The Velocity Mapping Toolbox

By Frank L. Engel and P. Ryan Jackson

User Guide for version 4.06

U.S. Department of the Interior
U.S. Geological Survey

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User Guide: The Velocity Mapping Toolbox

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Introduction

The Velocity Mapping Toolbox (VMT) is a Matlab®-based software for processing and visualizing ADCP data collected along transects in rivers or other bodies of water. VMT allows rapid processing, visualization, and analysis of a range of ADCP datasets and includes utilities to export ADCP data to files compatible with ArcGIS®, Tecplot®, and Google Earth®. The software can be used to explore patterns of three-dimensional fluid motion through several methods for calculation of secondary flows (e.g., Rhoads and Kenworthy, 1998; Lane et al., 2000). The software also includes capabilities for analyzing the acoustic backscatter and bathymetric data from the ADCP. A user-friendly graphical user interface (GUI) enhances program functionality and provides ready access to two-and three-dimensional plotting functions, allowing rapid display and interrogation of velocity, backscatter, and bathymetry data.

To-date no standardized technique exists for combining velocity data from multiple ADCP transects to produce a composite depiction of three-dimensional velocity fields. To address this important need, the a new software tool has been developed, the Velocity Mapping Toolbox (VMT), for processing, analyzing, and displaying velocity data collected along multiple ADCP transects. VMT can be run using either the Matlab® source code or compiled standalone executables. Users with access to Matlab® are encouraged to run the source code for the most versatility. However, some older versions of Matlab®, for example version 7.0.4, are not able to run GUIs like VMT that are created with newer versions of Matlab®. In this case, run the executables rather than the source code. The VMT and utility executables require the Matlab® Runtime Library 2012a 32 bit[1] to be installed prior to running. Input to the Matlab®-based toolbox consists of ASCII output files from the Teledyne RD Instruments® ADCP data-collection software.

[1] *http://www.mathworks.com/products/compiler/mcr/index.html*

The main processing component of the software projects data collected along several irregular ship tracks, or measurement transects, onto a straight-line plane that defines a measurement cross section. The velocity data from individual transects are then averaged to produce a composite representation of the cross-sectional flow field. For more details see Velocity Mapping Toolbox (VMT): a processing and visualization suite for moving-vessel ADCP measurements, ESPL, by Parsons and others (2013).

Limitations

- Only moving-boat transects are supported. The software does not support stationary profile data.
- Presently (2014) the software accepts input from TRDI ADCPs, including RioGrande 600 and 1200 MHz, RiverRay, and StreamPro. It does not support input from other ADCP manufacturers/models.
- The program has not been tested extensively on many platforms. Some issues may result with plotting, saving figures, etc. on platforms with different graphics capabilities and screen resolution. Please report these issues via the VMT forum (*http://hydroacoustics.usgs.gov/list_info.shtml*).
- Due to forward compatibility issues, the current version of VMT is not compatible with older versions of Matlab® (for example, v.7.0.4). If you experience issues of Matlab® crashing when running VMT, please either upgrade Matlab® to the newest version or run the compiled version of VMT.

Overview of the VMT User Interface

When starting VMT, you are presented with the Graphical User Interface (GUI) shown in Figure 1. The GUI has a menu bar with access to most functions/operations, and a toolbar allowing quick access to common functions. Processing workflow is organized into procedural panels.

All menus, panels, and options are explained in detail in the next section.

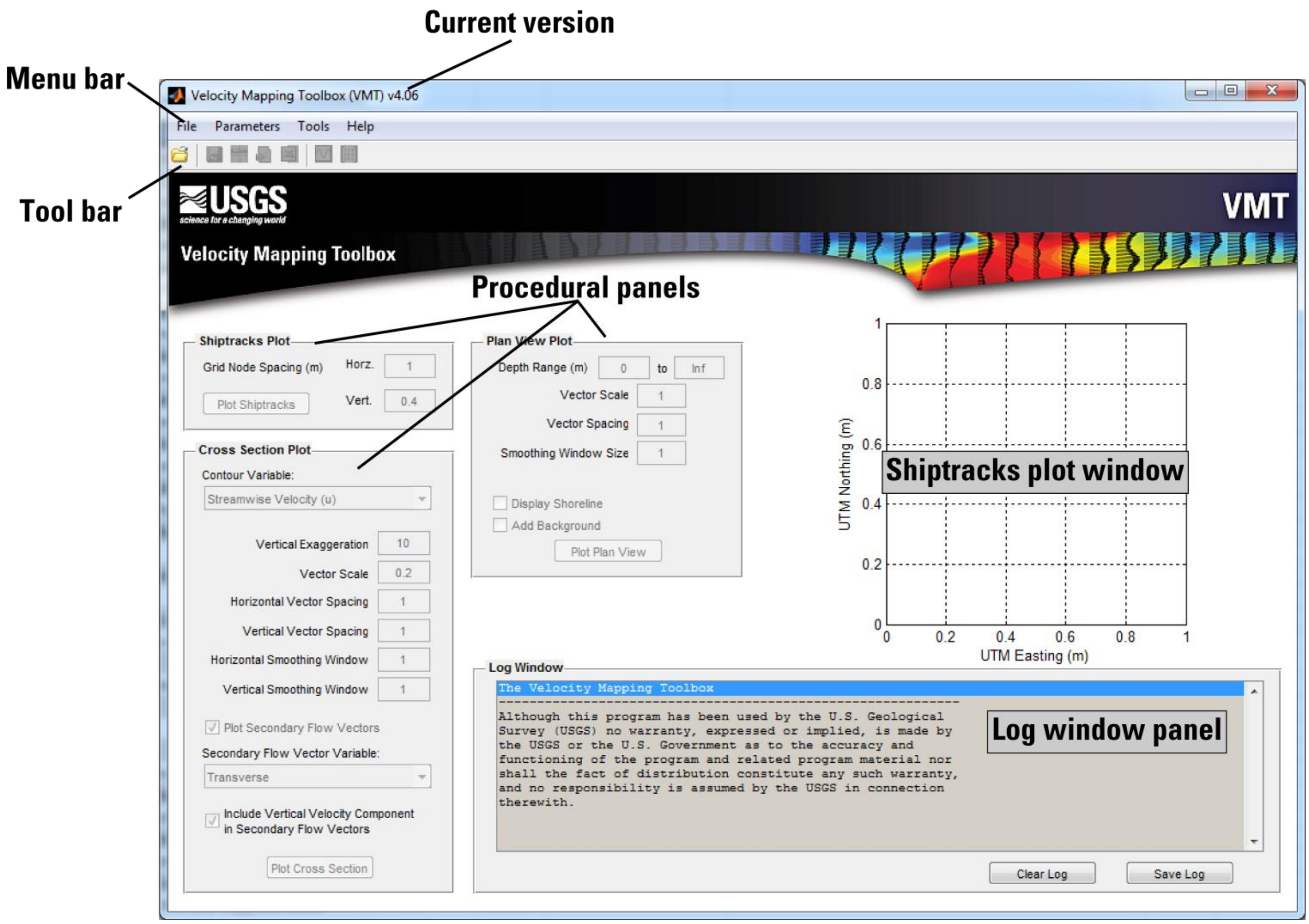


Figure 1. The VMT graphical user interface (GUI).

Menu Bar

File

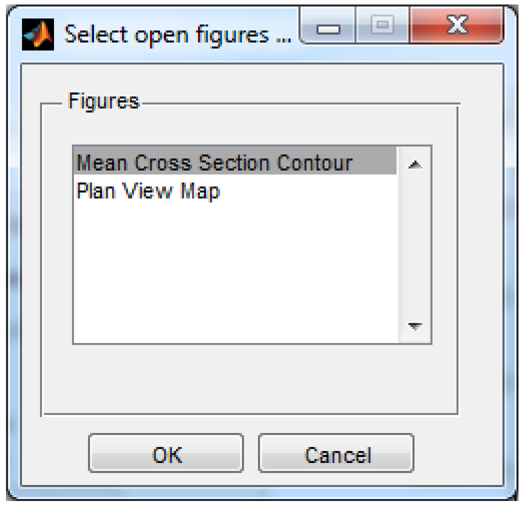
Provides access to various I/O tools. The following submenus are included:

1. Open
   a. ASCII Files (Ctrl+O): Prompts to load TDRI ASCII output files created by the WinRiver II software package
   b. MAT File: Prompts to load MAT file created by VMT from previously processed data
2. Save MAT File (Ctrl+S)
3. Export

a. Figure Export Settings

i. Print or Presentation: Choose between two standard figure formats

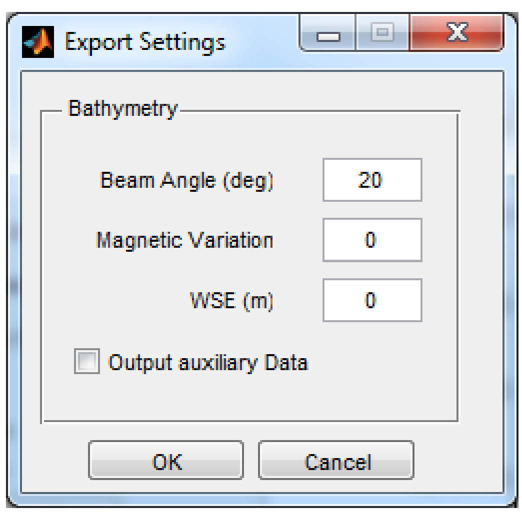
b. Export Figures as Graphics: Prompts to save currently open figures as PNG or EPS graphics files



Choose the desired figure from the list of currently available figures ans press OK to export graphics.

c. Export iRic ANV File: Prompts to save a text file in a format recognizable in the iRic modeling framework

d. Bathymetry Export Settings: Opens the following dialog allowing for adjustment of parameters related to bathymetry.



Beam Angle (deg): This is the angle between the beams of the ADCP. The angle is dependent on the ADCP manufacturer.

Magnetic Variation: The modeled or measured magnetic variation from true north in degrees. This is used to correct compass headings if required. (this feature has been depreciated).

WSE (m): Elevation of the water surface in meters.

Output Auxiliary Data: If this box is checked, VMT will also export an auxiliary file with more information

  e. Export Multibeam Bathymety: Prompts to save a CSV file containing the bed elevations measured by all four individual beams (corrected for heading, pitch, and roll, and user-supplied water surface elevation).
  f. Export KMZ File: Prompts to save a KMZ file of the processed Mean Cross Section (MCS), using the specified Vertical Offset (Parameters□KMZ Offset). The vertical offset is equal to the height the cross section will be raised above the image plane in Google Earth®.
  g. Export Tecplot® File: Prompts to export a Tecplot® DAT file of the processed Mean Cross Section (MCS).
  h. Export Excel® File: Prompts to export an Excel® File of the processed Mean Cross Section (MCS).

Parameters

Adjust and set parameters used by VMT. The following submenus are included:

1. Processing
    a. Unit Discharge Correction: Activate or Deactivate the Unit Discharge Correction. The Unit Discharge Correction is deactivated by default (see Parsons et al. 2013 for more information).
2. Plotting
    a. Units
        i. Metric or English: Metric units are the default. NOTE: all data must be imported in metric units and this feature only controls the units of the figures.
    b. Set Cross-Section Endpoints

i. Automatic or Manual: Automatic is the default. Manual (fixed) endpoint may be entered by the user.

c. Style

i. Print or Presentation: Presentation is the default.

3. KMZ Export: Prompts to set the vertical offset to apply when exporting the Mean Cross Section as a KMZ file to be viewed in Google Earth®.

Tools

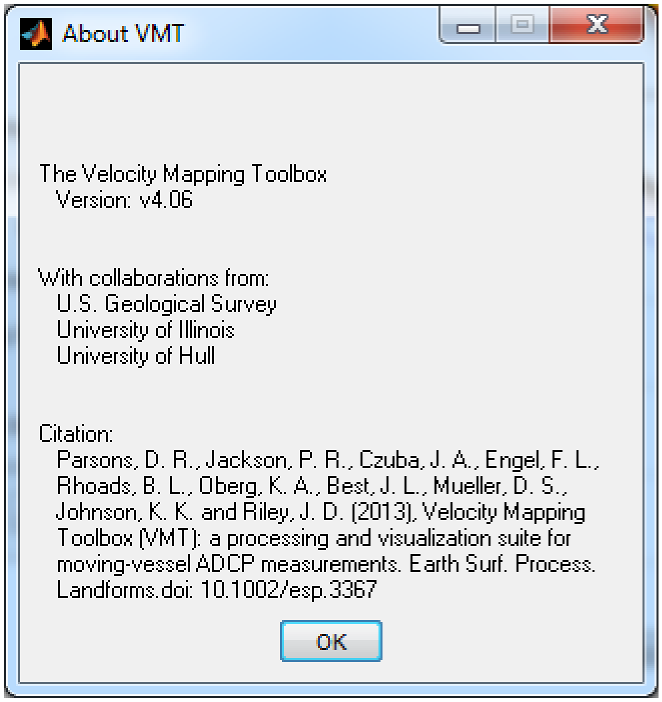
Start standalone tools packaged with VMT. The following tools are included:

1. ASCII to GIS: Opens a new GUI window for exporting the depth- or layer-averaged ADCP data to a GIS formatted CSV table. Also allows basic plotting of data.
2. ASCII to KML: Prompts to save currently loaded Shiptrack data as line features in a KML file for viewing in Google Earth®.
3. Open Batch Mode: Opens a new GUI window that runs the VMT processing engine in a batch mode, enabling you to process multiple transects for multiple cross sections with the click of a button.

Help

Displays help information. The following submenus are included:

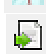
1. Users Guide: Opens the web version of this User Guide. This feature requires an active internet connection.
2. Function Library: Opens a web-formatted (stored locally) documentation library of all of the functions and files included in the VMT software. This is especially useful for understanding the source code.
3. Check for Updates: Checks the currently running version of VMT against the most recently released version, and alerts you of the status. This feature requires an active internet connection.
4. About: Displays the following information window (your version number may be different).



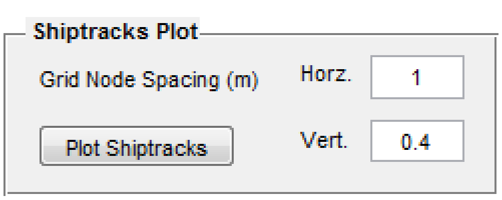
Toolbar

The VMT toolbar allows for quick access to common tasks. Table 1 shows each toolbar item and its function. In addition, tooltips will appear when you hover the mouse over a toolbar icon.

Table 1. VMT toolbar item descriptions.

Icon	Description
	Open ASCII File(s)
	Save MAT File
	Export multibeam bathymetry file
	Export figure(s)
	Plotting parameters
	Processing parameters (currently unused)

Shiptracks plot



The Shiptacks Plot Panel is the first panel in the VMT User Interface (Figure 1), and consequently is the typical starting point for any processing you do. There are two items in this panel:

Horizontal Grid Node Spacing (m): This is the horizontal resolution of the Mean Cross Section (MCS). The default is 1 meter, but you may set it to whatever you wish. However, it is recommended that you chose a value representative of the data being processed. VMT will make a suggested spacing, which is displayed in the Log Window (see the Log Window Panel).

Vertical Grid Node Spacing (m): This is the vertical resolution of the MCS. The default value varies depending on the data type currently loaded. For TDRI RioGrande and StreamPro ADCPs, the default is the bin size. For TDRI RiverRays, the default is 0.4 meters.

Plot Shiptracks: This button will process the currently loaded dataset, and display a map in the Shiptracks Plot Window.

Shiptracks plot window

The Shiptracks plot (Figure 1) is intended to be a quick reference tool for viewing the processed Mean Cross Section (MCS) and the original ADCP recorded Shiptracks. When VMT starts, this plot is initialized as an empty chart.

Task: To create a Shiptrack Plot, ensure that data are loaded and press [Plot Shiptracks button] in the Shiptracks Plot Panel.

