



DSAS 4.0

Installation Instructions and User Guide

* updated for version 4.2



In cooperation with Innovate! Inc.
<http://www.innovateteam.com>

Himmelstoss, E.A. 2009. "DSAS 4.0 Installation Instructions and User Guide" *in*: Thielier, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan. 2009 Digital Shoreline Analysis System (DSAS) version 4.0 — An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2008-1278. *updated for version 4.2.

Contents

1	Introduction	4
1.1	Overview	4
1.2	System Requirements	5
2	Installation Prerequisites	5
2.1	Installation Steps for Digital Shoreline Analysis System 4.0	9
3	Sample data	11
4	DSAS Toolbar	12
5	Required Inputs	13
5.1	Geodatabase	13
5.1.1	Creating a new geodatabase	
5.1.2	Upgrading a preexisting geodatabase	
5.2.1	Tips for collecting shoreline data	
5.2.2	Appending shorelines	16
5.2.3	Shoreline attribute field requirements	18
5.3	Baseline	19
	Baseline attribute field requirements	19
	Baseline attribute field requirements	22
6	DSAS Workflow	24
6.1	Set Default Parameters window	26
6.1.1	Cast Transect Settings tab	26
6.1.2	Shoreline Calculation Settings tab	28
6.1.3	Metadata Settings tab	
6.1.4	Log File Output	
	Cast Transects	32
	Using Select Features Tool (baseline)	
6.2.2	Transect Feature Class Attribute Fields	
	Modifying the Transect and Baseline Feature Classes	37
6.4	Using transects from previous versions of DSAS	40
6.5	Calculating Change Statistics	41
	How to view results spatially	44
	Clipping transects to the Shoreline Change Envelope (SCE)	46
6.7	Using the Select Features Tool (shoreline)	48
7	Statistics	49
7.1	Shoreline Change Envelope (SCE)	50

7.2	Net Shoreline Movement (NSM)	51
7.3	End Point Rate (EPR)	52
7.4	Linear Regression (LRR)	53
7.5	Weighted Linear Regression (WLR)	55
7.6	Supplemental Statistics	57
7.6.1	Standard Error of the Estimate (LSE and WSE)	
7.6.2	Standard Error of the Slope with Confidence Interval (LCI and WCI)	
7.6.3	R-squared (LR2 and WR2)	
	Least Median of Squares (LMS).....	61
8	External Module Interfacing	63
8.1	Module Calc File	64
8.2	Module Info File	66
8.3	Module Input File	67
8.4	Module Output File	70
9	Metadata	71
10	References	73
11	Appendix 1 – Troubleshooting	75
12	Appendix 2 – A case study of complex shoreline data	76
12.1	Using shoreline data referenced to different proxies	76
12.2	Representing lidar shorelines as calibrated routes	76
12.3	Storing bias and uncertainty data in a table (requirements)	79
12.4	Proxy-datum bias correction (NU_ and NB_)	80
	Contact Information	81

1 Introduction

1.1 Overview

The Digital Shoreline Analysis System (DSAS) is a freely available software application that works within the Environmental Systems Research Institute (ESRI) Geographic Information System (ArcGIS) software. DSAS computes rate-of-change statistics for a time series of shoreline vector data. Version 4.2 was released in August 2010 and is compatible with ArcGIS v.9.2 and 9.3.x. It is supported on both Windows XP and Vista operating systems. If you use it, please cite the following publication and make note of the current version:

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., and Ergul, Ayhan, 2009. Digital Shoreline Analysis System (DSAS) version 4.0 — An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2008-1278. *current version 4.2

This user guide describes the system requirements, installation procedures, and necessary inputs to establish measurement locations with transects and compute rate-of-change calculations using DSAS. The DSAS software was developed in the early 1990s. Updates have focused on improving the rate-of-change statistics as well as the user interface and are designed to be compatible with the current version of ESRI ArcView software.

Updates to DSAS 4.2 include

1. A new menu option to generate a copy of the specified transect file clipped to the shoreline change envelope (SCE), or the maximum extent between all included shorelines. This feature was designed to enhance display options where longer transects indicate areas of greater movement in shoreline position.
2. DSAS now outputs a unique intersect table (with time stamp) for each statistical calculation run. Previous versions generated a single intersect table that was overwritten each time statistics were calculated.
3. The confidence interval options have been expanded. Drop-down selections now include 1-sigma, 2-sigma, and 3-sigma options. Users may also manually enter any confidence interval value (up to two decimal places).

Although the nomenclature for this software utility is based on use in a coastal environment, the DSAS application is also useful for computing rates of change for any boundary-change problem that incorporates a clearly-identified feature position at discrete times, such as glacier limits, river banks, or land use/cover boundaries.

1.2 System Requirements

Before installing the DSAS 4.2 application, ensure that your system meets the following software requirements (note that installation of these applications on your system requires administrative rights):

1. Microsoft .NET Framework 2.0.
2. ArcGIS Desktop 9.2 (with a minimum of Service Pack 2) or 9.3.
3. .NET Support Feature for ArcGIS (available on ArcGIS installation media).
4. Freely available MATLAB component runtime library utility.

2 Installation Prerequisites

Important! Before installing DSAS 4.2, the following steps should be taken:

1. Make sure that the Microsoft .NET Framework 2.0 is installed on your machine.

You should see Microsoft .NET Framework 2.0 Configuration listed in at least one of these locations:

A. Start>Control Panel>Administrative Tools

or

B. Start>Control Panel>Add/Remove Programs

Windows Vista users should note that the .NET Framework version 2.0 is not supported. Instead, Vista users should install either Microsoft .NET Framework 3.0 or Microsoft .NET Framework 3.5. Either framework version will meet the software requirements.

The .NET Framework downloads are available from the Microsoft web site www.microsoft.com/downloads:

- A. Windows XP users should search for:

.NET Framework Version 2.0 Redistributable Package (x86)

B. Windows Vista users should search for:

.NET Framework Version 3.0 or .NET Framework Version 3.5

2. Determine your ArcGIS service pack

DSAS requires a minimum of ArcGIS Desktop 9.2, Service Pack 2; however, it is recommended that you update to the most recent service pack for your version before installing DSAS. Service packs are cumulative and will include fixes for all previous patches and service packs. For example, if you are using ArcGIS Desktop 9.2 and have installed Service Pack 1 you can update to Service Pack 6 directly without installing Service Packs 2-5.

ESRI provides a utility for each version of ArcGIS (ServicePackFinder92.exe for version 9.2 and PatchFinder93.exe for version 9.3) that when run will report what service pack is currently installed on your machine. Both versions of the utility can be accessed at:

<http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.gateway>

3. Ensure that you have installed the ESRI .NET Support feature for ArcGIS

A. DSAS is a .NET application for ArcGIS. To use DSAS, you must have the .NET Support resources for ArcGIS desktop installed on your computer.

B. You can determine whether the ESRI .NET Support feature is installed on your machine by going to the default installation directory for ArcGIS (for example, C:\Program Files\arcgis) and locating the DotNet folder (**fig. 1**). Confirm that the folder contains a number of .dll files and is not empty. If this folder does not exist or is empty, the ESRI .NET support feature is not on your machine and must be installed.

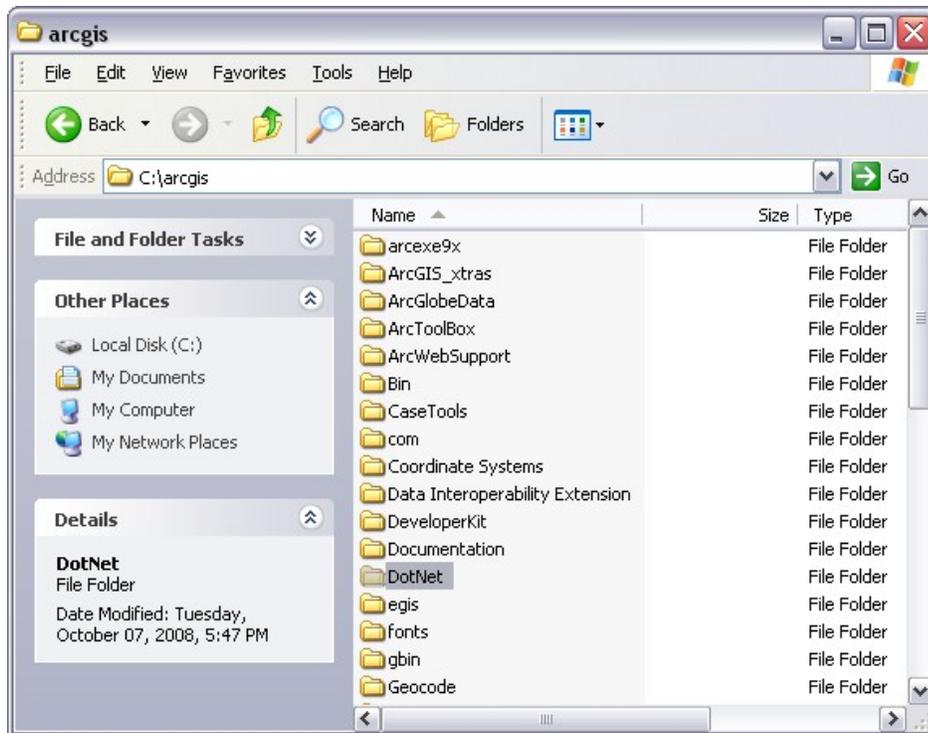


Figure 1. Location of DotNet folder which can be used to verify existence of .NET Support feature. Check to be sure the folder is not empty and actually contains .dll files.

- C. The ESRI .NET Support feature is automatically included as part of the ArcGIS installation (either 9.2 or 9.3) if Microsoft .NET Framework 2.0 or above is detected on your machine; however, if ArcGIS was installed before the Microsoft .NET Framework 2.0 was installed (see step 1 above) you will need to add the .NET Support feature from the ESRI media. The .NET Support feature setup is available on the ArcGIS DVD media in the DotNet20 folder.
- D. If you need to add the ESRI .NET Support feature, make sure you have the ESRI ArcGIS installation media on hand and have already installed Microsoft .NET Framework 2.0 (step 1). Then follow these steps:
 - a. Go to Control Panel > Add/Remove Programs > ArcGIS Desktop (**fig. 2**).

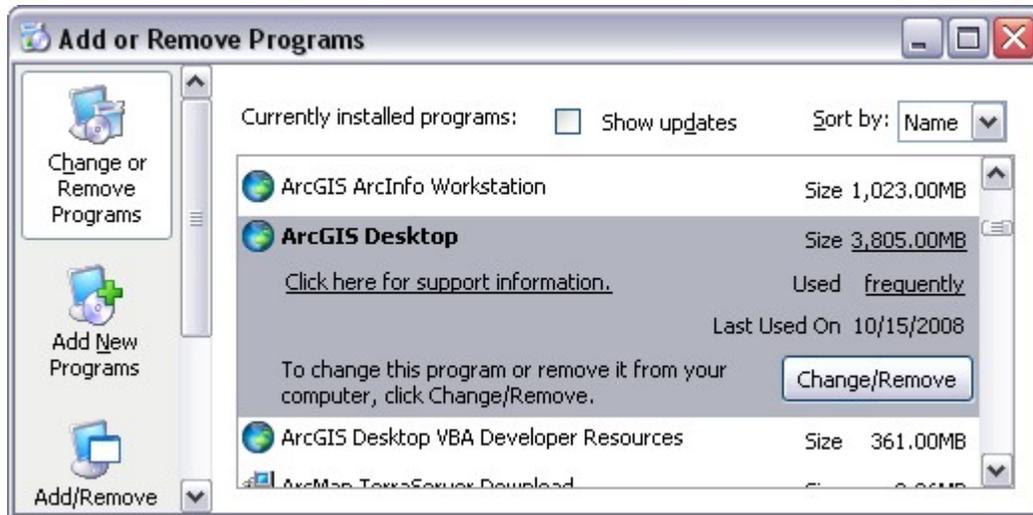


Figure 2. Locate ArcGIS and select the Change/Remove button in the Add/Remove Programs window.

- b. Click the Change/Remove button (**fig. 2**) to bring up the application maintenance dialog box.
- c. Choose Modify from the application maintenance dialog box (**fig. 3**).

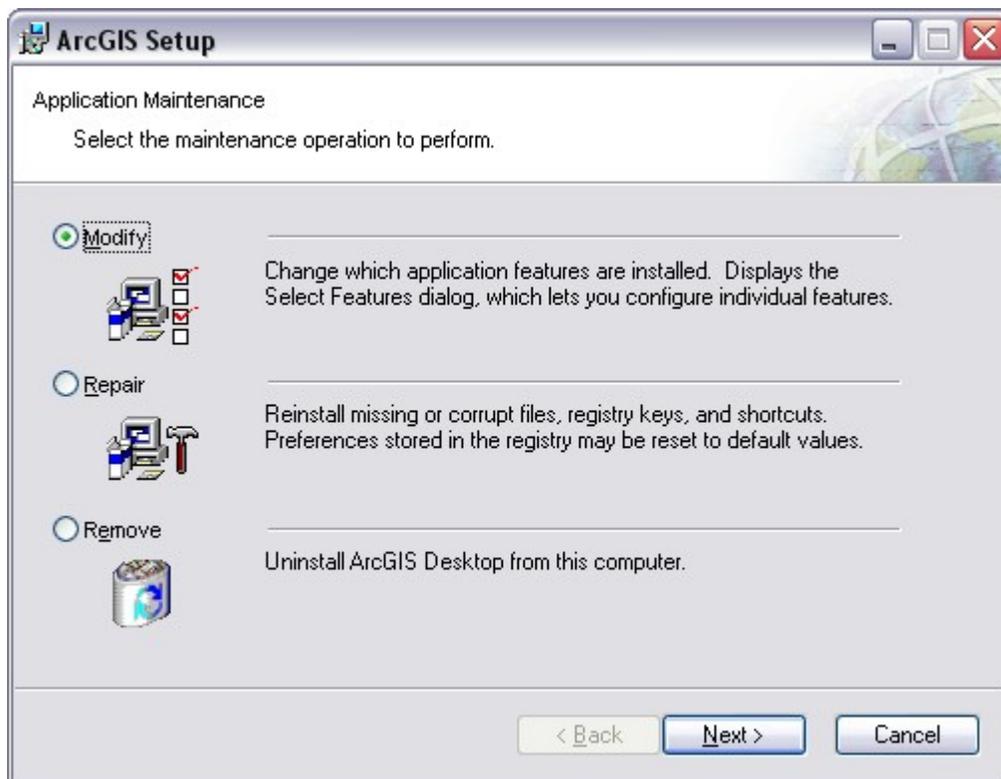


Figure 3. To add the ESRI .NET Support feature choose Modify from the list of options.

d. In the Select Feature Dialog check the .NET Support feature and install (**fig. 4**).

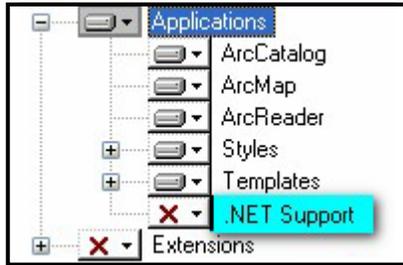


Figure 4. Location of the Select Feature Dialog Box and where to select the .NET Support for installation.

4. Install the MATLAB Component Runtime (MCR) library utility by double-clicking the MCRInstaller.exe which can be downloaded from the DSAS web site. Confirm that the MCR installation was successful by locating the directory C:\Program Files\MATLAB\MATLAB Compiler Runtime\v78.

Installation Steps for Digital Shoreline Analysis System 4.2

The application is available for download at the web site (<http://woodshole.er.usgs.gov/project-pages/dsas/>).

1. Make sure that you have **UNINSTALLED** any prior version of the Digital Shoreline Analysis System software before installing this version (DSAS 4.2).
2. Make sure that you have **CLOSED ALL ARCGIS SOFTWARE** running on your local machine.
3. Extract the .zip file to a preferred location (for example, C:\Program Files\DSAS)
4. Highlight the setup.exe application, and double-click to launch the setup wizard.
5. Choose an installation folder (the default is C:\Program Files\DSAS\Digital Shoreline Analysis System) and click Next (**fig. 5**).
6. The program should confirm that a successful installation has occurred and require you to click Close to exit.



Figure 5.

If the DSAS toolbar application is not automatically added to ArcMap, go to Tools > Customize > DSAS Toolbar (**fig. 6**).

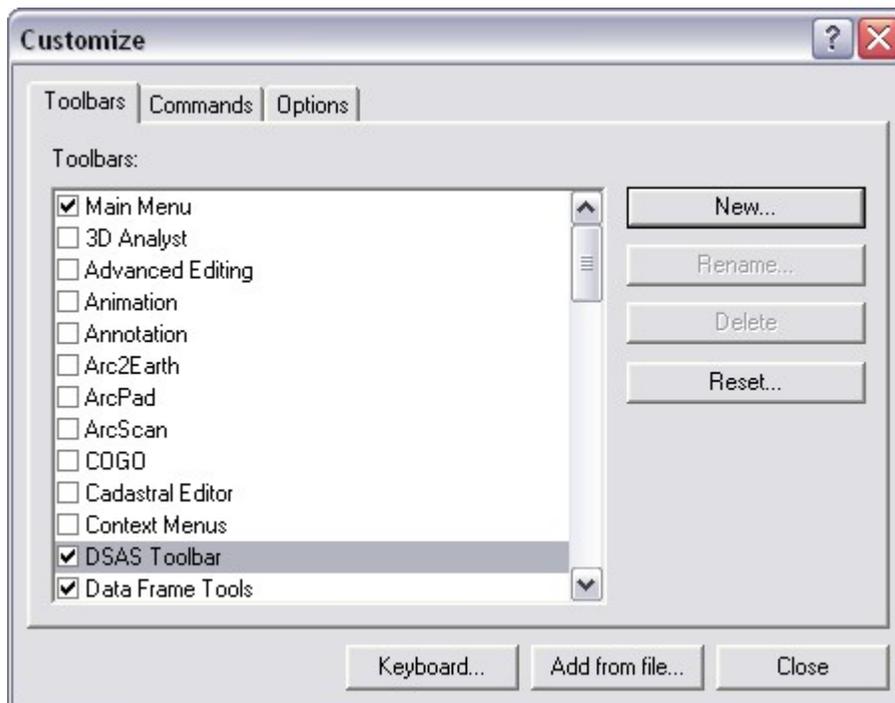


Figure 6. How to add the DSAS toolbar to your ArcMap project if it is not added automatically.

3 Sample data

A sample dataset for DSAS 4.2 is available for download on the DSAS web site (<http://pubs.usgs.gov/of/2008/1278/>). The sample data include four shoreline positions for a section of the North Carolina coast near Rodanthe along the Outer Banks; these data are a subset of data from Miller and others, 2005. The shoreline positions from 1842, 1946, and 1980 were digitized from coastal survey maps, called “T-sheets,” and mark the location of the mean high water line. The shoreline from 09/26/1997 marks the location of the tidal-based operational mean high water line and was extracted from lidar data following the techniques described in Stockdon and others, 2002, and Weber and others, 2005. The lidar data illustrate how to incorporate shoreline data that include more complex attributes into DSAS analysis. Advanced users are encouraged to review **appendix 2**, which describes these data and their use in DSAS.

The sample data also include a reference baseline from which the DSAS transects are cast. The sample data are referenced throughout the user guide and have been designed as an example to help users set up their own data for use in DSAS. The DSAS_sample_data.mdb file is distributed as an ArcGIS (v. 9.2) geodatabase (**fig. 7**) that meets the minimum software requirements for DSAS 4.2.



Figure 7. View of the sample data from ArcCatalog. The DSAS_sample_data.mdb geodatabase contains baseline and shoreline feature classes along with an example of an advanced-use shorelines_uncertainty table.

4 DSAS Toolbar

This section provides a quick reference and explanation for each button on the DSAS toolbar interface. It has been updated to reflect functionality added in version 4.2

	<p>Set/Edit default parameters specifies file names for the baseline and shoreline inputs and other settings, such as transect spacing.</p>
	<p>Cast transects generates a new (or overwrites an existing) transect feature class based on the user-specified default parameters.</p>
	<p>The drop-down menu lists all recognized transect files added to the active ArcMap project.</p>
	<p>Calculate statistics launches a dialog box populated with a selectable list of change-rate statistics to be calculated.</p>
	<p>Clip transects to SCE launches a dialog box providing users with the option to generate a copy of the specified transect file that is clipped to the shoreline change envelope (SCE) or the maximum distance between all shorelines.</p>
	<p>Launches the DSAS help feature.</p>
	<p>About DSAS provides information about the software, including the version number.</p>

5 Required Inputs

This section describes the data requirements, including file format and field attributes that are necessary for DSAS to properly recognize and compute rate-of-change statistics. It includes instruction on how to produce the required files and field elements.

5.1 Geodatabase

All DSAS input data must be managed within a personal geodatabase, which also serves as the storage location for the program-generated transect feature class and related statistical output tables. Preexisting data, such as shapefiles, can be imported as feature classes within a geodatabase in ArcCatalog. The geodatabase not only serves as a storage container for all of the data used and produced by DSAS but provides a data structure that enables the enforcement of topology, meaning that spatial relationships among the feature classes can be enforced (this is explained more fully in **section 6.3**). DSAS also requires that data be in meter units in a projected coordinate system (such as Universal Transverse Mercator or State Plane).

5.1.1 Creating a new geodatabase

Follow the steps below to create a new personal geodatabase. Once a geodatabase has been created, existing data can be imported as individual feature classes into a geodatabase within ArcCatalog. More information can be found using the keywords “importing data geodatabase” in ArcGIS Desktop Help.

