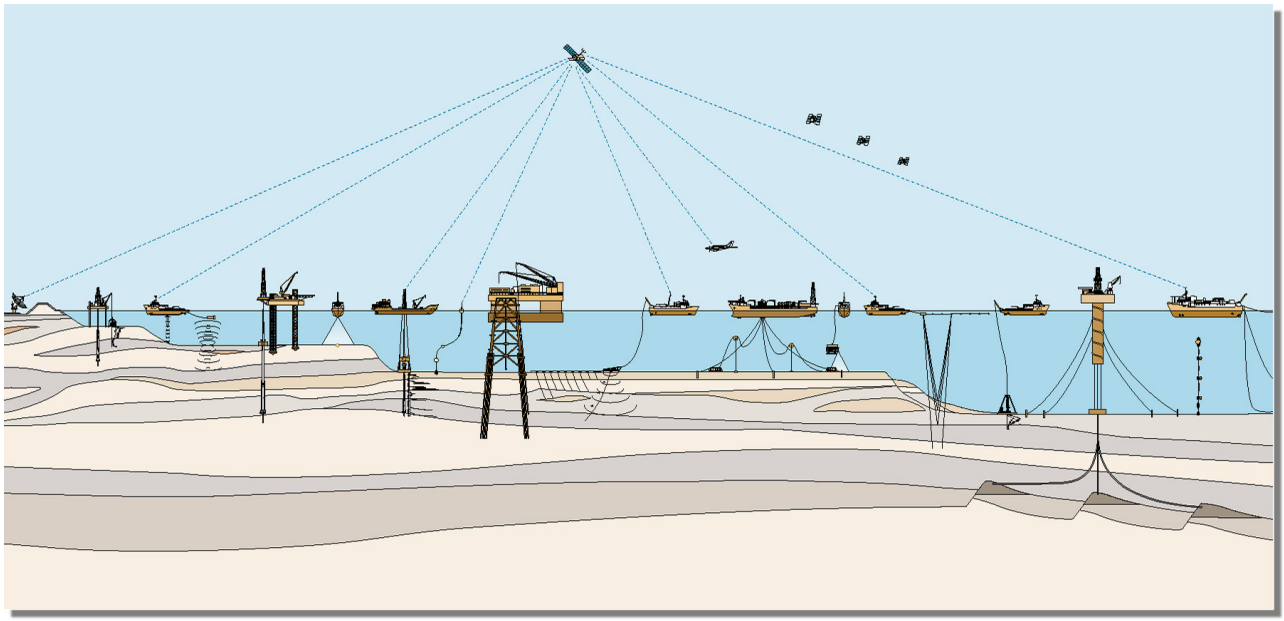
Rock Physics Module for PowerLog

User Guide

RPM for PowerLog version 2.7

August 25, 2006



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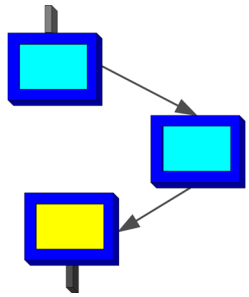

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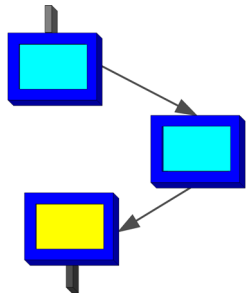


USING THIS DOCUMENT

This section describes the initial tasks and information you want to know prior to first installing the Rock Physics Module (RPM) for PowerLog software. It includes:

Introduction

Audience

This document is for petrophysicists, geophysicists, geologists, and reservoir engineers who want to develop standard and customized workflows for determining rock physics and pore fluid properties in well curves.

Where to find information

RPM for PowerLog — Getting Started Guide:

- Section 1, "*Using this Document*", describes (**a**) locating information in the RPM for PowerLog documents, (**b**) documentation font conventions used, (**c**) effective procedures for using Adobe Acrobat documentation, and (**d**) Technical Support contact information.
- Section 2, "*Installation*", describes the procedures needed to install the RPM for PowerLog software and a brief introduction to rock physics workflows.
- Section 3, "*Frequently Asked Questions*", describes answers to common questions and work-around procedures for specific software issues.
- Section 4, "*Best Practices*", provides some advice about handling specific situations in RPM for PowerLog, based on some initial software testing by the Fugro-Jason Professional Services group.
- Section 5, "*Release Notes"*, provides last-minute information about (**a**) issues resolved in this release, (**b**) known issues the development team is correcting, and (**c**) new features added from the previous RPM for PowerLog software release.
- *Glossary*, explains terminology used in this document.
- *Index,* provides a quick method to locate information throughout this document.

RPM for PowerLog — User Guide:

- Section 1, "*Using this Document*", describes (**a**) locating information in the RPM for PowerLog documents, (**b**) documentation font conventions used, (**c**) effective

procedures for using Adobe Acrobat documentation, and (**d**) Technical Support contact information.

- Section 2, "*RPM Concepts*", shows you the components that make up the elemental calculation nodes and how these nodes assemble as a workflow.
- Section 3, "*Planning Workflows*", describes how to manage and plan your workflow. This involves defining input PowerLog curves, creating named constants, preparing mix defaults, and organizing rock physics properties.
- Section 4, "*Building Rock Physics Workflows*", illustrates the step-by-step procedures used to create a complete workflow.
- Section 5, "*Performing Advanced Workflow Tasks*", describes how to better organize the workflow, setup user preferences, troubleshoot calculations, import another RPM project parameters, and do curve fitting.
- Section 6, "*Tutorial Workflows*", uses several workflows to illustrate general principles for developing a workflow, while providing individual users the freedom to create customized workflows with their unique methodologies. Topics covered include:
  - Setting up input curves and rock parameters
  - Organizing computations into groups
  - Comparing calculated values against measured logs
  - Selecting different error evaluation criteria
  - Reducing the number of nodes for a mature workflow by using the **SimpleExpression** function
  - Using conditional logic within the workflows
- Section 7, "*RPM User Interface*", describes the organization of the Windows menus, mouse button three (right-click) functionality, tool bars, and significant dialog windows you use in developing the RPM workflow.
- *Glossary*, explains terminology used in this document.
- *Index,* provides a quick method to locate information throughout this document.

RPM for PowerLog — Function Reference Guide:

- Section 1, "*Using this Document*", describes (**a**) locating information in the RPM for PowerLog documents, (**b**) documentation font conventions used, (**c**) effective procedures for using Adobe Acrobat documentation, and (**d**) Technical Support contact information.
- Section 2, "*Rock Physics Introduction*", provides information common to the rock physics and basic functions. Topics include:
  - Relevant publications
  - Common Greek symbols used for rock properties
  - Parameter types and how mineral default values are selected
  - Rock and Fluid properties
  - Algorithms for mix velocity rho, Vp, and Vs
- Section 3, "*Function Overview*", provides a one line summary of each basic (math, trigonometry, conditional logic, statistics, and random numbers) and rock physics function provided by RPM. RPM organizes the functions into these groups:
  - Anisotropy
  - Anisotropy Inversion Support Arithmetic
  - Arithmetic
  - Discrimination and Conditional Logic
  - Empirical Velocity
  - Fluid/Rock Physics Functions for Brine, Gas, and Oil
  - Gardner's

  - Gassmann's Functions for Fluid Substitution
  - Greenberg-Castagna
  - Media-Bounds Functions (Two-phase Media)
  - Media-Bounds Functions (Three-phase Media)
  - Miscellaneous Supporting Functions
  - Random Numbers
  - Simple Modulus-related Functions
  - Statistical
  - Trigonometric
  - Velocities for Bounds
  - Velocity-Synthesis Functions

- Section 4, "*Rock Physics Functions*", uses a terse, standard presentation format to describe how to use each rock physics function.
- Section 5, "*Basic Functions*", uses the same standard presentation format to describe the use of basic mathematical, trigonometric, conditional logic, statistical, and random number functions.
- *Glossary*, explains terminology used in this document.
- *Index,* provides a quick method to locate information within the document.

Document conventions

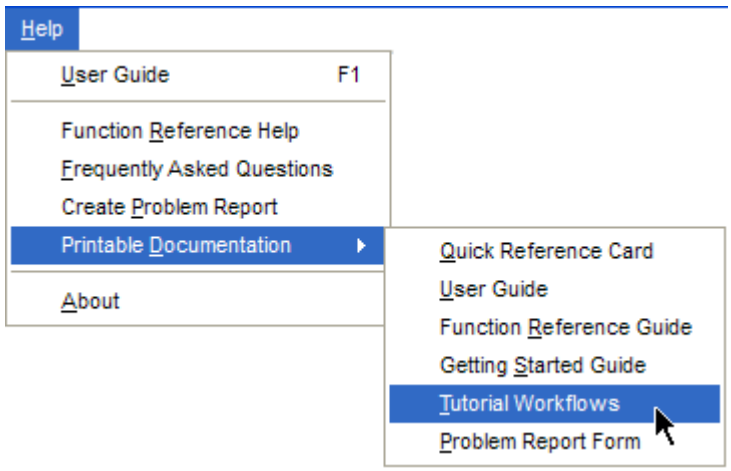
This guide uses a concise menu notation, typeface changes, and reader alerts to set apart information in a structured way that makes it easy for the user to read.

Menu selection notation

Throughout the RPM for PowerLog documentation set, a shorthand notation is used to indicate the exact manner to invoke a specific menu command. The notation uses the format **Menu > Command (or cascading menu name) > Command** and displays the text in a bold font.

Example If the documentation shows how to select the command needed to display the *RPM for PowerLog Getting Started Guide*, you would see **Help > Printable Documentation > Getting Started Guide** in the text.

Figure 1. Help menu for RPM for PowerLog



Typeface notation

Table 1. Typeface conventions and symbols

Typeface convention	Purpose
italics	• Document or software titles • Introduction of a new term • Words that require emphasis
Bold	Denotes graphical user interface objects and RPM functions. For example, RPM function names, menus, button labels, window names, option buttons, text fields, drop-down selection lists, and so forth.
`[Alt+F]`	Keyboard keys are enclosed in square brackets and bold font. If the keys must be pressed simultaneously, a plus sign is used in the text.
{ }	Text surrounded by braces (or curly brackets) indicates more than one option.
[ ]	Text surrounded by plain square brackets indicate optional elements
...	Horizontal ellipsis indicates you can supply more than one value or parameter for the preceding item(s)

Reader alerts

These reader alerts provide valuable information throughout the *Rock Physics Module for PowerLog* documentation set.

Note Note text that alerts you to additional information to help with the work procedure. The note does not contain information necessary for you to complete the procedure. The note may extend the circumstances (If you want to save your project to a network drive) of a procedure.

Hint Hint text provides you with shortcuts or insight that help you gain the more experience and efficiency with the RPM software.

Caution! The cautions text alert you to situations when you can possibly lose information or work that was just performed. For example, cautions are used for situations where project files can potentially get corrupted or you could accidently delete critical files.

Example This is an in-line example used to quickly clarify a point just made in the document.

Step 1 The tutorial step 1 begins a series of tutorial steps that stand-out from the text to call attention to this procedure for the user.

Step 2 Second step

Step 3 Step number three

Step 4 Second to the last step

Step 5 Final step of the tutorial procedure.

Using the Acrobat online guides

The online Fugro-Jason documentation can be read using the Adobe Acrobat™ Reader. (If you do not have this software, you can download a free version of the Acrobat Reader software from Adobe's Internet site - **http://www.adobe.com/**) The Adobe Portable Document File (PDF) displays the Fugro-Jason guides in full color and acts similar to an online help system. With the online guides you can:

- Control the size of the displayed document
- Print all or a portion of an RPM for PowerLog guide
- Find a specific topic using full-text search procedure
- Use bookmarks and hyperlinks to swiftly navigate among the pages.

Note Throughout the Fugro-Jason documentation you will see text that is colored as **Blue**. This text is a hyperlink (active link) that takes you to another portion of the document or to an external Internet site.

Displaying the online user guides

Step 1 Select the **Help > Printable Documentation** command and choose from the documents found on the cascading menu.
or
Outside the RPM application, use Microsoft Explorer to find the Acrobat PDF document in the `X:\Pwrlog32\RPM` installation directory and double-click on one of these guides:

- *RPM_PowerLog_User_Guide.pdf*
- *RPM_PowerLog_Function_QuickRef_Guide.pdf*
- *RPM_Freq_Asked_Questions.pdf*
- *RPM_PowerLog_Getting_Started_Guide.pdf*

Step 2 Click in the left pane to display the table of contents **Bookmarks** and access specific document pages.

Setting the navigation menu for the online user guides

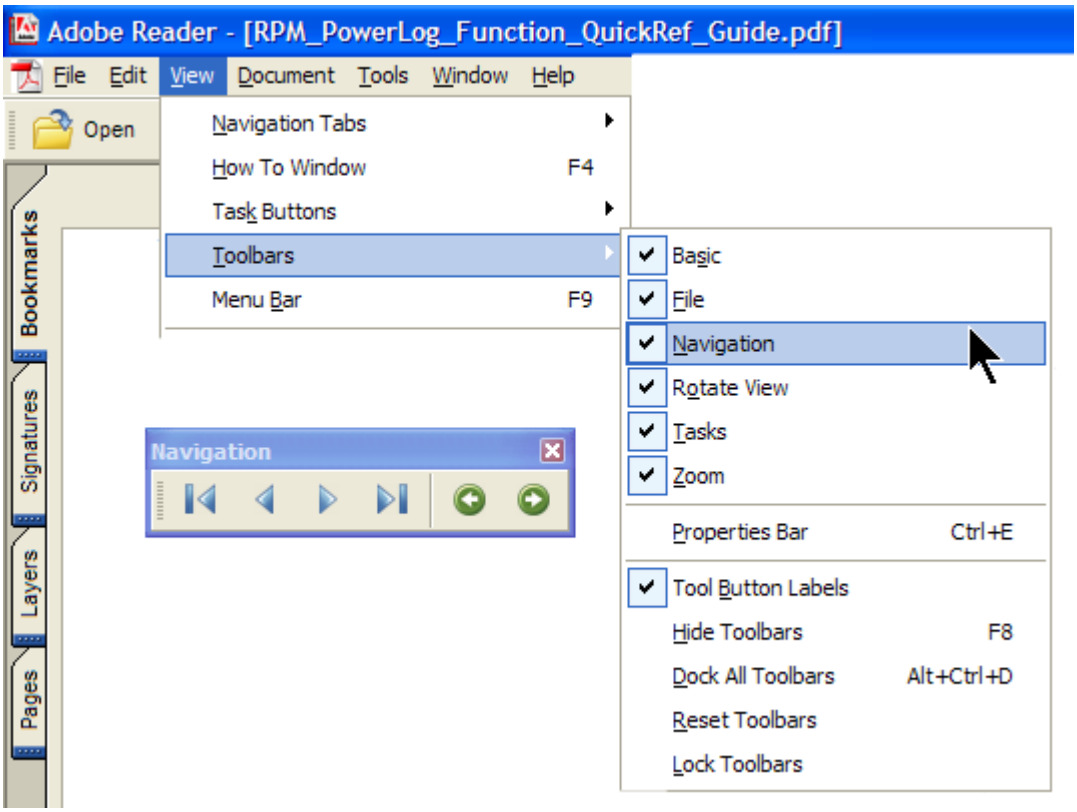
The RPM for PowerLog documentation files can be navigated similar to HTML pages on the Internet, using a Forward and a Back button to display pages. To display the Acrobat Navigation toolbar for this functionality, do this:

Step 1 Choose the **View > Toolbars** command.

Step 2 Ensure that the check box beside the **Navigation** toolbar is selected. Your screen should look like **Figure: 2, 'Display the Acrobat Navigation toolbar", on page 12**, for version 6 of Acrobat Reader.

Step 3 [Optional] To dock the **Navigation** toolbar with other Acrobat toolbars, press **`[Alt+Ctrl+D]`** keys.

Figure 2. Display the Acrobat Navigation toolbar



Changing the display size of online user guide text

Step 1 Press `[Ctrl+M]` keys to access the **Zoom To** dialog box.

Step 2 Type a value for the **Magnification** and click **OK**. The user guide page displays at the specified magnification.

Viewing an online user guide with bookmarks

Step 1 Click the **Bookmarks** tab on along the left side of the Acrobat Reader window. The bookmarks display as an interactive table of contents.

Step 2 Click the Bookmark for the user guide section you want to view. The **Bookmark's** page and location display in the Acrobat window.

Jump to a specific page in an online guide

Step 1 Press `[Ctrl+Shift+N]` keys to display the **Go To Page** dialog.

Step 2 Type a value for the **Page** and click **OK**. The specified user guide page displays.

Printing part or all of an online user guide

Step 1 Choose the **File > Print** command or press `[Ctrl+P]` keys to access the **Print** dialog.

Step 2 Select the printer and specify the number of copies to print.

Step 3 Type the page numbers (starting and ending) in the **From** and **To** text fields.

Step 4 Click **Print** button.

Note To print an online user guide, you must have Adobe Acrobat Reader or the full Acrobat Exchange product installed on your computer.

Searching an online user guide

Step 1 Choose the **Edit > Find** command or press `[Ctrl+F]` keys to display the **Search PDF** pane.

Step 2 Type your search in the **What word or phrase would you like to search for?** area. It can be a word, words, or part of a word.

Step 3 Search only **in the current PDF document** (**Figure: 3, 'Acrobat search text", on page 14**). Select any of the applicable check boxes below the **All PDF Documents in** drop down-selection list:

- **Whole words only**—finds only occurrences of the complete word typed.
- **Case-Sensitive**—finds only occurrences of words in the exact combination of lower- and upper-case you typed in the search area.
- **Search in Bookmarks**—searches the text in the Bookmarks pane as well as the document text.
- **Search in Comments**—searches the comment annotations and the document text. Any Comment instances found have an icon beside the search word and a word or two of the context.

Step 4 Click **Search** button.

Step 5 When the search results display (**Figure: 4, 'Acrobat search results displayed", on page 14**), click the underlined search words (hyperlinked) to go to this page in the online user guide.

Step 6 If you want to do another search or refine your current search to yield a more specific result, click the **New Search** button.

Figure 3. Acrobat search text

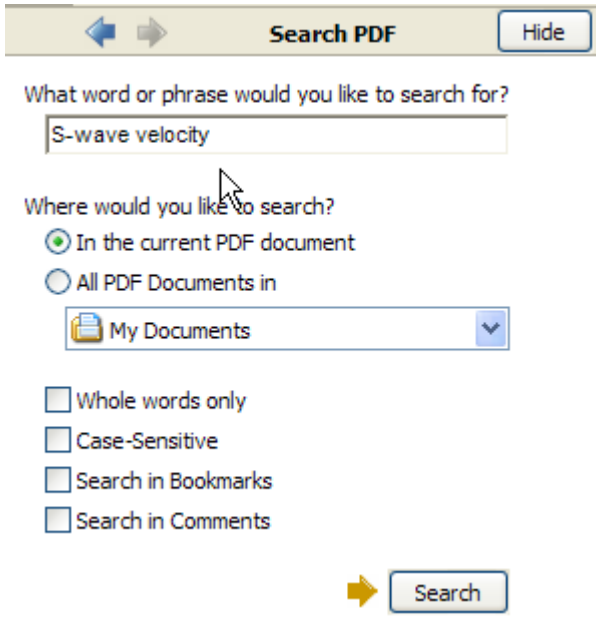
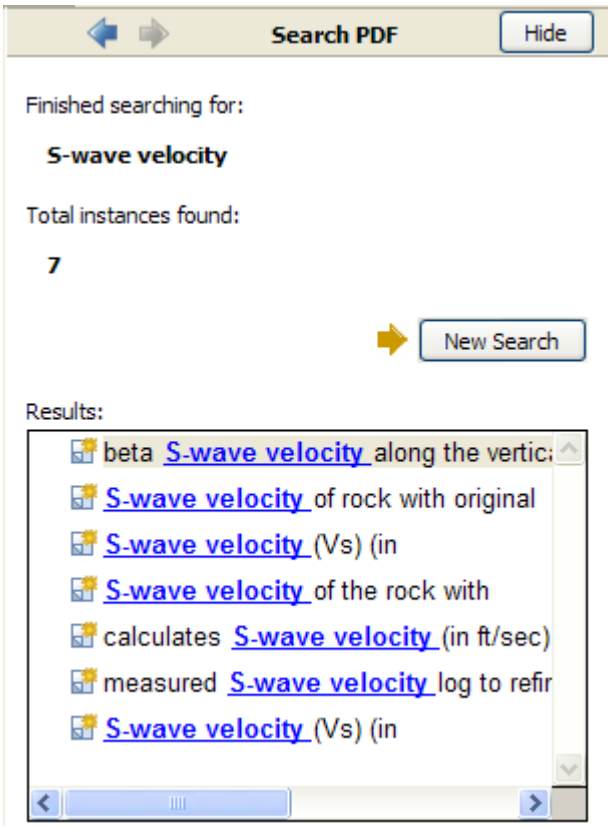


Figure 4. Acrobat search results displayed



Document revisions

Revisions and corrections to the Rock Physics Module for PowerLog documentation modules are recorded in the next table.

Table 2. Document revisions

Date	Author	Changes made
04/03/2006	Lance Smith	Internal Beta release - Convert reference documents to FrameMaker and make Acrobat file
04/18/2006	Lance Smith	Revised miscellaneous user interface elements. Streamlined terminology usage
05/01/2006	Lance Smith	Revised document into three RPM for PowerLog Guides. Added mix functions descriptions to function reference.
05/16/2006	Lance Smith	Ensure rock physics function parameters match the RPM user interface.
06/08/2006	Lance Smith	Added RPM concepts
06/12/2006	Lance Smith	Added RPM user procedures

Technical support

Fugro-Jason provides detailed documentation to help you efficiently install, configure, and use your purchased software investments. Fugro-Jason documentation is designed to help you find descriptions of product functionality and step-by-step procedures to accomplish your exploration goals. For answers to your technical support questions or to suggest ways to improve this Fugro-Jason product, please contact us.

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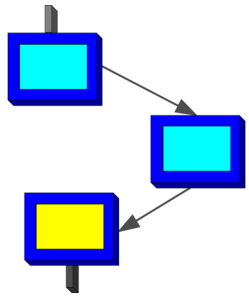


RPM CONCEPTS

Major sections include:

What is the Rock Physics Module for PowerLog?

RPM for PowerLog works with PowerLog as an add-on module to integrate the log analysis of PowerLog with rock physics elastic modeling for seismic **AVO** analysis.

Some of RPM for PowerLog's foremost features are:

- Directly stores its rock physics elastic modeling results in PowerLog so you can professionally display your log plots, crossplots, and other data together in a management-ready presentation.
- Constructs a rock physics model consistent with your logs so you can create quality synthetic shear logs for AVO analysis and **inversion**.
- Uses sophisticated rock physics algorithms and simple averaging methods such as Voigt, Reuss, and Hashin-Shtrikman.
- Estimates fluid properties based on formulas developed by Batzle and Wang.

In addition to the simple averaging methods mentioned, RPM for PowerLog contains these general classes of rock physics algorithms (among others):

- Fast approximation of the Xu and White model
- Greenberg and Castagna relation
- Gassmann's fluid substitution equation
- Gardner's relations
- Modified Hashin-Shtrikman method (lower and upper bounds)

Seismic wave propagation in a fluid-filled porous rock depends on the rock matrix composition and structure, plus the pore fluid properties. These factors influence a correct velocity estimation. RPM for PowerLog enables you to create a theoretical rock model to derive the effective elastic rock properties from fluid, mineral, and rock structure parameters. You calibrate the derived model parameters by comparing the synthetic to the measured elastic sonic logs.

Once you construct a rock model, you can perform fluid-substitution and inversion corrections. Your rock model can also enable you to predict elastic curves for lithology parameters that were not recorded in the wells.

Using workflows

The RPM for PowerLog module helps a user create rock models using repeatable workflow calculations, integrated with Petrophysical quality control procedures.

For many projects you can use petrophysics, rock physics, and empirical models to:
- Perform quality control of elastic logs
- Do quality control of petrophysical calculations
- Synthesize missing or poor log data
- Correlate elastic logs with borehole effects
- Perform fluid substitution
- Provide a framework to interpret seismic inversion results

For projects with more far-reaching objectives, building a rock model adds value beyond the simple empirical models derived from petrophysical quality procedures.

Building rock physics models with RPM workflows can help you:
- Handle more complex models (three phase media)
- Perform fluid substitution easily
- Expose errors
- Increase understanding of rocks
- Extrapolate results in a more straightforward manner

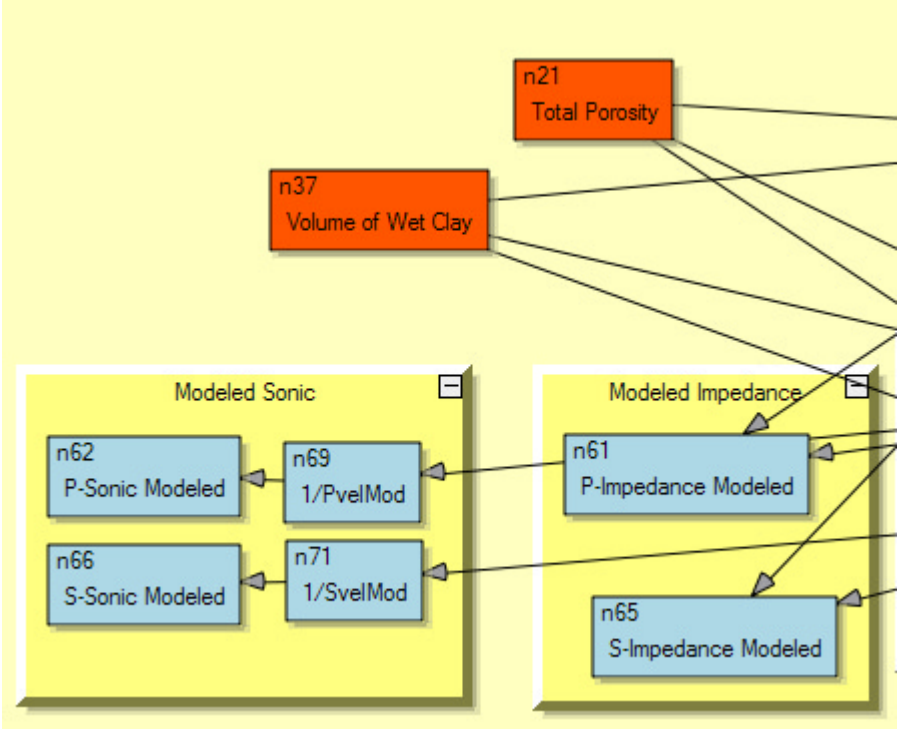
Note Documented RPM workflows are discussed in **"Tutorial Workflows" on page 84**. Example RPM for PowerLog workflow projects and additional Adobe Acrobat PDF documentation are in this directory: `C:\Pwrlog32\RPM\Workflow Templates`.

Introduction to workflows

RPM for PowerLog integrates rock physics calculations using a **workflow** (sometimes called a directed graph) developed on a screen area (**workspace**). Unlike a spreadsheet approach, the workflow directly reveals the calculation dependencies in the form of **ancestors** (nodes that affect this node's inputs) and **descendents** (nodes affected by this node's output).

The main user interface is a workflow that shows a **directed graph**, containing **node**s (where calculation **function**s operate) and **connection**s (directed lines) that determine the calculation dependencies. The workflow represents the functional dependencies, that is, which node calculations must be done before others.

Figure 5. Partial RPM workflow example



For each node, RPM provides you easy access to its large library of algorithms, along with smart menus to guide your input parameter selection.

Workflows are organized into projects and each project has its own rock and fluid properties, constants, defaults for mixing, and its own workflow graphic. Because project files can be easily modified, constants and properties can be copied and *customized* from one RPM project to another.

Simple workflow example

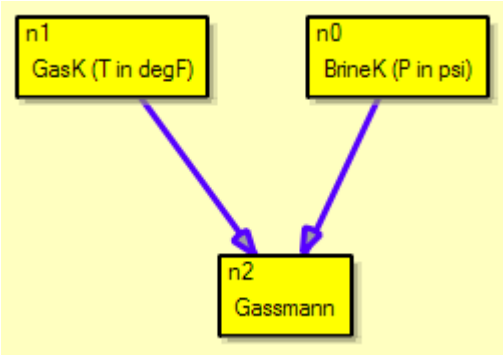
Nodes can be linked together in workflows by using the output value or output curve of one node as an input for another node.

In this example you can calculate a new bulk modulus for a sandstone when the original fluid (100% gas) is replaced by 100% water.

Consider this three node workflow that looks like **Figure: 6, 'Simple three node workflow", on page 19**, one node for each rock physics function:

- **GasK**—calculates the original fluid bulk modulus.
- **BrineK**—calculates the bulk modulus for the water for specific physical conditions in the reservoir.
- **Gassmann**—requires a bulk modulus for a replacement fluid (`K_F_new`) and an original fluid (`K_F_old`) for two of it's input parameters.

Figure 6. Simple three node workflow



The input for **GasK** is `P`=2900 psi, `T`=176 degrees F, and `spec_grav`=0.6. The result is a value for the node (node `n1`) of 4.0502e7 N/m^2.

Similarly, the input for **BrineK** is `P`=2900 psi, `T`=176 degrees F, and `salin`=35000 ppm, but yields the value for the node `n0` of 2.64747e9 N/m^2.

Once `n0` and `n1` are calculated, the **Gassmann** function node `n2` inputs become:

`Kbulk` = 12.29e9 N/m^2
`Kmineral` = 36.0e9 N/m^2
`Porosity` = 0.20
`K_F_new` = node n0 (**BrineK** - bulk modulus of brine node)
`K_F_old` = node n1 (**GasK** - bulk modulus of gas node)

The connecting arrows in **Figure: 6, 'Simple three node workflow"** display when the `n2` node is saved, because node `n2` is an output descendent of nodes `n0` and `n1`.

When the **Gassmann** function node calculates, the result is a node `n2` with the constant value 1.7148e10 N/m^2, which is the sandstone bulk modulus with the replacement fluid (water).

This workflow can be modified to use curves (also curve alias names) instead of `UserValue`s for pressure and temperature in **BrineK** and **GasK**, thus actual measured pressure and temperature variations in the well are used for the computation. Curves for pressure and temperature in PowerLog can be used. The resulting bulk density curve will vary in value, but still be approximately 1.7e10 N/m^2.

Workflow building blocks

A workflow is a collection of calculations designed to operate in a specific sequence and that forms an "integrated" solution to a rock physics or reservoir investigation. RPM for PowerLog acts as a calculation engine to deliver results to the user and create log curves for storage in the PowerLog project files. Once you store your results in PowerLog, you can take advantage of PowerLog's curve presentation, crossplot, and other graphical tools to display and plot results.

So what are the building blocks of an RPM workflow? For an existing workflow on the RPM for PowerLog main window, you first see rectangles (nodes), directed lines between rectangles (connections), and organized collections (groups) of nodes.

Nodes

A node is a location where a calculation (function) or input to a calculation is defined. Most RPM for PowerLog nodes consist of:

- one or more inputs (values or curves)
- a basic mathematics or rock physics function
- an output (used in other workflow nodes or stored as a PowerLog curve)

For a complete list of all basic and rock physics functions, see the ***RPM for PowerLog Function Reference Guide***.

Nodes all into three classifications, based on function:

- **Input nodes**—Use PowerLog *curve names* and constants, along with the **GetCurve**[1] function for these nodes.
- **Connection nodes**—These nodes create outputs that are used as input parameters for other nodes. You should always use the *node name* for the input parameter, even if the output curve has a different name. This creates the visual connections between workflow nodes.
- **Output nodes**—These nodes produce curves that you want to store in the PowerLog project well. Specify a curve name for the result you want stored.

Caution! PowerLog requires curve names with a maximum of eight characters and no blank spaces.

Using the **Edit > Preferences** command, you can set the default color and border width of the nodes. You can also right-click (MB3) on any node and assign it a color.

Node inputs

The inputs to a node can be one of these items:

- **Nodes**—the calculation output from another node
- **Curve**—curve samples from a PowerLog curve
- **Curve Alias**—an alias name that substitutes for several well log curve names of a similar type. PowerLog uses the alias to refer to multiple curve names across multiple wells within a single PowerLog project. (See PowerLog documentation for the procedure to setup curve alias names.)
- **RockProperty**—a rock, mineral, or fluid property stored in your RPM project file.
- **Constant**—a named value defined for calculations or a value a user wants to refer to by name in the workflow
- **UserValue**—a user-defined number typed for this node

Note The ***RPM for PowerLog Function Reference Guide*** describes what inputs are appropriate for each function.

Functions

An RPM function is an operation that uses mathematics, conditional logic, and rock physics empirical results to calculate a single value or an output curve.

The RPM for PowerLog classifies its functions into these groups:

- Arithmetic

1. The **GetCurve** function permits you to show these PowerLog curves as Input nodes in your workflow. No computations happen with the curve.

- Discrimination and Conditional Logic
- Empirical Velocity
- Fluid/Rock Physics for Brine, Gas, and Oil
- Gardner
- Gassmann's Fluid Substitution
- Greenberg Castagna
- Media Bounds Functions (Two-Phase Media)
- Media Bounds Functions (Three-Phase Media)
- Miscellaneous supporting
- Random Numbers
- Simple modulus-related
- Statistical
- Trigonometric
- Velocities for Bounds
- Velocity Synthesis

For additional details, see the ***RPM for PowerLog — Function Reference Guide***

Node outputs

The output of a calculation node has these characteristics:

- **Name**
- **Curve or value?**
- **Type**
- **Units**

Name

The name of the function output can be either:

- A *curve name* that is written to the PowerLog files. This is often used to store significant intermediate or final results from an output node.
- A *node number* (`n0`, `n20`, and so forth). Used to provide input to another node calculation.

Curve or value?

The physical node output is either:

- A *curve*, having a depth range and a defined number of samples. Some of the samples can be undefined (`UNDEF`).
- A single *value*.

What determines if a node generates a curve (samples) or a single value?

If the function contains *at least one* input curve (curve alias name), a *curve* is the function output.To state it conversely, if all inputs are single values, the function output is a *value*.

Exceptions to the statements apply to functions that specifically create *only a single value* for output. See the ***RPM for PowerLog Function Reference Guide*** for functions marked: **Output Single Value Only**.

Type

The output from any RPM node can be assigned an output *type*. RPM function input parameters take a specific type, such as bulk modulus or shear velocity. You can define your output as a specific type. Later, when you need that node as an input to another function (that requires this type), the selection list displays only nodes with the appropriate type. See **Figure: 9, 'Example node list of acceptable inputs", on page 25**.

RPM for PowerLog currently defines the types listed in **Table 3, "Node Output types," on page 22**.

Table 3. Node Output types

Node Output types	Node Output types	Node Output types
any	freqdepth	p_sonic
none	freqtime	p_velocity
algorithm	gammaray	shear_modulus
api	gardner	s_sonic
aspect_ratio	gas_oil_ratio	s_velocity
azimuth	greencast	spec_grav
bulk_modulus	inv_compressibility	thomsen_delta
concentration	krief_gurevich_goldberg	thomsen_epsilon
conditional	lithfrac	thomsen_gamma
density	modulus	time
depth	pressure	version
dip	porosity	vp/vs

Units

Each node output can specify the output units of the value or curve it calculates. If you specify the output type (for example, `velocity`), then the units are restricted to the velocity PowerLog English units (for this example, ft/sec).

Hint Some functions inherently are setup to know the required output type and units; for example **GardnerStoRho** generates a `density` type in units of g/cc.

Connections

Whenever you supply a node input parameter with another node in the workflow, you create a workflow connection (symbolized by a directed line). These connections define the calculation order or sequence, Using the **Edit > Preferences** command, you can set the default color and the line width of the connections. Significant connections can be assigned a unique color to highlight significance. See **Figure: 5, 'Partial RPM workflow example", on page 18**.

Groups

A collection of nodes that work together to accomplish a significant workflow goal. This collection can be assigned a name (group name) and nodes can be associated with this group. For example, you may organize the nodes that estimate Vs (shear velocity) or find the difference between the measured and computed Vp. Group names can be edited. Using the **Edit > Preferences** command, you can set the default color and the border width of the groups. You can also right-click (MB3) on any group and assign it a color. See **Figure: 5, 'Partial RPM workflow example", on page 18**.

Other node relationships

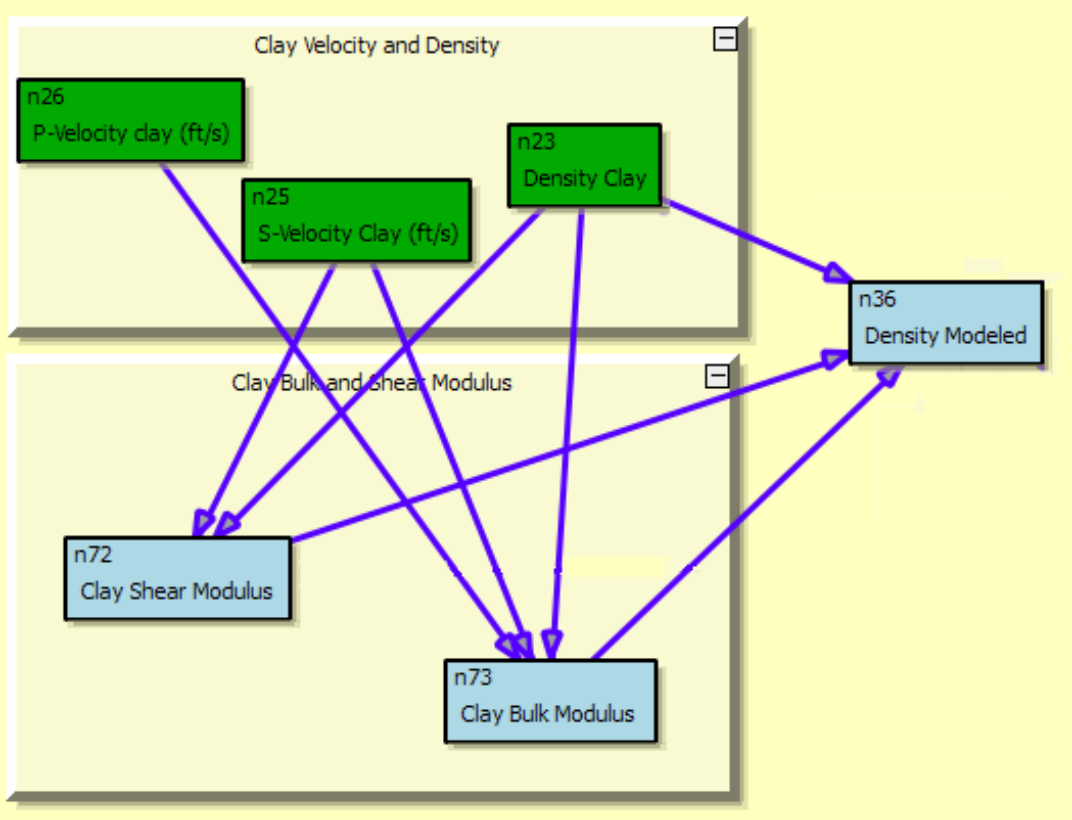
RPM for PowerLog defines several collections of nodes that it uses to perform calculations or to highlight node relationships:

- **Ancestors**—set of nodes whose outputs affect the input parameters of a node.
- **Descendents**—collection of nodes affected by the output of a single node.
- **Path**—arbitrary set of RPM nodes defined by a selected beginning node, a selected final node, and all connection nodes between the two selections.

In **Figure: 7, 'Example of ancestors, descendents, and a path", on page 23**, we can see all these relationships:

- **Ancestors**—`n23`, `n25`, and `n26` nodes affect `n73` clay bulk modulus calculation.
- **Descendents**—Node `n25` affects descendent nodes `n72` and `n73`.
- **Path**—selecting n26 as a beginning node and `n36` as an ending node defines the calculation `n26 - n73 - n36` path.

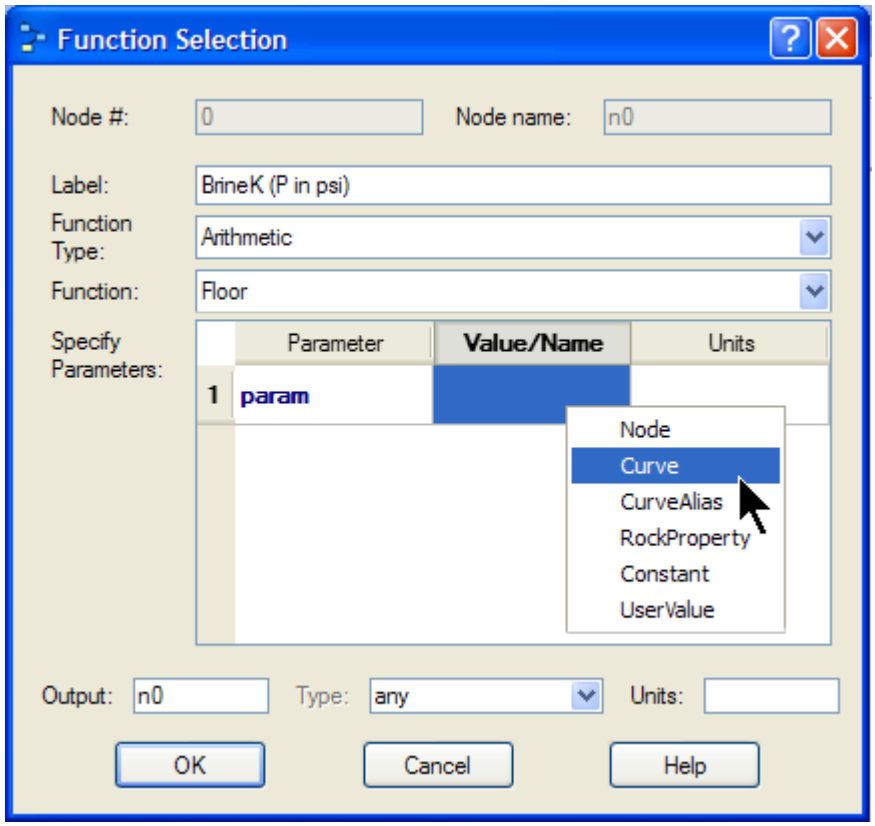
Figure 7. Example of ancestors, descendents, and a path



Inputs for function calculations

When you add or edit a node, the **Function Selection** dialog displays the current function name and its set of input parameters. Right-clicking on the input parameter in the **Value/Name** column displays the appropriate inputs for this parameter.

