

# Pumps 'n Pipeline (PnP) v1.7

User Manual

By

**in<sup>2</sup>Dredging Pty Ltd**

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## Software Program Revision Record

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1.7	24/06/2023	<ul style="list-style-type: none"><li>• Added Transport Energy (PrSEC-diagram) Graph</li><li>• Added new variable "Minimum Mixture Density" and modified algorithm to calculate the density range</li><li>• Implemented correction for hydrostatic pressure for pump 2</li><li>• Fixed problem opening helpfile</li><li>• Fixed problem in several graphs with auto sorting</li></ul>	Ralph Brevet	Simon Burgmans

## Document Revision Notice

This is a managed document. All copies of this document preceding this release are obsolete and shall be destroyed.

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# 1 Overview

## 1.1 General Information

Pumps 'n Pipeline (PnP) estimates suction and discharge production for any dredging or mining equipment that hydraulically transports soil like materials. PnP is a generic and powerful tool, but is still simple and intuitive to use, with a Graphical User Interface (GUI) derived from decades of estimating experience. PnP can accurately and robustly estimate production for any dredging or mining equipment using a unique collection of empirical relationships based on decades of field measurements.

Although extensive literature on hydraulic transport is available, all this information complicates the practical production of estimates. Literature is often very specific and includes many hidden model scale effects and sub-optimisations. To overcome these issues, PnP only applies empirical relationships that have been proven in the field.

PnP can be used to support:

- Estimating suction and discharge production
- Designing pump-drive systems and pipeline configurations
- Determining equipment feasibility for projects
- Selecting gear(s) or, for example, the rainbow nozzle diameter required for a project
- Evaluating performance of pump-drive systems
- Determine the transport energy efficiency for pipeline systems

PnP's GUI interface consists of multiple tabs that provide the user with an easy overview. The tabs are:

- Pumps - one tab for each pump
- Pipeline
- Mixture
- Diagrams
- Results

All PnP's input parameter fields accept values in either SI or American imperial units of measure, with the tool using SI units by default. However, this can easily be changed to use American imperial units (see *Section 2.1.4* for further information). For some input parameters, standard values or ranges are provided thus ensuring calculations are realistic.

PnP can estimate production for almost any project, although a few constraints have been built-in to ensure it is user friendly. The main constraint is that only a maximum of ten (10) pumps in series can be entered. More pumps can be entered for pumps in series, if the pumps' characteristics are summated and entered as one pump.

In addition to PnP, i2D has at its disposal *PnP Expert*, a proprietary program not available to the public that overcomes any constraints, and can be used on less typical, special, advanced projects. *PnP Expert* is not constrained by a graphical user interface and is thus very flexible, fast to customise and easy to integrate with other estimation tools. PnP and *PnP Expert* have been developed and verified concurrently in two different computer languages to ensure results are mathematically correct.



If you have any questions, comments, ideas or feedback on PnP please contact i2D via the contacts page [www.in2Dredging.com/contact](http://www.in2Dredging.com/contact) or at [support@in2dredging.com](mailto:support@in2dredging.com).

## 1.2 Introduction

As previously mentioned, PnP's GUI includes multiple tabs. All but the last tab allow users to set values for the input parameters to be used by PnP. Once PnP has run its calculations using the values inputted by the user, the results of the calculations are presented on the last tab, *Results*.

The *Results* tab displays several graphs, which allows users to check the input deck and displays the suction or discharge production results. The calculations are run by clicking the **Run Project** button located on the **Toolbar** (the button has a calculator icon) or by pressing the **F9** shortcut key on the keyboard. If no user input errors are encountered by PnP, the results are displayed on the **Results** tab. If PnP returns an input error message, users will be required to either enter missing data or to modify the data entered in the input box specified in the error message.

Users are unable to input field values that are outside the standard logical data range. If the graphs returned on the **Results** tab are out of range, users can tweak the values they entered on the **Diagrams** tab to bring the graphs within range.

Once the calculations have run, the Project file with its inputted values and results, can be saved as a \*.pnp file onto the file system by clicking the **Save Project** button on the **Toolbar**. The Project file can be reopened at a later stage by clicking the **Open Project** button on the **Toolbar** and selecting the required \*.pnp file from the file system.

Similarly, users can open or save a pump's specifications into a \*.pmp file and build their own pump database. For further information on this feature, please refer to *Section 0*.

Detailed help on PnP's use and functionality can be found in later sections of this document. Press **Ctrl + F1** on the keyboard or select **Help/PnP Document** from the **Menu Bar** to reopen this document.

## 1.3 Abbreviations

<b>CRC</b>	Cyclic Redundancy Check
<b>CSD</b>	Cutter Suction Dredger
<b>GUI</b>	Graphical User Interface
<b>i2D</b>	in2Dredging Pty Ltd
<b>NPSHr</b>	Nett Positive Suction Head required
<b>PnP</b>	Pumps 'n Pipeline
<b>RPM</b>	Revolutions per Minute
<b>SI</b>	Système International (International System of Units)
<b>TSHD</b>	Trailer Suction Hopper Dredger
<b>UWP</b>	Under Water Pump

## 1.4 Getting Started

You can download a demo version of *PnP v1.7* from the PnP [web page](#).

The demo version allows unlimited use of *PnP v1.7* over a trial period of 30 days. This demo version is fully functional except for the *Pumps* tab, which has been disabled.

To acquire a licensed version of *PnP v1.7*, users need a licence key, which can be obtained in the following manner:

1. Pay for the licence key online.
2. A link to the latest PnP licensed version will then be sent to you via email.
3. Download and install the PnP licensed version using the link provided.
4. Send the *Registration Number* and *Username* to [support@in2Dredging.com](mailto:support@in2Dredging.com).
5. An *Unlock Code* will be sent to you from [support@in2Dredging.com](mailto:support@in2Dredging.com) to unlock the licensed version of PnP.

Once you have installed the licensed version of PnP, you can reliably estimate suction and discharge production. A sample Project file called *example.pnp* is also provided with PnP to get you started faster.

## 2 PnP's GUI and Functionality

### 2.1 General

#### 2.1.1 Menu

Table 1 lists the PnP menu structure and functions.

Table 1: PnP's menu structure

Menu Item	Sub-menu Item	Function
File	New	Resets all input parameters to default.
	Open	Opens a PnP Input file, which has a *.pnp extension.
	Save	Saves the current input to a PnP file
	Save As	Saves the current input to a new PnP file
	Print	Prints all inputs and charts. The standard printer dialog can be used to print to PDF
	Export Input Data to Textfile	Exports current input to a textfile for use in i2D's PnP Export software
	Export Diagram Data	Exports current diagram data to a text file
	Export Charts to File	Saves all charts to Windows Meta Files.
	MRU Files	Lists the five most recently used files. Note that the <i>Ctrl-L</i> shortcut opens the last used file.
	Exit	Exits the PnP application
Run	Checks the input and feeds back any input warnings and/or errors. If no errors are found the calculation is performed and charts are generated. Note that this menu option has a short cut key of <i>F9</i> .	
Options	Curve Fit Regression Coefficients	Opens a screen for creating curve fitting regression coefficients using a text file containing the points to be curve fitted.
	Apply Affinity Laws to Pumps	Opens a screen for applying affinity laws when changing pump RPMs or impeller diameter.
Help	PnP Document	Opens the PnP User Manual
	About	Opens the PnP About dialog

### 2.1.2 Toolbar

The *Toolbar* is located above the tabs and contains the program buttons as shown in *Figure 1* below.



Figure 1: Toolbar

From left to right, the buttons have the following functions:

- New Project File;
- Open Project File;
- Save Project File;
- Print Project;
- Run Project; and
- Toggle Units of Measure mode.

### 2.1.3 Status Bar

The status bar is located at the bottom of the PnP window and is shown in *Figure 2* below.

