WinXSPRO, A Channel Cross Section Analyzer, User's Manual, Version 3.0.

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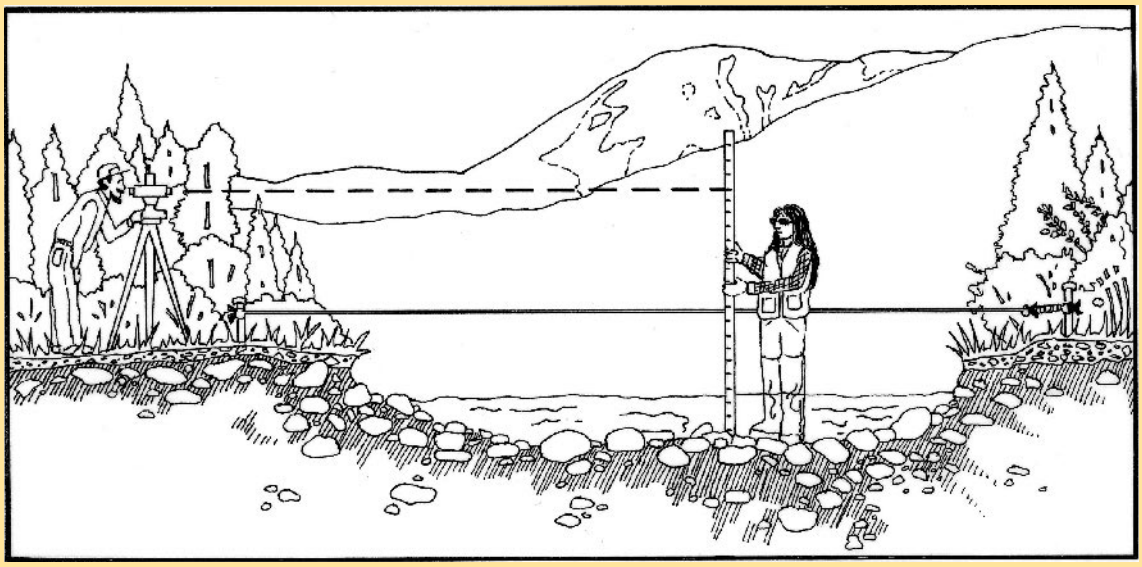
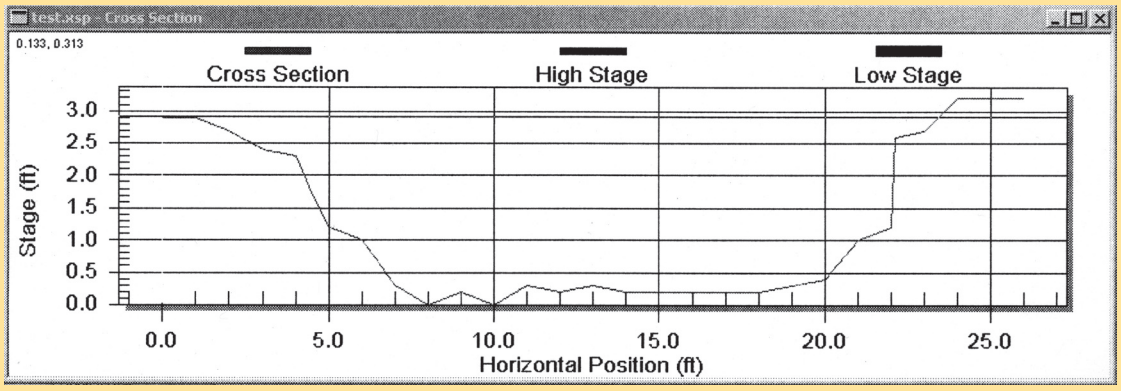
Thomas Hardy, Palavi Panja, and Dean Mathias





WinExample.out

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
0.50	T	3.89	13.70	13.45	0.28	0.29	0.0100	0.060	1.07	4.17	0.18
0.70	T	6.64	14.43	14.07	0.46	0.47	0.0110	0.059	1.57	10.43	0.32
0.90	T	9.52	15.17	14.69	0.63	0.65	0.0120	0.059	2.04	19.45	0.47
1.10	T	12.55	16.56	16.00	0.76	0.78	0.0130	0.058	2.45	30.69	0.61
1.30	T	15.90	17.82	17.11	0.89	0.93	0.0140	0.057	2.87	45.60	0.78
1.50	T	19.35	18.30	17.32	1.06	1.12	0.0150	0.056	3.37	65.13	0.99
1.70	T	22.83	18.79	17.54	1.22	1.30	0.0160	0.056	3.87	88.31	1.21
1.90	T	26.36	19.25	17.72	1.37	1.49	0.0170	0.055	4.38	115.34	1.45
2.10	T	29.92	19.71	17.90	1.52	1.67	0.0180	0.054	4.89	146.30	1.71
2.30	T	33.52	20.17	18.08	1.66	1.85	0.0190	0.053	5.41	181.37	1.97
2.50	T	37.30	21.72	19.43	1.72	1.92	0.0200	0.053	5.76	214.68	2.14

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ABSTRACT

WinXSPRO is an interactive Windows™ software package designed to analyze stream channel cross section data for geometric, hydraulic, and sediment transport parameters. WinXSPRO was specifically developed for use in high-gradient streams (gradient > 0.01) and supports four alternative resistance equations for computing boundary roughness and resistance to flow. Cross section input data may be from standard cross section surveys using a rod and level or sag-tape procedures. WinXSPRO allows the user to subdivide the channel cross section into multiple sub-sections and has the ability to vary water-surface slopes with discharge to reflect natural conditions. Analysis options include developing stage-discharge relationships, evaluating changes in channel cross-sectional area, and computing sediment transport rates. Resource specialists can use the estimated stream-channel geometry cross section hydraulic characteristics and sediment transport output to assist with channel design and monitoring, instream flow analysis, the restoration of riparian areas, and the placement of instream structures.

The AUTHORS

Thomas Hardy, Associate Director of the Utah Water Research Laboratory, Utah State University, Logan, UT 84322-8200

Palavi Panja, Research Programmer, Utah Water Research Laboratory, Utah State University, Logan, UT 84322-8200.

Dean Mathias, Lead System Analyst, Utah Water Research Laboratory, Utah State University, Logan, UT 84322-8200.

WinXSPRO

A Channel Cross Section Analyzer
User's Manual

Prepared by

Thomas Hardy
Palavi Panja
Dean Mathias

Institute for Natural Systems Engineering
Utah Water Research Laboratory
Utah State University

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The development of a Windows™-based program renamed WinXSPRO, Versions 2.x, was supported by the USDA Forest Service, Rocky Mountain Research Station, Stream Systems Technology Center, Fort Collins, Colorado. Version 2 added and improved many of the channel hydraulics features of the program and added bed load sediment transport modeling capabilities provided by Dr. Jon Nelson, Research Hydrologist, U.S. Geological Survey, Water Resources Division, Denver, Colorado. Programming, document revision, and coding of the sediment transport relations were supervised by Mr. Marty Teal, WEST Consultants, Inc., San Diego, California. This version was distributed as: **USDA Forest Service, 1998. WinXSPRO, A Channel Cross-Section Analyzer, User's Manual. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO, unpublished manuscript.**

Version 3 is also a Windows™-based version of WinXSPRO supported by the USDA Forest Service, Rocky Mountain Research Station, Stream Systems Technology Center, Fort Collins, Colorado. It contains numerous enhancements and improvements derived from user input and feedback from using previous versions of the software. Programming and document revision was supervised by Dr. Thomas Hardy, Utah State University, Institute for Natural Systems Engineering while programming changes were made by Mrs. Palavi Panja and Mr. Dean Mathias.

The authors wish to thank the numerous Forest Service and other users who tested earlier versions, identified "glitches" and provided useful suggestions for improving the program. We especially wish to thank Dr. Gordon Grant, Dr. Jon Nelson, Jim Fogg, and Toby Hanes for critical review of the software and documentation. Finally, we wish to thank Larry Schmidt and John Potyondy of the Stream Systems Technology Center for their leadership and diligent work in making this Windows™ version of the WinXSPRO program a reality.

DISCLAIMER

This software is in the public domain, and the recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced program. WinXSPRO is provided "as-is" without warranty of any kind, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The user assumes all responsibility for the accuracy and suitability of this program for a specific application. In no event will the USDA Forest Service, WEST Consultants, Inc., or Utah State University, be liable for any damages, including lost profits, lost savings, or other incidental or consequential damages arising from the use of or the inability to use this program.

DOWNLOAD INFORMATION

This User's Guide and the WinXSPRO program can be downloaded from:

http://www.stream.fs.fed.us/publications/software.html.

This publication may be updated as features and modeling capabilities are added to the program. Users may wish to periodically check the download site for the latest updates.

WinXSPRO is supported by and limited technical support is available from USDA Forest Service, Washington Office Watershed, Fish, Wildlife, Air, & Rare Plants Staff, Streams Systems Technology Center, Fort Collins, CO. The preferred method of contact for obtaining support is to send an e-mail to rmrs_stream@fs.fed.us requesting "WinXSPRO Support" in the subject line.

USDA Forest Service
Rocky Mountain Research Station
Stream Systems Technology Center
2150 Centre Ave., Bldg. A, Suite 368
Fort Collins, CO 80526-1891
(970) 295-5983

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Chapter 1 - Introduction

1.1 Purpose of WinXSPRO

WinXSPRO is an interactive, Windows™ software package designed to assist watershed specialists in analyzing stream channel cross section data for geometric, hydraulic and sediment transport parameters. Although the program can be used with streams of any gradient, it has been specifically developed to handle channel geometry and hydraulic conditions for single transects in steep (gradient > 0.01) streams. Several resistance equations are supported, including those specifically designed for large roughness channels. Analysis options include developing stage-to-discharge relationships, calculating depth required to inundate valley floor surfaces, evaluating changes in channel cross-sectional area, and computing sediment transport rates. Both graphical and tabular output can be generated. WinXSPRO can assist resource specialists in analyzing instream flow needs, performing hydraulic reconstructions, designing effective channel and riparian structures, and monitoring channel changes.

1.2 Applications of WinXSPRO

Information on stream-channel geometry, hydraulic characteristics, and sediment transport rates is useful for channel design, restoration of riparian areas, and placement of instream structures. The analyses of cross section hydraulics, along with an evaluation of flood frequency, are primary considerations in channel design. Once a desired bank-full flow is defined, the channel is designed to contain that flow, and higher flows are allowed to spread over the floodplain. Such periodic flooding is extremely important for the formation of channel macro-features (e.g., point bars and meander bends) and for establishment of certain kinds of riparian vegetation. A cross section analysis may also help in optimal placement of such items as culverts and fish habitat structures.

Additionally, knowledge of the relationships between discharge, channel geometry and hydraulics is useful for reconstructing the conditions associated with a particular flow situation. For example, in many channel stability analyses, it is customary to relate movement of streambed materials to some measure of stream power or average bed shear stress. If the relations between streamflow and certain hydraulic variables (e.g., mean depth and water-surface slope) are known, it is possible to estimate stream power and average bed shear at any given level of flow. Thus, a channel cross section analysis makes it possible to estimate conditions of streambed particle movement at various levels of streamflow. WinXSPRO also includes two sediment transport relations: the Parker model for gravel-bed rivers and the Ackers-White model for sand-bed channels.

Finally, cross section analyses provide important information for instream flow assessments. Various riparian resource values may be altered by changes in hydraulic parameters associated with changes in streamflow. For example, the relation between low-water discharge and channel wetted perimeter may be an important consideration for macroinvertebrate production or the scenic enjoyment of a stream. Similarly, cross section data may be used to define the depth-discharge relationship for analysis of fish habitat. Also, if the recurrence frequencies of various discharges are known, a depth-duration

relationship may be constructed. The applications of WinXSPRO are not limited by those described here; with some imagination, the user will find others for which the tools in the program will serve.

1.3 Overview of User's Manual

This manual describes the fundamental concepts, methodologies, capabilities and limitations, features, input requirements, and output of WinXSPRO. The manual is organized into the following sections:

Introduction (Chapter 1)

This chapter.

Theoretical Basis (Chapter 2)

Chapter 2 describes the theoretical basis for the hydraulic, flow resistance, and sediment transport calculations used in WinXSPRO.

Field Procedures and Techniques (Chapter 3)

Chapter 3 provides guidance on selection of reaches and representative cross sections where information is to be collected and field procedures to be used in the collection.

Running WinXSPRO (Chapter 4)

Chapter 4 covers information on installing the program, setting up projects and plans, and navigating through the program itself. Input and output data and all options available within WinXSPRO are described in this chapter.

Example Problems (Chapter 5)

Chapter 5 provides example applications of WinXSPRO.

References (Chapter 6)

Chapter 6 is a listing of references cited.

Appendices

Appendix A is a list of symbols that are used in this manual and Appendix B addresses use of WinXSPRO with spreadsheet programs. Appendix C is a glossary of terms and phrases used in this manual, and Appendix D lists and explains the warning and error messages used in WinXSPRO. Appendix E explains typical sample files distributed with the software.

1.4 Features of WinXSPRO

The WinXSPRO program is designed for analyzing channel cross section data in an interactive, user-friendly environment. The program is run under Microsoft® Windows™ with easy-to-read input and output screens and many other features common to Windows™ programs. WinXSPRO uses a resistance-equation approach (e.g., Manning's equation) to single cross section hydraulic analysis, and is capable of analyzing the geometry, hydraulics and sediment transport potential of a given channel cross section (including sections with undercut banks). WinXSPRO was specifically developed for use in high-gradient streams and supports four alternative resistance equations for computing boundary roughness and resistance to flow. The program allows the user to subdivide the channel cross section so that overbank areas, mid-channel islands, and high-water overflow channels may be analyzed separately. WinXSPRO also allows input of water-surface slopes such that the slope will vary with discharge to reflect natural conditions. The user can overlay plots and compute the difference in area between two cross sections using a special feature of the program. Sediment transport calculations can be performed using one bed load equation and one total load equation.

1.5 Computer Requirements

WinXSPRO requires Microsoft® Windows™ Version 3.1 or higher, a minimum of 4 MB hard disk space and 4 MB RAM. Eight (8) MB RAM is recommended for faster operation. Installation of the program is described in Chapter 4.

Chapter 2 - Theoretical Basis

2.1 General

The theoretical background for analyzing channel cross section data is derived from the basic continuity, momentum, and energy equations of fluid mechanics. Specifically, streamflow at a cross section is computed using the simplified form of the continuity equation where discharge equals the product of velocity and cross-sectional area of flow. Computation of cross-sectional area is strictly a geometry problem; it is determined by inputting incremental depths of water (stage) to a channel cross section defined by distance-elevation pairs. In addition to cross-sectional area, the top width, wetted perimeter, mean depth, and hydraulic radius are computed for each increment of stage (Figure 2.1).

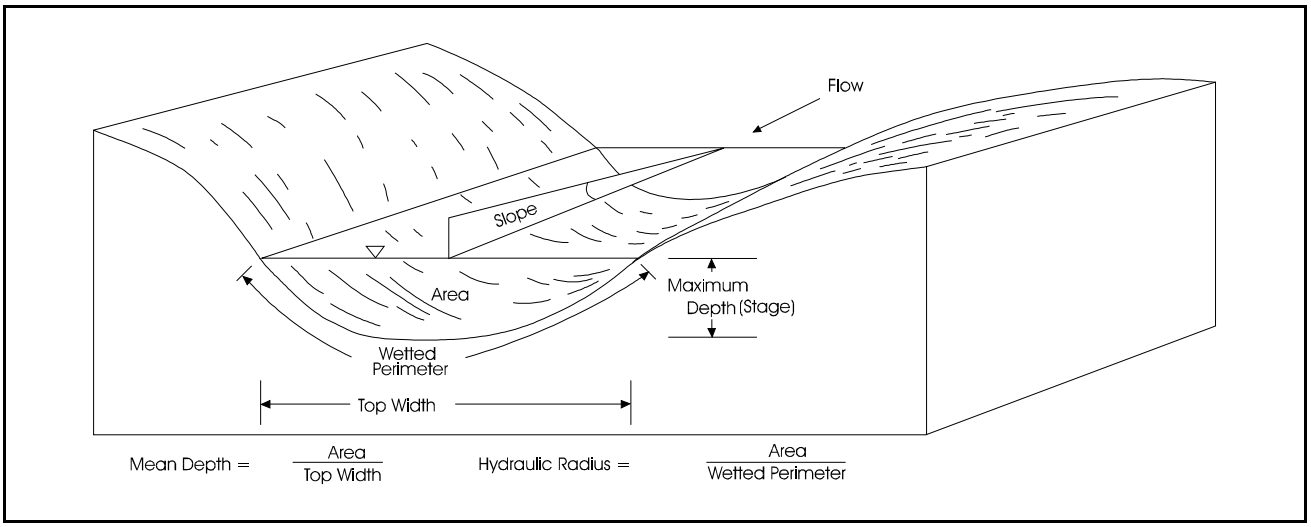


Figure 2.1. Computational elements of hydraulic properties.

Once the channel geometry has been computed for a given stage, an estimate of mean cross section velocity is needed to produce an estimate of streamflow. Analysis of the momentum and energy equations requires that, under certain streamflow conditions, gravitational forces that cause water to move downhill are balanced by frictional forces at the channel boundary that tend to resist the downhill flow. Under these conditions it is possible to estimate resistance to flow and, hence, mean velocity at the channel cross section. Thus, various resistance equations have been developed for estimating mean velocity as a function of cross section hydraulic parameters.

Sediment transport relations have also been developed based on hydraulic parameters, most notably shear stress and velocity. For steep streams, sediment transport is mostly as bed load, i.e., by particles rolling or sliding along the streambed, or moving by short jumps (saltating). For streams with smaller gradients, transport generally will occur as both bed load and suspended load (where some particles are supported above the bed by turbulence and transported at about the local flow velocity).

2.2 General Assumptions and Limitations

As indicated, the mean velocity of streamflow in a cross section can be computed when certain flow conditions are met. The main criteria for these flow conditions is that the bed slope, the water-surface slope, and the total energy grade line are essentially parallel. The total energy of the stream is a function of the position of the streambed above some arbitrary datum (potential energy), the depth of the water column (pressure energy), and the velocity of the water column (kinetic energy). The slope of the total energy grade line indicates the rate at which energy is dissipated through turbulence and boundary friction. When the slope of this line is known, the various resistance formulas allow computation of mean cross-sectional velocity. When the water-surface and the energy grade line parallel the streambed, the energy grade line slope is assumed to be the same as the water-surface slope.

Under conditions of constant width, depth, area, and velocity, the water surface slope and energy grade line approach the slope of the streambed, producing a condition known as "uniform flow." One feature of uniform flow is that the streamlines (the traces of the path that a particle of water would follow in the flow) are parallel and straight (Roberson and Crowe 1985). Perfectly uniform flow rarely occurs in natural channels, but the condition is approached in some reaches where the geometry of the channel cross section is relatively constant throughout the reach. Conditions that tend to disrupt uniform flow include bends in the stream course; changes in cross section geometry; obstructions to flow caused by large roughness elements such as channel bars, large boulders, and woody debris; or other features that cause convergence, divergence, acceleration, or deceleration of flow (Figure 2.2). Resistance equations also may be used to evaluate these non-uniform flow conditions (gradually varied flow); however, energy-transition calculations (backwater) must then be included in the analysis. This requires the use of multiple transect numerical models (e.g., HEC-2, HEC-RAS, WSPRO).

2.3 Flow Resistance Equations

WinXSPRO supports four sets of resistance equations for estimating mean velocity at a cross section. Each equation or set of equations was developed from specific sets of data; therefore, use of a particular resistance formula to estimate velocity is subject to the limitations of the data used to develop that formula, as well as the assumptions of the formula itself. Also, because each resistance equation estimates channel resistance or roughness in a slightly different way, the different formulas may require different inputs from the user and will likely produce somewhat different results. Selection of the appropriate resistance equation requires understanding the assumptions and limitations of each approach.

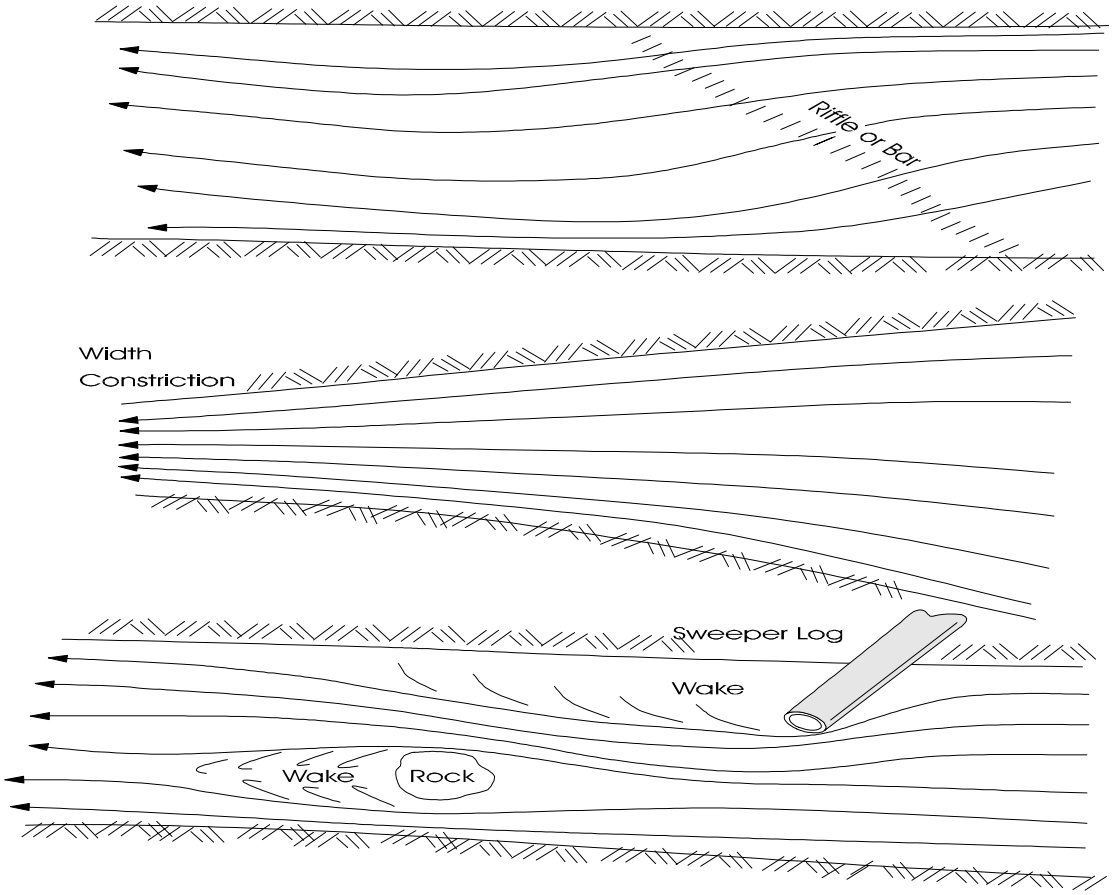


Figure 2.2. Typical channel configurations that disrupt uniform flow.

2.3.1 Manning's Equation

WinXSPRO supports the use of Manning's equation for estimating mean cross section velocity. Manning's equation was developed for conditions of uniform flow (described previously). Lacking a better solution, it is assumed that the equation is also valid for non-uniform reaches that are invariably encountered in natural channels if the energy gradient is modified to reflect only the losses due to boundary friction (Dalrymple and Benson 1967). The Manning equation for mean velocity is given as:

$$V = \frac{k}{n} R^{2/3} S^{1/2} \tag{1}$$

where:

V	=	average velocity in the cross section (ft/s or m/s)
k	=	1.0 for metric units and 1.486 for English units,
n	=	Manning's roughness coefficient,
R	=	hydraulic radius (ft or meters) , and
S	=	energy slope (ft/ft or m/m) (water-surface slope for uniform flow).

In Manning's equation, resistance to flow due to friction at the channel boundary is addressed through the use of a roughness coefficient, n, supplied by the user of the equation. The roughness coefficient may be thought of as an index of the features of channel roughness that contribute to the dissipation of stream energy.

There are three methods for estimating Manning's roughness coefficient for natural channels: direct solution of Manning's equation for n (given R, S, and V in the above equation), comparison with computed n values for other channels, and formulas relating n to other hydraulic parameters. Each method has its own limitations and advantages.

The method of direct solution entails measuring stream discharge and dividing by the cross sectional flow area to obtain a mean velocity. The mean velocity, hydraulic radius (roughly equal to mean depth for wide channels), and water-surface slope are entered into Manning's equation, and the equation is solved directly for the roughness coefficient, n. This approach gives an estimate of n that is as accurate as the associated measurement of discharge, cross sectional area, and water-surface slope. However, the n value obtained is only applicable to the particular stage and cross sectional geometry at which the flow was measured. Even at a given stage the n value can vary seasonally due to vegetation and temperature effects.

Since the features of channel roughness that contribute to energy dissipation will vary with water level, n also will vary with water level; therefore, it is desirable to directly estimate n at more than one level of streamflow. Most authors cited have found that n values decrease with increasing stage, at least up to bank-full flow. If streamflow can be measured at several different stages, n may be calculated for a range of flows and the relationship between n and stage determined.

The second method for estimating n values at a cross section involves comparing the reach to a similar, measured reach for which Manning's n has already been computed. This is probably the quickest and most commonly used procedure for estimating Manning's n and is usually done from either a table of values or by comparison with photographs of natural channels. Tables of Manning's n values for a variety of natural and artificial channels are common in the literature on hydraulics (e.g., Chow 1959; Van Haveren 1986). Photographs of stream reaches with computed n values have been compiled by Chow (1959) and Barnes (1967); Arcement and Schneider (1984) extended this work for floodplain areas.

When the roughness coefficient is estimated from table values or by comparison with photographs of natural channels with known n, the chosen n value is considered a base value, n_b, that may need to be adjusted for local channel conditions. Several publications provide procedures for adjusting n_b to account for channel irregularities, vegetation, obstructions, and sinuosity (Chow 1959; Benson and Dalrymple 1967; Arcement and Schneider 1984; Parsons and Hudson 1985). The most common procedure uses the formula proposed by Cowan (1956) to estimate the value of n:

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \qquad (2)$$

where:

n_b	=	base value of n for a straight, uniform, smooth channel in natural materials,
n_1	=	correction for the effect of surface irregularities,
n_2	=	correction for variations in cross section size and shape,
n_3	=	correction for obstructions,
n_4	=	correction for vegetation and flow conditions, and
m	=	correction for degree of channel meandering.

Table 2.1 is taken from Aldridge and Garrett (1973) and may be used to estimate the base n values for stable channels and floodplains, where stable channels are defined as those where the bed is composed of firm soil, gravel, cobbles, boulders, or bedrock and which remains relatively unchanged through most of the range of flows. The base values of Benson and Dalrymple (1967) generally apply to conditions that are close to average whereas Chow's (1959) base values are for the smoothest reach attainable for a given bed material. Table 2.2 is also taken from Aldridge and Garrett (1973) and may be used to estimate each of the correction factors in Equation 2 to produce a final estimated n.

Table 2.1. Base values of Manning's n [modified from Aldridge and Garrett (1973) Table 1].

Channel or floodplain type	Median size of bed material		Base n value (n_b)	
	Millimeters	Inches	Benson and Dalrymple (1967)[1]	Chow (1959)[2]
Concrete	-	-	0.012-0.018	0.011
Rock cut	-	-	-	0.025
Firm soil	-	-	0.025-0.032	0.020
Coarse sand	1-2	-	0.026-0.035	-
Fine gravel	-	-	-	0.024
Gravel	2-64	0.08-2.5	0.028-0.035	-
Coarse gravel	-	-	-	0.026
Cobble	64-256	2.5-10.1	0.030-0.050	-
Boulder	>256	>10.1	0.040-0.070	-

[1]Straight uniform channel.
[2]Smoothest channel attainable for indicated material.

Table 2.2. Factors that affect roughness of the channel (modified from Aldridge and Garrett (1973), Table 2).

	Channel conditions	n value adjustment[1]	Example
Degree of irregularity (n_1)	Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
	Minor	0.001-0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
	Moderate	0.006-0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
	Severe	0.011-0.020	Badly sloughed or scalloped banks of natural streams; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
Variation in channel cross section (n_2)	Gradual	0.000	Size and shape of channel cross sections change gradually.
	Alternating occasionally	0.001-0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross sectional shape.
	Alternating frequently	0.010-0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross sectional shape.