1. Open ArcCatalog and navigate to the location where you want to store your data in the file tree.
2. Right-click on the folder where you want the geodatabase to be stored.
3. Navigate to New > Personal Geodatabase in the popup menu.

5.1.2 Upgrading a preexisting geodatabase

This version of DSAS (4.2) is compatible with ArcGIS 9.2 and above. Each ArcGIS version includes updates and improved geodatabase capabilities. Geodatabases created in earlier versions of ArcGIS must be upgraded to the current version. For example, a geodatabase created in ArcGIS 9.1 must be upgraded before using the data in ArcGIS 9.2, and a geodatabase created in ArcGIS 9.2 must be upgraded before using the data in ArcGIS 9.3. This can be done in ArcCatalog by right-clicking on the geodatabase, selecting Properties from the popup menu, and clicking on the Upgrade Geodatabase

button as illustrated in **figure 8** (this will also inform you of version status of the geodatabase). You may also choose to create a new geodatabase in the current version of ArcGIS and copy existing features from the preexisting geodatabase.

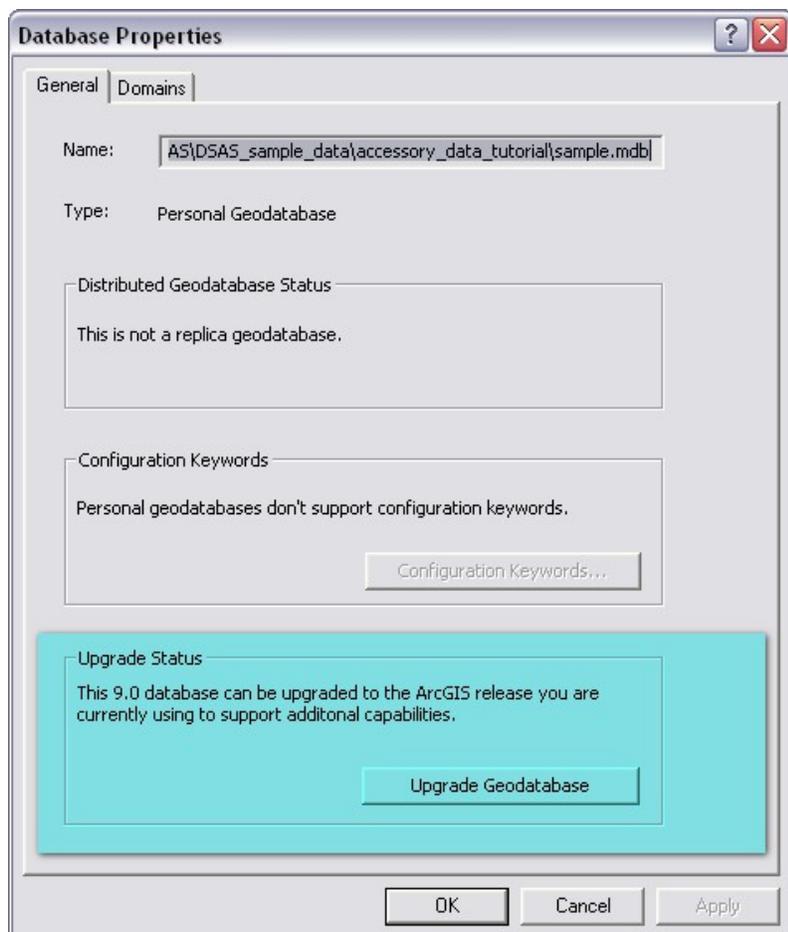


Figure 8.

, this window will provide the option to upgrade to the current version. DSAS requires that the geodatabase match the current version of ArcGIS (either 9.2 or 9.3).

This section provides guidelines on collecting shoreline data and lists the necessary attribute fields users must create in the shoreline feature class. All shoreline data must reside in a single feature class within a personal geodatabase. If the shorelines are collected as shapefiles, they must be appended to a single file and then imported into a geodatabase within ArcCatalog. DSAS also requires that the

feature class be in meter units in a projected coordinate system and meet the attribute field requirements described in **section 5.3.2** below.

Tips for collecting shoreline data

Shoreline positions can reference several different features such as the vegetation line, the high water line, the low water line, or the wet/dry line. They can be digitized from a variety of sources (for example, satellite imagery, digital orthophotos, historical coastal-survey maps), collected by global-positioning-system field surveys, or extracted from lidar surveys. It is strongly recommended that initial data-preparation steps be taken to reference all shoreline vectors to the same feature (for example, mean high water) before using DSAS to compute change statistics. See **appendix 2** for one example of how to reconcile horizontal offsets between shorelines.

Each shoreline vector represents a specific position in time and must be assigned a date in the shoreline feature-class attribute table. The measurement transects that are cast by DSAS from the baseline will intersect the shoreline vectors. The points of intersection provide location and time information used to calculate rates of change. The distances from the baseline to each intersection point along a transect (**fig. 9**) are used to compute the selected statistics.

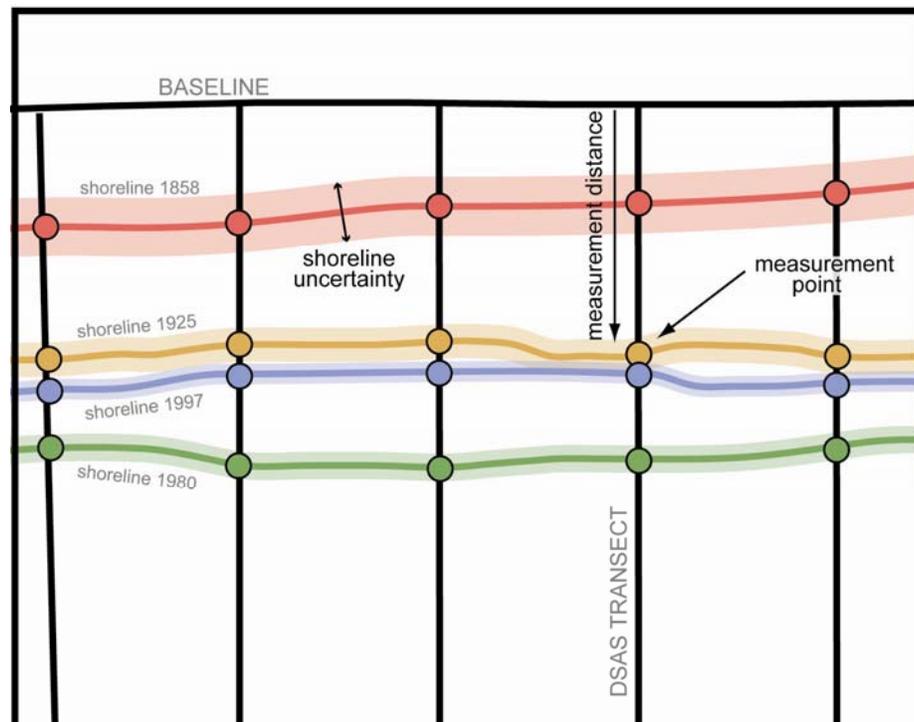


Figure 9

The calculated rates of change provided by DSAS are only as reliable as the shoreline data. To better quantify the statistical reliability of the computed rates, users must account for measurement and sampling errors when compiling each shoreline position (Anders and Byrnes, 1991; Crowell and others, 1991; Thieler and Danforth 1994; and Moore 2000). Users have the option of specifying for each shoreline an overall uncertainty value, which should account for both positional and measurement uncertainties. Refer to Morton and others, 2004; Morton and Miller, 2005; Hapke and others, 2006; and Hapke and Reid, 2007 for examples of how to calculate an overall shoreline uncertainty. The shoreline uncertainty will be incorporated into the calculations for the standard error, correlation coefficient, and confidence intervals, which are provided for the simple and weighted linear regression methods. For any shoreline vectors assigned a value of zero or null, DSAS will use the value specified by the user in the Set Default parameters window. Please refer to **section 6.1.2** for more information.

5.2.2 Appending shorelines

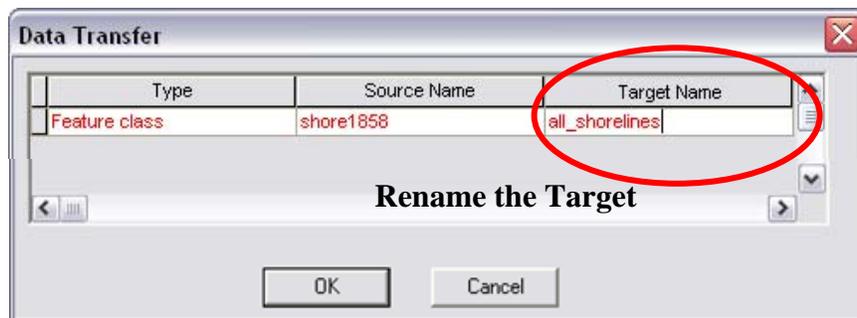
All shoreline positions that are to be used in the change-rate analysis must reside in a single feature class in the geodatabase. Once the shoreline data have been combined, the selection tools in ArcMap can be used to calculate change statistics on subsets of the entire dataset. See **section 6.7** for more information. The steps below describe how to append multiple feature classes into a single feature class in a geodatabase.

1. Confirm that all shoreline files have the same spatial reference and that the required shoreline attribute fields have been created and populated with data. For example, use caution when combining shorelines if the date field is not complete.
2. In order to append all input shorelines to a single existing file, the target file must already exist. Make a copy of the file to which you wish to append all other shoreline data (**fig. 10**) and rename the copy to indicate that it will contain the combined shorelines (**fig. 11**).



Figure 10

These actions will generate the window depicted in **figure 11**.



. The Data Transfer window will appear once the copied feature class has been pasted into the geodatabase. Choose a Target Name to indicate that this copy will represent the feature class to which all other shoreline data will be appended.

3. Open the Append tool from ArcToolbox (Data Management Tools > General > Append).
4. Add all of the shoreline feature classes (except for the copied shoreline file that you are appending to) to the input features list in the Append window. This tool can be used on feature

classes in a geodatabase as illustrated but can also be used to append data from multiple shapefiles.

5. Designate the copied dataset (**fig. 11**) as the target.

DSAS also requires that the feature class be in meter units in a projected coordinate system (for more information, please refer to the ArcGIS Desktop Help: About Projected Coordinate Systems) and have the following attribute fields:

Shoreline attribute field requirements

Field name	Data type		
OBJECTID	Object ID	Auto-generated	
SHAPE	Geometry	Auto-generated	
SHAPE_Length	Double	Auto-generated	
DATE_	Text	User-created	Length = 10 or
			Length = 22
UNCERTAINTY	Any numeric field	User- created	

DATE_	<p>This field is required but not name-specific (meaning you can use something other than “Date_” as the field name). A length of 10 is used for shoreline change spanning days, months or years, and dates are set up as mm/dd/yyyy. In the sample data provided, the default when month and day are unknown is July 1st (07/01).</p> <p>A length of 22 is used for shoreline data spanning different hours within the same day and will have dates set up as mm/dd/yyyy hh:mm:ss (using either 24-hour time or AM/PM).</p>
UNCERTAINTY	<p>This field is required but not name-specific (meaning you can use something other than “Uncertainty” as the field name). The calculated rates of change provided by DSAS are only as reliable as the measurement and sampling errors that the user must account for when compiling each shoreline position (Anders and Byrnes, 1991; Crowell and others, 1991; Thieler and Danforth, 1994; and Moore, 2000). Different measurement uncertainties can be provided for each shoreline segment. The uncertainty value should ideally account both for positional uncertainties associated with natural influences over the shoreline position (wind, waves, tides) and measurement uncertainties (for example, digitization or global-positioning-system errors). For any shoreline vectors assigned a value of zero or null, DSAS will use the value specified by the user in the Set Default parameters window (described in section 6.1.2 below).</p>

5.3 Baseline

This section provides guidelines on proper baseline construction and lists the necessary attribute fields users must create within the baseline feature class. DSAS uses a measurement baseline method (Leatherman and Clow, 1983) to calculate rate-of-change statistics for a time series of shorelines. The baseline is constructed by the user and serves as the starting point for all transects cast by the DSAS application. The transects intersect each shoreline at the measurement points used to calculate shoreline-change rates.

Checklist of baseline requirements

1. Must be a feature class within a personal geodatabase.
2. Must be in a projected coordinate system in meter units.
3. May consist of a single line or be a collection of segments.
4. Each baseline segment must be placed entirely onshore or offshore with respect to the shorelines.
5. Must meet the attribute field requirements described in **section 5.3.2** below.

5.3.1 Tips for constructing a baseline

The baseline should be established adjacent to the series of shoreline positions. Transects will be cast perpendicular to this baseline (at a user-defined spacing) and intersect the shorelines to establish measurement points. The orientation of the transect through the shorelines is highly dependent on the position of the baseline (**fig. 12**). Users must consider the appropriate scale at which the baseline should conform to changes in the combined orientation of the shoreline positions. The recommended position for transects is perpendicular to the general trend of the shorelines so that shoreline change rates describe the area immediately seaward of the current shoreline.

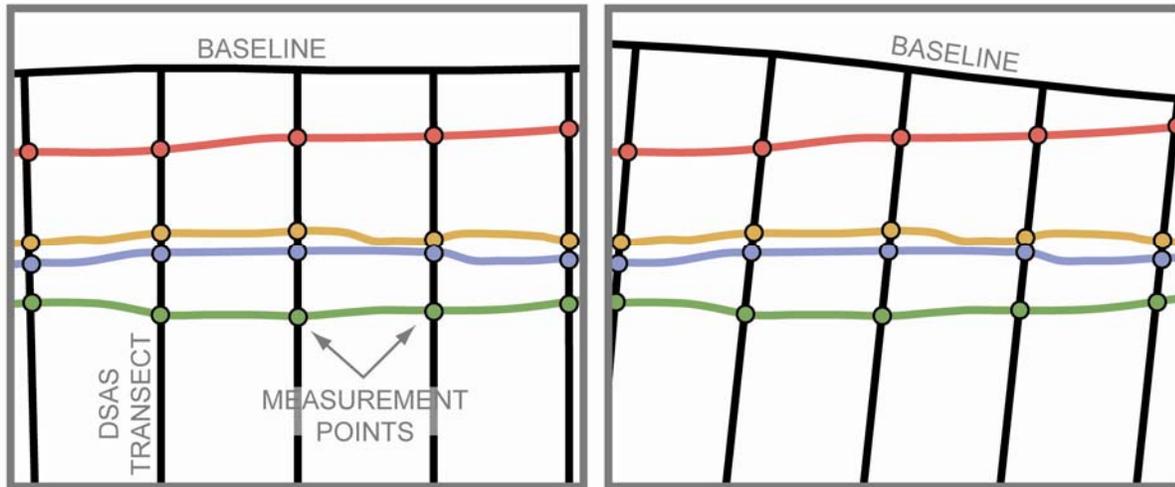


Figure 12.

There are three ways to create a baseline:

1. Start with a new feature class.
2. Buffer an existing shoreline.
3. Use a preexisting baseline.

Approach one: Start with a new feature class

Create a new personal geodatabase in ArcCatalog by right-clicking on the destination folder in the file tree and choosing New > Personal Geodatabase. Once you have a geodatabase, right-click on it and choose New > Feature class. Provide a name (for example, baseline) and choose Line Features from the dropdown menu under Type of features stored in this feature class. Click the Next button and define the coordinate system. Note: DSAS requires data to be in a projected coordinate system using meter units.

Once your baseline feature class is created, you can add it to an ArcMap project. Begin an edit session with the target being set to the new baseline feature class. Manually draw and edit the line using standard ArcMap editor tools. Refer to the ArcGIS Desktop Help menu for further instructions; you can enter “lines,” “vertices,” or “moving features” as keywords.

Approach two: Buffer an existing shoreline

Generate a baseline from an offset of an existing shoreline. Select one of the shoreline segments. The most landward, if onshore, or most seaward, if offshore, will often work best. Specify a distance that will place the resulting buffer entirely landward or seaward of all other shoreline positions. Refer to the ArcGIS Desktop Help menu for more detailed information on how to (1) create a buffer and isolate it in a separate annotation group from the shoreline feature class, (2) convert the polygon buffer to a polyline, and (3) split and remove the unwanted segments. Suggested keywords include: “buffering selected graphics,” “copying features,” “splitting features,” and “polygon to line.”

Approach three: Use a preexisting baseline

DSAS will recognize baselines created for use in previous versions as long as the feature class meets the field requirements described in **section 5.3.2**. The baseline may be constructed landward or seaward of the shorelines, but each baseline segment must be placed with all shorelines to one side (**fig. 13**). The baseline location (onshore or offshore) with respect to the shorelines is set by the user in the default parameters (**section 6.1.1**). DSAS requires that the proper attributes be set for each baseline segment to express rates of change as negative (erosion) and positive (accretion) values.

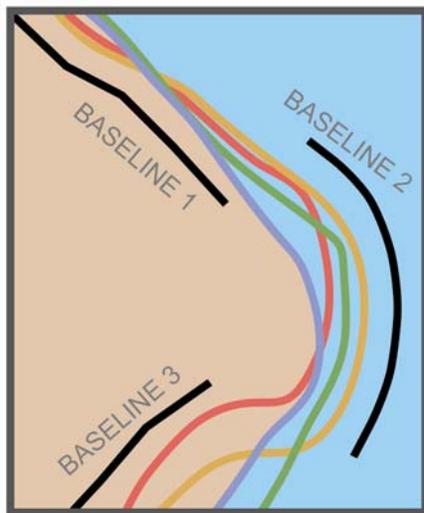


Figure 13.

5.3.2 Baseline attribute field requirements

The attribute field requirements for the baseline provide necessary information to DSAS about the alongshore order of transects as well as the location of the baseline with respect to the shorelines (onshore or offshore). This information is incorporated into the calculations so that rate-of-change statistics properly denote erosion as negative and accretion as positive.

Field name	Data type		
OBJECTID	Object ID	Auto-generated	Required
SHAPE (alias: Shape)	Geometry	Auto-generated	Required
SHAPE_Length (alias: Shape_Leng)	Double	Auto-generated	Required
ID	Long Integer	User-created	Required
Group	Long Integer	User-created	Optional
OFFshore	Short Integer	User-created	Optional
CastDir	Short Integer	User-created	Optional

ID	This field is required by DSAS and the name is specific. DSAS uses this value to determine the ordering sequence of transects when the baseline feature class contains multiple segments. If you create this attribute field prior to drawing baseline segments, the ID value defaults to zero. You must edit the attribute table and designate a unique ID value for each segment of the baseline. DSAS will not cast transects along baseline segments where the ID value is zero.
Group	This optional field can be used for data-management purposes to aggregate transects on the basis of physical variations alongshore (for example, tidal inlets, change in coastal type, or hard stabilization features). Providing a group value will not affect any of the change statistics provided within DSAS, but if used, a group field will be added to the transect feature class to facilitate later sorting and analysis of the data.
OFFshore	This field is required if a combination of onshore and offshore baselines is used. The name of this field is specific, meaning that the field must be called OFFshore and is case-sensitive. A value of “0” indicates that the baseline segment is onshore or landward of the input shorelines. A value of “1” indicates that the baseline is offshore or seaward of the input shorelines.
CastDir	This field is required in conjunction with OFFshore. The name of this field is specific, meaning the field must be called CastDir, and case sensitive. A value of “0” will result in transects being cast to the left of the baseline on the basis of the segment flow (flow from the start vertex of the line segment to the last vertex that the ends line segment). Similarly, a value of 1 will result in transects being cast towards the right of the baseline on the basis of the flow direction (fig. 14).

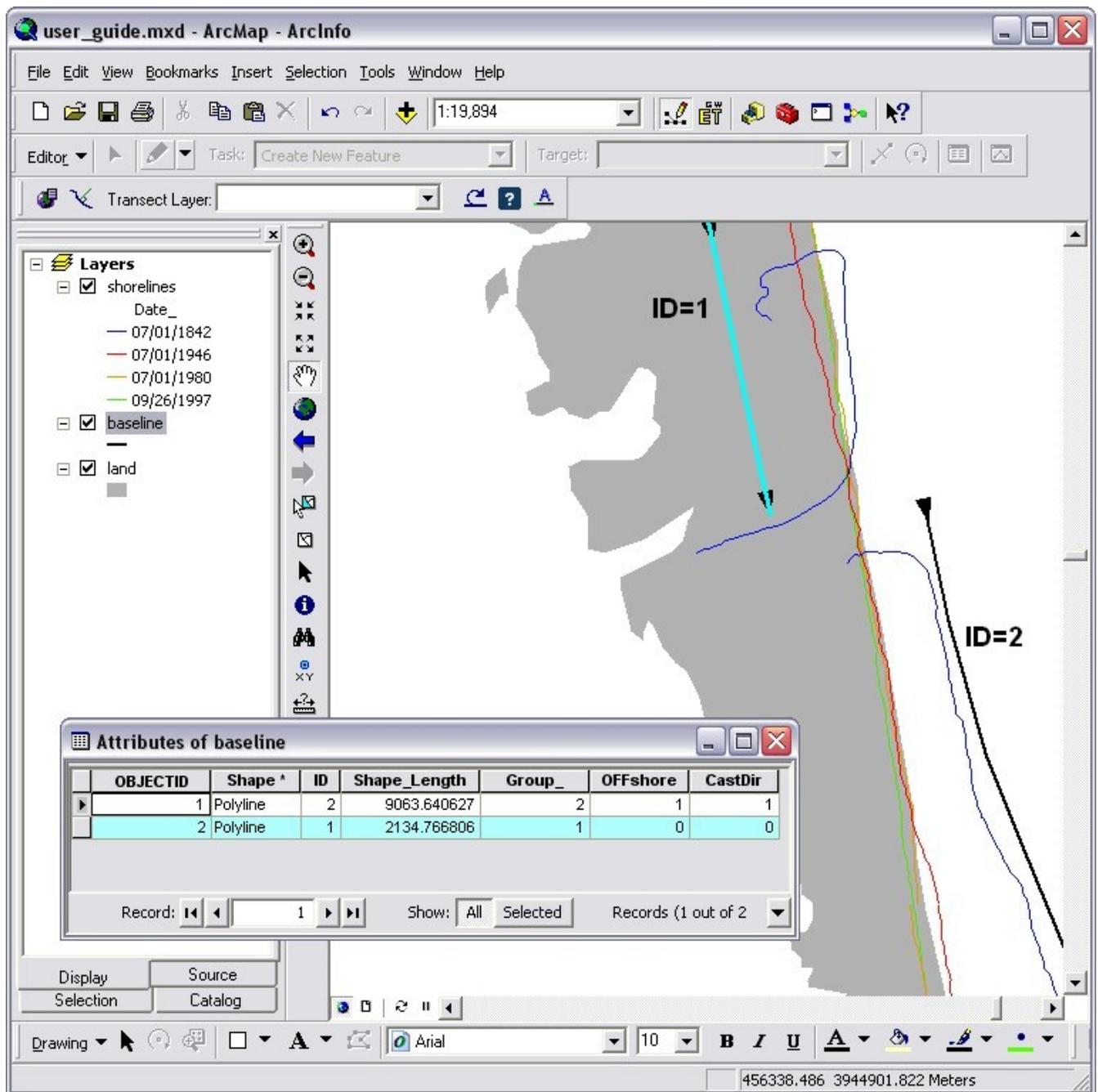


Figure 14

(ID=1) the other offshore or seaward of the shorelines (ID=2). The arrows indicate the direction of “flow” of the baseline, pointing towards the end of the line. When transects are cast, they will begin at the baseline designated “ID=1” and continue in the sequential order of baseline ID numbers.