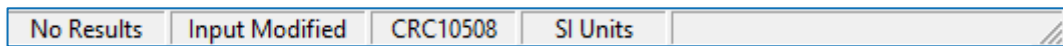


Figure 2: Status bar

From left to right, the following information is shown on the status bar:

- Whether a calculation has already been performed;
- Whether input data has been modified since the project was last saved;
- The CRC (Cyclic Redundancy Check) value of the current output results  
When two (2) sets of output data have the same CRC value, there's a 99.9985% probability that the two data sets are identical;
- The unit of measure current being used by PnP; and
- Messages - e.g. shows whether a calculation is in progress.

### 2.1.4 Units of Measure

PnP accepts parameter values in either SI or American imperial units of measure, with SI units being the default unit of measure. However, this can easily be changed by selecting the **Imperial Units** radio button on the **Diagrams** tab or by toggling the button in the toolbar (refer to *Section 2.5.5*) for a screenshot of this tab showing the *Units* radio buttons). The currently selected units of measure is also shown on the Status Bar (as shown in *Figure 2* above).

All screenshots used in this manual are of PnP using the default unit of measure. However, all PnP screens have a corresponding screen for entering values in American imperial units. To provide an example of this, *Figure 4* and *Figure 5* overleaf show the *Pumps* tab in both SI and American imperial unit of measure mode.

## 2.2 Pumps Tab

The *Pump* tab screen is used to enter pump specification data. On this screen, it is possible to select multiple pumps in series. PnP has a ten pumps constraint, which should be sufficient as most projects only use a maximum of three pumps. However, i2D can perform calculations using an unlimited number of pumps with its *PnP Expert* tool.

The number of pumps can be specified in the **Total Number of Pumps** field on the first Pump screen and the required Pump tabs will then be adjusted accordingly automatically.

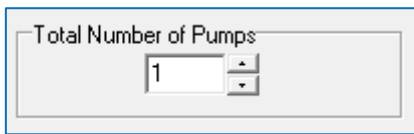


Figure 3: Field to specify the number of pumps required

Each dredge pump's specification data entered on a *Pump* screen, can be saved to a \*.pmp file for reuse in the future. Over time, the saved \*.pmp files essentially form a pump database, which can be used to quickly retrieve pump specification data.

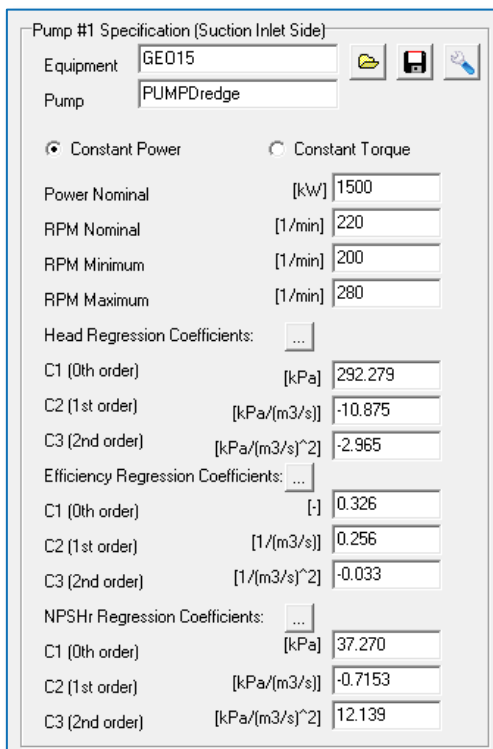


Figure 4: Pump Specification input panel in the SI units of measure mode

Pump #1 Specification (Suction Inlet Side)

Equipment: GEO15

Pump: PUMPDredge

Constant Power  Constant Torque

Power Nominal [hp(imp)] 2010.7

RPM Nominal [1/min] 220

RPM Minimum [1/min] 200

RPM Maximum [1/min] 280

Head Regression Coefficients: ...

C1 (0th order) [psi] 42.39

C2 (1st order) [psi/(USG/min)] -9.9511E-05

C3 (2nd order) [psi/(USG/min)^2] -1.7117E-09

Efficiency Regression Coefficients: ...

C1 (0th order) [-] 0.326

C2 (1st order) [1/(USG/min)] 1.6151E-05

C3 (2nd order) [1/(USG/min)^2] -1.3135E-10

NPSHr Regression Coefficients: ...

C1 (0th order) [psi] 5.41

C2 (1st order) [psi/(USG/min)] -6.5453E-06

C3 (2nd order) [psi/(USG/min)^2] 7.0079E-09

Figure 5: Pump Specification input panel in American Imperial units of measure mode

The *Pumps Specification* panels depicted in Figure 4 and Figure 5, are explained overleaf.

### 2.2.1 Name Fields

The **Equipment** and **Pump** fields at the top of the *Pump Specification* panels are used to identify the equipment and type of pump being specified in subsequent fields on the panels. The names entered in this field have no bearing on the results and are thus at your discretion.

### 2.2.2 Open Pump File and Save Pump File Buttons

All data entered in the *Pump Specification* panel pertaining to a particular pump, can be saved to the file system by clicking the **Save Pump File** button located next to the **Equipment** field, and has the standard Windows *Save* icon. The Pump Specification file has a \*.pmp extension.

To open a previously saved Pump Specification file, click the **Open Pump File** button, which is also located next to the **Equipment** field and has the standard Windows *Open* icon, and select the required \*.pmp file.

An empty pump specification file can be opened to clear all the fields at once. A pump without specifications is not considered in the calculations.

Pump #1 is at the suction inlet end and must always be specified. All Pump tabs between the first and last pump, must be populated.

### 2.2.3 Affinity Laws Button

The **Wrench** button (i.e. the button with the wrench tool) located to the right of the **Save Pump File** button, is used to apply affinity laws to the currently selected pump. This lets you change the pump's characteristic to allow for different RPMs or Impeller diameters.

Refer to *Section 0* for more information on applying affinity laws using the *Affinity Laws Tool*.

### 2.2.4 Constant Power and Constant Torque Radio Buttons

Select either the **Constant Power** or **Constant Torque** radio button to indicate whether your pump engine generates constant power or constant torque.

A pump driven by an electrical engine typically generates constant power when the pump load on the engine reaches the nominal power. On the other hand, a pump driven directly by a diesel engine typically generates constant torque. It is best to acquire the engine's specifications, as these usually indicate the pump engine's revolutions versus torque.

### 2.2.5 Power Nominal [kW or hp(imp)] Field

The nominal power value entered in this field is the maximum power of the engine on the shaft either in SI or American imperial units, depending on the unit of measure chosen (see *Section 2.1.4* for further information). Hydraulic power is limited by the nominal power value entered in the field and is dependent on the pump's efficiency.

The nominal engine power may decrease due to various reasons. Therefore, ideally a torque and a Revolutions Per Minute (RPM) measurement should be taken regularly to check the engine's performance.

### 2.2.6 RPM Nominal [1/min] Field

The nominal RPM value entered in this field should match the RPM value used to obtain the pump regression coefficients. See sections 2.2.9 and 2.2.10 below for further information on pump regression coefficients.

### 2.2.7 RPM Minimum [1/min] Field

The minimum RPM value is typically set as 70 to 80% of the previously entered nominal RPM value.

### 2.2.8 RPM Maximum [1/min] Field

The maximum RPM value is typically set to 120% of the previously entered nominal RPM value.

This field is disabled when the **Constant Torque** radio button is selected, since the maximum RPMs of a dredge pump directly driven by a diesel engine are the same as the nominal RPMs.



### 2.2.9 Head Regression Coefficients [kPa or psi] Fields

The three head regression coefficients, entered in fields **C1**, **C2** and **C3**, describe a second order polynomial.

$$y = C1 + C2 * x + C3 * x^2 \quad (1)$$

The coefficients can easily be calculated by using the curve fitting equation (1) above with water operating points. A minimum of three points, but ideally at least five operating points, should be used to fit the polynomial curve.

In the above equation, **x** is the discharge in m<sup>3</sup>/s (or USG/min) and **y** is the manometric head in kPa or psi, depending on the unit of measure mode chosen (see *Section 2.1.4* for further information).

### 2.2.10 Efficiency Regression Coefficients Fields

Efficiency is defined as hydraulic power divided by engine power.

The three efficiency regression coefficients, entered in this second set of **C1**, **C2** and **C3** fields, describe the same second order polynomial as shown in equation (1) above.

