S12764	33.05271	-84.52511	2.93	
4	S12765	33.04299	-84.52855	3.92	
5	S12766	33.04275	-84.52905	4.60	
6	S12767	33.05816	-84.52328	2.61	
7	S12768	33.05783	-84.52347	2.81	
8	S12769	33.05754	-84.52363	3.27	
9	S12770	33.05725	-84.52379	4.64	
10	S12771	33.05692	-84.52390	4.05	
11	S12772	33.05659	-84.52390	3.59	
12	S12773	33.05618	-84.52376	3.54	
13	S12774	33.05571	-84.52359	3.99	
14	S12775	33.05540	-84.52351	3.61	
15	S12776	33.05506	-84.52344	3.16	
16	S12777	33.05466	-84.52343	3.16	
17	S12778	33.05426	-84.52343	3.71	
18	S12779	33.05389	-84.52354	4.11	
19	S12780	33.05362	-84.52374	3.31	
20	S12781	33.05335	-84.52413	3.90	
21	S12782	33.05313	-84.52449	3.48	
22	S12783	33.05294	-84.52480	2.76	
23	S12784	33.05271	-84.52510	2.99	

Delete other header information. The revised spreadsheet should appear as shown here.

Although the depth data was originally imported in centimeters, we converted these values to meters.

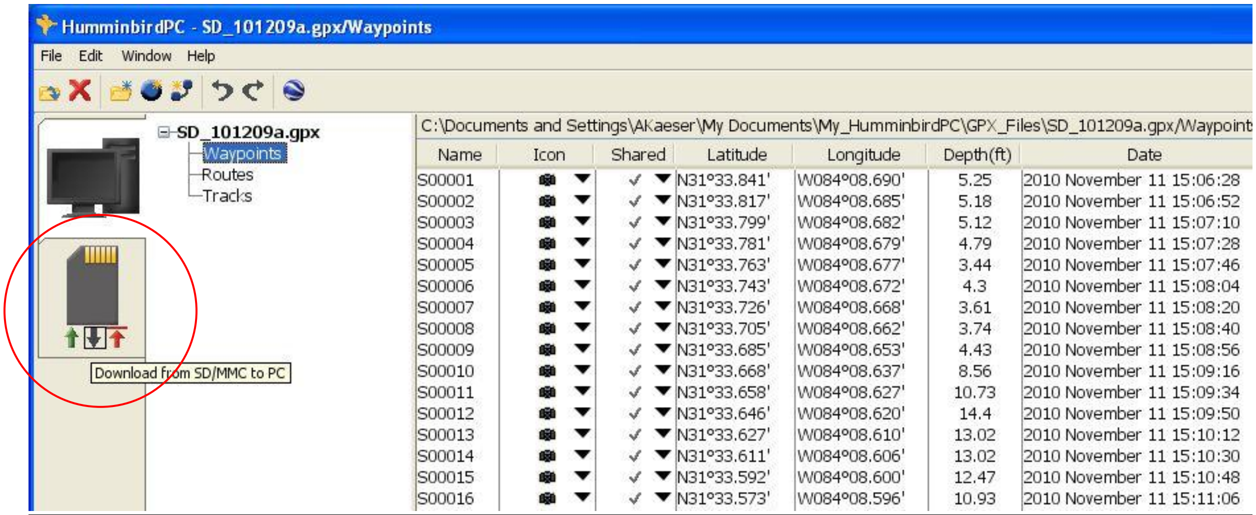
Save this Excel file to the sonar survey data folder.

With the cursor in the spreadsheet's data range, resave the file as a DBF IV file into the **raw_sonar_data** folder.

Transferring Waypoint Coordinates from 1197c

<u>At the end of a survey- prior to powering down the control head- *and while the GPS is still connected and turned on*</u>, access the Nav menu and Export All Nav Data to the SD card in the control head. Remove and connect the SD card to your desktop computer using a card reader or port. Next, open HumminbirdPC version 3.0.26 and select the option <Download from SD/MMC to PC>, the middle arrow under the flash card icon.

Oddly enough, if the GPS device is disconnected from the control head the entire Nav menu disappears, and you cannot export the waypoint data to the SD card!

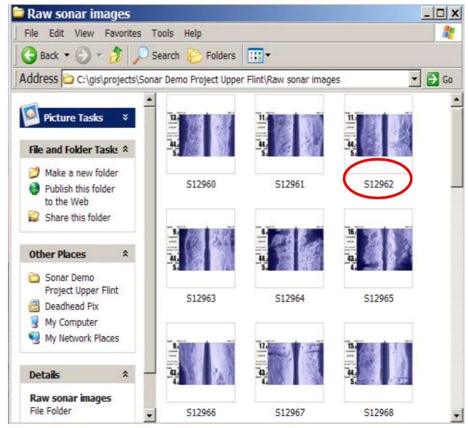


A .gpx file will appear in the table of contents, and can be expanded to display waypoints, routes, or tracks. (A copy of this .gpx file is automatically saved to Documents and Settings under My Documents- My_HumminbirdPC- GPX_files, but a copy can and should be saved to another location for backup redundancy if deemed necessary). Select Waypoints to display the set of downloaded coordinates, along with depth and time information. Under the Edit menu, you can set the coordinates to decimal degrees, and convert depth to meters in the spreadsheet if desired.

Use the cursor to highlight/select all of the waypoint entries you wish to examine/process. Under the Edit menu select <Copy>, and navigate to a blank Excel spreadsheet where you can paste the data. Follow instructions provided on page 11 to manipulate this data set into the proper format. To remove the N and W and degrees icon from the coordinate set use the Excel function <Data-Text to Column-Fixed Width> and create break lines that separate these elements. Make sure you have created a few empty columns first so that you don't overwrite data. When the spreadsheet has been reformatted, save the file to the sonar survey data folder using an appropriate file name (e.g., raw_wpts_date.xls).

Note: If you are using ArcGIS 9.3 or higher, you do not have to save this Excel file as a .dbf file as described earlier. This version of the software can be used to add the data directly from the .xls spreadsheet using <Tools- Add XY data>.

Transferring Raw Sonar Images

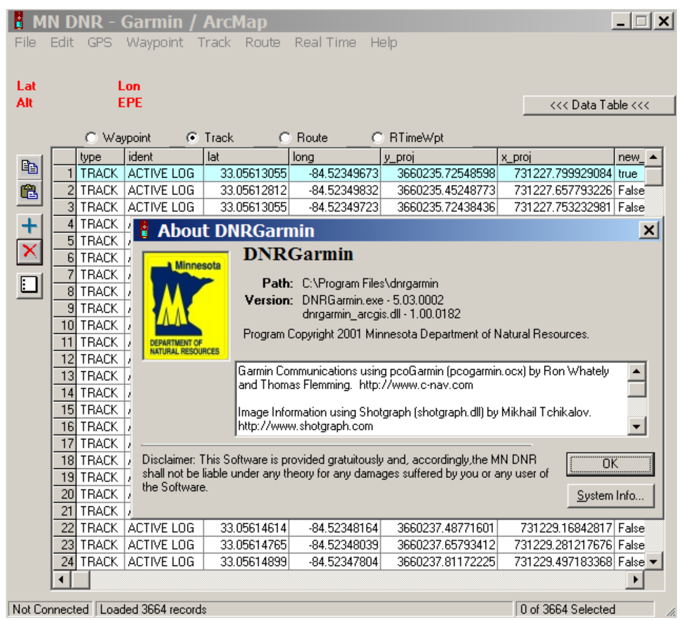


Remove the SD storage card from the control head, insert into an SD/MMC card reader, and transfer a copy of these images to the **raw_sonar_images** folder. It is good practice to maintain a copy (backup) of raw images (and all other raw survey data) in a separate location to safeguard against data loss.

Note: Each sonar image is identified by the waypoint number created when the image was captured. Consecutive images should contain an area of overlap.

Transferring Survey Route Coordinates (Track points)

During the survey, a "breadcrumb" track file consisting of geographic coordinates for the boat route (specifically the position of the onboard GPS device) was recorded at 3-sec intervals. This track information is critical in our approach to geoprocessing sonar imagery. A Garmin GPSMap76 receiver was used to collect the track data and the free DNRGarmin software developed by the Minnesota Department of Natural Resources was used to download the track data. Depending on the GPS used, methods to download will differ from those outlined below. Suffice it to say, the track point data must be downloaded and formatted in a way that it can be opened and viewed spatially in ArcMap.



Steps:

- Connect the GPS device to a computer.
- Start the MNDNR software.
- Select <Track> then <Download> option to import the track points.
- Next, under the <File> tab, select <Save to> and <File> as a Dbase IV (*dbf).

Alternatively:

- The MNDNRGarmin program allows you to specify a projection for data files. Under <File> select <Set Projection>, select the Projection tab, and select ArcMap. Near the bottom of the window select <Load PRJ>and navigate to the projected coordinate system appropriate to your data set (for this demo, UTM-NAD 1983-UTM Zone 16N).
- If ArcMap is open, *and* the project Data Frame Properties- Coordinate system is undefined (No projection), you can Select <File> <Save to> <ArcMap> <Shapefile Layer>, and save the file using an appropriate name into the folder you have created for raw sonar data. The projected shapefile will appear in the ArcMap project. The file can also be saved under <File> <Save to> <File> type= ArcView shapefile projected, and then loaded using the Add data function. ***Make sure to Define the Output Shape as a Point feature***

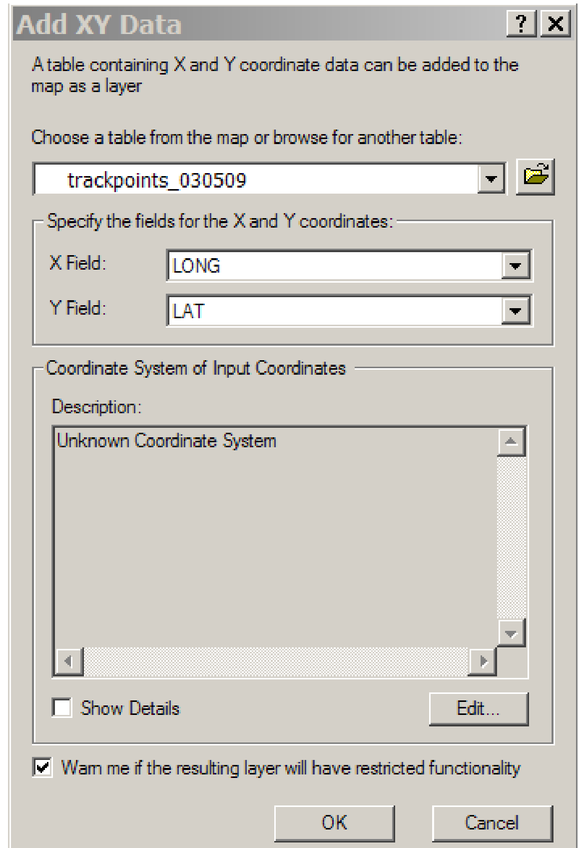
Preparing Coordinate Data

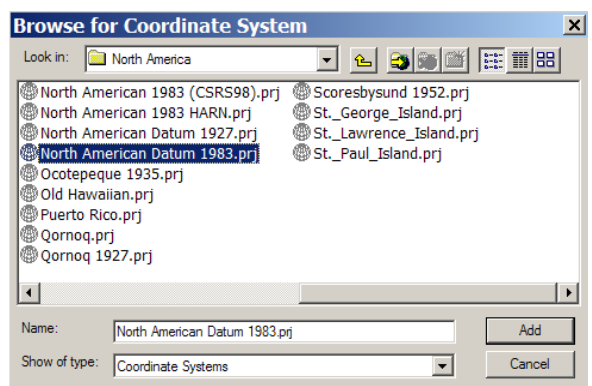
Adding Data to ArcMap

The track point and waypoint data are now ready to be added to a map project for review and editing.

Steps:

- Open the project named **sonar_demo/ mxd/sonar_processingtools_9x.mxd** in ArcMap 9.x or **sonar_demo/ mxd/sonar_processingtools_10_0.mxd** in ArcMap 10.0.
- If working with a .dbf table for track points: Under the <Tools> tab select <Add XY Data>, browse to the sonar survey data folder and select the appropriate track point file (**trackpoints_030509.dbf**). This command can be found under <File><Add Data> in ArcMap 10.0.
- Add, and specify the <X Field> as Long, and <Y Field> as Lat. Note that the coordinate system is unknown. Select <Edit>, and for this particular data set select from the predefined coordinate systems- <Geographic Coordinate Systems> - <North America-- North American Datum 1983.prj>.
- Repeat this process for the waypoints file (**waypoints_030509.dbf**) specifying the <X Field> as DDX, and <Y Field> as DDY.
- Create a folder named **shapes** in the **sonar_demo** project directory. Right click on the trackpoints Event layer and select <Data> <Export Data>. Navigate to the created **shapes** folder, and save under an appropriate name, eg. **trackpoints_030509**. Repeat for the waypoints Event layer.
- If you already saved the track point file as a projected shapefile, there is no need to execute the steps above.

