DAN-W Release 10
Dynamic Analysis of Landslides

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USER'S MANUAL

DAN-W

DYNAMIC ANALYSIS OF LANDSLIDES

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A INTRODUCTION

A.1 Purpose and limitations

DAN-W is an MS Windows-based program used to model the post-failure motion of rapid landslides. The basic premise of the analysis is that, as a result of sliding or other failure, a pre-defined volume of soil or rock ("the source volume") changes into a fluid and flows downslope, following a path of a defined direction and width. The mass can entrain additional material from the path and eventually deposits, when it reaches slopes that are sufficiently flat ("the deposition area"). The model implements a one-dimensional Lagrangian solution of the equations of motion and is capable of using several alternative rheological relationships.

IMPORTANT NOTICE: DAN-W is a tool suitable for estimating the runout behaviour of landslides on the basis of specific data on geometry and material properties, supplied by the program user. The results of the calculations are entirely dependent upon the data provided by the user. Therefore, persons using the program to make runout estimates should be geoscience professionals thoroughly familiar with landslides, soil and rock material behaviour and rheology, who have studied recent research publications on landslide dynamics, including the relevant references listed at the end of this manual. The properties entered into the program should always be checked by back-analysis of real landslide case histories, similar to the existing or potential landslide being studied. The results of the analysis should never be relied on exclusively, but should be interpreted carefully by a qualified person in the light of field observations, empirical estimates, other analyses and appropriate judgment and experience.

DAN-W is based on shallow flow assumptions and is best suited to shallow mass movements, where the flow thickness is at least an order of magnitude less than the length of the moving mass and the movement vectors are approximately parallel with the bed. Where this condition is not satisfied, the results should be viewed with caution.

The solution may be unstable in certain cases where the flow is deep, or where abrupt changes of slope occur. Beginning with Release 9, issued in September, 2008, the program implements a velocity-smoothing algorithm, which removes most (though not all) instability problems. As a consequence of velocity smoothing, the solution results, i.e. the degree of longitudinal spreading of the moving mass, are now somewhat dependent on the time interval used in the solution.

The optimal time interval is now set automatically by the program. It can be changed by the user, but this should only be done together with careful testing of the effects. If the solution shows signs of instability such as the appearance of irregular or translatory waves, the results should not be trusted. In many cases, such problems can be overcome by using a smaller number of reference blocks (50 is the recommended standard), shorter time interval or switching between vertical and normal geometry. (The normal geometry is usually considered superior).

A.2 Calibration approach

DAN-W uses the "equivalent fluid" approach, as described by Hungr (1995) and used implicitly by many other researchers, before and after 1995. The flowing mass of the landslide is simulated as a mass of simple fluid which is always frictional internally, but with a basal flow resistance developed according to one of several alternative simple rheological models. The best-fitting rheological model and the associated parameters can be determined by independent laboratory tests only in cases of small-scale laboratory model landslides. Thus, verification testing was carried out by analysing laboratory flume experiments using dry sand and viscous oil (e.g. Savage and Hutter, 1978, Hungr, 1995and 2008).

Full-scale natural or man-caused landslides involve complex rheologies, affected by soil-water interactions, gross heterogeneity, scale and rate effects, most of which are effects not suitable for sampling and laboratory testing. The rheological properties of the "equivalent fluid" can therefore only be determined by back-analysis of real landslide precedents. The general approach is to back-analyse known cases and assess the performance of the model in terms of runout distance, length of deposit, deposit thickness distribution, flow duration and distribution of flow velocities, where known in the field. Given the relative simplicity of the basal rheology relationships, it is feasible to select the optimal model and parameters that can then be used for forward predictions, provided the landslide under analysis is similar in scale and character to the calibration cases. Generally, the model results are much less sensitive to the internal friction angle than to the basal rheological parameters.

A further discussion of the calibration approach and some examples are given in Paragraph 4.9 of Hungr et al. (2005, copy enclosed with program package).

A.3 Additional precautions for use

- DAN-W is a shallow-flow solution. Highly curved slopes are not recommended for analysis with deep slide masses, although some reasonably good results can be obtained (Mancarella and Hungr, in review, 2010, copy enclosed with program package). DAN-W has the option of using slices that are either vertical or normal to the path profile. If the walls of the boundary blocks are normal to the slope profile, a highly curved slope will cause the top surface of a deep landslide to loop on itself, creating an apparently incorrect geometry, as shown in Figure 1 (a) and (b). Surprisingly, verification testing shows that this condition does not necessarily downgrade the results. Vertical slices do not have this problem (Figure 1c), however, they may in fact be less accurate on steep slopes because the equations of motion are in this case resolved in the horizontal direction. Where the problem exists, it is recommended to run both configurations and take the more conservative result.

- As much as possible, the time step suggested by the program should be used. In some instances, it is possible to eliminate instability problems by decreasing the time step slightly, but using too small time steps may lead to "over-smoothing" and distortion of the shape of the flowing mass. To speed up analysis, the user can select smaller number of reference elements (although a warning will be issued if the number is less than 50).

- DAN-W graphics do not implicitly show the decoupling of a slide mass when a convex peak on a path is reached and one part of the mass flows forward while the other lags upslope of the peak. Note that the model is not affected by this decoupling, however the graphics are, so there is a straight line drawn between the two material accumulations.

- Running the front of a slide mass a significant distance past the extents of the path geometry can result in solution instability or inaccuracy. It is recommended that a sufficient distance be included in the path profile to prevent flow beyond the extents.

- The equations of motion are developed in a one-dimensional framework, so there is an implicit assumption that all resisting stresses arise only at the base of the flow, while the flow depth is constant in the direction perpendicular to movement. Thus, additional flow resistance that could be generated by the lateral flow boundaries in highly confined flow paths is not accounted for. This should be kept in mind when designing calibration programs: the back-analysis cases should have similar confinement conditions as the case being analysed.

- Path Roughness: The input sequence in DAN-W requires the user to enter the path geometry as a series of points, which the program fits by a spline function. The spline appears during input or editing of the path geometry points and the user is responsible to use just enough points to make the spline conform to the known path geometry. The geometry input does not allow for overhags or sharp corners, which would make the solution unstable. This need for smoothing precludes direct input of x-y data into the program. Instead, the user should plot the path profile using a graphics program, post the resulting image as a background image in the Edit/Geometry screen and place sufficient points to correctly define the spline. Please do not attempt to enter excessively complex geometry with intricate roughness details: it will not improve accuracy and may make the solutions unstable. Ideally, the path profile will be defined by 20 to 30 input points. The points should be evenly distributed, except in places where it is necessary to force the spline to follow a sharp change in angle.

- Defaults: Recent benchmark testing was carried out using default options as listed in the Edit/Options/Analysis screen, namely: Time Interval (automatic), Smoothing Coefficient (0.02), Tip Ratio (0.5), Stiffness Coefficient (0.05), Stiffness Ratio (5), Centrifugal Forces (on), Trajectory (off), Boundary Block Geometry (normal) and Lateral Stress Assumption (modified). It is recommended to keep these defaults for routine analyses.

A.4 Problem size limits

- Maximum number of materials: 20
- Maximum number of boundary blocks: 1000
- Maximum number of geometry input points: 100

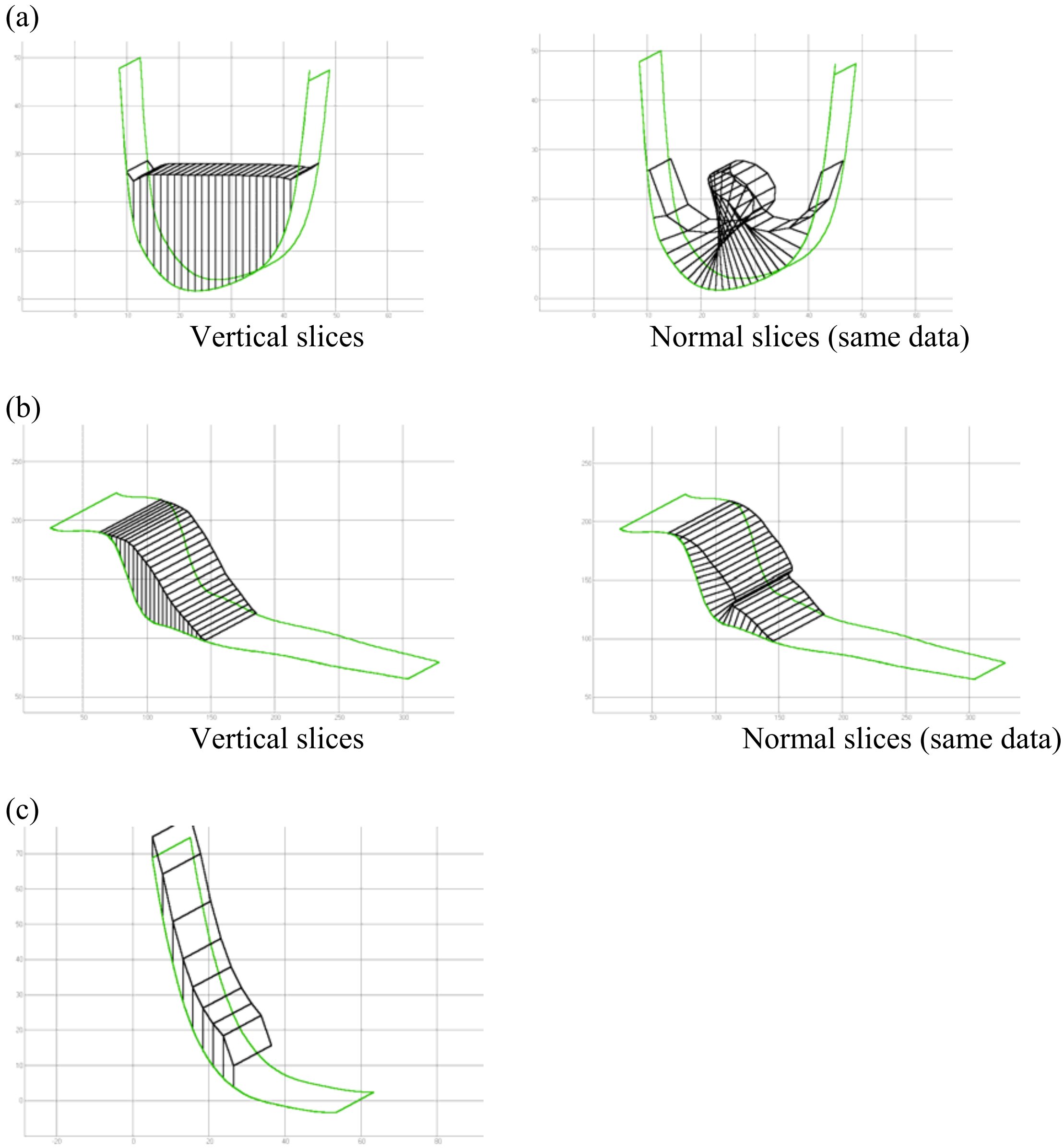


***Figure 1**: (a) An exaggerated example showing how the use of normal slices on a highly curved slope can cause the slide mass to loop on itself. (b) A more practical example of the above. (c) An example of how the mass elements become stretched in a steep-slope problem that uses vertical slices.*

B PROGRAM ORGANIZATION

B.1 Installation of the program

Run program setup.exe in the distribution folder. This will install DAN-W and its Help Files in a chosen sub-directory on the hard drive. If setup does not work, it is sometimes possible to start the program by double-clicking the DAN_Rel_10.EXE file. The user may create a shortcut to DAN-W using Windows facilities. Run DAN-W through the Start menu, or by double-clicking its name or shortcut. On starting, DAN-W presents a title screen which disappears by clicking the mouse or any key on the keyboard. An Initial Menu appears, prompting for one of two choices:

- Create a new file
- Open an existing file

IMPORTANT NOTE: While operating DAN-W on certain computers outside North America, please do not forget to set your system to recognize dot, rather than comma, as the decimal symbol. To do this, please go to Control Panel, Regional Settings.

B.2 Program layout

DAN-W has three main functions: data input, analysis, and data output. The data input component allows the user to define the problem geometry, material properties, and analysis options. Once the problem is defined, the user can run an analysis. Data is collected during the analysis and can be output in various ways after the run is complete.

B.3 Coordinate system

The main screen of DAN-W shows an isometric view of the slope profile and flowing mass along the centre-line of the path. Horizontal distance, in metres, is shown from left to right while elevation, also in metres, is shown from bottom to top. In the three-dimensional configuration (default), the width of the channel is drawn in an isometric view defined by a projection angle (see Section C.9).

During data input, the screen's coordinate system changes depending on the data being input. When inputting the slope and flowing mass's profiles, the horizontal axis shows horizontal distance from left to right, while the vertical axis shows elevation. When inputting the path width, the vertical axis changes to width, in metres.

SLIDING DIRECTION:
It is important to note that the program was designed primarily for a sliding direction of left to right. Therefore, a mass flowing from left to right will result in positive velocities while a mass sliding from right to left will result in negative velocities. It is recommended that the problem be described so that the sliding mass begins on the left side and flows to the right of the screen.

B.4 2D / 3D configurations

DAN-W has a two-dimensional as well as a three-dimensional configuration. The two-dimensional configuration works the same as 3D, except that the program assigns constant 1m channel width. The three-dimensional configuration allows for a varying channel width, assigned by the user along the length of the slope. To read about how to change configurations, please refer to the Section C.4. For details on how channel width is defined, refer to Section C.8, Section C.1, and Section D.1.

B.5 Opening and saving data files

Problems created in DAN-W can be saved under the file extension *.DNW. An ASCII character file is saved containing all the input data, including problem geometry, material properties, and material locations. Old files created in the DOS version of DAN (file extension *.DAN) can be opened by DAN-W. However, some old data files may be incomplete and all data should be checked.

To save a *.DNW file, choose the *File-Save* or *File-Save As* menu selection in the main menu. To open a *.DNW file, choose the *File-Open* menu selection. To open a *.DAN file, choose the *File-Open .DAN* menu selection.

B.6 The main menu

The program is controlled primarily through the Main Menu, which allows the user to access the data input/edit screens, run an analysis, and control the output of data during analysis. The Main Menu returns at the conclusion of each function. The following is a list of all the options found in the Main Menu with a short description of each:

- *File*: The items under this menu deal with file manipulation.
    - *File-New*: Opens a new file with all the data either empty or set to a default value. Also initializes the New-File Sequence (see Section C.3) that guides the user through all the necessary data input screens.
    - *File-Open*: Allows the user to open a previously saved *.DNW file.
    - *File-Open .DAN*: Allows the user to open an old *.DAN file previously created and saved in the DOS version of DAN.
    - *File-Save*: Saves the current problem in the current directory and under the current *.DNW file name.
    - *File-Save As*: Allows the user to save the current problem in any available directory as a *.DNW file.
    - *File-Exit*: Ends and closes DAN-W.