In this case, however, **x** is the discharge in m<sup>3</sup>/s (or USG/min) and **y** is the dimensionless efficiency.

### 2.2.11 NPSHr Regression Coefficients [kPa or psi] Fields

These set of fields are only available on the Pump #1 Specification tab.

The three NPSHr regression coefficients, entered in this third set of **C1**, **C2** and **C3** fields, describe the same second order polynomial as shown in equation (1) on the previous page.

In this case, however, **x** is the discharge in m<sup>3</sup>/s (or USG/min) and **y** is the Nett Positive Suction Head required (NPSHr) in kPa or psi, depending on the unit of measure mode chosen (see *Section 2.1.4* for further information).

It is not mandatory to enter values for NPSHr regression coefficients, but if you wish to do so, values can only be entered for Pump #1 on the *Pumps* tabs. However, NPSHr calculations can be made separately for subsequent pumps using the Regression Curve Fitting Tool (please refer to *Section 3.1* for further details), as the coefficient results are only shown in the *Suction Performance* graph and do not influence any other results.

Please note that these coefficients can be saved as part of a pump's *Pump Specification* file.

### 2.2.12 Pipeline Length from Pump #1 [m or ft] Field

This field is not available on the *Pump #1 Specification* panel. It is only available on subsequent pump specification panels.

This field is used to specify the pipeline length from the previous pump. For Pump #2 you specify the pipeline length to Pump #1, and for Pump #3 you specify the pipeline length to Pump #2, etc.

### 2.2.13 Regression Coefficients Buttons

The **More** buttons (i.e. the buttons with the three dots) located to the right of the *Head*, *Efficiency* and *NPSHr Regression Coefficients* titles are used to fit a curve through a number of pump characteristic points to obtain regression coefficients.

Refer to *Section 3.1* for more information on creating regression coefficients using the *Regression Curve Fitting Tool*.

## 2.3 Pipeline Tab

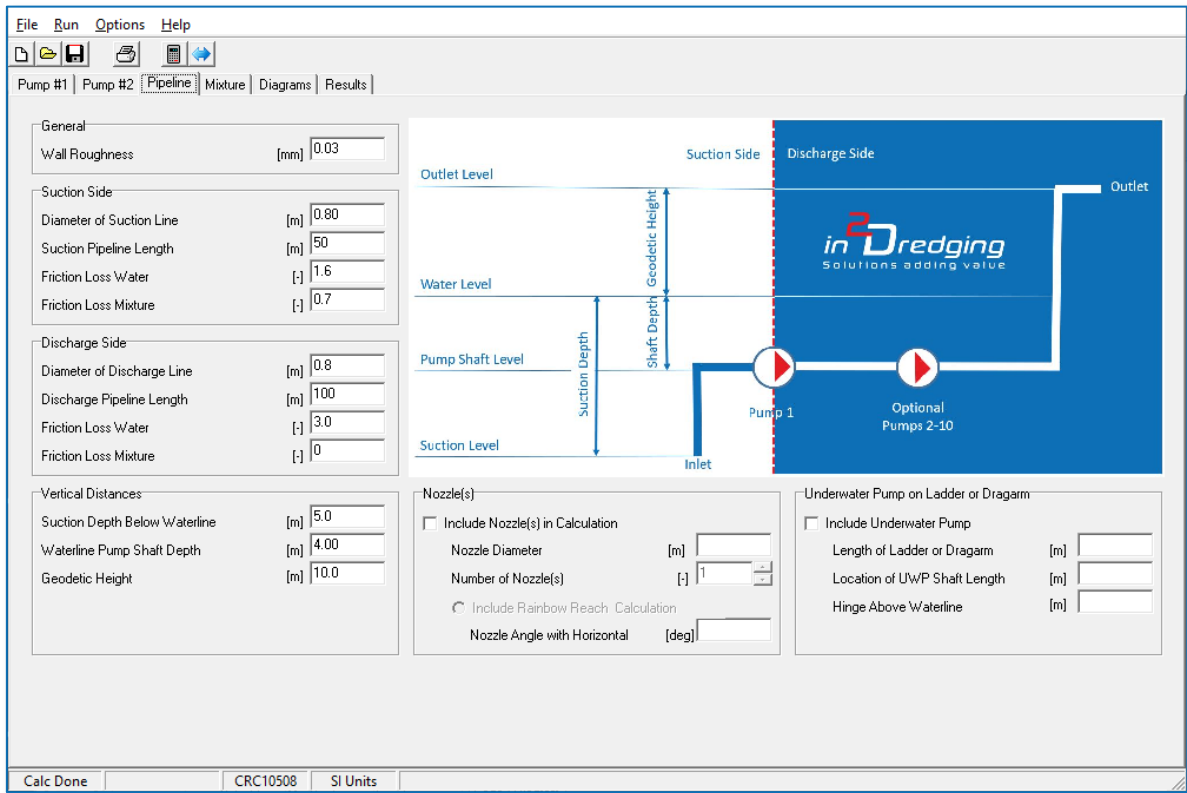


Figure 6: Pipeline tab - used to enter pipeline specifications

The *Pipeline* tab's screen is divided into six sections, all of which are described below.

### 2.3.1 General Section

#### 2.3.1.1 Wall Roughness [mm or mil] Field

The **Wall Roughness** field is typically set to 0.04 mm (or 1.57 mil) for steel pipelines and 0.008 for HDPE pipelines, as is shown in *Table 2* below. These relatively high values take into account the impact of flanges and wear on pipelines.

Table 2: Typical wall roughness values

Description	Wall Roughness [mm]	Wall Roughness [mil]
Steel pipeline	0.04	1.57
HDPE pipeline	0.008	0.31

## 2.3.2 Suction Side Section

In this section of the panel, values are only entered for Pump #1's suction side.

### 2.3.2.1 Diameter of Suction Line [m or inch] Field

Used to set the diameter of the suction line.

### 2.3.2.2 Suction Pipeline Length [m or ft] Field

Used to set the total length of the pipeline at Pump #1's suction side.

### 2.3.2.3 Friction Loss Water [-] Field

This field is used to set friction losses in the suction pipeline. Typical values for local friction losses in suction pipelines at the suction side are provided in the *Table 3* below.

*Table 3: Typical friction losses at the pipeline's suction side*

Description	Friction Loss [-]
Accelerating water or mixture	1.0
Inlet	0.5
Drag of cutter head (this value is also soil dependent)	0.7 - 7.0

Note that significant friction losses in the suction pipeline can affect the pump's performance.

### 2.3.2.4 Friction Loss Mixture [-] Field

Used to set friction losses in the suction pipeline depending on soil mixture. The soil mixture could increase the local friction losses.

Typical friction loss values for a Trailing Suction Hopper Dredger (TSHD) and a Cutter Suction Dredger (CSD) are between 1 and 2.

### 2.3.3 Discharge Side Section

The discharge side starts upstream of Pump #1.

#### 2.3.3.1 Diameter of Discharge Line [m or inch] Field

Used to set the diameter of the discharge pipeline.

#### 2.3.3.2 Discharge Pipeline Length [m or ft] Field

Used to set the length of the pipeline upstream of Pump #1.

#### 2.3.3.3 Friction Loss Water [-] Field

This field is used to set friction losses in the discharge pipeline when the pipeline is in water. Typical values for local friction losses in the discharge pipeline when in water are provided in *Table 2* below.

*Table 4: Typical friction losses in the discharge pipeline*

Description	Friction Loss [-]
90-degree bend	0.5
T-piece	1.2
Rubber hoses, manholes, straight Y-piece	0.05

#### 2.3.3.4 Friction Loss Mixture [-] Field

This field is used to set additional friction loss in the discharge pipeline due to the soil mixture.

### 2.3.4 Vertical Distances Section

Pictorial definitions for the vertical distances used in this section's fields are provided in the diagram on the *Pipeline* tab (see *Figure 6*).

Please note that the vertical positions of pumps after Pump #1 are ignored by PnP.