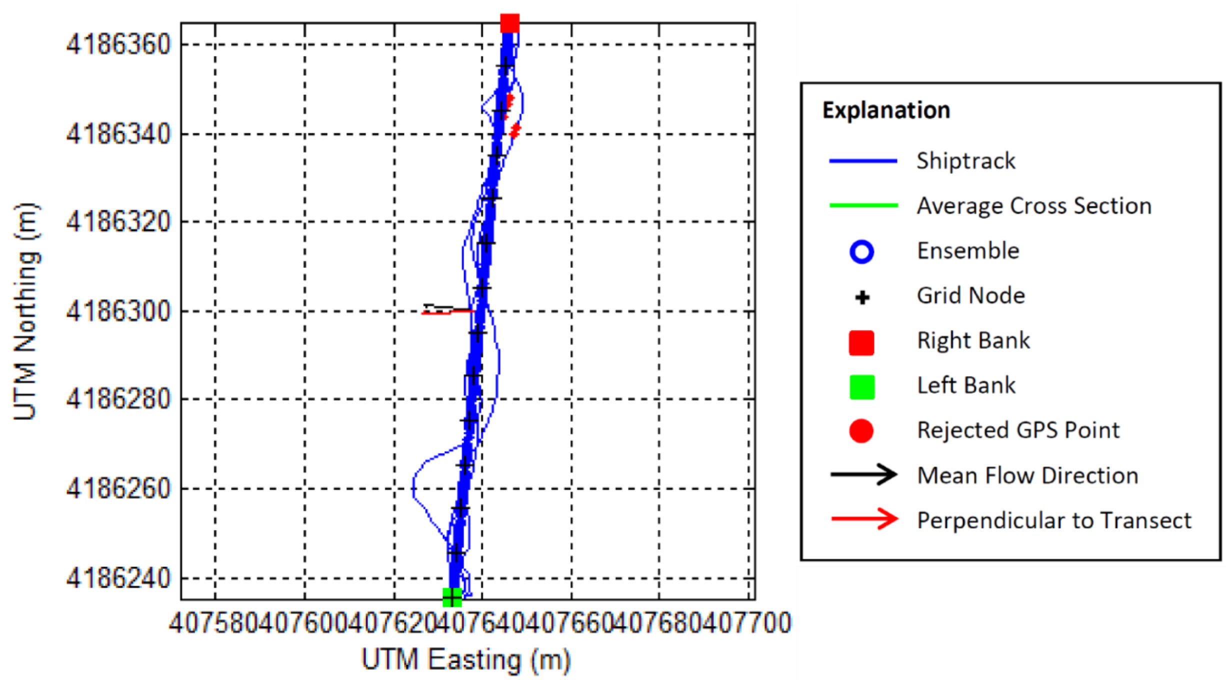
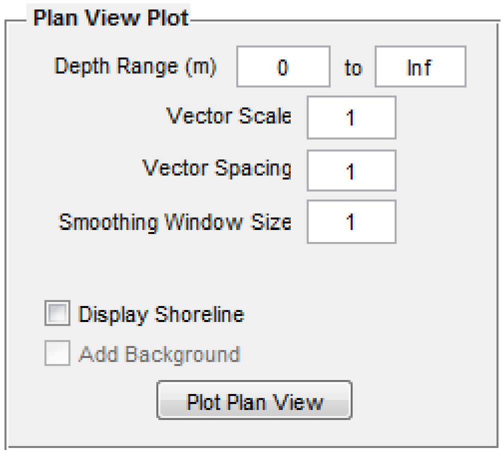


Figure 2. VMT shiptracks plot explanation.

Plan view plot panel



The Plan View Plot Panel (Figure 1) allows you to control the depth- or layer-averaged parameters used to produce the Plan View Map Figure. In includes the following options:

Depth Range (m): You may select the vertical depth range over which VMT will average the ENU (East, North, Up) velocities used to produce the Plan View Map Figure. The default is the full depth range (that is, depth of 0 to infinity). VMT use the following equation to determine layer-averaged quantities:

$$V_{la} = \frac{1}{d_2 - d_1} \int_{d_1}^{d_2} V dz \qquad (1)$$

where d_1 minimum depth for layer-averaging

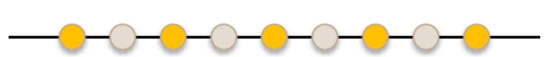
d_2 maximum depth for layer-averaging

V_{la} layer-averaged velocity

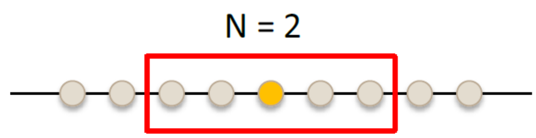
Vector Scale: You can adjust the length of plotted vectors in the Plan View Map Figure with this parameter. Vector lengths are determined using an autoscaling procedure. The Vector Scale quantity is a simple multiplier of the vector lengths. For example, to produce a vector twice the length as the default, set Vector Scale to 2. The default is 1.

Vector Spacing: This is the "index skip factor" (VS) used by VMT to plot only particular vectors along the Mean Cross Section (MCS). Setting Vector Spacing to 2 will make VMT plot only every other vertical in the MCS. The map distance between vectors is the Vector Spacing multiplied by the Horizontal Grid Node Spacing. For example, with a node spacing of 2.5 meters and vector spacing of 2, VMT will plot vectors which are 5 meters apart. The default Vector Spacing is 1, and this value must be an integer greater than 0.

$$VS = 2$$



Smoothing Window Size: This sets the window size (N) which VMT uses to apply a 1-D moving average to the layer-averaged velocities. The window size specifies the number of nodes on either side of the central node which is used in the average. VMT ignores any missing data in the computation. The default Smoothing Window Size is 1, and this value must be an integer greater than 0.



Display Shoreline: If selected, VMT will prompt you to load a simple text file with coordinates corresponding to vertices of lines defining the shoreline of the channel or water body you are processing (See Plan View Map Figure).

Add Background: If selected, VMT will prompt you to load one or more georeferenced image files, to be added as a background of the Plan View Map Figure. NOTE: the background imagery or file must have a UTM projection to plot properly. Several programs, including ArcGIS®, are available to change projections and coordinate systems of georeferenced images and shapefiles.

Tip: Though the intent of the Add Background functionality is to display image files (e.g., GeoTiff, TIFF/JPEG/PNG with a world file), VMT will recognize the following spatial data types:

- Shapefiles (point, line, or polygon classes)
- ARC ASCII GRIDs
- SDTS Rasters

Plot Plan View: This button will process the currently loaded dataset, and display the Plan View Map Figure.

Plan view map figure

The Plan View Map figure (Figure 3) is a planform plot of depth- or layer-averaged velocity vectors produced by the averaging procedure of VMT. When processing for a single cross section, the Plan View Map figure will contain only one set of vectors along the mean cross section (Figure 3A). Multiple cross sections can be viewed at once and all referenced to the same scale by loading several previously processed VMT transects (MAT files) (Figure 3B). You may also visualize a vector shoreline (Figure 3C) and/or aerial imagery (Figure 3D). A colorbar provides the scale for the planview vectors. The title displays the range over which vectors have been averaged, and the units designation. All planview plots in VMT are in UTM coordinates.

Task: To create the Plan View Map figure, ensure that data are loaded, adjust parameters in the Plan View Plot panel as desired, and press. Plot Plan View

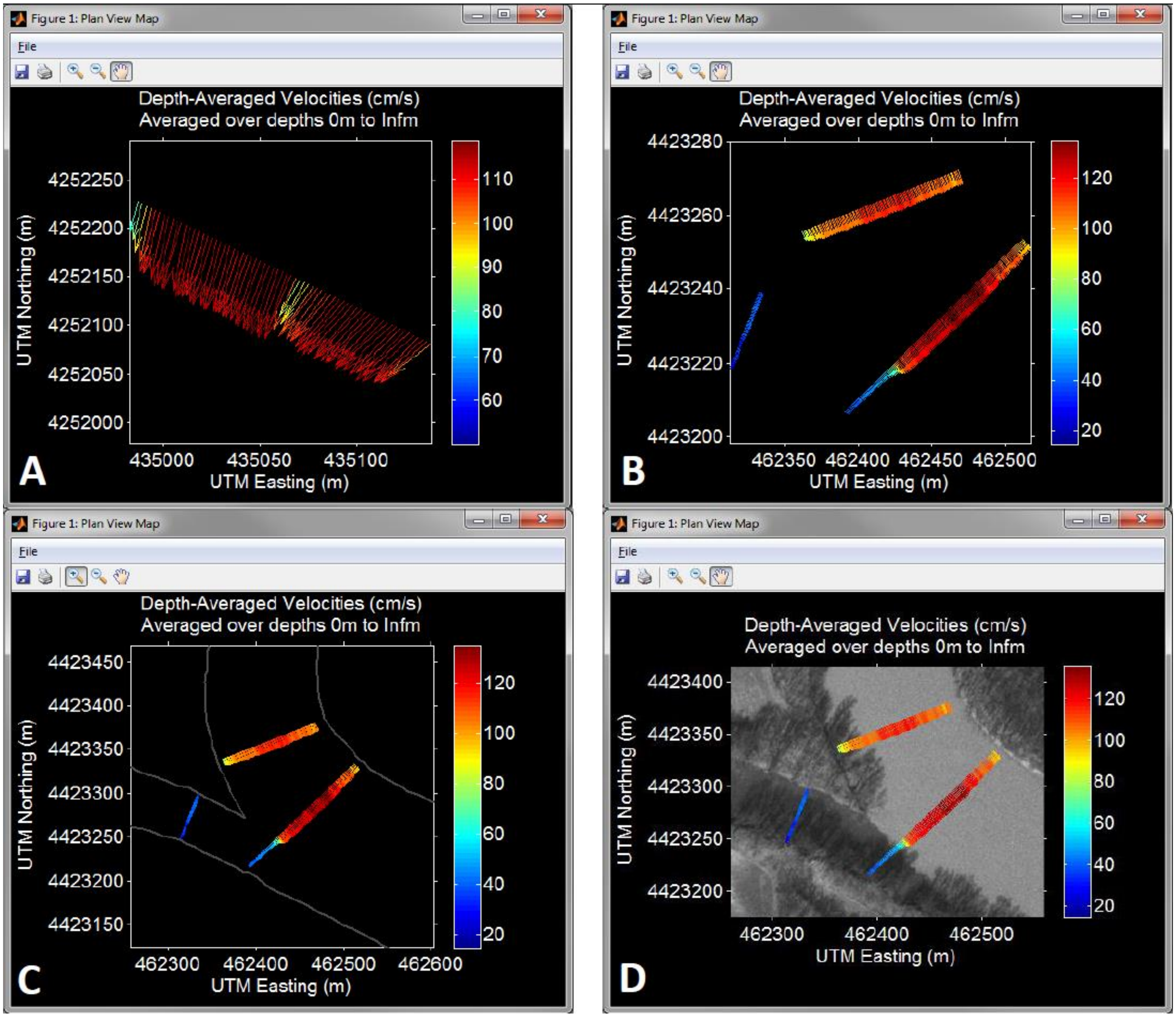


Figure 3. Layout of the Plan View Map figure in VMT.

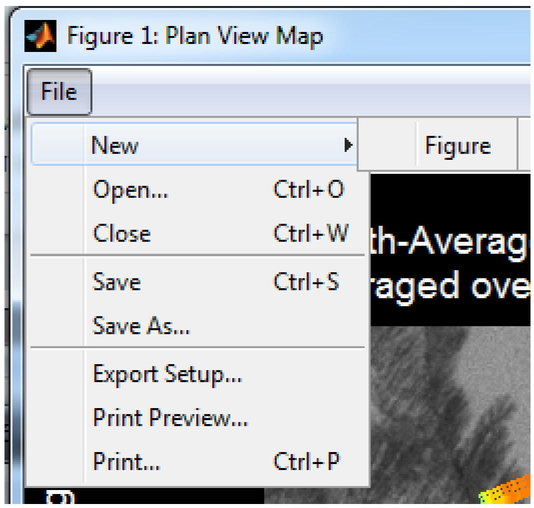
The Plan View Map figure can be manipulated by several means to produce a plot suitable to your needs. To resize the figure, Left click-hold on any edge of the figure and drag to desired dimensions. Use the figure window toolbar to zoom in or out, and pan the viewable extent of the figure.

You may also save a Matlab® native file of the figure (*.fig file), or print the figure using the Matlab® default export settings, all from the toolbar.

The Figure Toolbar: 

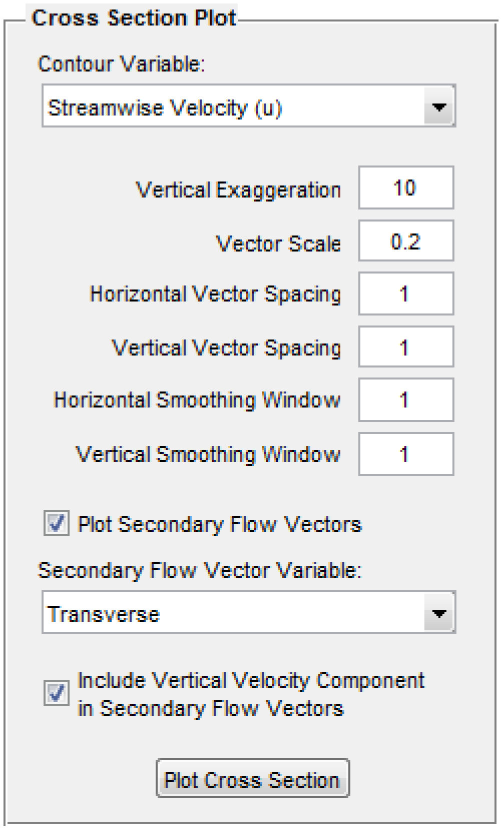
Tip: Once you have setup a figure the way you want it to look, use the Save feature in the File menu to create a *.fig file. Then, you can use the Open… figure menu item to reload the figure. VMT will still recognize the reloaded figure.

Using the File Menu, you may perform other optional actions, some of which are not technically part of VMT, but are included within the Matlab® MCR environment VMT was compiled in.



Note: Though it is possible to export the figure from the File→Export Setup… dialog, it is recommended that you use the Export Figure functionality within the Main VMT User Interface. If the predefined export settings in the VMT interface are not sufficient for your purposes, the File→Export Setup… option provides customizable export files.

Cross section plot panel



The Cross Section Plot Panel (Figure 1) allows you to control the parameters used to produce the Mean Cross Section Figure. In includes the following options:

Contour Variable: This is the primary variable used to create a colored contour rendering in the Mean Cross Section Contour Figure. There are several options (Table 2).

Vertical Exaggeration: This is the ratio of the horizontal to vertical axes that VMT uses in the Mean Cross Section Contour Figure. The default is 10.

Vector Scale: You can adjust the length of plotted vectors in the Mean Cross Section Contour Figure with this parameter. Vector lengths are determined using an autoscaling procedure. The Vector Scale quantity is a simple multiplier of the vector lengths. For example, to produce a vector twice the length as the default, set Vector Scale to 2. The default is 0.2.

Horizontal Vector Spacing: This is the “index skip factor” used by VMT to plot only particular vectors along the horizontal axis of the Mean Cross Section Contour Figure. Setting the Horizontal Vector Spacing (HVS) to 4 will make VMT plot only every fourth horizontal grid node location in the MCS. The map distance between vectors is the Horizontal Vector Spacing multiplied by the Horizontal Grid Node Spacing (for example, with a node spacing of 2.5 meters and horizontal vector spacing of 2, VMT will plot vectors which are 5 meters apart in the horizontal. The default Horizontal Vector Spacing is 1, and this value must be an integer greater than 0.

Vertical Vector Spacing: This is the “index skip factor” used by VMT to plot only particular vectors along the vertical axis of the Mean Cross Section Contour Figure. Setting the Vector Spacing (VVS) to 2 will make VMT plot only every other vertical grid node location in the MCS. The map distance between vectors is the Vertical Vector Spacing multiplied by the Vertical Grid Node Spacing (bin size) For example, a bin size of 0.1 meters and vertical vector spacing of 2 will produce a plot of vectors which are 1 meter apart in the vertical. The default Vertical Vector Spacing is 1, and this value must be an integer greater than 0.