- *Edit*: The items under this menu allow the user to access the various data input/edit screens as well as the options screen. This menu is enabled only when a file is loaded.
    - *Edit-Control Parameters*: Opens the Control Parameters Screen (see Section C.4) which allows the user to input and modify the current file's identifying labels and problem boundaries, define the number of materials and boundary blocks, set initial velocity and choose a cross-section shape factor, a 2D or 3D configuration, end conditions and the uniform thickness option.
    - *Edit-Material Properties*: Opens the Material Properties Screen (see Section C.5) which allows the user to choose the rheology of each material and input/edit each material's relevant properties. This screen also allows the user to add and delete materials.
    - *Edit-Material Locations*: Opens the Material Locations Screen (see Section C.6) which allows the user to define where the various material segments are located along the path profile.
    - *Edit-Path*: Opens the Edit Path Screen (see Section C.7) which allows the user to input/edit the slope profile.
    - *Edit-Top*: Opens the Edit Top Screen (see Section C.7) which allows the user to input/edit the initial flowing mass profile.
    - *Edit-Width*: Opens the Edit Width Screen (see Section C.8) which allows the user to edit the width of the channel. This item is only available in the three-dimensional configuration.
    - *Edit-Options*: Opens the Options Screen (see Section C.9) which allows the user to change various boundary, display, and analysis options.
- *Solve*: This menu accesses the analysis component of the program. It is enabled only when a file is loaded. The selection activates the Run Control Box (see Section D.3) which allows the user to run an analysis of the problem.
- *Output*: The items under this menu deal with data output. This menu is enabled only when a file is loaded.
    - *Output-Report*: Displays a report (see Section E.1) summarizing the most recent analysis.
    - *Output-Export ASCII Graph Files*: Allows the user to choose at what time intervals data is to be collected and placed into ASCII files (see Section E.3).
    - *Output-Observation Point-View Data*: Displays plots of the velocity and the thickness of the sliding mass at a pre-specified location along the path, as functions of time. This item is only available when the Observation Point (see Section E.5) option is chosen in the Options Screen.
    - *Output-Observation Point-Export Data*: Allows the user to export the velocity and thickness data collected at the Observation Point to an ASCII data file. This item is only available when the Observation Point option is chosen in the Options Screen (see Section C.9).
    - *Output-Copy to Clipboard*: Copies the current image on the main screen to the clipboard. In the *Depth-Profile* mode, the two graphs shown are

separate images. To copy either of these graphs, click on the desired graph and then select this menu option.

- *View*: The items under this menu allow the user to change the main-screen view from a three-dimensional isometric view of the problem to a two-dimensional depth profile.
    - *View-Isometry*: Displays in the main screen a three-dimensional isometric view of the problem, as described in Section D.1.
    - *View-Depth Profile (2D)*: Displays in the main screen a two-dimensional depth profile showing the sliding mass's current velocity and thickness distributions as functions of the horizontal distance, as described in Section D.1.
    - *View-View Options*: Gives rapid access to the 'display' portion of the Options Screen (see Section C.9).
- *Help*: Provides access to the DAN-W Help system.

C DATA INPUT

C.1 Data preparation

Before creating a data file for analysis in DAN-W, the user should be aware of the following assumptions used by the model:

- All geometry is two-dimensional. The slope and top surface profiles do not vary in the transverse direction (perpendicular to movement). The path profile must be constructed along the expected center-line of movement, even if curved in plan.
- The direction of flow of the slide mass in the model is parallel to the plane of the profile (i.e. from left to right of the screen).
- The top surface geometry has a rectangular lateral cross-section defined by the hydraulic depth of the slide mass and the channel width at that location along the slope (see discussion of the Shape Factor, Section C.4.).
- The slide mass is assumed to be a homogeneous "apparent fluid". Its internal strength is frictional, controlled by the "internal friction angle, φ_i". The basal strength is determined by one of the several alternative rheological models. Both the internal and external rheology may change along the length of the path.

The first step is to prepare an elevation-distance slope profile, with two lines: the path of the landslide and the ground surface defining the top of the unstable mass, in its original position ("path and top" lines). The origin of the coordinate system should be in the lower left corner of the screen, with the slope profile in the centre of the screen, as shown in Figure 2. Data points containing elevation vs. horizontal distance along the slope from the source to beyond the expected runout should then be chosen. True elevations can be used, but the distance should start from 0 at the left corner.

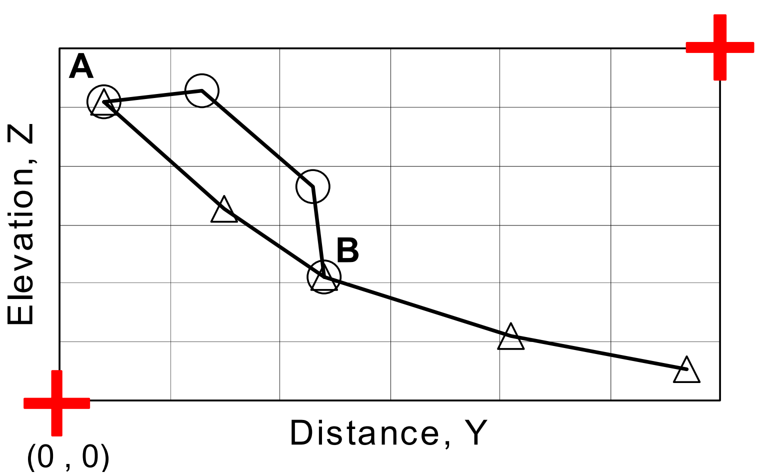


Figure 2: Vertical cross-section of a simple profile showing the layout of the coordinate system and the position of the origin. Triangular data points represent the path and circular data points represent the top of the slide mass in its original position. Points A and B must be coincident on both lines. The path line can begin to the left of Point A, but it is not recommended. Ideally, Point A (the crest of the source volume) should be the first point on both the path and top lines.

IMPORTANT NOTE: The input profile should be made reasonably smooth to avoid instability. Do not use too many points and avoid details such as minor steps in the profile. Round out abrupt slope changes. The user should test the influence of such simplification (usually it has relatively small effect on the results, but excessive roughness could unrealistically reduce the runout). Ideally, a slope profile should have about 15-25 input points.

To create the top profile, the same coordinate system is used. Once again, elevation versus horizontal distance data points should be chosen in the same way as described above.

For the three-dimensional configuration, width data is defined by the top-surface width of the channel as a function of the same horizontal distance axis as described above. Enough data points should be taken to sufficiently approximate the width profile of the channel (they need not coincide with points defining the profile).

Next, data on the properties of the various materials encountered on the slope must be prepared. Each material can be approximated by one of the provided rheologies, as described in Section C.5 and Section A.5 of Appendix 1. If material varies along the path, the beginning and ending locations of each material segment along the profile of the slope must also be determined. These locations must correspond to data points on the slope profile.

C.2 Problem geometry setup

Once the data input is complete, DAN-W constructs the problem's geometry by interpolation. The program creates a smooth slope profile by interpolating between data points using the spline function. The top surface profile, on the other hand, is created by linear interpolation between the data points. This surface is then split into the chosen number of equally-spaced boundary blocks.

C.3 New file sequence

The New File Sequence, accessed through *File-New* in the main menu, or from the startup screen, is a sequence of screens that guides the user through all the data input steps that are required to create a new file. Once the sequence is complete and the user is returned to the main screen, the problem is sufficiently defined to allow analysis to begin.

IMPORTANT NOTE: When the input or review of each data screen is complete, press the menu item *"Continue"* to accept the data and, either continue the input sequence, or return to the Main Menu.

The input sequence of screens is as follows:

1. Control Parameters screen.
2. Material Properties screen.
3. Edit Path/Top screen.
4. Edit Width screen (this screen is skipped if the 2D configuration was chosen in the Control Parameters screen).
5. Material Locations screen (this screen is skipped if only one material was chosen in the Control Parameters or Material Properties screens).

These screens can be visited individually after the sequence is finished. Note that the Edit Path/Top screen cannot be exited until sufficient geometry data points are entered for both the slope profile and the top surface. Also note that if the *Cancel* option is chosen from the menus in the Control Parameters and Material Properties screens during the New File Sequence, then the new file will be closed and exited without being saved.

C.4 Control parameters screen

The Control Parameters screen, shown in Figure 4, is accessed through the *Edit-Control Parameters* option in the main menu. It is also the first input screen in the New File Sequence. This screen is used to input or edit the problem's identifying labels, geometry extents, and other parameters.

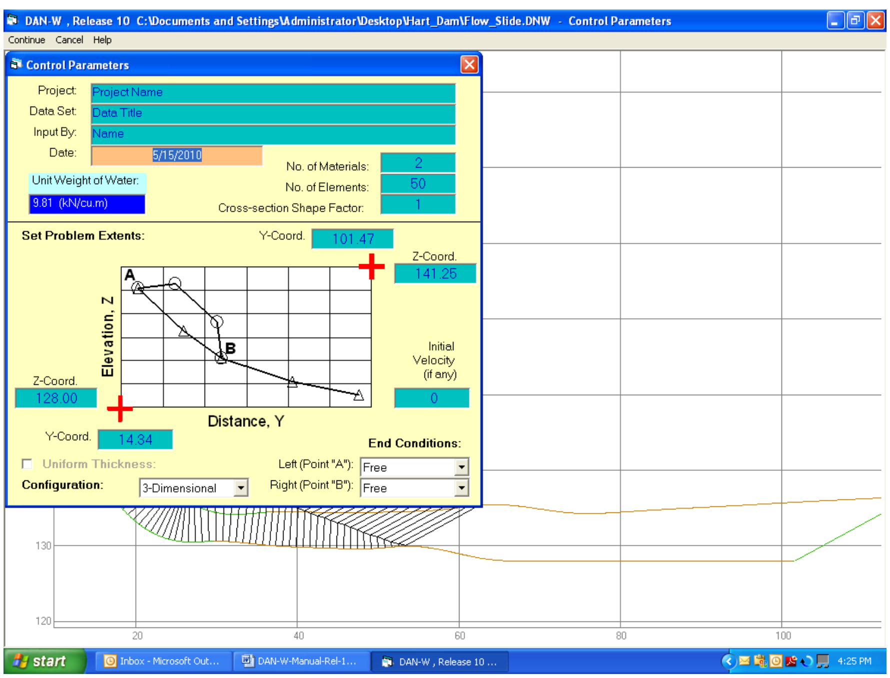


Figure 3: Control Parameters screen.

The following is a list of the input labels found on this screen and a description of each:

- PROJECT: Optional. Any alphanumeric string of any length representing the name of the project.
- DATA SET: Optional. Any alphanumeric string of any length representing the data set used in the project.
- INPUT BY: Optional. Any alphanumeric string of any length representing the user's name.
- DATE: Automatically updated to the system's calendar. Can be changed to any string.
- UNIT WEIGHT OF WATER: Initially set to 9.81 kN/m^3. All units are therefore in SI metric units, including: metres (m), kilonewtons (kN) and kilopascals (kPa). The Imperial units option is disabled in this version of DAN-W.
- NUMBER OF MATERIALS: The number of materials or rheologies used in the problem. There must be at least one material. The maximum number of materials is 20. Please remember that materials other than number 1 will only be used, if they are specified in the *Material Locations* screen.
- NUMBER OF ELEMENTS: The number of constant-volume mass elements that the slide mass is split into for analysis. There must be at least one element. The recommended maximum number of elements is 200. Note that to prevent instability due to numerical divergence and to increase precision, the more mass elements are used, the smaller the time step should be during analysis. This relationship is set automatically during the analysis.
- CROSS-SECTION SHAPE FACTOR: A factor that accounts for the shape of the channel cross-section. It is defined as the ratio between the hydraulic (average) depth and the maximum depth of the channel cross-section. For example, a triangular channel has a factor of 0.5 and an elliptical channel has a ratio of 0.67, as illustrated in Figure 4. A rectangular channel has a factor of 1. This factor allows the user to input the geometry of the slide mass in terms of the maximum channel depth. The factor must be greater than zero.

IMPORTANT NOTE: Only one constant depth factor can be used for the entire path. Therefore, a depth factor of less than 1.0 should only be used for highly confined paths, that remain confined for most of their length.

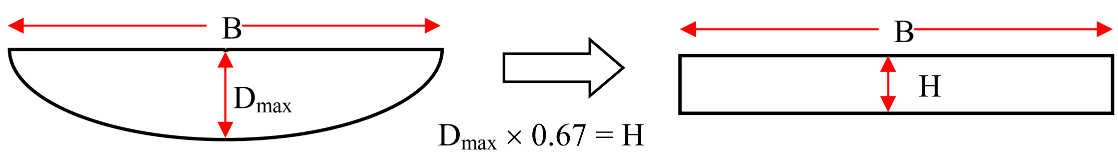


Figure 4: Illustration of how DAN-W uses the cross-section shape factor to convert the maximum depth of a non-rectangular channel (D_{max}) to the corresponding hydraulic depth (H). B is the channel width.

- SET PROBLEM EXTENTS: The problem extents, described in Section C.1, are defined by the coordinates of the bottom left and upper right corners of the problem, as indicated by the graphic on this screen.
- INITIAL VELOCITY (if any): A constant initial velocity in m/sec can be input to be used in the next run. This variable is **not** stored in the problem file and is reset to zero each time a new file is read, or whenever the Control Parameters screen is re-open.
- UNIFORM THICKNESS: Optional. Allows the user to enter a uniform thickness (in metres) for the top surface geometry. If chosen, DAN-W will create a top surface that will have the defined uniform thickness everywhere above the slope. Note that this thickness is measured parallel to the type of slices used (normal or vertical). Please refer to Section C.7 for further details.
- CONFIGURATION: Allows the user to choose between the two-dimensional configuration and the 3-dimensional configuration
- END CONDITIONS: Allows the user to fix the front or the rear of the slide mass in their initial position. A fixed end will not flow during analysis. This option is useful in cases where the movement of an end point is restrained by the presence of a wall (Figure 5).

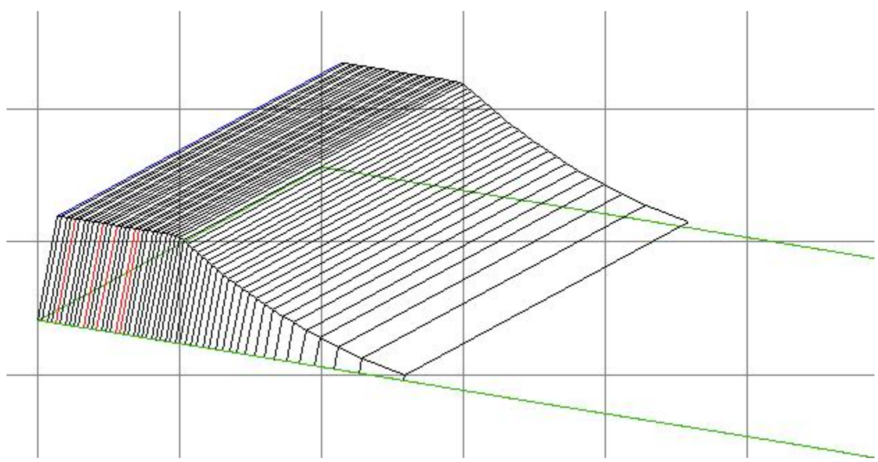


Figure 5: Example where the left end condition is fixed and the right end is free.

The *Continue* item in the menu will accept all the input data and either return to the main menu or continue to the next input screen in the New File Sequence. The *Cancel* option will ignore any changes made in this screen and return to the main menu. Note that choosing Cancel during the New File Sequence will cancel the new file completely.

C.5 Material properties screen

The Material Properties screen, shown in Figure 6, is accessed through the *Edit-Material Properties* option in the main menu. It is also the second input screen in the New File Sequence. This screen is used to input or edit the problem's material rheologies and properties. It also allows the user to add and delete materials. The user has a choice of eight rheologies, including:

- Frictional
- Plastic
- Newtonian
- Turbulent
- Bingham
- Coulomb Frictional
- Voellmy

These rheologies are described in Appendix 1, and in Hungr (1995). Each rheology requires input of specific material properties, as listed in the first column of the table. Properties that are not associated with a given rheology type are disabled (yellow letters). The colour field above the columns indicates the colour of the line drawing the segment occupied by the given material.