In addition, in a vast majority of projects, the incoming pressure for pumps other than Pump #1 is not relevant, or not a concern, and therefore it is ignored as a production limitation in PnP. However, i2D can perform more detailed calculations with *PnP Expert* if the incoming pressure of pumps other than Pump #1 is of concern.

#### 2.3.4.1 Suction Depth Below Waterline [m or ft] Field

Used to enter the vertical distance between the inlet (e.g. cutter head or drag head) and the water level.

#### 2.3.4.2 Waterline Pump Shaft Depth [m or ft] Field

This field is used to enter the vertical distance between the pump shaft level and the water level.

Please note that the waterline pump shaft depth only affects suction production.

#### 2.3.4.3 Geodetic Height [m or ft] Field

Used to enter the vertical distance between the water level and outlet levels. For example, the vertical distance of the rainbow nozzle or outlet from the sand fill.

### 2.3.5 Nozzle(s) Section

Setting the fields in this section allows you to include the friction loss of the discharge pipeline's nozzles or rainbow nozzle in the calculations.

#### 2.3.5.1 Include Nozzle(s) in Calculation Checkbox

If the **Include Nozzle(s) in Calculation** checkbox is ticked, the nozzle(s) resistance is included in the calculations.

#### 2.3.5.2 Nozzle Diameter [m or inch] Field

This field is used to set the nozzle diameter. This nozzle's diameter value must be smaller than the discharge pipeline's diameter value.

#### 2.3.5.3 Number of Nozzle(s) [-] Field

This field specifies the number of nozzles used on the project. Nozzles are on the discharge line and total area of the nozzles must be smaller than the discharge pipeline cross sectional area.

#### 2.3.5.4 Include Rainbow Reach Calculation

If the Include **Rainbow Reach Calculation** radio button is selected, the reach of the rainbow is calculated and shown in the *Pump and Pipeline Characteristics (QHL-Diagram)* graph.

#### 2.3.5.5 Nozzle Angle from Horizontal [deg] Field

This field is used to set the angle of the nozzle from the horizontal. This value is then used to calculate the reach of the rainbow beam.

## 2.3.6 Underwater Pump on Ladder or Dragarm Section

The *Underwater Pump on Ladder or Dragarm* section fields have been provided to help estimate the extent to which vacuum limits suction production in shallow water.

### 2.3.6.1 Include Underwater Pump Checkbox

If the ***Include Underwater Pump*** checkbox is ticked, the ***Waterline Pump Shaft Depth*** value entered in the *Vertical Distances* section is overwritten with a calculated figure based on the values inputted in this section.

### 2.3.6.2 Length of Ladder or Dragarm [m or ft] Field

Used to enter the length of the ladder or dragarm. The length measurement is taken from the hinge to the suction mouth of the cutterhead or the heel of the drag head.

### 2.3.6.3 Location of UWP Shaft Length [m or ft] Field

This field is used to enter the location of the Underwater Pump's (UWP) shaft length. This length measurement is taken from the hinge to the UWP's shaft.

### 2.3.6.4 Hinge Above Waterline [m or ft] Field

Used to enter the vertical height of the hinge from the waterline.

A negative value needs to be entered in this field to indicate that the hinge is below the waterline.

## 2.4 Mixture Tab

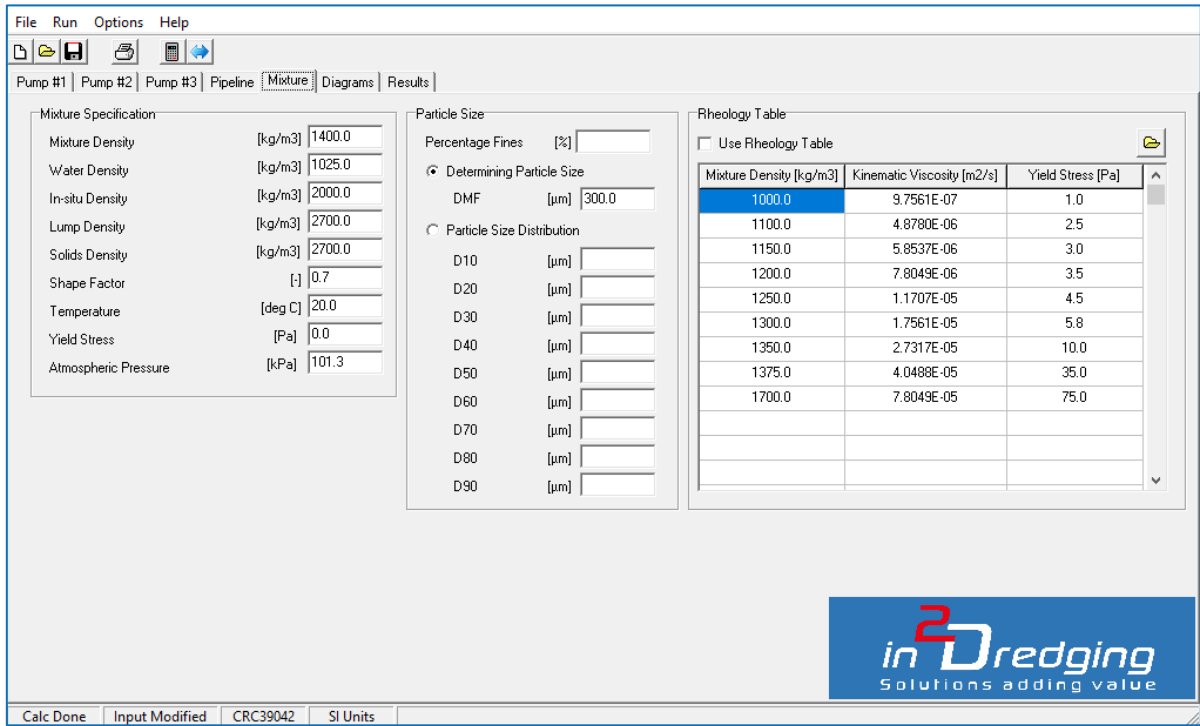


Figure 7: Mixture tab - used to enter mixture specifications

The *Mixture* tab's screen is divided into three sections, namely the **Mixture Specification**, the **Particle Size** and the **Rheology Table** sections. All these sections are described in detail below.

### 2.4.1 Mixture Specification Section

#### 2.4.1.1 Mixture Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

The **Mixture Density** value entered in this field should be between the *Water Density* value and the *In situ Density* value.

The *Mixture Density* value set in this field is utilised in the *Pump # Range Diagram* provided on the *Results* tab. A range of mixture density values between the *Water Density* and *Mixture Density* values, incremented by 100 kg/m<sup>3</sup> (or 6.24 lb/ft<sup>3</sup>), are applied throughout the operating points calculations.

The mixture density value applied in this field can be related to the maximum production generated at, for example, the drag head, suction head, cutter head or in the hopper.



#### 2.4.1.2 Water Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

This field is used to set the density of water. Seawater typically has a density of 1,025 kg/m<sup>3</sup> (or 64 lb/ft<sup>3</sup>).

#### 2.4.1.3 In situ Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

In the *In situ Density* field, soil density values for unstirred and fully saturated soil samples are entered. Typical in situ soil density ranges are given in *Table 5* below.

*Table 5: Typical in situ soil density ranges*

Soil Description	In situ Density [kg/m <sup>3</sup> ]	In situ Density [lb/ft <sup>3</sup> ]
Silt, mud and clay	1,300 – 2,200	80 - 140
Sand	1,800 – 2,000	110 - 125
Gravel	2,000 – 2,100	125 - 130
Rock	2,000 – 2,700	125 - 170

The production (in situ m<sup>3</sup>/hr or yd<sup>3</sup>/hr) values displayed in the graphs on the *Results* tab are based on the in situ density entered in this field.

#### 2.4.1.4 Lump Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

The *Lump Density* field value is used to allow for clay balls in the soil.

The *Lump Density* value entered must be smaller than 2,650 kg/m<sup>3</sup> (or 165 lb/ft<sup>3</sup>) to accurately estimate the effects of clay balls. If no clay balls remain intact, enter the lump density as a value greater than 2,650 kg/m<sup>3</sup> (or 165 lb/ft<sup>3</sup>).