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base Manning's n value before multiplying by the adjustment for meander, m.

Table 2.2. Factors that affect roughness of the channel – (continued).

	Channel conditions	n value adjustment[1]	Example
Effect of obstruction (n_3)	Negligible	0.000-0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders, that occupy less than 5 percent of the cross sectional area.
	Minor	0.005-0.015	Obstructions occupy less than 15 percent of the cross sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects than are used for sharp-edged angular objects.
	Appreciable	0.020-0.030	Obstructions occupy from 15 to 20 percent of the cross sectional area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
	Severe	0.040-0.050	Obstructions occupy more than 50 percent of the cross sectional area or the space between obstructions is small enough to cause turbulence across most of the cross section.
Amount of vegetation (n_4)	Small	0.002-0.010	Dense growths of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, cottonwood, arrowweed, or saltcedar growing where the average depth of flow is at least three times the height of the vegetation.

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base Manning's n value before multiplying by the adjustment for meander.

Table 2.2. Factors that affect roughness of the channel – (continued).

	Channel conditions	n value adjustment[1]	Example
Amount of vegetation (n_4) - continued	Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1- to 2-year-old willow trees in the dormant season, growing along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 feet.
	Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of vegetation; 8- to 10-year-old willow or cottonwood trees intergrown with some weeds and brush (none of the vegetation in foliage) where the hydraulic radius exceeds 2 feet; bushy willows about 1 year old intergrown with some weeds along side slopes (all vegetation in full foliage) and no significant vegetation along channel bottoms where the hydraulic radius is greater than 2 feet.
	Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of vegetation; bushy willow trees about 1 year old intergrown with weeds along the side slopes (all vegetation in full foliage) or dense cattails growing along channel bottom; trees intergrown with weeds and brush (all vegetation in full foliage).

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base Manning's n value before multiplying by the adjustment for meander.

Table 2.2. Factors that affect roughness of the channel – (continued).

	Channel conditions	Meander adjustment, m[1]	Example
Degree of meandering[1] (adjustment values apply to flow confined in the channel and do not apply where downvalley flow crosses meanders)	Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
	Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
	Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

[1]Adjustments for degree of irregularity, variations in cross section, effect of obstructions, and vegetation are added to the base n value before multiplying by the adjustment for meander.

While estimating Manning's roughness coefficient from a table of values or by comparison with photographs of channels with known n is the quickest and most commonly used method, most experienced hydrologists and river engineers simply estimate n from experience -- often the tables and photographs are not even consulted. For that reason, this method is subject to the most variability between individuals and is probably the least consistent method for arriving at Manning's n. Also, the method ordinarily is used to produce a single value for roughness, which is then applied throughout the entire range of flow, often introducing large errors for the estimate at high or low flows.

The third method of determining Manning's roughness coefficient for a cross section uses empirical formulas relating n to other hydraulic parameters. Many of these formulas assume that a representative particle size in the channel boundary dominates the hydraulic roughness; hence, the empirical relationships usually correlate n with some statistical index of bed material size distribution. As such, these formulas do not adjust n for changes in depth of flow at the cross section. To compensate for changes in roughness with depth of flow, several formulas have been developed that use a relative roughness term relating some representative particle size (e.g., the 84th-percentile particle size) to the hydraulic radius or mean depth. Changes in depth of flow therefore change roughness and n values. Some empirical formulas, such as the Jarrett (1984) formula described later, do not use particle size but relate the roughness coefficient n to other hydraulic parameters, such as slope and hydraulic radius.

Just as Manning's n may vary significantly with changes in stage (water level), channel irregularities, obstructions, vegetation, sinuosity, and bed material size distribution, n may also vary with bed forms in the channel. The hydraulics of sand and mobile-bed channels produce changes in bed forms as the velocity, stream power, and Froude number increase with discharge (note, however, that bed forms rarely occur in sediments coarser than approximately 0.6 mm [ASCE, 1966]). As velocity and stream power increase, bed forms evolve from a plane bed to ripples, to dunes, to washed-out dunes, to plane bed

again, to antidunes, and to chutes and pools. Ripples and dunes occur when the Froude number is less than 1 (subcritical flow); washed out dunes occur at a Froude number near 1 (critical flow); and plane bed, antidunes, and chutes and pools occur at a Froude number greater than 1 (supercritical flow). Manning's n attains maximum values when dune or anti-dune bed forms are present, and minimum values when ripples and plane bed forms are present (Parsons and Hudson 1985).

Vegetation can cause Manning's n to change, sometimes drastically, between seasons. The effect of vegetation depends mainly on height, density, distribution, and type of vegetation, as well as the flow conditions. The depth of flow is important because as the water level in a stream rises, different types, distributions, stiffness, and densities of vegetation may be encountered. Also, under flows of sufficient depth, many types of vegetation such as grasses and weeds will bend over to produce lower n values. The slope of the channel can amplify this effect because a steep slope causes greater velocity, which leads to greater flattening of vegetation.

Because Manning's roughness coefficient varies with different flows and cross section characteristics, it is important to define the variability of n over the entire range of flows when conducting cross section analyses. If possible, this is best accomplished by measuring discharge at several different water levels (stages), solving Manning's equation for the true value of n at each stage, and developing a relation between stage and Manning's n. If Manning's n is estimated from a table of values or by comparison with photographs, estimates should be made for several stages, and the relationship between n and stage defined for the flow range of interest. If empirical formulas are used to estimate n, it is best to select a formula that is sensitive to mean depth or hydraulic radius, such as the formulas that use a relative roughness term. It is wise to perform a sensitivity analysis to show the effect of changes in n values on hydraulic parameters such as discharge and velocity, especially if bed forms or vegetative characteristics vary over the range of discharges.

2.3.2 Thorne and Zevenbergen's Recommended Equations

Resistance equations that include a term for relative roughness (the ratio of the bed material size to the flow depth or hydraulic radius) have an inherent sensitivity to changes in depth for low to moderate flow depths. Thorne and Zevenbergen (1985), in a review of resistance equations developed for mountain streams, tested several formulas using relative submergence terms for estimating mean velocity in steep, cobble/boulder-bed channels (note that any consistent set of units may be used with these equations). For small relative roughness values (relative submergence, R/d_{84}, greater than 1), Thorne and Zevenbergen recommended an equation developed by Hey (1979) for estimating mean cross section velocity:

$$\frac{V}{(gRS)^{1/2}} = 5.62\log\left(\frac{a'R}{3.5d_{84}}\right) \tag{3}$$

$$a' = 11.1\left(\frac{R}{D_{\max}}\right)^{-0.314} \tag{4}$$

where:

V	=	mean cross section velocity (ft/s),
g	=	acceleration due to gravity (ft/s^2),
d_{84}	=	intermediate axis for the 84th-percentile particle size (ft), and
$D_{\max}$	=	maximum depth of section (ft),

Similarly, for large relative roughness values (relative submergence, R/d_{84}, less than or equal to 1), Thorne and Zevenbergen recommended Bathurst's (1978) equation for estimating mean cross section velocity:

$$\frac{V}{(gRS)^{1/2}} = \left(\frac{R}{0.365 d_{84}}\right)^{2.34}\left(\frac{W}{\overline{D}}\right)^{7(\lambda_E - 0.08)} \tag{5}$$

$$\lambda_E = 0.039 - 0.139 \log\left(\frac{R}{d_{84}}\right) \tag{6}$$

where:

$\overline{D}$	=	mean flow depth (ft or m), and
W	=	water surface width (ft or m).

WinXSPRO supports these formulas as an option for calculating mean cross section velocity. However, in applying these formulas to a cross section analysis, the assumptions of the equations must be considered, i.e., that channel gradients generally exceed 1 percent, channel beds are predominately cobble and boulder substrate, and relative roughness is large. Thorne and Zevenbergen (1985) reported average errors of only 6 percent when using the Hey equation for small values of relative roughness (relative submergence $R/d_{84}>>1$), but even the best equations over predicted mean velocity by as much as 30 percent for the highest values of relative roughness (relative submergence $R/d_{84}<1$), an error they attributed to difficulties in measuring bed material sizes. An additional factor to consider is that WinXSPRO approximates the mean flow depth with the hydraulic depth (area/top width). In cross sections lacking a single, well-defined channel, erroneous values may result.

2.3.3 Jarrett's Equation for Manning's Roughness Coefficient

The previous discussion of Manning's equation alluded to the existence of empirical formulas for n that do not make use of particle-size data as an index of relative roughness. These formulas tend to relate the roughness coefficient to other hydraulic parameters. Jarrett (1984) developed the following equation for n, relating the roughness coefficient to water-surface slope and hydraulic radius at the section:

$$n = 0.39\, S^{0.38}\, R^{-0.16} \tag{7}$$

where R is in feet. Jarrett's equation for n has no explicit term for relative roughness; however, he reported a positive correlation between water-surface slope and coarse bed material particle size. Thus, although particle size is not an explicit part of the equation, it is still implicit in the slope term. Jarrett also reported a slightly stronger correlation between Manning's n and slope than the correlation between n and d_{84} particle size.

Jarrett (1984) also compared n values calculated with the above equation to actual n values obtained from cross sections with measured hydraulic geometry and flow data. The average standard error of the estimated n values was 28 percent, and ranged from -24 percent to +32 percent. Jarrett found the equation to slightly overestimate n, with the greatest errors typically associated with low-flow measurements when the ratio of R/d_{50} is less than 7.

WinXSPRO supports the use of Jarrett's equation for estimating Manning's roughness coefficient and mean cross section velocity. Again, the limitations of the data from which the equation was developed should be considered when performing a cross section analysis. Specifically, the equation is limited to the following conditions:

1. Natural channels having stable bed and bank materials (gravels, cobbles, and boulders),
2. Water-surface slopes between 0.2 and 4.0 percent,
3. Hydraulic radii from 0.5 to 7.0 feet (0.15 to 2.1 meters),
4. Cross sections unaffected by downstream obstructions (i.e., no backwater), and
5. Streams having relatively small amounts of suspended sediment.

Because Jarrett's equation includes hydraulic radius as a parameter for estimating Manning's n, it is sensitive to changes in depth. The negative exponent associated with the hydraulic-radius term indicates diminishing resistance with increasing depth. However, the relatively low value of this exponent (n is only sensitive to the 0.16 power of hydraulic radius) means that n will change only slightly through the normal range of stage at a section. An independent evaluation of the equation on Idaho mountain streams confirmed this (Potyondy 1990). Jarrett's n appeared to fit the measured data best at flows at or above bank-full stage; the poorest fits occurred at low flow. Potyondy concluded that the equation was best applied to bank-full flow estimates, with low-water n values supplied from field measurements of hydraulic geometry and discharge.

2.3.4 Nelson et al. Method

This method is primarily intended for use in steep, mountainous channels that have large bed material (i.e., large particle sizes) relative to the flow depth (typically gravel, cobble, and boulder channels). The vertical flow structure and the relation between bottom stress and velocity are not well predicted by existing resistance equations in these channels with high relative roughness. The Nelson et al. approach uses measured sediment size data in conjunction with a simple model for the extraction of momentum associated with flow around and over the large sediment particles on the bed to determine the stage-discharge relation for a given channel geometry. The method assumes that by far the majority of the drag on the flow is produced by flow over bed particles, that is, drag due to features other than bed particles is negligible. The Nelson et al. method is best used in channels with beds composed of sediment sizes that are a significant fraction of the flow depth, that is, the size of the largest particles should be at least 5% of the flow depth.

Determining a stage-discharge with the Nelson et al. method requires information about the bed particle size distribution. Because the relative protrusion of the particles into the flow varies significantly with flow depth, the computed vertical velocity structure also varies with flow depth. As the flow becomes very deep, the vertical structure over most of the depth asymptotically approaches a quasi-logarithmic profile. At shallower depths, the velocity profile varies in a relatively complicated manner as a function of the grain geometry of the bed. Due to this complexity, approaches using constant friction or Manning coefficients frequently fail to yield valid predictions of the stage-discharge relation. Using the computational procedures described in Nelson et al. (1991), the spatial variation in velocity profile is computed and a relation between the velocity profile and the depth is found using bed particle size data that is relatively easy to measure. The computations provide a link between the discharge and boundary shear stress distribution of the channel bed that is used along with the stream geometry to obtain a stage-discharge relation. To compute the discharge for a given stage, the computed velocity profiles for various depths are integrated vertically and across the channel using the surveyed cross section. Complete details about the theoretical basis and the equations used in the computations can be found in Nelson et al. (1991).

2.4 Subdivision of Cross Sections

Natural channel cross sections are rarely perfectly uniform, and it may be necessary to analyze hydraulics in a very irregularly shaped cross section. Frequently, high-gradient streams have overflow channels on one or both sides that carry water only during unusual high-flow events. Even in channels of fairly regular cross section, overbank areas convey water at discharges above bank-full. These areas usually have hydraulic properties significantly different from those of the main channel. Generally, overflow channels and overbank areas are treated as separate subchannels.

When subdividing a channel cross section into main channel, side channels, and overbank areas, WinXSPRO assumes frictionless vertical divisions ("smooth glass walls") between individual subsections. The assumption of negligible shear between subsections avoids the formidable task of estimating small energy losses due to friction and momentum exchange between adjacent moving bodies of water. WinXSPRO also assumes that flow can access each subsection as the stage reaches the lowest elevation of that subsection; i.e., the overflow channel or overbank area is not blocked off from the flow at some upstream location such as in a leveed channel. If the user desires to exclude these areas from consideration, the geometric data for those areas should be removed for the range of flows where the channel banks are not overtopped. A cross section can be subdivided into a maximum of five subsections (see section 4.7.2 for additional description of subsections). For any given stage, the energy slope is assumed to be the same for each subsection, and the discharge is computed separately for each of these subsections. The discharges from each subsection are added for the total section discharge.

2.5 Gini Coefficient

The Gini coefficient (G) describes the distribution of channel depth measurements, and thus the channel cross sectional shape. This coefficient was adapted from economics and plant population biology and its application to stream channels was presented by Olson-Rutz and Marlow (1992). The Gini coefficient (G) is the arithmetic average of the differences between all pairs of depths (Y_i - Y_j):

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|Y_i - Y_j\right|}{2n^2 Y_{avg}} \tag{8}$$

where n is the number measured depths and Y_{avg} is the average depth. It equals a minimum value of 0 when all depths are equal. A wide flat channel has a low G value. In contrast, a deep and narrow channel has a greater distribution of depths and the Gini coefficient approaches its maximum value of 1.

The change in the Gini coefficient for a cross section over time describes the change in channel shape. An increase in the Gini coefficient indicates the channel is becoming deeper and narrower. Conversely, a decrease indicates the channel is becoming flatter and wider.

Changes in cross section shape can affect hydraulic and geomorphic processes, which, in turn, can influence stream biota. Change-in-area indices do not always describe channel form. Observational assessments of stream form to estimate roughness coefficients or to determine habitat suitability are stage dependent, as are measurements of width/depth (w/d) to estimate water discharge. In contrast, permanent measurements of channel cross sections are not influenced by water level. Water level can be noted, however, during critical times to allow for evaluation of underwater channel shape or usable fish habitat. A w/d value from permanent transects gives a relative indication of channel shape. However, because the width is fixed, this ratio can be misleading. The Gini coefficient is another repeatable index that quantifies stream channel form independent of stage height and cross sectional area. The direction and magnitude of change in G over time describes whether a channel is becoming wider and flatter or narrower and deeper in response to management or natural events. Because many fish species prefer cool, slow, deep channels, early detection of changes in channel form may be important to fisheries management. Note that because channel width increases faster than depth in downstream progression, all index comparisons should be made over time at the same location or between streams of equal order or drainage area.

2.6 Sediment Transport

WinXSPRO supports one bed load transport function appropriate for gravel-bed steams and one bed material load transport function appropriate for sand-bed streams. The bed load function is that of Parker (1990). The Parker (1990) relation estimates the quantity of material rolling, sliding or jumping (saltating) along the bed through the given cross section. The bed material load function, that of Ackers and White (1973), calculates the total bed material load being transported through the cross section (i.e.,

bed load plus suspended bed material load). These methods are described in more detail below. All the sediment transport calculations in WinXSPRO use a single representative grain size to compute sediment load.

2.6.1 Parker 1990 Function

The original Parker equation (1982) was developed using field data collected from Oak Creek, Oregon, and several other gravel bed rivers. It allows computation of the sediment flux in a gravel-bed channel using mean grain size by applying a similarity argument for the fluxes in various grain size classes. Parker (1982) estimates the total bed load flux over a poorly sorted gravel bed by:

$$q_B = q_B^* \left[\left(\frac{\rho_s - \rho}{\rho} \right) g d^3 \right]^{1/2} \tag{9}$$

$$q_B^* = W^* \left(\tau^* \right)^{3/2} \tag{10}$$

$$\tau^* = \frac{\tau_o}{(\rho_s - \rho) g d} \tag{11}$$

where q_B is the bed load flux per unit width, ρ and ρ_s are water and sediment density, respectively, and d is the mean grain size of the surface layer.

$$W^* = \begin{cases} 0.0025 \exp[14.2(\Phi_{50} - 1) - 9.28(\Phi_{50} < 1)^2] & 0.95 < \Phi_{50} < 1.65 \\ 11.2 \left(1 - \dfrac{0.822}{\Phi_{50}} \right)^{4.5} & \Phi_{50} > 1.65 \end{cases} \tag{12}$$

In equation (12), Φ_{50} is defined in terms of the boundary shear stress and the critical shear stress. Using the non-dimensionalization defined in equation (9), Φ_{50} is given by

$$\Phi_{50} = \frac{\tau^*}{1.18 \tau_c^*} \tag{13}$$

The value of τ_c^* was set using the model for critical shear stress developed by Wiberg and Smith (1987b) with a pocket angle of 30°. This yields the critical stress for first motion rather than significant motion (see Wiberg and Smith [1987b] for a more detailed discussion), as required for use in the Parker equation if surface particle sizes are used. The Wiberg-Smith model yields a value of about 0.028 for τ_c^*, in good agreement with the value of 0.0299 reported by Parker et al. (1982). In WinXSPRO, the lower limit of Φ_{50} in equation (24) is 0.8 in place of 0.95 in keeping with the adaptation of Nelson (1993).

The volumetric bed load fluxes per unit width calculated from the Parker equation are multiplied by sediment density and integrated across the channel width for each discharge using the surveyed channel cross section. This yields the total mass of bed load discharge as a function of flow discharge.

Parker (1990) resulted from modifications to the 1982 formulation, mostly to improve matching of W^* and its derivative at the divisions between the ranges of Φ values. Also, the 1982 function was formulated using the particle size(s) of the substrate, whereas the 1990 function uses the particle size(s) of the surface layer. The reformulated definition is:

$$W^* = \begin{cases} 0.00218\exp[14.2(\Phi_{50}-1)-9.28(\Phi_{50}-1)^2] & 1<\Phi_{50}<1.59 \\ 11.93\left(1-\dfrac{0.853}{\Phi_{50}}\right)^{4.5} & \Phi_{50}>1.59 \\ 0.00218\Phi_{50}^{14.2} & \Phi_{50}<1 \end{cases} \tag{14}$$

All variables are defined and the bed load discharge is calculated in the same manner as described above. WinXSPRO performs bed load calculations using a single representative grain size (D_{50}).

For situations where the total volume of sediment moved is all that is needed, Parker 1990 with the d_{50} size is sufficient provided the grain size distribution is typical of gravel channels. If the grain size distribution is poorly sorted or bimodal, it is probably better to use a different formulation of the Parker function that permits computation by individual size fractions.

2.6.2 Ackers and White (1973) Function

This relation differs from the bed load function in that it is designed to calculate the total sediment load, i.e., the bed load and suspended bed material sediment load combined. The equations presented here are intended for the computation of sand transport in sand-bedded streams with bed material ranging from 0.04 to 2.5 mm. Calibration of the relation was accomplished using 925 sets of data from 14 investigators. Ackers and White developed a general sediment transport function that determines the rate of transport in terms of three dimensionless parameters: size, mobility, and transport. The relations are:

$$G_{gr} = f(F_{gr}, D_{gr}) \tag{15}$$

where:

G_{gr}	=	dimensionless sediment transport rate
F_{gr}	=	sediment mobility number
D_{gr}	=	dimensionless sediment size

The sediment mobility, F_{gr}, is described by:

$$F_{gr} = \frac{u_*^n}{\sqrt{gd_{50}(s-1)}} \left[\frac{V}{\sqrt{32 \log\left(\alpha \frac{D}{d_{50}}\right)}} \right]^{1-n} \tag{16}$$

where:

d_{50}	=	median sediment diameter
D	=	mean flow depth
n	=	a transition exponent depending on sediment size
s	=	mass density of sediment relative to the fluid
V	=	mean flow velocity
u_*	=	shear velocity (See Appendix A)
α	=	coefficient in rough-turbulent equation
g	=	acceleration of gravity

The particle size is expressed by the dimensionless grain diameter, D_{gr} :

$$D_{gr} = d_{50} \left| \frac{g(s-1)}{v^2} \right|^{1/3} \tag{17}$$

and where sediment transport is defined in terms of a general transport parameter, G_{gr}:

$$G_{gr} = \frac{XD}{sd_{50}} \left(\frac{u_*}{V} \right)^n \tag{18}$$

where X is the sediment transport (mass flux per unit mass flow rate). Equation (18) is based upon Bagnold's (1966) concept of stream power. Ackers and White have further hypothesized that the transition parameter, n, is a function of D_{gr}.

Using flume data from other investigators, Ackers and White (1973) developed a new general transport relation and evaluated the associated coefficients:

$$G_{gr} = C \left(\frac{F_{gr}}{A} - 1 \right)^m \tag{19}$$

in which the coefficients C, A, m, and n would vary with sediment size as presented in the following. For the transition range, with $1.0 < D_{gr}$ £ 60 (0.04 mm silt size to 2.5 mm sand size), the coefficients are:

$$n = 1.00 - 0.56 \log D_{gr} \tag{20}$$

$$A = \frac{0.23}{\sqrt{D_{gr}}} + 0.14 \tag{21}$$

$$m = \frac{9.66}{D_{gr}} = 1.34 \tag{22}$$

$$\log C = 2.86 \log D_{gr} - (\log D_{gr})^2 - 3.53 \tag{23}$$

and the coefficients for the coarse sediments, D_{gr} >60, could be expressed as n = 0.00, A = 0.17, m = 1.50, and C = 0.025. Fine size material with D_{gr} less than 1 exhibit cohesive properties and conventional sediment transport equations do not apply.

Ackers and White suggested that d_{35} be used in place of d_{50} for graded and coarse sediments. For a detailed report of the Ackers and White method (background, application, and verification), the reader is referred to Bunte (1994).

To calculate the sediment discharge, the following procedure is used:

1. The value of D_{gr} is calculated using equation (17).
2. The values of A, C, n, and m are computed {equations (20-23)} or selected for this D_{gr} value.
3. The value of F_{gr} is calculated using equation (16).
4. The value of G_{gr} is computed using equation (19).
5. The mass flux X is calculated from equation (18).
6. The sediment discharge, Q_s, is

$$Q_s = XQ \tag{24}$$

where Q is the flow in the channel.

Chapter 3 - Field Procedures and Techniques

3.1 General

A good cross section analysis depends on good field data, which requires careful reach selection and proper field techniques. Whether a critical or representative reach is to be analyzed must be determined and then the uniform flow assumptions of Manning's equation must be considered in reach selection. Proper field techniques must be followed in survey procedures, particle-size determinations, and streamflow measurements. Harrelson et al. (1994) give an excellent illustration of proper field techniques.

3.2 Reach Selection

The intended use of the cross section analysis plays a large role in locating the reach and the cross section. The user must decide whether the section is to be located in a critical reach or in a reach that is considered representative of some larger area. The reach most sensitive to change or most likely to meet (or fail to meet) some important condition may be considered a critical reach. A representative reach will typify a definable portion of the channel system and can be used to describe that portion of the system (Parsons and Hudson 1985).

Once a reach has been selected, the channel cross sections are sited in the locations considered most suitable for meeting the uniform flow requirements of Manning's equation. The uniform flow requirement is approached where width, depth, and cross sectional area of flow remain relatively constant from cross section to cross section, and the water-surface slope and energy grade line approach the slope of the streambed. For this reason, marked changes in channel geometry and discontinuities in the flow (steps, falls, change in discharge, and hydraulic jumps) should be avoided. Generally, the section should be located where it appears the streamlines are parallel to the bank and each other.

Straight channel reaches with uniform flow are rare in nature and, in most cases, may only be approached to varying degrees. If a reach with constant cross sectional area and shape is not available, a slightly contracting reach is acceptable, provided that there is no significant backwater effect from the constriction for the range of flows or stages under consideration. Backwater occurs where the upstream stage-discharge relationship is controlled by the geometry of a single downstream cross section or a break in bed slope. Manning's equation assumes the stage-discharge relationship of the cross section is controlled by the geometry and roughness of a long reach of channel downstream of the section (channel control); thus, Manning's equation will not produce an accurate stage-discharge relationship in pools or other backwater areas. In addition, expanding reaches also should be avoided, as there are additional energy losses associated with channel expansions that are not accounted for in Manning's equation. When no channel reaches are available that meet or approach the condition of uniform flow, it may be necessary to use multitransect models (e.g., HEC-2) to analyze cross section hydraulics.

3.3 Field Procedures

The basic information to be collected in the reach selected for analysis is a survey of the channel cross section and water-surface slope, a sample of the bed material or measurement of bed material particle-size distribution, and a discharge measurement.

3.3.1 Survey of Cross Section and Water Surface Slope

The basic data required for a channel cross section analysis are a surveyed channel cross section and water surface slope. The cross section is established perpendicular to the main body of the flow, and the points across the section are surveyed relative to a known or arbitrarily established benchmark elevation. The distance-elevation paired data associated with each point on the section may be obtained either by sag-tape or rod-and-level survey. The basic setups for these methods are illustrated in Figures 3.1 and 3.2, respectively. The intricacies of correct survey procedures are beyond the scope of this document. For details of the sag-tape procedure, the reader is referred to Ray and Megahan (1979). Benson and Dalrymple (1967) present an excellent overview of rod-and-level surveying procedures, including guidance on equipment, field notes, and vertical and horizontal control.

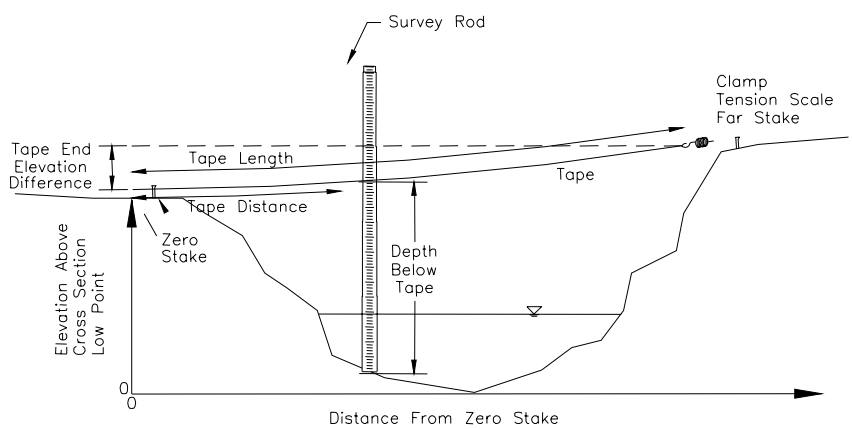


Figure 3.1. Sag tape survey configuration.