$HVS = 4, VVS = 1$

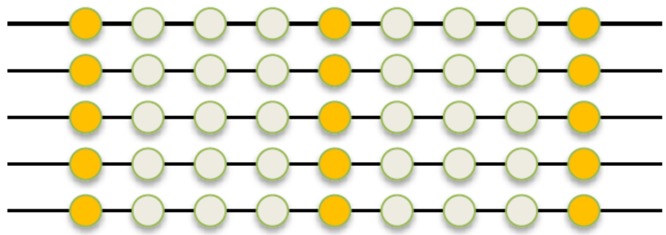


Table 2. Contour Variable options for the Mean Cross Section Contour Figure (see Parsons and others 2013 for more information on primary and secondary flow definitions).

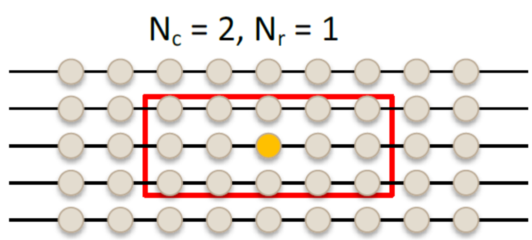
Contour variable	Description
Streamwise Velocity (u)	Component of velocity perpendicular to the MCS
Transverse Velocity (v)	Component of velocity parallel to the MCS
Vertical Velocity (w)	Component of velocity in the vertical axis
East Velocity (E)	East component of velocity ENU frame of reference
North Velocity (N)	North component of velocity ENU frame of reference
Error Velocity	Vertical error velocity as reported by the ADCP[1]
Primary Velociy (zsd)	Primary component of velocity after zero net secondary discharge rotations
Secondary Velocity (zsd)	Secondary component of velocity after zero net secondary discharge rotations
Primary Velociy (Roz)	Primary component of velocity after Rozovskii discharge rotations
Secondary Velocity (Roz)	Secondary component of velocity after Rozovskii discharge rotations
Prim. Vel. (Roz, downsream component)	Component of primary velocity in the streamwise (u) direction computed from Rozovskii discharge rotations
Prim. Vel. (Roz, cross-stream component)	Component of primary velocity in the cross-stream (v) direction computed from Rozovskii discharge rotations
Sec. Vel. (Roz, downsream component)	Component of secondary velocity in the streamwise (u) direction computed from Rozovskii discharge rotations
Sec. Vel. (Roz, cross-stream component)	Component of secondary velocity in the cross-stream (v) direction computed from Rozovskii discharge rotations
Backscatter	Backscatter intensities as reported by the ADCP[2]
Flow Direction (degrees)	Flow direction in geographic degrees (compass heading)

[1]Error velocity is reported in the same manner as it is output by the ADCP software

[2]Backscatter can be decibels or counts, depening on options chosen in ADCP software

Horizontal Smoothing Window: This in tandem with the Vertical Smoothing Window sets the horizontal window size (Nc) which VMT uses to apply a 2-D moving average to Mean Cross Section (MCS) velocities. The window size specifies the number of nodes on either side of the central node which are used in the average. VMT ignores any missing data in the computation. The default Horizontal Smoothing Window Size is 1, and this value must be an integer greater than 0.

Vertical Smoothing Window: This in tandem with the Horizontal Smoothing Window sets the vertical window size (Nr) which VMT uses to apply a 2-D moving average to Mean Cross Section (MCS) velocities. The window size specifies the number of nodes on above and below of the central node which are used in the average. VMT ignores any missing data in the computation. The default Vertical Smoothing Window Size is 1, and this value must be an integer greater than 0.



Note: To determine the spatial extent of the smoothing window, multiply the Horizontal Smoothing Window by the Horizontal Grid Node Spacing times 2, and the Vertical Smoothing Window by the Vertical Grid Node Spacing (that is bin size) times 2. For example, with a bin size of 0.25 meters, horizontal grid size of 1 meter, and horizontal and vertical smoothing window size of 3 and 2 respectively, VMT will perform a 2-D moving average of a region 6 meters wide, by 1 meter deep, centered on a node.

Plot Secondary Flow Vectors: when selected, VMT will add superimposed cross-stream and vertical vectors to the Mean Cross Section Contour Figure. The default is checked.

Secondary Flow Vector Variable: this is the secondary variable used to create superimposed vertical and cross-stream vectors on the Mean Cross Section Contour Figure. There are several options (Table 3). The default variable is Transverse.

Table 3. Secondary Flow Variable options for the Mean Cross Section Contour Figure (see Parsons and others 2013 for more information on primary and secondary flow definitions).

Secondary flow variable	Description
Transverse	Component of velocity parallel to the MCS
Secondary (zsd)	Secondary component of velocity after zero net secondary discharge rotations
Secondary (Roz)	Secondary component of velocity after Rozovskii discharge rotations
Secondary (Roz, cross-stream component)	Component of secondary velocity in the cross-stream (v) direction computed from Rozovskii discharge rotations
Primary (Roz, cross-stream component)	Component of primary velocity in the cross-stream (v) direction computed from Rozovskii discharge rotations

Include Vertical Velocity Component in Secondary Flow Vectors: when selected, VMT will include the Vertical Velocity (w) component in the vectors. When unchecked, only the selected Secondary Flow Vector Variable is used to create the vectors. The default is checked.

Plot Cross Section: This button will process the currently loaded dataset, and display the Mean Cross Section Contour Figure.

Mean cross section contour figure

The Map Cross Section Contour plot (Figure 4) displays the transect-averaged data in both a color-coded contour plot and a vector field. You can control what variables are plotted for both the contour plot and the vector field. In addition, you have the option to not include the vertical velocity component in the vector field. Unmeasured area near the surface and bed is shown and no data is interpolated into these regions. A colorbar provides the scale for the contour plot and a reference vector is provided for the vector field. The title displays the currently plotted velocity components (both contour and vector) and units designation.

Task: To create the Map Cross Section Contour figure, ensure that data are loaded, adjust parameters in the Cross Section Plot panel as desired, and press Plot Cross Section.

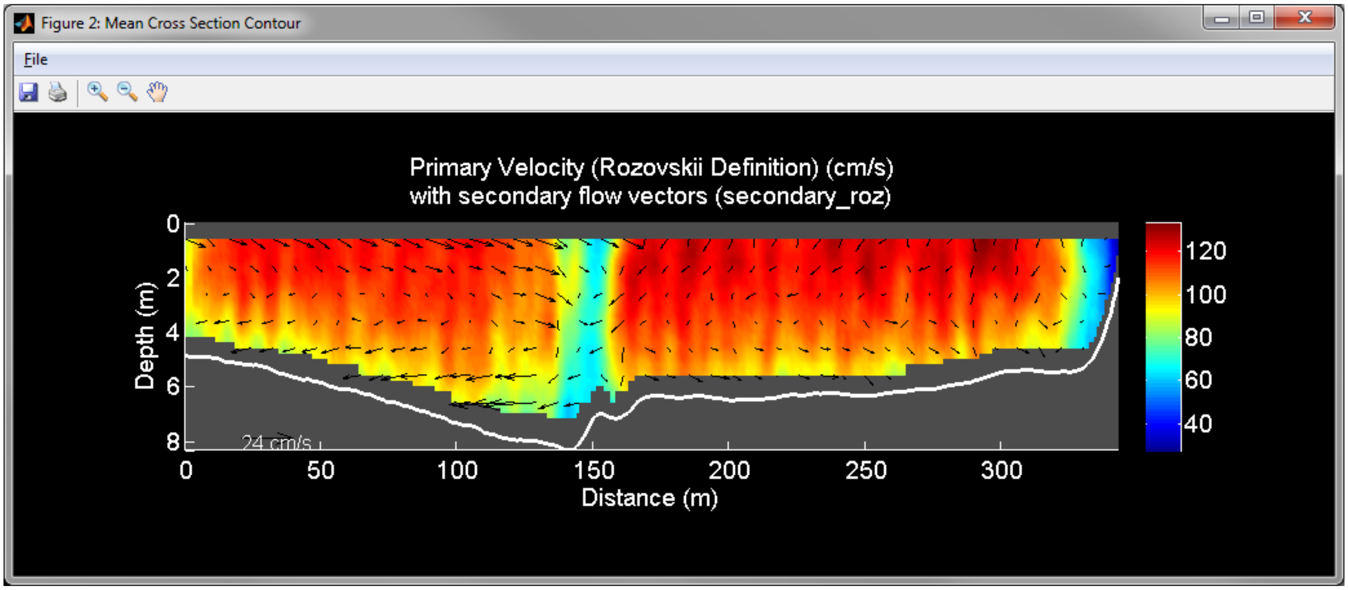


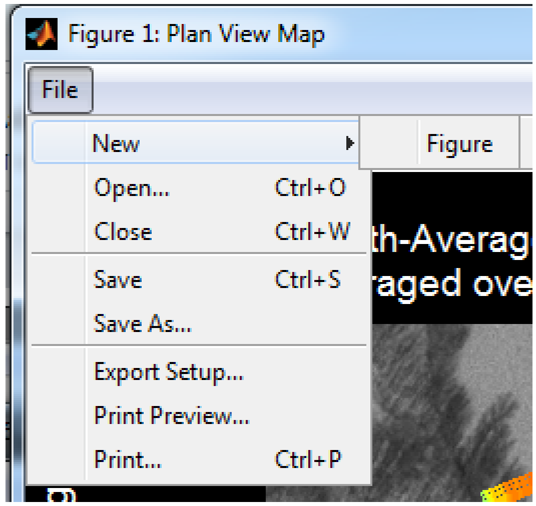
Figure 4. Layout of the Mean Cross Section figure in VMT.

The Map Cross Section Contour figure can be manipulated by several means to produce a plot suitable to your needs. To resize the figure, Left click-hold on any edge of the figure and drag to desired dimensions. Use the figure window toolbar to zoom in or out, and pan the viewable extent of the figure. You may also save a Matlab® native file of the figure (*.fig file), or print the figure using the Matlab® default export settings, all from the toolbar.

The Figure Toolbar: 

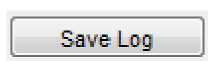
Tip: Once you have setup a figure the way you want it to look, use the Save feature in the File menu to create a *.fig file. Then, you can use the Open… figure menu item to reload the figure. VMT will still recognize the reloaded figure.

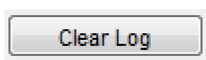
Using the File Menu, you may perform other optional actions, some of which are not technically part of VMT, but are included within the Matlab® MCR environment VMT was compiled in.



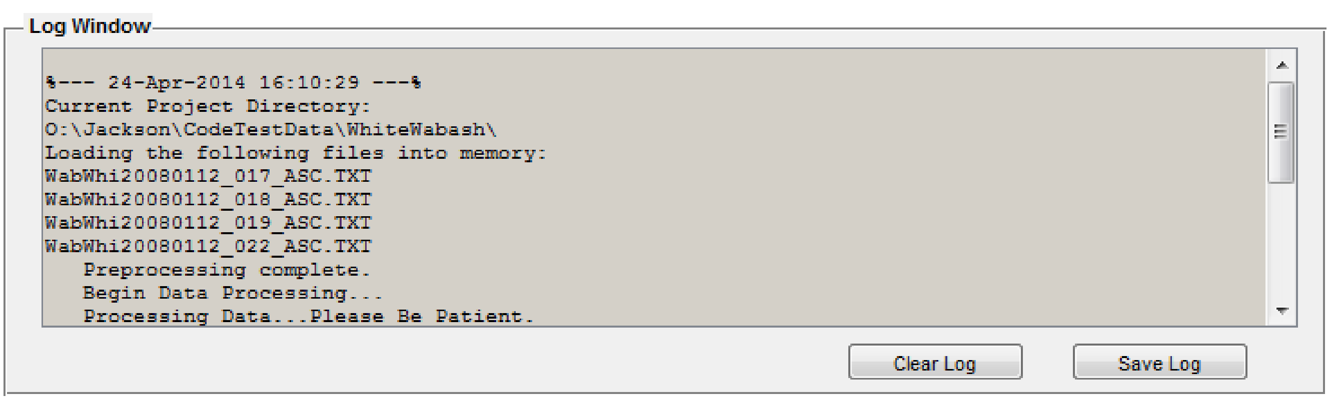
Note: Though it is possible to export the figure from the File→Export Setup… dialog, it is recommended that you use the Export Figure functionality within the Main VMT User Interface. If the predefined export settings in the VMT interface are not sufficient for your purposes, the File→Export Setup… option provides customizable export files.

Log window panel

The Log Window Panel displays helpful information about processing and plotting parameters in VMT. You may scroll through previous messages generated during the current session. To save the log of the current session to a text file, press 

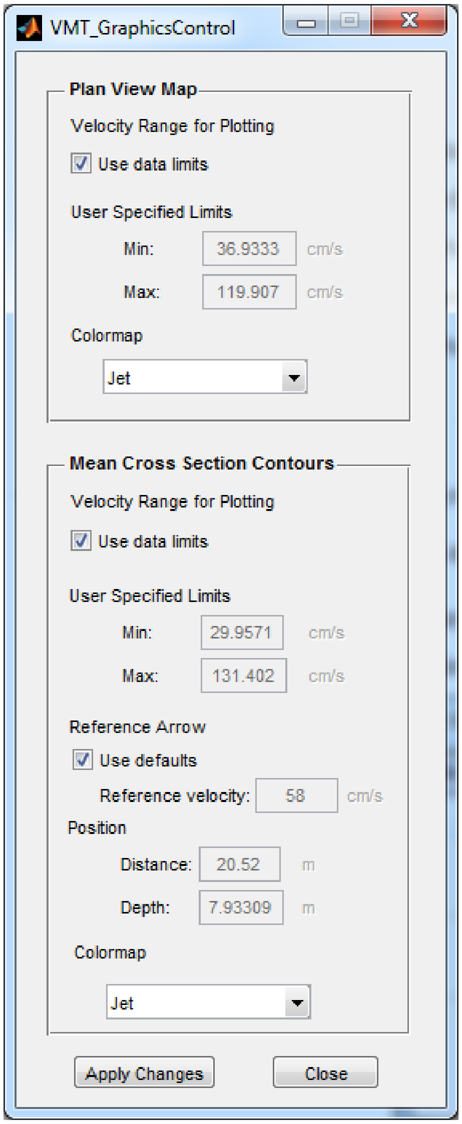
. Conversely, you may clear the current log by pressing 

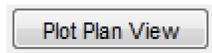
.



Tip: When processing a large dataset it is very helpful to save your logs. In this way, you can recall the settings and parameter used to produce a particular figure and/or dataset at a later time.

Graphics control sub-GUI (VMT_GraphicsControl)



The Graphics Control Sub-GUI gives you more flexibility in the feel and appearance of the Plan View Map and Mean Cross Section Contour Figures. The Sub-GUI automatically opens whenever either the 

or 

buttons are pressed.

Fields in the Sub-GUI are automatically populated by the limits and default parameters in the currently loaded dataset. The following options, grouped by panel are included:

Plan View Map Panel

User Specified Limits: You can adjust the limits of the velocity range plotted in the plan view figure by changing the Min and Max values. The boxes remain greyed out until you uncheck Use Data Limits.

Colormap: Choose from a variety of built in colormaps (Figure 5), or browse for a custom colormap specified in the CPT file format.

Mean Cross Section Contours Panel

User Specified Limits: You can adjust the limits of the velocity range plotted in the contour figure by changing the Min and Max values. The boxes remain greyed out until you uncheck Use Data Limits.

Reference Velocity: You can adjust the magnitude of the reference vector by changing this value. The box remains greyed out until you uncheck Use defaults.

Position: You can specify the location of the tail of the Reference Vector by adjusting the Distance and Depth Values. The boxes remain greyed out until you uncheck Use defaults.

Colormap: Choose from a variety of built in colormaps (Figure 5), or browse for a custom colormap specified in the CPT file format.

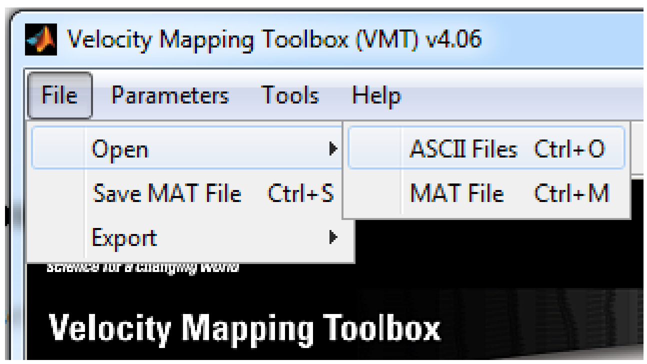
Figure 5. Built in VMT colormaps.

