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WELLBORE HYDRAULICS MODEL (HYDMOD3)

THEORY AND USER'S MANUAL

DEA 67
PHASE II

MAURER ENGINEERING INC.
2916 West T.C.Jester
Houston, Texas 77018

WELLBORE HYDRAULICS MODEL (HYDMOD3)

Theory and User's Manual

By

MAURER ENGINEERING INC.
2916 West T.C. Jester Boulevard
Houston, TX 77018-7098

Telephone: 713/683-8227 Facsimile: 713/683-6418
Internet: http://www.maureng.com
E-Mail: mei@maureng.com

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1. Introduction

Users not wishing to read the User's Manual can go directly to Section 6.2 — HYDMOD3 QUICK START (Page 6-25) to run the example shown in Chapter 6.

The HYDMOD3 Windows application has been developed by Maurer Engineering Inc. jointly for the DEA-44 project to "Develop and Evaluate Horizontal Well Technology" and the DEA-67 project to "Develop and Evaluate Coiled-Tubing and Slim-Hole Technology." This program, written in Visual Basic 3.0, is written for use with IBM compatible computers with Microsoft Windows 3.0 or later versions.

HYDMOD3 is an integrated computer model of comprehensive drilling hydraulics. It covers detailed hydraulics, from surge and swab to nozzle selection – almost every aspect of hydraulics. The window-style program graphically displays the data and allows the user to quickly optimize the hydraulics program. Many potential problems and sources of confusion (whether the formation will break down or a kick will occur, what the optimized nozzle area should be) can be clarified.

1.1 FEATURES OF HYDMOD3

The new or expanded features of HYDMOD3 are its ability to:

1. Support English, metric and customized systems of units. The customized system of units allows the user to select a different unit for different variables ranging from US to SI (metric).
2. Automatically save the unit system information and recall them the next time HYDMOD3 is run.
3. Deal with deviated and horizontal wells.
4. Handle up to five BHA sections, ten drill strings and twenty well intervals.
5. Offer five calculation options covering different aspects of hydraulics: hydraulics analysis, surge/swab, cuttings transport, volumetric displacement, and well planning.
6. Graphically show flow pattern of turbulent or laminar flow in the wellbore.
7. Allow correlation between predicted and actual pressure drop by an "effective viscosity."
8. Show the influence of parameters on hydraulics by sensitivity analysis.
9. Display ECDs and other hydraulics details at various locations in the well by clicking on the wellbore schematic.
10. Allow input of pore pressures and fracture pressures for different well intervals.

11. Animate the volumetric displacement of up to ten different fluids each pumped at up to ten different rates including shut-down periods.
12. Plan wellbore hydraulics for specific mud programs.
13. Support color printers for graphics.

The output window is a compilation of child windows of text reports and graphs. Each calculation option has one to six output child windows depending on the option. These are described in Section 5.1.3 "Output Window."

1.2 REQUIRED INPUT DATA

There are six data files associated with HYDMOD3: the well data file (.WDI), the survey data file (.SDI), the formation data file (.FDI), the tubular data file (.HT3), the parameter data file (.HP3), and the project data file (.HY3) containing the paths and filenames of the other five files.

WDI (Well Data File):

1. Well data (company name, project name, well location, etc.)

SDI (Survey Data File):

2. SDI - Directional survey data for the well. Survey must start with zero depth, zero azimuth, and zero inclination.

FDI (Formation Data File)

3. Vertical depth of the bottom of each formation layer with its pore and frac pressure gradients.

HT3 (Tubular Data File):

4. Casing shoe depth
5. Surface combination type
6. Nozzle size or TFA
7. Lengths, ID, OD, pressure drop of BHAs
8. Lengths, ID, OD of drill strings
9. Tool joint OD and length

HP3 (Parameter Data File):

10. Calculation options
11. Rheology model, mud weight
12. Pump stroke rate and stroke displacement
13. Pipe running speed (for surge and swab analysis)
14. Cuttings size and density (for cuttings transport)

All input data saved on the disk or in the memory are in the English system of units.

The data sharing information for each analysis option is listed below in Table 1-1.

TABLE 1-1. Analysis Options and Required Data

	Parameters	Hydraulics Analysis	Surge Swab	Cuttings Transport	Volumetric Displacement	Well Planning/ Nozzle Selection
SDI		●	●	●		
FDI	Pore/Frac Pressure	●	●			
HT3	Casing shoe depth	●	●			
	Surface combination	●				●
	Nozzle size or TFA	●				
	Length, OD of BHAs	●	●	●	●	●
	Pressure drop of BHAs	●				●
	ID of BHAs				●	
	Length, OD of drill string	●	●	●	●	●
	ID of drill string	●			●	●
	Positions, ID, pore and frac pressures of well interval	●	●	●	●	●
HP3	Rheology model	●	●	●		
	Mud weight	●	●	●		
	Stroke rate and displacement	●		●	●	
	Pipe running speed		●			
	Cuttings size and density					
	Fluid colors, pumping schedule				●	
	Pump properties (nozzle selection)					●
	Mud program					●

1.3 DISCLAIMER

No warranty or representation is expressed or implied with respect to these programs or documentation, including their quality, performance, merchantability, or fitness for a particular purpose.

1.4 COPYRIGHT

Participants in DEA-44/67 can provide data output from this copyrighted program to third parties and can duplicate the program and manual for their in-house use, but cannot give copies of the program or manual to third parties.

2. Theory

2.1 HYDRAULICS ANALYSIS

The models most commonly used in the drilling industry to describe fluid behavior are the Bingham plastic and power-law models. They can be used to calculate frictional pressure drop, swab and surge pressures, etc. HYDMOD3 is based on equations derived in *Applied Drilling Engineering* (Bourgoyne et al., 1986) and API SPEC 10. The more sophisticated Herschel-Buckley model has not been included in this program because of lack of experimental data, but it will be considered for future versions.

2.1.1 Bingham Plastic Model

The Bingham plastic model is defined by Eq. 2-1 and is illustrated in Figure 2-1.

$$\begin{aligned} \tau &= \mu_p\dot{\gamma} + \tau_y \quad ; \quad \tau > \tau_y \\ \dot{\gamma} &= 0 \quad ; \quad \tau_y \geq \tau \geq -\tau_y \\ \tau &= \mu_p\dot{\gamma} - \tau_y \quad ; \quad \tau < -\tau_y \end{aligned} \tag{2-1}$$

where:

τy = Yield stress
μ_p = Fluid viscosity
τ = Shear stress
$\dot{\gamma}$ = Shear rate

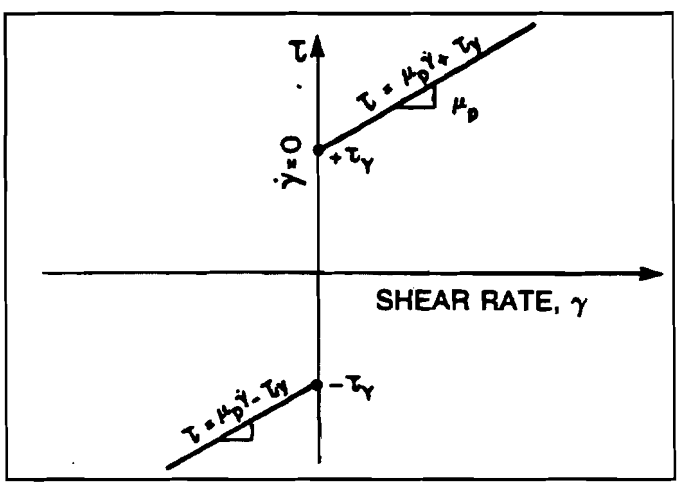


Figure 2-1. Shear Stress Vs. Shear Rate for a Bingham Plastic Fluid (Bourgoyne et al., 1986)

As shown in Figure 2-1, a threshold shear stress known as the yield point (τ_y) must be exceeded before mud movement is initiated.

The mud properties μ_p and τ_y are calculated from 300- and 600-rpm readings of the viscometer as follows:

$$\begin{aligned} \mu_p &= \theta_{600} - \theta_{300} \\ \tau_y &= \theta_{300} - \mu_p \end{aligned} \qquad (2\text{-}2)$$

where:

θ_{600}, θ_{300} = shear readings at 600 and 300 rpm, respectively.

Calculation of frictional pressure drop for a pipe or annulus requires knowledge of the mud flow regime (laminar or turbulent).

1. Mean Velocity

The mean velocities of fluid are calculated by Eq. 2-3 and 2-4.

For pipe flow:

$$\bar{v} = \frac{Q}{2.448 d^2} \qquad (2\text{-}3)$$

For annular flow:

$$\bar{v} = \frac{Q}{2.448 (d_2^2 - d_1^2)} \qquad (2\text{-}4)$$

Where:

$\bar{v}$ = Mean velocity, ft/sec

Q = Flow rate, gal/min

d = Pipe diameter, in.

d_2 = Casing or hole ID, in.

d_1 = Drill string OD, in.

2. Hedstrom Number

The Hedstrom number, N_{HE}, is a dimensionless parameter used for fluid flow regime prediction.

For pipe flow:

$$N_{HE} = \frac{37{,}100 \, \rho \, \tau_y \, d^2}{\mu_p^2} \qquad (2\text{-}5)$$

For annular flow:

$$N_{HE} = \frac{24{,}700\,\rho\,\tau_y\,(d_2 - d_1)^2}{\mu_p^2} \qquad (2\text{-}6)$$

Where:

ρ = Mud weight, lb/gal

3. Critical Reynolds Number

The critical Reynolds number marks the transition from laminar flow to turbulent flow. The correlation between Hedstrom number and critical Reynolds number is presented in Figure 2-2. The data in Figure 2-2 have been digitized in the program for easy access.

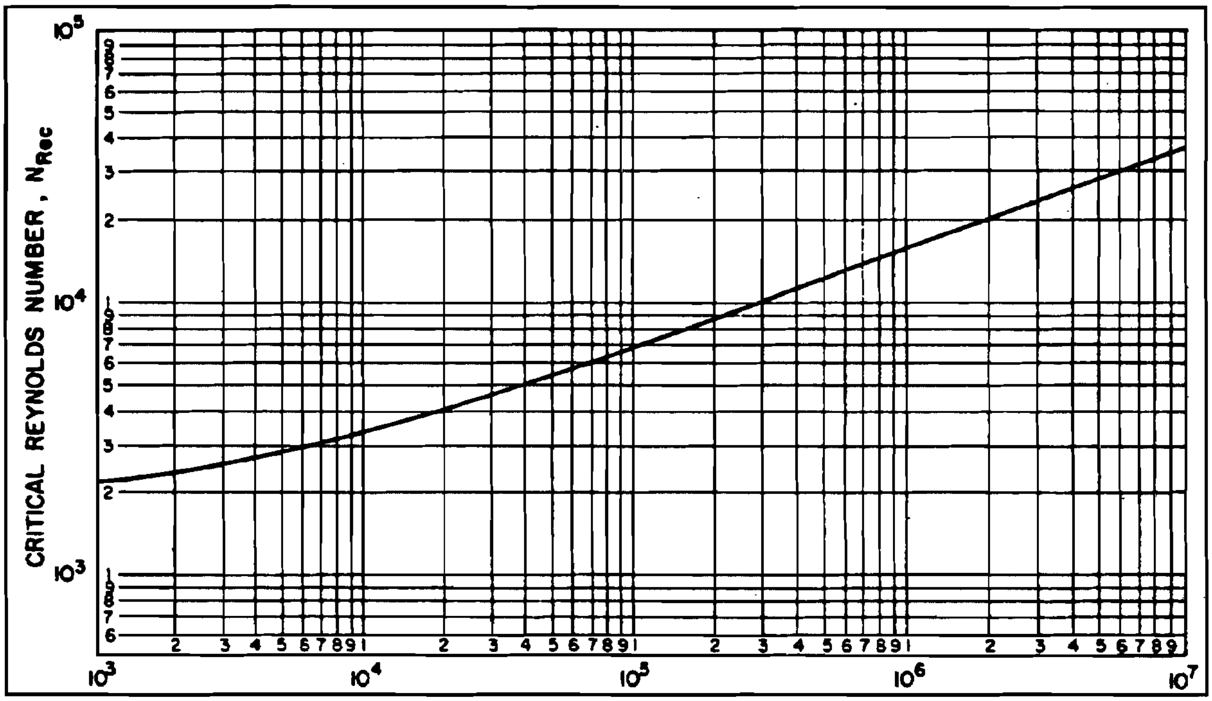


Figure 2-2. Critical Reynolds Numbers for Bingham Plastic Fluids (Bourgoyne et al., 1986)

4. Reynolds Number

Reynolds number, N_{Re}, is another common dimensionless fluid flow parameter.

For pipe flow:

$$N_{Re} = \frac{928\,\rho\,\bar{v}\,d}{\mu_p} \qquad (2\text{-}7)$$

For annular flow:

$$N_{Re} = \frac{757\,\rho\,\bar{v}\,(d_2 - d_1)}{\mu_p} \tag{2-8}$$

5. Frictional Pressure Drop Calculation

For pipe flow, the frictional pressure drop is given by:

(1) Laminar flow (N_{Re} < Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{\mu_p \bar{v}}{1500\ d^2} + \frac{\tau_y}{225\,d} \tag{2-9}$$

(2) Turbulent flow ($N_{Re} \geq$ Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{f\,\rho\,\bar{v}^2}{25.8d} \tag{2-10}$$

where f is the friction factor given by

$$\sqrt{\frac{1}{f}} = 4\ \log\left(N_{Re}\sqrt{f}\right) - 0.395 \tag{2-11}$$

For annular flow, the frictional pressure drop is:

(1) Laminar flow (N_{Re} < Critical $_{NRe}$)

$$\frac{dP_f}{dL} = \frac{\mu_p \bar{v}}{1000\ (d_2 - d_1)^2} + \frac{\tau_y}{200(d_2 - d_1)} \tag{2-12}$$

(2) Turbulent flow ($N_{Re} \geq$ Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{f\,\rho\,\bar{v}^2}{21.1\ (d_2 - d_1)} \tag{2-13}$$

where f is determined using Eq. 2-11.

2.1.2 Power-Law Model

The power-law model is defined by Eq. 2-14 and illustrated in Figure 2-3.

$$\tau = K\dot{\gamma}^{\,n} \tag{2-14}$$

where:

K = Consistency index, equivalent centipoise (see Bourgoyne et al., 1986)

n = Flow behavior index, dimensionless

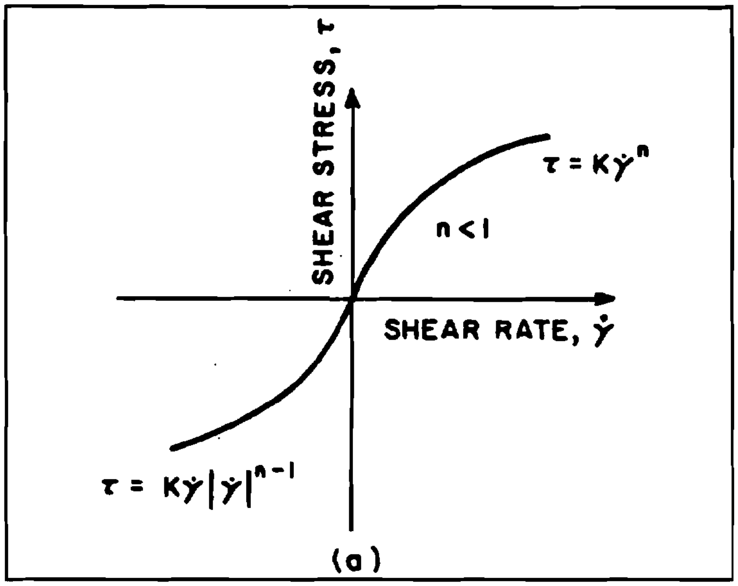


Figure 2-3. Shear Stress Vs. Shear Rate for a Power-Law Fluid (Bourgoyne et al., 1986)

The fluid properties n and K are calculated as follows:

$$n = 3.32 \log \frac{\theta_{600}}{\theta_{300}}$$

$$K = \frac{510\ \theta_{300}}{511^n} \qquad \text{(eq cp)} \tag{2-15}$$

Occasionally, the consistency index is expressed in units of lbf • s^n/sq ft. The two units of consistency index can be related (at sea level) by

1 lbf • s^n/sq ft = 47,900 eq cp.

The critical Reynolds number must be determined before the frictional pressure drop can be calculated.

1. Mean Velocity

For pipe flow:

$$\bar{v} = \frac{Q}{2.448d^2} \tag{2-16}$$

For annular flow:

$$\bar{v} = \frac{Q}{2.448(d_2^2 - d_1^2)} \tag{2-17}$$

2. Critical Reynolds Number

The critical Reynolds number can be read from Figure 2-4 for a given flow behavior index n.

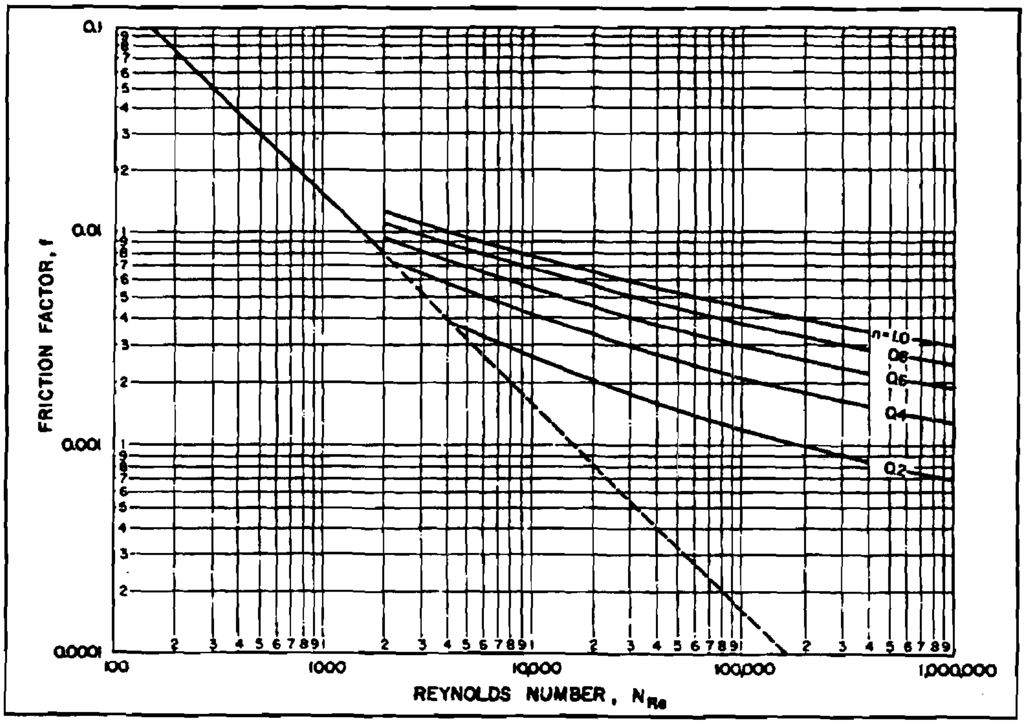


Figure 2-4. Friction Factors for Power-Law Fluid Model (Bourgoyne et al., 1986)

The data in Figure 2-4 can be approximated by the following (Leitão et al., 1990):

$$\begin{aligned} &\text{Critical } N_{Re} = 4200 && \text{for } n < 0.2 \\ &\text{Critical } N_{Re} = 5960 - 8800\,n && \text{for } 0.2 \le n \le 0.45 \\ &\text{Critical } N_{Re} = 2000 && \text{for } n > 0.45 \end{aligned} \tag{2-18}$$

3. Reynolds Number

For pipe flow:

$$N_{Re} = \frac{89{,}100\,\rho\,\bar{v}^{(2-n)}}{K}\left(\frac{0.0416\,d}{3 + 1/n}\right)^n \tag{2-19}$$

For annular flow:

$$N_{Re} = \frac{109{,}000\rho\,\bar{v}^{(2-n)}}{K}\left[\frac{0.0208(d_2 - d_1)}{2 + 1/n}\right]^n \tag{2-20}$$

4. Frictional Pressure Drop Calculation

For pipe flow:

(1) Laminar flow: (N_{Re} < Critical N_{re})

$$\frac{dP_f}{dL} = \frac{K\bar{v}^n}{144{,}000\,d^{(1+n)}}\left[\frac{3 + 1/n}{0.0416}\right]^n \tag{2-21}$$

(2) Turbulent flow ($N_{Re} \geq$ Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{f\rho\bar{v}^2}{25.8\,d} \tag{2-22}$$

where the frictional factor f is given by:

$$\sqrt{\frac{1}{f}} = \frac{4.0}{n^{0.75}}\log\left(N_{Re}f^{(1-n/2)}\right) - \frac{0.395}{n^{1.2}} \tag{2-23}$$

For annular flow:

(1) Laminar flow: (N_{Re} < Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{K\bar{v}^n}{144{,}000(d_2 - d_1)^{(1+n)}}\left[\frac{2 + 1/n}{0.0208}\right]^n \tag{2-24}$$

(2) Turbulent flow ($N_{Re} \geq$ Critical N_{Re})

$$\frac{dP_f}{dL} = \frac{f\rho\bar{v}^2}{21.1(d_2 - d_1)} \tag{2-25}$$

where f is calculated using Eq. 2-23.

2.1.3 Bit Pressure Drop

Three assumptions are made to calculate the bit pressure drop. They are:

1. The change in pressure due to change in elevation is negligible.
2. Upstream velocity is negligible compared to nozzle velocity.

3. Frictional pressure drop across the nozzle is negligible.

Nozzle velocity equals

$$V_n = \frac{Q}{3.117\,A_T} \tag{2-26}$$

where:

V_n = Nozzle velocity, ft/sec

Q = Flow rate, gal/min

A_T = Total nozzle area, in.^{2}

and bit pressure drop equals

$$\Delta P_b = \frac{\rho\,Q^2}{12{,}032\ C_d^2\ A_T^2} \tag{2-27}$$

where:

C_d = discharge coefficient factor (recommended value = 0.95) (Bourgoyne et al., 1986)

The hydraulic horsepower (HHP) and the impact force (F_i) at the bit are

$$HHP = \frac{\Delta P_b\,Q}{1714} \tag{2-28}$$

$$F_i = 0.01823\ C_d\ Q\sqrt{\rho\,\Delta P_b} \tag{2-29}$$

The total pressure drop in the system equals:

$$P_{total} = \Sigma P_p + \Sigma P_a + \Delta P_b$$

Where:

$\sum P_p$ = Summation of pressure losses inside the pipe

$\sum P_a$ = Summation of pressure losses in the annulus

Therefore, the pump horsepower (PHP) is

$$PHP = P_{total} \frac{Q}{1714} \tag{2-31}$$

2.1.4 Surface Equipment Pressure Loss

Surface equipment consists of the standpipe, hose, swivel washpipe and gooseneck, and the kelly. Four common combinations of surface equipment are listed below.

CASE NO. 1	
40 ft of 3 in.	ID Standpipe
45 ft of 2 in.	ID Hose
4 ft of 2 in.	ID Swivel
40 ft of 2¼-in.	ID Kelly
CASE NO. 2	
40 ft of 3½-in.	ID Standpipe
55 ft of 2½-in.	ID Hose
5 ft of 2½-in.	ID Swivel
40 ft of 3¼-in.	ID Kelly
CASE NO. 3	
45 ft of 4 in.	ID Standpipe
55 ft of 3 in.	ID Hose
5 ft of 2½-in.	ID Swivel
40 ft of 3¼-in.	ID Kelly
CASE NO. 4	
45 ft of 4 in.	ID Standpipe
55 ft of 3 in.	ID Hose
6 ft of 3 in.	ID Swivel
40 ft of 4 in.	ID Kelly

To estimate the overall pressure drop more closely, the curves of the surface equipment pressure losses versus flow rate for various combinations are generated based on a table in the *"Hydraulics Manual"* by Security Drill String Systems. Equations are generated to fit the curves.

The following equations are employed in HYDMOD3 to calculate the surface equipment losses.

$$\begin{aligned} &\text{Case 1:} \quad \Delta P_{surf} = 0.002901\ Q^{1.8} \\ &\text{Case 2:} \quad \Delta P_{surf} = 0.001073\ Q^{1.8} \\ &\text{Case 3:} \quad \Delta P_{surf} = 0.000676\ Q^{1.8} \\ &\text{Case 4:} \quad \Delta P_{surf} = 0.000473\ Q^{1.8} \end{aligned} \tag{2-32}$$

where:

ΔP_{surf} = surface equipment pressure loss, psi

Q = flow rate, gal/min

For coiled-tubing operations, the frictional pressure drop in the surface equipment is calculated from the length of the remaining tubing on the reel. Calculation dimensions will be taken from those in the topmost section of the drill string (coiled tubing).

