Vermont Stream Geomorphic Assessment

Appendix B

Phase 3
Data Management System Instructions

Vermont Agency of Natural Resources
April, 2004

Phase 3 Data Management System (DMS)

The Phase 3 data management system (DMS) consists of a spreadsheet workbook and a database. The spreadsheet workbook pre-processes the data before the data is entered into the database where analysis, queries and report development is conducted. Responsibility for entering raw field data into the spreadsheet workbook will fall upon the assessor. Once data is entered into the workbook it can be sent to the River Management Program (RMP). River management staff will be responsible for transferring the data to the Phase 3 database. A set of standard reports will be generated and made available to the assessor. People interested in custom reports will have the opportunity to work with the RMP to have such reports generated.

Phase 3 Spreadsheet Workbook

Overview

The spreadsheet workbook is designed to perform the following functions:

- Accept field data collected using Vermont's Geomorphic Assessment Phase 3 field protocols;
- Perform a number of calculations using these data;
- Organize calculated data into summary tables for review and printing; and
- Format the information for export to a permanent Access database.

The Phase 3 Workbook has seven individual worksheets (the "tabs" that show up at the bottom of the screen). They are:

- Rch Loc. And Desc.
- QAQC (Quality Assurance Sheet)
- Long. Profile and Pattern
- Pebble Count
- Cross-Section
- Bank Erodibility
- Meander Geometry

These worksheets accept field data. To increase efficiency of the data entry process, they have been designed to look similar to the field forms used during Phase 3 assessment. There are other hidden worksheets in the workbook that are used solely to format and store data for transfer to the database. As these worksheets are critical to the data transfer process they have been locked to prevent accidental changes from being made.

The phase 3 workbook is color coded for ease of use. The key to the color-coding scheme is as follows:

- **Blue:** Data entry cells,
- **White:** Calculation results,
- **Grey:** Titles, headings, and background.

Drop down menus and check boxes are data entry mechanisms on several of the worksheets that do not follow the color coding scheme (as they are colored white).

Most of the blue data entry cells have detailed instructions in the form of cell comments. They're marked by red triangles in the upper right corner of the cell. To bring up the instructions simply place the cursor over the cell of interest.

Opening and Saving the Workbook

It is highly recommended that the Phase 3 workbook be saved as a Microsoft Excel Template. This will ensure that a blank copy or template is always available for receipt of new data. Follow these steps to open a clean copy that is ready to accept field data:

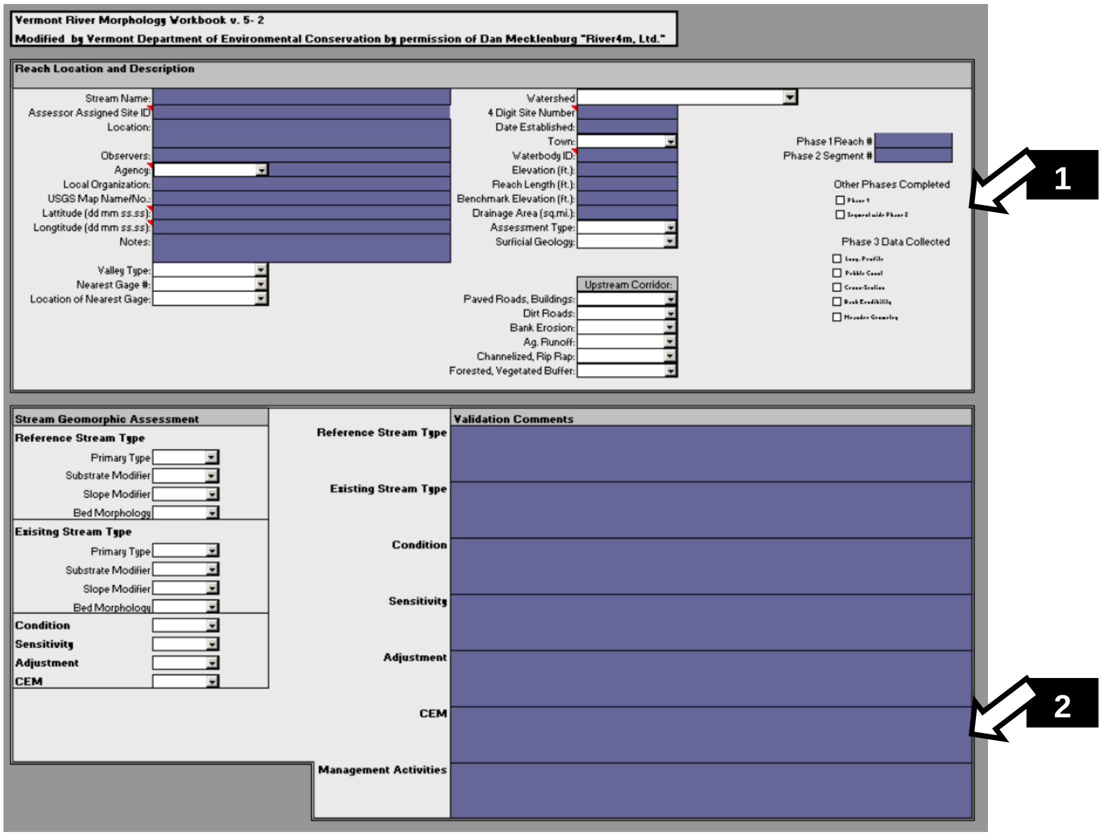
1. Put a copy of the template (or a Shortcut pointing to it) in the folder MS Excel looks to for templates. Usually it's is one of these folders:
   C:\Program Files\Microsoft Office\Templates\Spreadsheet Solutions
   C:\Windows\Application Data\Microsoft\Templates
   C:\Windows\Profiles*user_name*\Application Data\Microsoft\Templates
   C:\Windows\Profiles*user_name*\Application Data\Microsoft\Excel\XLStart
2. With MS Excel open, select File>New… and double-click on the DMS template.
3. Click "Enable Macros" if asked.
4. Click "NO" if asked whether to update any linked files. (A clean version of the template will open.)
5. Save the workbook (when you're finished entering data) as you would any other workbook.

For more information on creating and using Excel templates go to the help library in the Excel program.