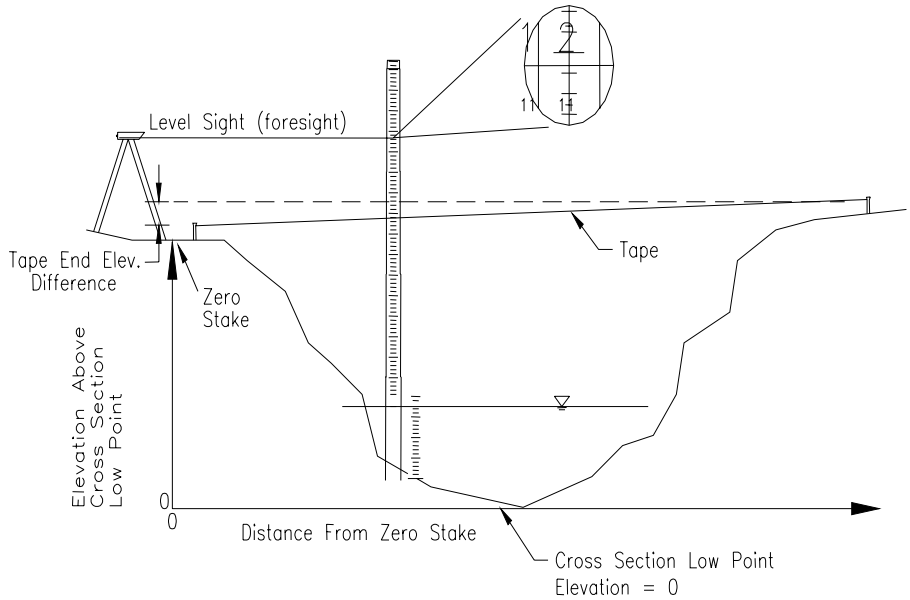


Figure 3.2. Rod and level survey configuration.

Information on water surface slope also is required input for a cross section analysis. The survey of water surface slope is somewhat more complicated than the cross section survey in that slope of the individual channel unit at the location of a section (e.g., pool, run, or riffle) must be distinguished from the more constant slope of the entire reach (see Grant et al., 1990 for a detailed discussion on recognition and characteristics of channel units). Water-surface slope in individual channel units may change significantly with changes in stage and discharge (as shown in Figure 3.3), while the slope of the entire reach will remain essentially unchanged. Thus, at low flow, the slope of the individual channel unit will have a strong influence on the stage-discharge relationship, while at high water, the average slope of the reach will control the stage-discharge relationship. This is an important distinction for the WinXSPRO software, which allows the user to specify different slopes for high- and low-water stages. For this reason, when water-surface slopes are surveyed in the field, low-water slope may be approximated by the change in elevation over the individual channel unit where the cross section is located (approximately 1 to 5 channel widths in length), while high-water slope is obtained by measuring the change in elevation over a much longer reach of channel (usually at least 15 to 20 channel widths in length). An estimate of the high-water slope can also be obtained by measuring the slope from one channel feature to another, such as from the top of one riffle to the top of the next riffle in the stream.

3.3.2 Bed Material Particle Size Distribution

Computing mean velocity with resistance equations based on relative roughness, such as the ones suggested by Thorne and Zevenbergen (1985), or with methods based on the particle size and orientation, such as the one proposed by Nelson et al. (1991), requires an evaluation of the particle-size distribution of the bed material of the stream. Most sediment transport functions require this data as well. For streams with no significant channel armor and bed material finer than medium gravel, bed material samplers developed by the Federal Inter-agency Sedimentation Project (FISP 1986) may be used

to obtain a representative sample of the streambed. If the stream is relatively shallow, bulk samples may be collected manually (usually with a shovel). The bed material is then passed through a set of standard sieves to determine percent-by-weight of particles of various sizes. The cumulative percent of material finer (smaller) than a given size may then be determined. Particle-size data are usually reported in terms of d_i, where i represents some nominal percentile of the distribution and d represents the particle size, usually expressed in millimeters, at which i percent of the total sample is finer. For example, 84 percent of the total sample, by weight, would be finer than the d_{84} particle size. For additional guidance on bed material sampling in sand-bed streams, the reader is referred to Ashmore et al. (1988).

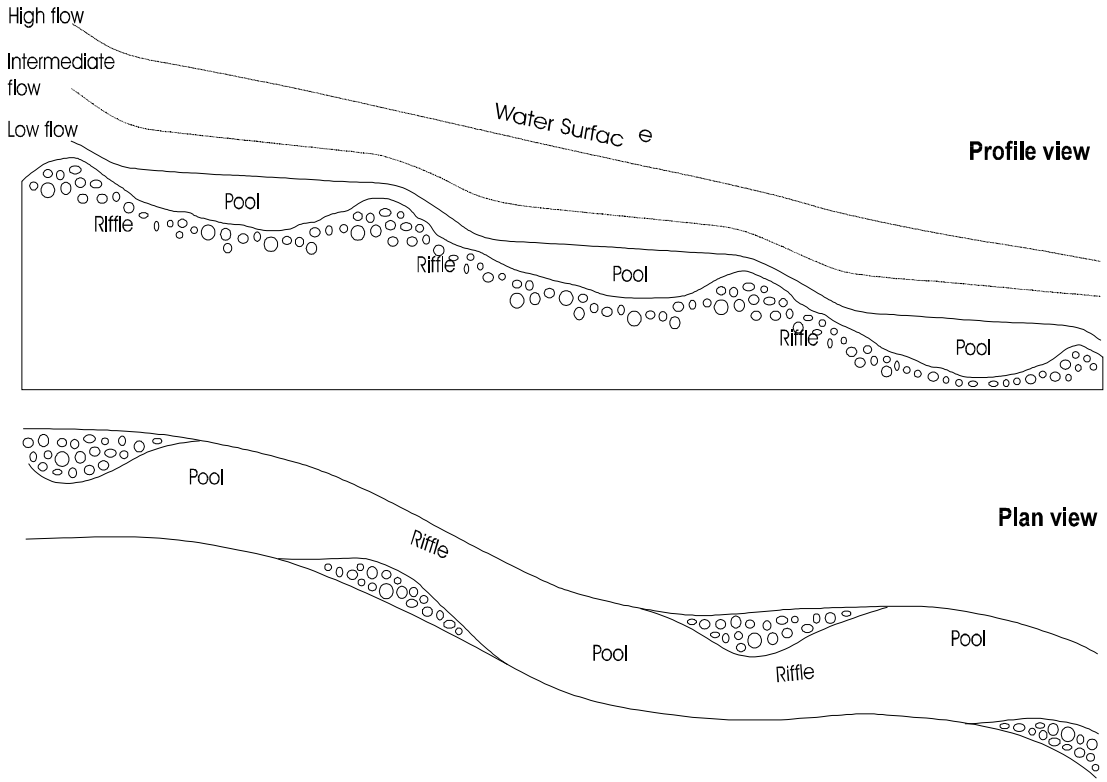


Figure 3.3. Diagram of longitudinal profile and plan view of a pool-riffle sequence. Water surface profiles in upper figure represent high, intermediate and low flow conditions.

WinXSPRO supports resistance equations for estimating velocity in steep mountain rivers with bed particles that can be much coarser than the medium-gravel limitation of FISP samplers. In addition, the bed load sediment transport functions in the program are intended for use with larger grain sizes often found in steep channels. For these streams, the most common method used to measure bed particle size is a pebble count (Wolman 1954), in which at least 100 bed material particles are manually collected from the streambed and measured. A grid pattern of sampling points is paced or staked along the stream, and at each sample point, a particle is retrieved from the bed and the intermediate axis (not the longest or shortest axis) is measured. The measurements are tabulated as to number of particles occurring within predetermined size intervals and the percentage of the total in each interval is then determined. Again,

the percentage in each interval is accumulated to give a particle-size distribution, and the particle-size data are reported as described above. Additional guidance for bed material sampling in coarse-bed streams is provided in Yuzyk (1986) and Bunte and Abt (2001).

3.3.3 Discharge Measurement

When analyzing channel cross section data, it is desirable to have at least one good measurement of discharge at the section. Although a discharge estimate is not required to execute WinXSPRO, the availability of streamflow data will greatly improve the quality of the input and provide a good check on the accuracy of the output (i.e., data on stage, discharge, and other hydraulic parameters). If only one discharge measurement is obtained, it is likely during low water and would be useful for defining the lower end of the rating table. If two measurements can be made, it is desirable to have a low-water measurement and a high-water measurement to define both ends of the rating table and to establish the relationship between Manning's n and stage. If high water cannot be measured directly, it may be necessary to estimate the stage-discharge relationship using WinXSPRO. Using the Jarrett formula (Jarrett, 1984) or the resistance equations recommended by Thorne and Zevenbergen (1985), the discharge and equivalent n values are calculated at the stage intervals defined by the user. If several discharge measurements can be made over a wide range of flows, relations between stage, discharge, and other hydraulic parameters may be developed directly without the use of WinXSPRO. However, WinXSPRO can still be helpful in determining these hydraulic parameters at stages between those where measurements exist.

It is beyond the scope of this document to discuss all the intricacies of correct streamflow-measurement techniques. The reader is referred to Buchanan and Somers (1969) and Rantz et al. (1982) for an in-depth treatment of this subject. Also, Smoot and Novak (1968) present procedures for calibration and maintenance of current meters to ensure accurate measurement of velocity and discharge. When equipment is functioning properly and standard procedures are followed correctly, it is possible to measure streamflow to within 5 percent of the true value. The data gathered from a standard discharge measurement also include information on top width and cross sectional area from which mean velocity and mean depth may be computed. This information is extremely useful for improving quality of results from any channel cross section analysis program.

Chapter 4 - Running WinXSPRO

4.1 Windows™

WinXSPRO was written for use under the Windows™ operating system (it cannot be used from DOS). It is assumed in this manual that the user has a rudimentary knowledge of Windows™ operating system and is familiar with the concepts of pull-down menus, buttons, scroll bars, opening/closing/moving/resizing windows, and so forth. Although this program can be used without a mouse, it is not recommended. The instructions and examples herein will assume the user has a mouse. If the keyboard is used instead of a mouse, the usual Windows™ conventions apply:

1. To select a field, press **Alt+X** (hold down the **Alt** button while pressing **X**), where **X** is the letter underlined in the field name.
2. To advance from one dialog box field to the next, use the **Tab** key. Use **Shift-Tab** to move to the previous field.

Help is available from within the program by using one of three methods:

1. Click on specially placed help buttons within selected windows for context-sensitive help.
2. Select **Help** from the pull-down menu for an index of subjects or instructions on how to use the help system.
3. Click on the help button from the toolbar (help on Windows™ items only).

A more detailed description of the help system is provided in Section 4.9.6.

4.2 Program Installation

Place the WinXSPRO distribution CD into the CD-ROM drive and double click on the file **SetupWinXSPRO3_0.exe** or download the file from the Internet to your hard drive and double click on it to begin installation. Follow the instructions on the installation screen.

The setup program automatically installs files in a directory called WinXSPRO on drive C unless another subdirectory and/or drive are specified using the Set Location button. If you wish to put files in a subdirectory other than WinXSPRO, click on the **Set Location** button and at the prompt type in the name of the directory where you wish the files installed. WinXSPRO or any other directory entered will be created for you if it does not already exist. After the setup program has completed installing the requested files, simply double-click on the **WinXSPRO** icon to begin using the program.

4.2.1 Uninstall

Use the Windows™ Control Panel and the **Add/Remove Programs** feature to uninstall WinXSPRO. When Windows™ has finished uninstalling the software, the WinXSPRO directory (located where you indicated it to be created at install time) can be deleted.

4.3 Overview of Program Use

Use of WinXSPRO can be divided into two main areas: **Geometric and Hydraulic Analysis**, and utility programs from the **Toolbox**. The **Toolbox** programs are described under the Pull-down Menus heading in Section 4.9. To perform a geometric or hydraulic analysis, the following steps are taken:

1. Create a plan (addressed in Section 4.4)
2. Fill-in the necessary data fields on the **Main Plan Window** (described in Section 4.5)
3. Run the analysis either by clicking on the **Run** button (shown in Figure 4.1), selecting **Run** from the **Plan** pull-down menu (described in Section 4.9.1), or clicking on the **Run** icon from the **Toolbar** (discussed in Section 4.10)
4. Fill out the necessary fields in the **Stage and Section Window**.
5. When you have finished, click on the **Calc** button. After the analysis is completed, the output file will be displayed on your screen in its own window.

The above description is valid except when analyzing hydraulics using the user supplied Manning's n approach. For the Manning's n analysis, there is an additional step between Step 4 and Step 5 where window(s) are presented for you to assign roughness value(s). Example problems illustrating the use of the program are presented in Chapter 5.

4.3.1 Renaming Files in Windows™

When creating files for input to WinXSPRO it is important to understand that many existing Windows™ programs assign their own default file name extensions (e.g., *.txt, *.csv). To rename a file in Windows™, use **Explorer** or **My Computer** to display the file. Highlight the file and then right click the file name. Select the **Rename** option and then change the extension to the appropriate naming convention required by WinXSPRO (e.g., *.sec for cross section files). Ignore the Windows™ warning, "*If you change a filename extension the file may become unstable.*" The file will work just fine. If data is created in Excel, use the **Save As** menu item, and then select the output format as Delimited Text file type. Make sure to use **Rename** to modify the default file extension to the appropriate extension.

4.4 Creating a Plan

The first suggested step in using WinXSPRO consists of creating a plan. Creating a plan is not required but often facilitates analysis. When you first start the program, your screen should look similar to Figure 4.1 (the appearance may be slightly different for machines with different monitors).

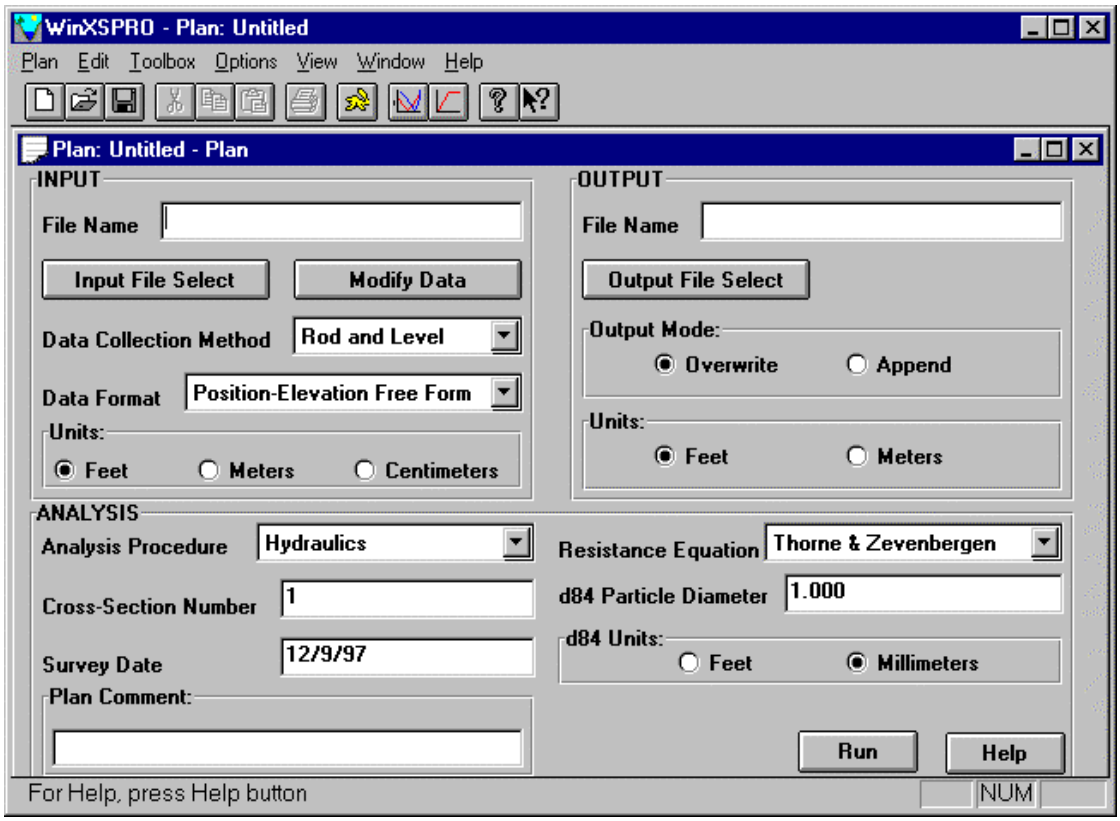


Figure 4.1. Main plan window.

A plan consists of the grouping of parameters, options, and input and output files shown in Figure 4.1. These are described in more detail in subsequent sections. A plan has the file extension *.xsp and is nothing but a convenient way to store the input parameters when the user first enters the values. This helps the user have future runs of the program using the same data set, without having to re-enter the input parameters. Any particular project you may be working on will probably have several different plans. For convenience, a subdirectory (folder) should be created that will contain all the plans for each particular project.

Examples of project subdirectories with plans in them include:

C:\WINXSPRO\BEAVER\ {Subdirectory for Beaver Creek plans}
BCXS1.XSP {Cross Section 1}
BCXS2.XSP {Cross Section 2}

C:\DEER_M32\ {Subdirectory for the cross section on Deer Creek at river mile 32}
DEER82.XSP {1982 cross section analysis}
DEER92.XSP {1992 cross section analysis}

C:\PUTAH\RM27\	{Subdirectory for analyses on Putah Creek, river mile 27}
RM27MAN.XSP	{Analysis using Manning's n for resistance}
RM27T&Z.XSP	{Analysis using Thorne and Zevenbergen approach for resistance}
RM27JAR.XSP	{Analysis using Jarrett's equation for resistance}

4.5 Main Plan Window

The Main Plan Window (Figure 4.1) must have certain fields filled in before a plan may be run. Plans are saved after an analysis is performed. A description of these fields is provided in the following sections. If a plan is not saved before it is run, you will be prompted to save it so that the combination of parameters may be reused on subsequent runs.

4.5.1 Input Parameters

In this section of the window, located in the upper left quadrant of Figure 4.1, the information related to the geometric data for the cross section under study is specified. The geometric data, consisting of station-elevation pairs (x,y data) may be read from an existing file or entered via use of the keyboard as described below. When using an existing file, the file should contain the station-elevation pairs on each line, with the values separated by a comma (,) or by tabs (tab delimited). Input files can be created with the WinXSPRO **Input Data Editor** (sec 4.5.1.2), any other data editor (e.g., Windows™ Notepad), or with spreadsheet programs like Excel saving the files in a tab delimited format (see section 4.3.1). In all of these instances, the created file containing the geometric data for a cross section should be checked to ensure that the filename extension is renamed to *.sec.

4.5.1.1 Input File Selection

An input file must be specified in this field in order for WinXSPRO to run (although any file name may be used, input files have a default extension of *.sec). For new files, you must first create a new plan and then you can type the name for the cross section geometry file you wish to create in the blank field and select the **Modify Data** button to enter your cross section point coordinates. For existing files, either type the name directly in the blank field, or choose the **Input File Select** button. Selecting this button will lead to a typical Windows™ file dialog, where an input file may be searched for anywhere within your computer system. To select a file from the list, simply click on the file name, then click on **OK**, or just double-click on the file name.

4.5.1.2 Creating/Modifying Input File Data

When the **Modify Data** button is chosen from the Main Plan Window, the **Input Data Editor** appears on the screen (Figure 4.2). If the input file already exists, you will see columns of data in the chosen file. If you are creating a new file the editor will not contain any data.

The **Input Data Editor** works like most popular spreadsheet programs. To add data or edit a cell, simply click on the cell and type in the data. Double-clicking on a particular cell will cause a cursor to appear in the cell so that individual numerals and text may be edited. To insert a row, click on the **Insert**

Row button and a row will be inserted above the currently highlighted row. To insert a column, click on the **Insert Column** button and a column will be inserted to the left of the currently highlighted column. To delete a row or column, simply click on the appropriate button and the currently highlighted row or column will be deleted. To cut, copy and paste rows and columns, use the Windows™ shortcut keys (**CTRL-X**, **CTRL-C** and **CTRL-V**, respectively). Note that data copied to the Windows™ clipboard from other programs may be pasted directly into the **Input Data Editor**.

To specify a stable point (used in the **Geometry Analysis** and **Compare Area Option**), type in the letter **S** next to the appropriate value in the second column read by the program (see row 12 in Figure 4.2). For position-elevation or elevation-position data collection methods, this will be column B. For **User Defined File Format**, it will be the column corresponding to the highest number specified in the **User Defined File Format Dialog** (e.g., 2 = column B, 3 = column C, etc.).

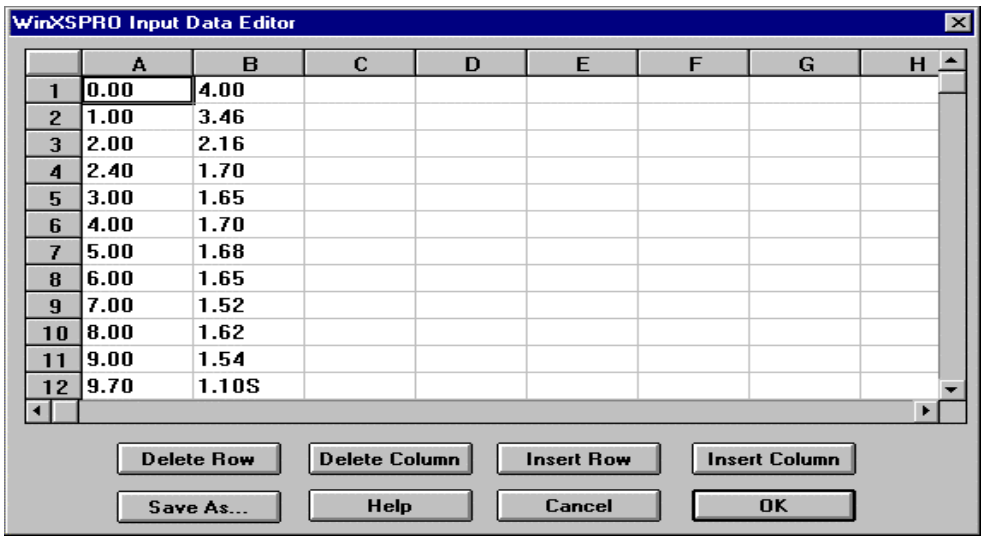


Figure 4.2. Input data editor.

The letter **S** must be in the same cell as the value shown in Figure 4.2. If the **Geometry Analysis** is selected, and a stable point has not been specified, WinXSPRO will automatically set the stable point to the end point with the highest elevation. For the **Compare Areas** option, if there was no stable point specified, then a message box comes up that reminds the user that no stable point is specified.

Up to six digits will be retained for the position and elevation data. You may enter up to 200 rows and 50 columns. When you select **Run** from the main menu, data will be read from the file and put through the analysis. Be sure that the data file you are using is formatted correctly. Refer to the Data Format section for information on input file formats. [Note: although the order of the points in the input file is not important for all formats <u>other</u> than Undercut Banks, it is recommended that the position coordinate increases for each successive point].

Comment lines may be inserted into the input file. A comment line will begin in the first column of the file and the first character in the cell must be an asterisk (*) or a semi-colon (;). Comment lines must appear above the numerical data and should not appear after the numerical data.

To save a new or modified file, click the **Save As** button. This will bring up the **Save As** dialog where the file name and location may be specified. The **Save As** button may also be used to save a modified file under a different name (although this will not alter the file name in the input file field on the Main Plan Window). If an existing file is changed in the data editor and you select the **OK** button, the changes to the file will be saved and you will exit the data editor. Clicking on the **Cancel** button after making changes to a file will cause you to exit the data editor without saving the changes.

4.5.1.3 Data Collection Method

WinXSPRO supports two data survey methods: **Sag Tape** or **Rod and Level**. To select an option other than the one currently shown for this field, click once on the **down arrow** just to the right of the field. Then click on the desired option from the list of possible options (note that other fields such as **Data Format** work in this same way).

For the two survey types (Sag Tape or Rod and Level), data correction may be made for uneven tape end elevations, tape physical characteristics, and tape sag. The sag tape forms a catenary curve and if elevation data are measured from the streambed to the tape, these data will be incorrect. If the survey method was rod and level, the tape is assumed to be without sag. If the tape ends for either method are uneven, distance measurements using that method will be incorrect.

If you select either of the two specific survey methods (**Sag Tape** or **Rod and Level**), you will be prompted with an input window to enter the data to be used for correction of the sag. For rod and level, an elevation difference between the ends of the tape needs to be entered only if the tape elevations at both are not the same. For sag tape, a tape end elevation difference, a tape tension, and a tape weight need to be entered. Note that by choosing either of these methods, WinXSPRO performs the data adjustments <u>internally</u>, i.e., no data is actually changed in the geometry input file. Also, the distance and/or corrections are made assuming that the end of the tape is at horizontal station 0.

4.5.1.4 Input File Data Format

Each selection associated with input data (files) corresponds to a different format for the input file. The files will normally contain two columns of numbers representing a position-elevation pair on each row that defines each point on a cross section. There are currently four formats available: **Position-Elevation Free Format, Elevation-Position Free Format, User Defined Format,** and **Undercut Banks**. In this context, 'Free Format' means that data pairs contained in the input file are separated by commas (,) or tabs.

The special case of selecting **User Defined** from the data format options involves specifying which columns contain the data values in your file. This is provided for an input file that may contain more than just the position and elevation data for a cross section. For example, if you have four columns of data in a file and one of those columns contains a position value and another contains an elevation value, but they are not the first two columns or are not adjacent, you should select **User Defined** from the menu to select the correct columns. All you will need to tell WinXSPRO is which column numbers to use for the data (WinXSPRO recognizes space or TAB delimited columns).

Figure 4.3 shows the dialog that is opened after selecting **User Defined** as the input file data format. The values for the column containing the x-position data and the column for the elevation data have been entered (i.e., column 3 and column 4). Figure 4.4 shows a portion of a sample input file where the data are not in a specific order. In this particular file, the x-position values are located in column 3 and the elevation values are located in column 4. As you can see, these values have been entered in Figure 4.3.

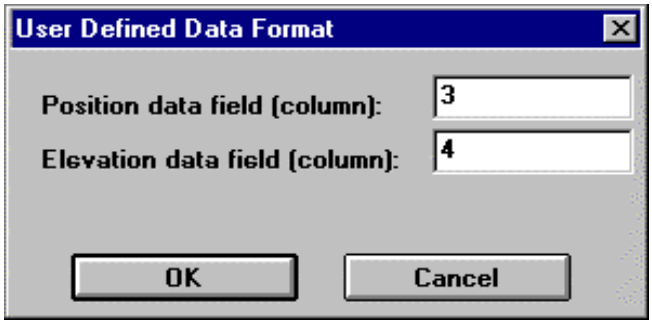


Figure 4.3. User Defined Data Format Dialogue Box.

811024	101	0	4
811024	101	2	2.16
811024	101	2.4	1.7
811024	101	3	1.65
811024	101	4	1.7
811024	101	6	1.65
811024	101	8	1.62
811024	101	9	1.54
811024	101	9.7	1.10S
811024	101	10	0.99
811024	101	12	0.8
811024	101	14	0.51
811024	101	16	0.3
811024	101	18	0
811024	101	20	0.66
811024	101	22	1.85
811024	101	23	2.5
811024	101	24.3	3.58

Figure 4.4. Portion of user defined sample input file where data are not in a specific order.

Selecting **Undercut Banks** assumes a position-elevation data format in which the horizontal stationing (i.e., x-position) follows the proceeding one, even if the position value (i.e., bed elevation) decreases from one point to the next. When this format is selected, no internal data manipulation (i.e., **Rod and Level** or **Sag Tape**) is allowed.

<u>Special Requirements for the Nelson et al. Resistance Method</u>

If the cross section geometry input file is to be used with the Nelson et al. resistance method, it must be named *sitename*.sec, where *sitename* is any valid Windows™ file name describing your site. Unlike other methods, the x-position values in the input geometry file must be constantly increasing. When using the Nelson et al. Resistance Method, an additional input file must be supplied (described below) and must use the same root file name but use a *.dat extension (i.e., *sitename*.dat). Given this, it is a good idea to use short file names when this method is used. The *.dat file contains grain geometry and orientation information from field surveys, with each line having the following format:

position, exposure, x, y, z, a, b, c

Position is an arbitrary number describing the data location or measurement technique. If the grain geometry measurements (e.g., pebble counts) are carried out using a random walk technique, position can be an integer (1,2,...) assigned to each measurement. If the measurements were obtained by taking uniform increments along a tape measure, position can be the reading of the tape measure for each sample. Exposure is the vertical distance the grain sticks up from the surrounding bed surface, in centimeters. The next three numbers, x, y, and z, are the downstream, cross-stream, and total vertical length of the particle as it occurs on the bed, also in centimeters. The final three numbers, a, b, and c, are the standard long, intermediate, and short axes of the grain in centimeters. Remember this data file must use the same root filename as the geometry data and have a filename extension of *sitename*.dat.