2.1.5 Equivalent Circulating Density

Of particular importance is the equivalent circulating density (ECD) at a given depth. The ECD is the density of fluid that will have the same hydrostatic pressure as the circulating pressure i.e.,

$$ECD = \frac{P_o}{0.052 \times TVD} \qquad \text{(lb/gal)} \tag{2-33}$$

where:

P_o = Pressure at the point, psi

TVD = True vertical depth at the point, ft

2.2 SURGE AND SWAB PRESSURES

Equations 2-9 through 2-13 and 2-21 through 2-25 were presented for frictional pressure drop calculation, the first set for Bingham plastic fluid and the second for power law fluid. These models can also be applied to determine surge and swab pressure if running speed of the drill pipe is known. Surge pressure is the pressure increase caused by lowering pipe into the well. Pressure decrease resulting from withdrawing pipe from the well is called swab pressure.

For closed pipe, the estimated annular velocity is (Moore, 1974):

$$v = \left[K + \frac{d_1^2}{d_2^2 - d_1^2} \right] v_p \qquad \text{(2-34)}$$

where:

v_p = Pipe running speed, ft/min

v = Average annular fluid velocity, ft/min

K = Clinging constant (recommended value = 0.45).

Moore suggested using maximum fluid velocity to take into account acceleration and deceleration of the pipe. In general, the maximum fluid velocity equals:

$$V_m = 1.5v \qquad \text{(2-35)}$$

Surge and swab pressures are calculated by substituting mean velocity in the previously presented frictional pressure drop equations with maximum fluid velocity.

Of particular importance is the equivalent circulating density (ECD) due to surge and swab pressures. The calculation of ECD can be performed using Eq. 2-33.

2.3 SLIP VELOCITY AND CUTTINGS TRANSPORT

Removal of drilled rock fragments from the annulus is one of the primary functions of the drilling mud. The particle slip velocity, which defines the rate at which a cutting of a given diameter and specific gravity settles out of the well, is often of concern to the drilling engineer. Unfortunately, accurate prediction is difficult because of the complex geometry and boundary conditions.

Two correlations will be used, although other models exist. It must also be noted that the following analysis is valid only for vertical sections of a well. As hole angles begin to increase from vertical, cuttings transport efficiency begins to fall.

2.3.1 Moore Correlation

Moore proposed a procedure for determining the slip velocity through a mud system. His method involves obtaining the apparent Newtonian viscosity as follows:

$$\mu_a = \frac{K}{144} \left(\frac{d_2 - d_1}{\overline{V}_a} \right)^{1-n} \left(\frac{\frac{2+1}{n}}{0.0208} \right)^n \qquad \text{(2-36)}$$

where:

V_a = Mean annular velocity

The particle Reynolds number is computed as follows:

$$N_{RE} = \frac{928 \rho_f V_{sl} d_s}{\mu_a} \tag{2-37}$$

where:

ρ_f = Mud weight, lb/gal

d_s = Particle diameter, in.

V_{sl} = Slip velocity, ft/min

In the equation above, the slip velocity V_{sl} is undetermined and is obtained by the following iterations:

For Reynolds numbers greater than 300, the slip velocity is:

$$V_{sl} = 1.54 \sqrt{d_s \frac{\rho_s - \rho_f}{\rho_f}} \tag{2-38a}$$

where:

ρ_s = Solid density, lb/gal

For Reynolds numbers of 3 or less, the slip velocity becomes:

$$V_{sl} = 82.87 \frac{d_s^2}{\mu_a} (\rho_s - \rho_f) \tag{2-38b}$$

For Reynolds numbers between 3 and 300, the slip velocity approximation is given by:

$$V_{sl} = \frac{2.90\, d_s (\rho_s - \rho_f)^{0.667}}{\rho_f^{0.333}\ \mu_a^{0.333}} \tag{2-38c}$$

2.3.2 Chien Correlation

Chien's correlation uses a similar computation of an apparent Newtonian viscosity for use in the particle Reynolds number determination. The apparent viscosity is calculated using

$$\mu_a = \mu_p + 5\frac{\tau_y d_s}{V_a} \tag{2-39}$$

The particle Reynolds number is calculated using Eq 2-37.

For Reynolds numbers greater than 100, the slip velocity is:

$$V_{sl} = 1.89\sqrt{\frac{d_s}{1.72}\left(\frac{\rho_s - \rho_f}{\rho_f}\right)} \tag{2-40a}$$

For Reynolds numbers less than 100, the slip velocity is:

$$V_{sl} = 0.0075\left(\frac{\mu_a}{\rho_f d_s}\right)\left[\sqrt{\frac{36{,}800\, d_s}{\left(\frac{\mu_a}{\rho_f d_s}\right)^2}\left(\frac{\rho_s - \rho_f}{\rho_f}\right) + 1} - 1\right] \tag{2-40b}$$

As can be seen, both correlations may require several iterations and/or trial and error.

2.3.3 Cuttings Transport Ratio

Cuttings transport ratio is defined by the following equation:

$$F_t = 1 - \frac{V_{sl}}{V_a} \tag{2-41}$$

For positive cuttings transport ratios, the cuttings will be transported to the surface with more or less transport efficiency. For negative cuttings transport ratios, cuttings will become concentrated in the annulus. Therefore, this is an excellent measure of the carrying capacity of a particular drilling mud.

2.4 VOLUMETRIC DISPLACEMENT

HYDMOD3 calculates drill string and annular volume. The time and strokes to pump mud from surface to bit, from bit to surface and one full circulation are computed. The program also tracks the fluid interface through the tubing and annulus as one mud displaces another.

2.4.1 Calculation of Volumes

The equations used in volume calculations are:

Pipe Volume:

$$V_p = 0.0407967\ d^2,\ \text{gallons/ft} \tag{2-42}$$

Annular Volume:

$$V_a = 0.0407967\ (d_2^2 - d_1^2),\ \text{gallon/ft} \tag{2-43}$$

2.4.2 Pump Selection

The majority of pumps in use are of duplex (two-cylinder) or triplex (three-cylinder single acting) design. They are illustrated in Figure 2-5.

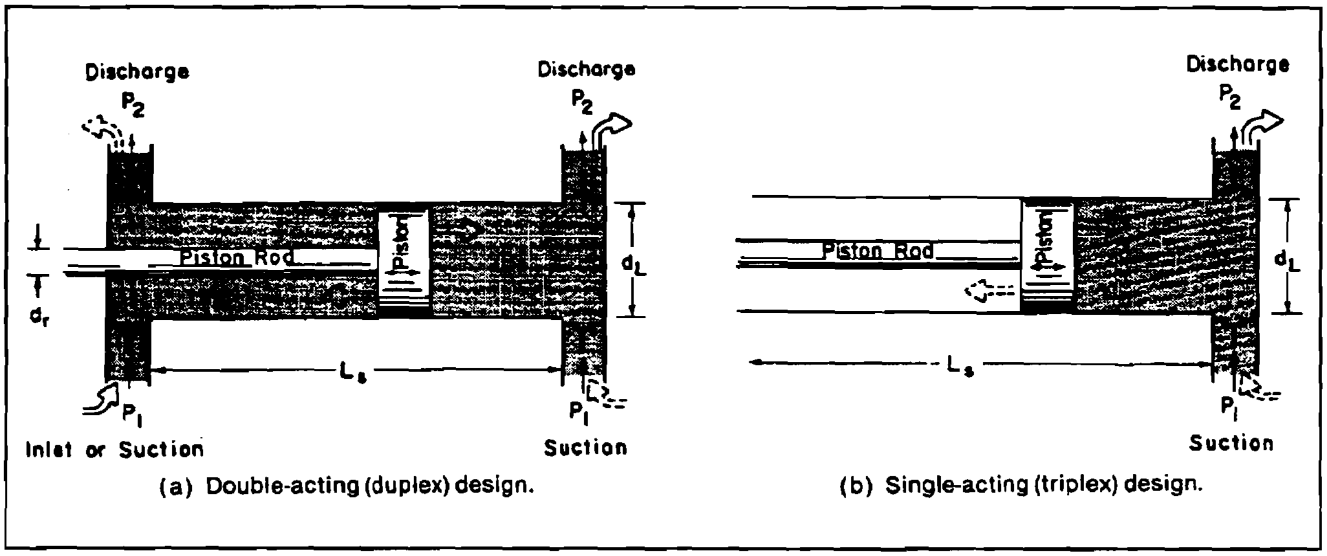


Figure 2-5. Schematic of Valve Operation – Triplex and Duplex Pumps (Bourgoyne et al., 1986)

For a duplex pump, the total volume discharged per complete pump cycle is given by:

$$F_p = \frac{\pi}{4}(2) \cdot L_s\ (2d_l^2 - d_r^2)\ E_v \tag{2-44}$$

where:

L_s = Stroke length, in.

d_l = Liner diameter, in.

d_r = Rod diameter, in.

E_v = Volumetric efficiency

For a triplex pump, the total pump displacement per pump cycle is:

$$F_p = \frac{3\pi}{4} L_s E_v d_l^2 \qquad (2\text{-}45)$$

2.5 WELL PLANNING AND NOZZLE SELECTION

The optimization of bit hydraulics increases the penetration rate and improves the cleaning action at the hole bottom. There is controversy as to whether maximization of hydraulic horsepower or impact force produces the best results. The program utilizes both optimization method. Actually, both theories provide almost the same results. If hydraulic horsepower is maximum, the jet impact force will be 90% of the maximum and vice versa.

2.5.1 Maximum Jet Impact Force

The pump pressure loss, ΔP_p, is expended by the (1) total frictional pressure loss, the so-called parasitic pressure loss, ΔP_d, and (2) the bit pressure loss, ΔP_b. Then

$$\Delta P_p = \Delta P_b + \Delta P_d \qquad (2\text{-}46)$$

The parasitic pressure, ΔP_d, can be represented by

$$\Delta P_d = CQ^m \qquad (2\text{-}47)$$

Where m is the flow exponent, usually taken as 1.75, and C is a constant representing mud properties and wellbore geometry.

The jet impact force is given by Eq. 2-29.

$$F_j = 0.01823\ C_d\ Q\sqrt{\rho \Delta P_b} = 0.01823\ C_d\ Q\ \sqrt{\rho\ (\Delta P_p - CQ^m)}\ , \text{lbf} \qquad (2\text{-}48)$$

where:

C_d = Discharge coefficient (0.95)

Using calculus to determine the flow rate at which the bit impact force is a maximum gives

$$\Delta P_d = \frac{2}{m + 2} \Delta P_p \tag{2-49}$$

2.5.2 Maximum Hydraulic Horsepower

Bit hydraulic horsepower, HHP, is given by Eq. 2-28,

$$HHP = \frac{\Delta P_b Q}{1714} = \frac{(\Delta P_p - CQ^m) Q}{1714} \tag{2-50}$$

Using calculus, the above equation can be maximized and resolved into

$$\Delta P_d = \frac{1}{m + 1} \Delta P_p \tag{2-51}$$

2.5.3 Flow Exponent Calculation

Although the value of the flow exponent m is usually assumed as 1.75, it is generally best to determine m from two sets of pump pressure data (field data) for two flow rates.

$$m = \frac{\log \dfrac{(\Delta P_{p1} - \Delta P_{b1})}{(\Delta P_{p2} - \Delta P_{b2})}}{\log \left[\dfrac{Q_1}{Q_2} \right]} \tag{2-52}$$

where:

Q_i = (I=1,2) pump rates

ΔP_{pi} = (I=1,2) pump pressure drop

ΔP_{bi} = (I=1,2) bit pressure drop

2.5.4 Graphical Method

The most convenient method for the selection of bit nozzle sizes is the graphical solution technique involving the use of log-log paper as shown in Figure 2-6.

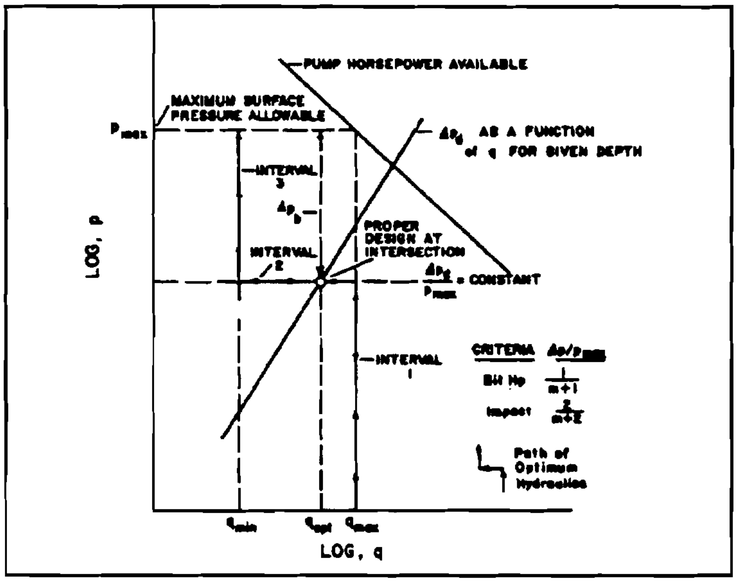


Figure 2-6. Use of Log-Log Plot for Selection of Proper Pump Operation and Bit Nozzle Sizes (Bourgoyne et al., 1986)

The path of optimum hydraulics is constructed by three intervals:

1. $q \; = q_{max}$, based on the pump specification
2. ΔP_d = const., based on the criterion used (bit power or impact force)
3. $q \; = q_{min}$, based on acceptable annular velocity for cuttings transport

After the graph is constructed, calculate the total frictional pressure loss ΔP_d under a given flow rate and draw a line through the point $(Q, \Delta P_d)$ with the slope m. The intersection of the line with the path of optimum hydraulics determines the optimum flow rate. Because minimum and maximum flow rates exist, the optimum may not be between the minimum and maximum flow rates. The planned flow rate is therefore the closest flow rate to the optimum within the maximum and minimum limits.

2.5.5 Well Planning

It is sometimes desired to estimate the proper pump operating conditions and nozzle sizes for hydraulics optimization during the planning phase of the well. The data required for planning include mud program, hole geometry, and assumed flow rate. The equations in Section 2.1 are employed to calculate the frictional pressure drop at various planning depths. Based on frictional pressure drop, the program calculates the optimum hydraulics based on either the maximum jet impact force or maximum hydraulic horsepower criterion.

The results of hydraulics optimization indicate only the optimized total nozzle area. Since the jet bit may have two, three, or more nozzles, a large number of nozzle size combinations will result that will approximate the optimized total nozzle area closely. The program calculates several potential combinations of nozzle diameters for two, three, four, and five nozzle designs. The area variance for each combination is also given.

3. Program Installation

3.1 BEFORE INSTALLING

3.1.1 Hardware and System Requirements

HYDMOD3 is written in Visual Basic®. It runs in either standard or enhanced mode of Microsoft Windows 3.0 or higher. The basic requirements are:

- IBM-compatible machine built on the 80286 processor or higher
- Hard disk
- Mouse
- CGA, EGA, VGA, 8514, Hercules, or compatible display (EGA or higher resolution is recommended)
- MS-DOS version 3.1 or higher
- Windows version 3.0 or higher in standard or enhanced mode

A 386 (or higher) IBM compatible PC and Windows 3.1 (or higher) are highly recommended for fast performance.

For assistance with the installation or use of HYDMOD3 contact:

Gefei Liu or Lee Chu
Maurer Engineering Inc.
2916 West T.C. Jester Boulevard
Houston, Texas 77018-7098 U.S.A.
Telephone: (713) 683-8227 Fax: (713) 683-6418
Internet: http://ww.maureng.com
E-Mail: mei@maureng.com

3.1.2 Program Disks

The program disks you receive are two 3½-inch, 1.44 MB disks.

Disk 1 (set up) contains fourteen files, which are listed below.

HYDMOD3	EXE
HYDTEST	FDI
HYDTEST	HP3
HYDTEST	HT3
HYDTEST	HY3
HYDTEST	SDI
HYDTEST	WDI
LOOKTBL	MD_
SETUP	EXE
SETUP	LST
SETUP1	EXE
SETUPKIT	DL_
VBRUN300	DLL
VER	DL_

Disk 2 contains thirteen files.

CMDIALOG	VB_
COMMDLG	DL_
GRAPH	VB_
GRID	VB_
GSW	EX_
GSWDLL	DL_
MDICHILD	VB_
MSAES110	DL_
MSAJT110	DL_
SPIN	VB_
SPREAD20	VB_
THREED	VB_
VBDB300	DL_

We recommend that all .VBX and .DLL files that have the potential to be used by other DEA-44/67 Windows applications be installed in your Microsoft Windows\SYSTEM subdirectory. This applies to all the .VBXs and .DLLs included here. The HYDMOD3 executable (HYDMOD3.EXE) file should be placed in its own directory (default "C:\HYDMOD3") along with the example data files "HYDTEST.*". All these procedures will be done by a simple set up command explained in Section 3.2.

In order to run HYDMOD3, the user must install all the files into the appropriate directory on the hard disk. Please see Section 3.2 to set up HYDMOD3.

It is recommended that the original diskettes be kept as a backup, and that working diskettes be made from them.

3.1.3 Backup Disks

It is advisable to make several backup copies of the program disks and place them in different storage locations. This will minimize the probability of all disks developing operational problems at the same time.

The user can use the COPY or DISKCOPY command in DOS, or the COPY DISKETTE on the disk menu in the **File Manager** in Windows.

3.2 INSTALLING HYDMOD3

The following procedure will install HYDMOD3 from the floppy drive onto working subdirectories of the hard disk (i.e., copy from A: drive onto C: drive subdirectory HYDMOD3 and WINDOWS\SYSTEM).

1. Start Windows by typing "WIN" <ENTER> at the DOS prompt.
2. Insert Disk 1.
3. In the File Manager of Windows, choose Run from the File menu. Type **a:set up** and press Enter.
4. Follow the on-screen instructions.
5. Before completing the set up process, the set up program checks the AUTOEXEC.BAT file in the computer's root directory. If AUTOEXEC.BAT file contains the SHARE command, it will end the set up. If not, a message appears on the screen.

> Please add <PATH>SHARE.EXE/L:500 to your AUTOEXEC.BAT
>
> OK

Any text edit program can be used to add the SHARE command to the AUTOEXEC.BAT file. Without loading the SHARE program, the database look-up table will not function.

This is all the user needs to do to set up HYDMOD3. After set up, there will be a new Program Manager Group which contains the HYDMOD3 application, as shown in Figure 3-1.

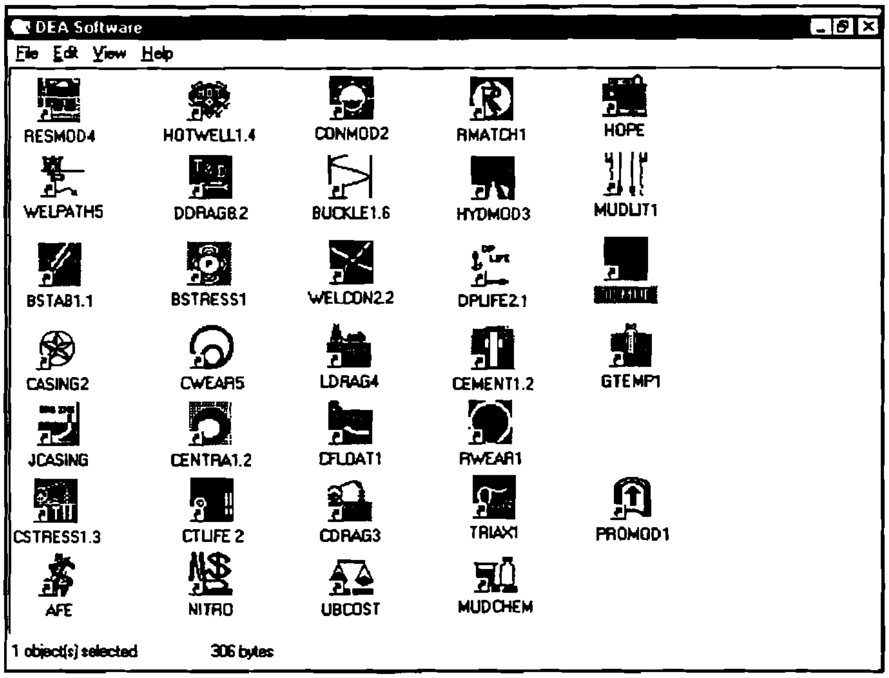


Figure 3-1. DEA Application Group Created by Set Up

3.3 STARTING HYDMOD3

3.3.1 Starting HYDMOD3 from Group Window

To run HYDMOD3 from Group Window, the user simply double-clicks the "HYDMOD3" icon, or when the icon is focused, press <ENTER>.

3.3.2 Using Command-Line Option from Windows

In the Program Manager, choose **Run** from the **File** menu. Then type C:\HYDMOD3\HYDMOD30.EXE <ENTER> as shown in Figure 3-2.

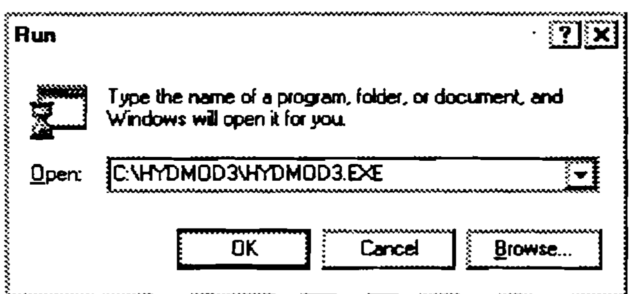


Figure 3-2. Using Command-Line to Start HYDMOD3

4. Windows Environment

HYDMOD3 runs in the Microsoft Windows environment.

For comprehensive information about Windows, see *Concise Guide to Microsoft Windows 3.1* by Kris Jamsa (Microsoft Press, 1992). This section presents only a brief description of the Windows environment.

4.1 ELEMENTS OF A WINDOW

Let's consider the parts of a typical window. Figure 4-1 shows the INPUT Window (see Section 5.1.2 for details).

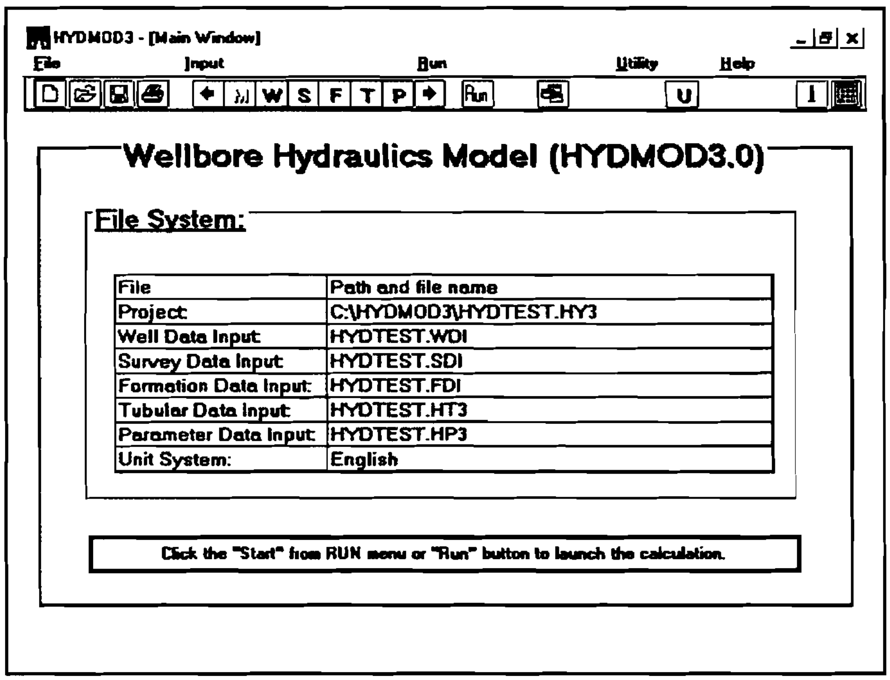


Figure 4-1. Parts of a Window

1. **The Title Bar**

   The title bar serves two functions: one is to display the name of the current window and the other is to indicate which window is active. The active window is the one whose title bar is in color. (On monochrome monitors, the difference is shown by the intensity of the title bar). The user can make a window active by clicking anywhere within its border.