Worksheet Layout

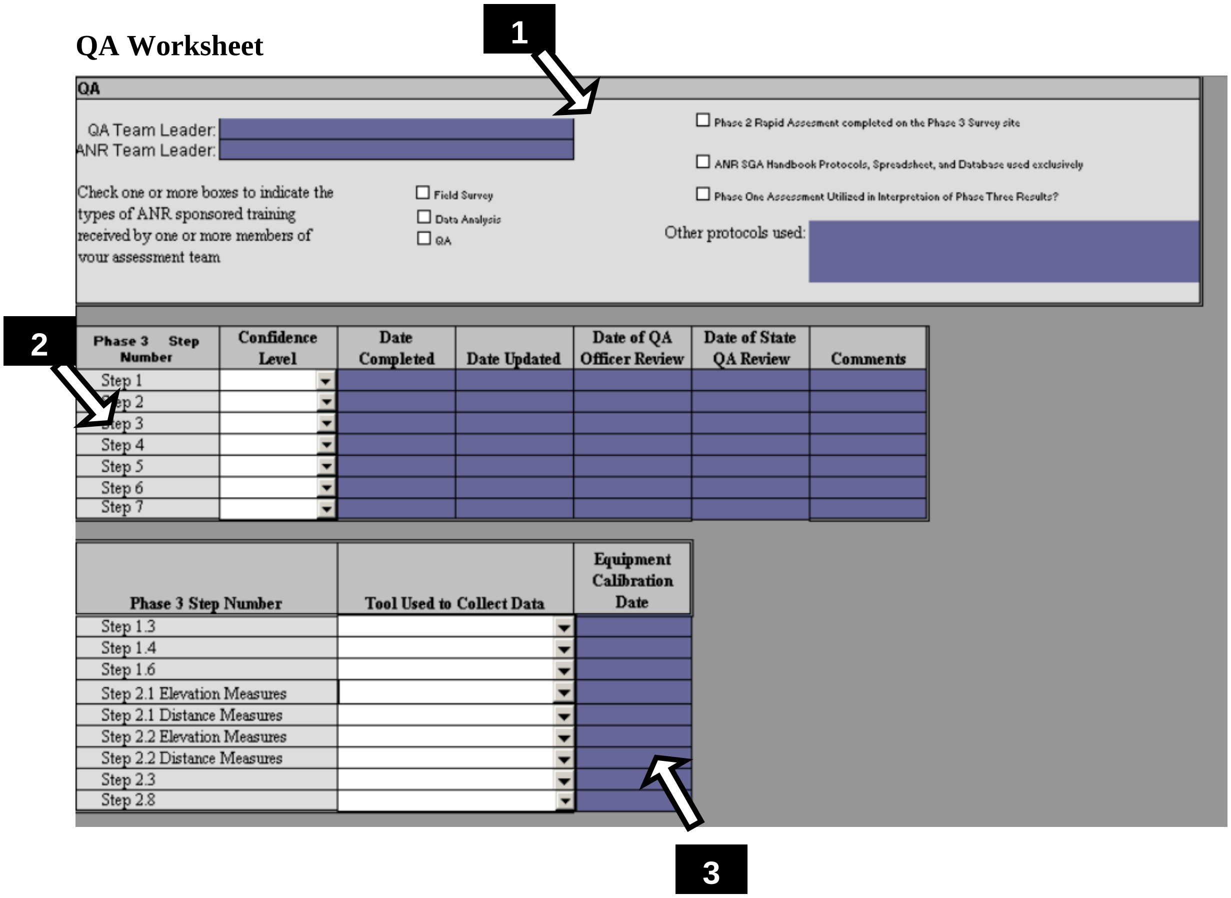
The following pages show pictures of the worksheets and briefly describes the layout of each. More detailed instructions can be found in the cell comments.

Reach Location and Description Worksheet



1. **Reach Location and description.** Enter general information about the study site in this sheet. You may find you want to fill in some of this information after you have entered and analyzed some of the field data. For instance, it may be easier to determine the stream type after you have looked at the cross section data.
2. **Geomorphic Assessment.** This data will help you to decide: how your study reach has departed from its reference condition; how the channel may be adjusting to achieve equilibrium; through what channel evolution process are these adjustments occurring; and the stream's sensitivity to further disturbance.

QA Worksheet


1
2
3

QA

QA Team Leader:
ANR Team Leader:

Check one or more boxes to indicate the types of ANR sponsored training received by one or more members of your assessment team

☐ Field Survey
☐ Data Analysis
☐ QA

☐ Phase 2 Rapid Assessment completed on the Phase 3 Survey site
☐ ANR SGA Handbook Protocols, Spreadsheet, and Database used exclusively
☐ Phase One Assessment Utilized in Interpretaion of Phase Three Results?