6 DSAS Workflow

Once the required geodatabase and input-feature classes have been created or imported from shapefiles and all necessary feature classes have been added and properly attributed, the DSAS Application can be used within ArcMap to establish transect locations and calculate change statistics. **Figure 15** shows a typical DSAS workflow.

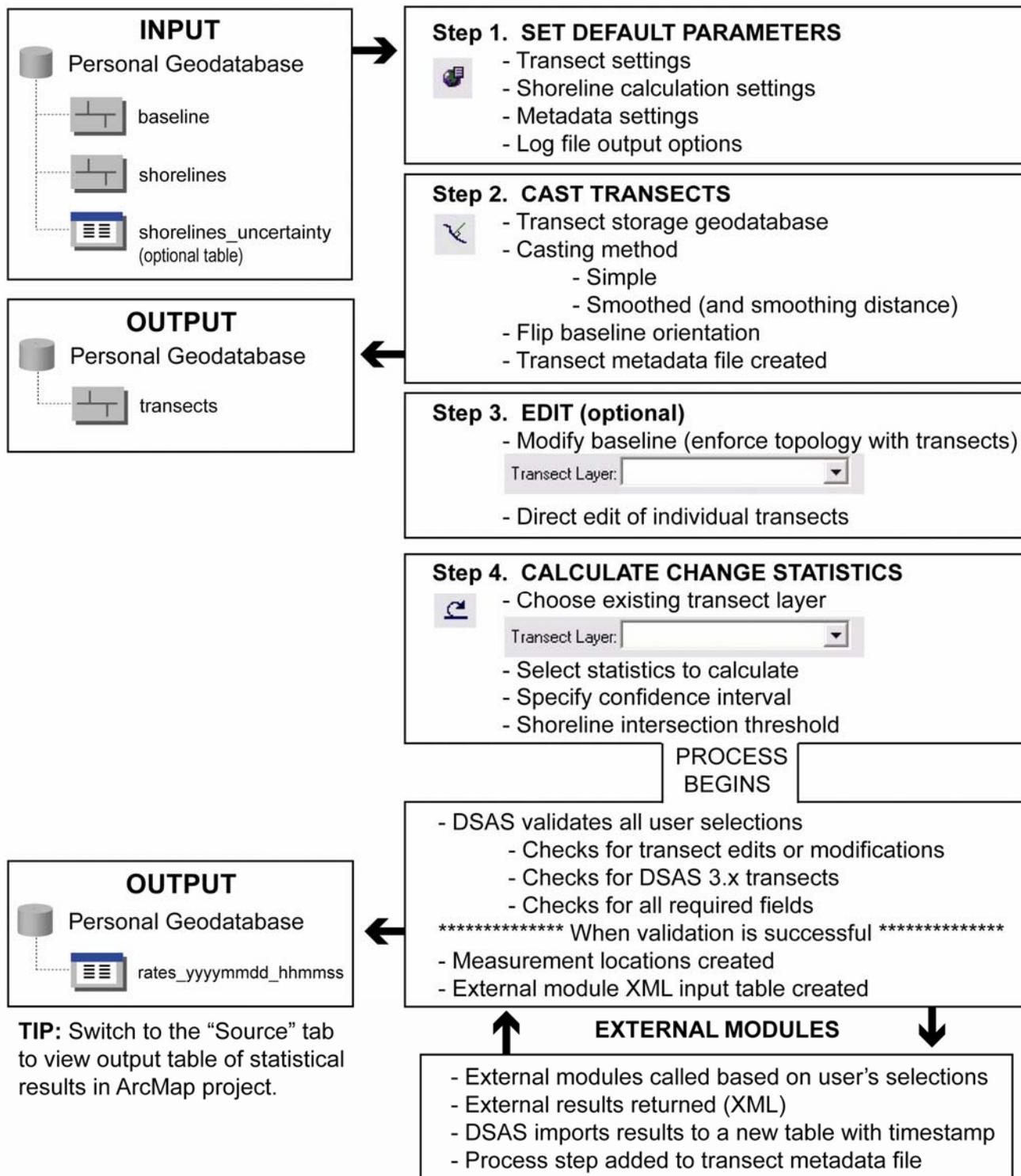


Figure 15.

6.1 Set Default Parameters window

Begin the transect-generation process by selecting your preferred default settings in the Set Default Parameters window. This window can be accessed from the DSAS toolbar (**fig. 16**) and contains three tabs: (1) Cast Transect Settings, (2) Shoreline Calculation Settings, and (3) Metadata Settings.



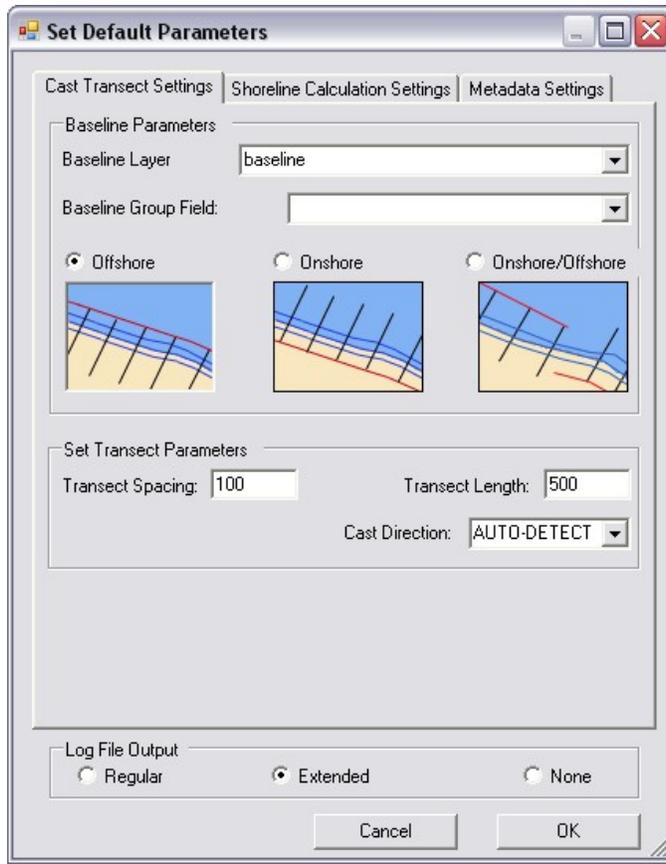
Figure 16

6.1.1 Cast Transect Settings tab

The Cast Transect Settings tab (**fig. 17**) is one of the three components of the default parameters. These settings manage the placement, length, and spacing of the transects used to establish measurement points for rate calculations. The available options are described below.

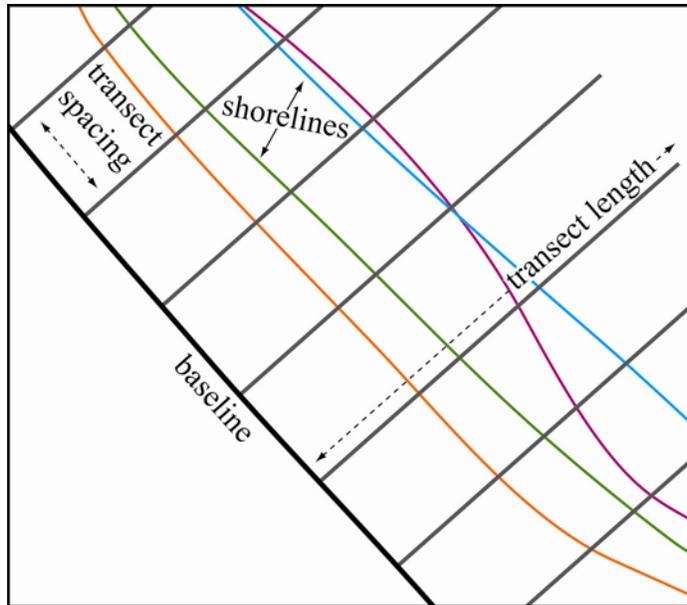
Baseline Parameters

- **Baseline layer:** Select the baseline layer to be used (for example, the “baseline” feature class in the sample data). It is one of the required input feature classes within the geodatabase.
- **Baseline group field:** This is an optional field the user may add to the baseline feature class. It can be used as a data-management field to separate transects based on physical variations alongshore (for example, at inlet openings). If no value is specified, DSAS will assign all transects a group value of zero. Group field values will not affect any of the change statistics provided in DSAS.
- **Baseline location:** There are three options to choose from: (1) onshore, (2) offshore, or (3) onshore/offshore combination. Choosing onshore/offshore will require the additional “OFFShore” and “CastDIR” fields described in **section 5.2.2**.



Set Transect Parameters

- **Transect Spacing:** Enter the desired spacing distance in meters between transects along the baseline.
- **Transect Length:** The length of each transect. Users can use the measure tool in ArcMap to determine the minimum length needed for a transect to extend from the baseline to the farthest shoreline.
- **Cast Direction:** By default, DSAS is set to auto-detect the direction by trying to cast transects along both sides of the first baseline segment until a shoreline intersection is found. If a cast direction is specified, DSAS will orient right and left based on the flow of the first baseline segment (start vertex to end vertex; see **section 5.3.2** and **figure 14** for more information). Note that this is not applicable when the onshore/offshore baseline option is used.

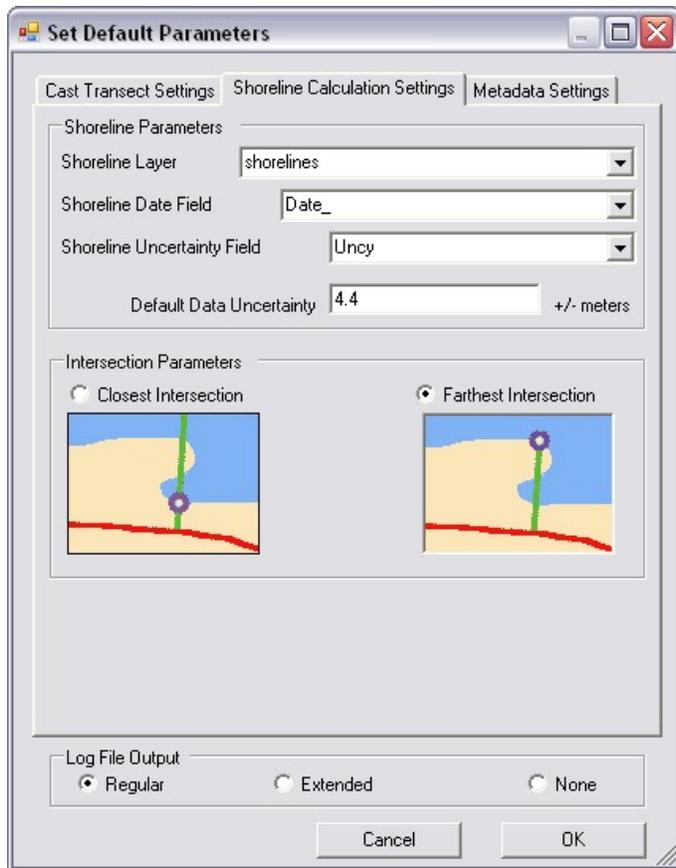


User-specified output parameters include transect spacing and transect length.

The Shoreline Calculation Settings tab (**fig. 19**) is one of the three components of the default parameters. These settings specify the attribute fields containing the date and shoreline uncertainty values. The available options are described below.

Shoreline Parameters

- **Shoreline Layer:** Specify the shoreline layer to be used. All shorelines must reside in a single feature class. Individual shorelines can be selected from this feature class to compute shoreline rates-of-change for a subset of the whole dataset. See **section 6.7** for more information.
- **Date Field:** Specify the field that stores date information. Field requirements are described in **section 5.3.3**.
- **Uncertainty Field:** Select the field storing the positional/measurement uncertainty value.
- **Default Data Uncertainty:** Choose a default uncertainty for any shoreline segments that do not have a value entered in the designated **Uncertainty Field**.



Screenshot showing the DSAS Set Default

Intersection Parameters

- **Closest Intersection:** Choosing closest intersection instructs DSAS to use the first transect/shoreline measurement location when calculating change statistics.
- **Farthest Intersection:** Choosing farthest intersection instructs DSAS to use the last transect/shoreline measurement location when calculating change statistics.

Metadata Settings tab

DSAS automatically generates FGDC-compliant metadata with minimal user input for the transect feature class. Metadata generated by DSAS is structured to meet the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) v. 2.0. The metadata record contains standardized data elements as well as a description of the Process Steps performed by DSAS to generate the transect feature class and compute change- rate statistics. The Metadata Settings tab (**Figure 20**) minimizes the amount of input needed from users by restricting it to standard data

elements (for example, Abstract, Purpose, Contact Information) that are often specific to organizational users. Metadata is an important component of data integrity and maintenance. Capturing metadata in a format that meets accepted standards facilitates data distribution, enables replication of work, and provides automatic recordkeeping of the default settings and calculation parameters used when generating the transect feature class or computing rate-of-change data.

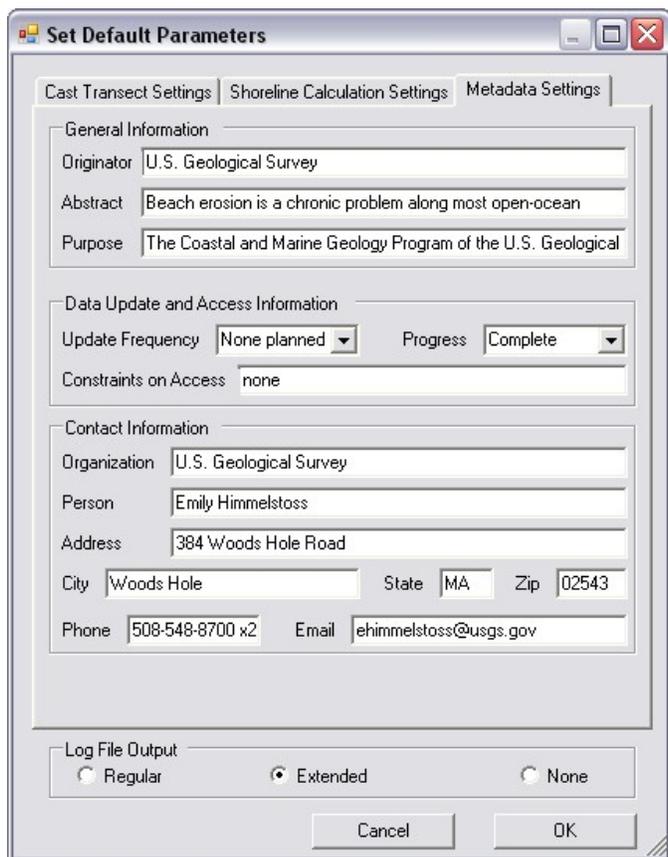


Figure 20.

The metadata file is written in XML format to the same geodatabase as the transect feature class. DSAS captures all of the variables defined by the user in the three tabs of the Set Default Parameters window on the DSAS Toolbar and automatically adds the bounding coordinates, spatial reference information, and attribute definitions. Several of the user-specific fields under the Metadata Settings tab of the Set Default Parameters window require input for DSAS to construct a complete metadata file that meets the FGDC CSDGM standard. Once a user has entered this information, DSAS will retain it for all future uses. There are no restrictions on the metadata record after it is generated, so users may modify the existing file by using a metadata editor of their choice.

The metadata record will be compliant with the FGDC CSDGM v. 2.0 content standard only if the user provides information for all fields under the Metadata Settings tab. For more information on the content standard, please visit <http://www.fgdc.gov/metadata>.

General Information

- **Originator:** The individual or organization responsible for creation of the dataset.
- **Abstract:** Provides background information on the project and study area.
- **Purpose:** A general description of the shoreline dataset and the intended uses.

Data Update and Access Information

- **Update Frequency:** Select from dropdown options how often transects will be updated.
- **Progress:** Choose from dropdown descriptions the appropriate status of the transect dataset.
- **Constraints on access:** Describe any restrictions or legal prerequisites for using the data.

Contact Information

- **Organization:** The name of the organization responsible for the data.
- **Person:** The individual within the organization who is using DSAS to cast transects.
- **Address:** Contact information for the organization and/or individual.

6.1.4 Log File Output

At the bottom of the DSAS Set Default Parameters window is an option to generate a log file (figs. 17, 19 and 20). When the DSAS application is used to create a new transect file or to calculate change statistics, a suite of behind-the-scenes data-processing steps take place. These process steps can be written to a log file for bookkeeping or troubleshooting purposes. The log file is saved to `C:\temp\DSAS_log.txt` and is cleared every time ArcMap is opened.

- **Regular:** Includes basic information about each process step. Useful for bookkeeping purposes.
- **Extended:** Includes more detailed information about each process step. Useful for troubleshooting purposes.
- **None:** No log file will be generated.

Cancel: Discards any information entered, and closes the Set Default Parameters window.

OK: Sets the entered information as the default parameters.

6.2 Cast Transects

In previous versions of DSAS, casting transects and computing rates composed a single process step. The transect attribute table was used as the output location for computed statistics. In DSAS 4.0, casting transects and calculating rates are separate process steps. This reduces the processing time for the construction of the transect feature class and enables users to preview and, if desired, edit the transect or baseline positions before proceeding to the rate-calculation process.

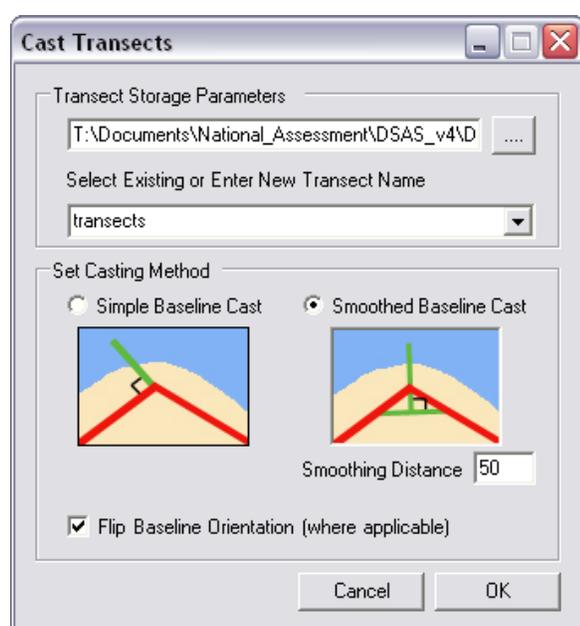


Figure 21.

Transect Storage Parameters

- **Geodatabase:** DSAS will automatically select the geodatabase where the input feature classes (baseline and shoreline) are stored (**fig. 21**). The user may browse to a different geodatabase to save the measurement transects if desired. Note that your geodatabase must match the version of ArcGIS you are using. This can be done in ArcCatalog by right-clicking on the geodatabase and selecting Properties. Under the General tab, confirm the Upgrade Status of the geodatabase at the bottom. If the geodatabase needs to be upgraded, the Upgrade Geodatabase button will be accessible. See **section 5.1** for more information on geodatabases.

- **Transect Name:** A preexisting set of transects can be selected if it has been added to the ArcMap project. It will appear as a selectable option in the dropdown menu. A new transect feature class can be created by entering a name for the file (ESRI conventions do not allow a feature class filename to begin with a number). Note that if a preexisting transect layer is selected, DSAS will prompt you before overwriting any existing data.

Set Casting Method

- **Simple Baseline Cast:** Each simple transect is cast at a 90-degree angle from the baseline segment at which it originates. Transects are generated at user-specified intervals along the baselines.
- **Smoothed Baseline Cast:** This option is used to orient transects along curved sections of baseline. A supplemental baseline is temporarily created to determine the orientation of the measurement transect (**fig. 22**).