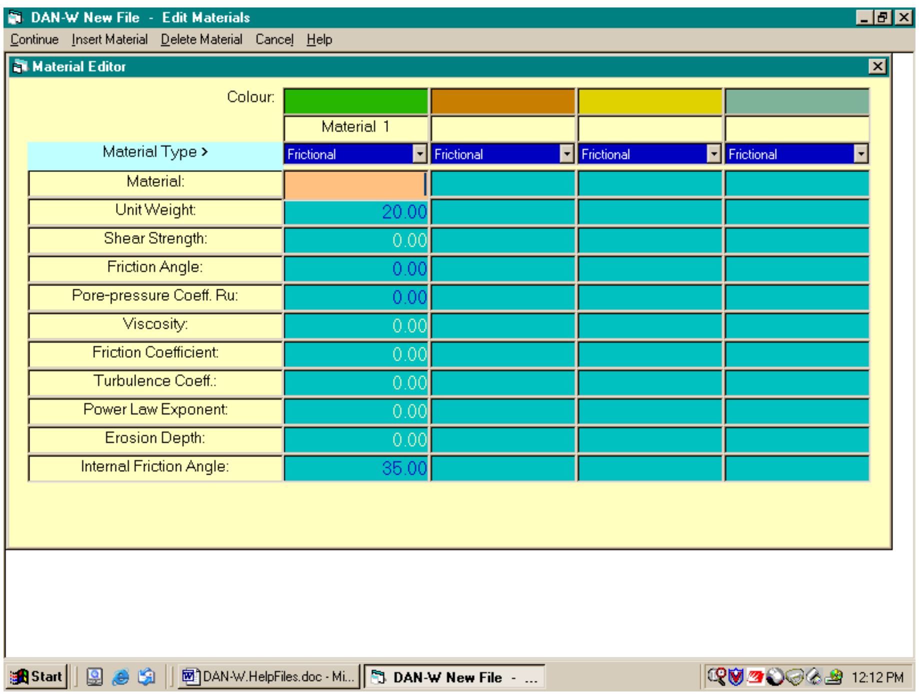


Figure 6: Material Properties screen.

The following is a list of all the material properties shown in this screen and a brief description of each. For further explanation of the parameters see Appendix 1.

- MATERIAL: Optional. Any alphanumeric string representing the name of the material.
- UNIT WEIGHT: Unit weight of the material in kN/m^3. Must be greater than 0.
- SHEAR STRENGTH: Constant shear strength of the material, such as the constant steady state undrained strength of a liquefied soil (plastic model).

- FRICTION ANGLE: Basal friction angle, in degrees (frictional model).
- PORE-PRESSURE COEFFICIENT: Ratio of the pore pressure to the total normal stress at the base of the sliding mass (frictional model).
- VISCOSITY: Dynamic viscosity of the fluid (kPa .s) (viscous model).
- FRICTION COEFFICIENT: First coefficient used in the Voellmy model. It is equivalent to the tangent of the basal friction angle (dimensionless).
- TURBULENCE COEFFICIENT: In the turbulent rheology: number that represents the roughness coefficient in the Manning equation. In the Voellmy rheology it is the coefficient that defines the turbulent term of the basal flow resistance equation, which equals the square of the Chezy coefficient (m/s^2).
- EROSION DEPTH: Maximum depth to which the material is eroded after the whole slide mass passes over it (in metres). A positive value indicates material erosion.
- INTERNAL FRICTION ANGLE: Angle that defines the internal friction acting within the body of the flowing mass, as it stretches or contracts. This is used to derive the tangential stress coefficients k_a and k_p (see Appendix 1). DAN-W assumes that all materials are frictional when they deform internally. A zero value should be used for fluids. NOTE: A default value of the internal friction angle is set to 35°, which is appropriate for dry fragmented rock. The user should experiment with other values, although generally, the model is not too strongly sensitive to it.

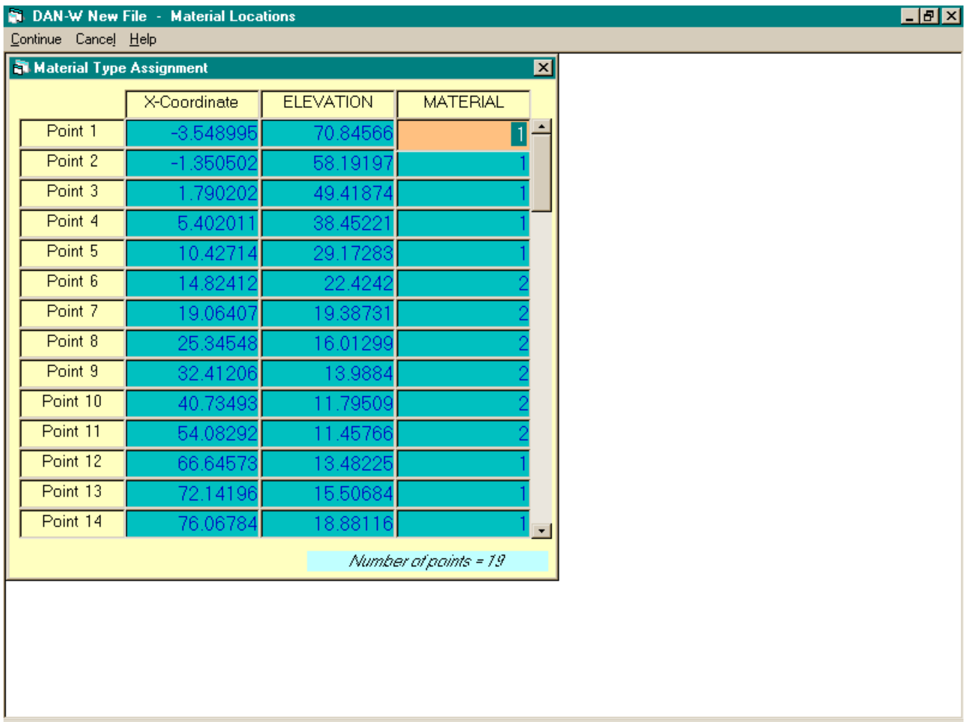
Each material is assigned a colour, shown in the top row of the table. These colours are used to draw the material segments in the isometric or profile view of the problem. To add a material, place the cursor in the next available column in the table. To insert a material in front of another material, place the cursor on the column where the new material is to be inserted. Then select the *Insert Material* option from the menu. To delete a material, place the cursor on the column to be deleted and select the *Delete Material* option from the menu.

The *Continue* option in the menu will accept all the input data and either return to the main menu or continue to the next input screen in the New File Sequence. The *Cancel* option will ignore any changes made in this screen and return to the main menu. Note that choosing Cancel during the New File Sequence will cancel the new file completely.

C.6 Material locations screen

The Material Locations screen, shown in Figure 7, is accessed through the *Edit-Material Locations* option in the main menu, or as the final screen in the New File Sequence. This screen allows the user to determine the location of each material segment along the length of the slope profile. The coordinates of all the points input in the Edit Path screen are shown on the left of the table. The user can set what material is located at which path segment(s) by inputting the appropriate material's code number in the MATERIAL column. If no or the wrong material code is given, then DAN-W automatically assumes the first material. The material properties of each element change when a new segment is entered by it. Sometimes, two materials can be identical, but differ in erosion depth.

The *Continue* option in the menu will accept all the input data and return to the main menu.



	X-Coordinate	ELEVATION	MATERIAL
Point 1	-3.548995	70.84566	1
Point 2	-1.350502	58.19197	1
Point 3	1.790202	49.41874	1
Point 4	5.402011	38.45221	1
Point 5	10.42714	29.17283	1
Point 6	14.82412	22.4242	2
Point 7	19.06407	19.38731	2
Point 8	25.34548	16.01299	2
Point 9	32.41206	13.9884	2
Point 10	40.73493	11.79509	2
Point 11	54.08292	11.45766	2
Point 12	66.64573	13.48225	1
Point 13	72.14196	15.50684	1
Point 14	76.06784	18.88116	1

Figure 7: Material Locations screen.

C.7 Edit path/top screen

The Edit Path/Top screen, shown in Figure 8, is accessed through the *Edit-Path* or the *Edit-Top* options in the main menu, or as the third screen in the New File Sequence. This screen allows the user to input and edit the problem's slope (path) and sliding mass (top) profiles. The coordinate system used in this screen is described in Section B.3.

The data, prepared as described in Section C.1, can be input graphically by clicking the mouse in the appropriate positions on the screen. Alternatively, data can be input numerically in the provided table. Points can only be input from left to right, without forming vertical steps or overhangs.

Points can be inserted between two existing points by selecting the *Points-Insert Point* option from the menu and clicking either on the screen or in the table in the desired position. Points can be deleted by selecting the *Points-Delete Point* option from the menu and clicking the point to be deleted on the screen or in the table. All the points in the selected line can be deleted by selecting the *Points-Delete Line* option from the menu.

The user can toggle between the path profile and the top profile on the menu. The current profile being edited is drawn in red, while the other profile is drawn in blue. If the user selected a uniform thickness top surface in the Control Parameters screen, then only the first and last data points entered for the top surface will be read. These two points will determine the front and the rear of the slide mass, while the slide mass in between these points will follow the path profile at the uniform thickness specified. The thickness will be measured according to the type of boundary block geometry chosen in the Options screen (either normal or vertical). It is recommended that normal slices be used with the uniform thickness option.

As the points are entered, the spline function, which DAN-W uses to smooth out the path profile for analysis, appears as a purple line. The input points should be strategically placed, so that the spline will approximate the actual path profile to the maximum extent. In case of uneven paths, this may require insertion of additional points in some location. The front and the rear of the slide mass (first and last points in the top profile) should coincide with points on the path profile. To simplify this process, this screen has a built-in “snap” function that automatically snaps points together when they are close together.

IMPORTANT NOTE: The profile actually analysed by DAN-W is the spline profile, shown by the purple line. The red lines on the input screen are merely straight line connections between adjacent points.

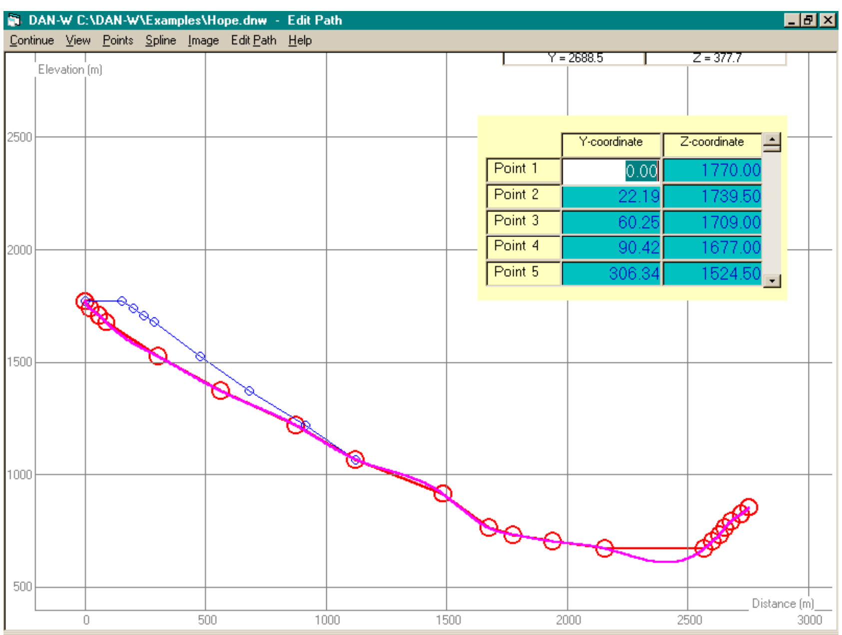


Figure 8: Edit Path/Top screen. In this figure, the path is selected in red, while the spline interpolation is drawn over it in purple. The top profile is drawn in blue.

As an alternative, the input points can be entered in the table on the upper right side of the screen. Points can also be inserted or deleted directly in the table. To prevent obstruction of screen graphics, the table can be dragged to any position on the screen. It can also be made invisible by right-clicking the mouse.

A background bitmap image can be loaded and scaled to the screen coordinates to allow the user to trace a pre-drawn cross-section. Loading and scaling an image is done by choosing the *Image-Load Image* option in the menu. Once an image is loaded, the user is asked to input the coordinates of two known points on the image. These two points must be located on the bottom left and the top right of the picture, as shown in Figure 9. The user is then asked to locate these two points on the image shown on the screen. Note that the more precisely these points are located on the image, the better the image scaling will correlate with the screen coordinate system. The image should then scale itself to the screen. The image can be unloaded or rescaled by selecting the appropriate option under the *Image* menu. The image will remain in the background of this screen as long as the current file remains loaded in DAN-W or until the *Unload* option in the menu is chosen. Sometimes the scaling may become distorted during editing operations. The best way to correct this is to unload the image and re-load it again.

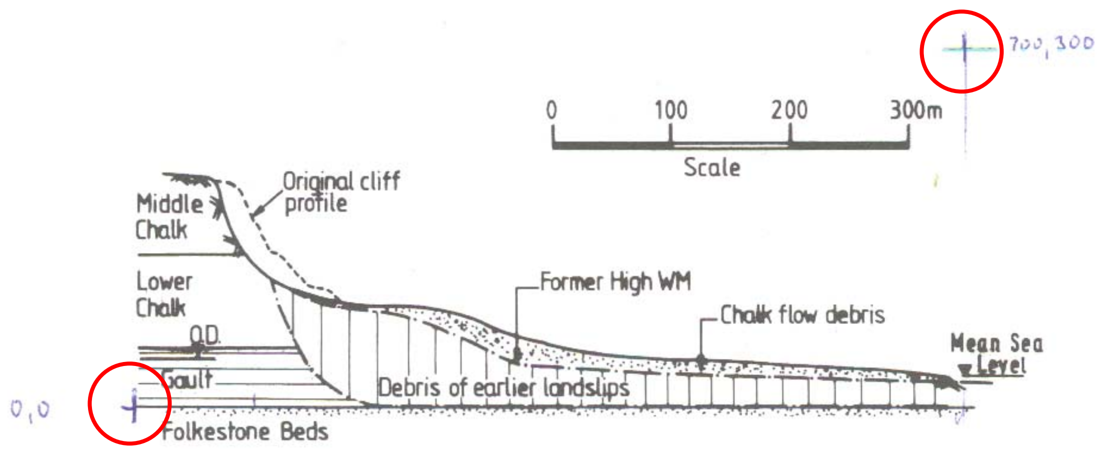


Figure 9: Example of a scanned image with known coordinates marked in blue at the bottom left and upper right corners of the image.

The screen can be zoomed in or out to help with the graphical input of points. To zoom in, select the *View-Zoom In* option in the menu and click the centre of the desired region. To zoom in on a specific rectangular region, select the *View-Zoom Box* option then click and drag across the region to be zoomed. Click the Zoom button in the bottom left of the screen to zoom in on the red extents drawn on the screen. To zoom out, select the *View-Zoom Out* option in the menu. The *View-Fit to Screen* option will return the screen to its original zoom position.

Pressing and holding the SHIFT key and the left mouse button together, allows the user to drag the profile (including the background image) across the screen. This is useful when tracing images at higher zoom levels.

The *Continue* option in the menu will accept all the path and top geometry data and will return to the main menu or to the next screen in the New File Sequence. Alternatively, the user can continue to the Edit Width Screen by choosing *Edit-Edit Width* from the menu. In either case, the user will be warned if the path or top geometry has been input incorrectly or is incomplete and will not be allowed to continue.