Figure 8. Input parameter selection types

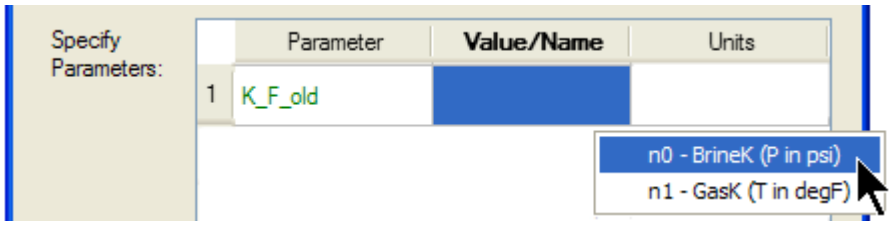


For some input parameters, a curve name, curve alias name, or the output from another node is the appropriate type. Other parameters need a single value such as a rock, mineral, gas, or fluid property, a defined named constant, or a User Value.

Node

Once a node is defined, you can use the node Output as a parameter in another node. By right-clicking (MB3) on the input parameter in the **Value/Name** column and selecting **`Node`**, RPM displays a list of all nodes that can act as an input for this parameter. RPM for PowerLog examines the Output type of each workflow node and presents only suitable nodes. For example, if the rock physics function required a V_p as its input parameter, only nodes having a acoustic **`p_velocity`** output or the type **`any`** would display in the node list. A sample node list looks like **Figure: 8, 'Input parameter selection types", on page 24**.

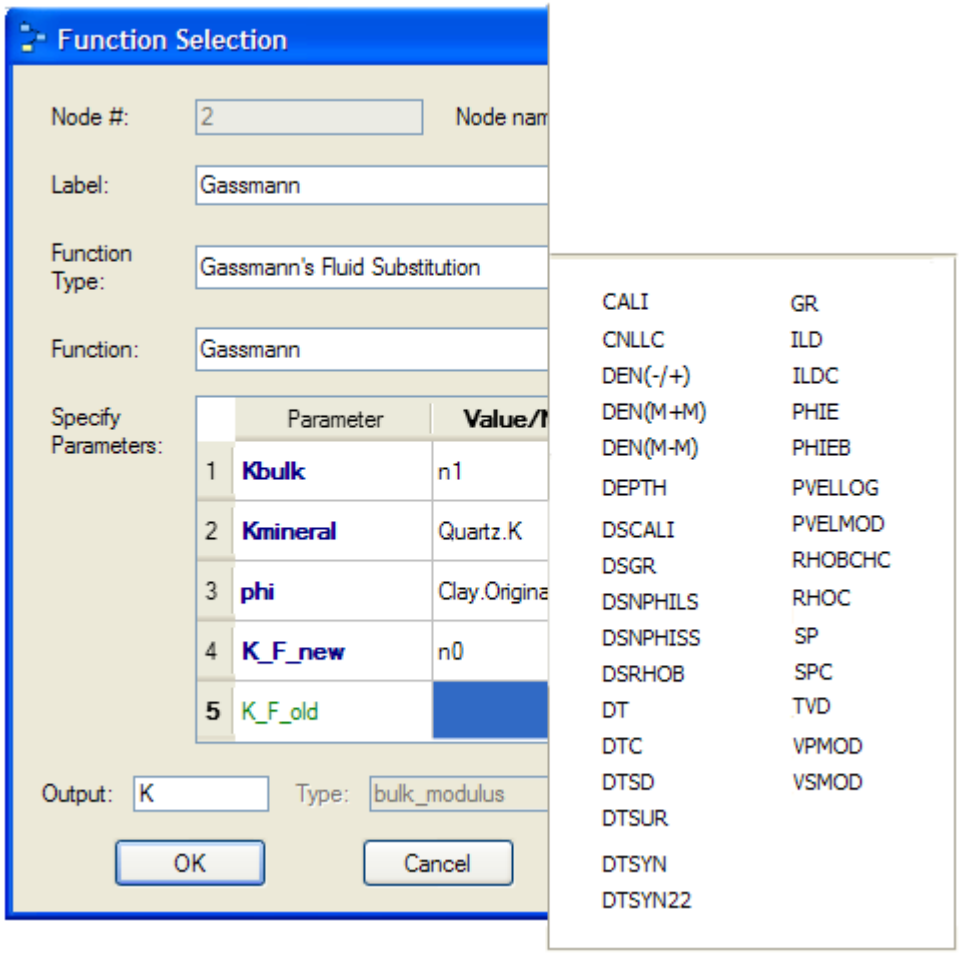
Figure 9. Example node list of acceptable inputs



Curve

Often, during workflow construction, you want to use PowerLog well curves as inputs to your calculations. Right-clicking (MB3) on the **Value/Name** column parameter and selecting **`Curve`**, RPM displays the curve names found in the chosen PowerLog project well. A curve list would look similar to **Figure: 10, 'Example curve list"**.

Figure 10. Example curve list

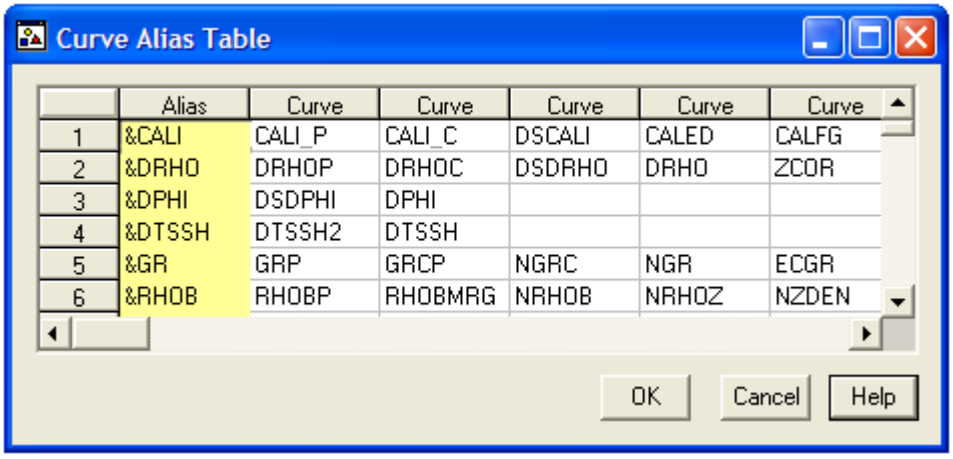


Curve alias name

In the RPM software, using a curve name which starts with the ampersand character (**&**), designates a curve alias rather than an actual well curve. When you use a curve alias in a function input parameter, RPM searches the PowerLog **Curve Alias Table** for the first available curve name in that row. Curve aliases can be used for any RPM function input parameter as a substitute for an actual curve name.

The Curve Alias Table is accessed through **Tools > Curve Alias Table** command in PowerLog. **Figure: 11, 'PowerLog Curve Alias Table"** shows an example of how curve aliases are defined in the PowerLog dialog. The yellow column is the alias name. You can associate a maximum of 49 curve names in the adjacent columns. The alias resolves the actual curve name by searching from left to right—the first curve available in the well is used.

Figure 11. PowerLog Curve Alias Table



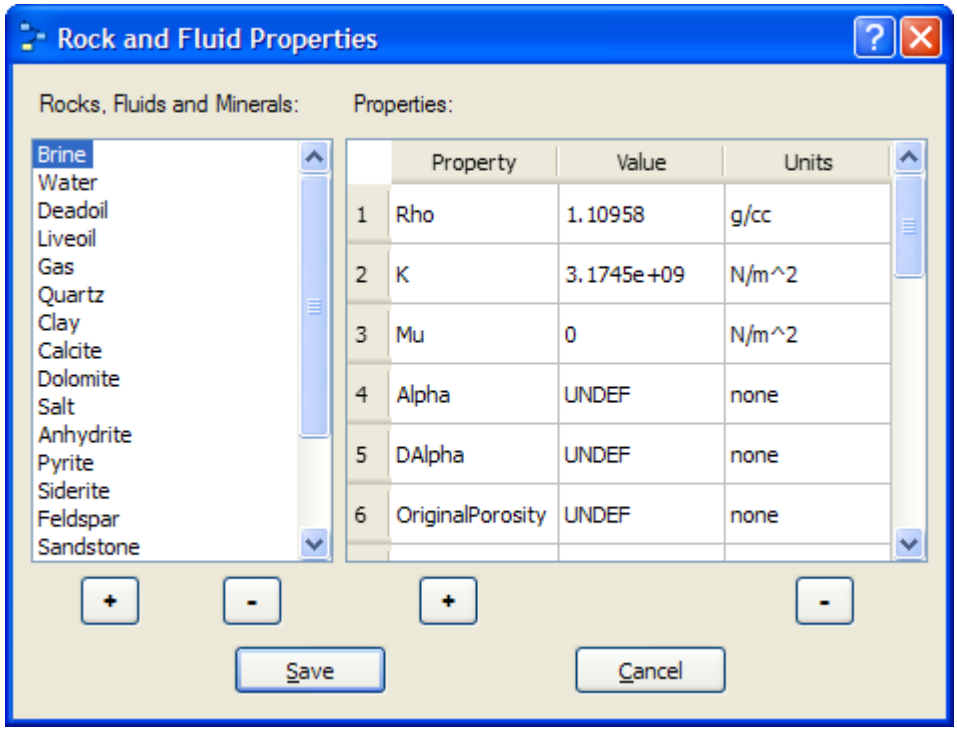
Example If we use the alias **`&GR`** as an RPM function input, RPM for PowerLog first tries to use **`GRP`**, then **`GRCP`**, but if they are absent in the well, it ends up using **`NGRC,`** which is the third choice. In situations where your RPM project is used with multiple wells in a project reservoir, you want to use PowerLog curve alias names as inputs nodes to your workflow.

Right-clicking (MB3) on the **Value/Name** column parameter and selecting **`CurveAlias`**, RPM displays the curve alias names found in the PowerLog project file An example curve alias list would look similar to the **Figure: 10, 'Example curve list", on page 25**, only all the alias names begin with an ampersand (&).

Rock, mineral, gas, and fluid properties

Every RPM for PowerLog project comes with a pre-defined set of rock, mineral, gas, and fluid properties provided. You can add, change, or delete the value of each property using the **Data > Rock Fluid Properties** command. Additional parameters can be added for each rock, mineral, gas, and fluid using this same dialog, plus you can define other rocks, minerals, gases, and fluids. When you add a new rock, mineral, gas, or fluid, you choose the appropriate type in a drop-down selection list.

Figure 12. Rock, Mineral, and Fluid properties example



Note If you need to import the rock, mineral, and fluid properties used from another project, use the procedure found in the *Installation* section of the ***RPM for PowerLog — Getting Started Guide***.

Note You cannot delete an RPM-defined rock, fluid, gas, or mineral. These RPM objects are protected and an information message displays if you attempt to delete one.

Rock and mineral properties default differently!

RPM for PowerLog handles minerals and rocks, differently, to the extent of using rock property default values differently from mineral property default values. How the defaulting mechanism described in the **"RPM mixing functions" on page 35**, differs for minerals and rocks, requires additional explanation.

RPM makes a distinction between minerals (such as quartz and calcite) and rocks (sandstone and limestone). Properties unsuitable for minerals (such as original porosity `OriginalPorosity)` have values that are initially set as undefined (`UNDEF`). Properties unsuitable for rocks (such as the density, `Rho`, which would imply dependencies on other Properties table parameters such as porosity) have values which are also initially undefined. From **RPM mixing functions**, only property values associated with minerals (not rocks) can be used as an automatic default in an RPM function parameter.

Example If the bulk modulus of a mineral phase is required as input parameter `K_1` in **MixVelocityVp** function and the user does not specify a value, the quantity found in the **Rock and Fluid Properties** for `mineral1.K` is used; as indicated by the tool tip displayed when the cursor hovers over the input field. If `mineral1` is quartz, then the default is `quartz.K`.

Caution! This automatic default value mechanism **does not** apply to rocks. There is no specification of a default rock or rocks, and rock values are not automatically used from the **Rock and Fluid Properties** if the user leaves the input parameter blank for a rock.

Example In **MixVelocityVp**, if the `Orig_Poro1` parameter is blank, it cannot default to `OriginalPorosity` for a rock, such as sandstone, because there is no default rock, and cannot default to `OriginalPorosity` for the default mineral. The user may change the `UNDEF` values for a rock or mineral in the **Rock and Fluid Properties** to specific values, but such property values associated with a rock or mineral are still not used as a default if the user leaves an input field associated with a rock blank (as opposed to a mineral) in a function. Input fields associated with rocks that are left blank default to undefined (`UNDEF`) values. The documentation and the tool tips indicate which input parameters default to undefined values for this reason.

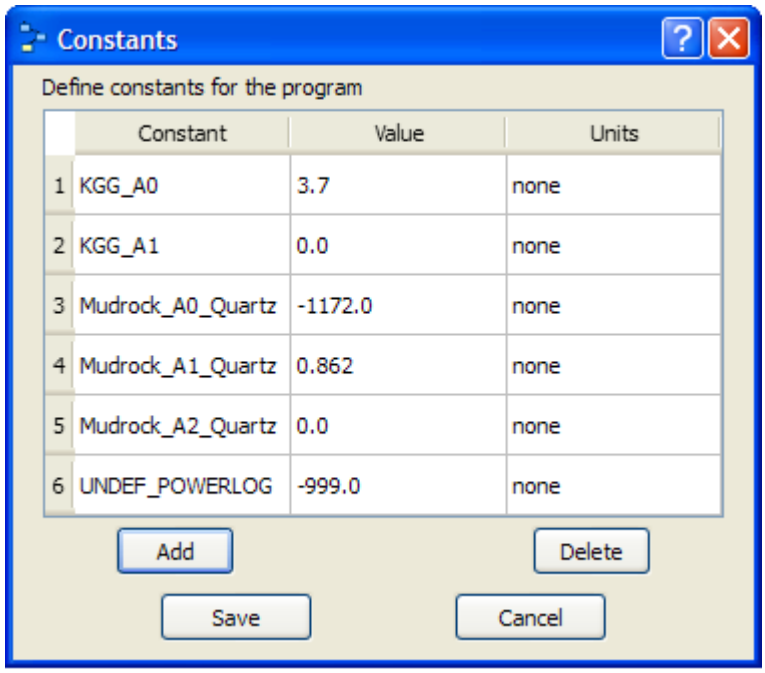
The limitations on automatic defaulting described, do not inhibit your ability to explicitly select a rock or mineral value from the **Rock and Fluid Properties**, rather than entering a numerical value, as a rock input for a function.

Named constant

Throughout your workflows, you can add your own *named* constants and refer to these values in the calculations by the assigned name. Right-clicking (MB3) on an input parameter in the **Value/Name** column of the **Function Selection** dialog, and selecting `Constant`, you can select the desired constant. Use the **Data > Constants** command to add, change, or delete a named constant from your RPM project.

Caution! You cannot delete an RPM-defined named constant. These RPM constants are protected and an information message displays if you attempt to delete one.

Figure 13. User named constants list



User values

By right-clicking (MB3) on an input parameter in the **Value/Name** column of the **Function Selection** dialog, and selecting **`UserValue`**, you can directly type a value for a function input parameter.

Calculations

A large amount of information can go into a single node, as you observed in the previous section. So how do nodes become a workflow? We stated earlier, that nodes often fall into three classifications, based on their function:

- **Input nodes**—Use PowerLog *curve names* and constants, along with the **GetCurve** function for these nodes.
- **Connection nodes**—These nodes create outputs that are used as input parameters for other nodes. You should always use the *node name* for the input parameter, even if the curve has a different name. This creates the visual connections between workflow nodes.
- **Output nodes**—These nodes produce results that you want to store in the PowerLog project well. Specify a curve name for the result you want stored.

Figure: 14, 'Example of different node types", on page 30 shows all three node types.

Organizing input nodes

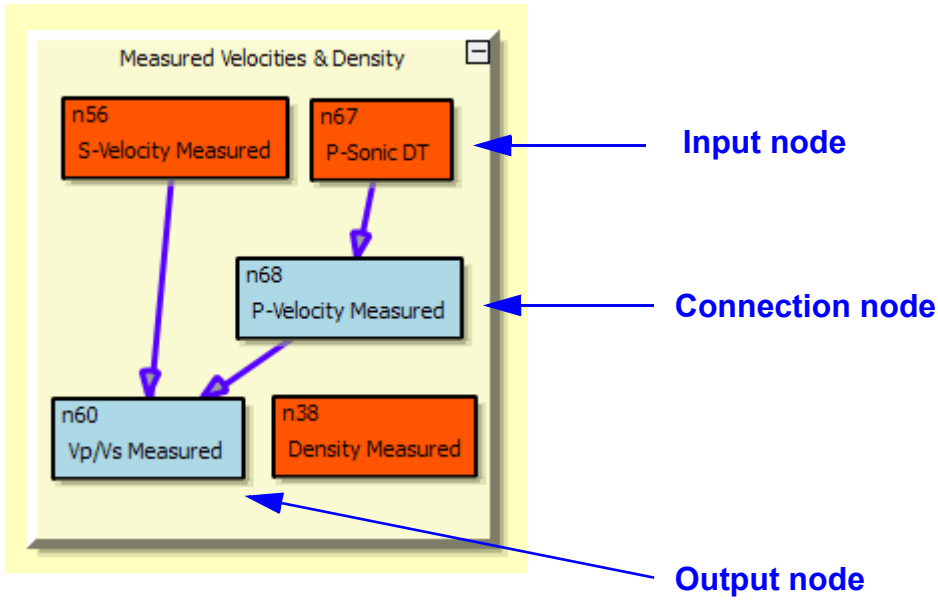
Several nodes within your workflow are classified as *input nodes*, that is, nodes that use PowerLog curve names (or curve aliases), named constants, or values to define an output that can be connected to nodes throughout the workflow.

Input nodes are either a:

- User value
- Named constant from the **Constants** dialog
- Property from the **Rock Fluid Properties** dialog
- Single curve read from the PowerLog well (use the `GetCurve` function to specify the curve as a node input)
- Simple computation using a PowerLog curve and a constant (such as converting a sonic log to a measured velocity representation).

In this example, a group contains the measured velocities and density nodes. The red nodes designate PowerLog curves (DT and RHOC, for example).

Figure 14. Example of different node types



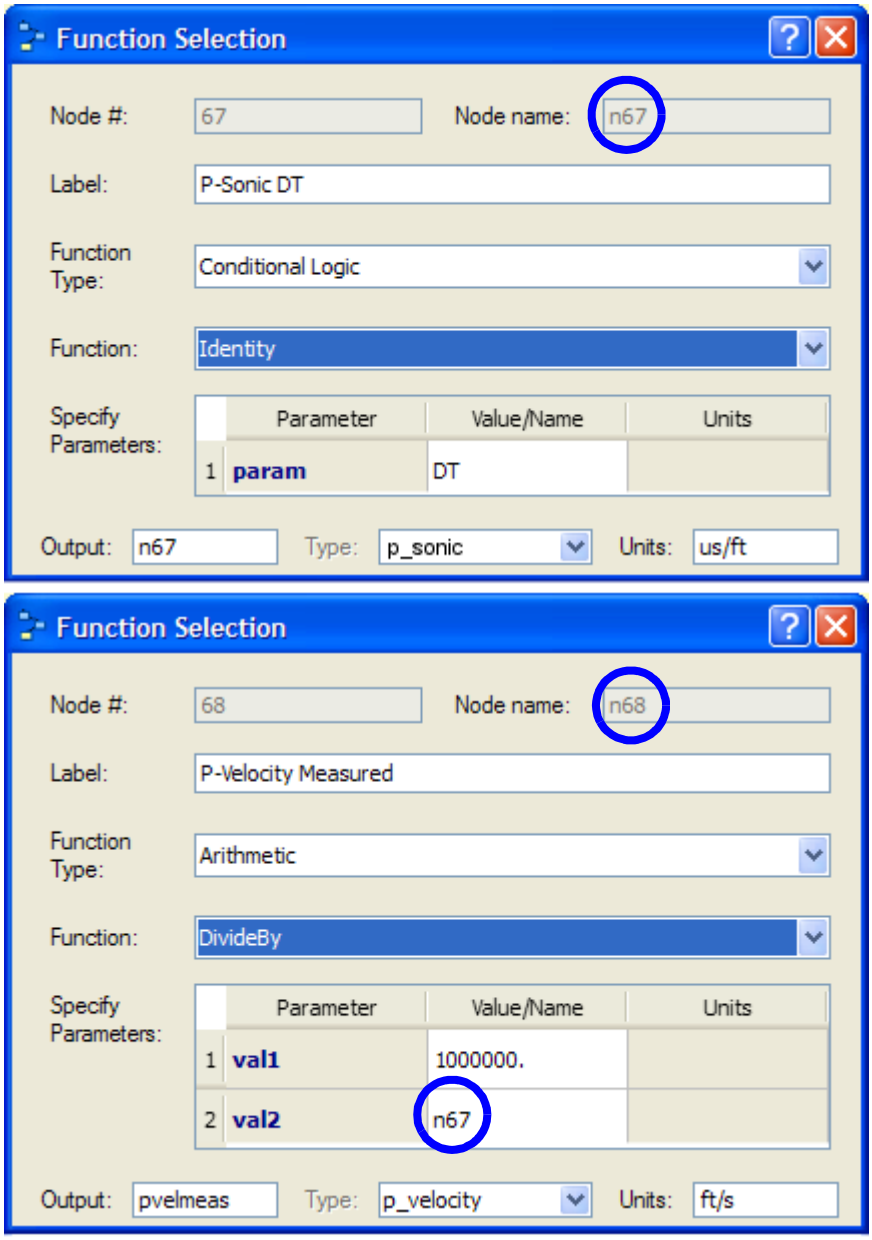
Hint Its an excellent idea to assign one color (for example, red) for input PowerLog curves and another color (green) for the input constants. When you have completed a workflow and it works for a single well, you often use the RPM project with another PowerLog well or PowerLog project. One of your first tasks, when working with another well is to check to see that all required input curves exist for the new well. Next, you might review your defined constants to verify that these values are also appropriate for this project.

Note Input nodes *are not required* for your workflows. However, using this organizational method helps you move your RPM projects from one PowerLog project well to another. Additionally, the data flow is more clearly expressed using the input nodes.

Connecting nodes

In RPM for PowerLog, when you define the output of a node as the input to another node, the software shows this relationship with an arrow (for example, see nodes `n67` and `n68` in **Figure: 14, 'Example of different node types", on page 30**). A connection between the example nodes is established when you used `n67` as an input parameter to the calculation in `n68` in **Figure: 15, 'Creating a connection between nodes"**.

Figure 15. Creating a connection between nodes



Creating an output

An output node is the final node of a branch in the workflow. In **Figure: 15, 'Creating a connection between nodes", on page 31**, the output of node **`n68`** provides the measured acoustic velocity. This log is stored in PowerLog with the well curve name **`pvelmeas`** and compared against the modelled acoustic velocity. A created node output can be used by any number of other workflow nodes.

Calculation types

During the development of your rock physics model you can test all or portions of your workflow:

- **Node**
- **Path**
- **Group**
- **Workflow (all nodes)**

At any selected node in the workflow, you can right-click (MB3) and choose the appropriate option under the **Calculate** command. Results always display in the **Output Log** and the status bar (see **"Output Log and status bar" on page 35**).

Node

Often you want to test only the currently selected node in your workflow. Right-click and use the **Calculate > Calculate Node** shortcut command.

Path

When you need to see how one calculation affects descendent nodes (later calculations), you can select a path (use the **View > Select Path** command to select the start and end path nodes). Right-click and use the **Calculate > Calculate Path** shortcut command to generate results.

Group

This RPM calculation option takes each node in a named group and performs the function calculations. Usually one of the group nodes produces an intermediate or final workflow result. Select a group, right-click, and use the **Calculate > Calculate Group** shortcut command to focus on this section of the workflow.

Workflow (all nodes)

This RPM calculation option goes through all the workflow nodes sequentially performing each defined calculation. You can use the menu **Calculate > Calculate Workflow** command, right-click in any open workspace area (no node, group, or connection) and use the **Calculate > Calculate Workflow** shortcut command, or press **[F8].**

Results quality control

Whenever you run a calculation on part of a workflow (node, path, group) or the entire workflow, calculation results and error messages are stored. You can see errors and results for each node using the **Output Log** dialog and the status bar. The results a from each node are displayed in the status bar when you position your cursor over the node. If the message says the node is undefined, the calculation encountered an error.

Help building your workflow

Throughout the RPM for PowerLog user interface, you have access to all the assistance and documentation needed to successfully build a robust rock model with your workflow. While the entire RPM user interface helps you construct the workflow, these items provide you more guidance as you add additional complexity and test the workflow.

To effectively build rock physics models, use:

- **Documentation**
- **Function Help buttons**
- **Shortcut menus**
- **Right-click selection lists**
- **Node tool tips**
- **Output Log and status bar**

Documentation

The ***RPM for PowerLog — User Guide*** (currently reading) covers (**1**) key RPM concepts, (**2**) user procedures needed to build and test your workflows, (**3**) the RPM user interface that helps you implement the workflow procedures, and (**4**) descriptions of tutorial workflows you can use as examples to develop your own models.

The ***RPM for PowerLog — Getting Started Guide*** helps you install the RPM for PowerLog software and access your first RPM project. This document contains some common questions asked by users and some best practices (recommendations) for creating robust workflows. Additionally, if you want Fugro-Jason to add some key functionality, before you submit an enhancement request, please look over the list of functionality we are adding during 2006.

The ***RPM for PowerLog — Function Reference Guide*** provides a comprehensive reference for all the basic and rock physics functions available in the RPM for PowerLog software. It contains a complete reference of all rock physics functions (including examples, developer commentary, and literature citations).

Function Help buttons

When you are editing a node (**Function Selection** dialog) you can click **Help** to display specific information about the currently selected function. Clicking **Help** displays the function reference material in an Internet browser window.

Once the function reference displays, you can:

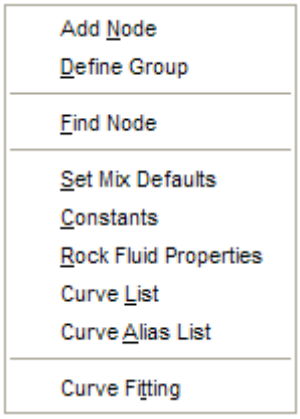
- Minimize, resize, or maximize the browser window
- Adjust the text size to your preference
- Click on related links to see reference material about other RPM functions
- Jump to the Help table of contents or index to explore information about all the RPM functions

Shortcut menus

In the RPM for PowerLog user interface, there are four context-sensitive shortcut menus that display whenever you select the object and right-click (MB3) the mouse:

- **Node shortcut menu**—select any node to perform these functions.
- **Connection shortcut menu**—select any connection to customize its color.
- **Group shortcut menu**—select any group to perform these functions.
- **Workflow shortcut menu**—right-click anywhere in the workspace that does not have a node, group, or connection to display this shortcut menu.

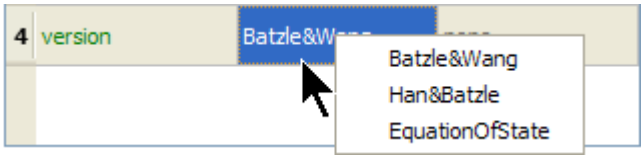
Figure 16. Workflow shortcut menu



Right-click selection lists

In some of the RPM dialogs, you must select an input type, an input curve, an algorithm, or a node number. You can right-click (MB3) on some **Value/Name** cells and a selection list displays appropriate values.

Figure 17. Example of a right-click selection list



Other examples shown in the *RPM Concepts* section include:

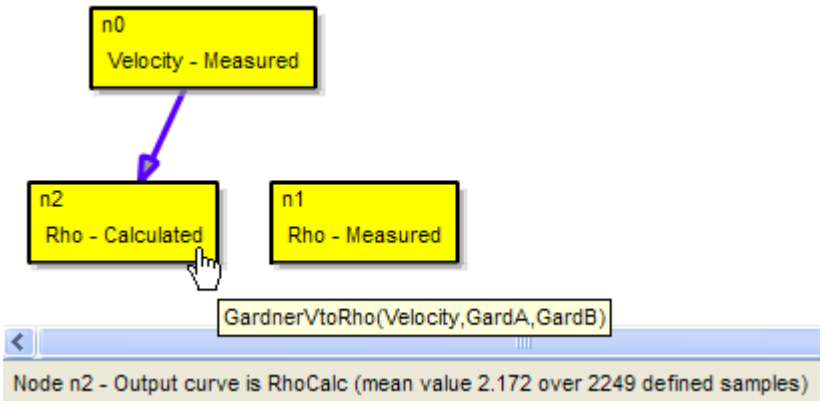
- **Figure: 8, ‘Input parameter selection types”, on page 24**.
- **Figure: 9, ‘Example node list of acceptable inputs”, on page 25**.
- **Figure: 10, ‘Example curve list”, on page 25**.

Node tool tips

At any time during the workflow construction, you can place the mouse cursor over a node and a brief function description displays in the tool tip (small pop-up text).

Figure: 18, ‘Tool tip and status bar example”, on page 35 illustrates a function tool tip and the status bar showing the results of the node calculation.

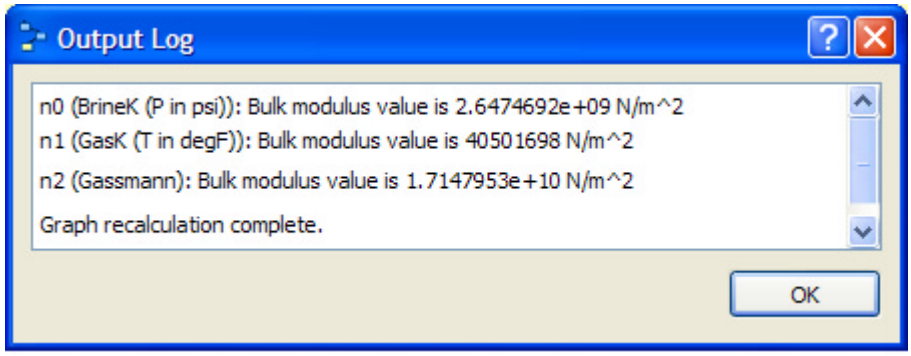
Figure 18. Tool tip and status bar example



Output Log and status bar

After you have performed calculations for a portion or the entire workflow, you can place the cursor over each node involved and see a result or an error message in the status bar. The **Output Log** lists all the messages created during the calculation for a node, a path, a group, or an entire workflow.

Figure 19. Output Log example



RPM mixing functions

Currently, you can use the **Set Mix Defaults** dialog and select these minerals for end members 1 and 2:

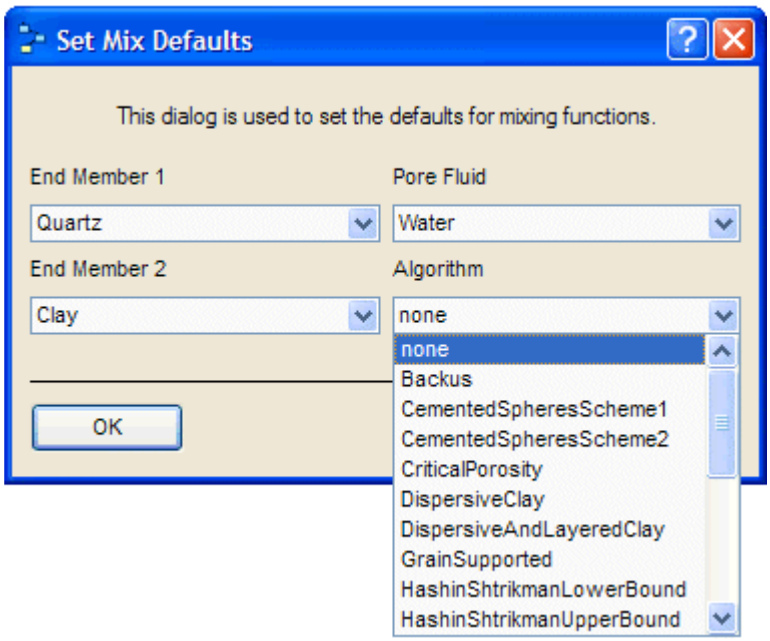
- Anhydrite
- Calcite
- Clay
- Dolomite
- Feldspar
- Quartz

- Pyrite
- Salt
- Siderite

You can select from these pore fluids:

- Brine
- Deadoil
- Gas
- Liveoil
- Water

Figure 20. Set Mix Defaults dialog



Mix algorithms

Currently, RPM provides these mixing algorithms:

- **Backus**
- **Cemented Spheres** Scheme 1 [2]
- **Cemented Spheres** Scheme 2 [2]
- **Critical porosity** [2]
- **Dispersive and layered clay** [2]
- **Dispersive Clay** [2]
- **Grain supported** [2]
- Hashin-Shtrikman Lower Bound
- Hashin-Shtrikman Upper Bound
- Krief-Gurevich-Goldberg
- **Layered clay** [2]

2. These algorithms are valid only for two member mixing.

- **Matrix supported** [2]
- Reuss
- **Self consistent**
- Voigt
- Voigt-Reuss-Hill
- Woods
- **Wyllie**
- **Xu-White**
- **Xu-White Approximation** (fast)

Notes for mixing algorithms

All of these algorithms, except the Critical Porosity and Cemented Spheres Schemes, start from the Kuster-Toksöz theory **[20]** to account for the effect of mixing in pores with a given height-width (α) pore aspect ratio. The algorithms assume material isotropy, that is directional uniformity in the material, such that physical properties do not vary in different directions. In all cases, Gassmann's method **[24]** is used to fill empty pores with fluid, assuming low acoustic frequencies. When more than two rock members are present, the methods can be applied iteratively to any desired level of rock complexity.

Note All algorithms need a porosity log and a lithology fraction log.

Note Values for original and critical porosity should range between 0 and 0.9.

Backus

This algorithm is a combination of harmonic and simple averages.

Caution! Not suitable for low clay fractions (lower than 10%).

Cemented Spheres

[Scheme 1 or 2] This algorithm models sandstones consisting of spheres (quartz) with cement (clay) at the grain contacts. The cement is deposited only at the grain contacts (scheme #1) or evenly distributed around the grains (scheme #2). Extending the original model to larger clay fractions, excess clay is modeled as an additional layer and added to the sand using Backus averaging. The porosity is attributed to the first component (usually sand) only. In other words, "wet clay" is assumed as cement. [3] **[13]**

Critical porosity

This algorithm is based on the observation that rock properties exhibit transitions when the porosity increases beyond a certain *critical porosity*, that is, when the rock goes from consolidated to unconsolidated. It implements a Voigt-based critical porosity model, using a non-critical averaging to incorporate the sand and shale mixing. It is an approximation to the Xu-White model, but significantly faster computationally. This method makes for an excellent quick-look analysis. [4] **[29]** **[24]**

Dispersive and layered clay

This method is based upon the Dispersive Clay model described, except that the excess clay is modeled as a *solid* layer and added to the sand using Backus

3. These algorithms require rock parameter values be supplied for original porosity.
4. This algorithm requires rock parameter values for critical porosity for the sandy rock and the shaley rock.

averaging. All porosity is attributed to the *sand* component only, that is, the clay is assumed to be “wet clay.” [3]

Dispersive Clay

This algorithm assumes the primary medium (sand) had the original porosity partially filled with the second medium (clay). The pore space insertion is also done iteratively. [3] [32]

Caution! Suitable for low clay fractions (<10%) and porosities lower than the original porosity.

Grain supported

In this model, spherical clay inclusions are inserted into the quartz mineral. Then the pores are introduced in the mixture. [32]

Caution! Not suitable for high clay fractions (greater than 80%).

Layered clay

This algorithm calculates the elastic properties of a medium consisting of layers of the two members. (The default minerals are sand and shale.) The fluid is included in the layers with the approximate Xu-White method. For the estimation of the effective properties of the layered medium, the Backus filtering is used.

Matrix supported

For this model, spherical quartz inclusions are introduced into the clay. Then pores are introduced into the mixture. [32]

Caution! Not suitable for low clay fractions (lower than 10%).

Self consistent

Similar to the Xu and White algorithm, this method uses Berryman’s self-consistent technique, rather than the Differential Effective Medium (DEM) method. [32] [4]

Note This method is better than Xu and White where the porosity exceeds 30%.

Wyllie

This algorithm calculates the mix properties assuming a simple volumetric average of velocities.

Xu-White

This algorithm mixes the two rock members volumetrically, while iteratively inserting pore space. The pore space is inserted iteratively using the Differential Effective Medium method, based on the relations by Kuster and Toksöz [20].

No assumptions are made about the structure of the mixture of the two rock members: a generic averaging is used (the time-average model). Consequently, it is not *a priori* limited to a particular member fraction range. However, that also means that the results may be less accurate for certain very specific mixture structures.[39]

Caution! The Xu and White approximation is less suited for very high porosities (30% or higher).

Xu-White Approximation

A non-iterative approximation to the original Xu-White model, using the approach of Keys and Xu. This model is the default algorithm and selected when the **Figure: 20, ‘Set Mix Defaults dialog”, on page 36** first displays. [18]

Curve Fitting

To be added in July.

RPM related publications

Table 4. Selected RPM Publications

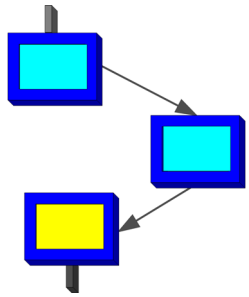
Document title	
[1]	Avseth, P., Mukerji, T. and Mavko, G. (**2005**) *Quantitative Seismic Interpretation: Applying Rock Physics Tools to Reduce Interpretation Risk*, Cambridge University Press, ISBN 0521816017, 376_pages.
[2]	Baldwin, J. (**2006**) Petrophysics/Rock Physics Integration: PowerLog and RPM Log Modeling. RPM Rollout-July, *Fugro-Jason Internal Communication*, PowerPoint Presentation.
[3]	Batzle, M.N. and Wang, Z. (**1992**) *Seismic properties of pore fluids*: Geophysics, **57**, pages 1396-1408.
[4]	Berryman, J. G. (**1992**) *Journal of Acoustic Society of America* 68 (1980) pages 1809-1831 [reprinted in *Seismic and Acoustic Velocities in Reservoir Rocks*, volume 2, Z. Wang and A. Nur (editors), Society of Exploration Geophysics (SEG), Geophysics reprint series, No. 10.]
[5]	Berryman, J. and Milton, G. (**1991**) Exact results for generalized Gassmann's equations in composite porous media with two constituents. *Geophysics*, Volume **56**, Issue **12**, pages 1950-1960.
[6]	Brie, A., et al. (**1995**) Shear sonic interpretation in gas-bearing sands, *SPE* 30595, pages 701-710.
[7]	Carcione, J.M. and Helle, H.B. (**2002**) Rock Physics of Geopressure and Prediction of Abnormal Pore Fluid Pressures Using Seismic Data. *CSG Recorder*, September 2002, pages 9-32.
[8]	Castagna, J.P., Batzle, M.L., and Eastwood, R.L. (**1985**) Relationships between compressional-wave and shear-wave velocities in clastic silicate rocks. *Geophysics*, Volume **50**, Issue **4**, pages 571-581.
[9]	Castagna, J.P. and Smith, S.W. (**1994**) Comparison of AVO indicators: a modeling study, Geophysics, volume 59, paages 1849-1855.
[10]	Chen, Q. and Nur, A. (**1994**) Critical concentration models for porous material. Corapcioglu, M.Y. (Editor), *Advances in Porous Media* (Vol. **2**), Elsevier, pages 169-308.
[11]	Chopra, S. et al. (**2004**) Integrated Reservoir Characterisation - a successful interdisciplinary working model. *CSEG National Convention* paper.
[12]	Dvorkin, J., Moos, D., Packwood, J.L., and Nur, A. (**1999**) Identifying patchy saturation from well logs, *Geophysics*, volume **64**, number **6**, pages 1756-1759.
[13]	Dvorkin, J. and Nur, A. (**1996**) Elasticity of high-porosity sandstones: Theory of two North Sea data sets: *Geophysics* **61**, pages 1363-1370.

Table 4. Selected RPM Publications (Continued)

Document title	
[14]	Goldberg, I. and Gurevich, B. (**1998**) A semi-empirical velocity-porosity-clay model for petrophysical interpretation of P- and S-velocity. *Geophysical Prospecting* **46**, pages 271-285.
[15]	Goodway W., Chen, T. and Downton, J. (**1997**) Improved AVO fluid detection and lithology determination using Lamé parameters, $\lambda\rho$, $\mu\rho$, and λ/μ fluid stack from P and S inversions, *CSEG National Convention Expanded Abstracts*, pages 148-151.
[16]	Goodway, W. (**2001**) AVO and Lamé constants for rock parameterization and fluid detection. CSEG Recorder, June 2001, pages 39-60.
[17]	Greenberg, M.L. and Castagna, J.P. (**2000**) *Geophysical Prospecting* **40** (1992) pages 195-209. [reprinted in *Seismic and Acoustic Velocities in Reservoir Rocks*, volume 3, Z. Wang and A. Nur (editors), Society of Exploration Geophysics (SEG), Geophysics reprint series, No. 19 (2000) pages 402-416]
[18]	Keys and Xu, S. (**2000**) *SEG 2000 Proceedings*, paper RPB 6.2, page 1830.
[19]	Kumar, Dhananjay. (**2006**) A Tutorial on Gassmann Fluid Substitution: Formulation, Algorithm, and Matlab Code. *Geohorizons*, January 2006. pages 4-12.
[20]	Kuster, G.T. and Toksöz, M.N. (**1992**) *Geophysics* **39** (1974) pages 587-618 [reprinted in *Seismic and Acoustic Velocities in Reservoir Rocks*, volume 2, Z. Wang and A. Nur (editors), Society of Exploration Geophysics (SEG), Geophysics reprint series, No. 10]
[21]	Marion, D. and Nur, A.. (**1992**) Pore-filling material and its effect on velocity in rocks. *Geophysics*, Vol **56**, #2, pages 225-230.
[22]	Mavko, G. Chan, C. and Mukerji, T. (**1995**) Fluid substitution: Estimating changes in V_p without knowing V_s: *Geophysics* **60**, pages 1750-1755.
[23]	Mavko, G., Katahara, K., and Smith, T. (**2005**) Expert Answers, *CSG Recorder*, May 2005, pages 8-12.
[24]	Mavko, G., Mukerji, T. and Dvorkin, J. (**2003**) *The Rock Physics Handbook: Tools for Seismic Analysis of Porous Media*, Cambridge University Press, Second Edition, ISBN 0521543444, 339 pages.
[25]	Mavko,G., Mukerji, T., and Dvorkin, J. (**1998**) *The Rock Physics Handbook*: Cambridge University Press, section 7.8.
[26]	Mavko, G. and Mukerji, T. (**1995**) Seismic pore compressibility and Gassmann's relation. *Society for Exploration Geophysicists*, Volume 60, No. 6, pages 1743-1749.
[27]	Mavko, G. and Mukerji, T. (**1995**) Fluid substitution: Estimating changes in V_P without knowing V_S. *Society for Exploration Geophysicists*, Volume 60, No. 6, pages 1750-1755.
[28]	Mukerji, T. and Mavko, G. (**2006**) Recent Advances in Rock Physics and Fluid Substitution. *CSEG Recorder*, 2006 Special Edition, pages 123-127.
[29]	Nur, A., Mavko, G., and Dvorkin, J. (**1998**) Critical Porosity, *The Leading Edge*, vol.**17**, no.**3**, pages 357-362.
[30]	Russell, B.H., Hedlin, K., Hilterman, F. and Lines, L.R. (**2001**) Fluid-property discrimination with AVO: A Biot-Gassmann perspective. *CREWES Research Report*, Volume 13, pages 403-419.