For missing data, insert a -1 (negative one) in the missing data field. Allowable missing data include: (1) the *z* variable (the total vertical extent of the pebble/rock) may be coded as missing data in instances where, for example, a rock cannot be dug up and measured, or it may be coded –1 for the entire data set; and (2) the *a* variable (the longest particle axis) and the *c* variable (the shortest particle axis) may be coded as missing data to accommodate pebble count data sets where only the *b* variable (the intermediate particle axis) may have been measured.

4.5.1.5 Units

The units of the cross section input data is selected by clicking on the appropriate button of the **Main Plan Window**. The three choices are **Feet**, **Meters**, or **Centimeters**. Input data may not be in mixed units, e.g., distance in meters and elevation in feet or centimeters.

4.5.2 Analysis Parameters

4.5.2.1 Analysis Procedure

You must choose how the program will perform the analysis. Three selections are possible:

- Geometry only — The only values computed for each stage increment are partial area and partial wetted perimeter (values between the datum and the low point of the cross section). The area, wetted perimeter, width, hydraulic radius, and hydraulic depth are also computed for the total section below the datum. This option is useful for comparing cross section changes in geometry over time. The output data are reorganized to represent the depth of the stream and will go from the specified datum (defined with the stable point or as the high stage in the data) to the lowest elevation on the cross section.

- Hydraulics only — Values computed for this analysis are area, wetted perimeter, top width, hydraulic radius, hydraulic depth, Manning's n, average velocity, discharge, and shear stress. The data are organized from the low-stage value up to the high-stage value.

- Both Hydraulics and Regression	This selection gives you the hydraulic analysis and will also perform a regression on the discharge versus hydraulic radius and discharge versus stage values.

4.5.2.2 Cross Section Number, Survey Date, Comment

These three fields are optional and contain user-supplied data that will be printed in the analysis output. Entry of this data is highly recommended. The comment field is limited to 80 spaces and characters.

4.5.2.3 Resistance Equation

You may choose to use one of four methods: **1) Thorne & Zevenbergen** (1985) where either the Hey (1979) or Bathurst (1978) equations will be used; **2) Jarrett**, where his equation (1984) is used to compute a Manning's n; **3) User supplied Manning's n** where you supply your own n values; or **4) Nelson et al.** iterative method (1991). The Nelson et al. method cannot be used with undercut banks. The Thorne & Zevenbergen option employs a user supplied d_{84} diameter for the bed material at the cross section. If you choose this method, the input fields for d_{84} diameter and units will be activated on the screen; the other three selections do not use these fields and so, for those selections, the fields will be unavailable.

4.5.2.4 d_{84} Particle Diameter and Units

The units of the diameter of the d_{84} particle can be in feet or millimeters. The particle diameter is a number representing the intermediate axis diameter of the 84th percentile particle in the bed material. Only if you select the **Thorne & Zevenbergen** equations will you be required to enter this information.

4.5.3 Output Parameters

4.5.3.1 File Name

The output file will contain the user-selected parameters chosen with the **Analysis Output Format** function (under **Preferences** on the **Plan** pull-down menu). The format of the output data allows easy importing of the data to your favorite spreadsheet program's using its import text file feature. A file name matching the **Input Filename** is automatically assigned as the **Output** file name and given a *.OUT extension. The filename may be changed by typing in another name directly, or the **Output File Select** button may be used to search your system for an existing file name where the results will be output (see next section).

4.5.3.2 Output Mode

You may select **Overwrite** or **Append** to indicate how the data from the next run will impact the existing file if it has the same output file name (the selection does not matter for the first run using a new output file). Overwriting will completely erase the file and then write the new data to the file. Appending will simply add the new output to the end of the file, preserving all previous output in the file. If you print an appended file, all of the data in that file will be printed. The current version of WinXSPRO limits the size of the output file to 500 lines per run or 1000 lines total.

4.5.3.3 Units

The units of the output data can be either in meters or feet. This is also a menu selection type field. All output will use the units selected here regardless of the input units.

4.6 Cross Section Window

When the required information has been entered on the **Main Plan Window**, and the plan is run, the **Cross Section Window** is one of two that appears on the screen for all analysis methods. The other window that appears is the **Stage and Section Window**, described in the next section (these two windows are shown together in Figure 5.4). The Cross Section Window shows the cross section as it has been read in by the program, and after any corrections have been made for the data collection method (Sag Tape or Rod and Level). By right clicking on the graph, you may view the data points, include data labels, allow for zoom and also change the look of the graph. You may also change the fonts, colors, and other properties of the plot, or send the plot to the printer by using the options available under the **Options** pull-down menu, described in Section 4.9.4.

4.7 Stage & Section Window

This window appears below the **Cross Section Window** (described above) and provides you with fields that need to be filled with the additional parameters needed to complete the analysis. These windows are shown in Figure 5.4. The window is divided into two areas: one for stages and slopes, and the other for section boundaries. When all the information has been entered, click on the **Calc** button and view the output file. If you have selected a hydraulic analysis using Manning's equation, the **Manning's n Window(s)** must be completed before the analysis can finish as described in Section 4.8.

4.7.1 Stages and Slopes

4.7.1.1 Hydraulics or Hydraulics and Regression Analysis

For a Hydraulics or Hydraulics and Regression analysis, all fields must be completed in this area of the input data window. As the values are accepted in the **Low Stage** and **High Stage** fields, these limits are drawn on the **Cross Section Window**. The analysis will only be performed between these specified limits. The high stage entered may be up to 1.5 meters or 5 feet higher than the highest cross section

elevation, although specification of a high stage above your highest cross section elevation is strongly discouraged. The program will assume vertical banks and extrapolate discharge for values above the highest cross section elevation. Data that are extrapolated are marked with an '*' after the discharge value on the output.

The water surface slope (equal to the energy slope for uniform flow conditions) for each stage limit is entered in the field next to the stage. For stages between the high and low limits, the slope will be linearly interpolated (if your analysis uses the Nelson et al. method, only a single slope may be entered which is used for all stages). The same low- and high-flow slope can be used if the slope does not change.

Finally, the stage increment must be entered in the last field. This is the increment that WinXSPRO will use to step through from the low- to high-flow stages (if your analysis uses the Nelson et al. method the stage increment is not used - a total of twenty stages including the entered low and high stages will be output at equal stage intervals). The analysis will start at the low stage value and will increase by the value you input in the increment field, up to, but not past, the high-stage value. In the output you will see an evaluation of the cross section at every increment. At stages where more than one defined channel is present (see **Section Boundaries** below) the data for that stage will be computed for each subsection and a sum of the values across the stream will be computed.

4.7.1.2 Geometry Analysis

For the Geometry Analysis option, entering the data is almost identical to the procedure described above. However, the low stage is set at zero and the slopes are not needed (these fields are inactive). The default high stage is already entered for you and is drawn on the plot in the cross section window. This stage corresponds to the stable point marked in your input file, or, if none has been marked, the highest point in the cross section. If you wish to change this value, simply enter the new value in the high stage field (note that changing this value here will not change the marked stable point in the input file, if one exists). This upper boundary represents the stable or reference level and will be indicated in the output as stage 0. The channel geometry will be calculated from this point downward to the lowest elevation on the cross section at intervals indicated by the value entered in the **Stage Increment** field. Note that the first interval may be less than the specified interval, depending on whether the specified interval divides evenly into the difference between the stable point and the lowest point on the cross section.

4.7.2 Section Boundaries

WinXSPRO can divide a channel cross section into several subsections, each of which is analyzed separately for each stage as was described in Section 2.4. After you have filled in the stage and slope information, you may define section boundaries if you wish (if you desire only a single section, leave the section boundary fields blank). Because most of the resistance formulas were derived from single-channel cross sections, inaccurate hydraulic results may occur if cross sections with multiple channels are not divided into separate sections. The **User Supplied Manning's n** option must be specified for the hydraulics to be computed separately by each defined section. The other options ignore section boundaries and treat the channel as a single unit even if sections are assigned.

To define a section boundary, enter the horizontal position (station) at which you want the boundary. The actual position of the boundary will be shown in the next field over and the boundary will appear on the plot in the cross section window. If you wish to change this boundary, simply enter a new station value in the boundary field. Subsection boundaries are not allowed in undercut areas if the **Undercut Bank** format is being used. Up to five sections (four unique boundaries) may be defined. Each section will then be analyzed separately. In the output file, the total cross section discharge for the current stage will be the sum of all of the separate section discharges. Examples of use of the section boundaries are shown in Chapter 5.

4.8 Manning's n Window

If you are performing a hydraulic analysis with the **User-Supplied Manning's n** resistance method, this window will appear after the stage and section window is completed. Because the roughness values can vary with flow depth, you may specify both low and high stage n values. These low and high stages can be different from the ones used to define the boundaries of the analysis in the stage and section window. For example, n values calculated from field discharge measurements can be used. WinXSPRO will linearly interpolate a Manning's n value for each incremental stage, and will compute a flow-weighted average for the output summary. WinXSPRO will not accept an n value of less than 0.01.

A Manning's n window will appear for each section defined. A dashed vertical section boundary line on the cross section plot will indicate the right edge of the section under consideration and the horizontal limits of the current section are displayed in the window's title bar. A dashed horizontal line will be drawn on the cross section plot for each of the stages entered in the Manning's n window. After the stage and Manning's n information has been entered for one section, click on the **Next** button and the window for the next section will appear (WinXSPRO begins with the leftmost section and proceeds across the channel to the right). When the information has been entered for the last section, click on the **Calc**. button to complete the analysis and view the output file. If you are dealing with multiple sub-sections in your analysis, the **Back** button may be used to back up to the Manning's dialog for a previous subsection.

4.9 Pull-down Menus

There are seven basic pull-down menus available in WinXSPRO: **Plan**, **Edit**, **Toolbox**, **Options**, **View**, **Window**, and **Help**. Not all options under each menu are available at all locations within the program (e.g., plotting options are not available until you have a plot window open). Unavailable options will appear in gray instead of black letters. Options will be unavailable if you have not performed an operation or condition to activate them.

4.9.1 Plan Menu

The options found under this menu are **New**, **Open**, **Save**, **Save As**, **Run**, **Preferences**, **Print**, **Print Preview**, **Print Setup**, and **Exit**. In addition, the names of the last four plans that have been saved are displayed for easy access.

4.9.1.1 New

This option creates a new plan in WinXSPRO. Shortcuts for performing this same task include using **CTRL-N** from the keyboard or the **Create New Plan** icon in the toolbar (see Section 4.10).

4.9.1.2 Open

This option accesses the **Plan Open** dialog box and allows you to open an existing plan. This option can also be selected by using **CTRL-O** from the keyboard or the **Open Existing Plan** button on the toolbar (see Section 4.10). The Plan Open dialog box contains the following elements:

Plan Name
Type or select the plan name you want to open. This box lists Plans with the extension *.XSP.

Drives
Select the drive in which WinXSPRO stores the plan that you want to open.

Directories
Select the directory in which WinXSPRO stores the plan that you want to open.

Network...
Choose this button to connect to a network location, assigning it a new drive letter.

4.9.1.3 Save

Use this command to save the active plan to its current name and directory. When you save a document for the first time, WinXSPRO displays the **Save As** dialog box so you can name your plan. If you want to change the name and directory of an existing plan before you save it, choose the **Save As** command (see below). Shortcuts for accessing the **Save** command are **CTRL-S** from the keyboard or the icon from the toolbar (see Section 4.10)

4.9.1.4 Save As

Use this command to save and name the active plan. If you open a plan, and use **Save As** to save a modified version under a different plan name, the original plan will not be affected. To save a plan with its existing name and directory, use the **Save** command. With the **Save As** command, WinXSPRO displays the **Save As** dialog box so you can name your plan. This dialog box contains the following fields:

File Name
Type a new file name to save a plan with a different name. A filename can contain more than eight characters acceptable to Windows™ and an extension of up to three characters. You will receive a warning if the file already exists and will be asked if you wish to overwrite the existing file. Naming a plan with other than the *.xsp will result in the file not being visible when using the default **Open** menu when selecting a plan to analyze.

Drives
Select the drive in which you want to store the plan.

Directories
Select the directory in which you want to store the plan.

Network...
Choose this button to connect to a network location, assigning it a new drive letter.

4.9.1.5 Run

This command initiates the analysis using the parameters and selections in the active plan. Shortcuts to use this command are **CTRL-R** from the keyboard or the run icon from the toolbar (see Section 4.10). Note that if the **Output Mode** on the **Main Plan Window** is set to **Overwrite**, selecting the **Run** command will cause the listed output file to be created, overwriting any existing file with the same path and file name.

4.9.1.6 Preferences

This option allows you to specify preferences for output variables and format for geometry and hydraulic analyses and also lets you set default variables for new plans.

Plan Defaults
Every time you create a new plan, the various parameters listed will be set to the chosen default values. The items for which default values may be set are Data Collection Method, Analysis Procedure, Data Format, Resistance Equation, Position and Elevation column numbers for the User Defined File Format option, d_{84} particle diameter, Units for input, output and d_{84}, and Output Mode.

4.9.1.7 Print

This print command can be used to print text or graphs and charts. The **Print** command under the **Options** menu can also be used to print graphs and charts. Shortcuts for using this command are **CTRL-P** from the keyboard or the print icon from the toolbar. This command will bring up the **Print** dialog box, which contains the following options:

Printer
This displays the active printer and printer connection. Choose the **Setup** option to change the printer and printer connection.

Setup
Displays a **Print Setup** dialog box so you can select a printer and printer connection (see **Print Setup** option, Section 4.9.1.9).

Print Range
Specify the pages you want to print:

All	Prints entire document
Selection	Prints currently selected text.
Pages	Prints the range of pages you specify in the **From** and **To** boxes.

Copies
Specify the number of copies you want to print for the above print range.

Collate Copies
Prints copies in page number order, instead of separated multiple copies of each page.

Print Quality
Select the quality of the printing. Generally, lower quality printing takes less time to produce.

4.9.1.8 Print Preview

Use this command to display the active document as it would appear when printed (the command is available only for text files, not graphs and charts). When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The print preview toolbar offers you options to view one or two pages at a time; move back and forth through the document; zoom in and out on pages; and initiate a print job.

4.9.1.9 Print Setup

Use this command to select a printer and a printer connection. This command presents a **Print Setup** dialog box where you may select the following options:

Printer
Selects the printer you want to use. Choose the **Default Printer**, or choose the **Specific Printer** option and select one of the current installed printers shown in the box. You can install printers and configure ports using the Windows™ **Control Panel**.

Orientation
Choose **Portrait** or **Landscape**.

Paper Size
Select the size of paper that the document is to be printed on.

Paper Source
Some printers offer multiple trays for different paper sources. Specify the tray here.

Options
Displays a dialog box where you can make additional choices about printing, specific to the type of printer you have selected.

Network...
Choose this button to connect to a network location, assigning it a new drive letter.

4.9.1.10 Displayed (1,2,3,4) Plans

Use the numbers and plan names listed at the bottom of the **Plan** menu to open the last four plans you previously closed. Choose the number that corresponds with the plan you want to open.

4.9.1.11 Exit

Use this command to end your WinXSPRO session. If you have not previously saved the current plan or if modifications have been made to the plan, you will be asked if you want to save before you exit.

4.9.2 Edit Menu

The features under this menu, found in many Windows™ applications, allow you to copy or cut selected data from text files to the clipboard and to paste data from the clipboard into a text file. It will also allow you to undo the last cut, copy or paste action performed.

4.9.2.1 Undo

This option allows you to undo the last cut, copy or paste action performed. This option can also be selected by pressing **CTRL-Z** from the keyboard.

4.9.2.2 Cut

This option allows you to cut (remove) the selected text from the current document and places the text on the Windows™ clipboard. Shortcuts for this option are **CTRL-X** from the keyboard or the scissors icon from the toolbar.

4.9.2.3 Copy

This option allows you to copy the selected text from the current document and places the text on the Windows™ clipboard. Shortcuts for this option are **CTRL-C** from the keyboard or the copy icon from the toolbar.

4.9.2.4 Paste

This option allows you to paste the contents of the Windows™ clipboard into the current document at the cursor location. Shortcuts for this option are **CTRL-V** from the keyboard or the paste icon from the toolbar.

4.9.3 Toolbox Menu

This pull-down menu contains several "tools" that are available to the user: **Area Comparison** between two cross sections, **Grain Size Analysis**, **Bed Load Rating Curve** generation using the Parker bed load function, **Bed load Discharge** hydrograph generation, **Modify Discharge** in a hydrograph file, and **Ackers and White Transport** which calculates bed material sediment discharge. These options are described in more detail below.

4.9.3.1 Compare Areas

This function will compare the cross sectional areas of two cross sections between user-specified boundaries (i.e., within the right and left horizontal limits specified by the user). To activate this function, either choose **Compare Areas** from the **Toolbox** pull-down menu or click on the **Compare Areas** icon from the toolbar (see Section 4.10 below). This will bring up the **Area Comparison** dialog (Figure 4.5). When you are finished comparing areas, clicking on the **Close** button will return you to the **Main Input Screen**.

<u>Plotting Cross sections and Horizontal Boundaries</u>

Files to be used for comparison should have a stable point specified in them. Once file names have been entered in the fields for **File 1 Name** and **File 2 Name** (either by entering the names from the keyboard or selecting the files by clicking on the **File 1** and **File 2** buttons, Figure 4.5), the cross sections from these files may be plotted by clicking on the **Plot** button.

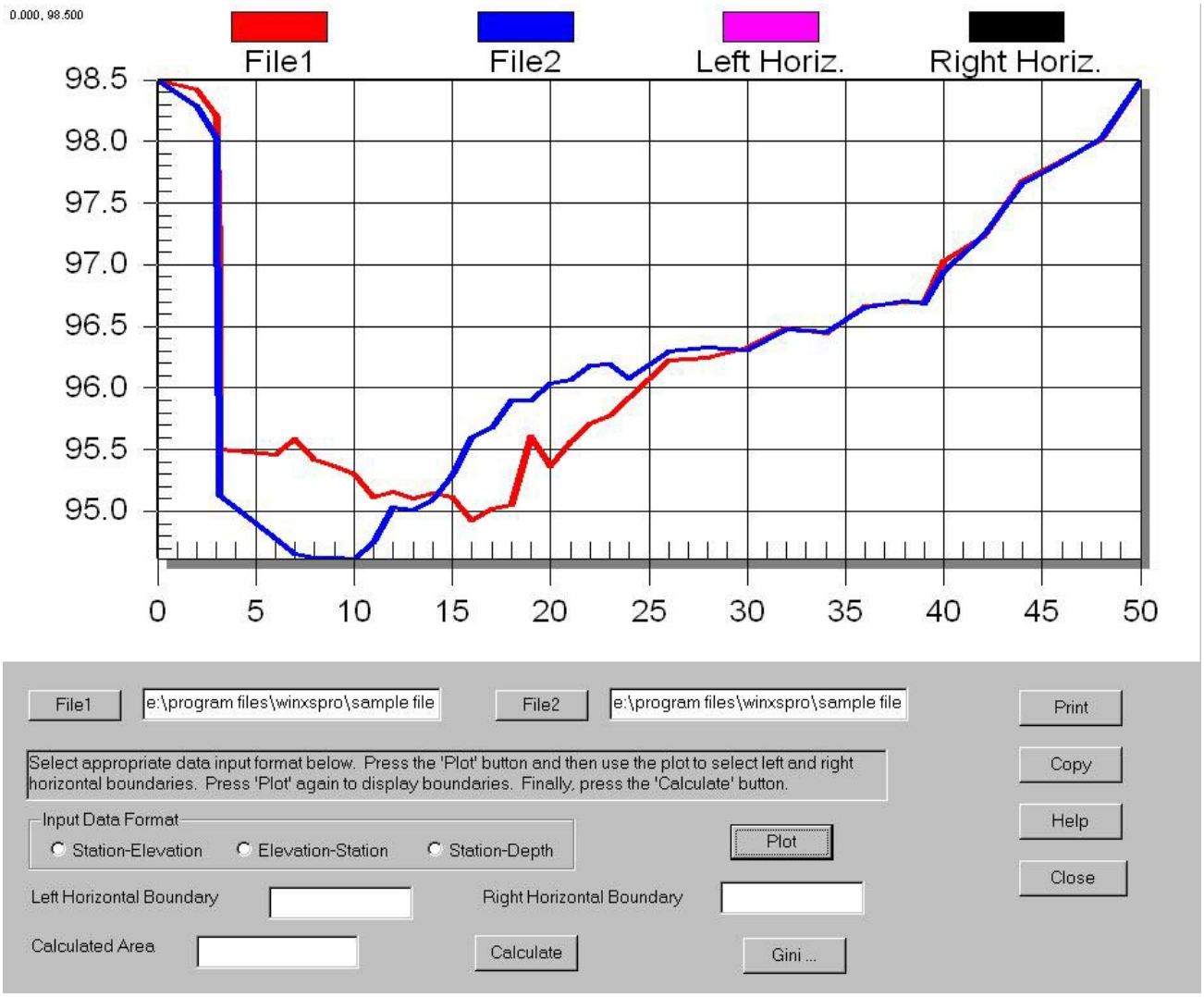


Figure 4.5. Area comparison window.

The **Input Data Format** area allows three different formats to be correctly plotted (both files must share the same format). The cross sections from the two files will be overlaid, and the axis scales will automatically adjust to contain both sections. The program assumes that the stable point for each of the cross sections is the same physical point in space. Therefore, it is important that the stable points be correctly defined before comparing areas. Refer to Section 4.5.1.2, **Creating/Modifying Input File Data**, for information about coding the stable point.

To plot the horizontal boundaries between which the area calculations will be performed, first enter horizontal (x-axis) values in the **Left Horizontal Boundary** and **Right Horizontal Boundary** fields (see Figure 4.5), then click on the **Plot** button again. To change either boundary, simply enter a new value in the desired field (**Left or Right Horizontal Boundary**) and click on **Plot** once again. The boundaries will automatically be redrawn.

Calculating the Area Between Two Cross sections

When the file name and boundary information has been entered, clicking on the **Calculate** button will cause the program to compute the area between the two cross sections in the region defined by the horizontal boundaries. If the cross section from **File 2** is below the cross section from **File 1** in a given region, the calculated area in that region will be positive. When the cross section from **File 2** is higher than that of **File 1**, the area of the region will be negative. WinXSPRO uses a repeated Simpson's Rule to compute the difference in areas. Simpson's rule simply integrates the area under the water surface elevation line and the bed topography to derive the cross-sectional area (i.e., Simpson's rule is a formula that gives a numerical approximation to the value of a definite integral).

Plot Manipulation

The **Copy** button will send the image of the overlaid cross sections to the clipboard from which it may be pasted into other Windows™ applications. The **Print** button will cause a dialog box to appear to set the print options.

Gini Coefficient Calculation

To calculate the Gini coefficient of each of the sections, and the difference between the two values, click on the **Gini** button. A dialog will then appear showing the computed values. Note that WinXSPRO calculates each Gini coefficient independently; therefore, each cross section may have a different number of measured depths (data points). However, to correctly compare the change in Gini coefficient between the two cross sections as described in Olson-Rutz and Marlow (1992), the two cross sections should have the same number of measured depths (data points).

4.9.3.2 Grain Size Analysis

This selection will provide output of the cumulative grain size for the a, b, or c axes, downstream length, cross-stream length, vertical length, exposure, or equivalent spherical diameter. You will be queried for a site name (WinXSPRO will then look for the file *sitename*.dat which contains the sediment data) and the user must also select the axis to be analyzed. An ASCII output file (*sitename*.gsd) is created in the current directory. When the **OK** button is selected, the cumulative grain size plot will be displayed in one window and the output file in a separate window. The format of the input file is described in Section 4.5.1.4. The output file (*.gsd) consists of data in two columns, one being the grain size (in centimeters) and the other the cumulative percent finer for the grain size (i.e., the percentage of the sample with a grain size less than the grain size in question). The output graph is plotted with linear scales on both the x and y-axes. Grain size distributions are often plotted with a logarithmic scale on the x-axis. To do this, go to the toolbar, click on **Options**, then **General**, then go to the **Axis** tab and check the **Log** button under x-axis followed by clicking the **Apply** or **OK** button.

4.9.3.3 Bed load Rating Curve

Selecting this option will compute and plot a bed load rating curve using the Parker (1990) bed load function. NOTE: You must first have run the Nelson et al., method for computing the resistance equation in order to generate the required default output file necessary to use this option. You may then rerun any of the other resistance equations before proceeding with your bed load rating curve analysis. You will be prompted for an input file name. The input file name should be the name of your hydraulic output file (usually having a *.out extension). When the **OK** button is selected, a plot of the bed load rating curve is displayed in one window, and the bed load output file is displayed in a separate window. The text output file will be saved in the current directory with the same name as the input file but with the extension *.P90. The output file consists of two parts. The first part lists the output by subsection (if being used) including the width, shear stress, discharge and bed load discharge. The second part immediately below contains three columns: the first column contains the stage values, the second has the discharge values, and the third contains the sediment discharge values.

4.9.3.4 Bed Load Discharge

This selection will compute and plot the annual sediment yield for the year of daily stream flow values included in the analysis. You must supply an input file name (usually the results from your sediment rating curve file, i.e., having an extension of P90 or ACK) and a discharge file name (the discharge file must have a .DIS extension). If you have not already run the bed load rating curve option, you will be told to do so before continuing. The .DIS file contains one water year of discharge data for the given site, and each line of data will contain two numbers: in the first column, the water day (1 through 365) and in the second column, the discharge value. WinXSPRO assumes that the units of the discharge values are in cubic meters per second if the sediment rating curve file (see sections 4.9.3.3 and 4.9.3.6) has metric units and in cubic feet per second if the sediment rating curve file has English units. (NOTE: The **Help** file for **Toolbox>Bed load discharge** specifies that the second column of the *.DIS input file must be in cubic meters per second and should be ignored). The When the **OK** button is selected, a plot of the annual sediment yield discharge over the water year is shown in one window, and the output file (saved as *filename*.abd in the current directory) is displayed in another. The output file consists of three columns: the first is the day of the water year (1 to 365), the second is the discharge for that day, and the third is the bed load discharge for that day. At the end of the file is the value of the **Average Annual Sediment Yield**, which is equal to the sum of the mean daily sediment discharges.

4.9.3.5 Modify Discharge

This selection queries the user for an input discharge file (with the format described in the above section) and allows the user to modify that discharge file in a variety of menu-selected manners to simulate discharge changes due to dams, diversions, and other phenomena. The user is also queried for the new (modified) discharge file name. Click the **Compute** button to perform the calculations, and then the **Save** button to save the results to the new discharge file. The new file name can then be used with the **Bed load Discharge** option to assess the effect of discharge alterations on bed load flux. When selecting the **Smooth Discharge** option, the user is prompted for a value between 1 and 100. This value will specify the number of times a three-point moving average will be used to smooth the data.

4.9.3.6 Ackers and White Transport

This selection will calculate a bed material load rating curve for your cross section using the Ackers and White (1973) transport method. Note that the Akers-White transport calculations are strictly applicable to sand bed streams and that such streams are typically wide and shallow. Irrational results may be obtained when this method is applied to streams with a small width:depth ratio. When you choose this option, a dialog will appear which will ask you for the output file name (usually *.OUT) from which the stage-discharge data will be read, the median grain diameter (d_{50} in millimeter) of the sediment sample, and the temperature in degrees centigrade of the water will also be read. The *.OUT file must be from a hydraulics or hydraulics and regression analysis performed with any of the available resistance methods. When this information has been supplied and the **OK** button is selected, two windows will appear on the screen. One will contain the sediment rating curve (discharge versus sediment discharge) and the other will contain the output file, saved as *.ACK in the current directory. In evaluating output, remember that the Acker and White model is intended for sediment sizes from 0.04 to 2.5 mm.

4.9.4 Options Menu

The items found under this menu apply to the graphics and charts available under WinXSPRO. The main sub-menus under the Options Menu are **General**, **Axis**, **Copy**, **Print**, **Save As**, **Ratio**, **Plot Parameters** and **Export**. You can format any element of a WinXSPRO chart by changing settings in a dialog box displayed by making a selection from **Option** menu. Most WinXSPRO dialog boxes provide sets of options grouped on separate tabs. As you click on each tab, the controls in the dialog box change to allow you to edit a different set of options. Any options that are not appropriate for the current chart type or situation are grayed. The descriptions of options presented below are intended to provide a brief overview of what each option can do, more detailed information on each item can be found in the help screens. Alternatively, right clicking on the chart with the mouse will also bring up options to change the chart accordingly.