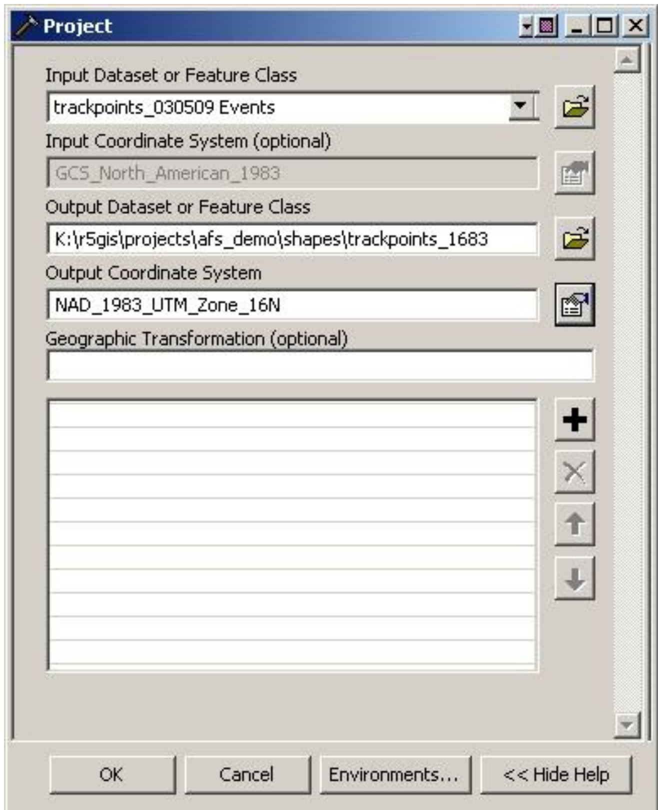




Projecting Data

For the processing tools to work the track point and waypoint files **must be projected** from geographic coordinates (i.e. latitude and longitude) into a rectangular coordinate system (e.g. Universal Transverse Mercator (UTM). If necessary, project the track point shapefile in UTM coordinates as follows:

<u>Steps:</u>



- Open the <ArcToolbox>.
- Under <Data Management Tools> select <Projections and Transformations>, then <Feature>, and <Project>.
- Select the trackpoint shapefile (**trackpoints_030509.shp**) as the input dataset using the folder browse tool.
- The <Input Coordinate System> is predefined <GSC_North_ American_1983> – accept this.
- Use the folder browse tool to specify the output data set location and name. Save it in the **sonar_demo/shapes** folder. Give the projected track point file a meaningful name, for example **trackpoints_raw.shp**.
- For this data set, define the <Output Coordinate System> as <Projected Coordinate Systems> <UTM> <NAD_1983 UTM_Zone_16N>. Do not add the new shapefile to the project.
- Repeat this process for **waypoints_030509.shp** shapefile.
- Once the waypoint and track point layers have been projected, remove the XY event layers **waypoints_030509.dbf** and **trackpoints_030509.dbf** from the theme list, and add the **trackpoints_raw.shp** and **waypoints_raw.shp** from the shapes folder to the project.

Inspecting and Cleaning Up Data

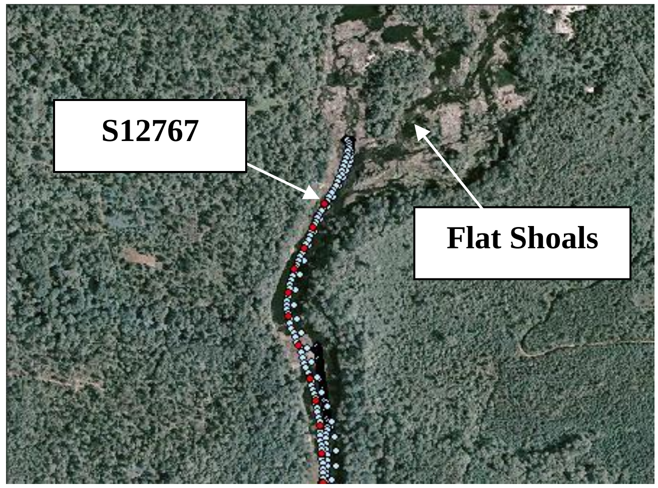
The data are ready to be inspected and cleaned. Three primary objectives are addressed in concert during this phase:

Objective 1: Edit waypoint and track point shapefiles- remove all waypoints and track points that will not be used during geoprocessing of survey segments.

Objective 2: Inspect coordinate data position- check that coordinates are properly positioned on the map. Errant points can be manually corrected/adjusted.

Objective 3: Identify processing segments (Bookkeeping)- identify and generate a list of the starting and ending waypoint numbers for each geoprocessing segment.

Objective 1- Edit Coordinate Shapefiles



To facilitate editing and inspection of coordinate data we typically load digital aerial imagery, such as NAIP imagery.

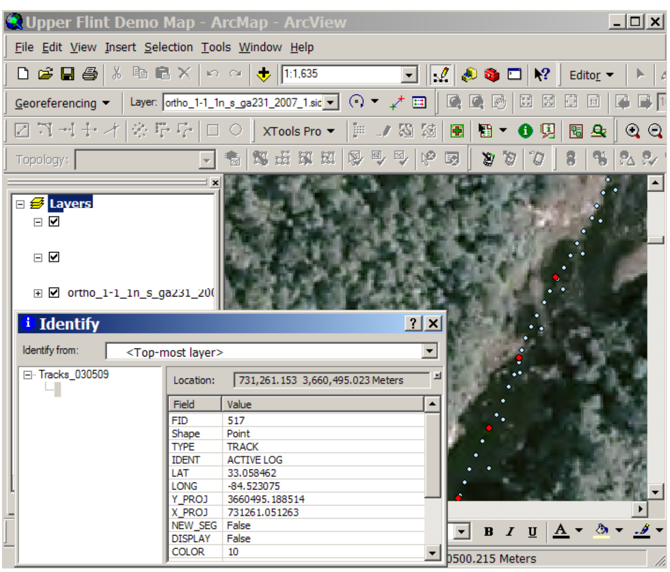
In this example, the starting point of the survey was at the base of Flat Shoals and the first waypoint and image captured was number S12767. However, we began logging track points prior to reaching the base of Flats Shoals and beginning the survey. Here, and throughout our project area, we must remove the track points that do not represent the boat's navigational path during the sonar survey. This is critical, as only the track points between consecutive waypoints are used to georeference sonar images.

Steps:

Make sure **trackpoints_raw.shp** is loaded. To create a new shapefile for editing purposes, right click on the layer and select <Export Data>, choose <Export> <All features> and save the file as **sonar_demo/shapes/trackpoints _edited.shp**. Add it to the view and use it for all track point editing, keeping the "raw" file in reserve.

Note: The first image captured in a sonar survey is not usually geoprocessed. However, if you want to try and process this image, be sure to keep the appropriate number of track points upstream of the first waypoint. This number will vary with boat speed and track point interval; in this example ~ 5-6 track points exist between waypoints. We chose to retain the six track points logged before the first waypoint.

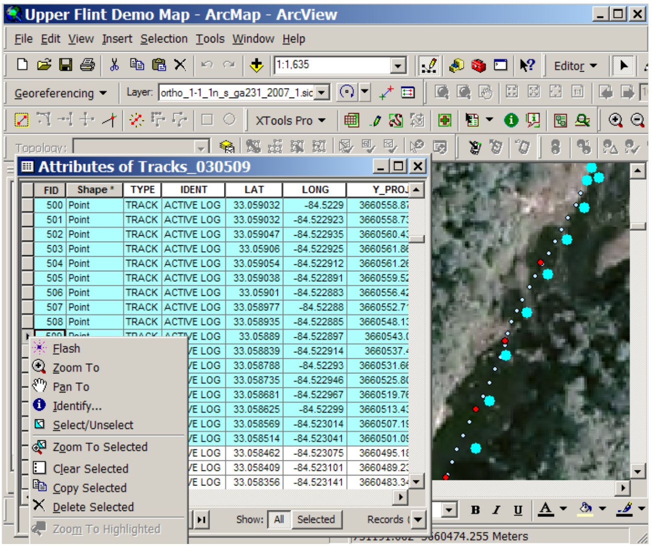
Option 1- Remove Track Points Manually



Remove Manually:

- From the <Editor> toolbar select <Start editing>.
- Select the track point shapefile (e.g. **trackpoints_edited.shp**) as the target.
- Use the <Arrow> tool select the points and delete.
- From the <Editor> toolbar select <Stop editing>, and save edits.

Option 2- Remove Track Points from the Attribute Table



Remove from Table:

- Identify the FID of the 1st track point in the series to retain upstream of waypoint S12767 (in this example, FID= 517).
- Open an Edit session and specify **trackpoints_edited.shp**.
- Open the attribute table for **trackpoints_edited.shp**.
- Select (highlight) FID points 0-516.
- Right-click and choose <Delete selected> from the options.
- From the <Editor> toolbar select <Stop editing>, and save edits.
- *Alternatively*, use the SQL Select by Attributes dialog creator (under Options) to define the trackpoints to remove.

What remains is a clean, edited version of the tracks at the beginning of our first processing segment. These same methods may be used to “clean up” (edit) the track and waypoint files throughout the data inspection process. Bear in mind that we do have a copy of the original, unedited track file saved as both a .txt file and as a shapefile (**trackpoints_raw.shp**) if needed.

Objective 2- Inspect Coordinate Position

During single pass surveys we attempt to maintain position in the middle of the stream channel. Thus we should find our track and waypoints in mid-channel if good GPS accuracy was achieved during the survey. Minor deviations are to be expected as a result of survey vessel drift and typical GPS position variability.

We cannot overstate the importance of reliable GPS data for use in sonar processing, as these coordinates will ultimately determine the geographical position of the sonar image maps. Factors such as heavy canopy cover, channel entrenchment, and mountainous terrain can impair GPS reception and accuracy. If GPS accuracy in the field is suspect, we suggest conducting an exploratory investigation before investing in a large-scale sonar survey.

To check for errant track points, scroll downstream through the entire survey route and look for problems. Also look for missing points or unusual gaps in the coordinate sets that might have occurred as a result of temporary loss of GPS signal. Whenever problems areas are located, it is a good idea to maintain a log of the affected waypoints for reference. As you work through inspection and editing, each problem area can be addressed and checked off the list. Areas that cannot be “repaired” may serve as breakpoints for sonar processing segments.

Below is an example of a reach where the coordinates appear to have drifted toward the right bank (assuming the NAIP image is itself correctly positioned in this area). If you wish to better fit the images to a base layer, like the NAIP photography, this can be accomplished by manually shifting the track and waypoint files to better fit the apparent channel.

Note: We do not recommend manually altering the position of sonar survey GPS data. If this type of data alteration is performed, it should be documented and reported with any and all end products.

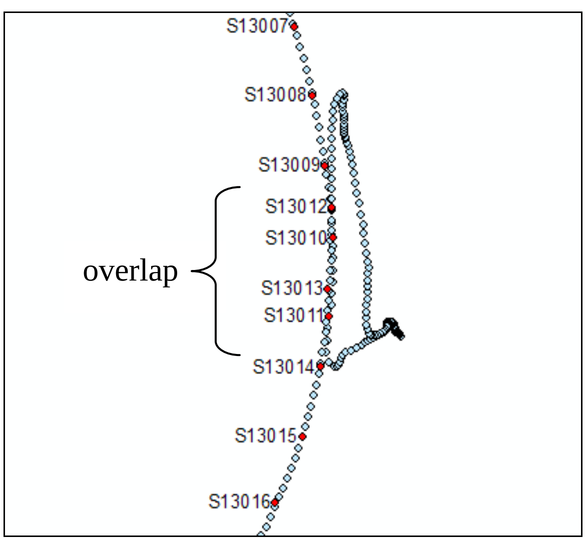
<u>Steps</u>:

Load the **waypoints_raw.shp** file. Right click on the layer and select <Export Data>, choose <Export> <All features> and save the file as **sonar_demo/shapes/waypoints _edited.shp**. Add it to the view and use it to edit the waypoints, maintaining the "raw" file in the project.