#### 2.4.1.5 Solids Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

This field is used to enter the solid density of soil particles.

The solid density of sand particles is typically 2,700 kg/m<sup>3</sup> (or 170 lb/ft<sup>3</sup>). Clay or peat particles have a lower solid density than sand, while rock particles may have a higher solid density than sand.

### 2.4.1.6 Shape Factor [-] Field

Enter values in this field to allow for the shape of various soils.

Various soil shape factor values have been provided in *Table 6* below.

*Table 6: Typical soil shape factor values*

Soil Description	Shape Factor [-]
Clay balls	1.0
Silica sand	0.7
Intact shells	0.5
Crushed shells	0.3

### 2.4.1.7 Temperature [deg C or deg F] Field

Enter the water temperature in this field. The temperature must be given either in degrees Celsius or degrees Fahrenheit.

### 2.4.1.8 Yield Stress [Pa or dyn/cm<sup>2</sup>] Field

This field is used to enter the yield stress of clay, mud, or slime mixtures, with the yield stress value needing to be given in Pascals or dyn/cm<sup>2</sup>.

If no value is specified in this field, the yield stress value defaults to zero.

Please note that if the *Use Rheology Table* checkbox is checked, then the value entered in this field is ignored and the Rheology Table's yield stress values are used instead. The values in the Rheology Table are interpolated yield stress values, which are dependent on mixture density.

In addition, please be aware that yield stress values below critical yield stress do not allow the mixture to flow easily.

Yield stress, which is measured with a viscometer, can significantly affect production rates.

### 2.4.1.9 Atmospheric Pressure [kPa or psi] Field

In this field, enter the atmospheric pressure, given in kPa or psi. The default value is 101.325 kPa or 14.71 psi.

The atmospheric pressure figure entered in this field only affects the *Suction Performance Pump #1* graph.

## 2.4.2 Particle Size Section

This section is used to set particle size(s). In the Particle Size section, users can select either the *Determining Particle Size* or the *Particle Size Distribution*.

Please note that the most accurate production estimates for mixtures coarser than 1,000 µm (or 40 th) are obtained by entering the entire particle size distribution.

### 2.4.2.1 Percentage Fines

If a value >0 is entered in this field, the water viscosity value, which is only a function of temperature, will be ignored and the so called apparent viscosity is used instead. The higher the percentage fines, the more viscous the carrier fluid becomes.

Please note that the value in the **Percentage Fines** field will be ignored if the *Use Rheology Table* checkbox is checked.

### 2.4.2.2 Determining Particle Size [µm or th] Field

The determining particle size ( $D_{MF}$ ) can be calculated using the following equation (3):

$$DMF = \frac{D_{10} + D_{20} + D_{30} + D_{40} + D_{50} + D_{60} + D_{70} + D_{80} + D_{90}}{9} \quad (3)$$

If the *Particle Size Distribution* (PSD) is not defined, then the *Average Particle Size* ( $D_{50}$ ) can be used instead as a best estimate.

### 2.4.2.3 Particle Size Distribution [µm or th] Fields

If the *Determining Particle Size* is larger than approximately 1,000 µm (or 40 th), then higher less conservative discharge production rates can be estimated by entering the entire *Particle Size Distribution* (i.e.  $D_{10}$  to  $D_{90}$ ).

## 2.4.3 Rheology Table Section

### 2.4.3.1 Use Rheology Table Checkbox

If this checkbox is checked, both the water viscosity value and the apparent viscosity value, which is a function of percentage fines, are ignored. Instead the kinematic viscosity [ $m^2/s$  or  $ft^2/s$ ] is interpolated using specified viscosities as a function of mixture density [ $kg/m^3$  or  $lb/ft^3$ ].

Secondly the value specified in the *Yield Stress* field in the *Mixture Specification* section of the screen will be ignored and the interpolated yield stress values specified in the *Rheology Table* will be used instead.

No extrapolation is allowed to avoid getting unrealistic values. Furthermore, the mixture density range specified in the table must, at a minimum, cover the range between the *Water Density* and the *Mixture Density* values specified in the *Mixture Specification* section.

### 2.4.3.2 Import ASCII File Button

The **File Open** button located to the right of the *Use Rheology Table* checkbox, allows you to import values into the *Rheology Table* from an ASCII file.

The values in the ASCII file can be space, tab or comma delimited and the import assumes that the first line of the file is normal data. Therefore, no header or title line can be used in the ASCII file.

In addition, the Rheology Table only allows 50 lines of input data to be entered. If the ASCII file contains more than 50 lines, any line thereafter will be ignored.

## 2.5 Diagrams Tab

The *Diagrams* tab is divided into five (5) sections, namely the:

- Calculation Parameters section;
- Display Parameters section;
- Show Labels section;
- Calculation Step Sizes section; and
- Unit sections.

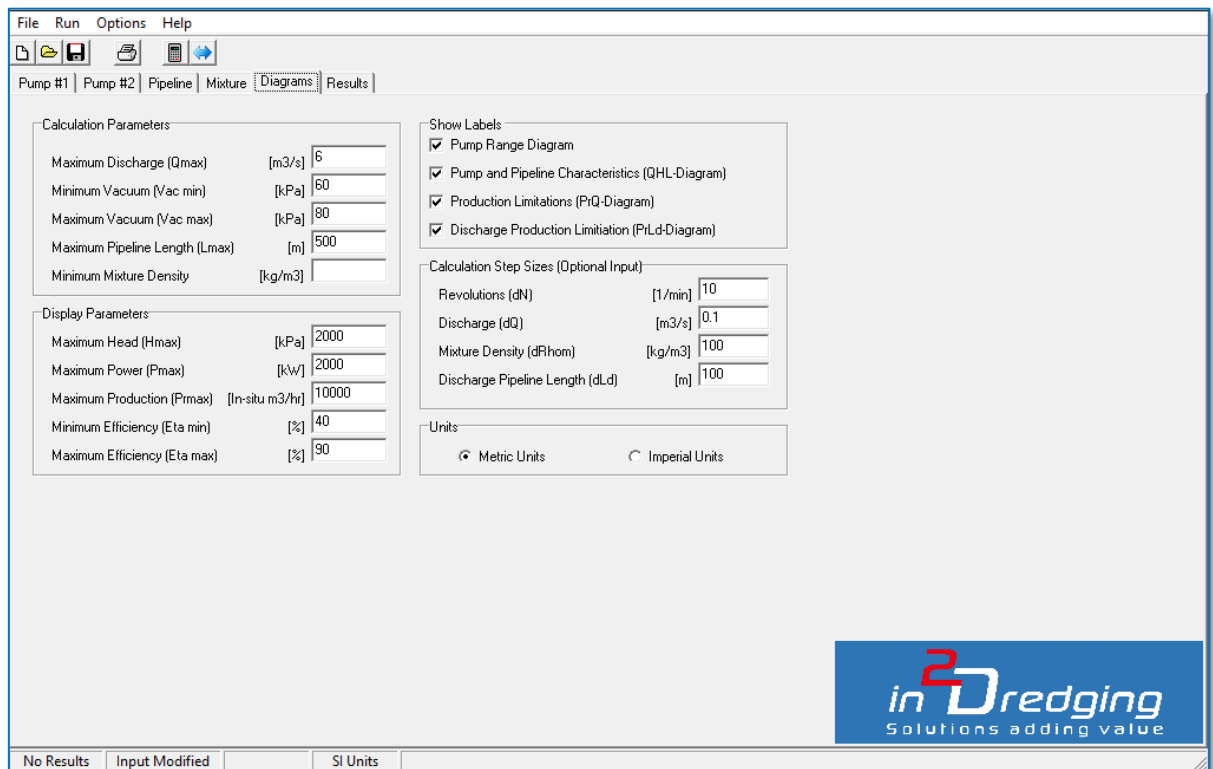


Figure 8: Diagrams tab - used to set diagram specifications

The *Diagrams* tab's above-mentioned five sections are described in detail below.