2. **The Control Boxes**

At the left side of the title bar is the control box. It has two functions. First, it can display the CONTROL menu, which enables the user to control the window size using the keyboard. Second, double-clicking the control box will end the current program.

During execution of HYDMOD3, the control boxes are not needed. The program will run according to its own flow chart.

3. **Minimize and Maximize Boxes**

At the right side of the title bar are the MINIMIZE and MAXIMIZE boxes. The box with the up arrow is the MAXIMIZE box. The box with the down arrow is the MINIMIZE box. If a window has already been maximized, the MAXIMIZE box changes to a RESTORE box with both up and down arrows, as shown in Figure 4-1.

- Clicking on the MINIMIZE box will reduce the window to the size of an icon. The window's name in the title bar appears below the icon. To restore a window from an icon, double-click on the icon.
- Clicking on the MAXIMIZE box will make the window take up the total working area.
- Clicking on the RESTORE box will make the window take up a portion of the total working area, which is determined by how the user manually sizes the window.

The user should avoid clicking those boxes while running HYDMOD3 unless necessary.

4.2 WINDOW FUNCTIONS

In a dialog box of a normal window, the user will usually find one or more of the following sections.

1. **Text Boxes**

TEXT boxes display the information that the user enters. Sometimes there is text already typed in for the user. The user can utilize arrow keys to edit the existing text. Figure 4-2 shows a typical text box.

Figure 4-2. Text Box

2. **Check Boxes**

A CHECK box indicates whether a particular condition is on or off. When it is on, an X appears. When it is off, the box is empty. Figure 4-3 shows a typical check box.

Figure 4-3. Check Box

3. **Option Buttons**

OPTION buttons are exclusive settings. Selecting an option immediately causes all other buttons in the group to be cleared. Figure 4-4 is a typical option box.

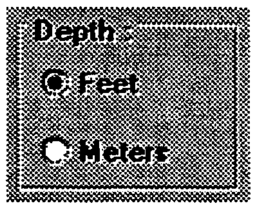


Figure 4-4. Option Buttons

4. **Command Buttons**

A COMMAND button performs a task when the user chooses it, either by clicking the button or pressing a key. The most common command buttons are the **OK** and **Cancel** buttons found on almost every dialog box. In most cases, there is a button with a thick border—the default button which will be executed if you press <ENTER>. Figure 4-5 shows a typical command button:

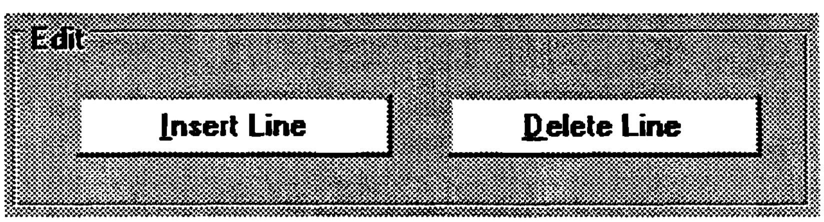


Figure 4-5. Command Buttons

5. **List Boxes**

A LIST box gives the user a list of options or items from which to choose. If the LIST box is too small to show all possible selections, a SCROLL box will appear on the right side of the box. The user makes a selection from a LIST box by clicking on it, or from the keyboard, highlighting the desired item with the arrow keys, and then pressing <ENTER>. Figure 4-6 is a typical list box.

Figure 4-6. List Box

6. **Drop-Down List Boxes**

A DROP-DOWN LIST box is indicated by a small arrow in a box to the right of the option. The current setting is shown to the left of the arrow. When the user clicks on the small arrow, it drops to list all selections. A typical drop-down list box is shown in Figure 4-7.

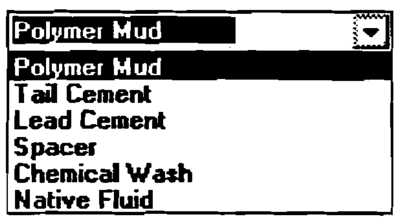


Figure 4-7. Drop-Down List Box

7. **Scroll Bars**

SCROLL BARS are graphical tools for quickly navigating through a long line of items. There are two types of scroll bars: HORIZONTAL and VERTICAL SCROLL BARS.

The small box inside the bar is called the SCROLL BOX. The two arrows on the ends of the scroll bar are scroll buttons (Figure 4-8). Clicking the scroll buttons or moving the SCROLL BOX will change the portion of the information you are viewing.

Figure 4-8. Scroll Bar

8. Grids

GRID displays a series of rows and columns (Figure 4-9). In case of a long list of items or a large amount of information, scroll bars will attach to the grid providing easy navigation.

No. #	Description	From [ft]	I.D. [in]
1	Casing		11.00
2		4000.0	11.20
3	Shale	4950.0	12.50
4		5000.0	11.20

Figure 4-9. Grid

In the INPUT window, grids are used to let the user input data. Some columns of grids only allow numerical input. Typing of an alphabetical character is prohibited by the program. The user can edit an entry by typing desired characters or pressing the <BACKSPACE> key to delete. In many grids, just like a spreadsheet, the user can insert and delete a row.

On the other side, grids are for presentation only in the OUTPUT window. They do not allow editing.

The grid supports word-wrapped text presentation, resizeable columns and rows, etc. Even though the user can manually change the cell's column width or row height, we do not recommend this because all grids in HYDMOD3 are carefully designed to fit the length of the appropriate data string.

5. Basic Operation of HYDMOD3

HYDMOD3 runs in the Windows environment. Windows' graphical user interface (GUI) and point-and-click environment give the user the power and flexibility. In this chapter, the basic operation and functions of HYDMOD3 are introduced.

5.1 WINDOWS IN HYDMOD3

There are four principal types of windows in HYDMOD3: INTRODUCTORY, UNIT SYSTEM, INPUT, and OUTPUT. The HYDMOD3 Windows flow diagram is shown in Figure 5-1.

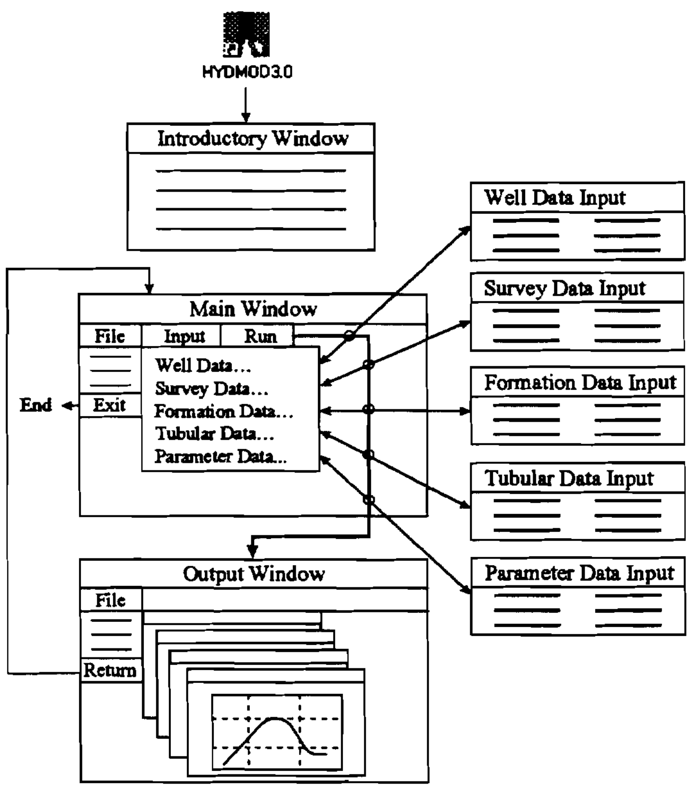


Figure 5-1. Flow Diagram of HYDMOD3

5.1.1 Introductory Window

Figure 5-2 shows the INTRODUCTORY Window containing information on the program and the disclaimer.

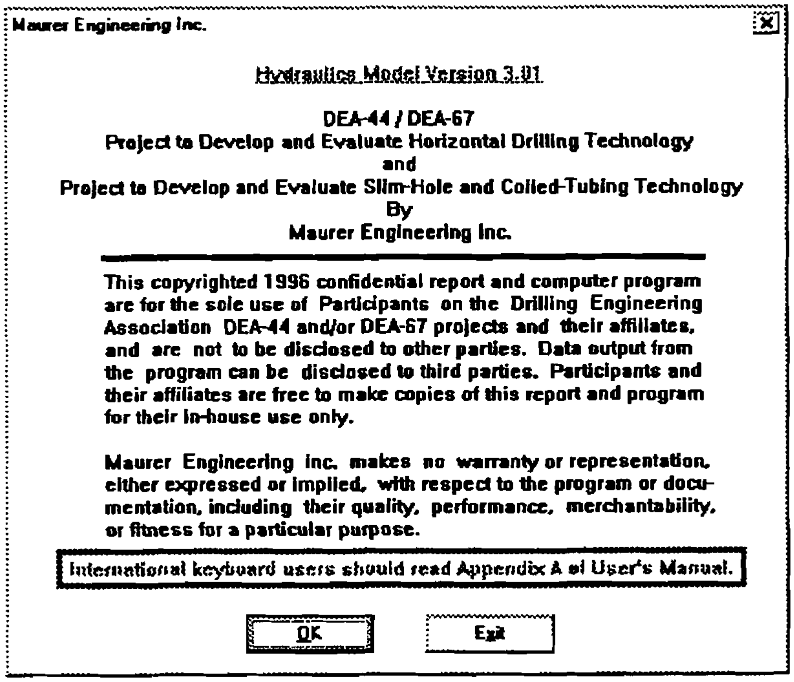


Figure 5-2. Introductory Window

There are two command buttons, "OK" and "Exit." Clicking "Exit" terminates the program. The "OK" button is the default command that allows the user to advance to the Project Window by pressing <ENTER> or clicking on the button.

5.1.2 Input Window

INPUT Windows consist of five windows for data input of different categories. They are: Project, Well Data Input, Survey Data Input, Formation Data Input, Tubular Data Input, and Parameter Data Input Windows.

5.1.2.1 Main Window

Figure 5-3 shows a typical Main Window.

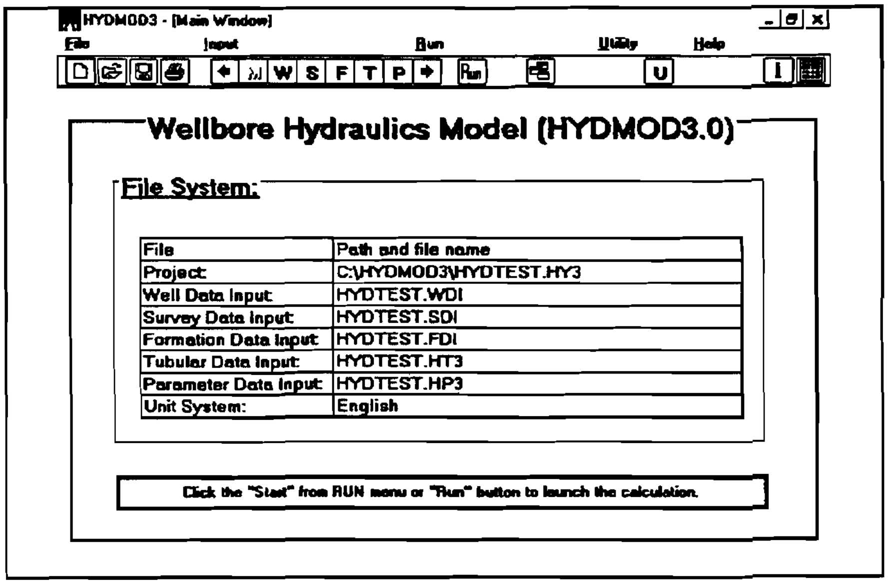


Figure 5-3. Main Window

The Main Window consists of three segments:

1. Path and name of each input data file
2. System of units currently in use
3. Calculation progress indicator

5.1.2.2 Well Data Input Window (WDI)

Figure 5-4 shows a typical WELL DATA INPUT window.

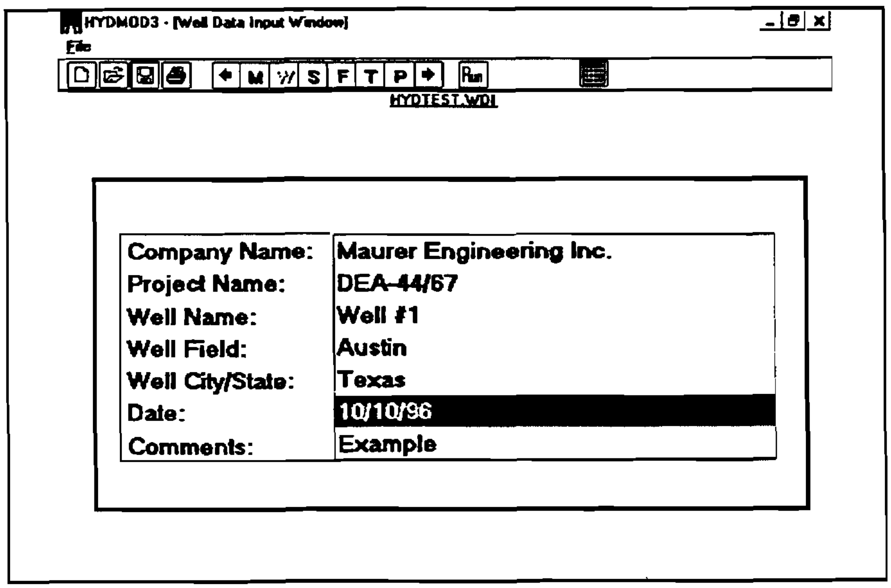


Figure 5-4. WDI Window

The user is asked to input text describing company name, project name, well location, date, and comments. They are optional and need not be completed. They are not used in the calculations or in the filename specifications.

String lengths must be less than 30 characters.

Well data files for HYDMOD3 have the extension "WDI."

5.1.2.3 Survey Data Input Window (SDI)

Figure 5-5 shows a typical SURVEY DATA INPUT window.

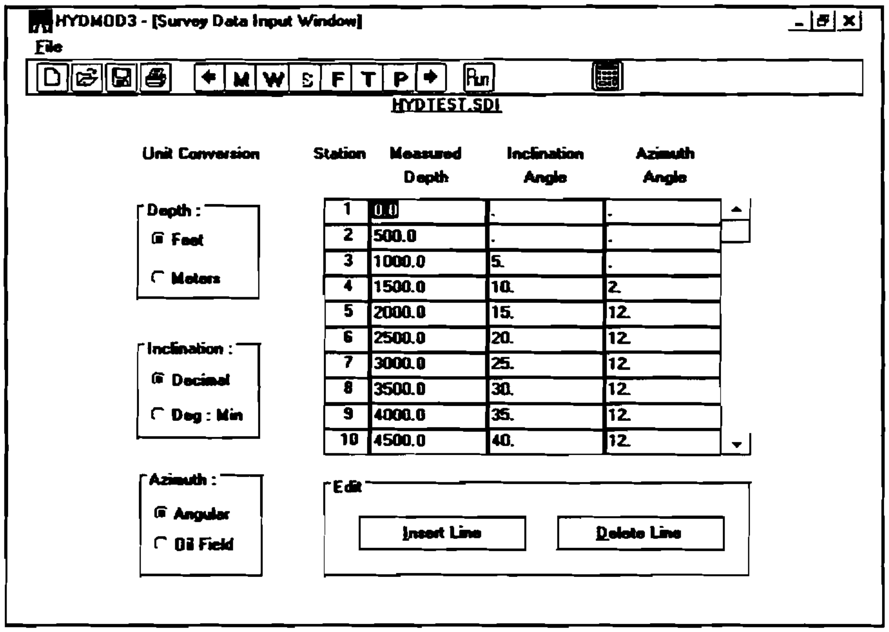


Figure 5-5. SDI Window

The user can input up to 400 survey data points.

The measured depth, inclination angle, and azimuth angle each have two unit or format options, which are independent of the application system of units (Metric or English) the user selects for the application. The default unit for measured depth is "feet." The default format for inclination is "Decimal," and for the azimuth is "Angular." Units can be changed any time while editing, and will not affect the system units selected in the Main Window.

To edit a number in the text box, press ← or → key to move the cursor left or right within the box.

To move the cursor to the next box, press <ENTER> or click the next text box. The focus will move to the desired box. When the focus is at the azimuth text box, hit <ENTER> to bring the focus to the measured depth text box in the next row. If the focus is at the last row and last column of the table, pressing <ENTER> will add a new row at the end of the table, and the cursor will go to the first text box of this new row.

To move the cursor to the upper or lower rows, press the ↑ or ↓ key, or press the "Page Up" or the "Page Down" key.

To move the cursor to the left or right text box, hold down the <Ctrl> key and press ← or → key. The user can also use the tab key to position the cursor.

To append a new survey point at the bottom of the table, move the cursor to the last row of the table and press ↓ key to add a new row.

Clicking the "Insert Line" button inserts a blank row before the current row. Clicking the "Delete Line" button deletes the current row. There is a prompt before deleting to avoid any accidental action.

The SDI files used in HYDMOD3 are compatible with any SDI files in other DEA software applications developed by MEI. The SDI files have the extension "SDI."

5.1.2.4 Formation Data Input Window (FDI)

Figure 5-6 shows a typical Formation Data Input Window.

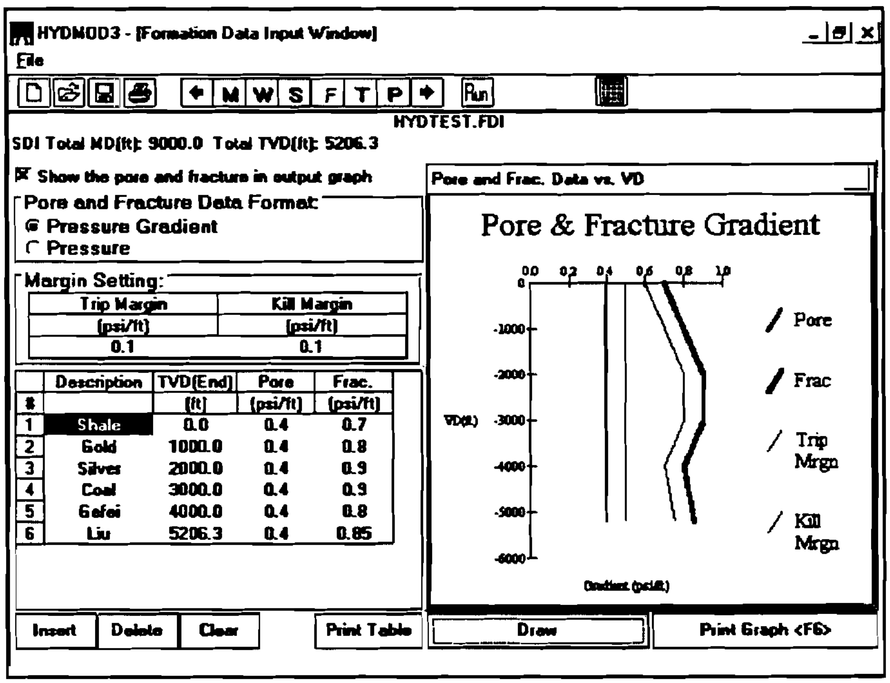


Figure 5-6 FDI Window

The FDI Window has four entry fields: option to show pore and fracture pressure in the output graph, pore and fracture data format, margin setting, and pore/fracture data.

1. Option to show the pore and fracture in the output graph:

   The user can choose to show or not show the pore and fracture pressures together with the annular pressure profile in the output graph.

2. Pore and Fracture Data Format:
   The pore and fracture data can be input in two formats. One is pressure gradient (psi/ft) or (kPa/m). The other one is pressure (psi) or (kPa).

3. Margin Setting:
   Margin setting allows the user to specify the safety factors for hydraulics planning.

   The annular pressure is normally designed to provide at least an acceptable trip margin above the anticipated formation pore pressure. This is to prevent the flow of formation fluid into the well (i.e., to prevent a kick).

   Similarily, when possible, a kick margin is subtracted from the true fracture-gradient line to obtain a design fracture-gradient line.

   Commonly used trip and kill margins are 0.5 lbm/gal (=0.026 psi/ft).

4. Pore/Fracture Data:
   HYDMOD3 can handle up to 100 pore/fracture changes. But the user must provide at least two data points: the information at surface and at any other place, usually vertical depth of bottom hole.

   - Description — Formation name
   - TVD — True vertical depth of the ending point of a particular formation zone
   - Pore — Pore pressure at the TVD or gradient within that zone.
   - Frac — Fracture pressure data, the TVD or gradient within that zone

   After the pore and fracture data are input, the user can click the "Draw" button to view the "Pore/Frac Data versus VD" graph located at the right side of the window.

   The formation data input files for HYDMOD3 have the extension "FDI."

5.1.2.5 Tubular Data Input Window (TDI)

Figure 5-7 shows a typical Tubular Data Input Window.

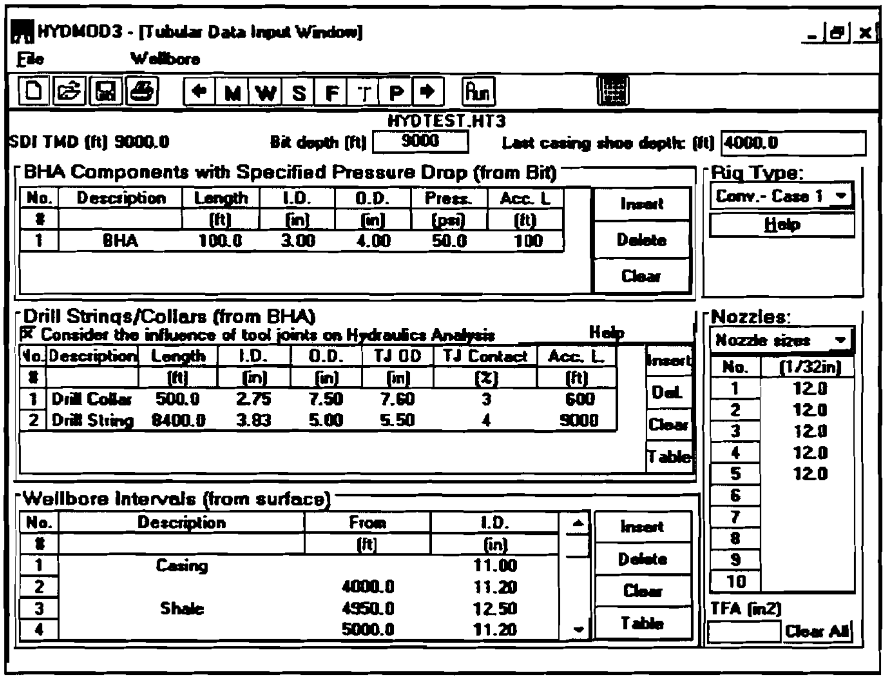


Figure 5-7. TDI Window

The TDI Window has six entry fields: BHA Components with Specified Pressure Drop, Drill Strings/Collars, Wellbore Intervals, Casing Shoe Depth, Rig Type, and Nozzles.

1. BHA Components with Specified Pressure Drop (from Bit):

   HYDMOD3 can handle up to 5 different BHA components with specified pressure drop, such as MWD, motor, etc.

   - Description — Name of the BHA component
   - Length — BHA component length
   - ID — BHA component ID
   - OD — BHA component OD
   - Press. — Specified pressure drop within the component
   - Cum. L. — Cumulative length of BHA components. As the user types the length of the BHA component, the cumulative length will be updated. The bit depth label shown in the upper center of the window reflects any change in the length.

2. Drill Strings/Collars (from BHA):

   HYDMOD3 can handle up to 10 drill strings/collars. It also lets the user consider the influence of tool joints on the hydraulics analysis.

- Description — Name of the drill string/collar
- Length — Drill string or drill collar section length
- ID — Drill string or drill collar inner diameter
- OD — Drill string or drill collar outer diameter
- TJ OD — Tool joint outer diameter (needed only if the user selects the influence of tool joints on hydraulics).
- TJ Contact — Tool joint contact percentage (needed only if the user selects the influence of tool joints on the hydraulics analysis). The estimation of tool joint contact percentage can be found in the "Help" window which is displayed below. The user can click the "Help" button above the drill string table.