Procedures and typical workflows

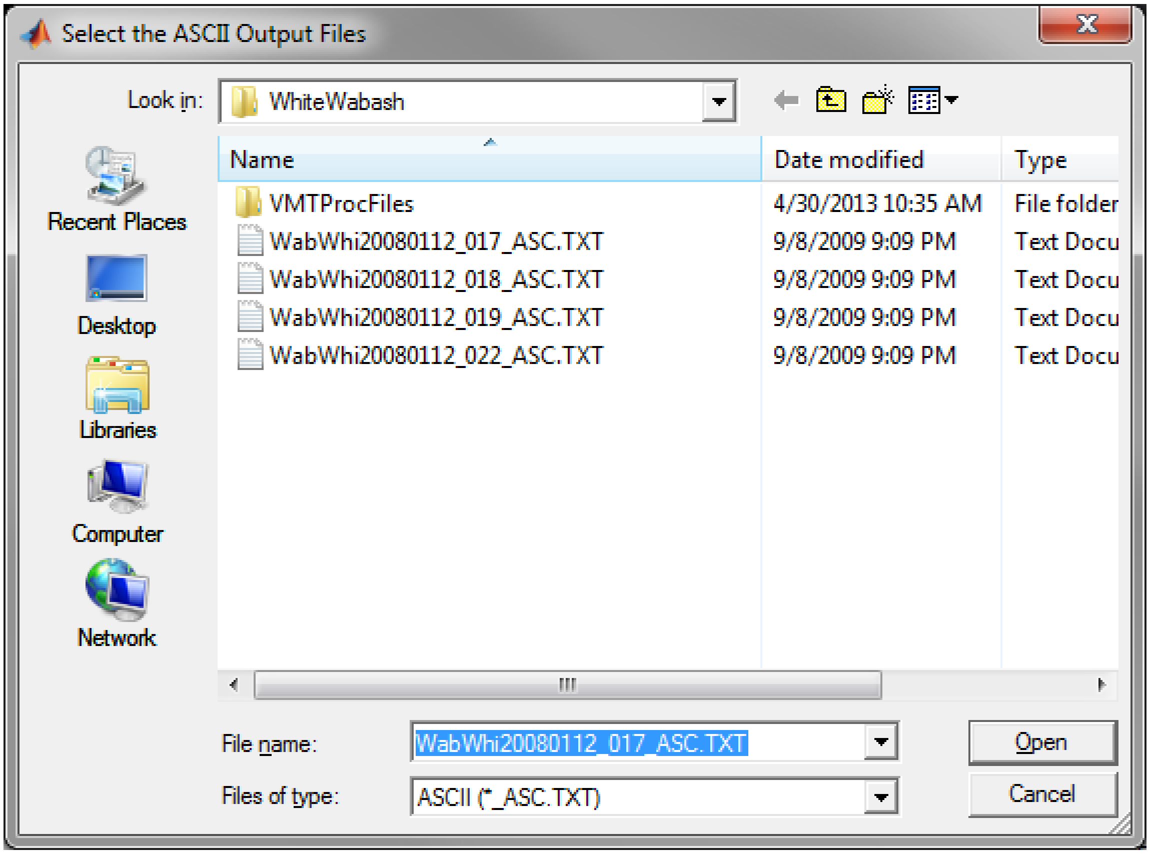
This section is organized into a set of tasks typically performed when analyzing data in VMT. It follows a logical progression similar to what you might use in your own work.

Loading raw ASCII data from WinRiver II®

VMT can read data exported in WinRiver II® using the Classic ASCII option. To load raw ASCII data (see note about formatting below), choose File→Open→ASCII Files. (Conversely you can press Ctrl+O, or click the  button).



You will be prompted to navigate for ASCII (*._ASC.TXT) files. If you have used VMT before, it will remember the last folder you loaded ASCII files from. NOTE: VMT looks for files with the (*._ASC.TXT) format, so if you rename your ASCII files after producing them in WinRIver II® (for example adding an additional text to the end of the filename), VMT will not recognize your ASCII files. Make sure your files all end in "_ASC.txt".



Select the ASCII files corresponding to one cross section (i.e., all transects which were on the same tag line or cross section in the river) by holding the Shift or Ctrl keys and Left Clicking the file names. Press Open. VMT will load the files (you will see a progress bar), and push information to the Log Window Panel about the current processing session.

Tip: Loading the files is not the same as processing the data. To process the data, you must press one of the plot buttons. After loading, processing, and plotting the ASCII files, it is recommended that you save your work for future reference. See Creating a figure that suites your needs is an iterative process. Explore how changing parameters affects the plot. See the sections titled Planview Map Figure and Mean Cross Section Figure for details about the various adjustments you can make to the figure.

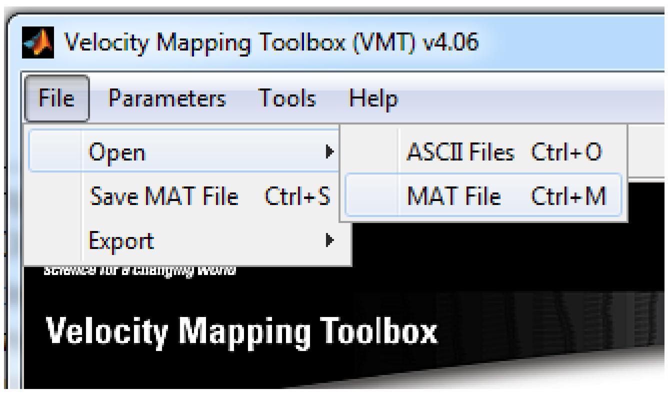
Note: There are some specific data input requirements.

1. WinRiver II® ASCII data must be "Classic ASCII Output Format" using the "Output Backscatter Data" option.
2. *SI Units (metric) must be used.* VMT will warn you if you attempt to import an ASCII file using English units.
3. It is recommended that there be no spaces in the file names, though this is no longer required. If you have trouble loading ASCII data, this is a first thing to check
4. Files should have the standard naming convention format ("*_ASC.TXT") for easiest browsing.
5. Data must include valid GPS data within the ASCII file (VMT currently does not read the *GPS.txt files).
6. Google Earth® must be installed if outputting KMZ files (free download from Google®).
7. VMT is best suited for repeat transects at a single cross section (they will be used to compute an average cross section and velocity distribution). The software will handle a single transect however. Note that transects at a site with significant variation in the channel bathymetry and/or variation in the position of the transect may result in unusual averaging for the bathymetry and water velocities. Processing single transects in this case is recommended and will preserve bathymetry and flow variation.
8. It is helpful for to know the maximum depth within a study reach for setting the vertical offset and vertical exaggeration. When multiple cross sections are mapped in a reach, the user should set these values for the transect with the maximum depth and keep these values constant for the remaining transect sites in the reach. This ensures that vertical scaling and offsets are consistent throughout the reach (especially true for the KMZ offset—see below).
9. Occasionally, WinRiver II® will produce ASCII files with errors. If an ASCII file will not load into VMT, try exporting the ASCII file again in WinRiver II® (you may need to restart WInRiver II®) and importing into VMT again. This can usually solve the problem.

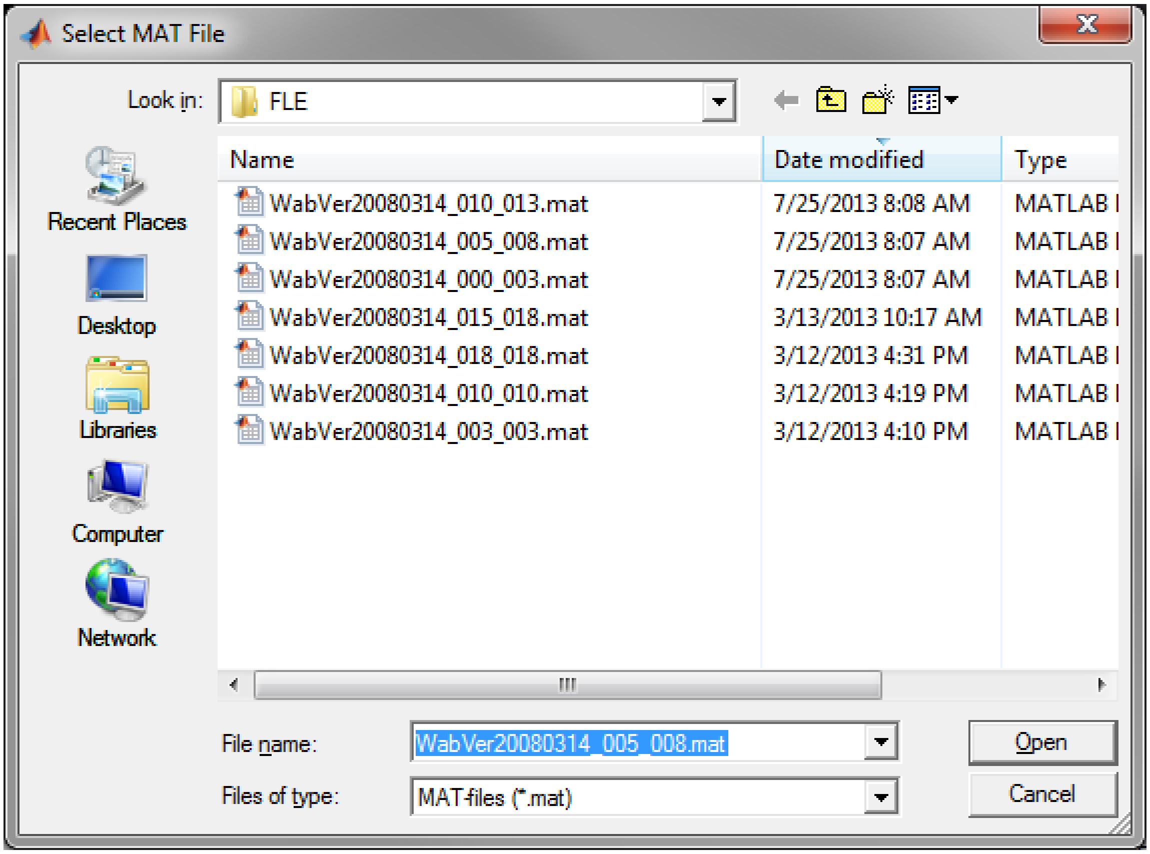
The user should have notes handy that list the repeated transects at each cross section. The user will be asked to select these ASCII output files at each cross section to determine the average cross section and velocity field for the cross section. If filed notes are poor, the user can determine the spatial locations of each transect by using the ASCII2KML_GUI utility (generates a Google Earth® KML file for each transect shiptrack for easy identification of spatial positions).

Loading previously processed VMT data

VMT can load previously processed results for reanalysis and/or plotting of multiple transects (in the Plan View Map Figure). To open previously processed VMT data files, choose File→Open→MAT File



You will be prompted to navigate for MAT-files (*.mat). If you have used VMT before, it will remember the last folder you loaded MAT files from. You can either chose one MAT file, or multiple MAT files. VMT behaves differently depending on your choice.



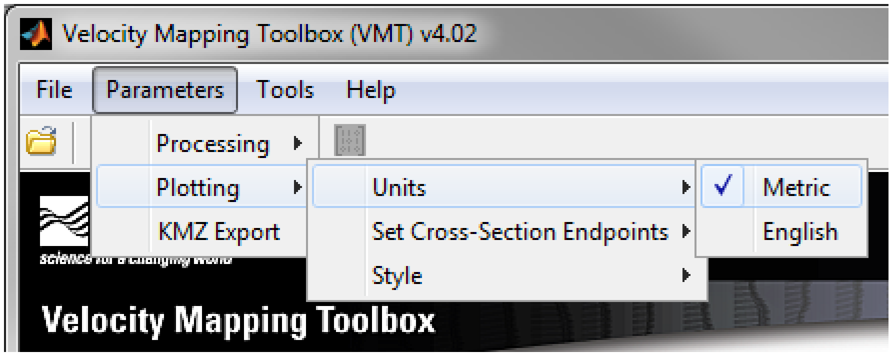
Loading a Single MAT File: This is analogous to loading several raw ASCII Output files for a single cross section. Once the MAT file is loaded, you may reprocess the data, create plots, or export results.

Loading Multiple MAT Files: This option is used to create a Plan View Map Figure which contains multiple Mean Cross Section (MCS) results (e.g., for an entire study reach). Also, you may export the depth- or layer-averaged MCS results for an entire study site in batch by loading multiple MAT files.

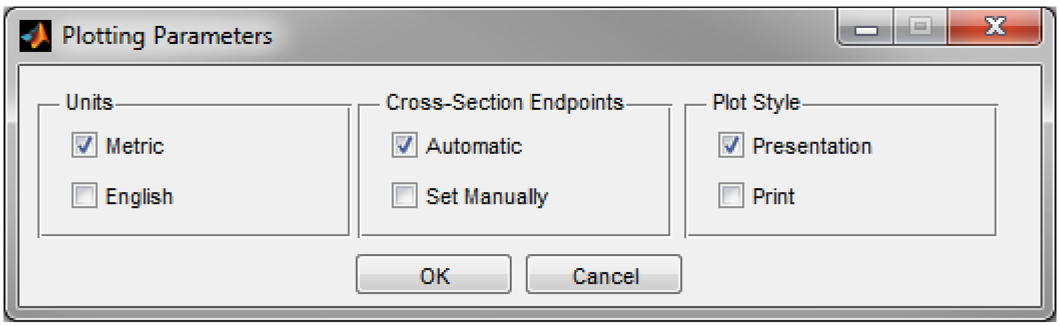
Changing the default units

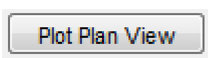
By default, VMT uses SI units in all plots. You can switch between SI and English units by a couple of different methods.

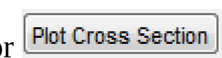
Method 1: Choose Parameters→Plotting→Units→Metric (or English)



Method 2: Click the  on the toolbar to open the Plotting Parameters dialog. Toggle the check boxes and press OK.

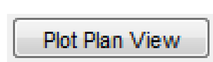


Note: You must click either 

or 

to reflect any changes in units.

Creating and manipulating a plot of planview vectors

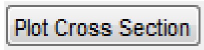
Once data are loaded (Raw ASCII Output, Single or Multiple MAT files), you can create a Plan View Map plot. Choose the parameters in the Plan View Plot Panel to suite your needs, or use the defaults as a starting point. Press 

to process the currently loaded data and create (or refresh) the figure.

Creating a figure that suites your needs is an iterative process. Explore how changing parameters affects the plot. See the sections titled Planview Map Figure and Mean Cross Section Figure for details about the various adjustments you can make to the figure.

Note: If you load multiple MAT files, the Plan View Map (and the Plan View Plot Panel) are the only options available. Though you can export data, you cannot create the Mean Cross Section Contour figure.

Creating and manipulating a plot of the mean cross section

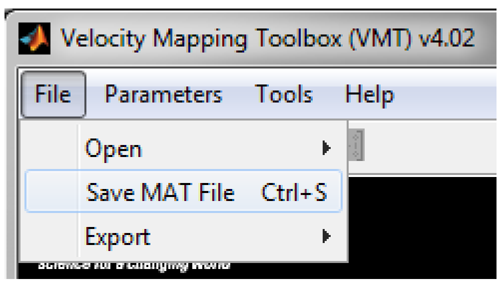
Once data are loaded (Raw ASCII Output or Single MAT file), you can create a Mean Cross Section Contour plot. Choose the parameters in the Cross Section Plot Panel to suite your needs, or use the defaults as a starting point. Press 

to reprocess the loaded data and create (or refresh) the figure.