4.9.4.1 General

This option brings up a customization dialog. This has several tabs that allow you to change the look and feel of the chart.

4.9.4.2 Axis

Under this sub-menu you may choose **Format**. The **Format** option lets you specify the number of places shown after the decimal point (0 to 3) for values on each of the axes.

4.9.4.3 Copy

The **Copy** command will copy the selected chart to the Windows™ clipboard. The chart may then be pasted into another Windows™ application.

4.9.4.4 Print

Selecting **Print** will cause a dialog box to appear that sets the print options. The print icon from the toolbar may also be used for this command.

4.9.4.5 Save As

This command allows you to save the chart to a file. Three formats are available: Windows™ Metafile, Windows™ Bitmap and Windows™ JPEG. As with the other **Save As** dialog boxes, you may select the drive and subdirectory where you wish the file to be saved. If you wish to convert either of these formats to another, see Section 4.9.4.9.

4.9.4.6 Ratio

Two preset plot ratios are available for viewing channel cross sections: 1 horizontal unit to 1 vertical unit (1:1) and 10 horizontal units to 1 vertical unit (10:1). The 1:1 scale is how the cross section would appear in nature, i.e., no vertical exaggeration. However, vertical exaggeration is often desired to accentuate the cross section features. The **Ratio** option is only available when the **Cross Section Window** is active.

4.9.4.7 Plot Parameters

This command may be used to plot output variables versus each other. When the command is selected, two columns of variables are presented in the dialog box (Figure 4.6); one for the x-axis and one for the y-axis. Select the variables that you wish to plot, and then click on the **Plot** button to see the plot. Only valid variables may be selected (for example, shear will not be available if the output is from a **Geometry Only** analysis). Note that the data plotted is taken from the last plan output (shown in the File 1 field) unless a different file is selected by clicking on the **File 1** button or typing in a different file name. Therefore, if you wish to make plots from a plan that was previously analyzed, it is not necessary to re-analyze the plan first. Also note that the number of data points used in the plots is directly related to the stage increment chosen for your plan.

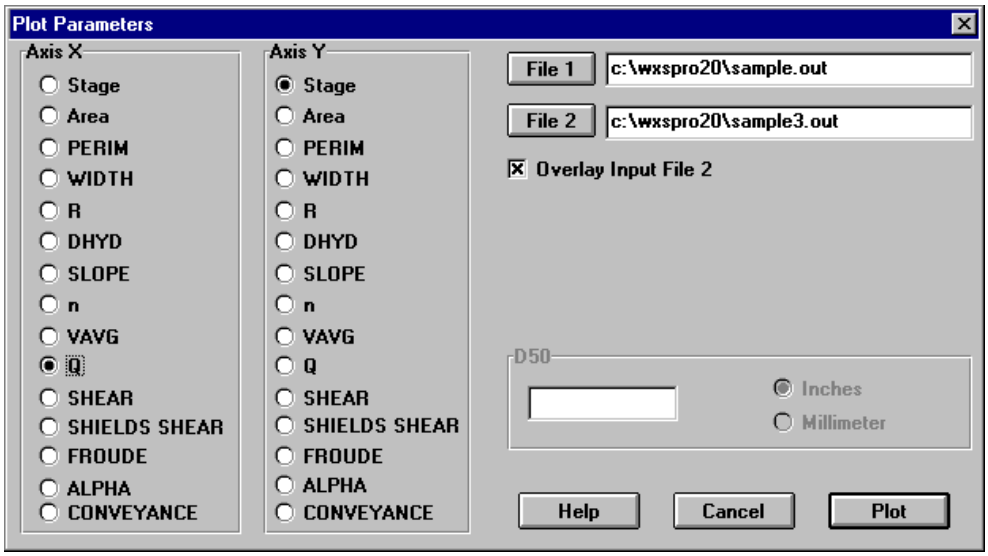


Figure 4.6. Plot parameters dialog box.

Sometimes it is useful to overlay data points from a second output file onto your plot. For example, you might want to see how the change in a cross section's shape with time has affected its computed stage-discharge curve. To include data points from a second output file, click on the **Overlay Input File 2** box. When this box is checked, you may then enter the second file name directly in the **File 2** field, or search for the file clicking on the **File 2** button. Clicking on the **Plot** button will then overlay the two plots for the selected parameters. When changing the plot settings with the other features of the **Options** pull-down menu (**Axis**, **Legend**, etc.), the input **File 1** curve is the default "active" curve to which the changes will apply. If you wish to change the settings for the input **File 2** curve, click on that curve to make it the active one before proceeding with the changes.

If **Shields Shear** is chosen as one of the plot parameters, the D_{50} area of the dialog becomes active because its value is needed to calculate the Shields (dimensionless) shear stress.

Note that measured data points can be added to the resulting plot by using the **Plot Measured** option.

4.9.4.8 Discharge Rating Curve Plot

This command may be used when the active window contains any of the output plots. Activating the command will bring up the **Select Measured Data File** dialog from which you must select the file containing the measured data you wish to overlay on top of the existing plot. WinXSPRO assumes that the measured data file consists of two columns, the first containing the X data and the second the corresponding Y data. The file can have any name and extension selected by the user, e.g., *.txt, *.dat,

or *.mrd (measured rating data). Because the program has no way to check the validity of the measured data, it is assumed that the X and Y parameters correspond to those on the active chart window and that the units are also the same.

4.9.4.9 Export

The **Export** command allows you to take any previously created chart in Windows™ Metafile format (*.WMF files) and export it in another format. The available export formats are:

Windows™ Metafile (*.WMF)
Windows™ Bitmap (*.BMP)
Joint Photographic Experts Group bitmap (*.JPG)

Selecting **Load** will produce the **Open File** dialog from which a file may be chosen. The **Export** button will activate a **Save As** dialog for the user to name the exported file, the file type, and the location where the file will reside.

4.9.5 View Menu

The options under this menu are **Toolbar** and **Status Bar**. A check will be placed to the side of any option when it is displayed.

4.9.5.1 Toolbar

The toolbar is displayed across the top of the application window, below the menu bar. The toolbar provides quick mouse access to many tools used in WinXSPRO. The keyboard shortcut for hiding or displaying the toolbar is **ALT+V+T**. A description of the icons found in the toolbar is offered in Section 4.10.

4.9.5.2 Status Bar

Use this command to display and hide this status bar, which describes the action to be executed by the selected menu item or depressed toolbar button, and the keyboard latch state (i.e., if the **Caps lock**, **Num lock** and **Scroll lock** are on).

4.9.6 Window Menu

The following options are available under the Window Menu:

Cascade	Arranges windows in a cascading overlapped fashion.
Tile	Arranges windows in non-overlapped tiles.
Arrange Icons	Arranges the icons of minimized windows at the bottom of the main window. Note that some or all of these icons may not be visible if an open plan window overlaps them.

Window 1,2...	Displays a list of currently open windows. A check mark appears in front of the active window. Choose from this list to change active windows.

4.9.7 Help Menu

The Help menu offers the following commands that provide you with assistance:

Index	Offers an index of topics on which help is available.
Using Help	Provides general instructions on how to use the help system.
About	Displays the version number and date of this application.

4.10 Toolbar

Many of the toolbar icons duplicate options found under the pull-down menus (see Section 4.9). The following icons are available:

Create New Plan - Opens a new Plan Input Screen.

Open Existing Plan - Provides a dialog to open an existing plan (*.XSP file).

Save Current Plan - Saves the current plan. If current plan has not been previously saved, will provide a Save As dialog box.

Run Current Plan - Executes the analysis of the current plan.

Cut Selected Text - Removes selected text from the current file and places on the clipboard.

Copy Selected Text - Copies selected text from the current file and places on the clipboard.

Paste From Clipboard - Inserts the clipboard contents into the document at the cursor location.

Compare Areas - Brings up the calculator to compare areas (see Section 4.9.2.1).

Plot Parameters - Lets you create 2-D plots (Y vs. X) from WinXSPRO output files.

Print Selected Output File - After the analysis has been completed, will print the output file to the selected printer.

About - Provides information on the version number of WinXSPRO.

Windows Help - After this button is activated, a cursor that looks identical to the button appears. The cursor may then be moved to the item of interest, and a click will access the available help information on that item. Note that only help on windows features (e.g., headers, scrollbars, the toolbar) can be accessed with this button. For help on WinXSPRO items, such as input fields, use the pull-down help menu or the help button in each particular window.

4.11 Output Files

Depending on the type of analysis chosen and the variables selected using the **Preferences** command (see Section 4.9.1.6), the output files will vary in appearance. Output files for the **Toolbox** options are described above in Section 4.9.3. Description of the output files for the **Geometry**, **Hydraulics**, and **Hydraulics and Regression** analyses are provided below.

4.11.1 Geometry Analysis

The output file for the Geometry Only analysis will list properties starting at the lowest point in the channel and proceed at the input stage increment up to the datum, which is the input stable point (or the highest point in the cross section if no stable point was chosen).

The file header lists the input and output files used, the run date, and other pertinent input data. The channel subsections are indicated by letters, and the dividing stations between subsection(s) are given. For each stage, properties are listed first for each subsection (letters A, B, etc.) and then for the total section (letter T). The **PARTIAL AREA** column lists the area contained between the lowest point in the channel and the current distance above it. Likewise, the **PARTIAL PERIM** column contains the wetted perimeter of the cross section between the lowest point in the channel and the current distance above the lowest point given in the first column. The last section of the output file shows channel properties at the highest point in the channel, including area, wetted perimeter, top width, hydraulic radius, and hydraulic depth.

4.11.2 Hydraulic or Hydraulic and Regression Analysis

For the Hydraulics or Hydraulics and Regression analyses, the properties will be listed beginning at the channel low point (the **Low Stage**), proceeding upwards at the specified stage increment to the highest stage in the cross section or the **High Stage** input by the user. A sample output file from a Hydraulics and Regression analysis using the Thorne and Zevenbergen resistance method is shown in Figure 4.7. The output files for other resistance methods are similar.

The file header lists the input and output files used, the run date, the type of analysis being performed, whether the horizontal distances have been adjusted or not and pertinent input data. The channel subsections are indicated by letters, and the dividing stations between subsection(s) are given. For each stage, properties are listed first for each subsection (A, B, etc.) and then for the total section (T). The geometric and hydraulic properties listed in columns three through twelve are: area, wetted perimeter, top width, hydraulic radius, hydraulic depth, slope, equivalent Manning's n value, average velocity, discharge, and shear stress. In the next section of the output file, two total-section properties are also listed for each stage: the velocity distribution coefficient (Alpha) and the Froude Number.

The velocity distribution coefficient (Alpha) is an index of how uniform (i.e., 1.0) or non-uniform the velocity for a given stage is distributed between defined channel subsections. It is computed as the ratio of resistance of each defined section divided by the total cross section resistance. Resistance for each section and the total for the cross section are computed using elements of Manning's Equation:

$$\text{Resistance} = 1.486 * \text{Area} * \text{Hydraulic Radius}^{(2/3)} * 1/n$$

$$\text{Alpha} = \text{Resistance (subsection)} / \text{Resistance (total section)}$$

Note that data that are extrapolated (i.e., the stage is higher than one of the ends of the cross section) are marked with an '*' after the discharge value on the output.

If the Hydraulics and Regression analysis was selected, the results of the regression analysis are also displayed at the bottom of the file. The regression equations for hydraulic radius versus discharge and stage versus discharge are shown along with their respective regression coefficients (a and b), the square of the correlation coefficient (r^2) and the number of data points (n). For regression results to be computed, the combination of user-defined stage limits and stage increment must yield a minimum of five data points. Note that regression results will vary for a single cross section depending on the number of data points that are available.

```
*******************************WinXSPRO*********************************
C:\Thom\WinXsPro\SAMPLE.out
Input File:            C:\Thom\WinXsPro\SAMPLE.DAT
Run Date:              03/12/03
Analysis Procedure:    Hydraulics & Regression
Cross Section Number:  1
Survey Date:           07/21/02


Subsections/Dividing stations
C /  15.86/ A /  37.82/ B / 113.64/

Resistance Method:     Thorne and Zevenbergen
            D84:       0.500 ft

Unadjusted horizontal distances used
```

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	A	5.47	13.54	12.95	0.40	0.42	0.0100	0.069	1.18	6.46	0.25
1.00	B	1.75	10.60	10.46	0.17	0.17	0.0100	0.116	0.39	0.68	0.10
1.00	T	7.22	24.13	23.41	0.30	0.31	0.0100	0.067	0.99	7.14	0.19
2.00	A	23.82	21.71	20.43	1.10	1.17	0.0100	0.051	3.09	73.49	0.68
2.00	B	20.22	21.63	21.27	0.93	0.95	0.0100	0.056	2.56	51.78	0.58
2.00	T	44.04	43.35	41.70	1.02	1.06	0.0100	0.053	2.84	125.27	0.63
3.00	A	44.59	22.93	21.12	1.94	2.11	0.0100	0.045	5.11	227.97	1.21
3.00	B	44.43	26.31	25.69	1.69	1.73	0.0100	0.047	4.47	198.64	1.05
3.00	T	89.02	49.25	46.82	1.81	1.90	0.0100	0.046	4.79	426.60	1.13
4.00	A	66.07	24.15	21.82	2.74	3.03	0.0100	0.043	6.81	449.67	1.71
4.00	B	75.44	40.91	40.07	1.84	1.88	0.0100	0.045	4.99	376.37	1.15
4.00	C	2.19	5.60	5.38	0.39	0.41	0.0100	0.060	1.32	2.90	0.24
4.00	T	143.70	70.67	67.28	2.03	2.14	0.0100	0.041	5.77	828.94	1.27
5.00	A	88.02	24.40	21.97	3.61	4.01	0.0100	0.041	8.50	748.09	2.25
5.00	B	120.98	54.90	53.66	2.20	2.25	0.0100	0.043	5.87	710.24	1.38
5.00	C	8.75	9.43	8.50	0.93	1.03	0.0100	0.054	2.61	22.86	0.58
5.00	T	217.75	88.73	84.12	2.45	2.59	0.0100	0.040	6.80	1481.19	1.53
6.00	A	109.98	24.40	21.97	4.51	5.01	0.0100	0.040	10.12	1112.86	2.81
6.00	B	175.69	57.16	55.68	3.07	3.16	0.0100	0.041	7.64	1342.73	1.92
6.00	C	18.42	11.84	10.69	1.56	1.72	0.0100	0.047	4.25	78.28	0.97
6.00	T	304.10	93.41	88.34	3.26	3.44	0.0100	0.039	8.33	2533.87	2.03
7.00	A	131.95	24.40	21.97	5.41	6.01	0.0100	0.039	11.64	1536.01	3.37
7.00	B	234.24	63.49	61.91	3.69	3.78	0.0100	0.040	8.85	2072.49	2.30
7.00	C	30.05	14.11	12.72	2.13	2.36	0.0100	0.044	5.61	168.43	1.33
7.00	T	396.24	102.00	96.60	3.88	4.10	0.0100	0.039	9.53	3776.92	2.42

STAGE	ALPHA	FROUDE
1.00	1.306798	0.313530
2.00	1.025219	0.487836
3.00	1.013425	0.612455
4.00	1.094992	0.695602
5.00	1.147894	0.745100
6.00	1.101487	0.791423
7.00	1.094711	0.829413

```
Q = aR^b     a=131.605881  b=2.478097  r^2=0.994863  n=7
Q = aZ^b     a=0.670020  b=4.314  r^2=0.963502  n=7
```

Figure 4.7. Sample output screen.

Chapter 5 - Example Problems

5.1 Example Problem 1

Based on the channel cross section below (Figure 5.1), determine the channel discharge at one-foot stage increments from the channel invert (low point) to a water surface elevation of 288 ft. The Manning's n values are given in Figure 5.1 for each section of the channel. Use a constant slope of 1% (0.01). The coordinate data are as follows:

X-distance	Elevation
-5	290
0	290
10	286
20	286
25	284
30	286
40	286
50	290
290	

Use Notepad to enter these data as x-y pairs (tab between values) and save the data with the filename Examp

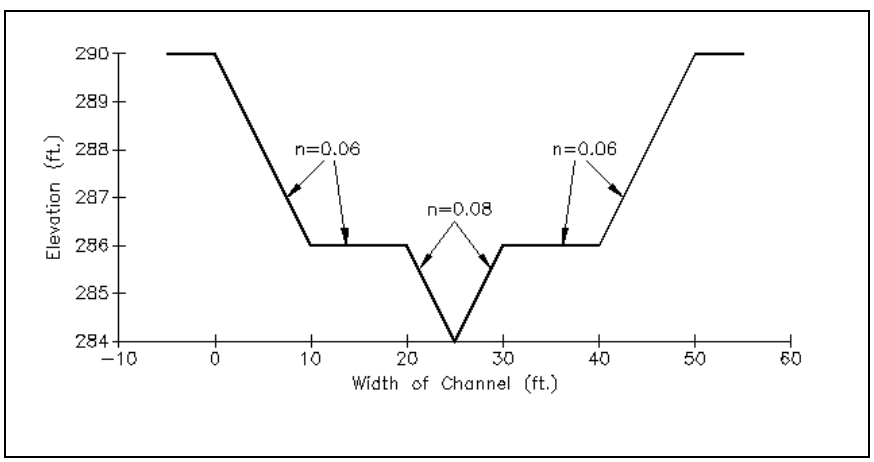


Figure 5.1. Example cross section.

Start the WinXSPRO software. The user should be presented with a blank Plan as shown in Figure 5.2.

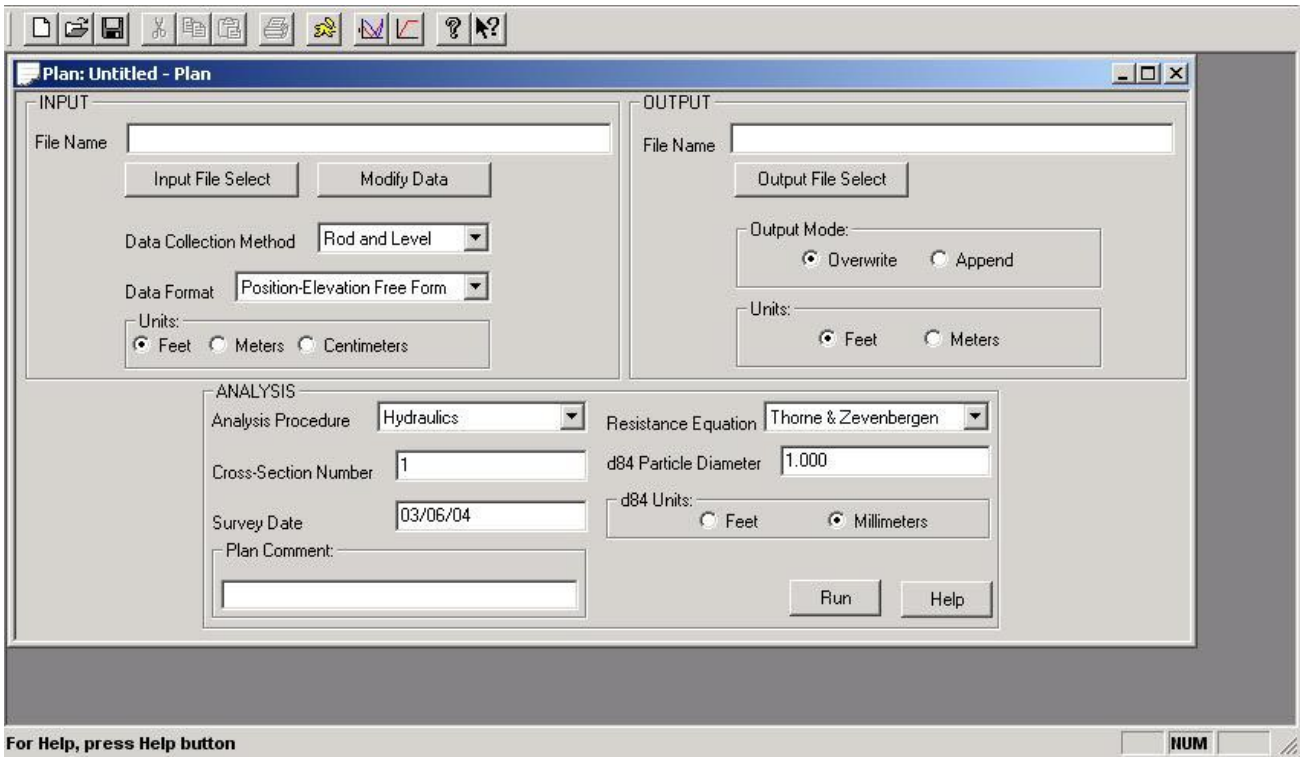


Figure 5.2. Initial blank plan.

Use the **Input File Select** button and navigate to the **Example_1.sec** file you created and select it. Once the file is selected, WinXSPRO will prompt the user to specify if the tape is horizontal. For this exercise, answer **Yes**. The **Plan** window should update as illustrated in Figure 5.3.

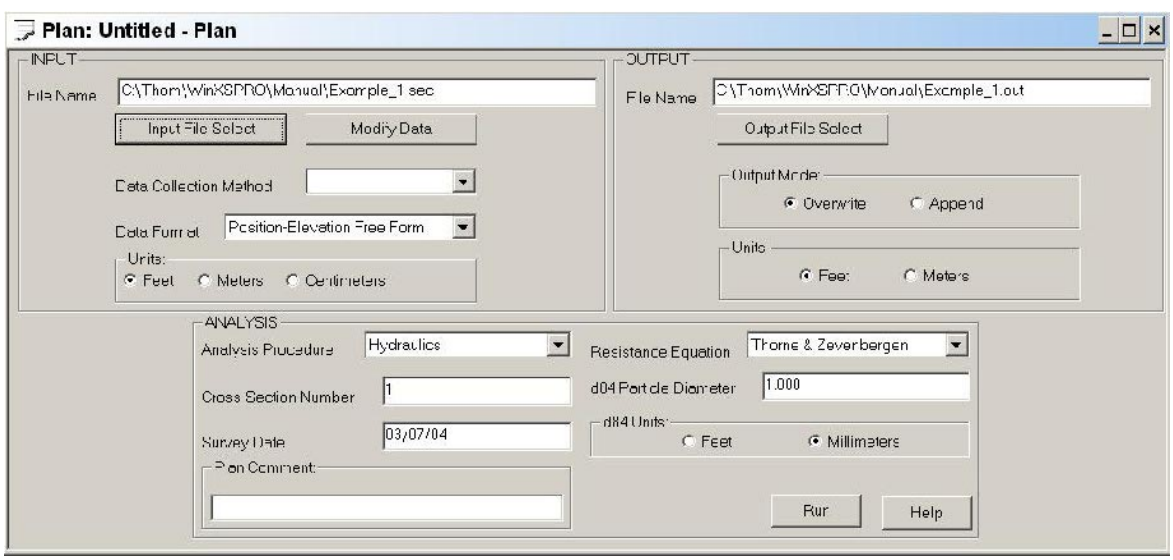


Figure 5.3. Updated WinXSPRO plan window after cross section geometry file is selected.

You can verify that the data has been imported correctly by selecting the **Modify Data** button. Once you have verified that your data has been imported correctly, close the **Input Data Editor** to return to the **Plan** window. Enter **Example Problem 1** in the **Plan Comment** field and then change the **Resistance Equation** to **User Supplied Manning's n**. Use the **Plan – Save As** menu to save the plan using the filename *Example_1* (you do not need to specify an extension). The **Plan** window should now look like Figure 5.4.

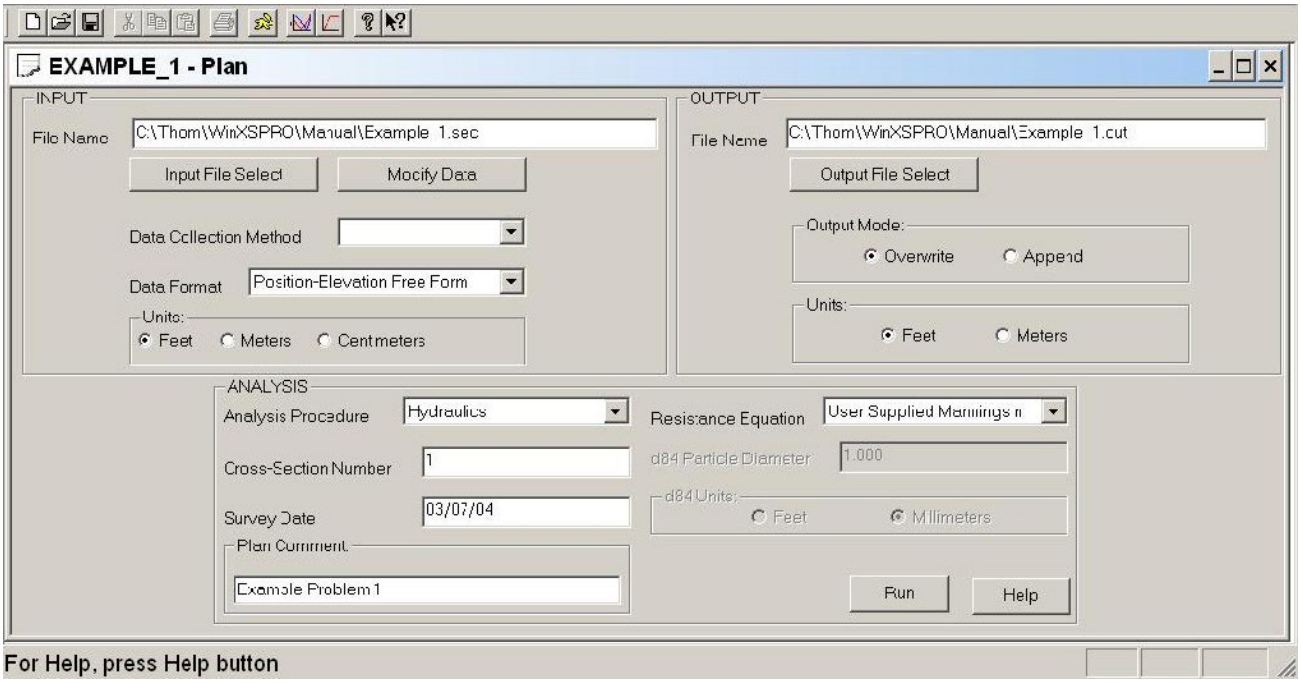


Figure 5.4. Updated WinXSPRO plan window after setting initial analysis options.

We can move to the next step in our analysis by clicking on the **Run** button (alternatively, **Run** may be activated from the pull-down menu or the toolbar). This will open two new windows as illustrated in Figure 5.5. In this example, we wish to analyze the channel hydraulics for stages from 0.01 to 4 feet (elevations 284 to 288) at one-foot increments. Enter 0.01 for the Low Stage, 4.0 for the High Stage and 0.01 for both slopes, and 1.0 for the Stage Increment.

Because the channel has varying Manning's n values (see Figure 5.1), the user needs to tell WinXSPRO to subdivide the cross section into three separate subsections, i.e., left bank to start of the low flow channel at 20 feet, the low flow channel between 20 and 30 feet, and then the end of the low flow channel to the end of the cross section. The position co-ordinates (stations) of the change in n values, 20 ft. and 30 ft., are entered in the **Section Boundaries** part of the form. As the stages and section boundaries are entered in the **Section Boundaries** part of the form, they are drawn in the cross section window. Figure 5.6 illustrates all data fields with their appropriate values for this example problem.