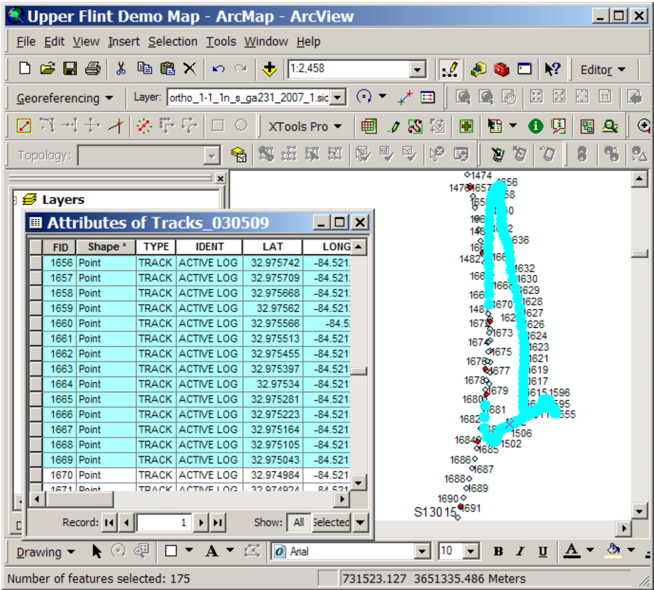
- From the <Editor> toolbar initiate an editing session.
- Select the **waypoints_edited.shp** as the <Target>.
- Manually select and reposition each point (new position shown in yellow here).
- The same procedure can be used to reposition the errant track points in **trackpoints_edited.shp**, though it may be more efficient to select and shift multiple points at once.

Objective 3- Identify Processing Segments

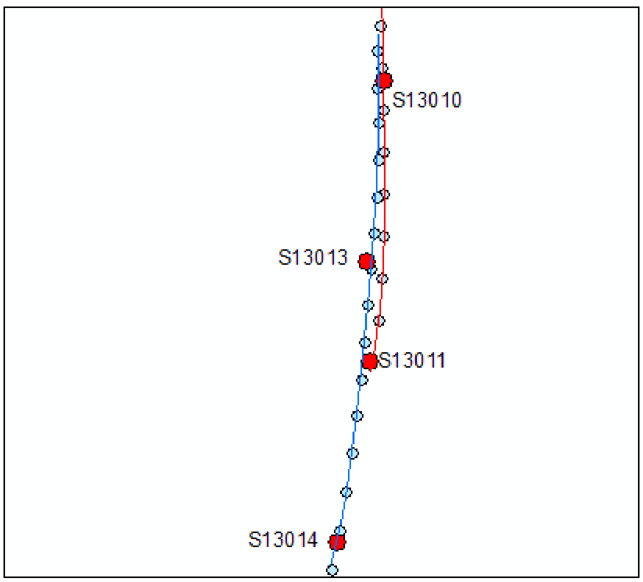
To automate image processing, it is mandatory to identify blocks of consecutive images that can be processed as a group (i.e. a geoprocessing segment). Stops made during the survey or changes in range setting provide natural breaks that define segments. To help identify these natural breaks it is good practice to record breaks and range changes during the sonar survey. We made a lunch stop after waypoint S13011. Upon returning to the survey, we headed upriver a short distance to ensure that no gaps in sonar coverage would exist in the data set. Note that S13012, our first waypoint logged upon restarting the survey, is located upstream of S13011.



To address objective 3, waypoints can either be removed or retained. In this example, waypoint S12312 was removed, leaving only a small area of overlap between the two adjacent segments. Waypoint S13011 will be the endpoint of one processing segment, and S13013 the first waypoint in the next segment.



Using the methods described earlier, we identified the unnecessary track points, and quickly removed them in an editing session.



What remains are only those coordinate necessary to define the geographic location and spline of the sonar images that will be processed for each segment.

Illustrated here is the spline of the upstream segment that terminates at S13011 in red; and the next segment defined by the track points we chose to retain in blue.

Organizing Data into Processing Segments

Once the entire data set has been cleaned, the waypoint and track point files must be subset into the processing segments identified during inspection (i.e. breaks in navigation, change in range settings, etc.).

<u>Steps:</u>

- Open the waypoints attribute table.
- From the table select (highlight) the records that define the segment.
- Right click on layer and select <Export Data>, choose <Export> <Selected features>.
- Select the <Browse to Folder> icon and save in the **sonar_demo/shapes** folder, providing a name that helps to identify it during processing (e.g. **waypoints_seg_a1.shp**).
- Repeat this process for the track point shapefile. Remember to include a number of track points (6) before (upstream) and after (downstream) the first and last waypoints in each processing segment. **Note:** Do NOT export data using the attribute table's <Options> tab.

Track Line Processing

Generating the Track Line

For this demonstration we selected a reach that includes images S12960-S12990. The next step is to create a line representing the boat path for each processing segment using the track file.

Steps:

Load the edited track point shapefile created for this segment, **trackpoints_seg_a1.shp**.

- Open the attribute table of the track point layer, select from <Options> - <Add field>, name the field "line", and set <Type> as <Short Integer>. Close the attribute table.
- Open the ET GeoWizards Tool, select the <Convert> tab, select <Point to Polyline>, and click <Go>.
- Select point layer **trackpoints_seg_a1.shp** (i.e. the tracks layer).
- Create a name for the output feature class (e.g. **trackline_seg_a1.shp**), and save to the project **shapes** folder.
- Specify the <ID field> as the "line" field created earlier, then <Finish>. The created layer is added to the map. Inspect this line - it should originate at the first track point in the segment and end at the last, extending through all of the track points.

Smoothing the Track Line

To remove irregularities in the resulting line from this "connect-the-dots" approach, smooth the line using tools available in ET GeoWizards.

Steps:

- Open ET GeoWizards, select the <Polyline> tab, select <Smooth>, and click <Go>.
- Specify <Select polyline layer:> as **trackline_seg_a1.shp**.
- Specify <Output feature class:> as **trackline_seg_a1_smooth.shp**. Click <Next>.
- Specify <Select smooth method> as <Bezier curve> and click <Next>.
- Set <Smoothness> = 5, check the box for <Densify before smoothing>, and set <Tolerance> = 2 meters (do not check <Generalize after smoothing>). Click <Finish>.

Inspect the smoothed line. By smoothing the track line the image processing results are ultimately improved. Remove the older track layers from the project, leaving only the smoothed track line layer and the waypoint layer for the segment.

Creating a Segmented and Attributed Track Line

In this step, use the waypoint layer to split the smoothed track line layer into individual segments. Each line segment represents not only the distance between consecutive waypoints, but also the length of the non-overlapping portion of sonar imagery captured for this part of the stream- a relationship we exploit during georeferencing to generate a control point network for each clipped sonar image. (The control point network is later defined in *Generating the Image Control Network*.) It is important to understand that the goal in this step is to generate a series of line segments that can be matched to adjacent waypoints by way of the FID field in the attribute table for each layer.

Sort the Waypoint File

For this process to succeed, the waypoint file must be sorted such that consecutive waypoints appear in the attribute table in the order that defines the sequential arrangement on the map. In most cases, the entries will already be sorted by waypoint number.

Steps:

- Open ET GeoWizards, select the <Basic> tab, select <Sort shapes>, click <Go>
- Specify <Select layer:> **waypoints_seg_a1.shp**.
- Specify <Output feature class:> **waypoints_seg_a1_sort.shp**.
- Specify <Select sort fields:> **WAYPOINT**.
- Specify <Select sort order:> Ascending, click <Finish>.

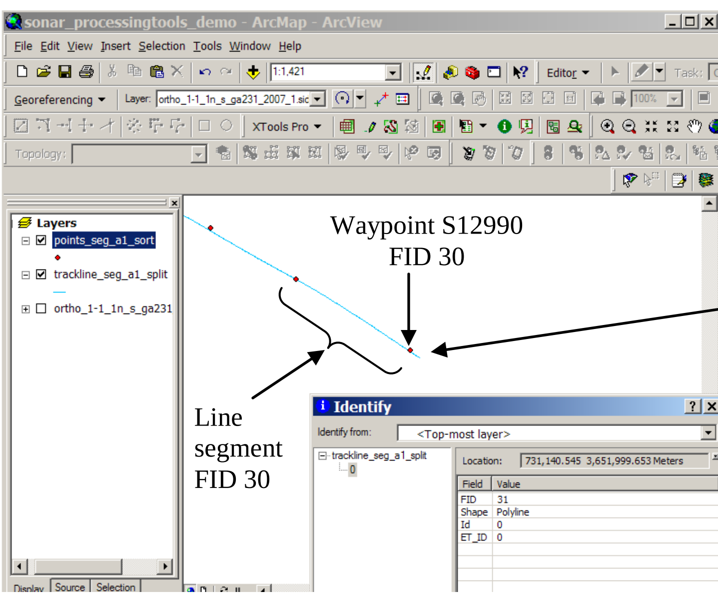
Note: Select Ascending in this case because each consecutive, downstream waypoint is a proceeding higher number.

Split the Track Line with Waypoints

Steps:

- Open ET GeoWizards, select the <Polyline> tab, select <Split Polyline With Layer>, click <Go>.
- Specify <Select polyline layer:> as **trackline_seg_a1_smooth.shp**.
- Specify <Select split layer> as **waypoints_seg_a1_sort.shp**.
- Specify <Output feature class> as **trackline_seg_a1_split.shp**, click <Next>.
- Specify <Assign search tolerance> as 10 meters, and click <Finish>.

Inspect this line file by opening the attribute table. If processed correctly, there should be one more line segments in the file than waypoints used to split the line. In this example, there are 36 records (segments) in the split line file; 35 waypoints were used to split the feature.



Click on the last waypoint in the segment- its FID is 34. Click on the adjacent (upstream) line segment- its FID is also 34 (the correct result).

The extra, short line segment is shown here at the end of the processing segment. Using Identify, we find that its FID is 35 (the last segment in a series of 35 entries, 0 through 34).

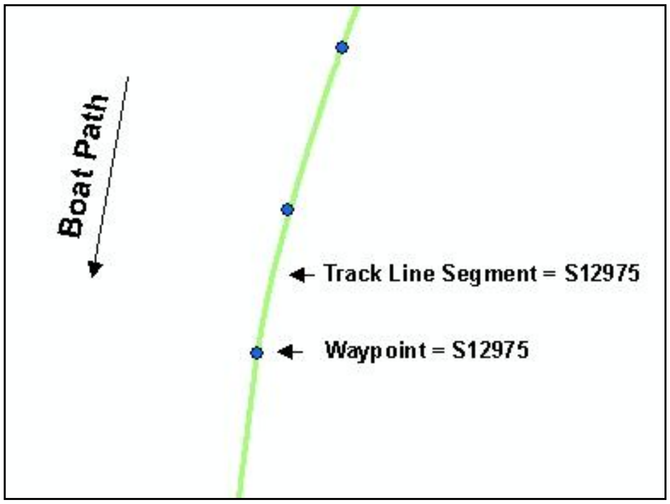
With the <Identify> tool, inspect both the line and waypoint layers to ensure that each segment has been assigned an FID number that matches the FID of the adjacent, downstream waypoint. Remove the older, unnecessary line and point layers from the project leaving only the sorted waypoint layer and the split track line layer.

Note: <u>The free version of ET Geowizards limits the number of points that may be used to split a line (100 max)</u>. A processing segment containing >100 waypoints will have to be subset accordingly. **Alternatively,** see the Appendix (page 42) for a description of the <u>Split Line Tool</u> included in the new sonar processing toolkit that can split a line with an unlimited number of points.

Move Waypoint Attributes to the Segmented Line File (Join)

The last step in Track Line Processing is to join the two layers using the common field (FID). In doing so we add the waypoint coordinate value to the attribute table of the segmented line.

<u>Steps:</u>



- Right click on the split track line layer, select from <Joins and Relates- Join>.
- Select the <Join attributes> from the drop down menu.
- Select FID as the field in the layer to base the join on.
- Select the **points_seg_a1_sort.shp** layer as the table to join.
- Select FID as the field to base the join on and click <OK>.
- Use the Identify tool to inspect the attributes of the line segment layer to ensure the join was successful. The coordinates for the associated waypoint should be included in the attribute table for the line segment.
- To make the join permanent, right click on the split track line layer, select <Data> <Export Data>, and create a new name for this layer (eg. **trackline_seg_a1_comp.shp**, as in complete).
- Remove all layers from the project.

Notes: It is imperative that the waypoint coordinates are applied to the line segment that precedes the waypoint otherwise the geoprocessed image will not be positioned correctly.

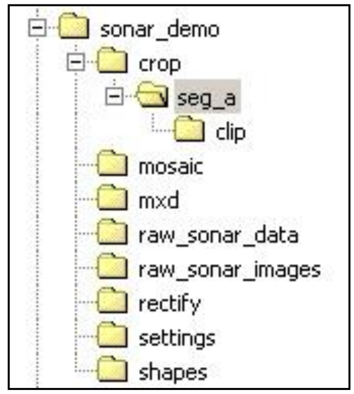
In this demonstration, track line processing was conducted on a short survey segment that included only 35 consecutive waypoints. During processing of large sonar survey data sets it is possible to execute track line processing on much longer stream segments that remain undivided by natural breaks (i.e. survey stops), thereby reducing the overall time spent on this step. In other words- it is best to minimize natural breaks during extensive sonar surveys.

Image Processing

During this phase, the images collected in the field and the segmented track file created in the previous steps will be processed into geographic space. See Appendix for a list of enhancements made to the processing toolkit in November 2010.