Table 4. Selected RPM Publications (Continued)

Document title	
[31]	Sams, M. (**2006**) Reservoir Engineering vs. Seismic Inversion. RPM Rollout-July, *Fugro-Jason Internal Communication*, PowerPoint Presentation.
[32]	Sams, M. and Andrea, M. (**2001**) *Geophysical Prospecting* 49, pages 128-150.
[33]	*Schlumberger Educational Services*. (**1989**) Log Interpretation Principles/Applications.
[34]	Schmidt, D. and Barnett, M. (**2005**) PowerLog 2.61 Online User's Guide - Project, well, curve management, and presentation displays. *Petcom, Inc.*, version 2.61.
[35]	Smith, G.C. and Gidlow, M. A comparison of the fluid factor with λ and μ in AVO analysis. (**2000**) ann. Int. Mtg., *SEG*. Expanded Abstracts, pages 122-125.
[36]	Thomsen, L. (**1986**) Weak elastic anisotropy: *Geophysics*, 51, 1986, pages 1954-1966.
[37]	Walls, J. D., Dvorkin, J. and Smith, B.A. (**1998**) Modeling Seismic Velocity in the Ekofisk Chalk, *Society for Exploration Geophysics*, 68th Annual International Meeting, pages 1016-1019.
[38]	White, R. and Xu, S. (**2000**) *Geophysical Prospecting* 43 (1995) page 91. and erratum in *Geophysical Prospecting* **48**, page 629.
[39]	Xu, S. and White, R.E. (**1995**) A new velocity model for clay-sand mixtures: *Geophysical Prospecting* **43**, pages 91-118. White, R.E., Simm, R. and Xu, S. (**1998**) *Geophysical Prospecting* **46**, page 323. Xu, S., Doorenbos, J., Raikes, S. and White, R. (**1997**) *Developments in Petrophysics*, edited by M.A. Lovell and P.K. Harvey, Geological Society London, Special publication 122, page 87.



PLANNING WORKFLOWS

RPM functionality

Command methods

You can select commands in the RPM for PowerLog software by using:

- Menus (below title bar)
- Right-click (MB3) shortcut menus
- Tool bar icons
- Keyboard shortcut keys

Command examples

RPM for PowerLog can perform all the calculations for an entire workflow. You can start this command using the four different techniques:

- **Menu**—Select the **Calculate > Calculate Workflow** command.
- **Shortcut menu**—Select a node, right-click (MB3), and select the **Calculate > Calculate Workflow** command.
- **Tool bar icon**—click the  icon.
- **Keyboard shortcut**—press the `[F8]` key.

Procedure convention

Throughout the next three sections, only the *Menu* method is described for each step-by-step user procedure. Consult the **"RPM User Interface" on page 119** the other methods (shortcut menus, toolbar icons, and keyboard shortcuts) you can use to invoke each RPM command.

To see a complete reference of all RPM user interface commands, go to the *RPM PowerLog at a Glance*.

Managing RPM projects

RPM for PowerLog is a calculation engine for implementing rock physics model computations. To display your input and resulting well curves for the best possible presentation, you use the PowerLog application. PowerLog contains many graphic views [log plots—with formation tops, histograms, cross plots, and cross-section collages] that automatically update (version 2.7 or greater) whenever your curves are updated with RPM and PowerLog calculations.

Relationship between PowerLog and RPM projects

PowerLog organizes a collection of wells into a single exploration project that you would use for petrophysical analysis or perform rock physics modeling with the RPM for PowerLog add-on software. Each well is a set of recorded well curves and supporting identification information.

RPM projects can be created whenever a user wants to build a workflow. While an RPM workflow is created with an initial PowerLog project and well, the RPM project *is not* constrained to any specific PowerLog well. A workflow only needs the required input PowerLog curves to operate.

Starting PowerLog

Before you can start the RPM for PowerLog add-on module for the first time, you must:

- Start the PowerLog application
- Select a PowerLog project
- Open at least one PowerLog well

To start PowerLog

1 Start the PowerLog application using the Windows Start menu (**Start > PowerLog > PowerLog** command) or the PowerLog desktop icon. 

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Selecting a PowerLog project and a well

When PowerLog starts, if it does not have a default project and well assigned, select the desired PowerLog project and well.

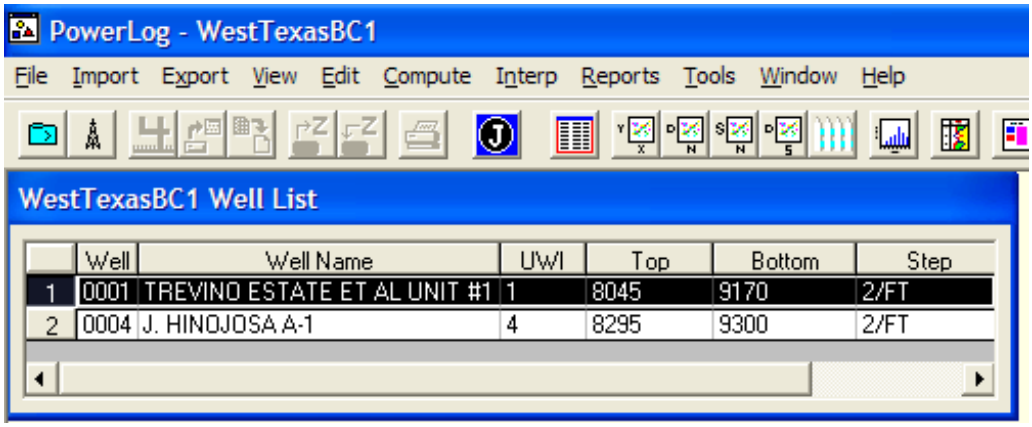
To select a PowerLog project and well

1 Select a PowerLog project using the PowerLog **File > Project > Open** command.

2 Display each well you need by repeatedly using the PowerLog **File > Well > Open** command. The well name, depth range, and sample interval display in a list similar to **Figure: 21, 'PowerLog window project title and <project name> Well List"**.

3 Select a single well from the project well list. You can now start RPM for PowerLog.

Figure 21. PowerLog window project title and <project name> Well List



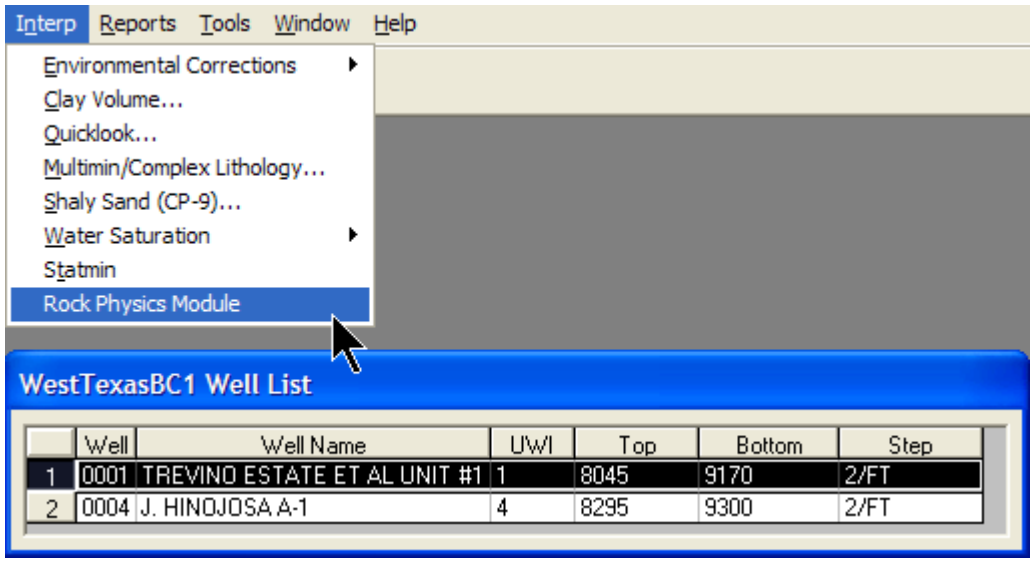
Starting RPM

Once you have (**1**) started PowerLog, (**2**) chosen a PowerLog project, and (**3**) selected a well within the PowerLog project, you can start the RPM for PowerLog software.

To start RPM for PowerLog

1 Using the PowerLog menus, select the **Interp > Rock Physics Module** command. **or** press the `[Alt + N + R]` key combination.

Figure 22. Starting RPM for PowerLog



Note If a PowerLog project and well are not selected and you start the RPM for PowerLog application, a warning dialog displays saying, "`No well selected`."

Adding a new RPM project

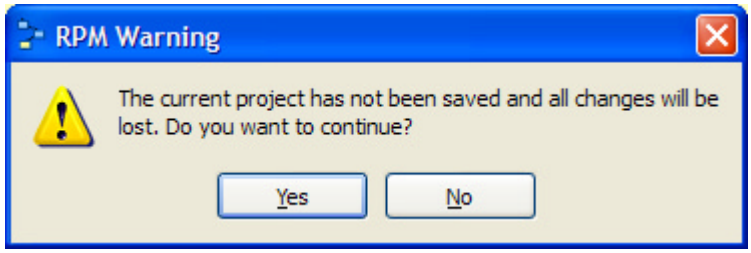
For situations when you need to start a workflow from the beginning, do this.

To add a new RPM project

1 Select the **File > New Project** command. A blank workspace displays.

Note If you made changes to your current RPM project before selecting the **New Project** command, a warning message displays. You can discard the changes (click **Yes**) or save the changes (click **No** and use the **Save Project** command).

Figure 23. New RPM project warning message



Using an existing RPM project

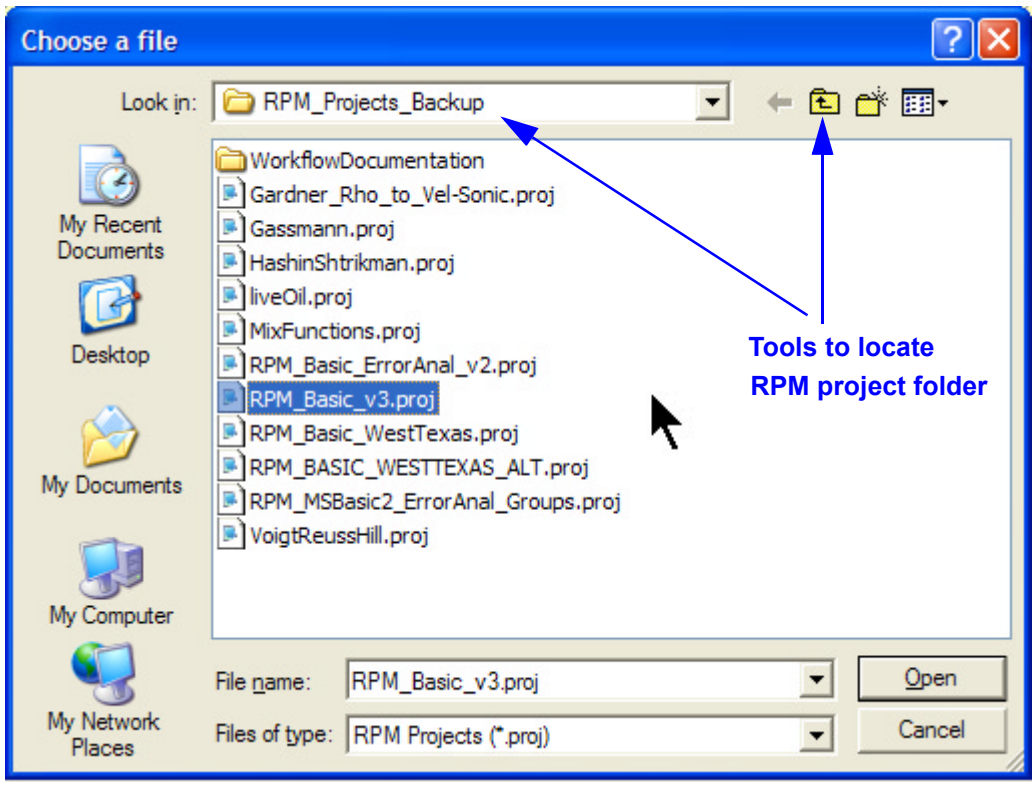
To start your work with an existing RPM project file, use this procedure.

To open an RPM project

1 Select the **File > Open Project** command.

2 When the **Choose a file** window displays, use the **Look in** drop-down selection list and the parent directory icon to move to your file folder containing the RPM projects. Use the **Look in** selection list to navigate within your local PC or mapped network drives containing file folders.

Figure 24. Choose a file window



3 Select the RPM project file name (`*.proj` file extension) in the desired folder. It displays in the **File name** text box.

4 Click **Open** to begin using this RPM project.

Saving your RPM project

As you develop your workflow, you want to save each major addition to your rock physics model.

To save your current RPM project

1 Select the **File > Save Project** command.

2 If your RPM project has not been saved, the **Save Project As** window displays and you follow the **"Backup your RPM project" on page 46** procedure, beginning at Step 2.

Otherwise, the message `Project Saved` displays in the status bar after your RPM project is saved. For more information about actual RPM project files, refer to the ***RPM for PowerLog — Getting Started Guide***.

Storing your RPM project workflows

RPM for PowerLog always remembers the last file directory you used to store an RPM for PowerLog project. Additionally, the software keeps a list of where you stored your last five RPM projects.

While RPM provides no constraints on where to store your workflow projects, you may want to consider:

- **General Workflows**—store these RPM projects in a common directory. Treat these RPM workflows similar to word-processing templates, starting points for developing other custom models.
- **Project Workflows**—store these RPM projects in the same file as your PowerLog wells, since these workflows may require specific input curves to perform the calculations successfully.

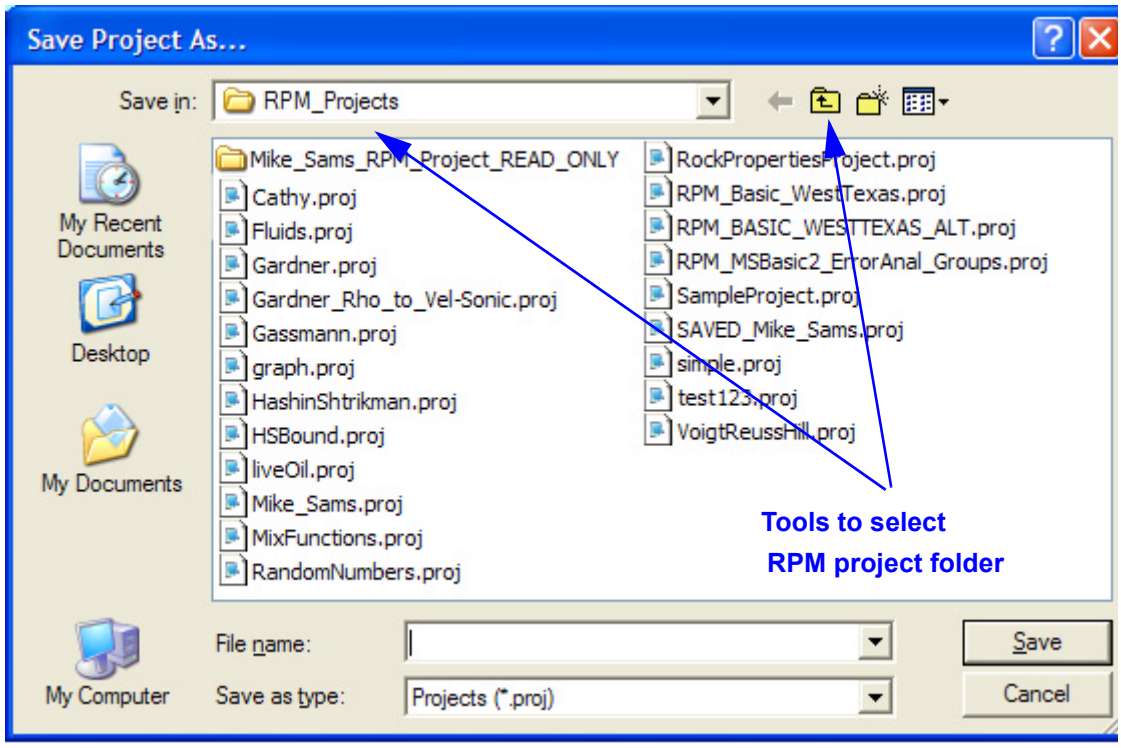
Backup your RPM project

Sometimes you need to save a copy of your workflow as a backup copy or to use this workflow with another well and make slight modifications.

To save the current RPM project under another name

1. Select the **File > Save Project As** command.
2. When the **Save Project As** dialog displays, you can navigate to another folder or create a new folder using the **Save in** drop-down selection list and the parent directory icon.

Figure 25. Save Project As dialog



3 In the **File name** text box, type the project name under which you want to save your information.

4 Click **OK**. Upon completion, the message `Project Saved` displays in the status bar.

Caution! When you use the **Save Project As** command, RPM for PowerLog continues working with *this* RPM project name as its *current* project.

Exiting RPM for PowerLog

To stop the RPM for PowerLog software

1 Select the **File > Exit** command. If all changes to the current RPM workflow are not saved, a Project Save Confirmation dialog displays.

2 Click **Yes** to save your changes. Click **No** to discard all changes made since you saved this RPM project with the **Save Project** or **Save Project as** commands.

Planning a workflow

Prior to developing your workflow, you may want to perform some preliminary steps to ensure that you have all the required rock model components. You can always perform any of these steps while building the workflow; however, focusing on these issues early in the workflow development can make your workflows easier to use.

Some issues to consider prior to constructing the workflow:

- **Determining workflow input curves**
- **Creating named constants**
- **Preparing Mix defaults**
- **Organizing Rock, Mineral, Fluid, and Gas Properties**
- **Setting up input curve and constant nodes**

Determining workflow input curves

Use PowerLog to display key input curves

PowerLog's presentation modules can help you create logplots and crossplots for one or more of your wells used with your RPM workflow. Use the logplots to quickly identify if any curves still need borehole or environmental corrections. Also, use the logplots to understand if substantial sections of your curves have undefined (`UNDEF`) values.

For additional information about using PowerLog's presentation modules

1. In the PowerLog application, press `[F1]` to display the PowerLog help table of contents.
2. Double-click the **Presentation** book icon to reveal more help topics.
3. Read the **Presentation Overview** topic.
4. Double-click the **Logplots** book icon and scan these topics:
   - Logplot Overview
   - Format Dialog Box
   - Default Curve Attributes
5. Double-click the **Crossplots** book icon and examine these topics:
   - Overview
   - Format
   - Discriminators
   - Grid and Label Options
   - Z-Axis Colors
   - Density Crossplots

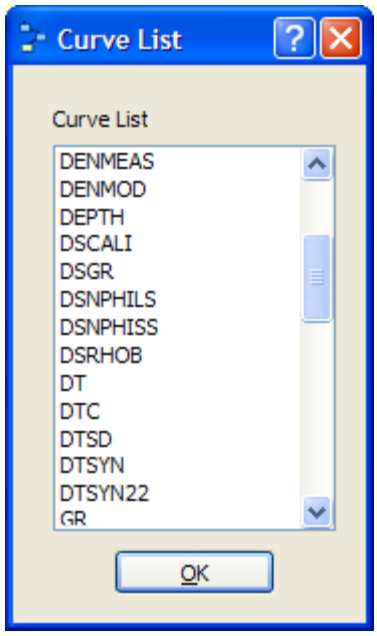
Displaying curves list

Once you add or begin using an RPM project, you can display all the curve names found in the currently selected PowerLog project well.

To display the RPM list of well curve names

1. Select the **Data > Curve** list command.
2. Once the **Curve List** window displays, note the curve names you need as inputs to your workflow.
3. Click **OK**. The **Curve List** window closes.

Figure 26. Curve List window (example well)



Displaying alias curve names

For workflows that you want to use across several wells, you may need to create one or more curve alias names to access all curve names needed for a specific workflow.

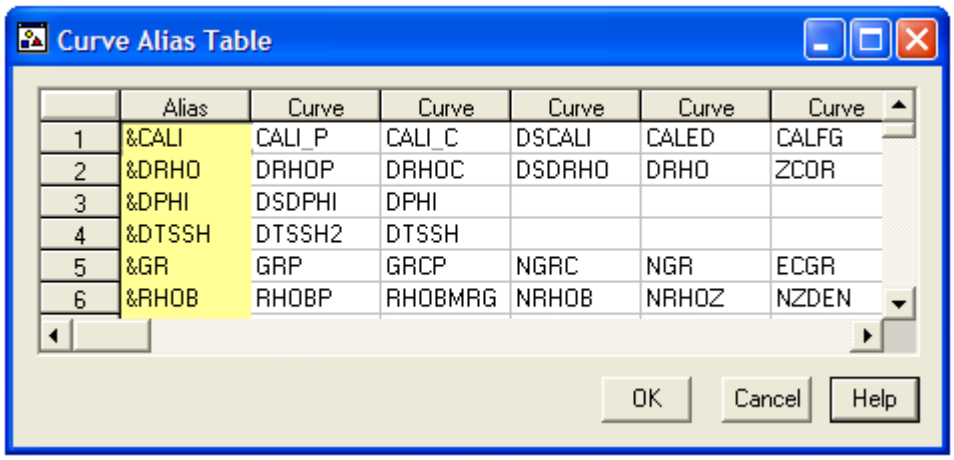
Example The gamma ray curve needed for workflow calculations to separate sands and shales may have several different names in the wells you want your workflow to access. Figure: 27, 'PowerLog Curve Alias Table", on page 50 shows an example of how gamma ray curve aliases could be defined in PowerLog. Example curve names in several wells could be **GRP**, **GRCP**, **NGRC**, **NGR**, and **ECGR** To access each of these curves in the different wells, you need an alias name for your input node.

To assign an alias name in PowerLog to several curve names

1. Display the **Curve Alias Table** by selecting the **Tools > Curve Alias Table** PowerLog command.
2. In the first yellow column, type the alias name that you want to use in PowerLog (plots) and in the RPM workflows (calculations).
3. Type one or more curve names in the adjacent columns of the same row you typed the curve alias name. You can associate a maximum of 49 curve names.
4. Click **OK.**

The alias resolves the actual curve name by searching from left to right—the first curve available in the well is used.

Figure 27. PowerLog Curve Alias Table



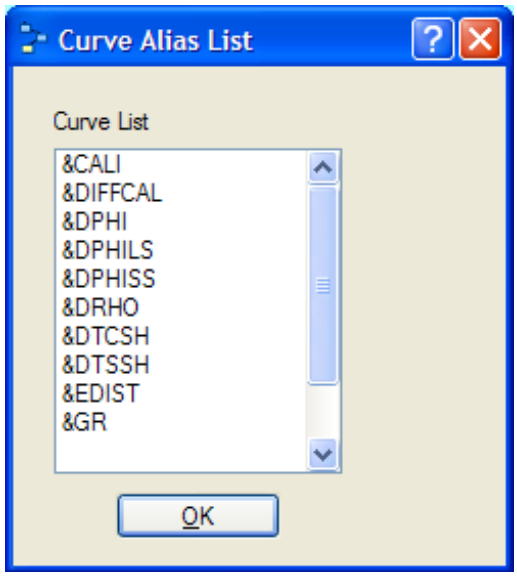
Once you have the alias curve names defined in PowerLog, you can display the alias curve names for your RPM project.

To display an RPM project curve alias list

1 Select the **Data > Curve Alias List** command. The **Curve Alias List** window displays

2 Click **OK**.

Figure 28. Curve Alias List example



Creating named constants

Throughout your RPM for PowerLog workflow, you can use constant values as inputs to node functions. Most node function input parameters allow you to use a named `Constant` input or just type a `UserValue` (for example, 26.5 g/cc). (See **"Node inputs" on page 20**.)

The reasons for using a named constant, include:

- Coefficients for unique mixing functions
- Documenting a constant value in the workflow
- Using the constant in multiple nodes and not retyping the same value

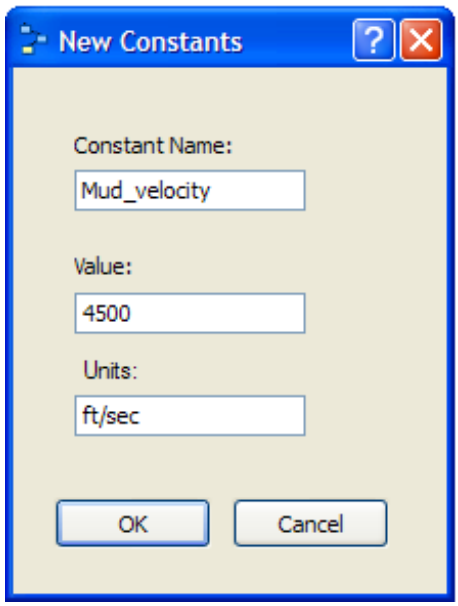
Adding named constants

Whenever you need to define a named constant, use this procedure. Once the constant is defined, you can insert it into any node input parameter that accepts a `Constant`.

To add user-defined named constants

1. Select the **Data > Constants** command.
2. When the **Constant dialog** displays, click **Add**.
3. The **New Constants** dialog displays. Type entries for these fields and click **OK**:
   - **Constant Name** (Names cannot contain spaces) [5]
   - **Value**
   - **Units**

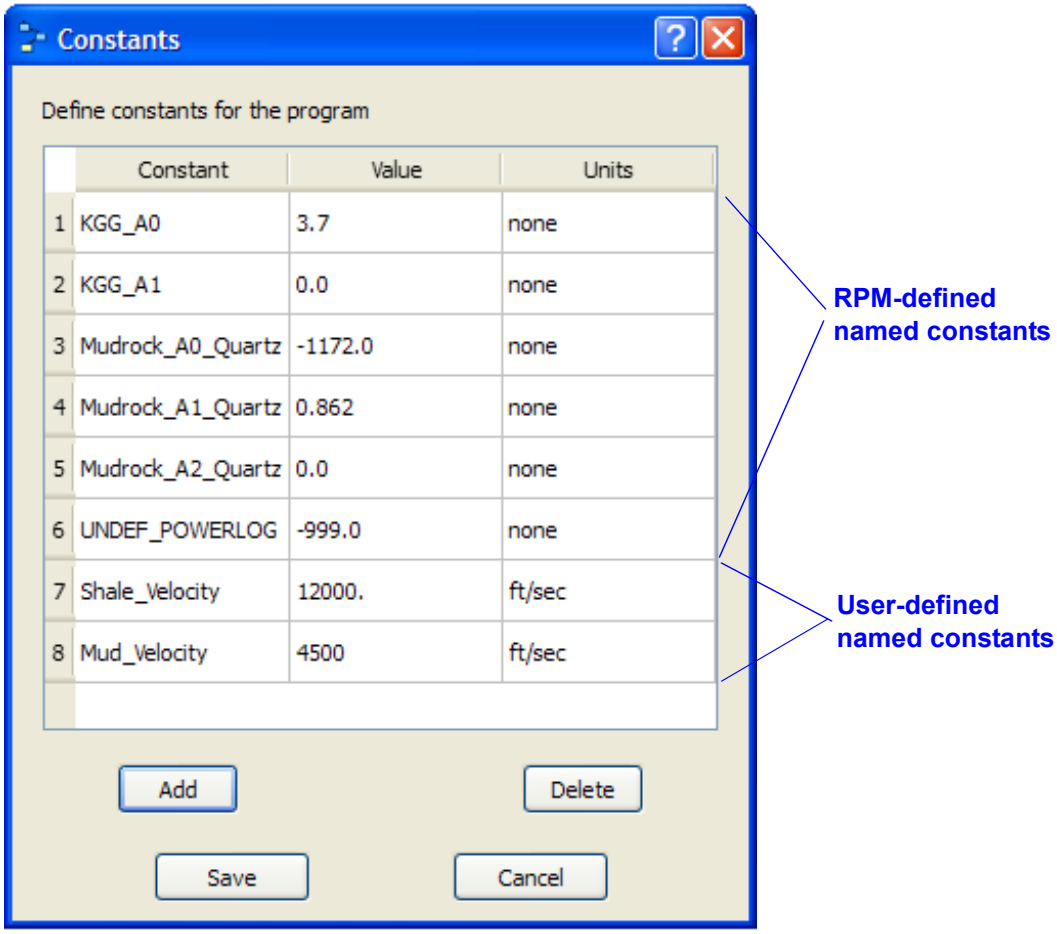
Figure 29. New Constants dialog



4. Repeat steps two and three to define each named constant.
5. Click **Save** to retain the new constants. Click **Cancel** to delete all changes.

5. If you insert a space in a constant name, RPM for PowerLog replaces the space with an underscore character.

Figure 30. New named constants added



Changing named constants

At any time you can modify the values of named constants.

To change named constants

1. Select the **Data > Constants** command (unless the **Constants** dialog is currently displayed).
2. Place your cursor in the **Constant**, **Value**, or **Units** cell of the constant to change.
3. Type your changes. Move the cursor to any other cells for this constant and make other required changes.
4. Repeat steps two and three to continue changing other constants.
5. Click **Save** to apply the changes. Click **Cancel** to disregard all changes.

Deleting named constants

To delete user-defined named constants

1. Select the **Data > Constants** command (unless the **Constants** dialog is already displayed).

2 Select the row in the **Constants** dialog containing the named constant. You can select any cell within the row.

3 Click **Delete**.

4 Repeat steps two and three for each named constant.

5 Click **Save** to delete the selected items. Click **Cancel** to prevent deleting the named constants.

Caution! When you press **Save** and delete one or more constants, a warning message *does not display*.

Caution! When you delete one or more named constants using the **Constants** dialog, any node that uses the deleted name constant(s) produces an undefined calculation message when you perform workflow calculations.

Note You cannot delete an RPM-defined named constant. These RPM objects are protected and an information message displays if you attempt to delete one.

Preparing Mix defaults

The **Set Mix Defaults** dialog provides you the tools to:

- Choose the two minerals that predominate in the reservoir rock
- Select a pore fluid
- Specify the default mixing method or algorithm.

Hint For a complete list of mixing methods and the limitations that accompany each algorithm, see **"RPM mixing functions" on page 35**.

Based on the mixing algorithm selected, key RPM function sets such as **Gassmann**, **Greenberg-Castagna**, and **MixVelocity** (Velocity synthesis) functions may required additional input parameters. Many of these needed mineral properties can be defined using the **Rock and Fluid Properties** dialog. (See **"Organizing Rock, Mineral, Fluid, and Gas Properties" on page 54**.)

Once you make the **Set Mix Default** choices (minerals, pore fluid, and algorithm), the rock, mineral, fluid, or gas Properties defined for the selected end minerals and fluid can act as default input parameters in many of the RPM rock physics functions.

To setup the mix defaults

1 Select the **Data > Set Mix Defaults** menu command.

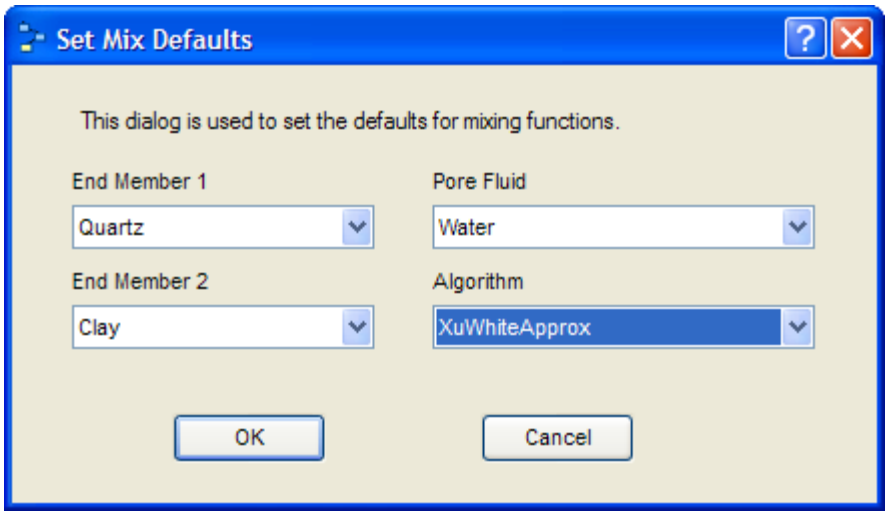
2 Use the **End Mineral 1** and **End Mineral 2** drop-down selection lists to select minerals.

3 Specify the pore fluid using the **Pore Fluid** drop-down selection list.

4 Choose the mixing method with the **Algorithm** drop-down list.

5 Click **OK**.

Figure 31. Set Mix Defaults dialog (mixing function defaults)



Organizing Rock, Mineral, Fluid, and Gas Properties

Structure

RPM for PowerLog comes with an RPM-defined set of rock, mineral, gas, and fluid properties. These RPM-defined rock physics properties can be changed to fit your reservoir geology. However, the RPM-defined set rock, mineral, fluid, and gas names *cannot* be deleted from the RPM software.

All user-defined property sets and values can be saved with the project, so that different geological regions can be customized with different rock physics parameters. Table 5 on page 54 shows the RPM-defined set of rock physics entities available in the RPM for PowerLog software.

All RPM- and user-defined rock physics items are classified as a:

- Rock
- Mineral
- Fluid or Gas

Table 5. RPM-defined rock, mineral, gas, and fluids

Type	RPM-defined rock physics item
Rock	`Anhydriterock`, `Dolomiterock`, `Limestone`, `Mudstone`, `Saltrock`, and `Sandstone`
Mineral	`Anhydrite`, `Calcite`, `Clay`, `Dolomite`, `Feldspar`, `Pyrite`, `Quartz`, `Siderite`, and `Salt`
Fluid or Gas	`Brine`, `Deadoil`, `Gas`, `Liveoil`, and `Water`

Why rock and mineral properties default differently!

RPM for PowerLog handles minerals and rocks, differently, to the extent of using rock property default values differently from mineral property default values. How the defaulting mechanism described in the **"RPM mixing functions" on page 35**, differs for minerals and rocks, requires additional explanation.

RPM makes a distinction between minerals (such as quartz and calcite) and rocks (sandstone and limestone). Properties unsuitable for minerals (such as original porosity `OriginalPorosity)` have values that are initially set as undefined (`UNDEF`). Properties unsuitable for rocks (such as the density, `Rho`, which would imply dependencies on other Properties table parameters such as porosity) have values which are also initially undefined. From **"RPM mixing functions" on page 35**, only property values associated with minerals (not rocks) can be used as an automatic default in an RPM function parameter.

Example If the bulk modulus of a mineral phase is required as input parameter `K_1` in **MixVelocityVp** function and the user does not specify a value, the quantity found in the **Rock and Fluid Properties** for `mineral1.K` is used; as indicated by the tool tip displayed when the cursor hovers over the input field. If `mineral1` is quartz, then the default is `quartz.K`.

Caution! This automatic default value mechanism **does not** apply to rocks. There is no specification of a default rock or rocks, and rock values are not automatically used from the **Rock and Fluid Properties** if the user leaves the input parameter blank for a rock.

Example In **MixVelocityVp**, if the `Orig_Poro1` parameter is blank, it cannot default to `OriginalPorosity` for a rock, such as sandstone, because there is no default rock, and cannot default to `OriginalPorosity` for the default mineral. The user may change the `UNDEF` values for a rock or mineral in the **Rock and Fluid Properties** to specific values, but such property values associated with a rock or mineral are still not used as a default if the user leaves an input field associated with a rock blank (as opposed to a mineral) in a function. Input fields associated with rocks that are left blank default to undefined (`UNDEF`) values. The documentation and the tool tips indicate which input parameters default to undefined values for this reason.

The limitations on automatic defaulting described, do not inhibit your ability to explicitly select a rock or mineral value from the **Rock and Fluid Properties**, rather than entering a numerical value, as a rock input for a function.

Rock and Fluid entity and property names

Names used in rock, mineral, fluid, and gas properties cannot contain blank spaces. A spaces in a name is replaced with underscore (_) character.

Property names belonging to a rock, mineral, fluid, or a gas are *case insensitive*. This means is that all four spellings for the mineral name `Barite` are equivalent and its property name `Shear_Velocity` spellings are equivalent.

See **Table , "Property or constant name variations," on page 56**.

Table 6. Name variations in RPM properties or constants

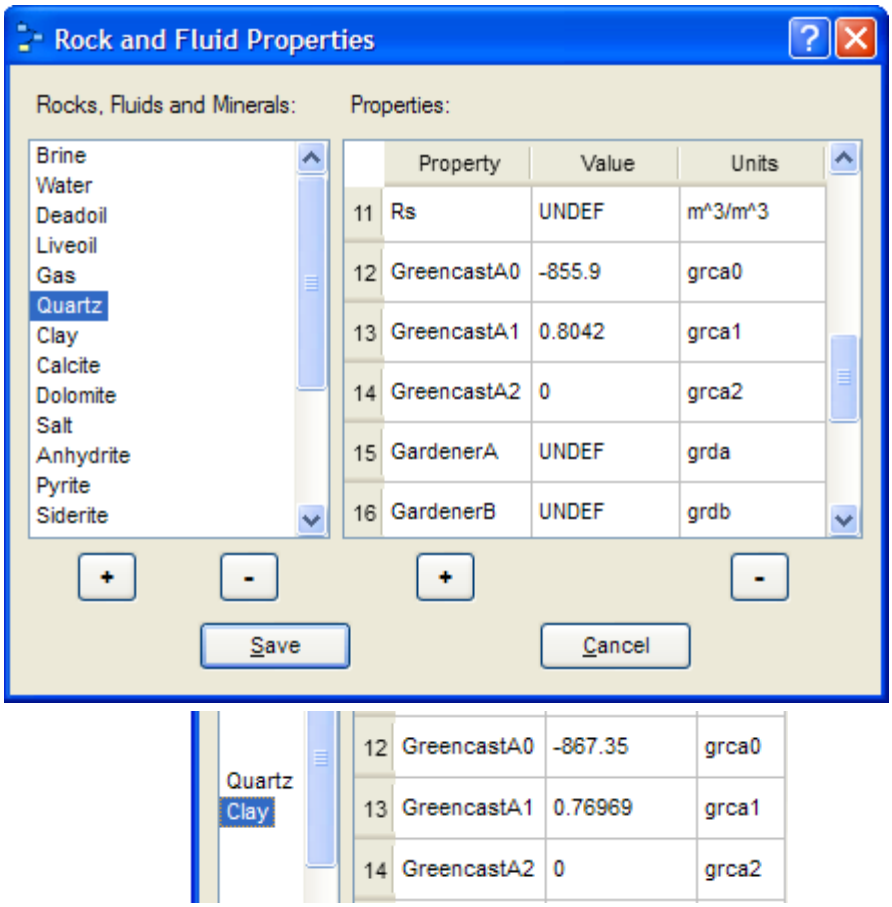
Rock, Mineral, Fluid, or Gas name variations	Property or constant name variations
`Barite`	`Shear_Velocity`
`BARITE`	`SHEAR_VELOCITY`
`barite`	`shear_velocity`
`BARite`	`Shear_velocity`

Rock and Fluid Properties dialog

The **Rock and Fluid Properties** dialog (**Figure: 33, 'Rock and Fluid Properties dialog"**) displays for each rock, mineral, fluid, or gas property, its **Name**, **Defined Value**, and **Units**. Each RPM-defined rock, mineral, fluid, or gas has a complete set of "standard" properties. For user-defined additions to the **Rocks, Fluids and Minerals** list, you can add as few or as many properties as you need.

Example If you needed to set the properties for an RPM function that uses two mineral members (quartz and clay) along with a brine fluid for coefficient correlations, the **Rock and Fluid Properties** dialog might look like this:

Figure 32. Quartz and Clay mineral properties example

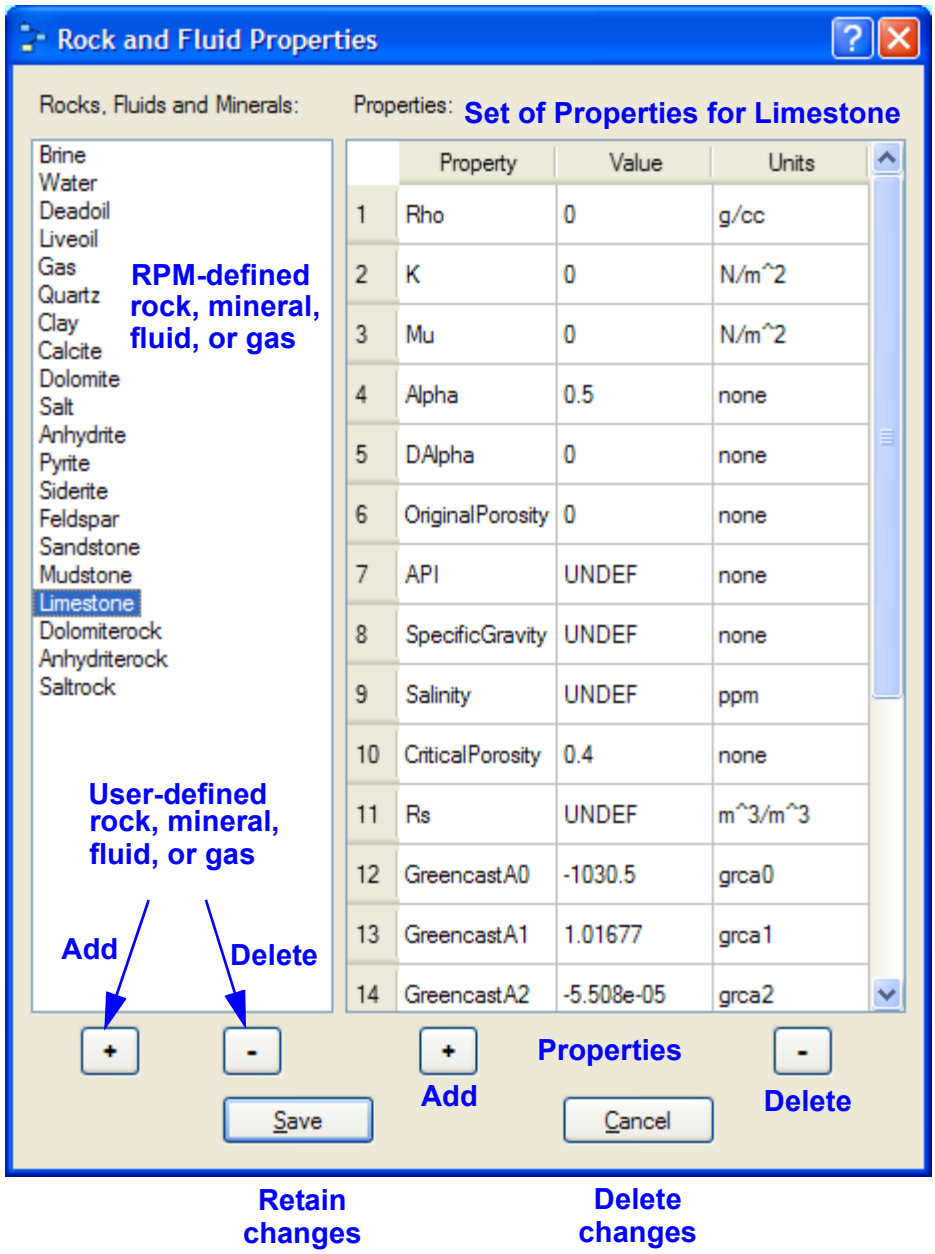


Caution! Since PowerLog expects US units for all of its operations, US units must be used in order to get accurate results. The exceptions are N/m^2 is used bulk and shear moduli and g/cc for density values. All other properties must be expressed in US units.

