12d Solutions Pty Ltd

Civil and Surveying Software

Version 8 Course Notes

CIVIL AND

SURVEYING SOFTWARE

THE 12D PERSPECTIVE

12d Model

STORMWATER DESIGN - Part 2

12d Solutions Pty Limited

ACN 056 019 713

Phone: +61 (2) 9970 7117   Fax: +61 (2) 9970 7118Email training@12d.com

12d Stormwater Course - Part 2 Notes

These course notes assume that the trainee has the basic 12d Model skills usually obtained from the "**12d Model Training Manual**"

These notes are intended to cover basic Stormwater Design. For more information regarding training courses contact 12d Solutions Training Manager.

These notes were prepared by
Robert Graham

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COURSE NOTES

STORMWATER DESIGN - Part 2

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1.0 Stormwater Design Part 2- Introduction

The **Stormwater Design Course Part 1** and this manual, the **Stormwater Design Part ,** describe the functions and processes of the 12d drainage module. In these documents, the generic term **pit** refers manholes inlets, catch basin and manholes.

The **Stormwater Design Course - Part 1 Notes** contain**:**

- create a super tin for pipe cover and pit cover levels,
- set drainage defaults and layout a drainage network from CAD and in 12d,
- use the 12d drainage network editor to assign names to the pit/pipes, avoid service clashes, grade pipes, align obverts, minimise depth and many other design tools,
- designate catchment areas and produce catchment plans,
- run the 12d storm rational hydrology and hydraulics engine,
- transfer data to and from electronic spreadsheets to enable the user to easily review the data and add user defined data to the 12d pipe network. This data may include such data as pipe bedding types and trench width,
- create a drainage template containing customised default design parameters,
- create pit setout schedules to export to spreadsheets or word processors for final formatting,
- produce long section drainage profiles including HGL data, flows, invert levels and service crossings,
- create plan drawings with pipe sizes, flows, pit symbols, linestyles for pipe sizes, design parameters for pit and pipes and user defined data,
- locate pits/manholes at exact chainage and offset locations.

This manual, the **Stormwater Design Course - Part 2,** is intended to describe the additional features of 12d model drainage and discuss the customisation of the package. This will include

- customising the drainage.4d file,
- 12d storm analysis with inlet capacity calculations and bypass flow,
- flooded width analysis and flooding at SAG pits,
- drainage trench excavation volume calculations,
- pipe and pit quantity calculations/reports,
- open channel calculations,
- adjusting pit locations for changes in horiz road geometry
- analysing the major flood events,
- design or evaluate the drainage system using by creating input files for the xpswmm/xprat-hgl, Windes, Drains and PCdrain drainage design packages,
- read the output from the drainage design packages and update the drainage network plus storing the hydraulic data, such as hgl (hydraulic grade line) levels, peak pipe

flows and pipe capacities,

- creating drainage symbols with grates and upstream side inlets,
- detailed drainage plan labelling and long sections with hatching under roads.

2.0 Starting with a Basic Drainage Network

In this document, the generic term **pit** refers to manholes, inlets, catch basin and manholes. When the term **manhole** is used on the 12d menu system it refers to any type of pit. Pit types, dimensions and inlet capacities of the pits are set in the drainage.4d file.

These course notes assume that you have completed the Stormwater Design Course and that you have experience creating 12d model drainage networks with catchments areas. This course will begin with a completed drainage design found in the directory

\12djobs\8.00\Courses\Drainage_Analysis

The project name is Local Road Complete.

3.0 Setup Files and Their Locations

The drainage module consists of the optional 12d Drainage Analysis, utilities, startup configuration files for RAT2000, XP SWMM and the 12d drainage configuration file (drainage.4d).

All setup files have been configured for the training version. However, when you start working on real projects you may want customise the drainage module. **More - Customising the drainage module**

The **drainage.4d** file contains pipe types (RCP, Class 2 etc.) and example pit inlet capacites for inlet pits. Detailed pit type descriptions and internal pit dimensions can be included in this file to be inserted into your pit schedules. For PCdrain and Drains users there are routines to read your gully pit/database files and create the drainage.4d file **More**.

REVIEW THIS DATA CAREFULLY! The **drainage.4d** file may be customised for any additional inlet capacity data you may have.

To edit the **drainage.4d** file, from the main menu select

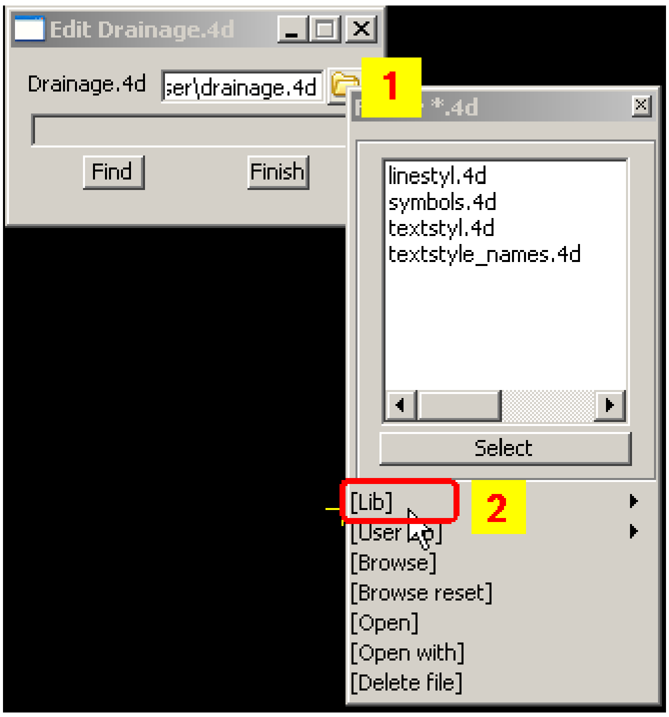
Design->Drainage-Sewer->More->Edit drainage.4d

Select the **Find** button to search the 12d path for the current **drainage.4d** file. If the file is found in the **set-ups** folder, it should be copied to the user folder or your current working folder before editting it (see below).

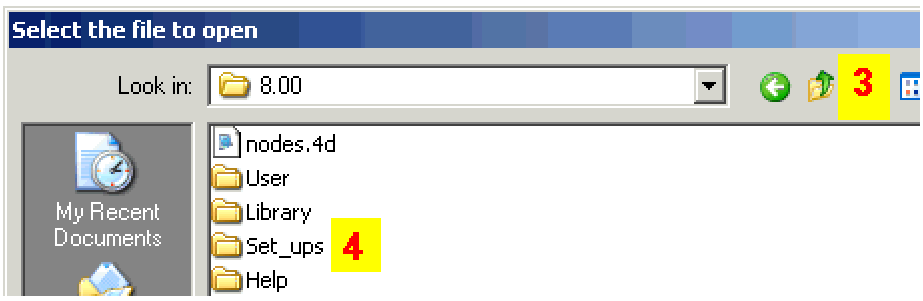
Select the **More info** button (the folder) and then **Open** to edit the file.

Copying the drainage.4d files

If the drainage.4d file is found in the 12d setups folder or if other drainage.4d files are to be used they can be copied from setups folder.



1. Select the **More info** button (the folder)
2. select **lib** to open the windows browse panel**.**
3. Select the up level icon.
4. Select the **Set_ups** folder. Now we are ready to copy the desired drainage.4d file.



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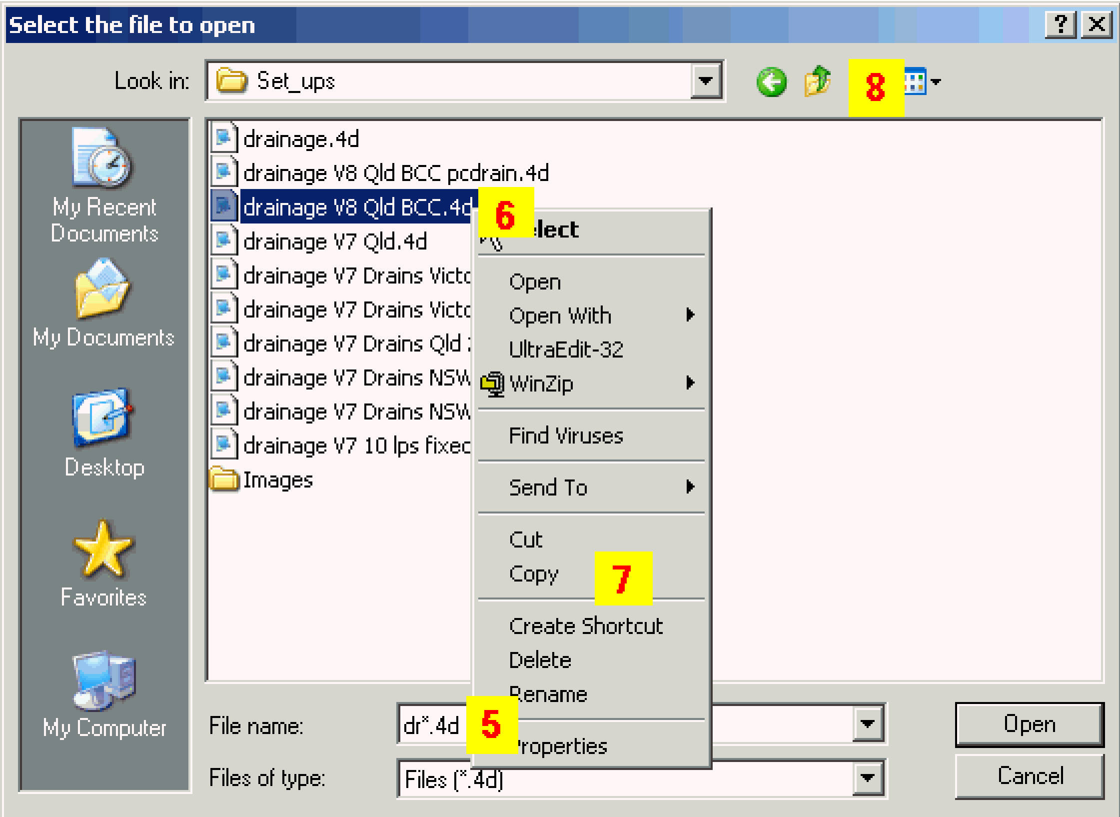
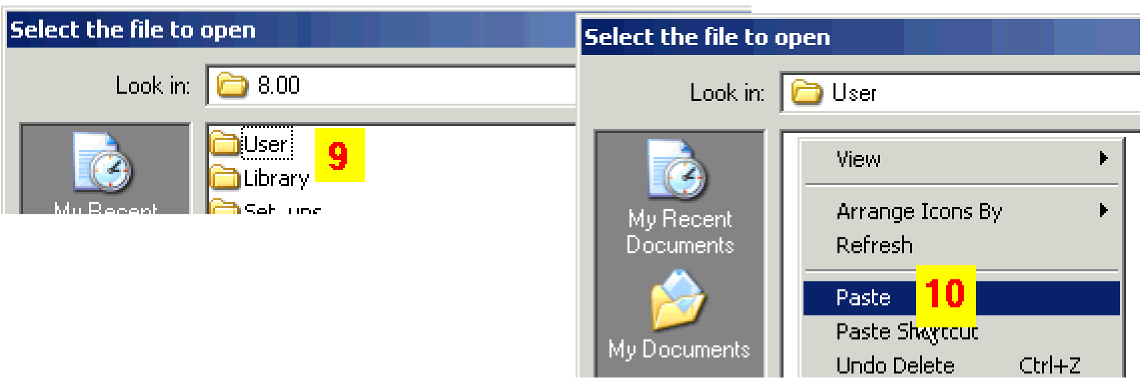


5. type **dr*.4d** and press **Enter** to get a list of the drainage.4d files.
6. RB the desired file
7. Select **Copy** to place the file on the clipboard.
8. select the **Up level** icon to move back up a level
9. Select the **User** folder
10. RB in the white space and then select**Paste.**
11. The file can now be renamed **drainage.4d** if it had another name.



You must restart 12d for these changes to become active. Select Project->Restart!

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At startup, if there are significant errors in the file, refer to the output window where 12d will print the line number where it give up. When looking in the long list of files, the drainage.4d file is loaded after the shp files.

See “The drainage.4d file” on page 21.

REVIEW THIS DATA CAREFULLY! A detailed description of the pit inlet capacity tables in this file is given in “Pit Inlet Capacities” on page 23. The **drainage.4d** file may be customised for any additional inlet capacity data you may have.

4.0 Bypass Flow

Bypass flow strings are used to trigger the bypass calculations in the network editor and are used as a centre line for flooded width calculations. The later requires unique names for the bypass flow strings.

The 12d storm analysis, and many of the design programs 12d exports to, allow for bypass flow. Bypass flow involves the calculation of inlet capacity which is based on the pit type and often on the road grade and/or crossfall upstream of the inlet.

Key Points

1. Set the pit type. (**Pit Type** on the **Pit** tab). For the 12d storm analysis these pit types must have inlet capacity data in the drainage.4d file.
2. Set the **Inlet config** on the **Pit->Main** tab (Manhole, Ongrade or SAG). This selection will be disabled if cap_config parameter sets the structure type in the drainage.4d file. Manholes have no inlet capacity and are not considered inlets (sealed), on grade inlets capture the water as it passes the inlet while SAG inlets trap the water flowing in from all directions (until the catchment overflows at the low point).
3. Draw an bypass flow string in the direction of flow so that it passes within 1 pit diameter of an inlet. When bypass flow strings join they must join within 1 pit diameter of an inlet (Manhole types are not considered inlets). If flooded with calculations are to be done later, the bypass flow string must have a unique name and the string should located in the flow channel.

   Enter the model name in the **Bypass flow model** field on the **Global->Utility Models** tab.
4. Many bypass strings may join at an inlet but only one bypass string should leave each inlet.
5. On grade pits may require road grade and/or crossfall data for inlet capacity. A setout string link is required to measure road grade. If road crossfall is needed then the centre string is also required. These strings are specified using the **Road design file** on the **Global->Utility Models** tab.
6. Pond depth measurements for a SAG inlet require a link to a catchment string. Also check that your grate level is correct (**Grate rl mode**).
7. Press the **Set Pit Details** button. Road grades, crossfalls, ponding depths and bypass pits will now be found on the **Pit->Bypass** tab of the **Network Editor**.
8. Bypass pits may be cleared using **Clear Bypass Links** on the Globals->Utility Models tab
9. Storm Analysis must have **Consider Bypass Flows** selected.

4.1 Drawing Bypass Flow Strings

The bypass flow string must be within 1. pit diameter of the drainage pit in be considered on the bypass flow path. If the bypass flow string is to be used for flooded width calculations in the future, the string must also be drawn in the main flow area of the cross section.

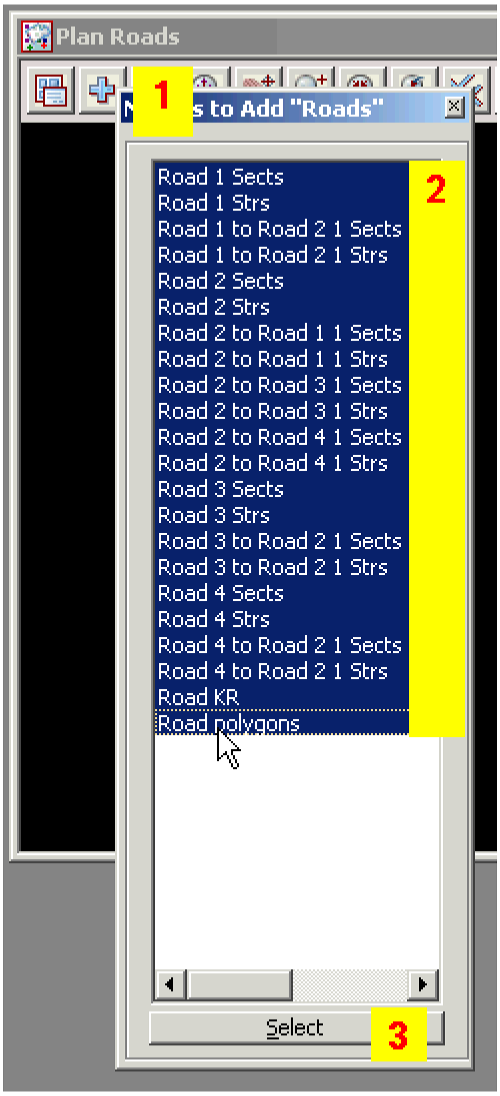
For project with roads it is easiest to copy a road string (invert strings are usually the best) into the flow model and then check the string to see if it flows down hill. You may be required reverse the direction of some strings, split some strings at major crests, join some strings that do not meet at inlets and finally add some flow lines where flow crosses the road.

Copying the Invert strings into the bypass model

First we will create a new view for just the road strings.

View->Create->Plan view

10. Type **Roads**
11. Select **Create**



1. Place your point over the + button and press **Shift+r** to display all of the models starting with R.
2. Drag your pointer across all of the road models to select them
3. Lb the **Select** button to add them to the view.

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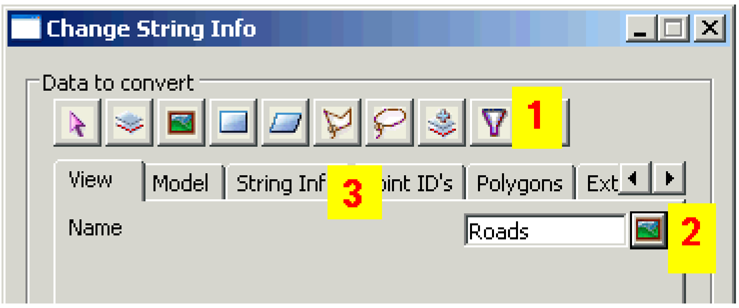
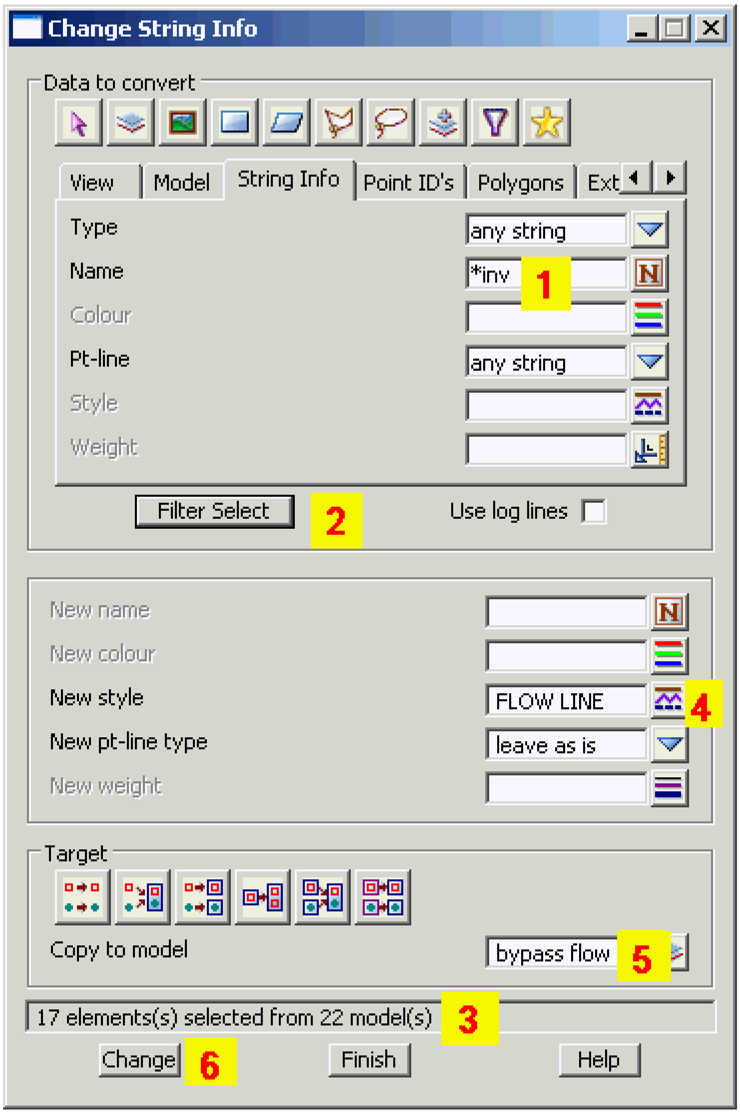
From the main menu select

Utilities->A-G->Change



1. Select the filter button
2. Select the View button and then select the **Roads** view
3. Select the **String Info** tab.



1. Type ***inv** to select the rinv and linv strings.
2. Select **Filter Select** to select the ***inv** strings from the **Roads** view.
3. Note that 17 strings have been selected from the roads models.
4. Either type **FLOW LINE** or select the line style button, then select the group **Drainage 12d** and finally **FLOW LINE** line-style.
5. type **bypass flow,1** for the new model. The **,1** will add the model to view 1 for you.
6. select **Change** to copy the strings to the new model with the new line style.

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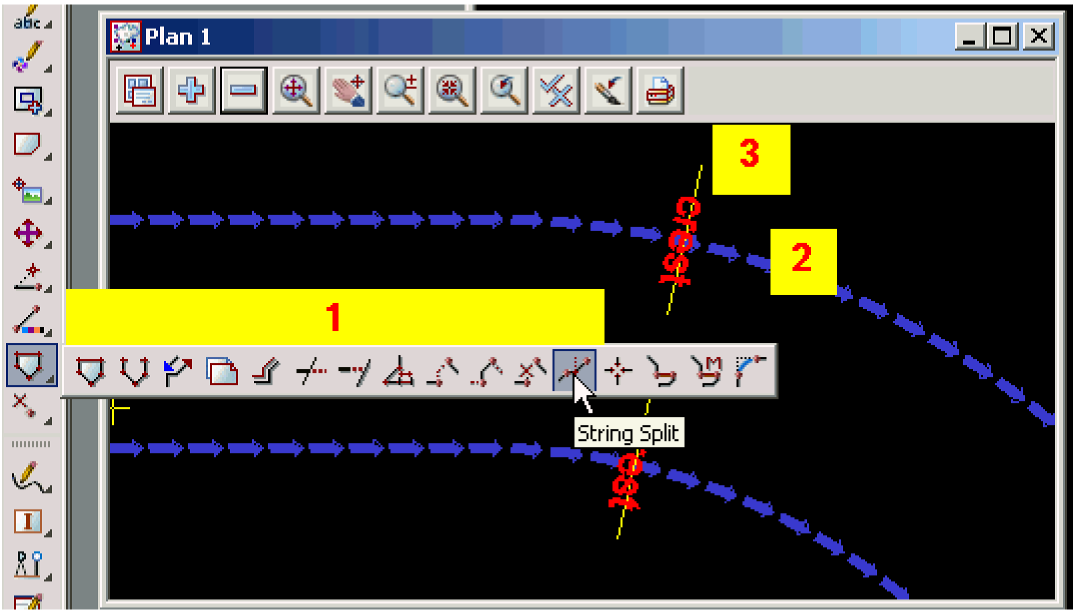
Splitting the Strings at Major Crests

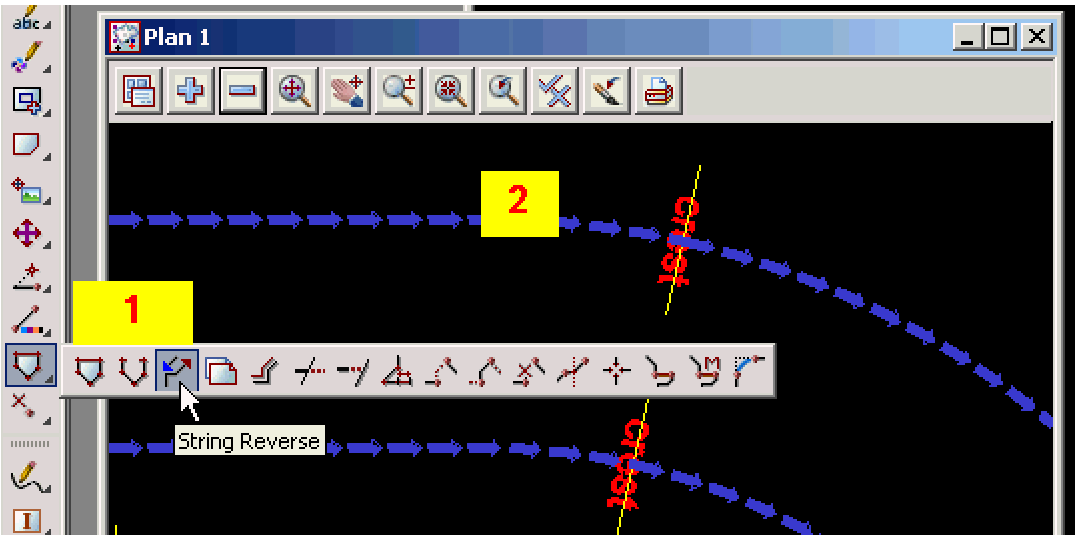
If the roads contain a major crest that defines a separate catchment then the flow lines will need to be split so that one segment can be reversed.

If you have labelled the crests and sag points then you can use these labels to quickly identify the crests.



1. Drag out the **CAD string** toolbar and select the **String split** icon.
2. Instructions will be given in the 12d message area (bottom left corner of the screen). Pick and accept the string to be split.
3. Pick and accept the split point or if you have them the crest marker. The string will now be split.
   repeat steps 2 and 3 for all strings to be split. Press **ESC** when finished.

Reversing the Strings if they flow in the wrong direction

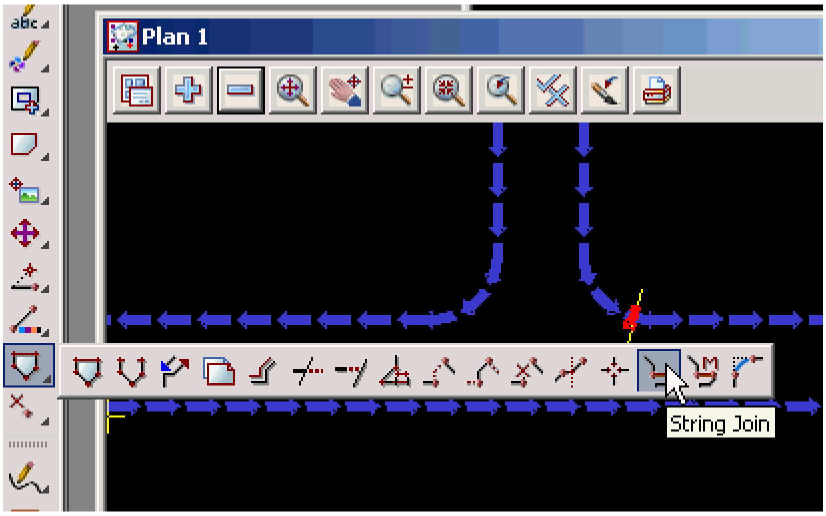


1. Drag out the **CAD string** toolbar and select the **String Reverse** icon.
2. Instructions will be given in the 12d message area (bottom left corner of the screen). Pick and accept the string to reverse.

   continue selecting strings to be reversed. Press **ESC** when finished.

Joining Flow Lines Together

If the flow lines join eachother within 1 manhole diameter of an inlet (not a manhole) then then do not need to be joined (but they can if desired). If there is no inlet at the join then you will have to join the strings together.



1. Drag out the **CAD string** toolbar and select the **String Join** icon.
2. Instructions will be given in the 12d message area (bottom left corner of the screen). Pick and accept the upstream string then pick and accept the downstream string. Since they are already drawn in the same direction you will not have to use a directional pick.

   continue selecting strings to be joined. Press **ESC** when finished.

Adding additional flow lines where the flow cross the road

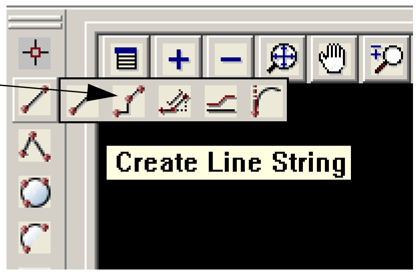
Use the **CAD toobar** to create the bypass flow paths. A unique name is required if you plan to calculated flooded widths after the analysis is done.

To use the **CAD toolbar** go to the **CAD data bar** and enter a string name and model name.

Select the line style (optional).

DRAG the **Create line** button and release at the **Create Line String** button.

When finished drawing the string press **ESC.**

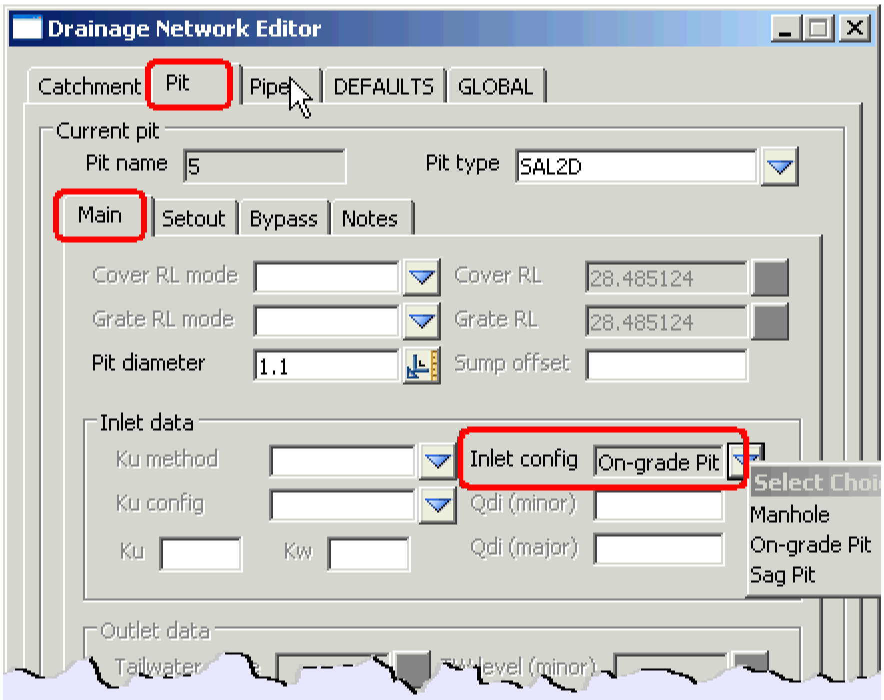


Starting at the upstream end. LB select an insertion point and MB or press return to accept the selection. Continue this until you reach the end of the flow path. The string will not be shown in the new linestyle until the screen is redrawn. Press **ESC** to finish drawing the string. MB on the plan view title area to redraw the screen. The correct linestyle will now appear.

If you reach a sag pit location you may terminate the string or continue defining the bypass flow path for a surcharging event out of the sag location.

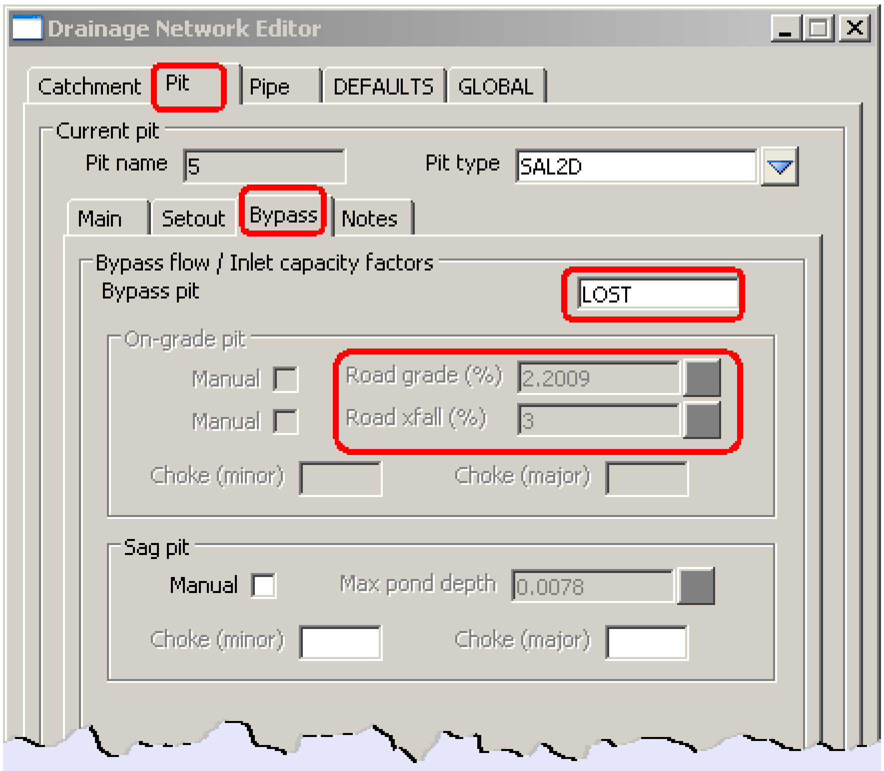
4.2 Set Pit Details - Calculate the Bypass Flow Data

Once the first 4 Key points of bypass flow (listed above) are complete, you are ready to calculate the bypass flow data. Select **Set Pit Details** and then select a pit on a bypass flow string. The bypass data is found on the **Pit->Bypass** and **Pit Main** tabs.



12d supports Manhole, ongrade and SAG configurations. The **inlet configuration** is set on the **Pit->Main**. This settings can be locked to the **Pit type** in the drainage.4d file using the cap_config command (discussed later). Manholes will not receive bypass flow and cannot have catchments assigned to them. On-grade pits are pit where the water will flow passed the pit if not captured and SAG pits are located at SAG locations where the water will pond around the pit if there is not enough inlet capacity.

The remaining bypass data is found on the **Pit->Bypass** tab.

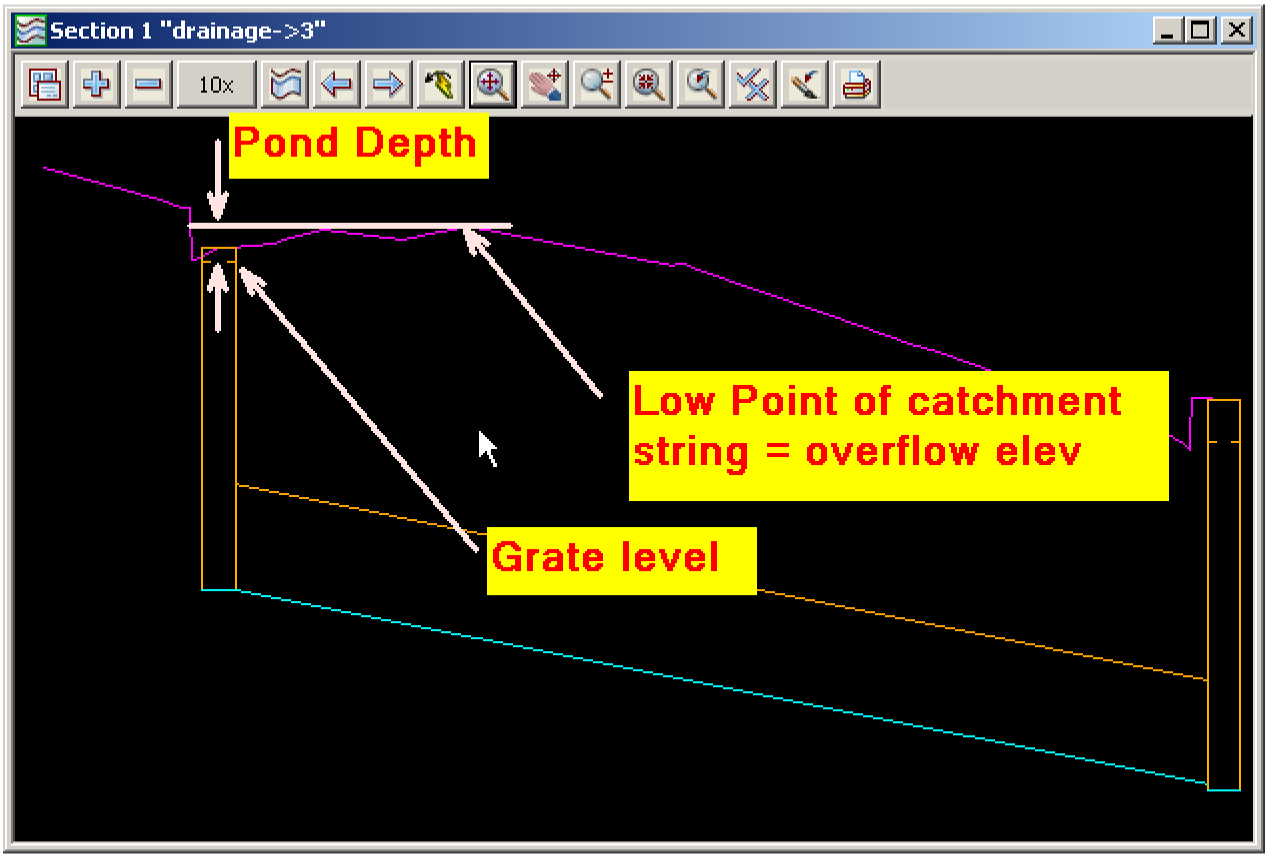


The downstream pit will now show in the **Bypass pit** field. If the bypass string does not go to another inlet (the network out is not an inlet) then the **Bypass pit** will be marked as **LOST**.

If **Pit on grade** is selected and a setout string was found (see **Pit->Setout** tab), the **Road grade** will appear in grey. You may override this value by selecting the **Manual** tick box beside the value and entering your own value. If a road centre string was selected, the **Road xfall** field will also have a value.

If **Sag pit** was selected and a catchment string was selected, the **Ponding depth** will be displayed. The catchment strings from all 3 sets are draped onto the finish surface tin and the low point located. The **Ponding depth** is calculated as

Ponding depth = catchment string low point - Grate RL).

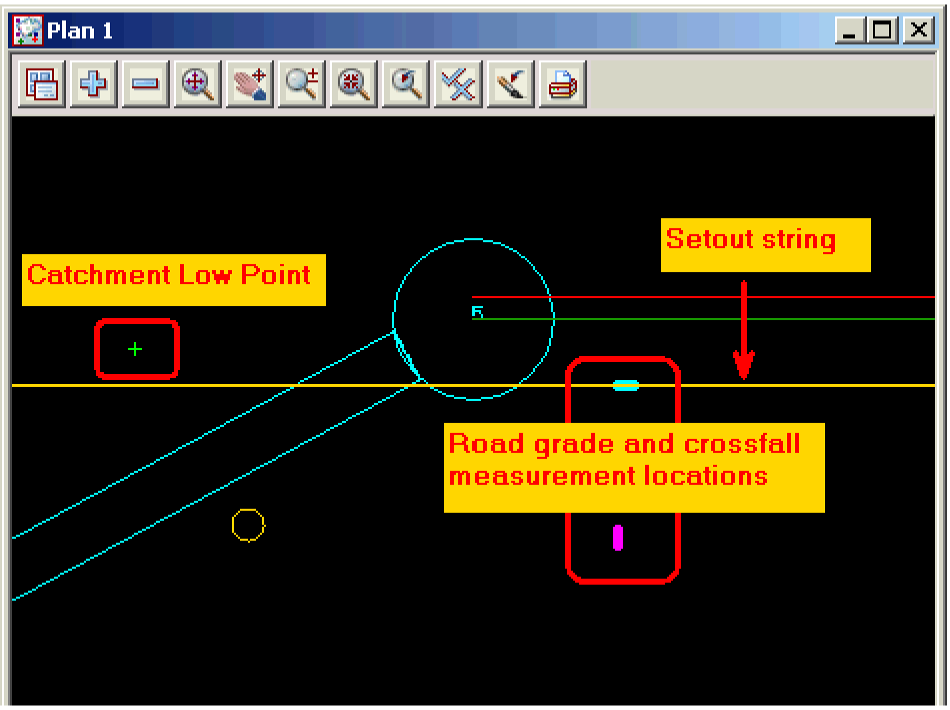


Negative Ponding Depths

Negative ponding depths are usually caused by one of two errors in input. The first may be that the grate level is too high. Often this happens when the Grate RL mode on the **Pit->Main** tab has not be set correctly or if **Sz + setout string** option is used the **Sz** value on the **Pit->Setout** tab has been entered correctly.

The second common error is that the catchment string has not been drawn around the crest of the catchment. The lowest section of the catchment string must be drawn carefully because it is the lowest point on the string that determines the overflow elevation. If in doubt, profile the catchment string with the design tin shown in the section view. Double check were the low point is. The location of the low point is also shown as a green vertex (plus sign) in **construction drainage data** model.

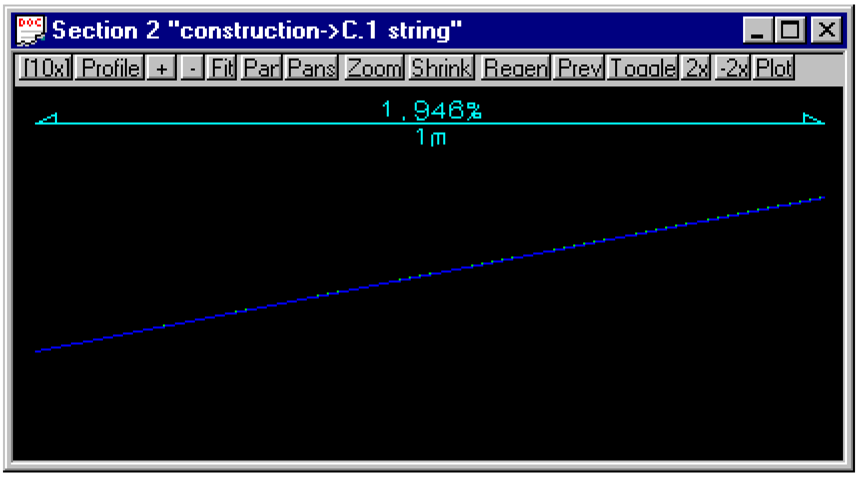
Verification strings in the same model confirm the locations where the road grade and crossfall have been measured. To check these strings add the **construction drainage data** model to the plan view. The following image shows a close up of the verification strings at a pit.



The green line indicates where road grade was measured and the magenta line indicates where the road cross fall was measured.

The default location of the road grade measurement is one pit diameter upstream of the setout point, along the setout string. The road crossfall is measure one pit diameter away from the setout point towards the road centreline. These are 3d super strings and therefore you may profile them in the section view. With the grades toggled on (check under **Toggle**) you can verify the slopes.

The location of the road grade and crossfall measurements can be changed in the **road design file**. The distance upstream to measure the road grade is controlled by the **Grade offset** column one the rows where the setout strings are defined. The road crossfall is controlled by the **Xfall offset** column on the rows where the road centre lines are defined. The distance the measurements are taken is controlled by the **Slope measurement distance**.



Important Notes

1. Pits with no inlet capacity defined will have a zero inlet capacity.
2. Manholes have no inlet capacity.
3. If no bypass flow string is supplied for a pit, the inlet capacity is set to 100%.
4. If you have a problem with the inlet capacity factors (Drains Version 1 and ILSAX), check the calculated crossfall and grade.

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5.0 The drainage.4d file

The drainage.4d file controls many of the settings for the pit and pipes types inside 12d. This section details the format of the drainage.4d file. Changes to this model take effect only after 12dmodel has been restarted.

The original **drainage.4d** file is found in the “program files\12d\12dmodel\8.00\set_ups” directory. **Do NOT** change this file. Copy it into “program files\12d\12dmodel\8.00\User” directory and edit it there. Files in the user directory are used by preference and they are never over written by a 12d update.

```
//=====================================================================
//NEW V8 MANHOLE FORMAT:
//======================================================================
//manhole "manhole type" {
//
//  //All entries inside a manhole entry are optional.
//
//  mhsize  <x.x> [<x.x>]  //Length [and optional Width] in <base units>
//  mhdesc  "verbose description of the manhole type"
//  mhnotes "extra remarks about this manhole type"
//  mhgroup "manhole group to which the type belongs"
//
//  //Inlet capacity data for all conditions (generic):
//
//  cap_multi   <x.x>
//  cap_fixed   <x.x>
//  cap_percent <x.x>
//  cap_coeff   <x.x>
//  cap_power   <x.x>
//
//  //Inlet capacity data for on-grade conditions (by road grade & xfall):
//
//  cap_curve_grade "curve 1" {
//    road_grade  <x.x>
//    road_xfall  <x.x>
//    cap_multi   <x.x>
//    cap_fixed   <x.x>
//    cap_percent <x.x>
//    cap_coeff   <x.x>
//    cap_power   <x.x>
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//  }
//  cap_curve_grade "curve 2" {
//    road_grade  <x.x>
//    road_xfall  <x.x>
//    cap_multi   <x.x>
//    cap_fixed   <x.x>
//    cap_percent <x.x>
//    cap_coeff   <x.x>
//    cap_power   <x.x>
```

```
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//  }
//  cap_curve_grade "curve n" {
//    road_grade  <x.x>
//    road_xfall  <x.x>
//    cap_multi   <x.x>
//    cap_fixed   <x.x>
//    cap_percent <x.x>
//    cap_coeff   <x.x>
//    cap_power   <x.x>
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//    coord <Qa> <Qin>
//  }
//
//  //Inlet capacity data for sag conditions:
//
//  cap_curve_sag "curve sag" {
//    cap_multi   <x.x>
//    cap_fixed   <x.x>
//    cap_percent <x.x>
//    cap_coeff   <x.x>
//    cap_power   <x.x>
//    coord <Depth> <Qin>
//    coord <Depth> <Qin>
//    coord <Depth> <Qin>
//  }
//}
//===============================================================================
//RULES FOR INLET CAPACITY DATA
//===============================================================================
//
//Qa  = pit approach flow rate
//Qin = pit inflow rate
//Qb  = bypass flow rate = Qa - Qin
//
//If there is no bypass pit (i.e. 100% capture): Qin = Qa
//
//Else: Qa >= Qin = choke*cap_multi*(  cap_fixed
//                                   + cap_percent*0.01*Qa
//                                   + cap_coeff*Qa^cap_power
//                                   + cap_curve_? {
//                                       cap_multi*(  cap_fixed
//                                                  + cap_percent*0.01*Qa
//                                                  + cap_coeff*Qa^cap_power
//                                                  + [Qin via coord lookup] )
//                                     }
//                                  )
//
//                   where: 'cap_curve_?' is the applicable curve data
//
//Default values for unspecified entries:
//  cap_multi   = 1.0
```

```
//  cap_fixed   = 0.0
//  cap_percent = 0.0
//  cap_coeff   = 0.0
//  cap_power   = 1.0
//
//Rules for 'cap_curve_grade' entries:
//  *Only applicable to on-grade pits.
//  *All cap_curve_grade entries must be uniquely named within a pit.
//  *The 'road_grade' and 'road_xfall' entries are both optional, but their
//     use must be consistent across all cap_curve_grade entries within a pit.
//  *If both 'road_grade' and 'road_xfall' entries are omitted, only one
//     cap_curve_grade entry is allowed within a pit.
//  *The 'road_grade' and 'road_xfall' entries must be specified in %, and are
//     interpreted as minimum threshold values.
//  *The cap_curve_grade 'coord' entries (if used) must be in order of
//     increasing Qa.
//
//Rules for 'cap_curve_sag' entries:
//  *Only applicable to sag pits.
//  *Only one cap_curve_sag entry is allowed within a pit, and it must have
//     a valid name.
//  *The cap_curve_sag 'coord' entries (if used) must be in order of
//     increasing Depth.
//  *It is recommended that all sag pits have 'coord' entries, because even
//     if there is no bypass pit (100% capture), the 'coord' entries are used
//     to reverse-calculate the flooded depth at the sag inlet, based on Qin.
//
//NB1: Flow rates must be specified in "cubic <base units> per second".
//NB2: Depths must be specified in <base units>.
//
//
=============================================================================
```

5.1 Pit Inlet Capacities

The pit inlet capacity tables contained within the **drainage.4d** file are used by the drainage design packages in different ways but with a common philosophy.