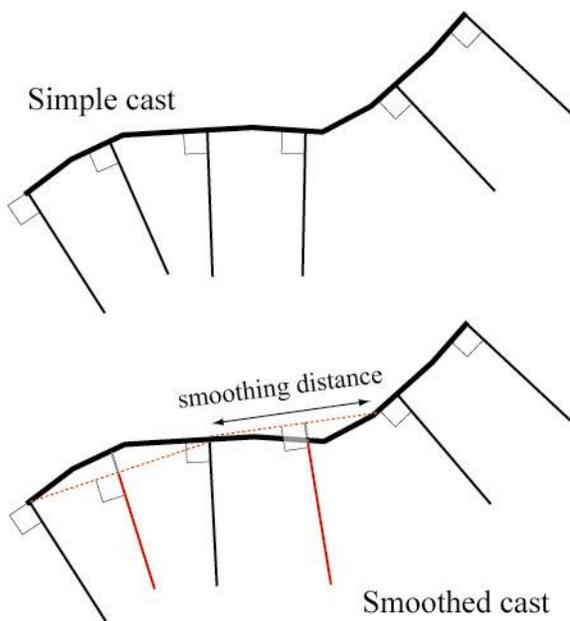


Figure 22.

- **Smoothing Distance:** The specified length of a supplemental baseline, with the transect location at the midpoint. The user-specified smoothing value creates a straighter orthogonal reference for casting transects. Larger values result in a longer reference line and produce more uniform transect orientations. Instead of transects fanning around a

- Flip Baseline Orientation:** DSAS creates transects sequentially along each segment of baseline (starting with baseline ID=1). Each baseline segment has a starting-point vertex and an ending-point vertex that describe the order in which the line segments were drawn. In some cases, sequential baseline segments may have been digitized in opposite directions alongshore. Previous versions of DSAS required the user to flip individual baseline segments so that the flow was in one direction to ensure that transects were numbered in the desired sequential order. Checking this box allows DSAS to automate that process (**fig. 23**). Transect casting order will be determined by the direction described as “start to finish” for the baseline segment with an ID=1.

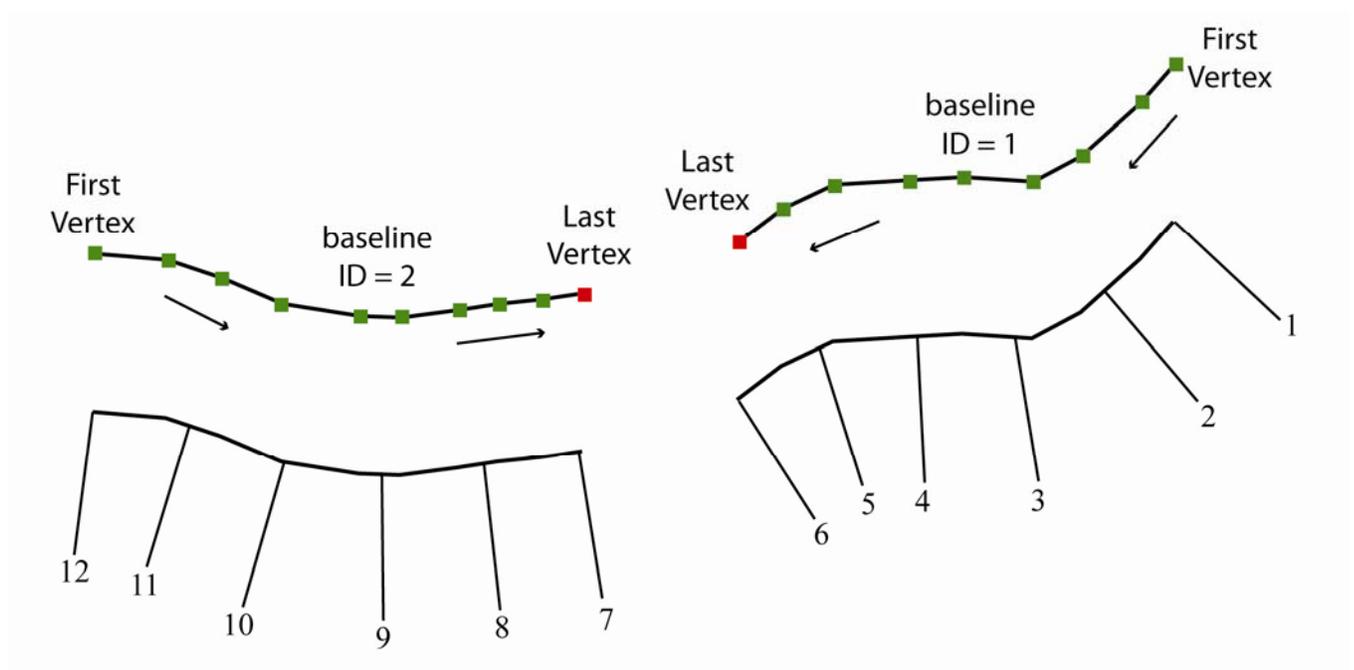


Figure 23

labelled “Flip Baseline Orientation,” the resulting TransOrder numbering sequence would be as shown above. Baseline ID=2 was automatically flipped to match baseline ID=1; otherwise, transect numbering for the second baseline would have begun with 7 at the leftmost vertex of baseline ID=2 (that is, at vertex 12 above), and the values would have increased from left to right.

Using Select Features Tool (baseline)

When a specific baseline feature is selected, DSAS will ignore all unselected baseline features when casting transects (**fig. 24**).

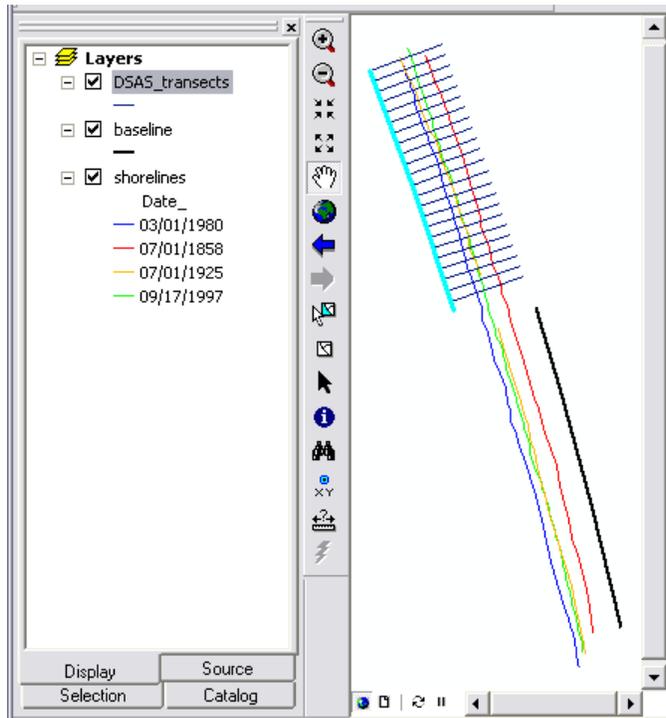


Figure 24.

6.2.2 Transect Feature Class Attribute Fields

DSAS will generate a new set of measurement transects based on the settings specified by the user in the Set Default Parameters window. Before casting transects, DSAS will perform a check on selected defaults to ensure that the user has selected all required elements and that those selected will not result in a program error. New transects are created by DSAS at user-specified intervals starting from the baseline. If a preexisting transect feature class is selected, the user will be warned that the existing file will be overwritten.

The attribute fields generated for the transect feature class by DSAS are described in the table below:

Field name	Data type	Field purpose
OBJECTID (aliases: object identifier, OID, or FID)	Object ID	The object identification field is automatically created and maintained by ArcGIS. It establishes a unique ID for each row in the attribute table. This number is used by DSAS to relate all shoreline-change result tables with the transects. Depending on the way in which your file was created, the field name may be called OID or FID.
SHAPE (alias: Shape)	Geometry	The geometry field is automatically created and maintained by ArcGIS. It provides a definition of the feature type (point, line, polygon).
BaselineID	Long Integer	Values in this field are assigned by DSAS to identify the baseline segment used to generate the measurement transect. Baseline segments assigned an ID = 0 are ignored by DSAS and no transects will be cast along those line segments. See section 5.3.2 for more information.
Group	Long Integer	Values in this field assigned by DSAS are based on input by user for grouping transects. Groups are assigned by DSAS by using the following logic: if a user selects a baseline-group field as input, then DSAS will use the group ID provided by the user for assigning to output transects; if user does not select a baseline-group field as input, then DSAS will assign all transects a group value of zero. This field is used to aggregate shoreline data and the resulting measurement locations established by the transects into groups. Please refer to the baseline field requirements in section 5.3.2 for more information.
TransOrder	Long Integer	Assigned by DSAS on the basis of transect order along the baseline or baselines. This field provides the user with a method to sort transect data from the start of the baseline segment with an ID=1 and increment sequentially to the end of the final baseline segment (fig. 23).
Proctime	Text	DSAS automatically records the date and time each transect was processed.
Autogen	Text	Indicates whether or not a transect was automatically created by DSAS (1= transect was auto-generated by DSAS; 0=transect was added by user).
StartX	Double	Used by DSAS to record the X coordinate of the beginning of the transect.
StartY	Double	Used by DSAS to record the Y coordinate of the beginning of the transect.

EndX	Double	Used by DSAS to record the X coordinate of the end of the transect.
EndY	Double	Used by DSAS to record the Y coordinate of the end of the transect.
Azimuth	Double	Used to record the azimuth of the transect measured in degrees clockwise from north.

6.3 Modifying the Transect and Baseline Feature Classes

Rate-of-change statistics are usually calculated to describe the behavior of the shoreline through time for the area directly seaward of the current shoreline position. It is therefore important to place each transect so that it intersects the shorelines at the appropriate location for rate calculations to be made. It is often difficult to visualize how transects will intersect the shorelines in advance, based on the position of the user-constructed baseline. Once transects are cast, it is useful to perform a visual assessment of the transect locations, because they establish the shoreline intersection points used for statistical computations. After the transect feature class has been created, the user can modify transect locations by using standard editing options in ArcMap. DSAS 4.2 has established a topological relationship between the baseline and transect feature classes to make the editing process more efficient. Users are still able to edit transects individually but can now adjust the position of the baseline to generate a localized update of the affected transects (**fig. 25**). The user is able to preview the updated transect positions resulting from baseline edits before saving changes in an edit session.

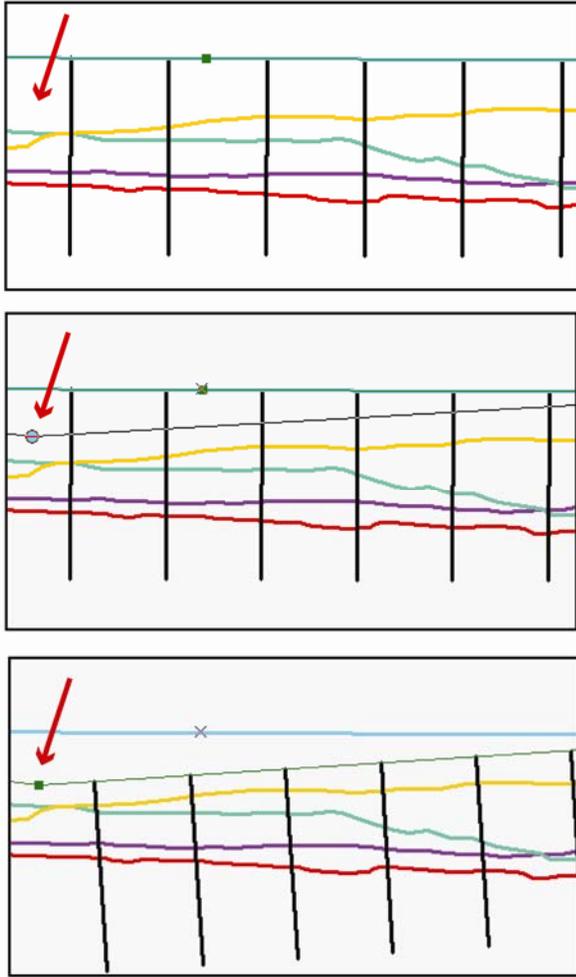


Figure 25

To begin an edit session and enforce the dynamic topological relationship between the baseline and transect feature classes, set the target layer in the ArcMap Editor toolbar to the baseline feature class (**fig. 26**).



Figure 26

Once the baseline feature class has been specified as the target in the ArcMap Editor toolbar, specify the transect feature class as the Transect Layer in the DSAS toolbar (**fig. 27**).



Figure 27

Using this approach, either the baseline or transect feature class can be edited and the topological relationship between the two will be maintained. For example, if you attempt to move a transect off the baseline, snapping is enabled and will force the transect to snap to the closest location on the baseline. If you modify the shape or position of the baseline, the target transect feature class will update. This update, which obviates the need to regenerate transects after editing a baseline file, is especially useful in cases where a large number of transects are used. Supported modifications to the baseline include rotation, vertex edits, splitting, merging, and deletion of line segments (**fig. 28**). When the dynamic topological relationship is used, the transect file is updated to reflect new baseline geometry during the edit session.

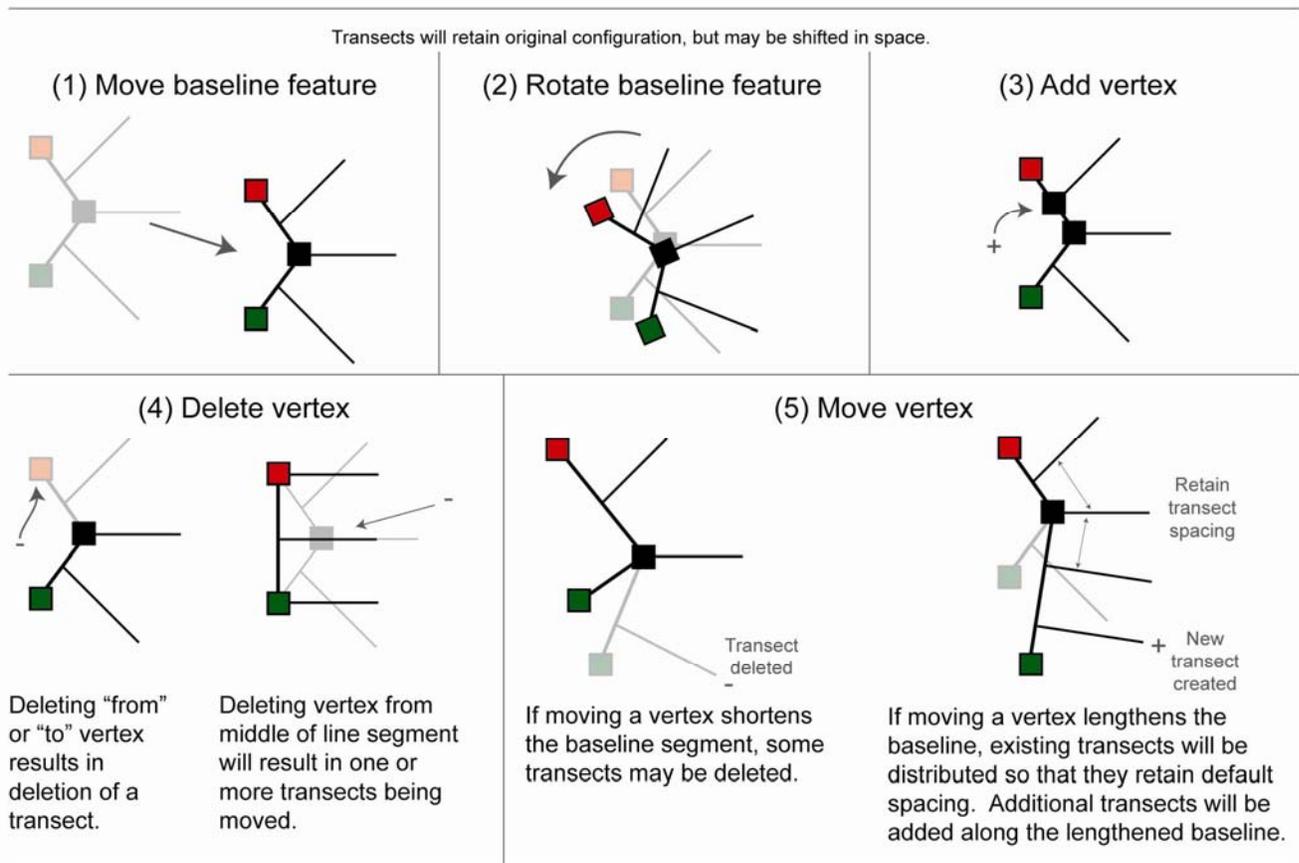


Figure 28.

6.4 Using transects from previous versions of DSAS

Transects from DSAS 3.x can be used in DSAS 4. Prior versions of DSAS combined the process of generating transects with the process of computing shoreline-change statistics. As described in **section 6.2** above, DSAS 4.2 has separated these into two separate process steps, allowing the user to generate and preview the transects so that any necessary edits or modifications can be made prior to running shoreline-change calculations. DSAS 4.2 will recognize transect feature classes generated by DSAS 3.x when they are added to the ArcMap project if both accessory tables (transect_Intersect and transect_Distance) have been added to the ArcMap project and the geodatabase has been upgraded to the current version of ArcMap. For information on how to upgrade, refer to **section 5.1.2**. Users should

make a backup copy of the original geodatabase prior to any upgrades. Users may encounter the message shown in **figure 29**.



Figure 29 users may encounter when DSAS recognizes transects from previous versions of DSAS. This message will appear if any of the extraneous fields listed in the message are detected in the transect feature class attribute table.

Transect feature classes from DSAS 3.x can be edited or otherwise modified by following the same guidelines and suggested procedures as outlined in the previous section. Preexisting transect feature classes will not contain the complete FGDC-compliant metadata file that would be generated for transect feature classes created in DSAS 4.2 (as explained in **section 6.1.3**). When DSAS 3.x transects are used to compute change statistics, a process-step description will be added to the metadata file describing which rate calculations and parameter settings were used. Refer to **section 9** for further information about metadata process steps.

Transects from DSAS 2.x cannot be directly imported to DSAS 4.2; they first must be updated to DSAS 3.x transects by using the stand-alone conversion utility which can be downloaded at http://woodshole.er.usgs.gov/project-pages/dsas/Transect_converter/DSAS_convert_transects.zip.

6.5 Calculating Change Statistics

Once the transect feature class has been created and all updates or modifications have been made, the data can be used to compute change statistics. It is recommended that the user review the default settings established in the Set Default Parameters window prior to computing statistics (see **section 6.1**). Select the transect layer from the dropdown menu in the DSAS Toolbar to be used to establish measurement locations for change-statistics calculations. Then click on the Calculate Change Statistics process button (**fig. 30**).

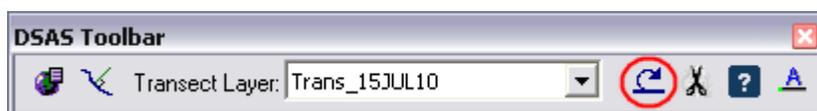


Figure 30. Screenshot of the DSAS toolbar with the Calculate Change Statistics button circled.

Select Statistics to Calculate

Choose from the list the statistical analysis that will be performed (**fig. 31**). Refer to **section 7** for descriptions of each statistic provided with DSAS 4.2.

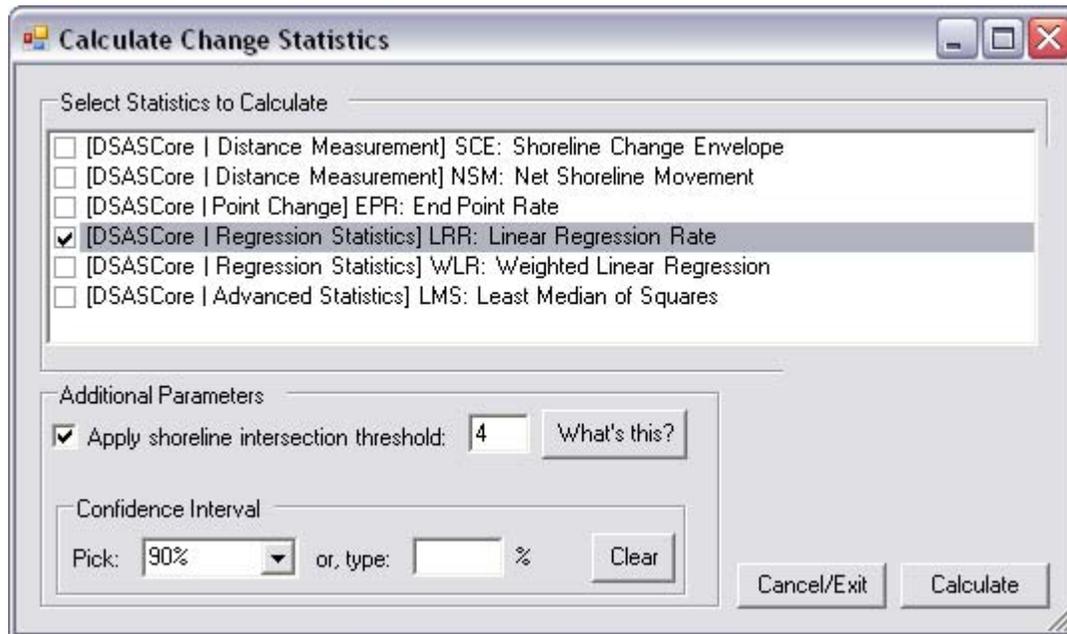


Figure 31. Screenshot of the Calculate Change Statistics window.

Additional Parameters

- **Apply shoreline intersection threshold**

This option provides users with the ability to establish the minimum number of shorelines a transect must intersect for it to be included in the selected statistical analysis. For example, if your data consist of four historic shoreline positions, but there are gaps in coverage alongshore, you may elect to set the intersection threshold to “4” so any transect that does not intersect all four shorelines is not included in any of the selected calculations (**fig. 32**). The program will skip that transect and move on to the next one. This feature provides a quality check so that all results are based on a minimum number of shorelines.