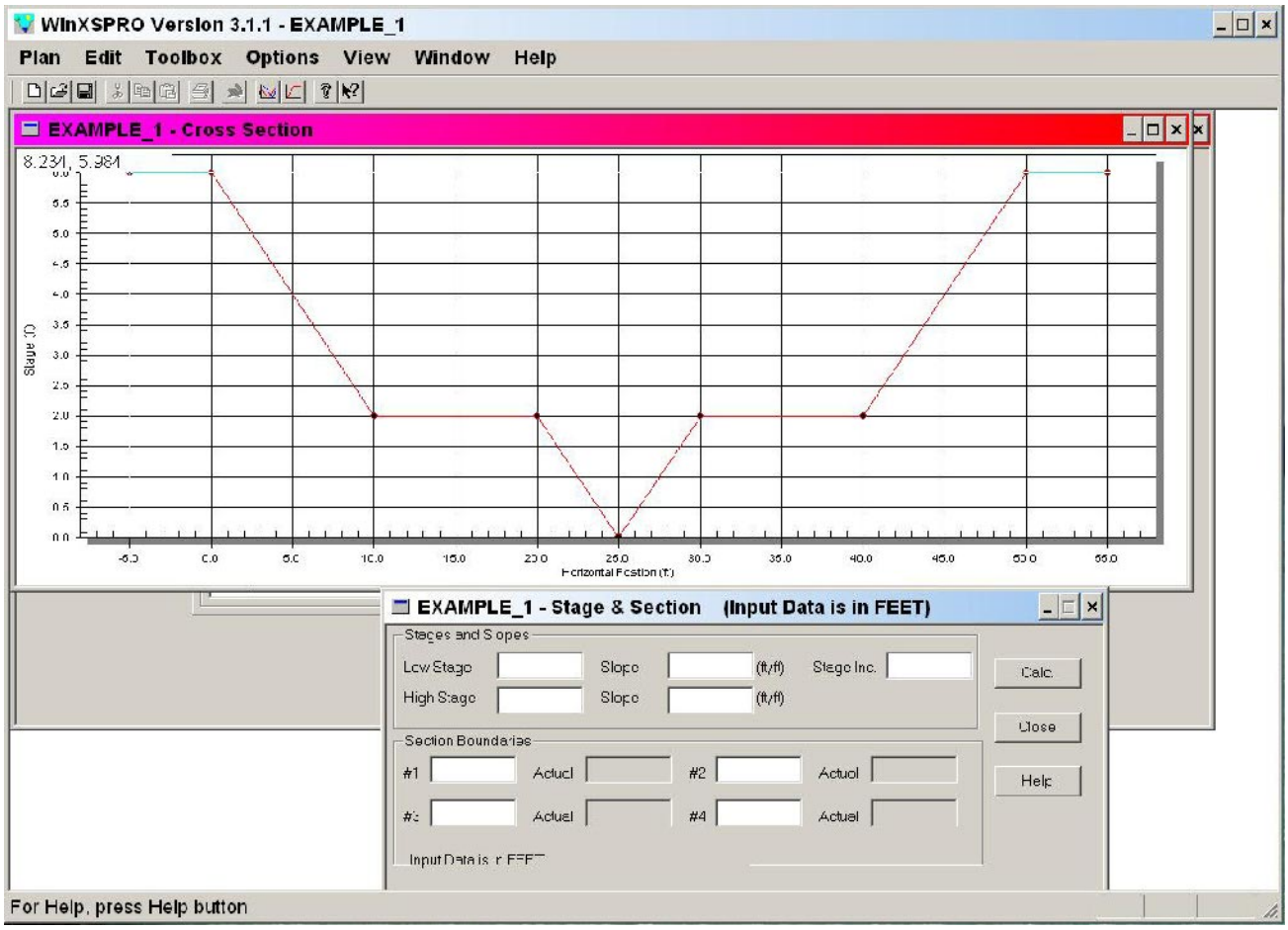


Figure 5.5. WinXSPRO cross section plot and stage and section input form.

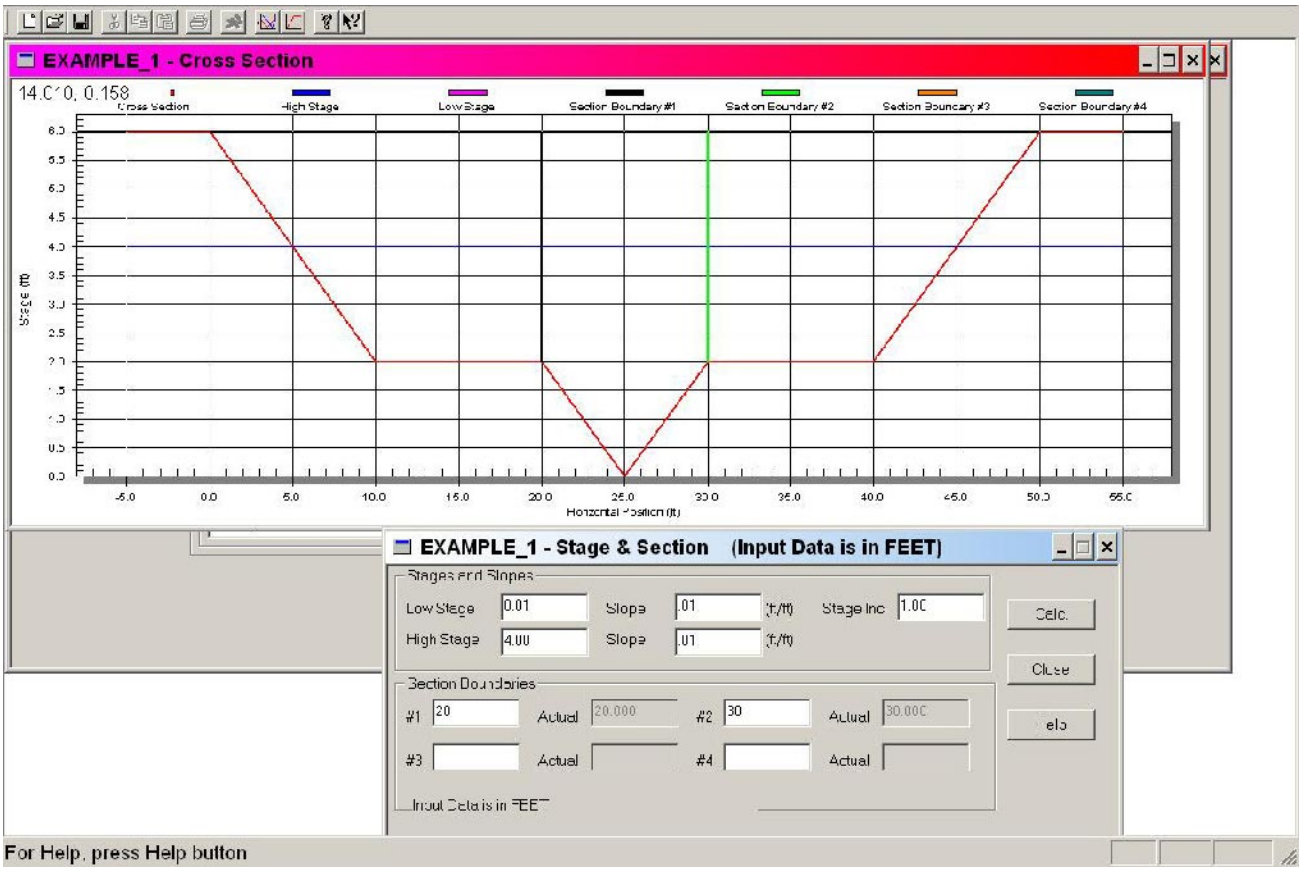


Figure 5.6. Completed Stage and Section form.

Once the user has entered the appropriate data in the **Stages and Section** form, the **Calc** button should be selected. This will open the **Manning's n** window in which the Manning's n values for each section must be entered. When the **Manning's n** window opens, the first section defined (i.e., from left to right) is displayed as shown in Figure 5.7.

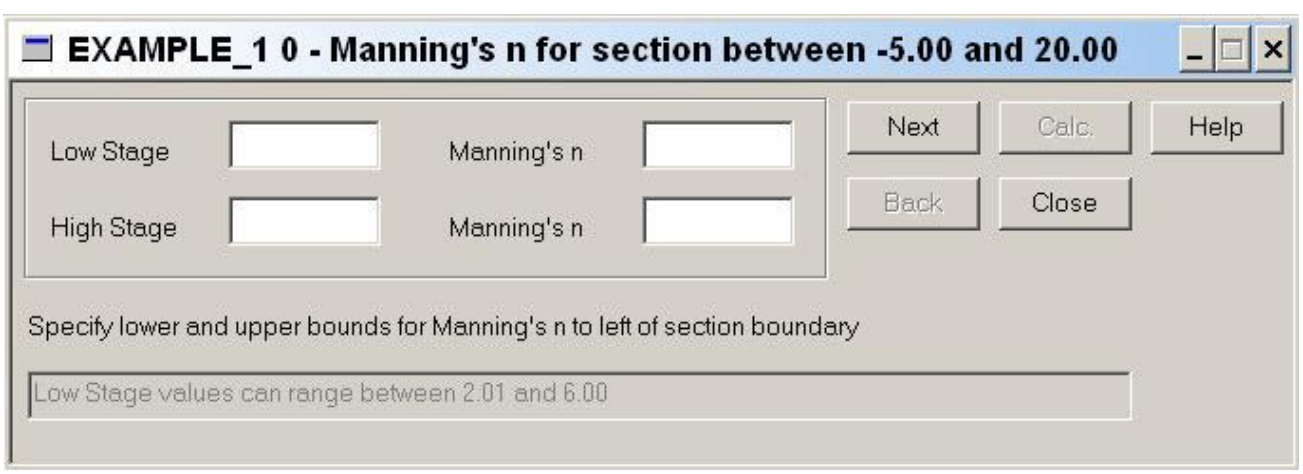


Figure 5.7. Manning's n input data screen for the first defined section.

The high stage at each subsection will be 4 ft. (elevation 288). The low stage entered will be 2 feet (elevation 286) for the channel between –5.0 and 20 feet and for the section between 30.0 and 55.0 feet. The low stage for the middle section (i.e., between 20.0 feet and 30 feet will be 0.01 feet (elevation 284). As shown in Figure 5.1, the Manning's n values for the first and third section should be 0.06 while the Manning's n value for the middle section should be 0.08. Figure 5.8 shows the stage and Manning's n entries for the first section.

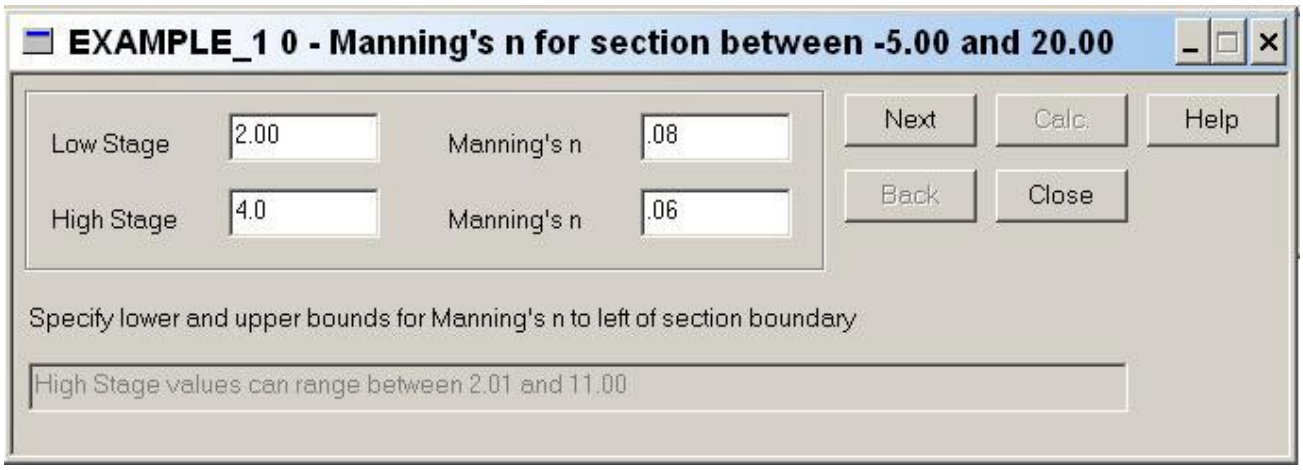


Figure 5.8. Stage and Manning's n values for the first (left-most) section defined for the channel.

Once the user has entered the appropriate stages and Manning's n values for the first section, the **Next** button should be selected, which will display the same input screen for the next defined section (i.e. the second or middle section for this example). The user should enter a low stage of 0.01 and a Manning's n of 0.08 for the Low Stage and 4.0 feet and Manning's n of 0.06 for the High Stage. Use the **Next** button to move to the final section and use the same values for both stage and Manning's n as used for the first section.

Once the data for the final section has been entered, the user can select the **Calc** button to actually conduct the desired analysis. WinXSPRO will then display the computational details in a new window as illustrated in Figure 5.9. For the information given in this problem WinXSPRO calculates a discharge of 319.1 cfs for a stage of 4 ft. (elevation 288 ft.).

```
*******************************WinXSPRO*********************************
C:\Thom\WinXSPRO\Manual\Example_1.out
Input File:            C:\Thom\WinXSPRO\Manual\Example_1.sec
Run Date:              03/07/04
Analysis Procedure:    Hydraulics
Cross Section Number:  1
Survey Date:           03/07/04
Example Problem 1

Subsections/Dividing positions
B /  20.00/ A /  30.00/

Resistance Method:      Manning's n
            SECTION         B          A          C
      Low Stage n         0.080      0.080      0.080
      High Stage n        0.060      0.060      0.060

Unadjusted horizontal distances used
```

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
0.01	T	0.00	0.05	0.05	0.00	0.01	0.0100	0.080	0.05	0.00	0.00
1.01	T	2.55	5.44	5.05	0.47	0.51	0.0100	0.075	1.20	3.06	0.29
2.01	A	10.10	10.77	10.00	0.94	1.01	0.0100	0.070	2.04	20.60	0.59
2.01	B	0.10	10.03	10.03	0.01	0.01	0.0100	0.080	0.09	0.01	0.01
2.01	C	0.10	10.03	10.02	0.01	0.01	0.0100	0.080	0.09	0.01	0.01
2.01	T	10.30	30.82	30.05	0.33	0.34	0.0100		2.00	20.62	0.21
3.01	A	20.10	10.77	10.00	1.87	2.01	0.0100	0.065	3.48	69.88	1.16
3.01	B	11.37	12.72	12.52	0.89	0.91	0.0100	0.070	1.98	22.51	0.56
3.01	C	11.37	12.72	12.52	0.89	0.91	0.0100	0.070	1.98	22.51	0.56
3.01	T	42.85	36.21	35.05	1.18	1.22	0.0100		2.68	114.89	0.74
4.00	A	30.00	10.77	10.00	2.79	3.00	0.0100	0.060	4.92	147.48	1.74
4.00	B	25.00	15.39	15.00	1.62	1.67	0.0100	0.060	3.43	85.81	1.01
4.00	C	25.00	15.39	15.00	1.62	1.67	0.0100	0.060	3.43	85.81	1.01
4.00	T	80.00	41.54	40.00	1.93	2.00	0.0100		3.99	319.10	1.20

STAGE	ALPHA	FROUDE
0.01	1.000000	0.129194
1.01	1.000000	0.297394
2.01	1.037301	0.602682
3.01	1.235911	0.427360
4.00	1.100321	0.497049

Figure 5.9. Example Problem 1 output file.

As a simple verification exercise, we will carry out the computations for estimated discharge by hand for the high elevation of 288 feet in order to verify the program results. Since the geometric and hydraulic parameters are identical for sections 1 and 3, computations will be carried out only for section 1.

We must first compute the areas (A) of each of our subsections. The area of section 1 can be determined by breaking it up into a triangle and a rectangle. The area of section 2 can determined by breaking it up into a rectangle and two triangles:

A_1 = Area of triangle + Area of rectangle

A_1 = 1/2(Base)(Height) + (Base)(Height)

A_1 = 1/2(5)(2) + 10(2)=25 sq. ft.

A_2 = Area of rectangle + Area of triangles

A_2 = (Base)(Height) + 2(1/2)(Base)(Height)

A_2 = 10(2) + 2(1/2)(5)(2) = 30 sq. ft.

The wetted perimeter (P) of each subsection is then computed. The wetted perimeter is defined as the length of the channel cross section that is in contact with the water. The length of the sloped portions of the channel can be found by applying the Pythagorean Theorem. In this channel the sloped portions of sections 1 & 2 happen to be the same length:

Pythagorean Theorem: $a^2 + b^2 = c^2$

where:	a and b	=	lengths of sides that are perpendicular to one another
	c	=	length of hypotenuse

Thus, in the case of our channel a=2, b=5, and $c = \sqrt{2^2 + 5^2} = 5.385$

P_1 = length of sloped portion + length of bottom = 5.385 + 10 = 15.385 ft.

P_2 = length of two sloped portions = 2(5.385) = 10.770 ft.

From the area and the wetted perimeter, the hydraulic radius (R) of each subsection can be found:

R = A/P

R_1 = 25/15.385 = 1.625 ft.

R_2 = 30/10.770 = 2.786 ft.

Substituting these values into Manning's equation (1) yields the mean velocity in each of the subsections of the channel:

$$V = \left(\frac{k}{n}\right) R^{2/3} S^{1/2}$$

$V_1 = (1.486/0.06)(1.625)^{2/3}(.01)^{1/2} = 3.423$ ft/s

$V_2 = (1.486/0.06)(2.786)^{2/3}(.01)^{1/2} = 4.904$ ft/s

Applying the continuity equation:

$Q = VA$

$Q_{TOT} = 2V_1A_1 + V_2A_2$

$Q_{TOT} = 2(25)(3.424) + 30(4.904) = 318.27$ cfs

WinXSPRO computed an overall discharge of 319.1 cfs for the channel described for a stage of 4 ft. Since the discharge calculated by the hand computations is within roundoff error (0.3% error) of the discharge calculated by WinXSPRO, the result is verified.

5.2 Example Problem 2

Assume the cross section in problem 2 to be from a steep, cobble/boulder bed channel. Using the same geometry and slope data as in example problem 1, determine the total discharge by using the equations for resistance to flow recommended by Thorne and Zevenbergen (1985). Take the d_{84} value to be 300 mm. Give the answer in English units.

We can use the existing **Plan** for *Example_1* as a starting point. First, change the output filename to *Example_2.out* in the **Output** portion of the **Plan** window. Next, change the Resistance Equation to Thorne and Zevenbergen and then set the d84 particle diameter to 300 mm. Change the text in the **Plan Comment** field to **Example Problem 2** and then use the **Plan – Save As** menu and rename the Plan to *Example_2.xsp*. When you have made these changes, select the **Run** button from the Plan window in order to conduct the analysis. WinXSPRO will again display the **Stage and Section** window for user input. Enter a low stage of 0.01 and a high stage of 4.0. The slopes for both stages should be set to 0.01. The stage increment can be set to 1.0. However, since only the total discharge is desired at a stage of 288 (i.e., 4 feet), there is no reason to mark subsection boundaries as was done in example problem 1. Therefore, all fields in the **Section Boundaries** window can be left blank. When the data have been entered, the **Calc** button can be selected to generate the results. WinXSPRO will compute the output parameters and display them in the output file window. The WinXSPRO output file is shown in Figure 5.10.

```
*******************************WinXSPRO*********************************
C:\Thom\WinXSPRO\Manual\Example_2.out
Input File:            C:\Thom\WinXSPRO\Manual\Example_1.sec
Run Date:              03/07/04
Analysis Procedure:    Hydraulics
Cross Section Number:  1
Survey Date:           03/07/04
Example Problem 2

Subsections/Dividing positions
A /  55.00/

Resistance Method:     Thorne and Zevenbergen
            D84:       300.000 mm



Unadjusted horizontal distances used


 STAGE  #SEC      AREA    PERIM   WIDTH    R       DHYD        SLOPE              n     VAVG      Q          SHEAR
  (ft)           (sq ft)   (ft)    (ft)   (ft)     (ft)       (ft/ft)                  (ft/s)   (cfs)        (psf)
  0.01    T       0.00     0.05    0.05  0.00     0.01        0.0100           29.688   0.00      0.00        0.00
  1.01    T       2.55     5.44    5.05  0.47     0.51        0.0100            0.117   0.77      1.96        0.29
  2.01    T      10.30    30.82   30.05  0.33     0.34        0.0100            0.121   0.59      6.10        0.21
  3.01    T      42.85    36.21   35.05  1.18     1.22        0.0100            0.068   2.46    105.28        0.74
  4.00    T      80.00    41.54   40.00  1.93     2.00        0.0100            0.058   3.95    315.81        1.20

 STAGE        ALPHA    FROUDE
  0.01     1.000000      0.000348
  1.01     1.000000      0.191043
  2.01     1.000000      0.178169
  3.01     1.000000      0.391613
  4.00     1.000000      0.491932
```

Figure 5.10. Example Problem 2 output file.

The calculations are performed by hand below in order to better understand the solution. In this problem we will not analyze the channel by dividing it into subsections. Therefore, we can simply sum up the areas and wetted perimeters from problem 1 to be used in this example:

$A_{TOT} = 2A_1 + A_2$
$A_{TOT} = 2(25) + 30 = 80$ sq. ft.

$P_{TOT} = 2P_1 + P_2$
$P_{TOT} = 2(15.385) + 10.770 = 41.540$ ft.

The hydraulic radius of the channel can then be found:

$R = A_{TOT}/P_{TOT}$
$R = 80/41.540 = 1.926$ ft.

We must choose from two equations when using the Thorne and Zevenbergen recommendations - either Hey's (1979) or Bathurst's (1978) equation. The appropriate equation to use is determined by the ratio R/d_{84}. The d_{84} value needs to be converted to English units:

$d_{84} = 300\text{mm} = 0.984$ ft.

$R/d_{84} = 1.926/0.984 = 1.957$

$R/d_{84} > 1 \quad \therefore$ use Equations (3) and (4) presented in Chapter 2.

Equations (3) and (4) [Hey's equation]:

$$\frac{V}{(gRS)^{1/2}} = 5.62\log\left(\frac{a'R}{3.5d_{84}}\right)$$

$$a' = 11.1\left(\frac{R}{D_{\max}}\right)^{-0.314}$$

where $D_{\max}$ is the maximum depth of four feet.

Rearranging equation (3) in order to solve for the mean cross section velocity (V):

$$V = 5.62(gRS)^{1/2}\log\left(\frac{a'R}{3.5d_{84}}\right)$$

$$a' = 11.1\left(\frac{(1.926)}{4}\right)^{-0314} = 13.96$$

Applying the continuity equation:

Q=VA

$$V = 5.62(32.2(1.926)(0.01))^{1/2}\log\left(\frac{13.96(1.926)}{3.5(0.984)}\right) = 3.95\ ftls$$

Q = 3.950(80) = 316 cfs

WinXSPRO calculated a discharge of 315.81 cfs. Since the discharge calculated by the hand computations is within roundoff error (0.5% error) of the discharge calculated by WinXSPRO, the result is verified.

5.3 Example Problem 3

Using the cross section data from the file SAMPLE.SEC (supplied on the WinXSPRO disks), determine the total discharge of the channel at a stage of 7 feet by the Manning's equation flow resistance approach. The Manning's n values are given in the Table 5.1 and correspond to Figure 5.11. Section boundaries are at 16, 72, and 94 feet.

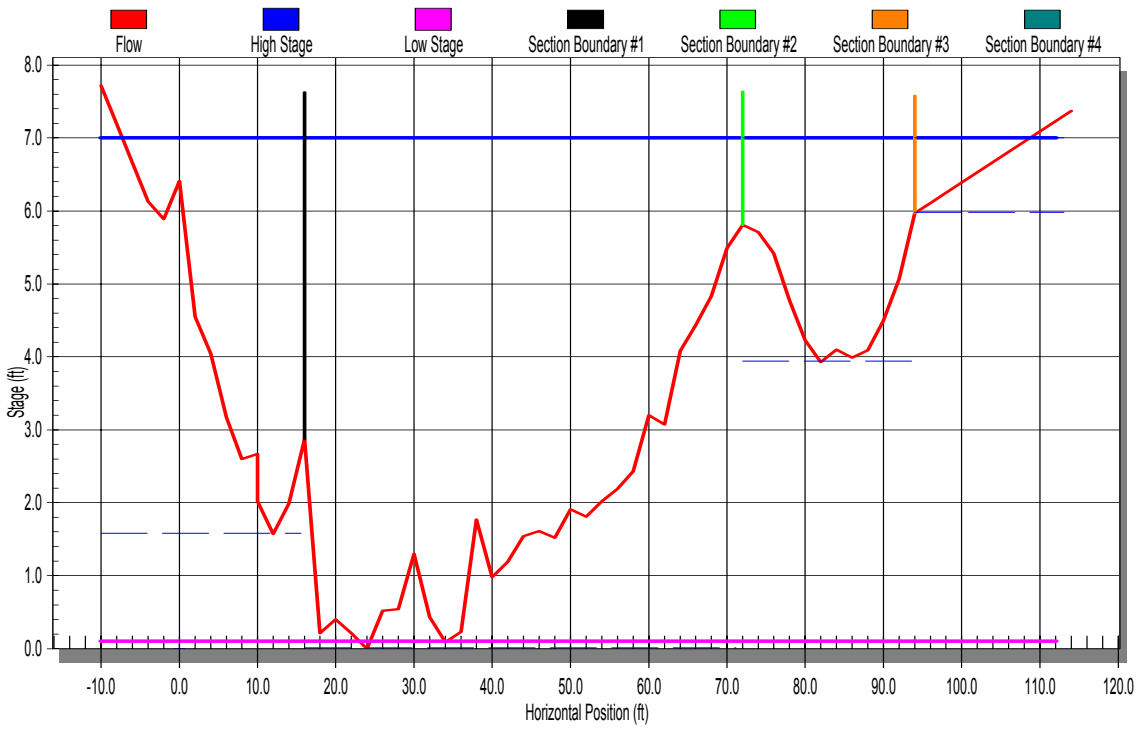


Figure 5.11. Example Problem 3 definition sketch.

Table 5.1. Example Problem 3 region and stage data.

Region	Low Stage n	High Stage n
I	0.080	0.060
II	0.070	0.035
III	0.070	0.060
IV	0.090	0.090

Use a constant slope of 0.005 for all regions and produce results in increments of 1 foot. Use the **Hydraulics and Regression** analysis to fit regression lines to the stage-hydraulic radius and stage-discharge data.

The **Plan** main window is completed similar to the previous examples with the input file specified as SAMPLE.SEC. The Manning's n values shown in Table 5.1 are used to complete the Manning window in WinXSPRO. The low stage at each section will be the minimum possible stage indicated by WinXSPRO in the message bar in the Manning window. The high stage will be 7 feet. The output file for this problem is shown in Figure 5.12.

```
E:\Program Files\WinXSPro\Sample Files\ManualSamples\Sample3.out
Input File:            E:\Program Files\WinXSPro\Sample Files\ManualSamples\SAMPLE.SEC
Run Date:              10/02/01
Analysis Procedure:    Hydraulics & Regression
Cross Section Number:  1
Survey Date:           10/02/01

Subsections/Dividing stations
B /  16.00/ A /  72.00/ C /  94.00/

Resistance Method:      Manning's n
          SECTION          B          A          C          D
     Low Stage n         0.080      0.070      0.070      0.090
     High Stage n        0.060      0.035      0.060      0.090

Unadjusted horizontal distances used
```

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
0.10	T	0.07	1.56	1.54	0.04	0.04	0.0050	0.070	0.19	0.01	0.01
1.10	T	13.35	21.40	20.26	0.62	0.66	0.0050	0.065	1.19	15.92	0.19
2.10	A	42.65	40.53	38.36	1.05	1.11	0.0050	0.060	1.83	78.09	0.33
2.10	B	1.26	4.45	4.25	0.28	0.30	0.0050	0.078	0.58	0.74	0.09
2.10	T	43.91	44.98	42.61	0.98	1.03	0.0050		1.80	78.83	0.30
3.10	A	84.55	46.96	44.26	1.80	1.91	0.0050	0.055	2.86	241.77	0.56
3.10	B	7.96	10.75	9.75	0.74	0.82	0.0050	0.074	1.16	9.22	0.23
3.10	T	92.51	57.72	54.02	1.60	1.71	0.0050		2.71	251.00	0.50
4.10	A	131.51	51.07	48.11	2.57	2.73	0.0050	0.050	4.00	525.64	0.80
4.10	B	18.95	13.43	12.24	1.41	1.55	0.0050	0.071	1.87	35.51	0.44
4.10	C	0.50	7.21	7.18	0.07	0.07	0.0050	0.069	0.25	0.13	0.02
4.10	T	150.95	71.72	67.53	2.10	2.24	0.0050		3.72	561.28	0.66
5.10	A	182.25	55.89	52.82	3.26	3.45	0.0050	0.045	5.20	948.58	1.02
5.10	B	32.71	16.06	14.59	2.04	2.24	0.0050	0.067	2.53	82.64	0.64
5.10	C	12.03	15.35	15.07	0.78	0.80	0.0050	0.066	1.35	16.27	0.24
5.10	T	226.99	87.30	82.48	2.60	2.75	0.0050		4.61	1047.49	0.81
6.10	A	236.92	59.16	56.00	4.00	4.23	0.0050	0.040	6.73	1593.40	1.25
6.10	B	48.11	20.13	18.22	2.39	2.64	0.0050	0.063	2.97	143.11	0.75
6.10	C	30.78	22.55	22.00	1.37	1.40	0.0050	0.063	2.06	63.41	0.43
6.10	D	0.12	1.86	1.86	0.06	0.06	0.0050	0.090	0.19	0.02	0.02
6.10	T	315.93	103.70	98.08	3.05	3.22	0.0050		5.70	1799.93	0.95
7.00	A	287.32	59.16	56.00	4.86	5.13	0.0050	0.035	8.63	2480.46	1.52
7.00	B	67.30	25.46	23.28	2.64	2.89	0.0050	0.060	3.36	225.90	0.82
7.00	C	50.58	22.55	22.00	2.24	2.30	0.0050	0.060	3.01	152.20	0.70
7.00	D	7.58	14.75	14.71	0.51	0.51	0.0050	0.090	0.75	5.69	0.16
7.00	T	412.78	121.92	116.00	3.39	3.56	0.0050		6.94	2864.25	1.06

STAGE	ALPHA	FROUDE
0.10	1.000000	0.157374
1.10	1.000000	0.258744
2.10	1.031663	0.311604
3.10	1.076654	0.365358
4.10	1.098263	0.438263
5.10	1.177007	0.490191
6.10	1.259911	0.559415
7.00	1.368948	0.648240

```
Q = aR^b     a=75.400925  b=2.800709  r^2=0.998676  n=8
Q = aZ^b     a=0.044076  b=5.705  r^2=0.924757  n=8
```

Figure 5.12. Example Problem 3 output file.