5.1.1 On grade pits

The grade and crossfall values for the tables are threshold values, i.e. the next set of capacity factors will not be used until the crossfall and grade are equal to or exceed the values for the curves. The curves are not interpolated!

12d Storm Analysis

Some sample Pit definitions follow to demonstrate how the pit inlet capacities are calculated.

```
Manhole "SEP 25" {

  mhsize  1.200 0.900
  mhdesc  "SEP with 25 l/s"
  mhnotes ""
  mhgroup "SA"

  cap_multi   1.0
  cap_fixed   0.025

}

Manhole "SEP 50 percent" {

  mhsize  1.200 0.900
  mhdesc  "SEP with 50%"
  mhnotes ""
  mhgroup "SA"

  cap_multi   1.0
  cap_percent 50.

}

Manhole "SEP Grade x 10" {

  mhsize  1.200 0.900
  mhdesc  "SEP with 25 l/s"
  mhnotes ""
  mhgroup "SA"

  cap_curve_grade "curve 1" {
    road_grade  1
    cap_multi   1.0
    cap_fixed   0.010
  }

  cap_curve_grade "curve 2" {
    road_grade  2
    cap_multi   1.0
    cap_fixed   0.020
  }

  cap_curve_grade "curve 3" {
    road_grade  3
    cap_multi   1.0
    cap_fixed   0.030
  }

  cap_curve_sag "curve sag" {
```

```
    cap_multi   1.0
    coord 0.0  0.000
    coord 0.1  0.010
  }
}
```

Drains Version 1 and ILSAX

The cap1, cap2, cap3 and cap4 values are used to describe the inlet capacity of the pit as described in their user manuals.

Drains Version +

The 12d inlet curve names are exported to Drains as the pit family.

xpswmm, xpstorm and RAT-HGL

If cap2, cap3 and cap4 are all equal to zero then a fixed inlet capacity equal to cap1 will be exported to RAT-HGL. If the sum of these three values is greater than zero then a pit type will be created in the format of **pit_type-crossfall-roadgrade**. For example SA2-3-2 for a SA2 pit with a road crossfall of 3% and a road grade of 2%. A rating curve with this name will have to exist inside RAT-HGL. 12d has no way of transferring the rating curve itself into RAT-HGL.

PC Drain

Similar to RAT-HGL, PC Drain has it own rating curves defined internally. The road grade is sent as a separate piece of data to PC Drain so that the pit inlet capacity may be determined.

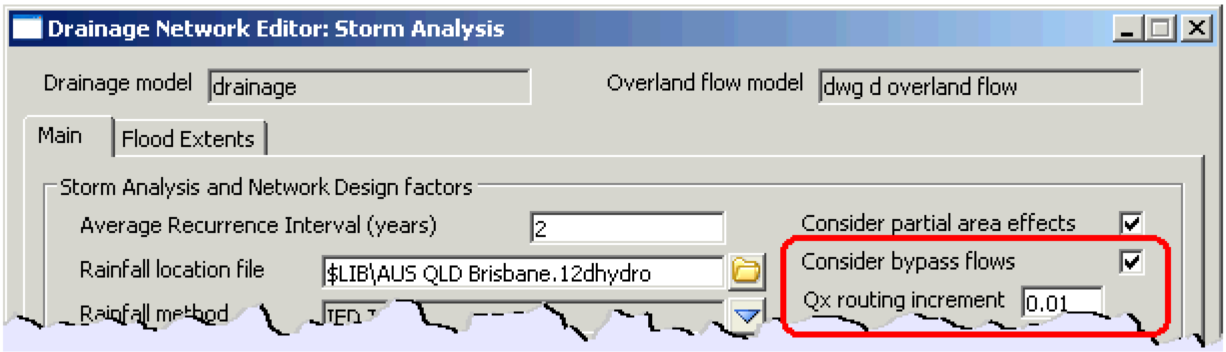
5.1.2 SAG Inlets

PC Drain

PC Drain places a suffix code in the pit type to specify that the pit is a SAG pit. For example an 9S.03 indicates that pit type 9 is a sag pit and the maximum depth before bypassing is 30mm.

6.0 12d Storm Analysis Bypass and Flooded Width Calculations

Once the bypass pits are selected and the drainage.4d file has been setup for bypass flow the storm analysis engine must have this feature enabled. Select **Consider bypass flow**.

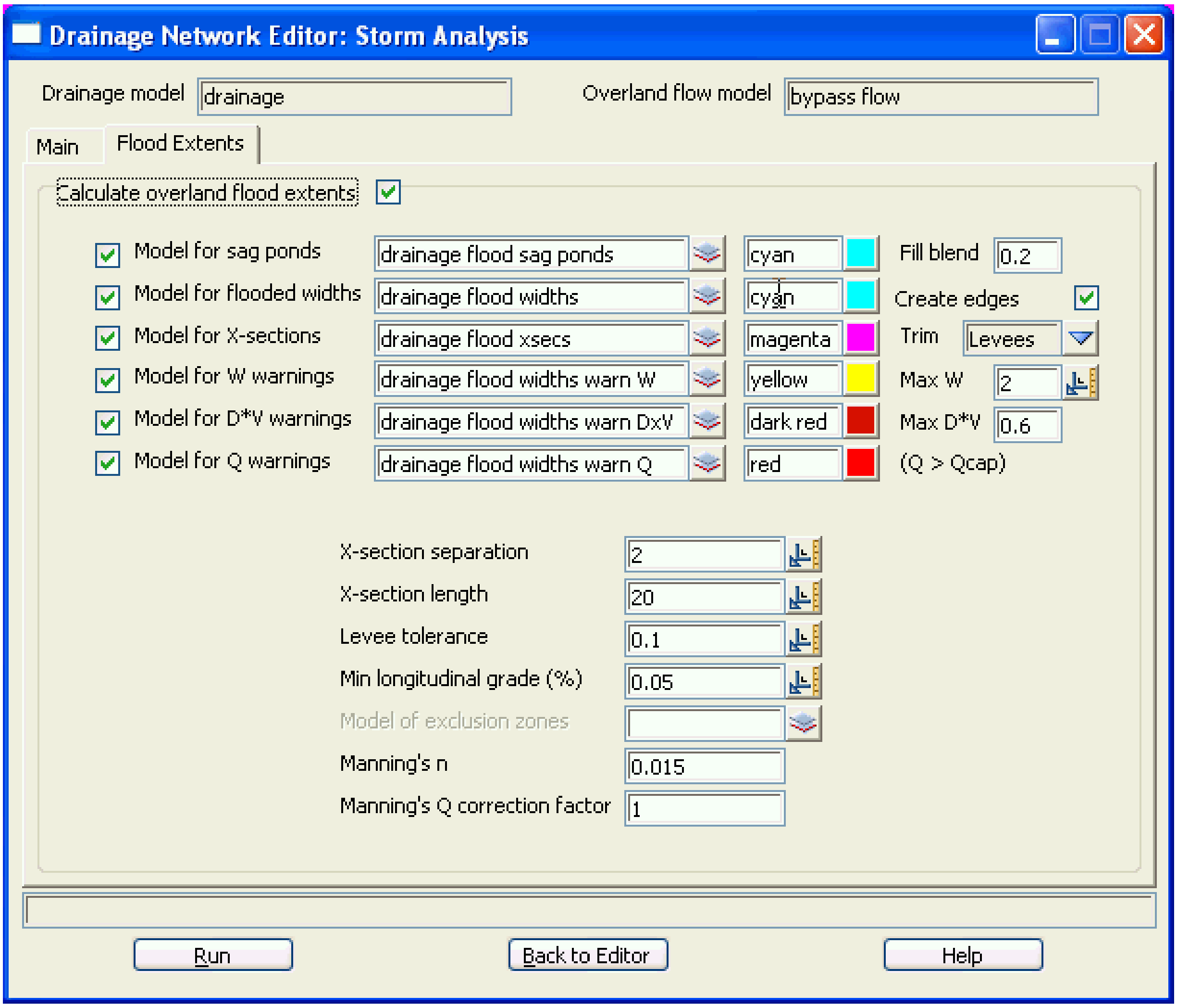


The **Qx** value controls how excess flow is handled in the bypass flow calculations. If the hgl at the pit reaches the grate level then no more water can enter the pit even if there is inlet capacity. The flow that will not enter the pit is considered excess flow. When a value greater than zero is entered here, the inlet will initially have its inlet capacity restricted by this value. Upstream inlets are done first as this may reduce the hgl in the downstream system. The system is rerun adjusting the flows by this amount each time.

If the inlet capacity is reduced to zero and the hgl is still above the pit then water is removed from the pit and considered as Qs (surcharge flow). In the hydraulic reports this value is found as a negative **Inlet Flow Qi**.

The storm analysis engine will calculated flooded widths from normal depths along the flow path and ponding extents at SAG inlets. A bypass flow model (**Global-Utility Models** tab) is required for these calculations.

The models and the input data for these calculations are entered on the **Flood Extents** tab.



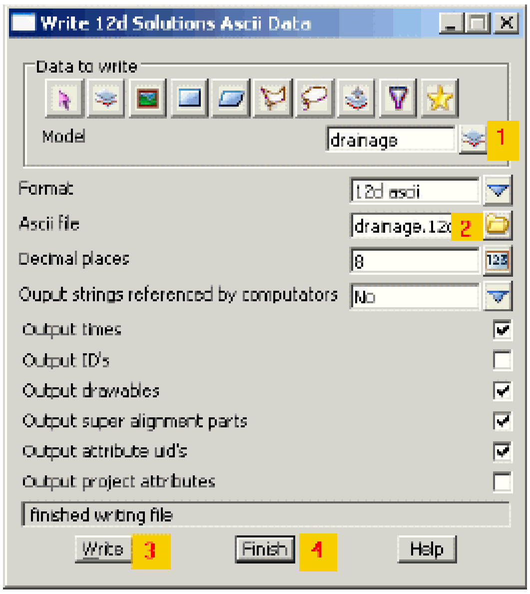
Select **Calculate overland flooded extents** to active the fields on the panel.

Model for sag ponds is used to hold string that indicate the extent of flooding at the These settings are used in the same way as the flooded width calculations previously discussed.

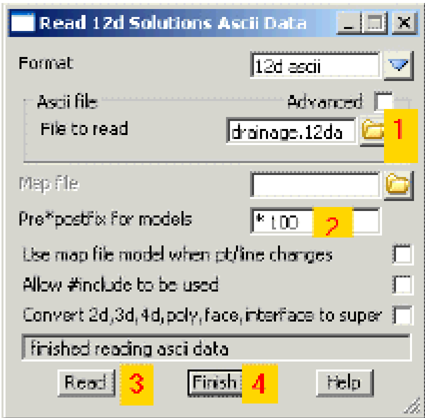
The **Model of exclusion zones** is optional and usually contains the sag ponds model. Flooded with calculations will not take place inside the polygons in this model.

7.0 Major Flood Events

If you want to keep the results for the minor and the major event then create a copy of your drainage network and add a suffix to the model name. Select **File IO->Data Output->12da/4da data.**



Now read the same file into 12d using a suffix 100. Select File IO->Data Input->12da/4da data.



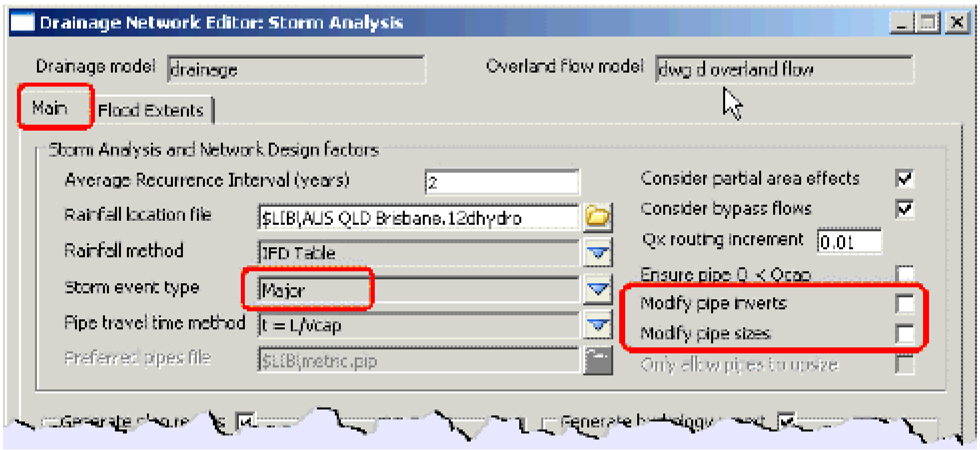
Use the DNW to select the new drainage 100 model.

For major flood events the user may desire to use an alternative set of values for

Catchment tc,
Catchment C,
Pit direct inflow (Qdi),
Pipe direct inflow (Qpi),

Pit choke factor for ongrade inlets,
Pit choke factor for SAG inlets,
Outlet tailwater levels.

The user will usually turn off the pipe design feature for both pipe size and inverts. These controls are found on the Storm Analysis Panel, **Main** tab.



Change the name of your report files and you may now run the analysis and the results will be kept separately.

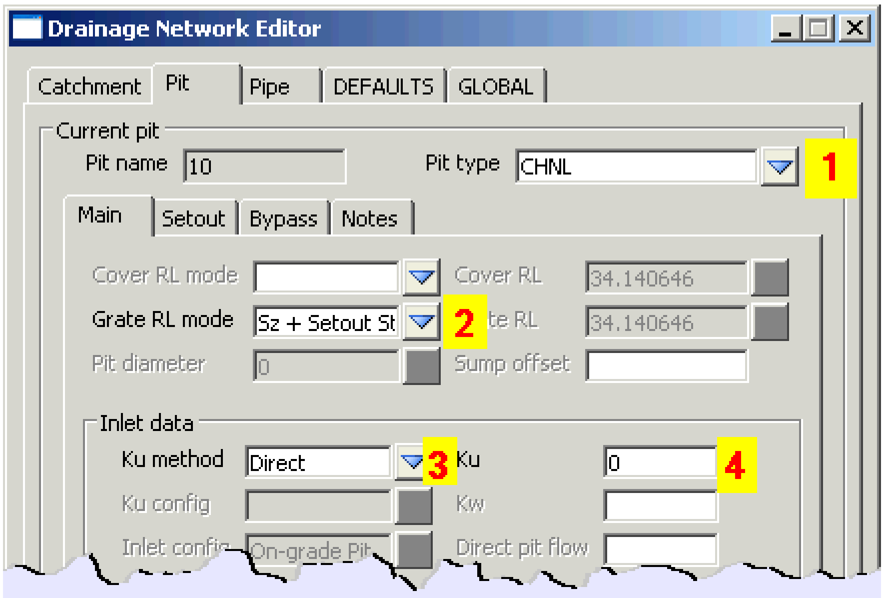
8.0 Open Channel Flow

12d can model flow in open channels a trapezoidal sections. Suggestions for drainage network editor settings are listed below.

Key points

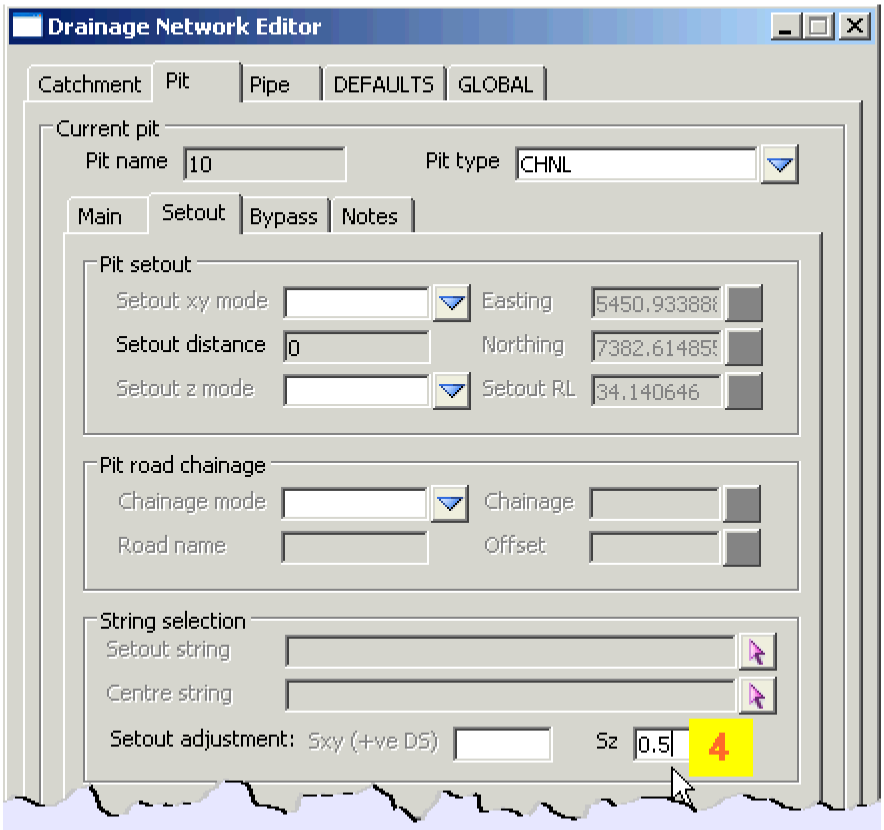
The pit grate level must always be at or above the top of the open channel conduit.

Pit-Main Tab



1. The **CHNL** pit type has a 200% inlet capacity and a diameter of zero. This will result in a single line on the drainage long sections instead of a pit.
2. Setting the **Grate RL mode** to a setout string plus and offset will allow us to use the invert of the drain as the setout string and then the offset as the height of the channel
3. Set the **Ku method** to Direct and enter a Ku of 0 for the channel change of grade points (pits).

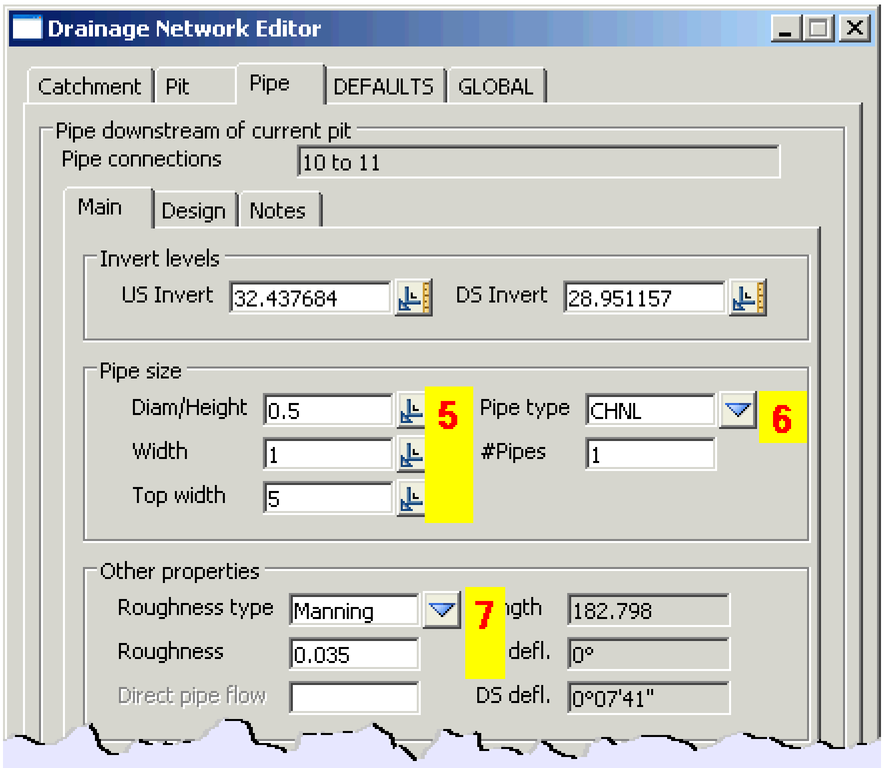
Pit-Setout Tab



4. Enter the Sz equal to the height of the channel. This will set the grate level at the top of the channel.

COURSE NOTES
STORMWATER DESIGN - Part 2

Pipe-Main Tab



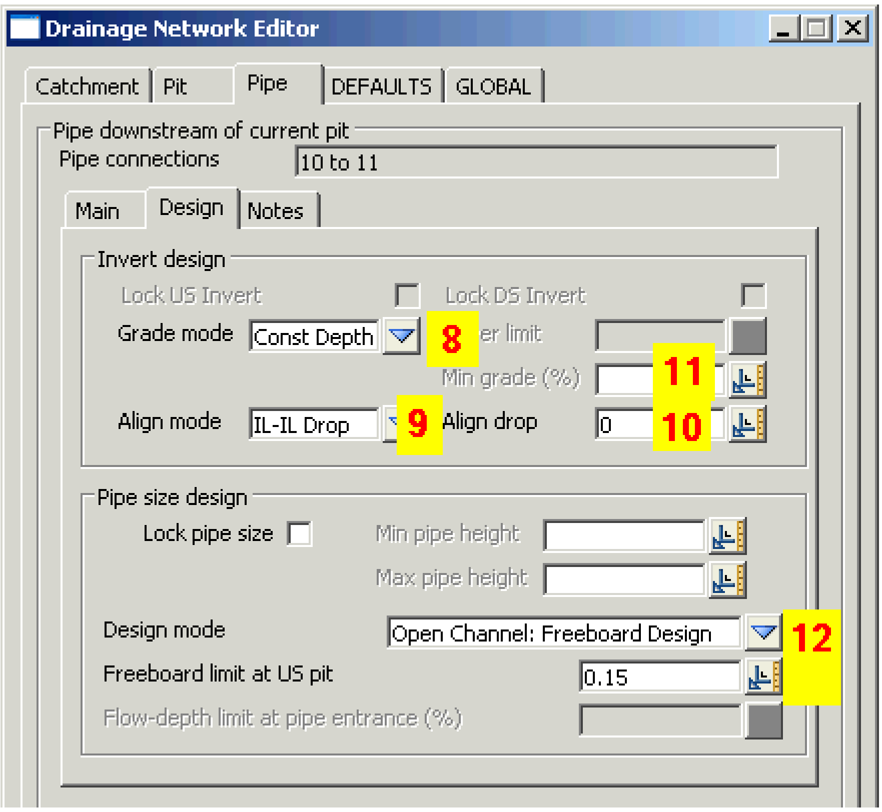
5. Set the **Height, Top width** and **Bottom width** of the channel.
6. Change the Pipe type to **CHNL**. This is for long section labelling and does not affect the calculations.
7. Set the **Roughness type** to **Manning** and enter a roughness for the open channel.

Note: The inlet at the end of the channel is often modelled as a SAG pit for inlet capacity. The Ponding depth will have to be entered manually (use the depth of the channel). Since the grate had to be placed at the top of the channel, 12d will not be able to plot to SAG pond for this pit.

COURSE NOTES

STORMWATER DESIGN - Part 2

Pipe-Design Tab



8. Set the **Grade mode** to either
   "Constant depth channel" or
   "Min depth" with a **Cover limit** of 0.0.

9. Set the **Align mode** to "IL-IL drop"

10. Set the **Align drop** value to 0 (unless you are designing drop structures for your channel.

11. **Min Grade %** for open channels is usually much less than pipes.

12. Set the **Design mode** to "Open Channel: Freeboard Design". This will allow supercritical flow to continue through the channel junctions. Often the **Freeboard limit** will be different for a channel than the pipe system.

COURSE NOTES

STORMWATER DESIGN - Part 2

9.0 Excavation Quantities

Sample templates are included in the courses section of 12djobs (\12djobs\courses\8.00\drainage\pipe template.tpl). The templates from this template library may be added to your project using

Design=>Templates=>Utilities=>Input.

This routine uses 12d templates to calculate the excavation volume for all of the drainage strings in a model. An option to create section for a tin on top of the pipe is also available so that the drainage long sections can include hatching between the obvert of the pipe and the design tin under roads.

Templates with names set to the pipe diameters (times 1000) are used for the calculations, thus trench shapes can be customised and over excavation for bedding materials can be included. Net area calculations to exclude pipe area are not supported.

Key points

1. One template for each pipe size (mm)
2. If obvert templates are used, add the prefix “obvert “ to the pipe size
3. Carefully consider the tin selected.

A template must exist for each pipe size in the model (pipe size x 1000). For example a 0.3m pipe will require a template to exist named 300. A 0.5ft pipe would require a template named 500. Sample templates are included in the courses section of 12djobs (\12djobs\courses\7.00\drainage). These may be copied to your *.project directory and then added to your project using **Design=>Templates=>Utilities=>Add=>All all to project.**

The templates are run along the strings and the total volumes are reported. Volumes for each strings are given in the report file. An example follows.

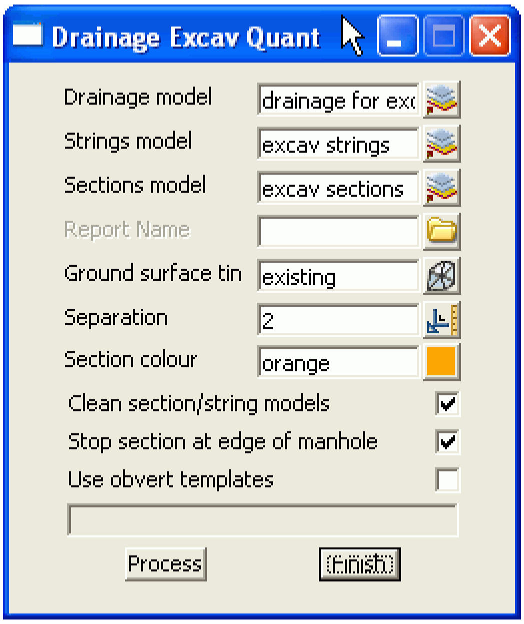
```
----------------------------- BEGIN APPLY TEMPLATE REPORT ------------------------------

 apply template to string report -

   string          E
   tin             design
   separation          10.000
   left template  375
   right template 375
   cut volumes and areas are negative
   fill volumes and areas are positive

chainage- ------sectional  information------  ------intermediate  information----    ---------accumulative  information-------
         ---------- ---cut area --fill area ------------ ----cut vol ---fill vol    -cut volume-- -fill volume- ---balance---


    0.000                -1.434       0.000                                              0.000         0.000         0.000
                                                          -0.771       0.000
    0.550                -1.367       0.000                                             -0.771         0.000        -0.771
                                                         -14.222       0.000
   10.000                -1.642       0.000                                            -14.992         0.000       -14.992
                                                         -15.293       0.000
   20.000                -1.416       0.000                                            -30.286         0.000       -30.286
                                                          -1.845       0.000
   21.313                -1.393       0.000                                            -32.130         0.000       -32.130
                                                          -0.794       0.000
   21.863                -1.493       0.000                                            -32.924         0.000       -32.924

total cut                        -32.924
total fill                         0.000
balance                          -32.924
ie excess of cut over fill        32.924

----------------------------- END APPLY TEMPLATE REPORT ------------------------------
```

If a tin is created from these strings then volumes by depth can be determined using **Design=>Volumes=>Exact=>Tin to tin**

Usage

Access this panel from the menu selection

Design => Drainage => Reports => Excavation Quantities



The fields and buttons used in this panel have the following functions.

Field Description	Type	Defaults	Pop-Up
Drainage model	input box		

Model to contain all of the pit and pipe network to be worked on.

Strings model model box

Strings generated from the templates will be stored in this model

Sections model model box

Sections generated from the templates will be stored in this model

Report name input box

cut and fill volumes will ne sent to this report

Ground Surface Tin tin box

tins from which the volumes will be calculated

Separation real box

distance between the sections

Sections colour colour box

Sections generated from the templates will be assigned this colour (strings colours are defined in the templates)

Clean section/strings model tick box

Delete the strings in these models before processing.

Stop section at edge of pit tick box

Template are run from pit centre to centre if this is not selected. The templates stop at the edge of the pit if selected. This is often selected with the following option ***Use obvert templates.***

Use obvert templates tick box

Templates must be named with the prefix "obvert". i.e. ***obvert 300.*** *The template is still run along the invert of the pipe but the user now has a section "set" of templates that can be used to create a tin on top of the pipe as well as below.*

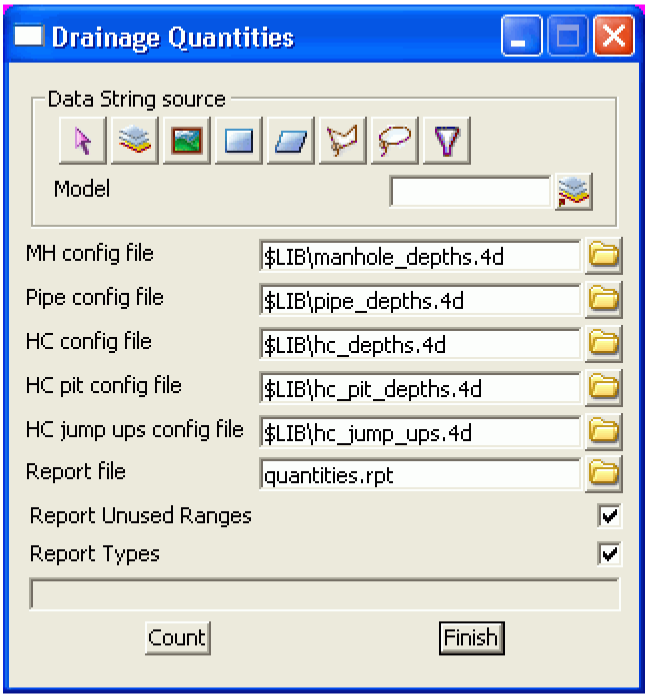
10.0 Network Quantities Report

This panel is accessed from the menu selection

Design => Drainage Sewer => Reports=> Network Quantities

Key points

1. Items are counted/totalled by depth and optionally type.
1. The routine will not "double count" items even if the ranges overlap.
2. Types are case sensitive, types with spaces in the name must be enclosed in quotes and the wild card * may be used.
3. Use vertically offset tins and "banded" depth ranges to get quantities under roads, foot paths etc. This is discussed later in detail.
4. Erase count file fields if the items are not to be counted.



The fields and buttons used in this panel have the following functions.

Field Description	Type	Defaults	Pop-Up
Data String Source	Choice		

usually the entire model is selected but view is also available for combining models

MH config file	file box		

This file specifies the types and depth ranges for the pits. Details of this file are contained below.

Pipe config file file box

This file specifies the types and depth ranges for the pipes. Details of this file are contained below.

HC config file file box

This file specifies the types and depth ranges for the house connections. Details of this file are contained below.

HC pit config file file box

This file specifies the types and depth ranges for the HC pits. Details of this file are contained below.

HC jump ups file file box

This file specifies the types and depth ranges for the house connections jump ups. Details of this file are contained below.

Report file file box

a sample report file is given below.

Report unused ranges tick box

*the depth ranges for the pit/pipe/house connections are defined in the *.4d files. Selecting this option will cause the depth ranges in the file to be printed even if there are no pit/pipe/house connections in these depth ranges (zero quantity values will be shown).*

Report types tick box

*Selecting this option will cause the pit/pipe/house connection types used in the model types to be listed (even if quantities are not requested in the *.4d files). Since this is a complete of the type used in the model, the list informs the user what types have not been included in the quantity calculation.*

Count button

executes the option.

Finish button

removes the dialogue from the screen

The *.4d files listed above are contained in the 12d **library** directory. Each line is the file performs a count (count lines). No items are counted twice. Therefore, if an item is counted its type and then a count line is found the wild card is used for the type, the type already counted will not be included in the count.

The format for a count line is three or four values (space delimited) per line. Size is optional.

```
<type (from drainage.4d)>  <size> <starting depth>   <ending depth>
```

Notes:

All **types** with spaces in the name must be enclosed in quotes The wild card * may be used.

The **size** is optional and if omitted the all sizes will be counted in this group (do not use the * for a wild card).

The **starting depth** and **ending depth** are required for all count lines.

Quantities Under Roads and Footpaths

By creating super tins with vertically offset sections, quantities under roads, footpaths etc. can be determined. for example.

Offset your road design tin up by 1000m (**Tins->Utility->Translate/Copy**) and then use the depth range 1000-1999 for pipes under roads.

Create a tin from the footpaths only, null by angle length with a small length to remove the road and then offset it vertically by 2000m. the depth range 2000-2999 is not the quantities under the footpath.

Sample count lines

```
// sum concrete cover manholes is various ranges

"CONC COVER" 0.0 1.6
"CONC COVER" 1.5 3.0
"CONC COVER" 3.0 999.9  // this is expected to be zero
"CONC COVER" -999.0 0.0 // trap errors

// any that are not Concrete cover will be counted here

* 0.0 1.6
* 1.6 3.0
* 3.0 999.9
```

```
Manhole Quantities
====================================


CONC COVER          0.00    1.60    13      16.506
CONC COVER          1.60    3.00     1       1.510
CONC COVER          3.00   999.9     0       0.000
CONC COVER        -999.0     0.0     0       0.000

*                     0.00  1.60     0       0.000
*                     1.60  3.00     0       0.000
*                     3.00 999.9     0       0.000

  total length = 18.016


  Types Used
  ----------

  CONC COVER

  Diameters Used
  ----------

  1.100
```

Since the **Report unused ranges** tick box was selected, these lines were printed even though there were no pits in the data ranges.

This data results from selecting the **Report types** tick box.

Sample count lines for pipes follow.

```
// sum class 2 pipes by diameter and for various ranges

// count 375

2 0.375 0.0 2.0
2 0.375 2.0 5.0
2 0.375 5.0 999.

// count 450

2 0.450 0.0 2.0
2 0.450 2.0 5.0
2 0.450 5.0 999.

// count 525

2 0.525 0.0 2.0
2 0.525 2.0 5.0
2 0.525 5.0 999.

// count pipe sizes that were missed

2 * 0.0 2.0
2 * 2.0 5.0
2 * 5.0 999.

// count all other missed pipes

* 0.0 999.
```

11.0 Exporting to Drainage Design Software Packages

12d contains most of the data required for your drainage design packages. However, each packages has specific design variables that 12d does not have access too. The design process is intended to export your data from 12d to the design package, design the drainage system and then read the results back into 12d for your long sections.

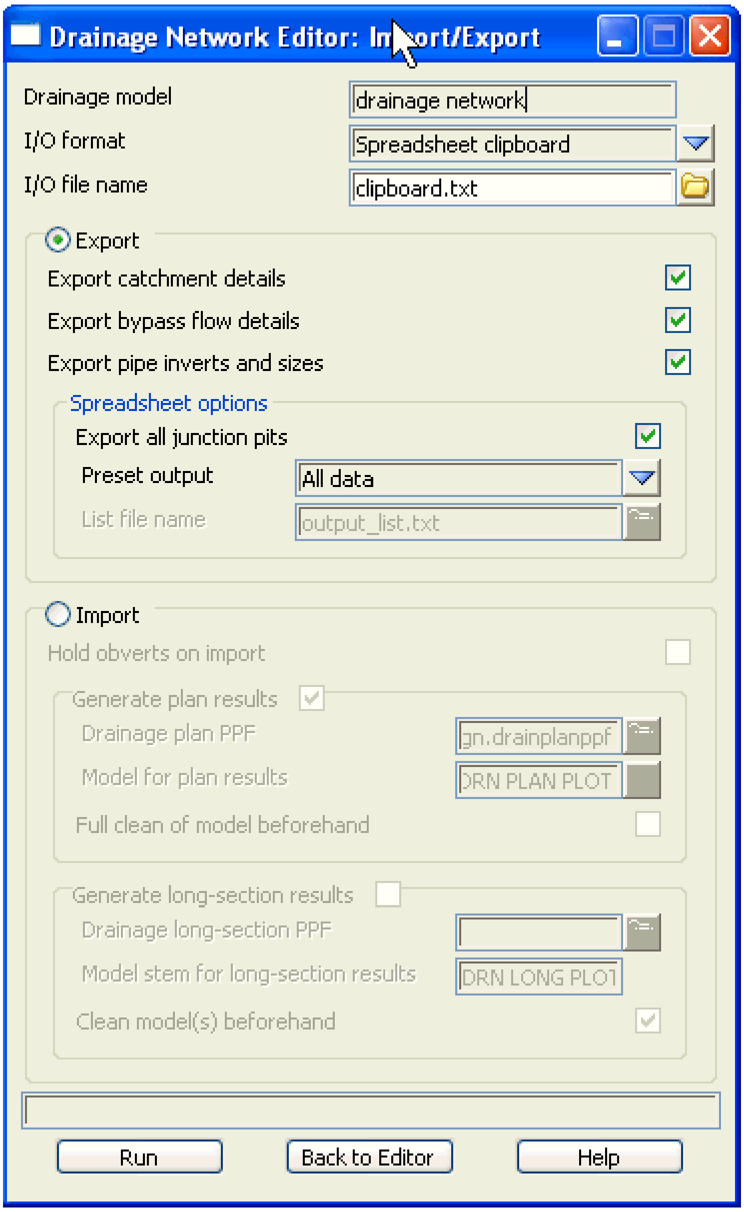
If pits/pipes are to be added/deleted from your network during the design process you are safest to add/delete the pit/pipe to 12d and to your design package separately.

Not recommended and as a poor alternative, you have the option of reading the results back into 12d, adding/deleting the pits/pipes and then exporting the data to a new drainage project in your drainage design software. **As 12d does not have access to all of the data in the design packages this method is not recommended!**

Some of the drainage design programs offer a third option that allows you to import data “on top of” an existing project thereby merging and over writing the existing data. Be sure to contact the drainage software supplier to obtain exact details of how the merging process is performed.

The interface is run by selecting **Import/Export** from the **Drainage Network Editor**

Design->Drainage-Sewer->Network Editor



The **Drainage model** is the model currently being edited.

The **I/O format** selects which external program the 12d is interfacing with. Some programs use the windows clipboard and others use files. If the clipboard is used the data will also be written to a file by 12d in case you need to take the data to another computer.

Export enables the export fields below and exports when **Run** is selected.

The **Export options** have slightly different effects depending on the **I/O format** (program) selected above. Therefore they will be discussed later with the various formats.

Export pipe diameters and inverts is generally select for existing systems only. If your design program will set invert levels and pipe sizes then turn this tick box off for new systems.Some design programs will require initial inverts and pipe sizes. In this case this box should be selected on the first export.

Export default catchment/pit parameters is generally selected for the first export. For subsequent exports turn this selection off and then only the catchment areas (if the model is supplied above) will be exported.

12.0 Drainage Data Input and Output to Spreadsheets

Spreadsheets are an effective method to manage the numerous variables urban drainage designers create in the modelling process. Spreadsheet data can be transferred to and from 12d in tab delimited files and stored within 12d as “user definable attributes”. These attributes are linked to the pit and pipes within a network. Drainage long section plots can display the pipe attributes in the “arrows” data area and pit attributes in the bubbles area. Drainage plan drawing can also show these pit and pipe attributes.

Drainage strings will be created if they do not exist in the model but pits cannot be added to existing strings.

See also

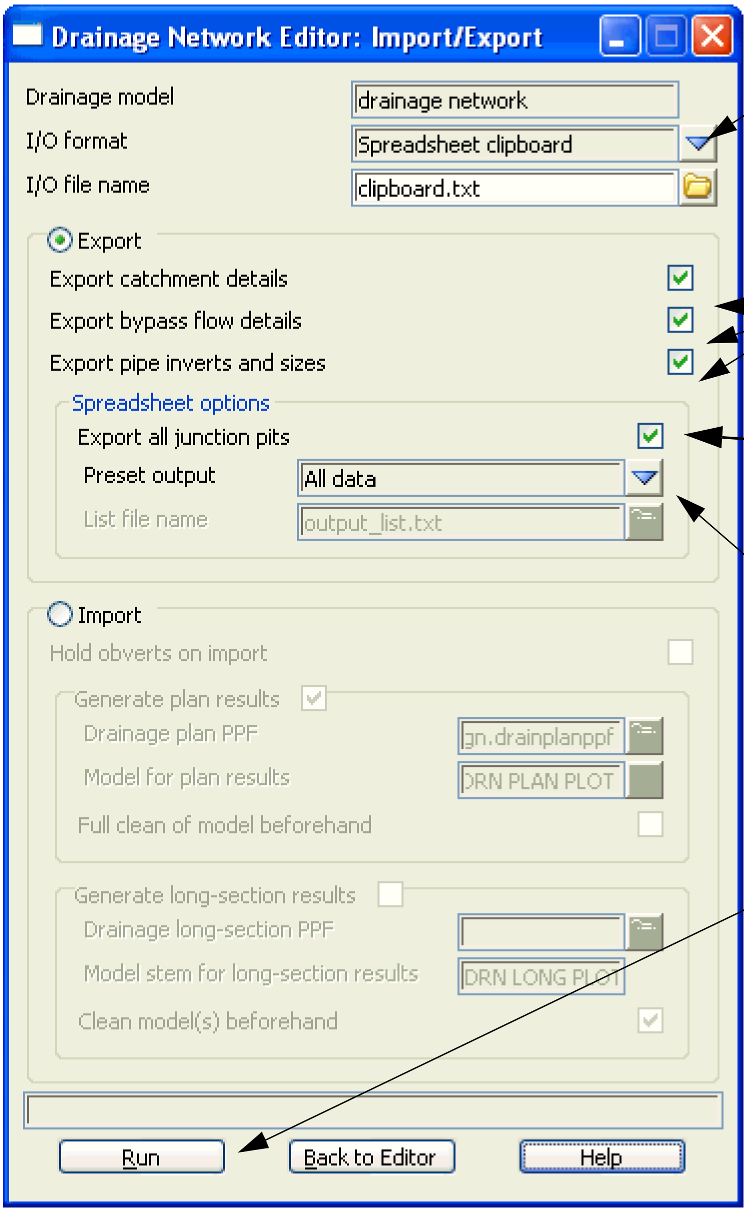
12d to spreadsheet transfers

Spreadsheet to 12d update and create

Spreadsheet options

12.1 12d to spreadsheet transfers

This interface is accessed the **Import/Export** button on the Drainage **Network Editor**.



Select **Spreadsheet clipboard**

These options are not used for spreadsheet export.

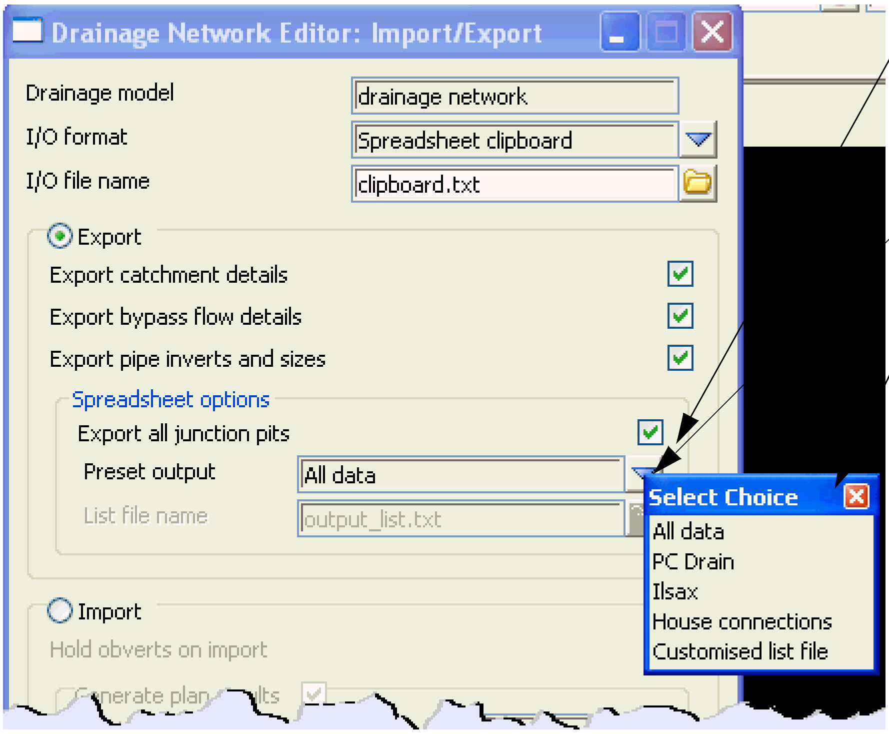
Usually leave this off! Select to export the junction pit at the end of all drainage lines (very rarely needed).

You may also select to limit the output if desired. If you like using spreadsheets for data entry, the PCdrain data and ILSAX data formats are useful for adding data for the first time for either program.

Select **Run** to place the data on the clipboard.

12.1.1 Options

The **Spreadsheet Options** section allows the user to define the amount of data exported.



Export all junction pits when selected will repeat the data for the junction pit at the end of each branch line.

Preset Output this choice box offers the following choices:

All Data: All of the 12d drainage string data and the user defined attributes will be exported to the clipboard in a tab delimited format. The 12d data names and the user defined attribute names will appear at the top of the spreadsheets columns.

ILSAX: For the ILSAX program, the spreadsheet column headings will change depending on the pipe and catchment indicators (P2 card) and the inlet type (P3 card). Therefore, use the ILSAX pipe editor macro to set up one pit/catchment for the type of data you wish to enter. Now when you export the pipe network data the column headings will include the names of the relevant parameters.

User defined below: The **Customised list file name** is used to define the drainage values, their order and format you desire.

The **customised list file** is a text file where each line contains a drainage variable or a spreadsheet IO command (blank lines are ignored unless preceded by the header command). The spreadsheet IO commands are all lower case and listed below:

header	to define a line of text to be exported
blank	to leave a blank column in the output
pit data	the following attributes are for the pit.
downstream pit data	the following attributes are for the downstream pit.
upstream pit data	the following attributes are for the upstream pit(s).
pipe data	the following attributes are for the pit's outlet pipe
downstream pipe data	the following attributes are for the downstream pipe(s)
upstream pipe data	the following attributes are for the upstream pipe(s)
variable name	a 12d drainage variable names
factor	the following variable is multiplied by this factor
decimals	the following variable will export with these decimal places

The simplest way to create your own customised tab delimited file is to set the **Preset Output** field to **All data** and leave the **customised list file name** field blank. Selecting **Set**, **Finish** and then **Copy** from the main dialogue. The data will be placed on the clipboard and a **customised list file**, named **output_list.txt** will be created containing the names of all of the drainage variables in the 12d model. Use a text editor to add/or delete the variable names, change their order and/or add spreadsheet IO commands. **Save the file with a new name!** The **output_list.txt** file is overwitten on every export.

A listing of a customised list file follows. Note the words in the header file have a “tab” between them so that they will be spaces across the spreadsheet columns.

```
header
Pipe Details
    header
    Name Length   U/S IL   D/S IL   Slope(%)   Class   Dia I.D.   Rough   Pipe Is   No. Pipes

    pit data
    *pit name

    pipe data
    *length
    low ch invert
    high ch invert

    factor
    100
    *grade

    pipe type

    factor
    1000
    diameter
```

After creating your customised list file, select **Options** again and change the **Preset Output** field to **User Defined below** and enter the new **customised list file** name that you saved above. Select **Set** then **Finish** and finally **Copy** to put the formatted data onto the clipboard.

The data can be pasted into a spreadsheet program for checking or additional formatting.

CUSTOM FORMATED DATA MIGHT NOT BE PASTED BACK INTO 12d!