C.8 Edit width screen

The Edit Width screen, shown in Figure 10, is accessed through the *Edit-Width* option in the main menu or as the fourth screen in the New File Sequence. This screen is used to input or edit the channel width and is not accessible in the two-dimensional configuration. The data should be prepared as described in Section C.1. This screen functions like the Edit Path/Top screen (see previous section), except that the vertical axis represents the channel width (in metres). The width of the problem should be completely defined by the user between the two purple lines. NOTE: Initially, when a file is being created, there is a default line defined by two points, with a uniform width of 1m (as in 2D configuration). These points can be dragged to correct locations and new points are then added.

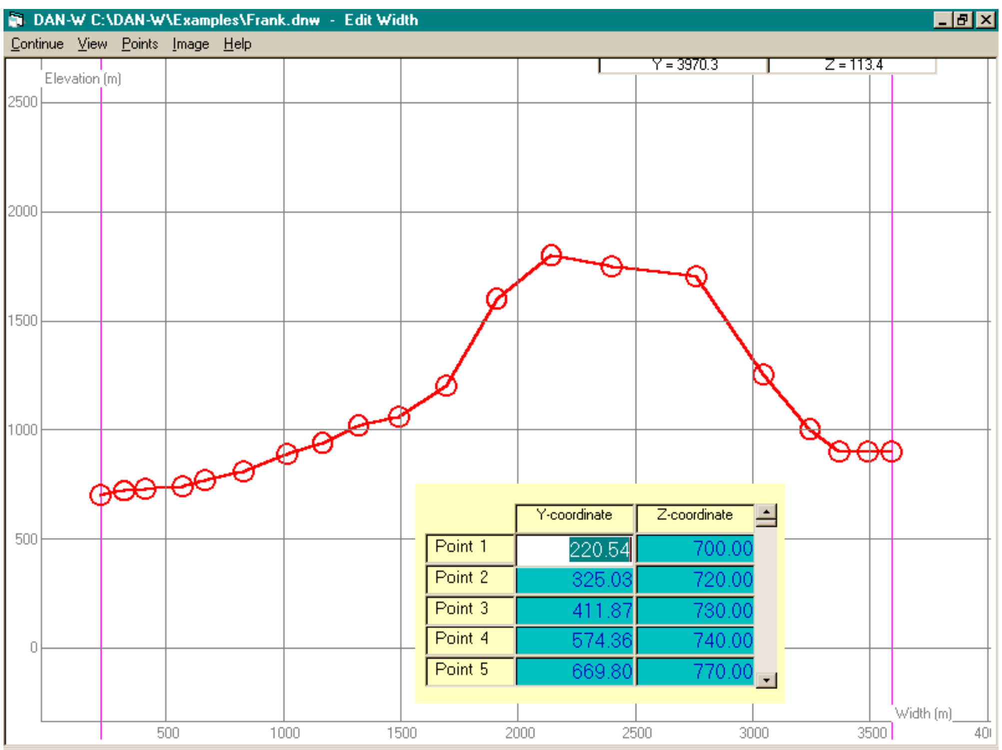


Figure 10: Edit Width screen.

C.9 Options screen

The Options screen, shown in Figure 11, is accessed through the *Edit-Options* or the *View-View Options* selections in the main menu. This screen has three tabs, allowing the user to edit various boundary, display, and analysis options.

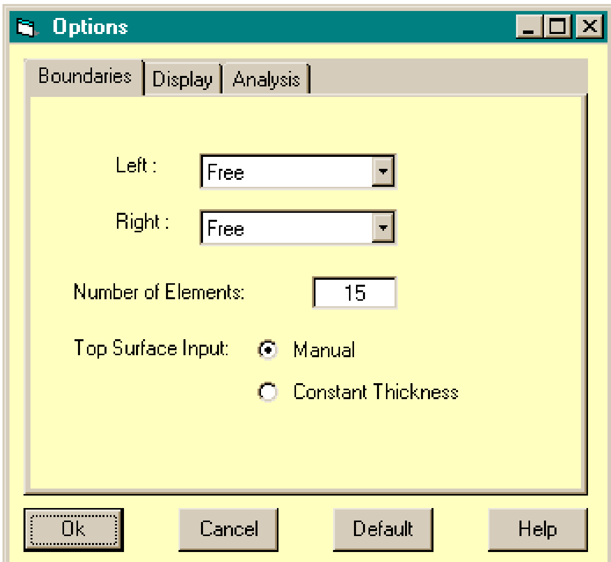


Figure 11: Options screen.

The following is a list of all the options with a brief description of each:

Boundaries Tab:

The options under this tab are also accessible in the Control Parameters screen.

- LEFT AND RIGHT BOUNDARIES: These options allow the user to fix the rear (left) or front (right) of the slide mass during analysis. For further details, please refer to Section C.4. Default = *Free*.
- NUMBER OF ELEMENTS: This option allows the user to specify the number of mass elements that the slide mass is to be split into. The recommended minimum is 50.
- TOP SURFACE INPUT: This option allows the user to choose the type of data input used to define the top surface. The *Manual* option requires that the user input data points through the Edit-Top screen. The *Uniform Thickness* option allows the user to input a slide mass of uniform thickness above the path profile, as described in Section C.4. Note that the thickness must be defined in the Control Parameters screen otherwise it defaults to 1 metre. Default = *Manual*.

Display Tab:

- PROJECTION ANGLE: This option allows the user to choose a projection angle in degrees for the three-dimensional isometric plot displayed in the main screen. This angle should be between 0 and 90 degrees. Default = 30.
- ENLARGEMENT OF FLOW DEPTH: This option allows the user to input a normal (or vertical) depth exaggeration ratio to help view the profile of very thin landslides. A value of 1 means no exaggeration. Default = 1. Note that the exaggeration ratio will also affect graphical output options. Large exaggeration ratios may induce apparent irregularities of the flow surface in highly curved paths. The depth exaggeration ratio has no effect on the analysis.
- PLOTTING MODE: This option allows the user to choose the type of plot shown in the main screen. If *Isometry* is chosen, an isometric view of the problem is shown in the main screen and is defined by the projection angle described above. If *Depth Profile (2D)* is chosen, the sliding mass's velocity and thickness profiles are plotted on the screen. These plotting modes are described in greater detail in Section D.1. Default = *Isometry*.
- VELOCITY EXTENTS: This option allows the user to specify the extents of the vertical axis of the velocity graph displayed in the main screen when the plotting mode is set to *Depth Profile (2D)*. This option essentially allows the user to zoom in or zoom out on the velocity profile. It is only available when the Depth Profile option is chosen. Default = *0 - 50 m/s*.
- OBSERVATION POINT: This option allows the user to place an observation point anywhere along the length of the path profile, as described in Section E.5. Default = *Off*.
- LOCATION ALONG X-AXIS: This option allows the user to specify the location of the observation point along the x-axis. It is only available when the Observation Point option is turned on. Default = 0.
- ANIMATION SPEED: UPDATE GRAPHICS EVERY … SECONDS: This option allows the user to specify how often the screen graphics are updated during analysis. A larger number causes the graphics to be redrawn fewer times during the run and hence increases the speed of the analysis. The animation, however, becomes less smooth. Note that this option affects the screen graphics only. Background analysis calculations still occur for every time step regardless of the animation speed. Default = 0.02 sec.
- LINES: This option allows using thick or thin lines in drawing the display.

Analysis Tab:

IMPORTANT NOTE: The following five parameters have an influence on the analysis process. It is recommended that the default values be used for routine work.

- SMOOTHING COEFFICIENT: This coefficient controls the intensity of the velocity smoothing process, as described in Appendix 1. It is recommended to accept the default value of 0.02, to which the automatic time step evaluation is calibrated. Specifying the coefficient as zero will turn off the velocity smoothing process.

- TIP RATIO: This option allows the user to define the shape of the first and last mass elements on the slide mass. A ratio of 0.5 represents triangular end elements, while a ratio of 1 represents rectangular end elements. Default = 0.5.
- STIFFNESS COEFFICIENT: This option allows the user to modify the stiffness coefficient, which is described in Hungr (1995). Default = 0.05.
- STIFFNESS RATIO: This option allows the user to modify the ratio between the unloading and loading stiffness, which is described in Hungr (1995). Default = 5.
- CENTRIFUGAL FORCES: This option allows the user to turn on or off the centrifugal forces caused by the curvature of the slope profile. Default = *On*.
- TRAJECTORY LAUNCH: This option turns on or off the option of the landslide launching into ballistic trajectory, as described in Section D.4. Default=*Off*.
- BOUNDARY BLOCK GEOMETRY: This option allows the user to choose between boundary blocks created by vertical slices or slices that are normal to the path. Vertical slices should be used if the rupture surface in the source area is highly curved. If normal slices were to be used in this situation, the geometry of the sliding mass would be distorted, as explained in Section C.2. Default = *Normal*.
- PRESSURE TERM: Recent research showed that the Savage-Hutter assumption of lateral stresses between slices may be incorrect in some cases, particularly those involving a large amount of lateral spreading (see Hungr, 2008, re-print attached with program package). Releases 8 and higher default to the Modified Savage-Hutter assumption, as described in the paper, which usually yields the best results. Other alternative assumptions, also described in the paper and in Section A.4 of Appendix 1, can be selected on the Edit/Options screen, but are not recommended.

D ANALYSIS

D.1 Graphics

Once all the data input is complete, two types of plots can be drawn in the main screen, as listed under the *View* option in the main menu. The default plot shows an isometric view of the slope and sliding mass profiles. An example is shown in Figure 12. This view shows one half of the entire channel from the central cross-section out to the left margin of the flow path. The grid lines on the screen relate to the central cross-section. The projection angle and vertical exaggeration of the profile can be defined in the Options screen. The sliding mass is drawn in black, while the slope profile is drawn in the appropriate material segment colours, as defined in the Material Locations screen. The boundary blocks within the sliding mass are shown in black when expanding, in red when under compression, or in blue when in ballistic trajectory.

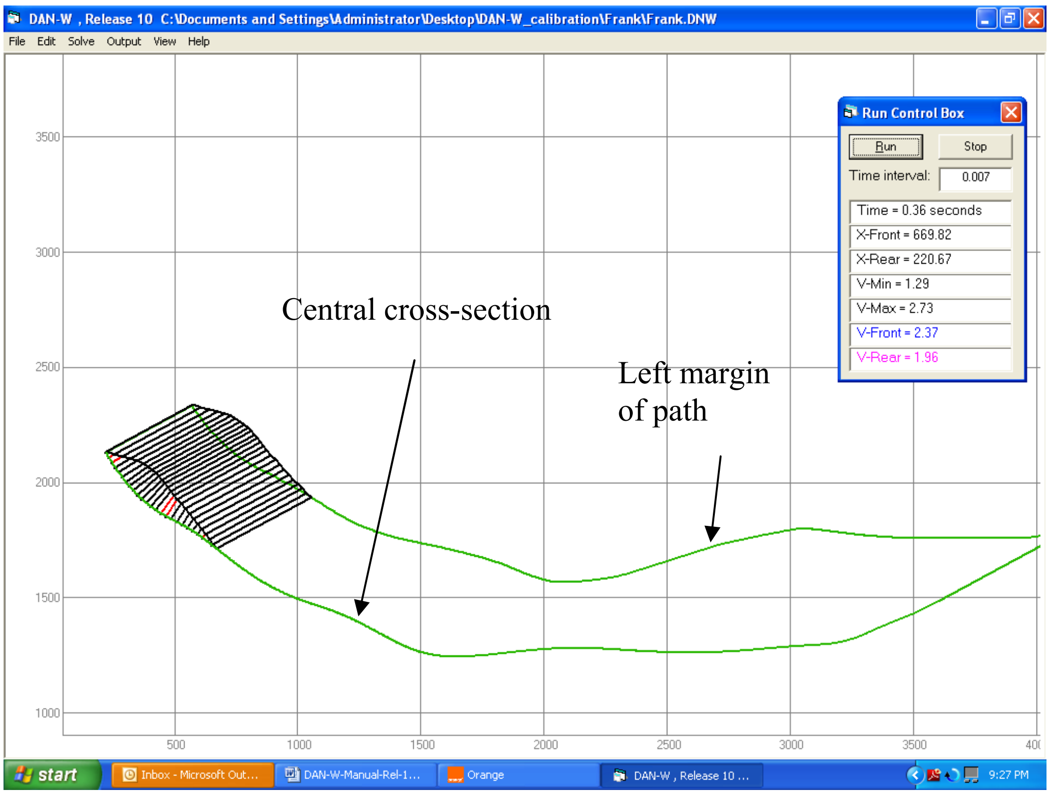


Figure 12: Three-dimensional isometric view.

The second type of plot shows a two-dimensional depth profile of the sliding mass. It consists of two graphs, one above the other, as shown in Figure 13. The upper graph shows the current velocity profile of the sliding mass (drawn in black), as well as the front velocity (drawn in blue) and rear velocity (drawn in purple) for each time step. The lower plot shows the thickness profile of the sliding mass, including the current location of all the boundary blocks (black normally and red if under compression). It also shows the current erosion or deposition profile in the appropriate material colours. The various material segments throughout the profile are also drawn for reference along the length of the x-axis, in their corresponding colours. During an analysis, if the velocity profile runs

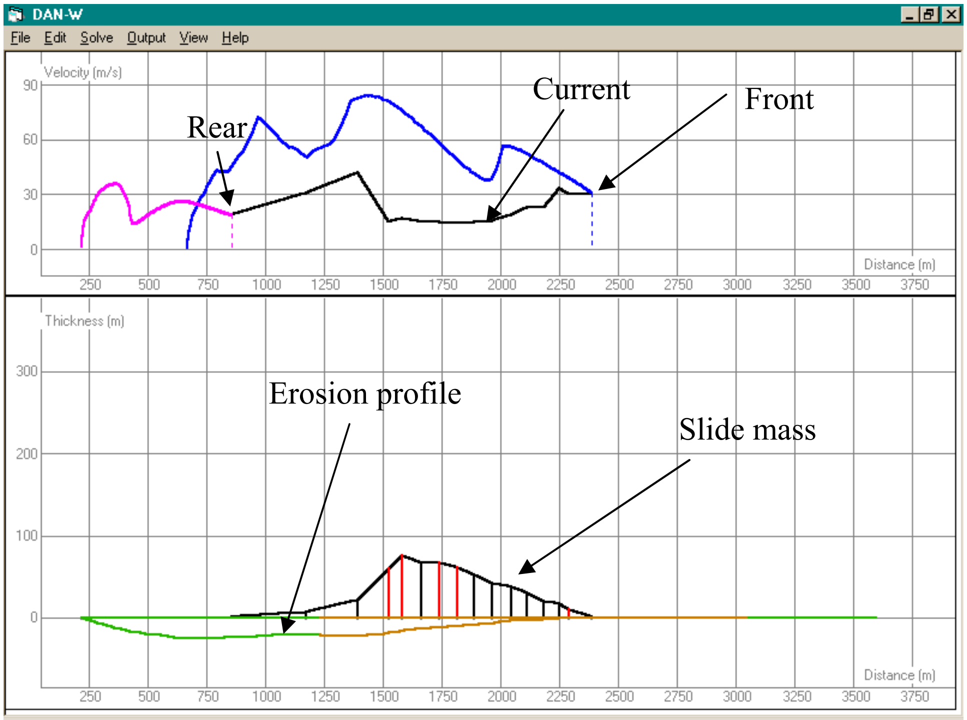


Figure 13: Two-dimensional depth profile view.

beyond the current extents of the graph, it automatically rescales itself. The extents of the velocity plot can also be set manually, as described in Section C.9.