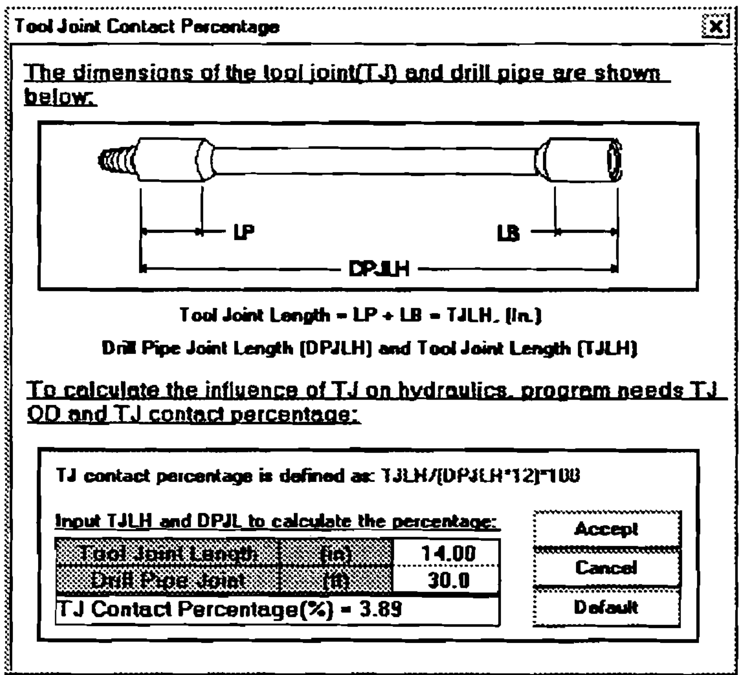


Figure 5-8 Tool Joint Contact Percentage

- Cum. L. — Accumulative length of all BHA components and drill string /collar. As the user types the length of drill string/collar, the cumulative length will be updated. The bit depth label shown in the upper center of the window reflects any length change.

3. Wellbore Interval (from surface):
   HYDMOD3 can handle up to 20 wellbore intervals.
   - Description — Wellbore section name
   - From — Wellbore section starting depth. The first starting depth is always 0 (on surface), and each following depth should be greater than the previous one.
   - ID — Casing inner diameter or open-hole diameter.

4. Casing Shoe Depth:

   As the name implies, this represents the measured depth of the casing shoe. However, it can be used to monitor any zone of interest along the wellbore, such as a weak zone, pay zone, etc.

5. Rig Type:

   There are five choices for rig type. Four of them are conventional rigs. The other one is a coiled-tubing rig.

   For conventional rigs, surface equipment consists of the standpipe, hose, swivel, and gooseneck. Combinations for four conventional cases are displayed (Figure 5-9) when the "help" button below the rig type drop-down list box is clicked.

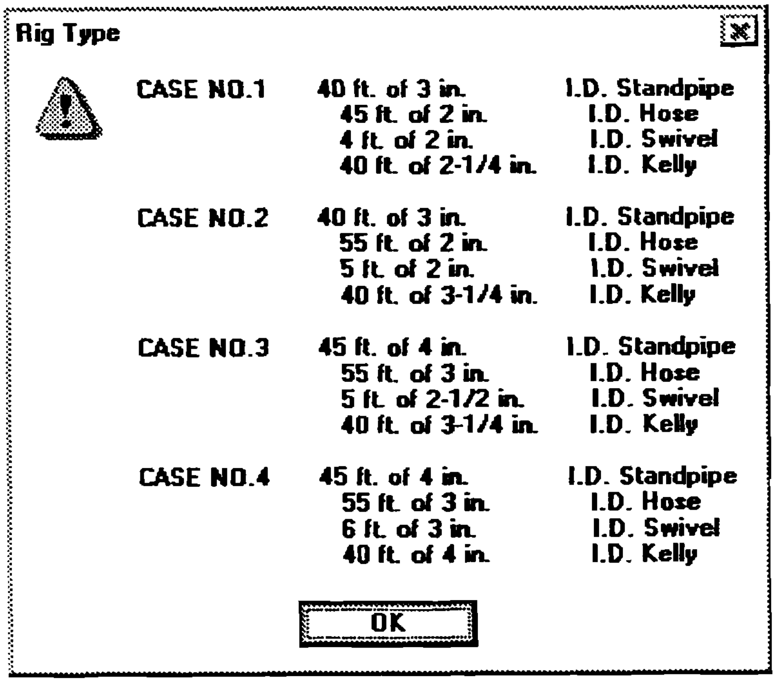


Figure 5-9. Surface Equipment Help Screen

For coiled-tubing operations, the user needs to provide the total length of coiled tubing. The explanation of the calculation is displayed in a "Help" window (Figure 5-10). The user can open this window by clicking the "Help" button below the rig type drop-down list box. This particular "Help" window only opens when the user selects the "Coiled-Tubing" for Rig Type.

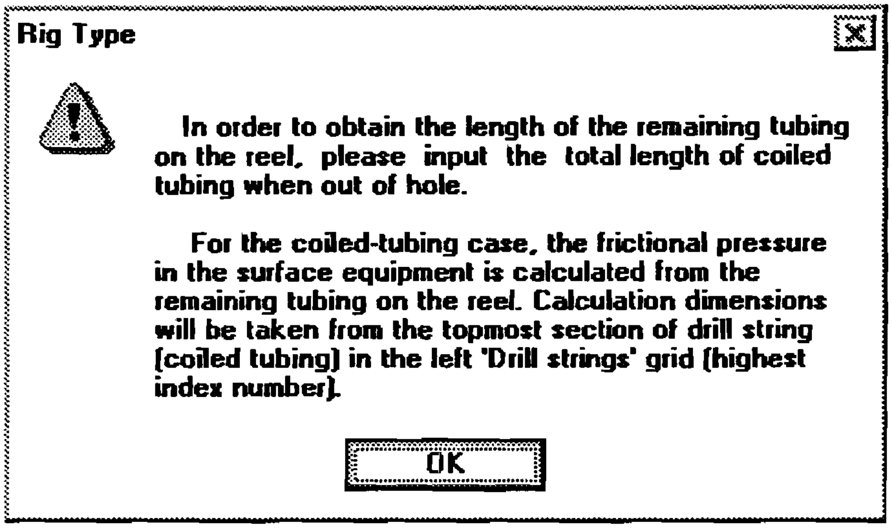


Figure 5-10. Rig Type — Coiled Tubing

6. Nozzles:

   There are two options to choose from:

   - Nozzle sizes — Up to ten nozzle sizes can be input
   - TFA — Total flow area can be specified instead of nozzle sizes

Tubular data input files for HYDMOD3 have the extension "HT3."

5.1.2.6 Parameter Data Input Window (PDI)

Figure 5-11 shows a typical PARAMETER DATA INPUT window.

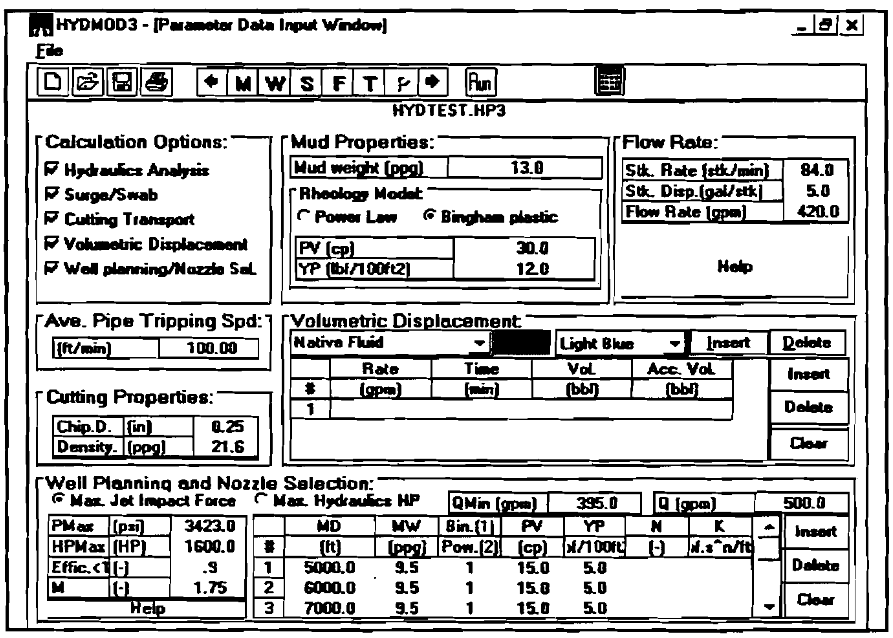


Figure 5-11. Parameter Data Input Window

HYDMOD3 offers five calculation options. Each option requires some distinct input data while some common parameters are shared by two or more calculation options.

For special analyses or to save computer memory, the user can select only part of the options. Then only data entry fields associated with the selected options will be enabled. Other non-related data entry fields will be disabled (i.e., the frame of the data group will be dimmed), and the user cannot access those entry fields. The program will only check the associated input for errors.

If the option "Volumetric Displacement" is selected, the fluid information and pumping schedule must be supplied by the user in the frame called "Volumetric Displacement." The user may add/remove a fluid by clicking the "Add"/"Delete" button beside the Fluid Description drop-down list box. The name of the fluid can be specified in the drop-down list box (20 characters). Remember to press <ENTER> to leave the drop-down list box after the name of the fluid is entered. It is very important that the user arranges the fluids in the right order; the item at the end of the list is the native mud and the remaining fluids are arranged from bottom to top in the order they are pumped.

When selecting a fluid in the drop-down list box, all other entries in the frame, such as fluid color and pumping schedule, pertain to that fluid. The fluid colors are for the use of fluid displacement animation.

There are two Help buttons on this page. One is for pump stroke displacement and is placed in the Flow Rate frame. Clicking on this button will display a separate Help window as shown in Figure 5-12.

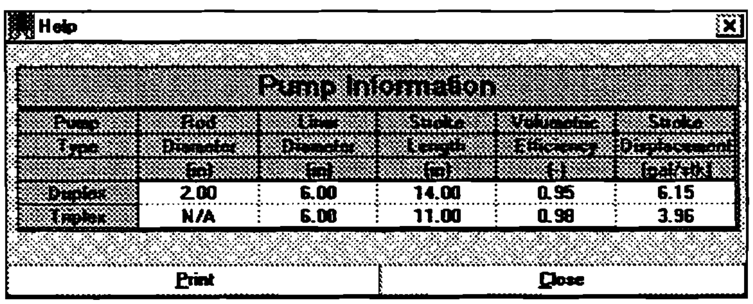


Figure 5-12. Pump Information Help Screen

It will calculate the pump volumetric discharge based on the liner size the user inputs. The equations are discussed in Section 2.4.2.

The other Help button is about the flow exponent (M) used in well planning and nozzle selection. It is located at the lower left corner. Pressing this button will display a Help window, as shown in Figure 5-13.

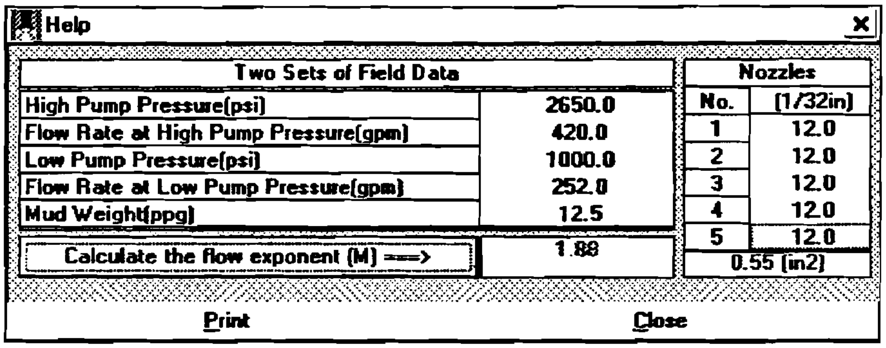


Figure 5-13. Flow Exponent (M) Help Screen

Two sets of pump pressure data and nozzle sizes are required to compute m. The equation used is presented in Section 2.5.3.

5.1.3 The Output Window

After all data are input, click the **Start** command from the **Run** menu in the Main Window to begin the calculation. When the calculation is finished, the program will unload the INPUT Window and show the OUTPUT Window.

Child windows are employed to display text reports, graphs for various calculation options. A child window is a window confined to its parent window – the OUTPUT window. Child windows can be displayed independently. The user can manipulate them just as normal windows: move, resize, close, etc. The arrangement commands in the Window Menu (Cascade, Tile, Arrange Icons) have the same functions as those of the Program Manager of Windows itself.

Each calculation option except "Cuttings Transport" has four or six child windows. To view the output of a particular calculation option, open the "window" menu and select the desired child window. See Section 5.2.2 for details. Only the child windows belonging to one calculation option can be displayed simultaneously.

Child windows in each calculation option are described in the following sections.

5.1.3.1 Hydraulics Analysis

There are six child windows under this category: Report, Pressure, Frictional Pressure, ECD, Velocity and Sensitivity.

1. Report

Figure 5-14 shows a typical Report Window.

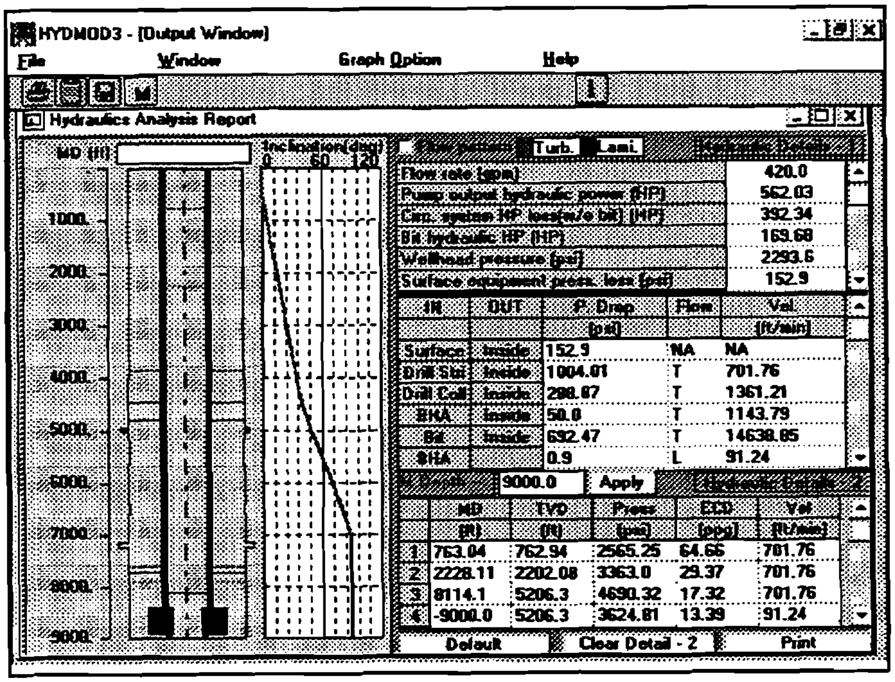


Figure 5-14. Report Window

On the left portion of the window is a wellbore schematic with the curve of the inclination angle of the wellbore. The flow pattern (turbulent or laminar) in the wellbore can be shown optionally as in Figure 5-15 by checking the "Draw Flow Pattern" check box. Red represents turbulent flow; blue represents laminar flow; and green indicates a section with specified pressure drop, such as BHAs. The user may find the wellbore geometry configuration not symmetric about its own center line. This is because the screen resolution is not high enough to show the fine detail.

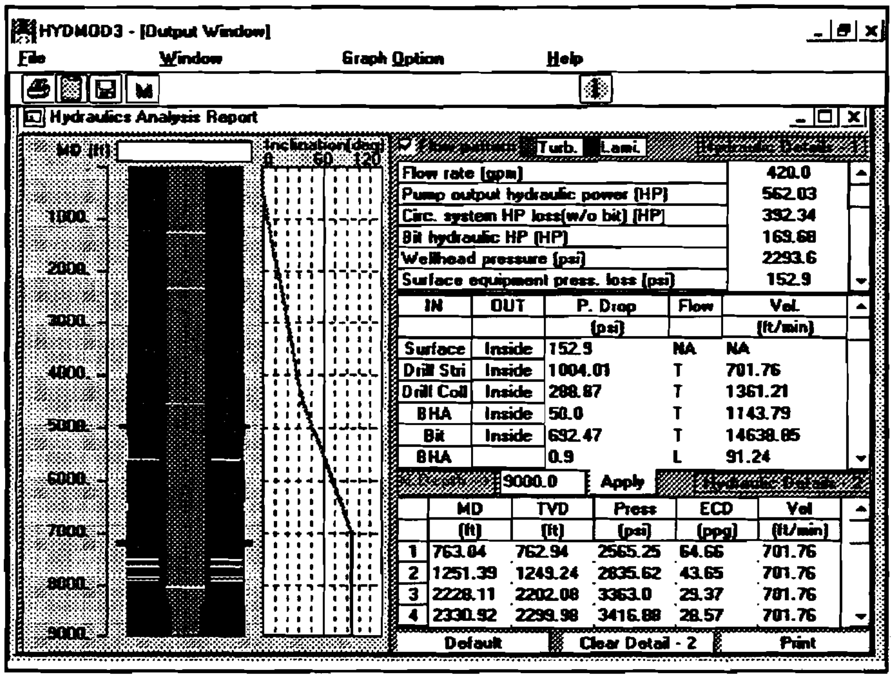


Figure 5-15. Report Window

To the right of the wellbore schematic, there are three grids displaying different hydraulic details. The top grid shows quantities like pump output hydraulic horsepower, bit hydraulics horsepower, wellhead pressure, etc. Frictional pressure drop, flow pattern, and average fluid velocity in each drill string and annular section are displayed in the middle grid.

Pressure and Equivalent Circulation Density (ECD) at particular locations in the wellbore can be illustrated with the bottom grid. What is unique about this grid is that it is interactively related to the wellbore schematic. The user can select desired points by clicking the mouse button while the mouse is within the flow area, inside the drill string or the annulus. Then the true vertical depth, pressure, ECD and fluid velocity at that location will be displayed in a row of the grid. While the user is moving the mouse over the wellbore schematic, the corresponding measured depth is shown in the box above the schematic. A positive number means a point inside the drill string, and a negative number means a location in the annulus.

The user can also specify the depth of interest and put the exact MD in the text box above the third grid and click the "Apply" button beside it.

2. Pressure

Figure 5-16 is a typical Pressure Window.

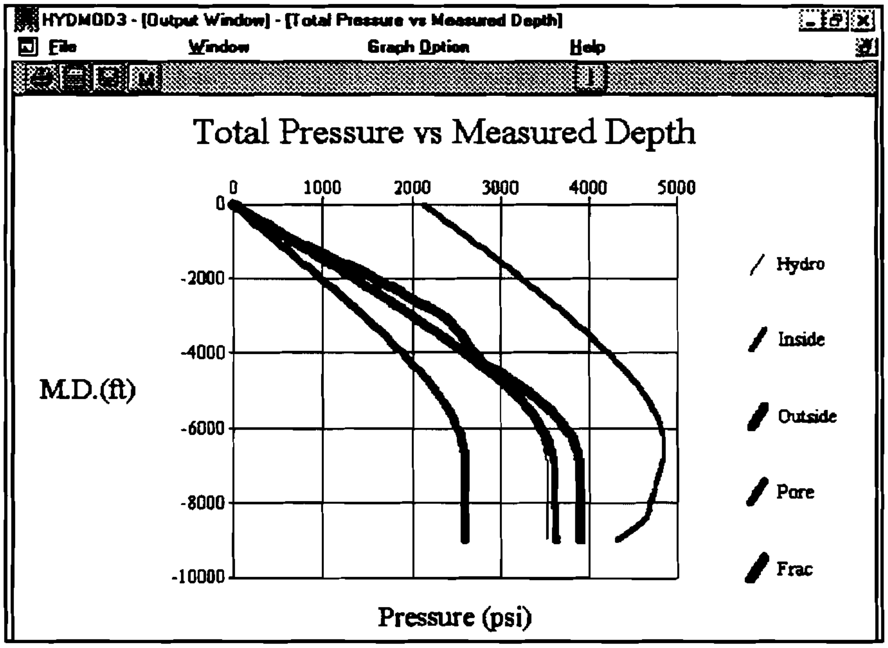


Figure 5-16. Pressure Window

The y-axis is measured depth. The x-axis is reserved for total pressure. If the user selects the "Show pore/fracture pressure" check box on the PDI page of the INPUT Window, the pore and fracture pressure curves will also be displayed.

3. Frictional Pressure

The frictional pressure drop along the wellbore is shown in Figure 5-17.

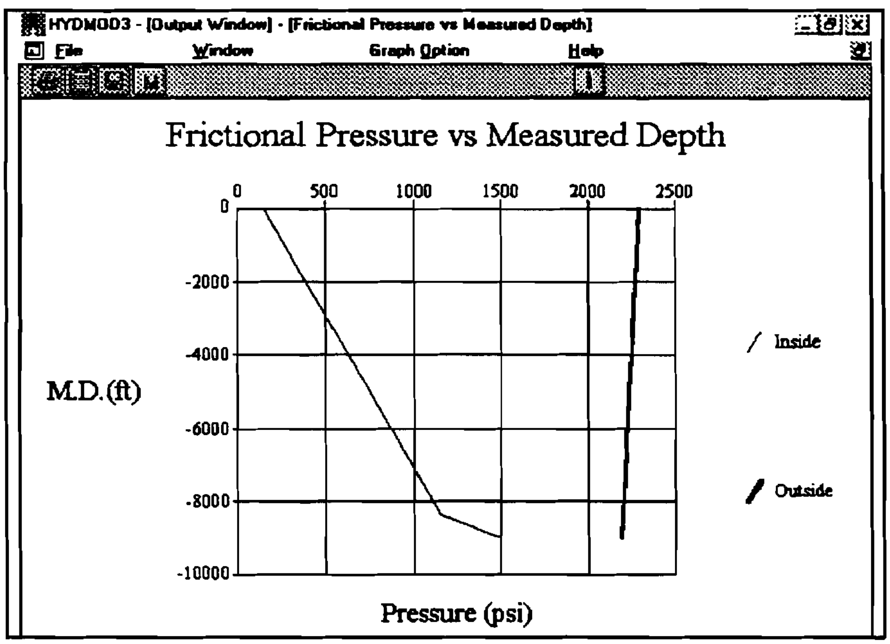


Figure 5-17. Frictional Pressure Drop

Figure 5-17 does not take the hydrostatic pressure into account. The left curve is for frictional pressure drop inside the drill string. Annular frictional pressure drop is expressed in the right curve. The discontinuity at the bottom of the curve is due to the pressure drop across the bit.

4. Equivalent Circulating Density (ECD)

   The ECD in the annulus is shown in Figure 5-18.

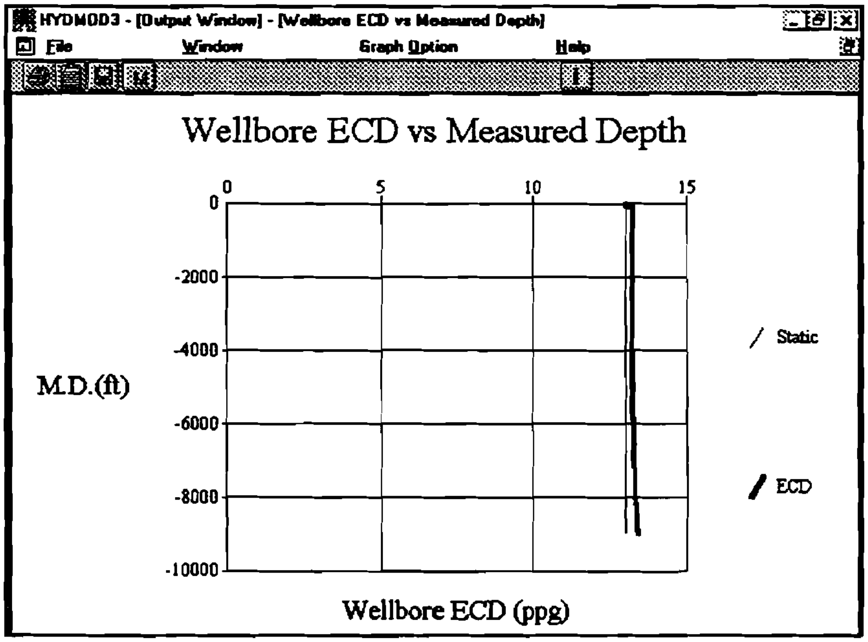


Figure 5-18. ECD in the Annulus

5. Velocity

   Figure 5-19 shows the velocity profile inside the drill string and annulus.