The data must be in the “12d drainage spreadsheet” format to be read into 12d.

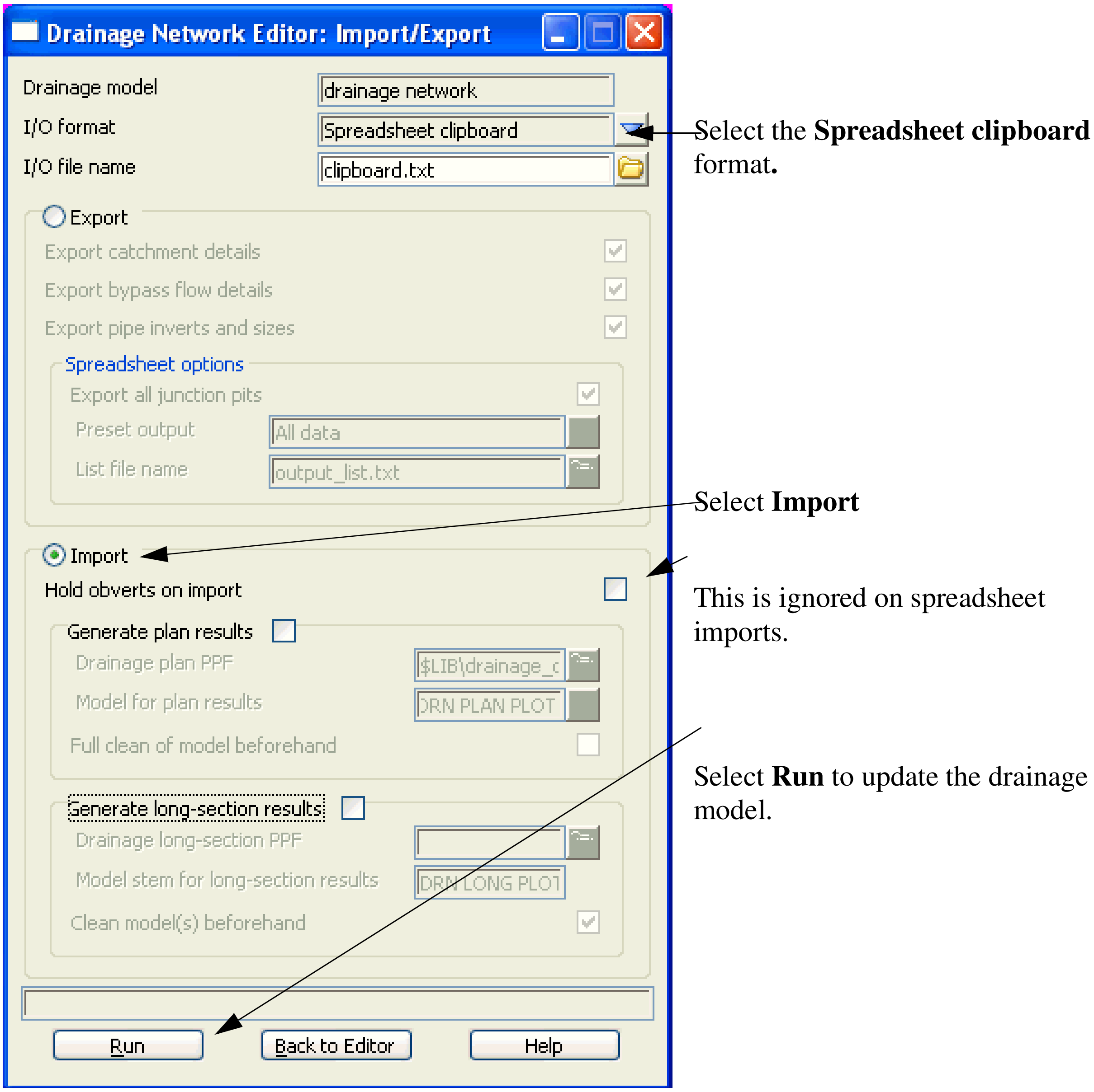
Caution with pit names in the form 1-1 or 1/1. Some spreadsheets will interpret these values as dates. If you use these formats for your pit names you will have to paste command them in once, format the columns that contain the pits names as text data and then paste the information in again.

One final word on using the copy/paste commands in the Microsoft Excel program. The Paste Special command using the “Skip Blanks” option will allow you to copy a large block of 12d data (with blanks in it) on top your data so that your data is preserved where it coincides with the blanks. To use this option paste the data into a blank spreadsheet and then select copy again. The Paste special option with “Skip Blanks” will now be available.

12.1.2 Spreadsheet to 12d transfers

This item is accessed from the **Import/Export** button on the **Drainage Network Editor**.

The following panel will appear.



Tab delimited, “12d drainage spreadsheet” format or “from to” format data must be on the clipboard in order to update a 12d drainage model or create a new model. These format are described below.

12.1.3 Updating an Existing Model

The data usually is generated by 12d using the **Export** option, pasted into a spreadsheet and then copied back to the clipboard so that 12d can be updated.

When 12d exports the drainage model to a spreadsheet it includes a column for the unique string identifier and a unique pit identifier (unique to the drainage model not the 12d project). The names of the strings and pits may be changed via the spreadsheet if these columns are present at import time.

If the pit id column is not present, 12d will search the drainage model for a matching pit name. When the pit is a junction between drainage lines, only the trunk line will be the data updated.

12.1.4 Creating a New Model

It is possible to create a new string or an entire drainage network using this format. However, pits cannot be added to an existing string. The entire drainage string must be created at once. Two formats are available, the "from-to pit" format and the "12d drainage spreadsheet" format.

At present the network editor must select a drainage string to become active. Therefore, if you are not adding strings to a network, you will have to great a drainage network with one "dummy" pit. Select this one "dummy" pit to activate the editor. After importing the data and the new drainage lines are created the "dummy" pit may be deleted.

12d drainage spreadsheet Format

The top left cell in the clipboard data must be the text "12d" to specify this format. The minimum amount of data required to create a new string is the string name, pit name, x and y coordinates. You can add as much additional data as you have available. This would include pipe diameters inverts etc. The pits must be listed from upstream to downstream order. If the string is to join a trunk line, the junction pit must be included for both the tributary and the trunk line.

An example file exists called **new_network.txt** is supplied in the library. Open this file in a spreadsheet or a text editor and copy it to the clipboard. Set the **I/O Action** to **Import** and select **Run**. The new drainage lines will exist in the model currently being edited.

From-to Pit Format

The top left cell in the clipboard data must be the text "from to" to specify this format. The minimum amount of data required to create a new string is the upstream pit name "*pit name), the downstream pit name (*ds pit name) and the x(x location) and y(y location) coordinates of the upstream pit. If the string is to join a trunk line, the junction pit must be included for both the tributary and the trunk line.

An optional column for the pit cover elev (cover elev) may be specified. Once the network has been created additional pipe and pit data may be added using the "12d drainage spreadsheet" format described above.

An example file exists called **new_from_to_network.txt** is supplied in the library. It is shown below. Open this file in a spreadsheet or a text editor and copy it to the clipboard. Enter a new model name in the **Drainage model** field and select paste. The new drainage model will now exist.

from to	pit	pit	pit	pit
*pit name	*ds pit name	x location	y location	cover elev
text	text	real	real	real
E/1	A/3	5309.458	7336.935993	29.2173
D/1	A/4	5277.189	7336.935989	28.5071
C/1	B/3	5251.238738	7423.99485	31.5257
A/1	A/2	5354.629222	7336.935998	30.2115
A/2	A/3	5340.019987	7322.035996	29.89
A/3	A/4	5293.458002	7322.035991	28.8652
A/4	A/5	5250.182625	7322.035986	27.9127
A/5	A/6	5217.194202	7322.035983	27.1867
A/6	A/7	5183.458002	7322.035979	26.4442
A/7		5152.698693	7322.035975	25.7672
B/1	B/2	5289.42875	7422.289079	32.7197
B/2	B/3	5264.638564	7393.947083	30.7948
B/3	B/4	5249.738564	7384.207593	30.4187
B/4	B/5	5249.738564	7351.201545	29.1444
B/5	A/5	5233.426685	7336.935984	27.544

12.2 “12d drainage spreadsheet” Format

Each column of data is used for a 12d drainage variable or a user defined attribute. Each row represents a pit and the downstream pipe (controlled by the direction of flow variable) within the drainage network. A sample is shown below.

12d	pit	pit	pit	pit	pit	pit
*string Name	*pit name	pit type	pit low ch invert	pit high ch invert	pit id	string id
text	text	text	real	real	integer	integer
E	E/1	SA2	28.108	28.108	1	67389
E	A/3	SA2	27.7559	27.7559	2	67389
D	D/1	SA2	27.3961	27.3961	3	68100
D	A/4	SA2	26.8018	26.8018	4	68100
C	C/1	SA2	30.67	30.67	5	72072
C	B/3	SA2	29.563	29.563	6	72072
A	A/1	SA2	29.1026	29.1026	7	82469
A	A/2	SA2	28.7811	28.7311	8	82469
A	A/3	SA2	27.7652	27.7059	9	82469
A	A/4	SA2	26.8127	26.7518	10	82469
A	A/5	SA2	26.0867	26.0244	11	82469
A	A/6	SA2	25.3442	25.2942	12	82469
A	A/7	SA2	24.6672	24.6672	13	82469
B	B/1	SA2	31.2759	31.2759	14	192066
B	B/2	SA2	29.351	29.301	15	192066
B	B/3	SA2	29.123	29.073	16	192066
B	B/4	SA2	28.0444	27.8951	17	192066
B	B/5	SA2	26.3447	26.2947	18	192066
B	A/5	SA2	26.0744	26.0744	19	192066

Duplicate Definitions

Strings Variables such as “direction” are may be defined for numerous pits on the same string. Searching in a top down direction through the file, the last definition found for the string will be set.

Invert levels may be set via pipe data or pit data or combined. It is recommended that the user only use one method and not combine them. Both are exported so delete the ones you are not going to use. The variables are processed from left to right, so if duplicate definitions of an invert level or found the right most data will be set.

The format definition

1. Row1, column 1 must contain either “12d”, or “from to”. Therefore, the first column must be a 12d drainage variable (cannot be a user defined attribute).
2. Row 1. The text <pit> at the top of the column indicates the column contains a user defined pit attribute and similarly <pipe> indicates a user defined pipe attribute.
3. Row 2. This row contains the names of the 12d drainage variable names and the pit/pipe attributes. All names are case sensitive so be careful where you use capital letters. A list of 12d drainage variables is found below.

   Names beginning with an asterix (*) will not be processed (except pit/string names when unique identifiers are present in the data). 12d drainage variables names beginning with an asterix indicate that this data was calculated at export time and cannot be read back into 12d (for example, pipe length, pipe grade and deflection angle).

Prefixing an user defined attribute name with “DELETE ” (no quotes, note the space after the DELETE) will cause the attribute to be deleted from all pits/pipes within the model.

4. Row 3. The text in this row define the type of attribute to be stored within 12d. The only valid choices are;

    integer
    real
    text

    If you want to change an attribute type you must delete the attribute and create it again. If you simply change the attribute type in the third row then that attribute will not be updated.
5. Blank lines may be inserted as desired.
6. You are not required to fill in all of the cells in the spreadsheets. Blank cells are ignored (you must use a space to remove all data from text attributes (the space will not be stored).
7. Pipe names are included in the data so that they can be changed but they are **<u>not</u>** used to identify the pipe. Pipe data will always be assigned to the pipe following the pit in the direction of **<u>ascending</u>** chainage. If flow directions is ascending then the pipe data will be for the downstream pipe. If the flow direction is descending then the pipe data will apply to the upstream pipe.

12.3 12d Drainage Variable Names

Manhole Variables	Pipe Variables	String Variables
*string Name	pipe name	direction
*pit name	pipe type	[illegible]
pit type	low ch invert	[illegible]
pit diameter	high ch invert	string id
pit low ch invert	diameter	
pit high ch invert	*length	
pit road chainage	*grade	
pit road name	low hgl	
*pit angle	high hgl	
*pit drop	pit hgl	
*pit depth	flow	
*pit chainage	velocity	
x location		
y location		
cover elev		
*fs elev		
*ns elev		
pit id		

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13.0 Running PCdrain for Windows

Data is exchanged to and from PCdrain via the interchange (*.int) file. Gutter profiles and inlet type must be specified in PCdrain before the interchange file is read into PCdrain.

The data sent to PCdrain includes

- pit names and types, easting and northing data with surface levels
- pipe deflection angles at pits
- finished surface profile along the centre line of the pipes
- optional - crossing services - level, size and location along the pipes
- optional - bypass inlets, road grades and SAG inlet ponding depths
- optional - up to 2 catchment areas per inlet
- optional - default catchment characteristics, k values and overland travel times
- optional - pipe sizes and invert levels

13.1 PCdrain Requirements

Pit names

The pit name from 12d is assigned to both the structure and catchment name in PCdrain. These names cannot exceed 7 characters.

Pit type

The 12d pit type is transferred to the structure type in PCdrain. These names must match those specified in the PCdrain Inlet charts selected (**Data=>Inlet charts**). Select the desired inlet charts BEFORE importing the interchange file.

12d pit types with an “S” in the name are treated by 12d and PCdrain as a SAG inlet pit. 12d will strip off all characters after the “S” before adding the ponding depth. If a catchment string in set #1 is available for the SAG pit then the ponding depth will be calculated.The12d pit type will remain unchanged. A typical example would be a pit type “1TC” with the sag tick box on would become “1TC0.100” if a ponding depth of 0.1 was calculated.

Bypass Flow

When a catchment string is specified for the pit, the maximum depth before bypass flow commences is calculated. The lowest point on the catchment string is determined by draping it onto the drainage strings tin. The maximum depth before bypass is calculated pit setout level less the setout to grate offset less the lowest point on the catchment string.

PCdrain differentiates between pits (no surface inflow) and gully pits via the 12d pit type. The bypass flow strings can only be drawn within 1 pit diameter of the gully pits. Keep the bypass flow strings away from the PCdrain pits.

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Catchments

Again, since PCdrain differentiates between inlets and manholes (using the 12d pit type), ensure that catchments are only drawn for gully inlet and NOT manholes.

12d to PCdrain Pit Data

12d	PCdrain
Pit-Setout-Easting (northing)	Table 1- Easting (Northing)
Pit-bypass-bypass pit	Table 1 - Bypass structure
Pit-Main-grate Level	Table 5- Surface Level Overrider
Pit-Bypass-Road Grade (%)	Table 5- Road grade over rider
Pit-Setout-Chainage	Table 5- Road Chainage
Pit-Setout-Offset	Table 5- Road offset
Pipe-Main -length	Table 7 - Pipe length
Pipe-Main-diam	Table 7 - Pipe1 size
Pipe-Main-# pipes	Table 7 - Pipe1 number of conduits
Pipe-Design-Alignment Modes	Table 7 - Alignment of conduits
Pit-Main-Ku(Kw)	Table 8 - Ku (Kw)
Pipe-Main-US invert	Table 9 - Upstream level of pipe
Pipe-Main-DS invert	Table 9 - Downstream level of pipe

12d to PCdrain Catchment Data

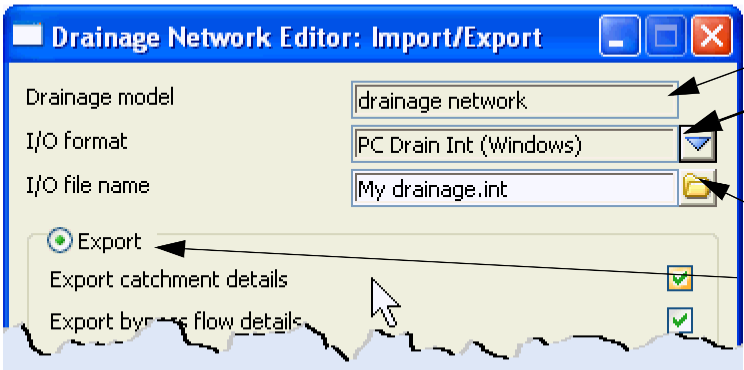
Perviouus Impervious	12d	PCdrain
Total	Area	Catchment Area
Total	Area (set 2)	Catchment Area2
Pervious	C minor and Major	Minor coef; Major coef
Pervious	C minor and Major (set 2)	Minor coef2; Major coef2
Pervious	Tc minor (Direct method only)	Time of concentration overrider
Pervious	Length	Length of overland flow
Pervious	Slope	Grade of overland flow
Impervious	Length	Length of gutter
Impervious	Slope	Grade of Gutter

13.2 12d to PCdrain

1. Export the data to PCdrain selected via the Network editor

Design=>Drainage-Sewer=>Drainage Network Editor

After selecting the drainage network, select the **Import/Export** button and the following dialogue will appear.



The drainage model will be completed by the editor.

Select **PCdrain Int (Windows)** from the drop down list.

Enter the name of the int file to be created.

Select **Export**.

Select the **Run** button and the interface file will be created.

2. Launch the PCdrain for Windows program. If you have a project set up with the design parameters, rainfall data, inlet charts and gutter profiles then open it now and skip to step 8. Otherwise continue with step 5.
3. The Design Parameters can be set as desired with the menu selection **Data=>Design Parameters**.
4. Select the rainfall data using the **Data=>Rainfall** menu selection.
5. Select the inlet charts using the **Data=>Inlet Charts** menu selection. The pit types specified in 12d must be included in these settings. **More - PCdrain to 12d pit converter**
6. At least one gutter profile in PCdrain needs to be defined. These are set through the menu selection **Data=>Gutter Profiles**. The default gutter section name (**Road ID**) from 12d is **4d** and therefore it is recommended you create a profile with this name and your own description. If you have changed the profile names in 12d (through the spreadsheet interface or the Attribute editor) these new profile names will have to exist in PCdrain.
7. Save this file now so that you can retrieve it later if required. It can be used as a starting template for new jobs.
8. **File=>Import** from the menu. Select the file exported in step 1. The information from 12d may be viewed by selecting **Data=>Network** and then selecting the desired tabs.
9. The HGL level and the pipe elevation at the outlet should be set using the menu selection **Data=>Outlet.**
10. If you have not exported pipe data then the pipe size must be determined. Use the menu selection **Process=>Select Pipe Sizes.**

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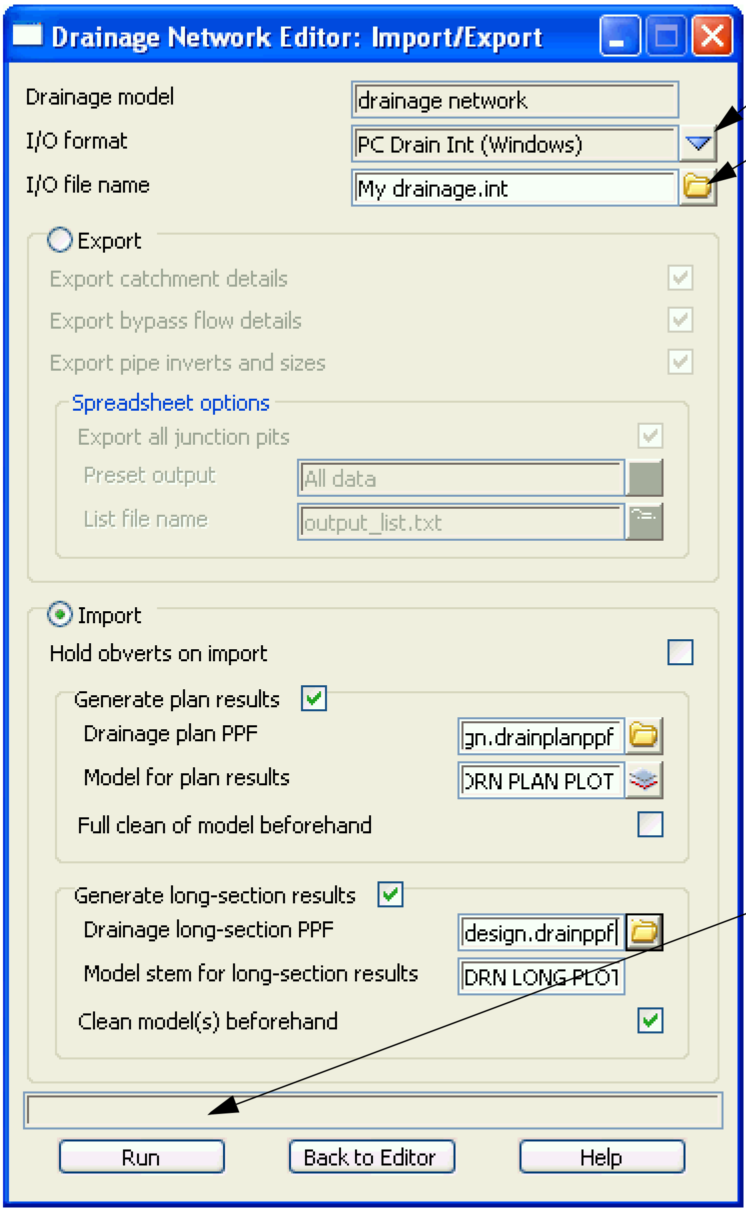
13.3 PCdrain to 12d

Export the results to 12d using the **File=>Export** menu selection. Note the name of the interchange file you are creating as you will need to enter it inside 12d.

Return to 12d and select **Import/Export** from the network editor and the following dialogue will appear,



Select **PCdrain Int (Windows)** from the drop down list.

Select the output file name you created in PCdrain.

Select **Run** and the file will be read into 12d and the drainage network will be updated. To see the changes in a section view, select **Regen.**

A listing of the data imported is stored on the 12d output window.

Inlets that have been specified as SAG inlets will have the ponding depth removed from the end of the PCdrain structure type before the data is stored as the12d pit type.

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14.0 Running Drains - Version 2 onwards

Key Points

1. The Drains database (each project has its own) and the12d database (drainage.4d) must be synchronised (**More**).
2. 12d Version 8 needs you to create a new drainage.4d file to include the new inlet capacity curves (pit groups are no longer used).
3. For pits with a bypass pit and road grade defined (non ILLUDAS), 12d selects pit families for Drains in the following way

   The users selects the pit type (Drains pit size) in 12d and 12d selects the ongrade or sag curve from the drainage.4d file (see inlet capacity calculations). The names of these curves are the Drains pit families. If there are no curves for the pit type in the drainage.4d file then the Drains pit type is exported as ILLUDAS with no family or size data.

   If the 12d pit type is **Headwall** then the pit will be exported as a headwall.
4. Catchment lengths, slopes and roughness values are NOT exported in the Drains Rational format. The default values for these parameters are NOT exported in the Drains ILSAX format but the explicit settings from the catchment panel are exported. If used, Drains requires length, slope and roughness for both impervious (paved) and pervious (grass). Supplementary values must entered in Drains.
5. Data is copied from 12d to the Windows clipboard and then pasted into Drains. 12d can not delete any objects in Drains, it can only add and update.
6. When updating 12d from Drains, always copy the DATA to 12d before the results. 12d will update the network but will not add or delete pits.
7. If a new pit is added in Drains, the user willhave the option to create it in 12d. If it is created only the pit will be added and not the pipes.

Why Do I get ILLUDAS pits?

1. The bypass pit is blank. There must bypass pit for the water to go to. Bypass flow strings must pass within 1 pit diameter (beware pits with zero manhole diameters) and you can enter them manually.
2. The pit type selected has no capacity curves in the drainage.4d file. The curve names become the pit family for the export to Drains. No pit family means ILLUDAS.

   If you are intentionally using a drainage.4d file with NO inlet capacity curves, the pit families you set in Drains will be remembered by 12d when you import back into 12d. The inlet capacity curves will not be required for your next export to Drains.

14.1 Drains Interface Overview

The Drains program performs the rational or ILSAX hydrology calculations as well as hydraulic grade line calculations that determine pipe sizes and pipe invert levels.

The data sent to Drains includes

- pit names and types, easting and northing data with surface levels
- finished surface profile along the centre line of the pipes
- **Headwalls** and their levels
- optional - bypass inlets, road grades/crossfalls and **SAG Inlet Calculations** (ponding volumes and depths). Pit family selection using road grade and crossfall data.
- optional - composite catchment area create from three12d areas per inlet (must alter the mapping file)
- catchment characteristics, k values and overland travel times
- pipe sizes, type and invert levels

Data is copied from 12d to the Windows clipboard and then pasted into Drains **(Edit=>Paste data from spreadsheet)**. 12d can not delete any objects in Drains, it can only add and update.

The Drains menu selection **Run=>Design** is used to design the network. Once the drainage network has been designed in Drains the updated design data (**Edit=>Copy data to spreadsheet)** and/or the hydraulic results (**Edit=>Copy results to spreadsheet)** are sent back to 12d via the clipboard.

Always copy the DATA to 12d before the results as the results are deleted inside 12d with every update of the data!

14.2 Catchment Data

Drains has one catchment per inlet and therefore only 12d's catchment set one is used in the interface. The 12d catchment is split a pervious (grass) area and an impervious (paved) area using the percent impervious fraction. The rational and ilsax spreadsheet export formats (selected in the import/export panel) are different.

The Rational format of the Drains interface does not export Drains "more detailed data". The ilsax format does support the "more detailed data" format but the user must define the length, slope and roughness in the catchment panel. No 12d DNE default data will be exported. As 12d does not have a supplementary area this data will have to be entered into Drains. Gutter lengths and slopes are calculated from the upstream section of the longest overland flow path entering the inlet.

Supplementary data entered in Drains will be remembered in 12d for the next export. The grassed percentage for the next export is calculated as the (100 - % impervious - % supplementary).

14.3 Synchronising the Drains database and the drainage.4d file.

The 12d pipe types are always used to interface with Drains. **Ongrade** or **SAG** pits will be created for export to Drains if the 12d pit has a bypass pit, road grade and a pit type with inlet capacity curves. If all three are not present it will be exported as an ILLUDAS pit.

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Every Drains file begins with a default database and Drains uses that database for the life of the project. This database must by synchronised with the **drainage.4d** file in 12d to ensure the Drains pit families, pit sizes, pipe types and overflow route types match. Therefore it is highly recommended that copy of the drainage.4d file be kept in the 12d working folder.

The Drains and 12d data must match as follows.

Drains database	**drainage.4d**
Pipe type	Pipe type entries
Only if bypass flow is required	
Drains database	**drainage.4d**
Pit size	Pit type
Pit famly	ongrade or sag curve names
Overland route database	default in mapping file

Note: If Drains is to be used to select the pit size then an exact match in pit types is not required. For this case the 12d pit type need only be the prefix of the Drains pit size.

The following 6 steps will help ensure 12d is synchronised with Drains. More details are given in the sections below.

1)Prepare the Drains Pit Database

IF 12d is to select the Drains **Pit Size**, then the Drains **Pit Size** and 12d **Pit types** have to match, exactly! If Drains is used to determine the pit size then you may skip this step.

The pit databases supplied by Drains often have road grade and/or crossfall attached to the end of the pit size. **THIS EXTRA DATA MUST BE REMOVED**!

For example, in Drains database you may find the following

Pit family	Pit size
NSW RTA SA Inlet, 3% crossfall, 1% grade	SA1 (Type 2) - 1% longitudinal grade
and	
NSW RTA SA Inlet, 3% crossfall, 3% grade	SA1 (Type 2) - 3% longitudinal grade

The pit size for both is the same, **SA1,** but 12d can not tell this because of all the extra data at the end. In Drains, simply remove the extra information so that they are both **SA1**. If the network already exists in Drains, then Drains will automatically change the names of the sizes you have already selected. No time lost here.

Once you have changed the Drains pit size names, you are ready to use the **Drains to drainage.4d** routine to create a drainage.4d file that is synchronised with Drains.

2)Export the Drains database from your Drains file

Inside Drains Open your drains file or begin with a blank file. Select **Project=>Overflow Route**

database. Then select **OK** and then **YES**. This will cause Drains to export the database to the file "Drains Connection Data.txt" and store it in the folder with the Drains program.

3)Create a drainage.4d file from the Drains file

- From the 12d menu select **Design->Drainage-Sewer->More->Drains to drainage.4d**.
- Select **Copy Drains database** to copy the file to the 12d working folder.
- select **Create drainage.4d.** The Drains database dump file is copied to the 12d working folder and a drainage.4d file is created in the 12d working folder.
- **More details below**.

4)Edit the drainage.4d file

From the 12d menu select **Design->Drainage-Sewer->More->Edit drainage.4d**. Select **Find** then edit from the file **more info** button. Set the road grade and crossfalls for the 12d pit groups.**More details below.**

5)Restart 12d

From the 12d menu select **Project->Restart**.

6)Set the Overflow shape, Update Pit and Pipe types (Optional)

If the network has already been created using pit and pipe types that no longer exist in the drainage.4d file, they will have to be updated before the export to Drains can occur. You may update them using the drainage network editor (one at a time) or you may set **all** of the pit and pipes types to **one value** using this routine.Later you may change them individually using the **Drainage network editor**

This routine will also set a default overflow route shape for export (values can be modified in the Drains program if desired).

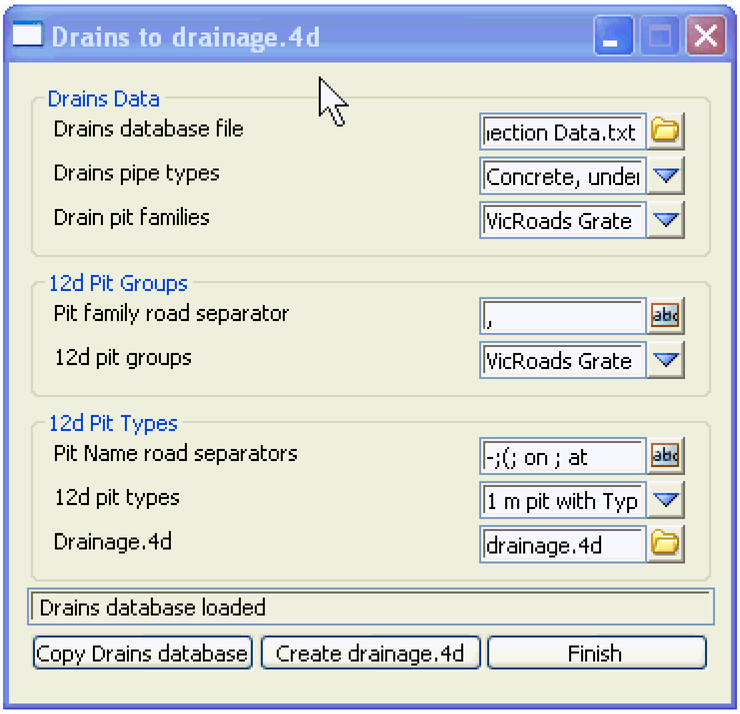
From the 12d menu select **Design->Drainage-Sewer->More->Drainage io defaults.**

More details below.

14.4 Drains to drainage.4d file

Position of option on menu: Design =>Drainage-Sewer =>More=>Drains to drainage.4d

On selecting the Drains to drainage.4doption, the Drains to drainage.4d panel is displayed.



Key Points

When you are finished, open the drainage.4d file and check the road grade and crossfall values for the ongrade curves!

1. If Drains is used to selected the pit sizes
   then the 12d pit type must be the prefix of the Drains pit size (**Pit Name road separators** are used).

   If 12d is used to select the pit sizes to export to Drains, the Drains **Pit Size** and 12d **Pit types** have to match, exactly! The pit databases supplied by Drains often have road grade and/or crossfall attached to the end of the pit size. If pit sizes are to be sent from 12d, **this must be removed**! Find **Prepare the Drains Pit Database** for more details.
2. Select **Copy Drains database (12d will search the usual locations for the Drains database).**
3. Review the **Drains pipe types** and **Drains pit families** lists to ensure you have the correct database.
4. 12d pit groups are not used in Version 8.
5. **Pit Name road separators** can only be used if **Drains** is selecting the pit types. If 12d pit types are to be exported to Drains, this field should be left blank. If you change these entries you must press the enter key to update the **12d pit types** list below.
6. Check the **12d pit types** and if they are acceptable select **Create drainage.4d.**

The Details

YOU MUST RESTART 12D FOR THE NEW DRAINAGE.4D FILE TO BECOME ACTIVE!

Field Description Type Defaults Pop-Up

Drains database filefile Drains Connection Data.txt

You must update this file from Drains before each use of this panel. Inside Drains select Project=>Overflow Route database. Then select OK and then YES. This will cause Drains to export the database to the file "Drains Connection Data.txt".

*Selecting **Copy Drains database** will cause the panel to search for the database dump in the folders **C:\Program Files\Drains\Program** and **C:\Program Files\Drains\Demo\Program**. If the Drains program is installed in another folder then you must browse for the file. The file will be read and the panel updated with eother selection.*

Drainage.4d file drainage.4d

The drainage.4d will be created in the 12d working folder unless otherwise specified. It will only be used for 12d projects in this folder.

Pit families choice Drains pit families

*These are the Drains pit families that will be exported to the drainage.4d file. These will become the names ongrade inlet capacity curves for all the pit sizes that belong to the family. The pit family name will be searched for words like **grade**, **slope** etc to try to determine the values for road grade and crossfall for the 12d capacity curves.*

Pipe type choice Drains pipe types

These are the Drains pipe types that will be exported to the drainage.4d file.

Pit group separatorinput

*Pit groups are not used in Version 8. These characters will be used to remove the road grade crossfall data from the **Pit families** above. The data before this character will become the **12d pit groups.** Press **Enter** or select **Read Drains database** to create a new list of **12d pit groups.***

12d pit groups choice 12d pit groups

*These are created from the Pit family list above by deleting all text after the **Pit group separator**.*

Create drainage.4dbutton

Create a drainage.4d file.

14.5 Editing the Drainage.4d file

Position of option on menu: Design =>Drainage-Sewer =>More=>Edit drainage.4d

On selecting the Edit drainage.4d option, the Edit drainage.4d panel is displayed.

Select the **Find** button to search the 12d path for the current **drainage.4d** file. Select the **More info** button and then **Edit** to edit the file.

The drainage.4d file contains Manhole and Pipe commands. 12d also uses the Manhole commands to specify a pit group by using the prefix “group”. Details follow.

Headwalls

The pit type “Headwall” (case sensitive for Drains) is reserved for the inlet headwall for a conduit. Drains does not use this for an outlet headwall.

If the inlet type is On Grade or there is no bypass pit, the grate level is exported as the Drains surface level. If the Inlet type is marked as a SAG pit then the surface level will be calculated from the low point on the catchment string (catchment set #1). Also see **SAG Inlet Calculations**.

Pit Families

Version 2+ of the Drains clipboard interface uses a **pit family** to describe the kerb shape and optionally, the name include the road crossfall and/or grade attached as a suffix.

An example pit group is the drainage.4d file is shown below.12d uses the road grade and/or the road crossfall to select which pit family should be sent to Drains. In this example the road crossfall would not be used in selecting the pit family.

It is up to the user to decide the grade when the next pit family should be used. In this case the threshold value for the gutter grade is set midway between the published values of the inlet curves. For example at a gutter grade of 2% 12d starts sending the ***NSW RTA Pits - 3% slope*** pit family.

The pit families listed on the right must match exactly with those in the Drains pit database.

Pit Types and Pit Sizes

Each Drains **pit family** has several **pit sizes**. The Drains **pit sizes** link to the12d pit types and therefore all Drains **pit sizes** should exist in the 12d drainage.4d file.

The **pit size** will be read back from Drains into 12d as the **pit type** so that it can be placed on the drainage long sections and pit schedules. If no matching pit type is found in 12d then a character will be dropped off the end of the Drains pit size and 12d will be searched for the new shorter pit type. This will be repeated till a match is found (or there are no more characters in the Drains pit size).

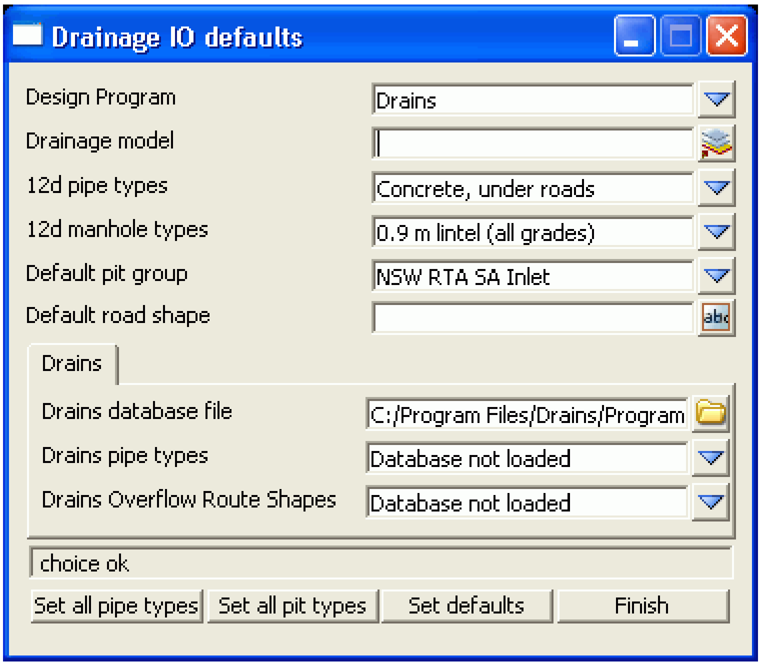
Pipe Types

The pipe type selected in 12d must exist in the pipe database inside Drains. Simple “2” for class 2 or “RCP “do not exist in Drains.

14.6 Setting the Overflow Route, the Pit and Pipe types

Position of option on menu: Design =>Drainage-Sewer =>More=>Drainage IO Defaults

On selecting the Drainage IO Defaults option, the Drainage IO Defaults panel is displayed.



The routine changes ALL of your pit and pipe types in a model to a single value. If you have changed your drainage.4d file after creating you drainage network, the pit and pipe types you originally selected may no longer be valid (i.e. in the drainage.4d file).

Field Description Type Defaults Pop-Up

Design Program choice Drains Drains, PCdrain

The drainage model to be updated.

Drainage model file

The drainage model to be updated.

12d pipe types choice values from drainage.4d

***Set all pipe types** will set all pipes in the model to this value*

12d pit types choice values from drainage.4d

***Set all pit types** will set all pits in the model to this value*

Default pit groupschoice values from drainage.4d

*pit definitions in the drainage.4d file that have **group** as a prefix are included.*

Default road shapechoice values from drainage.4d

*type the desired name or if using Drains select the desired shape from the **Drains Overflow route shapes**.*

Drains Tab

Drains database filefile

pressing enter in this field will start a search for the Drains database dump. The search path is the specified folder, C:\Program Files\Drains\Program then C:\Program Files\Drains\Demo\Program. If *the file is found the choice fields below are populated.* ***It is highly recommended that this file be in the 12d working folder.***

Drains pipe types choice 1 values from Drains file

the pipe types are retrieved from the last Drains database dump. Changing this value will update the ***12 pipe types*** *above.*

Drains Overflow Route Shapes choice values from Drains file

the overflow route shapes are retrieved from the last Drains database dump. Changing this value will update the ***Default road shape*** *above.*

Set all pipe types button

all pipe types in model are set to this value

Set all pit types button

all pit types in model are set to this value

Set defaults button

the defaults for the **Drains Overflow Route Shapes** and **12d pit group** are set

Finish button

removes the panel

14.7 Drains Version 2+ Requirements

Pit Names

The 12d pit names cannot be more than 9 characters long. 12d uses 2 additional characters to the pit name at export time create names for the pipes, overflow routes and catchments. For example pit "A-1" will have a bypass route "F A-1", a catchment "C A-1" and a downstream pipe "P A-1".

Bypass Flow (Overland Flow Routes)

There are 3 requirements for Drains bypass flow (bypass pit, pit inlet capacity curve and road grade/crossfall).

1. Select a **pit type** that has ongrade or sag inlet capacity curves defined in the drainage.4d file. The Drains and 12d databases must be in sync.
2. Bypass strings in the **Bypass route model** specified (Network editor->Global->Utility Models->Bypass flow model. For more details see **Bypass Flow.**
3. Road grade and crossfall calculated (Network editor->Global->Utility Models->Road design file)

The overland flow strings are not allowed to pass through the outlet pit on the network.

SAG Inlet Calculations

SAG inlets are inlets where the water ponds at the surface rather than flowing past. If a SAG inlet has a catchment string the overflow depth and volume are calculated. The catchment string from Set

#1 is draped onto the design tin and the lowest point in found on the draped string (stored as a 12d pit attribute ***overflow level***. The storage volume inside the string up to this point is measured and stored as a 12d pit attribute ***overflow volume from level***. and are subtracted from the to determine

The Max Ponding Depth = **overflow level- grate level**

If the **manual flag** is selected for the "sag pit pond depth", 12d will NOT calculate the value but will use the value entered by the user. 12d will check if a volume has been calculated before or imported from Drains. If the volume exists then it is exported. If it does not exist, this ponding depth will be used calculate the ponding level (depth + grate level). The ponding level will be used to calculate a ponding volume from the design tin and the catchment boundary.

If you want to manually delete this volume and force 12d to recalc to volume using the user defined level, delete the pit attribute, "overflow volume from level". To delete the attribute use Strings->Properties->Attributes, select the pit, go to the pit tab, right mouse select the row with this attribute and select delete).

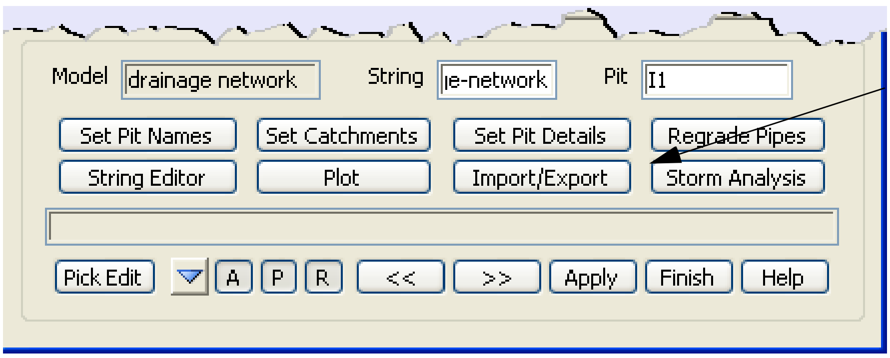
Results

Drains exports the maximum data from all of the rainfall events analysed. Therefore, ensure you analyse only the rainfall events desired before coping the results to the clipboard. To verify the data that is being sent to 12d, copy the data into a spreadsheet so you can view it there first. The pit sizes selected in Drains will be stored in 12d as the pit type. Therefore the pit sizes in Drains should exist as pit types in the drainage.4d file. If pit families are changed in Drains the pit group in 12d will be updated by search for the pit family in the drainage.4d file.

14.8 12d to Drains

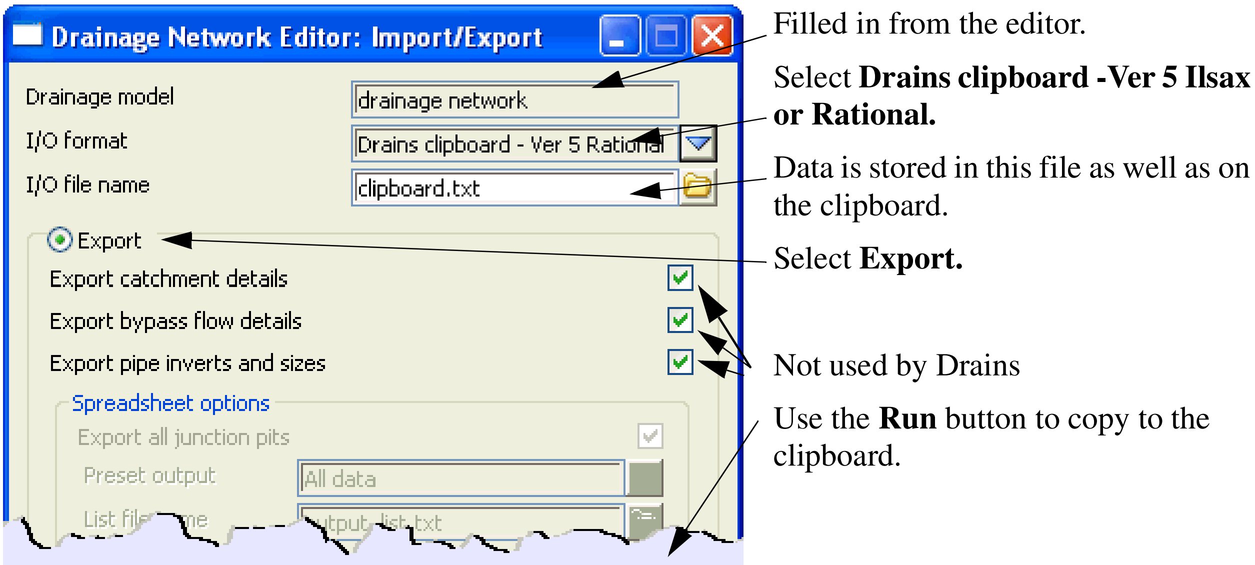
Setup your drainage network models and ensure they have been assigned pit names.

1. Copy the data to the clipboard



From the Drainage network editor select the **Import/Export** button.

The following interfaces dialogues will appear.

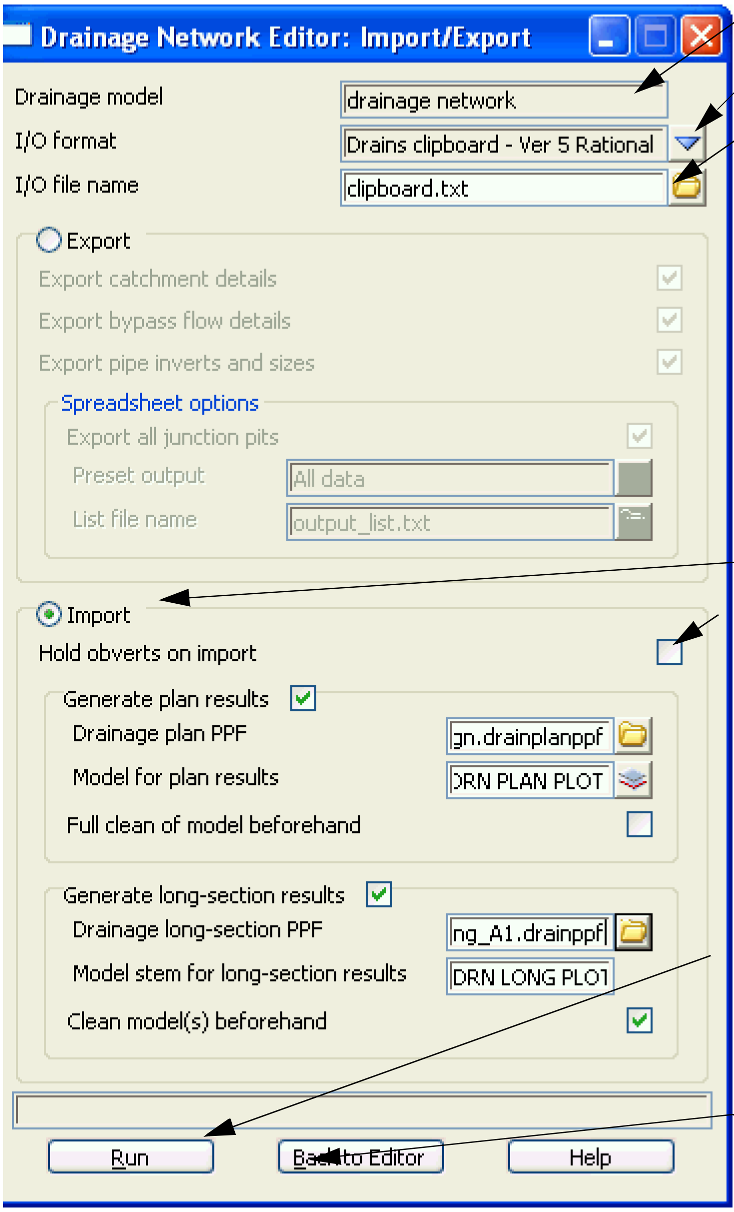


2. From within the Drains program select **Edit =>Paste data from spreadsheet**. If you paste the data into a Drains project that has a hydrological model and rainfall data already defined the project will be ready to run.
3. Use the Drains Run=>Standard design to design your pipe sizes and invert levels. The Run=>Advanced Design will select the size of the pits as well.