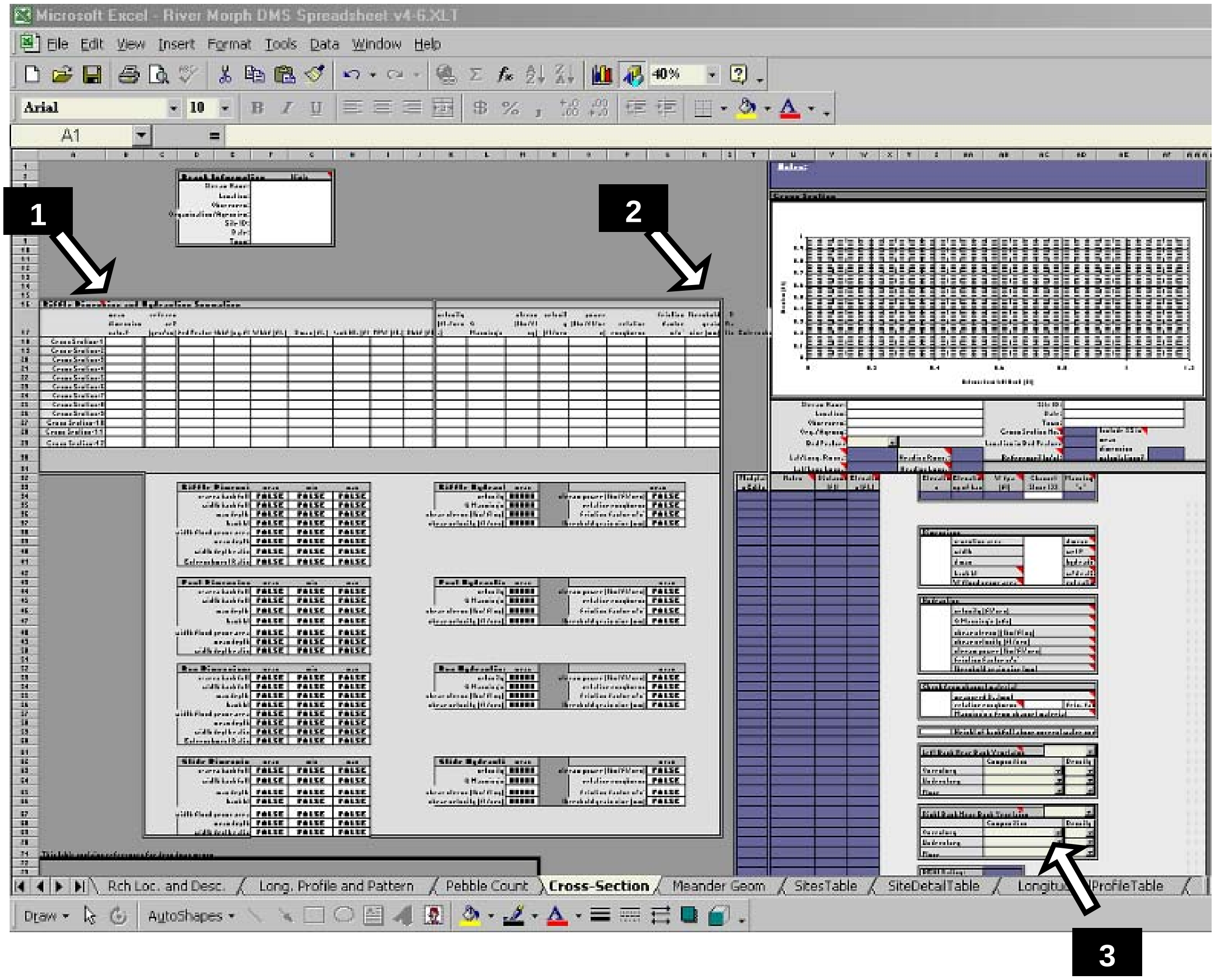
Other protocols used:

Phase 3 Step Number	Confidence Level	Date Completed	Date Updated	Date of QA Officer Review	Date of State QA Review	Comments
Step 1						
Step 2						
Step 3						
Step 4						
Step 5						
Step 6						
Step 7						

Phase 3 Step Number	Tool Used to Collect Data	Equipment Calibration Date
Step 1.3		
Step 1.4		
Step 1.6		
Step 2.1 Elevation Measures		
Step 2.1 Distance Measures		
Step 2.2 Elevation Measures		
Step 2.2 Distance Measures		
Step 2.3		
Step 2.8		

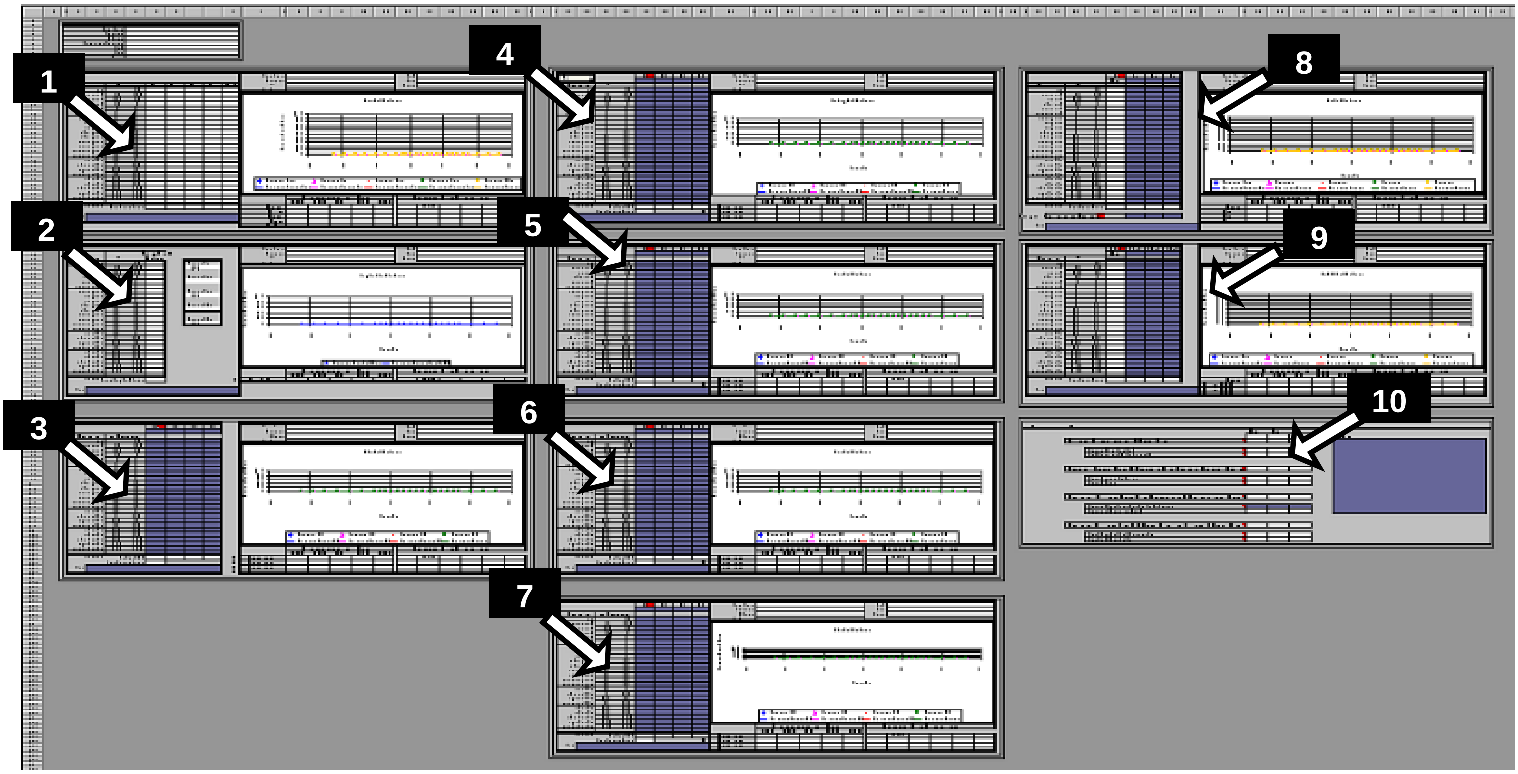
1. **Training and Protocols.** QA information on the training of the assessment team.
2. **Confidence Level and Completion Dates.** Documents the level of confidence the assessment team has in the results of each step. Also documents the assessment and QA review dates.
3. **Equipment Used.** Type and calibration information for the equipment used on each step.