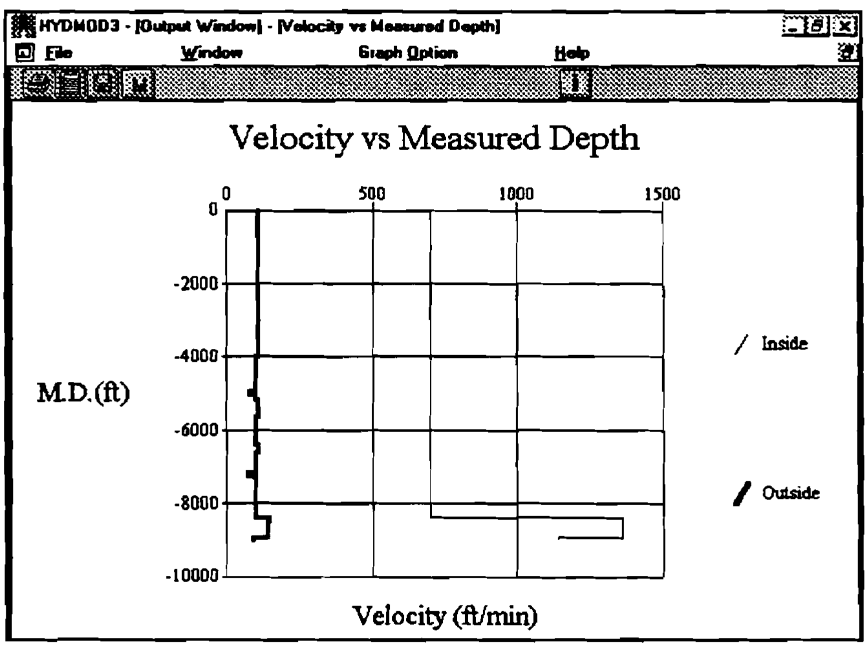


Figure 5-19. Velocity Profile Inside the Drill String and Annulus

6. Sensitivity

Figure 5-20 shows the hydraulics sensitivity analysis. This is actually an independent window, not a child window, but no user input (keyboard or mouse) can occur in any other window until this window is unloaded.

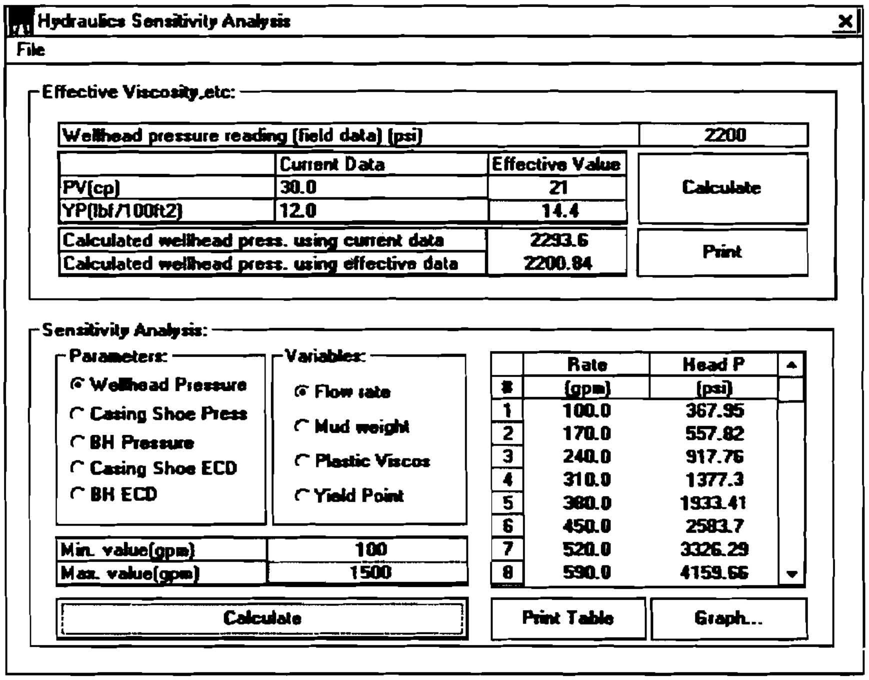


Figure 5-20. Hydraulics Sensitivity Analysis

This window allows correlation between predicted and actual pressure drops by "effective" plastic viscosity and yield point or n and k depending on the rheology model.

For the sensitivity analysis, five variables can be monitored. They are wellhead pressure, casing-shoe pressure, bottom-hole pressure, casing-shoe ECD and bottom-hole ECD. Four variables - flow rate, mud weight, PV (or n), and YP (or K) - can be varied to see how they affect the above-mentioned parameters.

The range of variables to be varied is specified in the "Min. Value" and "Max. Value" grid. Clicking the "Recalculate" button will display the result in the grid to its right. The results can be presented graphically by pressing the "Graph..." button (Figure 5-21).

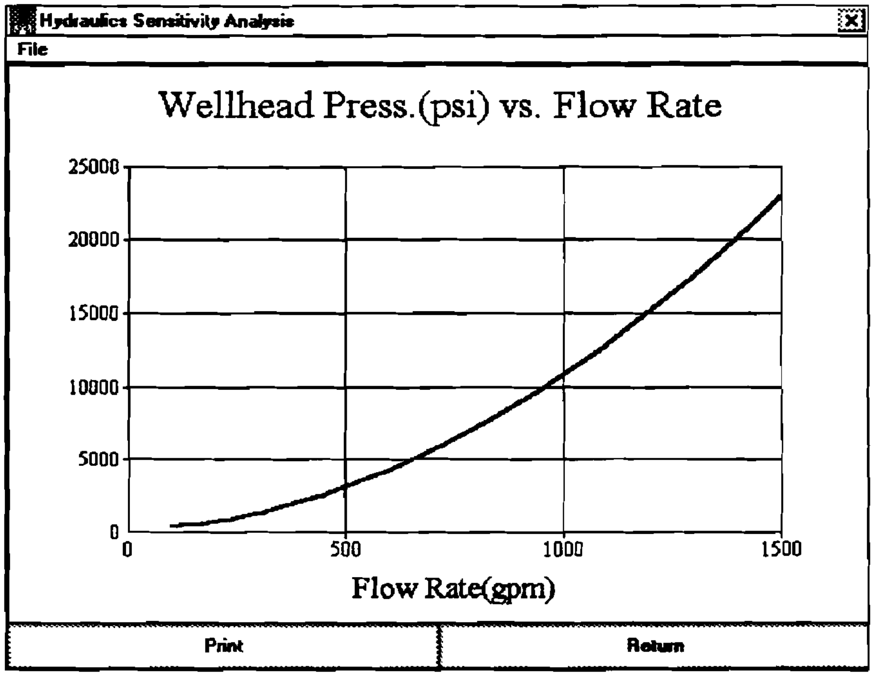


Figure 5-21. Graph of Hydraulics Sensitivity Analysis

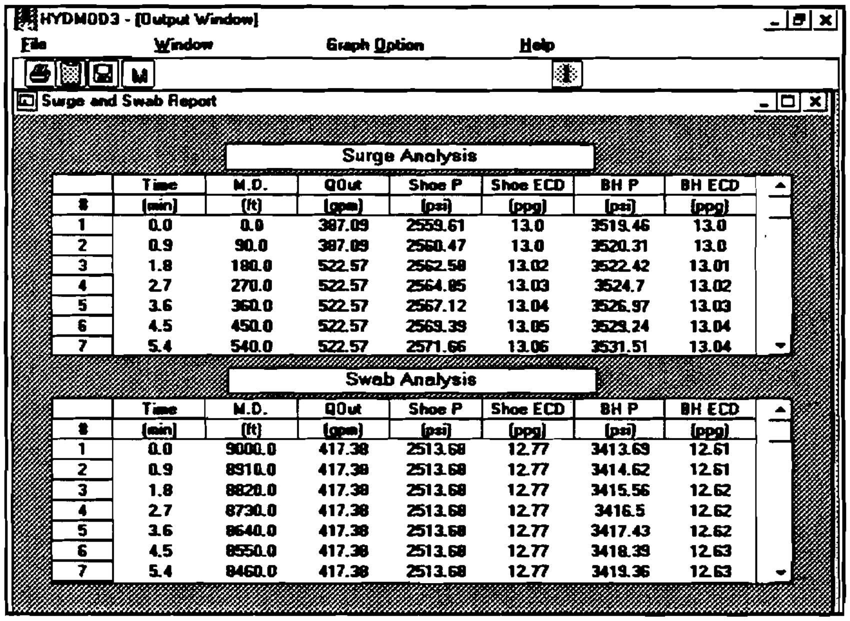
Select "Quit" from the File menu to unload the sensitivity analysis window and return to the Output Window.

5.1.3.2 Surge and Swab (Closed Pipe)

Six "child" windows are implemented under this category: Report, Return Flow Rate, Casing-Shoe Pressure, Casing-Shoe Equivalent Mud Weight (EMW), Bottom-Hole Pressure, and Bottom-Hole EMW.

1. Report

   Figure 5-22 shows a typical Report Window for surge and swab.



Surge Analysis

#	Time (min)	M.D. (ft)	QOut (gpm)	Shoe P (psi)	Shoe ECD (ppg)	BH P (psi)	BH ECD (ppg)
1	0.0	0.0	387.09	2559.61	13.0	3519.46	13.0
2	0.9	90.0	387.09	2560.47	13.0	3520.31	13.0
3	1.8	180.0	522.57	2562.58	13.02	3522.42	13.01
4	2.7	270.0	522.57	2564.85	13.03	3524.7	13.02
5	3.6	360.0	522.57	2567.12	13.04	3526.97	13.03
6	4.5	450.0	522.57	2569.39	13.05	3529.24	13.04
7	5.4	540.0	522.57	2571.66	13.06	3531.51	13.04

Swab Analysis

#	Time (min)	M.D. (ft)	QOut (gpm)	Shoe P (psi)	Shoe ECD (ppg)	BH P (psi)	BH ECD (ppg)
1	0.0	9000.0	417.38	2513.68	12.77	3413.69	12.61
2	0.9	8910.0	417.38	2513.68	12.77	3414.62	12.61
3	1.8	8820.0	417.38	2513.68	12.77	3415.56	12.62
4	2.7	8730.0	417.38	2513.68	12.77	3416.5	12.62
5	3.6	8640.0	417.38	2513.68	12.77	3417.43	12.62
6	4.5	8550.0	417.38	2513.68	12.77	3418.39	12.63
7	5.4	8460.0	417.38	2513.68	12.77	3419.36	12.63

Figure 5-22. Report Window for Surge and Swab

Note: the "Q Out" in the Swab Analysis is actually the annular fluid drop rate (at the surface) during the swab operation. HYDMOD3 assumes that there is no air column in the annulus during the swab operation.

2. Return Flow Rate

   The Return Flow Rate Window is shown in Figure 5-23. It predicts the return flow rate as the drill string is lowered (surge).

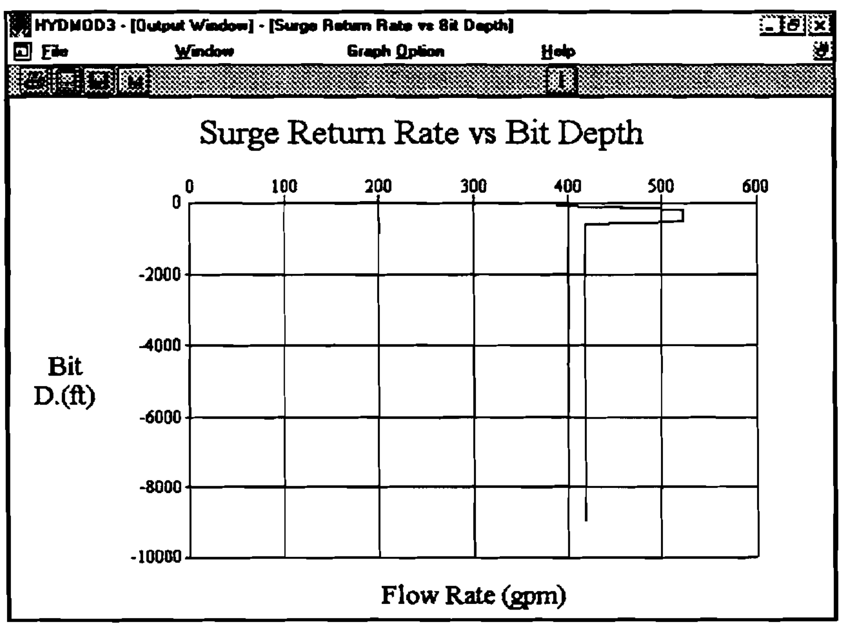


Figure 5-23. Return Flow Rate

3. Casing-Shoe Pressure

Figure 5-24 shows a typical Casing-Shoe Pressure Window. Pressures at the casing shoe due to both surge and swab are presented.

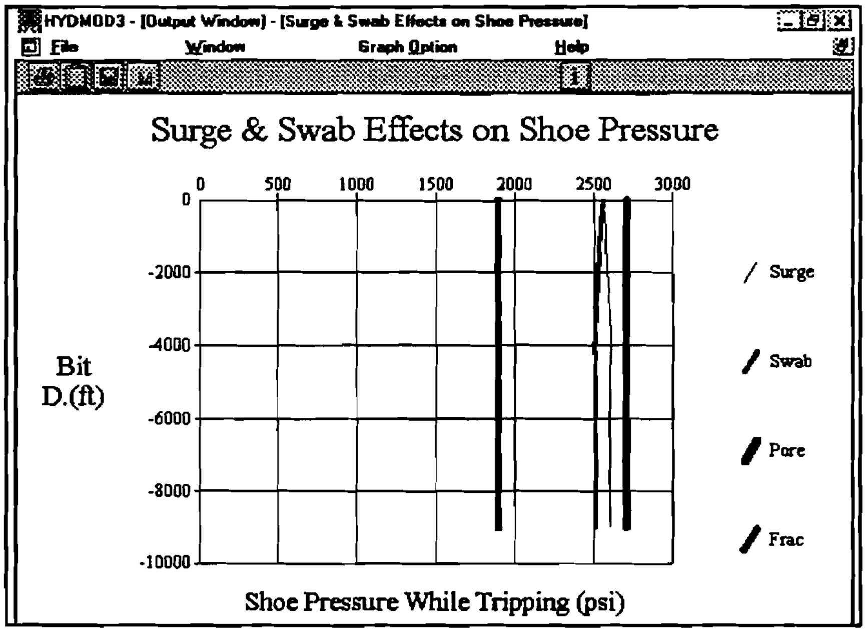


Figure 5-24. Surge and Swab Effects on Shoe Pressure

4. Casing-Shoe Equivalent Mud Weight (EMW)

Casing-Shoe EMW Window is displayed in Figure 5-25.

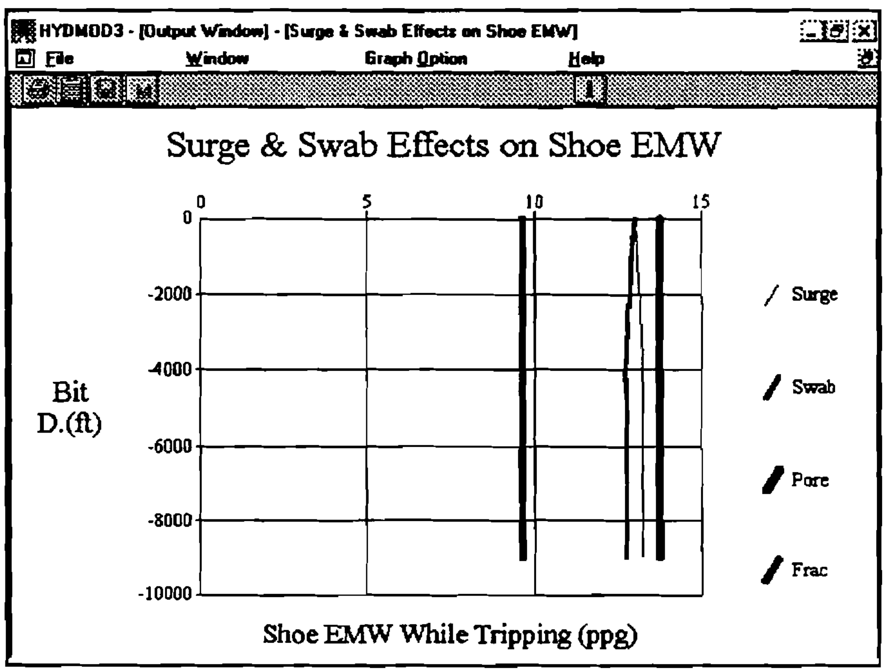


Figure 5-25. Surge and Swab Effects on Shoe EMW

5. Bottom-Hole Pressure

Bottom-hole pressures due to surge and swab are shown in the window as follows:

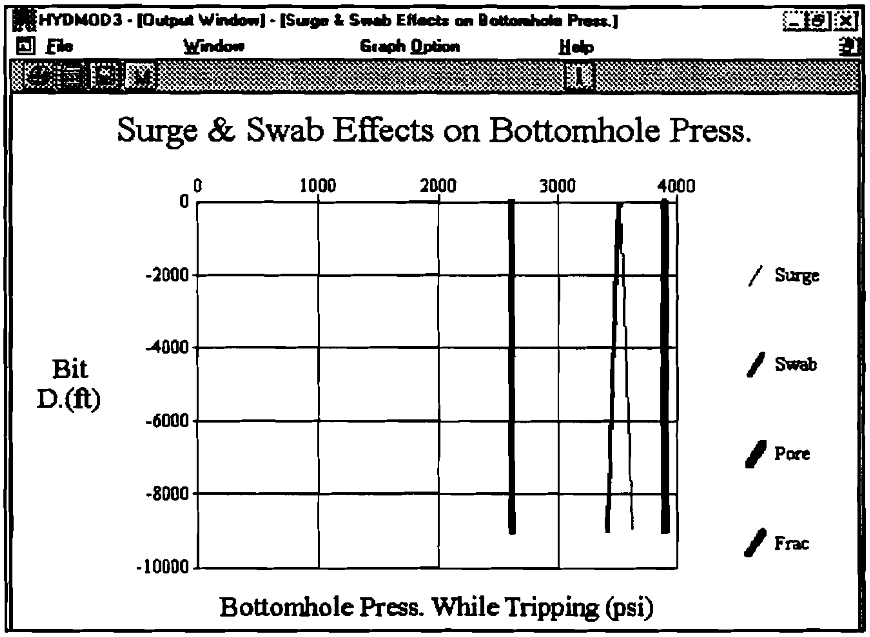


Figure 5-26. Surge and Swab Effects on Bottom-Hole Pressure

6. Bottom-Hole EMW

Figure 5-27 shows the resultant bottom-hole EMW window.

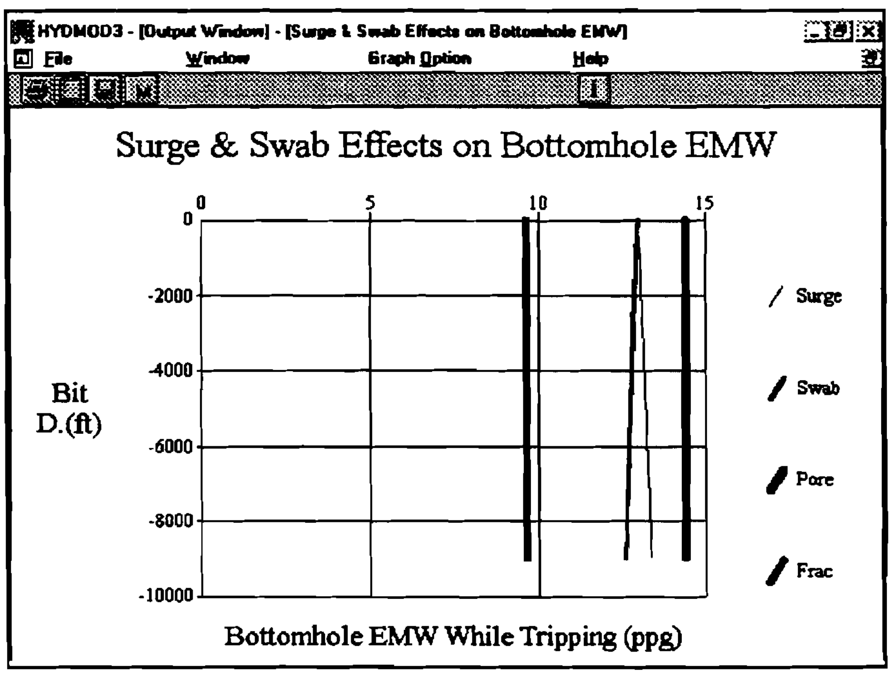


Figure 5-27. Surge and Swab Effects on Bottom-Hole EMW

5.1.3.3 Cuttings Transport

There is no child window associated with this calculation option. The output window will display graphs and tables as follows:

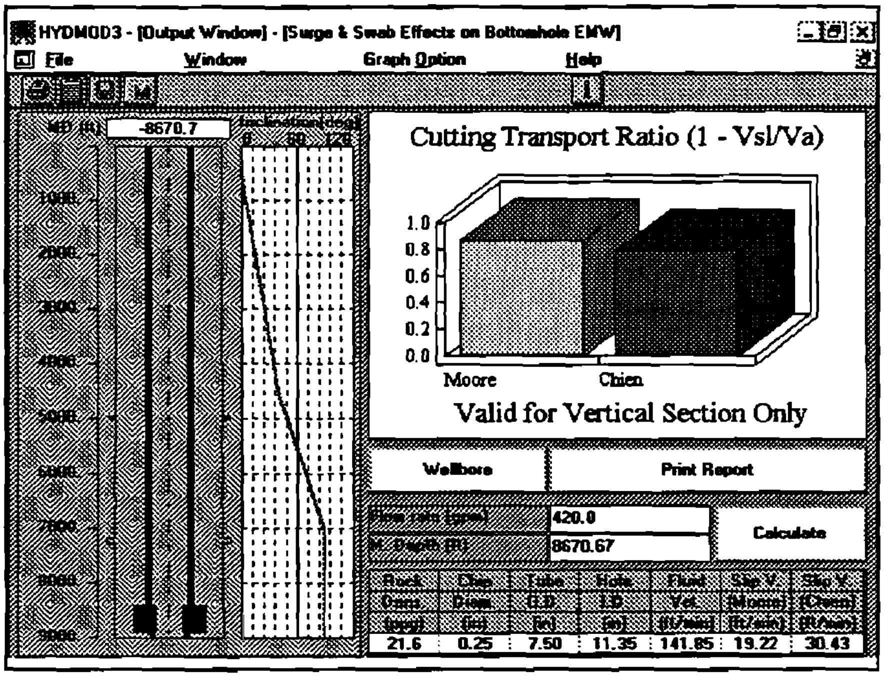


Figure 5-28. Cuttings Transport

The user can vary the flow rate locally to see how it influences the slip velocity and transport ratio. Any change of flow rate inside the screen will not affect other calculation options.

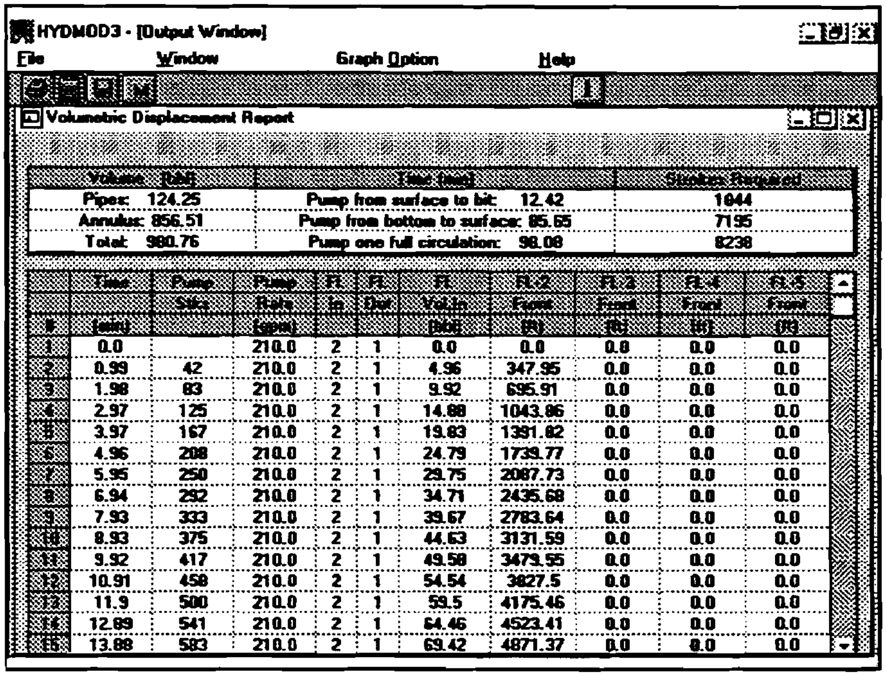
To see the slip velocity at various annular location, the user can either input the measured depth in the text box or click the mouse button when the mouse pointer is in the annulus of the wellbore schematic.