- **Confidence Interval**

The dropdown menu provides options for commonly used statistical confidence intervals that apply to certain rate-of-change calculations performed by DSAS (see **section 7.6.2** for more

information). Users also have the option of manually entering a desired confidence interval up to two decimal places. The chosen confidence interval will determine the criteria used for computing values for some of the supplemental statistics.

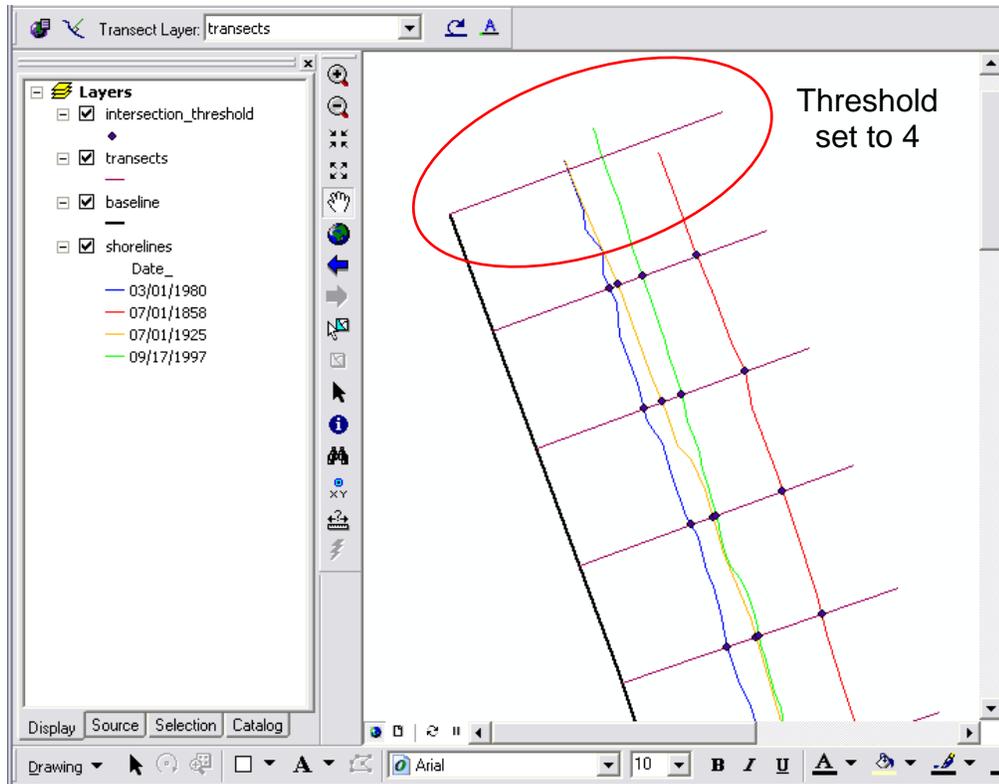


Figure 32. Screenshot of ArcMap project illustrating the transect-shoreline intersection points used in selected rate-change calculations. The shoreline intersection threshold will compute change statistics only for transects that intersect the number of shorelines set by the threshold (four in this example). Transects that do not intersect at least this number of shorelines are ignored.

The Calculation Process

Once the desired calculations have been selected from the Calculate Change Statistics window, the Calculate button can be clicked to begin the calculation process. Rate calculations are performed by MATLAB executables bundled within the DSAS installation. Users are not required to have MATLAB installed on their computer but must install the MATLAB Component Runtime (MCR) library utility provided on the DSAS website (see **section 2** step 4). DSAS generates all required information from the input baseline, shoreline, and transect files (examples include, distance to each shoreline from the baseline, the date for each shoreline, the position of the baseline, and group information). The

information is written to an XML formatted file and is sent to each module selected by the user in the Calculate Change Statistics window.

6.5.1 Statistical Output

When the selected calculations have finished processing, the results are returned to DSAS and are provided in a table. The table will have the same name as the transect file along with a time stamp. For example, if the transect feature class was named “transects,” the file would be called “transects_rates_yyyymmdd_hhmmss.dbf.” A process-step description capturing all of the parameters used during this calculation will also be added to the metadata record for the transect feature class (see **section 9**). The time stamp serves as a unique link between the results table and the metadata-process step that contains details about parameter settings used during computation of the selected statistics. In addition to the rates table, a new transects_intersects table (with time stamp) is generated when rates are calculated. The intersect and rates tables can be accessed by switching to the Source view tab at the bottom of the ArcMap table of contents window (**fig. 33**).

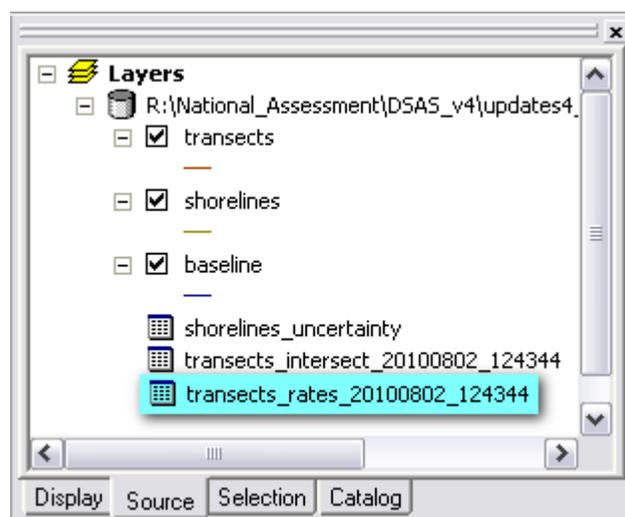


Figure 33. Computed rate-of-change statistics (highlighted) and the transect/shoreline intersects are added as new tables to the ArcMap project; switch to the Source tab to view the table. Both tables are named after the transect feature class with a time stamp appended to the filename. The time stamp is used to link the intersection points table and the rate calculation results table to the new process-step description added to the transect metadata file.

6.5.2 How to view results spatially

To display the statistical calculation output spatially in ArcMap, join the statistics table to the transect feature class by the Transect ID field, which has the same values as the ObjectID field in the transect feature class. The Join Data window can be accessed from the Options button when either the transect feature class attribute table or the output table of statistics is viewed (Options > Joins and Relates > Join). **Figure 34** provides an example of how to join data within ArcMap.

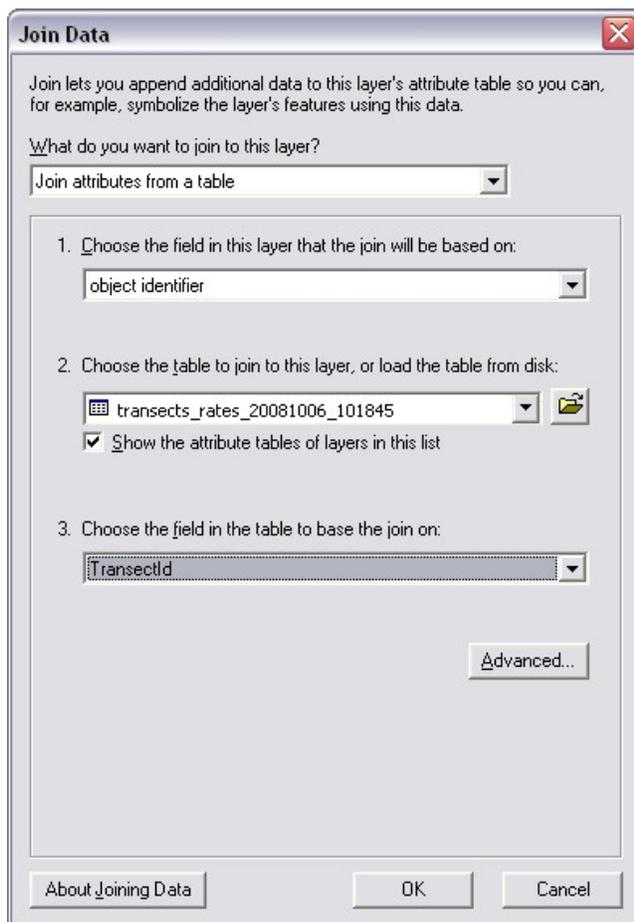


Figure 34. Screenshot of Join Data window in ArcMap. The table of statistical results is joined to the transect feature class by the field they share in common. The values in the TransectID field of the results table are equal to the object identifier field (ObjectID) in the transect feature class. Completing a join allows the rates to be used as a value field to change the symbology of the transect feature class.

6.6 Clipping transects to the Shoreline Change Envelope (SCE)

This is a stand-alone option on the DSAS toolbar, added in version 4.2, which can be performed any time after change statistics have been run.



Figure 35

The Clip to Shoreline Change Envelope (SCE) function will create a copy of the original transects clipped to the SCE extent. The SCE dialogue requires the user to specify which transect layer is used. In version 4.2, a new intersect file is generated (with time stamp) every time rate calculations are run (in previous versions the intersect file was overwritten for each run). In addition to the transect-shoreline intersections used in the rate calculation process, the intersect file also contains the information necessary to clip the data to the SCE extent; a separate SCE calculation is not required for the tool to function (**fig 36**).



Figure 36

The clipping process will create a copy of the specified transect file, cropped to the greatest extent between shorelines (see **Section 7.1** for illustration). Users can then join the rate calculation table to the clipped transects file (see **Section 6.5.2**) and modify the symbology to generate a spatial display of the calculated shoreline change rates (**fig 37**).

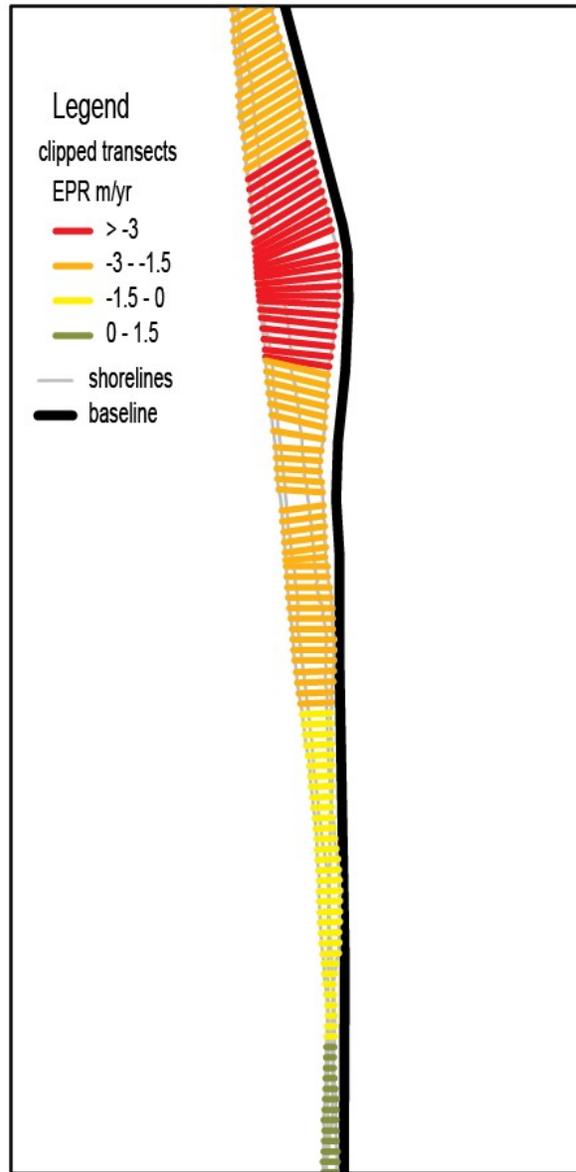
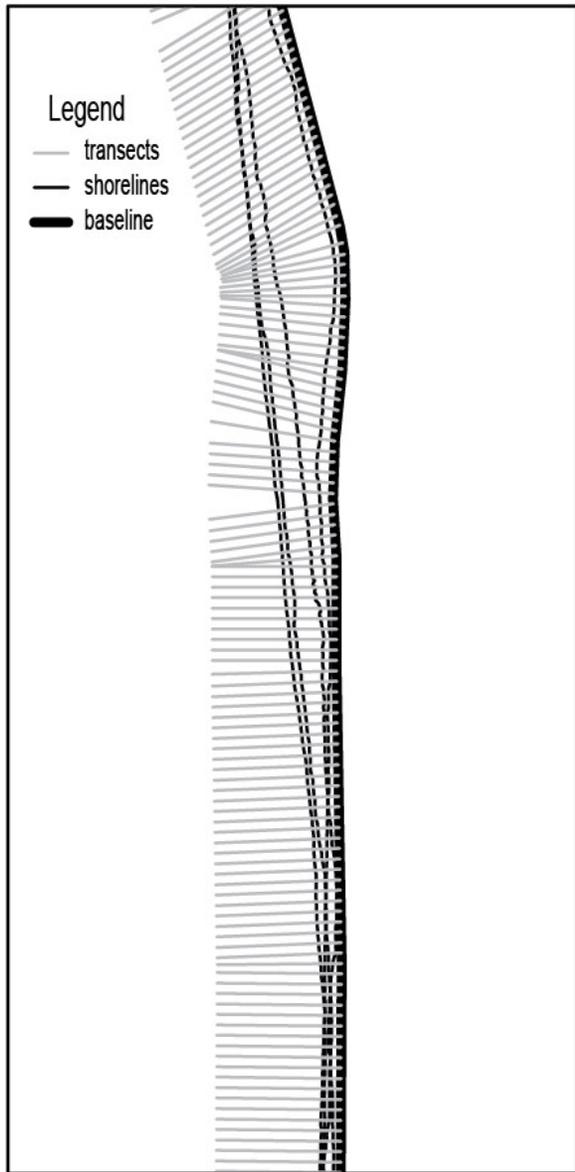


Figure 37.

6.7 Using the Select Features Tool (shoreline)

Although DSAS requires that all shoreline data reside within a single feature class, change statistics can be computed for subsets of the dataset. Users can select specific shorelines interactively from the map view, directly from the shoreline attribute table, or use the Select By Attributes option from the main menu in ArcMap. DSAS will ignore all shorelines that are not selected and compute change statistics for the selected set (**fig. 38**).

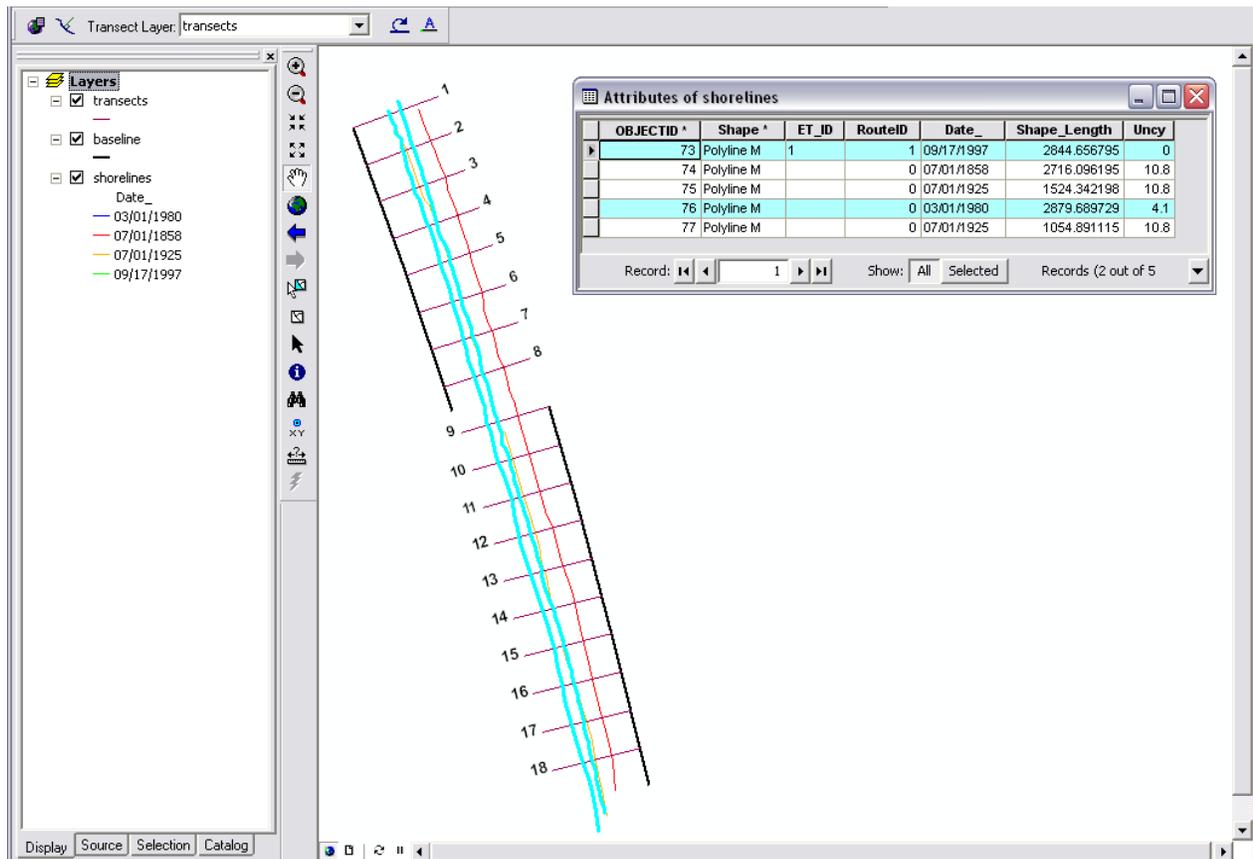


Figure 38.

7 Statistics

Each method used to calculate shoreline rates of change is based on measured differences between shoreline positions through time. The reported rates are expressed as meters of change along transects per year. When the user-selected rate-change calculations have finished processing, DSAS merges the individual module calculations, and the output is made available as a table in ArcMap. The rate-change statistics provided with DSAS have the standardized field headings listed in the first column of **table 1** below.

NSM	Net Shoreline Movement	
SCE	Shoreline Change Envelope	
EPR	End Point Rate	
LRR	Linear Regression Rate	
LSE	Standard Error of Linear Regression	
LCI	Confidence Interval of Linear Regression	LCI95, LCI90
LR2	R-squared of Linear Regression	
WLR	Weighted Linear Regression Rate	
WSE	Standard Error of Weighted Linear Regression	
WCI	Confidence Interval of Weighted Linear Regression	WCI95, WCI90
WR2	R-squared of Linear Regression	
LMS	Least Median of Squares	

Table 1. Table of standardized field headings provided by DSAS for change calculations. The third column provides examples illustrating how the user-selected confidence interval is specified.

Shoreline Change Envelope (SCE)

The shoreline change envelope reports a distance, not a rate. The SCE is the distance between the shoreline farthest from and closest to the baseline at each transect (**fig. 39**). This represents the total change in shoreline movement for all available shoreline positions and is not related to their dates. A copy of the transect file can be clipped to this span for display purposes (see **Section 6.5.3**).

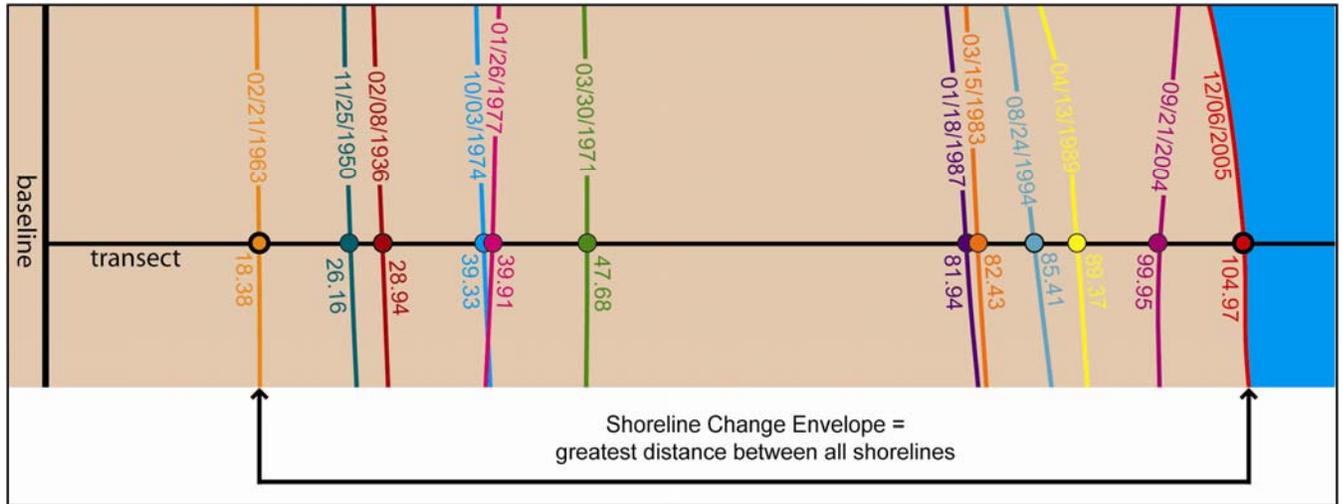


Figure 39. In the example above, the shoreline change envelope is the distance between the 2005 and 1963 shorelines of 86.59 meters; this distance is not associated with the age of the shorelines.

Net Shoreline Movement (NSM)

The net shoreline movement reports a distance, not a rate. The NSM is associated with the dates of only two shorelines. It reports the distance between the oldest and youngest shorelines for each transect (**fig. 40**). This represents the total distance between the oldest and youngest shorelines. (If this distance is divided by the number of years elapsed between the two shoreline positions, the result is the End Point Rate described in **section 7.3**).

