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Coastal Survey Maps: From Historical Documents to Digital Databases

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Coastal Survey Maps: From Historical Documents to Digital Databases

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Abstract: This paper describes the spatial data handling procedures used to create a vector database of the Connecticut shoreline from Coastal Survey Maps. The appendix contains detailed information on how the procedures were implemented using Geographic Transformer Software 5 and ArcGIS 8.3. The project was a joint project of the Connecticut Department of Environmental Protection and the University of Connecticut Center for Geographic Information and Analysis.

Keywords: Coastal Survey Maps, T-Sheets, rasterization, georectification, vectorization, datum conversion, Connecticut

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Advancing the use of geographic data and spatial analytic techniques at the University of Connecticut and in the region it serves

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Introduction

Coastal Survey Maps, which are also known as topographic sheets or T-sheets are topographic maps of the coastal perimeter of the United States and its major rivers (Figure 1). The maps are the most accurate depiction of the United States' shoreline and shoreline features such as piers, rocks, and tidal flats. Coastal Survey Maps are the primary product of the National Ocean Service (NOS), the modern-day successor to the U.S. Coast & Geodetic Survey. The U.S. Coast & Geodetic Survey was founded by President Thomas Jefferson in 1807 in an effort to survey and map the coasts of the United States (NOAA Coastal Services Center, 2004).

The first Coast Survey & Geodetic Survey Sheet was completed in 1834 for the Great South Bay of Long Island, New York, using a plane table and alidade (Daniels and Huxford, 2001). Utilizing these tools, surveyors and cartographers actually drew the maps in the field as surveyors walked the beach.

These sheets were primarily intended to be navigational aids surveying all major land/water boundaries in the U.S. They also served as a reference database for the production of nautical charts. The use of these sheets today, however, is far broader. T-Sheets are used to identify historic property boundaries, to act as a reference for marine boundary limits, to determine baselines for flood insurance, and to aid in the management of coastal resources (NOAA Coastal Services Center, 2004).

One of the more important uses of these historical maps in coastal resource management is their role in depicting changes in coastal shorelines as they evolve over time. Current shoreline positions can be extracted from high resolution satellite imagery (Li, et al., 2003) but historical shoreline positions can only be ascertained from map documents prepared from survey measurements taken at the time. Determining past shoreline positions has involved using geospatial data processing techniques to convert the historical documents into digital databases. The National Ocean Service and the National

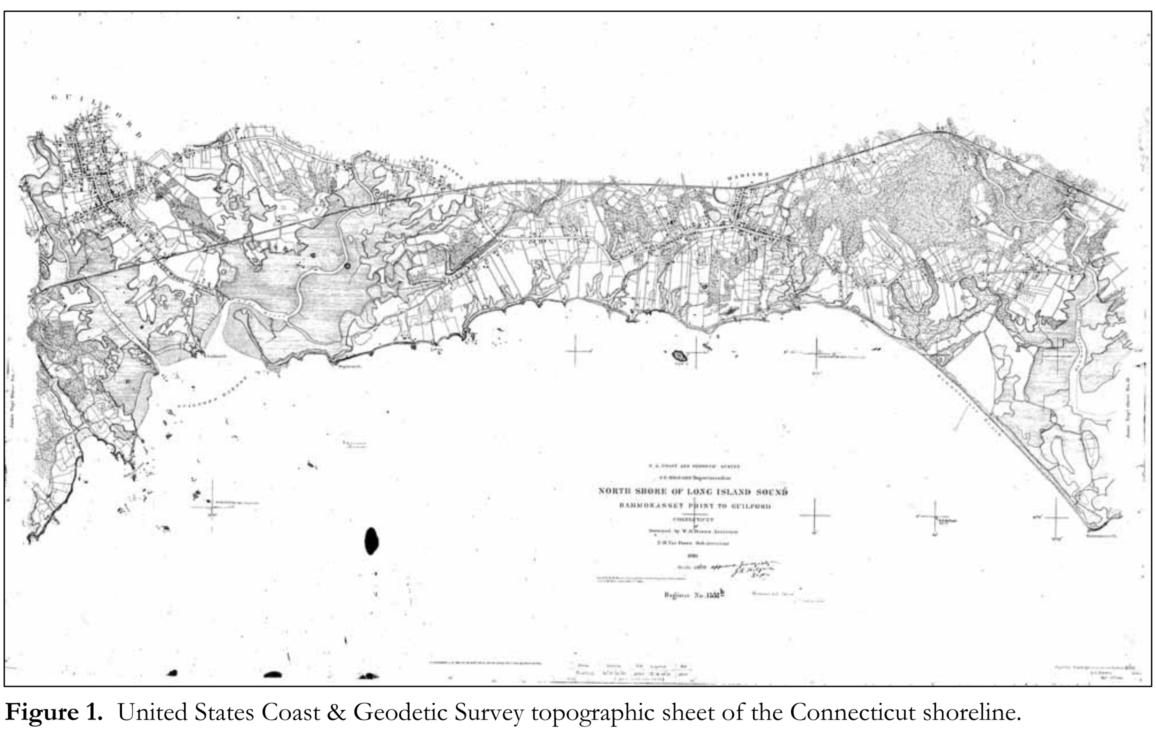

Figure 1. United States Coast & Geodetic Survey topographic sheet of the Connecticut shoreline.