You can use the **Rock and Fluid Properties** dialog to:

- Add new properties for a RPM-defined rock, mineral, fluid, or gas
- Change values of RPM-defined rock, mineral, fluid, or gas properties
- Add a user-defined rock, mineral, fluid, or gas
- Add, change, or delete user-defined rock, mineral, fluid, or gas properties

Figure 33. Rock and Fluid Properties dialog



Adding a user-defined rock physics entity

In addition to the 20 RPM-defined rock, mineral, fluid, and gases (see Table 5 on page 54), you can define your own rock, mineral, fluid, or gas properties. The properties associated with each item can be used and imported into other workflows that work with similar geology. (See *RPM for PowerLog — Getting Started Guide* for a procedure to import rock, mineral, fluid, and gas properties.

To add a user-defined rock, mineral, fluid, or gas

1 Select the **Data > Rock Fluid Properties** command.

2 When the **Rock and Fluid Properties** dialog displays, click (**+**) under the **Rock, Fluids and Minerals** list.

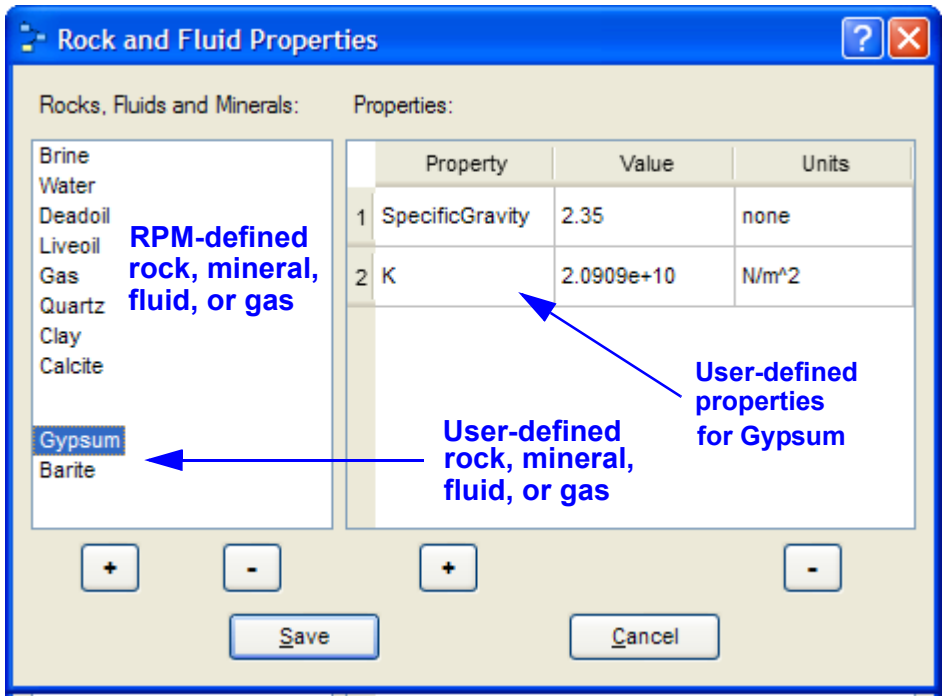
3 Type the new name in the **Rock or Fluid** text box of the **New Rock or Fluid** dialog. For example, **`Halite`**.The name *cannot* contain blank spaces.[6] [7]

4 Select the type from the **Type** drop-down list and click **OK**
- **`Rock`**
- **`Mineral`**
- **`Fluid`** or **`Gas`**

5 Repeat steps two through four for each user-defined rock, mineral, fluid, or gas.

6 Click **Save** to retain all your changes. Click **Cancel** to discard all changes. The new entities display at the bottom of the **Rock, Fluids and Minerals** list. See **Figure: 34, 'New rock, mineral, fluid, or gas and properties added"**.

Figure 34. New rock, mineral, fluid, or gas and properties added



Note When a user-defined rock, mineral, fluid, or gas is added, a default property (name of **`RenameProperty`**) is defined. You can immediately rename the property, add a value, and optionally add the property units.

Adding a property

To add a user-defined property

1 Select the **Data > Rock Fluid Properties** command.

2 When the **Rock and Fluid Properties** dialog displays, click (**+**) under the **Properties** area.

6. If you insert an entity name with a space, RPM for PowerLog replaces the space with an underscore character.
7. Duplicate names cannot be defined as illustrated in **Table 6, "Name variations in RPM properties or constants," on page 56**.

3 When the **New Rock or Fluid Property** dialog displays, type the entries for:
   - **Property Name**
   - **Property value**
   - **Units**
4 Click **OK** to close the New Rock or Fluid Property dialog.
5 Repeat steps two through four for all the properties to add.
6 Click **Save** to retain your new properties in the RPM project file. Click **Cancel** to discard all changes.

Renaming properties

To rename a user-defined property

1 Use the **Data > Rock Fluid Properties** command to display the **New Rock or Fluid Property** dialog.
2 Double-click in the desired property *name* cell under the **Property** column.
3 Change the property name by double-clicking and typing a new name in the cell.[8]
4 Repeat steps two and three for other property names.
5 Click **Save** to retain all your property name revisions. Click **Cancel** to discard all name changes.

Caution! If you have worked with user-defined rock, mineral, fluid, or gas properties in your workflow nodes and changes the names of one or more properties, you *must return to the nodes* where you used the *"old"* names. Right-click in the node input parameters with the "*old*" property name, select `RockProperty`, select the user-defined rock, mineral, fluid, or gas, and substitute the *new* property name.

Changing property value or units

To change RPM- or user-defined property information

1 Use the **Data > Rock Fluid Properties** command to display the **New Rock or Fluid Property** dialog.
2 Double-click in the desired property **Value** or **Units** cell.
3 Change the cell value to the desired number or other units.
4 Repeat steps two and three for other properties.
5 Click **Save** to retain property changes. Click **Cancel** to discard the changes.

Deleting a user-defined rock, mineral, fluid, or gas

To delete a user-defined rock, mineral, fluid, or gas

1 Use the **Data > Rock Fluid Properties** command to display the **Rock and Fluid Properties** dialog.
2 Select the user-defined rock, mineral, fluid, or gas to delete from the **Rock, Fluids and Minerals** list.
3 Click (**-**) under the **Rock, Fluids and Minerals** list.

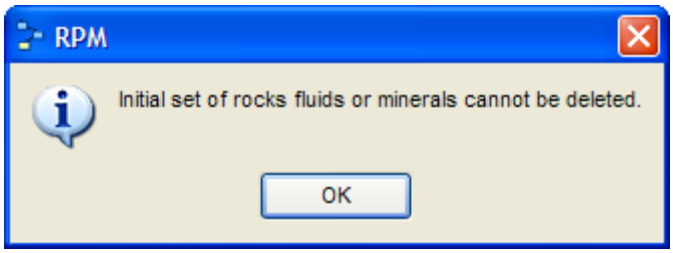
8. If you insert a space in the name, the space is changed to an underscore (_) character

4 Repeat steps two and three for each user-defined rock, mineral, fluid, or gas you want to delete.

5 Click **Save** to delete the items. Click **Cancel** to retain.

Caution! If you have worked with a user-defined rock, mineral, fluid, or gas properties in your workflow nodes and delete the names of one or more properties, you *must return to the nodes* where you used the property names and fix the input parameters. Right-click in the node input parameters with the "*deleted*" names, select **`RockProperty`**, select a new rock, mineral, fluid, or gas, and substitute another property name.

Note If you select one of the RPM-defined rock, mineral, fluid, or gas by accident, RPM prevents you from deleting this item and issues an information message.



Deleting a property

To delete a user-defined property

1 Use the **Data > Rock Fluid Properties** command to display the **Rock and Fluid Properties** dialog.

2 Select the user-defined rock, mineral, fluid, or gas from the **Rock, Fluids and Minerals** list.

3 Select the desired property by clicking in that row.

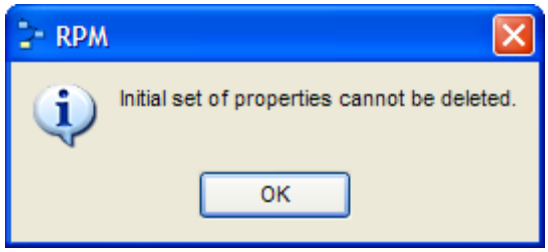
4 Click (**-**) under the **Properties** list.

5 Repeat steps two through four for each property.

6 Click **Save** to delete the properties. Click **Cancel** to discard changes.

Caution! If you have worked with user-defined rock, mineral, fluid, or gas properties in your workflow nodes and deleted the names of one or more properties, you *must return to the nodes* where you used the property names and fix the input parameter. Right-click in the node input parameters with the "*deleted*" property name, select **`RockProperty`**, select the user-defined rock, mineral, fluid, or gas, and substitute another property name.

Note If you select one of the RPM-defined properties by accident, RPM prevents you from deleting these properties and issues an information message.



Setting up input curve and constant nodes

Input curves

The final step in beginning to prepare a workflow is to identify the PowerLog well curves you need as inputs. To define these input nodes, follow the procedures found in **"Adding a node" on page 67**.

Constant nodes

Caution! RPM for PowerLog provides you with the **Constants** dialog (see **"Creating named constants" on page 51**) and the **Rock and Fluid Properties** dialog (see **"Organizing Rock, Mineral, Fluid, and Gas Properties" on page 54**) to define physical property constants, conditional logic constants, and computation flags. Using nodes to define constants unnecessarily *increases the complexity* of your workflows.

You may want to define `UserValues` or named constants to use in the workflow. There are several ways to create a `UserValue` constant node as these next four figures illustrate:

- Use the **GetCurve** function, type a value, and create the appropriate **Label** for the node. See **Figure: 35, 'GetCurve function used for a constant", on page 63**.
- Use the **GetCurve** function to create a constant that controls the workflow calculations with conditional logic (for example, a `Gas/Oil` flag where `oil=1`, `gas=0`). See **Figure: 36, 'Create constant as a computation flag", on page 63**.
- Use a simple calculation to create a meaningful constant. See **Figure: 37, 'Basic math operation used for a constant", on page 64**

Figure 35. GetCurve function used for a constant

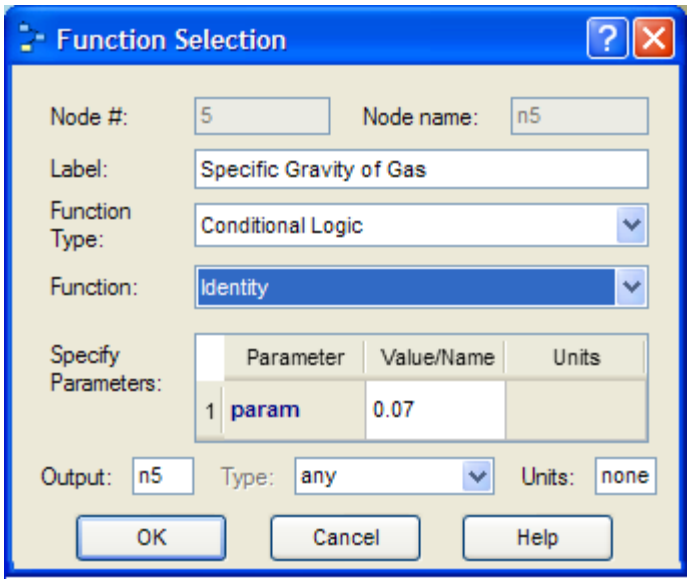


Figure 36. Create constant as a computation flag

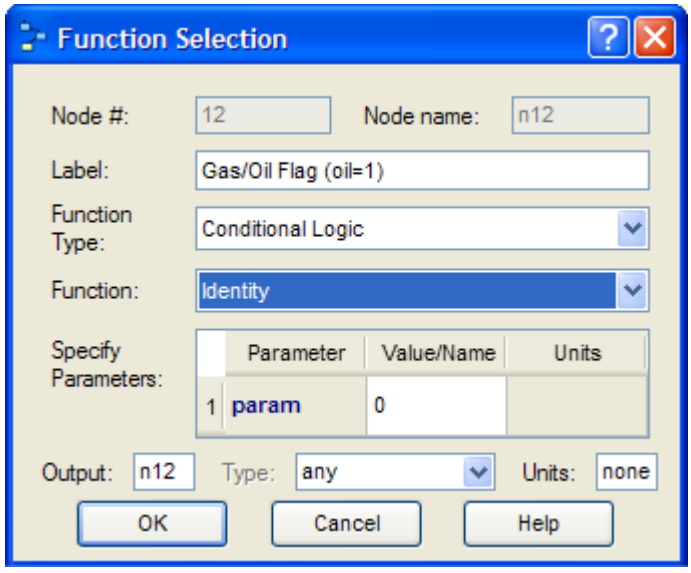
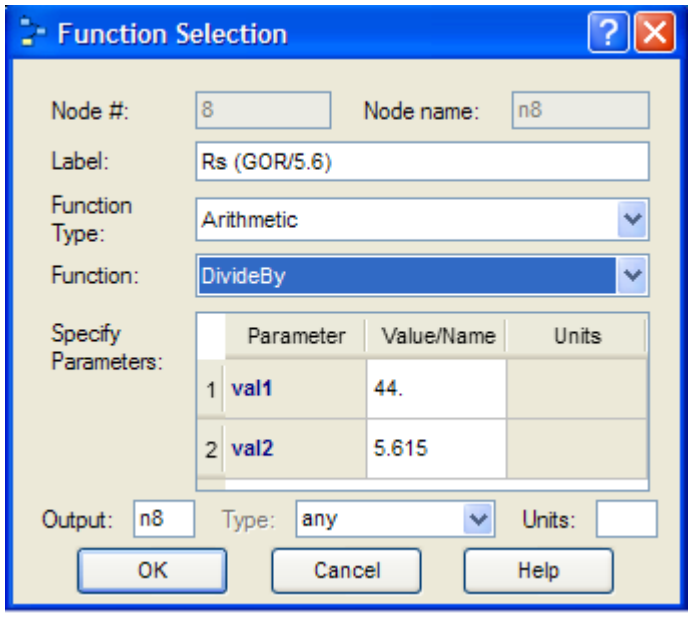


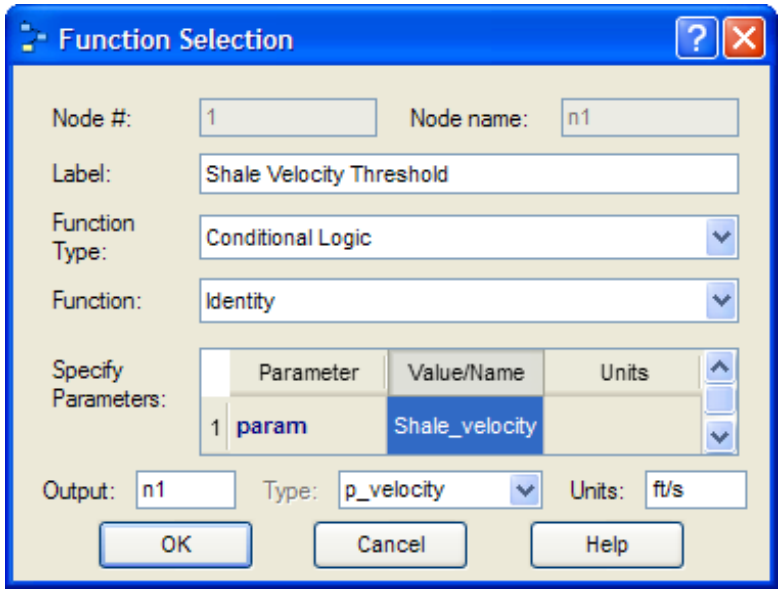
Figure 37. Basic math operation used for a constant



Hint Alternatively, you can defined named constants in the **Constants** dialog and use these throughout the workflow. To document the constant used in your workflow, you would use the **GetCurve** function and use the named constant as the input.

Note Using named constants (without nodes as documentation) can decrease the total number of workflow nodes and minimize extra connections. This results in a workflow that is easier to understand. You can use Groups to document your named constants and annotate elements of your workflow.

Figure 38. GetCurve function used to document a named constant



Input curve nodes

Input curves from a PowerLog project well usually consisted of measured velocity, density, gamma ray, sonic, and other petrophysical curves that are edited and have had appropriate environmental corrections made.

Most PowerLog input curves are defined in a:

- Color-coded node (**GetCurve** function) to document the curve as a workflow input (For an example, see **Figure: 39, 'GetCurve function for PowerLog input curve"**.)
- Simple calculation node. A common example is to convert a sonic log to a measured velocity curve. (For an example, see **Figure: 40, 'Creating an input curve with a calculation", on page 66**.)

Figure 39. GetCurve function for PowerLog input curve

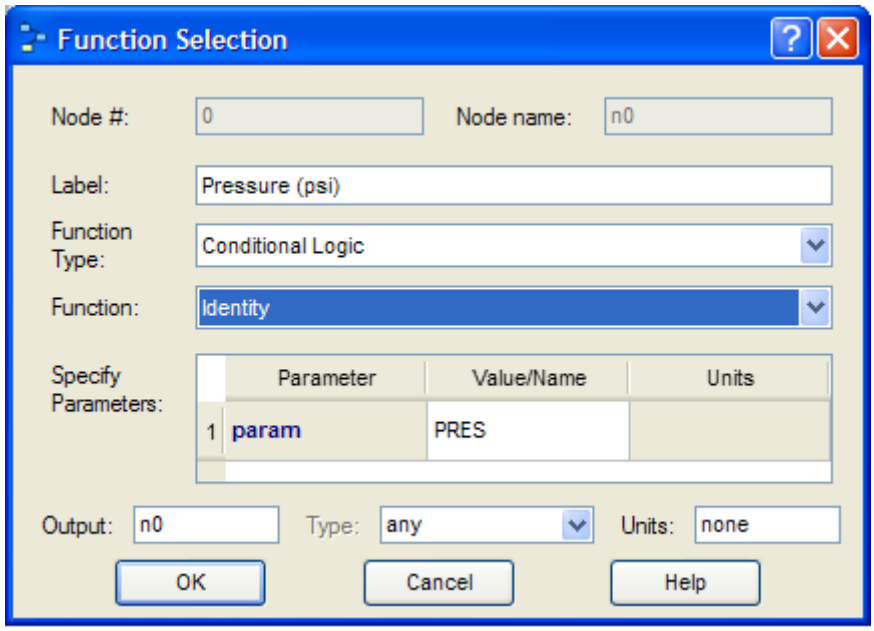
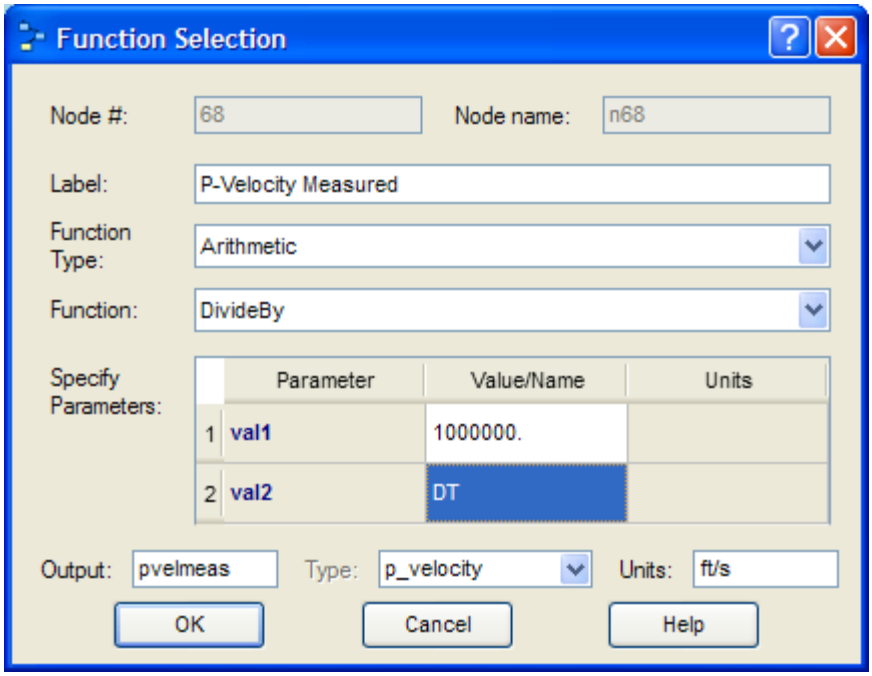
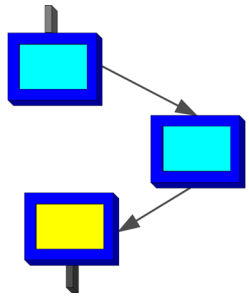


Figure 40. Creating an input curve with a calculation





BUILDING ROCK PHYSICS WORKFLOWS

Working with nodes and connections

Adding a node

Ways to add a node

Adding a node is one of the most common operations you perform when building a rock physics model workflow. You can invoke this command four different ways:

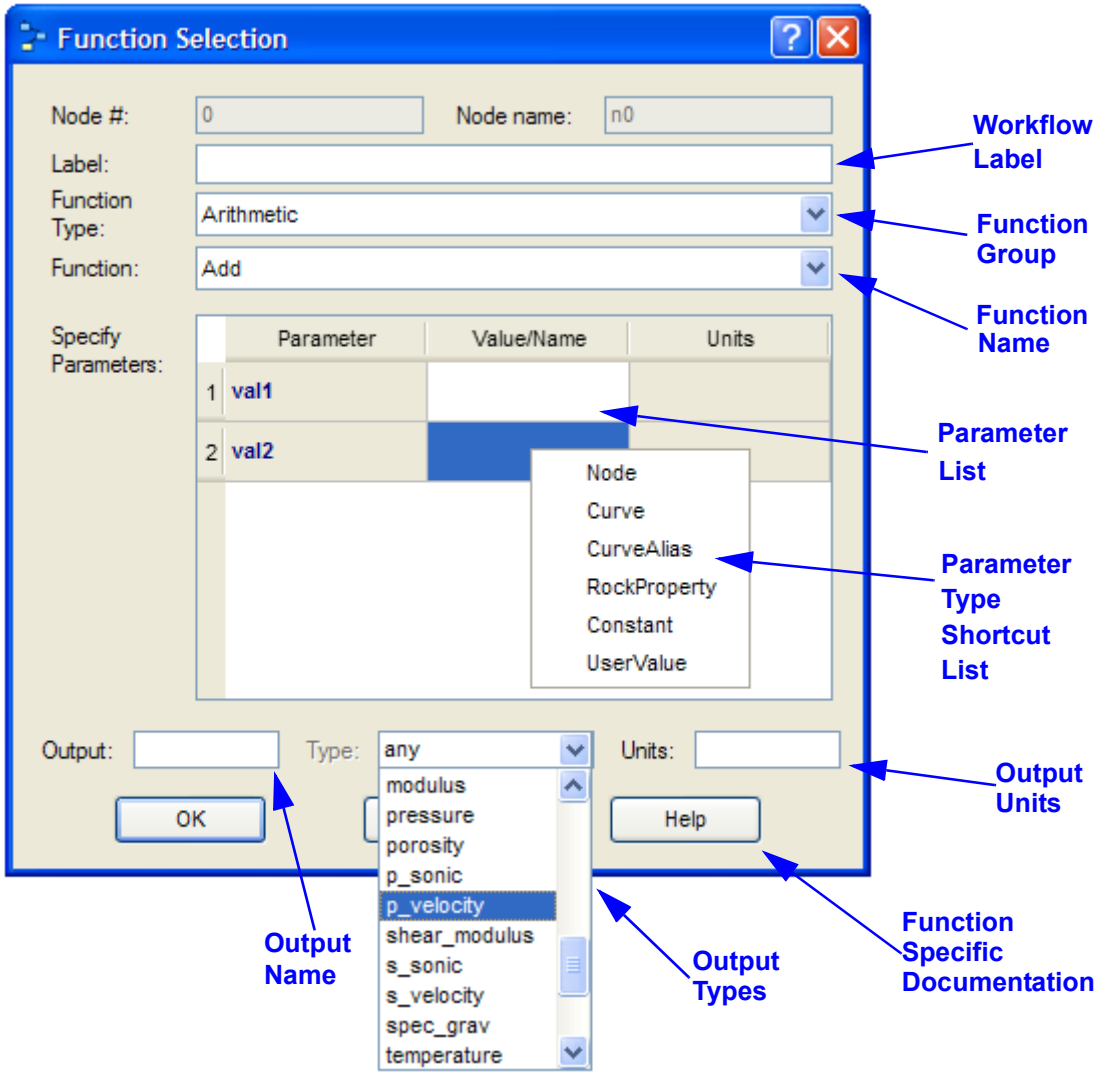
- **Menu**—Select the **Edit > Add Node** command.
- **Shortcut menu**—In a blank portion of the workspace, right-click (MB3), and select the **Add Node** command.
- **Tool bar**—click the  icon.
- **Keyboard shortcut**—press the `[cntl]` and the `[+]` key.

Parts of a workflow node

As **Figure: 41, 'Parts of a workflow node", on page 68** illustrates, a workflow computation node consists of a:

- **Label**—text that displays on the RPM workflow node box
- **Function**—performs arithmetic and conditional logic operations
  - **Type**—collection of related functions
  - **Function (name)**—specific function calculation
- **Output**—makes result available to workflow nodes or PowerLog curve storage
  - **Output** (name)—node name used in workflow or PowerLog curve name (maximum eight characters)
  - **Type**—resultant computation value type.
  - **Units**—imperial or metric units. For the first RPM release, with some exceptions, most output units are US Imperial measurements.

Figure 41. Parts of a workflow node



Adding a new node to the workflow

Adding a node to a workflow

1 Use one of the four methods (see **"Ways to add a node" on page 67**) to invoke the **Add Node** command.

2 When the cross-hair cursor displays, it can be moved to any position in the workflow. Click once (MB1) and a node of default size and color displays.

Hint Your color preferences (see **"Applying a color to a single node, connection, or group" on page 80**) define the initial node color.

3 Type in the **Label** text box a description that documents the node's computation role in your workflow.

4 Select the function group using the **Function Type** drop-down selection list.

Hint Use the context-sensitive help to find the desired function group and actual function-name. See the ***RPM for PowerLog — Function Reference Guide*** for the same information in a printed format.

5 Select the function name using the **Function** drop-down selection list.

6 [Optional] Click **Help** to display the function's documentation, information about function input parameters, and parameter defaults using the **Rock and Fluid Properties** dialog.

7 For each input parameter, right-click (MB3) and use the shortcut lists to choose the desired input parameters or directly type values.

8 For the **Output** text box, you can type either a:

- **Node number**—use the output results in other workflow nodes.
- **Curve name**—stores the results in a PowerLog curve. You can use a maximum of eight characters for a name.

9 [Optional] Identify the output **Type** for this node. Some functions specifically create only one output type, such as acoustic velocity. See **Figure: 41, 'Parts of a workflow node", on page 68**.

10 Specify the output **Units**, unless the function has a specific output type specified in step 9.

11 Click **OK**.

Naming nodes

Workflow calculation nodes can specify a node number or a curve name as the output (written to the PowerLog project well). Curves are created as the results of RPM node calculations and written to the PowerLog well project. On the positive side, populating PowerLog with a number of intermediate curve results can be helpful in reviewing your calculations as you develop the workflow. The downside, you may need to delete curves later or the curve selection list begins to contain too many entries.

The RPM calculation nodes can be classified into three categories:

- **Input nodes**—Use PowerLog *curve names* or constants, along with the **GetCurve** function for these nodes. See **"Determining workflow input curves" on page 48**.
- **Connection nodes**—These nodes create outputs that are used as input parameters in other nodes. You should always use the *node number* for the input parameter, even if the curve has a different name. This creates the visual connection links between workflow nodes.
- **Output nodes**—These nodes produce results that you want to store in the PowerLog project well. Specify a curve name [**maximum eight characters**, no blank spaces] for the result you want stored.

Editing a node

Changing node information

1 Double-click the desired node or right-click (MB3) desired node and select the **Edit Node** shortcut menu command.

Changing the Label, Output, or Units

1 Directly type new values for any of these fields you want to change.

2 Click **OK,** if this is the only information to change.

Selecting another function for this node

1 Using the **Function Type** drop-down selection list, select the desired function group. See **Figure: 42, 'Function Type selections and corresponding online help areas"** for the complete list of function groups and the way to access documentation about each function in a group.

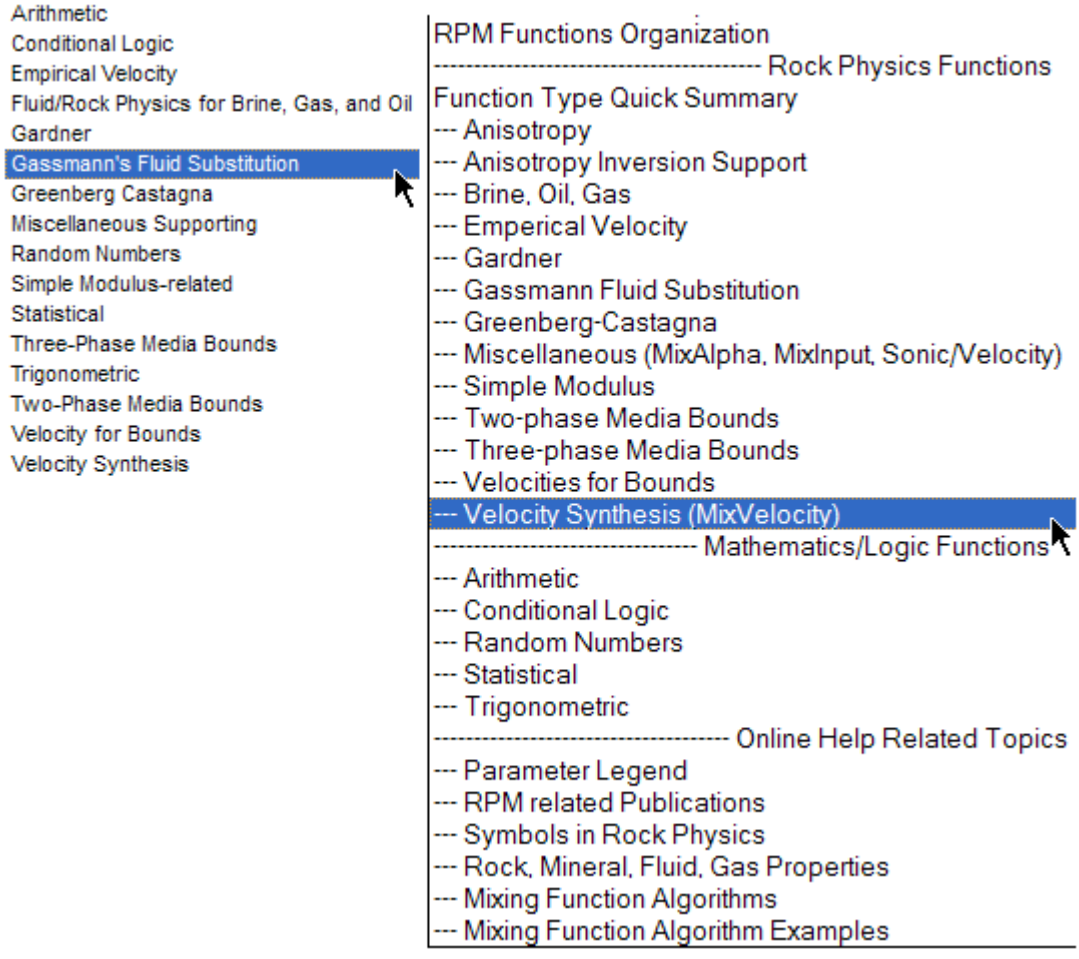
2 Use the **Function** drop-down list to select the actual rock physics or basic function you need. Click **Help** to display the function input parameters documentation.

3 Select the required input parameters for this function.

4 Click **OK**.

Hint Clicking the **Help** button displays the RPM function's documentation in an Internet browser window. You can use the **Select a Function Topic** drop-down selection list to choose any major area of the online help and immediately jump to that HTML page.

Figure 42. Function Type selections and corresponding online help areas



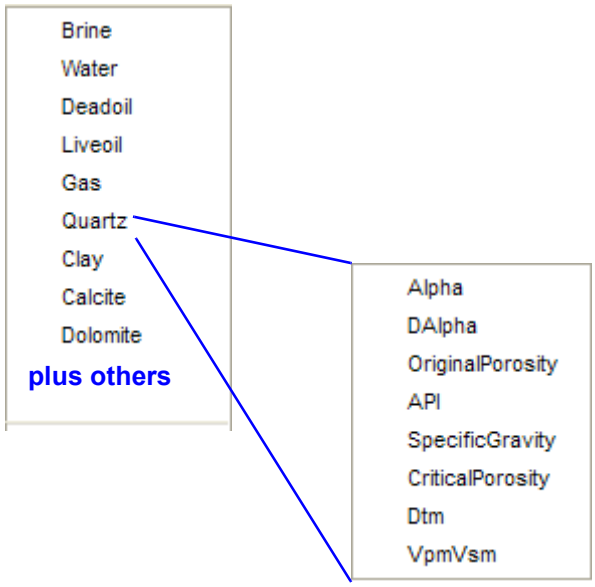
Selecting input parameters

Hint Before defining function input parameters for your first nodes, read **"Inputs for function calculations" on page 24**, for insight about the different input parameter types.

Selecting input parameters

1. Right-click on an input parameter under the **Value/Name** column and display the different input parameter types.
2. Select the parameter type and perform steps 3, 4, 5, or 6:
   - **`Node`**—displays list of node names in the workflow with matching output type
   - **`Curve`**—displays all PowerLog curves for this well
   - **`CurveAlias`**—displays all PowerLog curve alias names
   - **`RockProperty`**—displays all defined rock physics entities
   - **`Constant`**—displays all defined named constants
   - **`UserValue`**—user types a value
3. For a **`Node`**, **`Curve`**, or **`CurveAlias`** parameter, choose the desired item from the displayed selection list.
4. For a **`RockProperty`**:
   a. Choose the desired rock, mineral, gas, or fluid from the second selection list.
   b. For the chosen rock physics entity, select from the defined properties displayed in the subsequent selection list. (See **Figure: 43, 'RockProperty example selection lists"**.)
5. For a **`Constant,`** choose the named constant from the selection list.
6. For a **`UserValue`**, type the value directly in the cell. A typed value can be an integer (**`42`**), real number (**`2.65`**), or scientific notation (**`8.7e+09`**, **`2.3e-4`**).
7. Repeat steps one through six for all input parameters needed for this function.
8. Click **OK**.

Figure 43. RockProperty example selection lists



Naming a output

Determine if this node is an input, connection, or output node before deciding about the **Output** field. Consult the **"Naming nodes" on page 69** section for directions.

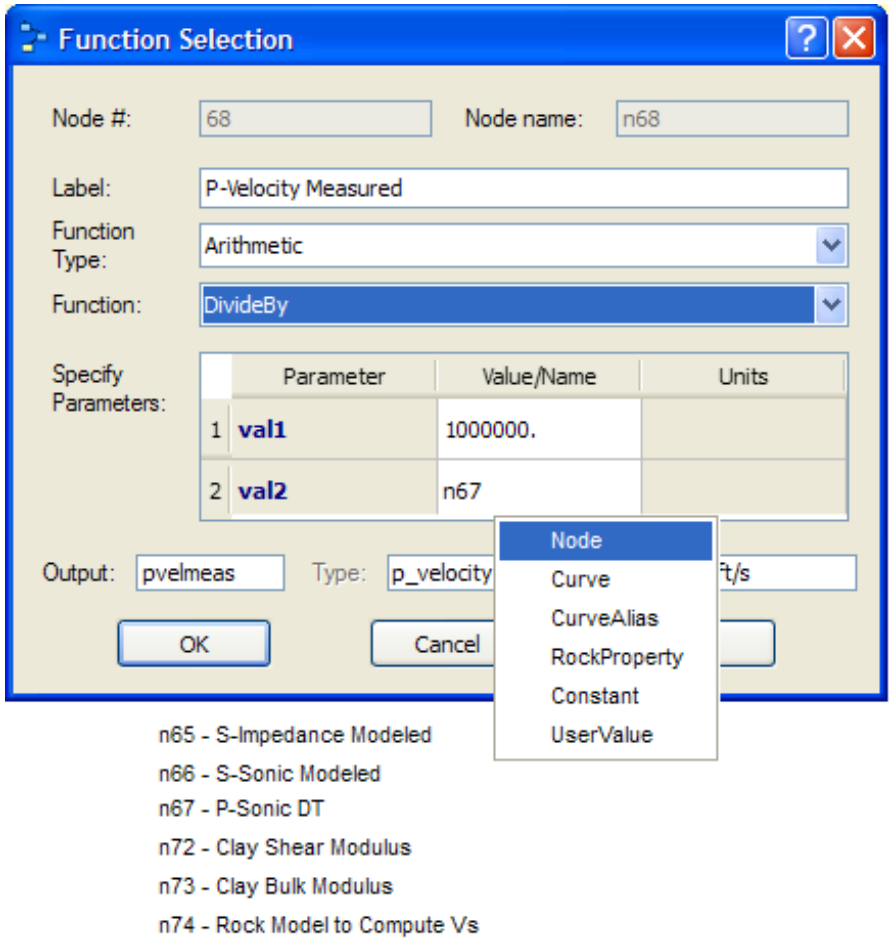
Connecting nodes

In RPM for PowerLog, when you define the output of one node as the input to another node, the workflow shows this relationship with a directed arrow (for example, see nodes **`n67`** and **`n68`** in **Figure: 14, 'Example of different node types", on page 30**).

Connect an output from one node to another

1. Double-click the node in which you want to use another node's output, or right-click (MB3) desired node and select the **Edit Node** menu command.
2. Right-click the input parameter under the **Value/Name** column and display the parameter types.
3. Select **`Node`**.
4. When the node selection list displays, choose the desired workflow node to use.
5. Click **OK**.

Figure 44. Creating a connection between nodes



A connection between the example nodes in **Figure: 14, 'Example of different node types", on page 30** is established when you use `n67` as an input parameter to the calculation in `n68` in **Figure: 44, 'Creating a connection between nodes"**.

Finding a node

RPM for PowerLog uses its **Find Node** function to help you locate any node within the workflow.

To find a node in the workflow

1 Use one of these methods to invoke the **Find Node** command:
   – Select the **View > Find Node** menu command.
   – Right-click in an empty workspace area and select **Find Node** from the Workspace shortcut menu.
   – Click the  toolbar icon.

2 When the **Node Locator** dialog displays, select the desired node and click **OK**.

   The specified node flashes with a yellow background twice. If the node location is outside the screen display area, the screen scrolls left or right to display the node.

If the specified node is hidden within a minimized group, the group opens to reveal the chosen node.

Deleting a node

RPM for PowerLog can delete workflow nodes that are not needed in your workflow computations.

Caution! Before deleting any node, check to see which workflow nodes depend upon this node for its output. Use the **View > Show Descendents** command and select the node you plan to delete. All impacted nodes impacted display with highlighted connections. Use **View > Clear Selections** command to clear the highlighted connections.

To delete a node

1. Select the node to delete with one mouse (MB1) click.
2. Right-click (MB3) and select the Delete Node command. RPM deletes the node.

Hint If you selected the wrong node, use the **Edit > Undo** command to restore the deleted node.

Deleting multiple nodes

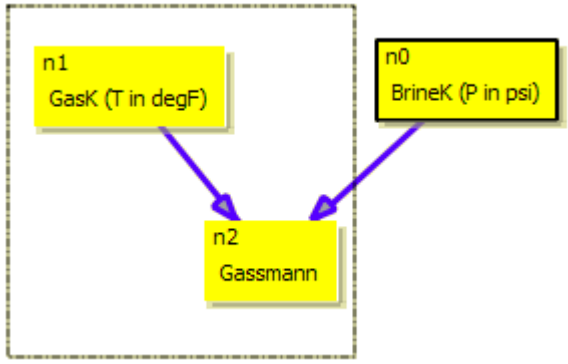
You can delete several nodes at once by selecting an area containing the nodes to delete.

Caution! Before deleting any node, check to see which workflow nodes depend upon this node for its output. Use the **View > Show Descendents** command and select the node you plan to delete. All impacted nodes impacted display with highlighted connections. Use **View > Clear Selections** command to clear the highlighted connections.

To delete several nodes at once

1. Move the nodes you want *to delete* by clicking and dragging each node to an unused portion of the workflow. Ensure that any nodes you want *to keep* are not in the area you select in the next steps.
2. Click and hold the mouse down at a point in the workspace representing the top left-hand corner of your node deletion area.
3. Drag the cursor to the bottom right-hand corner of the area containing all the nodes you want to delete. Release the mouse button. Your workflow would look similar to **Figure: 45, 'Deleting nodes within a workflow area"**.
4. Press the `[Delete]` key. This deletes the enclosed nodes.

Figure 45. Deleting nodes within a workflow area



Hint If you included a node you did not want to delete, use the **Edit > Undo** command to restore all the deleted nodes to your workflow.