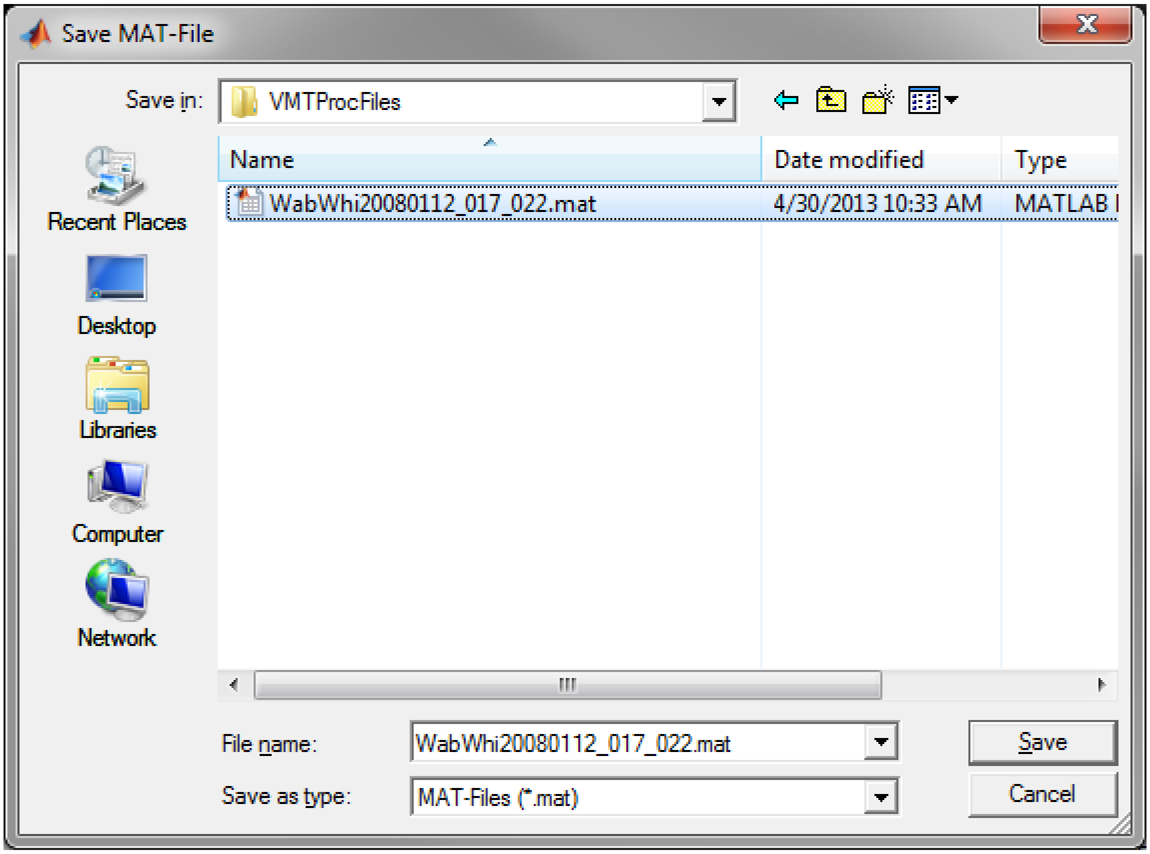
Creating a figure that suites your needs is an iterative process. Explore how changing parameters affects the plot. See the sections titled Planview Map Figure and Mean Cross Section Figure for details about the various adjustments you can make to the figure.

Saving VMT results for later use

When you have processed a dataset, you may wish to save the result for later use. To save the processed data choose File→Save MAT File (conversely you can press Ctrl+S, or click  from the toolbar)



VMT will prompt you to navigate to a location and save the file. VMT will attempt to construct a filename for you based on the standard naming convention used in WinRiver II® (BaseFileName_startingtransectnumber_endingtransectnumber).

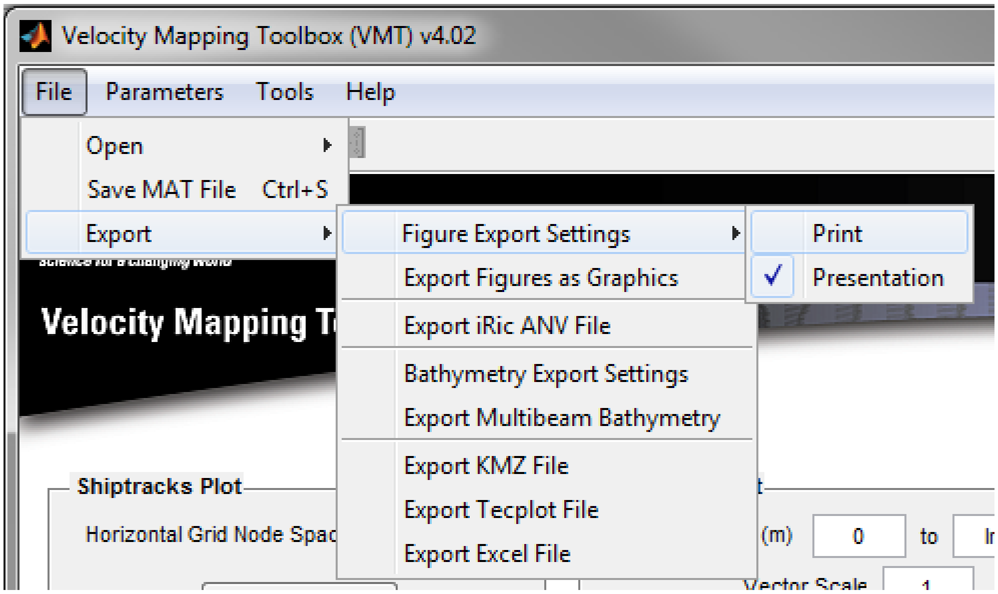


If you have used VMT before, it will remember the name and location of the last saved MAT file.

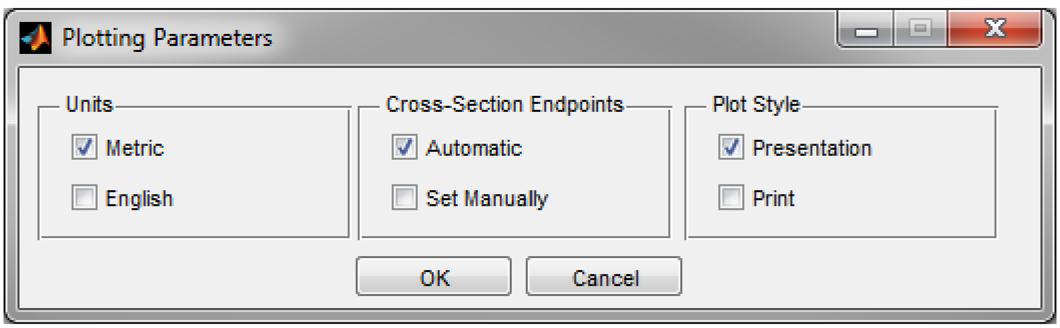
Note: The MAT file is a native Matlab® binary file format. You can view the contents of this file in Matlab®. See Appendix 2: Output File Specifications for details about the MAT file structure.

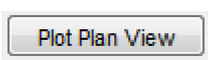
Exporting VMT figures

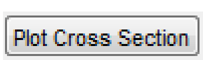
Once you have created and adjusted the VMT figures you wish, you can export these figures to either PNG or EPS image files. VMT comes with two figure presets (Print and Presentation), which you can switch freely between. The Print format is designed to work well with color printers, whereas the Presentation format is ideal for use in Microsoft PowerPoint® (or other presentation software). To choose the figure style, choose File→Export→Figure Export Settings→Print (or Presentation). The figure(s) will be automatically updated.



Conversely you can click  on the toolbar to open the Plotting Parameters dialog.



Note: you can also adjust the plotting units for the figures, however you must click either 

or 

to reflect the changes.

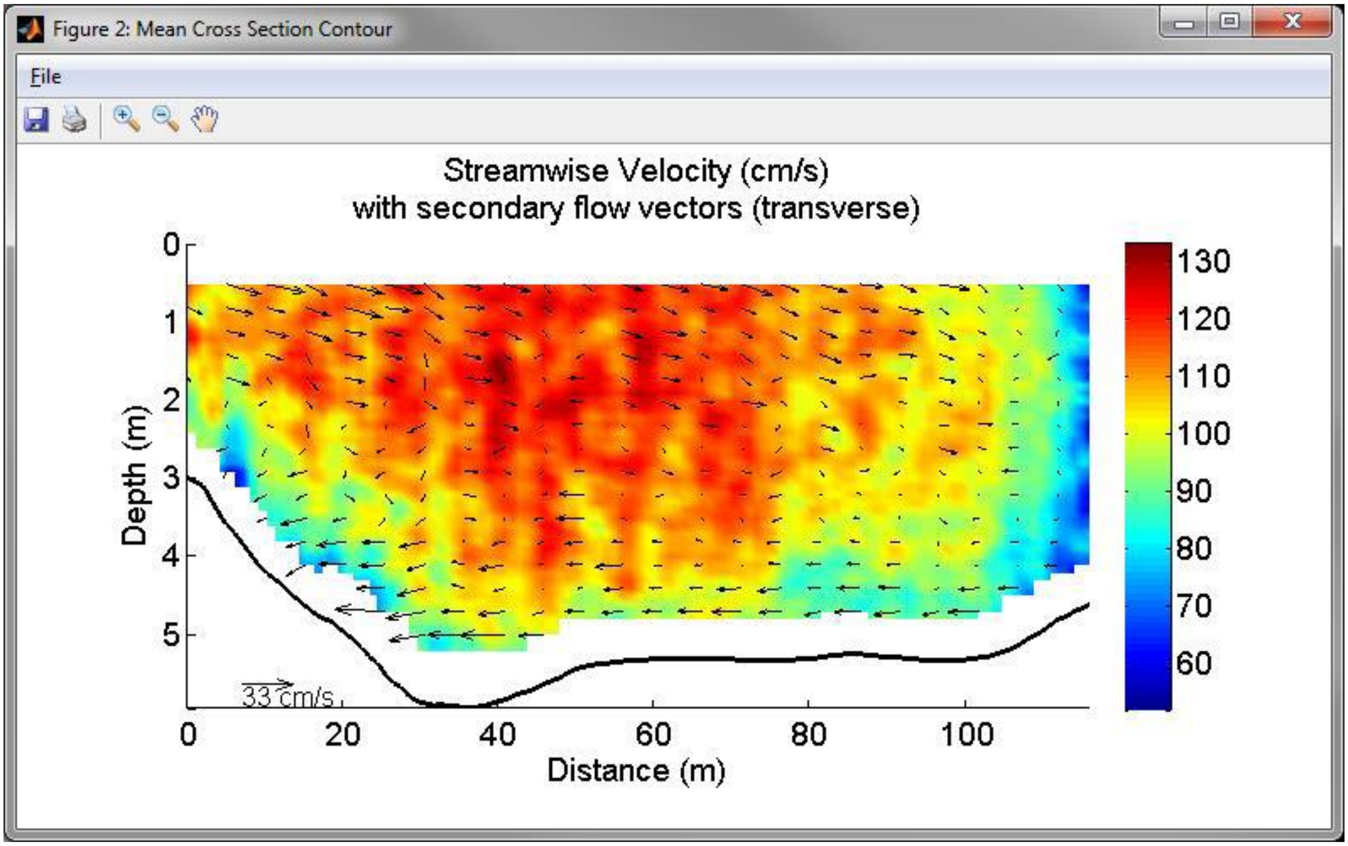
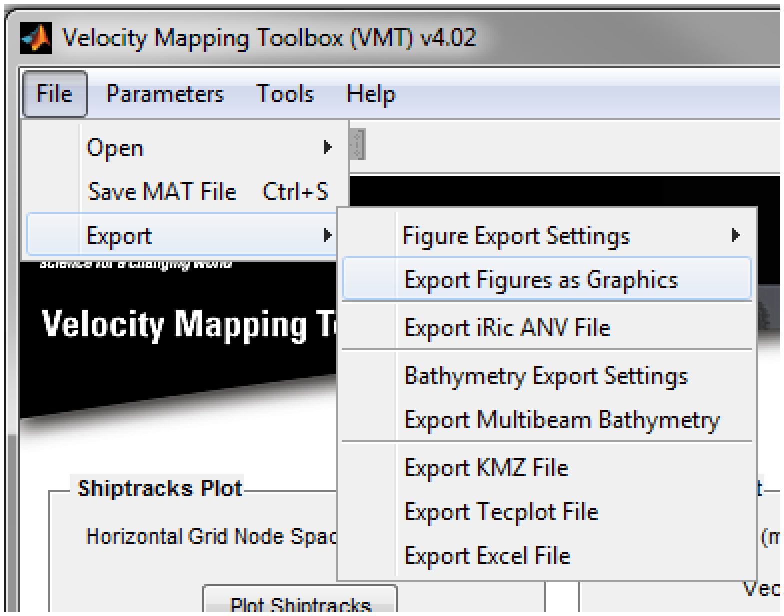
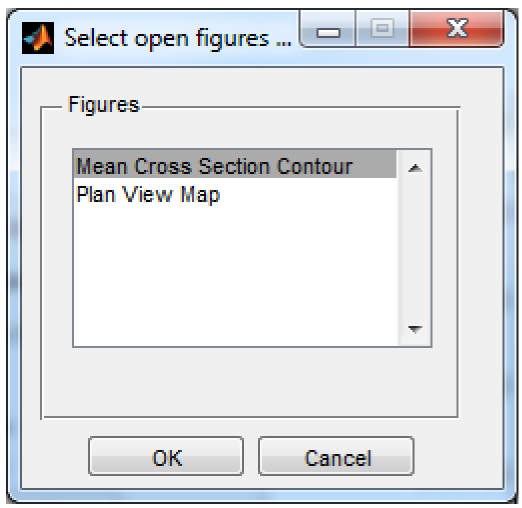


Figure 6. Example Mean Cross Section Contour figure using the Print figure style.

To Export the figures, choose File→Export-Export Figures as Graphics. Conversely, you can click  on the toolbar.



Then select the figures you wish to export from the list and click OK.



Choose either PNG or EPS format and VMT will prompt you to save a file in the location of your choosing. If you have used VMT before, it will remember the last place you save an image export file.

Exporting data for use outside of VMT

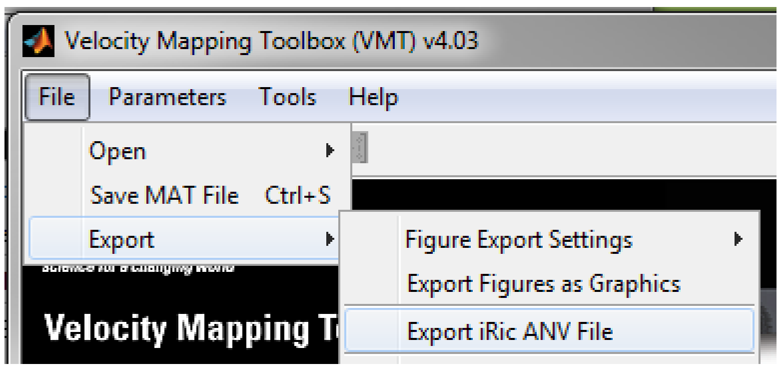
Once you have processed the input data according to your specifications, you may export the results to a variety of file formats. The details for each output file format are described in Appendix 2: Output File Specifications. A brief overview is given here.

iRic©

The iRic© river modeling interface allows input of vector velocity data for model calibration and validation (2-D) in the form of ANV files. VMT will export ANV files from the ASCII2GIS utility (depth-averaged velocity along the curvilinear boat path) and ANV files containing the depth- or layer-averaged velocity as displayed in the plan view plot with vector spacing and smoothing applied.

Before exporting an iRic© ANV file, you mush load and process raw data, and produce a Plan View Map Figure. VMT will export the depth- or layer-averaged vectors as specified in the figure (i.e., spacing, depth range, and smoothing are applied prior to the creation of the ANV file).