Oceanic and Atmospheric Administration (NOAA) initiated a project to convert all historic topographic sheets from paper to digital format (NOAA Coastal Services Center, 2004). In order to complete this task, the National Oceanic and Atmospheric Administration developed a cooperative program with state agencies. The goal of the program was to develop a nationwide digital line database from the topographic sheet series. The original paper T-sheets were scanned by NOAA and digital raster images of the files were being distributed for database compilation at the state level.

This paper describes the procedures used to convert T-sheet images into a vector database depicting the Connecticut shoreline. The project was a joint project of the University of Connecticut Center for Geographic Information and Analysis and the state's Department of Environmental Protection.

Evolution of Topographic Sheets as Shoreline Maps

The United States Coast & Geodetic Survey topographic sheets have evolved in several ways that significantly affect compilation of digital line work from T-sheets. Over the course of development of the series, different datums were used, different approaches to representing relief were used, and different symbols were used to depict physical features surrounding the coastline. As a result, the first of the coastal maps, which originated in the early 1800s, are significantly different from maps that were produced later.

Perhaps the most important difference is the choice of the reference datum used to create the maps. In order to depict features of the earth on a flat surface, a spheroid model representing the earth's surface is used to project the curved spheroid surface onto a two dimensional medium such as paper or mylar. In the early years of production, cartographers created these maps using idiosyncratic geographic datums that are currently obsolete. The United States did not adopt a universal datum until 1927 (Crowell, Leatherman. and Buckley, 1991). The North American Datum of 1927 was based on the Clarke 1866 reference spheroid (Snyder, 1987).

In addition to the change in map datum, the depiction of some physical features changed. One of the most obvious of these changes is the change in the symbols used to portray topographic relief. In the topographic sheets created before 1850, changes in elevation were represented using hatch marks (Figure 2) that were intended to show relief on the maps. These symbols have no actual usefulness as tools for measuring elevation, as do the contour lines shown on later versions of the coastal maps created after 1850.

Each series of topographic sheets depicts physical features surrounding the coastline in a different manner. As a result, any two sheets often look very different when compared. Fortunately, the most important feature, the line depicting the shoreline at the date the map was created, has been produced using a consistent methodology strictly applied on each of the maps created by the United States Coast & Geodetic Survey.

Definition of Mean High Water Line

Water levels in coastal areas change with tides and as a result of other physical geographic processes. How to choose a line that represents the coastline is a problem that has been discussed by Crowell, Leatherman, and Buckley (1991) in some detail. They consider 'High Water Line' and 'Mean High Water Line' two different terms that are often confused in their

Figure 2. Hatch marks depicting relief on an early topographic sheet.

association with the coastlines depicted on maps created by U.S. Coast & Geodetic Survey cartographers. On the actual topographic sheets, the term "Mean High Water" is identified as the standard used in creating the maps (Crowell, Leatherman, and Buckley, 1991). According to Shalowitz (1964), however, the map usage of the term "Mean High Water" is incorrect because the Mean High Water Line refers to a measurement made using a plane table of the average height of the high water line over a period of nineteen years, a measurement not actually made by U.S. Coast & Geodetic Survey surveyors. Instead, the surveyors approximated the Mean High Water Line by making themselves familiar with the tide at various phases and taking note of various physical characteristics of that point of the shoreline (Shalowitz, 1964).

The legitimacy of using the Mean High Water Line as an accurate shoreline change indicator has been questioned by Morton and Speed (1998) on the grounds that this mark is too sensitive to daily fluctuations in the level of the shoreline. For the process of extracting information from the topographic sheets, the mark described as "Mean High Water Line" is the only representation of the shoreline available, regardless of how the line was actually determined for cartographic purposes. It is this mapped line that was extracted using current spatial data processing techniques.

After the line for the Mean High Water has been established as the standard measure of the coastline, and the other features such as roads and topography have been represented on each of these topographic sheets, the map is created on paper in the field by ground survey teams, and published by the United States Coast & Geodetic Survey. Because of the age of these maps and the long span of time over which each map was created, care must be taken in converting these maps into a digital database.

Database Construction

Creating a digital vector line work for topographic sheets is a three step process involving the scanning or rasterization of the original paper maps, georectification of the rasterized maps, and vectorization of the line work features on the rasterized map to create a vector output file (Figure 3). The order in which the last two steps should be conducted is the subject of much debate in the literature. Although other researchers have reprojected the final vector database to NAD83 as the final step (Huxford, 1998), this project first reprojected the entire raster image. This enables the entire rasterized T-sheet to be used to verify the final vector product in a GIS. The correctly projected T-sheet can also be used as a backdrop image with other databases.