In the output file the subsections have been labeled A, B, C, and D corresponding to II, I, III and IV respectively (see Subsections/Dividing stations information at top of output file). The discharge versus hydraulic radius regression plot is shown in Figure 5.13.

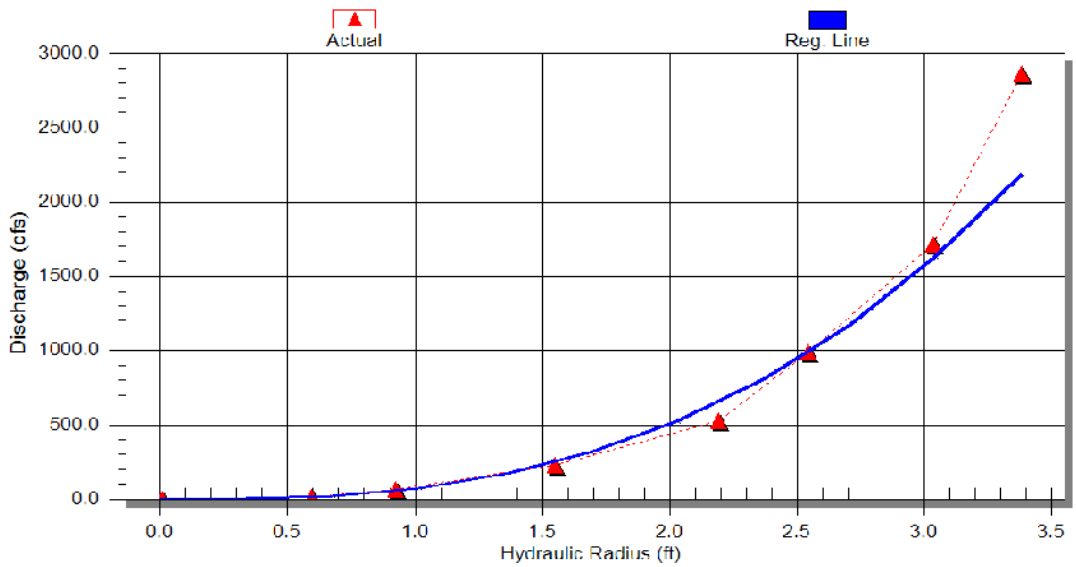


Figure 5.13. Discharge vs. Hydraulic Radius Regression Curve.

Notice that while the curve has a reasonable fit to the data points at lower values of the hydraulic radius (R), the last data point (where R is 3.4 feet, corresponding to a stage of 7 feet) is not near the curve. Similarly, Figure 5.14 shows that while the computed discharge was 2864 cfs at the 7-foot stage, the regression curve formula yielded a discharge of 2573 cfs, a 10% under prediction. This discrepancy is principally due to the small, perched channel on the right side of the cross section. The user of the program must be cautious in accepting regression results since channel geometry (e.g., multiple channels, a small channel opening out into wide overbanks above a certain stage) will skew the results.

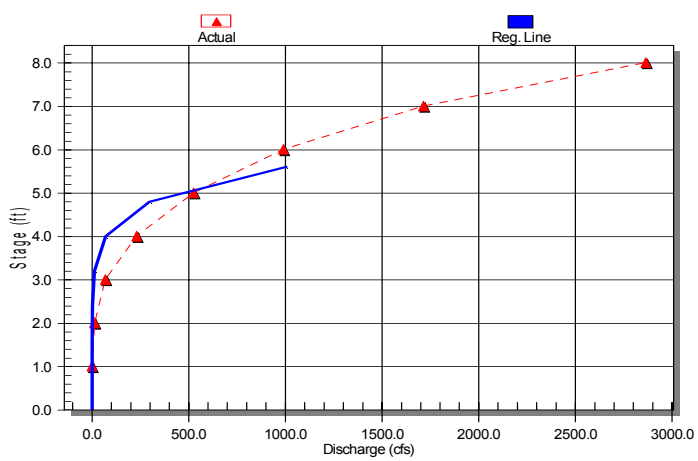
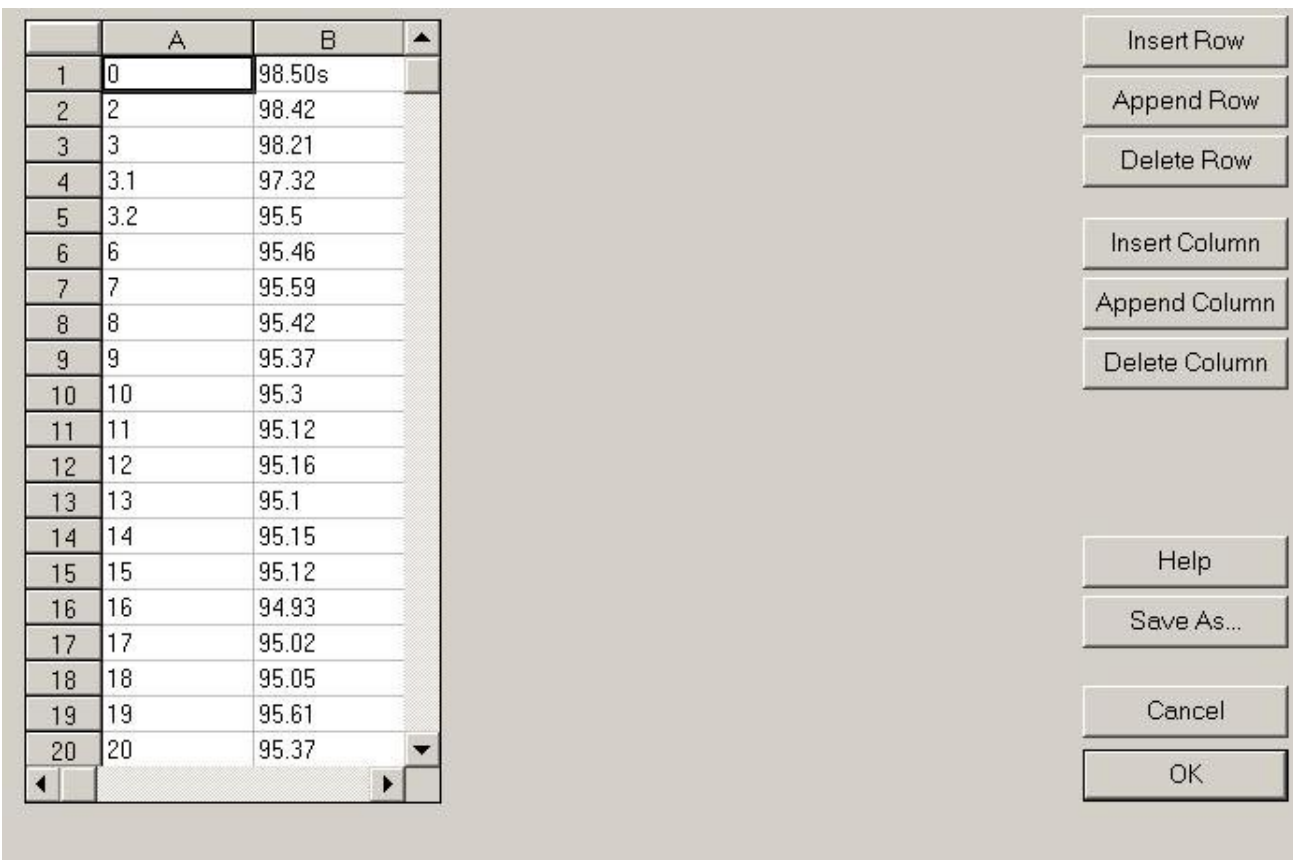


Figure 5.14. Stage-discharge regression curve.

5.4 Example Problem 4

As a result of a sand mining operation upstream, a channel cross section has recently been scoured. Channel geometry before and after the scour is supplied in the files BEFORE.SEC and AFTER.SEC. Determine the change in area for the two cross sections and compute the bed material load using the Akers and White Method.

The easiest way to find the difference in area between the before and after conditions is to use the **Compare Areas** feature. Before activating the function, a stable point must be identified for each cross section. Selecting BEFORE.SEC as the input file on the **Plan** window and clicking the **Modify Data** button brings up the input **Data Editor** (Figure 5.15). Note that the first point, point 1, has been selected as the stable point.



	A	B
1	0	98.50s
2	2	98.42
3	3	98.21
4	3.1	97.32
5	3.2	95.5
6	6	95.46
7	7	95.59
8	8	95.42
9	9	95.37
10	10	95.3
11	11	95.12
12	12	95.16
13	13	95.1
14	14	95.15
15	15	95.12
16	16	94.93
17	17	95.02
18	18	95.05
19	19	95.61
20	20	95.37

Figure 5.15. Modify Data screen using the BEFORE.SEC input file.

AFTER.SEC basically contains the same geometry data as BEFORE.SEC except for modified data points to reflect changes in geometry. In this example, the same stable point for AFTER.SEC was selected as indicated for the BEFORE.SEC file in Figure 5.15. The user can compare these two cross sections by clicking the **Compare Areas** icon from the toolbar or choosing **Compare Areas** from the **Toolbox** pull-down menu. This will bring up the **Area Comparison** dialog box. The user should set **File 1** as BEFORE.SEC and **File 2** as AFTER.SEC and then select the **Plot** button to display to two

cross sections. The **Input Data Format** should be set to **Position-Elevation**. Set the **Left Horizontal Boundary** to 0.0 and **Right Horizontal Boundary** to 50.0. The user can now complete the comparison by selecting the **Calculate** button and WinXSPRO will cause the calculated area difference to appear, as shown in Figure 5.16.

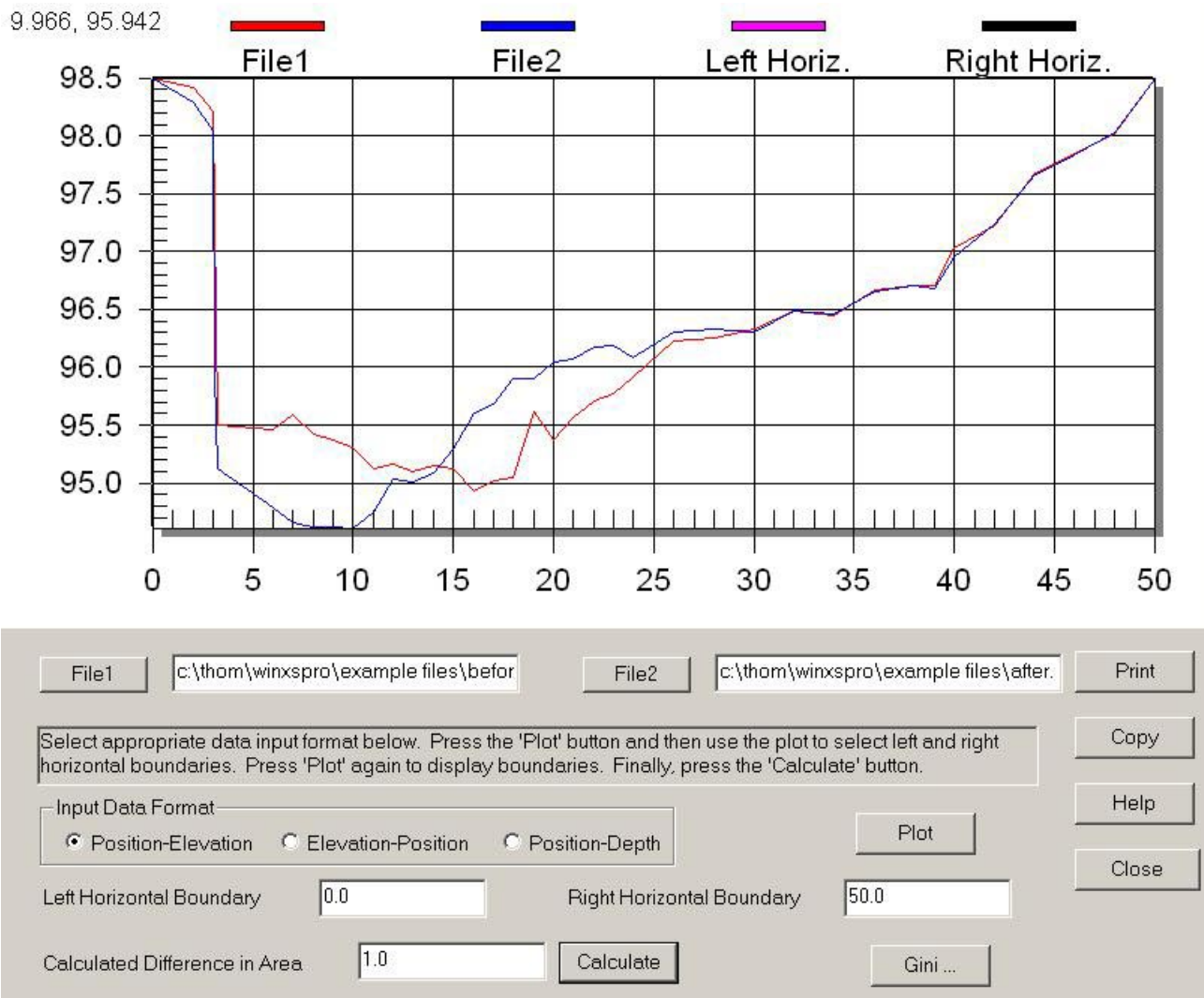


Figure 5.16. Example of Compare Areas window with values set for Example Problem 4.

If the **Gini** button is activated on the **Area Comparison** dialog, the Gini coefficient for each of the two sections and the difference between them is displayed (Figure 5.17).

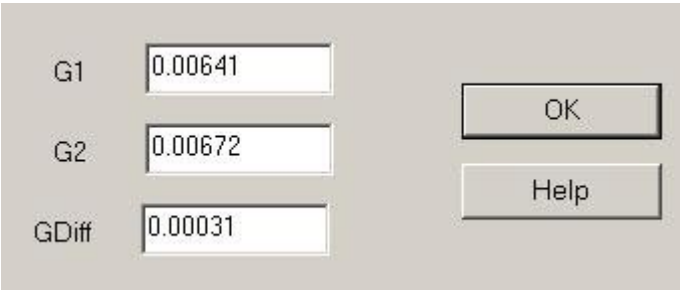


Figure 5.17. Difference between BEFORE and AFTER using the Gini coefficient.

The next task is to determine the bed material load using the Ackers and White method for sand-bed channels. Assume that the d_{50} has been determined to be 4.5 mm.

Before running the Ackers and White Method, a stage-discharge relationship needs to be generated using WinXSPRO for the file AFTER.SEC (i.e., set this as the input file in the Plan window). Change the **Plan Comment** field to be **Example Problem 4**. For this example we will use the user supplied Manning's n option from the main program window and then save the plan with the name *Example_4.xsp*.

The user should now select the **Run** button, which will display the **Stage and Section** window. Set the low stage at 0.1 and the high stage to 3.0, with corresponding slopes of 0.005. Use a stage increment of 1.0 foot. Since we want to analyze the whole cross section, we will not specify and segment boundaries, so the **Calc** button can be selected. This will display the **Manning's n** input window. Use a value for Manning's n of 0.045 for the low stage (0.1) and a value of 0.025 for the high stage (3.0). The user can now select the Calc button and WinXSPRO to generate the corresponding results as illustrated in Figure 5.18.

```
*******************************WinXSPRO*********************************
C:\Thom\WinXSPRO\Example Files\After.out
Input File:            C:\Thom\WinXSPRO\Example Files\After.sec
Run Date:              03/07/04
Analysis Procedure:    Hydraulics
Cross Section Number:  1
Survey Date:           03/07/04
Example Problem 4

Subsections/Dividing positions


Resistance Method:      Manning's n
            SECTION          A
      Low Stage n         0.045
      High Stage n        0.025

Unadjusted horizontal distances used


 STAGE  #SEC      AREA    PERIM   WIDTH    R       DHYD         SLOPE                n     VAVG       Q            SHEAR
  (ft)           (sq ft)   (ft)    (ft)    (ft)     (ft)        (ft/ft)                     (ft/s)    (cfs)         (psf)
  0.10    T       0.30     4.14    4.13  0.07     0.07         0.0050            0.045   0.41        0.12          0.02
  1.10    T      10.44    14.68   14.01  0.71     0.75         0.0050            0.038   2.20       22.99          0.22
  2.10    T      33.26    37.73   36.05  0.88     0.92         0.0050            0.031   3.10      103.25          0.28
  3.00    T      67.77    43.37   40.74  1.56     1.66         0.0050            0.025   5.67      384.61          0.49

 STAGE        ALPHA    FROUDE
  0.10     1.000000       0.266194
  1.10     1.000000       0.449780
  2.10     1.000000       0.569465
  3.00     1.000000       0.775390
```

Figure 5.18. Example Problem 4 hydraulic analysis output.

The output file, AFTER.OUT, along with the d_{50} determined previously (i.e., 4.5 mm) and the water temperature (assumed to be 25 degrees centigrade) are required input for the Ackers and White Method. The Ackers and White Method can be selected by choosing Ackers and White from the Toolbox pull-down menu. Use the AFTER.OUT file for the input, set the D50 as 4.5 mm, and the temperature to 25.0. Figure 5.19 illustrates the Ackers and White dialogue box with the appropriate input fields.

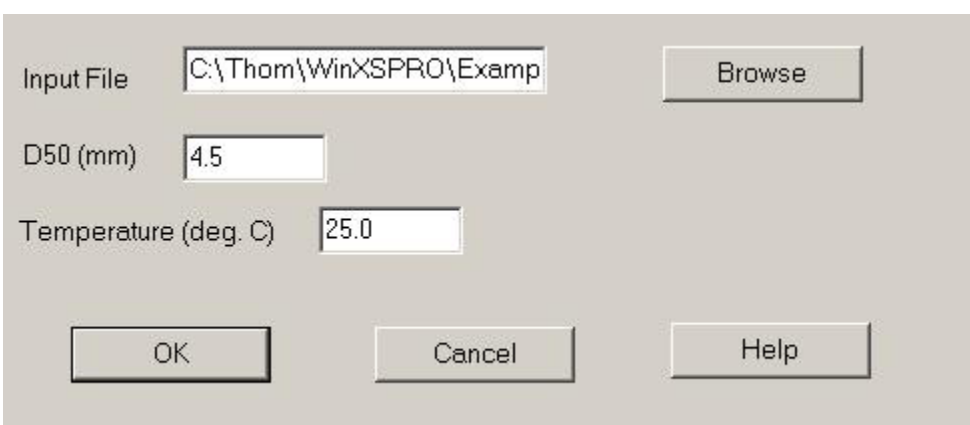


Figure 5.19. Ackers-White dialog box with data field for Example Problem 4.

Once these fields have been entered with the appropriate data, the user can select the **OK** button to conduct the analysis. In this example, WinXSPRO will display a dialogue box that indicates that no sediment transport has been computed based on the entered D50 grain size. Remember that Ackers and White is for sand-sized material typically less than 2 mm in size, but our grain size analysis for the sediment sample is 4.5mm! Close the tabular and graphical windows and open the **Ackers and White** window from **Tools** again. Set the D50 input box to 1 mm and set the temperature to 25.0 degrees, then press **OK**.

The graphical and tabular outputs appear on the screen after the method is run with the revised D50 for the bed material. The graph of bed material load versus discharge is shown as Figure 5.20.

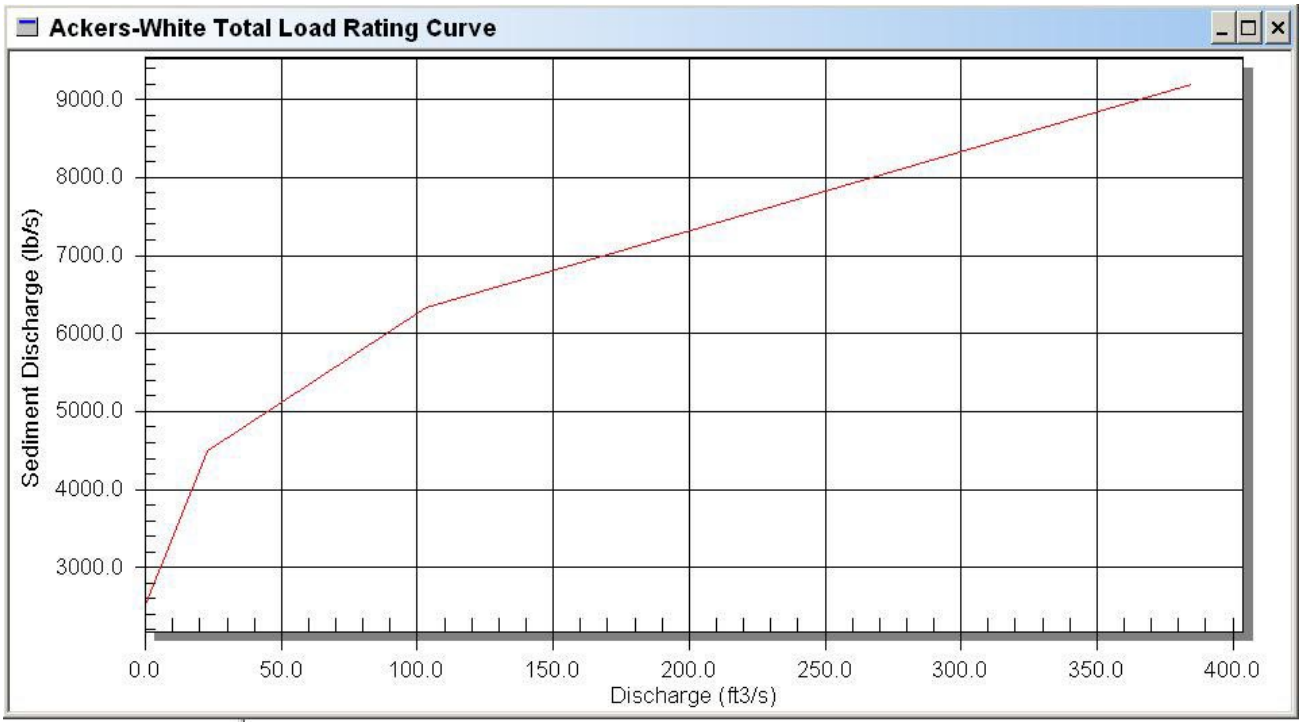


Figure 5.20. Ackers-White sediment rating curve.

Chapter 6 - References

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Appendix A – List of Symbols

a	=	length of longest axis of a sediment particle
A	=	value of the Froude number at nominal initial sediment motion
A_b	=	area of the streambed occupied by a particle
A_i	=	cross sectional area of a particle perpendicular to the flow
b	=	length of intermediate axis of a sediment particle **or** wake height
c	=	length of shortest axis of a sediment particle
C	=	coefficient in the Ackers-White sediment transport function
C_d	=	drag coefficient
d_{35}	=	intermediate diameter for the 35th-percentile particle size
d_{50}	=	intermediate diameter for the 50th-percentile particle size
d_{84}	=	intermediate diameter for the 84th-percentile particle size
D_{gr}	=	dimensionless grain size parameter
D_{max}	=	maximum depth at section
$\overline{D}$	=	mean depth
F_{gr}	=	dimensionless mobility number
g	=	acceleration due to gravity
G	=	Gini coefficient
G_{gr}	=	dimensionless general sediment transport
H	=	depth at flow subsection
k	=	1 for metric units and 1.486 for English units **or** von Karman's constant (=0.40)
K_t	=	eddy viscosity in Nelson et al. (1991) resistance method.
L_t	=	length scale in Nelson et al. (1991) resistance method.
m	=	correction factor for degree of meandering in Cowan's formula for Manning's n **or** exponent in the Ackers-White sediment transport function
n	=	Manning's roughness coefficient **or** Ackers-White transition exponent
n_i=	=	partial n value in Cowan's formula for Manning's n where i=b, 1, 2, 3 or 4
q_B	=	bed load flux per unit width
q_B^*	=	dimensionless bed load flux
Q_s	=	sediment discharge
R	=	hydraulic radius
s	=	specific gravity
S	=	energy slope (equal to water-surface slope for assumed uniform flow conditions)
u_*	=	shear velocity, equal to $\sqrt{(\tau_b / \rho)}$
U_r	=	reference velocity in Nelson et al. (1991) resistance method
U_t	=	velocity scale in Nelson et al. (1991) resistance method
V	=	mean cross section velocity
W	=	water surface width
W^*	=	dimensionless bed load parameter
X	=	sediment discharge concentration
Y	=	measured depth
z	=	the vertical coordinate

α	=	velocity distribution coefficient **or** coefficient in rough turbulent equation
γ_w	=	unit weight of water, 62.4 lb/ft^3, 9810 N/m^3 (equal to ρg)
ν	=	kinematic viscosity of water
ρ	=	water density
ρ_s	=	sediment density
τ^*	=	dimensionless boundary shear stress (Shields stress)
τ_c^*	=	critical Shields stress
τ_r^*	=	reference value of τ^*
τ_d	=	drag shear stress
τ_f	=	actual fluid shear stress
τ_o	=	average bed shear stress, equal to $\gamma_w RS$ or ($\gamma_w RHS$)
τ_{zz}	=	shear stress on a horizontal plane
ϕ_{50}	=	τ^* / τ_r^*

Appendix B – Using WinXSPRO With Spreadsheet Programs

WinXSPRO can use geometric data that has been saved previously to a spreadsheet program. As the WinXSPRO program reads geometric data from text files, a text file must be created from the spreadsheet before the data can be used in an analysis. There are two ways to create text files from a spreadsheet: (1) copying from the spreadsheet and pasting data into WinXSPRO using the Windows™ clipboard, or (2) saving the spreadsheet data directly to a text file.

To use the first method, open a new plan in WinXSPRO, and click the Modify Data button to enter the Input Data Editor. From your spreadsheet program, select the rows and columns of data you will use for the analysis. Copy the selected data to the clipboard by either pressing CTRL-C from the keyboard, clicking on the copy icon on the toolbar or selecting copy from the spreadsheet pull-down menu. Then, in the WinXSPRO Input Data Editor, click on the location where you wanted the data inserted. Then use the CTRL-V command from the keyboard to paste the data. Next, use the Save As button to save your new input data file. The name of the file will automatically be inserted in the Input File Name field on the Main Plan Window.

The second method of using spreadsheet data with WinXSPRO involves creating an ASCII text file from your spreadsheet program. Although the procedure may be different depending on the spreadsheet application you use, the concept is the same. Some spreadsheets use the Save As command to generate a ASCII text file while others use the Print to File command. The procedure outlined illustrates the steps necessary to create a ASCII text file from Microsoft® Excel 5.0 and Excel 2000.