5.1.3.4 Volumetric Displacement

This category contains four child windows: Report, Volume In, Fluid Fronts, and Wellbore Schematic.

1. Report

The Report Window is shown as follows:



Volume (bbl)	Time (min)	Strokes Required
Pipes: 124.25	Pump from surface to bit: 12.42	1044
Annulus: 856.51	Pump from bottom to surface: 85.65	7195
Total: 980.76	Pump one full circulation: 98.08	8238

#	Time (min)	Pump Stks	Pump Rate (gpm)	Fl. In	Fl. Out	Fl. Vol.In (bbl)	Fl. 2 Front (ft)	Fl. 2 Front (ft)	Fl. 4 Front (ft)	Fl. 5 Front (ft)
1	0.0		210.0	2	1	0.0	0.0	0.0	0.0	0.0
2	0.99	42	210.0	2	1	4.96	347.95	0.0	0.0	0.0
3	1.98	83	210.0	2	1	9.92	695.91	0.0	0.0	0.0
4	2.97	125	210.0	2	1	14.88	1043.86	0.0	0.0	0.0
5	3.97	167	210.0	2	1	19.83	1391.82	0.0	0.0	0.0
6	4.96	208	210.0	2	1	24.79	1739.77	0.0	0.0	0.0
7	5.95	250	210.0	2	1	29.75	2087.73	0.0	0.0	0.0
8	6.94	292	210.0	2	1	34.71	2435.68	0.0	0.0	0.0
9	7.93	333	210.0	2	1	39.67	2783.64	0.0	0.0	0.0
10	8.93	375	210.0	2	1	44.63	3131.59	0.0	0.0	0.0
11	9.92	417	210.0	2	1	49.58	3479.55	0.0	0.0	0.0
12	10.91	458	210.0	2	1	54.54	3827.5	0.0	0.0	0.0
13	11.9	500	210.0	2	1	59.5	4175.46	0.0	0.0	0.0
14	12.89	541	210.0	2	1	64.46	4523.41	0.0	0.0	0.0
15	13.88	583	210.0	2	1	69.42	4871.37	0.0	0.0	0.0

Figure 5-29. Report Window

2. Volume In

Figure 5-30 shows the fluid volume pumped in versus time.

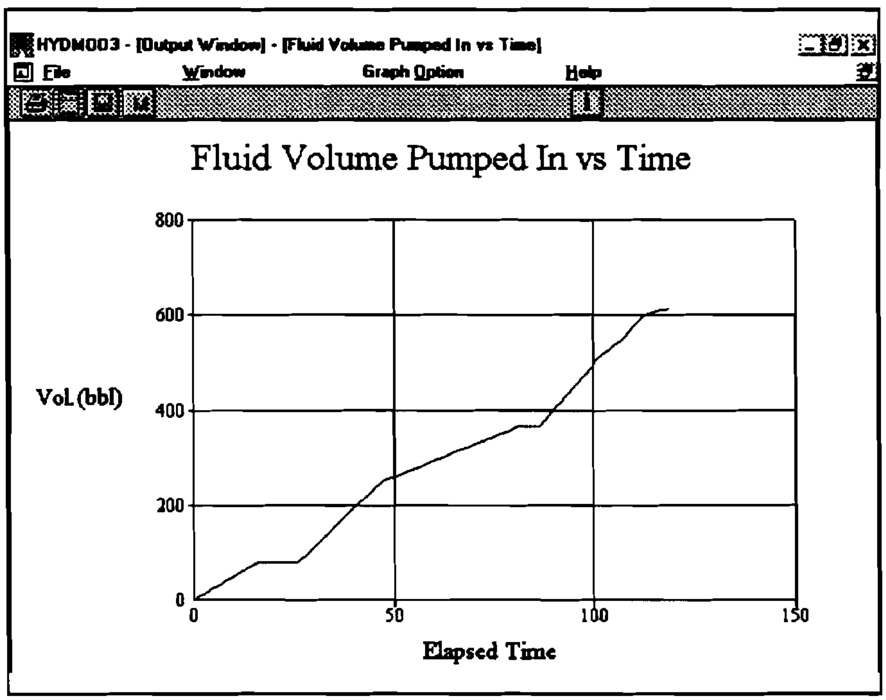


Figure 5-30. Fluid Volume Pumped in Vs. Time

3. Fluid Fronts

Up to four fluid fronts can be shown simultaneously in this child window as follows:

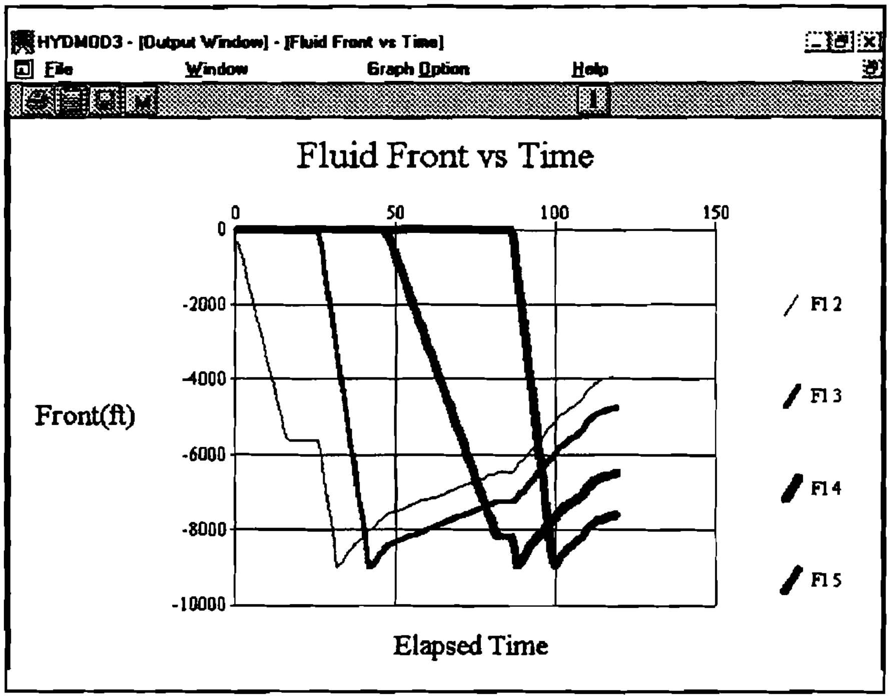


Figure 5-31. Fluid Fronts Vs. Time

For this version, only the fronts of the second, third, fourth, and fifth fluid are shown.

4. Wellbore Schematic

Figure 5-32 shows the Wellbore Schematic Window.

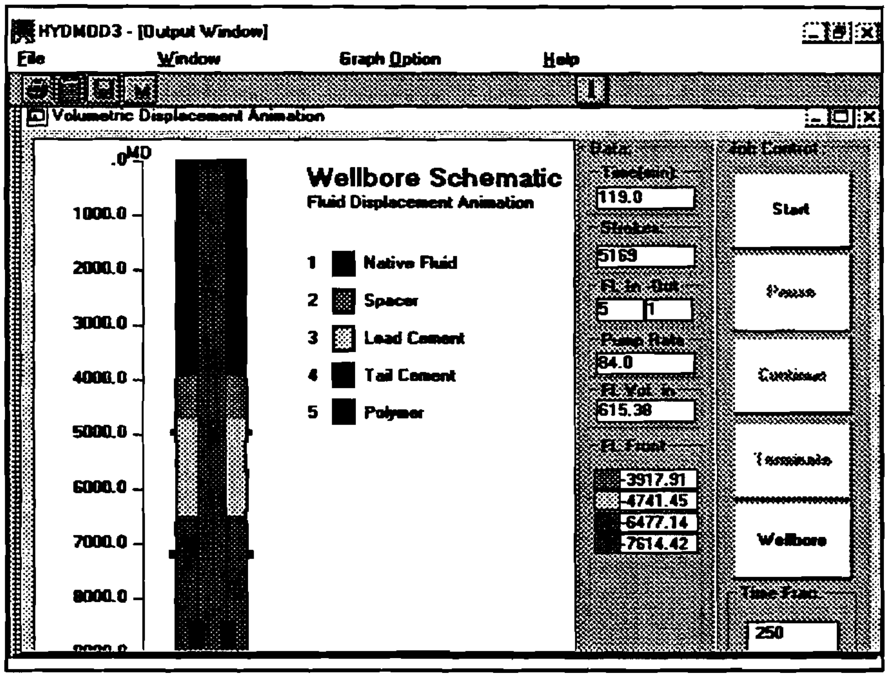


Figure 5-32. Wellbore Schematic Window

An animation of fluid displacement enables the user to visualize the displacement process on the screen. The user can monitor up to ten types of data (including elapsed time, strokes, fluid in, fluid out, pump rate, fluid volume in, and fluid fronts) displayed simultaneously as the fluids flow through the wellbore on the screen. The animation speed can be set from real-time speed to 2000 times faster. The user can interrupt the animation by pressing the "Pause" or "Terminate" command buttons. If the "Pause" is pressed, the animation can be resumed by pressing "OK."

5.1.3.5 Well Planning

Four child windows belong to this category: Report, Optimum Flow Rate, Optimum Nozzle Area, and Optimum Pressure.

1. Report

Figure 5-33 is a report child window for nozzle selection as well as well planning.

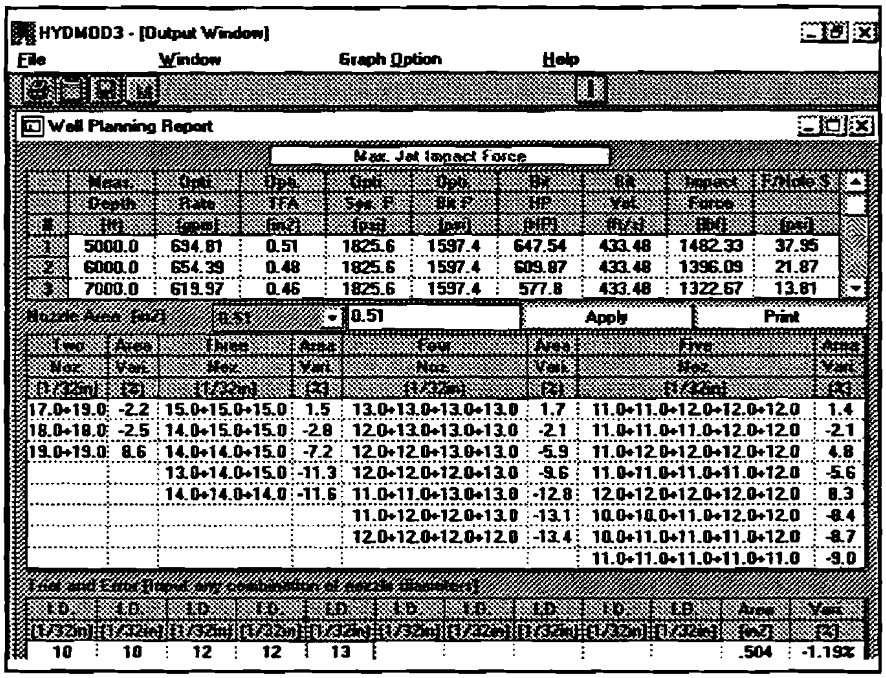


Figure 5-33. Report Window

There are three grids in this child window. The top grid shows the optimum and planned flow rates, nozzle area, etc., for different measured depths of the mud program. The middle grid displays several potential combinations of nozzle diameters for 2, 3, 4, and 5 nozzle designs. The area variance for each combination is also given. Note that all of these combinations are for a particular nozzle area shown in the text input box just above the grid. To the left of the text box is a drop-down list box containing the optimum nozzle areas from the top grid. Clicking any item in the list box will update the contents of the middle grid.

If the user does not have any of the combinations of nozzle sizes listed in the grid, the specially designed "trial and error" grid (bottom of the screen) can be used to input additional combination of nozzle diameters for up to five nozzles. Total nozzle area and area variance for the user-input combination will be displayed in the right two cells if the user presses <ENTER> after editing the nozzle diameters in any of the left five cells.

2. Optimum Flow Rate

Figure 5-34 shows a typical Optimum Flow Rate Window.

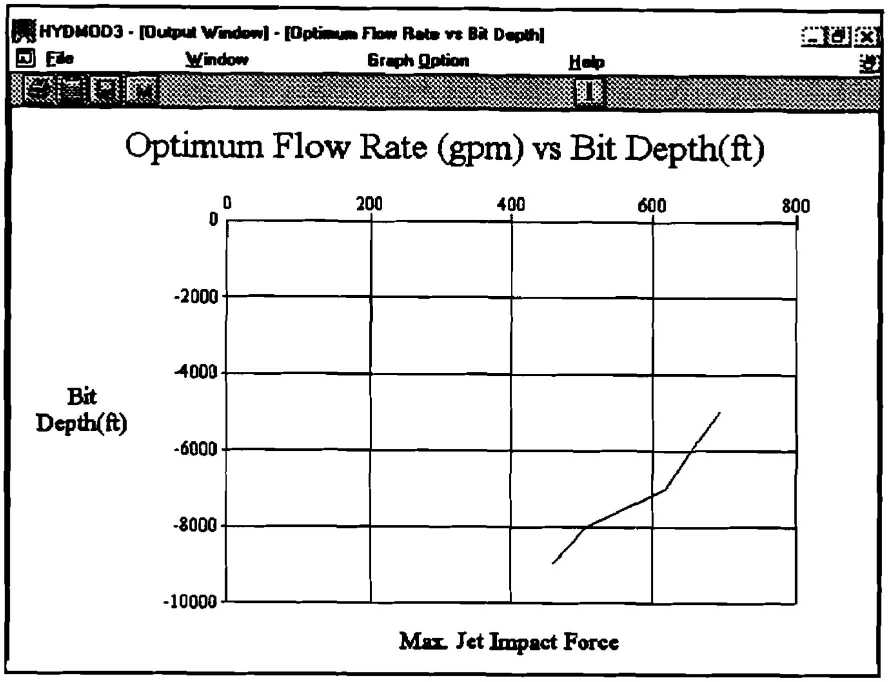


Figure 5-34. Optimum Flow Rate Window

The y-axis is the measured depth in the mud program.

3. Optimum Nozzle Area

Figure 5-35 shows a typical Optimum Nozzle Area Window.

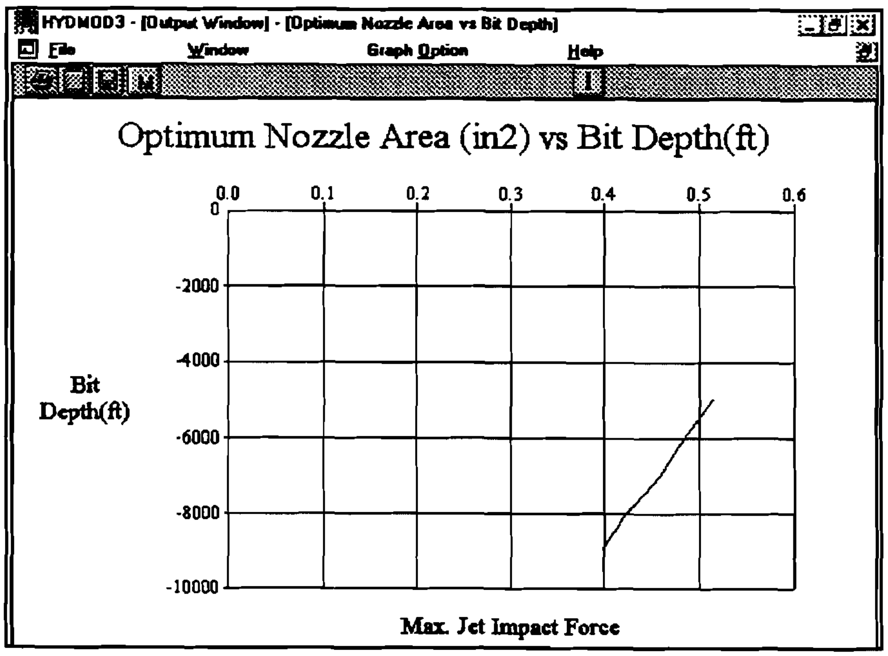


Figure 5-35. Optimum Nozzle Area Window

4. Optimum Pressure

   Figure 5-36 shows a typical Optimum Pressure Window.

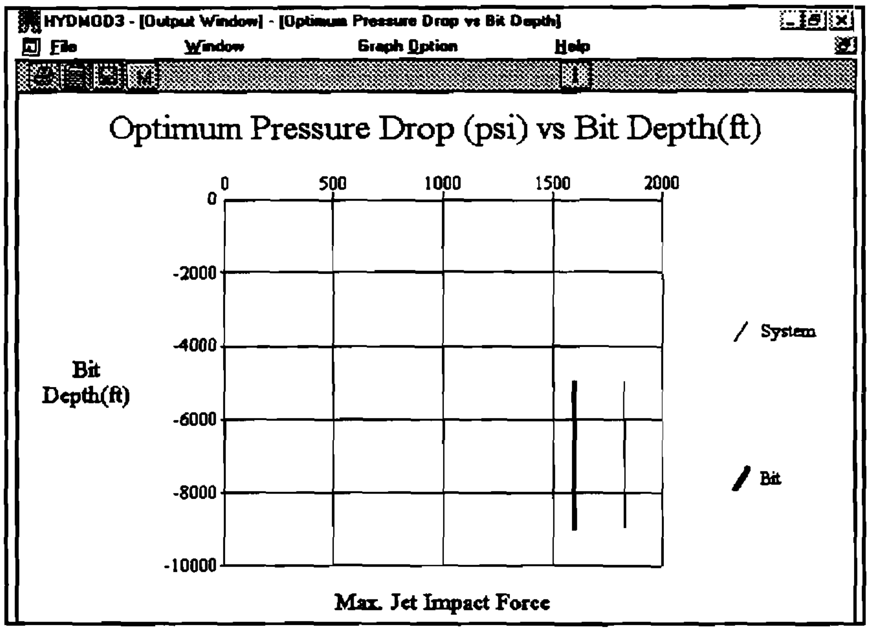


Figure 5-36. Optimum Pressure Window

There are two lines in this child window. One is the system pressure drop; the other is bit pressure drop. Since the pump pressure is expended by the system pressure loss (to and from bit) and bit pressure loss, the summation of two pressure losses at any depth should equal the maximum pump pressure.

5.1.4 Using Look Up Table - Database

Visual Basic V. 3 provides a function to communicate with database tables created by MS ACCESS V.1.1 and some other database software packages. Inside the HYDMOD3 program disk, there is a database file named "looktbl.mdb" which contains nine tables. These nine tables are: aluminum pipe, casing, premium pipe, Class 1, Class 2, Class 3, heavyweight, drill collar, and tubing. These tables may not be complete, but HYDMOD3 lets the user modify each table. HYDMOD3 does not allow the user to add a new table. The user can use Microsoft Access V. 1.1 to access this database file to edit or add tables.

If the user clicks the [Look Table] command buttons in HT3, the program opens the disk database file with the extension ".mdb". The default file is looktbl.mdb as shown in Figure 5-37.

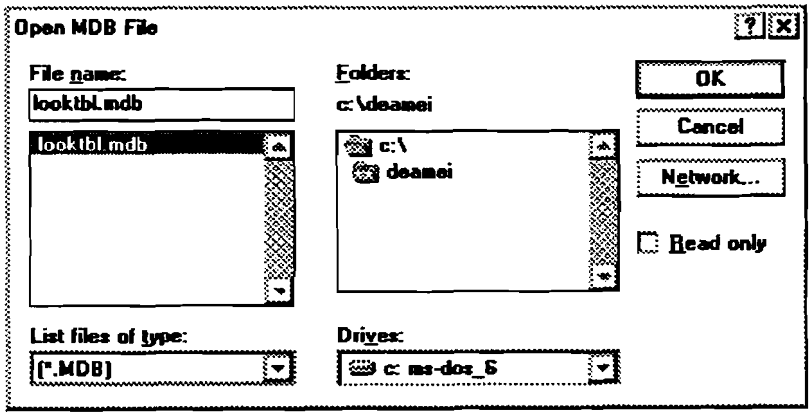


Figure 5-37. Open Look-Up Table Database File

5.1.4.1 Select Data Record

After retrieving the database file, the look-up table screen is displayed on the screen. The user needs to select the "class" (or name) of table by pulling the "Drop-Down List Table" on the top left corner, which is shown in Figure 5-38.

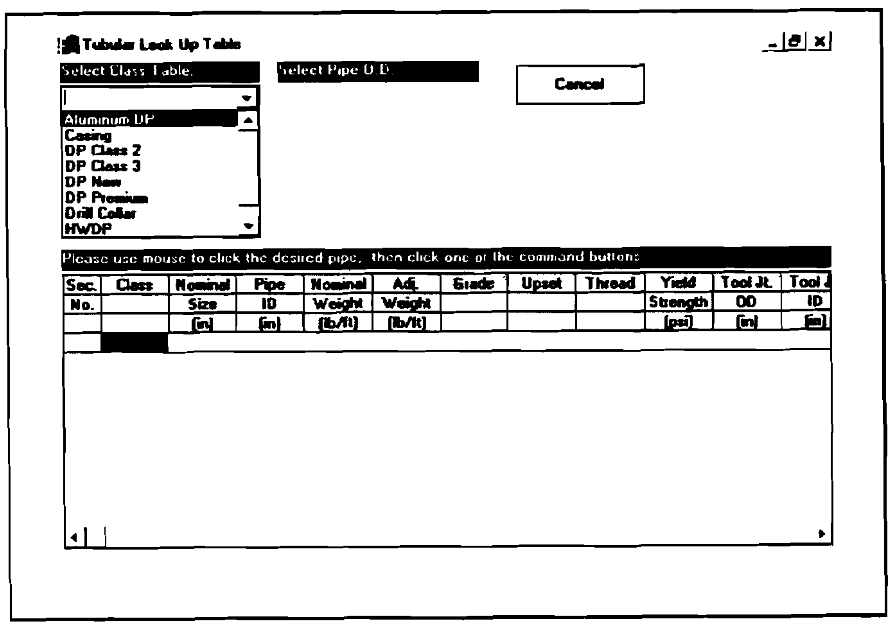


Figure 5-38. Listed Class Tables in Database file

After the table name is chosen, the user can select the available pipe size.

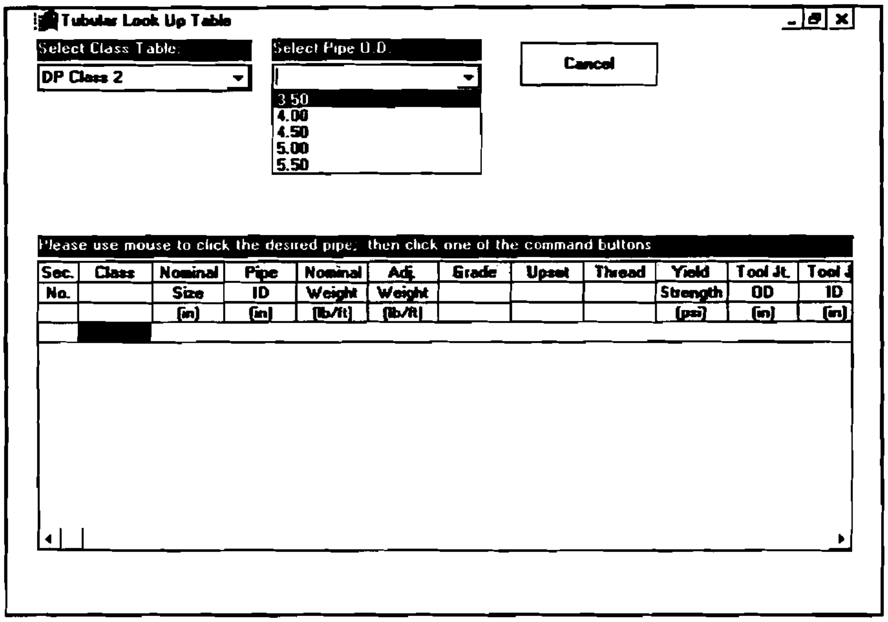
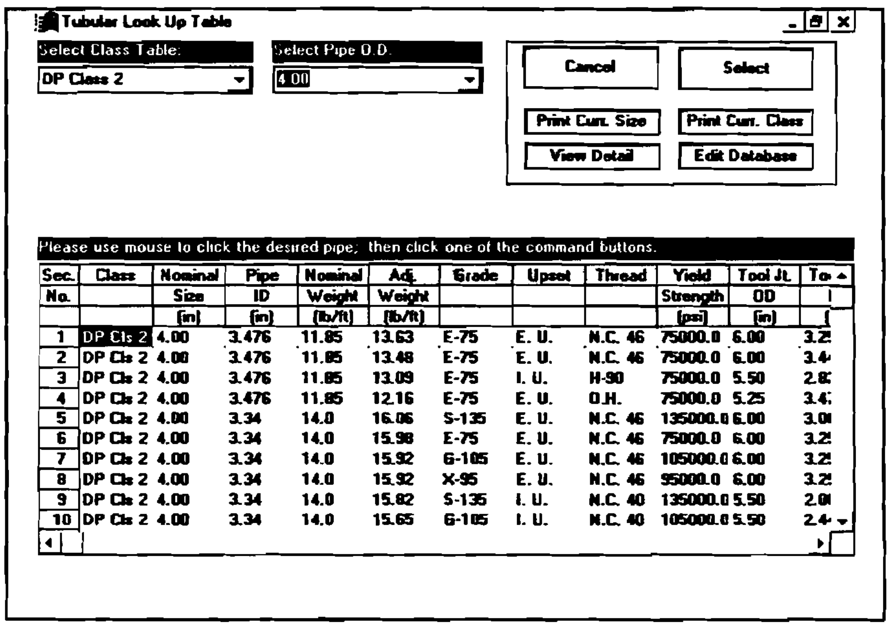


Figure 5-39. TDI Look-Up Table with Pipe Size

All the records with the same pipe OD in the table are then entered into the spreadsheet-like table, and the command panel appears on the top right side of the window (Figure 5-40).