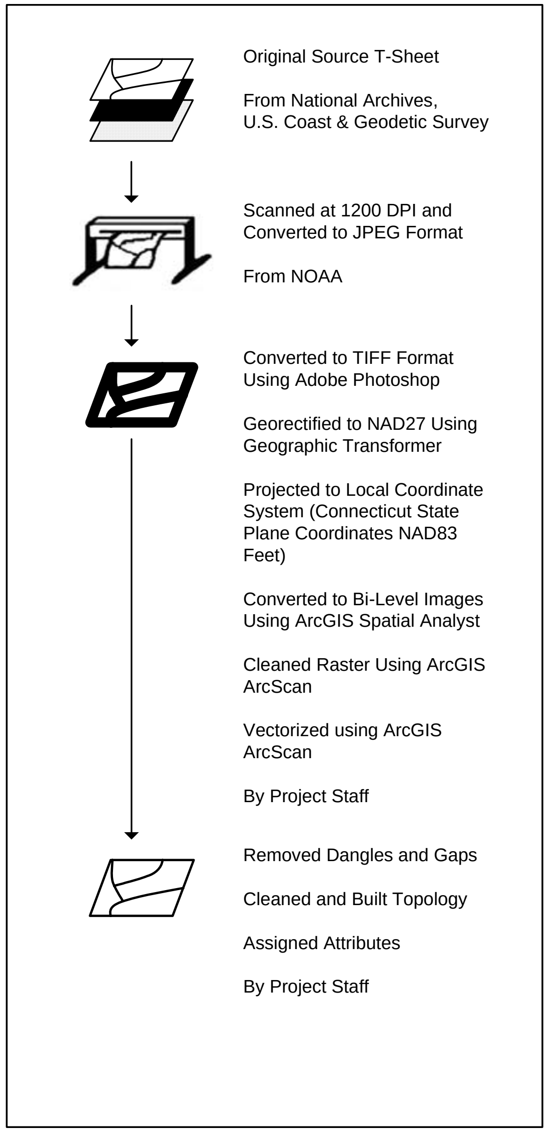

Figure 3. T-sheet processing. Adapted from Huxford, 1998.

Rasterization of Topographic Sheets

NOAA, in cooperation with several state agencies, developed a plan for creating a national historic coastline database for the entire United States. NOAA provided the high resolution scanned paper maps to state agencies, which, in turn, georectified and vectorized coastlines from the raster images. Only the processes of data georectification and feature vectorization from the map image are described here. The full process used in the Connecticut project is described in the Appendix.

Georectification of Topographic Sheets

In order to georectify an image, a minimum of four control points must be located on the original map whose real world locations can by easily identified in a modern coordinate system. Using more than four control points results in a more accurate georectification (Figure 4). On each U.S. Coast & Geodetic topographic sheet there may be any number of Geodetic Control Points with known current coordinates, Geodetic Control Points, that cartographers and surveyors use as geographic reference points are depicted by a point inside of a small triangle (Figure 5). Any Geodetic Control Points that are not used in the georectification process can be used for accuracy assessment after the image has been rectified using other controls points like latitude and longitude lines.

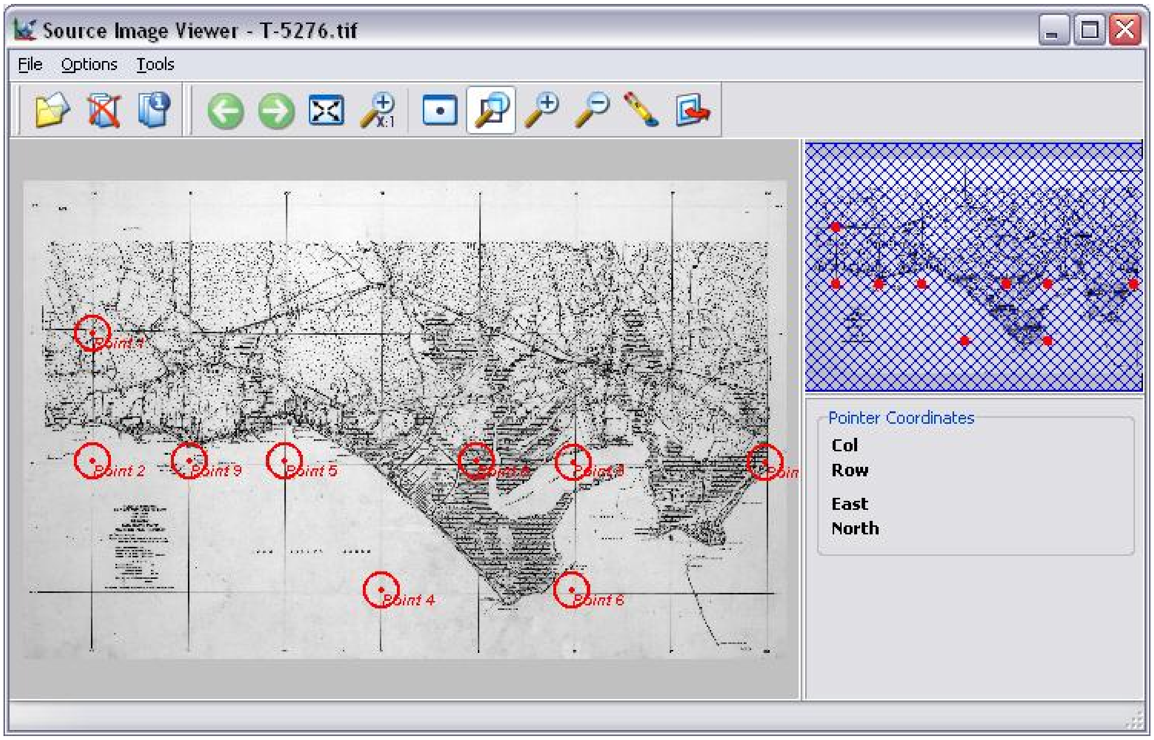

Figure 4. Control point selection.

Figure 5. Depiction of a geodetic control point.

After all control points have been selected and matched with corresponding points in a map projection, the image can be rectified in ArcGIS. The software applies a mathematical transformation to stretch the image to a coordinate system. Root Mean Square (RMS) error is computed and reported in this process. This RMS error value represents the difference between known point locations and their locations after rectification. The RMS value gives a standard mean error in pixels. The lower the value of the RMS error, the more accurate is the rectification (NOAA Coastal Services Center, 2004). In order for the map to pass the National Map Accuracy Standards, the RMS error must fall below 6.95 pixels.