Creating Requisite Processing Folders

Steps:



- To set the stage for image processing, expand the demo directory for the project as follows: create folders named **crop, rectify** and **mosaic**.
- Within the **crop** folder generate subfolders labeled by image processing segment. In this example there is only 1 processing segment, so a single subfolder called **seg_a** was created. This subfolder will store the cropped images that have had the collar removed.
- Within each crop segment subfolder generate a folder named **clip** (this folder must always be named **clip**). This folder will store the clipped sonar images for the segment.

There are 6 discrete steps to Image Processing: Image Cropping, Image Clipping, Generating the Image Control Network, Image Rectification, Mosaic File Preparation, and Mosaic Generation.

Image Cropping

In this step the unnecessary collar (border) and information column appearing in each raw sonar image is removed**.**

Irfanview Setup: Irfanview is used for two separate steps in Image Processing (Image Cropping and Image Clipping). Prior to any image processsing, Irfanview must be set up as follows (these modifications only need to be completed one time):

Irfanview Setup Steps:

- Open Irfanview and select <File>, then <Batch Conversion>.
- Switch the <Output format> to <PGM- Portable Graymap>, click the <Options> tab
- Under the PNG heading: **unselect** <Save Transparent Color>
- Under PBM/PGM/PPM heading: **select** <Ascii encoding>.

Image Cropping Steps:

- Open Irfanview.
- Under <File>, select <Batch Conversion/Rename>.
- Under <Batch conversion settings>, select <Output format> = JPG/JPEG Format or <Output format> = PNG – Portable Network Graphics. The JPG format is lossy, whereas the PNG format is lossless. We recommend the use of the lossless PNG image format.
- Click <Advanced>, select the <Crop> checkbox, then click <Load settings> at the bottom of the form, navigate to and select the file: **sonar_demo/settings/cropsettings_900.ini** (use if

processing 900 series imagery: 981c, 997c, 998c). Click OK. ** If processing 1197c imagery select the crop settings file **cropsettings_1197.ini**.

- Under <Output directory for result files>: browse to and select the **sonar_demo/crop/seg_a** folder.
- In <Look in>: navigate to the **raw_sonar_images** folder and click <Add all>.
- Click <Start Batch>. When completed, the crop folder should be populated with the cropped images for this processing segment.

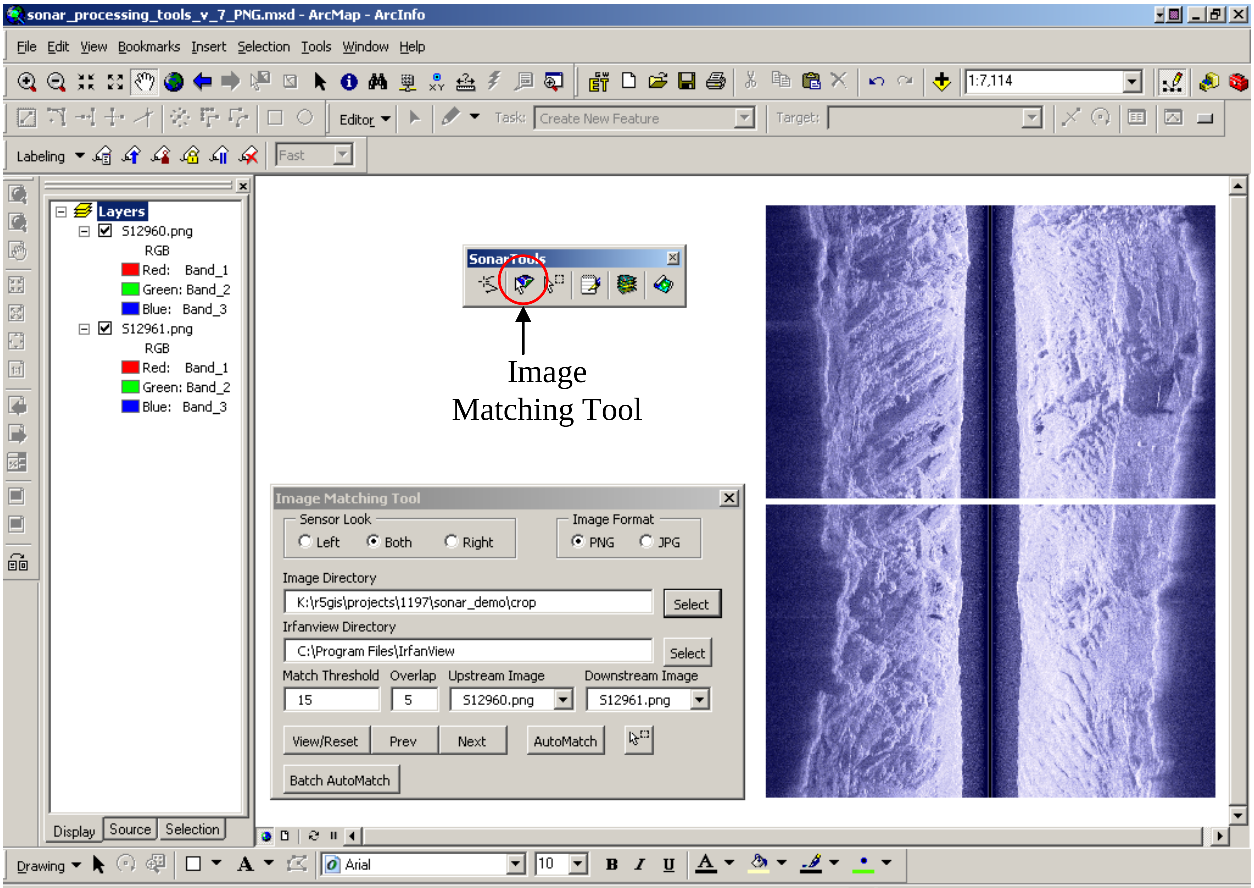
Image Clipping (Overlap identification)

In this step the small, overlapping (duplicated) portion of the next, consecutive downstream image sonar image is excised from all images within the cropped set.

Note: The <Output format> must be set to <PGM- Portable Graymap> during this stage in processing for the tool to run properly. See Irfanview Setup Steps above.

- Close the Batch Conversion window and Irfanview.
- Return to, or open the ArcMap project, and activate the Image Matching Tool.
- Specify the <Image Format> of the images either PNG or JPG. This is the format of the images cropped in the previous step.
- Specify <Sensor Look>, which is the side beam direction set on the sensor/transducer during the survey. Choose <Left> - if the sensor was set to look to the left side (PORT) of the vessel only; Choose <Right> - if the sensor was set to look to the right side (STARBOARD) only; Choose <Both> (default) - if the sensor was set to look to the left side (PORT) and right side (STARBOARD) of the vessel. Demo data was collected on both sides of the vessel.
- To specify the <Image Directory>, navigate to the folder containing the cropped jpeg images - **sonar_demo/crop/seg_a.** The first two cropped sonar images should appear in the project view. The <Upstream Image> in this example is S12960 (bottom of view), and the <Downstream Image> is S12961 (top of view). **Note:** Beware of "drilling-down" too far into the directory when selecting the folder that contains the images (or data) of interest. Simply click the folder name and open- do not click down into the folder itself, or images will not load and will seem to have disappeared.
- Specify the <Irfanview Directory>, which is the location of the **i_view32.exe** file. If you installed Irfanview on the C: drive using the default settings, the default shown on the tool is correct. If you installed Irfanview elsewhere you will need to navigate to the folder containing **i_view32.exe**.
- Specify the <Match Threshold>, which is the sensitivity of the image matching algorithm. The default is 15, which works well for most images. There may be times when your imagery may be pixilated (conflicting sensor, debris in the water, etc) or have a different tone from image to image (unknown cause). In these instances, the threshold sensitivity can be increased stepwise (e.g. increments of 20) until your images return a match. This has been tested with a <Match Threshold> as high as 200 with good results.
- Specify an <Overlap> of 5 (pixels).

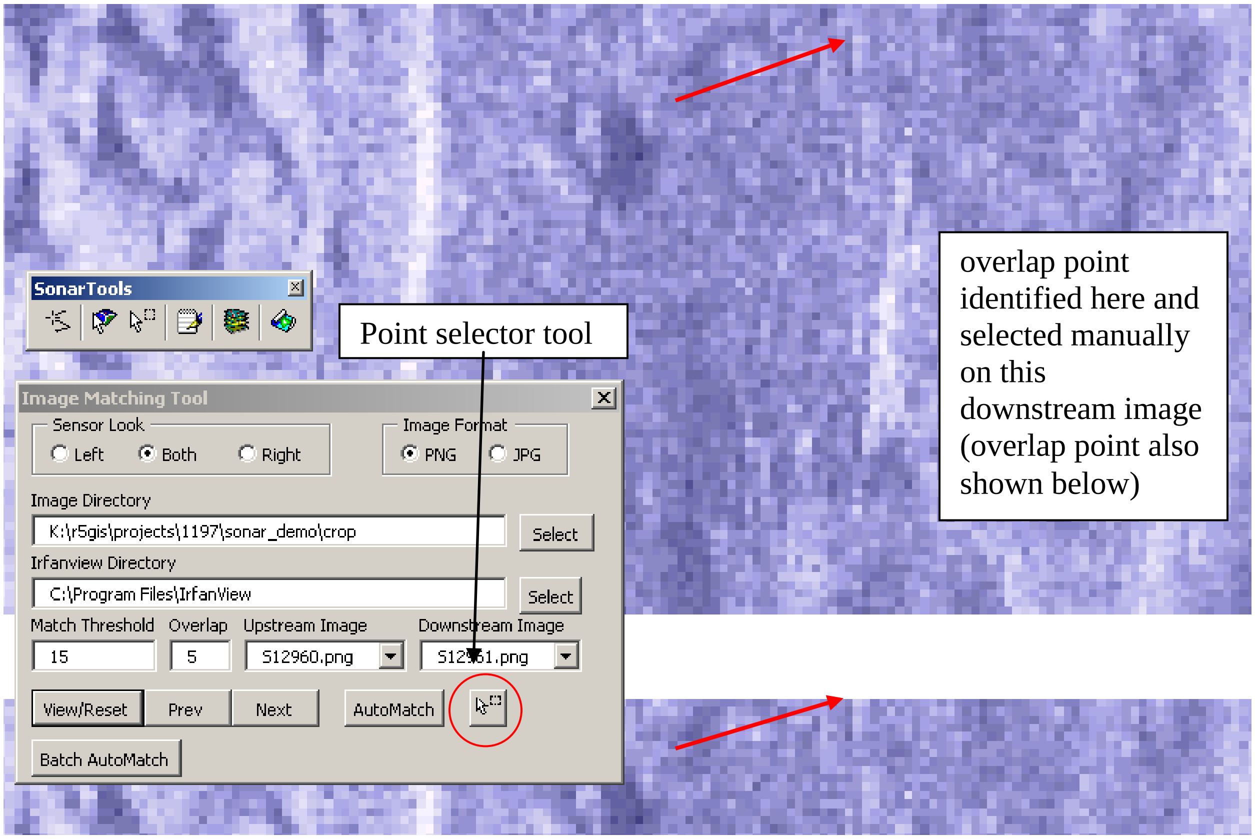
  Notes: If the threshold is increased beyond the default (15), review the images and ensure the match point returned is correct. This can be done by zooming to an overlapping area (below the match line) and toggling the top most image in the table of contents on and off. If the matching algorithm worked, there should be no discernable shift or change in the overlapping pixels. Using the <Batch AutoMatch> function is **NOT** recommended when the <Match Threshold> is increased beyond the default (15).



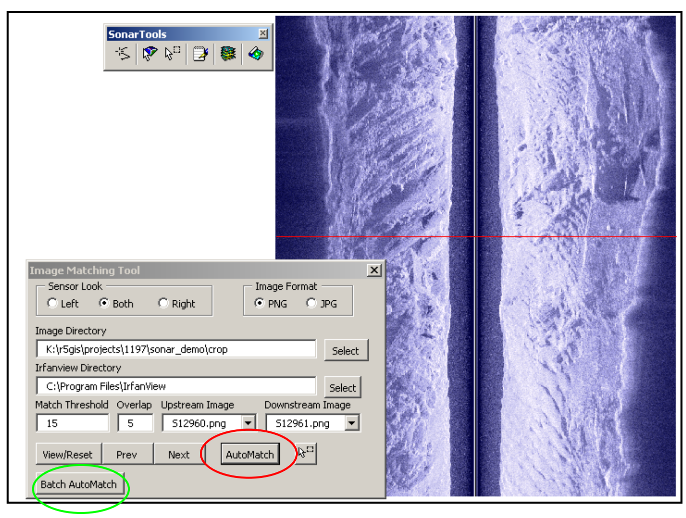
To match and clip the downstream (top) image, you can either 1) manually select the image overlap point using the selector tool; 2) use <AutoMatch> to find the overlap point; or 3) use <Batch Automatch> to auto match all images in the selected image directory.