The user can switch between these two plotting modes during an analysis. The run must first be paused and then the plotting mode can be chosen either through the *View* menu or through the *Display* tab in the Options screen (which can also be accessed through the *View* menu by selecting *View-View Options*).

D.2 How to run an analysis

To run an analysis on a problem, select the *Solve* option from the main menu or press Ctrl+R on the keyboard. This opens the Run Control Box which controls the analysis run. The analysis always begins with the sliding mass in its initial static condition, as drawn in the main screen. Once the run begins, the sliding mass is animated with each time step in the main screen. The speed of the animation can be set in the Options screen under the Display tab (see Section C.9).

D.3 Run control box

The Run Control Box, shown in Figure 14, is activated when the *Solve* option is selected from the main menu. This box controls the analysis run of the problem. The time step for the calculation is set automatically by the program, depending on the number of elements and the length of the path. Although it is possible to change the time step value in this window, the use of the default value is recommended for most analyses.

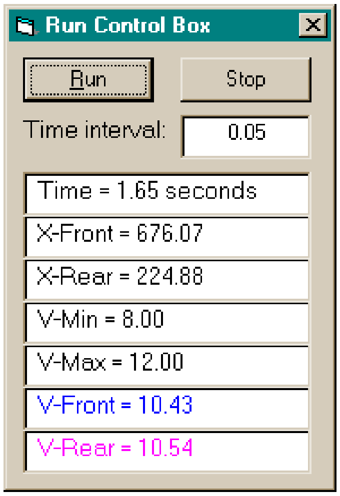


Figure 14: Run Control Box.

To begin the run, click the *Run* button or press Enter on the keyboard. The run can be paused by pressing the *Pause* button. Pressing *Run* again will continue the analysis from where it left off. Pressing *Stop* will finish and exit the run. Note that the plotting type (as described in Section D.1) can be changed in the Pause mode.

As the problem is running, data calculated at each time step is displayed. The following is a list of the displayed output along with a brief description of each:

- TIME: The total model time elapsed from the beginning of the run (seconds).
- X-FRONT: The current position of the front of the sliding mass along the horizontal axis (metres).
- X-REAR: The current position of the rear of the sliding mass along the horizontal axis (metres).
- V-MIN: The velocity of the slowest boundary block in the slide mass at the current time (m/s).
- V-MAX: The velocity of the fastest boundary block in the slide mass at the current time (m/s).
- V-FRONT: The current velocity of the front of the sliding mass (m/s).
- V-REAR: The current velocity of the rear of the sliding mass (m/s).

More detailed output can be accessed during the Pause mode by selecting the *Output-Report* option in the main menu. Please refer to Section E.1 for a description of this screen.

When the run is stopped and exited, ASCII graph files are created if the user requested it prior to the beginning of the run. Before completely exiting the run mode, the user is given the chance to view the final Report for the problem as well as Observation Point data if it exists.

D.4 Analysis options

1) Normal and Vertical Elements.
The DAN algorithm (Hungr, 1995) was originally created in terms of a depth-integrated Lagrangian solution, referenced to columns normal to the path. This is still considered the most reliable form of the solution, although the normal slice construction necessarily distorts the geometry in case of deep and strongly curving paths (cf. example problem SLUMP.DNW). The present version of the program also offers a solution formulated in terms of vertical slices. The selection is made on the Edit/Options screen. The advantage of vertical slices is that the geometry is not distorted on curved paths. Usually, there is not a very strong difference between the results of the two forms in cases where only gentle slopes are involved. On steeper slopes, the vertical mode may give somewhat different results. While the normal mode is probably superior, the results of a vertical run may need to be considered in some cases in the interest of conservatism.

2) Trajectory flight.
A new feature has been added in Release 7, that makes the flowing mass launch into a balistic trajectory when the normal stress on the base of the flow falls to zero. On screen

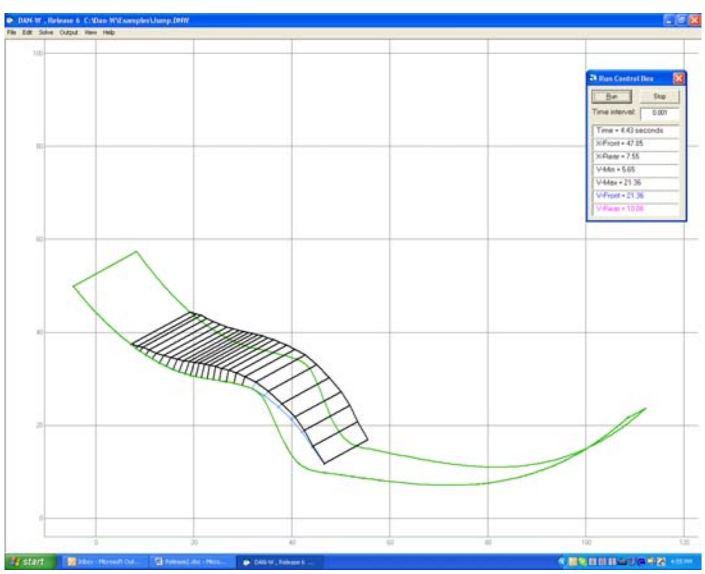


Figure 15. Trajectory flight

plots, a trajectory segment can be identified when the boundary elements appear in blue colour (see Figure 15). While in trajectory, no base resistance acts on the slide, regardless of the rheology. On landing, each element loses all of its momentum that is normal to the path at that point.

Tangential (downslope) momentum parallel with the local base is conserved. It is to be noted that this may be a conservative assumption in very strong (highly perpendicular) impacts. Under such conditions, the trajectory model may lead to overestimation of runout. When a strong impact occurs and the above method predicts a momentum loss of more than 20% for this impact and for the leading element, the program pauses and a dialog box appears, with the following information:

Large Impact:
Predicted loss of momentum amounts to 23%.
Enter estimated value of total momentum loss in %.

Press "OK" if you wish to retain the estimated percentage of momentum loss. Otherwise, you can enter your own estimate of the energy loss (ranging from 0 to 100%). The momentum loss you specify will be used for all "large" impacts from this point on. "Small" impacts (momentum loss <20%) will still be treated in the standard way, as specified at the beginning of this paragraph.

The trajectory option is turned OFF by default, but can be turned on in the EDIT/OPTIONS/ANALYSIS. It is always off when vertical slices are used.

IMPORTANT WARNING: No verification benchmark tests involving the trajectory option have so far been completed.

D.5 Model instability

The velocity smoothing algorithm is analogous to numerical damping used in many numerical dynamic models to reduce instability. As such, it can have a certain effect on the longitudinal spreading of the sliding mass. This influence could distort the results under certain circumstances, when very small time interval is used. The program has therefore been provided with a mechanism by which the time interval is set automatically, to a value that has yielded reliable results in a range of benchmark cases. The time interval is proportional to the number of elements. Therefore, smaller number of elements will need less time. The number of elements usually does not influence the runout results very strongly.

IMPORTANT NOTE: Do not use time intervals that are significantly smaller than the interval set automatically by the program.

Solution instability may still occur in certain problems. It generally manifests itself by series of translating waves, which rise in the rear of the slide mass and propagate to the front. If such waves are observed, it is advisable to decrease the time interval from that set automatically by a factor of 2 (but not more than a factor of 5).

EXAMPLE: The example "SLUMP.DNW, enclosed with the program package, illustrates the effects of instability. When run with normal slices (elements) and with the automatically-set time interval of 0.0009 secs, the problem exhibits visible instability of the flow front. The front horizontal runout position is 96.72 m and the final horizontal coordinate of the center of gravity is 52.88 m. When the time interval is reduced to 0.0002 secs, the translatory waves disappear and the front stops at x=84.30 and the center of gravity at 52.18 m. This result is considered to be superior in this case. The effect is even stronger when vertical slices are used.

In general, it is recommended to reduce the time interval only where instability is clearly apparent and only by the least amount necessary to remove the instability.

D.6 Verification testing

Releases 8 to 10 were checked against all of the verification benchmarks that were used to verify the original model and published in Hungr (1995). New benchmarks, specifically involving spreading flows are described in Hungr (2008). Comparisons between DAN-W and DAN3D are described in Hungr and McDougall (2008). New verification testing involving run-up against steep adverse slopes and accompanied by shocks (representing run-up of flowing granular material against protective dykes) has recently been completed (Mancarella and Hungr, in review, 2010, pre-print included with the program package). The results indicate that DAN-W run-up predictions tend to be conservative in case of runup against steep adverse slopes.

E DATA OUTPUT

E.1 Report

The Report screen, shown in Figure 16, can be accessed by selecting the *Output-Report* option in the main menu. This screen displays all the calculated values output during problem analysis. The screen can be opened when a run is paused, as described in Section D.3, or after the full completion of the run. The screen can also be printed by selecting the *Print* button. The data displayed in this screen is described in the next section. To export this data along with a list of materials and their properties into a text file, select the *Export* button. This opens a screen where an appropriate folder can be chosen to save the data in. Clicking *Export* in this screen creates a file called OUTPUT.TXT. In this file, all numerical values are tab delimited from their corresponding text descriptions. This allows the user to open the file in a spreadsheet program.

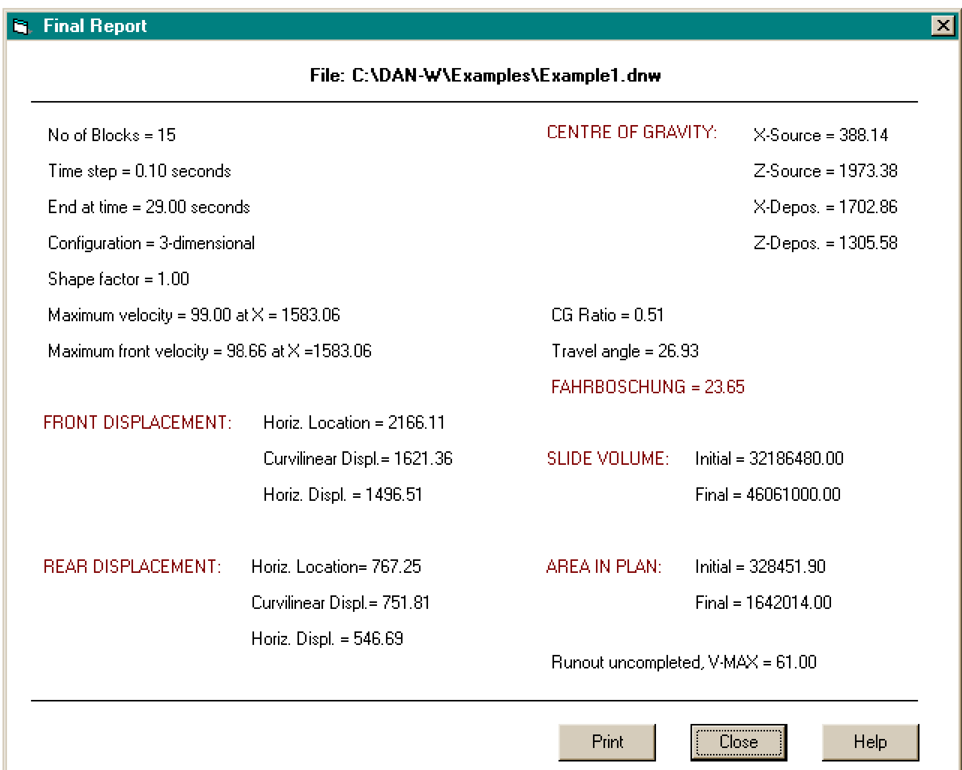


Figure 16: Sample Report screen.

E.2 Output data

The following is a list of the output values displayed in the Report screen along with a brief description of each:

- NUMBER OF ELEMENTS: The number of mass elements in the slide mass.
- TIME STEP: The time step used during analysis (seconds).
- END AT TIME: The total time elapsed since the beginning of the run (seconds).
- CONFIGURATION: Two-dimensional or three-dimensional configuration.
- SHAPE FACTOR: The cross-section shape factor used to define the shape of the channel cross-section.
- MAXIMUM VELOCITY: The maximum velocity reached by any boundary block during the whole run (m/s), occurring at the given horizontal distance (metres).
- MAXIMUM FRONT VELOCITY: The maximum velocity reached by the front of the slide mass during the whole run (m/s), occurring at the given horizontal distance (metres).
- FRONT DISPLACEMENT:
    - HORIZONTAL LOCATION: The final location of the front of the slide mass along the horizontal axis (metres).
    - CURVILINEAR DISPLACEMENT: The total displacement of the front of the slide mass along the path profile (metres).
    - HORIZONTAL DISPLACEMENT: The total horizontal displacement of the front of the slide mass (metres).
- REAR DISPLACEMENT:
- Same as for Front Displacement except for the rear of the slide mass.
- CENTRE OF GRAVITY:
    - X-SOURCE / Z-SOURCE: The coordinates of the centre of gravity of the initial, time zero position of the slide mass (metres).
    - X-DEPOSIT / Z-DEPOSIT: The coordinates of the centre of gravity of the slide mass at the end of the run (metres).
- CG RATIO: The ratio between the total vertical displacement of the centre of gravity and the total horizontal displacement of the centre of gravity of the slide mass (dimensionless).
- TRAVEL ANGLE: The horizontal angle between the original centre of gravity and the final centre of gravity (degrees).
- FAHRBÖSCHUNG: The horizontal angle between the original rear of the sliding mass and the final front of the sliding mass (degrees).
- INITIAL / FINAL SLIDE VOLUME: The initial and final volumes of the slide mass (m^3).
- INITIAL / FINAL AREA IN PLAN: The initial and final area in plan of the slide mass (m^2).
- RUNOUT UNCOMPLETED, V-MAX: The problem was not allowed to settle. The maximum velocity for the total run is displayed (m/s).

- RUNOUT TIME: The time it took the slide mass to completely settle (seconds).

E.3 How to create ASCII graph files

DAN-W can produce *.DAT data files in text (ASCII) format, which can be used to plot profiles using GRAPHER (TM, Golden Software Inc.), EXCEL or any other graphing software, including most spreadsheets programs. The types of profiles created and their format are described in Section E.4.

To create ASCII graph files, select the *Output-Export ASCII Graph Files* option in the main menu and then select the *Create ASCII Graph Files* option on the form that appears. This enables the rest of the labels on the form, as shown in Figure 17. Choose a time interval at which you want data to be collected for the profile plot and for the velocity plot. It is recommended that the velocity plot have a smaller time interval than the profile plot. Note, if you choose a time interval of zero, no files will be created. Next, choose a folder in which to save the graph files in. Be careful not to choose a folder that already contains other graph files of the same name, because they will be overwritten. Choose OK to accept the information entered on the form. Now, to create the graph files, the problem must be analyzed, as described in Section D.2. Once the run is stopped, a message will be displayed notifying the user that the files have been created in the chosen folder. Note that the vertical enlargement ratio, described in Section C.9, can be used to make the data files more clear.