Efficient techniques for working with nodes

Keyboard shortcuts

Using Undo and Redo commands

Refreshing the workflow display

Redrawing the complete display

Refreshing the workflow node connections

Select the **Edit > Reconnect** command or press the `[F6]` function key. RPM for PowerLog redraws and saves all the connections when the workflow gets complex.

Performing and understanding workflow calculations

DOC_001 - insert workflow calculations

Controlling creation of computation curves

Overwriting PowerLog curves

Displaying the node calculation order

What does this do

Blocking Curve Overwrite Warnings

DOC_001 - eliminating the warnings

Note The **Block Curve Overwrite Warnings** setting remains the same until you change the setting. That means, if you exit the RPM for PowerLog application, this setting is remembered from one RPM session to the next.

Caution! Curves must be write-protected in PowerLog to prevent RPM from overwriting (with or without the warning messages blocked).

Sending warning messages to the Output Log

xxxxxx

Performing a workflow calculation

Node

Group

Path

Workflow

RPM for PowerLog can perform all the calculations for the entire workflow. You can invoke this command four different ways:

- **Menu**—Select the **Calculate > Calculate Workflow** command.
- **Shortcut menu**—Select a node, right-click (MB3), and select the **Calculate > Calculate Workflow** command.
- **Tool bar**—click the  icon.
- **Keyboard shortcut**—press the `[F8]` key.

Displaying computation elements

Selecting a path

Finding a workflow node

A node's ancestors

DOC_005 determining inputs to a specific node calculation

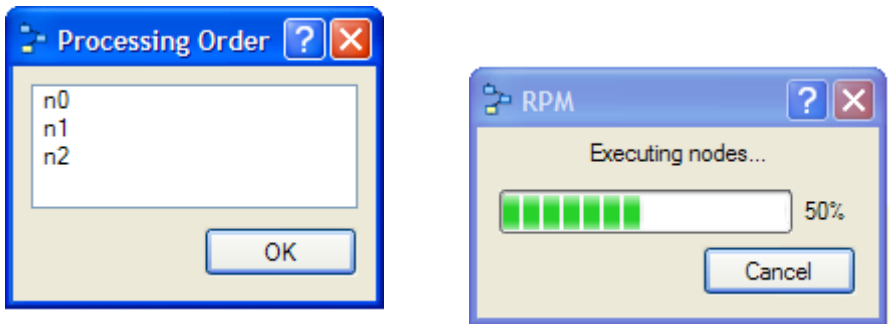
A node's descendents

Clearing a path display

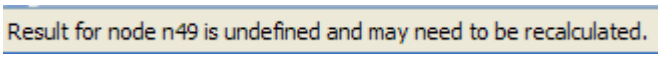
Troubleshooting a workflow calculation

The RPM for PowerLog application provides extensive freedom in structuring your workflow calculations. RPM first displays the **Processing Order** dialog to describe in what order RPM does the node calculations. Once you click **OK**, a calculation progress meter displays.

Figure 46. Node calculation order and progress meter



When a problem happens, such as in this example:



you need to begin a systematic procedure for eliminating possible calculation errors.

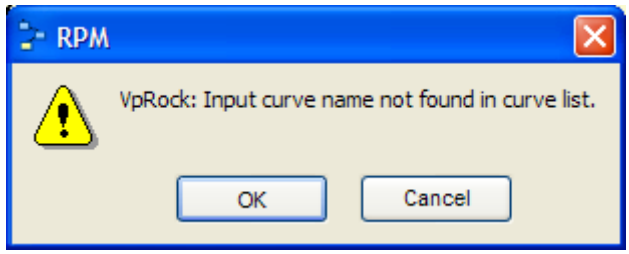
Tools—alert boxes, status bar, dialogs, and commands

The RPM for PowerLog software contains several user interface elements to help you create successful workflow calculations:

- Alert messages—during a calculation, these dialog boxes display error messages.
- Status bar—during the node calculations, the status bar displays messages for successful and failed node calculations
- Dialogs—the **Curve List** and **Curve Alias** dialogs can help identify missing well curves needed for this workflow. The **Function Selection** dialog can provide clues to invalid parameters or parameters that do not match this function.
- Commands—the **Show Ancestors** and **Show Descendents** commands (see **"View menu" on page 124**) help you retrace a calculation's steps.

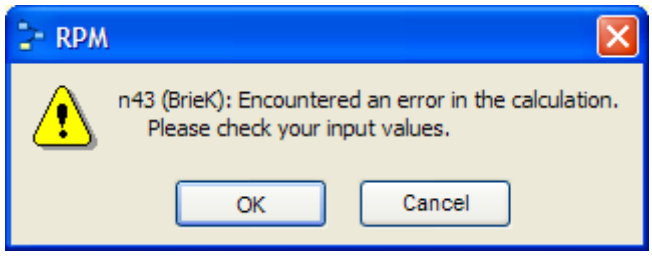
Checking input curves

Selected curves used in the RPM workflow come directly from the PowerLog project and the project well you selected. If you select another well or a different project, you should check the input curve names to ensure that each curve name or its alias exists in the well. Use the **"Curve List dialog" on page 141** and the **"Curve Alias List dialog" on page 143**. This situation is identified in the workflow calculation with an alert dialog that looks like:



Checking input values

Each of the functions available to any node in the workflow can receive inputs from other nodes. Use the **"Output Log dialog" on page 142** to determine possible output curves at other nodes that affect this node. Check the node function using the **"Node shortcut menu" on page 126** to determine its input parameters. When a calculation error happens, this alert message displays:



Fixing function parameters

Checking ancestors and descendents

In the previous section, we showed how to display a calculation's steps, using the Show Ancestors and Show Descendents commands.

When a node calculation fails:

- **Show Ancestors**—provides a visual identification of all nodes that define most of input parameter values and curves.

Developing workflow calculation nodes

Node input and output naming conventions

Using basic functions

Arithmetic Functions

Trigonometric Functions

Discrimination / Conditional Logic Functions

Random Numbers

Statistical Functions

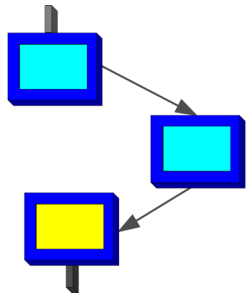
Using Rock Fluids Physics functions

Using miscellaneous functions

Using mixing functions

Adding custom constants

Adding custom rock, fluid, and mineral properties



PERFORMING ADVANCED WORKFLOW TASKS

Organizing your workflow

Setting preferences

Selecting colors

Selecting a usable workspace color

Node, connection, group, and path colors

Applying a color to a single node, connection, or group

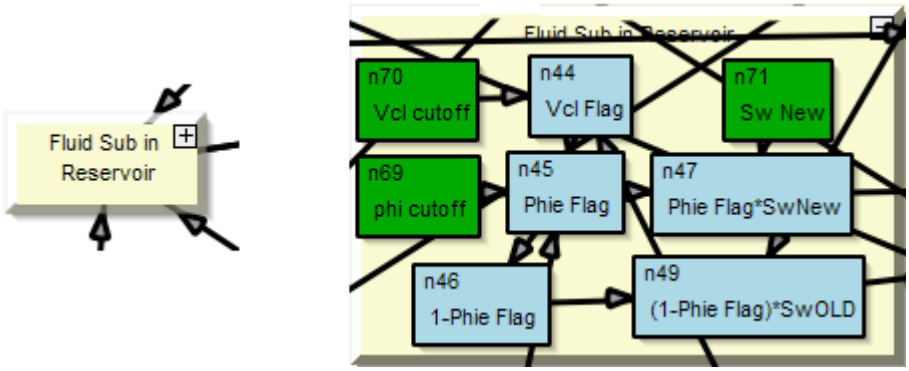
Refreshing and deleting a workflow

Organizing Nodes into Modular Groups

Groups

Nodes can be associated into groups by adding a group defined by drawing a rectangle around the desired nodes and dragging them into the group. The group can be minimized so that only one box shows in the place of all the nodes in the group. A group can be minimized or restored to its original size (see **Figure: 47, 'Group minimizing workflow complexity"**). You can assigned a very descriptive name to a group, which can span several text lines. The group can be moved around as a whole and individual nodes can be moved inside the group. Complex workflows can be simplified by using groups to manage a related set of nodes.

Figure 47. Group minimizing workflow complexity



Adding a group

To define a group

1. First select this **Edit > Define Group** command or click the **Group** tool bar button.
2. Click and drag the mouse to define the rectangular area containing all the desired nodes.
3. Drag the nodes, for which you want to establish an association or workflow partition, together
4. Drag any nodes you do not want in the group to a part of the workspace outside the rectangular area. Do this by clicking the mouse on the nodes and dragging them to another part of the workflow.

Note RPM considers any node, even partially contained in the group rectangle, to be a member of the group. If you want certain nodes are to be excluded, you need to physically move them to another part of the screen. The connections move with the nodes to the new locations. A node can be moved out of a group by clicking and dragging the node outside the group boundary.

The group can be minimized so that complex workflows can be made easier to use. It can be maximized when you want to show the nodes within the group. The upper right-hand corner of the group box contains the minimize and maximize control. You can resize groups by dragging the group edges or corners.

Deleting a group

Moving nodes on the workflow

Moving a node

Rubber-banding nodes

Moving a group of nodes

Deleting a group of nodes

Adding advanced workflow elements

Adding descriptive labels to document the workflow

Using conditional logic in calculations

Using SimpleExpression to minimize nodes

Importing parameters and constants from other projects

Figure 48.

Planning for multi-well RPM projects

Displaying Curve Alias list

Figure 49.

Troubleshooting calculations

DOC_005 determining inputs to a specific node calculation

Using more complex member mix functions

Understanding mixing algorithms

Figure 50.

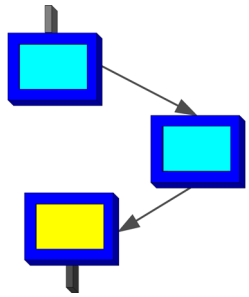
Supplying additional needed parameters

Fitting curves

Figure 51.

Figure 52.

Figure 53.



TUTORIAL WORKFLOWS

This section contains:

Rock Physics Models

What's the added value to my interpretation project?

Answer, a rock physics model that:

- Links the petrophysical analysis (ρ-density, P-sonic, and S-sonic logs) and seismic data to yield compatible seismic inversions.
- Enhances your comprehension of the reservoir production characteristics and the underlying geology.
- Provides a consistency check that demands that the elastic constants (*E*, *K*, λ, μ, and ν), minerals, and fluids match well logs and seismic data.
  - V_p, density, and V_s obtained from logs must match the values obtained from the RP model using *K*, μ, and ρ for the minerals and fluids.
  - Synthetic seismic data obtain from impedance and reflectivity curves must match the RP model using *K*, μ, and ρ for the minerals and fluids.
- Generates a P-sonic calculation that you can compare with the P-sonic measurements to check the porosity, minerals, and fluids.
- Computes S-sonic logs if AVO processing is unavailable.
- Uses algorithms to calculate density, V_p acoustic velocity, and V_s shear velocity
- Characterizes your reservoir
  - Model hypothetical fluid substitutions
  - Model impedance logs to create synthetic seismograms and compare these to seismic data.

What are the rock physics model elements?

A rock physics model usually consists of:

- Pore fluids
- Porosity (ϕ)
- Mineral density (ρ), bulk modulus (K), and shear modulus (μ)
- Temperature and pressure
- Density of pore fluids (ρ_{fluid}) and bulk modulus of fluid (K_{fluid})
- Grain and pore structure
- Mineral volume fraction for each mineral type
- Mineral grains for one or more types
- Water saturation (S_w), plus gas/oil ratio (GOR) if needed

Tutorial workflow names

The Fugro-Jason tutorial workflows included with the RPM software are:

- **Starting Point Workflow**—shows how to use basic curves and defined constants to develop basic properties and calculate bulk density, V_p and V_s for a rock physics model.
- **Curve Differences Statistics**—illustrates an approach to determining the RMS (root-mean squared) difference between a measured and a calculated (model) curve. Correlation coefficient and an average bias level are also calculated for the measured and calculated curves.
- **SimpleExpression formulas and logic**—demonstrates how to perform multiple testing logic and evaluate extensive mathematical and rock physics equations.
- **RP Properties for AVO Checks**—provides calculations of acoustic and shear velocities, effective porosity, and Z_p and Z_s impedances. Other elastic constants are computed from velocities and impedances such as:
  - Bulk modulus (K)
  - Shear modulus (μ)
  - Young's modulus (E)
  - Poisson's ratio (ν)
  - Shear modulus/density product ($\mu\rho$) proportional to shear impedance
  - Lamé's constant/density product ($\lambda\rho$) proportional to acoustic impedance
- **Fluid properties to estimate V_s**—uses named constants or PowerLog curves to calculate the fluid (brine, oil, and gas) properties, along with a mean value of each curve.
- **Lithology log construction**—demonstrates building a lithology log based on petrophysical curve values, that can be extended to building a lithology log with rock physics-derived parameters.
- **Gassmann fluid-substitution to predict seismic response**—demonstrates the computation of brine, oil, gas, and fluid properties for existing saturation and new fluid substitution. The results are used with the **GassmannFull** function to predict the acoustic velocity under fluid substitution conditions.

What is a workflow?

A *workflow* is an RPM for PowerLog project that:

- Serves a starting point to develop more complex and customized rock physics models
- Uses PowerLog input curves and named constant values that a user can quickly change
- Reuses different PowerLog projects and wells to achieve multiple project results

Workflows are calculated from input curves belonging to a single PowerLog well project and for limited well depth intervals.

Fugro-Jason provides workflows with RPM for PowerLog software so you:

- Can develop useful computations when you first begin using RPM
- Have an initial starting point to develop your own customized workflows
- Learn some effective development techniques to apply to your own workflows

These workflows illustrate *a single approach* to accomplish a particular rock-physics computation, not necessarily the best way or the only way. You, the geoscience professional, ultimately need to decide that a specific set of workflows is appropriate for the pore fluids, lithology, and goals of your project. The RPM for PowerLog software provides the tools to build your workflow, without a set of rigid constraints or methodology.

This document section describes the tutorial workflows that you can use as a starting point for developing your own reservoir project workflows. Use these examples as models and configure your workflow to meet your specific needs.

Symbols used in rock physics formulas

Table 7. Commonly used symbols in rock physics

Symbol	Name	Purpose
λ	lambda	Lamé's constant ($K - 2\mu/3$)
K	Kappa	bulk modulus
E	Epsilon	Young's modulus
μ	mu	shear modulus (G also used)
ρ	rho	(**1**) density or (**2**) correlation coefficient
φ	phi	porosity
σ	sigma	standard deviation (variance is σ^2)
ν	nu	Poisson's ratio
ω	omega	angular frequency
α	alpha (V_{p0})	(**1**) crack (pore) aspect ratio, (**2**) P-wave velocity along the vertical symmetry axis of a transversely isotropic media, (**3**) mean deviation.
β	beta (V_{s0})	S-wave velocity along the vertical symmetry axis of a transversely isotropic media

Table 7. Commonly used symbols in rock physics (Continued)

Symbol	Name	Purpose
Δ	Delta	Acoustic and shear sonic travel times (measured in μsec/ft.)
M	Mu	P wave modulus ($M = \rho V_p^2$)
Thomsen's anisotropy parameters - relates P-wave and S-wave velocities along the vertical symmetry axis to three phase velocities propagating in the direction of a deviated well.		
γ	gamma	The fractional difference in V_{sh} between the horizontal and vertical directions, and the normalized difference between V_{sh} and V_{sv} in the horizontal propagating S-waves.
δ	delta	Thomsen anisotropy parameter that relates P-wave and S-wave velocities along the vertical symmetry axis to the three phase velocities propagating in the direction of a deviated well.
ε	epsilon	Thomsen anisotropy parameter *for P-wave anisotropy* or the fractional difference in P-wave velocity between the horizontal and vertical directions.

Tutorial workflows overview

Characteristics

These tutorial workflows have several common characteristics:

- Nodes where you *must check for required curve names*, are colored **Red** to denote input curves from a PowerLog well. In these nodes you insert a curve name appropriate for your well or you can insert an appropriate curve alias name.
- Significant rock physics values and workflow flags are defined as named constants and documented in the **Rock and Fluid Properties** and **Constants** software dialog displays.
- Input PowerLog curves, resulting output curves, workflow formulas and RPM functions, and named constants are documented so that you can quickly grasp the workflow essentials.
- Workflow output curves are colored **Blue**.
- Nodes organized in groups, which can be minimized to hide details and show overall workflow organization.

Color schemes

RPM for PowerLog provides you the ability set the color preferences of your workflow elements:

- Node
- Group
- Connection
- Workspace background

Note The color scheme used to document the *Tutorial Workflows* section is described in the next table.

Table 8. Example workflow color scheme

Workflow Element	Color	Color Specification Red: xxx, Green: yyy, Blue: zzz
Workspace (background)		Red: 255, Green: 255, Blue: 192
PowerLog input curves (nodes)		Red: 255, Green: 85, Blue: 0
Computation nodes		Red: 255, Green: 255, Blue: 127
Groups (background)		Red: 255, Green: 170, Blue: 0
Output results (nodes)		Red: 173, Green: 216, Blue: 230
Labels - workflow and constants		Red: 85, Green: 170, Blue: 255
Connections	**Black**	Red: 0, Green: 0, Blue: 0

Starting Point Workflow

The *Starting Point Workflow*[9] helps you get oriented to organizing some of your workflow elements into various groups. In this workflow you calculate a density, V_p, and V_s curve using a number of common petrophysical curves and constants.

Objectives

The *Starting Point Workflow*:

- Calculates density, acoustic velocity, and shear velocity.
- Outputs PowerLog curves to use in the **Curve Differences Statistics** workflow to determine a quantitative measure of the modeling effort's success.
- Illustrates how the elastic moduli from brine, oil, and gas can be calculated using pressure, temperature, and salinity information.
- Shows how to use conditional logic functions to interchange gas and oil properties when computing the final hydrocarbon properties.
- Illustrates simple usage of MixVelocity functions using simple constants for modulus constants and clay velocities.
- Calculates the fluid bulk modulus using Brie's formula (Dvorkin at al. 1999 **[12]**) for patchy saturation.
- Describes and documents named constants to create an easy to use workflow.

9. Many thanks to Mark Sams of Fugro-Jason for developing the initial draft of this workflow.

Computed results

These PowerLog output curves are created when the entire workflow is calculated.

Table 9. Starting Point Workflow - output curves

Node	Curve Name	Type - Units	Description
n17	VpVsmeas	any none	Measured V_p/V_s ratio, calculated from V_p and V_s measured curves
n23	rhocalc	density g/cc	Calculated bulk density
n24	Pvelcalc	p_velocity ft/sec	Calculated acoustic velocity
n25	Svelcalc	s_velocity ft/sec	Calculated shear velocity
n26	Zpcalc	any none	Calculated acoustic impedance
n27	Zscalc	any none	Calculated shear impedance
n28	DTpcalc	p_sonic µsec/ft.	Calculated acoustic sonic
n29	DTscalc	s_sonic µsec/ft.	Calculated shear sonic
n30	VpVscalc	any none	V_p / V_s velocity ratio

Strategies

The key approach to solving this problem involves:

- Using the downhole temperature, pressure information, and named constants with the Fluid/Rock Physics for Brine, Oil, and Gas functions (**BrineRho**, **BrineK**, **GasRho**, **GasK**, **LiveOilRho** and **LIveOilK**).
- Use a conditional logic named constant `Gas_oil_flag` (oil=0, gas=1) to select one set of properties and designate these properties as the HC or hydrocarbon component.
- Specifying a set of clay velocity, density, and modulus constants, along with the clay pore aspect ratio to serve as inputs to the **MixVelocity** functions.
- Combine the brine and hydrocarbon fluid properties, with the clay properties, and use the Volume of wet clay curve as the fractional volume to run each of the MixVelocity functions (**MixVelocityRho**, **MixVelocityVp**, and **MixVelocityVs**).

PowerLog input curves

These PowerLog input curves are used to calculate the brine, gas, and oil properties. The water saturation curve is used in the Brie's patchy saturation formula (Brie et al. 1995 [6]) and to compute the density fraction of brine and hydrocarbons. The total porosity and V_{clay} curves are inputs to the **MixVelocity** functions.

Hint For your well, you may need to modify the curve names or replace them with a convenient curve alias name. The curve names in the previous table are from the tutorial `Starting_Point_Workflow` project.

Table 10. Starting Point Workflow - input curves

Node	Curve Name	Type and Units	Description
n0	**SW**	SW none	Water saturation
n1	**PHIT**	porosity none	Total porosity
n2	**VCL**	any none	Volume of Wet Clay
n3	**PRES**	pressure psi	Pressure of formation
n4	**T**	temperature degF	Downhole temperature
n5	**RHOC**	any none	Bulk density - measured
n6	**DT**	p_sonic µsec/ft.	P-sonic measured
n7	**VP**	p_velocity ft/sec	Vp measured
n8	**VS**	s_velocity ft/sec	Vs measured

Named Constants and Mineral Properties

This table displays the named constants, clay properties, grain/clay pore aspect ratios, and the conditional logic switch for gas and oil.

Table 11. Starting Point Workflow - named constants and rock/fluid properties

Name	Value	Units	Used in these workflow nodes
`Brine_salinity`	**150000**	ppm	n9, n10—concentration
`Gas_specific_gravity`	**.07**	none	n11, n12, n13, n14—spec-grav
`Gas_oil_ratio`	**44/5.615**	none	n13, n14—dimensionless Rs
`Oil_api`	**33**	api	n13, n14—oil density
`Gas_oil_flag`	**0 - Gas otherwise Oil**	none	n15, n16—select which hydrocarbon to use in the fluid computations
`Clay_Vs`	**6233.6**	ft/sec	Compute μ_{clay} and K_{clay}
`Clay_Vp`	**13714**	ft/sec	Compute μ_{clay} and K_{clay}
`Grain_aspect_ratio`	**.08**	none	n23, n24, n25—nonclay (Quartz) pore aspect ratio
`Clay_aspect_ratio`	**.05**	none	n23, n24, n25—Clay pore aspect ratio
`Brie_parameter`	**7**	none	n19—patchy saturation computation
`Clay.Mu`	**9.747e9**	N/m^2	n23, n24, n25—clay shear modulus = **MuFromVel** ($V_{s\text{-}clay}$, ρ_{clay})

Table 11. Starting Point Workflow - named constants and rock/fluid properties (Continued)

Name	Value	Units	Used in these workflow nodes
`Clay.K`	**`3.418e10`**	N/m^2	n23, n24, n25—clay bulk modulus = **KFromVel** ($V_{p\text{-}clay}$, $V_{s\text{-}clay}$, ρ_{clay})
`Clay_rho`	**`2.7`**	g/cc	n23, n24, n25—clay density
`Quartz.Mu`	**`4.433e10`**	N/m^2	n23, n24, n25—quartz shear modulus
`Quartz.K`	**`3.789e10`**	N/m^2	n23, n24, n25—quartz bulk modulus
`Quartz.Rho`	**`2.65`**	g/cc	n23, n24, n25—quartz density

Key workflow functions and formulas

The major expressions used in these workflow nodes are:

- **`n9`**—ρ_{brine} = **BrineRho**[10](**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Brine_Salinity)
- **`n10`**—K_{brine} = **BrineK**(**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Brine_Salinity)
- **`n11`**—ρ_{gas} = **GasRho**(**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Gas_specific_gravity, Batzle&Wang)
- **`n12`**—K_{gas} = **GasK**(**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Gas_specific_gravity, Batzle&Wang)
- **`n13`**—ρ_{oil} = **LiveOilRho**(**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Oil_api, Gas_oil_ratio, Gas_specific_gravity, *blank*, Batzle&Wang)
- **`n14`**—K_{oil} = **LiveOilK**(**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Oil_api, Gas_oil_ratio, Gas_specific_gravity, *blank*, Batzle&Wang)
- **`n15`**—K_{HC} = **ConditionalExpression**(Gas_oil_flag, ==, 0, K_{gas} , K_{oil}) [11]
- **`n16`**—ρ_{HC}= **ConditionalExpression**(Gas_oil_flag, ==, 0, ρ_{gas}, ρ_{oil})
- **`n17`**—V_p/V_{smeas} = **VP**$_{curve}$ / **VS**$_{curve}$
- **`n18`**—Density Fraction$_{HC}$= (1 - Gas_spec_gravity) * ρ_{HC}
- **`n19`**—K_{patchy} = (K_{brine} - K_{HC}) * **SW**$_{curve}$ ** Brie_parameter
- **`n20`**—Density Fraction$_{brine}$= **SW**$_{curve}$ * ρ_{brine}
- **`n21`**—ρ_{fluid} = (Density Fraction$_{brine}$ + Density Fraction$_{HC}$)
- **`n22`**—K_{fluid} = (K_{patchy} + K_{HC})

Hint All three MixVelocity functions (**MixVelocityRho**, **MixVelocityVp**, and **MixVelocityVs**) take the same input constants and PowerLog curve names shown.

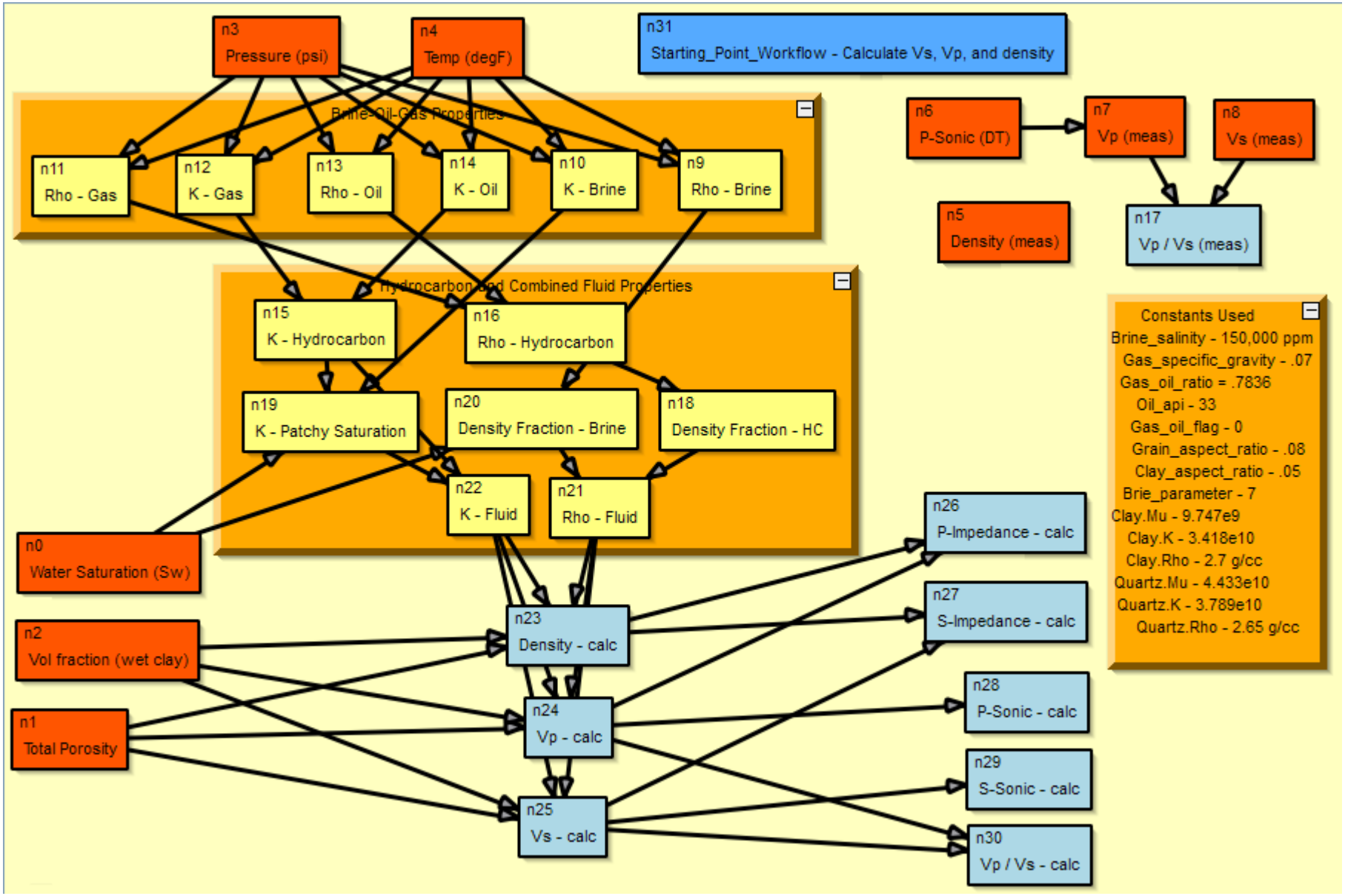
- **`n23`**— **`rhocalc`** = $\rho_{calculated}$ = **MixVelocityRho** (**PHIT**$_{curve}$, **VCL**$_{curve}$, `Quartz.K`, `Clay.K`, `Quartz.Mu`, `Clay.Mu`, `Quartz.Rho`, `Clay.Rho`, `Grain_aspect_ratio`, `Clay_aspect_ratio`, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, K_{fluid}, ρ_{fluid}, XuWhiteApprox)
- **`n24`**— **`Pvelcalc`** = $V_{p\_calculated}$ = **MixVelocityVp** (**PHIT**$_{curve}$, **VCL**$_{curve}$, `Quartz.K`, `Clay.K`, `Quartz.Mu`, `Clay.Mu`, `Quartz.Rho`, `Clay.Rho`, `Grain_aspect_ratio`, `Clay_aspect_ratio`, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, K_{fluid}, ρ_{fluid}, XuWhiteApprox)

10.Name of the RPM rock physics function used for this node. All other nodes use mathematical functions.
11.HC - Denotes hydrocarbon (oil or gas) selected with the **ConditionalExpression** RPM function for K_{HC} and ρ_{HC}.

- **n25— Svelcalc** = $V_{s\_calculated}$ = **MixVelocityVs** (**PHIT**$_{curve}$, **VCL**$_{curve}$, `Quartz.K`, `Clay.K`, `Quartz.Mu`, `Clay.Mu`, `Quartz.Rho`, `Clay.Rho`, `Grain_aspect_ratio`, `Clay_aspect_ratio`, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, *blank*, K_{fluid}, ρ_{fluid}, XuWhiteApprox)

- **n26— Zpcalc** = $Z_{p\_calculated}$ = $V_{p\_calculated}$ * $\rho_{calculated}$
- **n27— Zscalc** = $Z_{s\_calculated}$ = $V_{s\_calculated}$ * $\rho_{calculated}$
- **n28— DTpcalc** = $\Delta t_{p\_calculated}$ = 1000000. / $V_{p\_calculated}$
- **n29— DTscalc** = $\Delta t_{s\_calculated}$ = 1000000. / $V_{s\_calculated}$
- **n30— VpVscalc** = $V_{p}/V_{s\_calculated}$ = $V_{p\_calculated}$ / $V_{s\_calculated}$

Figure 54. Starting Point Workflow



Curve Differences Statistics

The *Curve Differences Statistics* workflow helps you to understand how accurately any calculated curve from a rock physics model workflow approximates the equivalent measured petrophysical log. A correlation value ≥ 0.8 suggests a *strong* correlation, while a value ≤ 0.5 suggests a *weak* correlation. You can use this workflow to assess the calculated results of the *Starting Point Workflow* against the measured well curves:

- Density (ρ)
- V_p (acoustic velocity)
- Shear velocity (V_s)
- V_p / V_s (acoustic / shear) velocity ratio

Objectives

The *Curve Differences Statistics* workflow:

- Provides information about the accuracy of a rock physics model curve calculation.
- Illustrates a workflow building block that can be used interchangeably with any set of measured and calculated curves
- Identifies if the measured and calculated (modeled) curves are strongly correlated, suggesting that the model approximates the measured response.
- Computes a quality control value in the form of the averaged RMS difference percentage between the calculated and measured curves. This value can be compared with other workflow calculations to see if the model error is decreasing or increasing due to parameter or model variations.
- Computes a bias function. A significant average bias function suggests there are unaccounted factors not described by the model.

Computed results

The *Curve Differences Statistics* workflow yields these results for each measured and calculated curves:

- **Error function curve (n2)**—curve stored in PowerLog that can be plotted beside the calculated and measured curves. Node **`n2`** is where you change the name of the output error function curve.
- **RMS Difference Percentage (n7)**—A value that describes the average difference between the calculated and measured curves. This value is the computed as: **`n7`**—RMS Difference Percentage = 100 * Δ_{RMS} / $mean_{meas}$, that is, the root-mean square of the curve difference, normalized by the mean of the measured curve
- **Correlation Coefficient value (n3)**—A value describing the amount of linear correlation between the measured and calculated curve. A correlation value ≥ 0.8 suggests a *strong* correlation, while a value ≤ 0.5 suggests a *weak* correlation.
- **Average Bias Percentage (n10)**—A value equal to the average deviation between the measured and calculated curve.

Strategies

The computations in the *Curve Differences Statistics* workflow are a straightforward usage of the **Correlation**, **Mean**, **Sum**, and **Rms** RPM statistical functions.

You can use the *Curve Differences Statistics* workflow in two ways:

- **Method One**—Change the names of the two input PowerLog curves and the single output curve and rerun the workflow four times with the desired curves. For example, the density, V_p, V_s, and V_p/V_s curves from the **Starting Point Workflow**.
- **Method Two**—Make three identical copies of these workflow nodes. You can then calculate the curve difference statistics for density, V_p, V_s, and V_p/V_s in a single workflow.

Table 12. *Curve Differences Statistics* workflow - curve names

Curve Type	Calculated Curve Node n0	Measured Curve Node n1	Output Error Function Name
Density	`rhocalc`	`RHOC`	`Rhoerr`
Vp	`Pvelcalc`	`VP`	`Vperr`
Vs	`Svelcalc`	`VS`	`Vserr`
Vp/Vs ratio	`VpVsmeas`	`VpVscalc`	`VpVserr`

Input curves

See **Table 12, "Curve Differences Statistics workflow - curve names," on page 95**.

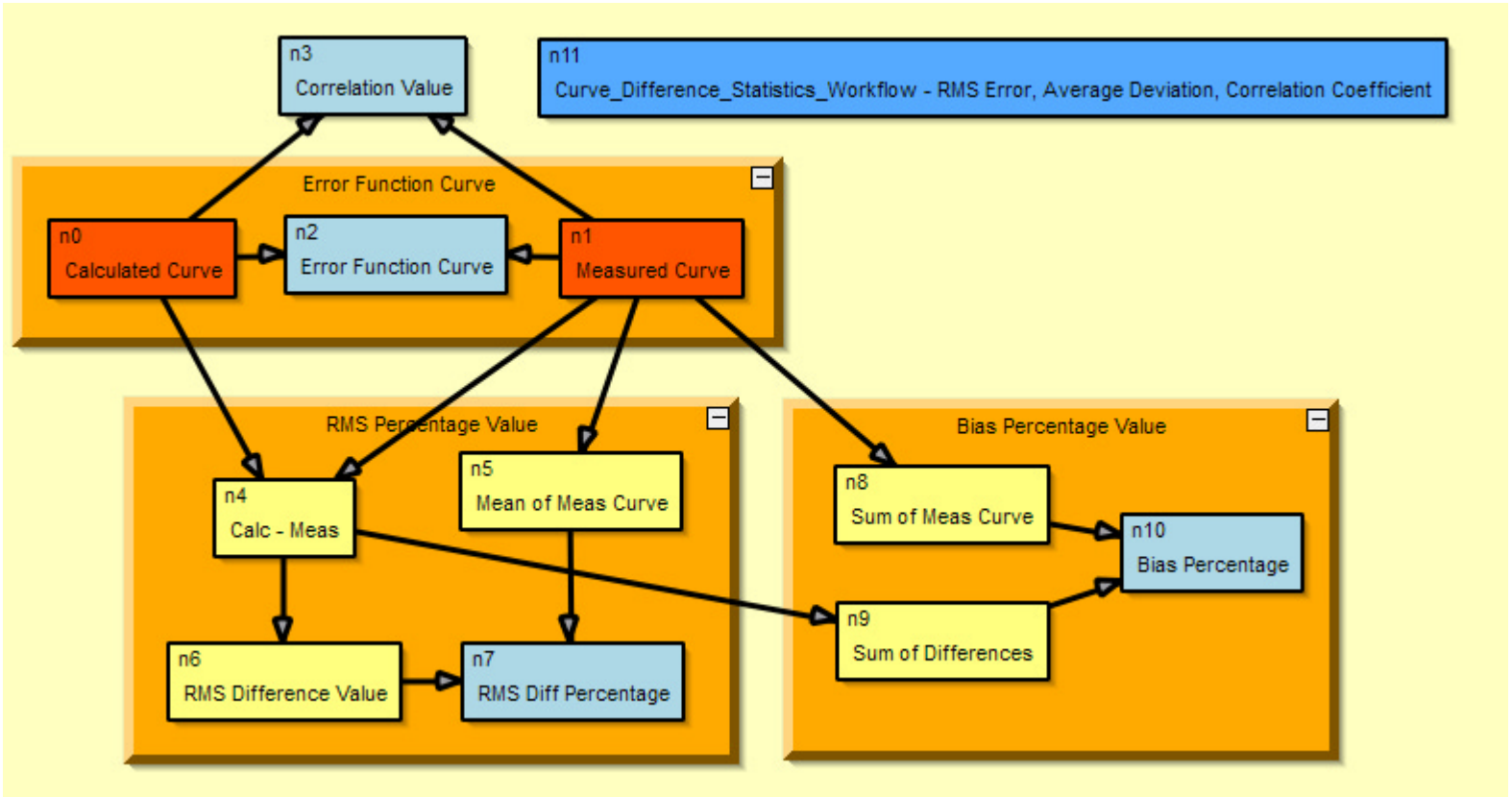
Named constants

The *Curve Differences Statistics* workflow uses no named Constants or Rock and Fluid Properties.

Key workflow functions and formulas

- `n2`—Difference function = $2 * (Meas_{curve} - Calc_{curve}) / (Meas_{curve} + Calc_{curve})$
- `n3`— ρ = **Correlation** $(Meas_{curve} , Calc_{curve})$
  m_{calc} = mean of calculated curve, m_{meas} = mean of measured curve
  σ_{calc} = Standard deviation of calculated, σ_{meas} = Standard deviation of measured
  Correlation Coefficient r =
  $(1/N) * \sum (curve_{meas} - m_{meas})(curve_{calc} - m_{calc}) / \sigma_{meas} * \sigma_{calc}$
- `n4`—$\Delta_{curve} = Meas_{curve} - Calc_{curve}$
- `n5`—$mean_{meas}$ = **Mean**$(Meas_{curve})$
- `n6`— Δ_{RMS} = RMS of curve difference = **Rms**$(Meas_{curve} - Calc_{curve})$
- `n7`—RMS Difference Percentage = $100 * \Delta_{RMS} / mean_{meas}$
- `n8`—$\sum_{meas}$ = **Sum** $(Meas_{curve})$
- `n9`— $\sum_{\Delta curve}$ = **Sum** (Δ_{curve})
- `n10`—Bias Percentage = $100 * \sum_{\Delta curve} / \sum_{meas}$

Figure 55. Curve Differences Statistics workflow



SimpleExpression formulas and logic

This workflow demonstrates some of the computational formulas and sophisticated logic possible with the **SimpleExpression** function in RPM for PowerLog.

Objectives

The *SimpleExpression formulas and logic* workflow demonstrates how to:

- Control the computation sequence using parentheses
- Implement multiple decision logic two ways to determine a:
  - curve that is limited between an minimum and a maximum value
  - lithology coding
  - fluid substitution value
- Implement a rock physics formula not found in RPM
  - Brie's patchy saturation formula
  - $\lambda\rho$ lambda-density product and $\mu\rho$ mu-density product
  - Poisson's ratio[12]
  - Young's modulus

Named Constants

This table displays the named constants, for the *SimpleExpression formulas and logic* workflow.

Table 13. SimpleExpression formulas and logic workflow - named constants

Name	Value	Units	Used in these workflow nodes
`Sonic_min`	**`90`**	µsec/ft.	n3, n5—minimum sonic transit time
`Sonic_max`	**`100`**	µsec/ft.	n3, n5—maximum sonic transit time
`Previous_value`	**`2`**	none	n6, used in n11 and n10—previous lithology log value determination
`Min_clay_volume`	**`.4`**	none	**`n7, n11`**—minimum clay volume for calcareous shale
`Min_coal_volume`	**`.1`**	none	**`n8, n11`**—minimum coal volume for calcareous shale
`Min_quartz_dominates`	**`.5`**	none	**`n9, n11`**—maximum quartz volume for calcareous shale
`Calcareous_shale`	**`1`**	none	**`n10, n11`**—value representing calcareous shale for lithology log
`Vol_clay_max`	**`.2`**	none	**`n12, n17`**—maximum clay volume permitted for fluid substitution
`Phi_effective_min`	**`.05`**	none	**`n14, n17`**—minimum effective porosity required for fluid substitution

12.The Poisson function does perform this calculation.

Table 13. SimpleExpression formulas and logic workflow - named constants (Continued)

Name	Value	Units	Used in these workflow nodes
Sw_new	.2	none	**n15, n17**—new water saturation is for fluid substitution
Z_conversion	92903.4	none	**n23, n24**—converts μρ and λρ to metric

Key workflow functions and formulas

The *SimpleExpression formulas and logic* workflow uses a few nodes and the **SimpleExpression** function to demonstrate each concept listed in the *Objectives*.

Computation Sequence

The *Computational precedence* group (in the workflow) demonstrates the use of parentheses to explicitly control how a complex mathematical expression is evaluated.

Without any parentheses inserted into a **SimpleExpression** function, the computation sequence defaults to trules two through six.

Operator precedence

Priority	Operator Type	Operators	Operator Description
1st	Parenthesis	(or)	Parenthesis control order
2nd	Arithmetic	^ or **	Raising a value to a power
3rd	Arithmetic	* or /	Multiplication and Division
4th	Arithmetic	+ or -	Addition and subtraction
5th	Comparison	< <= > >= = == != <>	Comparison
6th	Conditional	? or :	If-then and Else

Comments For each priority, operators that have the same rank level are evaluated from left to right.

Caution! The conditional operators are evaluated *right to left*.

Comments `( 8 - 2*3 + 3 ) ** 2` evaluates to `8 - 6 + 3 = 5 ** 2 = 25` because the `2*3` multiplication operator has precedence over other arithmetic operators and the parenthesis operator has higher priority than the power (`**`) operator.