Cross-Section Worksheet



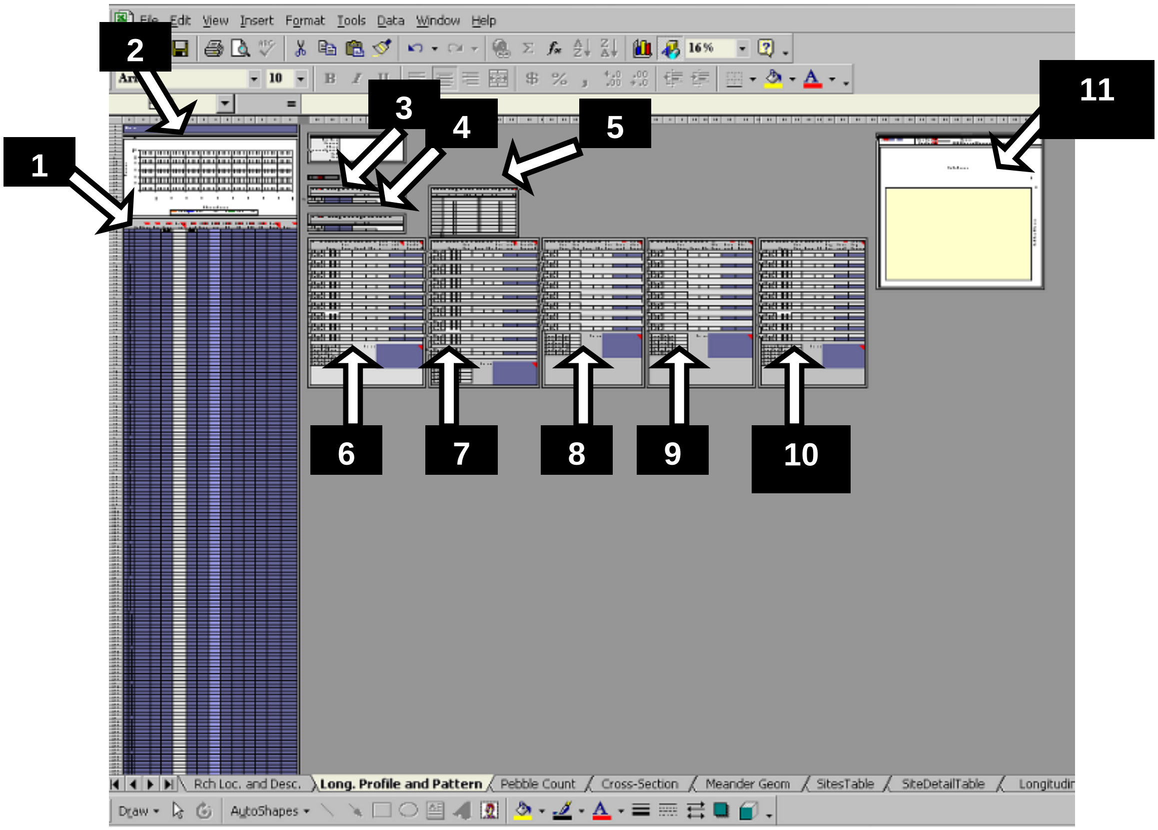
1. **Dimension and Hydraulics Summary.** Summarizes cross sectional dimensions and a number of calculated hydraulic parameters for the cross sections.
2. **Cross Section 1.** This portion of the worksheet accepts data for the first cross section, plots the data, and performs a number of calculations. Enter field data into the BLUE cells. There's room for eleven more cross sections to the right.
3. **Bank Vegetation.** Use these drop-down menus to describing near-bank vegetation.

Pebble Count Worksheet



1. **Total Pebble Count.** Summarizes and plots the pebble count data for each feature type and for the reach as a whole.
2. **Weighted Pebble Count.** Provides a particle size distribution that weights the distribution of each bed feature by the linear extent of that feature. The extent of each feature must be calculated on the "Long. Profile and Pattern" worksheet in order for the weighted pebble count to work.
3. **Other Pebble Count.** Accepts pebble count data for "Other" bed types and computes and graphs the distribution.
4. **Riffle/Step Pebble Count.** Accepts pebble count data for Riffles, Steps, or Plane Beds and computes and graphs the distribution.
5. **Run Pebble Count.** Accepts pebble count data for Runs and computes and graphs the distribution.
6. **Pool Pebble Count.** Accepts pebble count data for Pools and computes and graphs the distribution.
7. **Glide Pebble Count.** Accepts pebble count data for Glides and computes and graphs the distribution.
8. **Bar Pebble Count.** Accepts pebble count data for Bars and computes and graphs the distribution.
9. **Riffle BED Pebble Count.** Accepts pebble count data for Riffle BEDS and computes and graphs the distribution.
10. **Entrainment Calculations.** Uses riffle bed and bar data to calculate the critical dimensionless shear stress and the depth required to entrain specific particle sizes.