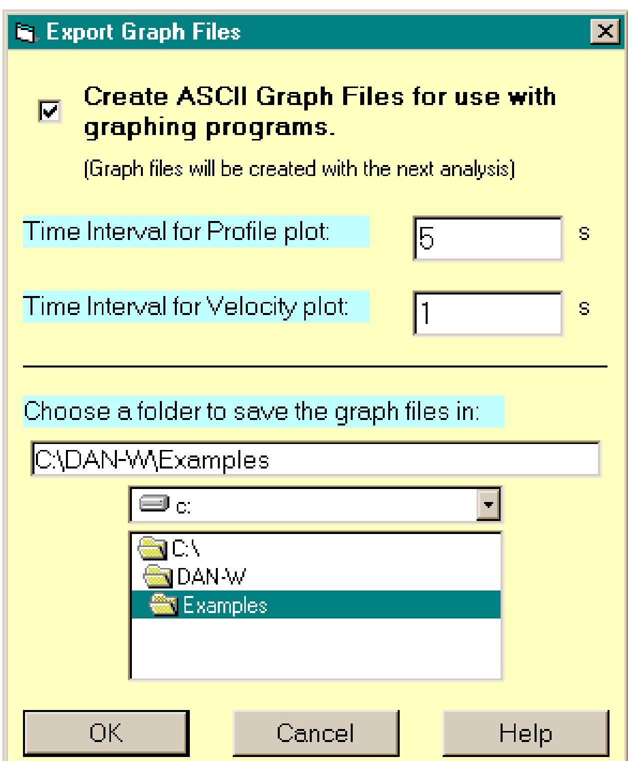


Figure 17: Export Graph Files screen.

E.4 ASCII graph file types

ASCII graph files containing profile data can be created by DAN-W, as described above. The following is a list of the eight types of *.DAT graph files created. Note that the column headings do not appear in the file, each column is tab delimited, and that the "a" characters are read as empty cells.

- PR.DAT: Records at first the path profiles (original and modified by erosion or deposition), then the slide mass profiles at the specified time intervals. An example of the format of the file is shown below. A sample plot created from this data file is shown in Figure 18.

X-Path	*Y-Path*	*Width*	*X-Dep*	*Y-Dep*	*Y-Top$_1$*	*Y-Top$_2$*
0.00	10.00	2.00	0.00	10.00		
0.10	9.95	2.00	0.10	9.95		
0.20	9.90	2.00	0.20	9.89		
0.30	9.85	2.00	0.29	9.84		
etc…						
0.03	"a"	"a"	"a"	"a"	10.05	
0.50	"a"	"a"	"a"	"a"	10.00	
1.00	"a"	"a"	"a"	"a"	10.00	
1.48	"a"	"a"	"a"	"a"	9.96	
1.83	"a"	"a"	"a"	"a"	9.67	
2.08	"a"	"a"	"a"	"a"	9.16	
0.04	"a"	"a"	"a"	"a"	"a"	10.05
0.50	"a"	"a"	"a"	"a"	"a"	10.00
0.99	"a"	"a"	"a"	"a"	"a"	9.91
1.60	"a"	"a"	"a"	"a"	"a"	9.66
2.44	"a"	"a"	"a"	"a"	"a"	9.21
etc…						

X-Path: X-coordinate of a point on the path.
Y-Path: Y-coordinate (elevation) of a point on the path.
Width: Path width.
X-Dep.: X-coordinate of a point on the path, modified by erosion or deposition.
Y-Dep.: Y-coordinate (elevation) of a point on the path, modified by erosion or deposition.
Y-Top$_1$: Y-coordinate of the top of each boundary block during the first profile time interval.
Y-Top$_2$: Y-coordinate of the top of each boundary block during the second profile time interval.

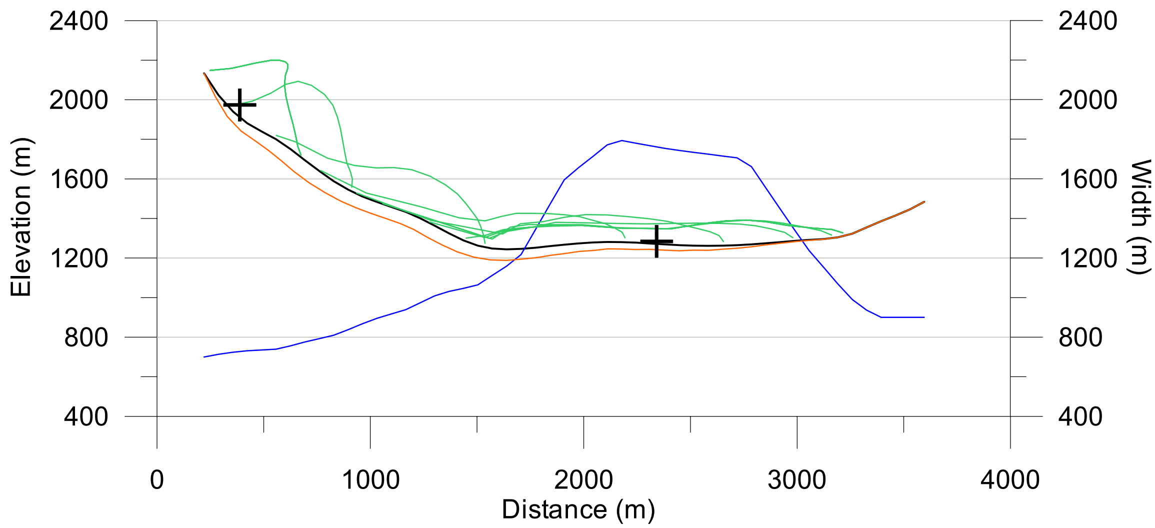


Figure 18: Sample profile plot created from PR.DAT, using GRAPHER (TM, Golden Software Inc.). Black is the path profile; green is the top profile; orange is the erosion profile; blue is the channel width; crosses indicate initial and final centres of gravity of the slide mass, taken from CG.DAT.

- TR.DAT: Records velocities and positions of the front and rear of the mass, vs. time. A sample plot created from this data file is shown in Figure 19.

Time	*X-Rear*	*V-Rear*	*X-Front*	*V-Front*	*V-Max*	*V-Min*	*X-CG*
0.00	0.00	0.00	2.00	0.00	0.00	0.00	1.16
0.10	0.00	0.08	2.04	0.82	0.82	0.00	1.18
0.20	0.01	0.07	2.14	1.58	1.58	0.00	1.22
0.30	0.01	0.00	2.32	2.31	2.31	0.00	1.28
0.40	0.01	0.00	2.55	2.96	2.96	0.00	1.37
0.50	0.01	0.00	2.85	3.53	3.53	0.00	1.49
0.60	0.01	0.00	3.18	4.03	4.03	0.00	1.63
etc…							

Time: Time in seconds, depending on the specified interval.
X-Rear: X coordinate of the rear of the sliding mass.
V-Rear: Velocity of the rear of the sliding mass.
X-Front: X coordinate of the front of the sliding mass.
V-Front: Velocity of the front of the sliding mass.
V-Max.: Maximum velocity at the current time.
V-Min.: Minimum velocity at the current time.
X-CG: X-coordinate of the centre of gravity of the flowing mass.

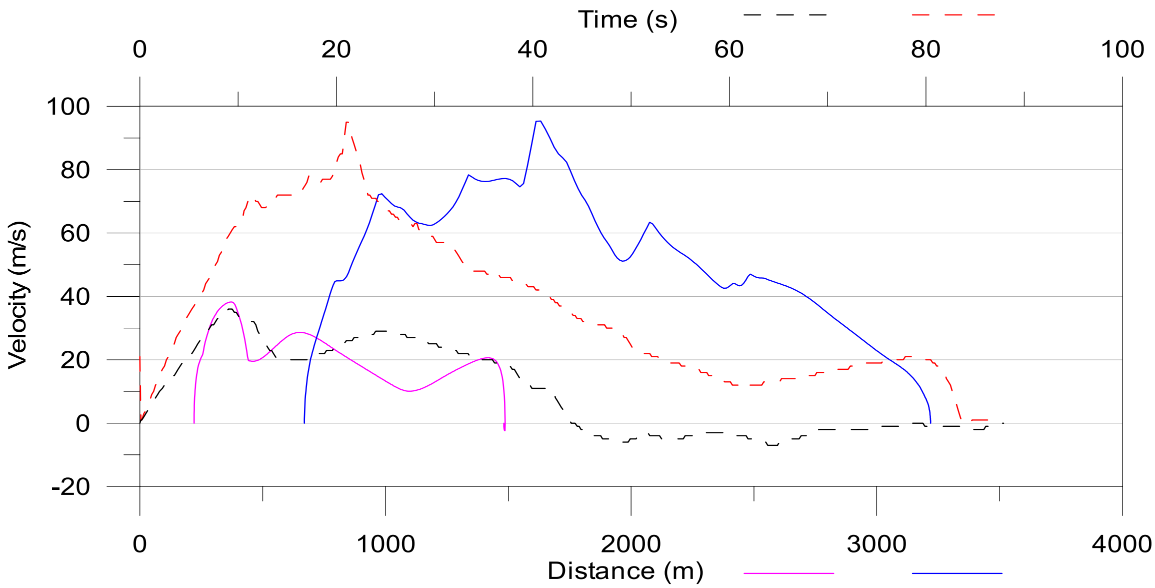


Figure 19: Sample velocity plot created from TR.DAT, using GRAPHER (TM, Golden Software Inc.). Blue is the front velocity vs. distance; pink is the rear velocity vs. distance; red is the maximum velocity vs. time; black is the minimum velocity vs. time.

- VE.DAT: Records the velocity distribution at each profile time interval, as a function of the X-coordinate. A sample plot created from this data file is shown in Figure 20.

X-Slide	*V-Slide$_1$*	*V-Slide$_2$*	*V-Slide$_3$*
-1.461	0.00		
0.285	0.00		
2.07	0.00		
3.857	0.00		
5.647	0.00		
etc…			
-1.455	“a”	0.346	
0.291	“a”	0.334	
2.075	“a”	0.332	
3.863	“a”	0.33	
5.652	“a”	0.328	
etc…			
0.823	”a”	“a”	6.509
2.507	“a”	“a”	6.272
4.317	“a”	“a”	6.23
6.144	“a”	“a”	6.19
7.983	”a”	“a”	6.154
etc…			

X-Slide: X-coordinate of each boundary block in the slide mass during each profile time interval.
V-Slide$_1$: Velocity of each boundary block in the slide mass during the first time interval.

V-Slide$_2$: Velocity of each boundary block in the slide mass during the second time interval.
V-Slide$_3$: Velocity of each boundary block in the slide mass during the third time interval.

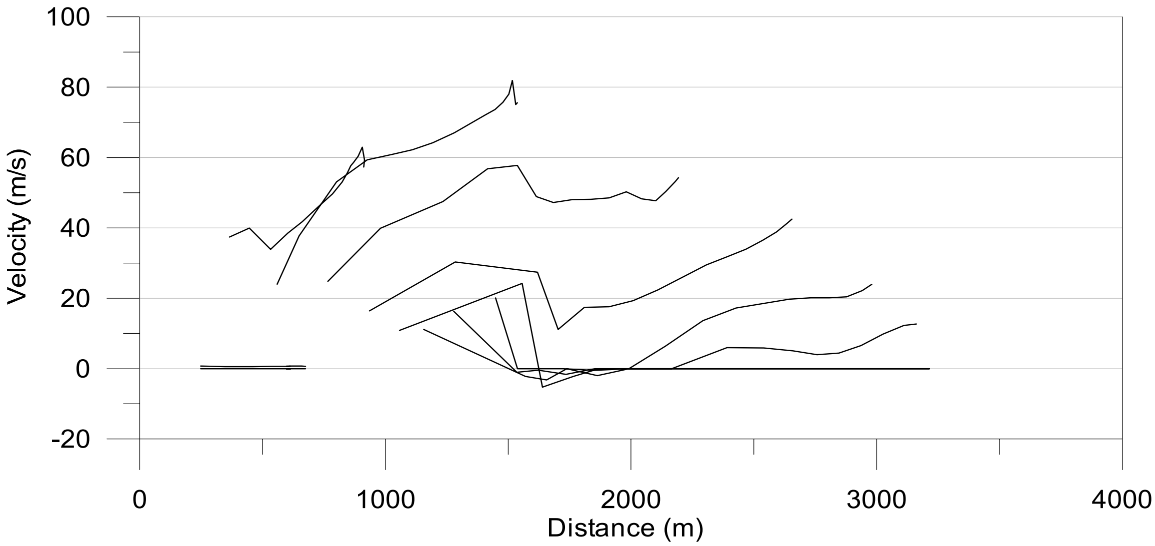


Figure 20: Sample velocity profile plot created from VE.DAT, using GRAPHER (TM, Golden Software Inc.). Each line represents the velocity profile across the slide mass at the same time intervals used in PR.DAT.

- CG.DAT: Records the X and Z coordinates of the centre of gravity before the slide and at the end of runout. This data can be plotted in the profile plot, as shown in Figure 16.

X-CG	*Z-CG*
11.53	52.39
64.72	17.82

X-CG: X-coordinate of the centre of gravity of the flowing mass.
Z-CG: Z-coordinate of the centre of gravity of the flowing mass.

- DE.DAT: Records the erosion or deposition depth distribution at each profile time interval, as a function of the X-coordinate. The format is the same as for VE.DAT.
- HT.DAT: Does the same for flow depths.
- K0.DAT: Does the same for the lateral earth pressure coefficient.
- DIS.DAT: Does the same for discharge.

E.5 Observation point

An Observation Point can be placed anywhere along the path profile to allow the user to monitor the velocity and the thickness of the sliding mass at that point through time. To set an Observation Point, choose the appropriate *On* option in the Options screen. The location of the point can then be specified in the same screen. Once an Observation Point is created, its location is shown in the isometric view by a short blue line on the front cross-section, and in the depth profile by a vertical blue line extending down the screen.

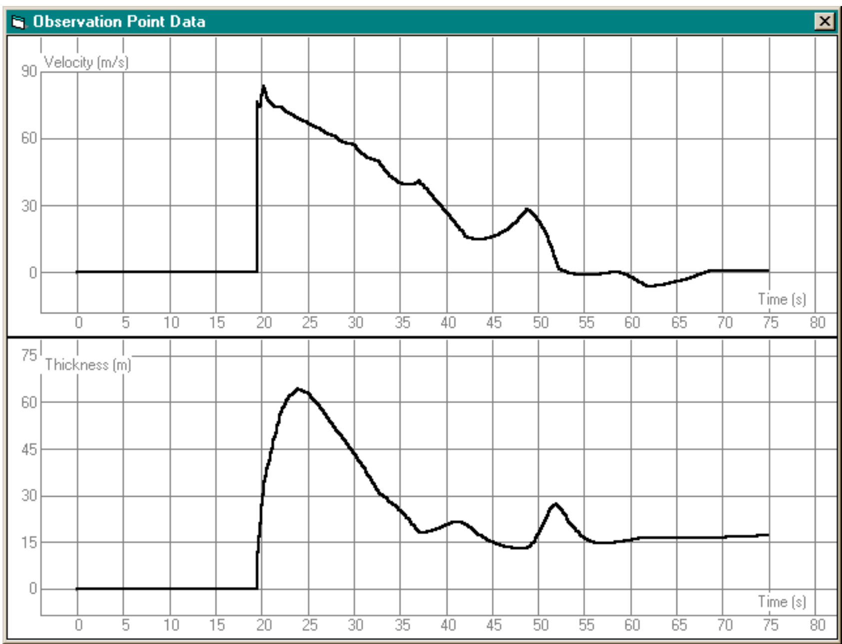


Figure 21: Example of a plot created by DAN-W, showing the velocity and thickness of the slide mass at a specified observation point location.