### 2.5.1 Calculation Parameters Section

#### 2.5.1.1 Maximum Discharge (Qmax) [m<sup>3</sup>/s or USG/min] Field

This field is used to set the Maximum Discharge value. The Maximum Discharge value entered in this field determines the domain of the calculation, which is between zero and the value entered.

The discharge is displayed on various graphs' horizontal axes.

### 2.5.1.2 Minimum Vacuum (Vac Min) [kPa or psi] Field

The *Minimum Vacuum* value entered in this field produces the lowest production parabola drawn in the *Production Limitation (PrQ Diagram)* graph.

The limiting vacua are calculated when the NPSHr regression coefficients are provided for Pump #1 (see *Section 2.2.11* for further information). The limiting vacuum is shown in the *Suction Performance Pump #1 (NPSHrQ-Diagram)* graph. This graph can be read and used to define the vacuum range.

The *Limiting Vacuum* value depends on the NPSHr, the mixture density and the pump's engine's RPMs. Therefore, the limiting vacuum does not easily allow for vacuum ranges that apply to certain working areas of the pump.

If the NPSHr of the pump is not known, then the typical limiting vacuum range for a pump can be used, which is between 50 – 80 kPa (i.e. 7.3 – 11.6 psi), depending on the design of the pump and its RPMs.

### 2.5.1.3 Maximum Vacuum (Vac max) [kPa or psi] Field

The *Maximum Vacuum* value entered in this field produces the highest production parabola drawn in the *Production Limitation (PrQ-Diagram)* graph.

The previous section (i.e. *Section 2.5.1.2*) provides guidance on determining the vacuum range.

### 2.5.1.4 Maximum Pipeline Length (LMax) [m or ft] Field

The Maximum Pipeline length value entered in this field is displayed on the horizontal axis of the *Discharge Production Limitations (PrLd Diagram)* graph.

### 2.5.1.5 Minimum Mixture Density [kg/m<sup>3</sup> or lb/ft<sup>3</sup>] Field

The minimum mixture density is an optional parameter to control the range of mixture densities to be evaluated in the calculations and shown in the graphs. If this field is left empty, the water density will be used as minimum density.

## 2.5.2 Display Parameters Section

Please note that the values entered in this section only affect the scales of the graphs' axes.

### 2.5.2.1 Maximum Head (Hmax) [kPa or psi] Field

The *Maximum Head* value entered in this field determines the *Pump # Range Diagram* and the *Pump and Pipeline Characteristic (QHL Diagram)* graphs' **Head (vertical)** axis.

### 2.5.2.2 Maximum Power (Pmax) [kW or hp] Field

The *Maximum Power* value entered in this field determines the maximum limit for the graphs' **Power (vertical)** axes.

### 2.5.2.3 Maximum Production (PRmax) [in situ m<sup>3</sup>/hr or yd<sup>3</sup>/hr] Field

The *Maximum Production* value entered in this field determines the maximum limit for the **Production (vertical)** axes of the *Production Limitations (PrQ Diagram)* and the *Discharge Production Limitation (PrLd Diagram)* graphs.

### 2.5.2.4 Minimum Efficiency (Eta min) [%] Field

The *Minimum Efficiency* value entered in this field determines the minimum limit for the **Efficiency (vertical)** axes in the *Pump # Range Diagram* graphs.

### 2.5.2.5 Maximum Efficiency (Eta max) [%] Field

The *Maximum Efficiency* value entered in this field determines the maximum limit for the **Efficiency (vertical)** axes in the *Pump # Range Diagram* graphs.

## 2.5.3 Show Labels Section

The tick boxes provided in the *Show Labels* section are used to select whether to show labels or not on the graphs specified in this section. The labels, if selected, indicate mixture densities.

## 2.5.4 Calculation Step Sizes Section

This section contains optional input fields, that allows you to adjust the calculation's default step sizes, if the default values are not showing the required results.

For instance, the default mixture density step size is 100 kg/m<sup>3</sup> (or 6.24 lb/ft<sup>3</sup>). However, when pumping very poor mixtures in a long discharge pipeline, for example, a more appropriate mixture density step size may be 50 kg/m<sup>3</sup> (or 3.12 lb/ft<sup>3</sup>), as this latter step size would provide results with more definition.

## 2.5.5 Units Section

The Units radio button allows you to instantaneously switch all input boxes from metric (SI) to American imperial units and vice versa. The units on the graphs' axes are updated after the **Run Project** button is clicked. The *Run Project* button is located on the **Toolbar** and has a calculator icon.

## 2.6 Results Tab

The calculation results are displayed as six different graphs on the *Results* tab. The required graph can be selected from the dropdown menu provided on the *Results* tab.

When the project has been calculated, and assuming no input errors were encountered, PnP automatically displays the *Results* tab. To run the project simulation, either select the **Run Project** button located on the **Toolbar** or click the **F9** shortcut key on the keyboard.

All graphs can be queried by clicking the **left mouse** button on a point of interest. This causes a box to appear that provides numerical values, including symbols and units, selected from the point of the cursor arrow. An example is shown in *Figure 9* below.

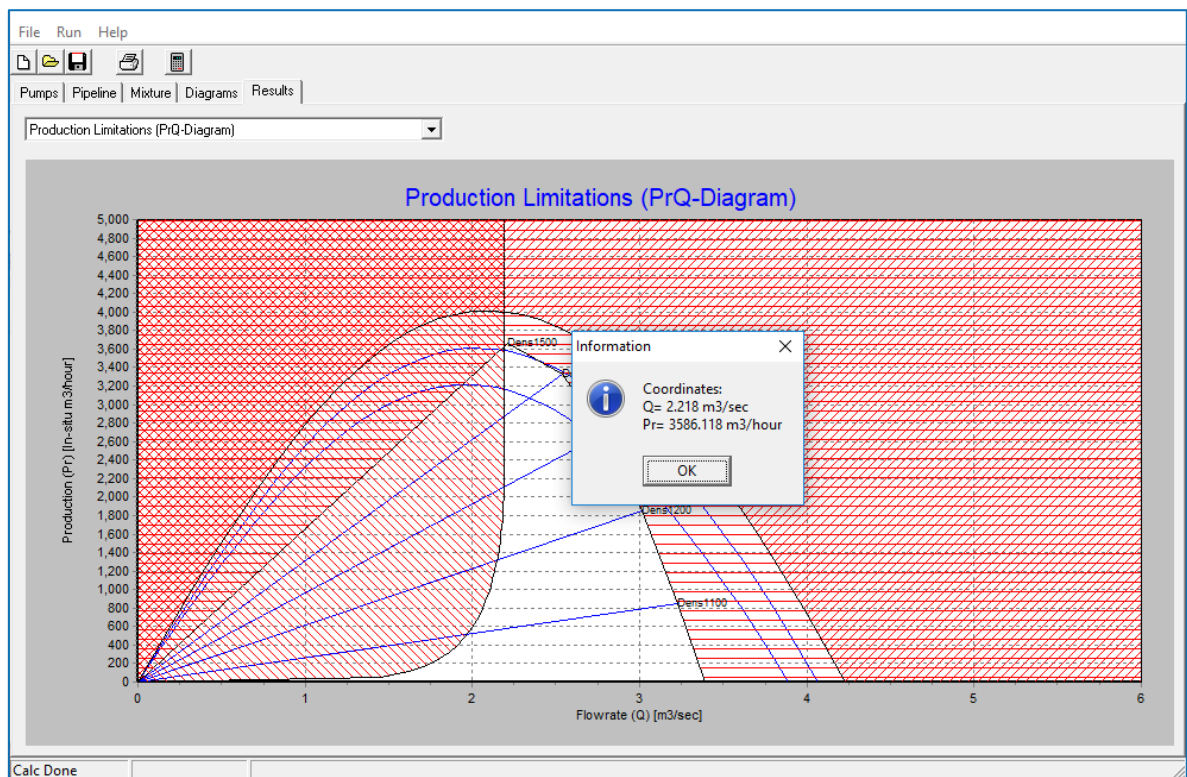


Figure 9: Information box from a specific point in a graph



## 2.6.1 Pump Range Diagram

The *Pump # Range Diagram* consists of three graphs:

- Top graph: Charts discharge (m<sup>3</sup>/s or USG/min) versus power on the shaft (kW or hp)
- Middle graph: Charts discharge (m<sup>3</sup>/s or USG/min) versus efficiency (%)
- Bottom graph: Charts discharge (m<sup>3</sup>/s or USG/min) versus manometric head (kPa or psi).