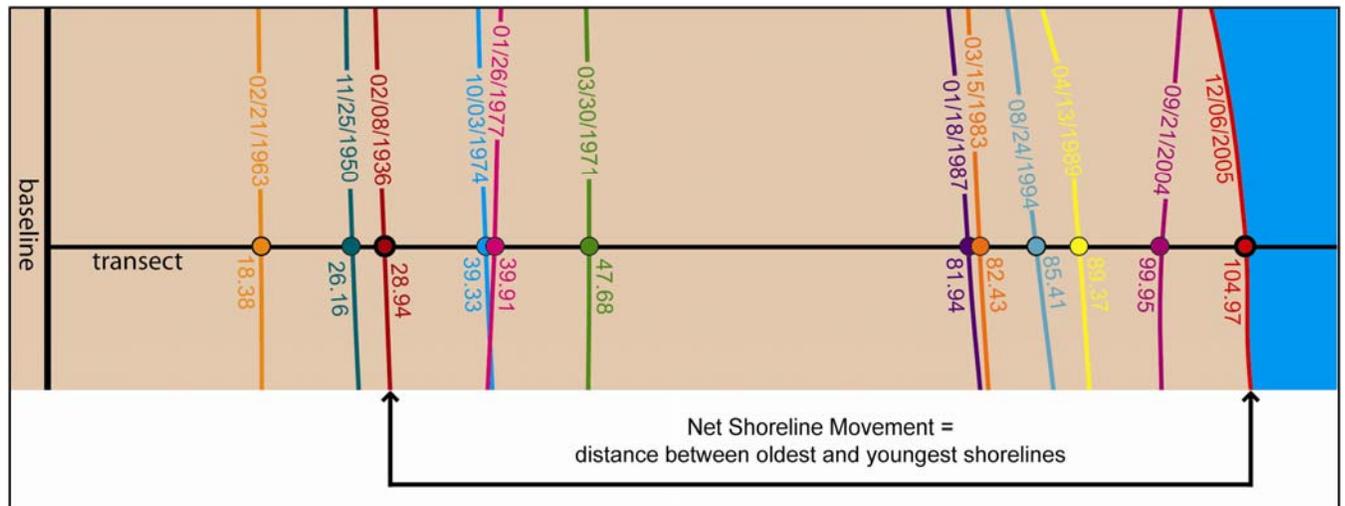


Figure 40. In the example above, the net shoreline movement is the distance of 76.03 meters between the most recent shoreline from 2005 and the oldest shoreline from 1936.

7.3 End Point Rate (EPR)

The end point rate is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (**fig. 41**). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored. Changes in sign (for example, accretion to erosion), magnitude, or cyclical trends may be missed (Crowell and others, 1997; Dolan and others, 1991).

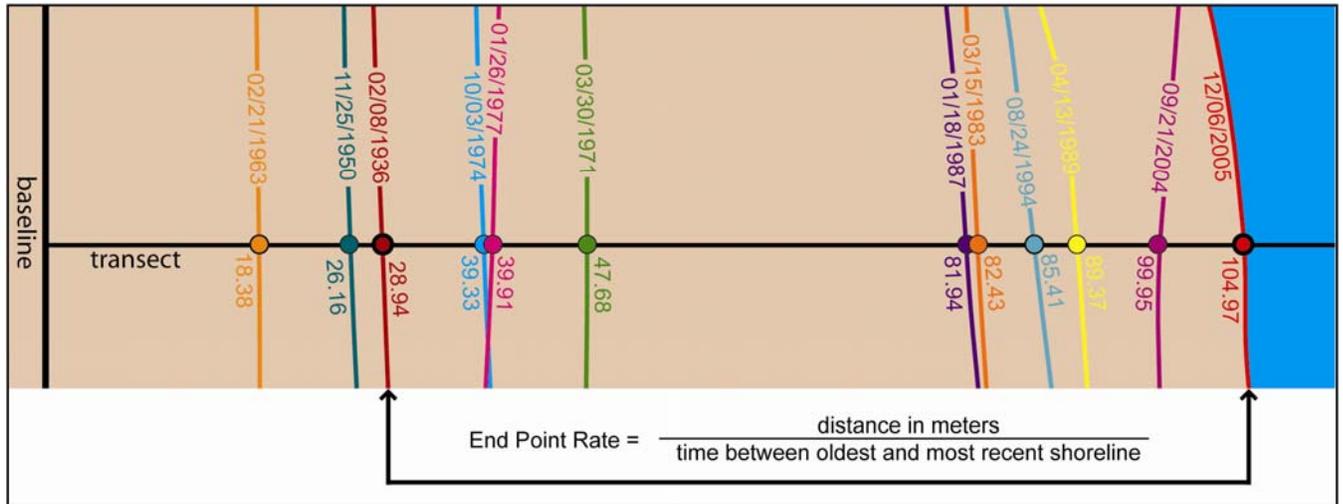


Figure 41. In the example above, the end point rate of 1.09 meters per year is the distance between the 2005 and 1936 shorelines (76.03 meters) divided by the span of time elapsed between the two shoreline positions (69.82 years). All other shoreline data are ignored in this computation.

7.4 Linear Regression (LRR)

A linear regression rate-of-change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect (**fig. 42**). The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. The method of linear regression includes these features: (1) All the data are used, regardless of changes in trend or accuracy, (2) The method is purely computational, (3) The calculation is based on accepted statistical concepts, and (4) The method is easy to employ (Dolan and others, 1991). However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics, such as EPR (Dolan, and others, 1991; Genz and others, 2007). In conjunction with the linear regression rate, the standard error of the estimate (LSE), the standard error of the slope with user-selected confidence interval (LCI), and the R-squared value (LR2) are reported (**section 7.6**).

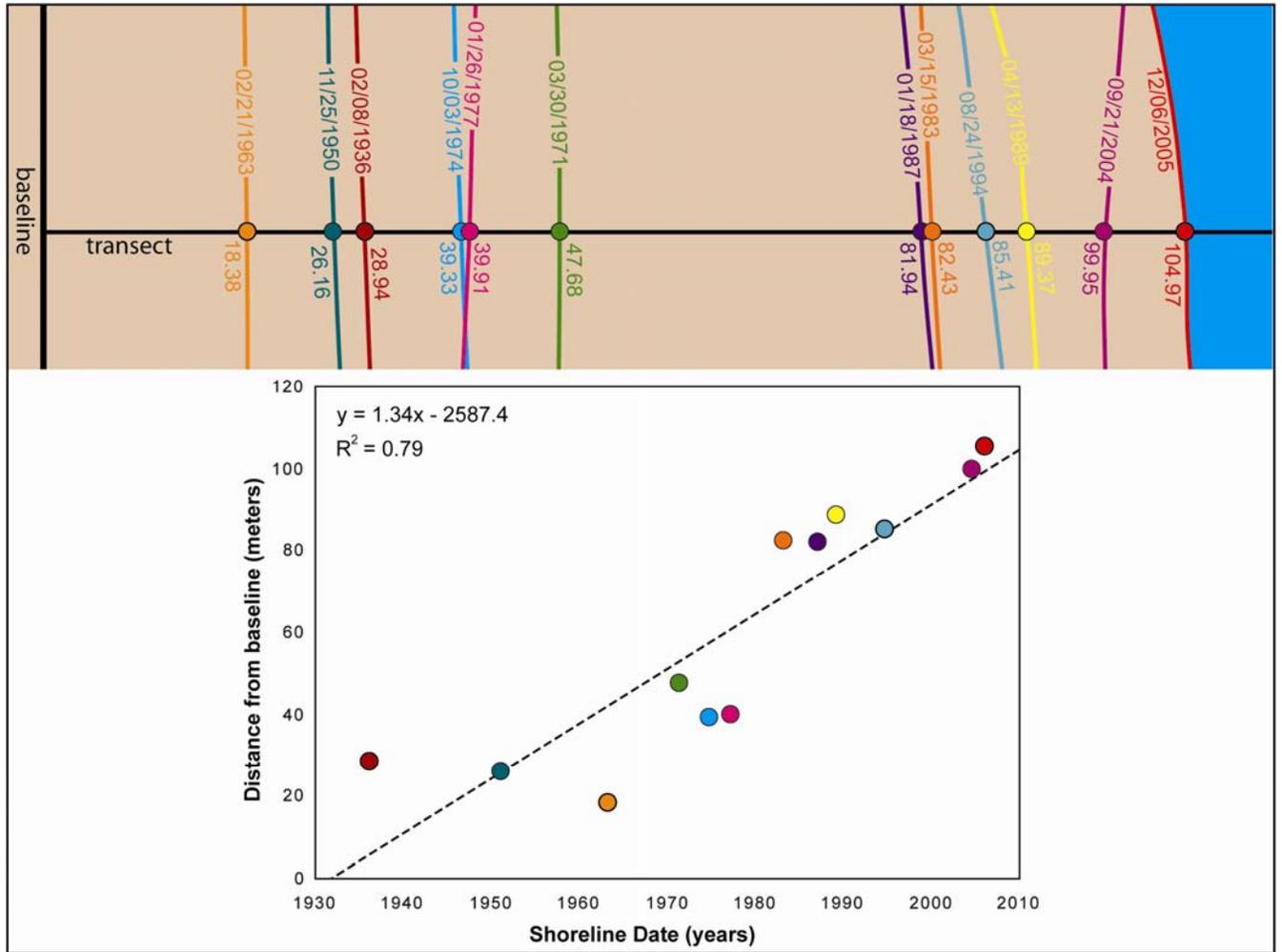


Figure 42.
rate (1.34 m/yr).

$y = 1.34x - 2587.4$. The slope of the equation describing the line is the

7.5 Weighted Linear Regression (WLR)

In a weighted linear regression, more reliable data are given greater emphasis or weight towards determining a best-fit line (**fig. 43**) In the computation of rate-of-change statistics for shorelines, greater emphasis is placed on data points for which the position uncertainty is smaller. The weight (w) is defined as a function of the variance in the uncertainty of the measurement (e) (Genz and others, 2007):

$$w = 1/ (e^2) \quad (1)$$

where

e = shoreline uncertainty value

The uncertainty field of the shoreline feature class is used to calculate a weight. In conjunction with the weighted linear regression rate, the standard error of the estimate (WSE), the standard error of the slope with user-selected confidence interval (WCI), and the R-squared value (WR2) are reported (see **section 7.6**).

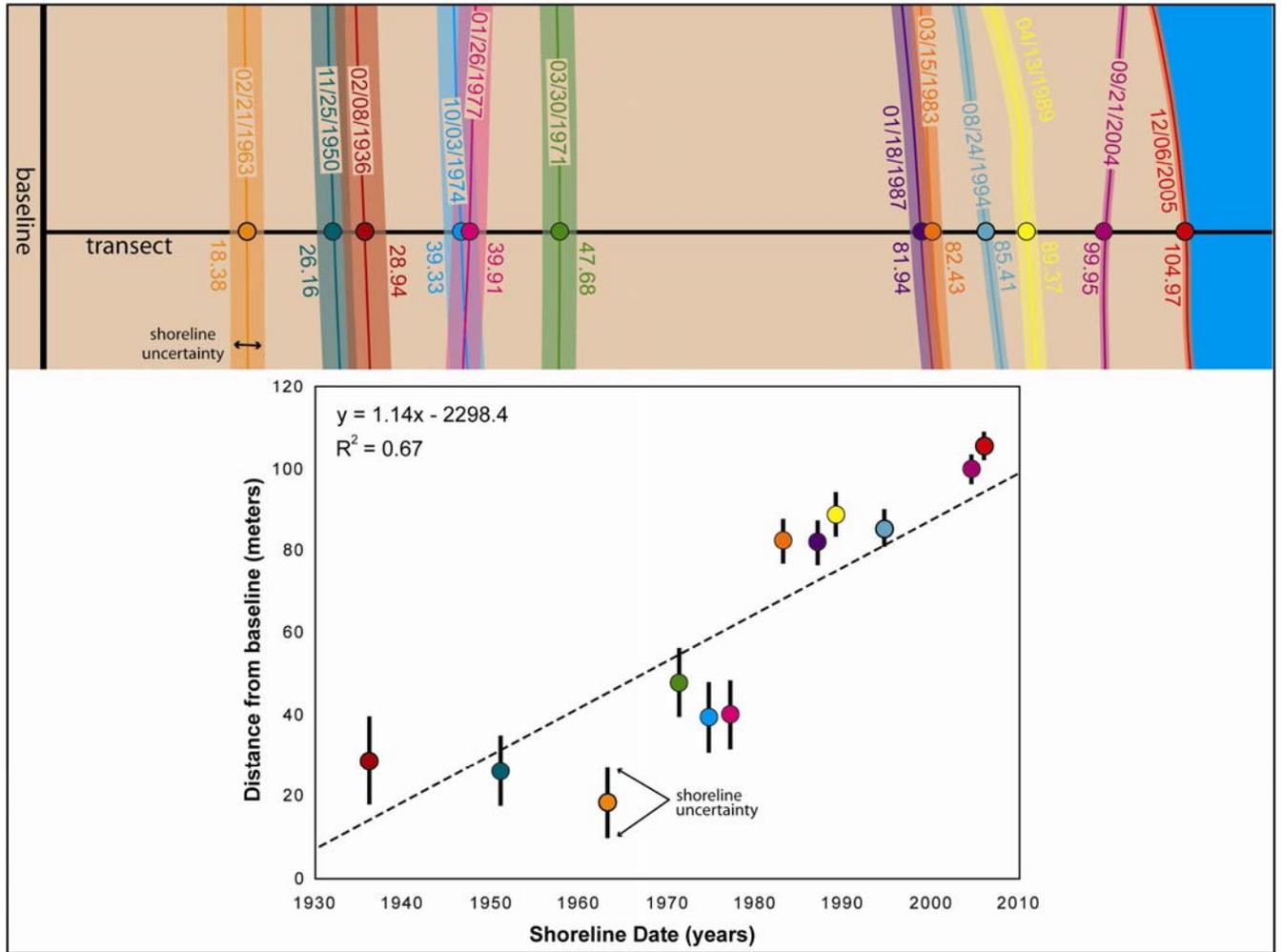


Figure 43.

fig. 42). The shoreline measurement points with smaller positional-uncertainty values had more influence in the regression calculation because of the weighting component in the algorithm. The slope of the regression line is the rate (1.14 m/yr).

The standard error, correlation coefficient, and confidence interval are computed for the two linear regression methods (LRR and WLR). These additional statistics provide information that is helpful in assessing the robustness of the computed regression rates.

WSE)

The predicted (or estimated) values of y (the distance from baseline) are computed for each shoreline point by using the values of x (the shoreline date) and solving the equation for the best-fit regression line:

$$y = mx + b \tag{2}$$

where

- y = predicted distance from baseline,
- m = slope (the rate of change),
- b = y -intercept (where the line crosses the y -axis).

The standard error of the estimate measures the accuracy of the predicted values of y by comparing them to known values from the shoreline point data. It is defined as (LSE for ordinary linear regression and WSE for weighted linear regression):

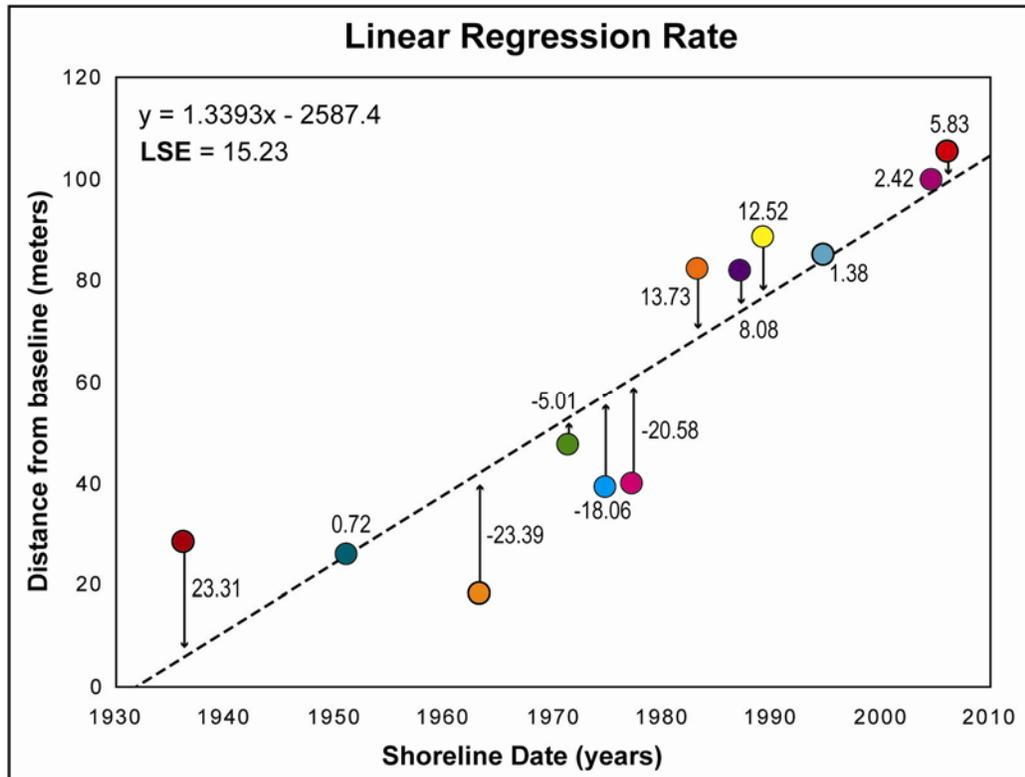
$$\frac{LSE}{\text{or}} \frac{WSE}{WSE} = \sqrt{\frac{\sum(y-y')^2}{n-2}} \tag{3}$$

where

- y = known distance from baseline for a shoreline data point,
- y' = predicted value based on the equation of the best-fit regression line,
- $n-2$ = number of degrees of freedom.

The total number of shoreline points (n) along the DSAS transect is subtracted by 2 because 2 of the parameters in the regression line are being estimated (the slope and the intercept). The predicted y -values are subtracted from the known y -values to compute the residuals ($y-y'$). The residual is squared,

and then the squared residuals (for each shoreline point) are added (along the DSAS transect) to get the sum of the squares of the residuals (which is the numerator in the equation above). This sum is divided by the number of degrees of freedom, and then the square root of the quotient is taken to compute the standard error of the estimate. The standard error of the estimate assesses the accuracy of the best-fit regression line in predicting the position of a shoreline for a given point in time (**fig 44**).



(x)

y

y

(y)

Standard Error of the Slope with Confidence Interval (LCI and WCI)

The standard error of the slope with confidence interval (LCI for ordinary linear regression and WCI for weighted linear regression) describes the uncertainty of the reported rate. Users may choose one of the following confidence levels from the drop-down menu: 68.3, 90, 95, 95.5 or 99.7 percent or manually enter a value up to two decimal places (section 6.5 and fig. 31). The LRR and WLR rates are determined by a best-fit regression line through the sample data. The slope of this line is the reported rate of change (in meters/year). The confidence interval (LCI or WCI) is calculated by multiplying the standard error (also called the standard deviation) of the slope by the two-tailed test statistic at the user-specified confidence percentage (Zar, 1999).

In the example illustrated in figure 45, the reported LRR is 1.34 m/yr and the 95 percent confidence interval (LCI95) is 0.50. The band of confidence around the reported rate-of-change is 1.34 +/- 0.50. In other words, you can be 95 percent confident that the true rate of change is between 0.84 and 2.34 m/yr. This leaves a 5 percent chance that the true line is outside those boundaries. Note that this is not the same as saying that the band of confidence contains 95 percent of the data points, and that some data points will fall outside the interval boundaries.

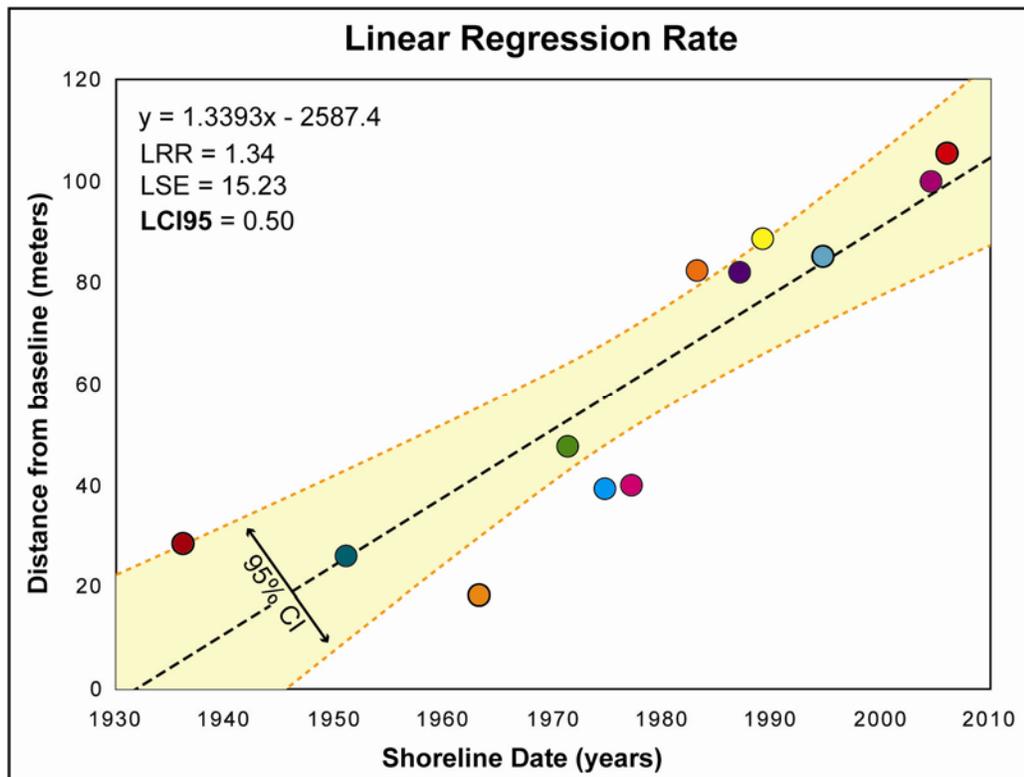


Figure 45.