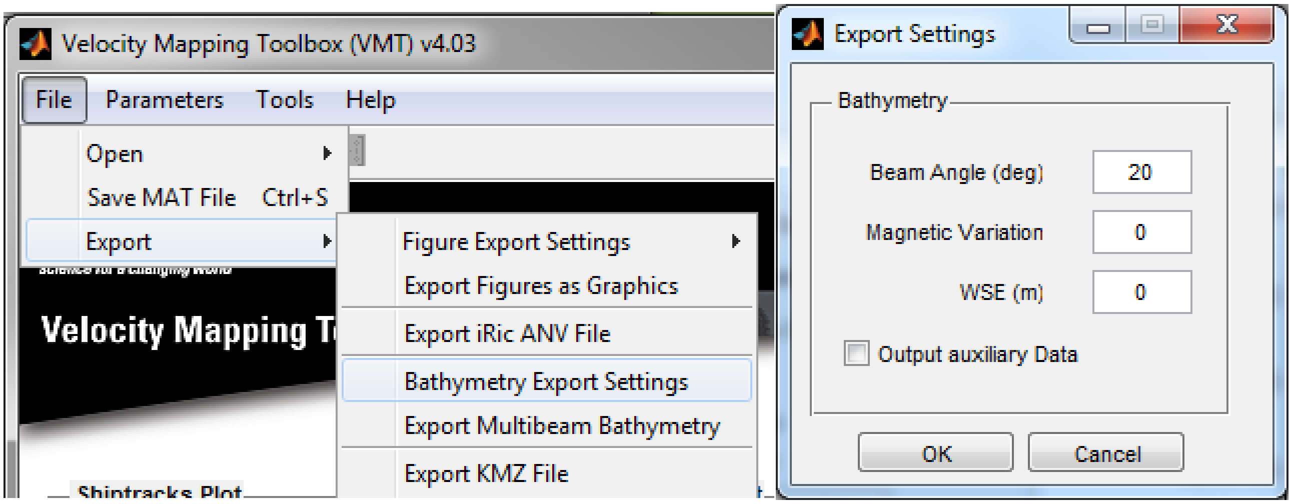
To create an iRic© ANV file, choose File→Export→Export iRic ANV File. VMT will prompt you to save the file in the desired location. If you have used VMT before, it will remember the name and location of the last saved file.



Multibeam bathymetry

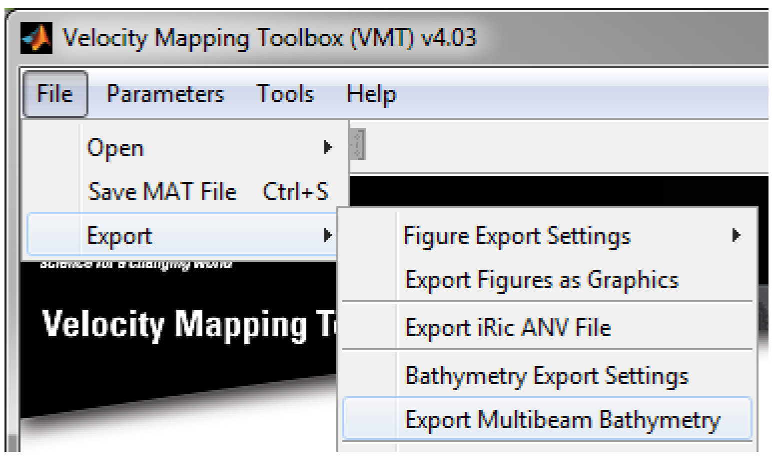
These files contain the bathymetry data from the four individual beams of the ADCP, corrected for heading, pitch, and roll using an algorithm provided by TRDI and in use in Dave Mueller's ADMAP (USGS Software). The data is formatted as a simple CSV (comma-separated value) file that is easily imported into ArcGIS® using the XY data import tool. The user has the option to add ancillary data to the data file.

To create the Multibeam Bathymetry file, first choose File→Export→Bathymetry Export Settings. Select the appropriate parameters. Choosing Output auxiliary data will add several handy computation to the resulting file (See Appendix 2: Output File Specifications for more details). Press OK when you are finished setting the Bathymetry Export parameters.



Tip: It is common to collect velocity data near stream gages, or other stage records. By entering a water surface elevation (WSE), you can correct bed depths to know elevations.

Next, choose File→Export→Export Multibeam Bathymetry



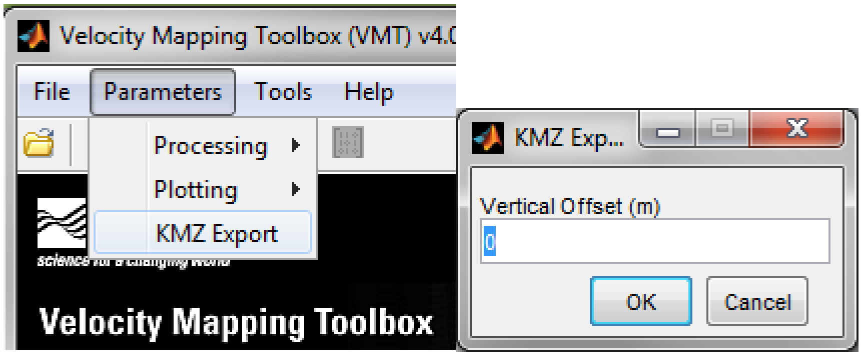
VMT will prompt you to save the file in the desired location. If you have used VMT before, it will remember the name and location of the last saved file.

Google Earth® KML and KMZ files

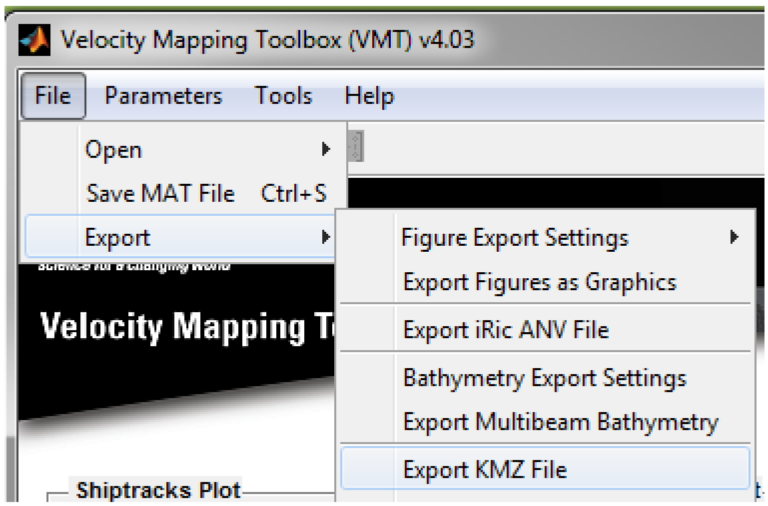
These files are generated to allow the user to display the transect shiptracks (*.kml) and mean cross sections (*.kmz) in Google Earth®.

The KMZ files are generated at the request of the user in the VMT interface and will open automatically in Google Earth® through a request in the VMT code.

To create KMZ files, first set the vertical offset by choosing Parameters□KMZ Export. Click OK to save the entered offset.



Next, choose File→Export→Export KMZ File



VMT will prompt you to save the file in the desired location. If you have used VMT before, it will remember the name and location of the last saved file.

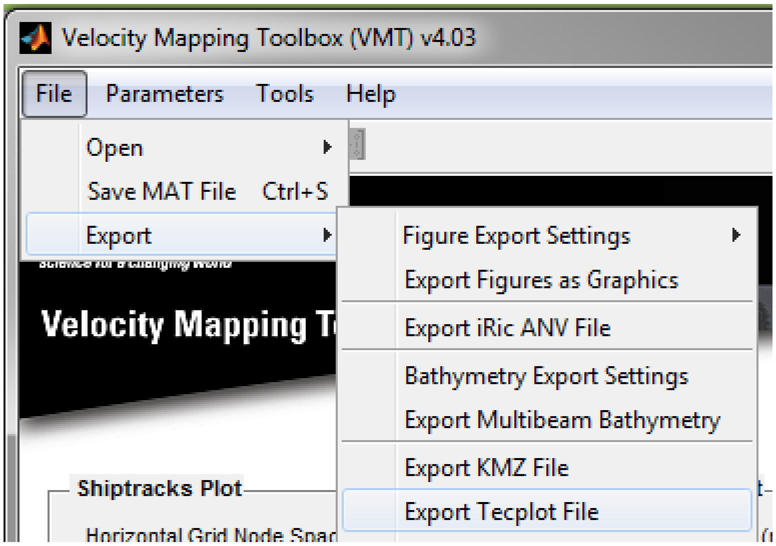
Note: The KMZ files are best viewed as 3-D cross sections so the user should adjust the view in Google Earth® to get the best display of the cross section. To display each KMZ file as a 3-D cross section, enter an offset in the VMT interface that is greater than or equal to the max depth in the reach. This will ensure the cross section is fully displayed above the image plane in Google Earth®.

The KML files are generated using the VMT utility ASCII2KML and the KML files must be loaded into Google Earth® for display.

Tecplot® DAT files

Files contain processed and averaged ADCP data formatted for direct import into Tecplot®. Choosing the Tecplot® export option will export the average cross-section data only with no smoothing or data reduction (vector spacing) applied. Data files contain a header with all necessary information. One data file (*_TECOUT.dat) contains the velocity and backscatter data array for the cross section while the other data file (*_TECOUT_XSBathy.dat) contains the georeferenced bed depth and bed elevation data.

To create the TecPlot® files, choose File→Export→Export Tecplot File. VMT will prompt you to save the file in the desired location. If you have used VMT before, it will remember the name and location of the last saved file.



Excel® files

VMT will produce an Excel® (*.xlsx) file of the processed results when prompted. There are two version of the file: Typical, single cross-section output; and, multiple transects loaded (i.e., plan view) output.

VMT writes 3 worksheets in the Excel® File:

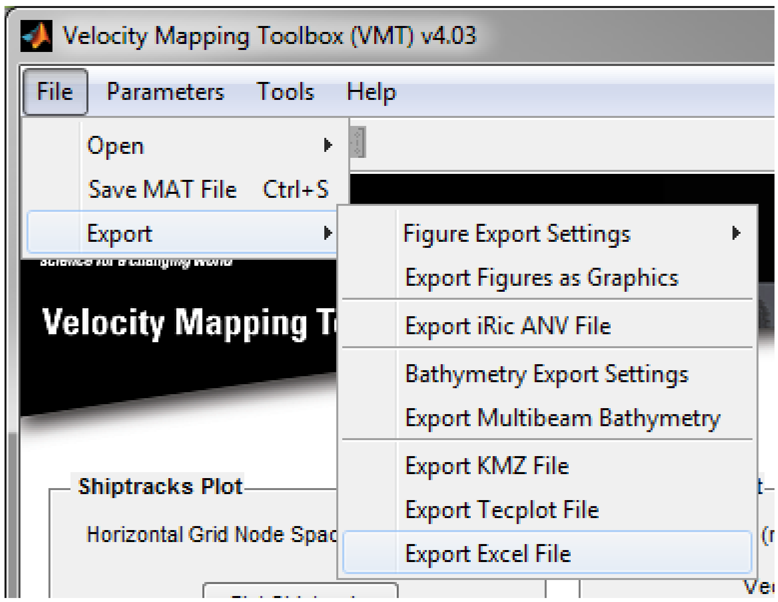
VMTSummary: this contains an overview of the data processed, including several parameters related to the MCS, and the raw ASCII Files associated with the processed data.

Planview: this contains the UTM coordinates, elevation, and depth- or layer- averaged velocities of the MCS. Data are organized in rows (one vertical per row). If you have selected a particular depth range, in the Plan View Plot Panel, VMT will output the resulting velocities for that layer only. The depth range used in the computation is appended to the name of the velocity fields for reference.

MeanCrossSection: this contains the UTM coordinate, distance along transect (stationing), elevations, bed elevations, and a suite of various velocity variable for every grid node of the MCS. Data are organized in block format, with rows representing vertical locations. Missing/non-data locations are denoted by a value of -9999.

Note: If multiple MAT files are loaded, the worksheet MeanCrossSection will not be written, and the worksheet Planview will contain all transect data.

To create the Excel® file, choose File→Export→Export Excel File. VMT will prompt you to save the file in the desired location. If you have used VMT before, it will remember the name and location of the last saved file.



Getting help

User guide

This User Guide is available for viewing and download on the Velocity Mapping Toolbox Google Code Page (*https://code.google.com/p/velocity-mapping-tool/*)

Velocity mapping forum (USGS Office of Surface Water)

The USGS Office of Surface Water (OSW) maintains a Hydroacoustics User Community forum. There is a child forum for velocity mapping, including VMT, that can be found at (*https://simon.er.usgs.gov/smf/index.php?board=38.0*). This is a great place to share news and ideas, request help, or report software issues. You are strongly encouraged to participate in the forums!

The OSW forum requires users to register.

- Registration Instructions (*http://hydroacoustics.usgs.gov/software/Forum_Reg1.html*)
- Link to OSW Forum Registration (*https://simon.er.usgs.gov/smf/index.php*)

Appendix 1: Input file specifications

Raw ASCII files (WinRiver II® lassic ASCII output)

Data are organized in a space delimited text file. Each ensemble has its own header which follows the format below. Rows 3–9 consist the ensemble header. Rows 10–Nens are the raw data in a rectangular matrix organized by bins.

```
1
2
3      20      25      12      75       1       9      12
4  8 1 12 10 43 13 60  4676       1   -1.120   -2.660   57.500    8.380
5  -15.93   -15.93  -32768  -32768 -32768.00   121.71     0.00   18.06     4.88     4.88     4.88     4.97
6  0.00         0.00         0.00         0.00         0.00
7  38.41461745   -87.74136552   -15.93   -23.09         0.0
8  -0.0          -0.0          -0.0           0.0          12.2           0.0           6.4  0.61   4.21
9  75 cm VTG dB 0.45  0.501
10   0.61     98.88    238.67  -84.5  -51.4   -5.8   -4.7  201.0  205.0  195.0  210.0  100 2147483647
```

Row 1	Notes (1st header only)
Row 2	Notes (1st header only)
Row 3	WS, WF, Draft, WN, WP, TPE, WM
Row 4	Yy, mm, dd, hh, mm, ssss, en, #en, Pitch, Roll, Heading, TW
Row 5	Ew, ns, ud, BTerr, dpth, Elv, Delv, Hdop/#Sat, D1, D2, D3, D4
Row 6	TEDist, TETime, TDTravelN, TDTravelE, TDMadeGood
Row 7	Latitude, Longitude, NavBTew, NavBTns, TDT_en
Row 8	Qmiddle, Qtop, Qbuttom, QStShore, DistStShore, QEndShore, DistEndShore, EndDTL, StDBL
Row 9	#B, unit, ref, int, scl, absr
Row 10	BDpth, Velmag, Veldir, Velew, Velns, Vud, Verr, [Backscatter 1 2 3 4], %Good , Qm^3

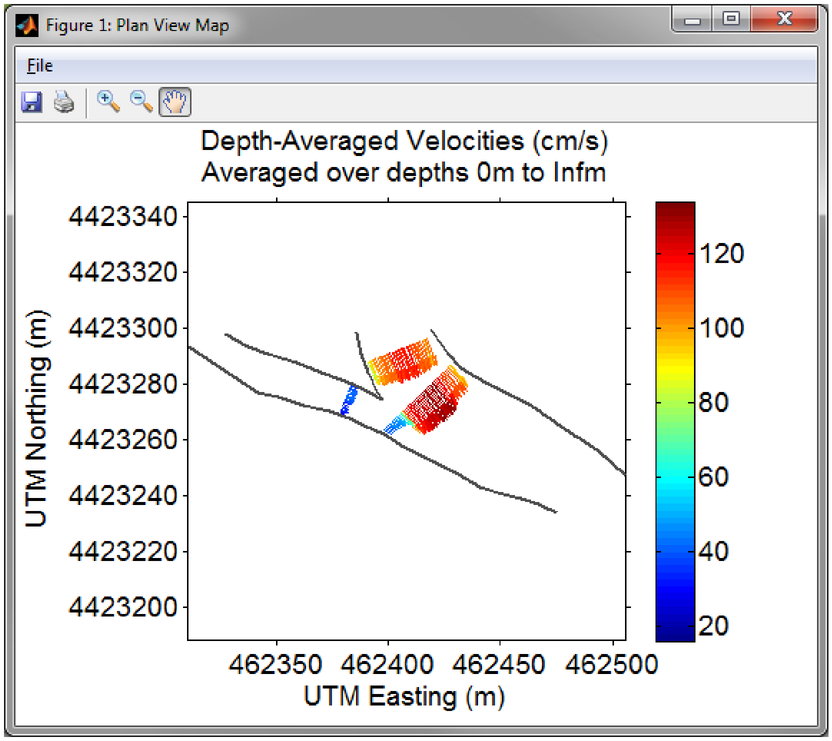
Shoreline file

The Shoreline file is a simple text file with no header. It can be tab, space, or comma delimited. The shoreline coordinates should be supplied in two columns (UTM_East & UTM_North). To create individual (i.e., separate) shorelines, separate coordinate pairs by the value -9999.