1) Manual Matching

- Identify and zoom into the area of image overlap using the ArcView magnifying glass tool. Zooming in helps in selecting the exact overlap point at the pixel level.
- Click on the lower, right hand corner icon (Point selector tool) of the Image Matching Tool.
- Locate and click on the row of pixels in the top image where overlap begins. After the overlap row is selected, the program visually splices the two images.
- If the results of the match are unsatisfactory, select <View/Reset> and try again. If satisfied, hit the <Next> button and advance to the next pair of images.
- See ***Handling Non-Overlapping Images*** below if images do not overlap.
- Continue through all images in the processing segment. The clipped images are placed in the **sonar_demo/crop/seg_a/clip** folder.



2) AutoMatch (circled in red)



- Simply click the <AutoMatch> button, and the <Upstream Image> and <Downstream Image> splice will be displayed on the map with a red line highlighting the match/splice point.

If the results are unsatisfactory (in rare cases the program does not select the correct row of pixels), click <View/Reset>, and manually select the match point.

If no overlap exists an alert message will pop up prompting the manual selection of an overlap point. See <u>*Handling Non-Overlapping Images*</u> below.

Note: Images may not match if <u>too much</u> overlap exists between consecutive images. Care must be taken during the survey to minimize, yet maintain a small portion of image overlap for the auto tool to function properly. See Appendix for how to obtain consecutive, overlapping snapshot images.

3) Batch AutoMatch (see Automatch figure above –Batch Automatch button is circled in green

- <Batch Automatch> will automatically match all files in the selected directory using the values specified for sensor look, match threshold, and overlap. Resulting clipped files will be placed in the **sonar_demo/crop/seg_a/clip** directory along with a text file (**noclip.txt**) which lists any images that were not matched during the process.

Note: Review the images listed in the noclip.txt file to ensure that overlap points were identified in all images. In very rare cases, the algorithm may fail to identify true overlap points that actually exist between consecutive images. Reviewing an unmatched image and the adjacent upstream image is easily done by recalling the images for display in the Upstream image and Downstream image boxes of the Image Matching Tool. If there is no match, follow the instructions for <u>*Handling Non-Overlapping Images*</u> below.

*****Use of the Batch AutoMatch tool is not recommended when the <Match Threshold> is increased beyond the default (15).**

<u>*Handling Non-Overlapping Images*</u>

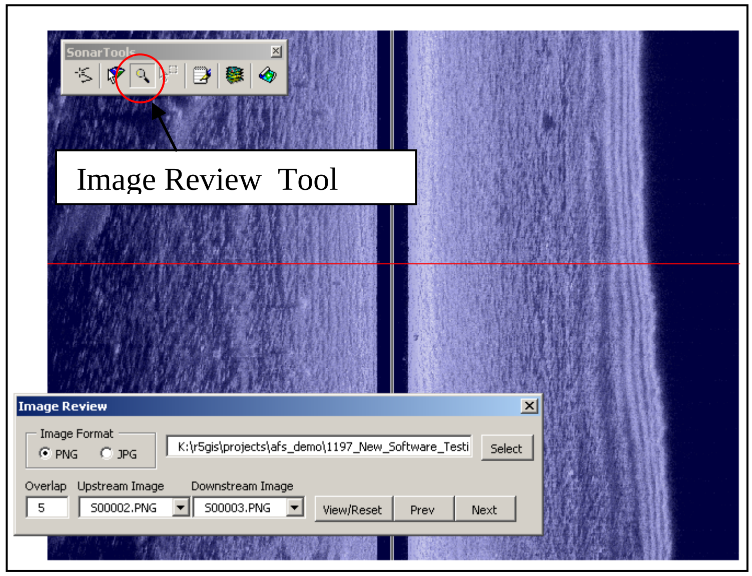
During the clipping process, a pair of non-overlapping images may be encountered. If using the AutoMatch tool and no overlap (or too much overlap) exists, an alert message will pop up prompting the manual selection of an overlap point. If using the Batch Automatch tool, review the file **sonar_demo/crop/seg_a/clip/noclip.txt** to identify images that were not successfully matched. Closely inspect unmatched images to make certain there is no overlap point (i.e. confirm that the failure to match is not attributable to a mistake by the matching program). A lack of overlap is normally the result of a failure to capture consecutive, overlapping images during the sonar survey. In many cases the image gap is small, with negligible data loss. If non-overlapping images are processed as is, they will be mated during rectification, thereby closing the gap. If such a result is intolerable, another option is to segregate and process the images in separate segments to preserve the gap.

In other cases, two images may not overlap if different range settings were applied to each, thereby thwarting an attempt to identify a match point with <AutoMatch>. As mentioned earlier, these images must be segregated into separate image processing segments.

If two images do not overlap the downstream (upper) image will remain unclipped. <u>It is critical to keep a list of unclipped downstream images</u> in the processing segment, regardless of whether Manual or AutoMatch methods are used. In this demo data set, the first pair of images that do not match up are **S12965** and **S12966**. Since the downstream image (**S12966**) will not be clipped, record this image number on the processing segment list. <u>Also keep in mind that the *first image in a set* (e.g. **S12960**) will not be clipped and should be on the list.</u>

When image clipping is complete, navigate to the **sonar_demo/crop/seg_a/clip** folder. Note that images **S12960**, **S12966**, **S12987**, and **S12990** are missing. Navigate to the **sonar_demo/crop/seg_a** folder, select these four images, and copy them to the **sonar_demo/crop/seg_a/clip** folder. **Note:** <u>**It is absolutely essential to transfer all of the unclipped images in a segment to the clip folder before proceeding to the next step.**</u> If unclipped images are not transferred, and you proceed through control point generation, the computer will hang up during rectification- a sure sign that something has failed.

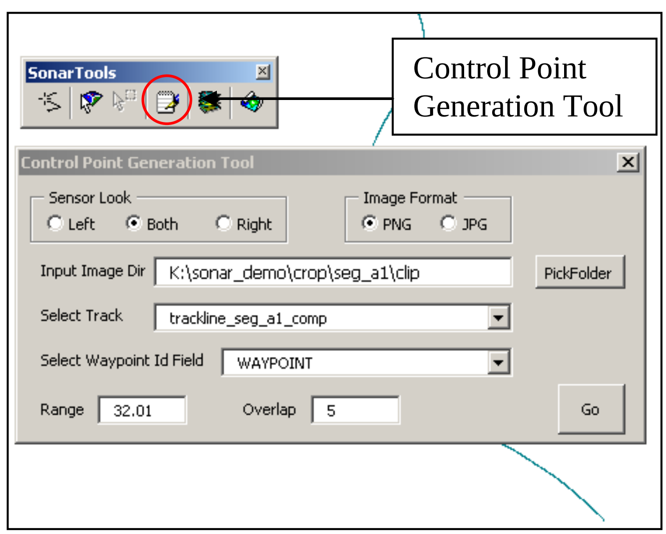
Reviewing Clipped Images



If you used the <Batch AutoMatch> function it is a good idea to review the images after you have completed Image Clipping (this includes identifying and accounting for unmatched images).

- Activate the <Image Review Tool>
- Specify the <Image Format> of the images either PNG or JPG. This is the format of the images cropped in the previous step
- To specify the <Image Directory>, navigate to the folder containing the clipped images - **sonar_demo/crop/seg_a/clip.** The first two clipped sonar images should appear in the project view. The <Upstream Image> in this example is S12960 (bottom of view), and the <Downstream Image> is S12961 (top of view). **Note**: Be sure select the **sonar_demo/crop/seg_a/clip** folder. Simply click the folder name and open- do not click down into the folder itself.
- Specify the <Overlap> this should be the same value entered during the image clipping process. The default is 5.
- Use the <Prev> and <Next> buttons to review the clipped images.
- If you find images that don't match (aside from those previously identified (e.g. **S12965** and **S12966))** try to match them manually. If there is no match follow instructions for *Handling Non-Overlapping Images* above. Keep in mind that unmatched images identified previously do not need to be revisited .

Generating the Image Control Network



In this step an image-to-ground control point network for each clipped image is generated. The image control point network is a grid of coordinates and measurements that provides the spatial address (or geographic template) of each clipped image. The control point network is required for image rectification.

<u>Steps:</u>

- Return to the map project and reload the **trackline_seg_a1_comp.shp** layer.
- Select the <Control Point Generation tool> (the Text pad and pen icon).
- Specify <Sensor Look>, which is the side beam direction set on the sensor/transducer during the survey. Choose <Left> - if the sensor was set to look to the left side (PORT) of the

vessel only; Choose <Right> - if the sensor was set to look to the right side (STARBOARD) of the vessel only; Choose <Both> (default) - if the sensor was set to look to the left side (PORT) and right side (STARBOARD) of the vessel. Demo data was collected on both sides of the vessel.

- Specify the<Image Format> of the images either PNG or JPG. This is the image format of the clipped images.
- Specify <Input Image Dir> as **sonar_demo/crop/seg_a/clip** using the <PickFolder> browser.
- Specify <Select Track> as **trackline_seg_a1_comp**.shp layer.
- Specify <Select Waypoint Id Field> as **WAYPOINT**.
- Specify <Range> as 32.01 **meters** (this is the range set during image capture for this data set). **Note: When processing your own survey data be sure to specify range units that match your coordinate system (i.e. if you are using State Plane, Units: Feet – then the range should be specified in feet – not meters.) Here we used UTM; Meters.**
- Specify <Overlap> as 5 (the same pixel row overlap specified during image clipping).
- Click <Go>.

Note: <u>Only one range setting per segment can be specified during control point generation</u>, which is why range setting changes during the survey create mandatory break points for new image processing segments. Do not attempt to generate control points for 2 sets of images captured using different range settings. Separate these data sets into separate segments and folders!

When complete, a text file with the image control point network values will be added to the **sonar_demo/crop/seg_a/clip** folder for each image. Each image must have a control point file to proceed. Navigate to the clip folder to check for control point files generated for each image.

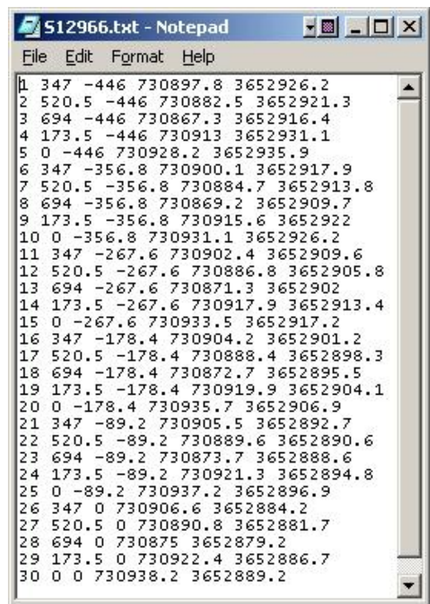
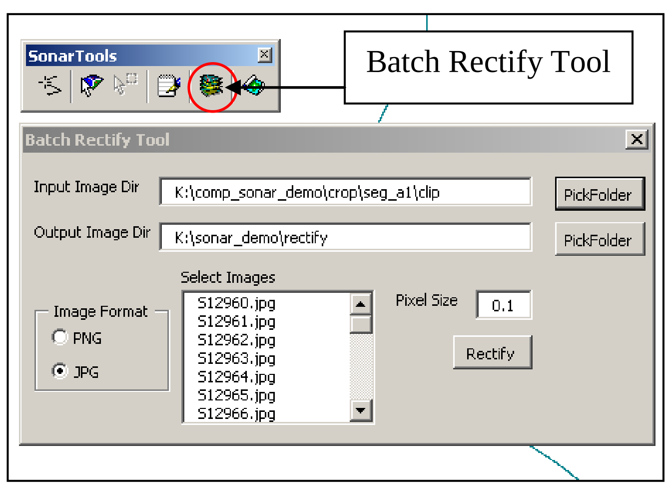


Image Rectification

In this step each clipped sonar image is transformed into a georeferenced raster layer.

<u>Steps:</u>

- Open the Batch Rectify Tool.
- Specify <Input Image Dir> as **sonar_demo/crop/seg_a/clip**. Using the PickFolder browser, specify <Output Image Dir> as **sonar_demo/rectify** (created earlier).
- Specify the <Image Format> of the images either PNG or JPG- the format of the clipped images.
- Select (i.e., highlight) all images to be rectified in the <Select Images> list box.