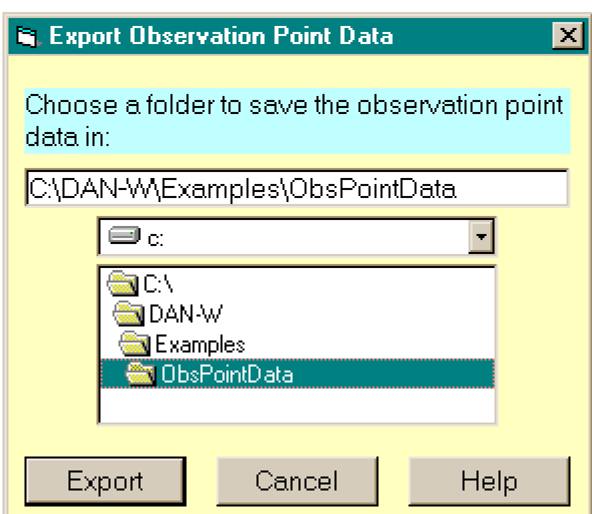


Figure 22: Export Observation Point screen.

After a run has been completed, the user can view a plot of the data collected, by selecting the *Output-Observation Point-View Data* option in the main menu. An example of the plot can be seen in Figure 21. The data can also be exported into a ASCII data file, similar to those described in Section E.4. To export the data, choose the *Output-Observation Point-Export Data* option in the main menu. A form, shown in Figure 22, appears in which the user can choose the appropriate folder to save the file in. When the *Export* button is chosen, the data is saved in the chosen folder under the name OBS.DAT. The first column in this file is time (in seconds) depending on the time interval chosen for the analysis. The second column is the thickness of the slide mass (in metres) at this location for each time interval. The third column is the velocity of the slide mass (in metres per second) at this location for each time interval.

Note that with each subsequent analysis, all the previous Observation Point data stored by DAN-W is replaced by the latest data.

APPENDIX 1

THEORY

The following paragraphs are a summary of the theory described in Hungr (1995 and 2008) and Mancarella and Hungr (2010).

The dynamic model DAN-W is based on the Lagrangian solution of St. Venant's equation. This equation can be derived by applying conservation of momentum to thin slices of flowing mass that are perpendicular to the base of the flow. These "boundary blocks" divide the slide mass into *n* "mass elements" of constant volume and are separated by trapezoidal "mass blocks". If there is no entrainment, each of the mass blocks carries a constant volume of (incompressible) material, so the equation of continuity is implicitly satisfied.

1.1 Normal boundary elements

The original version of the numerical Lagrangian shallow flow model "DAN" (Dynamic Analysis) was developed by Hungr (1995) and bears substantial similarity to the Savage-

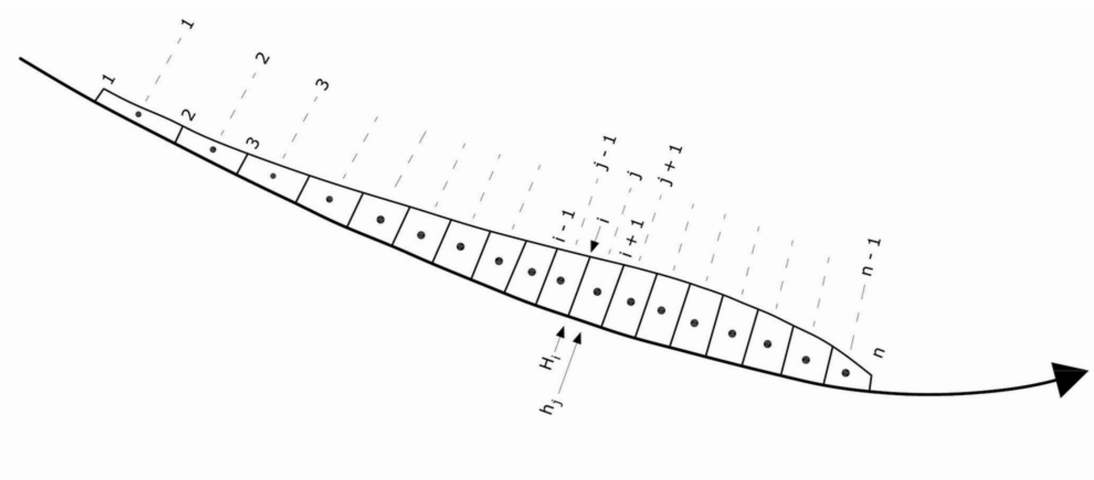


Figure 1.1
Discretization of the Equation of Motion. n boundary blocks of infinitesimal thickness, numbered i, are separated by (n-1) mass blocks, numbered j.

Hutter algorithm (Savage and Hutter, 1989). The equations are referenced to a moving curvilinear coordinate system with s being the local downslope direction, h the bed-normal thickness of the flowing sheet, α the slope angle, ρ density, t time, v mean velocity and k the ratio between bed-normal and bed-parallel (longitudinal) stress within the deforming sheet of material (see Figure 1.2a). Equation [1] is the momentum equation applied to the boundary column:

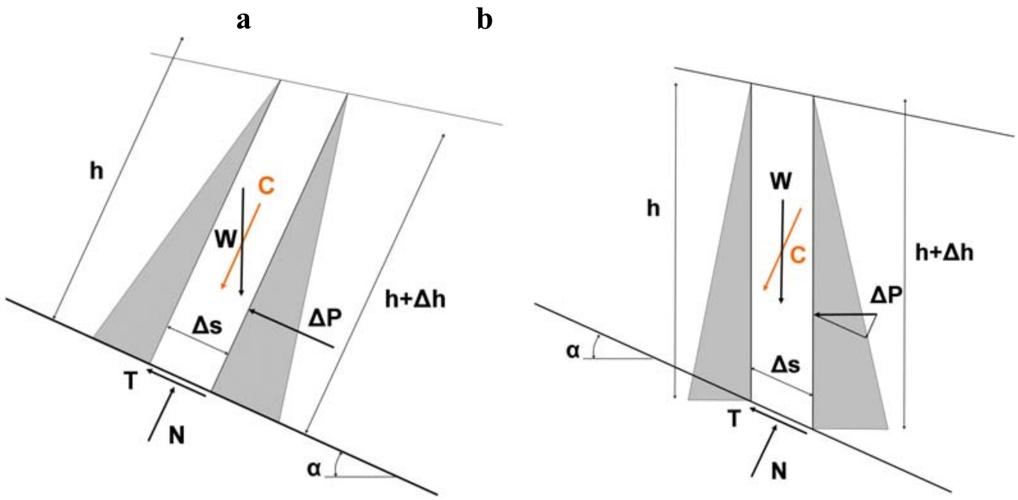


Figure 1.2
Boundary column. a) bed-normal orientation, b) vertical orientation.

[1] $$\rho h \frac{\partial v}{\partial t} = \rho h g \sin\alpha - k\sigma \frac{\partial h}{\partial s} - \tau_b$$

Given the shallow-flow assumption, the bed-normal stress, σ, acting on the base of the flow equals:

[2] $$\sigma = \rho h (g \cos\alpha + a_c)$$

Here, a_c is the centripetal acceleration due to vertical curvature of the path, with a radius R:

[3] $$a_c = \frac{v^2}{R}$$

In a frictional material without pore pressure, the resisting shear stress at the flow base, τ_b, equals $\sigma \tan\varphi_b$, where φ_b is the basal friction angle.

The coefficient k is the ratio between the bed-parallel and bed-normal stress and is described in Section A.2.4.

1.2 Vertical element orientation

The vertical element orientation sometimes leads to distortion of the geometry at locations where the path is strongly curved in the vertical plane. An alternative formulation of the equations of motion uses elements that are mutually parallel and vertical. In the vertical configuration, shown in Figure 1.2b, Equation [1] becomes:

[4] $$\rho h\frac{dv}{dt} = \rho gh\sin\alpha\cos\alpha - \rho h\frac{dh}{ds}k\cos\alpha(g + a_c\cos\alpha) - \tau_b$$

where h is now the flow depth, measured vertically.

Assuming that lateral (horizontal) unbalanced pressure acting on the vertical slice is transmitted vectorially to the slice base, the bed-normal stress, σ, acting on the base of the flow equals:

[5] $$\sigma = \rho h\cos\alpha(g\cos\alpha + a_c) + \rho h\frac{dh}{ds}k\sin\alpha(g + a_c\cos\alpha)$$

The remaining equations and the manner of their discretization and explicit solution are unchanged. The vertical framework produces similar results as the normal one. However, the latter approach is probably somewhat more reliable, although it produces more conservative results and apparently distorted plots where the path curvature is large. The reason for this opinion is that the normal slice approach balances momentum and impulse in the direction of motion.

One consequence of the shallow-flow assumption is that shear stress acting on planes parallel with the direction of integration, i.e. on the sides of the boundary blocks (Figure 1.2) is neglected. This simplification is inherent to all depth-integrated algorithms.

1.3 Method of discretization of the equations of motion.

The method of discretization of the equations was described in Hungr (1995, p.613) Calculations are applied to a set of n "boundary" blocks and (n-1) "mass blocks", each of which carries a constant volume of material (Figure 1.1). The discretized variables that apply to the boundary blocks include: bed-normal flow thicknesses, H_i, curvilinear displacements, s_i and mean velocities, v_i. Variables related to the mass blocks are block volumes, V_j, flow thicknesses at mid-points of the blocks, h_j and the pressure coefficients, k_j.

The analysis proceeds in an explicit manner, from the first block on the left. At each time step, the velocity and displacement of each boundary block is determined by a numerical integration of Equation [1] or [4]. This changes the curvilinear spacing of the boundary blocks and the mass blocks compress, or stretch accordingly. The flow thickness at the centre of each mass block is determined by Equation [6] (B is the local path width):

[6] $$h_j = \frac{2V_j}{(s_{i+1} - s_i)(B_{i+1} + B_i)}$$

The new thicknesses of the boundary blocks are determined as means of the adjacent mid-point thicknesses from Equation [6]. Now, all the boundary block variables have been updated and the analysis can proceed to the next time step. Longitudinal strain of the mass blocks is calculated and used to update the value of the k-coefficient. Other details of the procedure are given in Hungr (1995).

Note that DAN-W uses triangular end elements, therefore, the height of the first and last boundary blocks, respectively, is $h_1 / 2$ and $h_{n-1} / 2$.

1.4 Evaluation of the pressure term.

The usual assumption for shallow flow, developed originally for shallow, non-uniform flow of fluids, is that the bed-normal stress is equal to the normal component of the weight of the overlying fluid, plus a centrifugal force. The bed-parallel (longitudinal) stress in the flowing mass is then assumed proportional to the bed-normal stress. The proportionality ratio between the two stresses is referred to here as *k*, using a Soil-Mechanics convention.

Hydrostatic stress. In hydraulics, it is commonly assumed that *k* is one, i.e. that the internal pressure distribution is hydrostatic. This is reasonable for fluids, which lack internal strength. In DAN-W, the hydrostatic stress distrubution is used when the internal friction angle, φ_i, is zero.

Rankine stress states. If the flowing mass behaves as a frictional material with an internal friction angle φ_i and if the basal surface strength is negligible, the coefficient k can take a value calculated by the Rankine equations:

[7] $$k = \tan^2(\frac{\pi}{4} \pm \frac{\phi_i}{2})$$

When an element is expanding, the major principal stress is in the normal (or vertical) direction and the “active state” prevails, with the minus sign applicable in Equation [7]. Under compression, the "passive" state occurs and the sign is plus (Figure 1.3).

The “Rankine Passive Earth Pressure Coefficient”, k_p, is always greater than 1.0 and ranges up to about 5.0 for typical granular soils. The “Rankine Active Coefficient”, k_a, is less than 1.0 and ranges down to about 0.2.

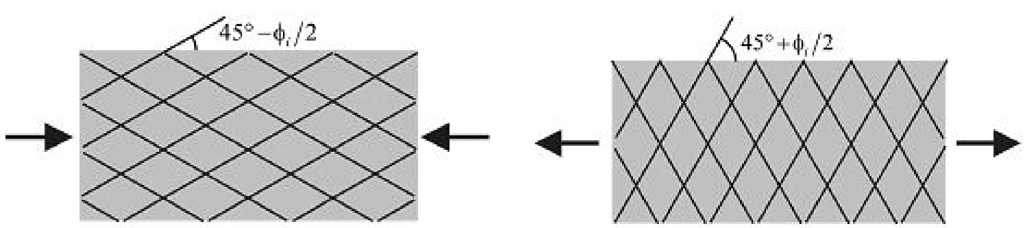


Figure 1.3
General shearing trajectories associated with the Rankine stress states. a) compression (passive) state, b) expansion (active) state. The major principal stress is horizontal in a) and vertical in b). (After McDougall, 2006)

The distinction between the two states is set by the sign of the longitudinal strain (Savage and Hutter, 1989). In the model proposed by Hungr (1995) and in the current DAN-W, there is a gradual transition between the two stress states. The model keeps track of the longitudinal strain in the sliding body and the earth pressure coefficients transit between passive and active value depending on the strain developed in response to changes of the path angle and on an assumed stiffness of the soil mass. The process is shown schematically in Figure 1.4. The value of stiffness does not influence the results of the model very strongly, but certain stiffness values are beneficial for improved model stability. A dimensionless stiffness value of 0.05 is recommended (Hungr, 1995). The rebound stiffness is larger than the loading stiffness, by a set "stiffness" ratio.

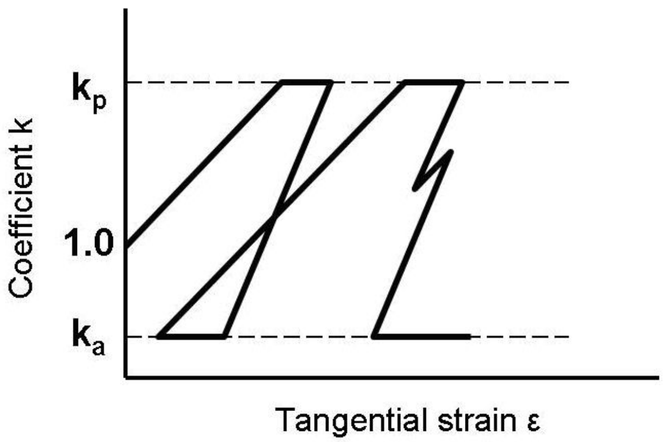


Figure 1.4 Development of the tangential pressure coefficient (k_a or k_p) with changing cumulative tangential strain. The slopes of the curve represent the stiffness. In DAN, a different stiffness is used on loading and unloading (after Hungr, 1995).

Savage-Hutter stress states. In cases where the basal friction angle, φ_b is more significant relative to the internal friction angle, the principal stresses rotate. While the Rankine states still exist within the material, it is no longer correct to assume that the principal stress directions align with the bed. Savage and Hutter (1989) used the geometry of the Mohr's Circle to derive an approximate equation for the ratio between the normal stress parallel and perpendicular to the bed:

[8] $$k_{(\min/\max)} = 2\left[\frac{1 \pm \sqrt{1-\cos^2\phi_i(1+\tan^2\phi_b)}}{\cos^2\phi_i}\right] - 1$$

Here again, the plus sign corresponds to the passive state, where bed-parallel compression is occurring and the minus sign to the active state. The basal friction angle φ_b may be the true dynamic friction between the base of the flowing mass and a moderately smooth bed surface. However, more generally, it is the angle corresponding to the current "friction slope", given as the arc tangent of the ratio between the basal shear stress and the normal stress.