Note: This option was added prior to the ability add background files and has found little use since the implementation of that feature. It may be depreciated in future versions.

The following Example produces the shoreline of the confluence of the Wabash and Vermillion Rivers shown in the figure.

```
462041.6347 4423367.286
462082.952 4423338.511
462128.6963 4423308.999
462165.5868 4423285.389
462201.0017 4423275.798
462248.2215 4423261.779
462293.228 4423251.45
462330.1185 4423238.907
462355.204 4423226.364
462392.0946 4423209.395
462426.7716 4423186.522
462472.5159 4423163.65
462523.4248 4423138.565
462561.7909 4423114.217
462597.2058 4423105.363
462637.7854 4423095.772
462667.2978 4423083.229
462701.9749 4423069.948
-9999 -9999
462822.9758 4423135.614
462799.3658 4423157.748
462772.8047 4423181.358
462735.9141 4423205.706
462699.0236 4423231.529
462654.755 4423261.779
462619.3401 4423280.224
462574.3337 4423301.621
462530.8029 4423326.706
462503.5039 4423356.219
462475.4671 4423396.061
-9999 -9999
462342.6613 4423392.372
462350.7772 4423353.268
462364.0578 4423319.328
462379.5518 4423286.127
462388.4 4423272.1
462371.4359 4423280.962
462334.5454 4423299.407
462285.8499 4423318.591
462234.2032 4423337.774
462183.2942 4423353.268
462147.8794 4423367.286
462105.8242 4423389.42
```



Background image(s)

The background image formats supported by VMT are

- GeoTIFF
- TIFF/JPEG/PNG with a world file (must be in the same folder, and have the same name)

In addition, VMT will recognize geospatial data in these formats (data must be in the UTM projection)

- Shapefile (point, polyline, polygon)
- ARC ASCII GRID
- SDTS raster

User supplied endpoints

The User Supplied Endpoints file is a simple text file with no header. It can be tab, space, or comma delimited. The endpoint coordinates should be supplied in two columns (UTM_East and UTM_North). If supplied, VMT will use the coordinates specified in the file to be the Mean Cross Section (MCS) rather than a linear regression best-fit line through the ensembles in the raw ShipTracks.

Example:

```
435280.84 4252077.57
434968.76 4252231.98
```

Appendix 2: Output file specifications

VMT MAT file

Once raw data are processed, using the Save MAT File option (Ctrl+S) will save a Matlab® native binary format file. If you have Matlab®, you may load this file and view its content. The file consists of two different structured arrays. The first, named (A), contains an organized representation of all of the raw data which was used to produce the Mean Cross Section (MCS), and any stored computations. The second, named (V), contains the resulting MCS, and all its variables. The two tables in this Appendix detail the complete structure of these arrays.

Definitions

nbins	number of total bins within a given vertical, or ensemble in a single original ADCP transect
noe	number of ensembles within a single original ADCP transect
itx	number of horizontal grid locations on the mean cross section
ity	number of vertical grid locations on the mean cross section

Table 4. Format of the A structured array (VMT processed and saved mat-file).

Level I	*Level II*	*Field Name*	*Description*	*Size*	*Class*	*Parent*	*Children*
A	Sup	absorption_dbpm	Sound adsorption in db/meter (See WinRiver II User Guide, pg. 102)	noe X 1	double	tfile	
A	Sup	bins	Maximum number of bins in each ensemble	noe X 1	double	tfile	VMT_PlotXSContQuiver, VMT_PreProcess, VMT_Rozovskii, VMT_Vorticity
A	Sup	binSize_cm	Bin size in centimeters	noe X 1	uint32	tfile	VMT_PlotXSContQuiver, VMT_PreProcess, VMT_Rozovskii, VMT_Vorticity
A	Sup	nBins	Maximum number of bins in each ensemble	1	uint32	tfile	VMT_FilterBS, VMT_FilterBS_IntensityRS
A	Sup	blank_cm	Surface blanking distance in centimeters	1	uint32	tfile	VMT_ReadFiles_Infill
A	Sup	draft_cm	User set transduced draft in centimeters	1	uint32	tfile	VMT_MBBathy
A	Sup	ensNo	Ensemble number assigned in WRII	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy, VMT_RepBadGPS
A	Sup	nPings	Number of pings per ensemble	1	uint32	tfile	
A	Sup	noEnsInSeg	Number of ensembles in each segment	noe X 1	double	tfile	
A	Sup	noe	Number of ensembles	1	double	tfile	VMT_FilterBS, VMT_FilterBS_IntensityRS, VMT_GridData2MeanXS, VMT_RepBadGPS

Leve l I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Sup	note1	User entered note line 1	[-]	char	tfile	
A	Sup	note2	User entered note line 2	[-]	char	tfile	
A	Sup	intScaleFact_dbpcnt	Echo Intensity scale factor in db/count (See WinRiver II User Guide, pg. 102)	noe X 1	double	tfile	
A	Sup	intUnits	Intensity units (db or counts)	1x1	cell	tfile	VMT_ReadFiles
A	Sup	vRef	Watertrack velocity reference	1x1	cell	tfile	VMT_ReadFiles
A	Sup	wm	Water mode	1	uint32	tfile	
A	Sup	units	Measurment units (cm or ft)	1x1	cell	tfile	
A	Sup	year	Year of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	month	Month of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	day	Day of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	hour	Hour of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	minute	Minute of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	second	Second of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	sec100	Hundreth second of each ensemble	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sup	timeElapsed_sec	Total time elapsed of each ensemble	noe X 1	double	tfile	
A	Sup	timeDelta_sec100	Time between ensembles in hundredth of a second	1	uint32	tfile	
A	Wat	binDepth	Depth below the water surface for each bin in meters or feet	nBins X noe	double	tfile	ASCII2GIS, STA_MeanProfile, STA_MeanProfileV2, VMT_GridData2MeanXS, VMT_ReadFiles_Infill
A	Wat	backscatter	Acoustic backscatter in decibels for each of the four beams per bin and ensemble	nBins X noe X 4	double	tfile	VMT_FilterBS, VMT_FilterBS_IntensityRS

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Wat	vDir	Geographic angle of the direction of flow in each bin	nBins X noe	double	tfile	VMT_CompMeanXS_UVW, VMT_PreProcess, VMT_ReadFiles_Infill
A	Wat	vMag	Magnitude of the flow velocity in each bin	nBins X noe	double	tfile	ASCII2GIS, STA_MeanProfile, STA_MeanProfileV2, VMT_CompMeanXS_UVW, VMT_PreProcess, VMT_ReadFiles_Infill
A	Wat	vEast	East component of flow velocity in each bin	nBins X noe	double	tfile	ASCII2GIS, STA_MeanProfileV2, VMT_PreProcess, VMT_ReadFiles_Infill
A	Wat	vError	Error velocity for each bin	nBins X noe	double	tfile	
A	Wat	vNorth	North component of flow velocity in each bin	nBins X noe	double	tfile	ASCII2GIS, STA_MeanProfileV2, VMT_PreProcess, VMT_ReadFiles_Infill
A	Wat	vVert	Vertical component of flow velocity in each bin	nBins X noe	double	tfile	ASCII2GIS, STA_MeanProfileV2, VMT_CompMeanXS_UVW, VMT_PreProcess, VMT_ReadFiles_Infill, VMT_unitQcont
A	Wat	percentGood	See TRDI Rio Grande Techical Manual (pg. 208)	nBins X noe	double	tfile	
A	Nav	bvEast	East component of boat velocity	noe X 1	double	tfile	
A	Nav	bvError	Boat error velocity	noe X 1	double	tfile	
A	Nav	bvNorth	North component of boat velocity	noe X 1	double	tfile	
A	Nav	bvVert	Vertical component of boat velocity	noe X 1	double	tfile	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Nav	depth	Depth of each beam, corrected for beam angle	noe X 4	double	tfile	ASCII2GIS, STA_MeanProfile, STA_MeanProfileV2, VMT_FilterBS, VMT_FilterBS_IntensityRS, VMT_GridData2MeanXS, VMT_MapEns2MeanXS, VMT_MBBathy, VMT_ReadFiles_Infill, VMT_unitQcont
A	Nav	dsDepth	Depth from depth sounder (must be activated in WinRiver II)	noe X 1	double	tfile	
A	Nav	dmg	Distance made good by the ADCP (linear)	noe X 1	double	tfile	
A	Nav	length	Total elapsed distance traveled (curvilinear)	noe X 1	double	tfile	
A	Nav	totDistEast	Total distance East traversed by ADCP	noe X 1	double	tfile	VMT_ComputeDispCoef, VMT_RepBadGPS
A	Nav	totDistNorth	Total distance North traversed by ADCP	noe X 1	double	tfile	VMT_ComputeDispCoef, VMT_RepBadGPS
A	Nav	altitude	Altitude of the GPS antenna	noe X 1	double	tfile	
A	Nav	altitudeChng	Change in altitude reported by GPS	noe X 1	double	tfile	
A	Nav	gpsTotDist	Total distance traveled as reported by GPS	noe X 1	double	tfile	
A	Nav	gpsVariable	GGA HDOP x 10 + # satellites/100	noe X 1	double	tfile	
A	Nav	gpsVeast	GPS track of East velocity component	noe X 1	double	tfile	
A	Nav	gpsVnorth	GPS track of North velocity component	noe X 1	double	tfile	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Nav	lat_deg	Ensemble latitude location in decimal degrees	noe X 1	double	tfile	ASCII2GIS, ASCII2KML, STA_MeanProfile, STA_MeanProfileV2, VMT, VMT_GridData2MeanXS, VMT_RepBadGPS
A	Nav	long_deg	Ensemble longitude location in decimal degrees	noe X 1	double	tfile	ASCII2GIS, ASCII2KML, STA_MeanProfile, STA_MeanProfileV2, VMT, VMT_RepBadGPS
A	Nav	nSats	Number of satellites with lock reported by GPS	noe X 1	double	tfile	
A	Nav	hdop	Horizontal dilution of position	noe X 1	double	tfile	
A	Sensor	pitch_deg	Pitch of the ADCP in degrees	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sensor	roll_deg	Roll of the ADCP in degrees	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sensor	heading_deg	Compass heading of the ADCP in degrees	noe X 1	double	tfile	ASCII2GIS, VMT_MBBathy
A	Sensor	temp_degC	External water temperature at the ADCP in degrees Celsius	noe X 1	double	tfile	ASCII2GIS
A	Q	endDepth	End bank depth for edge ensembles	noe X 1	double	tfile	
A	Q	endDist	User entered edge distance to bank at the end of the transect in meters	noe X 1	double	tfile	VMT_ComputeDispCoef
A	Q	bot	Estimated discharge at the bottom of each ensemble	noe X 1	double	tfile	
A	Q	end	Estimated discharge for ending bank	noe X 1	double	tfile	VMT_ComputeDispCoef
A	Q	meas	Measured cummulative discharge for each ensemble	noe X 1	double	tfile	
A	Q	start	Estimated discharge for starting bank	noe X 1	double	tfile	VMT_ComputeDispCoef

Leve l I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Q	top	Estimated discharge at the top of each ensemble	noe X 1	double	tfile	
A	Q	unit	Unit discharge (per bin, per ensemble)	nBins X noe	double	tfile	
A	Q	startDepth	Start bank depth for edge ensembles	noe X 1	double	tfile	
A	Q	startDist	User entered edge distance to bank at the start of the transect in meters	noe X 1	double	tfile	VMT_ComputeDispCoef
A	Clean	backstandf	Standard deviation of screened backscatter	nBins X noe	double	VMT_FilterBS	
A	Clean	bsf	Censored backscatter data having stdev > 10	nBins X noe	double	VMT_FilterBS	
A	Clean	bs	Filtered and cleaned backscatter	nBins X noe	double	VMT_FilterBS	
A	Clean	vMag	Filtered and cleaned velocity magnitudes	nBins X noe	double	VMT_GridData2MeanXS	
A	Clean	vEast	Filtered and cleaned East velocity component	nBins X noe	double	VMT_GridData2MeanXS	
A	Clean	vNorth	Filtered and cleaned North velocity component	nBins X noe	double	VMT_GridData2MeanXS	
A	Clean	vVert	Filtered and cleaned Vertical velocity component	nBins X noe	double	VMT_GridData2MeanXS	
A	Clean	vDir	Filtered and cleaned Velocity direction (geographic angles)	nBins X noe	double	VMT_GridData2MeanXS	
A	Comp	xUTMraw	Raw x UTM coordinates	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	yUTMraw	Raw y UTM coordinates	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	utmzone	UTM zone in which the data resides	1	char	VMT_MapEns2MeanXS	
A	Comp	gps_reject_locations	Logical array of any GPS data which are to be rejected	noe X 1	logical	VMT_RepBadGPS	
A	Comp	gps_fly_aways	GPS flyaways as determined using a velocity filtering technique	noe X 1	logical	VMT_RepBadGPS	
A	Comp	gps_dropped_ensembl es	Dropped ensembles with no GPS data	noe X 1	logical	VMT_RepBadGPS	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Comp	gps_repeat_locations	Repeat GPS locations	noe X 1	logical	VMT_RepBadGPS	
A	Comp	xUTMf	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	xUTMb	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	yUTMf	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	yUTMb	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	xUTM	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	yUTM	Temporary array for bracketing bottom track locations in GPS replacement algorithm	noe X 1	double	VMT_RepBadGPS	
A	Comp	xm	X coordinate of Centroid of locational data	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	ym	Y coordinate of Centroid of locational data	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	dx	Change in X from start point of each observation	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	dy	Change in Y from start point of each observation	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	dl	Distance from left bank of the MCS for an individual transect	noe X 1	double	VMT_MapEns2MeanXS	

Leve l I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Comp	dlsort	Distance from left bank sorted	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	vecmap	Temporary array formapping vectors to the proper stationaing in the MCS	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	sd	Array of any remaining repeated locations in the MCS	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	dlsortgpsfix	Linearly interpolated positions of missing data not replaced by the VMT_RepBadGPS function	noe X 1	double	VMT_MapEns2MeanXS	
A	Comp	itDist	Stationing of each ensemble on the MCS	ity X itx	double	VMT_MapEns2MeanXS	
A	Comp	itDepth	Depth of each ensemble on the MCS	ity X itx	double	VMT_MapEns2MeanXS	
A	Comp	mcsBack	Interpolated indvidual transect Backscatter onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	
A	Comp	mcsEast	Interpolated indvidual transect East Velocities onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	
A	Comp	mcsNorth	Interpolated indvidual transect North Velocities onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	
A	Comp	mcsVert	Interpolated indvidual transect Vertical Velocities onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	
A	Comp	mcsMag	Interpolated indvidual transect Velocities onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	
A	Comp	mcsDir	Interpolated indvidual transect Velocity Directions (geographic angles) onto MCS regular grid	ity X itx	double	VMT_GridData2MeanXS	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Comp	mcsBed	Interpolated indvidual transect beam-averaged depths onto MCS regular grid	itx	double	VMT_GridData2MeanXS	
A	Comp	u	Streamwise velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	v	Cross-stream velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	w	Vertical velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	psi	Angle of deviation of the flow from the MCS	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	u1	Streamwise velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	v1	Cross-stream velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	w1	Vertical velocities of the individual transect	ity X itx	double	VMT_CompMeanXS_UVW	
A	Comp	qyi	Y component unit discharge for each bin	ity X itx	double	VMT_CompMeanXS_PriSec	
A	Comp	qxi	x component unit discharge for each bin	ity X itx	double	VMT_CompMeanXS_PriSec	
A	Comp	qpi	Primary component unit discharge for each bin	ity X itx	double	VMT_CompMeanXS_PriSec	
A	Comp	qsi	Secondary component unit discharge for each bin	ity X itx	double	VMT_CompMeanXS_PriSec	
A	Comp	Qp	Total primary component discharge for the transect	1	double	VMT_CompMeanXS_PriSec	
A	Comp	Qs	Total secondary component discharge for the transect	1	double	VMT_CompMeanXS_PriSec	
A	Comp	vp	Decomposed primary velocities	ity X itx	double	VMT_CompMeanXS_PriSec	
A	Comp	vs	Decomposed secondary velocities	ity X itx	double	VMT_CompMeanXS_PriSec	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
A	Comp	mcsDirDevp	Computed velocity deviations from the primary direction	ity X itx	double	VMT_CompMeanXS_PriSec	
A	[-]	hgns	User entered Horizontal grid node spacing in meters	1	double	VMT	
A	[-]	vgns	User entered Vertical grid node spacing in meters	1	double	VMT	
A	[-]	wse	User entered water surface elevation in meters	1	double	VMT	

Definitions

nbins	number of total bins within a given vertical, or ensemble in a single original ADCP transect
noe	number of ensembles within a single original ADCP transect
itx	number of horizontal grid locations on the mean cross section
ity	number of vertical grid locations on the mean cross section

Table 5. Format of the V structured array (VMT processed and saved mat-file).