The pump for which the graphs are to be shown can be specified using the Pump # list.

The scale of these graphs' axes can be set and modified on the *Diagrams* tab.

These *Pump Range* graphs can be used to understand the pump characteristics for the specified mixture density and RPM range. The RPM ranges from minimum to maximum.

In order to obtain quick and accurate results, it is recommended that these pump range graphs be checked for possible input errors before proceeding to the estimation phase.

## 2.6.2 Pump and Pipeline Characteristic (QHL-Diagram) Graph

The *Pump and Pipeline Characteristic (QHL-Diagram)* graph charts the characteristics of the pumps and pipeline. If three pumps are specified, i.e. Pump #1 and Pump #1 + Pump#2, then a summation of all the pumps is displayed. The intersection of the pumps and the pipeline characteristics, or the operating points, are presented in the graph.

The graph charts a range of mixture densities against specific pipeline lengths to determine whether the pumps chosen for the project can pump the specified mixture through the specified pipeline.

For example, the pipeline could be too long thus the number of specified pumps must be reduced so that intersection points between the pumps and the pipeline characteristics can be determined.

If the ***Include Nozzle(s) in Calculation*** checkbox was selected on the *Pipeline* tab, then the horizontal range of the rainbow beam is also charted for each operating point.

## 2.6.3 Suction Performance Pump #1 (NPSHrQ-Diagram) Graph

The *Suction Performance (NPSHrQ-Diagram)* graph charts the ***Nett Positive Suction Head required (NPSHr)*** and the ***Limiting Vacuum***.

The NPSHr curves are shown for the pump's *RPM Minimal* and *RPM Nominal* values, which were entered on the *Pumps* tab.

The Limiting Vacuum curves are shown for the *RPM Minimal* and *RPM Nominal* revolutions, as well as for water and mixture densities, values for which were entered on the *Mixture* tab.

The *Limiting Vacuum* range used in this graph can be entered in the *Diagrams* tab's *Minimum* and *Maximum Vacuum* fields (see *Sections 2.5.1.2* and *2.5.1.3* for further information).

## 2.6.4 Production Limitations (PrQ-Diagram) Graph

The *Production Limitations (PrQ Diagram)* graph shows all the limitations of the submitted project at once. This graph essentially presents the critical components for making a project successful and shows:

- **Critical discharge for the largest pipeline diameter, usually on the suction side**

The velocity in the pipeline must stay above the critical velocity to avoid a bed of solid material forming in the pipeline. Typically, one would want to prevent the formation of a solid bed in the pipeline to reduce the possibility of unnecessary pressure losses.

A discharge below the critical velocity is hatched red on the graph.

- **Vacuum production parabolas for a specified range of vacua**

Production above the vacuum range is not possible and is to be avoided because the pump starts to cavitate and rapidly loses its efficiency.

The area above the maximum vacuum parabola is hatched red on the graph. In addition, the graph only displays the vacuum production for Pump #1, as it is only applicable to Pump #1.

Ensure your vacuum parabolas are accurate by entering NPSHr regression coefficients for the first pump and values in the *Minimum Vacuum* and *Maximum Vacuum* fields (see *Sections 2.5.1.2 and 2.5.1.3*) based on the *Suction Performance (NPSHrQ Diagram)* graph.

- **Operating points for a range of mixture densities**

The operating points are an outcome of the pump-drive system and the number of pumps specified.

The area outside the viable operating points is hatched red on the graph.

**Maximum production** is displayed above the red hatched area on the graph. The intersection of the critical discharge with the working point parabola, or vacuum parabola, normally indicates maximum production.

At minimum mixture velocity, *Minimal Pressure* is lost due to the lack of velocity and *Optimum Pressure* is lost due to optimum mixture density.

## 2.6.5 Discharge Production Limitation (PrLd-Diagram) Graph

The *Discharge Production Limitation (PrLd Diagram)* graph charts the *Pipeline Length* versus *In situ Production*. It charts the *maximum discharge production* for the specified mixture density range and maximum discharge pipeline length.

This graph indicates whether the project is feasible with the specified pumps, pipeline and mixture. Depending on the returned results, the user might have to reconsider, for example, the pump-drive systems intended to be used, whether a booster pump may be needed, or even if alternative equipment needs to be used on the project.

## 2.6.6 Pipeline Pressure Profile (LHm-Diagram) Graph

The *Pipeline Pressure Profile (LHm Diagram)* graph charts the *Pipeline Length* versus *Atmospheric Pressure*. The pressure profile is only shown, if the mixture density value provided on the *Mixture* tab, has an operating point on the *Pump and Pipeline Characteristic (QHL-Diagram)* graph.

The pressure profile charted on this graph is typically used to position a booster pump. The booster pump must have enough incoming pressure to avoid cavitation and the outgoing pressure must be below design pressure.

### 2.6.6.1 Incoming Pressure

A lower limit of 100 kPa (i.e. 14.5 psi) is typically used to avoid cavitation.

If NPSHr regression coefficients have been entered, more accurate calculations can be made as to whether the pump's incoming pressure is sufficient by comparing the limiting vacuum results from the *Suction Performance (NPSHrQ-Diagram)* graph with the incoming pressure.

### 2.6.6.2 Outgoing Pressure

To avoid exceeding the pump's design pressure, the incoming pressure must not be too high because the outgoing pressure may then exceed the pump's design pressure, or the pressure generated by gland water pumps.

## 2.6.7 Transport Energy Efficiency (PrSEC-Diagram) Graph

The *Transport Energy Efficiency (PrSEC Diagram)* graph charts the in situ production versus specific energy consumption for a pipeline system. For a range between the critical velocity and the maximum velocity. The graph shows how the energy consumption can be reduced by pumping higher mixture densities at lower velocity.

### 3 Options Menu Items

#### 3.1 Regression Curve Fitting Tool

##### 3.1.1 Fitting a Curve

This feature is used to calculate pump regression coefficients. A *Regression Curve Fitting Tool* screen showing sample results is provided in *Figure 10* below.

Almost any ASCII file containing x and y coordinates can be used for curve fitting. The data in the ASCII file can be space, tab or comma delimited, but must not include a header or title line.

The minimum number of points in the ASCII file must be two (2), but there is no maximum number of points. However, to determine the regression coefficients of a 2<sup>nd</sup> order polynomial, at least three (3) points need to be specified. Ideally, however, at least five (5) points should be specified to ensure that the regression coefficients are accurate.

Once the points have been provided, a second order curve fit is performed and the calculated coefficients are shown on screen both numerically and graphically, as per *Figure 10* below.