14.9 Drains to 12d Update

The following steps are required to update the 12d model with the Drains hydraulic results and changes to the pipe sizes and inverts.

1. To update the pipes and invert levels in 12d, select **Edit->Copy Data to Spreadsheet** from the Drains menu.
2. From within the 12d Drainage network editor select **Import/Export**.



F in by the editor.

Select Drains clipboard - Version 5

Leave as clipboaard.txt

Select **Import**

This will ignore the invert levels read from Drains and the current pipe obverts will remain fixed.

Plan and long section drawings may be created at the import time so that you can see the results on the drawings.

Select **Run** to update the drainage model. To see the changes in the section views you will have to select **Regen** on the section view toolbar.

To return to the network editor select **Edit**

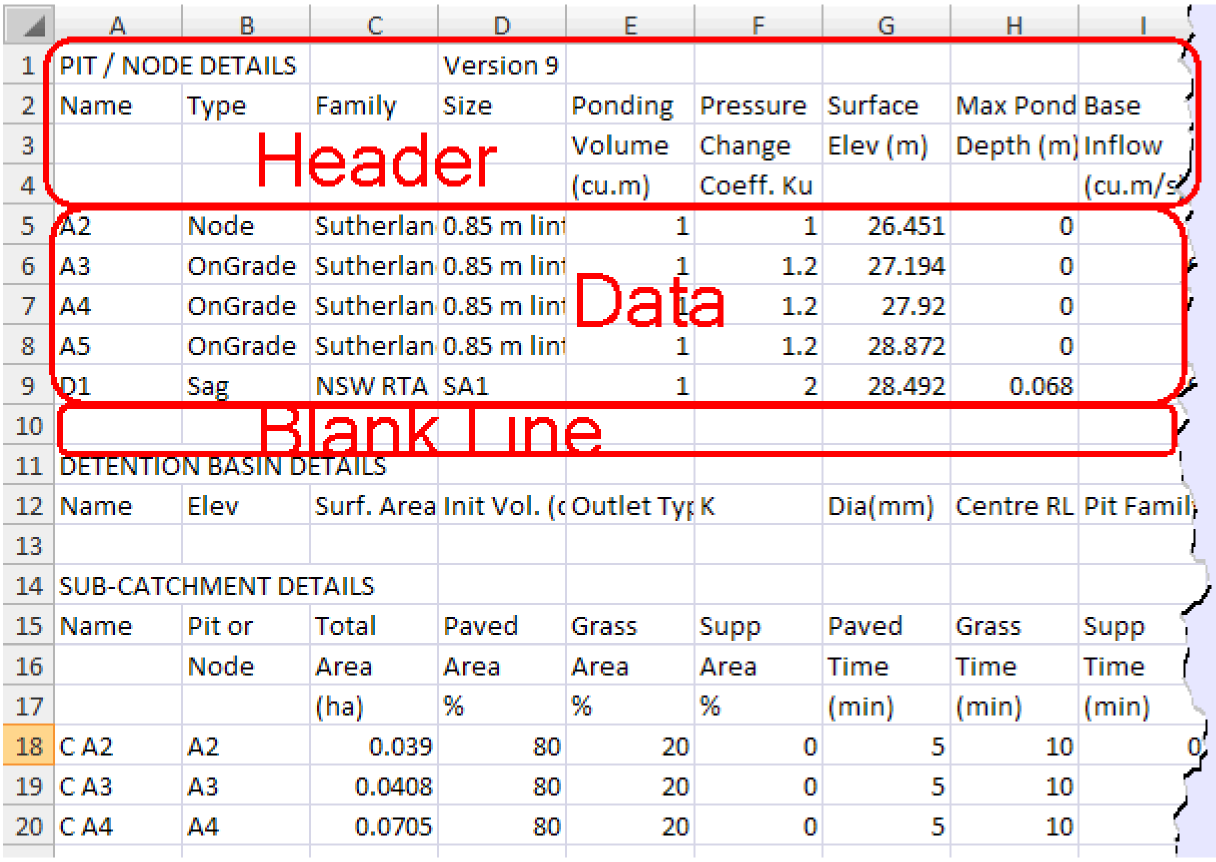
IMPORTANT: THE DATA MUST BE PASTED BEFORE THE RESULTS!

12d erases the hydraulic and hydrology data when the physical data is updated. Therefore, always paste the data before the results.

14.10 Drains Mapping File

The rational format and the ilsax format have separate mapping files.

The Drains spreadsheet format consists of sections starting with a header, then the data area and ending with a blank line. The mapping file defines the format of the section headers and the format of the data within the sections



	A	B	C	D	E	F	G	H	I
1	PIT / NODE DETAILS			Version 9					
2	Name	Type	Family	Size	Ponding	Pressure	Surface	Max Pond	Base
3					Volume	Change	Elev (m)	Depth (m)	Inflow
4					(cu.m)	Coeff. Ku			(cu.m/s
5	A2	Node	Sutherlan	0.85 m lint	1	1	26.451	0	
6	A3	OnGrade	Sutherlan	0.85 m lint	1	1.2	27.194	0	
7	A4	OnGrade	Sutherlan	0.85 m lint	1	1.2	27.92	0	
8	A5	OnGrade	Sutherlan	0.85 m lint	1	1.2	28.872	0	
9	D1	Sag	NSW RTA	SA1	1	2	28.492	0.068	
10									
11	DETENTION BASIN DETAILS								
12	Name	Elev	Surf. Area	Init Vol. (c	Outlet Typ	K	Dia(mm)	Centre RL	Pit Famil
13									
14	SUB-CATCHMENT DETAILS								
15	Name	Pit or	Total	Paved	Grass	Supp	Paved	Grass	Supp
16		Node	Area	Area	Area	Area	Time	Time	Time
17			(ha)	%	%	%	(min)	(min)	(min)
18	C A2	A2	0.039	80	20	0	5	10	0
19	C A3	A3	0.0408	80	20	0	5	10	
20	C A4	A4	0.0705	80	20	0	5	10	

The headers in the mapping file define the exact text to be exported in the Drains section headers. During an import the first 4 columns of the Drains header are compared to the headers in the mapping file to determine which section is being read. The data format line is then used to decode the the data.

15.0 Running XPSWMM and RAT2000

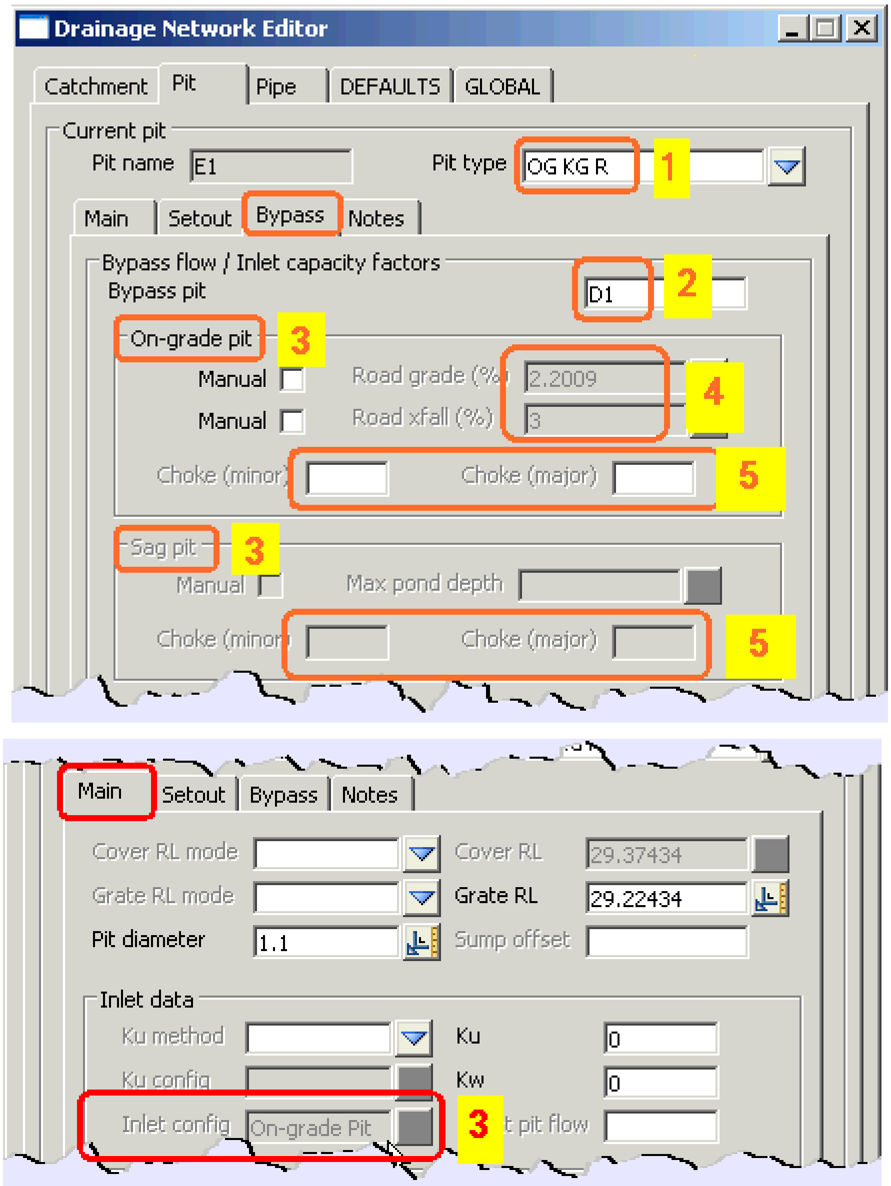
The drainage design with all three of the XP software programs follows the same methodology. The process is substantially automated with the XP-SWMM program so that the XPX file is automatically read by XP-SWMM and automatically created when leaving XP-SWMM.

Drainage design with XP programs includes the following steps.

1. 12d creates an XPX file that is read by the XP programs.
2. The XP program is then run in the design mode to determine the pipe sizes and invert levels.
3. If bypass and overland flows are to be modelled then the inlet capacities need to be defined and then run the XP program in the Full Analysis Model.
4. The XP program creates an XPX file for 12d to import.

15.1 xpstorm and xpswmm bypass requirements

12d will select the inlet capacity curves for the xp programs when the following bypass settings are complete

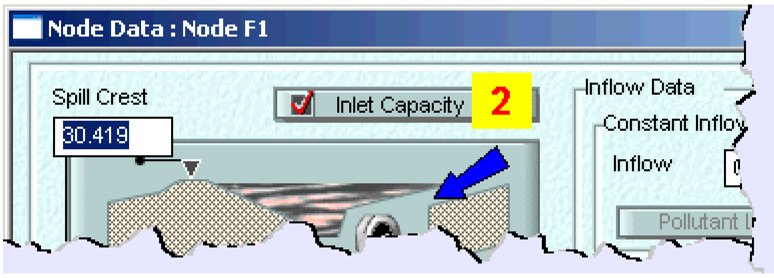


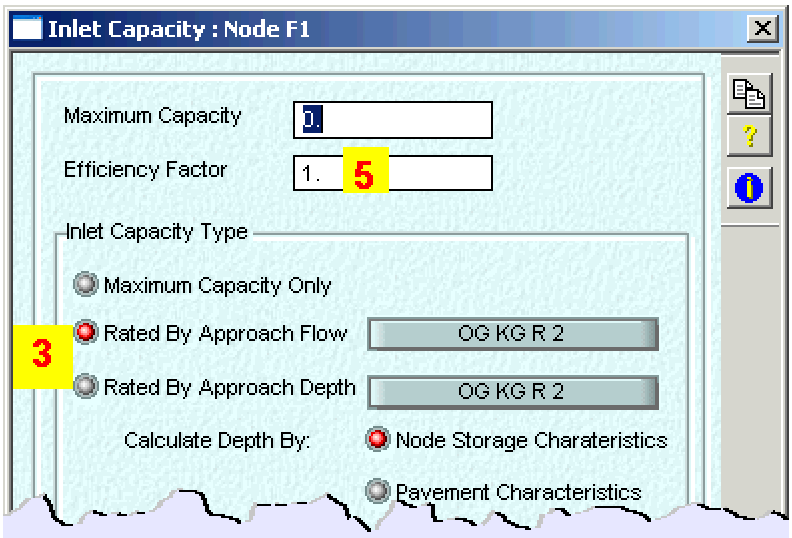
1. The 12d pit type determines the inlet capacity values or curves to be selected from.
2. The bypass pit must be defined for the pit. If the bypass pit follows the pipe network a xp-multi link with a natural channel is created. Otherwise a xp single link is created. The default xp natural shape is "Road Section"
3. The Ongrade/SAG pit on the Main tab determines whether depth or approach curves are exported to (details below).
4. If ongrade is selected then the 12d inlet capacity curves may be selected by road grade, crossfall, both or neither. (details below).
5. The 12d choke factors will be exported as the xp inlet effeciency factor (1 - 12d choke).

COURSE NOTES

STORMWATER DESIGN - Part 2

The numbers below relate the the same numbers in the 12d panels above.

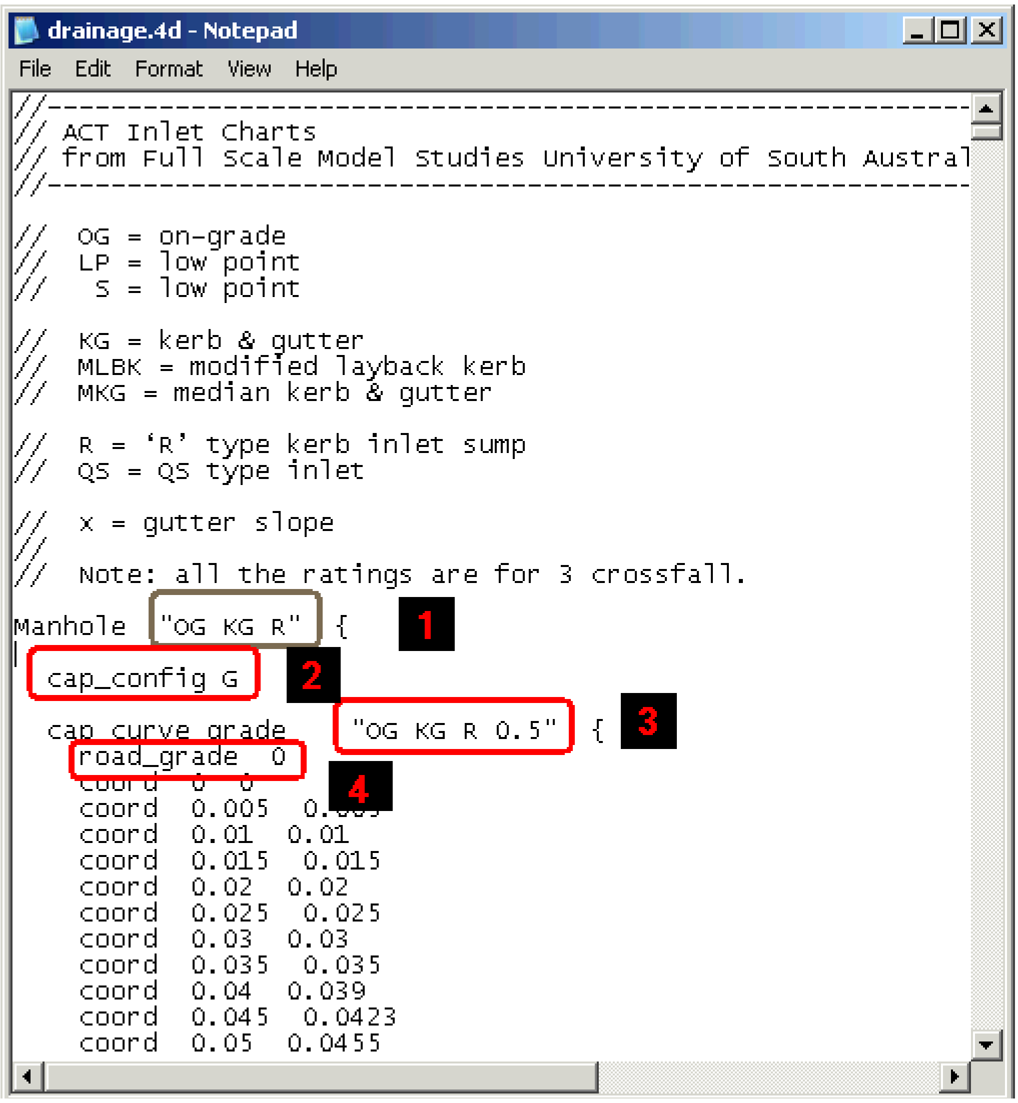




1.
2. Inlet capacity is turned on when 12d has a bypass inlet.
3. 12d **Ongrade** inlets export as **Rated by Approach Flow** and 12d **SAG** inlets export a **Rated By Approach Depth** with depth calculated by **Node Storage Characteristics.**
4.
5. The minor/major selection is the 12d export panel determines the effienciecy factors that are exported/ Efficiency factor = 1.0 - 12d choke.

12d Inlet Capacity Curve names

Below is an extract from the drainage.4d file for Canberrra rating curves.



```
drainage.4d - Notepad
File  Edit  Format  View  Help
//-------------------------------------------------------------
// ACT Inlet Charts
// from Full Scale Model Studies University of South Austral
//-------------------------------------------------------------

//  OG = on-grade
//  LP = low point
//   S = low point

//  KG = kerb & gutter
//  MLBK = modified layback kerb
//  MKG = median kerb & gutter

//  R = 'R' type kerb inlet sump
//  QS = QS type inlet

//  x = gutter slope
//
//  Note: all the ratings are for 3 crossfall.

Manhole  "OG KG R"  {
|
 cap_config G

 cap_curve_grade  "OG KG R 0.5"  {
   road_grade  0
   coord  0  0
   coord  0.005  0.
   coord  0.01  0.01
   coord  0.015  0.015
   coord  0.02  0.02
   coord  0.025  0.025
   coord  0.03  0.03
   coord  0.035  0.035
   coord  0.04  0.039
   coord  0.045  0.0423
   coord  0.05  0.0455
```


1. The manhole is the inlet type selected above.
2. cap_config G forces the inlet to be used as qa 12d ongrade inlet. An S would be SAG and an M a manhole.
3. The curve name indicated here is exported as the xp inlet capacity curve.
4. The curve name will be exported starting at road grade of 0. Since one curve has a road grade value all curves must have a road grade value and the user must have a road grade calculated on the 12d bypass tab.

15.2 12d to the XP Programs

The x,y pit layouts and the cover/surface levels are obtained from your drainage network while the catchment and overland flow data comes from the models specified in the drainage interface dialogue.

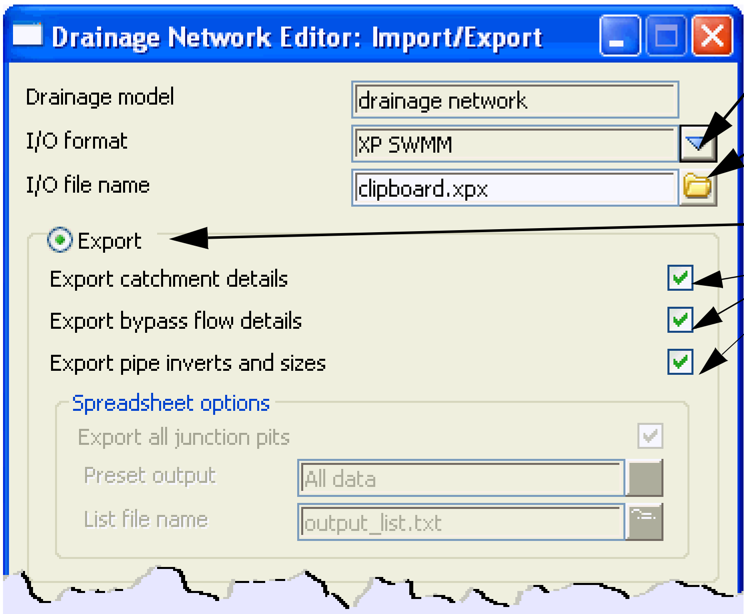
The steps required to transfer the data to the XP programs are as follows.

COURSE NOTES

STORMWATER DESIGN - Part 2

1. Setup your drainage network models.
2. To create the XPX file for XP programs start the Drainage Network Editor and select **Import/ Export**

The following interfaces dialogues will appear.



Select **XPSWMM or RAT HGL** from the drop down list.

Enter the name of the xpx file to be created.

Select **Export**

Not used at this time.

Finally, Select the **Run** button to create the file.

If exporting to RAT-HGL the following dialogue will appear.

If you are using old versions of RAT-HGL (1996 or earlier) select use **Local** otherwise select **4D units** (eastings and northings).

Select process.

3. The XP SWMM program will automatically startup and load the XPX file.

   From within RAT-HGL, either select **File =>New** and follow the input prompt or load a file that contains all of the pit inlet rating curves, hydrological and design data without a pipe network. Many users have such RAT-HGL files setup so as to streamline the design process.

   The xpx file for RAT2000 will have the file startup.xpx added to it so that you may include all the startup global data that you require. The
   Fixed inlet capacities and rating curve names indicating road grade and crossfall may be set in the **drainage.4d** file. The format for these names is pit name-crossfall-road grade (ex SA2-3-4). These curves must exist in this file.
4. To read in the pipe file created above, select **Special =>Import Data** and select the xpx data file. Warnings will be given stating that several fields are inactive. This is expected as more data is sent to RAT-HGL than is needed at this time. Select the **Close Square** on the Help title

area and the pipe network and catchments should now appear on the screen.

5. If you want RAT-HGL to redesign you network, change the analysis mode to Design mode by selecting **Special=>Job Control** and **S**elect Design mode. Do not do this if you want to analyse the network you layed out in 12d (used for existing systems).
6. Select the rainfall events to design/analyse and the **LB** (twice) on **OK** to return to the layout. Now select the outlet and enter the starting tailwater levels.
7. Now you can run RAT-HGL (**Special =>Solve**).

15.3 XP Programs to 12d

Once you have your design finished, the following steps are required to update your 12d model. Your design may contain several return periods in the analysis (Rp1 to Rp7) but 12d reads only the results from Rp1. The following table is taken from the RATHGL output file (*.out extension) and the results indicated are read back into 12d via the xpx file.

HGL PIPE NETWORK ANALYSIS SUMMARY RETURN PERIOD 5 YEARS
PROJECT:12d DRAINAGE LAYOUT

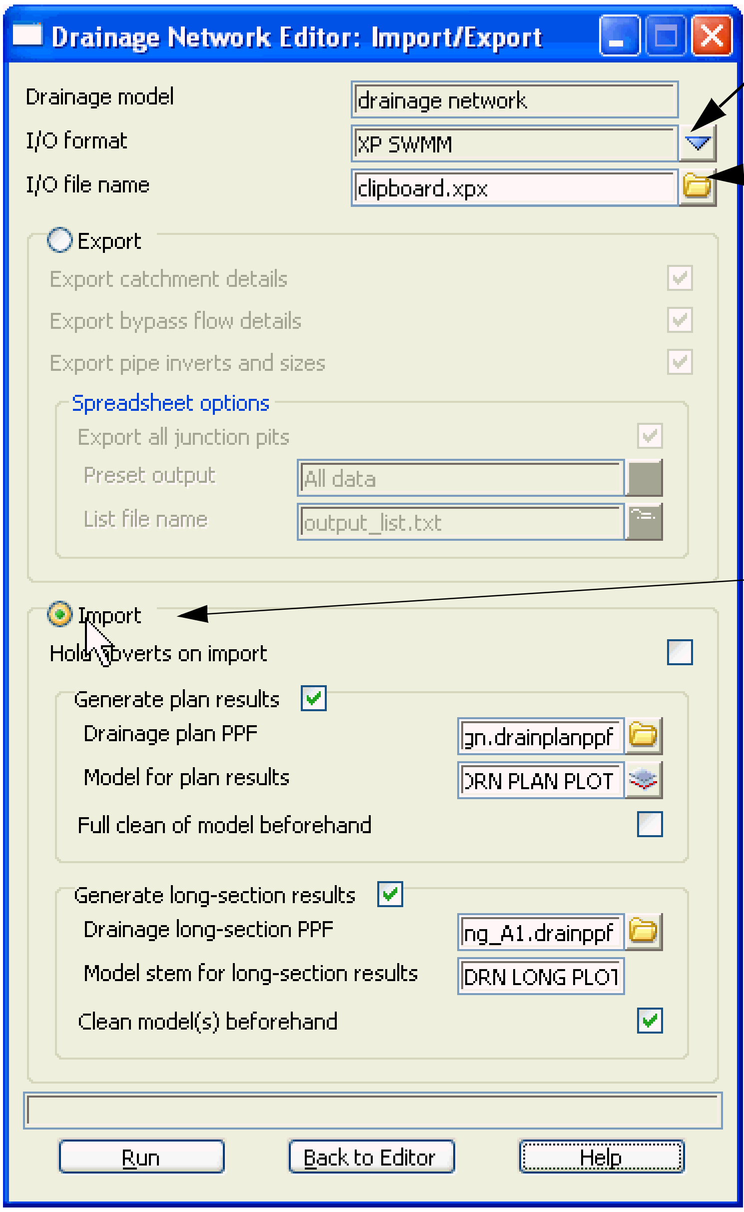
ITEM	DIM	RESULT						
RN	-	1	2	3	4	5	6	
NN	-	1-1	2-1	1-2	3-1	1-3	1-4	
DN	-	1-2	1-2	1-3	1-3	1-4	1-4	
MT	-	99	99	99	99	99	0	
DHGL	M	29.258	29.258	28.139	28.139	27.269	.000	**DS HGL**
DD	M	.225	.375	.375	.300	.450	.000	**Diameter**
DCTL		HGL	HGL	HGL	HGL	HGL		
DO	M	.225	.375	.375	.300	.450	.450	
QO	M3/S	.033	.181	.237	.075	.334	.353	**Flow**
VELD	M/S	.826	1.639	2.148	1.065	2.100	.000	
NORM	M	.106	.264	.271	.153	.289	.000	
CRIT	M	.152	.314	.345	.215	.396	.000	
KP	-	.00	.00	.00	.00	.00	.00	
SF	M/M	.0040	.0082	.0140	.0046	.0107	.0000	
LEN	M	45.93	18.44	54.65	31.31	49.91	.00	
HGLP	M	29.444	29.409	28.905	28.284	27.802	.000	**US HGL**
DU	M	.225	.375	.375	.300	.450	.000	
VELU	M/S	.826	1.639	2.148	1.065	2.100	.000	**Velocity**
UCTL		HGL	HGL	HGL	HGL	HGL		
KU	-	1.50	1.50	1.50	1.50	1.50	.00	**Ku**
KL	-	1.50	1.50	1.50	1.50	1.50	.00	
KR	-	1.50	1.50	1.50	1.50	1.50	.00	
KW	-	1.50	1.50	1.50	1.50	1.50	.00	**Kw**
UHGL	M	29.496	29.615	29.258	28.370	28.139	27.269	
LHGL	M	29.496	29.615	29.258	28.370	28.139	27.269	
RHGL	M	29.496	29.615	29.258	28.370	28.139	27.269	
UWSL	M	29.496	29.615	29.258	28.370	28.139	27.269	**HGL PIT**
MWSL	M	30.297	29.615	29.403	28.875	28.340	27.369	
AF	M3/S	.033	.207	.023	.094	.040	.000	
IF	M3/S	.033	.181	.023	.076	.023	.023	
IC	M3/S	.036	.227	.026	.076	.023	.023	
BF	M3/S	.000	.026	.000	.019	.017	.000	
ID	M	.000	.000	.000	.000	.000	.000	
ITW	M	.000	.000	.000	.000	.000	.000	
IVEL	M/S	.000	.000	.000	.000	.000	.000	
IVD	M2/S	.000	.000	.000	.000	.000	.000	
FC	-		*		#	#	#	

In addition to the results, the following input data is read back into the 12d model so that it may be exported back to RATHGL in the future (if required). 100% of your RATHGL data is not included in the XPX formats and the contents of the XPX file will depend upon your design mode. Therefore, use caution if you read an XPX file into an existing RATHGL model and check your data once inside RATHGL.

1. From within RAT-HGL, produce an XPX file for 12d to read by selecting **Special=>Export**

Data and following the default prompts.

2. From within 12d, select the **Import/Export** button on the Drainage Network Editor.The following panel will appear.



Select to select **RATHGL** or **XP-SWMM**.

Select the file name specified in step 1

Select **Import.**

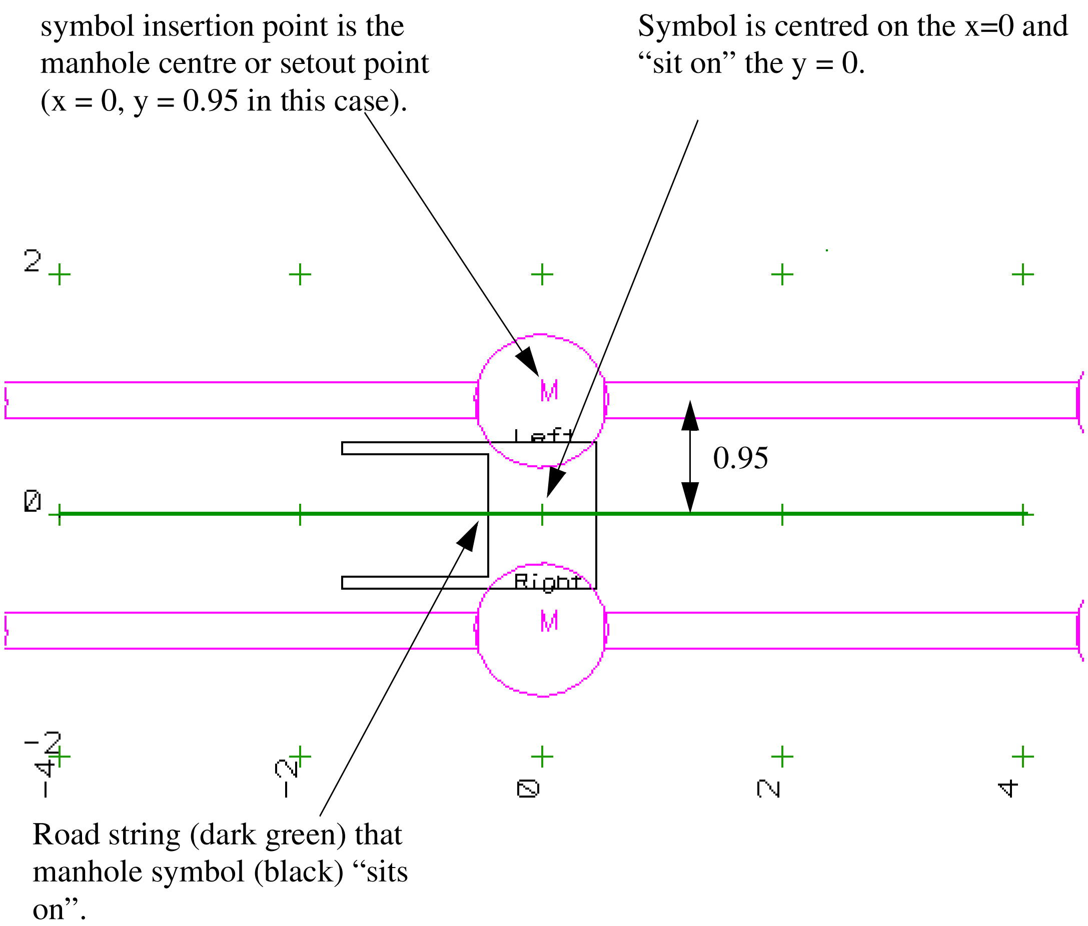
Select **Run** to update the drainage model and import hydraulic/ hydrological results.

16.0 Detailed Drainage Plan Drawing - Creating MH Symbols

There are many methods to create the drainage symbols and one is presented here. The pit symbol is drawn so that the symbol "sits on" the road string that it aligns with (the road string is the y reference). For drawing lintels and grates, assume the road is downhill to the right. See diagram below.

Two symbols are required, one for the left side of the road and one for the right side (referred to as the mirror symbol in the plan ppf). 12d checks the downhill direction of the road strings when using these symbols to determine which is the left and right side of the road.

Either draw your own symbol or import the symbols using **File IO->Data Input->4ds/12da data** and selecting the file **inlet symbols.12da**

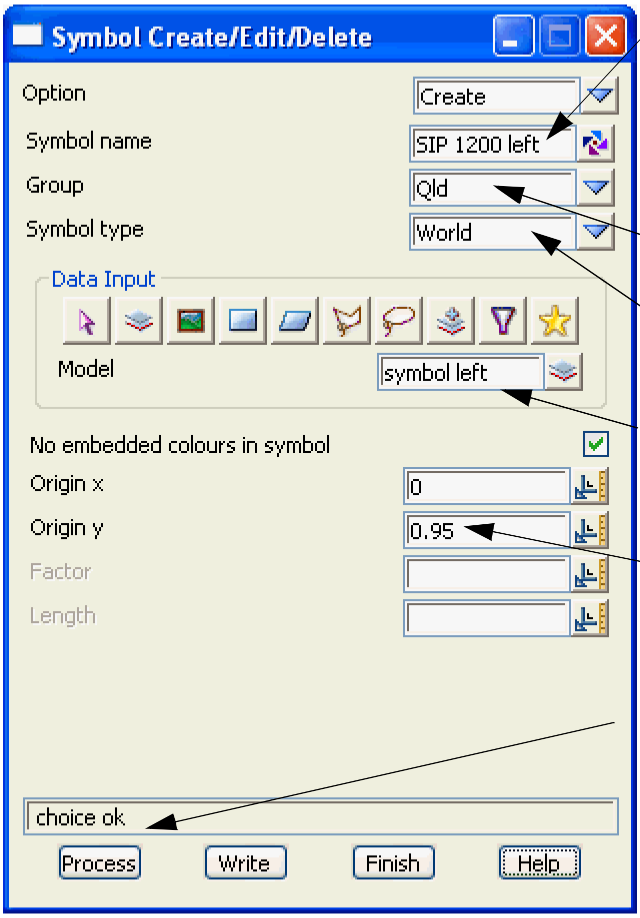


To create the symbol in 12d draw the left pit symbol in a model by itself. The pit should "sit on" the zero "y" grid line. A 900 wide by 600 long inlet with a 1.2m lintel is shown above.

From the main menu, select

Project->Tree

Expand **Project** then expand **Symbols** and finally select **Create Symbol**.



Enter the **Symbol Name**. Usually the name includes the size.

Select the **Group** the symbol is to appear in the symbol drop down menu and select **World** as the symbol type.

Select the **model** that contains the manhole drawing.

Enter the x,y location of the manhole centre in your drawing (0 is different then

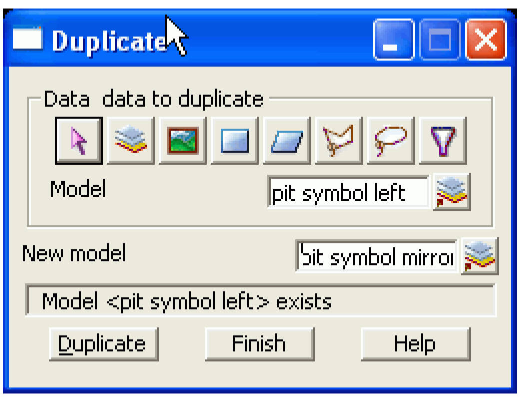
Process will create the symbol in the project.

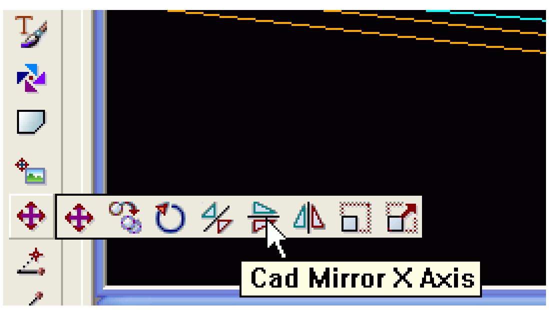
Change the **symbol name**, **origin y** and

Write will add the new symbols to the symbols.4d file so that they will be available to other projects.

Leave this panel open as we will need it after we create the mirror image of the pit.

To create the mirror image of the symbol about the x axis use the CAD mirror about X axis command. 12d will require you do this one string at a time. Version 7 does not mirror into a new model so you will want to duplicate the pit symbol model first using **Utilities->A-G->Duplicate.**





Now repeat the process of creating the right side mirrored symbol. Note that the location of the pit centre is now **negative** and add the suffix **mirrored** to the symbol name.

Do not forget to select **Write** again to save the symbols to the symbols.4d file.

These symbols can now be used in the **Maintenance hole** tab of the Drainage Plan Plot ppf editor. If your version of 12d supports, **native-size symbol**, in the ppf editor then use this mode. If not, select scalable symbol and enter the size equal to the full width of the symbol (height if it is greater).

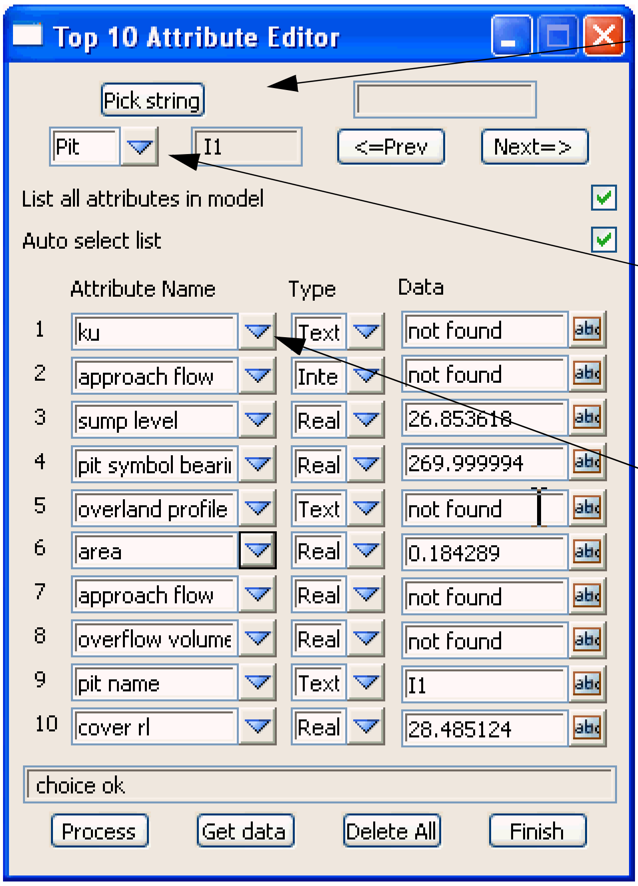
17.0 User Defined Attributes

These drainage attributes are automatically created by 12d when required but you are free to change them or add more as desired. The attributes may be exported to a spreadsheet and edited and then imported back into 12d. To edit/add the user defined attributes within 12d select either

Strings=>Properties=>Attributes or

Strings=>User=>Attribute Editor. This second editor is described below.

.



First Select **Pick** to select the string that contains the user attributes (the drainage string). The strings will be highlighted in white when they are selected.

All catchment data is store with the pits in drainage strings. To access the pit attributes, select the drop down icon and then select **pit**. A circle will be drawn around the pit selected. **Next** and **Prev** will now move you from pit to pit.

Select the drop down icon and then select the **Attribute Name** from the list of existing user defined attributes. These attributes include all of the attributes in the model that the string exists in.

They may not be defined for the pit you are editing. **Not found** will be displayed in the **Data** field if the pit does not have that attribute defined.

To change the value for the attribute enter the new value in the **data** field. If the attribute does not exist, deleting the **not found** text and adding data will create it. The message on the right will be displayed whenever you are creating a new attribute.

COURSE NOTES

STORMWATER DESIGN - Part 2

17.1 Drainage Pit attributes

Pit attributes are created and/or updated when the user selects **Set Pit Details.**

pit length	real	0	mhsize (first value) from drainage.4d file
pit width	real	0	mhsize (second value) from drainage.4d file
pit group	text		mhgroup from drainage.4d file
cover rl	real	446.685248	
grate level	real	446.685248	
setout z	real	446.685248	
setout x	real	299643.648	
setout y	real	6563620.716	
setout distance	real	0	
pit name	text	1-3	
pit type	text	SA2	
pit diameter	real	1.1	
pit chainage	real	118.61441375	
pit centre x	real	299643.648	
pit centre y	real	6563620.716	
pit centre fs level	real	446.685248	
pit centre ns level	real	446.685248	
ds invert	real	445.307	upstream invert level of exit pipe
ds pit	text	1-2	ds pit along the pipe network
sump level	real	445.307	
pit depth	real	1.378	

Extra Atttributes from Pit - Main Tab

cover rl mode	integer	1
design freeboard	real	0.4
direct flow	real	0.02
grate rl mode	integer	1
inlet type	integer	0
ku	real	0.2
ku config	integer	1
ku method	integer	1
kw	real	0.22
sump offset	real	-0.2

Extra Attributes from Pit-Setout Tab

road chainage	real	10
road chainage mode	integer	2
road name	text	My Road
road offset	real	12

setout adjustment	real	-1	
setout adjustment z	real	0.045	
setout xy mode	integer	0	
setout z mode	integer	8	

Extra Attributes from Pit-Bypass Tab

bypass pit	text	12.4P	
choke major	real	0.8	
choke minor	real	0.7	
choke pog major	real	0.8	
choke pog minor	real	0.7	
inlet capacity curve	text	Sutherland - 3% crossfall	
manual pit grade	integer	1	
manual pit xfall	integer	1	
pit grade	real	1	
pit xfall	real	3	

Extra Attributes from Pit-Notes Tab

reamrks	text	constructed by others	

Setout string selected

design model id	uid	52	
design string id	uid	61	
pit symbol angle	real	81.48609728	
pit symbol bearing	real	8.51390272	
pit symbol bearing dms	text	8°30'50"	
pit grade	real	4.00	if bypass pit present

Centre line string selected (with bypass and setout)

pit xfall	real	3.00	if bypass pit present
centre model id	uid	52	
centre string id	uid	92	
mirror pit	integer	1	mirror symbol required for plotting

Bypass Pit entered

bypass pit	text	1-2	next pit along bypass string
inlet type	integer	1	
choke major	real	0.8	ongrade or sag choke (see sag setting)
choke minor	real	1	ongrade or sag choke (see sag setting)
inlet capacity curve	text	SA2 3% Grade	
			calculate if pit grade and/or pit xfall present

			(pittype-inletcapcurvesdetermineswhicharerequired)
pit grade	real	4.00	if setout string selected
pit xfall	real	3.00	if centre line string selected

The following require the bypass string (manual entry of bypass pit is not enough).

bypass distance	real	33.995	distance to bypass pit
gutter length	real	99.79	dist. up the bypass string to next pit or end of string (longest bypass route if multiple)
gutter grade	real	2.70	(us pit fs levels - ds pit fs levels) / gutter length)

Catchment Tab data

area	real	0.1
percent impervious	real	60

Pervious Area only

c major pervious	real	0.9
c minor pervious	real	0.8

For both pervious and impervious (change pervious to impervious)

catchment grade pervious	real	1
catchment length pervious	real	900
catchment roughness pervious	real	0.1
tc major pervious	real	5
tc method pervious	text	Kinematic Wave
tc method pervious	text	Direct
tc minor pervious	real	5

Export Pit Atttributes (calculated when Export selected on Import/Export button))

inlet type	integer	updated to include 5 for headwalls
ds pit string id	uid	drainage string id for the ds pit
ds pit index	integer	index number of the ds pit (counter along the string)
area impervious	real	%impervious * area for set 1
area pervious	real	%pervious * area for set 1
area impervious2	real	%impervious * area for set 2
area pervious2	real	%pervious * area for set 2
area impervious3	real	%impervious * area for set 3
area pervious3	real	%pervious * area for set 3
pcdrain pit type	type	pit type with the pcdrain suffix (S + pond depth)

Export Pipe Atttributes (calculated when Export selected on Import/Export button))

locked diameter	real	pipe diameter (exists only if pipe locked)
locked invert us	real	pipe us invert (exists only if us invert locked)
locked invert ds	real	pipe ds invert (exists only if ds invert locked)
windes diameter	real	if pipe type is WINDES, value is neg diameter
roughness n	real	if "roughness type" is Manning then roughness value otherwise it is 0
roughness k	real	if "roughness type" is Colebrook then roughness value otherwise it is 0

17.2 Drainage Pipe attributes

Set Pit Details

invert us	real	28.47
invert ds	real	28.422
diameter	real	0.225
pipe size	text	225
pipe type	text	2
roughness text	text	n=0.010
calculated pipe length	real	9.58175349
calculated pipe grade	real	0.50095215
calculated pipe grade 1 in	real	199.6198644
calculated us deflection	real	71.75414547
calculated ds deflection	real	-36.3032794
pipe name	text	12.5P to 12.4P
minimum cover	real	1.04113728
calculated drop	real	0.03

Additional Pipe Attributes created via Pipe Tab setting

design alignment mode	integer	0
design cover	real	0.4
design cover mode	integer	0
design drop	real	0.03
design grade	real	0.1
design size mode	integer	0
diameter	real	0.225
direct pipe flow	real	0.01
lock ds il	integer	1
lock size	integer	1
lock us il	integer	1
max height	real	0.6

min height	real	0.3
remarks	text	extra pipe notes
roughness	real	0.012
roughness type	text	Manning
width	real	0.225
width top	real	6

COURSE NOTES

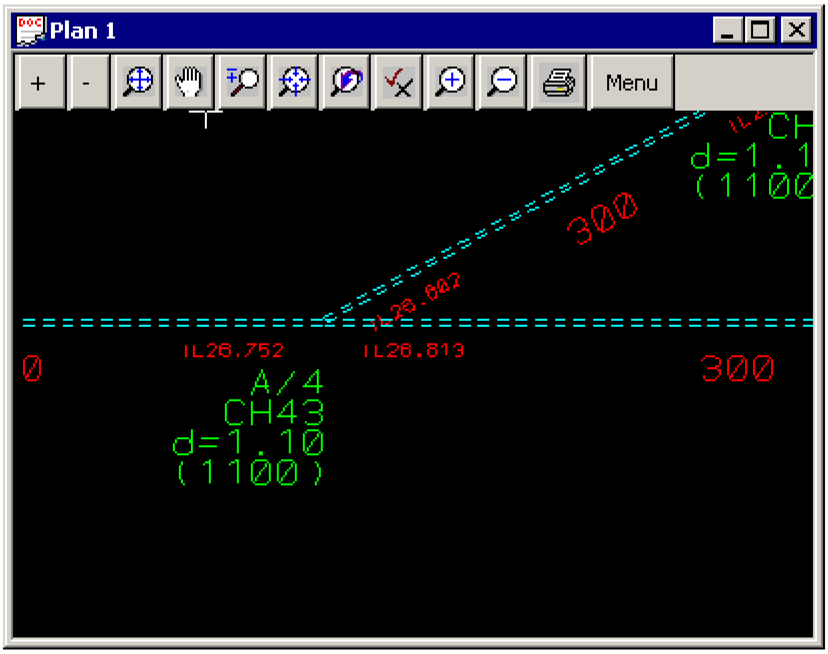
STORMWATER DESIGN - Part 2

18.0 Detailed Drainage Plan Drawing

12d drainage has the capability to create detailed drainage plan drawings with the following features:

- create symbols at the inlets and the type of symbol is controlled by the inlet type (given when you create the inlet).
- create text labels for inlet types and user defined pit attributes
- draw lines with line styles and colours to represent pipe sizes
- create text labels for pipe diameters, inverts and user defined pipe attributes
- create text labels for house connection types, invert levels and chainages
- indicate direction of flow on pipes.