Different processes were used to identify control points for georectifying maps. The choice of process depended on whether the maps were created before or after 1927 when the North American Datum of 1927 (NAD27) was established.

For T-Sheets before 1927. For those maps created before 1927, extra steps must be added to the georectification process. In order for these maps to be aligned with current geographic data, the obsolete datums must be updated using a prescribed manual, graphical, or computerized technique (Crowell, Leatherman, and Buckley, 1991). Several of the topographic sheets covering the Connecticut coastline had been updated with NAD 1927 latitude and longitude marks (Figure 6), while others had not.

Some maps contained multiple corrections to datums at one or more latitude/longitude intersections as shown in

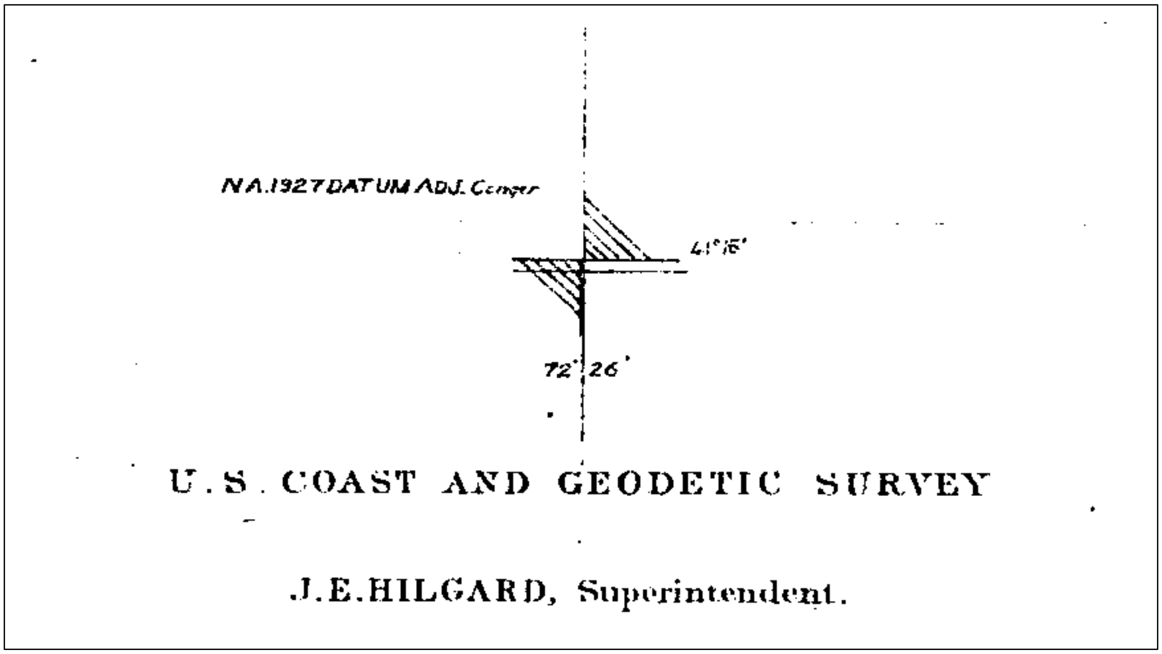

Figure 6. T-sheet with updated NAD27 tick mark.

(Figure 7). The first value is based on the Bessel spheroid of 1841 with astronomic data. It corresponds to the original projection shown on the survey sheet with black solid lines. The second of these values is based on the same spheroid but with the introduction of telegraphic longitude. This update made no change in the latitude value, but increased the longitude by 58.31", or 1,576.0 meters. This change includes the 20°25" due to cable connection between Cambridge Observatory and Greenwich, England. The third value is due to a change from the Bessel spheroid to the Clarke spheroid. The triangulation was still based on an independent datum. This effected a reduction in latitude of 1.64" or 50.2 meters, and a reduction in the longitude value of 1.02" or 27.4 meters.

The fourth value resulted from the adoption of the United States Standard Datum (N. A. Datum) and reduced the latitude value by 4.53" or 139.3 meters. The longitude value, however, was increased by 0.19" or 5.4 meters. The fifth and final value brought the measurement into conformity with the North American Datum of 1927. The latitude was reduced by 0.10" or 3.5 meters and the longitude was further increased by 0.83" or 22.1 meters (Shalowitz, 1964).

In some cases, if four or more geodetic control points with updated coordinates were shown on a map created before 1927, it was not necessary to manually update an obsolete datum on the map. The updated coordinates can be obtained by contacting the National Geodetic Survey or downloading the coordinate data from their website. If fewer than four updated control points were shown and there were not a sufficient number of updated latitude and longitude marks, a manual conversion of these coordinates may be necessary.