Level I	*Level II*	*Field Name*	*Description*	*Size*	*Class*	*Parent*	*Children*
V		mfd	Mean flow direction of the MCS (geographic angle)	1	double		
V		b	Intercept of the line of the MCS	1	double		
V		theta	Angle of the MCS (arithmetic angle)	1	double		
V		phi	Angle of the perpendicular to the MCS	1	double		
V		meddens	Median ensemble spacing	1	double		
V		stddens	Standard deviation of the ensemble spacing	1	double		
V		xe	East-most X coordinate bounding MCS	1	double		
V		ys	South-most Y coordinate bounding MCS	1	double		
V		xw	West-most X coordinate bounding MCS	1	double		
V		yn	North-most X coordinate bounding MCS	1	double		
V		dx	Total distance spanned in X of the MCS	1	double		
V		dy	Total distance spanned in Y of the MCS	1	double		
V		dl	Total segment distance of the MCS	1	double		
V		xLeftBank	X coordinate of the Left Bank	1	double		
V		yLeftBank	Y coordinate of the Left Bank	1	double		
V		xRightBank	X coordinate of the Right Bank	1	double		
V		yRightBank	Y coordinate of the Right Bank	1	double		
V		probeType	ADCP probe type	1	char		
V		mcsDist	Grid of MCS Distances from Left Bank	ity X itx	double		
V		mcsDepth	Grid of MCS depths	ity X itx	double		
V		mcsX	Grid of X coordinates of the MCS	ity X itx	double		

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
V		mcsY	Grid of Y coordinates of the MCS	ity X itx	double		
V		countBack		ity X itx	double		
V		mcsBack	Grid of backscatter intensity data for the MCS	ity X itx	double		
V		countMag		ity X itx	double		
V		countVert		ity X itx	double		
V		countBed		ity X itx	double		
V		mcsEast	Grid of East velocities for the MCS	ity X itx	double		
V		mcsNorth	Grid of North velocities for the MCS	ity X itx	double		
V		mcsVert	Grid of Vertical velocities for the MCS	ity X itx	double		
V		mcsError	Grid of Error velocities for the MCS	ity X itx	double		
V		mcsMag	Grid of velocity magnitudes for the MCS	ity X itx	double		
V		mcsDir	Grid of velocity directions for the MCS	ity X itx	double		
V		mcsBed	Depth to the bed for each vertical in the MCS	1 X itx	double		
V		mcsBedElev	Depths corrected by the user supplied Water Surface Elevation	1 X itx	double		
V		psi	Deviation angle of velocity from perpendicular for each sample in the MCS	ity X itx	double		
V		u	Streamwise velocities for the MCS	ity X itx	double		
V		v	Cross-stream velocities for the MCS	ity X itx	double		
V		w	Vertical velocities for the MCS	ity X itx	double		
V		Qy	Total discharge in the Y direction for the MCS	1	double		
V		Qx	Total discharge in the X direction for the MCS	1	double		
V		alphasp		1	double		
V		phisp		1	double		
V		Qp	Total discharge in the primary flow direction for the MCS	1	double		
V		Qs	Total discharge in the secondary flow direction for the MCS	1	double		

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
V		vp	Primary velocities (zero secondary flow definition) for each sample in the MCS	ity X itx	double		
V		vs	Secondary velocities (zero secondary flow definition) for each sample in the MCS	ity X itx	double		
V		mcsDirDevp		ity X itx	double		
V	Roz	U	Layer-averaged mean streamwise velocities for each vertical in the MCS	1 X itx	double	VMT_Rozovskii	
V	Roz	V	Layer-averaged mean cross-stream velocities for each vertical in the MCS	1 X itx	double	VMT_Rozovskii	
V	Roz	U_mag	Layer-averaged mean velocity magnitudes for each vertical in the MCS	1 X itx	double	VMT_Rozovskii	
V	Roz	phi	Deviation angle of velocity from perpendicular for each vertical in the MCS	1 X itx	double	VMT_Rozovskii	
V	Roz	phi_deg	Deviation angle expressed in degrees	1 X itx	double	VMT_Rozovskii	
V	Roz	u		ity X itx	double	VMT_Rozovskii	
V	Roz	v		ity X itx	double	VMT_Rozovskii	
V	Roz	u_mag		ity X itx	double	VMT_Rozovskii	
V	Roz	depth		ity X itx	double	VMT_Rozovskii	
V	Roz	theta		ity X itx	double	VMT_Rozovskii	
V	Roz	theta_deg		ity X itx	double	VMT_Rozovskii	
V	Roz	up	Primary velocities (Rozovskii definition) for each sample in the MCS	ity X itx	double	VMT_Rozovskii	
V	Roz	us	Secondary velocities (Rozovskii flow definition) for each sample in the MCS	ity X itx	double	VMT_Rozovskii	
V	Roz	upy	Y component of primary velocities (Rozovskii)	ity X itx	double	VMT_Rozovskii	

Level I	Level II	Field Name	Description	Size	Class	Parent	Children
V	Roz	usy	Y component of secondary velocities (Rozovskii)	ity X itx	double	VMT_Rozovskii	
V	Roz	upx	X component of primary velocities (Rozovskii)	ity X itx	double	VMT_Rozovskii	
V	Roz	usy	X component of secondary velocities (Rozovskii)	ity X itx	double	VMT_Rozovskii	
V	Roz	ux	X component of Rozovskii velocities rotated to global coordinate system	ity X itx	double	VMT_Rozovskii	
V	Roz	uy	Y component of Rozovskii velocities rotated to global coordinate system	ity X itx	double	VMT_Rozovskii	
V	Roz	uz	Z component of Rozovskii velocities rotated to global coordinate system	ity X itx	double	VMT_Rozovskii	
V	Roz	alpha		1	double	VMT_Rozovskii	

iRic© ANV file

The iRic© river modeling interface allows input of vector velocity data for model calibration and validation (2-D) in the form of ANV files. VMT will export ANV files from the ASCII2GIS utility (depth-averaged velocity along the curvilinear boat path) and ANV files containing the depth- or layer-averaged velocity as displayed in the plan view plot with vector spacing and smoothing applied. The format of these data files is as follows:

The vector files contain x, y, z, vx, and vy values in each line and separated by spaces. Units are MKS. x: x position (UTM Easting in m) y: y position (UTM Northing in m) z: z position - Presently the z- value is unused and can be set to zero. vx: the x or easting component of velocity vy: the y or northing component of velocity. There is no header with the number of points in the file. The extension for vector files is .anv

Example:

```
324149.52 855806.24 0 -0.157983784 0.003032246
324149.36 855806.27 0 -0.223229456 0.039234629
324149.26 855806.32 0 -0.124340297 0.073863539
324149.02 855806.33 0 -0.205609318 0.079592921
324148.7 855806.35 0 -0.056268607 0.036997848
324148.36 855806.36 0 -0.326218383 0.032733164
324148.09 855806.39 0 -0.352748183 0.081762639
324147.78 855806.5 0 -0.605494602 0.625695435
```

Multibeam bathymetry file

These files contain the bathymetry data from the four individual beams of the ADCP, corrected for heading, pitch, and roll using an algorithm provided by TRDI and in use in Dave Mueller's ADMAP. The data is formatted as a simple CSV (comma-separated value) file that is easily imported into ArcGIS® using the XY data import tool. The user has the option to add ancillary data to the data file. A description of the data files with and without the ancillary data is as follows:

Without Ancillary Data

```
NAME           DESCRIPTION
EnsNo          Ensemble Number
Easting        Easting (UTM, WGS84)
Northing       Northing (UTM, WGS84)
Elev_m         Elevation in meters
```

With Ancillary Data

```
NAME           DESCRIPTION
EnsNo          Ensemble Number
Easting        Easting (UTM, WGS84)
Northing       Northing (UTM, WGS84)
Elev_m         Elevation in meters
Year           Year of sample
Month          Month of sample
Day            Day of sample
Hour           Hour of sample
Minute         Minute of sample
Second         Second of sample
Heading_deg    Heading reading at time of sample in degrees from
               true north
Pitch_deg      Pitch reading at time of sample in degrees
Roll_deg  Roll reading at time of sample in degrees
```

Note: UTM coordinates referenced to the WGS84 reference frame if that was set in the GPS unit used during data collection (typical).

KML and KMZ files

These files are generated to allow the user to display the transect shiptracks (*.kml) and mean cross sections (*.kmz) in Google Earth®. The KML files are generated using the VMT utility ASCII2KML and the KML files must be loaded into Google Earth® for display. The KMZ files are generated at the request of the user in the VMT interface and will open automatically in Google Earth® through a request in the VMT code. The KMZ files are best viewed as 3-D cross sections so the user should adjust the view in Google Earth®® to get the best display of the cross section. In order to display each KMZ file as a 3-D cross section, the user must enter an offset in the VMT interface that is greater than or equal to the max depth in the reach. This will ensure the cross section is fully displayed above the image plane in Google Earth®. Failure to enter an offset will place the cross section below the plane of the background image in Google Earth®, thus blocking the view of the data.

Tecplot® files

Files contain processed and averaged ADCP data formatted for direct import into Tecplot®. Choosing the Tecplot® export option will export the average cross-section data only with no smoothing or data reduction (vector spacing) applied. Data files contain a header with all necessary information. One data file (*_TECOUT.dat) contains the velocity and backscatter data array for the cross section while the other data file (*_TECOUT_XSBathy.dat) contains the georeferenced bed depth and bed elevation data. The data files contain the following variables:

TECOUT.dat

NAME	DESCRIPTION
X	UTM Easting (m)
Y	UTM Northing (m)
Depth	depth (m)
Dist	dist across XS, oriented looking u/s (m)
u	stream-wise velocity magnitude per bin (cm/s)
v	cross-stream velocity magnitude per bin (cm/s)
w	vertical velocity magnitude per bin (cm/s)
vp	primary vel. component-0 discharge meth. (cm/s)
vs	secondary vel. comp.-0 discharge meth. (cm/s)
U (Rotated)	depth-avg. stream-wise magnitude (cm/s)
V (Rotated)	depth-avg. cross-stream magnitude (cm/s)
ux (Rotated)	component of vel. in X dir., rotated (cm/s)
uy (Rotated)	component of vel. in Y dir., rotated (cm/s)
uz (Rotated)	component of vel. in Z dir., rotated (cm/s)
Mag	vel magnitude (need better desc.) (cm/s)
Bscat	backscatter (dB)
Dir	direction deviation (degrees)
vp (Roz)	primary vel. per bin using Rozovskii (cm/s)
vs (Roz)	secondary vel. per bin using Rozovskii (cm/s)
vpy (Roz)	cross-stream comp. of primary vel. (cm/s)
vsy(Roz)	cross-stream comp. of secondary vel. (cm/s)
phi_deg (Roz)	depth-avg. vel. vector angle (degrees)
theta_deg (Roz)	individual bin vel. vector angle (degrees)

TECOUT_XSBathy.dat

NAME	DESCRIPTION
X	UTM Easting (m)
Y	UTM Northing (m)
BedDepth	Bed depth (m)
Dist	Dist across XS, oriented looking u/s (m)
BedElev	Bed Elevation (m) (Only accurate if user entered value in VMT GUI)

Excel® file

VMT will produce an Excel® (*.xlsx) file of the processed results when prompted. There are two version of the file: Typical, single cross-section output; and, multiple transects loaded (i.e., plan view) output.

VMT writes 3 worksheets in the Excel® File:

VMTSummary: this contains an overview of the data processed, including several parameters related to the MCS, and the raw ASCII Files associated with the processed data.

Planview: this contains the UTM coordinates, elevation, and depth- or layer- averaged velocities of the MCS. Data are organized in rows (one vertical per row). If you have selected a particular depth range, in the Plan View Plot Panel, VMT will output the resulting velocities for that layer only. The depth range used in the computation is appended to the name of the velocity fields for reference.

MeanCrossSection: this contains the UTM coordinate, distance along transect (i.e., stationing), elevations, bed elevations, and a suite of various velocity variable for every grid node of the MCS. Data are organized in block format, with rows representing vertical locations. Missing/non-data locations are denoted by a value of -9999.

Note: If multiple MAT files are loaded, the worksheet MeanCrossSection will not be written, and the worksheet Planview will contain all transect data.

GIS compatible ASCII file (ASCII2GIS)

These files contain georeferenced depth- or layer-averaged data for every ensemble along the curvilinear shiptrack. The file also includes ancillary data. Data is formatted in a CSV file with a header that allows direct import in to ArcGIS® using the XY data import tool. A description of the data contained in the file is as follows: GIS.csv files

```
NAME                DESCRIPTION
EnsNo               Ensemble Number
Year                Year of sample
Month               Month of sample
Day                 Day of sample
Hour                Hour of sample
Min                 Minute of sample
Sec                 Second of sample
Lat_WGS84           Latitude in WGS84
Lon_WGS84           Longitude in WGS84
Heading_deg         Heading reading at time of sample in degrees from true north
Pitch_deg           Pitch reading at time of sample in degrees
Roll_deg            Roll reading at time of sample in degrees
Temp_C              Temperature at time of sample in deg. C
Depth_m             Mean bed depth at time of sample in meters
B1Depth_m           Beam 1 bed depth at time of sample in meters
B2Depth_m           Beam 2 bed depth at time of sample in meters
B3Depth_m           Beam 3 bed depth at time of sample in meters
B4Depth_m           Beam 4 bed depth at time of sample in meters
Backscatter_db      Acoustic backscatter in dB
DAVeast_cmps        Depth- or Layer-averaged velocity (east component) in cm/s
DAVnorth_cmps       Depth- or Layer-averaged velocity (north component) in cm/s
DAVmag_cmps         Depth- or Layer-averaged velocity magnitude in cm/s
DAVdir_deg          Depth- or Layer-averaged velocity direction in degrees
                    from true north
DAVvert_cmps        Depth- or Layer-averaged velocity (vertical) in cm/s (+ is up)
U_Star_mps          Shear velocity estimate in m/s
Z0_m                Roughness length estimate
COD                 Coefficient of determination
```

Appendix 3: Keyboard accelerators and hotkeys

Acellerator	*Function*
F1	Opens this user guide in a web browser
Ctrl+O	Open WinRiver II® classic ASCII output file(s)
Ctrl+M	Open processed VMT mat-file(s)
Ctrl+S	Save processed VMT mat-file
Ctrl+F	Export current figure(s) as graphics
Ctrl+I	Export iRic© ANV text file
Ctrl+B	Export multibeam bathymetry (RioGrande and StreamPro only)
Ctrl+Z	Export 3-D Google Earth® KMZ file of MCS
Ctrl+T	Export Tecplot DAT txt file of processed MCS and bathymetry
Ctrl+E	Export Excel® file of processed MCS, or multiple processed files if loaded
Ctrl+1	Change graphics rendering endine to OpenGL (default)
Ctrl+2	Change graphics rendering endine to Painters (Adobe Illustrator)
Ctrl+3	Change graphics rendering endine to Z-buffer
Ctrl+G	Start the ASCII to GIS tool
Ctrl+L	Start the ASCII to KML tool
Ctrl+C	Start the Batch Processing tool
Ctrl+Shift+S	Hidden functionality to process SonTek RiverSurveyorLive data (no guarantees)
Ctrl+Alt+E	Open the custom flat-file export utility