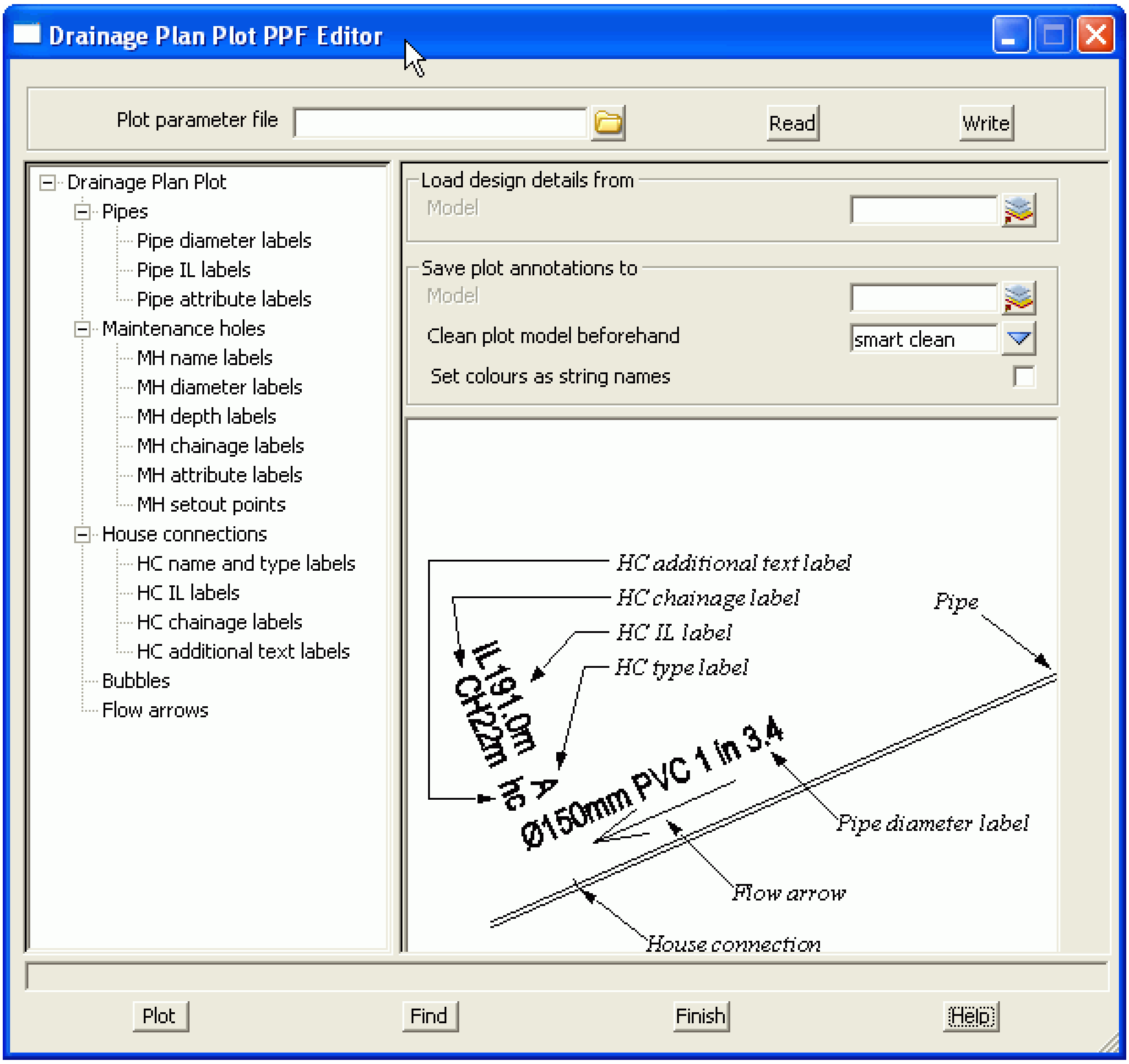
An example is shown below



Usage

This option is accessed from the menu selection

Design => Drainage-Sewer => Plots => Plan Annotations



The fields and buttons used in this panel have the following functions.

Field Description	Type	Defaults	Pop-Up

Plot parameter file file box

Optional - no dpf is required. The default settings will create a schematic drainage drawing. A custom dpf may be selected if desired.

Load design details from model box

data source for drainage strings to be labelled

Save plot annotations to modelmodel box *labels to be created are stored here, Undo will remove the labels created*

Clean plot model before hand choice box

smart clean will update text that has been moved and clean the rest. Full clean will all text from the plan annotations model.

Set colour as string name tick box

when selected the string colour will be used for the string name (to be used for DWG/DXF export using map files)

Plot button

Creates the labels in the model specified

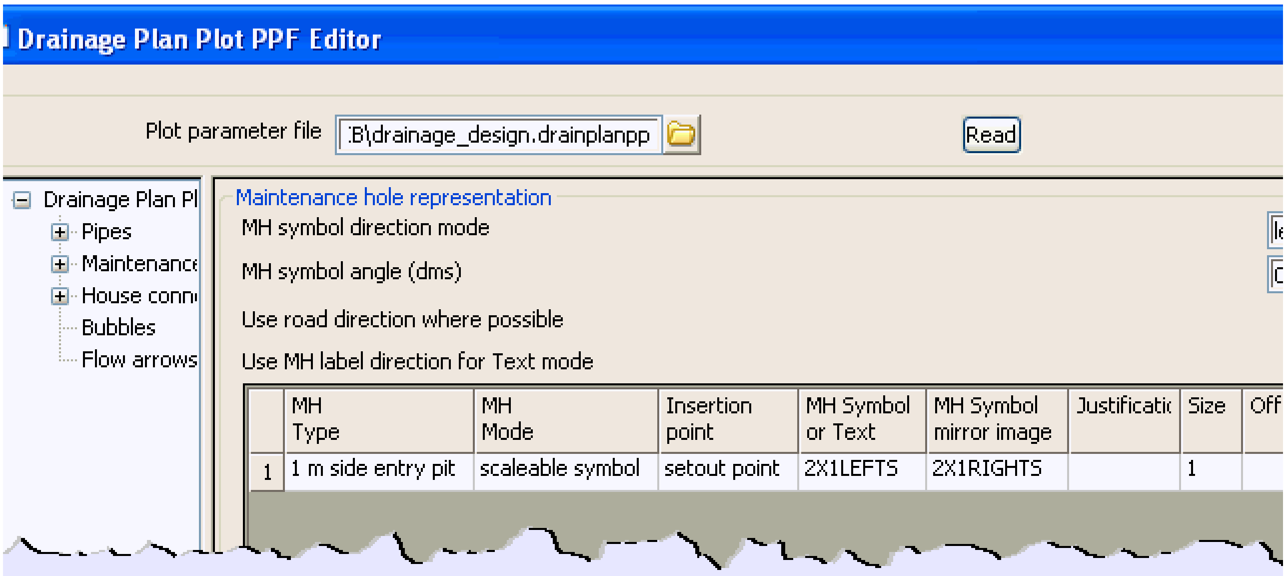
Find button

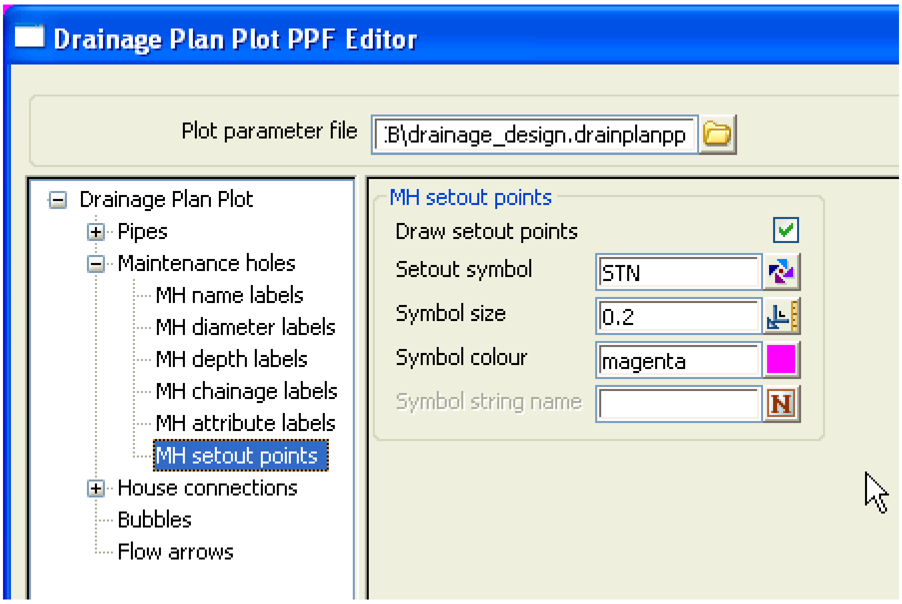
used to locate plot parameter input boxes using Version 5 plot parameter names

IMPORTANT! to turn off any data change the text height to zero.

Select **Maintenance holes** from the tree to set the symbols to be used for the various pit types.

Select the MH type as desired and use **scalable symbol** and **setout point**. For the symbols enter the names that you used when you created the symbols.





Plotting a symbol at the pit setout point is a good confirmation of the data printed in the setout reports. The settings to create this symbol are shown on the left.

19.0 Drainage Long Section Plotting - Hatching Under Roads

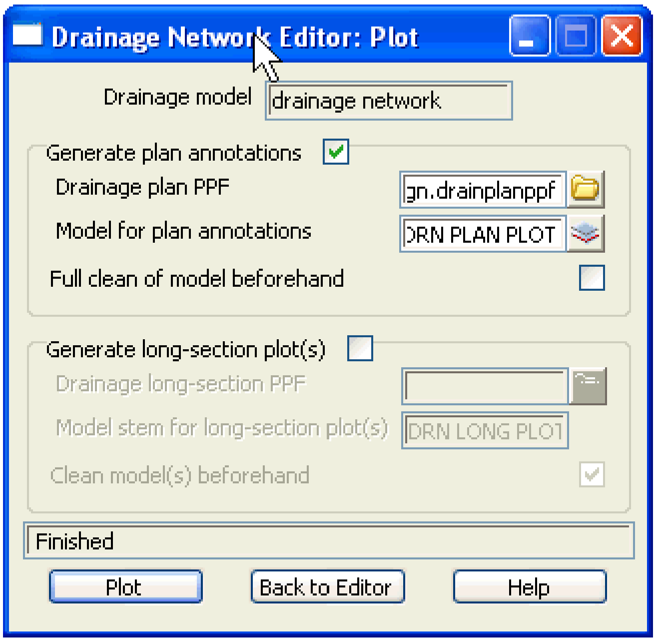
The drainage long section plotting has been discussed in the Intro Drainage Course. Here we will discuss the technique for hatching under roads and/or footpaths.

The following steps are required.

1. Run the Excavation volumes routine using the obvert templates to create sections and strings for a tin on top of the pipe (obvert tin). Select **Stop section at end of manhole** to prevent the pits from being hatched
2. Create the obvert tin from the strings and sections then and null by angle length with a small length value so that the tin is nulled near the pits.
3. Create a design tin that extends to the limit of the roads.
4. Use the hatching section of the drainage long section plot to select the hatching style.

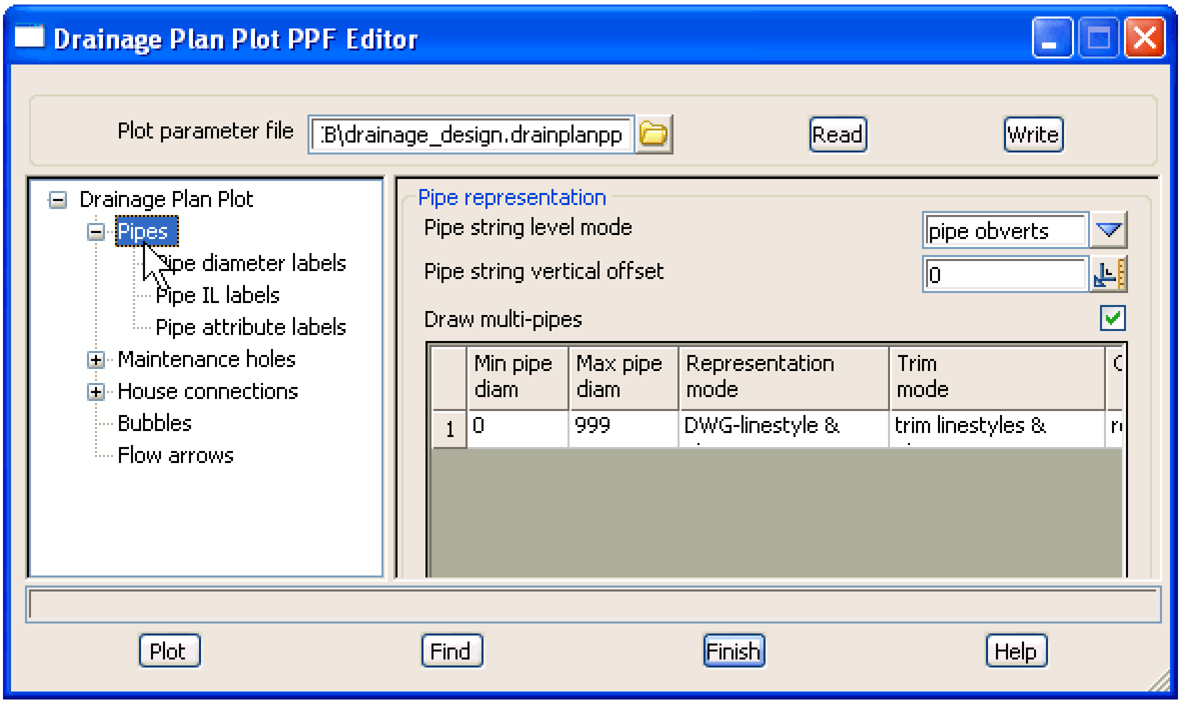
19.1 Creating the Obvert strings.

Run the Drainage Plan Plot by selecting Plot from the Drainage Network Editor.



Select the drainage_design ppf file from the library.

Select the folder icon then **Open** the ppf.

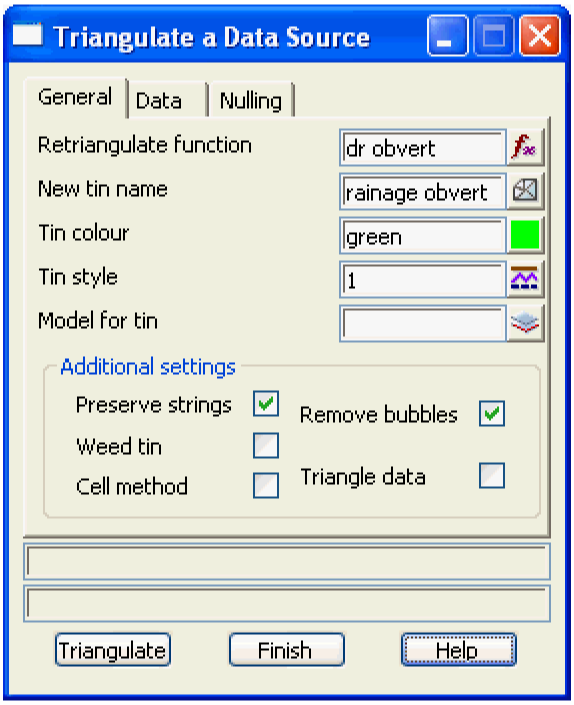


Confirm that the **Pipe string level mode** is set to **pipe obverts** and that all symbols with elevations are not used. This include:

- MH setout points,
- Flow arrows,
- pit symbols

Now plot the drawing and we will use the pipe strings at the obvert level to create a tin.

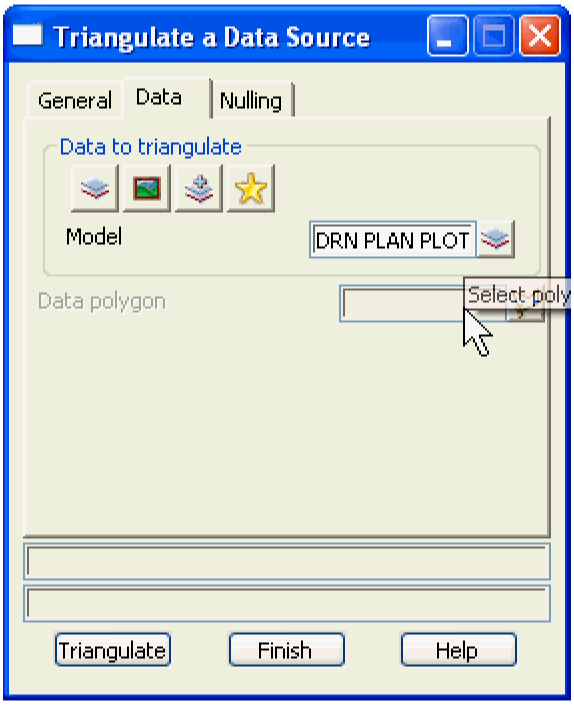
19.2 Create and Null the Obvert tin



To create the obvert tin select.

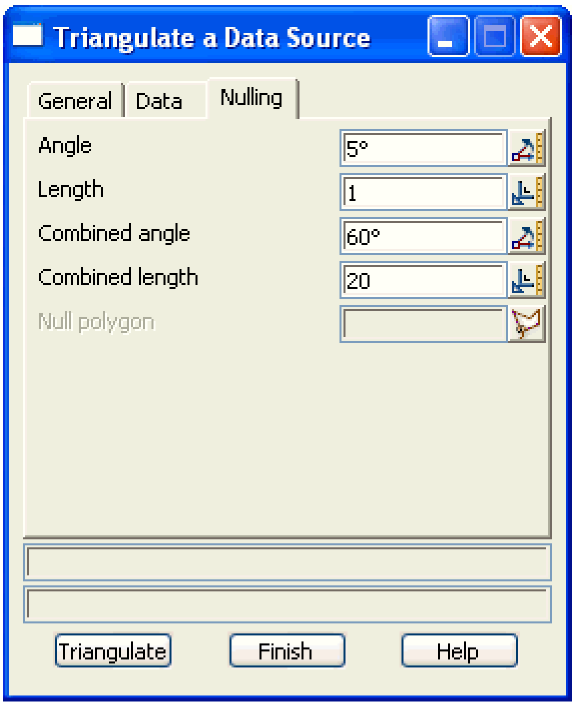
Tins->Create->Triangulate Data

Enter a **New tin name** as desired.



Select the **Data** tab.

Select the plot model created above.



Select the Nulling tab

Enter a **Length** that is less than the pit diameter and greater than the largest pipe.

Select **Triangulate**

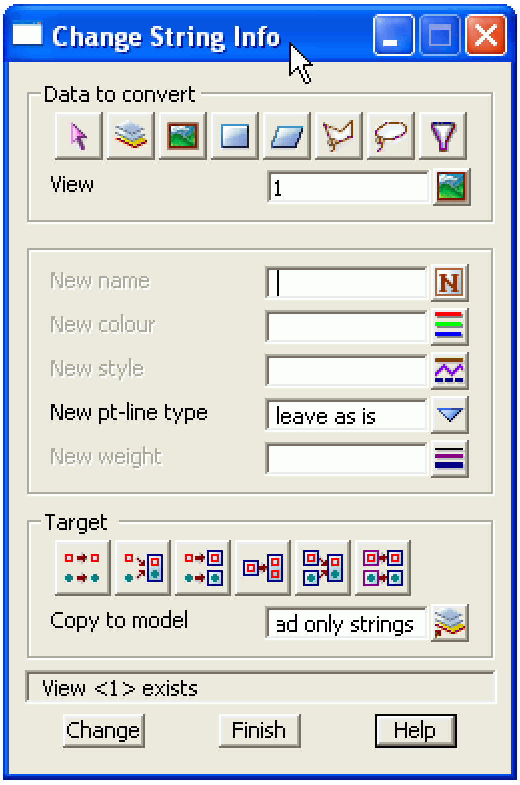
The tin will now only exist on top of the pipe and it is ready to use for hatching.

19.3 Create a Roads Only Tin

The design tin is already nulled to remove the long triangles. If the footpaths were to be excluded from the tin then they should be removed from the road design strings. You could run a template that did not include the footpath and has a **Final Maximum slope width** of zero or just copy the desired road strings to one model and remove unwanted strings. We will use the later techniques.

Add all of the road string and kerb return models onto one view and then select

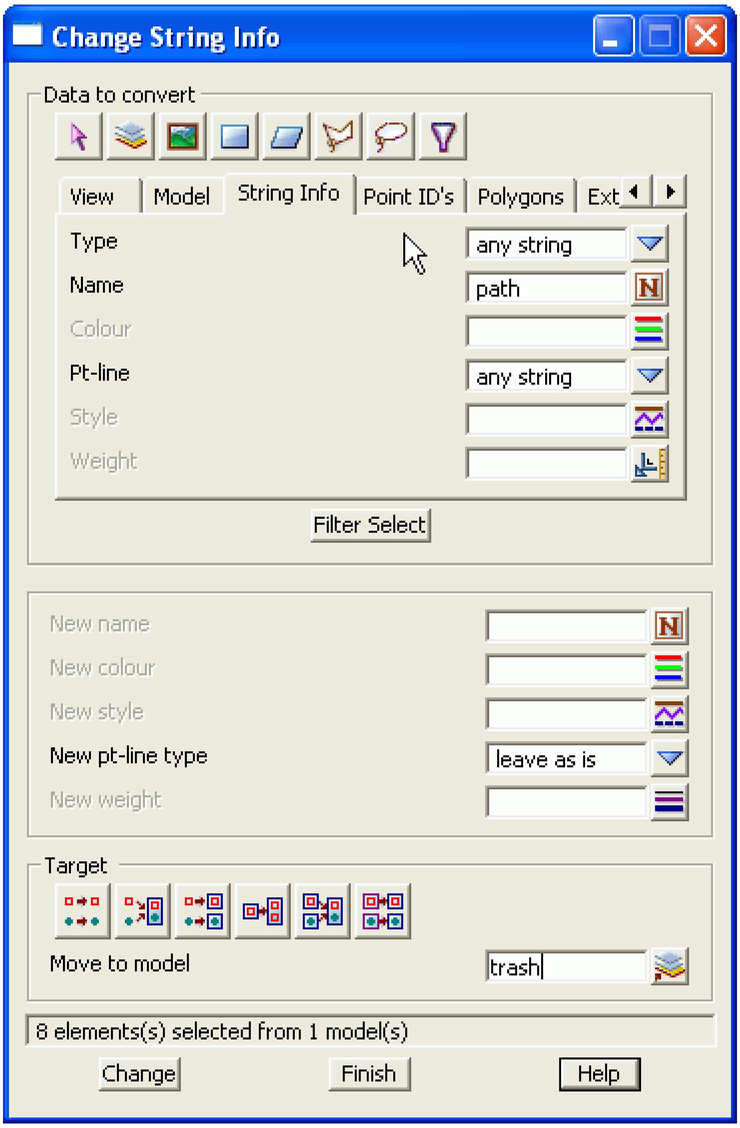
Utilities->A-G->Change



View select the view that contains all of the road strings

Copy to model type the name of a model for all of the road strings.

Select **Change** copy the strings.



Select the **Filter** icon at the end of the selection strip. Now select the **Model** tab and select the **Name** of the model that holds all of your road and kerb strings **road strings only** (tab not shown here).

Select the **String Info** tab and enter the name of the strings that you want to remove from the road only model. In this case it is **path.**

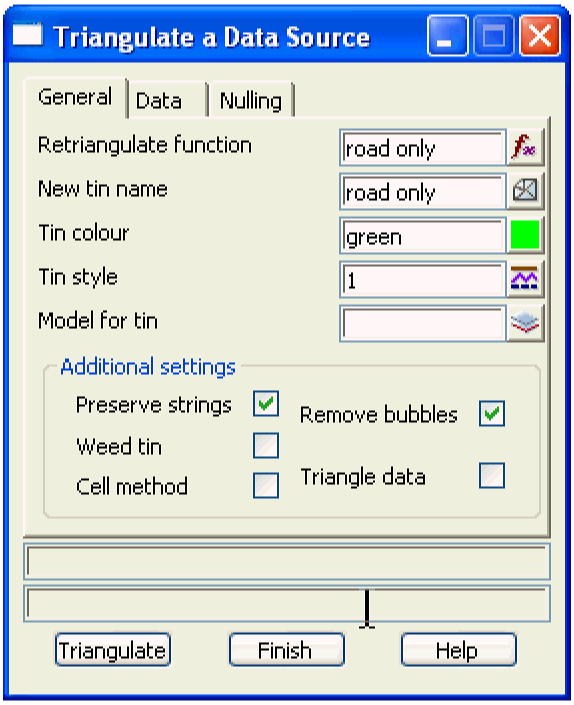
Select **Filter Select** to select these strings.

Select the second **Target** button **Move to model** and select the model **trash** and then select **Change**.

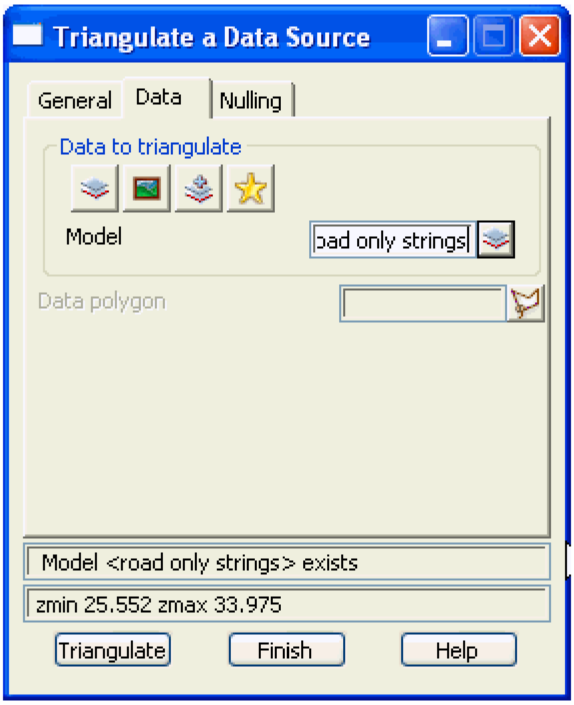
Repeat this for string names **int.**

We are now ready to triangulate the road only tin.

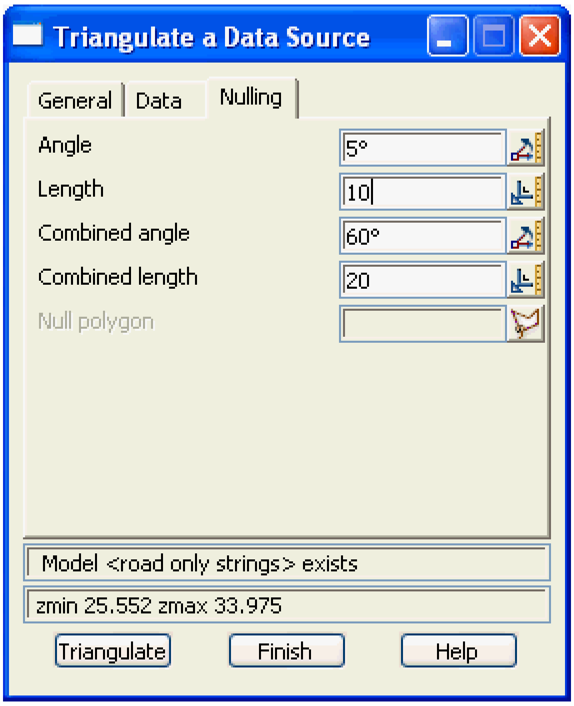
Now to create the tin select **Tins->Create->Triangulate data**



Enter a function name (optional) and **New tin name** and then select the **Data** tab.



Model - Select the model containing the road only strings.



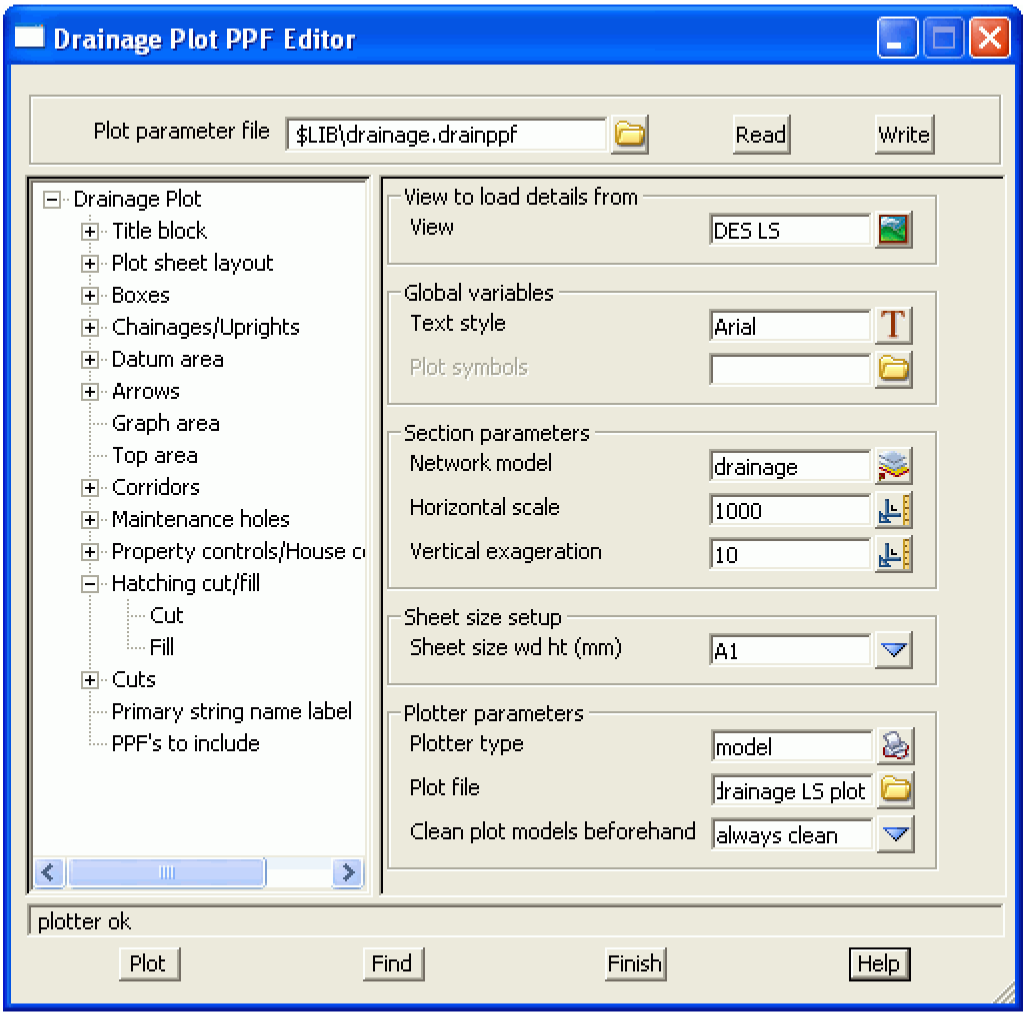
Length - Select a length just greater than the width of half the road so that the tin will not be nulled from the end of the roads.

Select **Triangulate.**.

19.4 Use the Hatching Feature in Drainage Longsections

We are now ready to create the drainage longsection plots. Set up a section view with the a string in the drainage model profiled, the vertical exaggeration set, the desired tins displayed and the service models added. From the main menu select,

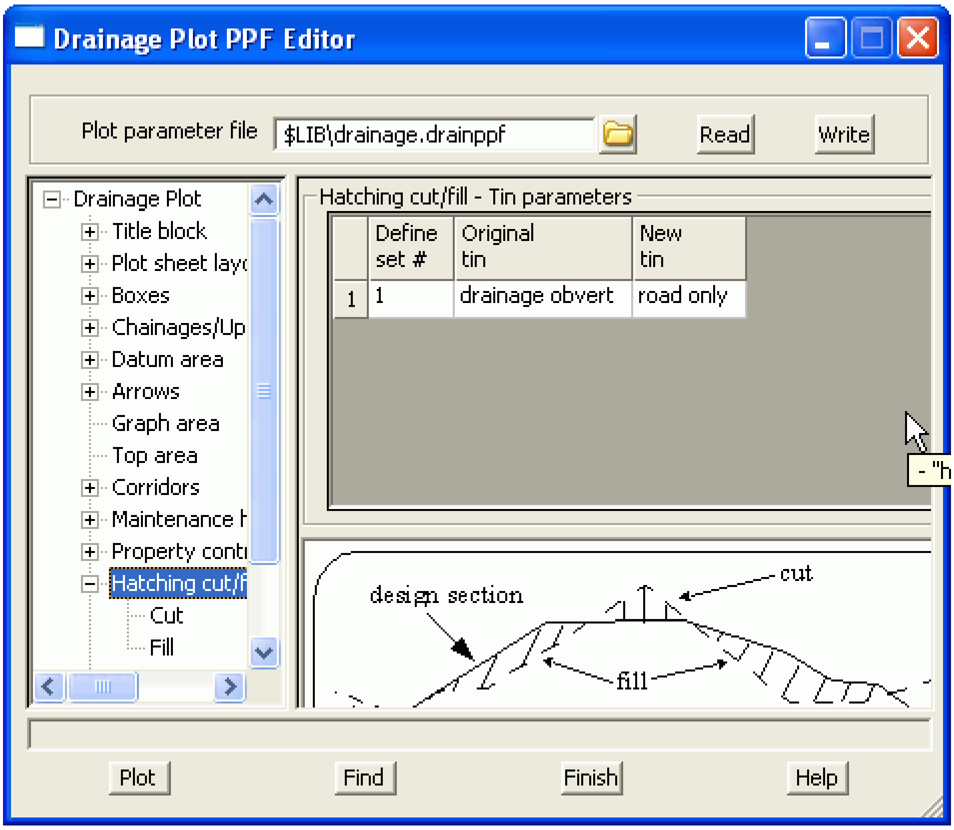
Design->Drainage-Sewer->Plots->Longsections



From the **Plot parameter file** field select a drainage longsection ppf from the library and then select **Read.**

In the **View to load details from** field select the section view you have setup for the drainage long section.

Now select **Hatching cut/fill**

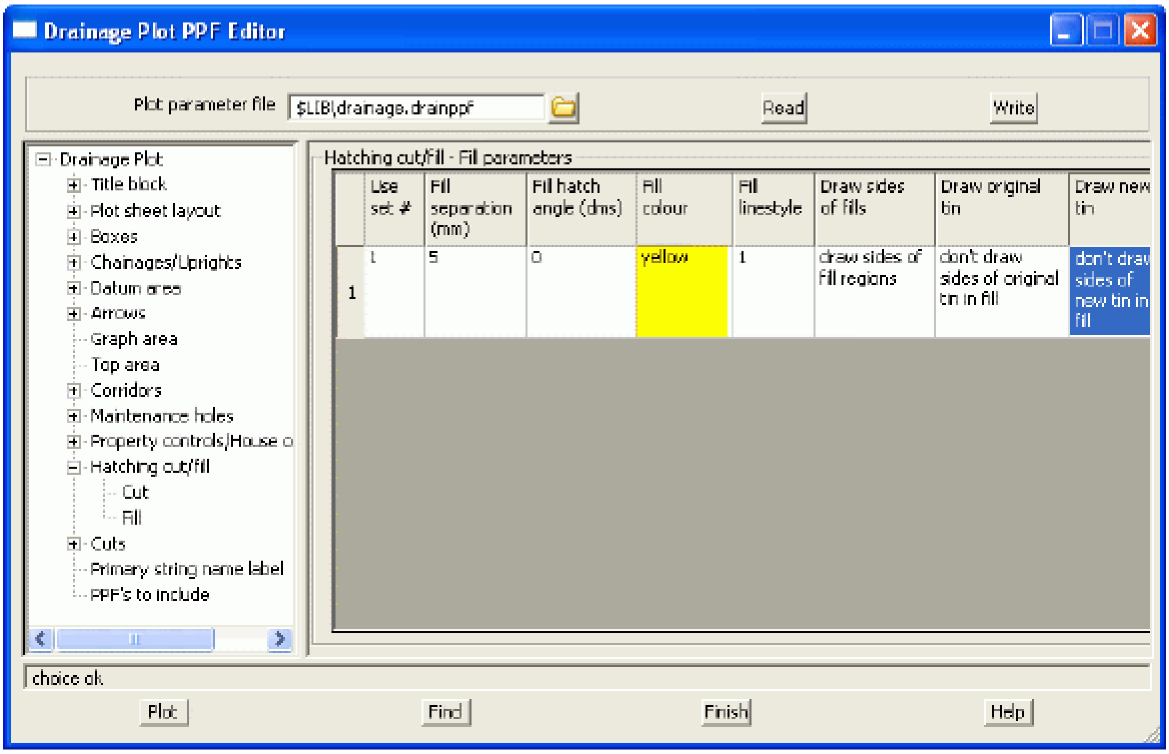


Define set is set to 1.

Original tin is set to the obvert tin.

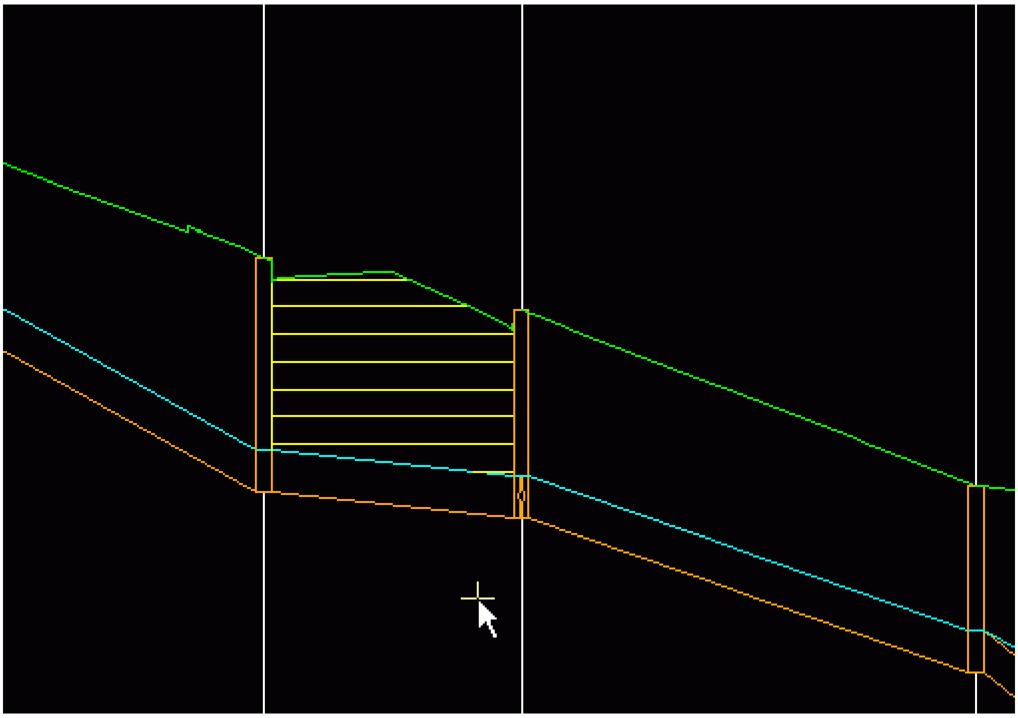
New tin is set to the road only tin.

Now select the + beside the **Hatching cut/fill** and then select **fill.**



Use set # is entered as 1. **Fill separation, hatch angle, colour and linestyle** selected as desired. **Draw sides of tin, Draw original tin** and **Draw new tin** are not required unless you want these extra line in the drawing.

Select **Plot** and add the plot model **drainage LS plot1** onto a PLAN view to preview the drawing.



The hatching is shown to the left at a 2mm spacing with the tins and sides not drawn.

COURSE NOTES

STORMWATER DESIGN - Part 2

20.0 Flooded Width Analysis and HEC RAS

There are 2 flooded width methods in the drainage module. The first can be used with any of the external drainage packages and the second is part of the 12d storm analysis. The first is described here.

The Calculate Flooded width procedure creates cross sections along the **bypass flow** paths and then calculates the flooded width at each section using Manning's normal depth calculations. A HEC-RAS project (same name as the bypass flow string) is also created for each line. The flooded width is indicated on each section as a blue line if it is less than a user defined width and a red line if the flooded width exceeds the limit. Details of the calculations such as the velocity, depth, wetted perimeter and slope can be exported to a spreadsheet for further analyse (velocity times depth calculations for example). The discharges imports from the urban stormwater design packages are shown in the following table.

Design Program	Discharge Event
PCdrain	Minor ARI
Drains	Maximum flow event analysed
ILSAX	Maximum flow event analysed
RAT HGL	First return period analysed

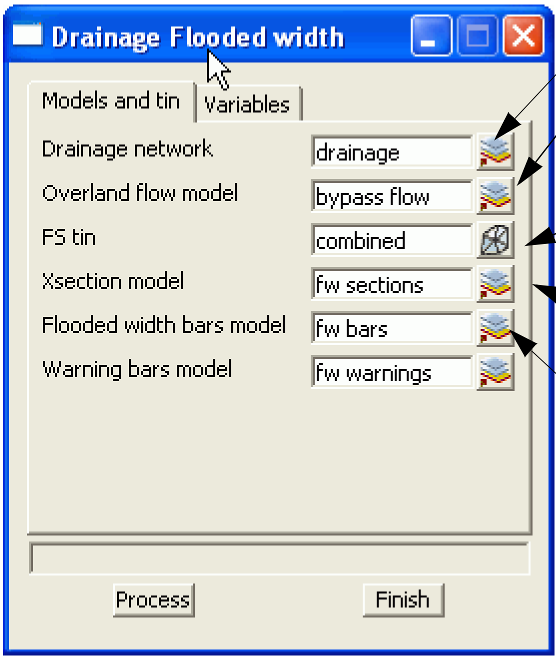
The user defines the length of these sections and the interval at which they are to be spaced. 12d calculates the normal flow depth interpolating the pit approach and bypass flows from the hydrology models (ILSAX, Drains, PC Drains or RAT HGL). The cross sections are taken perpendicular to the flow line and the slope is for the normal depth calculations is determined using the distance along the flow line and the change in elevation between the two lowest points in the primary flow channel. The flow line need not intersect the low points on the section but the flow line does mark the primary flow channel. If the depth of the flow exceeds the banks of the primary channel, then all adjacent flow channels will be considered as active flow area.

20.1 Limitations where overland flow lines join

Where overland flow lines converge at an inlet, 12d does not know the flow split between the 2 approaching paths. Therefore, 12d uses the total flow from all lines as the flow at the inlet for each line. This may overestimate the flooded width along the flow lines at these points.

20.2 Limitations at SAG pits

The flow width are not shown adjacent the sag inlets. The depth of flow due to ponding and the approach flow coming from several directions may overestimated flooded width in these areas. Therefore not flood depths are calculated approaching SAG inlets.



Enter the drainage network model.

Enter the bypass flow model.

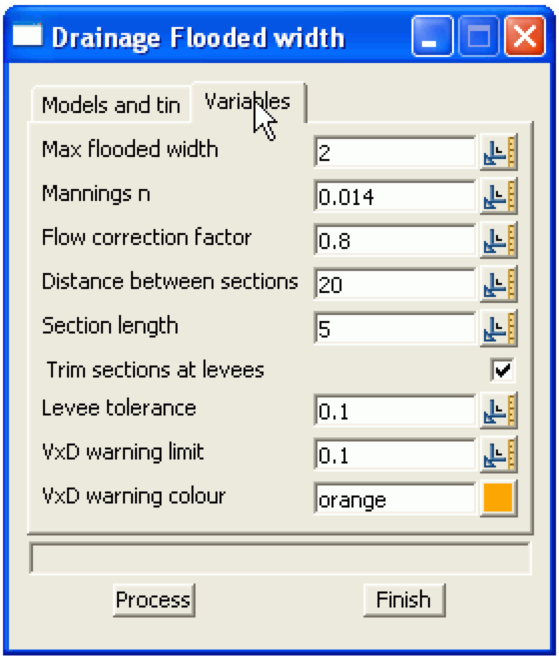
Enter the model that will contain the actual floode width lines.

Select the tin that will be used to create the cross sections.

Enter the model that will contain the cross section: The calculated values such as velocity and slope are stored with these lines.

The flooded width will be drawn in blue in the **results model** when it is less than the **Max floode width** (Variables tab**).** If the flooded width exceed this value it will be drawn in red.

If warnings are give for a section a yellow bar wil be placed in this model.



Max flooded width is the limit where the blue flooded width bars turn red.

Manning's n is the n value to be used in the norma depth calculations.

The **Flow correction factor** is the factor described i ARR 1987 for calculating depths of flow in gutter channels.

Distance between sections specifies the interval at which cross sections and therefore flooded width wi be calculated along the flow path.

Section Length defines the length of each cross sec tion. The cross section will be centred on the over-land flow path.

Trim sections at levee is used to create a cross section that stops at the crest on either side of the flow channel. A levee point is the crest in the cross section found as you move away from the flow line location. If a levee point is encountered then the section is trimmed here.

Levee tolerance is the amount the cross section needs to drop as you move away from the centre line in order to call this local crest a levee.

VxD warning limit is the velocity times depth limit that when exceeded will cause a flooded width bar to be generated in the **warning bars model**.

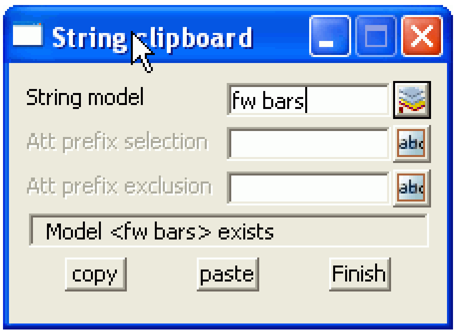
VxD warning colour is the colour of the bars mentioned above.

Process will always clean the sections, string and warning bars model before process.

Summary Tables

The hydraulic calculations and warning messages are stored as string attributes on the flooded width bars. If these attributes are exported to a spreadsheet via the clipboard a summary table my be created. To copy these attributes to the clipboard select

File IO->User->String attributes-properties to/from clipboard



The **string model** may be either the flooded width bars or the warning bars. Both models of strings contain attributes on the strings.

The prefix selection and prefix exclusion are filters for reducing the number attributes that are exported to the clipboard.