In addition to the issues associated with the issues associated with updating the datums used to create the topographical sheets, there are a number of other factors that may affect the final accuracy of digital products derived from scanning historical paper maps. These factors may be associated either with the paper map itself or introduced by humans in the process of converting the historical map to digital

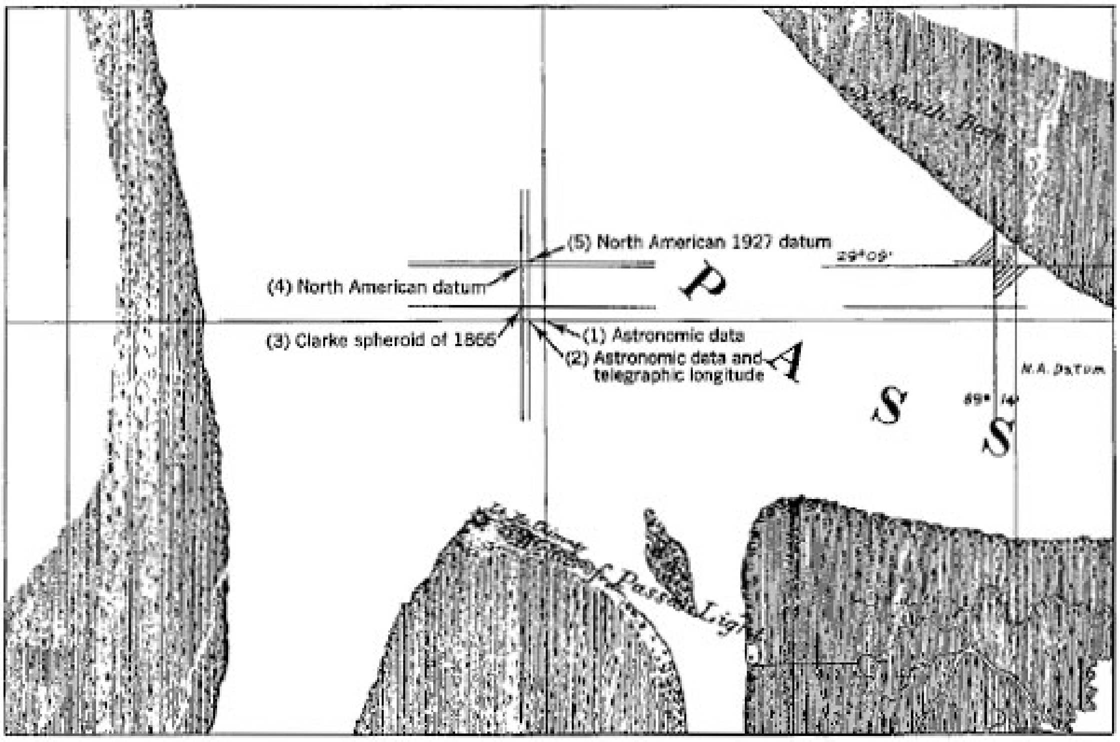

Figure 7. T-sheet with multiple corrections.

format. It is important to document sources of error in the map conversion process.

For T-Sheets after 1927. For those maps created after 1927, georectification was relatively simple. The latitude and longitude lines that appear on the map images are the same as the latitude and longitude lines that used today. These lines could therefore be used to register the digital map to earth-based coordinates. Once the georectification process was completed, the raster images were vectorized to capture the shorelines.

Vectorization of Topographic Sheets

In the past, the process of converting paper maps to digital format has been a practice that is extremely laborious and time consuming. With current improvements in automated vectorization techniques and enabling software, however, this process is not only becoming less time consuming, it is also becoming much more accurate.

In order to conduct analysis on raster images in ESRI's ArcGIS 8.3 software package, the scanned topographic sheets provided in JPEG format had to go through a two step conversion process. First, the JPEG images needed to be converted to TIFF format. After the images were saved in TIFF format, they could be imported into an ArcGIS map document. Second, in order to carry out automated vectorization in ArcGIS, the images had to be transformed from 256-bit grayscale images to bi-level images. Bi-level images are binary and display the scanned paper map data using an array of on or off pixels. In ArcGIS, the method for conducting this transformation is accomplished by deducing a threshold which encompasses all of the linework on the paper map, and leaves out most of the background data. This is accomplished by issuing a "reclass" command or by

classifying the data based on a two category natural breaks classification on the grayscale data. The natural breaks classification in ArcInfo 8.3 divides the grayscale values into two groups by minimizing the total within-group variation. An example T-Sheet before and after it has been converted to a bi-level image is shown in Figure 8.

In ArcGIS 8.3, an extension called ArcScan was implemented to aid in automated vectorization of the linework from the bi-level TIFF image. The ArcScan

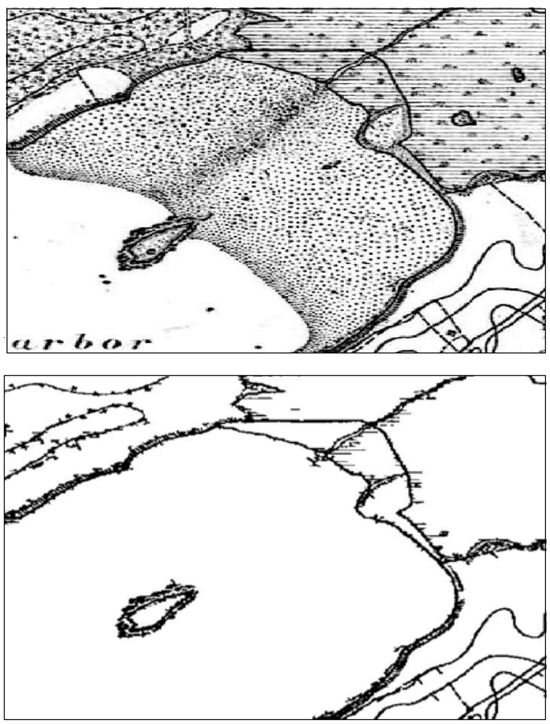

Figure 8. T-sheet image before (top) and after (bottom) conversion to a bi-level image.

software was developed exclusively to aid in the raster-to-vector conversion of scanned paper maps. The extension is comprised of a comprehensive set of tools including batch vectorization, raster tracing, and raster cleanup. The technology made available by such software, when used correctly, provides more accurate centerline vectors from raster images than manual methods. Each image was converted to bi-level format, cleaned, and lastly the vector line representing the shoreline was generated resulting in separate vector shoreline layers.