7.6.3 R-squared (LR2 and WR2)

The R-squared statistic, or coefficient of determination, is the percentage of variance in the data that is explained by a regression. It is a dimensionless index that ranges from 1.0 to 0.0 and measures how successfully the best-fit line accounts for variation in the data. In other words, it reflects the linear relationship between shoreline points along a given DSAS transect. It is defined as:

$$R^2 = 1 - \sqrt{\frac{\sum(y-y')^2}{\sum(y-\bar{y})^2}} \quad (4)$$

where

R^2 = coefficient of determination,

y = known distance from baseline for a shoreline data point,

y' = predicted value based on the equation of the best-fit regression line,

\bar{y} = mean of the known shoreline data points.

The R-squared value quantifies the proportion of the variability in the dependent variable y that is explained by the regression model through the independent variable x . The smaller the variability of the residual values around the regression line relative to the overall variability, the better the prediction.

- R^2 values close to 1.0 imply that the best-fit line explains most of the variation in the dependent variable. If x and y are perfectly related, there is no residual variance and the ratio of variance would be 1.0.
- R^2 values close to 0.0 imply that the best-fit line explains little of the variation in the dependent variable, and may not be a useful model. If there is no relationship between the x and y variables, then the ratio of the residual variability of the y variable to the original variance is equal to 0.0.

7.7 Least Median of Squares (LMS)

In ordinary and weighted least-squares regression, the best-fit line is placed through the points in such a way as to minimize the sum of the squared residuals. In the linear regression method, the sample data are used to calculate a mean offset, and the equation for the line is determined by minimizing this value so that the input points are positioned as close to the regression line as possible. In the least median of squares method the median value of the squared residuals is used instead of the mean to determine the best-fit equation for the line. This method is a more robust regression estimator that minimizes the influence of an anomalous outlier on the overall regression equation. In DSAS, the process of fitting the line to the data points follows the same logic as the LRR method. LMS is determined by an iterative process that calculates all possible values of slope (the rate of change) within a restricted range of angles by following an approach described in Rousseeuw and Leroy (1987).

For each of the input angles (iteration 1 uses -89° to 89°), the slope of the angle and the known x values (the dates from shoreline points) are used to calculate a y -intercept. These values determine the regression-line equation, which is then used to calculate predicted y -values (the distance from baseline) for each date. The residual (which is the offset between the known y -values from the sample data and the predicted values) is squared; this is also known as the squared residual. The median of the squared residuals is then calculated and saved; it is referred to as the offset for the iteration along with the slope and y -intercept. The first round of iterations progresses at increments of 1° (89° to 88° to 87°). When complete, the stored values are compared, and the minimum offset is determined (for example, at an angle of 56°). The second round of iterations progresses at tenths of a degree (56.1° to 56.2° to 56.3°). The minimum offset of this iteration is determined and compared with the minimum from the first round (to continue with the example, assume the minimum was at an angle of 56.1°). This process continues (the third round of iterations progresses at hundredths of a degree) until the difference between the minimal offset value between successive rounds is negligible according to the laws of significant figures. Once a minimum offset has been identified, the slope of the corresponding best-fit regression line is returned as the LMS value.

To better illustrate the difference between linear regression and the least median of squares, a side-by-side comparison of the returned slopes (rates) is illustrated in **figure 46**. In ordinary linear regression, each input data point has an equal influence on the determination of the best-fit regression line. The offset of each point (residual) is squared and these squares are added. In the least-median-of-

squares method, the offsets are squared and the median value is selected. This reduces the influence of shoreline data points with larger offsets (residuals) on the best-fit regression line.

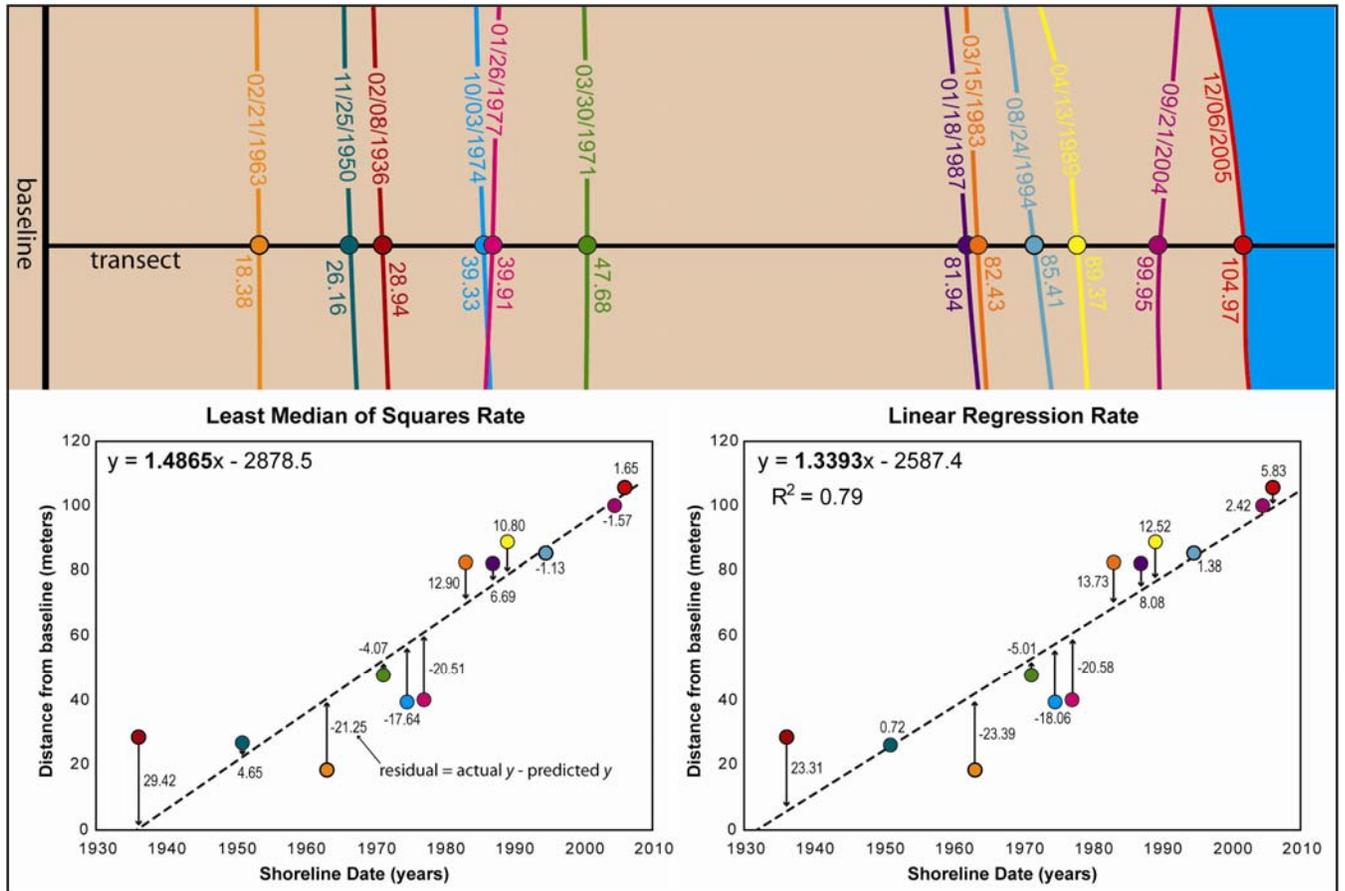


Figure 46.

8 External Module Interfacing

All statistical computations performed by DSAS are implemented by using an external module included in the DSAS distribution. This design allows programmers to develop their own calculation modules for use in DSAS. All modules must be in the form of a file recognized as an executable by the Windows operating system. These can either be binary executables (typically distinguished by their .exe file extension) or any file with a registered handler that will execute it, such as Python files with .py extension, Perl files with .pl and so on. Module authors should note that Python is installed as part of the ESRI ArcGIS platform and may generally be assumed to be available. As described below, the freely available MATLAB runtime library is required by the default module distributed with DSAS (DSASCore).

The code for the statistics calculated by DSAS was written in MATLAB and then compiled into a Windows binary executable file for distribution. As such, it makes calls to MATLAB runtime libraries that are freely available and must be downloaded and installed separately. A full install of MATLAB software is not required. (See **section 2** for more information.) When a user selects the Calculate Statistics button from the DSAS toolbar, DSAS searches the calc folder within the user-specified directory in which DSAS was installed (for example, C:\Program Files\DSAS\calc) for the following files:

[*module_name*].calc.[*file_extension*]
[*module_name*].info.xml

As an example, the module distributed by DSAS is called DSASCore.calc.exe, where

[*module_name*] = DSASCore
[*file_extension*] = exe

The first file, [*module_name*].calc.[*file_extension*], is the executable file that performs the desired computations.

The second file, [*module_name*].info.xml provides a list of the fields that will be generated as a result of the module's computations as well as the category information DSAS uses to organize and populate the list of selectable statistics in the DSAS calculate statistic window.

When a selection of statistics is made by the user and the calculations are run, DSAS executes any calc files that contain user-selected calculations, and then passes the transect measurement data and output file parameters to each module (see the Module Calc File section below for more information). When a module completes execution, DSAS appends the fields computed by the module to a rate output table with a name of the form: `[transect_layer_name]_rates_[YYYYMMDD_hhmmss]`. Where: `[transect_layer_name]` is the target transect file in the DSAS toolbar when the calculation process began.

Programmer Notes:

- Any module with `parallel="No"` designation will be run serially. Modules that access libraries that are not thread-safe should be run serially.
- If a module output contains fields that already exist in the transect layer, the user is warned and given an option to overwrite or discard the results.
- Any field that does not have a category will not be shown on the graphical user interface but can be calculated by the module and populated into the transect layer.
- Modules should open data files as read-only to prevent contention between multiple modules accessing the input data.

8.1 Module Calc File

DSAS passes input data to each user-selected calculation with several command-line parameters. For example

```
DSASCore.calc.exe -e -d “../data/20080315_130442. [source_transect_layer_name].in.xml” -o  
“../data/20080315_130442.EPR_WLR.out.xml” -c “EPR,WLR”
```

where

DSASCore.calc.exe is the name of the calculation module DSAS executes to calculate the selected statistics (EPR, and WLR in above example),

“../data/20080315_130442. [source_transect_layer_name].in.xml” is the DSAS-generated input file containing measurement-position information established by the transects,

“../data/20080315_130442.EPR_WLR.out.xml” is the output file generated by the module. DSAS will pull computational results from this file to populate the report table in ArcMap,

Execute (-e switch) indicates that the module should execute the calculations necessary for the separately specified statistics. As of DSAS 4.0, the module should do nothing if this switch is not provided (that is, if no other operational modes are available),

Data file (-d) switch is the name of the data file (either fully qualified or qualified relative to the location of the module). Module should open the file in read-only mode,

Output file (-o switch) is the name of the data file (either fully qualified or qualified relative to the location of the module to which the output is written. Module should overwrite the file if exists,

Calculations (-c switch) is the comma-separated list of the names of statistics that the module needs to calculate. These names correspond to the short names listed in the info file for the module (excluding the parameter expressions in curly braces). Unrecognized names should be skipped. If a name is associated with multiple values, all such values should be calculated.

Modules should exhibit the following characteristics for correct execution and integration by DSAS:

- A module should not include user prompts because it will be run by DSAS without the user ever seeing the prompt.
- A module should always output a well-formed and valid XML file even when inputs are unexpected or when errors occur.
- A module should be able to accept input file values that are very large.

It is also recommended, but not required, that modules exhibit other best characteristics for efficient operation:

- A module should use XML libraries available for the local software platform to read and write XML files; the use of XML libraries will minimize compatibility issues especially for module authors that are not very familiar with XML.
- A module should read only the values that it will need in computations.
- A module should use a streaming reader and keep in memory only the values required for current and future computations. For example, most statistics require no more than the intersect information for one transect at a time. The module can perform calculations as it reads through the input file and can write results to the output file. Loading all data into memory may slow down module operation significantly for large data sets and/or workstations that have limited resources.

8.2 Module Info File

Each DSAS module should be accompanied by an “info” file in XML format that describes the capabilities of the module. The naming convention for the info file is *[module_name].info.xml*. As an example, a module DSASCore.calc.exe would have a file called DSASCore.info.xml as its info file.

A sample info file might look like this:

```
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<DSAS_CALCULATIONS dynamic="No" parallel="Yes">
<FIELD name="SCE" alias="Shoreline Change Envelope" type="Double" length="" category="Distance Measurement"/>
  <FIELD name="NSM" alias="Net Shoreline Movement" type="Double" length="" category="Distance Measurement"/>
  <FIELD name="EPR" alias="End Point Rate" type="Double" length="" category="Point Change"/>
  <FIELD name="LRR" alias="Linear Regression Rate" type="Double" length="" category="Regression Statistics"/>
  <FIELD name="LR2" alias="R-squared LRR" type="Double" length=""/>
  <FIELD name="LSE" alias="Standard Error LRR" type="Double" length=""/>
  <FIELD name="LCI{CI}" alias="Confidence Interval LRR" type="Double" length=""/>
  <FIELD name="WLR" alias="Weighted Linear Regression" type="Double" length="" category="Regression Statistics"/>
  <FIELD name="WR2" alias="R-squared WLR" type="Double" length=""/>
  <FIELD name="WSE" alias="Standard Error WLR" type="Double" length=""/>
  <FIELD name="WCI{CI}" alias="Confidence Interval WLR" type="Double" length=""/>
  <FIELD name="LMS" alias="Least Median of Squares" type="Double" length="" category="Advanced Statistics"/>
</DSAS_CALCULATIONS>
```

DSAS_CALCULATIONS: Top-level element with attributes that apply to the entire module.

dynamic: Reserved for future use.

parallel: Yes or No.

- “Yes” indicates that the module may be run by DSAS in parallel with any other without conflicts.
- “No” indicates that the module would conflict with at least one other module and must be run serially (that is, as the only running module). All other conflicting modules must then also be marked as “No.”

FIELD: This element is required for each value that a module calculates for inclusion in the transect rate output table.

name: Abbreviated name for the field (typically the name to be used when the column is added to the transect rate output table). Known parameters (such as CI, Confidence Interval) may be used as part of the name with curly braces. For example, LCI{CI} with CI=99.9 means that the table column will be named LCI99_9. Nonalphanumeric characters are replaced by an underscore.

alias: A descriptive name for the field. This name will be used by DSAS when the program displays the Calculate Statistics window.

type: Field data type. Currently only the data type designated “double” is supported.

length: Field data-type length. Reserved for future use.

category: The category under which the field should be listed. If no category is specified, the field will not be listed but may still be calculated by the module and will be considered dependent on the last field before it that has a category specified. This is typical for statistics that calculate multiple related values; module authors may opt to display only the primary statistic and let the user turn on or off all related computations relating to the primary statistic.

8.3 Module Input File

The module input file is generated by DSAS and is passed as a command-line argument to each module. Input files are in XML format. Modules are required to open this file as read-only to avoid conflicts with other modules that might be accessing the file simultaneously.

A sample input file might look like this:

```
<DSAS_OUT>
  <Header>
    <CI>99.8</CI>
  </Header>
  <IntersectTable>
    <IntersectList>
      <Intersect>
        <TransectID>2</TransectID>
        <BaselineID>1</BaselineID>
        <BaselineDistance>50</BaselineDistance>
        <TotalCumulativeDistance>50</TotalCumulativeDistance>
        <Group>2</Group>
        <GroupDistance>50</GroupDistance>
        <Date>1936.10677846127</Date>
        <DistanceToBaseline>116.17</DistanceToBaseline>
        <MeasurementUncertainty>5</MeasurementUncertainty>
        <Bias>NaN</Bias>
        <BiasUncertainty>NaN</BiasUncertainty>
        <X>684211.5</X>
        <Y>2028794.27</Y>
      </Intersect>
      <Intersect>
        ...
      </Intersect>
    </IntersectList>
  </IntersectTable>
</DSAS_OUT>
```

The following is a list of variable definitions for the sample input file.

DSAS_OUT: Top-level element containing all shoreline measurement output from DSAS (that can be used as input to individual modules).

Header: Element that contains general information and/or parameters.

CI: User-selected confidence interval expressed as a percentage.

IntersectTable: Information related to intersections between transects and shorelines.

IntersectList: Element containing the list of intersections.

Intersect: Element containing information about a single intersect. This element is repeated for each intersection between transects and shorelines (except those eliminated for not meeting the intersect threshold set on the DSAS user interface).

TransectID: Permanent and unique identification number for each transect. This element can always be used as the link to a table of statistics, even if the transects are updated or modified at a later date. Note that these numbers may not increment sequentially alongshore (see transects 5, 11 and 6 in **figure 35**); however they will be sorted geographically alongshore in table. Corresponds to ObjectID/FID field in ArcGIS attribute table.

BaselineID: Each baseline needs a unique number which increments sequentially alongshore. This number is provided by the user. DSAS ignores baseline segments numbered “ID=0” when casting transects.

BaselineDistance: Cumulative alongshore distance from start of baseline to transect. Distance measurement starts over for each baseline segment.

TotalCumulativeDistance: Cumulative distance from start of first baseline, to the current transect. The distance across any gaps between adjacent baselines is measured from transect to transect. Dangling segments of baseline are ignored; see transects 7-8 in **figure 47**.

Group: Group identification. Baselines may be grouped into a combination of onshore and offshore features (**fig. 37**).

GroupDistance: Cumulative alongshore distance of transect from start of first baseline for group. (See transects 4-5 in **figure 47**). Distance measurement starts over for each group.

Date: Date of transect-shoreline measurement point. Output for each transect is sorted by date. Assigned date format for shoreline feature classes is mm/dd/yyyy or mm/dd/yyyy hh:mm:ss. If mm/dd/yyyy is specified, DSAS assumes noon for a time component; otherwise it takes what has been given. The date is then converted to decimal years by using 365.242199 days per year which normalizes the date to account for leap years. The decimal date is provided as output to the calculation modules.

DistanceToBaseline: Distance between baseline and measurement location along the transect. The distance values for each measurement position are used to compute the rates of shoreline change in the core-statistics module provided by DSAS. Offshore baselines are assigned negative distance values onshore baselines positive values so that the result indicates (+) accretion or (-) erosion of the shore.

MeasurementUncertainty: The positional uncertainty of **DistanceToBaseline** based on the user-assigned value pulled from the shoreline attribute table, or if null, assigned by the user in the Set Default Parameters window. This value will be interpolated based on input data for the lidar shoreline route.

Bias: The proxy-datum bias or the calculated horizontal offset between the two proxy-datum shorelines (for example, lidar tidal-based operational mean high water shorelines and air-photo derived high water line shorelines). This value is interpolated based on input data for lidar shorelines. The bias is used to apply a unidirectional shift to its associated measurement locations to correct for differences in shoreline proxies (Ruggiero and List, 2009).

BiasUncertainty: The estimated uncertainty of the proxy-datum bias. This is interpolated based on input data for the lidar shoreline route.

X: The x-coordinate of the measurement position (the intersection of the shoreline and transect). Units are based on the coordinate system in use.

Y: The y-coordinate of the measurement position (the intersection of the shoreline and transect). Units are based on the coordinate system in use.

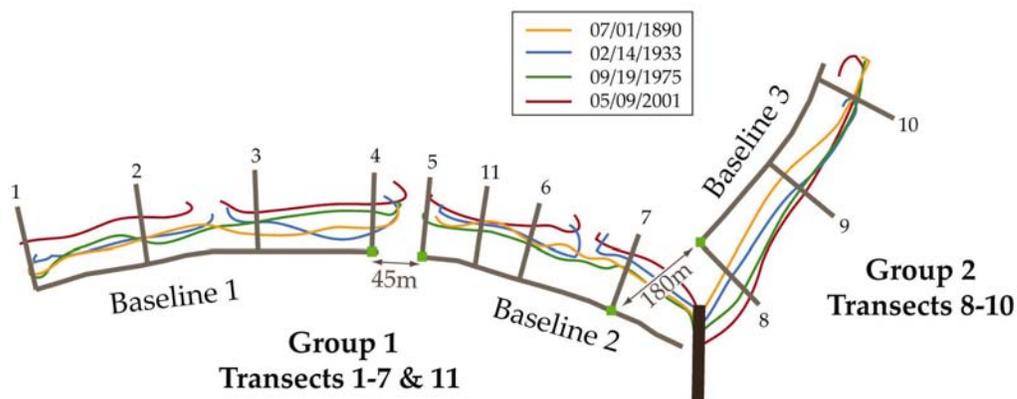


Figure 47.

8.4 Module Output File

The module output file is generated after a module is executed by DSAS. Output files are in XML format. Typically, the output file returns the calculated results for each transect and DSAS puts this information in the results table in ArcMap. A sample output file might look like this:

```
<DSAS_IN>
  <TransectTable>
    <TransectList>
      <Transect>
        <TransectID>2</TransectID>
        <SCE>68.63</SCE>
        <LRR>NaN</LRR>
        ...
      </Transect>
      ...
    </TransectList>
  </TransectTable>
</DSAS_IN>
```

The following is a list of variable definitions for the sample output file.

DSAS_IN: Top-level element containing all module results to be returned to DSAS (all output from module).

TransectTable: Information related to transects.

TransectList: Element containing the list of transects.