20.3 Cross Sections, Discharges and Warnings

The analyse flooded width will proceed along each flow path and identify every pit on the line. Cross sections will be constructed in the model with the length and interval entered in the input dialogue. These cross sections may be plotted using the main menu selection **Plot=>X plot=>X plot**. The **Sort Sections** must **not** be selected for these sections to be plotted.

Discharges will be determined for each cross section by linearly interpolating the discharge using distance between the pits. The bypass discharge (pit attribute - calculated bypass flow) will be taken from the upstream pit and the approach discharge (pit attribute - calculated approach flow) from the downstream pit.

The slope is calculated by subtracting the lowest points nearest to the centre line and dividing the cross section separation. The levee tolerance is NOT used for locating this point thus any rise in section moving away from the centre line marks the end of the low point search in that direction.

12d will give warning messages in the output window when it encounters the following conditions and these messages will be stored as string attributes on the flooded width strings. Descriptions of these messages follow.

Inverts do not go downhill

12d locates the lowest point (adjacent to the flow line without moving over a local crest) on each cross section to calculate the slope between the cross sections. This message indicates that the downstream minimum elevation is higher than the upstream minimum elevation.

Sometimes flow lines will go uphill. If you have specified an overflow from a SAG location then the flow line will go uphill until it crosses the overflow crest.

If the flow line is not supposed to be going uphill at this section, check to see where the flow line intersects the cross section located upstream of the one identified in the warning message. If it is in a local sag point that is not the lowest point on the section, move the flow line.

The program will use a slope of 0.5% to calculate a width at this location. This results in very wide flooded width sections to draw the user's attention to the problem area.

Vertical Walls Assumed at the Ends of the Cross Sections

If the depth of flow exceeds the ground surface elevation at the ends of the cross section a warning message the warning message shown above is shown. The cross sections causing the warning follows.

The vertical wall is placed at cross section chainage –20. Note that the flow line is always at chainage 0

21.0 Drainage Overflow Areas from Volumes

This option is used to graphically display the overflow storage volume at a sag pit. The following pit attributes must exist for the flood extents to be calculated.

overflow volume	value greater than zero required.
sag pit	must be equal to 1.
catchment model id	set by labelling catchments
catchment string id	set by labelling catchments

The maximum storage volume is read from the drainage pit attribute "overflow volume". This may be entered manually using the **Attribute Editor** or it will be created when data is read from the drainage design programs Drains or XP SWMM design programs.

This routine locates the lowest point on the catchment string by draping the string on the tin specified and adds the overflow limit specified to this value. This becomes the **overflow limit.**

The volume at this level is calculated and the compared to the **overflow volume** read from the user defined attribute.If the overflow volume is less than the volume in the catchment then the routine iterates to find the flood level for the overflow volume.

If the overflow volume is greater than the volume in the catchment, the results depend on the **Use overflow limit** tick box.

If the box is selected, the **overflow limit** (calculated above) is reported at the flood level in the catchment.

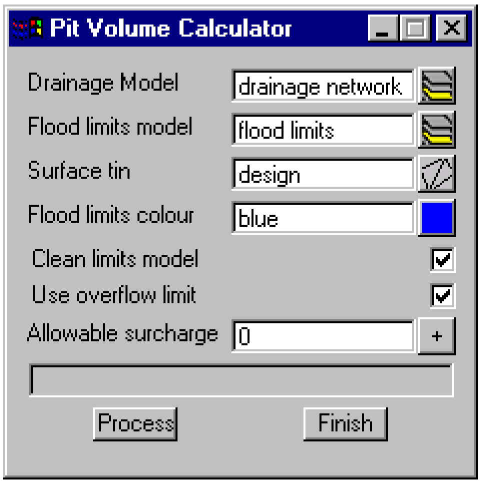
If the tick box is not selected the routine iterates to find the flood level where the storage equals the **overflow volume** read. This option allows the user to see the maximum flood level should the catchment low point become blocked.

See Also

Drainage overview

Usage

This panel is accessed from the menu selection **Design => Drainage Sewer => More=>Calc pit overflow areas**



The fields and buttons used in this panel have the following functions.

Field Description	Type	Defaults	Pop-Up
Drainage model	model box		

all pits in this model that have a non zero "overflow volume" and "sag pit" set to 1 will be processed

Flood limits model	model box		

flood limits strings will be created in this model

Surface Tin	tin box		

ground surface tin used to calculate the volumes and flood limits

Flood limits colour	colour box		

flood limits strings will be created using this colour

Clean limits model	tick box		

if selected all strings in the ***Flood limits model*** *will be deleted before the calculations commence.*

Use overflow limit	tick box		

if the elevation calculated from the storage volume is higher than the lowest point on the catchment string then the ***allowable surcharge*** *value below will be added to the lowest point on the catchment string and this elevation will be used to determine the flooding limits*

Allowable surcharge	real box		

this value is used only if ***Use overflow limit*** *is ticked. Its purpose is described in the field above.*

Process	button		

executes the option.

Finish	button		

removes the dialogue from the screen

22.0 Appendices

22.1 Appendix A: 12d V8 Drainage Analysis Detention Basins

22.2 Appendix B: 12d V8 Drainage Analysis Hydraulics

22.3 Appendix C: 12d V8 Drainage Analysis Ku Kw

12d Model

Civil and Surveying Software

Drainage Analysis Module

Detention/Retention Basins

Owen Thornton BE (Mech), 12d Model Programmer

owen.thornton@12d.com

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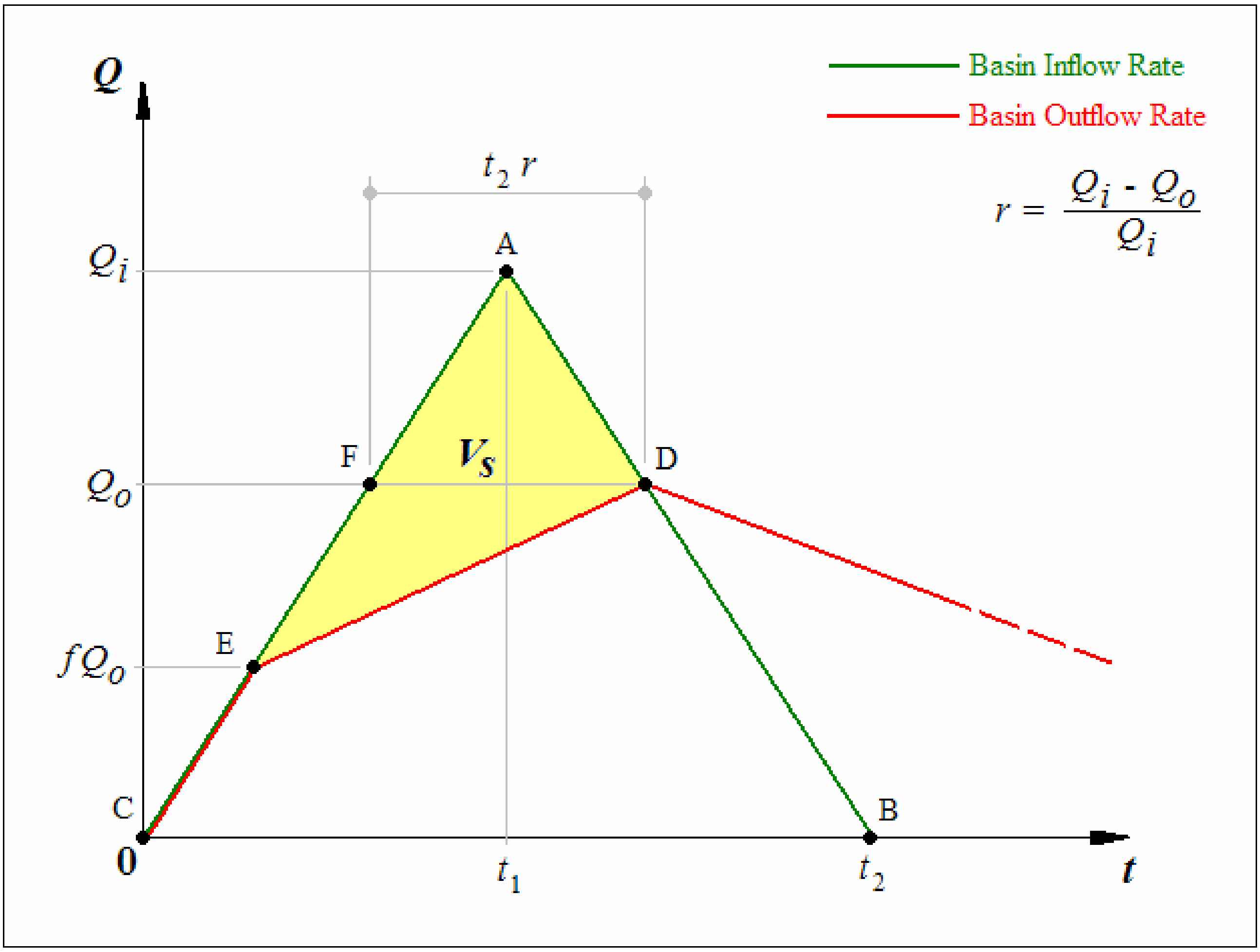
Revised:
04 April 2007
29 February 2008 (V8C1p)

This document describes the approximate method
for sizing detention basins via the *Rational Method*,
as implemented in the
Drainage Analysis module of *12d Model*.

An Approximate Method for Sizing Basins when using the Rational Method

For the design of stormwater detention and retention basins, a variety of simple and approximate methods may be adopted when using the *Rational Method*. These methods *do not* require detailed inflow hydrographs (derived from unsteady flow simulations), nor an accurate storage-discharge relationship, as would otherwise be required for the more complex and sophisticated method of solving the *Storage Equation*. For feasibility studies and preliminary design, these approximate methods should generally prove adequate. And for relatively small basins, or larger basins with *flow reduction ratios* (*r*) large enough to lessen the effect of storm temporal patterns, some approximate methods may even prove adequate for final design – though the *Storage Equation* may still need to be solved for verification of this.

An approximate method, attributed to Boyd, has been presented in both the ARR (1987) and the QUDM (2007), and three more, attributed to Basha, Carroll and Culp, in the QUDM (2007) only. All four methods are based on an assumed triangular inflow hydrograph with peak Q_i , and an assumed outflow hydrograph with a lesser peak Q_o , lying somewhere on the falling limb of the inflow hydrograph.



With reference to the inflow and outflow hydrographs shown in the figure above, the total basin inflow volume is given by the area below the inflow hydrograph:

$$V_i \quad = \quad \text{area ABCA} \quad = \quad \tfrac{1}{2}\, t_2\, Q_i \qquad (1)$$

And the required basin storage volume is given by the area contained between the inflow and outflow hydrographs:

$$V_s \;=\; \text{area ADEA} \;=\; \text{area ADFA} \;+\; \text{area FDEF}$$
$$=\; \tfrac{1}{2}\, t_2\, r\left(Q_i - Q_o\right) \;+\; \tfrac{1}{2}\, t_2\, r\left(Q_o - f\, Q_o\right) \qquad (2)$$
$$=\; \tfrac{1}{2}\, t_2\, r\left(Q_i - f\, Q_o\right)$$

where the factor f, between zero and one, defines the ratio of the initial outflow rate (with an empty basin), to the peak outflow rate, Q_o (with a basin full to capacity). For dry basins with a low-level outlet invert *below* the minimum basin water level, the outlet may begin discharging at some considerable rate, almost immediately as the basin begins to fill – thereby reducing the required size of the basin. It is for this type of outlet design where f should be set to an appropriate value greater than zero, and as such, f has been termed the *drop pit factor*.

The ratio of equations (1) and (2) may be expressed in terms of r and f, as:

$$\frac{V_s}{V_i} \;=\; r\left(\left[1 - f\right] \;+\; f\, r\right) \qquad (3)$$

Substitution of different values for f into equation (3), yields the four methods referred to above:

$$f \;=\; 0 \quad\rightarrow\quad \frac{V_s}{V_i} \;=\; r \qquad \text{… attributed to Boyd} \qquad (4)$$

$$f \;=\; 1/3 \quad\rightarrow\quad \frac{V_s}{V_i} \;=\; r\left(2 + r\right)/\,3 \qquad \text{… attributed to Basha} \qquad (5)$$

$$f \;=\; 5/8 \quad\rightarrow\quad \frac{V_s}{V_i} \;=\; r\left(3 + 5r\right)/\,8 \qquad \text{… attributed to Carroll} \qquad (6)$$

$$f \;=\; 2/3 \quad\rightarrow\quad \frac{V_s}{V_i} \;=\; r\left(1 + 2r\right)/\,3 \qquad \text{… attributed to Culp} \qquad (7)$$

It should be noted that results obtained from equation (3) are independent of the time at which the inflow peaks (t_1). So, while the *Storage Equation* can account for the differences caused by an early inflow peak, or a late inflow peak, for instance, equation (3) cannot. In most cases, however, such concerns are secondary. It is more important to estimate adequately, the design values for Q_i and V_i.

The *Rational Method* is normally only considered adequate for determining the *maximum peak inflow rate* ($Q_{i\,\max}$) when the *storm duration* (t_d) is equal to the *time of concentration* (t_c) of the catchment feeding the basin. It is far more common, however, for the critical t_d – the storm duration requiring the greatest basin storage volume – to be *considerably* longer than the t_c of the catchment. To correct for this, some have suggested that $Q_{i\,\max}$ be used for Q_i and that ($4\, t_c\, Q_{i\,\max} / 3$) be used for V_i, but this often under-predicts the basin size significantly, and there is little theoretical basis to support it. Instead, to follow the (ARR preferred) statistical interpretation of the *Rational Method* – which for the same average recurrence interval, applies the same runoff coefficients to storms of different durations – the design values for Q_i and V_i should be determined for longer storms as follows:

$$t_2 \;=\; t_d \;+\; t_c \qquad \cdots \qquad V_i \;=\; t_d\, Q_{i\,\max}\, \frac{I_d}{I_c} \qquad \cdots \qquad Q_i \;=\; \frac{2V_i}{t_2} \qquad (8)$$

where I_c and I_d are the average rainfall intensities for storms of duration t_c and t_d, respectively (as determined from IFD data) and $t_d \geq t_c$. The important thing to note about this formulation is that, for the same average recurrence interval, storm duration and runoff/infiltration model, V_i will *always* be the same as that of a hydrograph derived from a variable-intensity storm with *any* form of temporal pattern. Also note that Q_i is derived from a triangular hydrograph of volume V_i and base time t_2, to better represent the peak flow rate of a storm with an average temporal pattern.

Implementation in 12d Model

In *12d Model*, input values for f and either Q_o or V_s may be specified at the outlets of the drainage network – via the *Pit => Main* tab of the *Drainage Network Editor*.

The *Storm Analysis* process then uses equations (8) and (3) to solve for either V_s or Q_o, for a range of up to 52 different t_d values between 5 and 4320 minutes, including but not less than the full-area t_c of the catchment feeding the basin, and only those which yield an r between zero and one.

For each basin, a range of results is thus obtained, where the storm duration yielding either the greatest V_s or Q_o is selected as the critical t_d.

The following pit attributes are set on the drainage string outlets, upstream of each basin:

Inputs:

`"basin drop pit factor"`	= f
`"basin discharge"` *or* `"basin volume"`	= Q_o *or* V_s

Outputs:

`"calculated basin inflow"`	= critical Q_i
`"calculated basin inflow volume"`	= critical V_i
`"calculated basin tc"`	= full-area t_c of catchment
`"calculated basin storm duration"`	= critical t_d
`"calculated basin storm intensity"`	= critical I_d
`"calculated basin volume"` *or* `"calculated basin discharge"`	= V_s *or* Q_o

In addition, a detailed design report for each basin is reported in CSV format to the *Output Window*, which may be pasted into a spreadsheet for auditing and to produce design graphs. An example report with corresponding graphs is shown on the last page.

References

ARR (1987) "Australian Rainfall and Runoff : A Guide to Flood Estimation", Vol. 1, Section 7.5.6, *Instn. Engrs. Aust.*

QUDM (2007) "Queensland Urban Drainage Manual", Vol. 1, Section 5.05.1, *Queensland Govt. Dept. of NR&W, Brisbane.*

12D MODEL - BASIN DESIGN REPORT
Basin downstream of Outlet "1.1X"

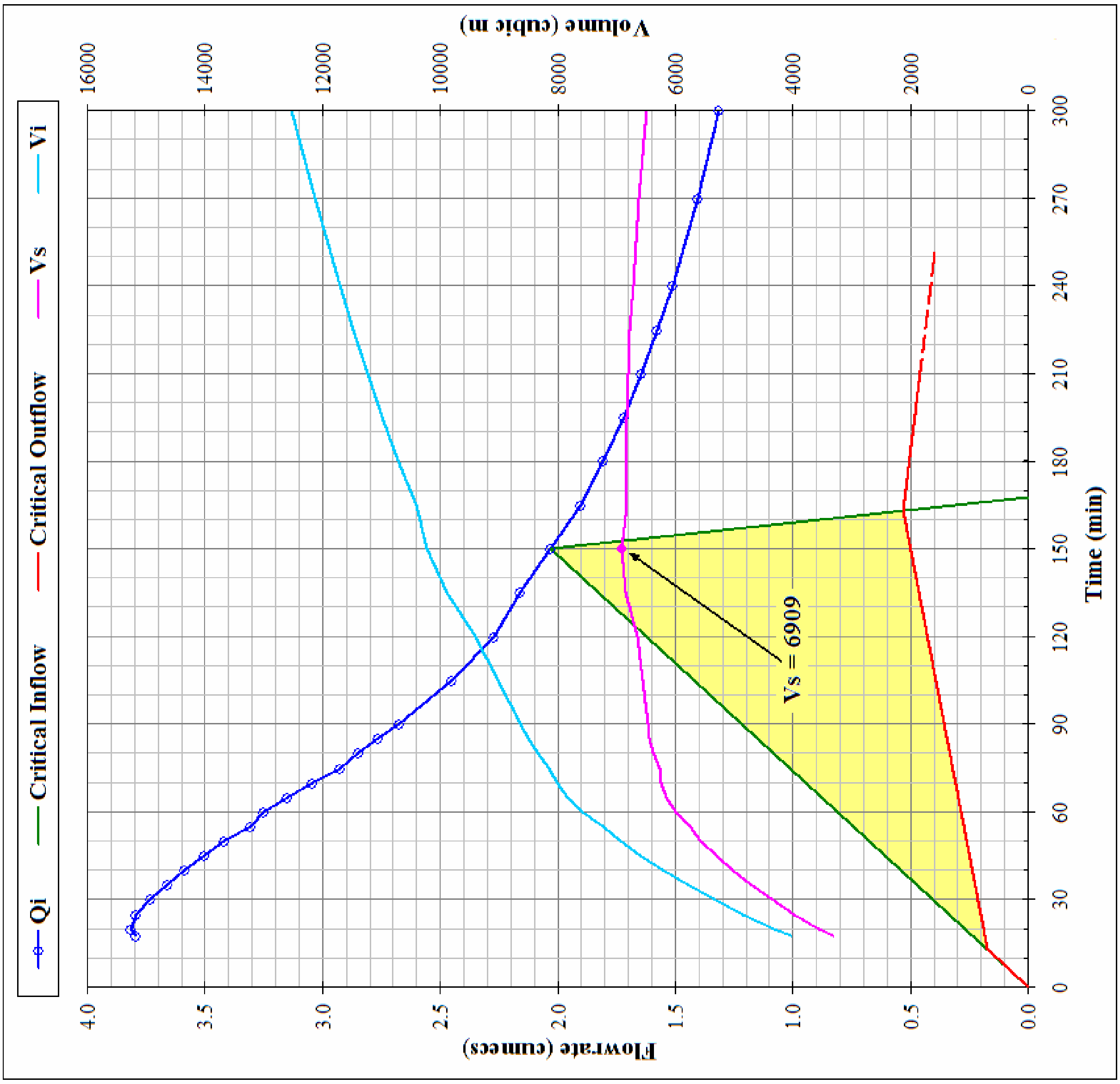
ARI	*Qo*	*tc*	*f*
(yr)	(cumecs)	(min)	(-)
50	0.530	17.7	0.33

td	*Vs*	*Vi*	*Qi*	*r*	*I*
(min)	(cubic m)	(cubic m)	(cumecs)	(-)	(mm/hr)
17.7	3314	4038	3.794	0.860	180.3
20	3547	4318	3.814	0.861	171.0
25	3988	4861	3.791	0.860	154.0
30	4367	5341	3.729	0.858	141.0
35	4714	5789	3.659	0.855	131.0
40	5035	6212	3.586	0.852	123.0
45	5314	6591	3.501	0.849	116.0
50	5567	6944	3.417	0.845	110.0
55	5745	7222	3.309	0.840	104.0
60	5998	7575	3.248	0.837	100.0
65	6147	7824	3.152	0.832	95.3
70	6238	8013	3.044	0.826	90.7
75	6270	8143	2.927	0.819	86.0
80	6378	8350	2.848	0.814	82.7
85	6445	8514	2.762	0.808	79.3
90	6470	8636	2.672	0.802	76.0
105	6558	9015	2.448	0.784	68.0
120	6649	9393	2.273	0.767	62.0
135	6853	9886	2.157	0.754	58.0
150	**6909**	**10227**	**2.032**	**0.739**	**54.0**
165	6819	10416	1.900	0.721	50.0
180	6849	10727	1.808	0.707	47.2
195	6825	10980	1.720	0.692	44.6
210	6811	11242	1.645	0.678	42.4
225	6772	11477	1.576	0.664	40.4
240	6720	11696	1.513	0.650	38.6
270	6620	12136	1.406	0.623	35.6
300	6490	12537	1.315	0.597	33.1
360	6138	13227	1.167	0.546	29.1
420	5787	13893	1.058	0.499	26.2
480	5385	14484	0.970	0.454	23.9
540	4935	14999	0.896	0.409	22.0
600	4516	15529	0.838	0.368	20.5
660	4062	15999	0.787	0.326	19.2
720	3537	16363	0.739	0.283	18.0

Critical Storm Duration = 150 min

Critical Hydrographs:

	t	*Q*
	(min)	(cumecs)
Inflow	0.0	0.000
	150.0	2.032
	167.7	0.000
Outflow	0.0	0.000
	12.9	0.175
	163.1	0.530
	251.6	0.398



Example of a Basin Design Report created by *12d Model*, showing the results for each storm duration tested, along with the inflow and outflow hydrographs of the *critical* storm duration. The corresponding graph on the right hand side shows each duration as a dot on the Q_i curve, and confirms that for the required 50Yr peak Q_o of 530 L/s, the storage volume required reaches a maximum of 6909 cubic metres, during the storm of 150 minutes duration.

12d Model

Civil and Surveying Software

Version 8

Drainage Analysis Module

Hydraulics

Owen Thornton BE (Mech), 12d Model Programmer

owen.thornton@12d.com

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04 February 2008 (V8C1p)

This document defines the various terms relevant to the hydraulic calculations performed by the *Drainage Analysis* module of 12d Model version 8, including how and where they are calculated.

The terms *pipe* and *channel* are sometimes used interchangeably, as are the terms *pit*, *manhole*, *inlet* and *structure*.

Definitions:

Q_{rat} = Peak Flow
The peak flow rate for the pipe, without consideration of bypass flows. It is determined from the contributing catchments via the Rational Method (and includes any *direct* pit or pipe flow that may have been specified upstream). It is shown in the Hydraulic Report as "Peak Flow Qrat", and is also set as a pipe attribute named "calculated peak flow".

Q_b = Net Bypass Flow
When considering bypass flows, Q_b for the pipe is determined from an analysis of *all* the upstream pits contributing to the pipe, as recommended in the *Australian Rainfall and Runoff*. It represents the sum of the peak bypass flows *approaching* these pits, *minus* the sum of the peak bypass flows *leaving* them. It is shown in the Hydraulic Report as "Net Bypass Flow Qb", and is also set as a pipe attribute named "calculated net bypass flow". **Note:** the peak bypass flow leaving each pit, is determined from the pit inlet capacity data, defined for each pit type in the *drainage.4d* setup file, as well as the relevant choke factor determined for each pit.

Q = Pipe Flow = $Q_{rat} + Q_b$
The peak flow rate in the pipe, represented by the sum of Q_{rat} and Q_b. It is shown in the Hydraulic Report as "Pipe Flow Q", and is also set as a pipe attribute named "pipe flow". **Note:** it is only when considering bypass flows, that Q may differ from Q_{rat}.

Q_x = Excess Pipe Flow
If the pipe flow, Q, is so large that the HGL would rise *above* the upstream pit's grate level, then Q_x will represent the difference between Q and the flow rate that would keep the HGL *just* at the grate level. It is shown in the Hydraulic Report as "Excess Pipe Flow Qx", and is also set as a pipe attribute named "calculated excess flow". **Note:** the excess flow amount, Q_x, is still included in the pipe flow, Q, and *is not* automatically re-routed to the overland system. However, when considering bypass flows, the user may set the *Qx routing increment* to a value greater than zero, which will initiate extra analysis passes to re-route just enough flow as is necessary, from the pipe network to the overland system, so as to eradicate the excess pipe flows. At each extra pass, an amount no greater than the *Qx routing increment* is removed from the pipe network – from the most upstream pipe(s) with excess flow(s) – and re-routed to the overland system. If flow is entering from the top of a pipe's upstream pit, the re-routing is achieved initially by reducing the pit's choke factor by an amount calculated to have the same effect. Once the choke factor is reduced to zero, however, any remaining Q_x is re-routed as *pit surcharge flow*, Q_s.

Q_s = Pit Surcharge Flow
When (and only when) excess pipe flows are re-routed to the overland system, it possible for some pits to surcharge (flow rising up and exiting the top of the pit). At such pits, the choke factor will have been reduced to zero, and Q_s will have a *positive* value equal in magnitude to the *negative* pit inflow. In the Hydrology Report, a negative value of "Inlet Flow Qi" indicates a surcharge flow, and Q_s is also set as a pit attribute named "calculated surcharge flow". **Note:** pit surcharge flow is automatically included in the bypass flow leaving a pit, and *may* re-enter the pipe network elsewhere.

Definitions: *cont …*

V_f = Full Pipe Velocity = Q / A_f

The velocity in the pipe when the pipe flow, Q, fills the entire cross-sectional area, A_f, of the pipe. This is the minimum velocity possible for this flow rate. It is shown in the Hydraulic Report as "Full Pipe Vel Vf=Q/Af", and is also set as a pipe attribute named "full pipe velocity". **Note:** V_f is the velocity used to determine pressure head and water surface elevation losses through the upstream pit. Typically, the loss coefficients K_u & K_w only apply to pipes under pressure.

Q_{cap} = Capacity Flow

For the particular size, grade and roughness of the pipe, and assuming no downstream tailwater restrictions, the capacity flow is the flow rate theoretically possible in the pipe, at the point where the flow would become pressurised (i.e. flowing *exactly* full). It is shown in the Hydraulic Report as "Capacity Flow Qcap", and is also set as a pipe attribute named "flow capacity".

V_{cap} = Capacity Velocity = Q_{cap} / A_f

The velocity corresponding to Q_{cap}. It is shown in the Hydraulic Report as "Capacity Vel Vcap=Qcap/Af", and is also set as a pipe attribute named "capacity velocity". **Note:** V_{cap} is sometimes referred to by others as *at grade velocity*, or more confusingly, as *full pipe velocity*. Great care should be taken, to avoid confusing V_{cap} with V_f.

Capacity Ratio = Q / Q_{cap}

This is simply the ratio of the pipe flow to the capacity flow. If greater than 1.0, Q will always be pressurised. If less than 1.0, Q may or may not be pressurised, depending on the conditions downstream. Some governing authorities specify that it should always be less than 1.0. It is shown in the Hydraulic Report as "Q/Qcap Ratio", and is also set as a pipe attribute named "flow capacity ratio".

Q_{mcap} = Max Capacity Flow

Similar to Q_{cap}, but representing the maximum unpressurised flow rate theoretically possible in the pipe. For a circular pipe, Q_{mcap} occurs at a depth of about 0.94xD. For a box-culvert, Q_{mcap} occurs at a depth just below the obvert (0.999xH, say). For circular pipes, Q_{mcap} is approximately 1.07xQ_{cap}. For box-culverts, Q_{mcap} may be considerably greater than Q_{cap}, due to the sudden increase in friction losses when the flow comes into contact with the top wall – an effect more pronounced as the culvert's width/height ratio increases. **Note:** Q_{mcap} is not calculated by 12d Model, as it is an inherently unstable flow, which can become pressurised with only the slightest increase in frictional resistance. Pipe manufacturers typically publish capacities which match more closely to Q_{cap}.

V_{mcap} = Max Capacity Velocity

The velocity corresponding to Q_{mcap}, that is: $V_{mcap} = Q_{mcap} / A_w$, where A_w is the wetted cross-sectional area at the depth at which Q_{mcap} occurs.

Definitions: *cont …*

d_n = Normal Depth
The depth in the pipe when the slope of the water surface of the pipe flow, *Q*, is parallel to the pipe slope. If *Q* is greater than Q_{cap}, d_n is set to the obvert of the pipe. It is set as a pipe attribute named "normal depth", and the value [d_n / <pipe height>] is set as "normal depth relative".

d_c = Critical Depth
The depth in the pipe when the local energy head (the sum of the pressure and velocity heads only, ignoring the gravity head) of the pipe flow, *Q*, is at a minimum. It is set as a pipe attribute named "critical depth", and the value [d_c / <pipe height>] is set as "critical depth relative".

V_n = Normal Depth Velocity
The velocity in the pipe when the pipe flow, *Q*, is flowing at the normal depth, d_n. This is the maximum velocity possible for this flow rate, in the most common case of a "steep" slope pipe (where $d_c > d_n$). In the rare case of a "mild" slope pipe (where $d_c < d_n$), it is possible for the velocity to be slightly greater near the downstream end of the pipe, if the flow "drops off the end" and the depth approaches d_c. It is shown in the Hydraulic Report as "Norm Depth Vel Vn=Q/An", and is also set as a pipe attribute named "normal velocity".

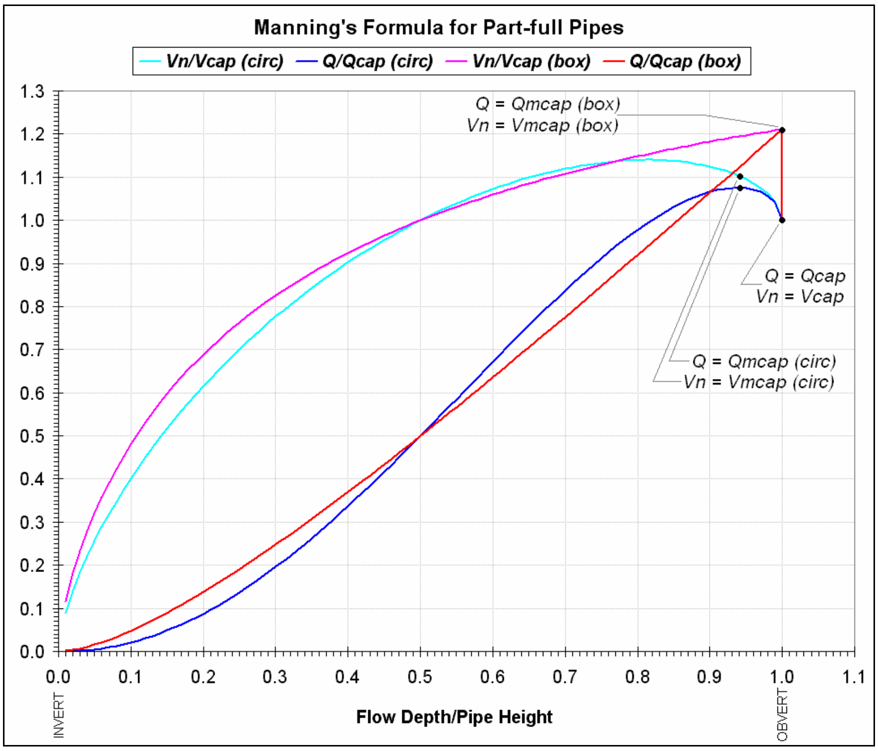
V_c = Critical Depth Velocity
The velocity in the pipe when the pipe flow, *Q*, is flowing at the critical depth, d_c. When the flow is slower than V_c (deeper than d_c) it is termed *tranquil flow*. When the flow is faster than V_c (shallower than d_c), it is termed *rapid flow*. It is shown in the Hydraulic Report as "Crit Depth Vel Vc=Q/Ac", and is also set as a pipe attribute named "critical velocity".

V_{min} & V_{max} = Allowable Velocity Ranges for V_n and V_{cap}
These velocity limits are often specified by governing authorities, to ensure that all pipe flows are fast enough to wash away impediments, but not so fast as to scour the pipes. If set on the *GLOBAL=>Main* tab of the *Drainage Network Editor*, they are checked against the calculated V_n and/or V_{cap} values. If ever a calculated velocity is too low or too high, a new pipe grade is recommended in the *Output Window*, to help remedy the problem.

V_a = Actual Velocity (VicRoads manual)
The Victorian "VicRoads" manual refers to a chart for determining the so-called *actual velocity*, V_a, in part-full pipes. The chart shows a relationship between Q / Q_{cap} values and V_a / V_{cap} values. The resultant V_a values from this chart, are equivalent to the normal depth velocity, V_n, values calculated by 12d Model.

Manning's Formula versus the Colebrook-White Formula:

The *Drainage Analysis* module allows pipe roughness to be specified as either Manning's n (based on metre-second units), or Colebrook's k (specified in mm in 12d). The choice of roughness type determines the formula – Manning or Colebrook-White – used to calculate: Q_{cap}, V_{cap}, d_n and V_n. It also governs how the friction slope is determined in both the Darcy-Weisbach equation and the Gradually Varied Flow equation, when calculating the HGL values along the pipe. The Colebrook-White formula may be seen as an empirical combination of the Rough and Smooth Pipe Laws of turbulent flow, which were both derived from boundary-layer theory by Prandtl and von Kármán, but adjusted to match the experimental results of Nikuradse, who performed a series of lab tests on small pipes of uniform roughness. Colebrook and White, however, performed tests on a range of *commercial* pipes (of non-uniform roughness) – with an equivalent k deduced from the constant friction factor, f, observed at high Reynolds number – and found that for most of the pipes they tested, their new combination-formula matched well. The turbulent range of the now widely-used *Moody Diagram*, is wholly based on the Colebrook-White formula, and represents the trend to be expected, in the absence of any specific data for particular pipes. Where non-circular pipes are used, or where part-full flow occurs in any kind of pipe or open channel of reasonably uniform cross-section, substitution of $4R$ for D (four times the *hydraulic radius* for diameter) can be justified, with the assumption that the mean shear-stress around the wetted perimeter is not too dissimilar from the uniform stress around a circular perimeter (true enough for box-culverts and many open channels). Because the Colebrook-White formula accounts for the variations in f dependent on the *relative* roughness (k/R or k/D) and the Reynolds number (Re), it is *slightly* more reliable, when considered across the range of pipe sizes and flow rates commonly found in stormwater systems. Most of the values published for Manning's n are for relatively large open channels, where the dependency on Re is slight, and relative roughness is implied in the n value. As such, Manning's formula is good for larger systems (especially natural channels), but when applied to smaller systems like typical stormwater pipes, the Colebrook-White formula suggests that these published n values should be reduced somewhat. Overall, the primary difficulty with *both* formulae lies in the selection of suitable n or k values, and significant errors are not uncommon. The following figure shows a normalised graph of Manning's formula, for a full range of flow depths in both circular pipes and (square) box-culverts. (The corresponding Colebrook-White graph is so similar on this normalised scale, that it may be considered identical.) Note the difference between Q_{cap} and Q_{mcap} on the graph.

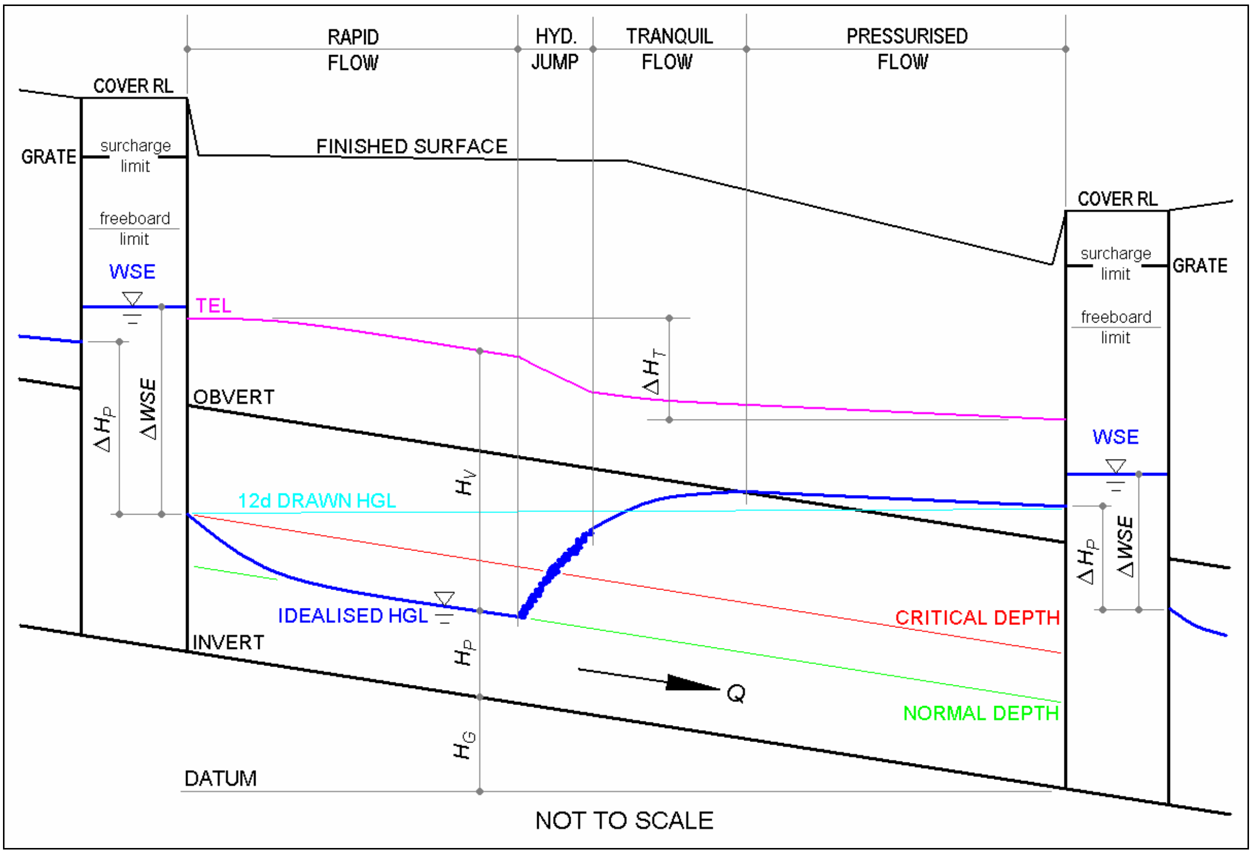


The Hydraulic Grade Line (HGL):

In 12d Model, when a Drainage string is profiled or plotted, you have the option to display the HGL determined from a storm analysis of the drainage network. The HGL represents the peak sum of the pressure and gravity heads throughout the network, and in 12d, it is idealised to show separate head losses along the pipes and through the pits. *In reality, these losses are not separate, but continuous, with the often highly un-developed flow near the pits, progressively forming fully-developed, one-dimensional flow, in the pipe reaches sufficiently distant from the pits.*

HGL Along Pipes: The HGL drawn along a pipe in 12d, is simply the straight line joining the pipe's idealised entrance and exit HGL levels. As such, in pipes where the steady flow is wholly pressurised, it is a good representation of the friction slope, and consequent loss of total head (ΔH_T) due to friction. However, where part-full flow occurs in any portion of the pipe, neither the friction slope nor the water surface slope is constant, and so the straight line implies nothing other than the idealised entrance and exit HGL levels. For these cases, the idealised HGL is calculated internally, assuming fully-developed flow, via numerical integration of the Gradually Varied Flow equation. This handles all possible cases of tranquil and rapid flow on mild and steep slope pipes, including the hydraulic jumps that can occur on steep slopes. Note that, due to the non-uniform velocity head in these cases, ΔH_T due to friction cannot be determined from the idealised HGL, and must instead be determined from the Total Energy Line (TEL).

HGL At Pits: The horizontal HGL drawn across a pit, represents the peak water surface elevation (WSE) in that pit, and is tested against the freeboard and surcharge limits imposed there. The jump in the HGL between a pit's entrance and exit, represents the change (normally a loss) in pressure head (ΔH_P) through that pit (it does *not* represent the loss in total head). If a pit's entrance HGL level is higher than the level formed by the minimum of d_n and d_c in an upstream pipe, then this HGL level also forms a tailwater condition for that upstream pipe. Note that ΔWSE is typically equal to, or slightly greater than ΔH_P, and that both these jumps may, to a certain extent, be thought of as the effect that a pit has on what would otherwise be fully-developed, one-dimensional flow.