Two example nodes make this very clear:

- **n0**— 1 + 2 + 3 * 4 ^ 5 * 6 + 7
  evaluates to
  1 + 2 + 3 * 1024 * 6 + 7
  1 + 2 + 3072 * 6 + 7
  1 + 2 + 18432 + 7 = 18442
- **n1**— (1 + 2) + (3 * 4) ^5 * (6+7)
  evaluates the same expression with parentheses to control the computation
  3 + (12) ^ 5 * (13)
  3 + 248832 * 13
  3 + 3234816 = 3234819

Curve range values limited, two implementations

The *Two curve range implementations* group shows how to limit the values within a PowerLog curve to a range between a minimum and maximum threshold:

- **n3**—all curve values are between the minimum and maximum values. If a curve sample exceeds the maximum, the curve sample is set to maximum threshold. Conversely, if a curve sample is less than the minimum, it is set to the minimum threshold.
- **n5**—uses the **SimpleExpression** to test each curve sample. If the curve sample exceeds either threshold value, the curve sample is set to an undefined value (**UNDEF_POWERLOG**).

Lithology coding decision making

The *Lithology coding decision making* group shows how to group multiple decision criteria into a single SimpleExpression statement and reduce the number of RPM nodes from four to one:

- **n7, n8, n9, and n10**—use the **ConditionalExpression** for each test and then a **SimpleExpression** function to check that all three tests were true.
- **n11**—uses the **SimpleExpression** to perform a boolean AND operation with three separate conditional tests.

The logic for the **n11** node can be diagrammed with each indentation level signifying a subordinate `If-then-else` structure (with PowerLog curves **VCL**, **VCLC**, and **VCLQ**):

```
VCL >= Min_clay_volume
                Then ? VCLC >= Min_coal_volume
                                Then ? VCLQ <= Min_quartz_dominates
                                                Then ? Calcareous_shale
                                                Else : n6
                                Else : n6
                Else : n6
```

Fluid substitution decision making

The *Fluid Substitution decision making* group shows two methods for selecting the appropriate water saturation value, based on clay volume and effective porosity:

- In nodes **n12** through **n16**, the **ConditionalExpression** function is used to decide whether to use the new S_w value or take the existing water saturation value.
- n17—using the **SimpleExpression** compresses the decision making logic to a single node.

The logic for the **n17** node can be diagrammed with each indentation level signifying a subordinate `If-then-else` structure (with PowerLog curves **VCL**, **PHIE**, and **SW**):

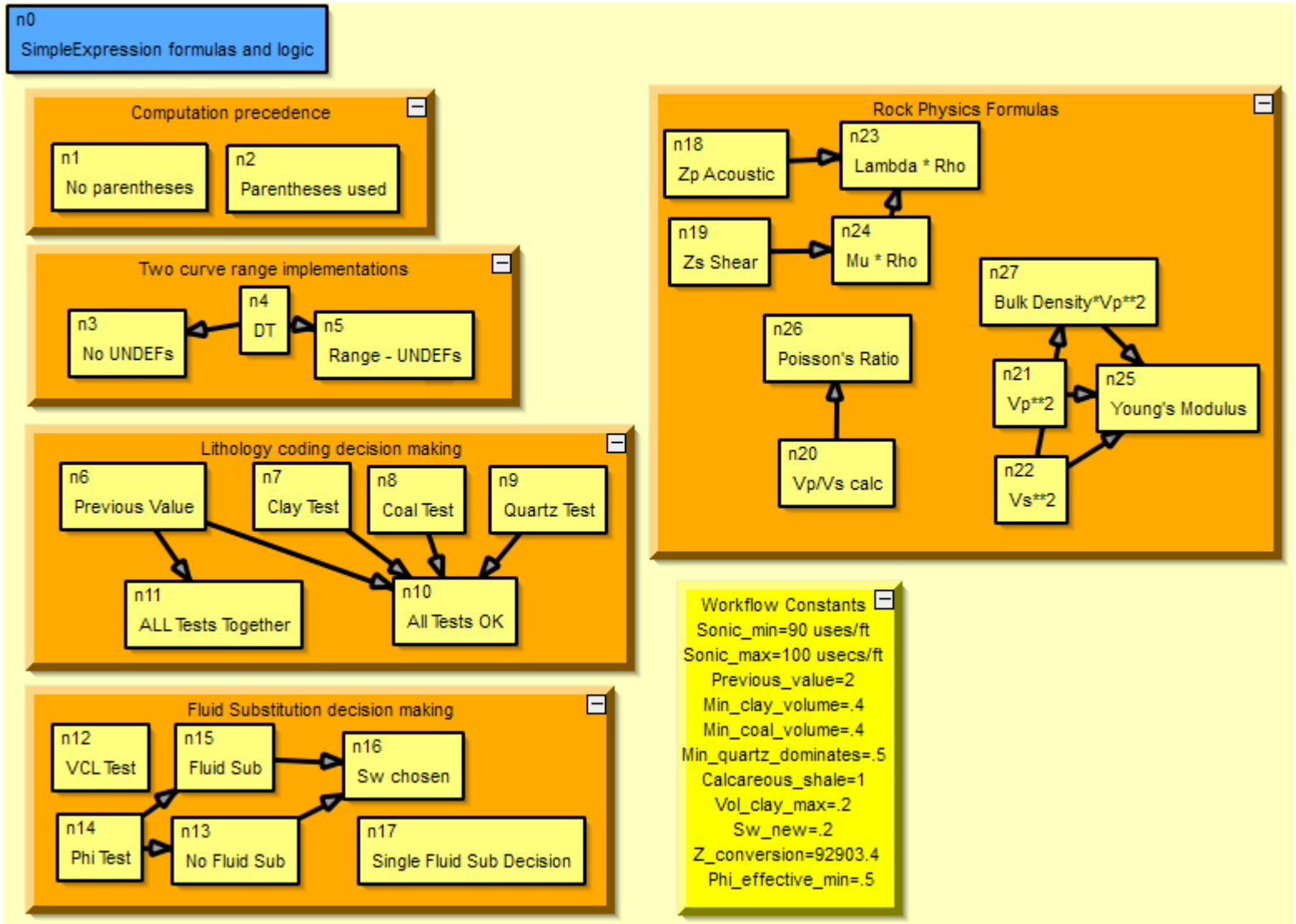
```
VCL < Vol_clay_max
        Then ? PHIE > Phi_effective_min
                        Then ? Sw_new
                        Else : SW
        Else : SW
```

Rock physics formulas

The *Rock Physics Formulas* group implements four expressions for elastic moduli:

- **`Poisson's ratio (n20`** and **`n26)`** — $\nu = (1/2) [(V_p/V_s)^2 - 2] / (V_p/V_s)^2 - 1)$
- $\lambda\rho$ and $\mu\rho$ **`(n18`**, **`n19`**, **`n23`**, and **`n24)`** —
  $\mu\rho = V_s^2\rho^2$ * `Z_Conversion,` where `Z_Conversion` converts to metric units
  $\lambda\rho = V_p^2\rho^2$ * `Z_Conversion` - $2*\mu\rho$
- **`Youngs Modulus (n21`**, **`n22`**, **`n25`**, and **`n27)`** —
  $E = \rho*V_s^2 * [(3*V_p^2 - 4*V_s^2) / (V_p^2 - V_s^2)]$

Figure 56. SimpleExpression formulas and logic workflow



RP Properties for AVO Checks

The *RP Properties for AVO Checks* workflow uses density, acoustic log, and shear velocity log to calculate elastic constants that are useful in checking direct hydrocarbon indicators. Goodway et al. [15] suggested that Lamé's elastic parameters λ and μ, and their products with density, can be useful tools in AVO analysis.

In particular, $\lambda*\rho$ is very sensitive to fluids, while $\mu*\rho$ has little variation within the reservoir zone. Smith and Gidlow [35] plotted Castagna and Smith's [9] set of 25 world-wide measurements of P- and S-wave velocities and densities. Cross-plot domain representations of 25 shale/brine sand, shale/gas sand, and gas sand/brine-sand sets using V_s vs. V_p crossplots and $\mu\rho$ vs. $\lambda\rho$ crossplots clearly showed the distinction between gas-sands and non-pay lithologies,

Objectives

The *RP Properties for AVO Checks* workflow:

- Provides standard calculations of V_p and V_s velocities along with the acoustic impedance I = $V_p\rho$ and shear impedance J = $V_s\rho$. for:
  - Corrected acoustic Δt_p, shear Δt_s, and density logs
  - Identify wet sand acoustic Δt_p, shear Δt_s, and density interval
  - Raw acoustic Δt_p, shear Δt_s, and density logs
- Calculate effective porosity based on measured volume of clay
- Calculate elastic moduli for bulk modulus (*K*), shear modulus (μ), Young's modulus (*E*), Poisson's ratio (ν), shear modulus*density product ($\mu\rho$), and Lamé's constant*density product ($\lambda\rho$).
- Illustrate how to restrict the range of a petrophysical curve values so that V_p/V_s ratios are reasonable. Curve values that exceed the range for Δt_s result in V_p/V_s points that are undefined (**UNDEF**).

Computed results

These PowerLog output curves are created when the entire workflow is calculated.

Table 14. RP Properties for AVO Checks Workflow - output curves

Node	Curve Name	Type and Units	Description
n12	Vp	p_velocity ft/sec	Acoustic velocity - corrected
n13	Vs	s_velocity ft/sec	Shear velocity - corrected
n14	VpVscor	any none	V_p/V_s ratio, calculated from V_p and V_s corrected
n16	Zp_cor	any none	Acoustic impedance - corrected
n17	Zs_cor	any none	Shear impedance - corrected
n21	Lithfrac	any none	Lithology fraction
n22	Phi_eff	any none	Effective porosity
n8	Vp_wet	p_velocity ft/sec	Acoustic velocity - wet sand

Table 14. RP Properties for AVO Checks Workflow - output curves (Continued)

Node	Curve Name	Type and Units	Description
n9	Vs_wet	s_velocity ft/sec	Shear velocity - wet sand
n10	Zp_wet	any none	Acoustic impedance - wet sand
n11	Zs_wet	any none	Shear impedance - wet sand
n18	Poisson	any none	Poisson's ratio
n19	MuRho	any none	$\mu\rho$ hydrocarbon indicator
n20	LameRho	any none	$\lambda\rho$ hydrocarbon indicator
n34	E_cor	any N/m^2	Young's modulus - corrected
n35	K_cor	bulk_modulus N/m^2	Bulk modulus - corrected
n36	Mu_cor	shear_modulus N/m^2	Shear modulus - corrected
n39	VpVs_raw	any none	V_p/V_s ratios from raw curves, where Vs was limited to specific range defined by the named constants: `Min_shear_tdel` to `Max_shear_tdel`. V_s values outside this range yield an undefined value for the corresponding V_p/V_s ratio.

PowerLog input curves

These PowerLog input curves are used to calculate the acoustic velocity and impedance, as well as the shear velocity and impedance. This workflow can use the corrected sonic and density logs, plus the raw logs for its V_p/V_s ratio calculations. The corrected density and velocities are used to calculate the three elastic moduli (Young's, bulk, and shear), plus Poisson's ratio and two AVO-related hydrocarbon indicators.

Hint For your well, you may need to modify the curve names or replace them with a convenient curve alias name. The curve names in the this table are from the tutorial *RP_Properties_for_AVO_Checks_Workflow* project.

Table 15. RP Properties for AVO Checks Workflow - input curves

Node	Curve Name	Type and Units	Description
n0	DTC	p_sonic µsec/ft.	P-sonic corrected
n1	RHOC	density g/cc	Density corrected
n2	DTS	s_sonic µsec/ft.	S-sonic corrected
n3	PHIT	porosity none	Total porosity
n4	VCL	any none	Volume of Wet Clay

Table 15. RP Properties for AVO Checks Workflow - input curves (Continued)

Node	Curve Name	Type and Units	Description
n5	DTC	p_sonic µsec/ft.	P-sonic (wet)
n6	RHOC	density g/cc	Density (wet)
n7	DTS	s_sonic µsec/ft.	S-sonic (wet)
n23	DT_raw	p_sonic µsec/ft.	P-sonic (raw) - uncorrected
n25	RHOCraw	density g/cc	Density (raw) - uncorrected
n24	DTS_raw	s_sonic µsec/ft.	S-sonic (raw) - uncorrected

Named Constants

The *RP Properties for AVO Checks* workflow uses these named constants:

- `Convert_Impedance_to_Metric`—92903.4
- `Max_shear_tdel`—300 µsec/ft.
- `Min_shear_tdel`—100 µsec/ft.

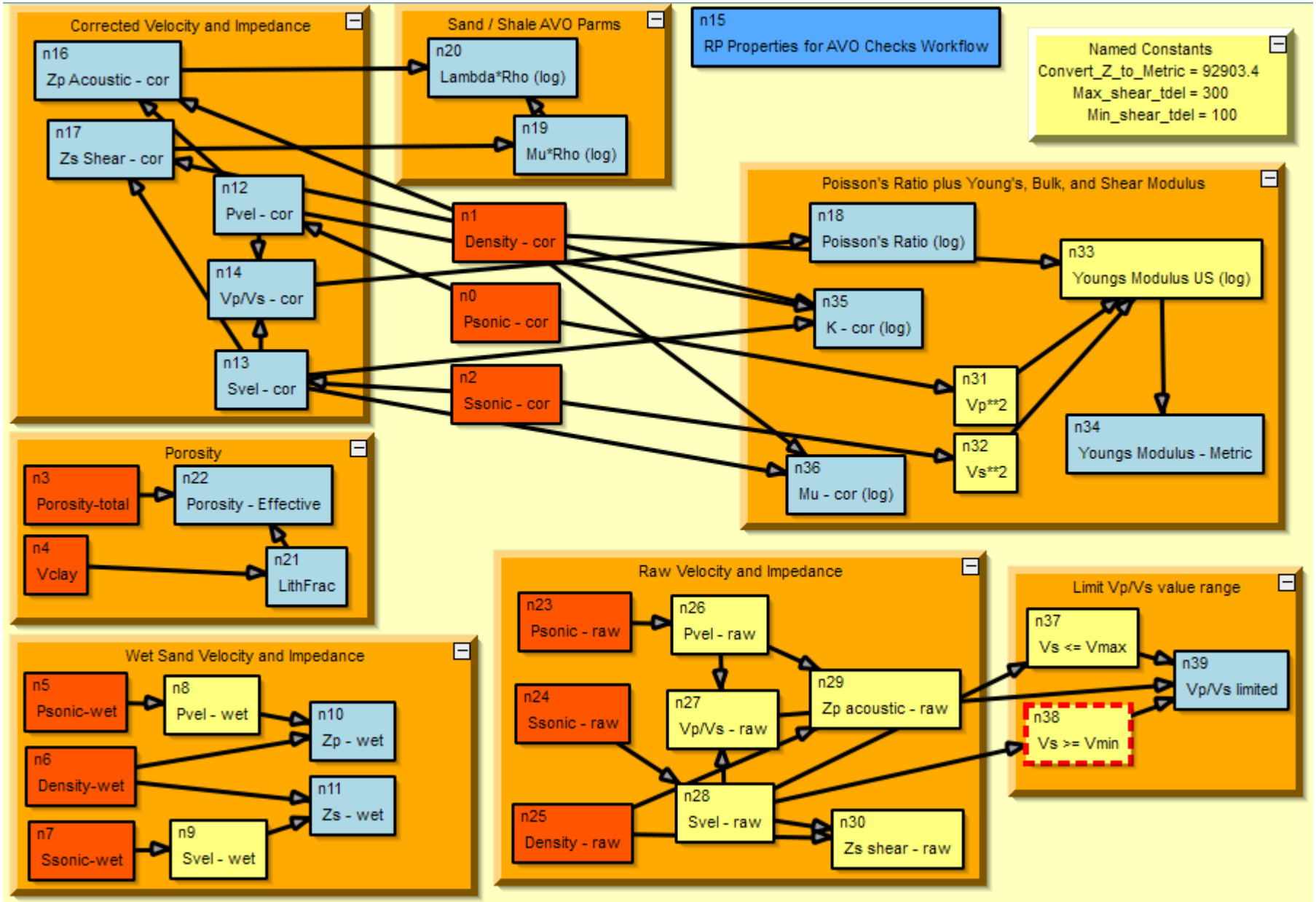
Key workflow functions and formulas

- **n8**, **n9**, **n12**, **n13**, **n26**, **n28**—these workflow nodes implement the simple division to convert a sonic log to the corresponding velocity values using the formula: $Velocity_{x\_curve} = 1000000 / \Delta t_x$, where x = $_p$ (acoustic), x = $_s$ (shear)

- **n10**, **n11**, **n16**, **n17**, **n29**, **n30**—these workflow nodes calculate the acoustic or shear impedance, using the product of the velocity and density curves: $Z_{x\_curve} = Velocity_{x\_curve} * \rho_{curve}$, where x = $_p$ (acoustic), x = $_s$ (shear)

- **n18**—Poisson's ratio computed using $\nu = (1/2) [(V_p/V_s)^2 - 2] / (V_p/V_s)^2 - 1)$
- **n19**—MuRho product = $\mu\rho = V_s^2\rho^2$ * `Convert_Impedance_to_Metric`
- **nn20**—LambdaRho product = $\lambda\rho = V_p^2\rho^2$ * `Convert_Impedance_to_Metric` - $2*\mu\rho$
- **n22**—φ_{eff_curve} = (1 - **Vclay**$_{curve}$) * **PHIT**$_{curve}$
- **n34**—Young's modulus $E = \rho*V_s^2 * [(3*V_p^2 - 4*V_s^2) / (V_p^2 - V_s^2)]$
- **n35**—Bulk modulus K = **KFromVel** (V_p, V_s, ρ)
- **n36**—Shear modulus μ = **MuFromVel** (V_s, ρ)
- **n39**—V_p/V_s measured = V_p/V_s , if `Min_shear_tdel` $\leq \Delta t_s \leq$ `Max_shear_tdel`
  otherwise V_p/V_s measured = **UNDEF_POWERLOG**

Figure 57. RP Properties for AVO Checks workflow



Fluid properties to estimate V_s

The *Fluid properties to estimate Vs* workflow calculates the density and bulk modulus for the subsurface fluids (brine, oil, and gas) as a function of:

- Pressure
- Temperature
- Salinity
- Oil and gas gravity
- Gas oil ratio

Objectives

The *Fluid properties to estimate Vs* workflow shows you:

- How to use conditional logic (named constant and **ConditionalExpression** function) to select between a PowerLog curve and a constant as an input parameter.
- Compute density and bulk modulus using the Brine, Oil, and Gas functions.
- Use named constants as physical parameters and as workflow logic switches.
- Select the oil or gas properties as the dominant hydrocarbon, using the **ConditionalExpression** function.

Computed results

These PowerLog output curves are created when the entire workflow is calculated. Additionally, when a PowerLog curve is selected for use, the mean value of the calculated curves is also determined in the workflow.

Hint If you do not want to add the mean calculation nodes to your workflow, you can use the **F8** (Calculate workflow) command to calculate the workflow. Once it finishes, you can place the mouse on each of the Curve Nodes in the next table. For each node, the function is shown in a tool tip and the node output curve name, mean value, and number of defined samples is displayed in the status bar. See **Figure: 87, 'Status bar", on page 146**.

Table 16. Fluid properties to estimate Vs workflow - output curves

Curve Nodes	Curve Name	Mean Nodes	Type and Units	Description
`n7`	`Salinity`	`n12`	salinity ppm	Salinity input
`n13`	`D_brine`	`n21`	density g/cc	Density of brine
`n14`	`K_brine`	`n22`	modulus N/m^2	Bulk modulus of brine
`n15`	`Den_gas`	`n23`	density g/cc	Density of gas
`n16`	`K_gas`	`n24`	modulus N/m^2	Bulk modulus of gas
`n17`	`Den_oil`	`n25`	density g/cc	Density of oil
`n18`	`K_oil`	`n26`	modulus N/m^2	Bulk modulus of oil
`n19`	`Den_hydr`	`n27`	density g/cc	Selected hydrocarbon density
`n20`	`K_hydr`	`n28`	modulus N/m^2	Selected hydrocarbon bulk modulus

PowerLog input curves

These six PowerLog input curves are used to compute the density and bulk modulus of the fluid properties.

Hint For your well, you may need to modify the curve names or replace them with a convenient curve alias name. The curve names in the this table are from the tutorial *Fluid_properties_to_estimate_Vs* project.

Table 17. Fluid properties to estimate Vs workflow - input curves

Node	Curve Name	Type and Units	Description
n0	**PRES**	pressure psi	Pressure of formation
n1	**T**	temperature degF	Downhole temperature
n2	**Sal**	salinity ppm	Brine salinity
n3	**API**	oil api	Oil gravity
n4	**SPEC**	any api	Gas specific gravity
n5	**GOR**	any none	Gas oil ratio

Named constants

The named constants for the *Fluid properties to estimate Vs* workflow consists of two groups; one set for physical fluid properties and the other to control the workflow computations.

Table 18. Fluid properties to estimate Vs workflow - named constants

Constant Name	Value	Units	Used in nodes
Salinity_brine	**72000**	ppm	**n7**
Oil_gravity	**43**	api	**n8**
Gas_specific_gravity	**.65**	none	**n10**
Gas_oil_ratio	**15000**	none	**n11**
Constant Name used as conditional logic flag	**Value**	**Units**	**Used in nodes**
Salinity_LogOrConstant	1 = Log, else constant	none	**n7**
Oil_grav_LogOrConstant	1 = Log, else constant	none	**n8**
Gas_grav_LogOrConstant	1 = Log, else constant	none	**n10**
GasOilRatio_LogOrConstant	1 = Log, else constant	none	**n11**
Hydrocarbon_gasoil_select	0 = Gas, otherwise oil	none	**n19, n20**

Key workflow functions and formulas

Most of the functions used in the *Fluid properties to estimate Vs* workflow, are the Brine, Oil, and Gas functions (see online help from each of the workflow nodes).

The **ConditionalExpression** function:

- Selects between a PowerLog curve and a constant value for salinity, oil gravity, gas specific gravity, and the gas-oil ratio inputs.
- Selects between the computed oil and gas constants (hydrocarbon density and bulk modulus) for this workflow calculation.

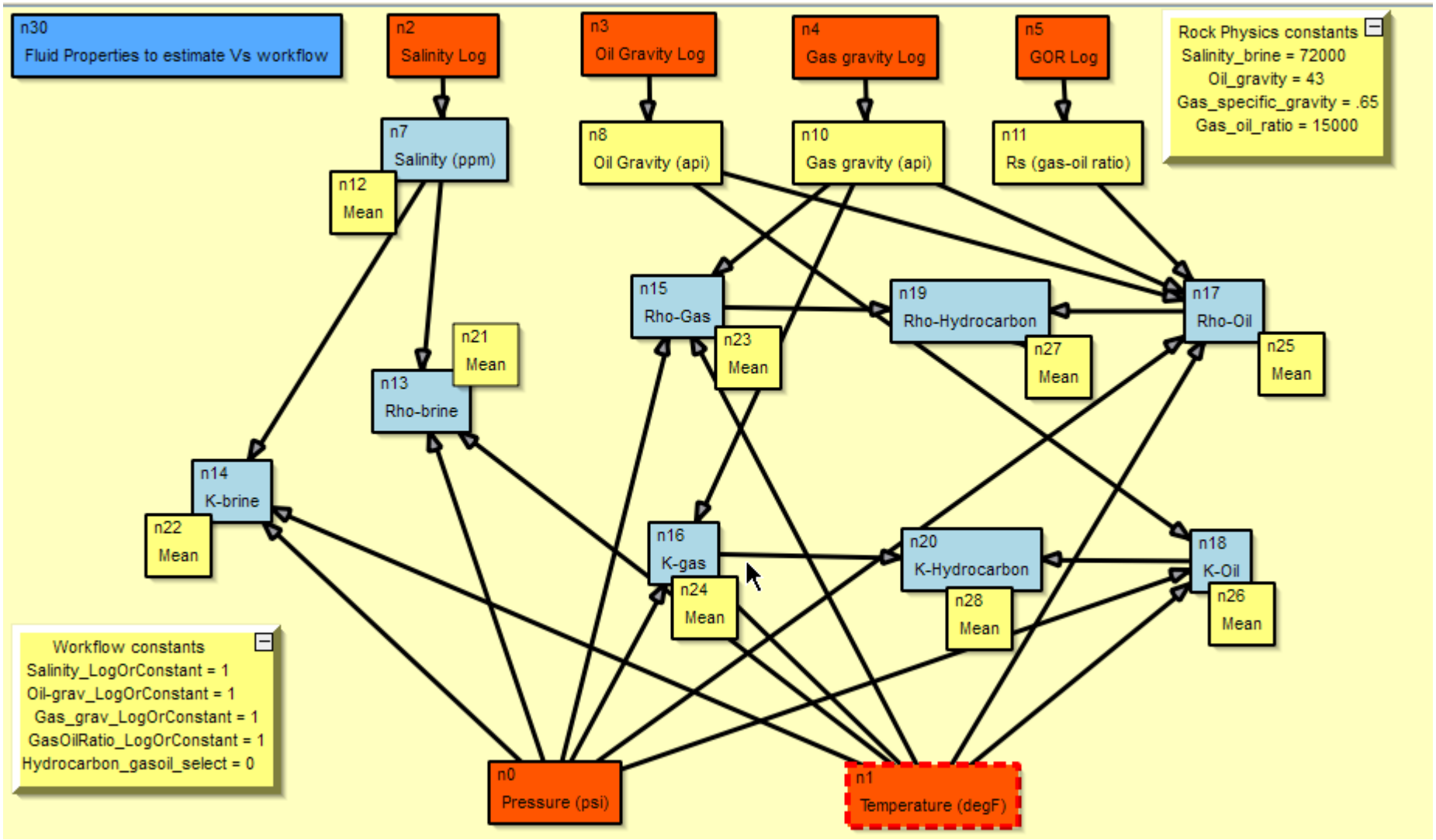
The Brine, Oil, and Gas functions used in this workflow are:

- **n13**—ρ_{brine} = **BrineRho** (**Pressure, Temp, salinitiy**)
- **n14**—K_{brine} = **BrineK** (**Pressure, Temp, salinitiy**)
- **n15**—ρ_{gas} = **GasRho** (**Pressure, Temp, spec, Batzle&Wang**)
- **n16**—K_{gas} = **GasK** (**Pressure, Temp, spec, Batzle&Wang**)
- **n17**—ρ_{oil} = **LiveOilRho** (**Pressure**, **Temp**, **oil_api**, **Rs**, **spec**, *blank*, **Batzle&Wang**)
- **n18**—K_{oil} = **DeadOilK** (**Pressure, Temp, oil_api, Batzle&Wang**)

The general form for the Conditional logic that selects a curve or constant is:
if (**curvename_LogOrConstant == 1**) then **Curve**, else **Constant**

The form for the Conditional logic that selects gas or oil is:
if (Hydrocarbon_gasoil_select **== 0**) then **Gas**, else **Oil**

Figure 58. Fluid properties to estimate Vs workflow



Lithology log construction

Petrophysicists construct lithology logs using many combinations of measured logs to infer geology and potential production zones. This RPM for PowerLog workflow uses six input PowerLog curves to construct a lithology coding log.

Objectives

The *Lithology log construction* workflow:

- Illustrates how a lithology log can be constructed by replacing petrophysical log measurements with rock physics parameters.
- Describes how to use name constants and RPM functions to define complex logical expressions.

Computed results

The *Lithology log construction* workflow result is a single PowerLog curve (`LITHTYPE, N26`) with lithology coding. The values are coded in the **Table 20, "Lithology log construction workflow - named constants," on page 111**.

- 0 = shale (default)
- 1 = calcareous shale
- 2 = limestone
- 3 = coal
- 4 = sand
- 5 = gas sand

PowerLog input curves

Hint For your well, you may need to modify the curve names or replace them with a convenient curve alias name. The curve names in the this table are from the tutorial `Lithology_log_construction_workflow` project.

Table 19. Lithology log construction workflow - input curves

Node	Curve Name	Type and Units	Description
`n0`	`VCLC`	any none	Volume of **calcite** relative to total volume (correct shale velocity)
`n1`	`VCOA`	any none	Volume of **coal** relative to total volume
`n2`	`VCL`	any none	Volume of **clay** relative to total volume
`n3`	`VQUA`	any none	Volume of **quartz** relative to total volume
`n4`	`PIGE`	any none	Effective porosity minus irreducible water
`n5`	`Sw`	Sw none	Water saturation

Named constants

The *Lithology log construction* workflow uses two sets of named constants; one to specify the decision making constants and another to implement the lithology coding.

Table 20. Lithology log construction workflow - named constants

Lithology coding constants	Value	Units	Used in nodes
Shale_lith	0	n/a	none
Calcareous_shale_lith	1	n/a	n20
Limestone_lith	2	n/a	n15
Coal_lith	3	n/a	n16
Sand_lith	4	n/a	n23
GasSand_lith	5	n/a	n26
Conditional logic constants	**Value**	**Units**	**Used in nodes**
Min_calcite_volume	.45	none	n15
Min_coal_dominates	.5	none	n16
Min_clay_volume	.4	none	n17
Min_coal_volume	.1	none	n18
Min_quartz_dominates	.5	none	n19
Min_quartz_volume	.45	none	n21
Min_porosity_effective	.08	none	n22
Max_Sw_gassand	.7	none	n25

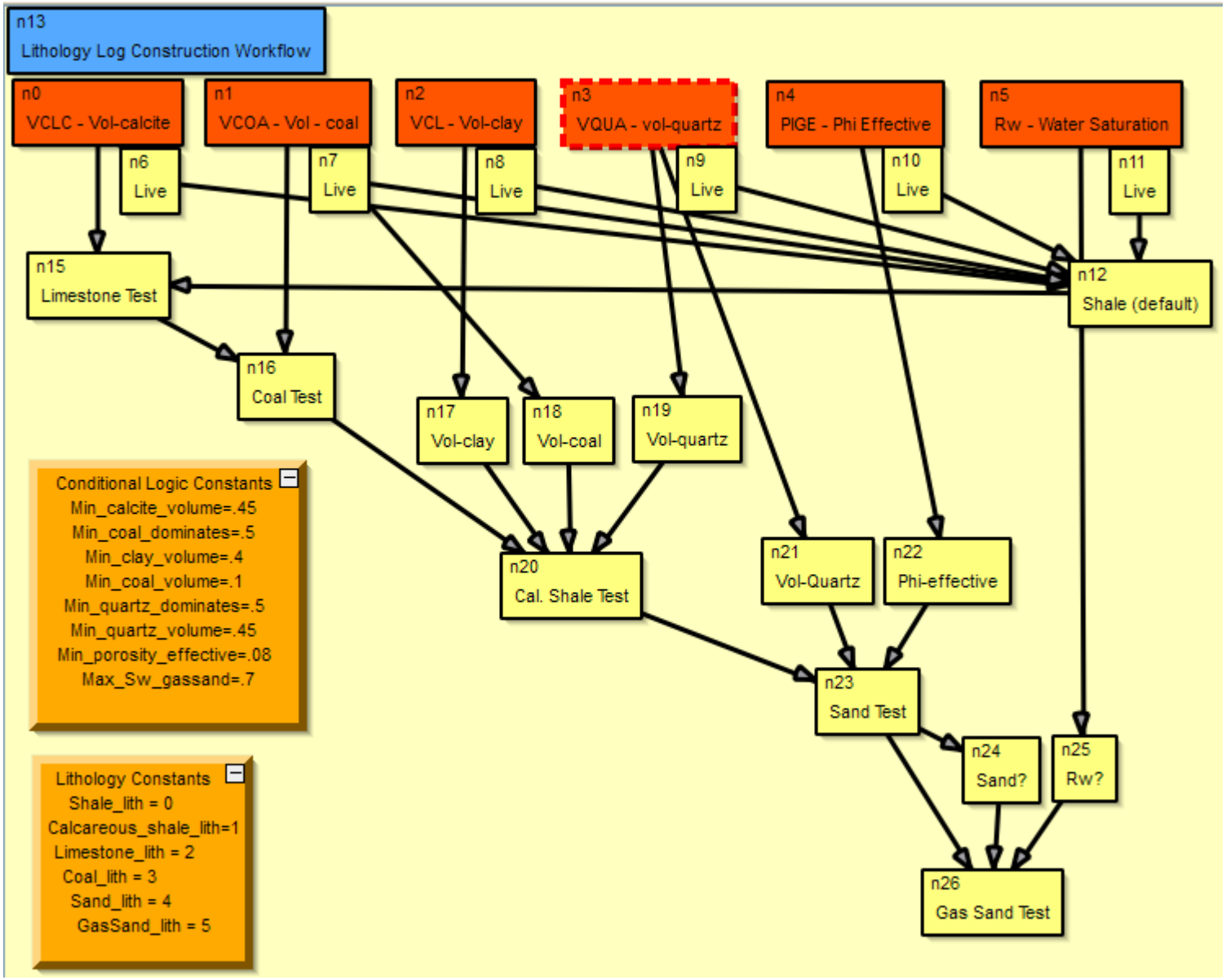
Throughout the conditional logic nodes in the *Lithology log construction* workflow, these values are used. If you want to extend these indicators, create additional named constants similar to the ones in the previous table.

Key workflow functions and formulas

Within these workflow nodes you can use either the **ConditionalExpression** or **SimpleExpression** functions to implement the decision logic. When multiple conditions must be combined (nodes **n17**, **n18**, and **n19**), set the output of each separate condition equal to 1 and test to see that all conditions (node **n20**) are true:

- **n12**— If (all curve samples not UNDEF) then **LITHTYPE** = **Shale_lith**, else **UNDEF**
- **n15**— If ($Vol_{calcite} \geq$ Min_calcite_volume) then **LITHTYPE** = Limestone_lith
- **n16**— If ($Vol_{coal} \geq$ Min_coal_dominates) then **LITHTYPE** = Coal_lith
- **n17, n18, n19, n20**— If ($Vol_{clay} \geq$ Min_clay_volume) AND ($Vol_{coal} \geq$ Min_coal_volume) AND ($Vol_{quartz} \leq$ Min_clay_volume) then **LITHTYPE** = Calcareous_shale_lith
- **n21, n22, n23**— If ($Vol_{quartz} \geq$ Min_quartz_volume) AND (**PIGE** ≥ Min_porosity_effective) then **LITHTYPE** = Sand_lith
- **n24, n25, n26**— If (**LITHTYPE** = Sand_lith) AND ($R_w \leq$ Max_Sw_gassand) then **LITHTYPE** = GasSand_lith

Figure 59. Lithology log construction workflow



Gassmann fluid-substitution to predict seismic response

The *Gassmann fluid-substitution to predict seismic response* workflow performs a hydrocarbon fluid substitution for the original brine in reservoir rocks so that the resulting velocity change can predict the seismic response of oil or gas in a reservoir. The S_w measured in the logs describes the original fluid composition.

Fluid substitution criteria

The workflow dynamically determines whether to perform the fluid substitution:

- For rocks with good porosity and low clay content (reservoir rocks), you perform a fluid substitution that reduces S_w to a lower level, thus increasing the hydrocarbon content.
- For rocks that do not meet the porosity and clay content criteria (non-reservoir rocks), the original S_w log is retained and no fluid substitution takes place.

The cutoff for wet clay content (V_{clay}) in good reservoirs is found in named constant, **`Vol_clay_max`**. The V_{clay} maximum is initially set at 0.20, but can be adjusted.The cutoff for effective porosity (**`PHIE`**) in good reservoirs is found in the named constant **`Phi_effective_max`**. You can change the value (effective porosity maximum = 0.05) by editing the named constant.

Thus rocks with V_{clay} < 0.2 and **`PHIE`**$_{curve}$ >0.05 are considered reservoir rocks and fluid substitution is performed in these rocks. S_w in these rocks becomes 0.20, instead of the initial value in the S_w curve. The replacement value for S_w is set in the named constant **`Sw_new`**, and can be adjusted.

Fluid substitution overview

PowerLog Pressure and Temperature logs are used in the Brine, Gas, and Oil Properties group to compute the properties of the individual fluids in the borehole.

The properties of the original combined fluid are computed in the **`Combined Fluid Properties (OLD)`** group. The Water Saturation (S_{w_old}) node inputs the S_w curve from PowerLog, which determines the S_w prior to any fluid replacement. Brie's formula for patchy saturation is used to compute the bulk modulus and density of the combined fluid in the **`Brie's Formula (OLD)`** group. The empirical Brie parameter (set to one) can be adjusted as the named constant `Brie_oldfluid_parameter`.

Next, the we compute the elastic parameters for a new fluid (brine in the original fluid replaced by hydrocarbons), but only in rocks with good porosity and low clay content. The selection of rocks with good porosity and low clay content (good reservoir rocks) takes place in the **`Fluid Substitution Criteria Check`** group. PowerLog for effective porosity, bulk density, (wet) clay content, and velocities are found in the **`Gassmann Inputs`** group.

The new S_w (the replacement value in reservoir rocks, the old value in all other rocks) is computed in the **`SwFluid Sub`** node in the **`Combined Fluid Properties (NEW)`** group. The bulk modulus and density of the replacement fluid are computed in this group just like the **`Combined Fluid Properties (OLD)`** group. Brie's patchy saturation formula in the **`Brie's Formula (NEW)`** group is used again. The Brie parameter is again set to one in the named constant `Brie_newfluid_parameter`.

The bulk modulus for the solid matrix is computed from a weighting of the *K* for clay (in the K_{clay} Fraction node) and the *K* for quartz (in the **`Kquartz`** Fraction node). Bulk modulus values for the minerals can be changed by using the **Rock and FLuid Properties** dialog.

Results from workflow

Finally, the Gassmann substitution, using the fluid parameters for the substituted fluid (which differ only in the reservoir rocks) is computed in the **`Gassmann FluidSub`** node. The rock density with the new fluid, P-sonic travel time, acoustic velocity (**GassmannFull** function), and impedance are calculated in the final workflow nodes.

Data consistency issues

Caution! There is sometimes a data-consistency issue with **GassmannFull** function in the **`Gassmann FluidSub`** node if input logs for the original rock (before the fluid substitution) are not sufficiently consistent with the relationship: $K = V_p^2 * \rho - 4/3*\mu$, where $\mu = V_s^2 * \rho$ and V_p, V_s, and ρ are calculated from log petrophysical analysis.

Bulk modulus *K* is independent of the input parameters for the densities and bulk and shear moduli of the mineral and fluid constituents of the rock-physics model. But *K* and the constituents of the model are used together in the Gassmann formula to calculate the bulk modulus of the rock with the initial fluid removed (the dry frame), and with a replacement fluid.

Problems in the Gassmann calculation can occur if the rock-physics model chosen is not consistent with the ρ, V_p, and V_s data from the logs (in other words, if the model just is not a good match for the rocks in the well), or if the log ρ and velocity data are not internally consistent. If such inconsistencies are present, the **GassmannFull** function displays error messages and stops before producing an output curve.

These parameter conditions produce error messages:

- $K \leq 0$, produces the error "`Input bulk modulus illegal`"
- K_{dry} (the bulk modulus of the rock frame without fluid), calculated from Gassmann's formula using $K \leq 0$, or greater than *K* for the mineral members, produces the error "`Calculated empty frame modulus illegal`".

Objectives

The *Gassmann fluid-substitution to predict seismic response* workflow:

- Dynamically tests V_{cl} to see if the clay content is too high and ensures the effective porosity exceeds a minimum level before performing a fluid substitution at each log depth.
- Uses Brie's formula to compute the bulk modulus (*K*) and density (ρ) of the combined fluid for the brine in reservoir rocks. It independently use's Brie's formula for patchy saturation again to compute *K* and ρ for the oil or gas replacement.

Computed results

The *Gassmann fluid-substitution to predict seismic response* workflow results permit you to predict appropriate seismic velocities and impedance.

Table 21. Gassmann fluid-substitution to predict seismic response workflow - output curves

Curve Nodes	Curve Name	Type and Units	Description
n30	SW_NEW	Sw none	Water saturation curve - taking into account the new fluid substitution
n36	Den_fsub	density g/cc	Bulk density with replacement fluid
n37	Vp_fsub	P-velocity ft/sec	Velocity for hydrocarbon substitution
n38	Sonic_fs	p_sonic µsec/ft.	Δt_p for hydrocarbon substitution
n39	Zp_fsub	any none	Acoustic impedance

Strategies

To perform the fluid substitution effectively:

- Elastic properties (bulk modulus and density) of the original fluid, composed of brine (plus some gas or oil) are computed.
- A **Gas/Oil** conditional logic named constant group to chooses gas or oil (oil may contain gas) in the original fluid.
- Elastic parameters for a new fluid (much of the brine in the original fluid is replaced by hydrocarbons) are computed for rocks with good porosity and low clay content.
- The cutoffs for V_{clay} and φ_{eff} porosity are defined; V_{clay} cutoff is initially = 0.20 and the initial value for the **PHIE** cutoff = 0.05.
- The new S_w (the replacement value in reservoir rocks, the old value in all other rocks) is computed in the **SwFluid Sub** node.
- The bulk modulus for the solid matrix is computed from a weighting of the *K* for clay.
- The Gassmann substitution, using the fluid parameters for the substituted fluid (which differ in the reservoir rocks), is done in the **Gassmann FluidSub** node.

PowerLog input curves

These PowerLog input curves are used to calculate the brine, gas, and oil properties. The water saturation curve is used in the Brie's patchy saturation formula and to compute the density fraction of brine and hydrocarbons. The total porosity and V_{clay} curves are inputs to the fluid substitution and $K_{mineral}$ groups.

Hint For your well, you may need to modify the curve names or replace them with a convenient curve alias. The curve names in the previous table are from the tutorial **Gassmann_fluid_substitution_predict_seismic_response** project.

Table 22. Gassmann fluid-substitution to predict seismic response workflow - input curves

Node	Curve Name	Type and Units	Description
n1	PRES	pressure psi	Pressure of formation
n2	T	temperature degF	Downhole temperature
n3	SW	Sw none	Water saturation

Table 22. Gassmann fluid-substitution to predict seismic response workflow - input curves

Node	Curve Name	Type and Units	Description
n4	**PHIE**	porosity none	Effective Porosity
n5	**VCL**	any none	Volume fraction of clay relative to total volume
n6	**RHOC**	any none	Bulk density - measured
n7	**Vpcalcr**	p_velocity ft/sec	Vp log
n8	**Vscalcr**	s_velocity ft/sec	Vs log

Named Constants and Mineral Properties

This table displays the named constants, clay and quartz bulk modulus, and the conditional logic switch (**Gas_oil_selection**) for gas and oil.