Sec. No.	Class	Nominal Size (in)	Pipe ID (in)	Nominal Weight (lb/ft)	Adj. Weight (lb/ft)	Grade	Upset	Thread	Yield Strength (psi)	Tool Jt. OD (in)	To
1	DP Cls 2	4.00	3.476	11.85	13.63	E-75	E. U.	N.C. 46	75000.0	6.00	3.2
2	DP Cls 2	4.00	3.476	11.85	13.48	E-75	E. U.	N.C. 46	75000.0	6.00	3.4
3	DP Cls 2	4.00	3.476	11.85	13.09	E-75	I. U.	H-90	75000.0	5.50	2.8
4	DP Cls 2	4.00	3.476	11.85	12.16	E-75	E. U.	O.H.	75000.0	5.25	3.4
5	DP Cls 2	4.00	3.34	14.0	16.06	S-135	E. U.	N.C. 46	135000.0	6.00	3.0
6	DP Cls 2	4.00	3.34	14.0	15.98	E-75	E. U.	N.C. 46	75000.0	6.00	3.2
7	DP Cls 2	4.00	3.34	14.0	15.92	G-105	E. U.	N.C. 46	105000.0	6.00	3.2
8	DP Cls 2	4.00	3.34	14.0	15.92	X-95	E. U.	N.C. 46	95000.0	6.00	3.2
9	DP Cls 2	4.00	3.34	14.0	15.82	S-135	I. U.	N.C. 40	135000.0	5.50	2.0
10	DP Cls 2	4.00	3.34	14.0	15.65	G-105	I. U.	N.C. 40	105000.0	5.50	2.4

Figure 5-40. TDI Look-Up Table with Listed Records Command Panel

Move the mouse and click on the desired record (click on the left-most column to highlight the desired record). Click the [Select] command to choose the data record of the selected pipe. The program then returns to the input subwindow and prompts with a confirmation box.

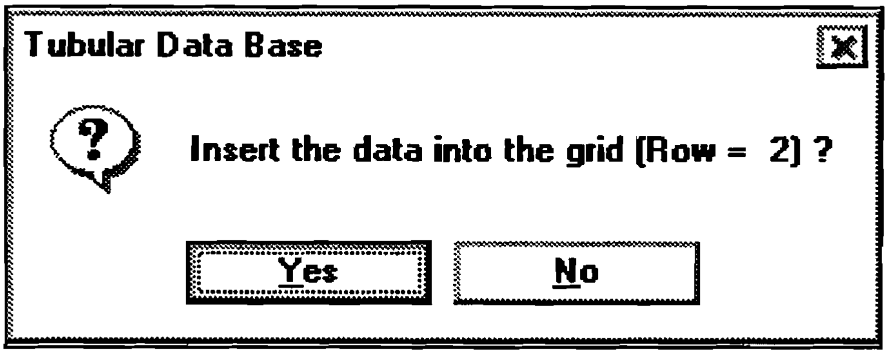


Figure 5-41. Confirmation Box

Clicking the [Yes] button will copy the related data field to the input grid. The row number of the grid where the data will be copied is determined by the user. Before entering the database window, if the user clicks grid row number "n," then the program assumes that row "n" is where the user wants the data placed.

5.1.4.2 Manipulate Data Record

1. [Cancel] command — leaves the look-up database table without selecting data record.
2. [Select] command — selects the focused record from the grid.
3. [Print Curr. Size] command — prints all the records in the grid table.
4. [Print Curr. Class] command — prints all the pipe records in the chosen table, which contain different size pipe.
5. [View Detail] command — views one record from the grid table at a time. The program will activate the other window, and the user can click [arrow] command button to go through all the records shown in the grid table. Figure 5-42 shows the detail window.

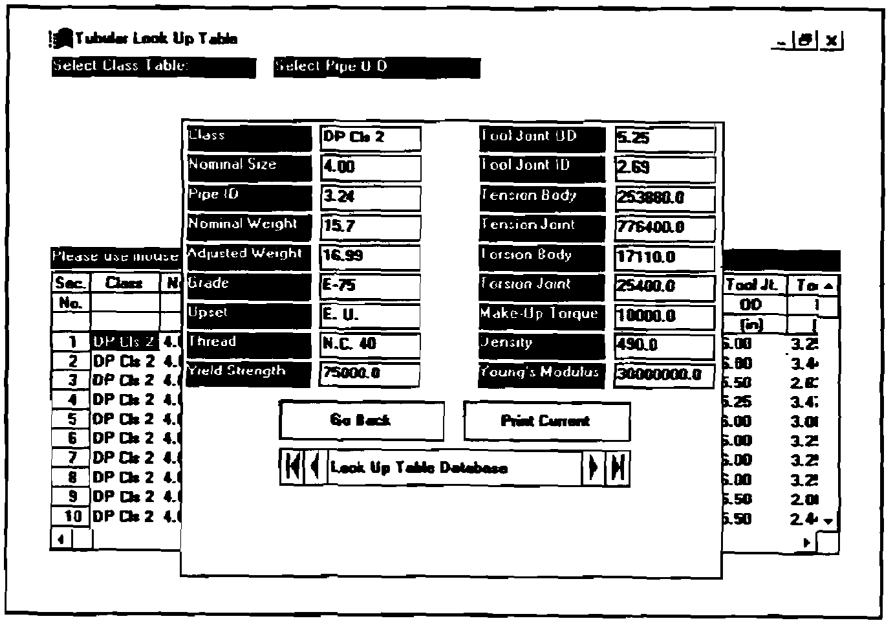


Figure 5-42. TDI Look-Up Table — Detail Window

6. [Edit Database] command — edits database record. Clicking this button will activate the same window as the [View Detail] command does, but provides more edit database command buttons on the bottom of the window as shown in Figure 5-43.

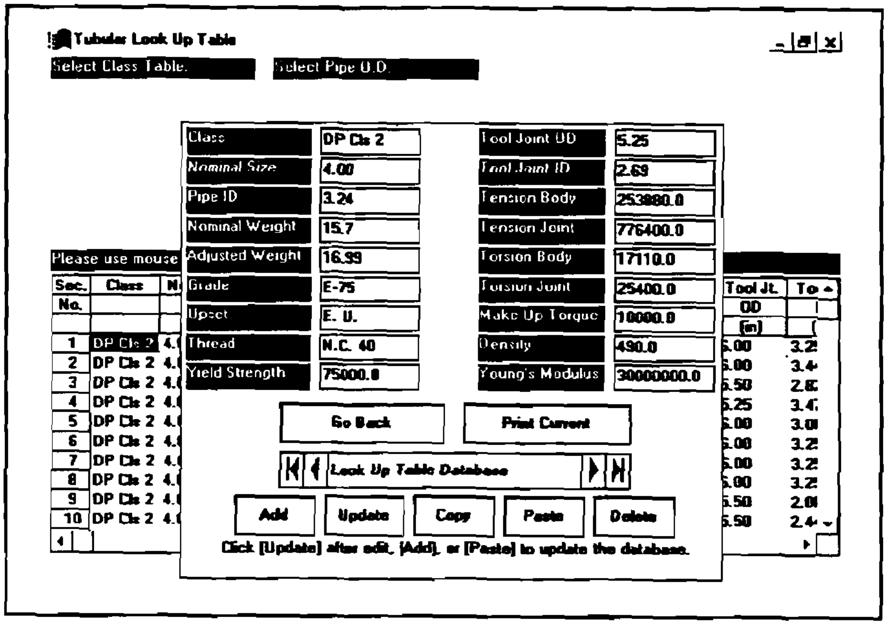


Figure 5-43. TDI Look-Up Table — Edit Database Command Button

The following are the operations to modify the database table.

a. Edit Record: Use [Arrow] command to show the desired record — Change the data inside the field text box, — Click [Update] command button to update database disk file.

b. Add New Record: Click [Add] button — Inputs all of the new data fields on text boxes, — Click [Update] command button to update database disk file.

c. Add New Record (which contains most of the same data as the existing record): Use [Arrow] button to highlight the desired existing record — Click [Copy] command to copy the record to memory — Click [Add] command to create new record — Click [Paste] command to paste the data from memory to screen — To edit the necessary data fields — Click [Update] command to update database file.

d. Delete Record: Use [Arrow] command to select the desired record — Click [Delete] command to confirm "Yes" or "No" buttons on the prompt window — Before using the other command buttons, click [Arrow] command to move to another record.

e. Add New Size Pipe in the Same Table: Click [Add] command to add new record — Input the data fields for the new record (with the new pipe OD). Click [Update] command to update the database field. **NOTE: To see the new size record, the user has to leave this editing window, then select the same class table again, pull down the pipe OD drop-down list box again, and the new size will be shown in the list box.**

5.1.4.3 <u>SHARE DOS Command</u>

In order to access the database file through HYDMOD3, the user must put the SHARE.EXE DOS command into the PC's AUTOEXEC.BAT file (See Section 5.2). Otherwise, the following message box will appear on the screen and terminate the program back to the window system.

Please add <PATH>SHARE.EXE/L:500 to your AUTOEXEC.BAT

[OK]

5.2 HYDMOD3 MENUS

The HYDMOD3 menu system provides many tools that you will use while running the application. As in other Windows applications, the user can pull down a menu by clicking the menu name with the mouse, or by pressing the ALT Key on the keyboard and then striking the first letter or the underscored letter of the menu name. Once a menu is displayed, the user selects a command by clicking the command name with the mouse or by highlighting the command name and pressing <ENTER>.

5.2.1 Menus in the Input Windows

Input windows of HYDMOD3 include five individual windows: One Main Window and five data input windows. The menus in these windows are described in this section.

5.2.1.1 Main Window Menus

There are six menus in this window: 1) **File**, 2) **Input**, 3) **Run**, 4) **Output**, 5) **Utility**, and 6) **Help**, as shown in Figure 5-44.

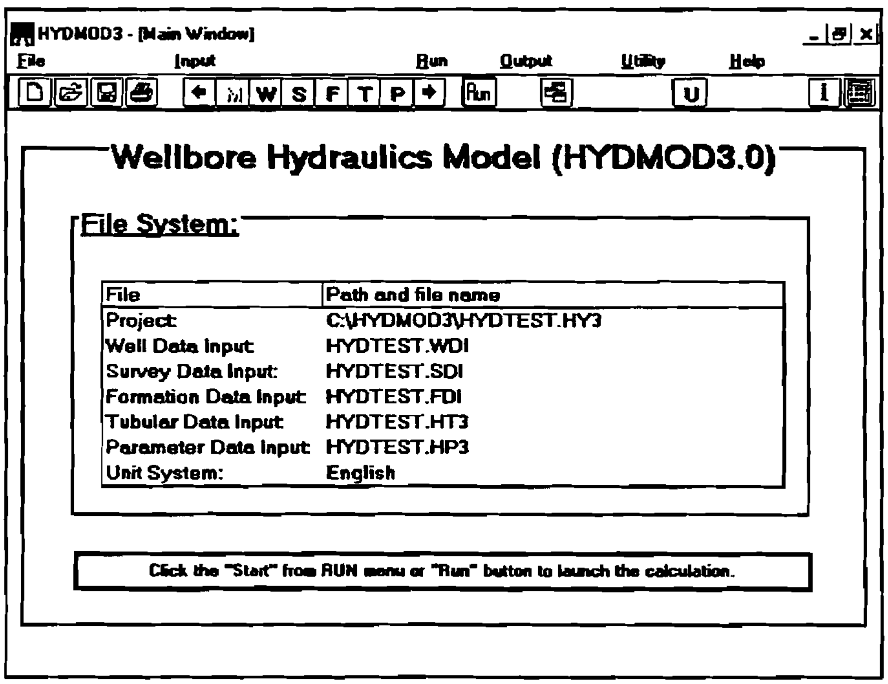


Figure 5-44. Main Window Menus

The File menu contains commands for creating, retrieving, saving, and printing project data, as shown in Figure 5-45.

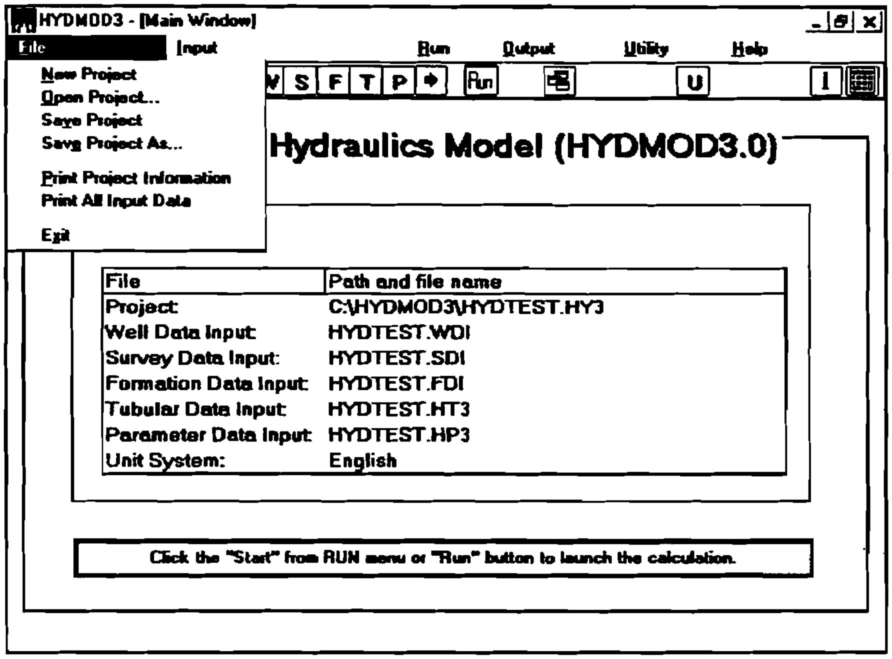


Figure 5-45. File Menu in the Main Window

The reason for using the project file is for quick future retrieval of a set of previously saved input data. The user can open an existing project file without opening each individual (.WDI, .SDI, .FDI, HT3, HP3) file. The project file, which is a collection of the paths and file names of all input data files, does the retrieving for the user.

The seven menu items under the File menu are explained below:

1. "New Project" command clears all input data and sets all file names to null string with corresponding extensions.

2. "Open Project..." command opens a dialog box that enables the user to explore the file system for input files with the extension "HY3." See Section 5.3.1 for a complete discussion.

3. "Save Project" command replaces the previous version of each of the input data files in the project with the one modified. Note that the project file (.HY3) does not contain any input data. It is simply a list of all the input data file names in the project. This list is updated every time the user saves the project.

4. "Save Project As..." command opens a dialog box. The user specifies the drive, directory, and the name of the project file. See Section 5.3.3 for details.

5. "Print Project Information" command allows the user to print out the information related to the current project, such as path and file name of each individual data file.

6. "Print All Input Data" command allows the user to print all input data along with the project information.

7. "Exit" command terminates the HYDMOD3 program. The program prompts the user to save the input files, if they have not been saved.

Files which make up a project do not have to be in one directory on your hard drive, since the project records the detailed path information on each input file. A single file, such as an SDI file, can be part of more than one project. However, if you rename or delete a file outside the HYDMOD3 application, and then run HYDMOD3 and try to open the file, HYDMOD3 displays an error message warning you that a file is missing.

The **Input** menu contains commands for opening and navigating through four individual data input windows as displayed in Figure 5-46.

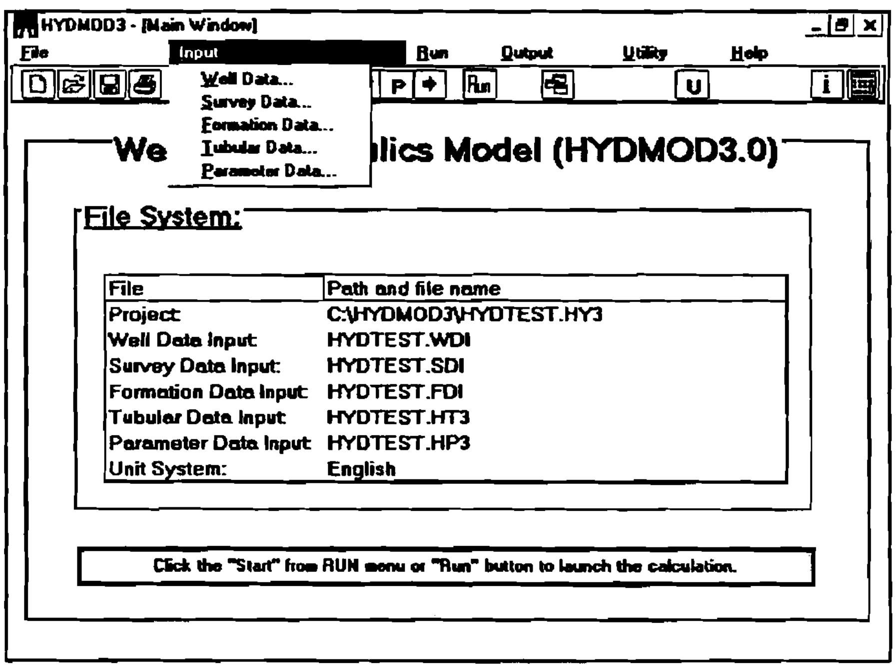


Figure 5-46. **Input** Menu in the Main Window

1. "Well Data..." command opens the Well Data Input Window.
2. "Survey Data..." command opens the Survey Data Input Window.
3. "Formation Data..." command opens the Formation Data Input Window.
4. "Tubular Data..." command opens the Tubular Data Input Window.
5. "Parameter Data..." command opens the Parameter Data Input Window.

The **Run** menu (Figure 5-47) contains a command the user selects when ready to start calculation. The "Start" command does just that. The program validates all data before calculating.

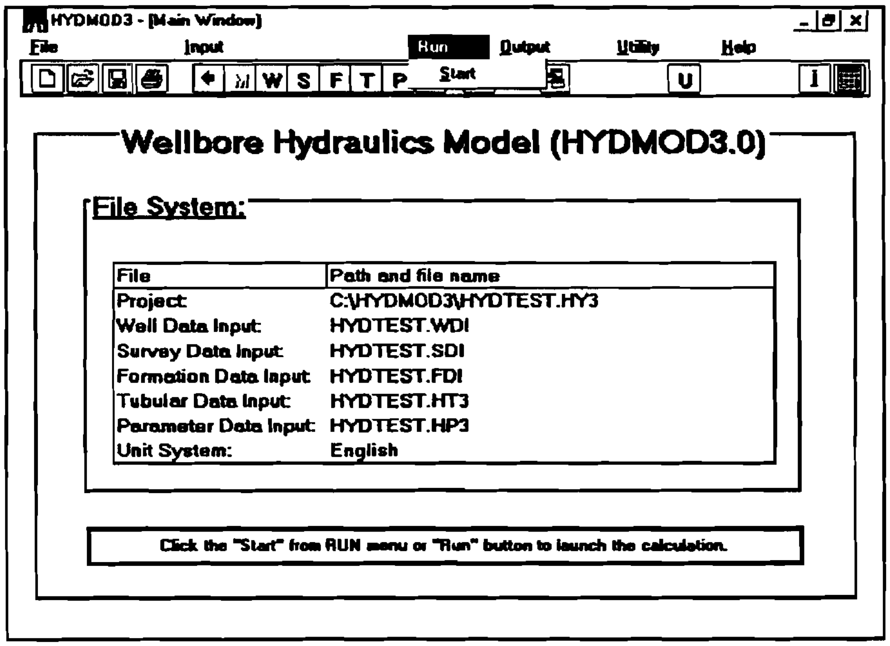


Figure 5-47. **Run** Menu in the Main Window

The **Output** menu (Figure 5-48) contains a command that allows the user to go to the Output Window without calculating, if the calculation has been completed and the input data have not been changed. This menu is disabled (dimmed) if the input data are modified, or if there are no input data.

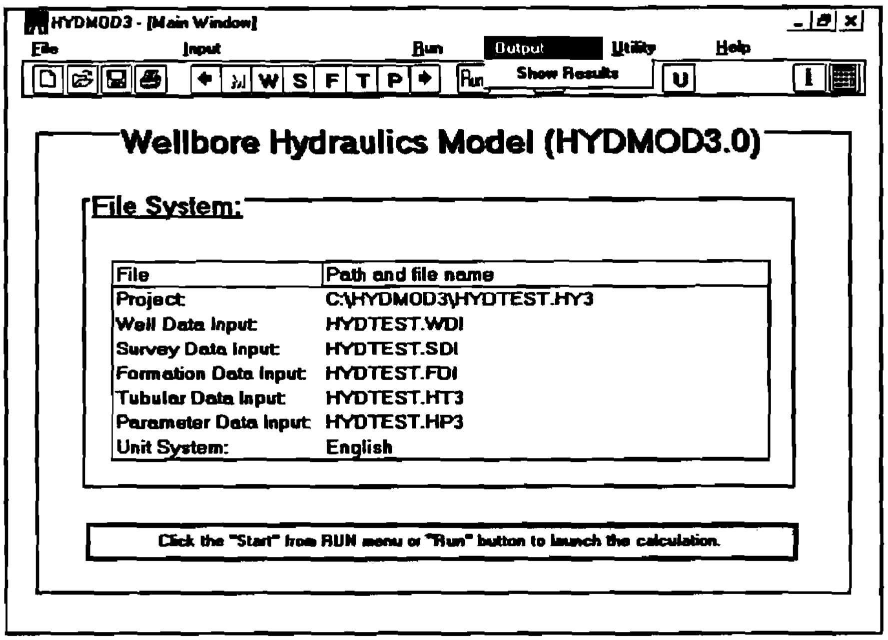


Figure 5-48. **Output** Menu in the Main Window

The Utility menu contains commands that enable the user to select the system of units and monitor type, as shown in Figure 5-49.

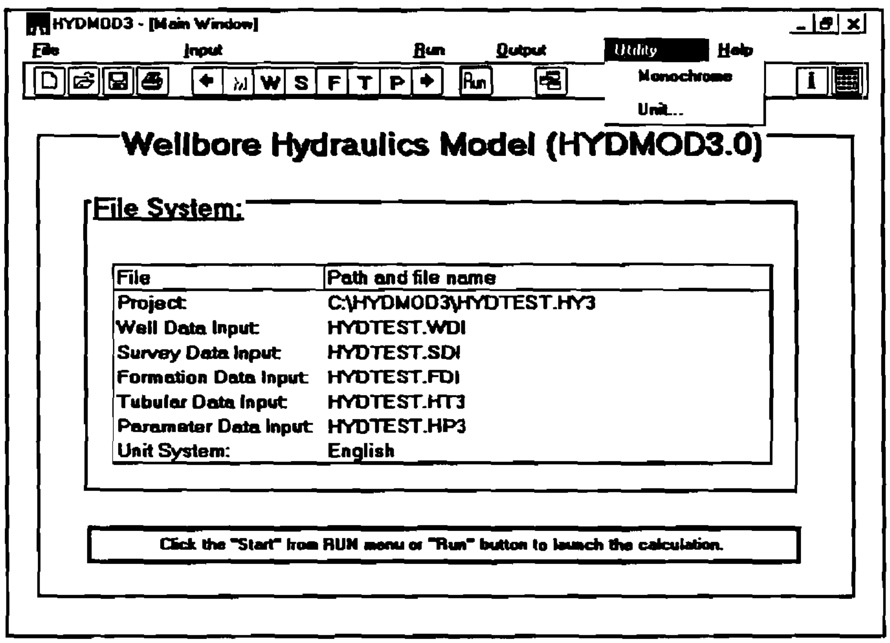


Figure 5-49. **Utility** Menu in the Main Window

1. "Monochrome" command changes all screen colors to black and white. Once the screens have been set to monochrome, the program cannot return to the color mode unless HYDMOD3 is restarted.