Schematic of a typical HGL in a steep slope pipe

Hydraulic Equations:

Bernoulli's Equation (for the head of a streamline)

$$H_T = H_V + H_P + H_G = \frac{V^2}{2g} + h + z$$

Reynolds Number (laminar flow < 2000 < critical zone < 4000 < turbulent flow)

$$\text{Re} = \frac{VD}{\nu} = \frac{4VR}{\nu}$$

Darcy-Weisbach Equation (for steady, uniform [pressurised] flow)

$$\frac{-\Delta H_T}{L} = S_f = \frac{f}{D}\frac{V^2}{2g} = \frac{f}{4R}\frac{V^2}{2g} = \frac{m}{R}\frac{V^2}{2g}$$

Gradually Varied Flow Equation (for steady, non-uniform [free-surface] flow)

$$\frac{dh}{dL} = \frac{S_0 - S_f}{\left(1 - \frac{V^2 B}{g A_w}\right)}$$

Manning's Formula (for complete turbulence, high Re)

$$\sqrt{\frac{8g}{f}} = \sqrt{\frac{2g}{m}} = \frac{R^{1/6}}{n}$$ (Manning's relation to Chézy's coefficient, for metre-second units)

$$V = \frac{S^{1/2} R^{2/3}}{n}$$ (for metre-second units) **OR** $$V = 1.49\frac{S^{1/2} R^{2/3}}{n}$$ (for foot-second units)

Colebrook-White Formula (for transition zone flow and complete turbulence, Re > 4000)

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k}{3.7D} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$$ (as published by Colebrook, 1939)

$$V = -2\sqrt{2gDS}\,\log_{10}\left(\frac{k}{3.7D} + \frac{2.51\nu}{D\sqrt{2gDS}}\right) = -4\sqrt{2gRS}\,\log_{10}\left(\frac{k}{14.8R} + \frac{0.314\nu}{R\sqrt{2gRS}}\right)$$

Pressure Head Change Formula (through pit directly upstream of pipe)

$$-\Delta H_P = K_u V_f^{\,2}/2g$$

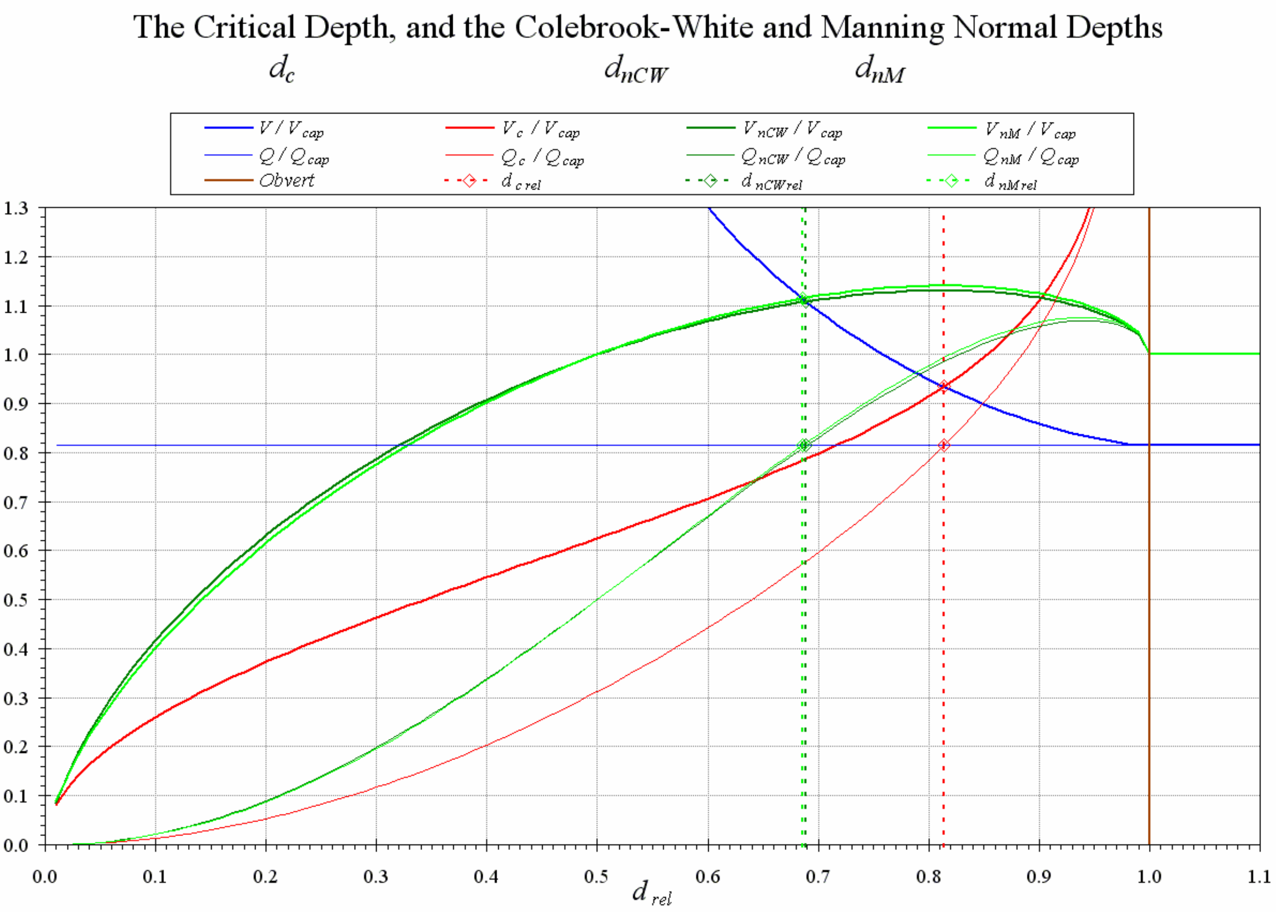
WSE Change Formula (between pit directly upstream of pipe and pipe entrance)

$$-\Delta WSE = K_w V_f^{\,2}/2g$$

where:		**[dimensions]**
H_T	= total head (energy per unit weight of water)	[L]
H_V	= velocity head = $V^2 / 2g$	[L]
H_P	= pressure head = h	[L]
H_G	= gravity head = z	[L]
V	= mean velocity of flow through a cross-section	[L/T]
g	= acceleration due to gravity	[L/T^2]
h	= pressure head (and depth of flow in an open channel) at a cross-section	[L]
z	= height of channel invert at a cross-section, from a constant horizontal datum	[L]
Re	= Reynolds number	[-]
ν	= kinematic viscosity of water	[L^2/T]
D	= diameter of circular pipe	[L]
R	= hydraulic radius of flow at a cross-section = $A_w / P_w = D/4$ for full circular pipe	[L]
A_w	= wetted cross-sectional area	[L^2]
P_w	= wetted cross-sectional perimeter	[L]
L	= plan length of channel	[L]
f	= Darcy friction factor (based on D)	[-]
m	= Fanning friction factor (based on R) = $f/4$ … confusingly, often denoted by f	[-]
dh/dL	= longitudinal slope of water surface at a cross-section, relative to S_0	[-]
B	= lateral breadth of water surface at a cross-section	[L]
S_0	= channel slope	[-]
S_f	= friction slope (energy lost, per unit weight of water, per unit length of channel)	[-]
S	= context dependent – typically: S_0 when solving for V; S_f when solving for S	[-]
n	= Manning roughness factor	[T/L$^{1/3}$]
k	= Colebrook roughness factor	[L]
WSE	= water surface elevation in pit	[L]
K_u	= pressure head change factor for pit directly upstream of pipe	[-]
K_w	= WSE change factor for pit directly upstream of pipe	[-]
V_f	= full pipe velocity	[L/T]

Determining the Critical and Normal Depths in Part-full Pipes:

Wherever the pipe flow, Q, is less than the capacity flow, Q_{cap}, the potential exists for part-full (free surface) flow to occur. In these instances, the critical and normal flow depths are determined by 12d Model, using the equations shown in the figure below. Note that the graph within the figure, shows the solutions for a circular pipe on a normalised scale.



$$Q = const < Q_{cap}$$

$$V_{cap} = -4\sqrt{2gRS_0}\,\log_{10}\left(\frac{k}{14.8R} + \frac{0.314\nu}{R\sqrt{2gRS_0}}\right) = \frac{S_0^{1/2} R^{2/3}}{n}$$

$$Q_{cap} = AV_{cap}$$

$$V = \frac{Q}{A_w}$$

$$V_c = \sqrt{\frac{gA_w}{B}}$$

$$V_{nCW} = -4\sqrt{2gR_wS_0}\,\log_{10}\left(\frac{k}{14.8R_w} + \frac{0.314\nu}{R_w\sqrt{2gR_wS_0}}\right)$$

$$V_{nM} = \frac{S_0^{1/2} R_w^{2/3}}{n}$$

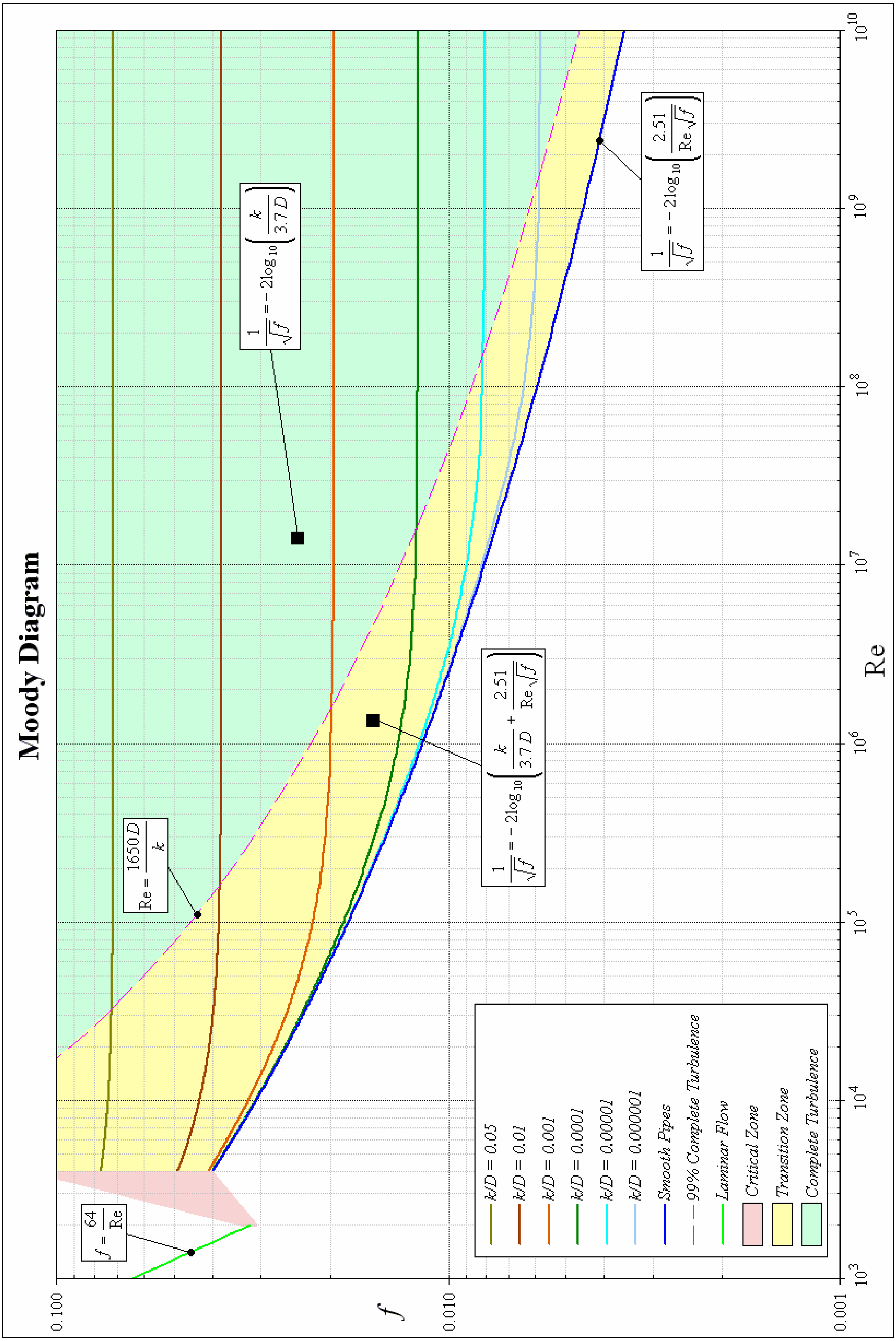
$$Q_c = A_wV_c;\quad Q_{nCW} = A_wV_{nCW};\quad Q_{nM} = A_wV_{nM}$$

Circular Pipes	**Box Culverts**
$A = \pi D^2/4$	$A = WH$
$R = D/4$	$R = WH/(2W + 2H)$
$\theta = \cos^{-1}(1 - 2d_{rel})$	
$B = D\sin\theta$	$B = W$
$A_w = (\theta - \frac{1}{2}\sin(2\theta))D^2/4$	$A_w = WH\,d_{rel}$
$R_w = A_w/(D\theta)$	$R_w = A_w/(W + 2H\,d_{rel})$

$$d_{c\,rel} = d_{rel}\,|(V = V_c) = d_{rel}\,|(Q = Q_c)$$

$$d_{nCW\,rel} = d_{rel}\,|(V = V_{nCW}) = d_{rel}\,|(Q = Q_{nCW})$$

$$d_{nM\,rel} = d_{rel}\,|(V = V_{nM}) = d_{rel}\,|(Q = Q_{nM})$$


Moody Diagram
f
Re
0.100
0.010
0.001
10^3
10^4
10^5
10^6
10^7
10^8
10^9
10^10
f = 64/Re
Re = 1650 D / k
1/√f = −2 log10 (k / 3.7 D)
1/√f = −2 log10 (k / 3.7 D + 2.51 / (Re √f))
1/√f = −2 log10 (2.51 / (Re √f))
k/D = 0.05
k/D = 0.01
k/D = 0.001
k/D = 0.0001
k/D = 0.00001
k/D = 0.000001
Smooth Pipes
99% Complete Turbulence
Laminar Flow
Critical Zone
Transition Zone
Complete Turbulence

More Hydraulic Equations (for reference only – not used in 12d):

Chézy's Formula (for complete turbulence, high Re)

$$V = \sqrt{\frac{8gRS}{f}} = C\sqrt{RS} \quad (C \text{ is Chézy's coefficient})$$

Laminar Flow Law (for Re < 2000)

$$f = \frac{64}{\mathrm{Re}} \quad \text{(via Poiseuille's formula)}$$

Smooth Pipe Law (for Re > 4000, very low *k/D*)

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{2.51}{\mathrm{Re}\sqrt{f}}\right) \quad \text{(adjusted to Nikuradse's data from uniform roughness pipes)}$$

$$\approx -1.8\log_{10}\left(\frac{7}{\mathrm{Re}}\right) \quad \text{(Colebrook's approximation: } f \text{ within } \pm 1.5\% \text{ for } 5000 < \mathrm{Re} < 10^8\text{)}$$

$$\approx -2\log_{10}\left(\frac{5.76}{\mathrm{Re}^{0.9}}\right)$$

Rough Pipe Law (for complete turbulence, high Re)

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k}{3.7D}\right) \quad \text{(adjusted to Nikuradse's data from uniform roughness pipes)}$$

$$\mathrm{Re} > \frac{170}{\sqrt{f}}\frac{D}{k} \quad \text{(range of Rough Pipe Law, based on Nikuradse's observations)}$$

$$\mathrm{Re} > \frac{1650D}{k} \quad \text{(range of Rough Pipe Law, based on C-W formula, for } f \text{ accurate to < 1\%)}$$

Converting *k* to *n* (by equating Manning's formula to the Colebrook-White formula)

$$n = \frac{R^{1/6}}{-4\sqrt{2g}\log_{10}\left(\frac{k}{14.8R} + \frac{0.314\nu}{R\sqrt{2gRS}}\right)}$$

Sources:

Colebrook, C.F., 1939, "Turbulent Flow in Pipes with particular reference to the Transition Region between the Smooth and Rough Pipe Laws", *J. Instn. Civ. Engrs.*, Vol. 11, 133-156.

Massey, B.S., 1989, "Mechanics of Fluids", 6th Ed., *Chapman & Hall.*

Pilgrim, D.H. (Ed.), 1987, "Australian Rainfall and Runoff ", Vol. 1, *Instn. Engrs. Aust.*

12d Model

Civil and Surveying Software

Version 8

Drainage Analysis Module

Ku & Kw Calculation

Owen Thornton BE (Mech), 12d Model Programmer

owen.thornton@12d.com

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This document describes the procedures for calculating Ku and Kw coefficients, as implemented in the *Drainage Analysis* module of *12d Model* version 8.

For stormwater pits, maintenance holes and culvert inlets:
Ku coefficients apply to pressure head (Hp) losses.

For stormwater pits and maintenance holes:
Kw coefficients apply to water surface elevation (WSE) losses.

Introduction

For the design of piped stormwater systems, the loss (or gain) in pressure head (ΔHp) *through a pit*[1], is typically assumed proportional to the velocity head at the entrance of the downstream pipe. Likewise proportional, but sometimes of different magnitude, is the corresponding change in effective water surface elevation (ΔWSE) *between the pit and the downstream pipe*. However simple this may seem, the two coefficients of proportionality (denoted by Ku for pressure head changes, and Kw for WSE changes) are generally dependent on so many different factors, that their adequate estimation still relies largely on the results of empirical study. Perhaps the most thorough sources emanating from such study, are the so called "Missouri Charts" (Sangster *et al*, 1958) and "Hare Charts" (Hare, 1981). The *Australian Rainfall and Runoff* (ARR, 1987), suggests the use of these sets of charts, in preference to any other method.

As originally published, the charts are highly complex, varied in presentation, and somewhat open to interpretation – reflective of the chaotic nature of flow through pits. A good deal of judgement is required in selecting the appropriate chart to use for a particular pit configuration, and in most cases, iterative calculations are required. For large stormwater networks, this typically leads to a huge time-cost for the designers, or alternatively, to an overly-conservative design approach. To overcome such problems, several semi-analytical methods have been proposed, with an aim to replace the dependence on charts. These range from the relatively simple methods suggested by Argue (1986), Hare *et al* (1990)[2], and Mills *et al* (1998), to the more accurate methods (which are arguably as complex as using the charts manually) suggested by Parsell (1992), and Stein *et al* (1999). A summary paper (O'Loughlin *et al*, 2002) reviewed the latter four of these methods, and concluded that none matched acceptably well, across the full range of pit configurations covered by the charts, and that more work was required to develop a practical method suitable for implementation with a computer.

12d Model adopts a method that is purely numerical, rather than semi-analytical. It is based on the fact that the majority of the chart data (i.e. the charts for pits with no more than a single upstream pipe) offer a range suitable for consideration in a continuous sense. This fact has allowed the chart data to be re-arranged and combined into a single database of Ku and Kw values – one that both spreads evenly across the full range of the charts used, and is convenient for computation. The resultant database is used to calculate values which match the charts *perfectly*, for those pits which coincide with one of the discrete chart configurations; otherwise, values are calculated which indicate a *linear transition* between particular charts. The Ku and Kw calculations are *all* based on a robust, programmed sequence of one-dimensional and/or three-dimensional interpolations within the database.

The method may be thought of as a particular, holistic way of interpreting the chart data. It has been developed with an aim to minimise user input, and increase the overall efficiency of the design process. Individual charts *do not* need to be nominated at each pit, and horizontal and vertical misalignment of pipes (a key factor affecting Ku and Kw) is considered with minimal interaction. The method is most reliable for pits with either no upstream pipe, or one upstream pipe. For pits with two or more upstream pipes (for which very few discrete charts exist) a single equivalent upstream pipe is determined, yielding results which compare adequately with the limited chart data available.

For culvert inlets, a different method is employed to calculate Ku values for culverts flowing under *inlet* control. In these cases, a Ku value must be specified directly for when the culvert flows under *outlet* control. The resultant headwater depth attained with this direct value, is then compared with the headwater depth calculated from variants of the weir or orifice flow formulae (modified to match published standard headwater nomographs for pipe and box culverts flowing under *inlet* control). If the latter headwater depth is greater, the culvert is assumed to be flowing under *inlet* control, and a higher Ku value is back-calculated to account for the greater loss in pressure head through the headwall.

[1] The term "pit" is extended in meaning here, to include *maintenance holes* (where no grate inlet flow from above is possible).

[2] Sometimes referred to as the "Hare Equations". These equations differ from the "Hare Charts", in that they offer only an approximation to the *preferred configuration* charts (see configurations: G1, T1, T2, T4, T8, T10).

Ku & Kw Calculations in 12d Model

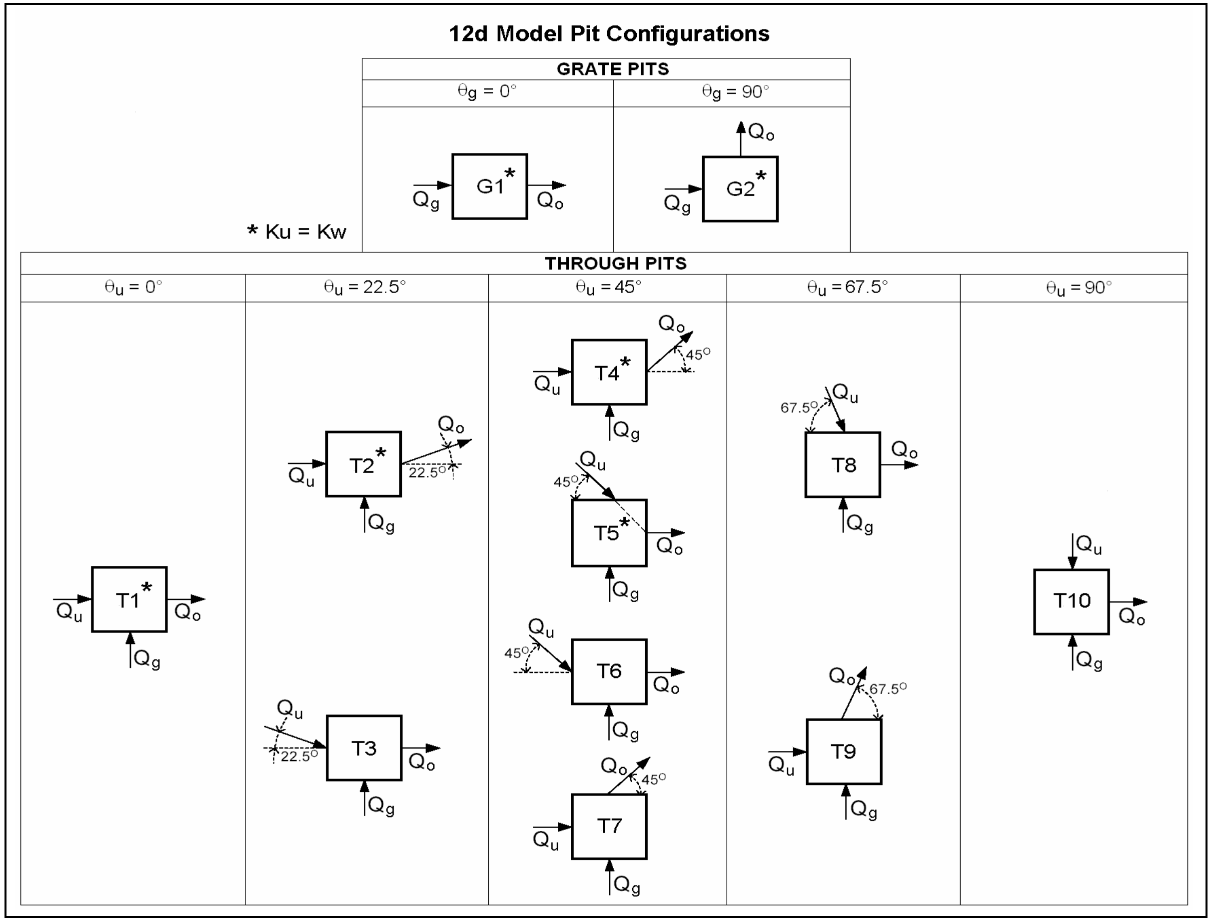


Chart Source 1: QUDM (1994).
Chart Source 2: ACTDS (2003).

In both source documents:
Chart for Grate Pits from Sangster *et al* (1958).
Charts for Through Pits from Hare (1981).

12d Pit Config	G1	G2	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
QUDM Ku Chart #	32	32	33	34	35	37	37	38	40	42	44	46
QUDM Kw Chart #	32	32	33	34	36	37	37	39	41	43	45	47
ACTDS Ku Chart #	1	1	2	13	14	10	9	16	18	20	22	7
ACTDS Kw Chart #	1	1	2	13	15	10	9	17	19	21	23	8
ACTDS Pit Type #	1	2	3	11	12	8	7	13	14	15	16	6

12d Controls	12d Settings	Remarks
Ku method	Direct	Ku & Kw entered directly - no charts used.
	Inlet Headwall	Special case: see *Culvert Inlets* on page 19
	Ku,Kw via Charts	Ku & Kw determined by chart interpolation.
	Ku,Kw>0 via Charts	If interpolated Ku or Kw is negative, set to 0.0.
Ku config	Preferred	Gives the lowest Ku & Kw (on average).
	Good	:
	Fair	:
	Poor	Gives the highest Ku & Kw (on average).

Independent Chart Variables :

θg = *angle between grate flow line and d/s pipe*
θu = *angle between equivalent u/s pipe and d/s pipe*
Qg/Qo = *equivalent grate flow ratio*
Du/Do = *equivalent pipe diameter ratio*
S/Do = *submergence ratio*

Procedural Steps :

1A) Grate Pit chart is used for pits where Qg/Qo = 1.0.
- G1 used where θg <= 15°; G2 used where θg > 15°.

1B) Through Pit charts are used for pits where 0.0 <= Qg/Qo <= 0.5.
- Interpolation within a Through Pit chart is based on Qg/Qo and Du/Do.
- Interpolation between Through Pit charts is based on θu and *Ku config* : Preferred, Good, Fair, Poor.

	0°	22.5°	45°	67.5°	90°
Preferred	**T1**	**T2**	**T4**	**T8**	**T10**
Good	**T1**	**T2**	**T5**	**T8**	**T10**
Fair	**T1**	**T3**	**T6**	**T9**	**T10**
Poor	**T1**	**T3**	**T7**	**T9**	**T10**

1C) For pits where 0.5 < Qg/Qo < 1.0, a further (linear) interpolation based on Qg/Qo is made, between the interpolated data from steps 1A and 1B.

2) Step 1A, 1B or 1C produces a Ku and a Kw curve (both versus S/Do). Actual S/Do values are calculated to intersect the Kw curve, and thus find the applicable S/Do for the final Kw & Ku values.

How does 12d Model determine the Ku & Kw chart inputs: Qg/Qo, Du/Do, θg, θu?

Example with grate flow and 3 u/s pipes:

Qg/Qo *equivalent grate flow ratio* (Steps: 1A, 1B, 1C)

	From Rational Method	Rescaled to Conserve Mass			
	Qrat	Qeq			
Qg	53.0	48.8			
Qu1	246.0	226.7			
Qu2	151.0	139.2			
Qu3	98.0	90.3			
Qu	495.0	456.2			
Qg + Qu	548.0	505.0			Qg/Qo = (Qg)eq / Qo
Qo	505.0	505.0	**Qg/Qo =** 48.8/505.0 =	**0.097**	0.0 <= Qg/Qo <=1.0

Du/Do *equivalent pipe diameter ratio* (Steps: 1B, 1C)

Pipe Diameters		Pipe Areas				
Du1	375	**Au1**	0.110			
Du2	300	**Au2**	0.071			
Du3	225	**Au3**	0.040			
		Au	0.221			Du/Do = SQR(Au/Ao)
Do	600	**Ao**	0.283	**Du/Do =** SQR(.221/.283) =	**0.884**	0.6 <= Du/Do <= 1.0

θg *angle between grate flow line and d/s pipe* (Steps: 1A, 1C)

Angle between setout string and d/s pipe	**θg =**	**32.0**	0° <= θg <= 90°

θu *angle between equivalent u/s pipe and d/s pipe* (Steps: 1B, 1C)

	Horiz θ	Drop	VAF*	θ			
							θu = θ1.Qu1/Qu
Qu1->Qo	0	20	1.547	0	**θu =** (0.0) 226.7/456.2 +		+ θ2.Qu2/Qu
Qu2->Qo	90	40	1.867	90	(90.0) 139.2/456.2 +		+ θ3.Qu3/Qu
Qu3->Qo	30	590	0.044	54.7	(54.7) 90.3/456.2 =	**38.3**	0° <= θu <= 90°

*VAF = Vertical Alignment Factor = (Do - Drop) / Du

For VAF < +0.25 (i.e. excessive vertical misalignment),

θ is increased linearly to compensate, viz:

+0.25 > VAF > -0.25

Horiz θ < θ < 90°

Grate Pits (i.e. grate flow only)

Example of Kw calculation (Ku = Kw) :

INPUT

θg	32.0
Do	0.300
Vo	0.920
ILo	27.224
HGLo	27.900

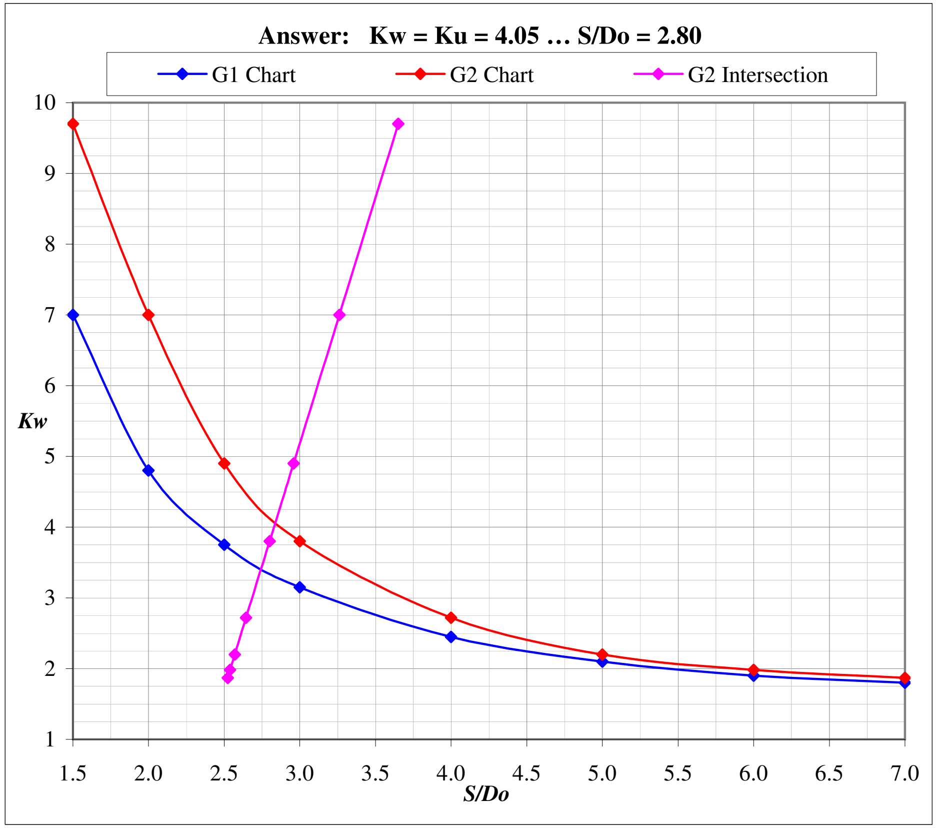
Chart :	G1	G2
θg	0°	90°
S/Do	Kw	Kw
1.5	7.00	9.70
2.0	4.80	7.00
2.5	3.75	4.90
3.0	3.15	3.80
4.0	2.45	2.72
5.0	2.10	2.20
6.0	1.90	1.98
7.0	1.80	1.87

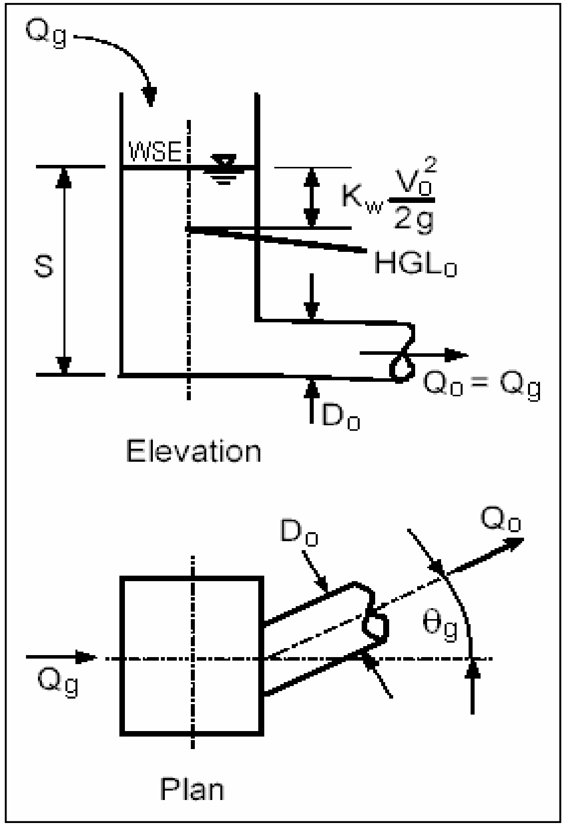
(G2)
(>15°)

$Kw.Vo^2/2g$	WSE	S	S/Do	Error
0.419	28.319	1.095	3.650	-2.150
0.302	28.202	0.978	3.261	-1.261
0.212	28.112	0.888	2.959	-0.459
0.164	28.064	0.840	2.800	0.200
0.117	28.017	0.793	2.645	1.355
0.095	27.995	0.771	2.570	2.430
0.086	27.986	0.762	2.538	3.462
0.081	27.981	0.757	2.523	4.477

G1 used where θg <= 15°
G2 used where θg > 15°
(as per Chart 32 of QUDM, 1994)

$-\Delta WSE = WSE - HGLo = Kw.Vo^2/2g$





Through Pits (i.e. through flow and grate flow)

Example of Ku & Kw calculation :

INPUT

θu	38.3
Qg/Qo	0.097
Du/Do	0.884
Ku config	Poor
Do	0.600
Vo	2.340
ILo	28.277
HGLo	29.100

Chart :	T3	T3	T3	T3	T7	T7	T7	T7
θu	22.5	22.5	22.5	22.5	45.0	45.0	45.0	45.0
Qg/Qo	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5
Du/Do	0.8	0.9	0.8	0.9	0.8	0.9	0.8	0.9

3-d interpolation factors

a	0.702	1 - a	0.298	a = (θu - 22.5) / (45.0 - 22.5)
b	0.246	1 - b	0.754	* b = (N - 0.0) / (0.5 - 0.0)
c	0.840	1 - c	0.160	c = (Du/Do - 0.8) / (0.9 - 0.8)

S/Do	Kw1	Kw2	Kw3	Kw4	Kw5	Kw6	Kw7	Kw8	Kw	$Kw.Vo^2/2g$	WSE	S	S/Do	Error
1.5	1.84	1.98	2.30	2.35	3.24	3.01	2.86	2.90	2.72	0.761	29.861	1.584	2.640	-1.140
2.0	1.57	1.69	2.00	2.05	2.81	2.65	2.55	2.53	2.38	0.665	29.765	1.488	2.479	-0.479
2.5	1.33	1.43	1.79	1.83	2.62	2.48	2.21	2.19	2.15	0.602	29.702	1.425	2.375	0.125
3.0	1.25	1.32	1.61	1.63	2.58	2.41	2.08	2.05	2.06	0.575	29.675	1.398	2.330	0.670
4.0	1.16	1.22	1.52	1.50	2.53	2.36	1.91	1.87	1.97	0.550	29.650	1.373	2.289	1.711

S/Do	Ku1	Ku2	Ku3	Ku4	Ku5	Ku6	Ku7	Ku8	Ku
1.5	1.60	1.71	1.79	1.79	2.40	2.40	2.55	2.59	2.23
2.0	1.44	1.53	1.69	1.72	2.20	2.21	2.23	2.29	2.03
2.5	1.25	1.32	1.66	1.61	2.13	2.18	2.13	2.09	1.92
3.0	1.09	1.12	1.57	1.54	2.07	2.09	1.99	1.97	1.81
4.0	0.96	1.00	1.50	1.44	1.97	2.00	1.82	1.81	1.70

General 3-d interpolation equation

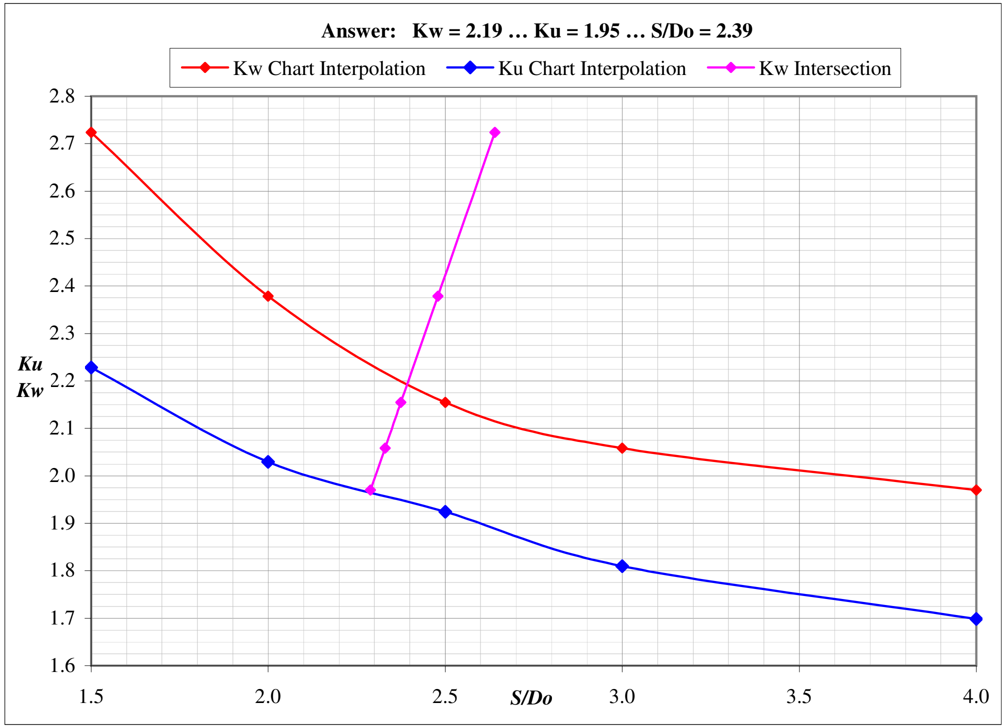
K =	(1-a) (1-b) (1-c)	K1	+	(1-a) (1-b) c	K2
+	(1-a) b (1-c)	K3	+	(1-a) b c	K4
+	a (1-b) (1-c)	K5	+	a (1-b) c	K6
+	a b (1-c)	K7	+	a b c	K8

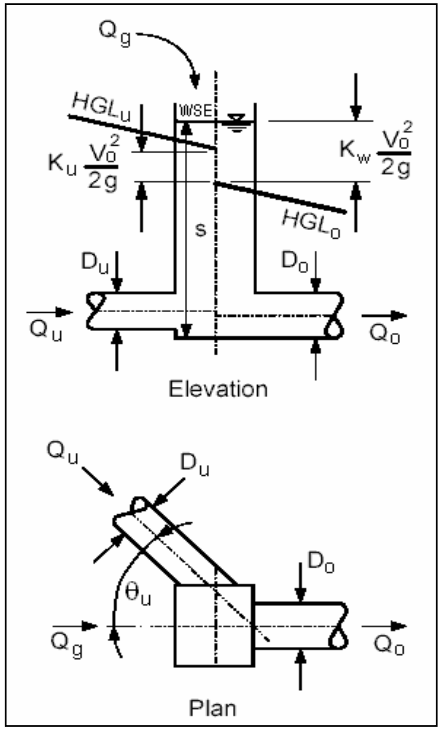
* Non-linear interpolation, as per QUDM (1994).