Summary

Historical maps have many potential uses beyond their customary use as reference documents. Because they depict the landscape at a past date, they can be used to help evaluate changes that have occurred over time. By compiling the information content of the historical map as a spatial data layer, this information can be used within modern technologies such as GIS to monitor changes in the environment like evolving coastal shorelines. This requires, however, care and sufficent metadata information so that the historical information can be correctly geo-rectified and merged into a digital geo-database.

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Appendix
Protocol for Georectifying and Vectorizing T-Sheets

GEORECTIFYING IMAGE TO NATIVE PROJECTION (NAD27 GEOGRAPHIC COORDINATE SYSTEM)

The following protocol is modified from NOAA's *Creating Georeferenced T-Sheets for Shoreline Vectorization: A Georeferncing Manual* to conform to version 5.0 of Blue Marble Geographic's Geographic Transformer Software.

Geographic Transformer Set Up

Locate the **Options** choice in the **Menu**. Click on **Options⇒Preferences**.

Click on the **General** tab and leave all options set at defaults.

Click on the tab to the right labeled **Reference Map Viewer**.

In the **Reference Map Coordinate Display** menu, click on the down arrow for the **Format** box. In the resulting list, highlight the **Degrees, minutes, seconds, and hemisphere** option to select the format used to enter map coordinates. Leave the **Precision** set to **2**, and make sure all three remaining boxes are checked.

In the **Reference Point List** menu, click on the down arrow for the **Format** box. In the resulting list, highlight the **Degrees, minutes, seconds, and hemisphere** option to select the format used to enter map coordinates. Leave the **Precision** set to **2**, and make sure all three remaining boxes are checked.

In the **Results Viewer** menu, click on the down arrow for the **Format** box. In the resulting list, highlight the **Degrees, minutes, seconds, and hemisphere** option to select the format used to enter map coordinates. Leave the **Precision** set to **2**, and make sure all three remaining boxes are checked.

Adding Data and Selecting Reference Points

To add the image to be georeferenced, click on the **Transform** tab.

In the first input box, under **Source Image**, select a **Source File** by click the ellipses (…).

When an image has been selected, a window labeled **Open Source Image File** will open. Navigate to a directory containing the image and add it to the Geographic Transformer GUI. The selected image will automatically be displayed in the **Source Image Viewer** window.

A Pop Up window will be displayed showing the default coordinate system. This may vary for each T-Sheet being georeferenced, and is usually noted near the scale information for a particular map. In some cases, NAD27 updated tic marks have been placed on maps created before the NAD27 standard was implemented. This coordinate system can be changed in the **Transform** tab.

The smaller overview image is on the right, and the main windows on the left will show a zoomed-in region of the area shown in a blue hatched box on the right.

The buttons on the toolbar of the **Source Image Viewer** window allow you to pan, zoom, and select control points.

A good distribution of reference points must be selected over the entire T-Sheet, and especially areas close to the shoreline. More about selecting appropriate reference points can be found in NOAA's guide for *Creating Georeferenced T-Sheets for Shoreline Vectorization: A Georeferencing Manual*.

To select a control point on the source image, click the **Select Point**, pencil icon, zoom in to an appropriate scale and click on the source image.

This will import the source image coordinates of the point you selected into the **Reference Point List** window.

Next, to assign reference coordinates for this point, enter the coordinates in the **Reference Point List** window in the following manner:

If the point you have selected corresponds to reference coordinates of:
72° 35' 00 W 41° 16' 00 N

The point is entered into the **Reference Point List** as:
72 35 00 W **East** 41 16 00 N **North**

The point can be named or numbered in the input box **Point Name.**

The point is added to the **Reference Point List** when the **Add** button is clicked.

To transform the image, a **2nd Order Polynomial** will be applied, which requires 6 control points to be selected. More than 6 control points can improve the rectifiication.

A guide for implementing the **Automatic Reference Point Selection Wizard** which allows the user to create a grid of control points is included with NOAA's guide for "Creating Georeferenced T-Sheets for Shoreline Vectorization: A Georeferncing Manual"

Once all control points have been selected, the RMS error value for the set of points shown at the bottom of the **Reference Point List** must be examined to ensure that the georeferenced product falls within the National Map Accuracy Standards according to the information below:

For maps of scale 1:5,000: RMS error must be **less than 15.6 units**
For maps of scale 1:10,000: RMS error must be **less than 7.8 units**
For maps of scale 1:20,000: RMS error must be **less than 4.0 units**
For maps of scale 1:40,000: RMS error must be **less than 2.0 units**

Individual RMS error values for each point are also shown in the **Reference Point List.** Making adjustments to the precise location of each control point and removing unnecessary control points can help to reduce the RMS error value. A plot of which

points are contributing the most error can be displayed by selecting **Window / Error Plot.**

Transforming the Image

The first step in transforming the image is to set the parameters that will be used in the transformation process, these settings will be entered in the **Transform** tab.

In the **Georeference Data** section, the **Reference File** input box can be utilized to load a previously created **Reference Point List** or the current **Reference Point List** can be saved by pressing the ellipses (...) button.

Next, in the **Georeference Data** section, the **Transform Model** is selected, as stated earlier, the **2nd Order Polynomial** model will be used.