Table 23. Gassmann fluid-substitution to predict seismic response workflow - named constant and rock/fluid properties

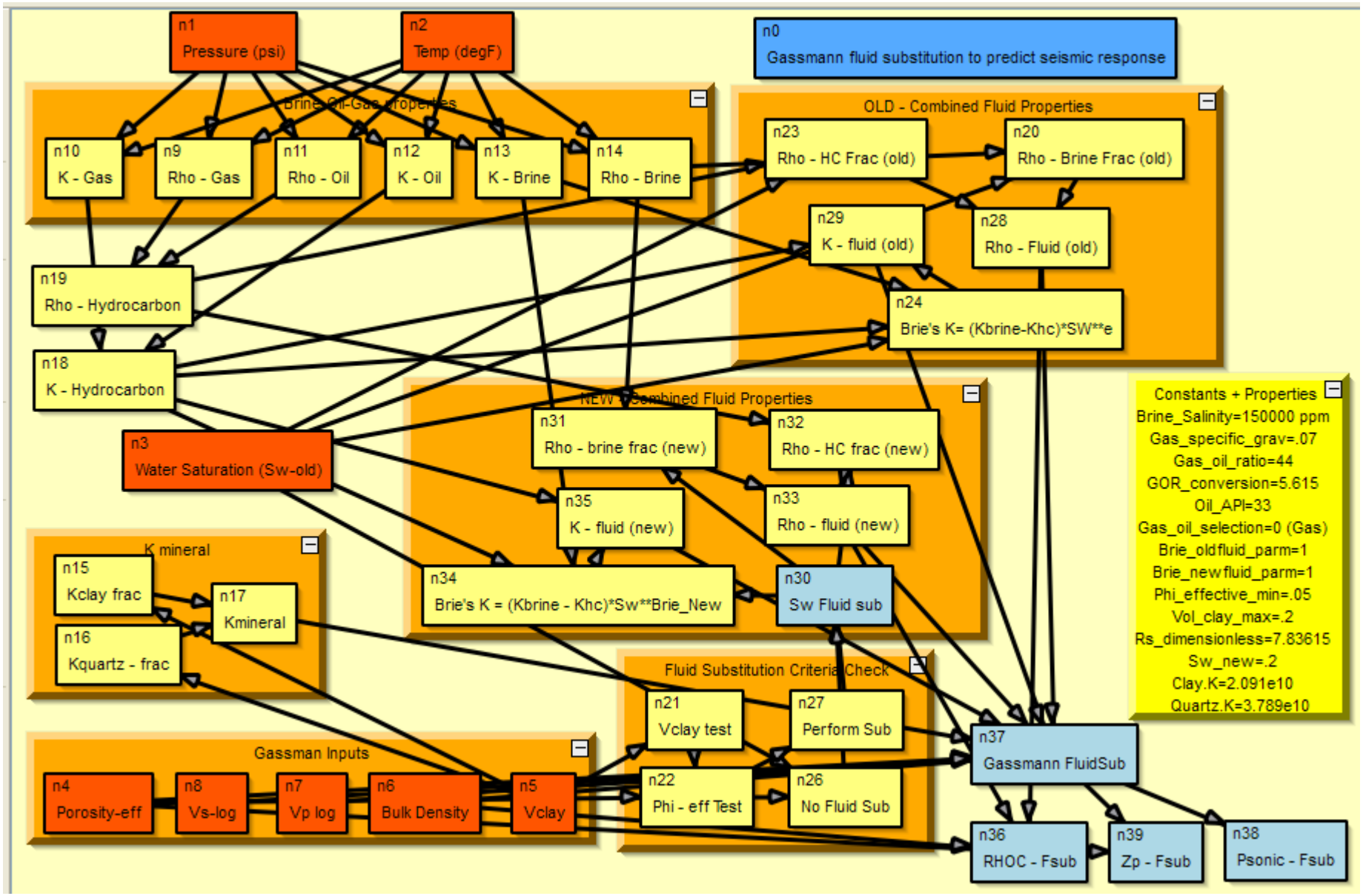
Name	Value	Units	Used in these workflow nodes
Brine_salinity	**150000**	ppm	**n13**, **n14**—concentration in ppm
Gas_specific_grav	**.07**	none	**n9**, **n10**, **n11**, **n12**— Gas spec-grav
Gas_oil_ratio	**44**	none	GOR (Gas Oil Ratio)
GOR_conversion	**5.615**	none	Factor compute dimensionless Rs
Oil_API	**33**	api	**n11**, **n12**—oil density
Gas_oil_selection	**0 - Gas else Oil**	none	**n18**, **n19**—select which hydrocarbon to use in the fluid computations
Brie_oldfluid_parameter	**1**	none	**n24**—Brie exponent for old fluid patchy saturation computation
Brie_newfluid_parameter	**1**	none	**n34**—Brie exponent for new fluid patchy saturation computation
Phi_effective_min	**.05**	none	**n22**—minimum porosity needed for fluid substitution
Vol_clay_max	**7**	none	**nxx**, **nxx**—maximum clay volume allowed for fluid substitution
Rs_dimensionless	**7.83615**	none	**n11**, **n12**—GOR dimensionless value
Sw_new	**.2**	none	**n21**—**Sw** replacement value
Clay.K	**2.091e10**	N/m^2	**n15**—clay bulk modulus
Quartz.K	**3.789e10**	N/m^2	**n16**—quartz bulk modulus

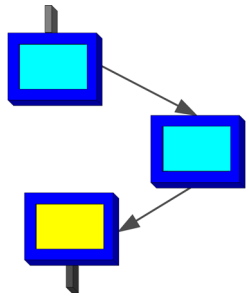
Key workflow functions and formulas

- **n09**—ρ_{gas} = **GasRho**[13] (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Gas_specific_grav, Batzle&Wang)
- **n10**—K_{gas} = **GasK** (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Gas_specific_grav, Batzle&Wang)
- **n11**—ρ_{oil} = **LiveOilRho** (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Oil_API, Rs_dimensionless, Gas_specific_grav, *blank*, Batzle&Wang)
- **n12**—K_{oil} = **LiveOilK** (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Oil_API, Rs_dimensionless, Gas_specific_grav, *blank*, Batzle&Wang)
- **n13**—K_{brine} = **BrineK** (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Brine_salinity)
- **n14**—ρ_{brine} = **BrineRho** (**Pres**sure$_{curve}$, **T**emperature$_{curve}$, Brine_salinity)
- **n15**—K_{clay_frac} = V_{cl} * **Clay.K**
- **n16**—K_{quartz_frac} = (1-V_{cl}) * **Quartz.K**
- **n17**—Kmineral = K_{clay_frac} + K_{quartz_frac}
- **n18**—K_{HC} = **ConditionalExpression**(Gas_oil_selection, ==, 0, K_{gas} , K_{oil}) [14]
- **n19**—ρ_{HC}= **ConditionalExpression**(Gas_oil_selection, ==, 0, ρ_{gas}, ρ_{oil})
- **n20**—$\rho_{Brine\_frac\_(old)}$ = ρ_{brine} * **SW**$_{curve}$
- **n21**—V_{clay} test = **ConditionalExpression**(V_{cl_curve}, <, **Vol_clay_max**, 1, 0)
- **n22**—φ_{eff} test = **ConditionalExpression**($\varphi_{eff\ \_curve}$, >, Phi_effective_min, V_{clay} test, 0)
- **n23**—$\rho_{HC\_frac\_(old)}$ = ρ_{HC} * (1 - **SW**$_{curve}$)
- **n24**—$K_{Brie\_(old)}$= (K_{brine} - K_{HC}) * **SW**$_{curve}$ ** Brie_oldfluid_parameter
- **n26**—No Fluid Sub = (1 - φ_{eff} test)* **SW**$_{curve}$ [*use S_w old*]
- **n27**—Fluid Sub = (φ_{eff} test)*Sw_new [*use S_w new*]
- **n28**—$\rho_{fluid\_(old)}$ = $\rho_{HC\_frac(old)}$ + $\rho_{Brine\_frac\_(old)}$
- **n29**—$K_{fluid\_(old)}$ = K_{HC} + $K_{Brie\_(old)}$
- **n30**—**SW_NEW**$_{curve}$ = $S_{w\_FluidSub}$ = Fluid Sub + No Fluid Sub
- **n31**—$\rho_{Brine\_Frac\_(new)}$ = $S_{w\_FluidSub}$ * ρ_{Brine}
- **n32**—$\rho_{HC\_Frac\_(new)}$ = (1 - $S_{w\_FluidSub}$) * ρ_{Brine}
- **n33**—$\rho_{Fluid\_(new)}$ = $\rho_{Brine\_Frac\_(new)}$ + $\rho_{HC\_Frac\_(new)}$
- **n34**—$K_{Brie\_(new)}$ = (K_{brine} - K_{HC}) * **SW**$_{curve}$ ** Brie_newfluid_parameter
- **n35**—$K_{Fluid\_(new)}$ = $K_{Brie\_(new)}$ + K_{HC}
- **n36**—**Den_fsub**$_{curve}$ = ρ_{Fsub} = RHOC$_{curve}$ + φ_{eff} * ($\rho_{Fluid\_(new)}$ - $\rho_{Fluid\_(old)}$)
- **n37**—**Vp_fsub**$_{curve}$ = **GassmannFull** (Vp$_{curve}$, Vs$_{curve}$, RHOC$_{curve}$, φ_{eff}, $K_{Fluid\_(new)}$, $\rho_{Fluid\_(new)}$, $K_{mineral}$, $K_{Fluid\_(old)}$, $\rho_{Fluid\_(old)}$)
- **n38**—**Sonic_fs**$_{curve}$ = Psonic - Fsub = 1000000. / **Vp_fsub**$_{curve}$
- **n39**—**Zp_fsub**$_{curve}$ = **Vp_fsub**$_{curve}$ * **Den_fsub**$_{curve}$

13.Name of the RPM rock physics function used for this node.
14.HC - Denotes hydrocarbon (oil or gas) selected with the **ConditionalExpression** RPM function for K_{HC} and ρ_{HC}.

Figure 60. Gassmann fluid-substitution to predict seismic response





RPM User Interface

Introduction

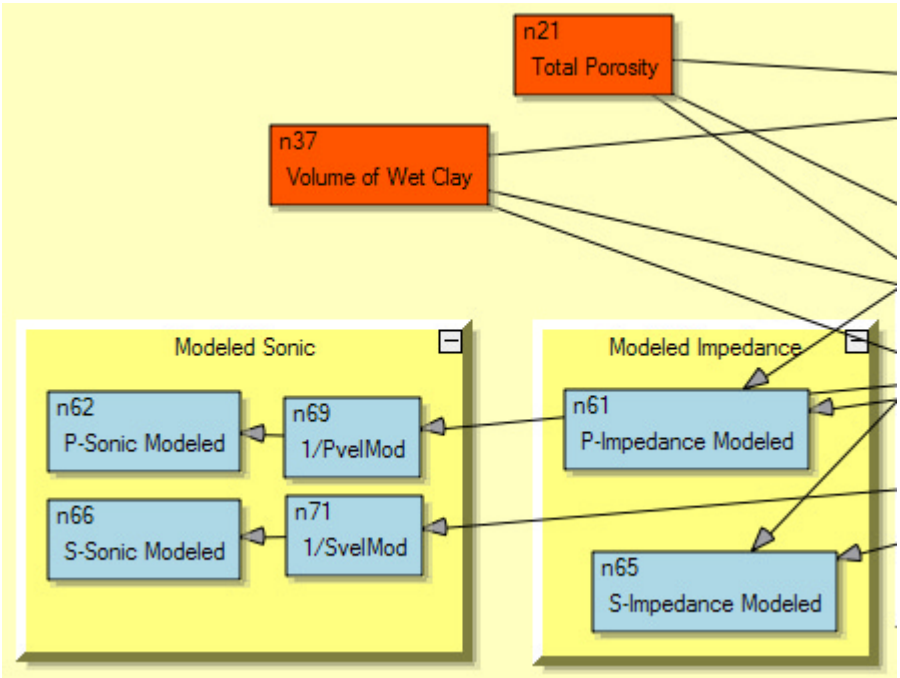
In RPM, you interact with a Windows application that uses these GUI elements:

- **A workflow model user interface**
- **Main menus**
- **Shortcut menus** (context-sensitive)
- **Application Dialogs**
- **Miscellaneous user interface tools** - tool bar, status bar, and tool tips

A workflow model user interface

RPM for PowerLog integrates rock physics calculations using a **workflow** (a directed graph) developed on a screen area (**workspace**). Unlike a spreadsheet approach, the workflow directly reveals the calculation dependencies in the form of **ancestors** (nodes that affect this node's inputs) and **descendents** (nodes affected by this node's output). The main user interface is a workflow that shows a **directed graph**, containing **node**s (where calculation **function**s operate) and connections (arrows) that determine the calculation dependencies.

Figure 61. Partial RPM workflow example



Workflow management

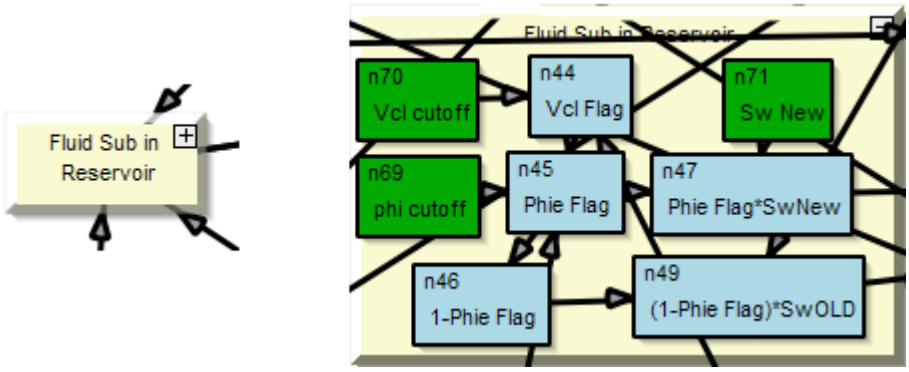
Nodes

The node layout can be changed by dragging the node with the mouse to the desired location. When a project is saved, the nodes and connections graphical positions are also saved. The workflow is redrawn the next time the project is opened with the nodes in the new locations. When the nodes are moved, the connections follow the nodes to which they are attached. The size of the node is defined by the size of the label you define for the node and cannot be customized.

Groups

Nodes can be associated into groups by adding a group defined by drawing a rectangle around the desired nodes and dragging them into the group. The group can be minimized so that only one box shows in the place of all the nodes in the group. A group can be minimized or restored to its original size (see **Figure: 62, 'Group minimizing workflow complexity"**). You can assigned a very descriptive name to a group, which can span several text lines. The group can be moved around as a whole and individual nodes can be moved inside the group. Complex workflows can be simplified by using groups to manage a related set of nodes.

Figure 62. Group minimizing workflow complexity



Context - node, group, connection, workspace

RPM uses the mouse cursor location to define the context of its operations. For example, if the cursor hovers over a node, RPM considers the node to be the current node and any operation from the node shortcut menu (such as Delete Node) applies to that node. The node can also be selected by clicking with the left mouse button (MB1). Similarly, if the cursor hovers over a connection line, that line is considered to be the current context. This is also true for groups. If the cursor is in the blank area outside of any group or node rectangles (that is, the workspace), then the RPM main menus apply.

Main menus

Menu functionality is active or inactive, based on the workflow and application context in which you select the menus. If a menu does not apply to the current context, it does not display in the shortcut menu or is grayed out in the main menus. The RPM application contains the **File**, **Edit**, **Data**, **Calculate**, **View**, and **Help** menus.

Keyboard shortcuts used in RPM for PowerLog

Note In the next six menu sections, the keyboard shortcuts (next to each menu command on the menus) corresponding to the RPM menu commands are displayed in brackets.

Example The keyboard shortcut combination for the **File > New Project** command is `[Ctrl+N]`, that is, the `Ctrl` (Control) and `N` key pressed together.

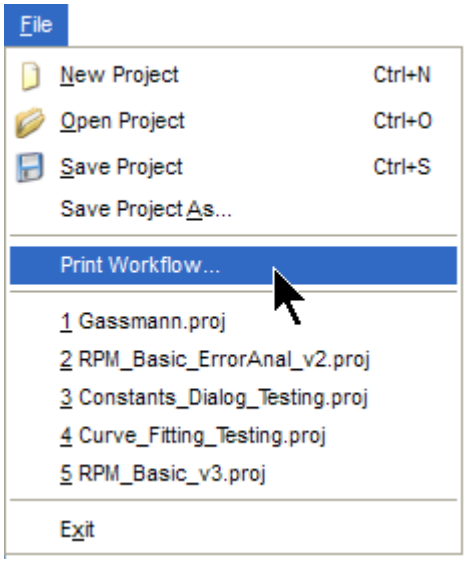
For Windows XP, you can selectively hide or display the underlined menu letters that designate the shortcuts.

To display the Windows XP keyboard accelerator underlined items

1. Select an unused area of the Windows XP desktop, right-click (MB3), and select the **Properties** command from the shortcut menu.
2. When the **Display Properties** dialog shows, select the **Appearance** tab.
3. Click the **Effects** button.
4. When the **Effects** dialog displays, un-select the check box with the label **Hide underlined letters for keyboard navigation until I press the Alt key**.
5. Click **OK** twice.

File menu

Figure 63. File menu



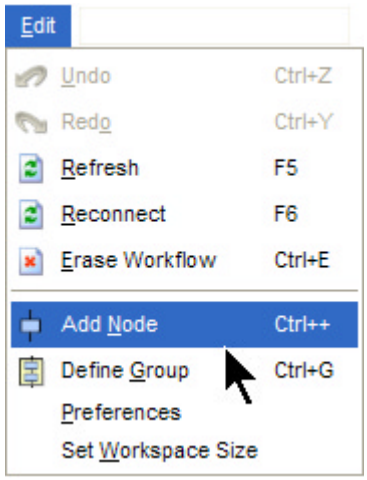
- **New Project** [`Ctrl+N`]—creates a new project; building new RPM project, node, and graphic workflow files with the project name you typed.
- **Open Project** [`Ctrl+O`]—opens a previously saved RPM project, plus the corresponding graphic workflow, and node files.
- **Save Project** [`Ctrl+S`]—saves the data for the current RPM project in its current files.
- **Save Project As** [`Alt+F+A`]—saves the current project file as a different name. It does not change the project name stored within the file and is used primarily to make a backup copy. of the RPM

- **Print Workflow**—sends a graphic workflow image to one of your printers.
- **Most Recently Used (MRU) List** [`Alt+F+1,2,3,4,or 5`]—provides quick access to the five most recently used RPM project files.
- **Exit** [`Alt+F+X`]—exits the RPM software. You are prompted to save data if you made changes to the workflow or functions.

Note Once a project is defined or opened, the **Edit**, **Data**, **Calculate**, **View**, and **Help** application menus become active.

Edit menu

Figure 64. Edit menu



The **Edit** menu helps you develop and build the workflow model in the workspace with several features, operations, and preferences:

- **Undo** [`Ctrl+Z`]—undoes the last workflow operation, such as deleting a node.
- **Redo** [`Ctrl+Y`]—redoes the last workflow operation after you selected an **Undo** operation.
- **Refresh** [`F5`]—redraws the currently displayed workflow.
- **Reconnect** [`F6`]—redraws all the connections for the current workflow.
- **Erase Workflow** [`Ctrl+E`]—erases the entire workflow.

Note The workflow can be restored by reopening the workflow prior to saving any project changes or by using the **Undo** command.

- **Add Node** [`Ctrl + Keypad "+"`]—adds a single node when you click a workflow location. You use this command each time to create an individual node.
- **Define Group** [`Ctrl+G`]—draws a rectangle around a group of nodes. This is useful for grouping nodes together that have a related workflow goal. Helps to minimize the number of graphic elements in a complex workflow.
- **Preferences** [`Alt+E+P`]—changes drawing characteristics (colors, line sizes, and so forth) for the workflow. Changes can apply to a specific node or to all the nodes by selecting the **Apply to existing nodes** check box.

- **Set Workspace Size** [`Alt+E+W`]—sets the size of the screen on which to draw the workflow. If the current workflow is truncated at its edges, resizing to a larger workspace size can fix the problem. The invalid area is shown by crosshatching in the background. The current size of the workspace is displayed in the status bar.

Note Setting the workspace size is critical for printing the workflow because the workflow size controls the scaling of the hardcopy image.

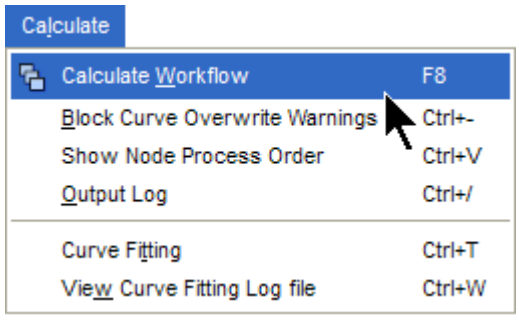
Data menu

The **Data** menu displays dialogs for defining specifics about the node or the project, or to examine the curves defined in PowerLog for the currently selected well:

- **Set Mix Defaults** [`Ctrl+M`]—sets the end members, fluid type, and the algorithm to use for mixing of curves. These mixing defaults are used in many functions when optional parameter values are not specified directly by the user. The parameters come from the mineral members Rock and Fluid properties. [15]
- **Constants** [`Ctrl+C`]—displays a list of named constants which can be customized to the particular needs of your current project.
- **Rock Fluid Properties** [`Ctrl+K`]—displays a list of rocks, minerals, gases, and fluids, along with their properties, which can be customized to the particular needs of your current project.
- **Curve List** [`Ctrl+L`]—displays the curve names curves available for the current well selected in PowerLog. The curve list is updated dynamically when a new curve is created in PowerLog.
- **Curve Alias List** [`Ctrl+A`]—displays the **Curve Alias List** from PowerLog. This displays log curve name aliases you can use for curve names that vary from well to well. Used for designing flexible workflows that can access the different curve names, when using a different well.

Calculate menu

Figure 65. Calculate menu



- **Calculate Workflow** [`F8`]—calculates all nodes in the current project workflow.
- **Block Curve Overwrite Warnings** [`Ctrl + Keypad "-"`]—a check box to turn off the overwriting curves check. This is useful when you recalculate the entire workflow. The status of this check box displays in the lower right on the status bar.

15.Currently only the Xu-White Approximation algorithm is defined.

If the item is checked, OVR (overwrite) displays in the status bar area (left of the workspace size) and the overwrite confirmation for each PowerLog curve *does not* display.

- **Show Node Process Order** [Ctrl+V]—prior to calculating the entire workflow, RPM can display the sequence in which the nodes are calculated. You can use this as a preliminary validation that your workflow sequence is correct. Select this command if you want to see the Node Process order display.
- **Output Log** [Ctrl+/]—receives internal status messages generated by the RPM application. These messages show calculation errors and helps you see which nodes may require additional work.
- **Curve Fitting** [Ctrl+T]—displays the **Curve Fit** dialog that helps you approximate a curve with one of the RPM function outputs. With this dialog you identify the (**1**) node with the function to approximate the curve, (**2**) curve to be approximated, and (**3**) the input parameter value ranges to use.
- **View Curve Fitting Log File** [Ctrl+W]—displays a file describing in detail the curve fitting algorithm computation parameters and iterative computation results.

Note The **Block Curve Overwrite Warnings** setting remains the same until you change the setting. That means, if you exit the RPM for PowerLog application, this setting is remembered from one RPM session to another.

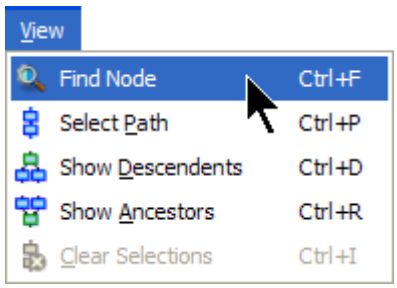
Note If you display the **Output Log** dialog and calculate a part or all of your workflow, the messages display in the **Output Log** dialog only. Individual error alerts do not display. If you want to see the individual alerts, close the **Output Log** dialog box.

Note You can copy-and-paste **Output Log** messages into other Windows applications using standard Windows commands.

Hint These messages can assist the technical support team to provide you provide better customer assistance, when you have a question or issue.

View menu

Figure 66. View menu



- **Find Node** [Ctrl+F]—finds and highlights a specific node in the workflow.
- **Select Path** [Ctrl+P]—highlights all nodes in the path between a starting and ending node to define a calculation sequence. You must first select this command, then click the beginning and ending nodes to define a calculation path. If there is no path between them, a message box warning displays.

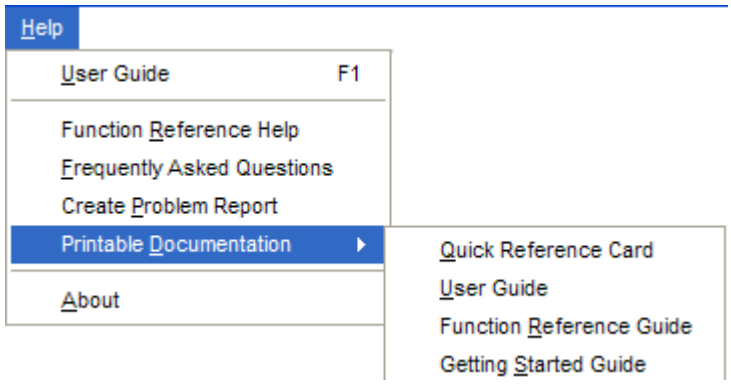
- **Show Descendents** [`Ctrl+D`]—highlights the nodes that are dependent upon (descendents of) a chosen node's output calculation.
- **Show Ancestors** [`Ctrl+R`]—highlights the ancestor nodes that provide calculation inputs upon which a chosen node depends.
- **Clear Selections** [`Ctrl+I`]—removes all highlighting of the selected path or nodes.

Help menu

Help menu (**Figure: 67, 'Help menu for RPM for PowerLog"**) provides you access to the online RPM for PowerLog documentation. Documentation is formatted as standard user guides (Adobe Acrobat files) and online HTML help.

- **User Guide**[`F1`]—displays the Acrobat online guide describing the RPM workflows, user guide, user interface, plus available functions and their usage. Examples of function calculations are provided.
- **Function Reference**—displays HTML help (Internet Browser window) that provides an explanation for every RPM function and its example usage.
- **Frequently Asked Questions** [`Alt+H+Q`]—displays an Acrobat PDF file providing answers to common questions and workarounds required by customers.
- **Create Problem Report** [`Alt+H+P`]—starts the Microsoft Word application and uses the RPM Problem Report template to help you report an RPM difficulty. You can save the Problem Report document, attach it to an email, then send a request to the Fugro-Jason support team.
- **Printable Documentation** [`Alt+H+D`]—displays a cascading menu that provides you a way to display the RPM for PowerLog documentation with Acrobat Reader. Once displayed, you can print sections of each document or search each online document for information. You can display and print the:
  - *Quick Reference Card*
  - *User Guide* (this document)
  - *Function Reference Guide*
  - *Getting Started Guide*
  - *Tutorial Workflows*
  - Problem Report Form
- **About** [`Alt+H+A`]—displays the RPM software version number and source code build date used to create this version of RPM for PowerLog. Technical support contact information (telephone, email, and fax numbers) is listed in this dialog.

Figure 67. Help menu for RPM for PowerLog



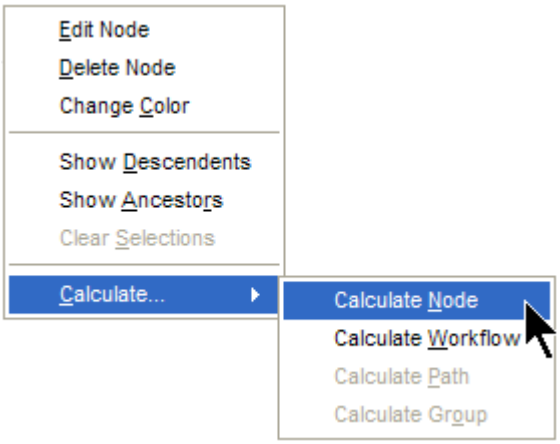
Hint Please supply the RPM software version number and source code build date to help Fugro-Jason provide you with superior customer support, whenever you have a question or issue.

Shortcut menus

Shortcut menus display when you click the third mouse button (MB3) or right-click in a specific area of the RPM application. These four shortcut menus are context-sensitive, that is, the menus contain only those commands or dialogs appropriate for this RPM workflow element.

Node shortcut menu

Figure 68. Node shortcut menu



Right-click (MB3) over a node to display this shortcut menu:

- **Edit Node**—displays the current function definition for a node. The **Function Selection** dialog can also be opened by double-clicking on the node.

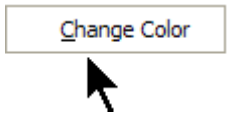
- **Delete Node**—deletes the node currently under the mouse cursor. A delete can also be done using the **`delete`** key.
- **Change Color**—displays the **Color Selection** dialog to help the user to define an existing or custom color for the node. This is useful in highlighting certain functions or areas of commonality in the workflow.
- **Show Descendents**—highlights the nodes that depend upon (descendents of) a chosen node's output calculation.
- **Show Ancestors**—highlights the ancestor nodes that provide calculations upon which a chosen node depends.
- **Clear Selections**—removes the highlighting of the selected path and nodes.
- **Calculate...**
  - **Calculate Node**—calculates the function defined for the current node. If no function is defined, a message box displays to alert you. Errors are reported and the calculation result is displayed in the status bar.
  - **Calculate Workflow**—calculates all workflow nodes by using a sorting algorithm; so that dependencies are calculated first and then all subsequent nodes are calculated in order.
  - **Calculate Path**—performs computations for the nodes in the selected path.
  - **Calculate Group**—performs computations for the nodes in the selected group.

Connection shortcut menu

Right-click (MB3) over a connection to display this shortcut menu:

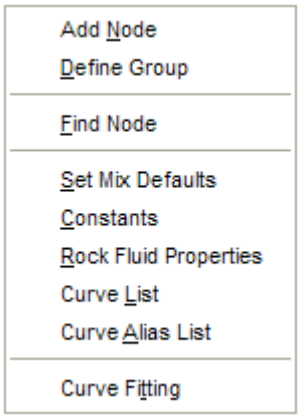
- **Change Color**—displays the **Color Selection** dialog to help you define an existing color or a custom color for this connection.

Figure 69. Connection shortcut menu



Workflow shortcut menu

Figure 70. Workflow shortcut menu

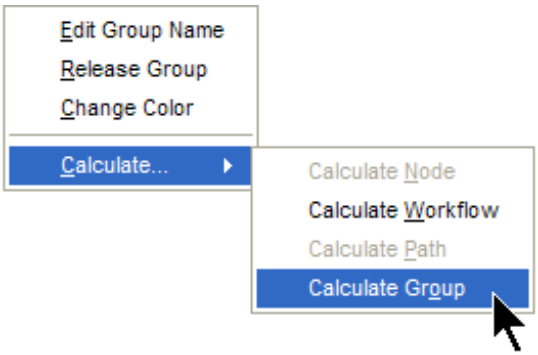


Right-click over a *blank* part of the workspace to display this shortcut menu. For screen shots of these dialogs, **See "Application Dialogs" on page 129**:

- **Add Node**—adds a single node when you click on a location in the worksheet. You must use this item each time to create a new nodes.
- **Define Group**—draws a rectangle around a group of nodes
- **Find Node**—finds and highlights a single workflow node.
- **Set Mix Defaults**—displays the **Set Mix Defaults** dialog.
- **Constants**—displays the **Constants** dialog where you can define named constants for use within the workflow nodes.
- **Rock Fluid Properties**—displays the **Rock and Fluid Properties** dialog.
- **Curve List**—displays the **Curve List** dialog.
- **Curve Alias List**—displays the **Curve Alias List** dialog.
- **Curve Fitting**—displays the **Curve Fit** dialog to approximate a curve with another RPM function node.

Group shortcut menu

Figure 71. Group shortcut menu



Right-click over a group box to display this shortcut menu.

- **Edit Group Name**—changes the default label that is shown in the group box. This name is displayed in the group box when it is minimized. The name can wrap and be several lines in length to describe this group's function.
- **Release Group**—removes a group from the workflow.
- **Change Color**—displays the color selection dialog to help you define an existing color or a custom color for the group box background.
- **Calculate**—performs calculations for the:
  - Node
  - Workflow
  - Path
  - Group

Application Dialogs

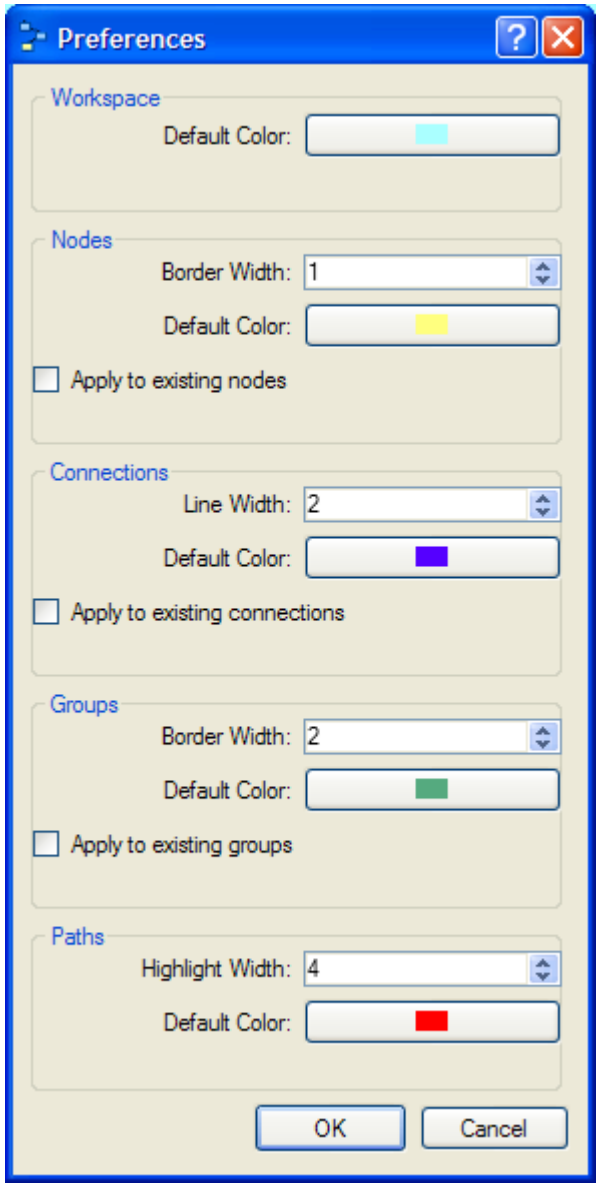
The RPM for PowerLog dialogs help you organize information, customize your display, and specify calculations for each node of the workflow. These dialogs include:

- **Preferences dialog**
- **Select color dialog**
- **Workspace Size dialog**
- **Function Selection dialog**
- **Set Mix Defaults dialog**
- **Rock Fluid Properties dialog**
- **Constants dialog**
- **Curve List dialog**
- **Output Log dialog**
- **Curve Alias List dialog**
- **Curve Fit dialog**

Preferences dialog

This dialog helps you to select preferences for the workspace, nodes, connections, groups, and paths such as line width and default colors. If you select a node, then request the **Preferences** dialog, the color of the node can be changed by choosing the color bar in the Nodes group and picking a new color for the node. If the user wants to make all of the nodes the same color, the **Apply to existing nodes/groups/ connections** check box can be selected. Clicking the **OK** button saves the changes.

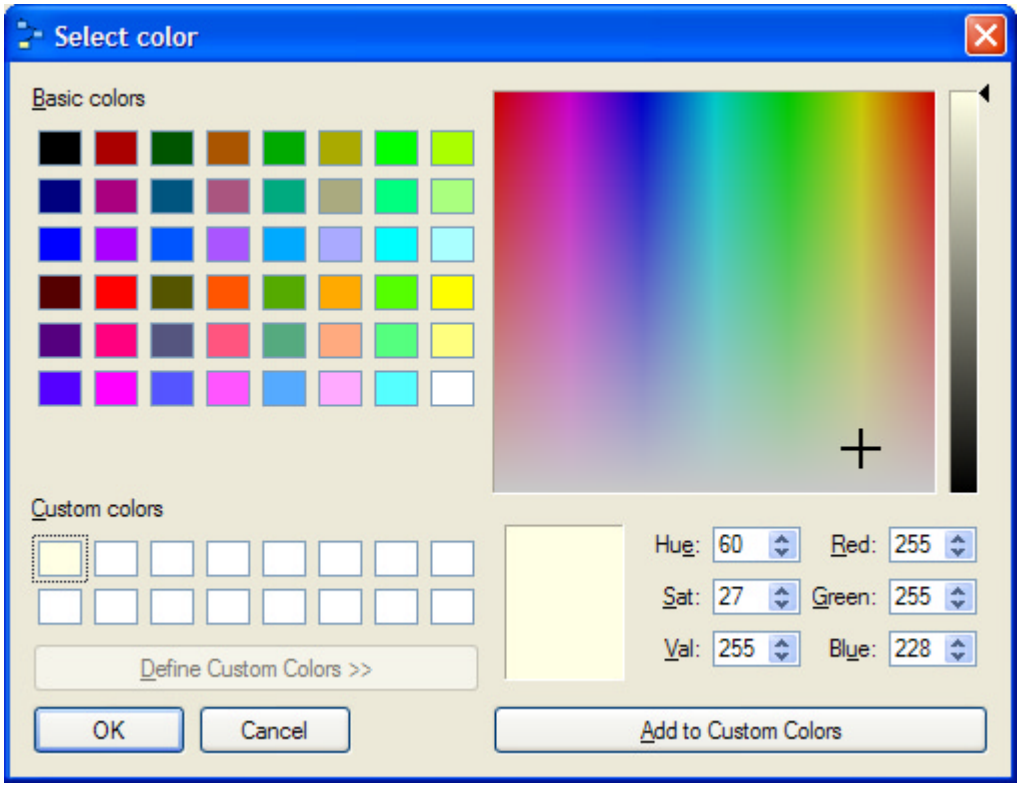
Figure 72. Preferences dialog



Select color dialog

This dialog displays when you select a **Default Color** button on the **Preferences** dialog. It helps you to pick a predefined or custom color for the current context, that is, for the current workspace, node, connection, path, or group.

Figure 73. Select Color dialog



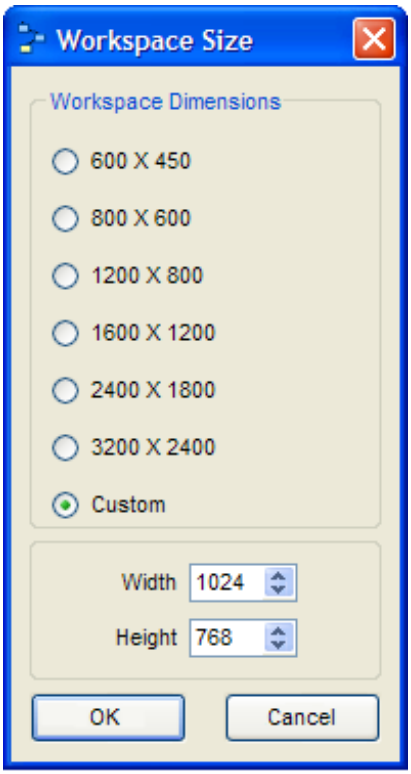
You can select standard colors or specify a custom color by:

- Typing in values for Red, Green, and Blue to specify the color.
- Typing in values for Hue, Saturation, and Val (lightness) to specify the color.
- Moving the cross-hair cursor to the desired color in the spectrum display.

Workspace Size dialog

This dialog displays when you choose the **Edit > Workspace Size** menu command. You can choose a desired size for the workspace (canvas where you draw the workflow), where the workflow is drawn. You also have an option to specify a non-standard workspace size. This option is very useful when you print a hardcopy of the workflow (see **"File menu" on page 121**). The chosen size displays in the lower right-hand corner of the main window in the Status bar.

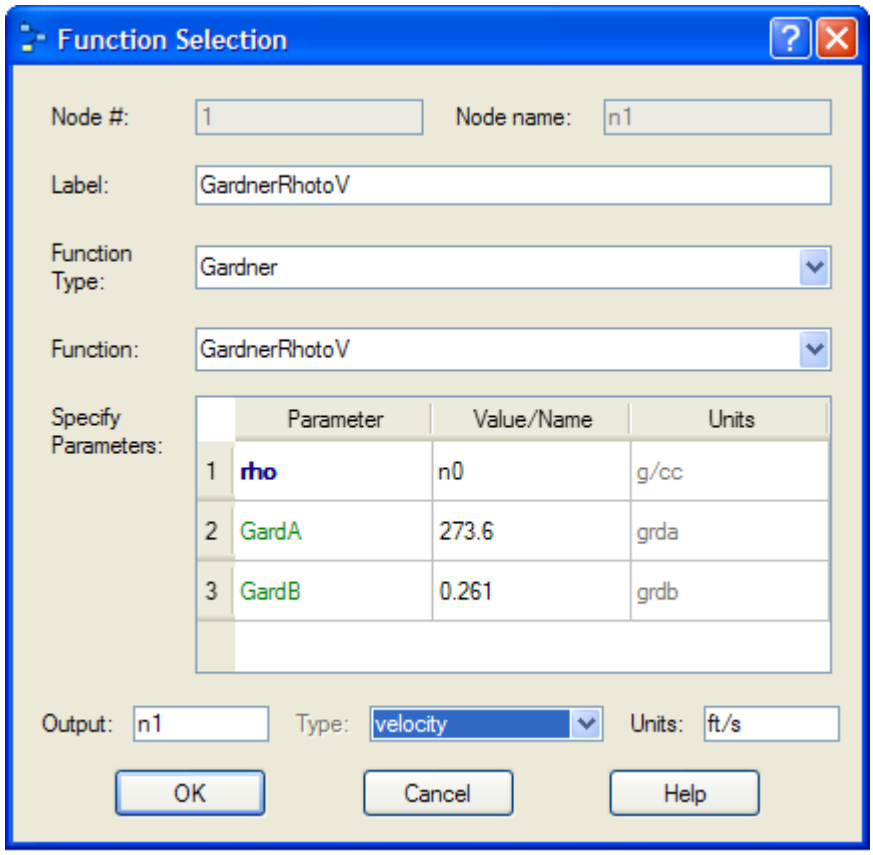
Figure 74. Workspace Size dialog



Function Selection dialog

This dialog provides all the centralized functionality necessary to change the calculation performed at a node. With this dialog, you select the function, define inputs parameters, specify the output (and sometimes the type), and supply a node name. The **Function Type** must be chosen first, followed by the specific **Function** in that category. The function name can be selected in the **Function** drop-down selection list. You can optionally supply a node label or a default label is created for you.