$N = 0.66\,(2.Qg/Qo - [Qg/Qo]^2)$

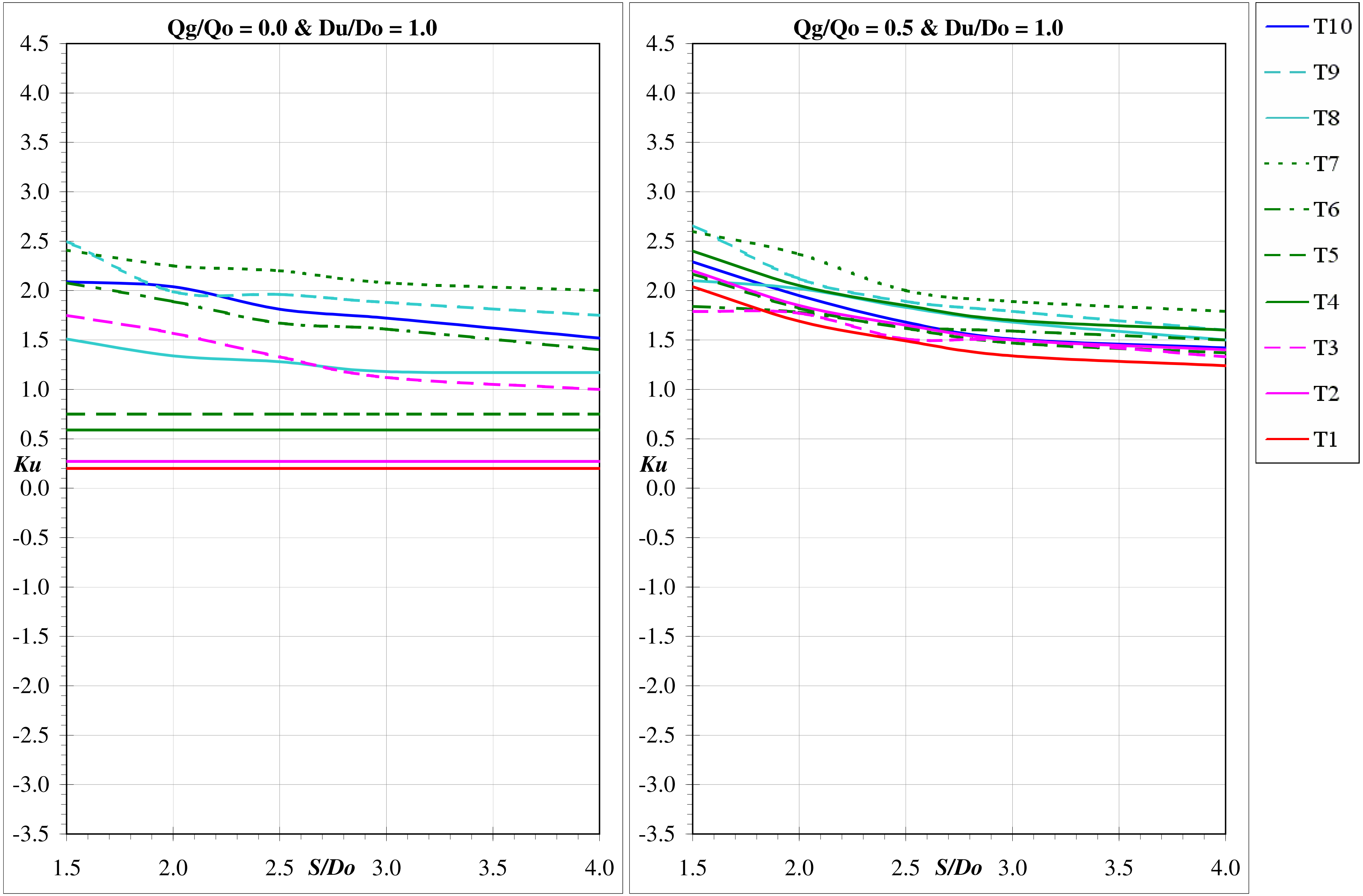
$-\Delta WSE = WSE - HGLo = Kw.Vo^2/2g$

$-\Delta Hp = HGLu - HGLo = Ku.Vo^2/2g$

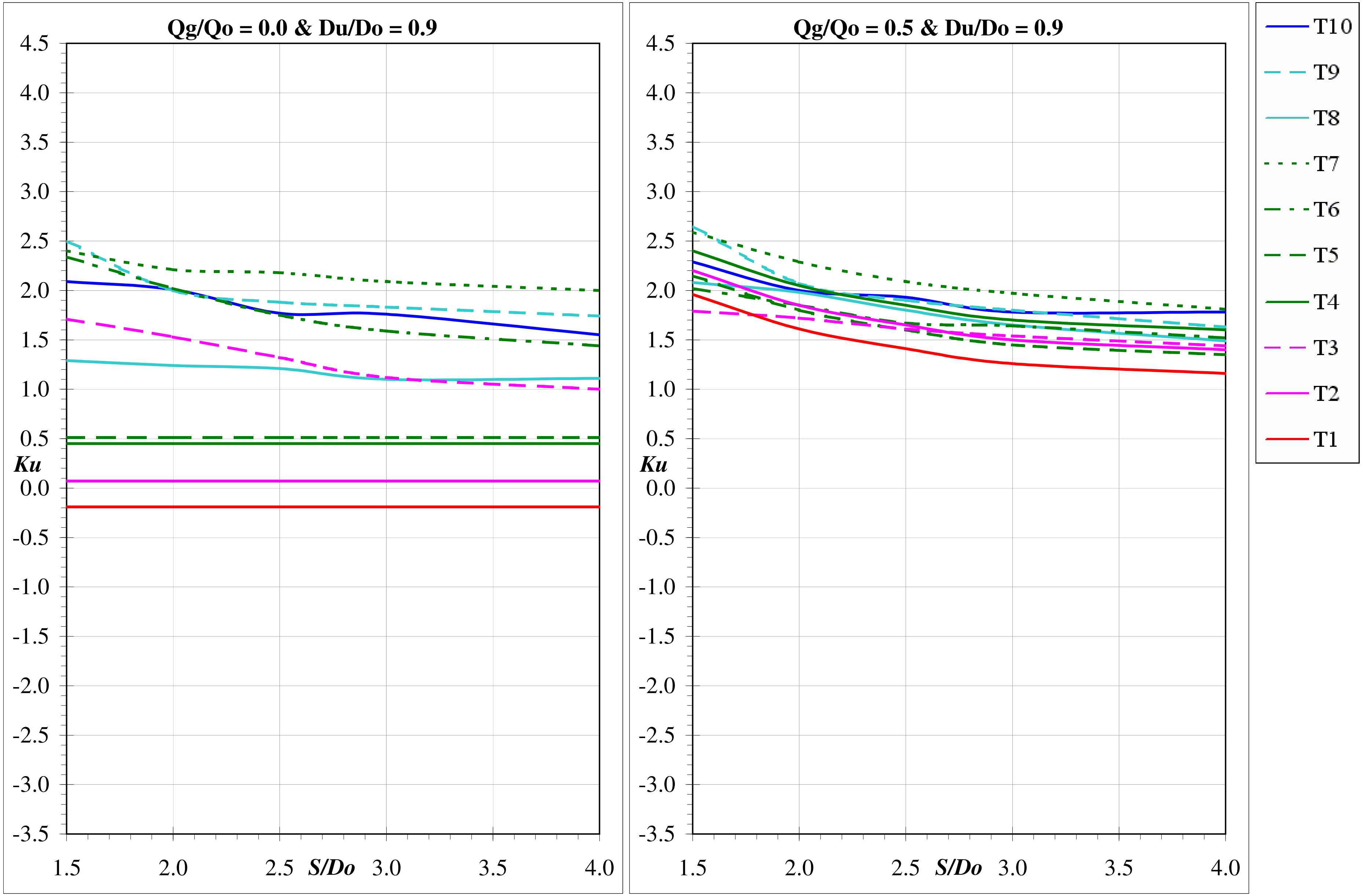




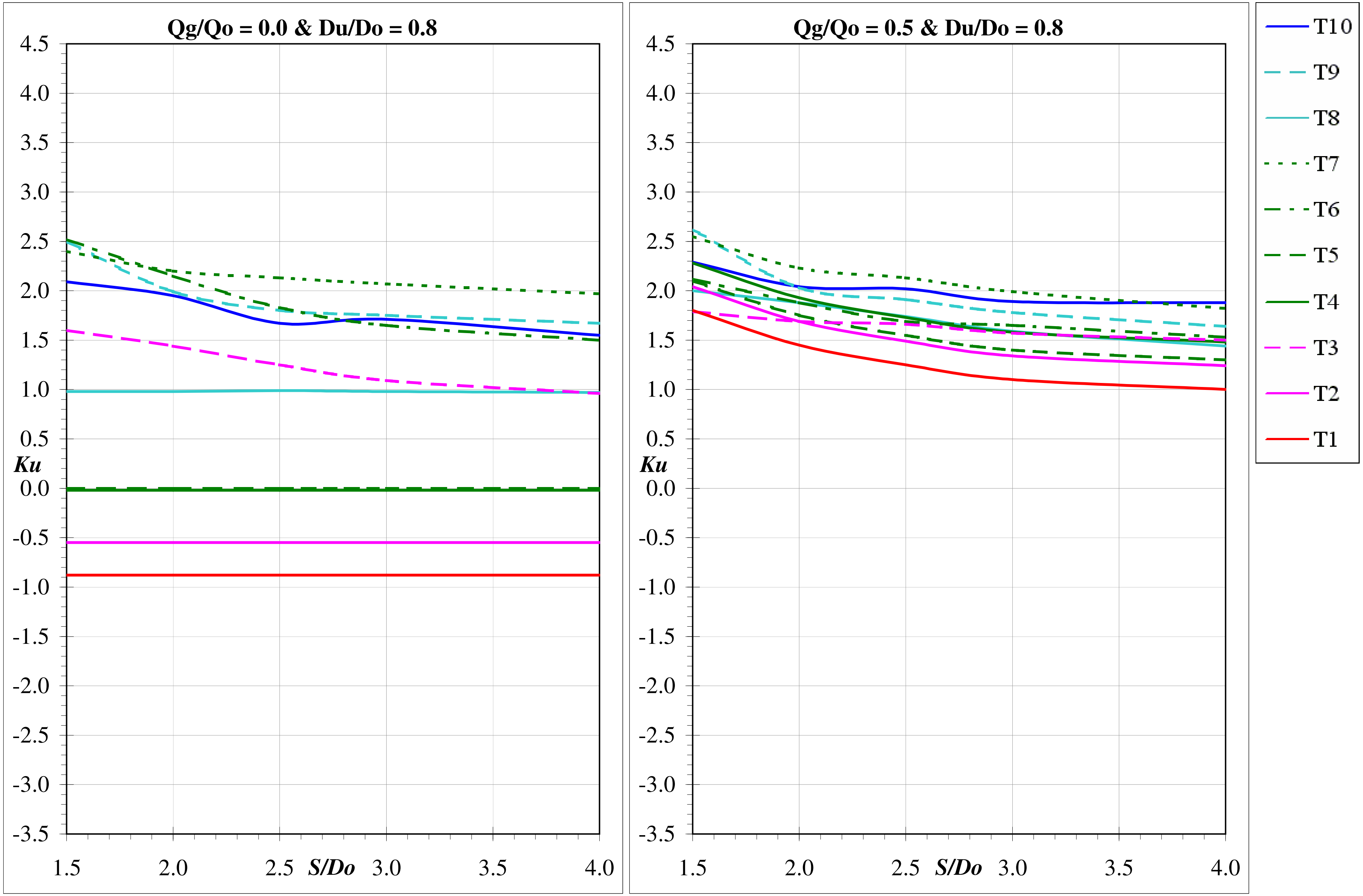
Ku Charts for Through Pits



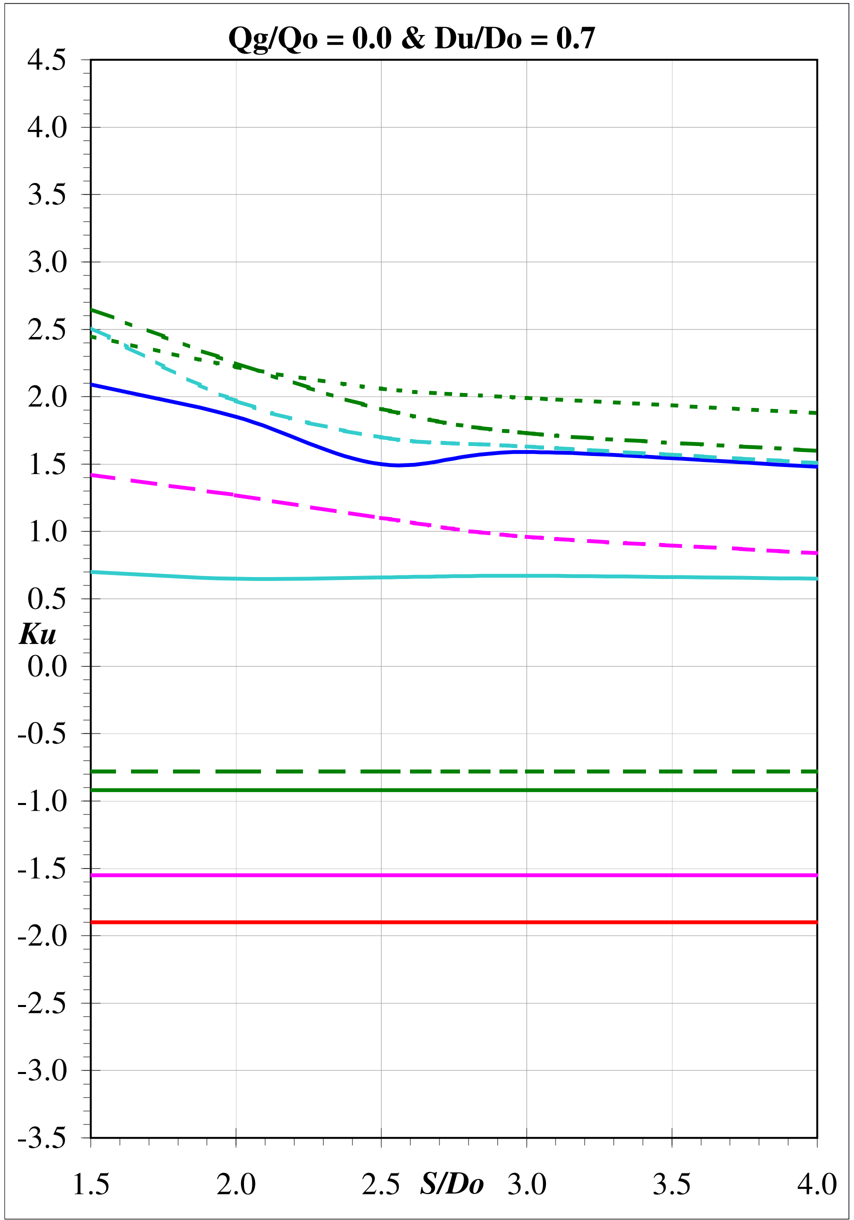
Ku Charts for Through Pits

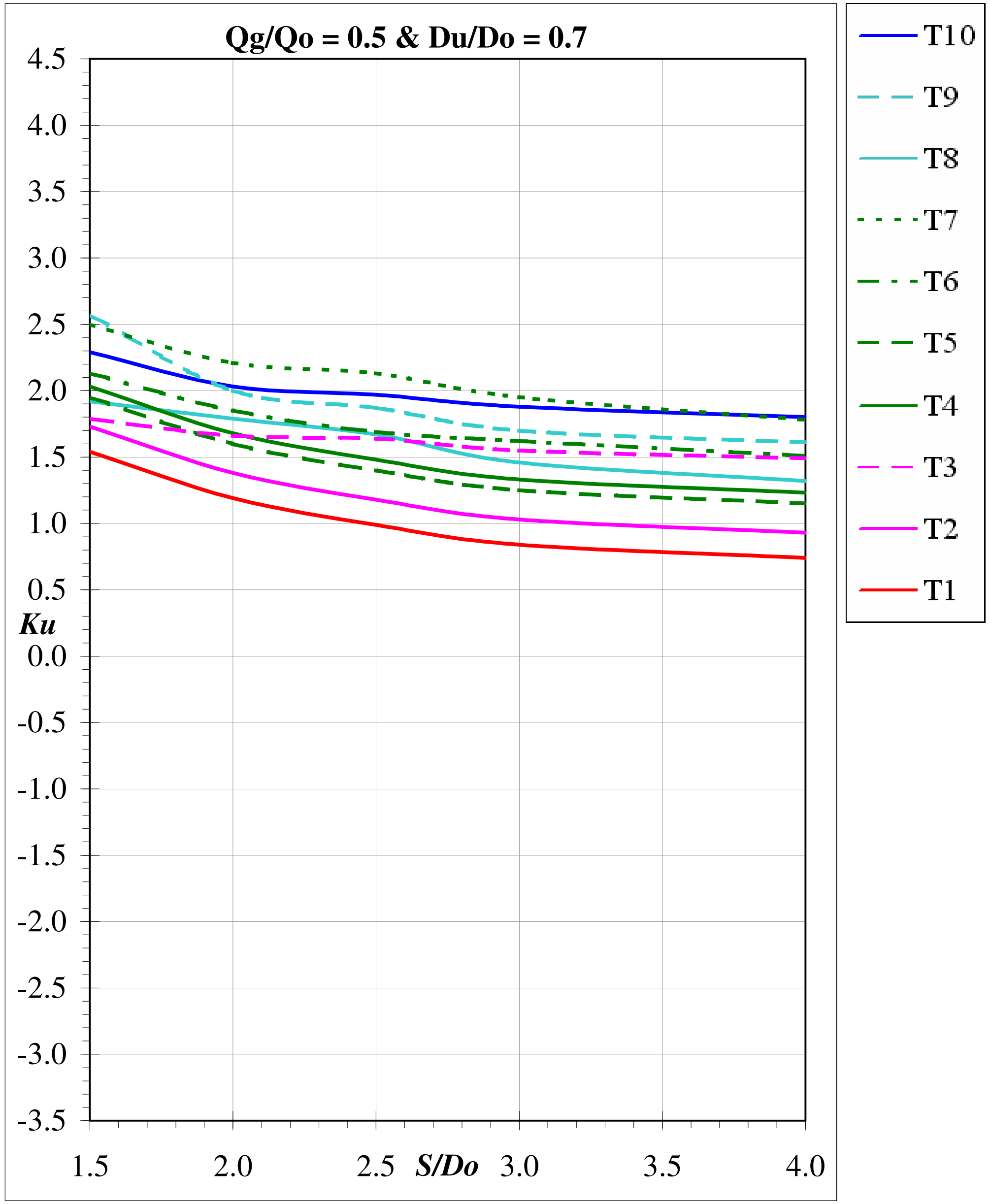


Ku Charts for Through Pits

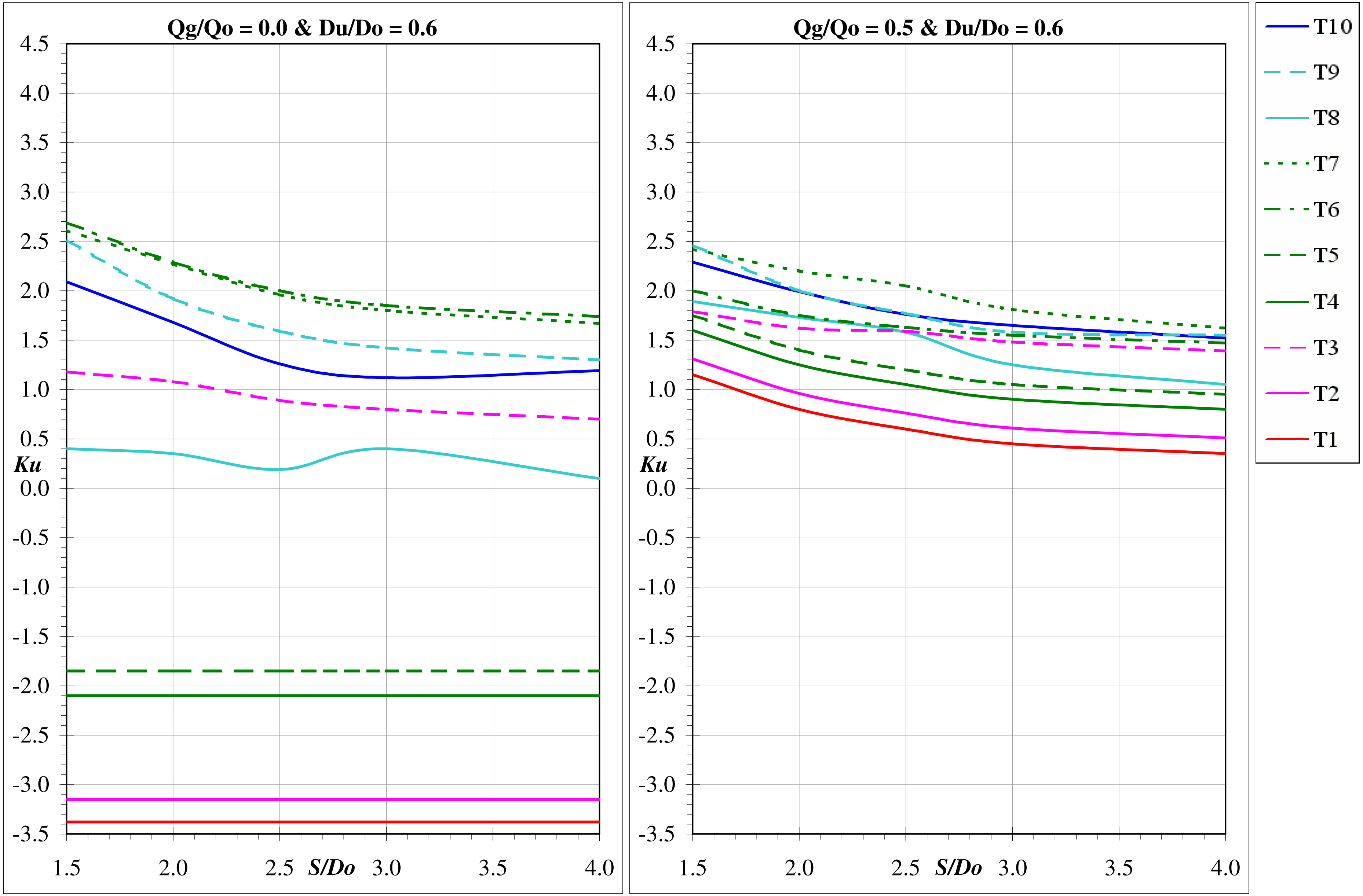


Ku Charts for Through Pits

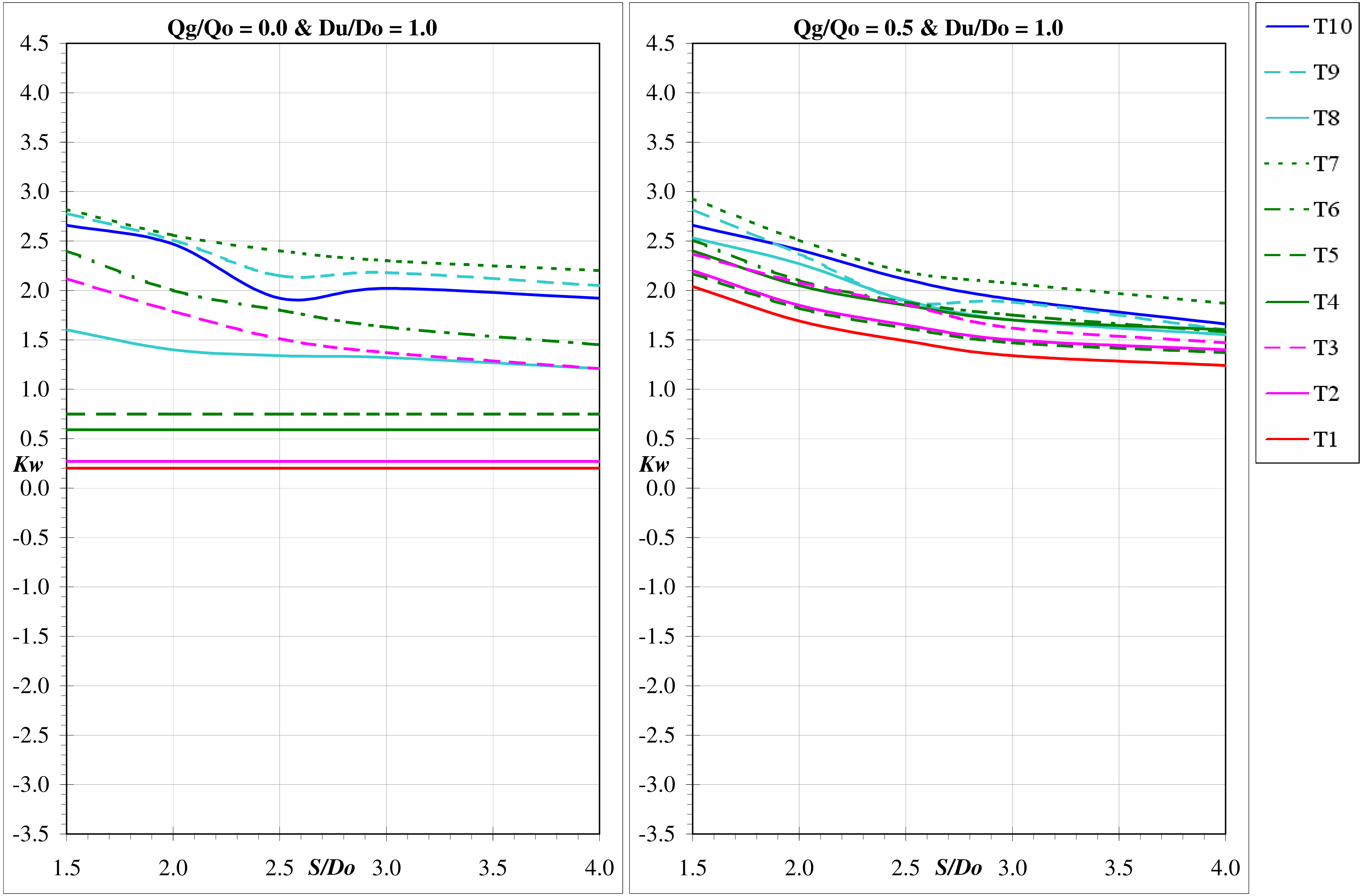




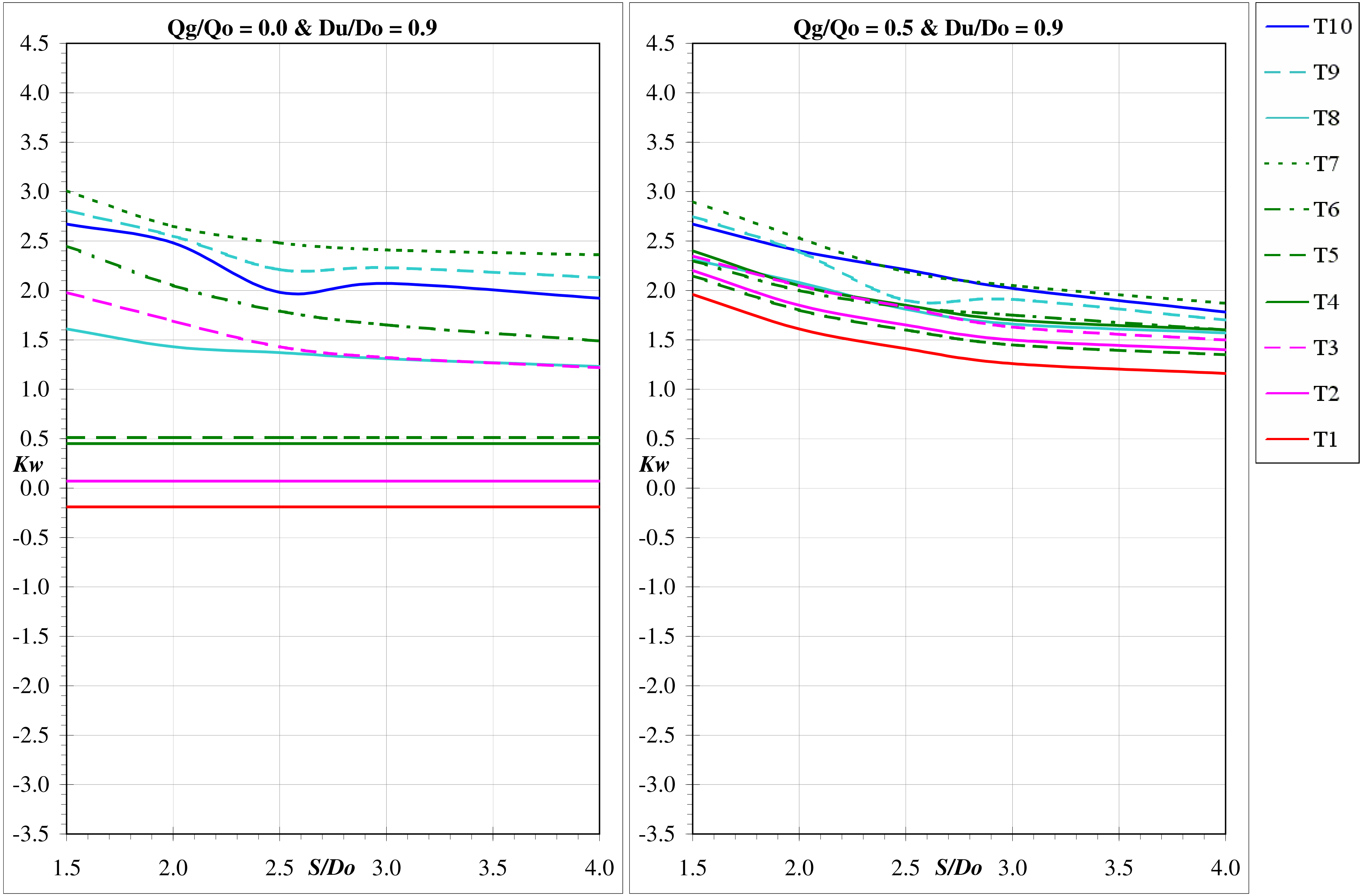
Ku Charts for Through Pits



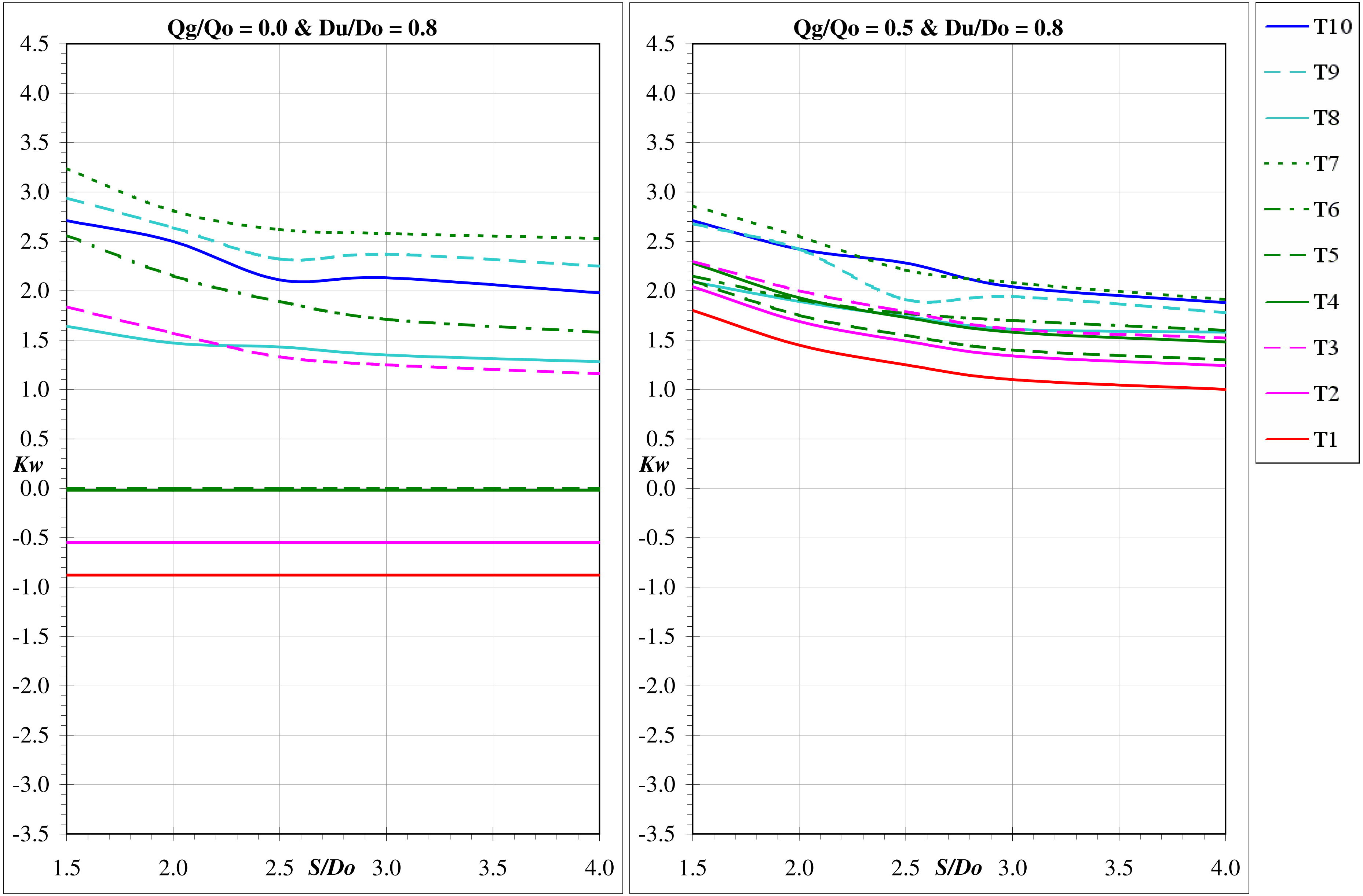
Kw Charts for Through Pits



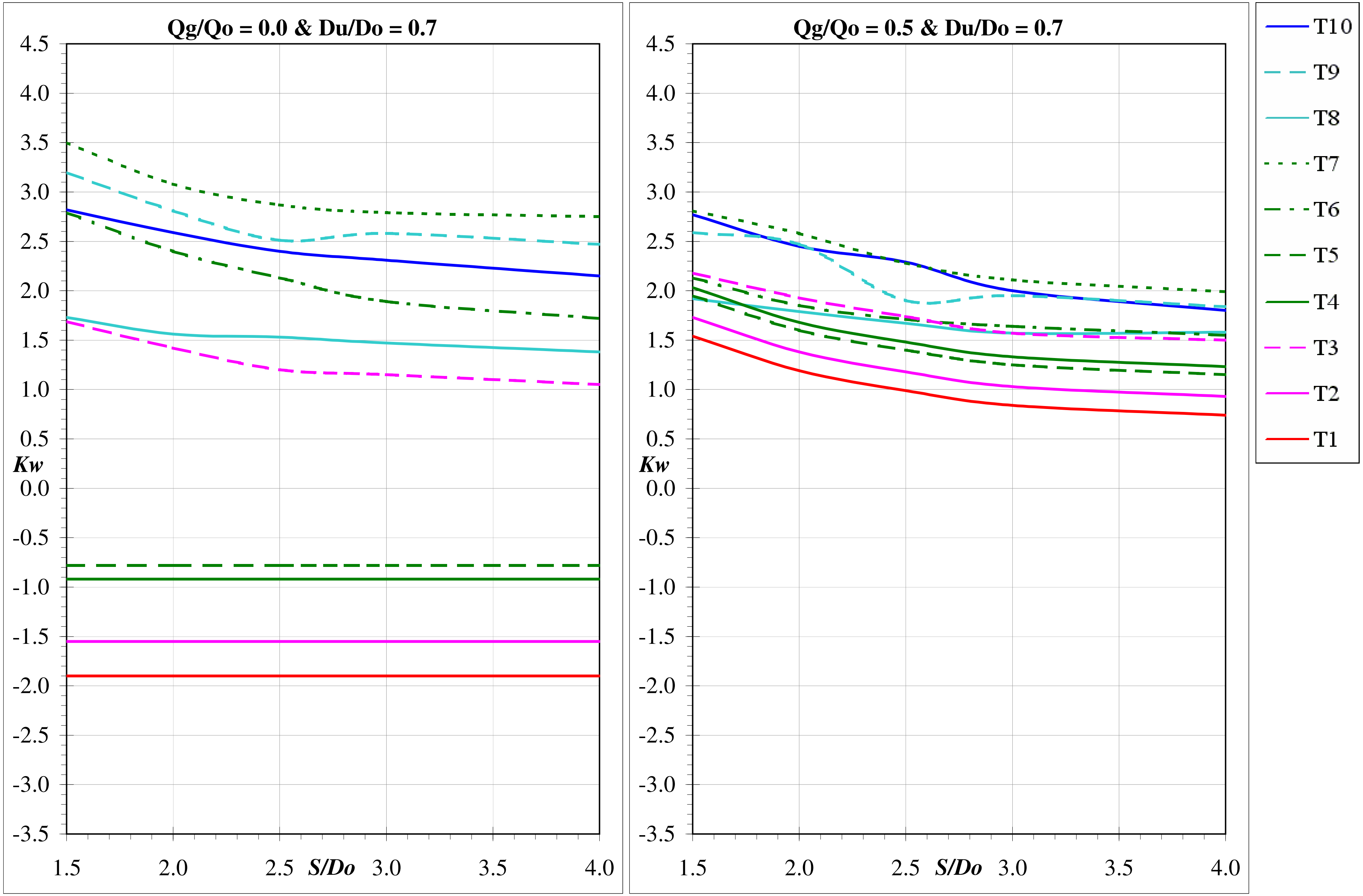
Kw Charts for Through Pits



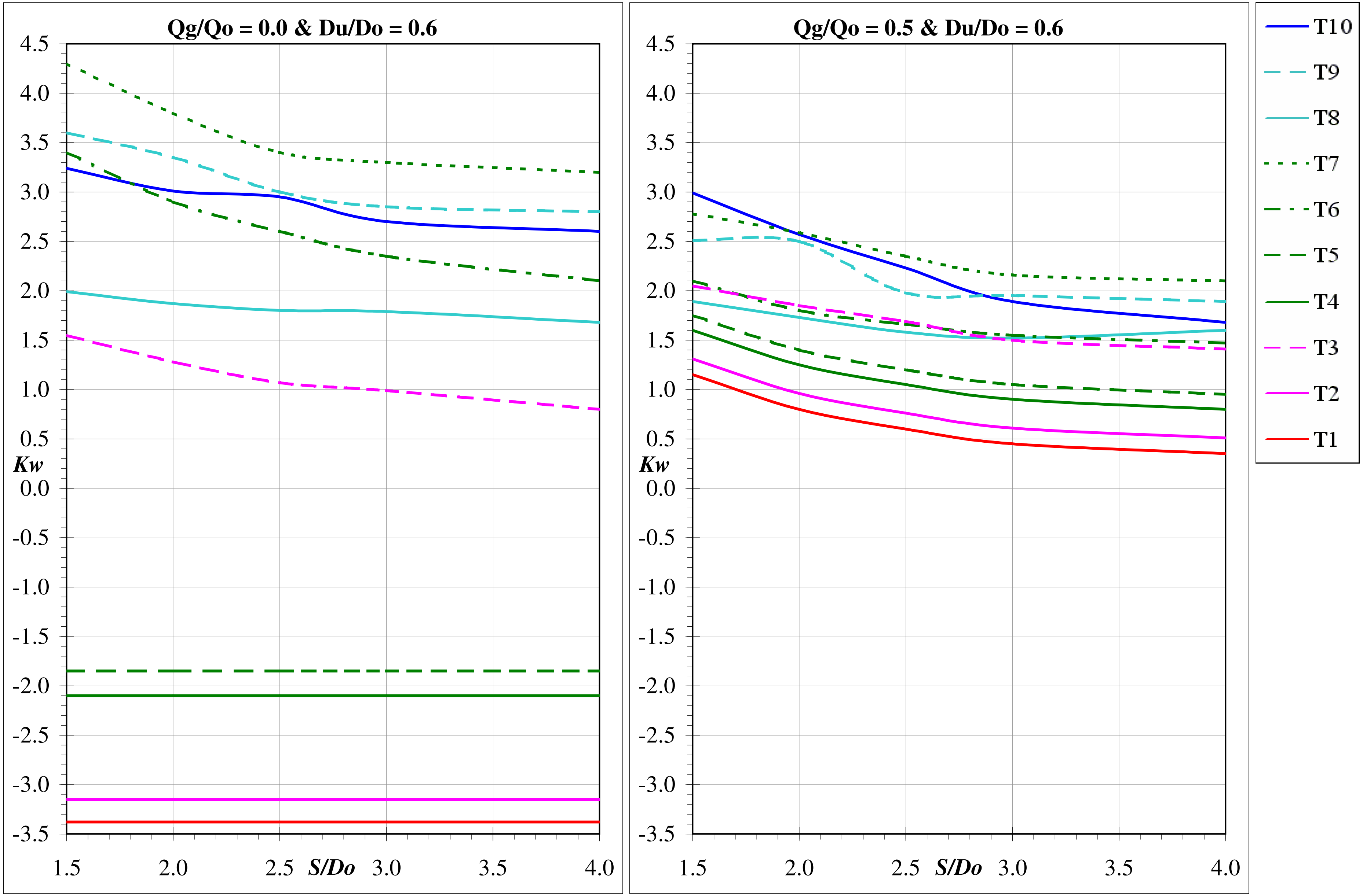
Kw Charts for Through Pits



Kw Charts for Through Pits

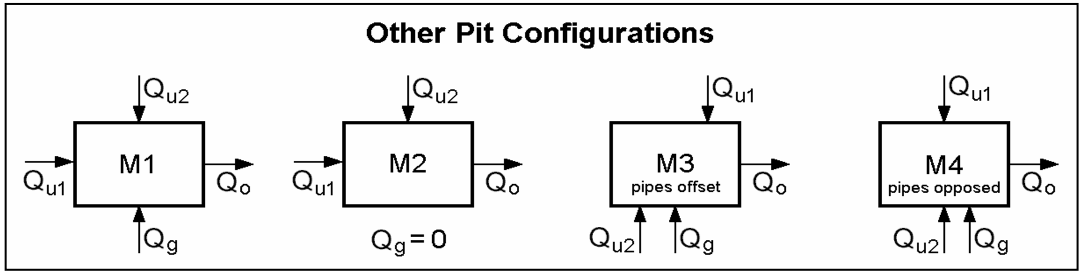


Kw Charts for Through Pits



Other Chart Data

Both source documents contain other charts not used by *12d Model*, covering the following limited set of four pit configurations, each with two upstream pipes:



Other Config	M1	M2	M3	M4
QUDM Ku Chart #	48	52, 53	49	49
QUDM Kw Chart #	48	52, 53	49	49
ACTDS Ku Chart #	3	4, 5, 6	11	12
ACTDS Kw Chart #	3	5, 6	11	12
ACTDS Pit Type #	4	5	9	10

The charts for M3, M4, and (under certain conditions) M2, suggest *slightly* independent (i.e. *slightly* different) Ku values for each of the two upstream pipes. However, the peak flows in each pipe (determined by *12d Model* via the Rational Method) do not, in general, occur at the same moment in time, and so provide little justification to account for these slight differences. As such, *12d Model* supports only a single Ku (and a single Kw) at each pit. The Rational Method is a statistical design method with much to commend it, but it is not sophisticated enough for these particular charts, which are perhaps better suited to a method based on unsteady flow simulations.

Using the *12d Model* method (of determining a single equivalent upstream pipe), the Ku and Kw values for M1 and M2 may be estimated adequately, if a little conservatively, with the *Ku config* set to “Fair”. For M3 and M4, adequate estimations are made regardless of the *Ku config* setting.

For other configurations of multiple upstream pipes – especially those where the jet of each upstream pipe projects wholly into the downstream pipe – *Ku config* settings of "Preferred" or "Good", may be more appropriate.

Notes :

The “Missouri Chart” used by *12d Model* for Grate Pits, possibly suggests conservatively high Kw values at low submergence ratios, compared with the evidence suggested by some other empirical and analytical studies. However, due to the typically low velocity head in the downstream pipe, a high Kw value rarely makes a significant difference in Grate Pits.

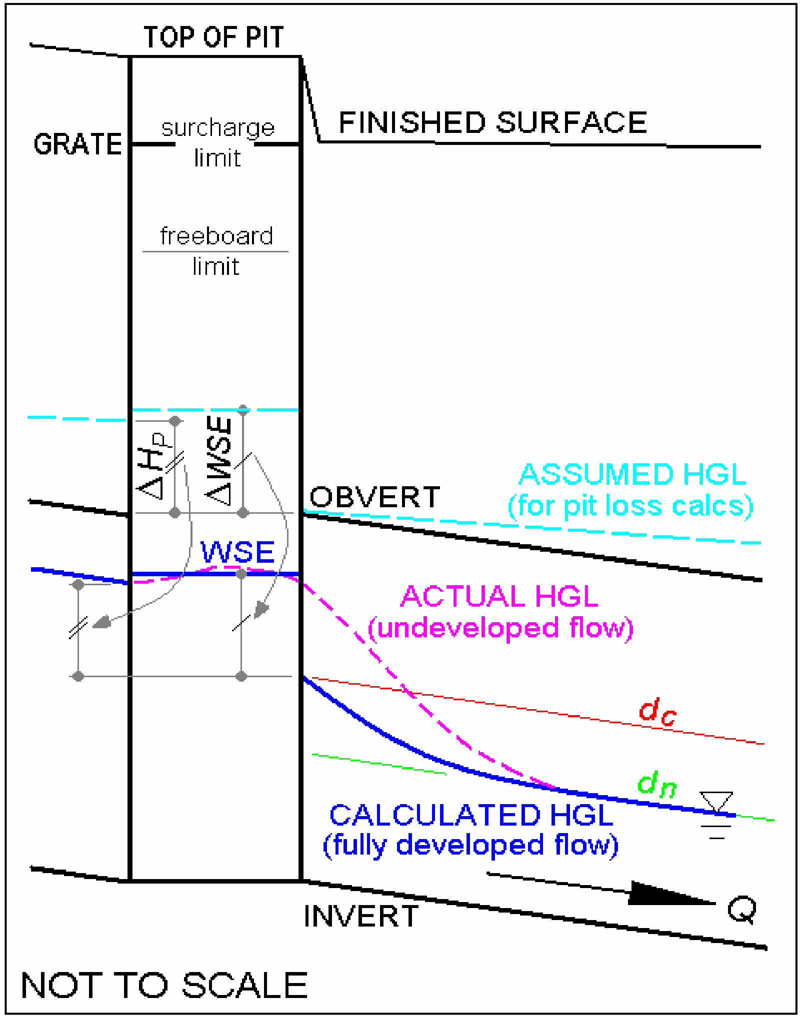
The “Hare Charts” used by *12d Model* for Through Pits, are all based on *square* pits with sides twice the diameter of the downstream pipe. Some of the comparable “Missouri Charts” consider pits with other geometries, and typically suggest lower Ku values.

If difficulties are encountered in adequately matching Ku and Kw values to a particular chart not considered by *12d Model*, simply set the *Ku method* to “Direct”, and enter the chart values manually. Alternatively, consider contacting the author (email: owen.thornton@12d.com) with information about the chart in question.

Part-full Flow and/or Extreme Submergence Ratios

Strictly speaking, the chart data are only applicable to pipes flowing full and under pressure. For pipes flowing part-full through pits, it is most common to assume reduced magnitudes of ΔHp and ΔWSE, which immediately questions the validity of the assumption that the head changes are proportional to the (higher, part-full) velocity head. Some of the current Australian design manuals provide estimation procedures for these uncertain cases, but they can often result in *increased* magnitudes of ΔHp and ΔWSE. In an attempt to provide a compromise, *12d Model* employs a procedure to ensure the magnitudes are neither increased nor reduced. At those pits where the downstream pipe flows part-full, *12d Model* determines Ku and Kw by assuming the HGL to be at the *obvert* of the pipe (with ΔHp and ΔWSE based on the *full pipe* velocity head). Once the head changes are determined in this way, they are applied from the calculated HGL in the downstream pipe, *not* the pipe obvert.

The chart data for Grate Pits give Kw values for S/Do ranging from 1.5 to 7.0, and for Through Pits give Ku and Kw values for S/Do ranging from 1.5 to 4.0. In *12d Model*, the chart data are assumed to be applicable for all S/Do values greater than or equal to 1.0, with Ku and Kw extending horizontally beyond the chart limits, when plotted against S/Do. With the "obvert assumption" outlined above for part-full flow, it is only ever a *negative* Kw value that may *potentially* cause S/Do to be calculated less than 1.0. Since this situation is far enough outside the range of the charts to be deemed "in doubt", *12d Model* handles such instances by simply (and conservatively) increasing the Ku and Kw values, so as to give S/Do equal to 1.0.



An Example of Part-full Flow

Culvert Inlets

For pipe or box culvert inlets, *12d Model* can determine whether the culvert is flowing under *inlet* or *outlet* control, and if under *inlet* contol, it can calculate a Ku value to give the required loss in pressure head. For these cases, the user need only ensure that the *Ku method* is set to "Inlet Headwall" and that a *direct* Ku value is specified (typically 1.2 to 1.9, where Ku = Ke + 1) for the culvert flowing under *outlet* control.

The backwater HGL analysis performed by *12d Model*, handles culverts flowing under *outlet* control, using the *direct* Ku value specified. A further calculation is then performed, to determine the culvert headwater depth under *inlet* control, using one or other of the following variants of the weir and orifice flow formulae:

$Q = a\,B\,(HW)^{1.5}$ … weir flow, *HW/D* <= 1

$Q = b\,A\,(HW - c\,D)^{0.5}$ … orifice flow, *HW/D* > 1

where:

Q = design flow rate per barrel (cumecs)
HW = headwater depth (m)
D = culvert diameter or box height (m)
B = culvert diameter or box width (m)
A = culvert x-sectional area per barrel (m^2)

		pipe	*box*
a	=	1.30	1.67
b	=	2.74	2.92
c	=	0.65	0.65

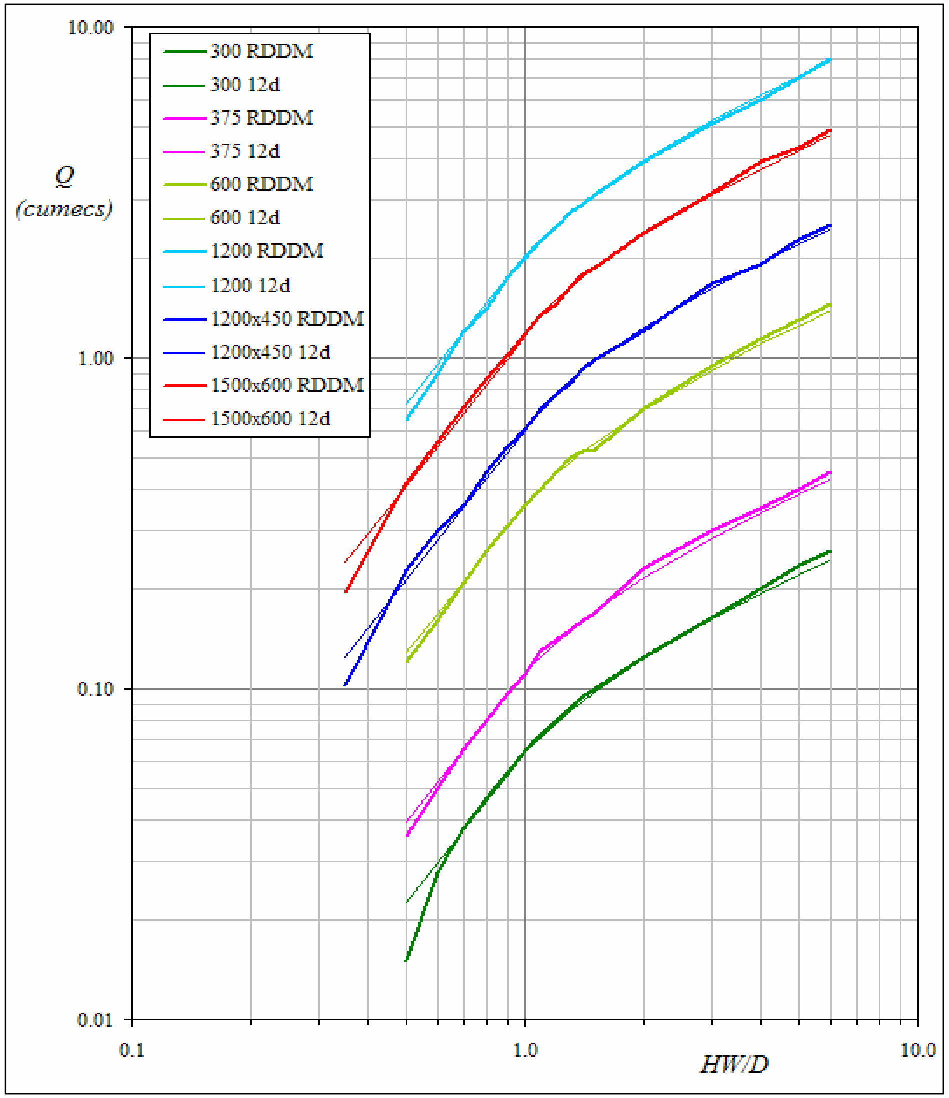
Note: the constants *a*, *b, c* have been chosen to match the results from standard headwater nomographs for concrete pipe and box culverts under *inlet* control, published in the RDDM (2002) as Figures 4.9A(1) & 4.9B(1).

If the headwater depth under *inlet* control is greater than the previously determined depth under *outlet* control, the culvert is assumed to be flowing under *inlet* control, and a higher Ku value is back-calculated to account for the greater loss in pressure head through the headwall, viz:

$Ku = (HW + IL - HGL_o) / H_v$

where:

IL = invert level at culvert entrance (m)
HGL_o = HGL level *inside* culvert entrance (m) - from backwater analysis
H_v = *full pipe* velocity head in culvert (m)

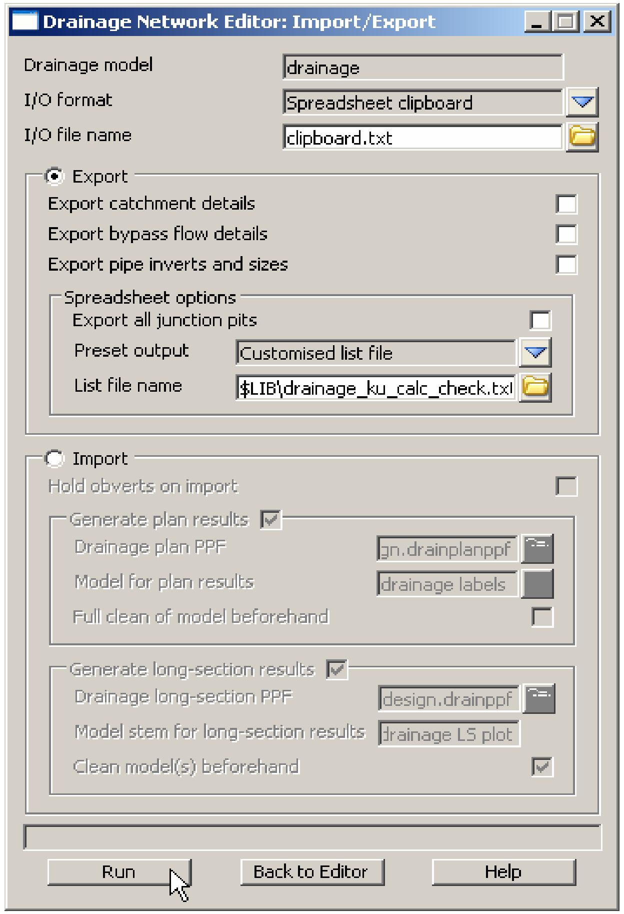


Comparison between results from RDDM headwater nomographs and 12d Model formulae, for several standard pipe and box culvert sizes (in millimetres)

Design Checks

Spreadsheet reports may be generated quickly and easily, to allow checking and auditing of the Ku and Kw values calculated by *12d Model* .

From the *Import/Export* panel of the *Drainage Network Editor* , simply *Export* to the *Spreadsheet clipboard* , using the *Customised list file* supplied in the installed *Library* folder (as shown below), and paste the results into your spreadsheet.



Standard "Customised list file" : $LIB\drainage_ku_calc_check.txt

header

Pit	Ku	Kw	V'head	P'head Loss	WSE Loss	Ku	Ku	Qg/Qo	Grate Flow	Pipe Flow	Du/Do	S/Do	Chart(s)

header

Name				(Ku.V'head)	(Kw.V'head)	Method	Config	Ratio	Deflection	Deflection	Ratio	Ratio	Used

header

(-)	(-)	(-)	(m)	(m)	(m)	(-)	(-)	(-)	(deg)	(deg)	(-)	(-)	(-)

pit data
pit name
calculated ku
calculated kw
pipe data
calculated velocity head
pit data
calculated pit pressure head loss
calculated pit wse loss
calculated ku method
calculated ku config
calculated ku grate flow ratio
calculated ku grate flow angle
calculated ku pipe flow angle
calculated ku diameter ratio
calculated ku submergence ratio
calculated ku chart

Sample Ku & Kw Design Check Report :

Pit Name	Ku	Kw	V'head	P'head Loss (Ku.V'head)	WSE Loss (Kw.V'head)	Ku Method	Ku Config	Qg/Qo Ratio	Grate Flow Deflection	Pipe Flow Deflection	Du/Do Ratio	S/Do Ratio	Chart(s) Used
(-)	(-)	(-)	(m)	(m)	(m)	(-)	(-)	(-)	(deg)	(deg)	(-)	(-)	(-)
1.6H	1.11		0.21	0.23	0.23	Inlet Headwall							Inlet Control
2.1S	1.83		0.07	0.13	0.13	Ku,Kw via Charts	Preferred	0.50		27.7	0.72	1.56	T2/T4
2.2S	7.37		0.06	0.48	0.48	Ku,Kw via Charts		1.00	90.0			1.93	G2
3.1G	0.72		0.57	0.41	0.41	Ku,Kw via Charts	Preferred	0.08		30.2	1.00	1.88	T2/T4
3.2G	0.42		0.49	0.21	0.21	Ku,Kw via Charts	Preferred	0.14		0.0	0.89	1.91	T1
3.4M	0.82	0.83	0.36	0.29	0.30	Ku,Kw via Charts	Good	0.00		48.3	1.00	2.74	T5/T8
3.8M	0.55		0.19	0.11	0.11	Ku,Kw via Charts	Good	0.00		35.5	1.00	2.83	T2/T5
3.9S	1.07		0.17	0.18	0.18	Ku,Kw via Charts	Preferred	0.26		29.5	1.00	3.48	T2/T4
3.10G	0.34		0.50	0.17	0.17	Ku,Kw via Charts	Good	0.00		25.9	1.00	4.79	T2/T5
3.11M	1.73	1.88	0.23	0.40	0.44	Ku,Kw via Charts	Fair	0.00		48.7	1.00	2.46	T6/T9
3.12G	0.83		0.24	0.20	0.20	Ku,Kw via Charts	Good	0.23		11.3	1.00	3.88	T1/T2
3.13G	1.59	1.63	0.17	0.27	0.28	Ku,Kw via Charts	Preferred	0.53	37.0	63.5	1.00	3.95	G2/T4/T8
3.14G	5.86		0.04	0.23	0.23	Ku,Kw via Charts		1.00	0.0			1.76	G1

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US FHWA, Turner-Fairbanks Highway Research Centre, Virginia.

*__ACTDS__ (2003) **- Errata in Appendix A**

Chart 5

a) Re the "Ku(bar) vs Dl/Do" graph: the y-axis range of Ku(bar) should be 1.3 to 2.5 (not 0.6 to1.8).

Chart 8

a) Re the "S/Do=2.5" graph: the "Qg/Qo=0.5" arrow label points to the wrong line.
b) Re the "S/Do=3.0" graph: the y-axis range of Kw should be 1.8 to 2.6 (not 2.6 to 3.4).
c) Re the "S/Do=4.0" graph: the y-axis range of Kw should be 1.6 to 2.4 (not 2.4 to 3.2).

Chart 12

a) Re the "H" graph (on left): missing "Qhv/Qo" arrow label.
b) Re the "L" graph (on right): missing "Qlv/Qo" arrow label.

Chart 16

a) Re the "S/Do=1.5" graph: the "Qg/Qo" brace labels should have 0.0 and 0.5 swapped around.
b) Re the "S/Do=2.0" graph: the "Qg/Qo" brace labels should have 0.0 and 0.5 swapped around.
c) Re the "S/Do=2.5" graph: the "Qg/Qo" brace labels should have 0.0 and 0.5 swapped around.
d) Re the "S/Do=3.0" graph: the lower arrow label should be "Qg/Qo=0.5" (not "Qg/Qo=0.0").

Chart 20

a) Re the "S/Do=3.0" graph: the y-axis range of Ku should be 0.8 to 1.8 (not 1.0 to 2.0).