If it was not set automatically when the **Source Image** was loaded, the **Coordinate System** must now be chosen from the drop down box. This is the native coordinate system that the original T-Sheet resides in, and all information (**Group/System/Datum**) for this coordinate system should be located on the original T-Sheet image.

Under the **Transformation Area** section, the **Computation Method** is set to **Image Extents** so that the entire image is transformed. Do not check the box for **Use a Different Coordinate System** because the coordinate system has already been defined in a previous step.

In the **Tiling Options** section, leave the **Scheme** set to **None**. Tiling allows the user to break up the image into smaller pieces which was not necessary for this project.

The last section defines the properties of the **Destination Image**. The first of the options is to set the **Destination File** by defining the name and location of the newly rectified image that will be created.

The destination **Coordinate System** is then set, which defines the system the final output will reside in. For this first approach, the same projection as the native data for the specific T-Sheet is used. The **Central Latitude** for the T-Sheet is the midpoint of the northernmost and southernmost latitude lines on the T-Sheet, and is used in computing the aspect ratio of the final image. Note that the central latitude does not have to be an actual line on the map.

The last option to set is the **Pixel Size.** The pixel size represents the destination resolution of the final product, and it is computed by taking into account the scanned image resolution and the map scale in the following manner as it is computed for this project:

Source Scale = 1:10,000.

This means 1 inch (in) = 833.333 feet (ft) because 10,000 in /(12 in/ft) = 833.333 ft.

Scanning Resolution = 1200 dpi
Source Image Resolution = (833.333 ft) / (1200 dpi) = .694 ft per pixel

Destination Resolution = (.694 ft per pixel) * (0.3048 meters per ft) = **.2115 meters per pixel**

Because extremely large files would result at this pixel size setting, **1 Meter** was used as the pixel size for this project.

The image is now ready to **Transform**. Save the transform settings in a file, which will save all of the settings that have just been entered. If any changes were made to the **Reference Point List**, the software will prompt users to save those changes also.

REPROJECTING THE TIFF FILE TO CONNECTICUT STATE PLANE NAD83 FEET

Reprojecting a TIFF file is a multi-step process in ArcGIS. The steps for this conversion are detailed here.

Convert TIFF Image to GRID

Since TIFF images cannot be directly reprojected in ArcGIS 8.3, the images must be converted to ESRI GRID format in order to perform the reprojection. This procedure can be done in ArcToolbox or ArcCatalog, but the commands listed here are the commands for ArcToolbox.

In ArcToolbox, under **Conversion Tools** select **Import to Raster**, then **Image to Grid**. For the **Input Image**, navigate to the transformed TIFF image created in the first step. **Band** should be set to **All**, even though there is only one band. Choose **Nearest Neighbor** as the **Resampling Method** and under **Optimize for use with:** select **ArcScan.** Next choose a destination filename and path, and press **OK** to complete the conversion.

Defining a projection for the GRID file

Projection information after the TIFF to GRID conversion is not transferred even though it was originally defined for the TIFF image produced in the first step. For this reason, the projection for this new GRID file must be defined before further processing can continue.

In ArcToolbox, under **Data Management Tools**, **Projections**, select **Define Projection Wizard**. In the first dialog box, choose **Define a coordinate system for my data to match existing data.** In the next window, choose the GRID file that was just created, then press **Next**. In the next window, the file with the desired projection information must be chosen.

For this Method, two ARC/INFO coverages were created for matching purposes, one with the NAD27 Geographic Coordinate System defined, and one with NAD83 CT State Plane Coordinate System defined. Interactive selection of a projection for a GRID file requires manual coordinate input, so this method was avoided for the sake of simplicity.

Once the coverage with the desired projection has been chosen, click **Next**. Confirm the projection information in the next window, and press **Next** again. Then press **Finish** in the final window to define the projection.

Projecting the GRID to NAD83 CT State Plane

The next step is to reproject the newly created GRID file to NAD83 CT State Plane. In ArcToolbox, under **Data Management Tools**, **Projections**, select **Project Wizard (coverages, grids)**. In the first window, choose **Project my data to match existing data**, and press **Next**. Choose the GRID whose projection was just defined in the previous step, and press **Next**. Now choose the existing dataset to match (the coverage with NAD83 CT State Plane defined, explained above). In the next window, first specify the location of a new GRID dataset. Choose **Nearest Neighbor** as the resampling method, and leave the two boxes unchecked, and press **Next**. In the next window, confirm the information, and press **Finish.** This process may take some time.

Converting GRID to TIFF

The final step is to convert the projected GRID image back to TIFF file format in ArcToolbox. To do this, select **Conversion Tools, Export from Raster,** then select **Grid to Image**. Under **Input grid** select the grid just created, and leave all other options at their defaults. Select an **Output Image** location and press **OK**.

VECTORIZING THE SHORELINE IN THE NAD83 CONNECTICUT STATE PLANE COORDINATE SYSTEM

Vectorizing the TIFF file used a series of ArcToolbox commands

Setup

To start the vectorization process, enable the ArcScan extension and add the Toolbar for this extension. To do this, start ArcMap with a new empty map, and select **Tools** from the main menu and then choose **Options.** Check the box for the **ArcScan** extension. Next chose **View** from the main menu and then **Toolbars**, and select the **ArcScan** toolbar. Repeat this process and add the **Editor** toolbar also at this time.

In order for the ArcScan toolbar to be activated, two map items need to reside in the table of contents: A bi-level version of the rectified image created in the first step, and a new, empty shapefile in an editing session to start the vectorization.