Longitudinal Profile and Pattern Worksheet

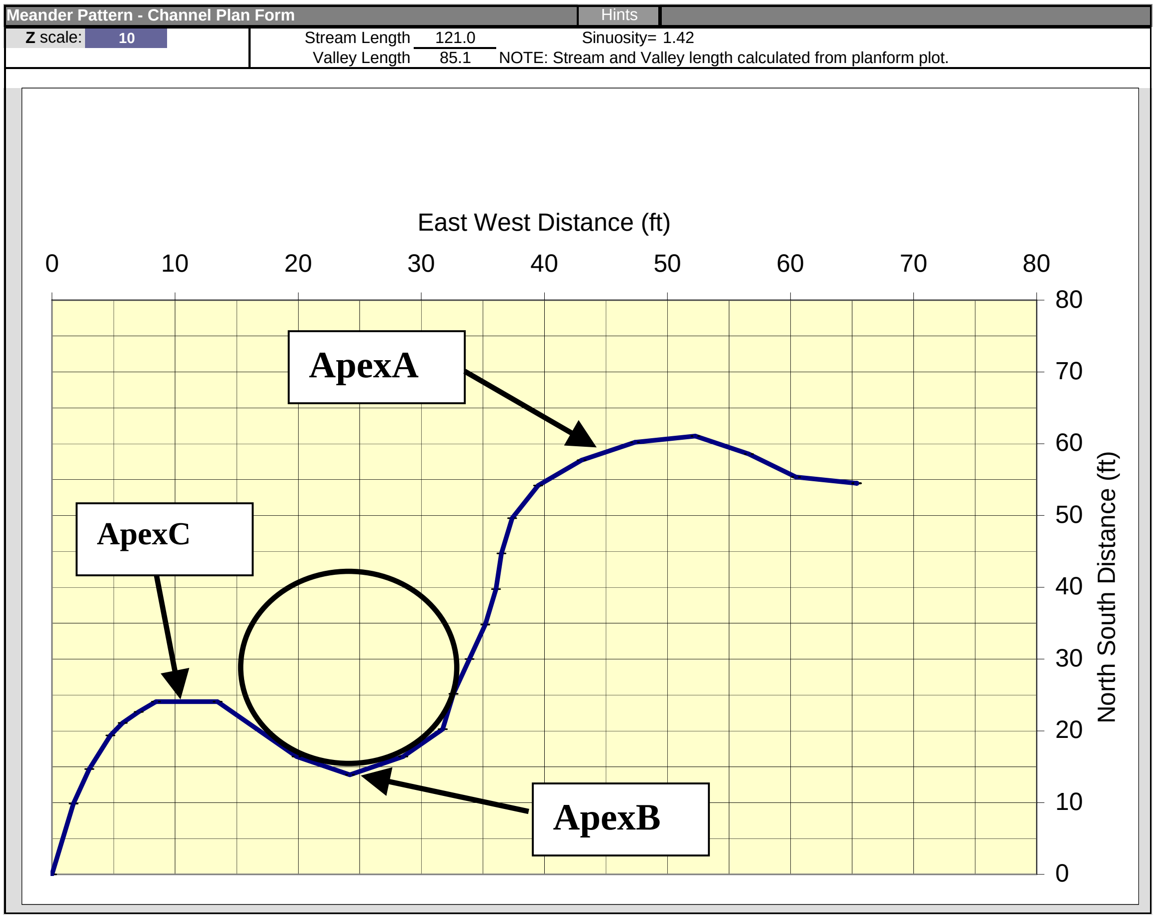


1. **Data Entry Section.** Most of the data from the longitudinal field survey gets entered in these blue cells. Read the cell comments at the top of each column for detailed instructions.
2. **Longitudinal Profile Plot.** Plots the elevation of the streambed, banks, bankfull, and water surface from upstream to down.
3. **Valley Length and Slope Calculator.** Calculates the length and slope of the valley using distances and elevations that you specify. Read the cell comments for detailed instructions.
4. **Stream Length and Slope Calculator.** Calculates the length and slope of the stream using distances and elevations that you specify. Read the cell comments for detailed instructions.
5. **Bendlength and Wavelength Calculator.** Calculates the along-channel bendlengths straight-line wavelength for each apex you identify in Section 1.
6. **Riffle Length and Slope Calculator.** Calculates the length and slope of riffles (both individually and as an average) and determines the percentage of the reach that is classified as riffle.
7. **Pool Length and Slope Calculator.** Same as #6, above, but for Pools.
8. **Run Length and Slope Calculator.** Same as #6, above, but for Runs.
9. **Glide Length and Slope Calculator.** Same as #6, above, but for Glides.
10. **Step Length and Slope Calculator.** Same as #6, above, but for Steps.
11. **Meander Pattern Plot.** Plots the meander pattern of the stream using the distance and azimuth values you entered in Section 1. When adjusted so the X and Y axes are scaled equally (see the cell comment for detailed instructions), circles can be drawn on the plot to determine radii of curvature for the reach.

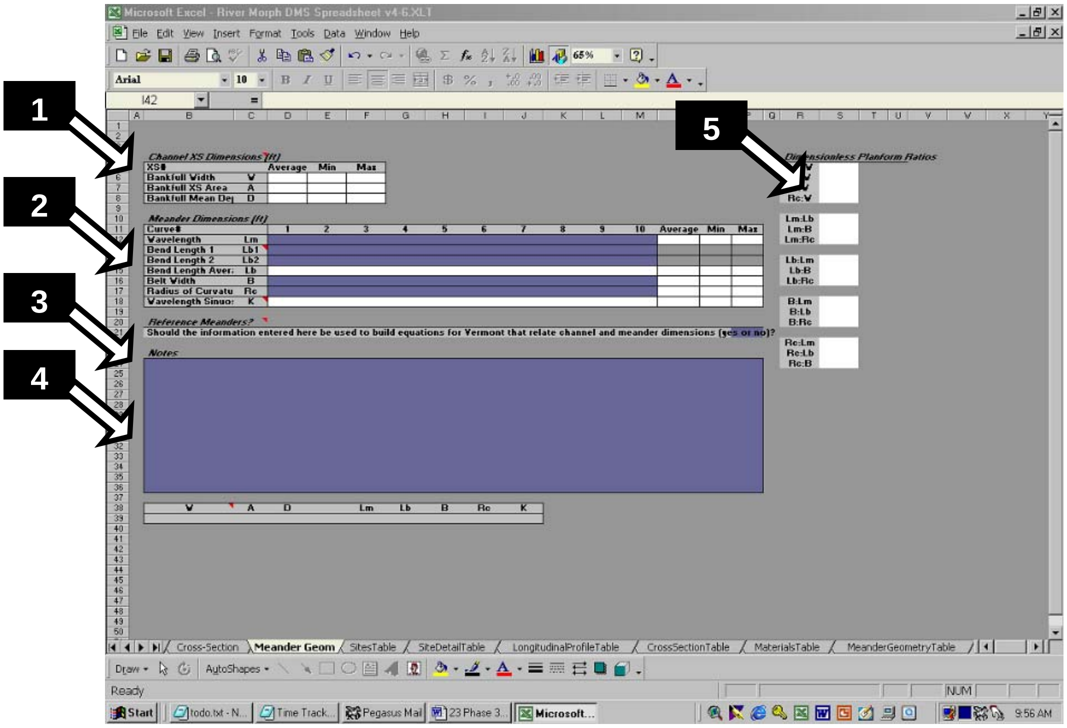
Using the longitudinal profile worksheet to measure planform geometry where azimuth readings have been collected as part of the longitudinal survey.