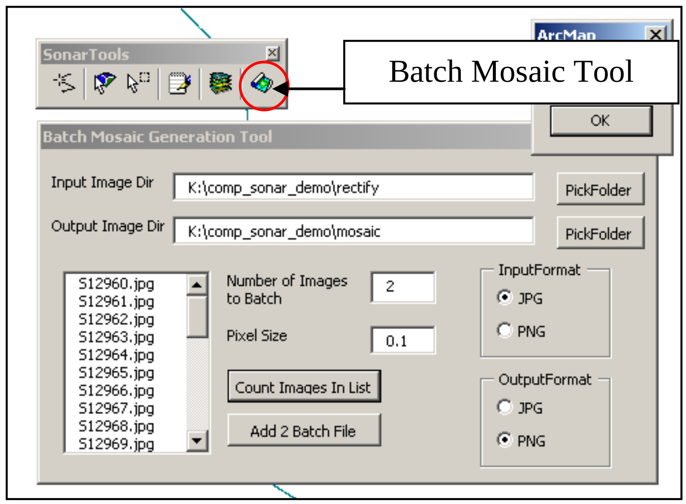
- Specify <Pixel Size> as 0.1 m (10 cm).
- Click <Rectify>. The computer will begin to process the images and the bar at the bottom of the map project will indicate the execution of this procedure.

Note: Once the process is complete the rectified image and supporting files (world files, pyramids, etc.) will be located in the **sonar_demo/rectify** folder**.** See Appendix for additional information on rectifying images.

*Mosaic File Preparation (****ArcGIS 9.2/9.3.x only****)*

Prior to mosaic generation, text files that specify the images that will constitute each mosaic must be generated. When a project contains many images, we often rectify all images first, then prepare the mosaics. If you are using ArcGIS 10.0 please see **Alternate Method for Mosaic Generation** in the Appendix.

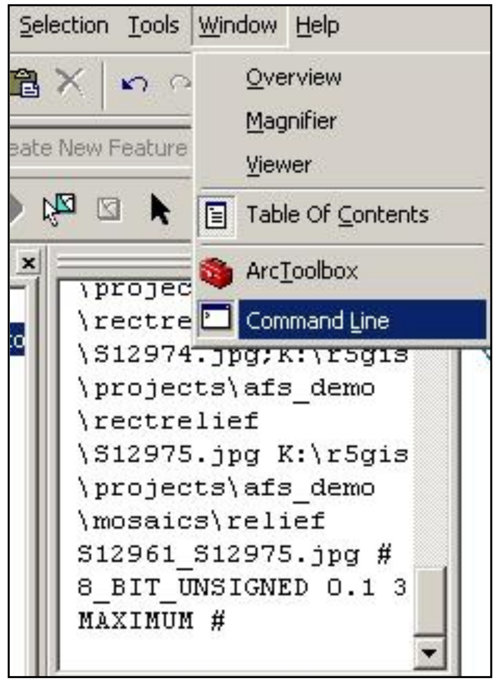
<u>Steps:</u>



- Open the Batch Mosaic Generation Tool.
- Specify <Input Image Dir> as **sonar_demo/rectify**.
- Specify <Output Image Dir> as **sonar_demo/mosaic**.
- Click the <Count Images In List> button to obtain an image count. We recommend the generation of mosaics ~15 images long.
- Set the <Number of Images to Batch> at 15, <Pixel size>= 0.1 m, <Input Format>, and <OutputFormat> (see **Note** below), and click <Add 2 BatchFile> once= <u>one click only!</u> The first 15 images in the list will be added to a **sonar_demo/rectify/batchmosaic.txt** file and will be removed from the list box.
- Count the remaining images in the list. In this example 16 images remain. Reset the <Number of Images to Batch> to 16 and click <Add 2 Batch File> once again. The remaining 16 images will be added to **sonar_demo/rectify/batchmosaic.txt** and the list box should now be clear. **Note:** If a former **batchmosaic.txt** file exists in the rectify folder, it will be overwritten during an attempt to create a new **batchmosaic.txt** file.
- Close the Batch Mosaic Generation Tool.

Note: Two output formats are offered. JPEG is “lossy” and visual clarity may be impaired in long mosaics (i.e. >15). PNG is “lossless” visual clarity won’t be impaired; however the output file size is larger.

Mosaic Generation* (*ArcGIS 9.2/9.3.x only****)**
In this final step, individual, rectified raster images are spliced into mosaics, or sonar image maps (SIMs). If you are using ArcGIS 10.0 please see **Alternate Method for Mosaic Generation** in the Appendix.



Steps:

- Click on the ArcMap <Window> menu and select <Command Line>. This will spawn the command line tool.
- Right click on the upper portion of the command line window select <Load>.
- Navigate to **sonar_demo/rectify**, select **batchmosaic.txt**, and click <Open>.
- Place the cursor at the end of the loaded text and hit <Enter> on the keyboard to run the mosaic program.
- When complete, 2 mosaics (or sonar image map layers) will be added to the project.

*Congratulations- these SIMs are the final product of sonar image geoprocessing!

Sonar Image Map Display and Inspection

After processing is complete it is vitally important and gratifying to check the overall quality and fit of the sonar image maps (SIMs). The visual quality of the SIMs may be improved by following these steps:

Steps:

- Right click on one of the SIM layers in the <TOC>, select <Properties>, and select the <Symbology> tab.
- Check the box for Display Background Value (R,G,B) to make the areas beyond the river boundary transparent.
- Specify <Stretch> as Standard Deviations and <n:> 5.
- Repeat for the remaining SIM layer(s).
- Using the <Shift> keyboard key, highlight both layers in the TOC, right click and select <Group>. Create a name for the <New Group Layer> (e.g. seg_a).
- Right click on the group layer, select <Properties>, then the <Display> tab.
- Specify <Contrast> as –10%, <Brightness> as –10%, and <Transparency> as 15%.
- Right click on the project view, select <Data Frame Properties>, select the <Frame> tab, and set the <Background> color to black.

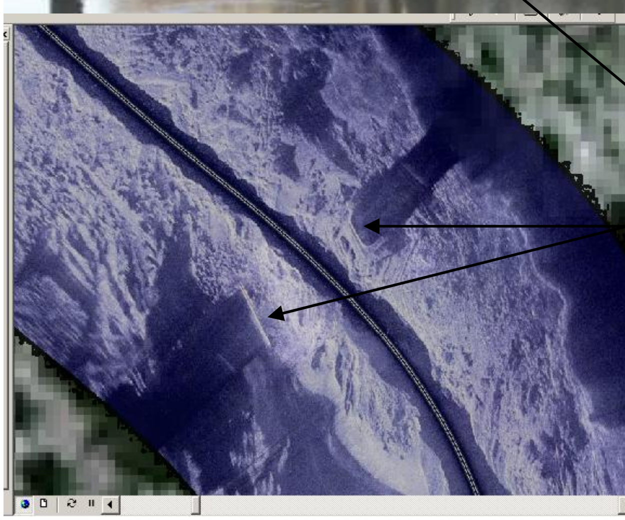
Note: We encourage you to experiment with alternative settings to identify optimal display quality for your computer monitor. Moreover, Irfanview's image effects functions can be used prior to image processing to manipulate images, perhaps improving image quality prior to sonar processing.

Check Image Positioning

Steps:

- Load the image **sonar_demo/misc/sonar_demo_naip.img** by dragging it from the **misc** folder into the Table of Contents. Set it below the SIMs in the Table of Contents.
- Toggle the SIMs on and off to inspect the fit to the river channel.
- Zoom to the area of the bridge crossing using the magnifying glass tool.
- Right click on one of the SIMs and select <Zoom to Raster resolution>, which is 1:378.

At this scale the underwater bridge abutments can be identified. By making the SIMs somewhat transparent, we can identify the span of the bridge where it passes above the river channel. Note that the bridge abutments are beneath the bridge span where they should be! Using the pan (hand) tool, scroll upstream a short distance (~100 m) to a second set of sonar shadow-casting features. These structures are relic abutments from an old railroad bridge, shown below in a digital photograph taken from a point downstream (probably the bridge). If we zoom out from this area, the old railroad grade is evident as a cut through the floodplain riparian forest.



During the survey, we passed between these 2 abutments.

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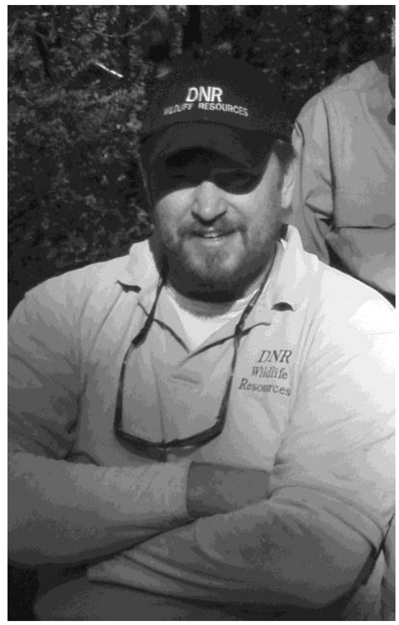


The tools and techniques presented in this workbook are not endorsed, funded or supported by Humminbird® or Johnson Outdoors. The tools are provided gratuitously, and without support from the authors. However, questions or problems relating to topics presented in this workbook can be directed to the authors who will attempt to assist inasmuch as possible. End users are responsible for adhering to the licensing agreements of the software used herein.

Appendix

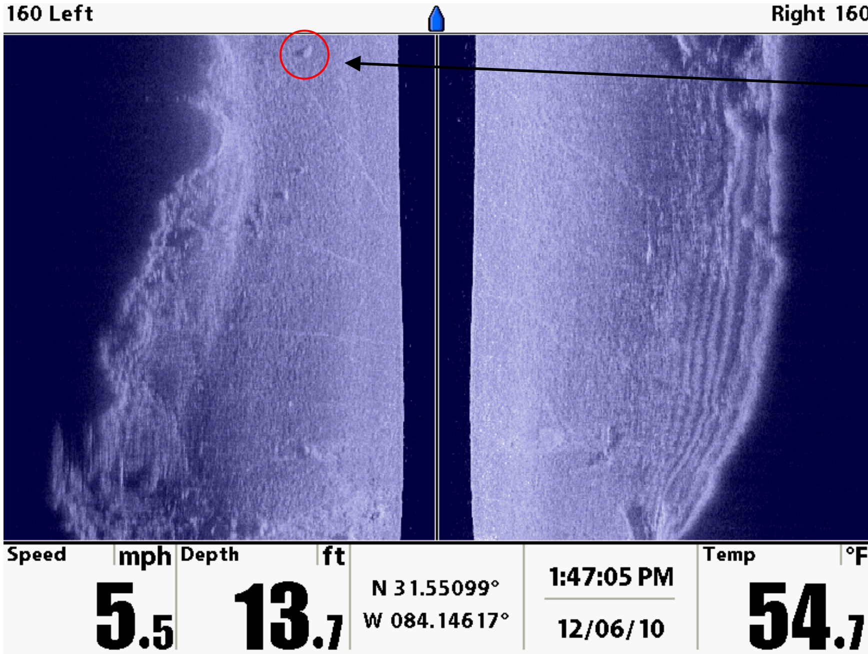
How to Capture Consecutive, Overlapping Images

For several years we worked exclusively with the 981c SI system for capturing sonar images. The image file format applied to sonar images was .BMP, a large file format that required several seconds to write to the SD card each time the capture image button was depressed. To capture consecutive, overlapping screen snapshots, we learned to identify a distinct object at the top of the screen when the snapshot button was depressed (screen freezes at this moment), and followed this object as it advanced down-screen when the waypoint/image save messages had cleared. We would count the number of seconds following the clearing of the messages for the object to approach the bottom of the screen and almost disappear, then use this count to time the capture of the next image.

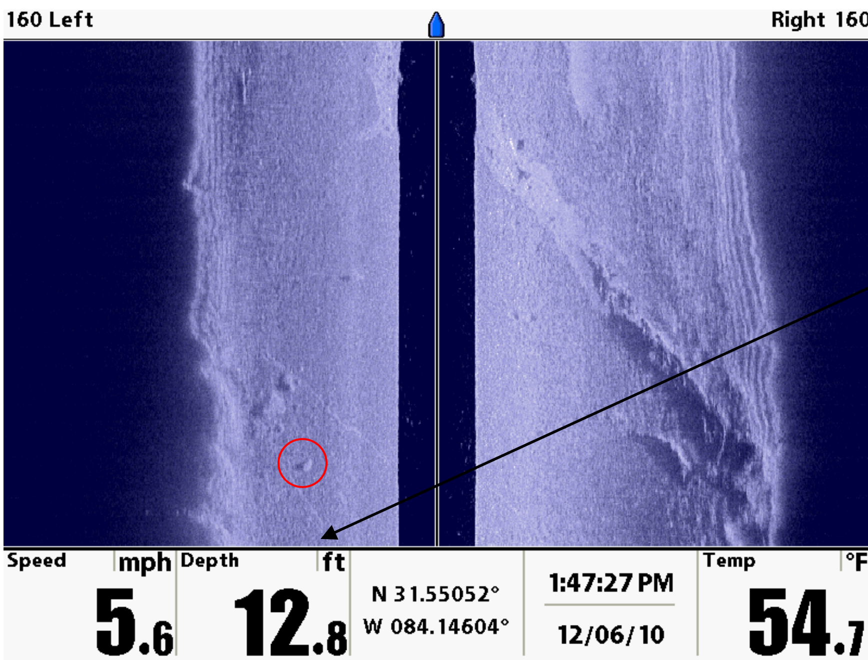
In most cases, the transit time of an object following the clearing of the screen messages was 5-10 seconds. This approach, however, was not without its challenges if you have anyone on board during the survey. Conversations inevitably occur, making it tough to count seconds! Furthermore, control head firmware updates changed the image file format saved from .BMP to .PNG, and the image save time (i.e., time screen was frozen) was significantly reduced. The messages cleared earlier, meaning more seconds had to elapse (and be counted by the operator) to maintain a small area of overlap among consecutive images. This proved to be too much to bear, even for this author! A new approach had to be developed.