"Modified" Savage-Hutter stress states. In case of spreading flows, where a very strong positive depth gradient may exist, the flow lines become curved and a varying additional clockwise shear stress is generated within the reference column by the unbalanced part of bed-parallel pressure. As shown by Hungr (2008), the solution can be corrected by replacing τ_b in Equation [8] with $\tau_{b,mod}$ so that:

[9] $$\tan\phi_{b,\mathrm{mod}} = \tan\phi_b - \lambda k(\partial h/\partial x)$$

The modified shear stress is limited in calculations to positive values: $\tan\phi_{b,\mathrm{mod}} \geq 0$. (Note: this parameter is not a basal stress and is not to be used in Equations [1] or [4].) After testing various alternatives, it was found that the value of 0.333 for the coefficient λ in Equation [9] produces the best results. The use of the Savage-Hutter relationship of Equation [8], modified by reducing the basal friction angle as shown in Equation [9], yields superior results in verification tests involving a variety of spreading flow geometries, some of which diverge substantially from the shallow flow assumption. It does not influence very strongly geometries that include shallow, elongated flow masses such as is the case in avalanches.

1.5 The flow resistance term, τ_b

The basal flow resistance term, T, in eq. 1, is governed by the rheology of the material. Eight rheologies are available in DAN-W. They are outlined below along with their appropriate equations for T. A more detailed discussion can be found in Hungr (1995).

Plastic: Flow controlled by a constant shear strength *c*:

[10] $$\tau_b = c$$

Friction: Flow controlled by the effective normal stress on the base of the boundary block:

[11] $$\tau_b = \sigma(1 - r_u)\tan\phi$$

where: r_u = pore-pressure coefficient = ratio of pore pressure to total normal stress at the base of a boundary block
φ = friction angle

NOTE: If r_u is assumed to be constant, the resisting stress remains a linear function of the normal stress and it is possible to replace the last term in Equation [11] $(1-r_u)\tan\varphi$ by the tangent of a constant "bulk friction angle" φ_b, where $\tan\varphi_b = (1-r_u)\tan\varphi$. This angle is the friction angle modified by pore-pressure and can reach values much smaller than the dry friction of the basal material.

Newtonian flow: Viscous flow where τ_b is a linear function of velocity:

[12] $$\tau_b = \frac{3v\mu}{h}$$

where: μ = dynamic viscosity of fluid (kP.s)

Turbulent flow: Flow where τ_b is a function of velocity squared:

[13] $$\tau_b = \gamma v^2 \left(\frac{n}{h^{1/6}}\right)^2$$

where: n = Manning roughness coefficient

Bingham flow: Flow where τ_b is a function of flow depth, velocity, constant yield strength and Bingham viscosity:

[14] $$v = \frac{h}{6\mu}\left(2\tau_b - 3c_b + \frac{c_b^3}{\tau_b^2}\right)$$

where: μ = Bingham viscosity
c_b = constant yield strength

Use of Equation [14] in the program requires the solution of a cubic equation at each time step. Occasionally, the cubic solution may diverge.

Coulomb viscous flow: Bingham flow with a yield strength dependent on the normal stress:

[15] $$c_b = \sigma(1 - r_u)\tan\phi$$

where the parameters are the same as for a friction flow

Voellmy fluid: Flow where τ_b contains a friction term and a turbulent term:

[16] $$\tau_b = f\sigma + \gamma\frac{v^2}{\xi}$$

Here, the constant friction coefficient, f, is equivalent to tan(φ_b) in the frictional model. The turbulence coefficient, ξ, is equivalent to the square of the Chezy constant for turbulent water flow and v is the vertically-averaged velocity of the flow.

For further description of the alternative rheological relationships, please refer to Hungr (1995 and 2008) and Hungr et al. (2005).

1.6 Material entrainment

The momentum flux term is based on how much material is deposited or entrained by the slide mass. Working within the "supply limited erosion" framework, a total erosion depth is specified within certain user-defined segments. As each mass element passes over the path within this segment, a fraction of this depth (and hence, volume), proportionate to the passing discharge, is eroded or deposited by the slide. The total erosion depth is only removed once the entire slide mass has passed over the given point. As the path material is entrained, the volume of the mass elements is increased by the volume of material eroded. Path elevation change is neglected. At the same time, a momentum correction is applied to the equation of motion, to account for the momentum required to accelerate the added increment of stationary mass, ΔM, to the current velocity of the boundary element, v. This is achieved by subtracting a quantity $\frac{\Delta M}{\Delta t}v$ in each time step of duration Δt from the right hand side of Equation [1] or [4]. Note that this momentum correction term would be zero for deposition of material (see Hungr, 1995, page 616).

IMPORTANT NOTE: In normal operation, deposition of material is routinely neglected (assuming that the full depth of the flowing mass will decelerate spontaneously). Thus, the erosion depth is never specified as a negative number.

1.7 Velocity smoothing

A major problem with the earlier versions of DAN-W was that the model, which included no damping, was not shock-capturing and tended to exhibit numerical instability when applied to complex path geometries, particularly those that induce shocks on transition between supercritical and subcritical flow. In order to prevent this, velocity smoothing was introduced in Release 8, as described in the following.

It was observed that numerical problems usually arose when pairs of adjacent boundary elements were forced close together, causing a rapid localized increase in depth in order to maintain volume continuity. In order to mitigate this condition, weighted averaging of the velocities of three adjacent boundary elements was introduced. The velocity of Element i, v_i was adjusted to a modified value v_i':

[17] $$v_i' = \frac{v_{i-1}w_l + v_i + v_{i+1}w_r}{w_l + 1 + w_r}$$

The weighting factors applied to velocities on the left and right of a given element, w_l and w_r are scaled in inverse proportion to the horizontal gaps between the boundary elements:

[18] $$w_l = \frac{\Delta x_{avg} c_s}{x_i - x_{i-1}} \qquad w_r = \frac{\Delta x_{avg} c_s}{x_{i+1} - x_i}$$

Here, x_i is the horizontal coordinate of Element i, Δx_{avg} is the current average horizontal spacing of all n elements and c_s is a user-selected Smoothing Coefficient, which controls the intensity of the smoothing process.

Two-point weighted averaging was applied to end points, where i=1 and i=n:

[19] $$v_1' = \frac{v_1 + v_2 w_r}{1 + w_r} \qquad v_n' = \frac{v_n + v_{n-1} w_l}{1 + w_l}$$

Extensive trial-and-error experimentation showed that good results could be obtained for a variety of previously-analysed verification problems with a Smoothing Coefficient value set at 0.02 for a line element, reduced to 0.004 for the two end elements.

In order to make the averaging process momentum-neutral, a momentum correction was imposed on the new velocities calculated by Equations [17] and [19], in order to maintain the overall momentum of the mass. The following procedure was used:

The positive and negative momentum changes resulting from the application of the smoothing equations during each time step was calculated:

[20] $$\Delta M^+ = \rho \sum (v_i' - v_i) h_i \qquad (v_i' - v_i) > 0$$

[21] $$\Delta M^- = \rho \sum (v_i' - v_i) h_i \qquad (v_i' - v_i) < 0$$

If the smoothing procedure was momentum-neutral, the two numbers would be equal and opposite in sign. If the absolute value of ΔM^+ was greater than ΔM^-, the positive velocity increments $(v_i' - v_i)$>0 were reduced by the ratio $\Delta M^+ / \Delta M^-$. In the opposite case, all the negative velocity increments were reduced by the inverse momentum increment ratio. In this way, the smoothing velocity changes were forced to remain momentum-neutral.

The smoothing algorithm is considered to be a simple and effective, albeit approximate, means towards obtaining a stable solution in "difficult" configurations, without the need to introduce artificial damping, or other shock-handling devices. Analyses of laboratory experiments and other verification exercises reported in Hungr (1995 and 2008) and Mancarella and Hungr (2010, in review) validate this approximate theory.

APPENDIX 2

REFERENCES

Ayotte, D. and Hungr, O., 2000. Calibration of a runout prediction model for debris flows and avalanches. Procs., 2nd. International Conference on Debris Flows, Taipei, Wieczorek, G.F. and Naeser, N.D., Eds., 505-514, Balkema, Rotterdam.

Ayotte, D., Evans, N. and Hungr, O., 1999. Runout analysis of debris flows and avalanches in Hong Kong. Proceedings, Slope Stability and Landslides, Vancouver Geotechnical Society Symposium May, 1999, 39-46.

Hungr, O. 1995. A model for the runout analysis of rapid flow slides, debris flows and avalanches. Canadian Geotechnical Journal 32: 610-623.

Hungr, O., 2008. Simplified Models of Spreading Flow of Dry Granular Material. Canadian Geotechnical Journal 45:1156-1168.

Hungr, O. and Evans, S.G., 1996. Rock avalanche runout prediction using a dynamic model. Procs., 7th. International Symposium on Landslides, Trondheim, Norway, 1:233-238.

Hungr, O., Dawson, R., Kent, A., Campbell, D. and Morgenstern, N.R., 2002. Rapid flow slides of coal mine waste in British Columbia, Canada. In "Catastrophic Landslides" Geological Society of America Reviews in Engineering Geology 15, pp. 191-208.

Hungr, O. and McDougall, S., 2009 Two numerical models for landslide dynamic analysis. Computers & Geosciences Computers & Geosciences 35 : 978–992.

Mancarella, D. and Hungr, O., 2010. Analysis of run-up of granular avalanches against steep, adverse slopes and protective barriers. Canadian Geotechnical Journal (in review)

McDougall, S. 2006. A New Continuum Dynamic Model for the Analysis of Extremely Rapid Landslide Motion across Complex 3D Terrain. Ph.D. Thesis, Department of Earth and Ocean Sciences, University of British Columbia (253 p.).

Revellino, P., Hungr, O., Guadagno, F.M. And Evans, S.G., 2002 Velocity and runout prediction of destructive debris flows and debris avalanches in pyroclastic deposits, Campania Region, Italy. Accepted by Environmental Geology, March, 2003.

Savage, S.B. & Hutter, K. 1989. The motion of a finite mass of granular material down a rough incline. Journal of Fluid Mechanics 199: 177-215.

Tse, C.M., Chu, T., Wu, R., Hungr, O. and Li, F.H., 1999. A risk-based approach to landslide hazard mitigation design. Procs., Hong Kong Institution of Engineers, Geotechnical Division Annual Seminar, May 1999, 35-42.

APPENDIX 3

LIST OF WARNINGS AND ERROR MESSAGES

ARE YOU SURE YOU WANT TO DELETE ALL THE POINTS IN THE SELECTED LINE?

All the points in the profile currently being edited will be permanently deleted.

ARE YOU SURE YOU WANT TO REVERT TO DEFAULT VALUES?

All values in the Options screen will be changed back to their default values.

CANNOT OPEN FILE ….

There is a formatting error in the file being opened.

CHOICE OF POINTS IS INCORRECT!

The first scale point must be located to the left and below the second scale point.

CROSS-SECTION SHAPE FACTOR MUST BE GREATER THAN 0.

The cross-section shape factor must be positive and non-zero.

FILE NOT FOUND. PLEASE TRY AGAIN.

The chosen image file is not found in the chosen directory. Check spelling or check another directory.

FRICTION ANGLE OF MATERIAL # … MUST BE BETWEEN 0 AND 45 DEGREES.

Friction angle must be within the specified bounds.

FRICTION COEFFICIENT OF MATERIAL # … MUST BE BETWEEN 0 AND 1.

Friction coefficient must be within the specified bounds.

GEOMETRY ERROR. PLEASE CHECK GEOMETRY POINTS.

The solver encountered an error when setting up the problem geometry. Check that all the data in the edit geometry screens corresponds to the rules described in Section C.1, Section C.7, and Section C.8. Common reasons for the appearance of this error are that the spline is very wavy or that all the top data points are below the interpolated path data points.

GRAPH FILES: PATH … ACCESS ERROR.

The folder chosen to save the ASCII graph files in is read only. Please choose a different folder.

IF YOU CHANGE TO A 2-DIMENSIONAL CONFIGURATION, YOU WILL LOSE ALL OF YOUR WIDTH DATA. ARE YOU SURE YOU WANT TO CONTINUE?

Changing from a three-dimensional configuration to a two-dimensional configuration will permanently replace all existing width data to unity.

LHS Y-COORDINATE MUST BE SMALLER THAN RHS Y-COORDINATE.

Problem extents must be defined by the lower left and the upper right coordinates of the problem.

LHS Z-COORDINATE MUST BE SMALLER THAN RHS Z-COORDINATE.
Problem extents must be defined by the lower left and the upper right coordinates of the problem.

MAXIMUM … ELEMENTS.
The number of mass elements must not exceed the specified amount.

MAXIMUM … MATERIALS ALLOWED.
The number of materials must not exceed the specified amount.

MUST HAVE AT LEAST ONE MASS ELEMENT.
The minimum number of mass elements is 1.

MUST HAVE AT LEAST ONE MATERIAL.
The minimum number of materials is 1.

NO OBSERVATION POINT DATA LOADED. YOU MUST RUN AN ANALYSIS TO LOAD DATA.
Observation Point data is stored during an analysis and can be exported only after the analysis is completed.

ONLY … POINTS ALLOWED.
Can't add any more geometry points. The maximum has been reached.

PATH NOT FOUND. PLEASE TRY AGAIN.
The chosen path is incorrect. Try another directory.

PLOTTING ERROR. PLEASE CHECK GEOMETRY POINTS.
The solver encountered an error when plotting the three-dimensional problem geometry. Check that all the data in the edit geometry screens corresponds to the rules described in Section C.1, Section C.7, and Section C.8. Common reasons for the appearance of this error are that the spline is very wavy or that all the top data points are below the interpolated path data points.

POINT … MUST BE TO THE RIGHT OF POINT ….
Points in the edit geometry screens must go from left to right and must not overlap.

PROJECTION ANGLE MUST BE BETWEEN -90 AND 90 DEGREES.
The projection angle for the isometric view in the main screen must be within the specified bounds.

RUNOUT COMPLETE.
The slide mass has fully settled. The run is complete.

SLPINE ERROR. PLEASE CHECK GEOMETRY POINTS.

The solver encountered an error when spline-interpolating between the path data points. Check that all the data in the edit geometry screens corresponds to the rules described in Section C.1, Section C.7, and Section C.8. Common reasons for the appearance of this error are that the spline is very wavy or that all the top data points are below the interpolated path data points.

STIFFNESS COEFFICIENT MUST BE GREATER THAN 0.

The stiffness coefficient must be positive and non-zero.

THE PROBLEM HAS REACHED THE PROFILE EXTENTS. DO YOU WISH TO CONTINUE?

The front of the sliding mass has reached the right-most extent of the slope profile. Continuing beyond this point may result in instability.

THICKNESS MUST BE GREATER THAN 0.

The uniform thickness of the top above the path must be positive and non-zero.

TIP RATIO MUST NOT BE ZERO.

The tip ratio must be positive and non-zero.

UNIDENTIFIED ERROR # … OCCURRED: ….

An unidentified error, as described, has occurred when loading the image.

WARNING: POINTS … AND … HAVE EQUAL Y-COORDINATES AND WILL MAKE THE SPLINE FUNCTION UNSTABLE. PLEASE MODIFY THE POINTS.

Path points with equal y-coordinates will cause the spline function to become dramatically unstable. Make sure these coordinates are not the same and then test the spline to make sure it gives the desired path profile.

WARNING, WIDTH ARRAY NOT DEFINED.

Must have at least two data points to completely define the channel width.

WEIGHT OF MATERIAL # … MUST BE GREATER THAN 0.

All materials must have a positive and non-zero unit weight.

WIDTH MUST BE GREATER THAN 0.

Must have at least two data points to completely define the channel width.

YOU MUST ENTER AT LEAST … POINTS IN ORDER TO PROPERLY DEFINE THE … GEOMETRY.

Must have at least the minimum number of data points specified to completely define the path, top, and width profiles.

ZOOM BOX EXTENTS ARE TOO SMALL

The chosen zoom box is too small. Please try again.