6. Use the Long. Profile and Pattern worksheets to determine Bendlengths and Wavelengths.
7. Enter longitudinal survey data in the *Long. Profile and Pattern* worksheet.
8. Identify the meander apexes in the second column (as the instructions at the top of the column indicate) by typing "Apex1", "Apex2", and so forth.
9. If you did not identify the apexes while in the field, look at the planform plot to help choose the apexes. You may need to count data points to determine, for instance, that the fifth surveyed point is an apex.
10. You need to identify three apexes for each curve you're analyzing:
11. the apex of the preceding curve (A),
12. the apex of the curve of interest (B), and
13. the apex of the next curve (C).
14. The program will calculate and display in the Bendlength and Wavelength Calculator section:
15. the along-channel distance from A to B (Bendlength1, Lb1),
16. the along-channel distance for B to C (Bendlength2, Lb2),
17. the straight-line distance from A to C (Wavelength, Lm).
18.
19. Use the Planform plot to Determine the Radius of Curvature.
20. As the instruction in the worksheet indicate, drag the axis of the graph so that the scale on the X and Y axis are the same.
21. For instance, you might have 50ft by 50ft square grids on the plot.
22. It's very important that the grids are square.
23. Turn on the drawing toolbar (if it's not already available) by selecting View>Toolbars…>Drawing.
24. Click on the Oval icon and use it to draw an oval on the plot.
25. Click and drag somewhere near the curve you're interested int.
26. Don't worry about locating and sizing the oval correctly on the first try.
27. Format the oval
28. Right-click on it and select Format Autoshape…
29. On the Colors and Lines tab, check the Semi-Transparent box.
30. On the Size tab, make the height and width the same and click OK.
31. Right click again on the circle and Select Format Autoshape…
32. Check the Lock Aspect Ratio box and click OK.
33. Resize the circle to fit your curve by dragging the corners (not the sides or it might turn back into an oval.
34. Move the circle into position with the mouse.
35. Print the plot and measure the on paper distance of the axis intervals and calculate the scale of the plot. For example you might set the axis intervals to 50ft. print out the plot and measure the on paper interval distance as 1 inch. You now know that the scale of the plot is 1 inch = 50 feet.
36. Measure the diameter of the circle and divide by two, or use a compass to measure the radius.
37. Use the Planform Plot to Determine the Beltwidth
38. Click on the line tool and draw a line connecting the apex proceeding your curve to the apex following your curve (e.g., a line connecting ApexA to ApexC which is the wavelength of the curve at ApexB).
39. Draw a second line that runs perpendicular to the one you just drew and connects that line to the apex of your curve (ApexB).
40. Print the plot, establish the scale as in step 2G above and measure the two lines created in steps a and b.

41. Recognize that the beltwidth is measured from outside of channel to outside of channel (rather than centerline). The line you just measured is probably (depending on where you drew your lines) based on the centerline of the channel and thus represents the *amplitude* of the curve and not the *beltwidth*. If necessary, adjust the measurement to get your final measurement of beltwidth.



Planform Worksheet



1. **Channels XS Dimensions.** Enter the dimensions (bankfull width and area) of cross sections that will be used in the analysis of the streams meander patterns. The instruction cells provide further guidance on selecting appropriate cross sections. If you previously entered cross-section data on the "Cross-Section" sheet, you may choose to use some or all of those cross sections. The spreadsheet does not automatically retrieve those data, however, because some of those cross sections may not be suitable for meander geometry analysis.
2. **Planform Dimensions.** Enter the dimensions for up to ten curves that will be used in the analysis of meander patterns. The instruction cells provide guidance for selecting appropriate curves. The worksheet calculates an average for each parameter, and this average is taken to represent the reach.
3. **Reference Meanders?** Specify whether the data you've entered should be used to develop equations relating stream channel dimensions to meander patterns. See the cell comment for further instructions.
4. **Notes Section.** Enter notes here explaining the source of the data, choices to include of exclude channel and meander dimension data, and any other information.
5. **Dimensionless Planform Ratios.** This section calculates ratios relating meander geometry variables to each other and to bankfull width.

The following figures show the layout of several of the reports that have been developed as part of the phase 3 Geomorphic Assessment Database.

Database Reports

The following figures represent two of the standardized Phase 3 reports that have been developed thus far. As more data is entered into the State Geomorphic Database other reports will become available.

Departure from Reference

SiteID: 0700000000520 Location: Gage
StreamType: B4C

Dimension

	Existing Channel	VT Reference Reach Data				Published Data		Design
		Mean	Range	Sample Size	Power	Mean	Range	
Entrenchment Ratio	1.27	1.70	1.20 - 2.35	4		*	*	
Width to Depth Ratio	24.33	29.94	22.06 - 41.95	4	26.74	*	*	
Bank Height Ratio		1.47	1.37 - 1.60	3				
Bankfull Width	123.13	99.38	74.10 - 132.50	4	104.38			
Bankfull Mean Depth	5.10	3.45	2.78 - 4.90	4	3.90			
Riffle X Sec Area	625.57	356.55	248.90 - 650.30	4	420.71			
Max Depth Ratio								
Riffle	1.40	1.43	1.25 1.72	3				
Run		1.56	1.42 - 1.69	3				
Pool	1.46	2.11	2.11 - 2.11	1				
Glide			-					
Area to Area Ratio								
Run		1.07	0.93 - 1.35	3				
Pool	0.80	1.18	1.18 - 1.18	1				
Glide			-					
Width to Width Ratio								
Run		0.97	0.78 - 1.21	3				
Pool	0.64	0.95	0.95 - 0.95	1				
Glide			-					

Profile

	Existing Channel	VT Reference Reach Data				Published Data		Design
		Mean	Range	Sample Size	Power	Mean	Range	
Riffle Slope Ratio		2.83	2.39 - 3.27	2				
Riffle Spacing Ratio			-				**	
Riffle % of Reach			-					

Pattern

	Existing Channel	VT Reference Reach Data				Published Data		Design
		Mean	Range	Sample Size	Power	Mean	Range / Value	
Meander Length Ratio			-					
Meander Width Ratio			-					
Radius To Width Ratio			-					
Sinuosity			-			*	*	
Meander Length					812.27		1,456.46 ***	
Bend Length					488.06		985.91 ***	
Belt Width					319.94		829.06 ***	
Radius Of Curvature					231.41		291.29 ***	