Transect: Element containing information about a single transect. This element is repeated for each transect that was included in the corresponding module input file.

TransectID: The unique identifier for the transect.

Other elements under Transect: Each element contains a value calculated by the module. Null values should be represented by the sequence “NaN.” The name of the element is used as a column name in the table generated by DSAS, should only consist of alphanumeric and underscore characters and be no longer than eight characters.

9 Metadata

Generating complete metadata is an important component of data integrity and maintenance. Unfortunately, it is often not a priority, and incomplete metadata documentation is fairly common. DSAS 4.0 was updated so that metadata are generated automatically when transect files are created and when calculations are performed. A new tab was added to the Set Default Parameters window (see **section 6.1.3**) for users to input a few essential components of the metadata information. The metadata interface is simple, requiring only input of basic information often specific to individual organizations. DSAS takes these user-input variables, captures processing-step descriptions and basic dataset information (such as bounding coordinates, attributes, and spatial reference information), and includes it in the transect feature class metadata file when transects are cast. Whenever the transects are used to calculate statistics, a process step is added to the transect metadata file that can be linked to the resulting rates table by the process time stamp. This step provides automated recordkeeping of calculation parameters and defaults used when generating the data. The resulting metadata record (**fig. 48**) is compliant with the FGDC CSDGM v. 2.0 (as long as all user-input fields are populated prior to casting transects) and is stored in the geodatabase with the output transect feature classes. Because there are no restrictions on the metadata record after it is generated, users may modify the existing file by using a metadata editor of their choice.

transects - Digital Shoreline Analysis System Version 4.0 Transect Feature Class

Description

Spatial

Attributes

Horizontal coordinate system

Details

Bounding coordinates

Horizontal

In decimal degrees

West: -75.890272

East: -75.877600

North: 36.625728

South: 36.601999

Lineage

FGDC lineage

Process step 1

Process description: Transect Features Generated. Parameters Used: baseline layer=baseline, baseline group field=NULL, transect spacing=100 meters, transect length=350 meters, cast direction=AUTO-DETECT, baseline location=on/off shore, cast method=two leg, smoothing distance=50 meters, flip baselines=not selected. For additional details on these parameters, please see the DSAS help file distributed with the DSAS software, or visit the USGS website at: <http://woodshole.er.usgs.gov/project-pages/dsas/>.

Process date: 20081006

Process step 2

Process description: Rate Calculations Performed. Parameters Used: shoreline layer=shorelines, shoreline date field=Date_, shoreline uncertainty field name=Uncy, the default accuracy=4.4 meters, shoreline intersection parameters=farthest, stats calculations=[End Point Rate (EPR), Linear Regression Rate (LRR)], shoreline threshold=4, confidence interval=90%, Output rate table name=transects_rates_20081006_101845.

Process date: 20081006

Figure 48.

10 References

- Anders, F.J., and Byrnes, M.R., 1991, Accuracy of shoreline change rates as determined from maps and aerial photographs: *Shore and Beach*, v. 59, pp. 17-26.
- Dolan, R., Fenster, M.S., and Holme, S.J., 1991, Temporal analysis of shoreline recession and accretion: *Journal of Coastal Research*, v. 7, pp. 723-744.
- Crowell, M., Leatherman, S.P., and Buckley, M.K., 1991, Historical shoreline change— Error analysis and mapping accuracy: *Journal of Coastal Research*, v. 7, pp. 839-852.
- Crowell, M., Douglas, B.C., and Leatherman, S.P., 1997, On forecasting future U.S. shoreline positions— a test of algorithms: *Journal of Coastal Research*, v. 13, n. 4, pp. 1245-1255.
- Genz, A.S., Fletcher, C.H., Dunn, R.A., Frazer, L.N., and Rooney, J.J., 2007, The predictive accuracy of shoreline change rate methods and alongshore beach variation on Maui, Hawaii: *Journal of Coastal Research*, v. 23, n. 1, pp. 87-105.
- Hapke, C.J., and Reid, D., 2007, National Assessment of Shoreline Change, part 4— Historical coastal cliff retreat along the California coast: U.S. Geological Survey Open-File Report 2007-1133. [<http://pubs.usgs.gov/of/2007/1133>]
- Hapke, C.J., Reid, D., Richmond, B.M., Ruggiero, P., and List, J. 2006, National Assessment of Shoreline Change part 3— Historical shoreline change and associated coastal land loss along sandy shorelines of the California coast: U.S. Geological Survey Open-File Report 2006-1219. [<http://pubs.usgs.gov/of/2006/1219>]
- Leatherman, S.P. and Clow, J.B., 1983, UMD shoreline mapping project: IEE Geoscience and Remot Sensing Society Newsletter, v. 22, pp.5-8.
- Miller, T.L., Morton, R.A., and Sallenger, A.H., 2005, The National Assessment of Shoreline Change— A GIS compilation of vector shorelines and associated shoreline change data for the U.S. Southeast Atlantic Coast: U.S. Geological Survey Open-File Report 2005-1326 [<http://pubs.usgs.gov/of/2005/1326>]
- Moore, L.J., 2000, Shoreline mapping techniques: *Journal of Coastal Research*, v. 16, pp. 111-124.
- Moore, L.J., Ruggiero, P., and List, J.H., 2006, Comparing mean high water and high water line shorelines— Should proxy-datum offsets be incorporated into shoreline Change analysis?: *Journal of Coastal Research* v. 22, n. 4, pp. 894-905.
- Morton, R.A., and Miller, T.L., 2005, National Assessment of Shoreline Change— part 2 Historical shoreline changes and associated coastal land loss along the U.S. southeast Atlantic coast: U.S. Geological Survey Open-File Report 2005-1401. [<http://pubs.usgs.gov/of/2005/1401>]
- Morton, R.A., Miller, T.L., and Moore, L.J., 2004, National Assessment of Shoreline Change— part 1 Historical shoreline changes and associated coastal land loss along the U.S. Gulf of Mexico: U.S. Geological Survey Open-File Report 2004-1043. [<http://pubs.usgs.gov/of/2004/1043>]
- Rousseeuw, P.J. and Leroy, A.M., 1987, Robust regression and outlier detection: John Wiley and Sons, New York.
- Ruggiero, P., Kaminsky, G.M. and Gelfenbaum, G., 2003, Linking proxy-based and datum-based shorelines on a high-energy coastline— implications for shoreline change analysis: *Journal of Coastal Research*, Special Issue 38, pp. 57-82.
- Ruggiero, P., Komar, P.D., McDougal, W.G. and Beach, R.A., 1996, Extreme water levels, wave runup, and coastal erosion: *Proceedings of the 25th Coastal Engineering Conference*, American Society of Civil Engineers, pp. 2793-2805.
- Ruggiero, P., Komar, P.S., McDougal, W.G., Marra, J.J., and Beach, R.A., 2001, Wave runup, extreme water levels and the erosion of properties backing beaches: *Journal of Coastal Research*, v. 17, n. 2, pp. 407-419.
- Ruggiero, P., and List, J.H., 2009, Improving accuracy and statistical reliability of shoreline position and change rate estimates: *Journal of Coastal Research*, v. 25, n. 5, pp.1069-1081
- Stockdon, H.F., Holman, R.A., Howd, P.A., and Sallenger, A.H., 2006, Empirical parameterization of setup, swash and runup: *Coastal Engineering*, v. 53 n. 7, pp. 573-588.
- Stockdon, H.F., Sallenger, A.H., List, J.H. and Holman, R.A., 2002, Estimation of shoreline position and change from airborne topographic lidar data: *Journal of Coastal Research*, v. 18, pp. 502-513.

Thieler, E.R., and Danforth, W.W., 1994, Historical shoreline mapping (1)— Improving techniques and reducing positioning errors: *Journal of Coastal Research*, v. 10, p. 549-563.

Weber, K.M., List, J.H., and Morgan, L.M.M., 2005, An operational mean high water datum for determination of shoreline position from topographic lidar data: U.S. Geological Survey Open-File Report 2005-1027. [<http://pubs.usgs.gov/of/2005/1027>]

Zar, J.H., 1999, *Biostatistical Analysis*, 4th ed: Prentice Hall, Upper Saddle River, NJ.

11 Appendix 1 – Troubleshooting

PROBLEM: Attempting to calculate statistics results in the following error message:

DSASCore.calc.exe – Unable To Locate Component

This application has failed to start because mclmerrt78.dll was not found. Reinstalling the application may fix this problem.

SOLUTION: This error message indicates that the MCRInstaller.exe (see step 4 of **section 2**) was not installed or did not install correctly. If already installed, it will appear in the list of Add/Remove programs (which you can access through the Control Panel on your computer). Uninstall and reinstall, or if it was not installed, run the MCRInstaller.exe file (which can be downloaded from the DSAS website <http://pubs.usgs.gov/of/2008/1278>).

PROBLEM: The transect file does not appear as a selectable option in the dropdown menu on the DSAS toolbar.

SOLUTION: Save the ArcMap project, then close and reopen the document.

PROBLEM: Unable to calculate statistics.

SOLUTION: If ArcCatalog is open, close it and run the statistics again.

PROBLEM: When the baseline was edited, the transect file did not update.

SOLUTION: Verify that the baseline feature class is the target in the ArcEditor toolbar and that the transect feature class is the target in the DSAS toolbar. If transects were just created, save the ArcMap project, then close and reopening the document. Closing ArcCatalog might also help.

PROBLEM: Attempting to calculate statistics results in the following error message:

DSAS

You have attempted to compute Weighted Linear Regression (WLR) where one or more of the input shorelines has been assigned an uncertainty value of zero (or null) in both the shoreline attribute table and the DSAS default parameters window. WLR assigns a weight component to each shoreline based on this shoreline uncertainty value. The weight is computed by taking the inverse square of the uncertainty, or $[1/(\textit{uncertainty})^2]$. An uncertainty value of zero has terminated the calculation of WLR and no values will be reported in the output table.

SOLUTION: Check for zero or null values in the uncertainty attribute field in the shoreline feature class (see **section 5.2.3**) or set the default uncertainty to a value greater than zero (see **section 6.1.2**).

12 Appendix 2 – A case study of complex shoreline data

12.1 Using shoreline data referenced to different proxies

The designs of many features in this version of DSAS have been influenced by the needs of the U.S. Geological Survey's (USGS) National Assessment of Shoreline Change project (Morton and others, 2004; Morton and Miller, 2005; Hapke and others, 2006; Hapke and others, 2007) including support for shorelines derived from data collected by aerial topographic mapping, such as lidar. Lidar beach-profile data are increasingly being used as a source for deriving shoreline positions. One method for deriving the shoreline is to calculate a linear regression fit through the foreshore section of the lidar profile (Stockdon and others, 2002; Weber and others, 2005). This calculation results in an operational Mean High Water (MHW) elevation value and represents a different shoreline proxy than the historical High Water Line (HWL) shoreline positions compiled from other commonly used sources, such as air photos. Several studies have determined that the proxy-datum bias between HWL and MHW shorelines is an unidirectional offset with the HWL position landward of the MHW position (Ruggiero and others, 1996; Ruggiero and others, 2001; Ruggiero and others, 2003; Morton and others, 2004; Moore and others, 2006; Stockdon and others, 2006; Ruggiero and List, 2009). DSAS is now capable of incorporating proxy-offset values into proxy-datum bias shifts to reconcile horizontal offsets between the MHW and HWL shoreline proxies.

12.2 Representing lidar shorelines as calibrated routes

In a methodology used by the USGS, operational MHW positions are extracted from a series of cross-shore profiles as point data (Stockdon et al., 2002; Weber et al., 2005) that can be converted into an alongshore shoreline feature by connecting adjacent profile points to form a vector shoreline feature. This is only one example of how shoreline positions may be extracted from lidar data and serves as a case study for advanced users. Each operational MHW shoreline point accounts for three values:

1. Measurement and positional errors (UNCY).
2. A calculated proxy-datum bias value that corrects for the unidirectional offset between the MHW elevation of the lidar and HWL shorelines (BIAS).
3. A measurement uncertainty in the total water level, which can also be thought of as the uncertainty in the position of the High Water Line (UNCYB).

To use these data in DSAS, the point data are first converted to a route by using standard ArcGIS tools. The unique cross-shore profile ID is stored as the M-value at each vertex. The route is calibrated based on the input-point data so that the measure value from the start to the end of the route is based on the known profile IDs stored at each vertex of the route. This profile ID is used as the common attribute field between the route feature class and an uncertainty table storing the positional uncertainty and bias values of the original lidar point data. DSAS uses linear referencing to retrieve a measure value for the intersection of each DSAS transect and the lidar shoreline. This measure value is based on the M-values (the cross-shore profile ID) stored at each vertex. The measure value at the transect intersection is used by DSAS to determine the adjacent vertices along the lidar route (**fig. 49**). The uncertainty, bias, and bias uncertainty values at the two adjacent vertices are read from the uncertainty table, which must be added to the ArcMap project. The uncertainty table can be linked to the lidar shoreline through cross-shore profile ID values they have in common. A weighted interpolation is computed based on the proximity of the transect to each of the adjacent lidar-shoreline vertices. The resulting values for uncertainty, bias, and bias uncertainty are assigned to the lidar-shoreline measurement point established by the DSAS transect. DSAS includes these values in the output file to all rate calculations. The values are used during the computation of measurements and rates in the core statistics module distributed with DSAS.

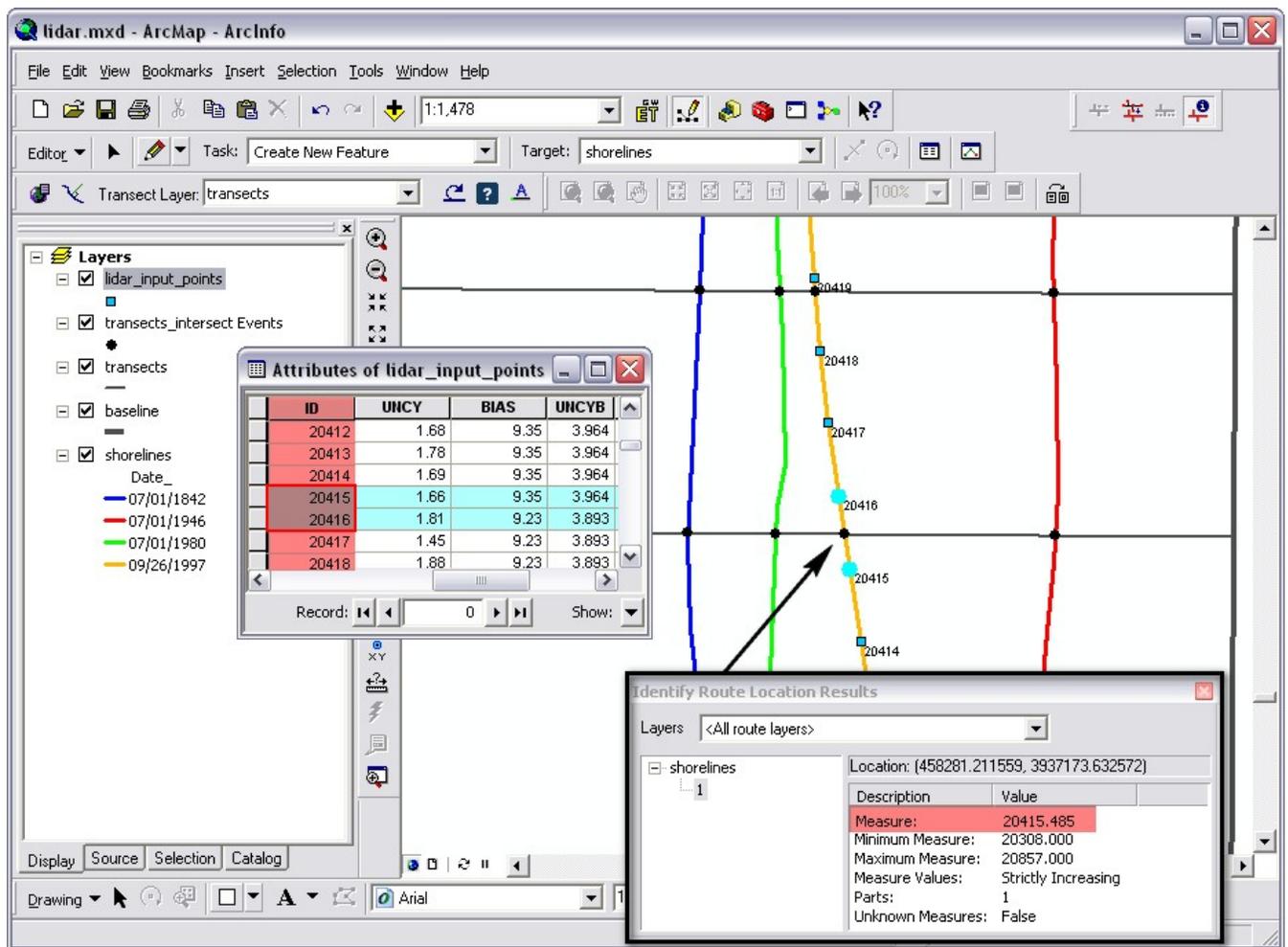


Figure 49

For more information on creating a route and calibrating it based on point data, please refer to the ArcGIS Desktop help (keywords: Linear Referencing). Once the lidar data have been converted to a route and calibrated, any additional shoreline data must be appended to the route feature class because all shoreline data must be contained in a single feature class. Note that the target dataset must be a copy of the calibrated route (lidar shoreline). Instructions on how to append shoreline data can be found in **section 5.2.2**.

12.3 Storing bias and uncertainty data in a table (requirements)

DSAS recognizes route data at the beginning of the rate-calculation process. It will search for an uncertainty table based on the shoreline filename specified in the DSAS Set Default Parameters window (section 6.1.2). For example, if the shoreline feature class is called “shorelines,” the uncertainty table must be called “shorelines_uncertainty.” This table must be created by the user by using a spreadsheet. It can be imported into the geodatabase in ArcCatalog by right-clicking on the geodatabase and choosing Import > Table (single) from the popup windows.

Field name	Data type	Established by
ID	Long Integer	user
UNCY	Any numeric field	user
BIAS	Any numeric field	user
UNCYB	Any numeric field	user

The following is a list of the definitions of the field names.

ID	This field is case-sensitive and name specific. The field contains a cross-shore lidar profile ID stored as the M-value (measure value) at each vertex in the calibrated shoreline route. This serves as the link between the lidar shoreline and the uncertainty table and must be a unique number at each point.
UNCY	This field is case-sensitive and name specific. The field contains a positional uncertainty associated with natural influences over the shoreline position (wind, waves, tides) as well as measurement uncertainties associated with the collection of the lidar data (for example, the accuracy associated with the global positioning system coordinates).
BIAS	This field is case-sensitive and name specific. The field contains a proxy-datum bias value describing the unidirectional horizontal offset between the MHW elevation of the lidar data and HWL shoreline positions.
UNCYB	This field is case-sensitive and name specific. The field contains the uncertainty in the position of the HWL associated with the calculated proxy-datum bias value.

Proxy-datum bias correction (NU_ and NB_)

The core-statistics calculations provided as part of DSAS utilize uncertainty and bias-correction data provided as part of the input shoreline feature class. This method is fully described under **section 12.1** above.

When bias values are detected (through the presence of an uncertainty table in the ArcMap project; see **section 12.3**), the core statistics included with DSAS report rate calculations as follows:

1. The standard field headings (for example, EPR and LRR) will report rates that include both the proxy-datum bias shift (BIAS) and additional HWL uncertainty (UNCYB). The UNCYB value is incorporated into each historical HWL shoreline uncertainty specified by the user by adding the errors in quadrature and taking the square root of the sum of the squares.
2. Any computations that are affected by the additional HWL uncertainty are also reported without the addition of the UNCYB field to the HWL uncertainty and are preceded by the no-uncertainty code “NU_” (for example, NU_WLR) in the field heading. These rate calculations still include the proxy-datum bias shift.
3. All selected rate calculations are also reported without the proxy-datum bias or the additional HWL uncertainty applied, and are preceded by the no bias code “NB_” (for example, NB_EPR) in the field heading.

The computed statistics are reported in a time-stamped results table (see **section 6.5.1**) and contain the additional fields described below:

General field heading	Description	Field heading examples
NU_*	Advanced shorelines— when users apply bias to a shoreline dataset, standard headings listed above are computed with the proxy-datum bias shift as well as the additional HWL uncertainty provided by the user. Fields in the output table that contain the code “NU_” to the left of the above headings indicate that the additional HWL uncertainty was not included (no uncertainty). The rate calculations still include the proxy-datum bias shift and any uncertainty information provided in the shoreline attribute or default parameter settings.	NU_WLR, NU_WSE, NU_WCI95, NU_WR2
NB_*	Advanced shorelines— Fields in the output table that contain “NB_” preceding the standard headings indicate that no bias or HWL uncertainty data was applied to the computation. These results reflect what would be reported if all of the advanced shoreline proxy-datum bias data were omitted from the computation.	NB_WLR, NB_WSE, NB_WCI95, NB_WR2

Contact Information

E. Robert Thiel

U.S. Geological Survey
Coastal and Marine Geology Program
384 Woods Hole Road
Woods Hole, MA 02543
rthieler@usgs.gov
(508) 548-8700

Emily A. Himmelstoss

U.S. Geological Survey
Coastal and Marine Geology Program
384 Woods Hole Road
Woods Hole, MA 02540
ehimmelstoss@usgs.gov

<http://pubs.usgs.gov/of/2008/1278/>

<http://woodshole.er.usgs.gov/project-pages/dsas/>

Programming by:

Innovate! Inc.

<http://www.innovateteam.com>

Jessica L. Zichichi

jzichichi@innovateteam.com

Ayhan Ergul

aergul@innovateteam.com