Figure 75. Function Selection dialog



Output curve names

The **Output** field helps you specify a name for the output curve that is created in PowerLog.

Note The Output curve names used for PowerLog are *case insensitive*. All PowerLog curve names display in capital letters.

Output node numbers

If no curve name is specified, the **Node name** is used by default.

Hint Using the **Node name** for the curve permits the node output to be referenced and used by multiple workflow nodes.

Output units

The output units are specified for the function that is selected. You can change the units for situations where the output units are designated as **`none`** to the appropriate units. This may be necessary if the node is used as input into another calculation which requires particular units. Each parameter in the dialog shows the expected units for that value.

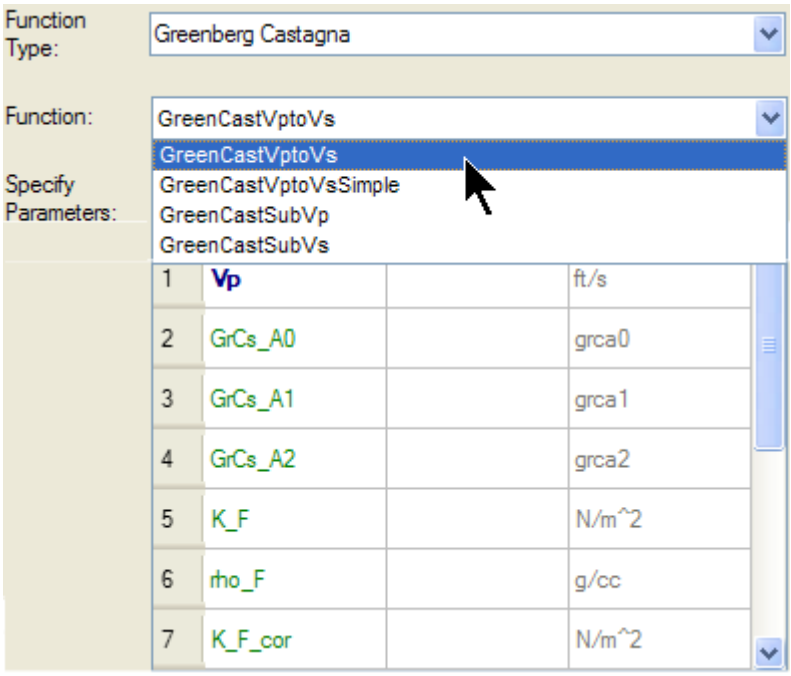
Note RPM only uses specific unit values and anything entered must conform to the RPM standard.

Function types

The RPM for PowerLog function classifications provided are:

- Arithmetic (14)
- Conditional Logic (8)
- Empirical Velocity (5)
- Fluid/Rock Physics for Brine, Gas, and Oil (13)
- Gardner (5)
- Gassmann's Fluid Substitution (3)
- Greenberg Castagna (4
- Miscellaneous Supporting (5)
- Random Numbers (5)
- Simple Modulus-related (5)
- Statistical (15)
- Three-Phase Media Bounds (3)
- Trigonometric (10)
- Two-Phase Media Bounds (7)
- Velocities for Bounds (4)
- Velocity-Synthesis (3)

Figure 76. Example functions for a single type



For the selected function, Help is available by clicking on the **Help** button on the **Function Selection** dialog. (**See "Help menu" on page 125**) for more details.

The individual input parameter cells help you choose the parameter values. The cells shows mandatory and optional parameters used by the function when it executes. The optional parameters may or may not have defaults that are used by the program.

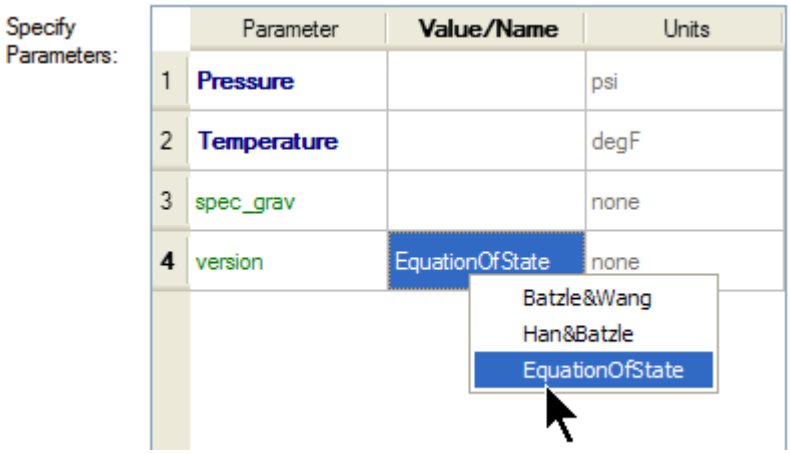
Right-clicking over a value cell displays a shortcut menu. You can select what type of node parameter to use and pick a value from the shortcut menu. Curve names are always capitalized in PowerLog. Alias curve names start with an ampersand (**&**).

For a complete list of the RPM functions and their usage, refer to the ***RPM for PowerLog — Function Reference Guide***.

Bulk modulus calculation version [Future Release]

For some of the rock physics algorithms, you can choose which bulk modulus calculation algorithm to use. This option displays on the **Function Selection** dialog and the `version` input parameter. The `version` selection defaults to Batzle &Wang.

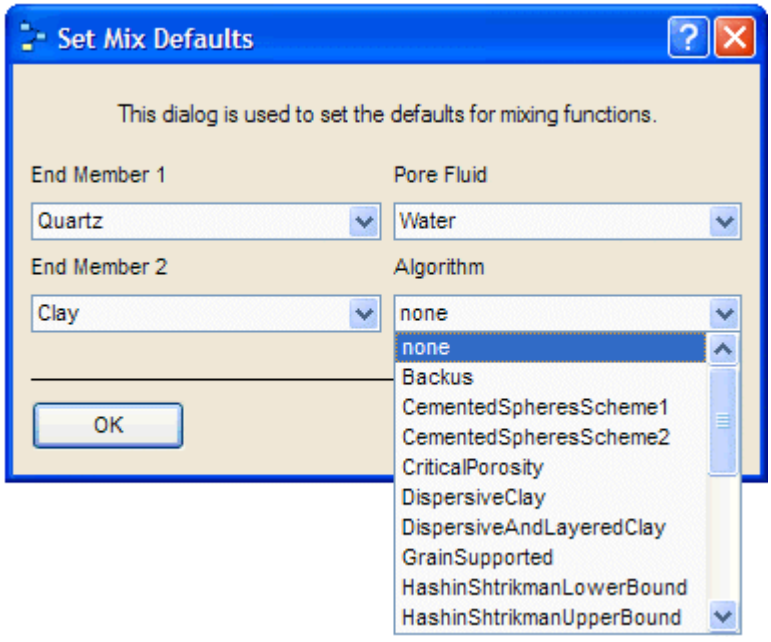
Figure 77. Bulk modulus calculation selection



Set Mix Defaults dialog

This dialog helps you choose defaults that are used by the project when calculating mixed curves, and when default values are required for optional parameters where the user did not specify a value. The two End Member fields have drop-down selection lists to help you choose the name of any mineral that is defined in the **Rock Properties** dialog.

Figure 78. Set Mix Defaults dialog



The complete list of algorithms available for calculating the members/fluid mix is described in **"RPM mixing functions" on page 35**.

The minerals list includes:

- Anhydrite
- Calcite
- Clay
- Dolomite
- Feldspar
- Quartz
- Pyrite
- Salt
- Siderite

The **Pore Fluid** drop-down selection list helps you choose the default pore fluid. The initial pore fluid list includes:

- Brine
- Water
- Dead Oil
- Live Oil
- Gas

The algorithms which you can choose are described in **"Mix algorithms" on page 36**.

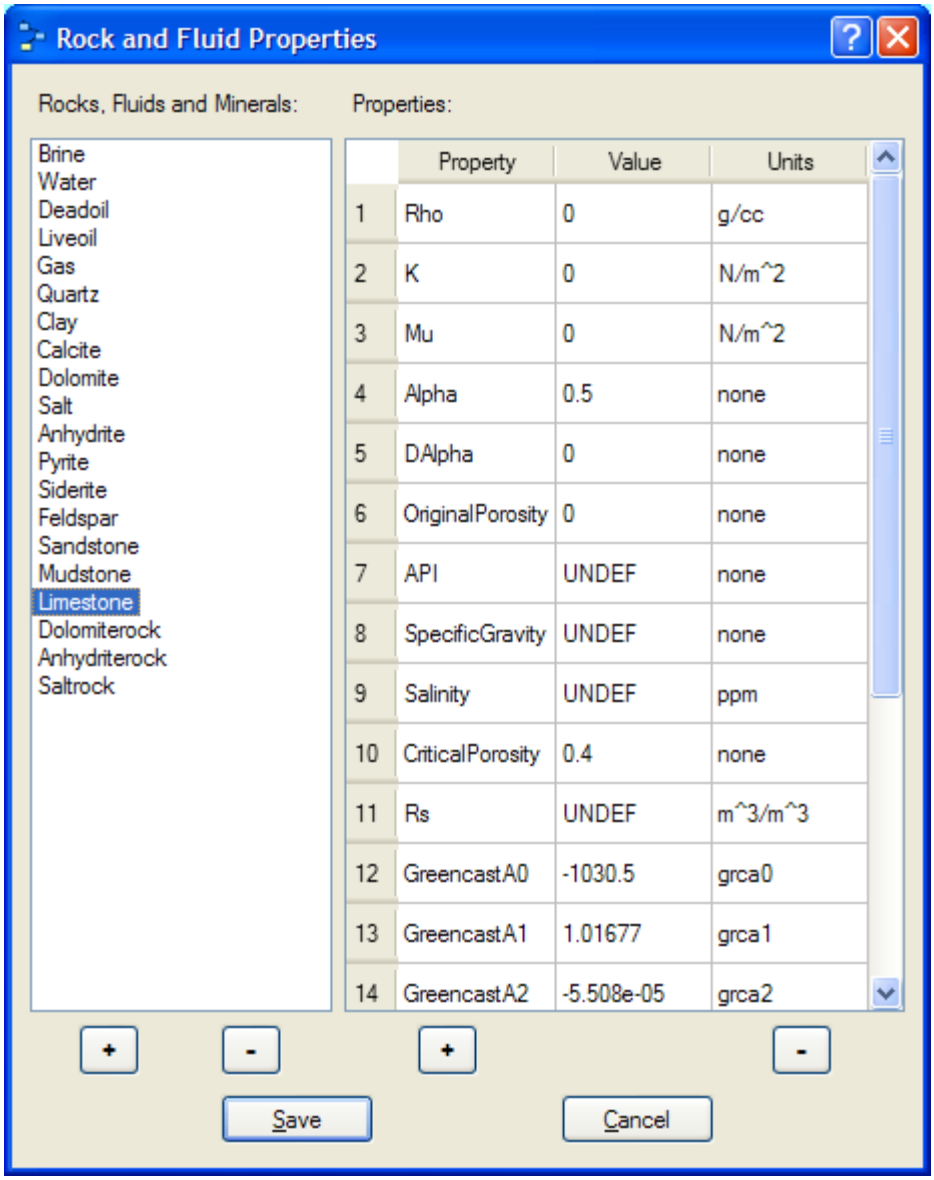
The values you choose are stored in the project file when the project file is saved and also displayed on the title bar of the application. You can refer to this at any time to see the current default values.

Rock Fluid Properties dialog

This dialog help you to create (or change existing values for) a new rock, mineral, or fluid definitions and values. The values can be saved with the project, so that different geographical regions can have regional values. The **Rocks, Fluids, and Minerals** list shows the current list of defined entities. The **Rock Fluid Rock and Fluid Properties** displays three columns, **Property Name**, **Defined Value**, and used **Units**.

Since PowerLog expects US units for all of its operations, US units must be used in order to get accurate results. (Exceptions are N/m^2 used for bulk and shear moduli and g/cc for density values, all other properties are in US units.)

Figure 79. Rock and Fluid Properties dialog



Entities or Values can be added by clicking the plus (+) button or removed by selecting the item and then selecting the minus (-) button. If the changes are not saved, they do not propagate to the calculations or are available when the **Rock Fluid Properties** dialog re-displays.

Why rock and mineral properties default differently!

RPM for PowerLog handles minerals and rocks, differently, to the extent of using rock property default values differently from mineral property default values. How the defaulting mechanism described in the **"RPM mixing functions" on page 35**, differs for minerals and rocks, requires additional explanation.

RPM makes a distinction between minerals (such as quartz and calcite) and rocks (sandstone and limestone). Properties unsuitable for minerals (such as original

porosity `OriginalPorosity)` have values that are initially set as undefined (**`UNDEF`**). Properties unsuitable for rocks (such as the density, `Rho`, which would imply dependencies on other Properties table parameters such as porosity) have values which are also initially undefined. From **RPM mixing functions**, only property values associated with minerals (not rocks) can be used as an automatic default in an RPM function parameter.

Example If the bulk modulus of a mineral phase is required as input parameter **`K_1`** in **MixVelocityVp** function and the user does not specify a value, the quantity found in the **Rock and Fluid Properties** for **`mineral1.K`** is used; as indicated by the tool tip displayed when the cursor hovers over the input field. If **`mineral1`** is quartz, then the default is **`quartz.K`**.

Caution! This automatic default value mechanism **does not** apply to rocks. There is no specification of a default rock or rocks, and rock values are not automatically used from the **Rock and Fluid Properties** if the user leaves the input parameter blank for a rock.

Example In **MixVelocityVp**, if the `Orig_Poro1` parameter is blank, it cannot default to **`OriginalPorosity`** for a rock, such as sandstone, because there is no default rock, and cannot default to **`OriginalPorosity`** for the default mineral. The user may change the **`UNDEF`** values for a rock or mineral in the **Rock and Fluid Properties** to specific values, but such property values associated with a rock or mineral are still not used as a default if the user leaves an input field associated with a rock blank (as opposed to a mineral) in a function. Input fields associated with rocks that are left blank default to undefined (**`UNDEF`**) values. The documentation and the tool tips indicate which input parameters default to undefined values for this reason.

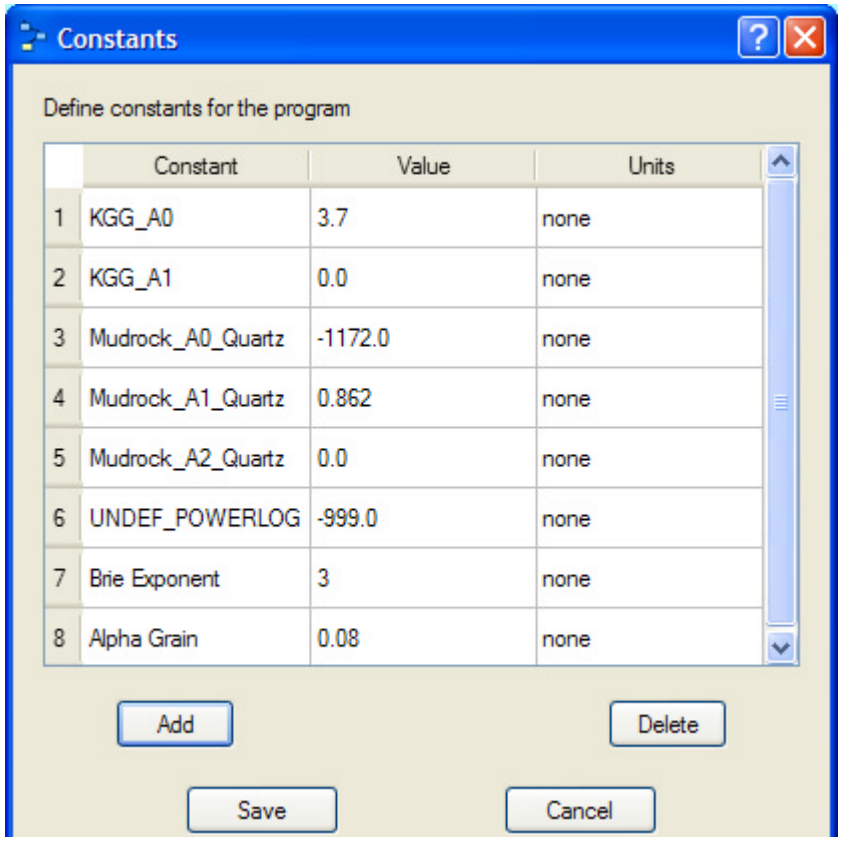
The limitations on automatic defaulting described, do not inhibit your ability to explicitly select a rock or mineral value from the **Rock and Fluid Properties**, rather than entering a numerical value, as a rock input for a function.

Constants dialog

This dialog helps you define named constants that can be used in the calculations. It is advantageous to define them once and use the constants in multiple calculations. Named constants can be added by clicking the **Add** button and filling in the fields of the **New Constants** Dialog. Constants can be deleted by selecting the value to be deleted and then clicking the **Delete** button. The dialog must be closed with the **Save** button for your changes to be saved.

Default values can be set as well as the actual value. If the actual value is blank, the default is used. The value `UNDEF` refers to the value `-999.0`, which is how undefined values are denoted in PowerLog.

Figure 80. Constants dialog

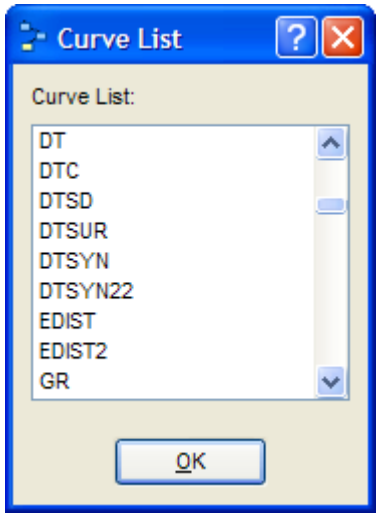


Curve List dialog

The **Curve List** dialog shows the current list of curves defined in PowerLog for the selected well. Once a function is performed, a new output curve name is dynamically added to this list. PowerLog Curve names are always capitalized.

Hint When a node is calculated, it is helpful to refer to the **Curve List** dialog to see that the newly calculated curve is added.

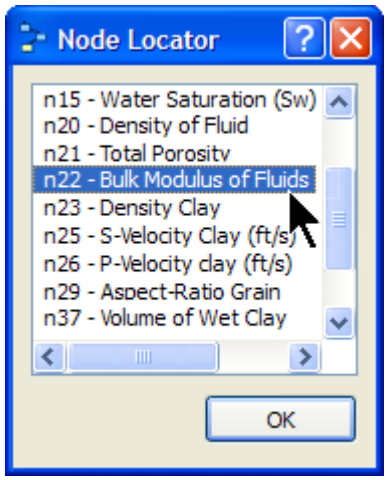
Figure 81. Curve List dialog



Find Node dialog

This dialog helps you locate a specific node within your workflow. Use the **View > Find Node** command or right-click in any empty workspace area and use **Find Node** shortcut menu command to display this dialog.

Figure 82. Node Locator dialog



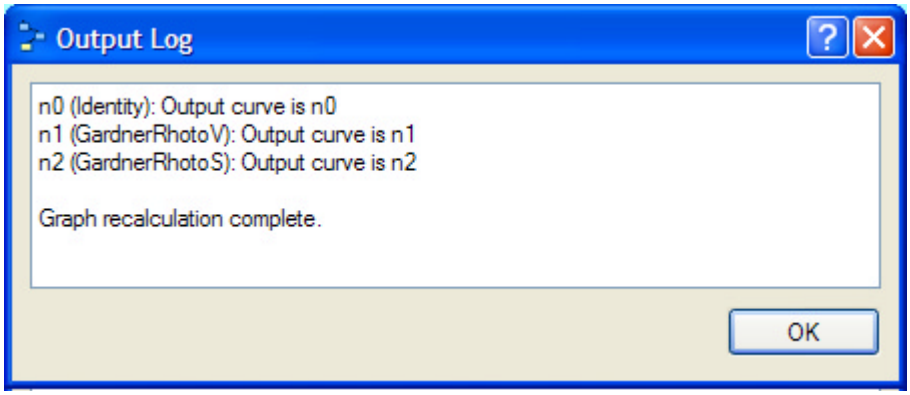
Once you select the desired node and click **OK**, the chosen node displays with a flashing color. If the node's location is outside the current screen display, the workspace display shifts left or right to show the node. If a minimized group contains the node, the group displays its nodes and the selected node displays with a flashing color.

Output Log dialog

The **Output Log** dialog has several uses within the RPM for PowerLog application:

- Provides a concise summary of the workflow calculations performed. Listed for each node is its number, function calculated, and the output curve name.
- Lists error messages that were displayed during the workflow calculation.

Figure 83. Output Log dialog

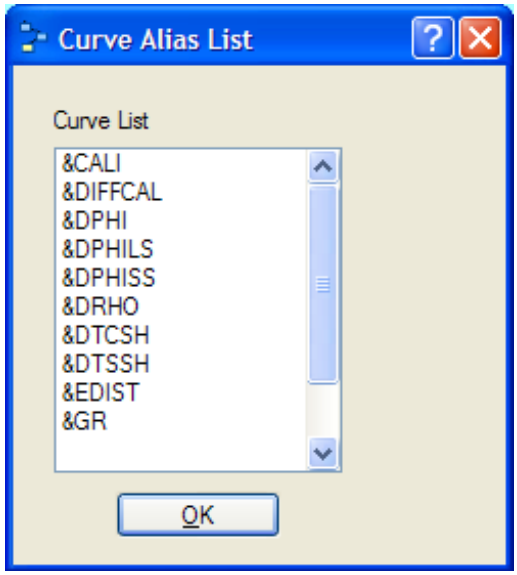


Curve Alias List dialog

The **Curve Alias List** dialog shows the current list of PowerLog project aliases defined. Aliases always start with an ampersand (**&**). Aliases help you in using workflows for multiple wells.

Currently RPM workflows use curves from only a single well at a time. Logs in multiple wells with different curve naming conventions can be referenced using common aliases. If you want to switch to another PowerLog well in which the curve names would be different, the curve alias names in your workflow nodes prevent you from having to constantly change curve names.

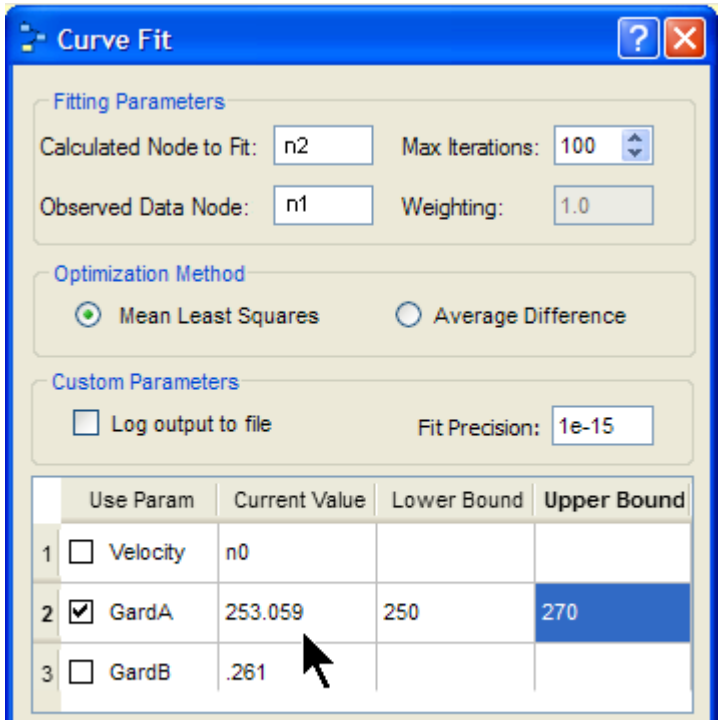
Figure 84. Curves Alias List dialog



Curve Fit dialog

The dialog is used by RPM to perform curve fitting; to find the best parameters to approximate an **Observed Data Node** (usually a measured velocity or density curve) with an RPM function node (**Calculated Node to Fit)**. The **Curve Fit** dialog displays the parameters from the RPM Function node (**Calculated Node to Fit)**.to permit you to set a lower and upper bound for each input parameter variation. You select which **Calculated Node to Fit** input parameters to vary and decide how much variation (range between lower and upper bound) to allow.

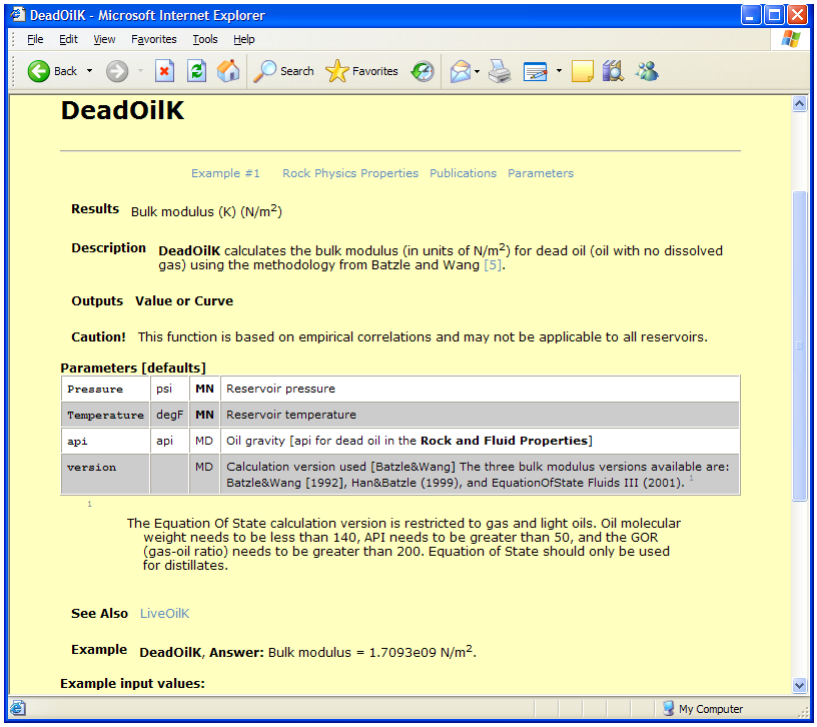
Figure 85. Curve Fit dialog



Help dialog

Every RPM function used in the **Function Selection** dialog has an HTML help file that contains information about the function's appropriate usage, input parameters, and default values. Each rock physics function has a least one example calculation and commentary.

Figure 86. Help displayed in an Internet Browser window



Miscellaneous user interface tools

The RPM for PowerLog software contains several miscellaneous tools to help you construct, test, and present your workflow:

- Tool bars
- Status bar
- Tool tips
- Logging files

Tool bars

These tool bar icons help you create a new project, open an existing project and save an RPM project. There are arrow icons that **Undo** and **Redo** the previous workflow operation. A tool tip, describing the function of that icon, displays if the mouse cursor hovers over the icon for a short period of time.

The tool bar icons that display under the RPM main menus:

- New Project
- Open Project
- Save Project
- Undo
- Redo
- Refresh (redraws the entire workflow)
- Erase Workflow
- Find Node
- Add Node
- Define Group
- Select Path
- Show Descendents
- Show Ancestors
- Clear Selection
- Calculate Workflow

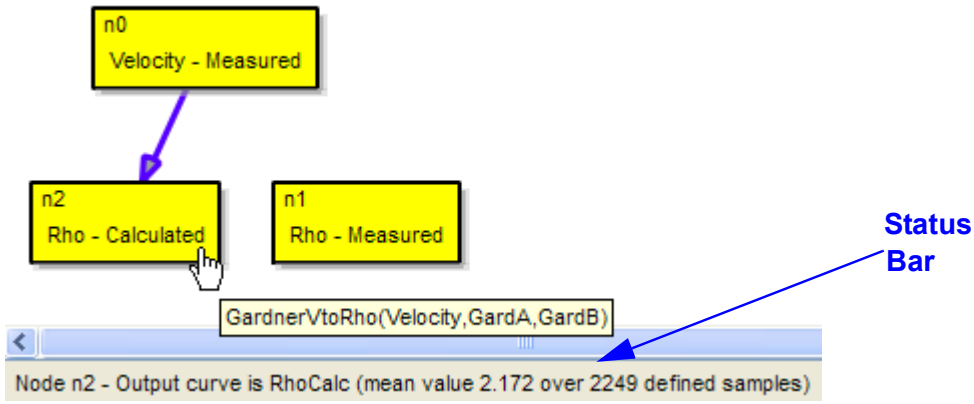
Status bar

The Status bar is located at the bottom of the drawing main window and displays Status messages generated by the RPM for PowerLog program.

If your mouse hovers over a:

- **Node**—the node number or curve output name displays in the Status bar. When a node is calculated, the node number and its value displays. If the output is a curve, the curve name, calculated mean value, and number of samples display.
- **Toolbar icon**—a description of that command's actions displays in the status bar.

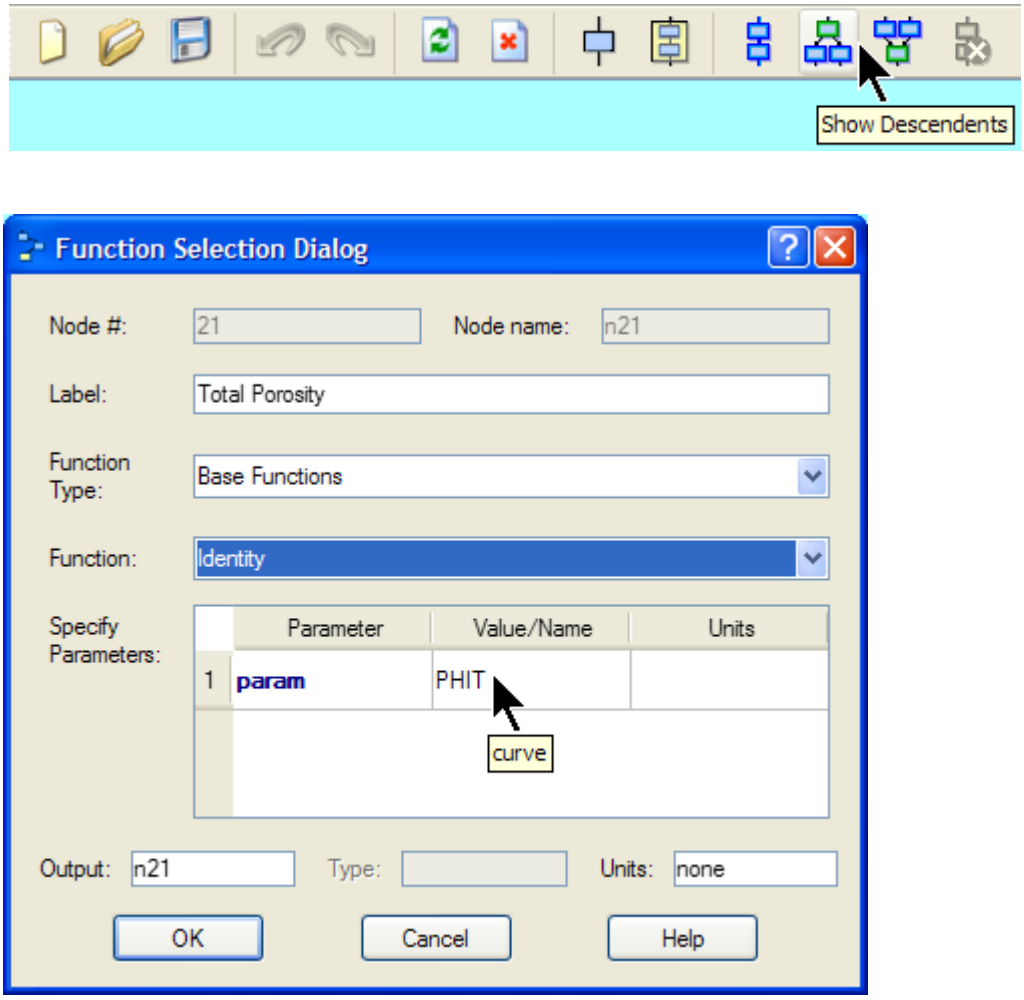
Figure 87. Status bar



Tool tips

If you hover over a cell in the **Function Selection** Dialog, you see an evaluation of the current parameter and its type, or the default parameter that RPM supplies if the field is left blank. Fields marked by bold blue text do not have any default parameters and input values are required.

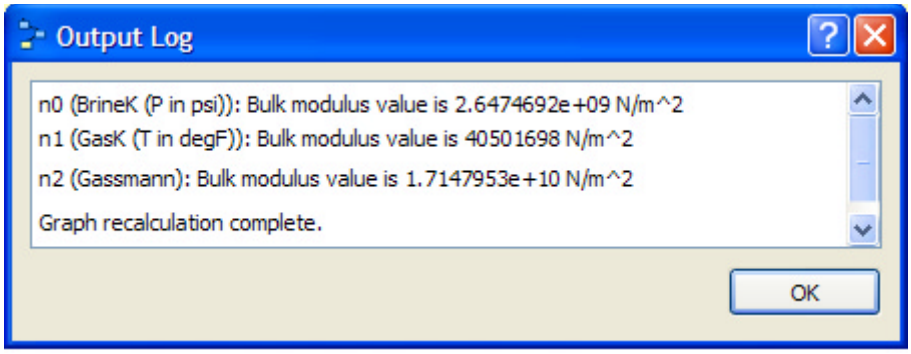
Figure 88. Tool tips examples



Logging files

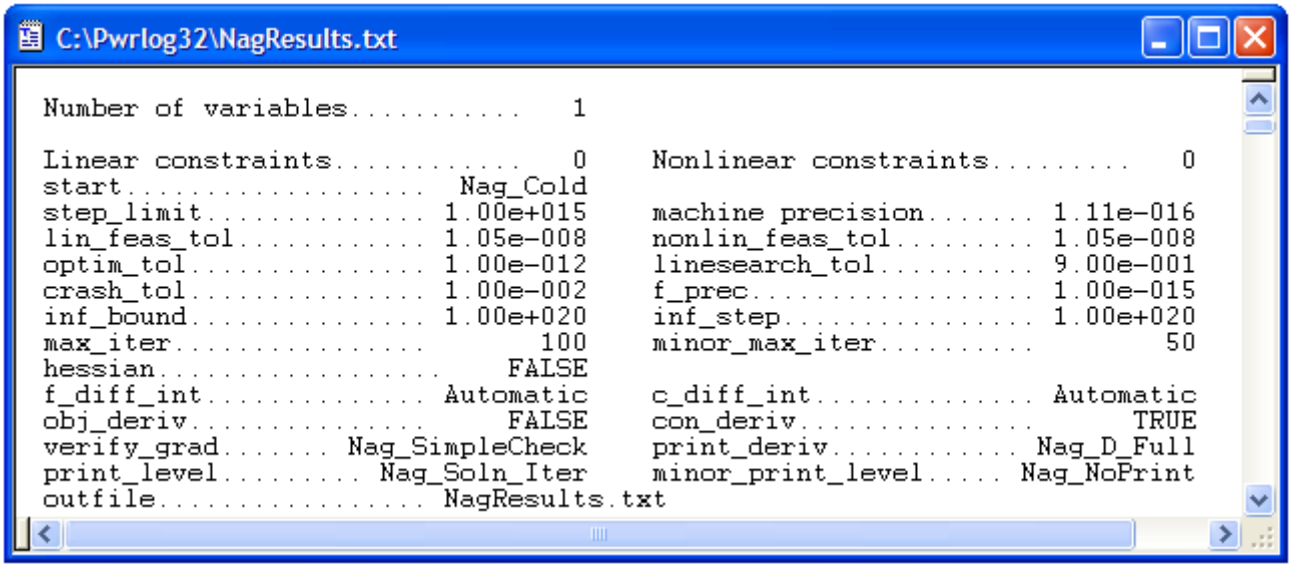
RPM for PowerLog has log files to (**1**) capture all the messages issued during a workflow calculation and (**2**) hold the details of the curve fitting computations.

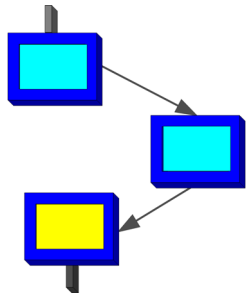
Figure 89. RPM log files



Workflow Calculation Messages

Curve Fitting Computation Details





GLOSSARY

ancestors

The collection of workflow nodes that affect the *input* connections *to* a selected node.

anisotropy

Predictable variation of a property of a material with the direction in which it is measured, which can occur at all scales. For a crystal of a mineral, variation in physical properties observed in different directions is anisotropic. In rocks, variation in seismic velocity measured parallel or perpendicular to bedding surfaces is a form of anisotropy. See **isotropy**.

AVO

Amplitude **V**ariation with **O**ffset. Variation in seismic reflection amplitude with change in distance between shotpoint and receiver that indicates differences in lithology and fluid content in rocks above and below the reflector. AVO analysis is a technique by which geophysicists attempt to determine thickness, porosity, density, velocity, lithology and fluid content of rocks. Successful AVO analysis requires special processing of seismic data and seismic modeling to determine rock properties with a known fluid content.

bubble point pressure

Pressure below which (for constant temperature) gas in solution in oil is released. Also called saturation pressure.

connection

Input from one node of a workflow to another node which defines the ancestor and descendent relationships within the workflow.

crack aspect ratio

Also called **pore aspect ratio**. The ratio [α = a/b] of the minor (a) and major (b) ellipsoidal axes that characterize the spheroidal pore shape of the representative reservoir rock.

critical porosity

Porosity *below* which compressive load is transmitted through mineral grain physical contact, and *above* which compressional load is transmitted through the pore fluid, and the rock becomes a slurry.

crossplot porosity

Porosity obtained by plotting two porosity logs against each other, normally a density and neutron porosity. The computation assumes a particular fluid, usually fresh water, and particular response equations. The result is largely independent of lithology and is often a more reliable porosity estimate than one porosity log.

dead oil

Oil that contains no gas in solution.

DEM

Differential **E**ffective **M**edium. This method is derived by assuming the composite is formed by successively mixing very small (infinitesimal) fractions of one inclusion material in another host material.

descendents

The collection of workflow nodes affected by the *output* connections *from* a selected node.

deviation

The angle at which a wellbore diverges from vertical. Wells can deviate from vertical because of the dips in the beds being drilled through.

directed graph

Another name for a workflow containing nodes (where calculation functions happen) and connections (with arrows) that determine the calculation dependencies.

effective porosity

Porosity due to movable plus hydrostatically bound fluids. The interconnected pore volume or void space in a rock that contributes to fluid flow or permeability in a reservoir. Effective porosity excludes isolated pores and pore volume occupied by water adsorbed on clay minerals or other grains. Usually less than **total porosity**.

function

A calculation or a boolean operation applied to one or more connection inputs and yielding an output (value or curve).

gas-oil ratio

The volume of liberated gas at one atmospheric pressure (and 15.6° C) produced per unit of oil produced. Given as Rs as a dimensionless volume ratio and as GOR in Scf/BBl.

group

A collection of nodes that can be named and manipulated together, so that the workflow complexity can be managed. These node collections help a user associate a workflow subsection with a computation goal.

inclination

The deviation from vertical, irrespective of compass direction, expressed in degrees. For most vertical wellbores, inclination is the only measurement of the path of the wellbore.

inversion

A mathematical process by which data are used to generate a model that is consistent with the data, the process of solving the inverse problem. In seismology, surface seismic data, vertical seismic profiles and well log data can be used to perform inversion, the result of which is a model of Earth layers and their thickness (seismic trace), density and P- and S-wave velocities. Successful seismic inversion usually requires a high signal-to-noise ratio and a large bandwidth.

isotropy

A quality of directional uniformity in material such that physical properties do not vary in different directions. In rocks, changes in physical properties in different directions, such as the alignment of mineral grains or the seismic velocity measured parallel or perpendicular to bedding surfaces, are forms of anisotropy. See **anisotropy**.

live oil

Oil that contains some gas in solution.

node

A point in the workflow where you can define a function, using one or more connection inputs (values or curves), and generate an output (value or curve). A node's output can be delivered to one or more other nodes.

MRU

Most **R**ecently **U**sed list. List of the last five RPM projects accessed with the RPM software on this computer.

path

A set of RPM nodes defined by a selected beginning node, a selected final node, and all connection nodes between the two selections. RPM for PowerLog permits you to perform all the calculations along a chosen workflow path.

RPM

Rock **P**hysics **M**odule for PowerLog. A porting of the rock physics portion of the Jason Geoscience Workbench product that uses a Windows graphical user interface and takes advantage of the project and well management capabilities of PowerLog. PowerLog provides presentation displays and also performs some of the computations found in the previous product.

saturation equation

An equation for calculating the water saturation from resistivity and other logs. There are many saturation equations. Practical equations are all extensions of the Archie equation, which is valid for a rock with very little clay, or very high salinity water, and with a regular pore structure. The majority deal with the problem of shaly sands, and can be divided into two main groups; (**1**) those that treat the shale as a volume of conductive material (V_{sh} models), and (**2**) those that analyze the effect of clay counter-ions.

V_{sh} models take many forms. Typical examples are the Simandoux, laminated sand, and Indonesian equations. The clay counter ion group includes the Waxman-Smits, Dual Water and SGS equations. Most nonshaly sand equations deal with the problem of mixed pore types, for example combinations of fractures, isolated pores, and intergranular pores.

specific gravity

The ratio of a material's density to the density of water; often used for gas.

survey

A completed measurement of the inclination and azimuth of a location in a well (typically the total depth at the time of measurement). In both directional and straight holes, the position of the well must be known with reasonable accuracy to ensure the correct wellbore path and to know its position in the event a relief well must be drilled. The measurements themselves include inclination from vertical, and the azimuth (or compass heading) of the wellbore if the direction of the path is critical.

total porosity

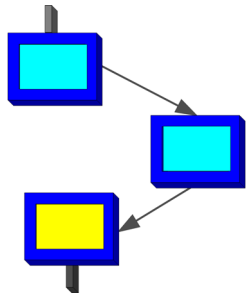
Total porosity = **effective porosity** + clay (electrostatically) bound porosity. The total pore volume per unit volume of rock. It is measured in volume/volume, percent or porosity units. Total porosity is the total void space and as such includes isolated pores and the space occupied by clay-bound water.

workflow

A set of nodes that define the order and calculation dependencies for a set of rock physics calculations. Nodes can be linked together by using the output value or output curve of one node as an input for another node. A workflow is developed in an iterative manner and refined as you develop your methodology.

workspace

A rectangular screen size chosen to construct and display the workflow.
The compass direction of a directional survey or of the wellbore as planned or measured by a directional survey. The azimuth is usually specified in degrees with respect to the geographic or magnetic north pole.



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