* Rosgen ** Leopold *** Williams

Materials

Riffle

	Existing Channel	Design
RiffleD16	0 mm	
RiffleD35	43 mm	
RiffleD50	86 mm	
RiffleD84	202 mm	

Reach Mean

	Existing Channel	Design
MeanD16	0.386 mm	
MeanD35	25.61 mm	
MeanD50	58.9 mm	
MeanD84	175 mm	

Bar

	Existing Channel	Design
BarD16	mm	
BarD35	mm	
BarD50	mm	
BarD84	mm	

Figure 1Example Database Reports

Interrelations Between Meander Features (Eqns 2-13)

Equation #2: Meander Length (ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	Lm=1.671Lb	4	127.8 - 698.5 ft	0.995
VT Power	Lm=1.232Lb^1.046	4	127.8 - 698.5 ft	0.967
Williams (1986)	Lm=1.25Lb	102	18 - 43600 ft	0.980

Equation #3: Meander Length (ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	Lm=3.244B	4	50 - 330 ft	0.938
VT Power	Lm=5.661B^0.873	4	50 - 330 ft	0.773
Williams (1986)	Lm=1.63B	155	12.1 - 44900 ft	0.980

Equation #4: Meander Length (ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	Lm=4.206Rc	4	56.9 - 263.5 ft	0.982
VT Power	Lm=3.111Rc^1.05	4	56.9 - 263.5 ft	0.987
Williams (1986)	Lm=4.53Rc	78	8.5 - 11800 ft	0.980

Equation #5: Bend Length (ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	Lb=0.597Lm	4	227.1 - 1181.5 ft	0.995
VT Power	Lb=0.99Lm^0.925	4	227.1 - 1181.5 ft	0.967
Williams (1986)	Lb=0.8Lm	102	26 - 54100 ft	0.980

Equation #6: Bend Length (ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	Lb=1.953B	4	50 - 330 ft	0.963
VT Power	Lb=3.366B^0.884	4	50 - 330 ft	0.896
Williams (1986)	Lb=1.29B	102	12.1 - 32800 ft	0.980

Equation #7: Bend Length (ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	Lb=2.512Rc	4	56.9 - 263.5 ft	0.976
VT Power	Lb=2.942Rc^0.963	4	56.9 - 263.5 ft	0.938
Williams (1986)	Lb=3.77Rc	78	8.5 - 11800 ft	0.960

Equation #8: Beltwidth (ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	B=0.299Lm	4	227.1 - 1181.5 ft	0.938
VT Power	B=0.667Lm^0.885	4	227.1 - 1181.5 ft	0.773
Williams (1986)	B=0.61Lm	155	26 - 76100 ft	0.980

Equation #9: Beltwidth (ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	B=0.503Lb	4	127.8 - 698.5 ft	0.963
VT Power	B=0.491Lb^1.013	4	127.8 - 698.5 ft	0.896
Williams (1986)	B=0.78Lb	102	18 - 43600 ft	0.980

Equation #10: Beltwidth (ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	B=1.268Rc	4	56.9 - 263.5 ft	0.949
VT Power	B=1.87Rc^0.924	4	56.9 - 263.5 ft	0.753
Williams (1986)	B=2.88Rc	78	8.5 - 11800 ft	0.960

Equation #11: Radius of Curvature (ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	Rc=0.235Lm	4	227.1 - 1181.5 ft	0.982
VT Power	Rc=0.366Lm^0.94	4	227.1 - 1181.5 ft	0.987
Williams (1986)	Rc=0.22Lm	78	33 - 54100 ft	0.980

Equation #12: Radius of Curvature (ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	Rc=0.394Lb	4	127.8 - 698.5 ft	0.976
VT Power	Rc=0.467Lb^0.974	4	127.8 - 698.5 ft	0.938
Williams (1986)	Rc=0.26Lb	78	22.3 - 43600 ft	0.960

Equation #13: Radius of Curvature (ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	Rc=0.771B	4	50 - 330 ft	0.949
VT Power	Rc=1.914B^0.816	4	50 - 330 ft	0.753
Williams (1986)	Rc=0.35B	78	16 - 32800 ft	0.960

Relations of Channel Size to Meander Features (Eqns 14-25)

Equation #14: XS Area (sq ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	A=0.151Lm	4	227.1 - 1181.5 ft	0.133
VT Power	A=28.029Lm^0.218	4	227.1 - 1181.5 ft	0.082
Williams (1986)	A=0.009Lm^1.53	66	33 - 76100 ft	0.922

Equation #15: XS Area (sq ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	A=0.258Lb	4	127.8 - 698.5 ft	0.145
VT Power	A=22.898Lb^0.273	4	127.8 - 698.5 ft	0.113
Williams (1986)	A=0.015Lb^1.53	41	20 - 43600 ft	0.903

Equation #16: XS Area (sq ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	A=0.554B	4	50 - 330 ft	0.265
VT Power	A=14.745B^0.396	4	50 - 330 ft	0.275
Williams (1986)	A=0.021B^1.53	63	16 - 38100 ft	0.941

Equation #17: XS Area (sq ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	A=0.692Rc	4	56.9 - 263.5 ft	0.229
VT Power	A=26.415Rc^0.295	4	56.9 - 263.5 ft	0.134
Williams (1986)	A=0.117Rc^1.53	28	7 - 11800 ft	0.941

Equation #18: Width (ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	W=0.062Lm	4	227.1 - 1181.5 ft	0.189
VT Power	W=11.117Lm^0.229	4	227.1 - 1181.5 ft	0.140
Williams (1986)	W=0.19Lm^0.89	191	26 - 76100 ft	0.922

Equation #19: Width (ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	W=0.106Lb	4	127.8 - 698.5 ft	0.196
VT Power	W=11.548Lb^0.242	4	127.8 - 698.5 ft	0.138
Williams (1986)	W=0.26Lb^0.89	102	16 - 43600 ft	0.941

Equation #20: Width (ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	W=0.223B	4	50 - 330 ft	0.306
VT Power	W=10.701B^0.288	4	50 - 330 ft	0.224
Williams (1986)	W=0.31B^0.89	153	10 - 44900 ft	0.922