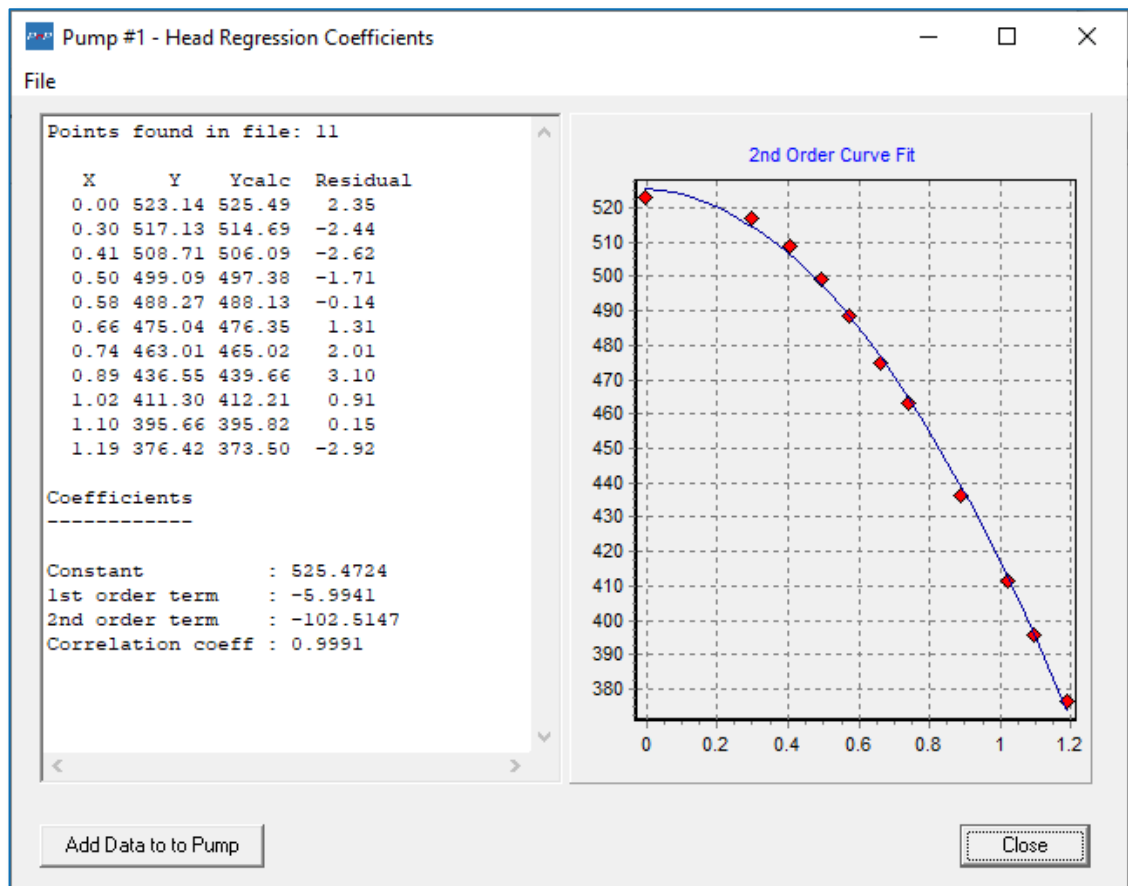


Figure 10: Sample Regression Curve Fitting tool screen

If the Regression Curve Fitting tool is accessed by clicking one of the **More** buttons (i.e. the button with the three dots) next to the *Regression Coefficients* titles on the *Pumps* tab, the **Add Data to Pump** button appears on the tool's screen. Clicking this button allows you to export the calculated regression coefficients back to the Pump# screen from which the **More** button was clicked.

If this tool is accessed from the **Options** menu, it is not possible to determine whether the coefficients are Head, Efficiency or NPSHr coefficients. Consequently, the **Add Data to Pump** button is not available on the tool's screen.

### 3.1.2 Notes

The Regression Curve Fitting tool works independently of the unit of measure (i.e. either SI or Imperial) currently selected for PnP. Therefore, you need to ensure that the input data in the ASCII file matches the unit of measure currently selected in PnP.

## 3.2 Affinity Laws Tool

### 3.2.1 Applying Pump Affinity Laws

Pump affinity laws are used to modify Head and Efficiency regression coefficients for the pump currently active within PnP by applying different pump RPMs or impeller diameters to the pump. An *Affinity Laws Tool* screen showing sample results is provided in *Figure 11* below.

The Affinity Laws tool can be accessed from both the **Options** menu and by clicking the **More** button (i.e. the button with the three dots) next to the **Save Pump File** button on the **Pumps** tabs.

This tool takes the original regression coefficients for the currently active pump within PnP and reconstructs Head or Efficiency curves that are within a certain interval using a specified number of steps. Then affinity laws are applied to these curves to show the effect a different RPM and/or impeller diameter would have on the pump.

Applying the affinity laws results in new regression coefficients. These new regression coefficients represent pump characteristics for the modified RPMs or impeller diameter, or both.

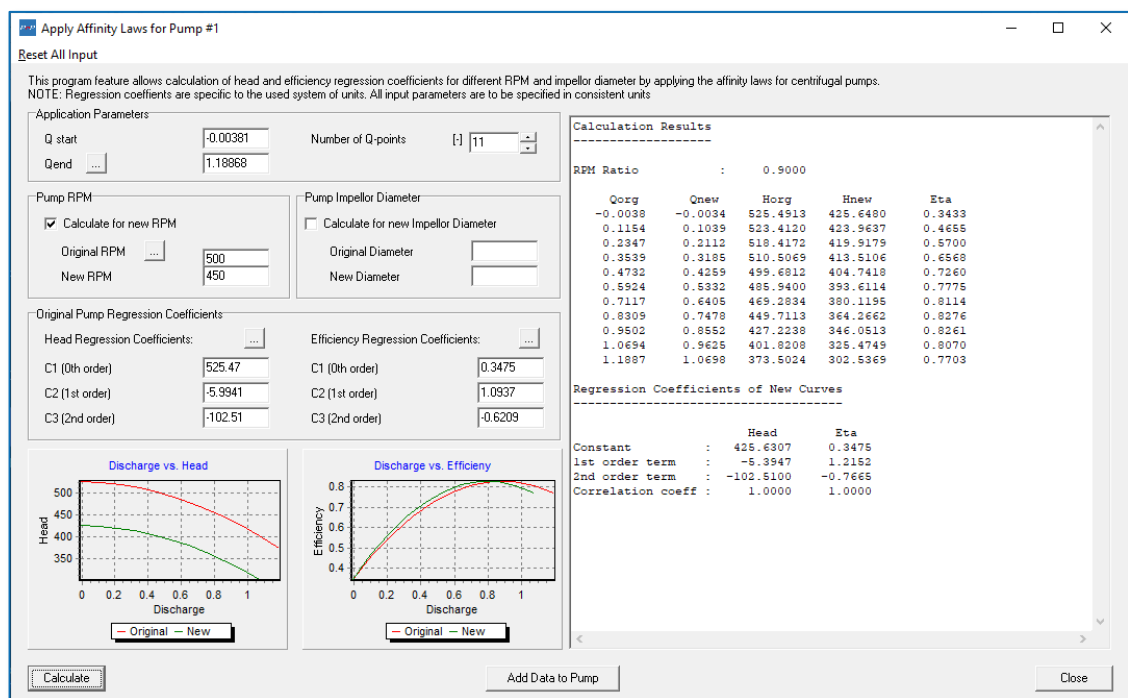


Figure 11: Sample Affinity Laws tool screen

### 3.2.1.1 Application Parameters Section

The parameters in this section determine the affinity law intervals and the number of points that will be applied by the tool.

Note that the **More** button (i.e. the button with the three dots) in this section can be used to import the maximum discharge values from the *Diagrams* tab, if these have already been entered on *Diagrams* tab.

### 3.2.1.2 Pump RPM and Impeller Diameter Sections

Affinity laws can be applied to either modify the currently active pump's RPMs and/or impeller diameter, or both. The tick boxes in these two sections allow you to choose to which parameter, i.e. RPM or Impeller Diameter or both, the laws will be applied.

The values in these sections represent the old and new RPMs and impeller diameters that correspond to the original regression coefficients.

Note that the **More** button (i.e. the button with the three dots) in the *Pump RPM* section can be used to import the original RPM values from the currently active *Pumps* tab.

### 3.2.1.3 Original Pump Regression Coefficients

The values in this section represent the original regression coefficients that correspond to the original RPM and Impeller Diameter values as entered on the currently active *Pumps* tab.

Note that the **More** button (i.e. the button with the three dots) in this section can be used to import the coefficients from the currently active *Pumps* tab.

### 3.2.1.4 Output

After the affinity laws have been applied, the results are shown in both numerical and graphical form on the *Affinity Laws Tool* screen, as shown in *Figure 11* above.

The calculated results can be exported to the currently active *Pumps* tab by using the **Add Data to Pump** button.

Please note that if this tool was accessed from the **Options** menu, the currently active tab is not a *Pumps* tab. Therefore, the **Add Data to Pump** button is not available as the pump to which the data should be copied cannot be determined.

## 4 Conclusion

Once a pump's power usage and production are well defined with the help of PnP, it is then possible to develop accurate and robust cost estimates and/or schedules for your dredging project.