Some internet research on stopwatches suggested we try the Seiko S057 Interval Timer. This watch costs ~$90, and we feel it is well worth the investment. Any interval timer that allows for endless repetition of a specified countdown interval with an alarm should suffice.

To effectively use the stopwatch we suggest the following method: prior to starting a survey, but ***after*** all critical settings adjustments have been made (most importantly the <u>range setting</u> and <u>screen scroll rate</u>), use the stopwatch to measure the exact time required for a distinct object that has appeared at the top of the screen to travel the length of the screen and nearly disappear (i.e., the transit time). The next page provides a set of 2 images that illustrate this point.



A single boulder appears at the top of the screen, and we start the stopwatch timer. Follow the object as it moves toward the bottom of the screen. **Sonar range and screen scroll rate affect the transit speed, but <u>boat speed has no effect</u>.



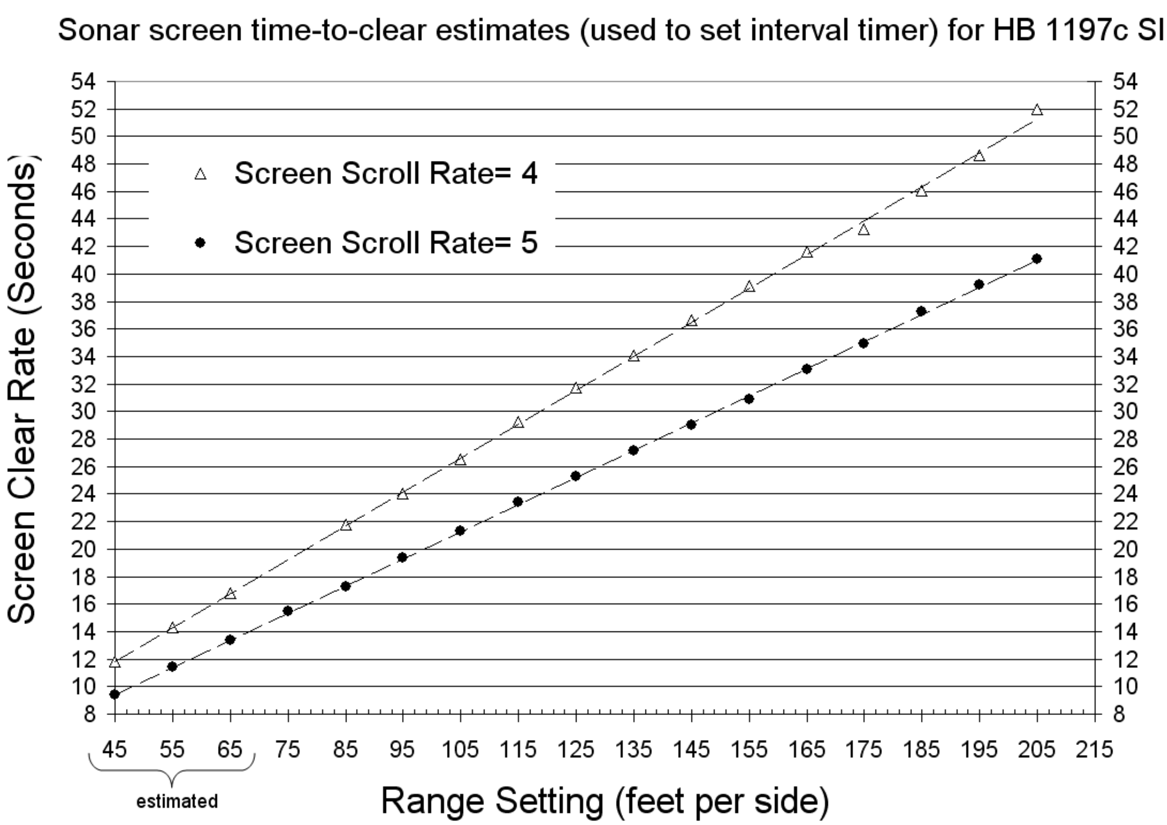
The boulder now approaches the bottom of the screen. We won't stop the timer until the object has nearly disappeared off the screen at this position.

The estimated transit time of this object was 25 seconds. We repeat this process on several more objects until a precise estimate of transit time has been estimated.

After timing several objects, a precise estimate of the transit time can be made. Let's say, for example, the measured transit time is 25 seconds. We then set interval timer 1 on the Seiko S057 to 23 seconds (leaving 2 seconds to err on the side of caution). The second interval timer is set to 0, and the cycle is set to repeat indefinitely. When ready to start the survey, we depress the screen capture button (i.e., Mark on the 1197c) and the stopwatch timer start button simultaneously, thus starting the interval countdown. Using this approach, the capture of consecutive screen snapshots with a small amount of overlap becomes relatively mindless and virtually failsafe. As the interval countdown approaches 0, the Seiko provides a beep on each of the last 3 seconds- reminding the operator that the end of the interval is approaching. Your finger is ready to press the Mark button when the alarm sounds. The next interval countdown begins as soon as the alarm sounds. As long as you never miss the button upon hearing the alarm, all of your images will have a very small portion of overlap, and no image data will ever be lost due to operator error.

*** Bear in mind that any time you change the range setting, or the screen scroll rate setting, you will have to re-estimate the transit time used on the interval timer.

To provide a guide to setting the interval on the timer we have generated the following graph of the relationship between range setting, screen scroll rate, and seconds to clear (i.e., time-to-clear or transit time estimates). All points except those at range settings 45-65 (estimated from linear relationship) represent the average of 3 separate timed measurements of object transit time on the screen in the field. To be safe, a user should consider setting an interval timer for a few seconds less than the transit time indicated on the chart. For example, at a range setting of 125 feet per side, and screen scroll rate of 5, the screen clear rate/transit time is ~25 seconds. We would likely set our interval timer for a 23 second interval between screen captures. ***Warning**- Please conduct some of your own tests in the field before adopting the data in the chart below. Who knows how different two SI systems might be?



Irfanview Installation

In previous versions of the processing toolkit, Irfanview must be installed in the default directory- **c:/program files/irfanview** - in order for the processing tools to work. In the new toolkit, you can specify the location of Irfanview if you have installed the program elsewhere. The prompt for Irfanview location appears in the Image Matching Tool dialog box when the tool is launched.

Clipped Images and Control Point Network .txt Files

It is possible to direct all the clipped images generated during image matching into a single **Clip** folder for the entire project. As control point network files are generated on a segment-by-segment basis, the **Clip** folder will be populated with the .txt files. The advantage of this is that you can then easily rectify, in a very large batch, all of your project images at once. You will, however, want to keep track of the images and their processing segments in order to mosaic them appropriately.

Image Rectification using Batch Rectify Tool

We recommend against performing other computer operations during the rectification process. We also recommend the creation of separate folders for each processing segment (e.g. **rectify_seg_a**) to be populated with the segment's rectified images (See *Mosaic Generation* below). If the rectified image file already exists in the output directory it will be skipped during the rectification process.

After image rectification, but prior to mosaic generation, it is advisable to load the individual rectified images into a map project and inspect for errors. In such cases, delete the rectified image from the folder and, using the Batch Rectify Tool, reselect the image from the list and rectify- in some instances re-rectifying an individual image may correct errors. Inspect the re-rectified image.

Problems During Rectification

Failure to transfer all necessary images in a processing segment to clip folder

Failure to transfer all necessary images prior to control point generation will likely result in the failure of the computer to rectify the image set. In such cases, the computer is attempting to rectify an image using the control point file from another image- we do not want this to happen! Simply deleting the control point files, transferring the necessary images into the proper folder, and regenerating new control point files may not correct the problem. One solution is to copy the proper image set into a new folder, delete the old image folder, then rename the new folder as the originally used folder name- regenerate the control point files, and then rectify. In other, more extreme, cases of computer rectification failure, we have split a processing segment into 2 parts at the image point at which the computer "hangs-up" during rectification. Reprocessing of the 2 parts of the segment separately may eliminate the problem.

Other reasons for tool malfunction

- You should have the most recent ESRI ArcView Service Pack installed on your workstation in order for image rectification to proceed smoothly (no hang-ups).

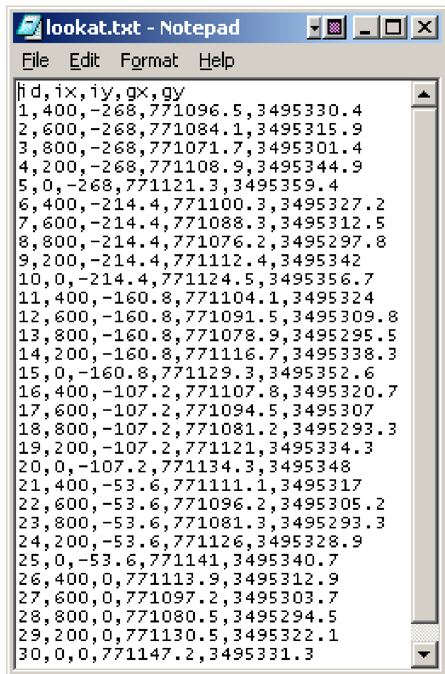
- If you open a project containing the sonar processing tools and the tool icons appeared to be inactivated (no-smoking sign/red circle with slash) check to make sure the VBA module has been installed on your workstation.

- We advise against conducting other computer operations during rectification or mosaic generation. These processing steps are demanding of the CPU and should be allowed to proceed without interruption.

How to Fix a Warped Image (i.e., a rectified image that has warped upon itself).

Occasionally an image will warp back onto itself in tight bends or areas where anomalies occur in the trackline. An example image with this problem has been provided in the demo dataset. The files described below are in the **img_warp/** folder.

1. Adjust the control point file for display in ArcGIS
   - Navigate to **img_warp /crop/clip** using Window Explorer.
   - Make two copies of the file **s00011.txt.**
   - Rename one of the files **s00011_Overlay.txt** and keep second copy as a backup.
   - Open **img_warp /crop/clip/s00011_Overlay.txt** in Notepad.
   - Replace all spaces with commas using the <Edit><Replace> tool. In <Find what> add a space, in <Replace with>: Add a comma(,), then click <Replace All>.
   - Add a line to the top of the file and type the following: id,ix,iy,gx,gy
   - The resulting file should look like the figure to the right.
   - Save this file.

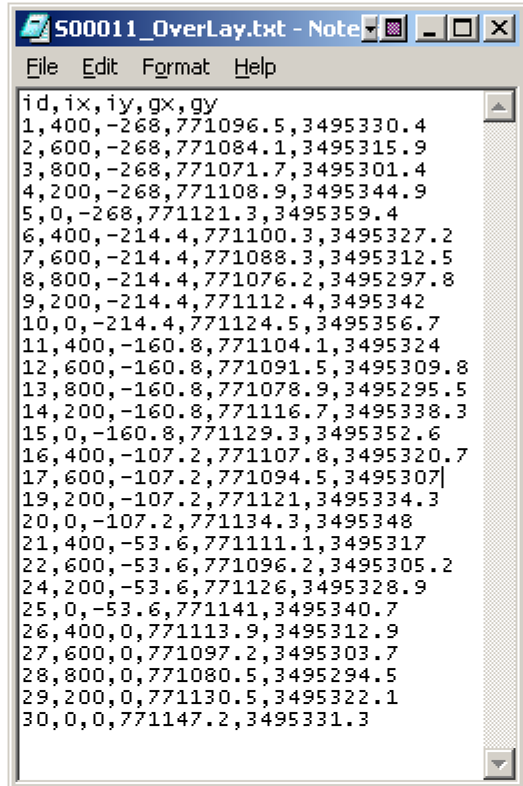



```
id,ix,iy,gx,gy
1,400,-268,771096.5,3495330.4
2,600,-268,771084.1,3495315.9
3,800,-268,771071.7,3495301.4
4,200,-268,771108.9,3495344.9
5,0,-268,771121.3,3495359.4
6,400,-214.4,771100.3,3495327.2
7,600,-214.4,771088.3,3495312.5
8,800,-214.4,771076.2,3495297.8
9,200,-214.4,771112.4,3495342
10,0,-214.4,771124.5,3495356.7
11,400,-160.8,771104.1,3495324
12,600,-160.8,771091.5,3495309.8
13,800,-160.8,771078.9,3495295.5
14,200,-160.8,771116.7,3495338.3
15,0,-160.8,771129.3,3495352.6
16,400,-107.2,771107.8,3495320.7
17,600,-107.2,771094.5,3495307
18,800,-107.2,771081.2,3495293.3
19,200,-107.2,771121,3495334.3
20,0,-107.2,771134.3,3495348
21,400,-53.6,771111.1,3495317
22,600,-53.6,771096.2,3495305.2
23,800,-53.6,771081.3,3495293.3
24,200,-53.6,771126,3495328.9
25,0,-53.6,771141,3495340.7
26,400,0,771113.9,3495312.9
27,600,0,771097.2,3495303.7
28,800,0,771080.5,3495294.5
29,200,0,771130.5,3495322.1
30,0,0,771147.2,3495331.3
```

2. Open the problem image and control point file in ArcMap
   - Add the image **img_warp /rectify_prb/s00011.png** to ArcMap.
   - Add the control point file **img_warp /crop/clip/s00011_Overlay.txt** created in Step 1 as an Event Layer: <Tools><Add XY Data> (ArcGIS 9.2+); <File><Add data><Add XY Data> (ArcGIS 10).
   - Navigate to and select **img_warp /crop/clip/s00011_Overlay.txt**; Set <X Field>: gx; Set <Y Field>:gy
   - Label the points: Right click on select **img_warp /crop/clip/s00011_Overlay.txt** in the table of contents and select <Label Features>.
   - You'll notice that the id values run in "columns" from top to bottom across the image ascending incrementally by values of five. However, the left most "column" of values

appears out of order. Notice points 18 and 23 are outside the incremental order and appear “down-river” of point 28. Knowing that point 28 should be the most downstream point in the network we’ll try deleting points 18 and 23 from the control point file. **img_warp /crop/clip/s00011_Overlay.txt** and re-rectify the problem image to fix it.