Since the scanned, transformed T-Sheet image is a 256-bit grayscale image, the image must be converted to bi-level format. The goal is to extract only the intended line work features from the T-Sheet and leave everything else as background data.

To accomplish this, load the newly transformed TIFF image into ArcGIS from the folder specified in the previous section. Right click on this image in the table of contents and select **Properties**. From the properties window, select the **Symbology** tab. In the left panel, choose **Classified**. In the **Classification** section on the right, change the number of **Classes** in the drop down box to **2.** If the classification method is not set to **Natural Breaks** by default, click the **Classify**

button and change the classification **Method** to **Natural Breaks (Jenks)** in the drop-down box.

This will produce a bi-level image. To change the color ramp so that the line pixels are black and the other pixels are white, under **Color Ramp**, click **Symbol**. From the menu that appears, select **Flip Colors**. Then click **Apply** to close the **Layer Properties** window and apply the changes.

Next, add a new, empty shapefile to the project to start the vectorization. To do this, start ArcCatalog and navigate to the project directory. From the menu, select **File,** then **New** and choose **Shapefile** from the list of choices. In the **Create New Shapefile** dialog box, enter a **Name** for the file and from the **Feature Type** drop-down box select **Polyline** as the new feature to be created.

In the **Spatial Reference** section, select **Edit** at the bottom of the window to bring up the **Spatial Reference Properties** window. Here is it possible to define a projection for the new shapefile. Click the **Import** button because we want to use the same projection and coordinate system as the transformed image. Navigate to the transformed image and select it. The projection and coordinate system properties should now appear in the **Details** window. Click **OK** to confirm the selections and create the new shapefile.

Add this new shapefile to the ArcMap project. The ArcScan toolbar still will not be active.

The next step is to click on the **Editor** button on the Editor toolbar and select **Start Editing.** Ensure the editing **Task** is set to **Create New Feature** and the **Target** is the newly created shapefile. Because all the prerequisites for utilizing the ArcScan extension have been met, the ArcScan buttons and menus should now be enabled.

Optional Cleanup

With the ArcScan extension, it is possible to perform some simple raster cleanup operations to remove some of the speckles and blotches on the map introduced in the scanning process.

Before this is done, it is a good idea to make a backup copy of the transformed image, because the cleanup changes permanently remove features and cannot be reversed after they are confirmed. It will also be helpful when digitizing to add this unaltered version of the transformed T-Sheet to the table of contents of the ArcMap project as a reference, before classifying the image as bi-level.

To start raster cleanup, click on the **Raster Cleanup** button on the ArcScan toolbar and choose **Start Cleanup.** There are three buttons at the right side of the ArcScan toolbar. The most useful of these buttons for this project is the middle button, **Find Connected Cell Area**. When this button is clicked, a small black area on the map can be selected, which brings up a dialog box called **Select Connected Cells.** This will select all those sets of connected cells whose total area is less than the value specified under **Enter total area.** This is useful for eliminating some pixels near the Mean High Water Line that may be unnecessary. Another raster cleanup button that is useful is the leftmost button that is called **Select Connected Cells**. By pressing this, an area of pixels can be selected with the cursor. When there is an active

selection that is unnecessary or may cause error in the digitizing process, choose **Erase Connected Cells** from the **Raster Cleanup** menu.

Vectorization

The ArcScan extension enables the user to partially automate the vectorization process in two ways. The first approach is to **Generate Features** automatically from the raster after vectorization settings have been entered. For the purposes of this project, this method was not appropriate because of the nature of the T-Sheets in question. The cartographic elements on these maps are sometimes of questionable quality due to their age, and often lines have breaks and cannot be identified automatically in an efficient manner. This approach would have entailed a great deal of post processing.

The other option, the one used in this project, was to use the ArcScan extension to assist in a mostly manual vectorization process using **Vectorization Trace**, similar to a partly automated on screen digitizing process. In this manner features are only created where they are required, instead of across the entire map. Automated vectorization can still be used in areas when the T-Sheet characteristics make the method appropriate (for example, if there are areas where the Mean High Water Line is clearly defined). Complete instructions on how to use all the features of the ArcScan extension can be found in "Using ArcScan for ArcGIS" published by ESRI Press.

To start the vectorization, click the **Vectorization** button and select **Vectorization Settings.** In this dialog box the settings for the automated vectorization can be set. For this project, load a predefined settings file by clicking the **Styles** button. From the list of choices, select the **Polygons** style which most closely approximates the type of features (shorelines) we are vectorizing.

Next, from the **Vectorization** button it is possible to change the general display **Options.** From this window, the **Vectorization Method** is set to **Centerline**. The colors and preview symbols can also be changed.

To start the vectorization, click the **Vectorization Trace** button. Pan to one side of the transformed T-Sheet and zoom in to an appropriate scale. At the start of the Mean High Water Line, press the '**s**' key to suspend tracing so that the vectorization can be started, and click at the start of the shoreline. If the shoreline is clean and there are no noise pixels around the shoreline, the next click should result in an automated trace of the shoreline until the shoreline cannot be resolved any further.

In areas where the shoreline is not clearly defined, it will be necessary to press and hold the '**s**' key to suspend automated tracing. By doing this, ArcScan is forced to act as if the user were screen digitizing.

Pressing the **CTRL-z** combination performs an undo operation.

Using this combination of suspending tracing and allowing ArcScan to perform automated vector tracing in areas where it is possible, the entire shoreline for each individual T-Sheet can be vectorized. The final product is a vectorized shoreline in the native coordinate system and projection of the original T-Sheet.