Equation #21: Width (ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	W=0.283Rc	4	56.9 - 263.5 ft	0.300
VT Power	W=10.759Rc^0.303	4	56.9 - 263.5 ft	0.220
Williams (1986)	W=0.81Rc^0.89	79	8.5 - 11800 ft	0.941

Equation #22: Mean Depth (ft) as a function of Meander Length (ft)

	Equation	n	Range	R2
VT Linear	D=0.003Lm	4	227.1 - 1181.5 ft	0.195
VT Power	D=2.546Lm^-0.011	4	227.1 - 1181.5 ft	0.002
Williams (1986)	D=0.04Lm^0.66	66	33 - 76100 ft	0.740

Equation #23: Mean Depth (ft) as a function of Bend Length (ft)

	Equation	n	Range	R2
VT Linear	D=0.005Lb	4	127.8 - 698.5 ft	0.234
VT Power	D=2.008Lb^0.03	4	127.8 - 698.5 ft	0.012
Williams (1986)	D=0.054Lb^0.66	41	23 - 43600 ft	0.810

Equation #24: Mean Depth (ft) as a function of Beltwidth (ft)

	Equation	n	Range	R2
VT Linear	D=0.01B	4	50 - 330 ft	0.355
VT Power	D=1.38B^0.11	4	50 - 330 ft	0.178
Williams (1986)	D=0.055B^0.66	63	16 - 38100 ft	0.810

Equation #25: Mean Depth (ft) as a function of Radius of Curvature (ft)

	Equation	n	Range	R2
VT Linear	D=0.013Rc	4	56.9 - 263.5 ft	0.248
VT Power	D=2.452Rc^-0.006	4	56.9 - 263.5 ft	0.001
Williams (1986)	D=0.127Rc^0.66	28	8.5 - 11800 ft	0.810

Relations of Meander Features to Channel Size (Eqns 25-37)

Equation #26: Meander Length (ft) as a function of XS Area (sq ft)

	Equation	n	Range	R2
VT Linear	Lm=3.473A	4	56.4 - 239.7 ft	0.133
VT Power	Lm=74.774A^0.377	4	56.4 - 239.7 ft	0.082
Williams (1986)	Lm=21A^0.65	66	0.43 - 225000 ft	0.922

Equation #27: Bend Length (ft) as a function of XS Area (sq ft)

	Equation	n	Range	R2
VT Linear	Lb=2.117A	4	56.4 - 239.7 ft	0.145
VT Power	Lb=39.116A^0.416	4	56.4 - 239.7 ft	0.113
Williams (1986)	Lb=15A^0.65	41	0.43 - 225000 ft	0.903

Equation #28: Beltwidth (ft) as a function of XS Area (sq ft)

	Equation	n	Range	R2
VT Linear	B=1.172A	4	56.4 - 239.7 ft	0.265
VT Power	B=5.686A^0.693	4	56.4 - 239.7 ft	0.275
Williams (1986)	B=13A^0.65	63	0.43 - 225000 ft	0.941

Equation #29: Radius of Curvature (ft) as a function of XS Area (sq ft)

	Equation	n	Range	R2
VT Linear	Rc=0.891A	4	56.4 - 239.7 ft	0.229
VT Power	Rc=13.183A^0.455	4	56.4 - 239.7 ft	0.134
Williams (1986)	Rc=4.1A^0.65	28	0.43 - 225000 ft	0.941

Equation #30: Meander Length (ft) as a function of Width (ft)

	Equation	n	Range	R2
VT Linear	Lm=9.345W	4	30.6 - 91.6 ft	0.189
VT Power	Lm=42.207W^0.612	4	30.6 - 91.6 ft	0.140
Williams (1986)	Lm=6.5W^1.12	191	4.9 - 13000 ft	0.922

Equation #31: Bend Length (ft) as a function of Width (ft)

	Equation	n	Range	R2
VT Linear	Lb=5.664W	4	30.6 - 91.6 ft	0.196
VT Power	Lb=31.067W^0.57	4	30.6 - 91.6 ft	0.138
Williams (1986)	Lb=4.4W^1.12	102	4.9 - 7000 ft	0.941

Equation #32: Beltwidth (ft) as a function of Width (ft)

	Equation	n	Range	R2
VT Linear	B=3.081W	4	30.6 - 91.6 ft	0.306
VT Power	B=7.418W^0.779	4	30.6 - 91.6 ft	0.224
Williams (1986)	B=3.7W^1.12	153	4.9 - 13000 ft	0.922

Equation #33: Radius of Curvature (ft) as a function of Width (ft)

	Equation	n	Range	R2
VT Linear	Rc=2.378W	4	30.6 - 91.6 ft	0.300
VT Power	Rc=6.999W^0.724	4	30.6 - 91.6 ft	0.220
Williams (1986)	Rc=1.3W^1.12	79	4.9 - 7000 ft	0.941

Equation #34: Meander Length (ft) as a function of Mean Depth (ft)

	Equation	n	Range	R2
VT Linear	Lm=216.464D	4	1.8 - 2.9 ft	0.195
VT Power	Lm=498.185D^-0.16	4	1.8 - 2.9 ft	0.002
Williams (1986)	Lm=129D^1.52	66	0.1 - 59 ft	0.740

Equation #35: Bend Length (ft) as a function of Mean Depth (ft)

	Equation	n	Range	R2
VT Linear	Lb=133.144D	4	1.8 - 2.9 ft	0.234
VT Power	Lb=193.533D^0.391	4	1.8 - 2.9 ft	0.012
Williams (1986)	Lb=86D^1.52	41	0.1 - 57.7 ft	0.810

Equation #36: Beltwidth (ft) as a function of Mean Depth (ft)

	Equation	n	Range	R2
VT Linear	B=71.796D	4	1.8 - 2.9 ft	0.355
VT Power	B=35.104D^1.623	4	1.8 - 2.9 ft	0.178
Williams (1986)	B=80D^1.52	63	0.1 - 59 ft	0.810

Equation #37: Radius of Curvature (ft) as a function of Mean Depth (ft)

	Equation	n	Range	R2
VT Linear	Rc=53.495D	4	1.8 - 2.9 ft	0.248
VT Power	Rc=118.005D^-0.08	4	1.8 - 2.9 ft	0.001
Williams (1986)	Rc=23D^1.52	28	0.1 - 57.7 ft	0.810

Figure 2 Empirically derived meander geometry equations (following Williams, 1986).