3. Adjust the control point file and re-rectify
   - Navigate to and open **img_warp /crop/clip/s00011.txt** with Notepad. **Note:** MAKE SURE YOU HAVE MADE A COPY OF THIS FILE BEFORE PROCEEDING.
   - Find the lines for control points 18 and 23. Delete them, making sure not to leave a blank line or delete any other text. The file should look like the figure to the right.
   - Save and close the file.
   - Return to ArcGIS, start <Sonar Tools><Rectify Tools>. Specify the <Input Image Dir> as **img_warp /crop/clip**; specify the output folder as **img_warp /rectify**; set the <Range> to 38.1m; and the <Overlap> to 5. Select the image s00011.png from the drop down list. Click <Rectify>. Add the resulting image, along with the other images in **img_warp /rectify**, to ArcMap and examine the results.
   - If you are happy with the results you are done, if not you can try experimenting by deleting other control points from the file.


S00011_OverLay.txt - Note
File Edit Format Help

```
id,ix,iy,gx,gy
1,400,-268,771096.5,3495330.4
2,600,-268,771084.1,3495315.9
3,800,-268,771071.7,3495301.4
4,200,-268,771108.9,3495344.9
5,0,-268,771121.3,3495359.4
6,400,-214.4,771100.3,3495327.2
7,600,-214.4,771088.3,3495312.5
8,800,-214.4,771076.2,3495297.8
9,200,-214.4,771112.4,3495342
10,0,-214.4,771124.5,3495356.7
11,400,-160.8,771104.1,3495324
12,600,-160.8,771091.5,3495309.8
13,800,-160.8,771078.9,3495295.5
14,200,-160.8,771116.7,3495338.3
15,0,-160.8,771129.3,3495352.6
16,400,-107.2,771107.8,3495320.7
17,600,-107.2,771094.5,3495307
19,200,-107.2,771121,3495334.3
20,0,-107.2,771134.3,3495348
21,400,-53.6,771111.1,3495317
22,600,-53.6,771096.2,3495305.2
24,200,-53.6,771126,3495328.9
25,0,-53.6,771141,3495340.7
26,400,0,771113.9,3495312.9
27,600,0,771097.2,3495303.7
28,800,0,771080.5,3495294.5
29,200,0,771130.5,3495322.1
30,0,0,771147.2,3495331.3
```

Mosaic Generation

During preparation of mosaic command line files (**batchmosaic.txt**), it will likely be important to segregate images from adjacent processing segments to maintain data integrity. For example, consider a break between processing segments that was the result of a gap in sonar image data. Clearly, we would not wish to combine the last image in the upstream geoprocessing segment with the first image in the downstream segment by preparing a batchmosaic.txt file that instructs the computer to mate these 2 images. However, when using the Batch Mosaic Generation Tool, flexibility to pick and choose images present in the Input Image Directory for the **batchmosaic.txt** file is limited. Therefore, we recommend creating separate **rectify** folders each processing segment to store only the rectified images from a given segment. When you select a specific rectify folder as the Input Image Directory, only those images within the segment will be available for inclusion in the **batchmosaic.txt** file.

Problems During Mosaic Generation

Failure to use the directory structure we recommend throughout this workbook can result in mosaic generation failure in the final step of image processing. For example, if you used the folder My Documents to store all of the files generated in a project you will find that mosaic generation will fail. Why? Because the folder My Documents has a space in the file name.

NOTE: NEVER USE FOLDERS OR FILENAMES IN YOUR PROJECT DIRECTORY THAT CONTAIN SPACES! (e.g., "segment a1" (BAD) vs. "segment_a1" (GOOD)).

Alternate Method for Mosaic Generation (ArcGIS 9.3+ / Mandatory for ArcGIS 10.0+)

At ArcGIS 10.0 the <Command Line> is no longer available. Instead of re-writing the mosaic procedure for use in the <Python Command Line>, a method to mosaic images into a Raster Dateset within a File Geodatabase is described below. This method also offers a distinct advantage in that many images (perhaps a entire processing segment – depending on the number and size of the images) can be added to a single mosaic layer in a File Geodatabase with little or no loss in performance (i.e. redraw speeds, etc). You can also add additional Raster and Feature datasets to a File Geodatabase, allowing you to maintain a neat and organized workspace. This procedures can also be applied in ArcGIS 9.3.

1. Create a file geodatabase
    - Open <ArcCatalog>
    - Navigate to and right click on the folder **sonar_demo\mosaic**
    - Select <New> <File Geodatabase>
    - Name it: **sonar_demo.gdb**

2a. Create a raster catalog
- In <ArcCatalog> right click on the file geodatabase: **sonar_demo/mosaic/ sonar_demo.gdb**
- Select <New> <Raster Catalog>
- Set <Raster Catalog Name> to: **demo_catalog**
- Set <Raster Management Type> to: <Unmanaged>
- Click <OK>
- Open <ArcToolbox>
- Navigate to <Data Management Tools> <Raster> <Raster Catalog> <Workspace to Raster Catalog>
- Set <Input Workplace>: **sonar_demo\rectify**
- Set <Target Raster Catalog>: **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog**
- Click <OK>

2b. Batch processing multiple raster catalogs

Batch processing of multiple raster catalogs can be performed simultaneously using the steps below. To access selection dialogs in batch mode, double click the appropriate cell and specify as stated below.
- In <ArcCatalog> right click on the file geodatabase: **sonar_demo/mosaic/ sonar_demo.gdb**
- Select <New> <Raster Catalog>
- Set <Raster Catalog Name> to: **demo_catalog**
- Set <Raster Management Type> to: <Unmanaged>
- Click <OK>
- Add additional raster catalogs as necessary using the above steps

- Open <ArcToolbox>
- Navigate to <Data Management Tools> <Raster> <Raster Catalog>
- Right click <Workspace to Raster Catalog>
- Select <Batch>
- Set <Input Workplace>: **sonar_demo\rectify**
- Set <Target Raster Catalog>: **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog**
- Add and populate as many <Workspace to Raster Catalog> definitions to the batch process as desired using the <Add Row> button on the right of the Batch Dialog.
- Click <OK>

After the raster catalog(s) is complete add it to ArcMap as a data layer. If the SIMs are only intended for substrate delineation no further work is needed to generate mosaics. If the intention is to deliver the SIMs as a data layer then the following steps must be performed in order to convert the raster catalog to a deliverable raster dataset.

3a. Create a raster dataset

- Open <ArcToolbox>
- Navigate to <Data Management Tools> <Raster> <Raster dataset> <Raster Catalog to Raster Dataset>
- Set <Input Raster Catalog>: **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog**
- <Output Raster Dataset> will auto fill to: **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog_RasterCatalogTo**
- Change <Output Raster Dataset> to: **sonar_demo\mosaic\ sonar_demo.gdb\demo_raster_dataset**
- Set <Mosaic Method> <MAXIMUM>
- Click<OK>

3b. Batch processing multiple raster datasets:

Batch processing of multiple raster datasets can be performed simultaneously using the steps below. To access selection dialogs in batch mode, double click the appropriate cell and specify as stated below.

- Open <ArcToolbox>
- Navigate to <Data Management Tools> <Raster> <Raster dataset>
- Right click <Raster Catalog to Raster Dataset>
- Select <Batch>
- Set <Input Raster Catalog>: **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog**
- <Output Raster Dataset> will auto fill to **sonar_demo\mosaic\ sonar_demo.gdb\demo_catalog_RasterCatalogTo**
- Change <Output Raster Dataset> to **sonar_demo\mosaic\ sonar_demo.gdb\demo_raster_dataset**
- Set <Mosaic Method> <MAXIMUM>
- Add and populate as many < Raster Catalog to Raster Dataset> definitions to the batch process as desired using the <Add Row> button on the right of the Batch Dialog.
- Click <OK>.

After the raster dataset has finished generating add it to ArcMap as a data layer. You have now successfully completed a sonar image mosaic.

Smoothing the Track Line (Alternative)

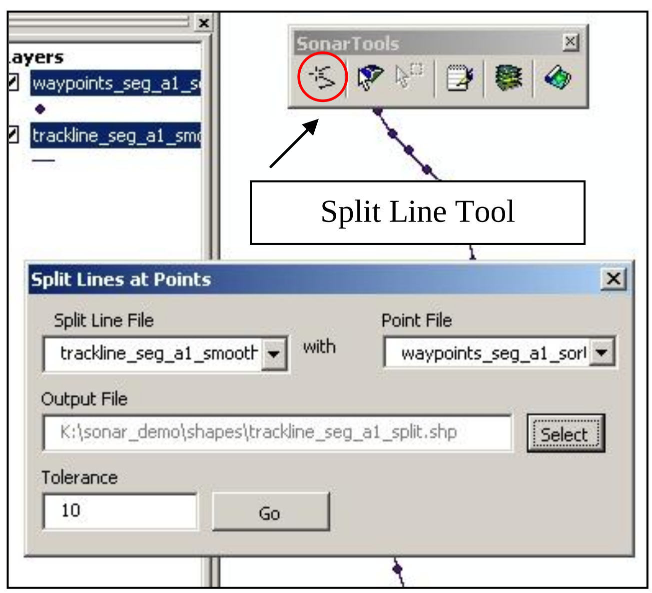
It is also possible to remove irregularities in the resulting line from this “connect-the-dots” approach by using tools Advanced Editing Tools available in ArcGIS.

Steps:

- Turn on the Advanced Editing Toolbar <View><ToolBars> and Select Advanced Editing.
- Create a backup of **trackline_seg_a1.shp.** <Right click on the file in the Table of Contents <Data> <Export Data> and save it as **sonar_demo\shapes\ trackline_seg_a1_smooth.shp** and add it to the view.
- Start an editing session and specify **trackline_seg_a1_smooth.shp** as the target**.**
- Use the <Select Features> tool to select the track line.
- Click the <Smooth> button on the <Advanced Editing> toolbar.
- Specify <Maximum Allowable Offset> as 0.5 and click <OK>.
- Compare the smoothed line **trackline_seg_a1_smooth.shp** to the original line in **trackline_seg_a1.shp**. If the results are acceptable, <Stop Editing> and <Save Edits>. If the results are not acceptable go to <Edit><Undo Smooth> and reapply the smoothing algorithm specifying different <Maximum Allowable Offset>
- By smoothing the track line the image processing results are ultimately improved.
- Remove the older track layers from the project, leaving only the smoothed track line layer and the waypoint layer for the segment.

Split the Track Line with Waypoints (Alternative)

Steps:



- Open the <Split Line Tool>
- Specify <Split Line File:> as **trackline_seg_a1_smooth.shp**.
- Specify <Point File> as **waypoints_seg_a1_sort.shp**.
- Specify <Output feature class> as **trackline_seg_a1_split.shp**, click.
- Specify <Assign search tolerance> as 10 meters, and click <Go>.
- The **trackline_seg_a1_split.shp** will be added to the Table of Contents. Inspect the file as per instructions on Page 19.
- When using the Split Line Tool it is advisable that the line you have generated extends well beyond the last waypoint in the series. To ensure the line extends far enough, create a line from a series of trackpoints, using several trackpoints captured beyond the last waypoint in the processing segment.