In the active worksheet select Save As.. from the File pull-down menu. The Save As.. dialog box will now be the active window (Figure B-1). Enter a name for your file in the box under File Name:, then choose Formatted Text (Space delimited) from the drop-down list under Save File as Type. Note that your file has been automatically assigned a **.**PRN (for Print files) file extension in Excel 5.0, but under Excel 2000 you could choose "Text (Tab delimited) and the file will be save with a **.txt extension. This is the default extension for the file type you have selected but may be assigned any three-character extension. A** .SEC extension would be consistent with the file extension used by WinXSPRO cross section data. You may need to rename the extension to *.DAT using Windows™ File Rename function previously described. When you have chosen a directory in which to store the file select OK. A message box will appear informing you that only the active sheet will be saved. Click on OK. When you exit Excel, a dialog box will appear prompting you to Save Changes in 'filename.*', if you have made any changes to the current spreadsheet which you want to save, click on Save, otherwise, choose No to exit.

You have just created an ASCII text file that may now be used by WinXSPRO. From the Main Plan Screen of WinXSPRO select the New Plan button from the toolbar, or choose New from the Plan pull-down menu. In the File Name field, type the name of the ASCII text file you have just created (be sure to include the full path where the file is located) or select your file using the Input File Select button. Be sure the Data Collection Method is set to the correct option for your data (refer to section 4.5.1.4). To view the geometric data in the text file you have just created, click on the Modify Data button. When finished viewing, choose Cancel to return to the Plan main window.

Appendix C – Glossary

ACCURACY Degree of conformity of a measure to a standard or true value.

ALLUVIAL STREAM A stream whose channel boundary is composed of appreciable quantities of the sediments transported by the flow, and which generally changes its bed forms as the rate of flow changes.

ARMOR LAYER See ARMORING

ARMORING The process of progressive coarsening of the bed layer by removal of fine particles until it becomes resistant to scour. The coarse layer that remains on the surface is termed the "armor layer". Armoring is a temporary condition; higher flows may destroy an armor layer and it may re-form as flows decrease. Or simply, the formation of a resistant layer of relatively large particles resulting from removal of finer particles by erosion.

BACKWATER PROFILE Longitudinal profile of the water surface in a stream where the water surface is raised above its normal level by a natural or artificial obstruction.

BED FORMS Irregularities found on the bottom (bed) of a stream that are related to flow characteristics. They are given names such as "dunes", "ripples", and "antidunes". They are related to the transport of sediment and interact with the flow because they change the roughness of the streambed. An analog to streambed forms are desert sand dunes (although the physical mechanisms for their creation and movement may be different).

BED LOAD Material moving on or near the stream bed by rolling, sliding, and sometimes making brief excursions into the flow a few diameters above the bed, i.e. jumping. The term "saltation" is sometimes used in place of "jumping". Bed load is bed material that moves in continuous contact with the bed; contrast with SUSPENDED LOAD.

BED LOAD MATERIAL The sediment mixture of which the moving bed is composed. In alluvial streams, bed material particles are likely to be moved at any moment or during some future flow condition. Bed material consists of both bed load and suspended load. Contrast with WASH LOAD.

BOULDERS See Table C-1.

BOUNDARY ROUGHNESS The roughness of the bed and banks of a stream or river. The greater the roughness, the greater the frictional resistance to flows; and, hence, the greater the water surface elevation for any given discharge.

CHANNEL A natural or artificial waterway that periodically or continuously contains moving water.

CHANNEL STABILIZATION A stable channel is neither progressively aggrading nor degrading, or changing its cross sectional area through time. It could aggrade or degrade slightly, but over the period of a year, the channel would remain similar in shape and dimensions and position to previous times. Unstable channels are depositing or eroding in response to some exterior conditions. Stabilization techniques consist of bank protection and other measures that work to transform an unstable channel into a stable one.

CLAY See Table C-1.

COBBLES See Table C-1.

CHANNEL ARMOR See ARMORING.

CRITICAL DEPTH If discharge is held constant and the water depth allowed to decrease, as in the case of water approaching a free overfall, velocity head will increase, pressure head will decrease, and total energy will decrease toward a minimum value where the rate of decrease in the pressure head is just counter-balanced by the rate of increase in velocity head. This is the critical depth. More generally, the critical depth is the depth of flow that would produce the minimum total energy head.

CRITICAL FLOW The state of flow where the water depth is at the critical depth and when the inertial and gravitational forces are equal.

CROSS SECTION Depicts the shape of the channel in which a stream flows. Measured by surveying the streambed elevation across the stream on a line perpendicular to the flow. Necessary data for the computation of hydraulic and sediment transport information.

CROSS SECTIONAL AREA The area of a cross section between the streambed and the water surface.

DEPTH OF FLOW The depth of flow is the vertical distance from the bed of a stream to the water surface.

DISCHARGE The discharge (Q) is the volume of a fluid or solid passing a cross section of a stream per unit time.

ENERGY GRADE LINE In open channel flow it is equal to the water surface elevation plus the velocity head, $\alpha V^2/2g$.

FREQUENCY The number of repetitions of a periodic process in a certain time period.

FROUDE NUMBER A dimensionless number defined as $V/\sqrt{gy}$ reflecting the ratio of stream velocity to wave velocity. If the Froude Number is greater than 1 the flow is supercritical; flow with the Froude Number less than one is subcritical.

GRADATION The proportion of material of each particle size, or the frequency distribution of various sizes, constituting a particulate material such as a soil, sediment, or sedimentary rock. The limits of each size are chosen arbitrarily. Four different gradations are significant: the gradation of the suspended load, the gradation of the bed load, the gradation of the material comprising the bed surface, and the gradation of material beneath the bed surface.

GRADATION CURVE Sediment samples usually contain a range of grain sizes, and it is customary to break this range into classes of percentages of the total sample weight contained in each class. After the individual percentages are accumulated, a graph, the "gradation curve", shows the grain size versus the accumulated percent of material that is finer than that grain size. These curves are used by movable boundary models to depict the bed sediment material properties (e.g., grain size distribution of the bed material).

GRAIN SIZE See Table C-1.

GRAIN SIZE DISTRIBUTION (GRADATION) A measure of the variation in grain (particle) sizes within a mixture. Usually presented as a graph of grain diameter versus percent of the mixture that is finer than that diameter.

GRAVEL See Table C-1.

HYDRAULIC DEPTH (DHYD) The ratio of the cross sectional area to the top width.

HYDRAULIC GRADE LINE In pressure flow it is equal to the elevation of the center of the pipe plus the pressure gradient, p/γ. In open channel flow it corresponds to the water surface elevation.

HYDRAULIC JUMP A sudden transition from supercritical to subcritical flow.

HYDRAULIC RADIUS Equal to the cross sectional area divided by the wetted perimeter.

HYDRAULICS The study and computation of the characteristics, e.g. depth (water surface elevation, velocity and slope, of water flowing in a stream or river.

MANNING'S EQUATION The empirical Manning's equation commonly applied in water surface profile calculations defines the relationship between surface roughness, discharge, flow geometry, and rate of friction loss for a given stream location.

MANNING'S *n* VALUE n is the coefficient of roughness with the dimensions of $T \cdot L^{1/3}$. n accounts for energy loss due to the friction between the bed and the water. In fluvial hydraulics (movable boundary hydraulics), the Manning's n value includes the effects of all losses, such as grain roughness of the movable bed, form roughness of the movable bed, bank irregularities, vegetation, bend losses, and junction losses. Contraction and expansion losses are not included in Manning's n, but are typically accounted for separately.

MATHEMATICAL MODEL A model that uses mathematical expressions (i.e., a set of equations, usually based upon fundamental physical principles) to represent a physical process.

MEAN DEPTH For a given stage, equal to the cross section area divided by the top width.

MEANDERING STREAM An alluvial stream characterized in planform by a series of pronounced alternating bends. The shape and existence of the bends in a meandering stream are a result of alluvial process and not determined by the nature of the terrain (geology) through which the stream flows.

MOBILE-BED STREAMS Streams where the channel boundaries can be modified by the force of the water being conveyed.

MODEL A representation of a physical process or thing that can be used to predict the process's or thing's behavior or state.

Examples: A conceptual model: if I throw a rock harder, it will go faster.
A mathematical model: F=m * a
A hydraulic model: Columbia River physical model.

NUMERICAL MODEL A numerical model is the representation of a mathematical model as a sequence of instructions (program) for a computer. Given approximate data, the execution of this sequence of instructions yields an approximate solution to the set of equations that comprise the mathematical model.

OVERBANK In a river reach, the surface area between the bank of the main channel and the limits of the floodplain. See Figure C-1.

PARAMETER Any set of physical properties whose values determine the characteristics or behavior of something.

PARTICLE SIZE A linear dimension, usually designated as "diameter", used to characterize the size of a particle. The dimension may be determined by any of several different techniques, including sedimentation sieving, micrometric measurement, or direct measurement.

PARTICLE SIZE DISTRIBUTION See GRAIN SIZE DISTRIBUTION.

RATING CURVE See STAGE-DISCHARGE CURVE.

REACH (1) The length of a channel, uniform with respect to discharge, depth, area, and slope, e.g., "study reach", "typical channel reach", or "degrading reach", etc. (2) The length of a stream between two specified gauging stations.

RECURRENCE INTERVAL The reciprocal of the probability of an event within one time unit. For example, if the probability of a certain flow occurring in one year is 0.01, then the recurrence interval (also sometimes called the return period) is 1/0.01=100 years. This means that spacing between events is on the average 100 years, **not** that the event will occur exactly every 100 years.

RELATIVE ROUGHNESS The ratio of the hydraulic radius to a representative grain size (usually defined as R/d_{84}.

RIPPLES Small triangular-shaped bed forms, similar to dunes but have much smaller heights and are 0.3m or less in length. They develop when the Froude number is less than 0.3.

SEDIMENT (1) Particles derived from rocks or biological materials that have been transported by a fluid. (2) Solid materials (sludges) suspended in or settled from water. A collective term meaning an accumulation of soil, rock and mineral particles transported or deposited by flowing water.

SEDIMENT DISCHARGE The mass or volume of sediment (usually mass) passing a stream cross section in a unit of time. The term may be qualified, for example; as suspended-sediment discharge, bed load discharge, or total-sediment discharge. See SEDIMENT LOAD.

SEDIMENT LOAD A general term that refers to material in suspension and/or in transport. It is not synonymous with either discharge or concentration. It may also refer to a particular type of load; e.g. total, suspended, wash, bed, or material.

SEDIMENT PARTICLE Fragments of mineral or organic material in either a singular or aggregate state.

SHEAR STRESS Frictional force per unit of bed area exerted on the bed by the flowing water. Equal to $\gamma_w RS$ where γ_w is the unit weight of water, R is the hydraulic radius and S is the energy slope. An important factor in the movement of bed material.

SHIELD'S SHEAR STRESS Equal to the ratio of the drag force to the gravitational force.

SIEVE DIAMETER The smallest standard sieve opening size through which a given particle of sediment will pass.

SILT See Table C-1.

STABLE CHANNEL A stream channel that does not change in planform or bed profile during a particular period of time. For purposes of this glossary the time period is years to tens of years.

STAGE-DISCHARGE (RATING) CURVE Defines a relationship between discharge and water surface elevation at a given location.

STEADY FLOW Flow that does not vary with time.

STREAM POWER The product of bed shear stress and mean cross sectional velocity at a cross section for a given flow.

STREAM PROFILE A plot of the elevation of a streambed versus distance along the stream.

SUBCRITICAL FLOW The state of flow where the water depth is above the critical depth. Here, the influence of gravity forces dominate the influences in inertial forces, and flow, having a low velocity, is often described as tranquil.

SUPERCRITICAL FLOW The state of flow where the water depth is below the critical depth, inertial forces dominate the gravitational forces, and the flow is described as rapid or shooting.

SUSPENDED BED MATERIAL LOAD That portion of the suspended load that is composed of particle sizes found in the bed material.

SUSPENDED LOAD Includes both suspended bed material load and wash load. Sediment that moves in suspension is continuously supported in the water column by fluid turbulence. Contrast with BED LOAD.

SUSPENDED-SEDIMENT DISCHARGE The quantity of suspended sediment passing a cross section in a unit of time usually given in tons/day. See SUSPENDED LOAD.

TURBULENCE In general terms, the irregular motion of a flowing fluid.

UNIFORM FLOW Flow that does not vary with distance, i.e., the mean velocity and depth remain the same at all sections along the channel.

VELOCITY COEFFICIENT This coefficient, symbolized by α, reflects the uneven distribution of velocities across a cross section.

WASH LOAD That part of the suspended load that is finer than the bed material. Wash load is limited by supply rather than hydraulics. What grain sizes constitute wash load varies with flow and location in a stream. Sampling procedures that measure suspended load will include both wash load and suspended and material load. Normally, that is of sediment particles smaller than 0.062 mm.

WATER COLUMN An imaginary vertical column of water used as a control volume for computational purposes. Usually the size of a unit area and as deep as the depth of water at that location in the river.

WATER DISCHARGE See STREAM DISCHARGE.

WATER SURFACE PROFILE See STREAM PROFILE.

WATERSHED A topographically defined area drained by a river/stream or system of connecting rivers/streams such that all outflow is discharged through a single outlet. Also called a drainage area.

WETTED PERIMETER The wetted perimeter is the length of the wetted contact between a stream of flowing water and its containing channel, measured in a direction normal to the flow.

Table C-1. Sediment Size Classes (USGS Methods for Water Data Acquisition Table 3.2, 1978, American Society of Engineering, Sediment Engineering, Table 2.1, 1977).

Class Name	Size (mm)
Colloid	< 0.00024
Clay	0.0002420 - 0.004
Silt	0.004 - 0.062
Sand, very fine	0.062 - 0.125
Sand, fine	0.125-0.25
Sand, medium	0.50 – 0.25
Sand, coarse	0.50-1.0
Sand, very coarse	1.0-2.0
Gravel, very fine	2.0 – 4.0
Gravel, fine	4-8
Gravel, medium	8-16
Gravel, coarse	16-32
Gravel, very coarse	32-64
Cobbles, small	64-128
Cobbles, large	128-256
Boulders, small	256 – 512
Boulders, medium	512 – 1024
Boulders, large	1024 – 2048
Boulders, very large	> 2048

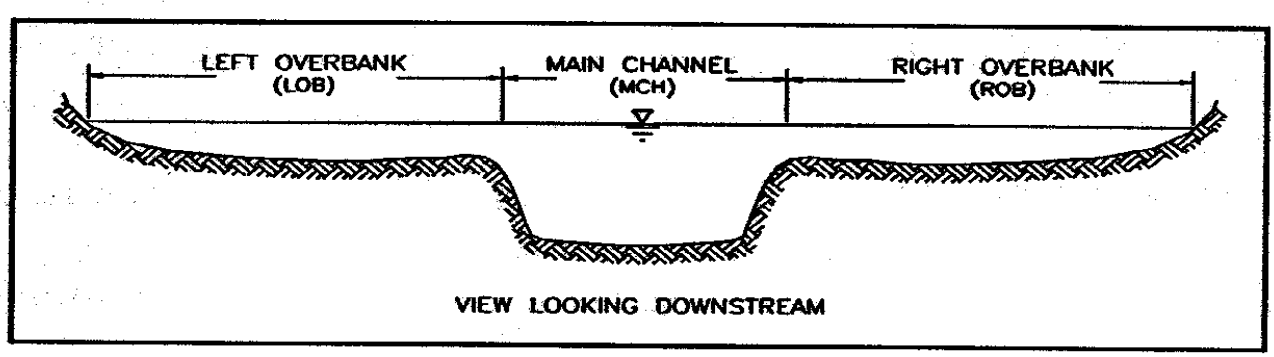

Figure C-1. Example of main channel versus left and right overbank roughness areas.

Appendix D – Error and Warning Messages

No.	WARNINGS/ERROR MESSAGE	MEANING/ACTION TO CORRECT
1	Do you really want to overwrite the existing file	Confirms the new analysis output should overwrite the existing file (yes or no).
2	Invalid range/duplicate data!	The cross section boundary is not valid or a duplicated value is entered in the Stage and Section data entry window. Enter a different value.
3	Invalid Entry	An invalid entry (e.g., entry is not numeric). Enter a correct value.
4	Maximum number of stage output is 500. Please Run the analysis again and select a larger value for stage increment	The maximum number of output stages (500) has been exceeded for the given stage limits and stage increment. Try increasing the stage increment and/or decreasing the stage range.
5	This is not a valid number.	Number is outside of allowable range or letters entered instead of numbers. Enter a number within the allowable range.
6	X is not a valid entry for (high/low) stage. Range Y to Z.	The number entered (X) is not within the allowed stage range. Enter a number in the allowed range, between values Y and Z.
7	X is above the range of input data! Use as is?	The high stage value X is above the highest endpoint of the cross section. If Yes is chosen, frictionless vertical walls will be assumed at the ends of the cross section.
8	File to large to open	Selected analysis variables produce a file which is larger than available memory. Try scaling back analysis to reduce file size.
9	X.XXX may be invalid, n values usually decrease! Use as is?	Manning's n values usually decrease with stage. Answering Yes will keep your entered value while No will clear the entry field.
10	Invalid entry. Please select/enter the Section Boundaries in increasing order.	Section boundaries need to be entered in increasing order (left to right) in the Stage and Section data entry window.
11	Please specify File 1 Name.	For Area comparison the name of file 1 is missing.
12	Please specify File 2 Name.	For Area comparison the name of file 2 is missing.

13	File X does note exist or invalid file name. Please check path and file name.	An invalid file name or path has been entered. Check to see that the name and path are correct and that the file exists.
14	File does not exist! Please select a different input file.	An invalid file name or path has been entered for the input data file in the main plan window. Check to see that the name and path are correct and that the file exists.
15	X. Cannot fine this file. Please verify that the correct path and file name are given.	An invalid file name or path has been entered. Check to see that the name and path are correct and that the file exists.
16	There are no stable points specified for input file X. Please specify the stable point.	For analysis requiring a stable point (e.g., area comparison) file X must have a stable point specified. Specify the stable point in the input file using the input data editor or any text editor.
17	Invalid data for Horizontal Boundary.	Data is outside the valid range in Area Comparison. Enter a value in the allowed range.
18	Horizontal Boundaries cannot be equal. Please correct value(s).	For the Area Comparison, the two boundaries cannot be the same station.
19	Left Horizontal Boundary cannot be bigger or equal to Right Horizontal Boundary. Please make the correction and try again.	For the Area Comparison, the value or the left boundary must be less than the value of the right boundary. Enter a new boundary value.
20	Some discharges are lower than the computed range. Bed load discharge for these points is set at 0.	Sediment discharges for flows less than the minimum on the sediment rating curve will be set to zero in the output file.
21	Some discharges are higher than the computed range. Bed load discharge for these points is set to the maximum value computed.	Sediment discharges for flows greater tan the maximum on the sediment rating curve will be set to the maximum sediment discharge value in the output file.
22	There is no option selected. Implementation cancel.	There is no option selected in the Modify Discharge. Select a Discharge option before proceeding.
23	There is no entry for discharge modification's parameter field.	One or both Modify Discharge Window's field (Discharge File or New Discharge File) is/are empty.

24	Discharge input file invalid or does not exist. Please check the path and file name.	The name or path of the input file is invalid. Check the path and file name and make sure the file exists.
25	There is no entry for the new discharge file.	Enter a new discharge file name to which the modified discharges will be written.
26	File X exists. Overwrite?	Requires user to confirm overwriting an existing file (e.g., data editor, output file).
27	Invalid file name for the Input File. Please check the file name.	The name or path of the input file is invalid. Check the path and file name and make sure the file exists.
28	There is no entry for discharge file.	In the Modify Discharge Window, Discharge field is empty. Enter the original (unmodified) discharge file name.
29	The Bed load rating curve file X does not exist. Check the site name and its path.	Invalid file name/path was provided for the Bed load Rating Curve window. Check the path and file name and make sure the file exists.
30	The discharge file X does not exist. Check the file name and its path.	Invalid file name/path was provided for the discharge input file. Check the path and file name and make sure the file exists
31	The data file for this site does not exist.	Invalid file name or path. Check the path and file name and make sure the file exists.
32	The Bed load data file does not exist for this site.	Invalid file name or path. Check the path and file name and make sure the file exists.
33	There is no Bed load equation selected.	Need to select one of the provided Bed load equations before analysis can be performed.
34	There is no grain size analysis selected.	Need to select an analysis method before analysis can be performed.
35	The survey file for this site does not exist.	An invalid file name or path is entered in the Modify Discharge window.
36	Ackers-White (using D50) computed concentration less than zero.	This method can generate negative concentrations. These will be set to zero in the output file.
37	There is no entry for input file.	No input file is entered. Enter a valid file and path name.
38	Invalid value for temperature.	The temperature entry data field in the Ackers-White window is either empty or has alphanumeric character(s). Only Numeric values can be entered.

39	Invalid value for D50.	The D50 entry data field in the Ackers-White window is either empty or has alphanumeric character(s). Only Numeric values can be entered.
40	Input file invalid or does not exist. Please check the path and file name.	In the main Plan Window, the Input File field contains incorrect data. Check to make sure file has right type of data and is correctly formatted.
41	There is no entry for the X Axis decimal point format.	In the Options menu, Axis Format, Axis X Decimal Point Number Format does not contain any data.
42	There is no entry for the Y Axis decimal point format.	In the Options menu, Axis Format, Axis Y Decimal Point Number Format does not contain any data.
43	Invalid number for the X Axis, range 0-3.	In the Options menu, Axis Format, Axis X Decimal Point Number Format, the valid range is 0 (no decimal point) to a maximum of 3 decimal points.
44	Invalid number for the Y Axis, range 0-3.	In the Options menu, Axis Format, Axis Y Decimal Point Number Format, the valid range is 0 (no decimal point) to a maximum of 3 decimal points.
45	File does not exist or Corrupt Input file! Please select a different input file.	In the main Plan Window, the entry for the Input File Name indicates an invalid or corrupted file. Check the path and file name, make sure the file exists, and check file data format.
46	There is no Column selected! Cannot perform Delete.	Select a column before performing Delete Column in the data editor.
47	There is no Row selected! Cannot perform Delete.	Select a row before performing Delete Column in the data editor.
48	Invalid entry. Number of digits after decimal point valid range is 1 to 5.	Under Plan menu, preferences, Analysis output format, the valid range of decimal points is 1 to 5.
49	One or more selected output columns has/have no entry for number of digits after decimal point. Please correct your selection.	Under Plan menu, Preferences, Analysis outpoint format, there is one or more fields with no data. Cannot set new configuration without filling all the fields.
50	Invalid file! Please check the original path of the output file and the version.	The Plan selected is invalid. Make sure the Plan is created with WinXSPRO Version 2.0 or above.

51	Invalid Plot Parameter Field(s) selected. Unable to locate the field(s) in the output file.	The output file selected for Plot Parameters does not contain the selected parameters for plotting. Make sure desired parameters are chosen using the Analysis Output format feature before running the analysis.
52	There is no data for D50. Shields Shear Stress requires D50 data and proper unit.	In the plot parameters window, a median grain size must be entered for the Shields shear stress to be calculated.
53	Invalid field name for Parker 1990 with Size Fraction. Please check the file name.	In the Bed load Rating Curve function, the Size function file entry is invalid. Check the file name, path and data format.
54	Invalid data for the Size Fraction File. Please check the data file.	The Bed load Rating Curve, Size Fraction File contains invalid data/format.
55	The size fraction file contains more than 100 rows of data. Maximum allowable is 100 rows. Cannot accept this input file.	The selected file has too many rows of data. Modify the file so that it contains 100 rows.
56	Invalid Hydraulics data file. Not all the required fields present.	Not all the required fields are in the output file for selected Bed load Rating Curve Analysis.
57	D84 is < = 0.0 for Thorne Equation.	The sediment size must be a positive number.
58	Less than 3 points in the cross section.	A cross section must have at least three data points.
59	The first point is not the leftmost or the last point is not the rightmost point on the section.	No undercuts are allowed at the very beginning or end of a cross section.
60	Subsection boundaries intersect.	Subsection boundary stations must be increasing order from left to right.
61	For one or more subsections(s), the first point is not the leftmost or the last point is not the rightmost point.	No undercuts are allowed at the very beginning or end of a subsection (i.e., subsection boundaries cannot pass through an undercut).
62	One or more subsection boundary station value does not tie with the existing ground shot.	WinXSPRO could not find a groundpoint near the entered boundary station. Enter a different station.
63	Error occurred while in function Undercut.	An unexpected/Unknown error occurred while performing undercut Analysis.
64	Cannot select Nelson et al. Default to Jarrett.	Undercut Analysis does not support Nelson et al. Hydraulic analysis method. Try using the Jarrett method instead.
65	File Seek Read Error! Output result not valid.	An error occurred while performing read/write during analysis.
66	Out of memory.	Not enough memory available to display analysis text data. Close one or more running applications and try again.

67	Cannot implement Ration 1:1, Position scaling too small.	Warning during Option, Plot Ratio, X:Y due to scaling factors.
68	Cannot implement Ration 1:1, Stage scaling too small.	Warning during Option, Plot Ratio, X:Y due to scaling factors.
69	Cannot implement Ration 10:1, Stage scaling too large.	Warning during Option, Plot Ratio, X:Y due to scaling factors.
70	Cannot implement Ration 10:1, Position scaling too large.	Warning during Option, Plot Ratio, X:Y due to scaling factors.
71	There is not entry for High Stage	There is no data for the High Stage Manning. Enter a valid value for the stage.
72	There is not entry for Low Stage	There is no data for the Low Stage Manning. Enter a valid value for the stage.
73	There is not entry for High Stage Manning's n	There is no data for the High Stage Manning. Enter a valid value for the stage.
74	There is not entry for Low Stage Manning's n.	There is no data for the Low Stage Manning. Enter a valid value for the stage.
75	Error, cannot Plot Parameters. Please check the Output file.	The files selected for Plot Parameters are invalid. Check the path and file name and the data format of the output file.
76	Error, Cannot find valid data for both plot parameters.	The required data cannot be found in the selected plot parameters input file field. Make sure the required parameters are output using the Analysis output Format feature.
77	Cannot accept a D84 particle diameter of zero or negative.	The value for D84 in the main Plan Window is invalid.
78	No cell selected, please select a cell.	There is no row selected for Delete in the data editor. Cannot perform the requested Delete action.
79	There is no valid entry for Stage Increment.	There is no entry in the Stage Increment field of the Stage & Section Window. Enter a value.

Appendix E - WinXSPRO Sample Files

The directory SAMPLES distributed with the WinXSPRO program contains files that are known to work for the major features of the program. If you encounter problems getting a particular feature to work, substitute one of these files to help identify data formatting errors. The information below provides addition information needed for some of the examples to produce reasonable results.

Typical Cross Sections

File: EXAMPLE.SEC

Example Creek is a typical gravel-bed river cross section. Data were collected with a rod and level, the tape was horizontal, and the data are in position-elevation format. The slope of the reach is 0.01. Bankfull discharge occurs at an elevation of 98.46 feet (stage = 3.53 feet) and bankfull discharge is estimated to be 237 cfs. For the Thorne and Zevenbergen resistance equation use a d_{84} of 225 mm. Manning's n values of 0.06 are suggested for low flows (low stage of 1.0 feet) and values near 0.03 are suggested for flows near bankfull discharge (high stage of 3.5 feet). Set high stage to 5.0 if doing bed load computations using the example discharge file.

File: SAMPLE.SEC

This file is the data file used in Example Problem 4.

Cross Section With Undercut Banks

File: UNDERCUT.SEC

A typical cross section containing an undercut bank.

Compare Two Cross Sections

Files: BEFORE.SEC and AFTER.SEC

These files compare a cross section over two time periods (before and after). The point (0,98.5) has been set as the stable point for each file be placing an "s" after the elevation value (0, 98.5s). The results below illustrate how various parts of the cross section might be compared.

Comparison	Change in area (ft^2)	Interpretation
Left side (3 to 14 feet)	5.8	Degradation (after area is larger)
Right side (14 to 30 feet)	-5.2	Aggradation (after area is smaller)
Entire X-sec (0 to 50 feet)	1.0	Degradation (after area is larger)

Nelson et al. Resistance Method and Bed Load Computations

Files: EXAMPLE.SEC – basic cross section file
EXAMPLE.DAT – grain geometry and orientation file
DISCHARGE.DIS – one water year of discharge data

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