2. "Units..." command opens the Unit window where the user can select "English" or "metric" or any combination of units. The Units Window is shown in Figure 5-50.

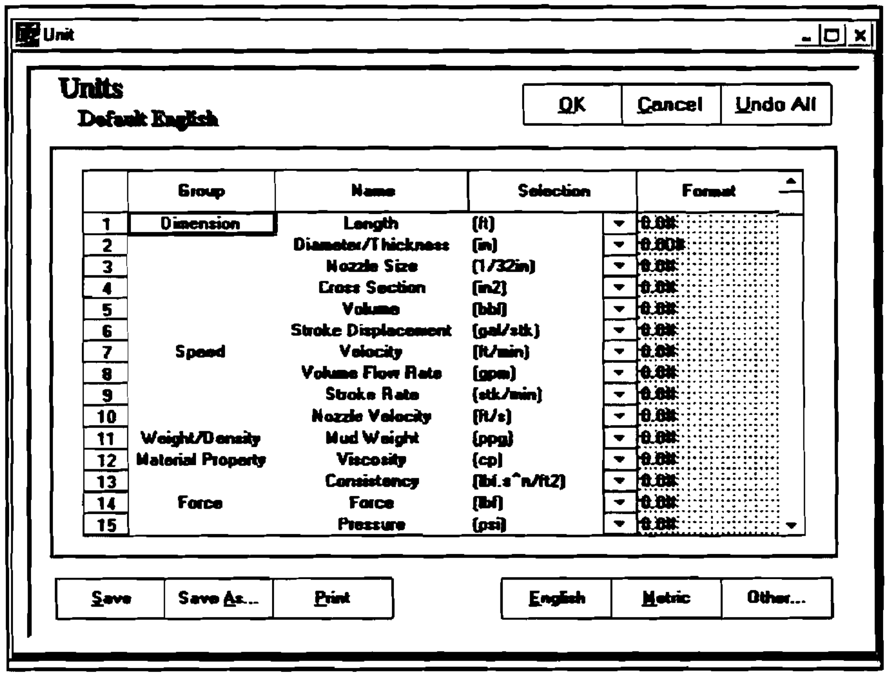


Figure 5-50. Units Window

The Units window includes a units table and several buttons. The units table has four columns. The left two columns are units group names, and the third column is a list of combo boxes. The combo box can be pulled down to select the unit desired. The right column is the data format list. Only the keys "#", "." and "0" can be used to change the data format.

If the units selection is not appropriate, three keys at the top of the window can be used to change the units system back quickly. Button [Undo All] will abandon all current selections and revert to original units, the button [English] or [Metric] will set the units system back to default English or metric unit systems. Clicking the button [Cancel] not only invokes "undo all" units section, but also closes the Units window and returns to the Main Window.

A custom units system can be saved by clicking either [Save] or [Save As...]. If [Save As...] is selected, a file save dialog box will appear to ask the file path and name. Clicking [Save] will save the units system file without any options.

The user can retrieve any custom units system previously saved by clicking the button [Other...]. A File Open dialog box appears to complete the selection. Each time the user runs HYDMOD3, the system of units set in the previous run is automatically loaded.

The Help menu gives the user information on assistance and the computer system.

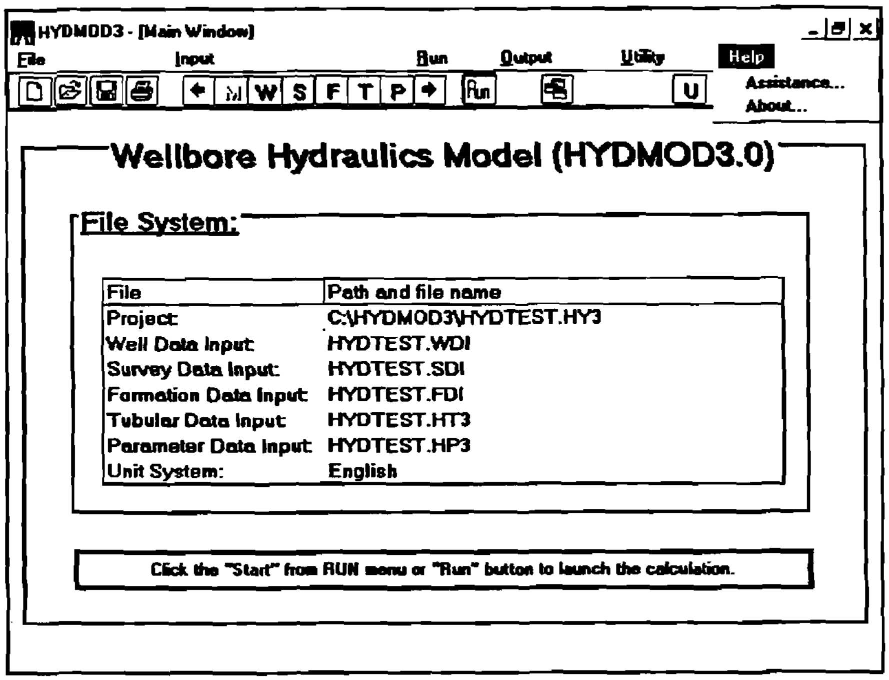


Figure 5-51. **Help** Menu in the Main Window

1. "Assistance..." command opens the "Assistance" dialog box that displays MEI's address, phone number, and other applicable information. See Section 5.3.6 for details.

2. "About..." command opens the "About" dialog box that gives the user instant reference information about HYDMOD3 and the current computer system information. See Section 5.3.7 for details.

5.2.1.2 Individual Data Input Window Menus

All Data Input Windows (.WDI, .SDI, .FDI, .HT3 .HP3) have only one menu **File** except in the TDI window. It contains commands for creating, retrieving, saving, and printing the corresponding data input file, as shown in Figure 5-52.

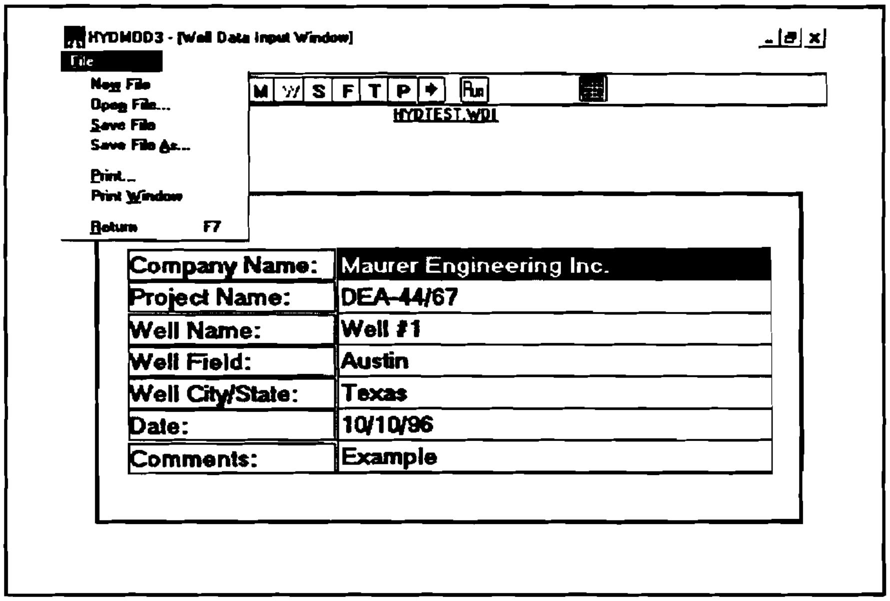


Figure 5-52. **File** Menu in the Individual Data Input Window

1. "New File" command clears every entry box in the current data input window.
2. "Open File" command opens the dialog box that enables the user to explore the file system for input files with the extension names, "WDI, "SDI," "FDI,", "HT3," or "HP3" depending on the current data input window.
3. "Save File" command replaces the previous version of the input data file.
4. "Save File As..." command enables the user to save a file under a new name, specified while also retaining the original file (Section 5.3.4). The new file is associated with the project file when you SAVE the project.
5. "Print" command allows the user to print the input data of the current input window.
6. "Return" command closes the current data input window and returns to the Project Window. HYDMOD3 prompts the user to save the file, if it has not been saved.

In the TDI window, beside the File menu, there is a Wellbore menu. It has one command "Schematic...". Click on "Schematic..." and a wellbore schematic window is displayed, as shown in Figure 5-53.

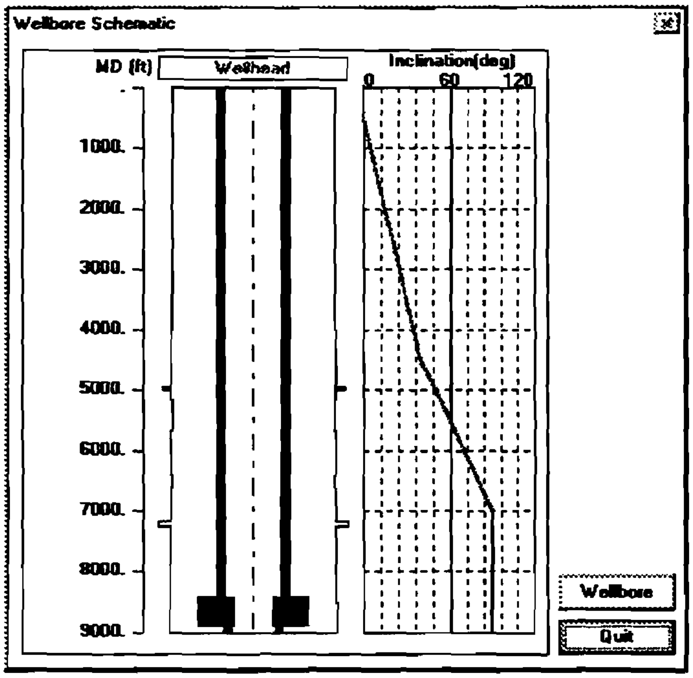


Figure 5-53. Wellbore Schematic Window

This window allows the user to check if the tubular and wellbore data input are correct.

5.2.2 Toolbar in the Input Window

Below the menu bar is the Toolbar. It contains buttons that are shortcuts to some commonly used menu items. Clicking a button on the toolbar will carry out the action represented by the icon. These commands are equivalent to the corresponding commands in the menu system. Figure 5-54 shows the toolbar in the Project Window.

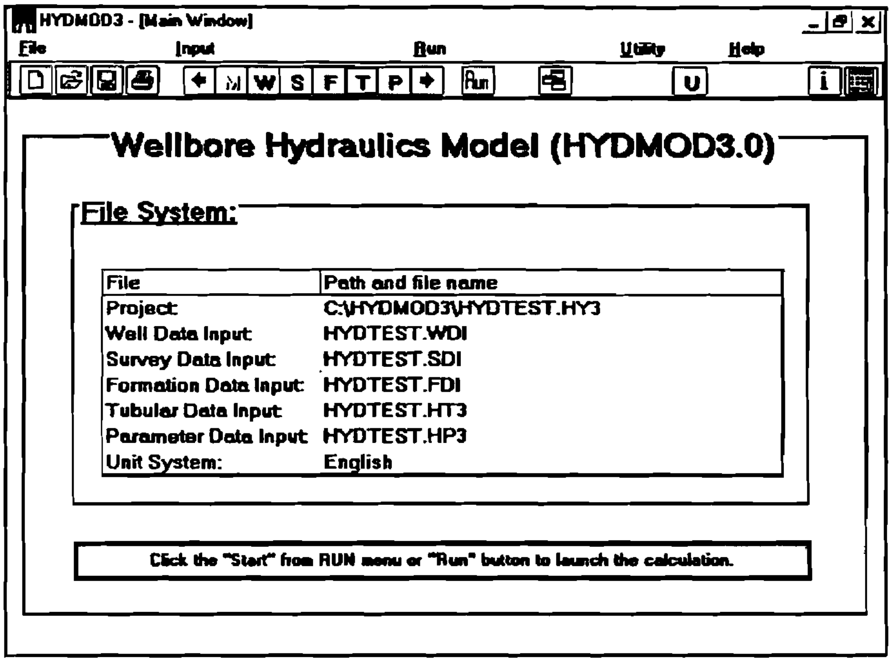


Figure 5-54. Toolbar in the Main Window

- Same as [New Project] or [New]
- Same as [Open Project...] or [Open File...]
- Same as [Save Project] or [Save]
- Same as [Print Project...] or [Print...]
- Go to previous Window
- M - Go to Main Window
- W - Go to WDI Window
- S - Go to SDI Window
- F Go to FDI Window
- T - Go to TDI Window
- P - Go to PDI Window
- Go to next Window

- Run - Same as [Run]
- - Same as [Output]
- U Same as [Units...]
- i - Same as [About...]

The logical order to input data is from the Main Window to WDI Window, to SDI Window, to FDI Window, to TDI Window, to PDI Window, and back to the Main Window.

The toolbars in the other data input windows are very similar to those in Figure 5-54. Note that when an input window is displayed, such as WDI window, the corresponding button in the toolbar, W, will be dimmed and disabled.

5.2.3 Menus in the Output Window

The Output Window has four menus: **File**, **Window**, **Graph Style**, and **Help** (Figure 5-55).

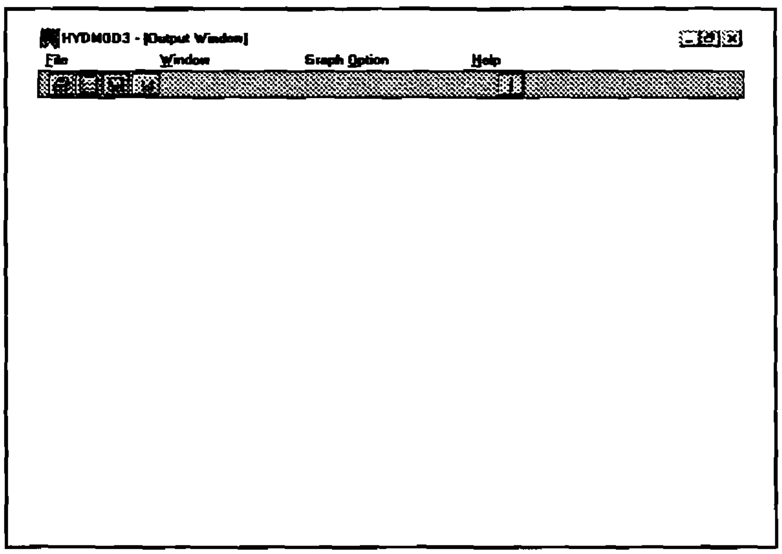


Figure 5-55. Menus in the Output Window

The **File** menu contains commands for printing and saving text reports and graphs and controlling application flow (Figure 5-56).

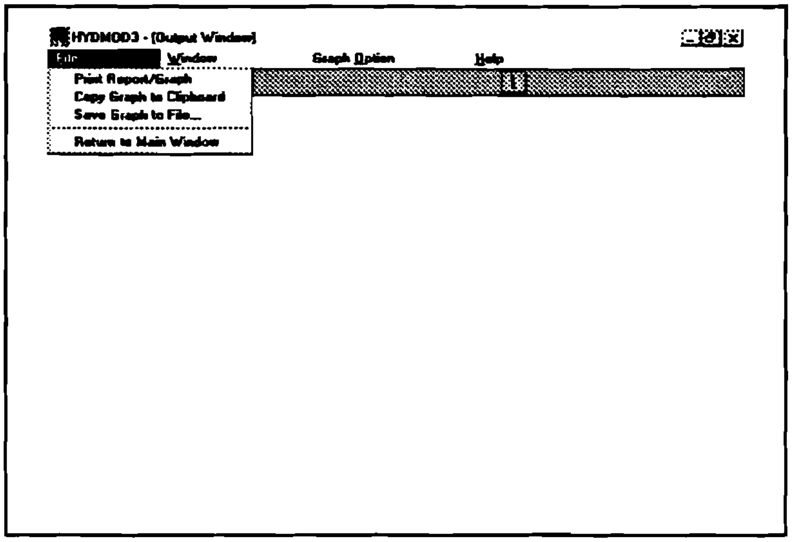


Figure 5-56. File Menu in the Output Window

1. "Print Report/Graph" command prints out the text report or graph in the currently active child window. The text report prints in the text mode. A high-quality image of the graph will be printed at the full resolution of the printer. HYDMOD3 offers the user the option of printing in color, as well as on a monochrome printer. With a color printer, the user may open the "**Graph Style**" menu and select "color" from the "Print Style." If printing in color on a monochrome printer, the printer uses a gray scale instead of color and may not produce the desired effect.

2. "Copy Graph to Clipboard" command copies the graph in the active child window to the Windows Clipboard in either a bitmap or metafile format. The format is selected in the "Image Format" of the menu "**Graph Style**." The graph image on clipboard can then be pasted to other Windows applications, such as Paintbrush.

3. "Save Graph to File..." command opens a dialog box (Section 5.3.5). The user specifies the drive, directory, and name of the image file. The image of the graph is written to disk as a bitmap (.BMP) or metafile (.WMF). The format is selected in the "Image Format" of the menu "**Graph Style**."

4. "Return to Main Window" command closes the Output Window and displays the Main Window.

The **Window** menu contains commands that allow the user to select, activate, stack, and tile the report and graph child windows.

Figure 5-57 shows the pull-down **Window** menu.

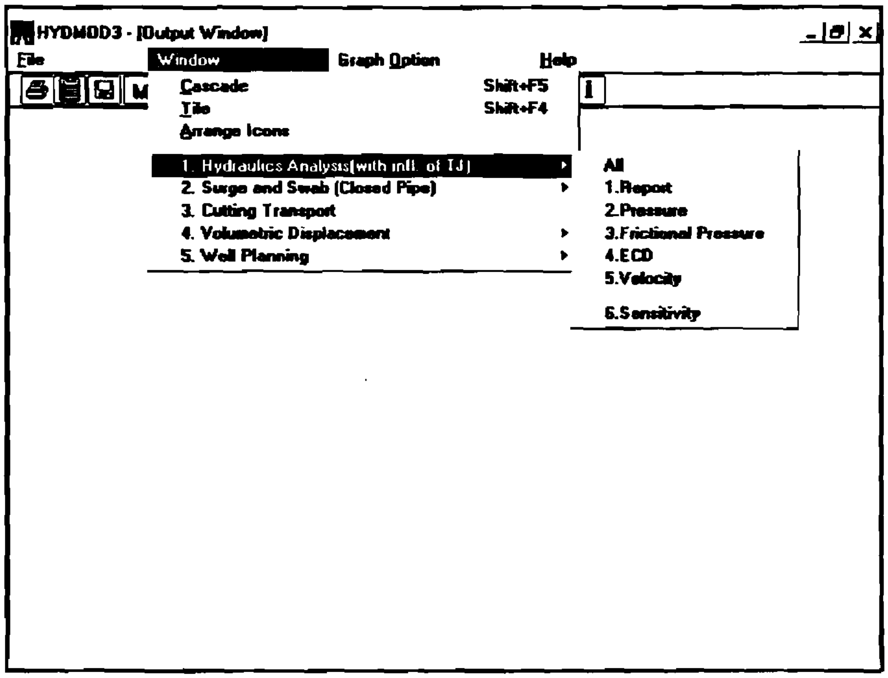


Figure 5-57. **Window** Menu in the Output Window

1. "Cascade" command stacks the windows, as shown in Figure 5-58. The program adjusts the size of each open window to occupy the same amount of display space. The windows are then stacked working from upper-left corner of the Output Window. Only their title bars are visible. To place a window in the foreground, click on the window's title bar with the mouse.

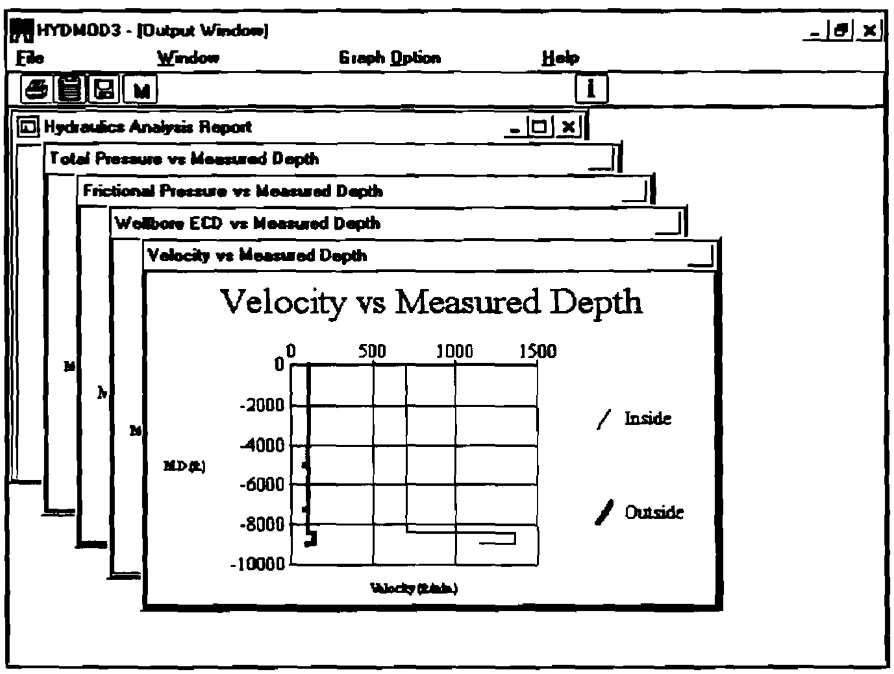


Figure 5-58. Cascaded Windows

2. "Tile" command tiles all the opened child windows, as shown in Figure 5-59.

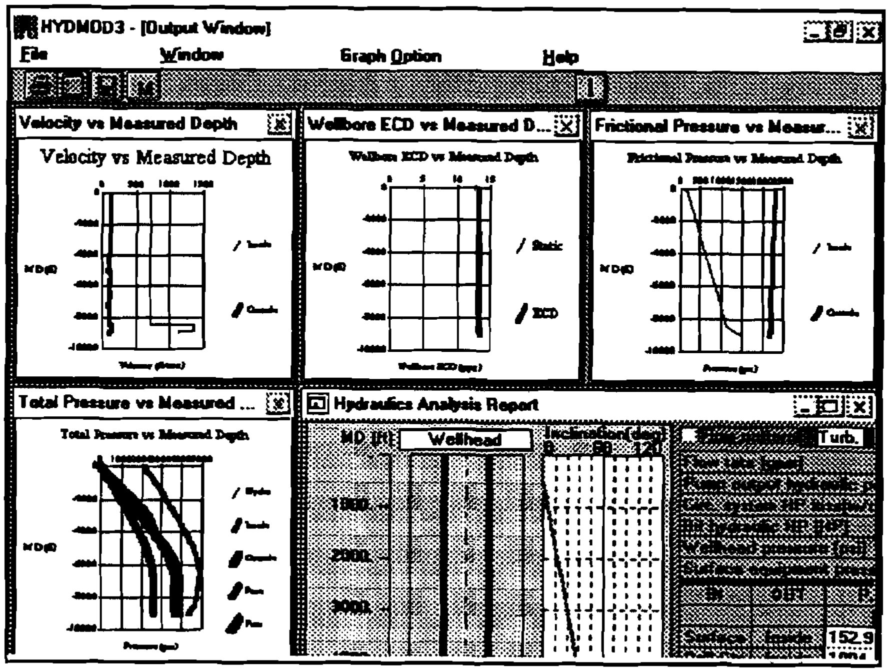


Figure 5-59. Tiled Windows

3. "Arrange Icons" command restores the alignment of the report and graph window icons, as shown in Figure 5-60.

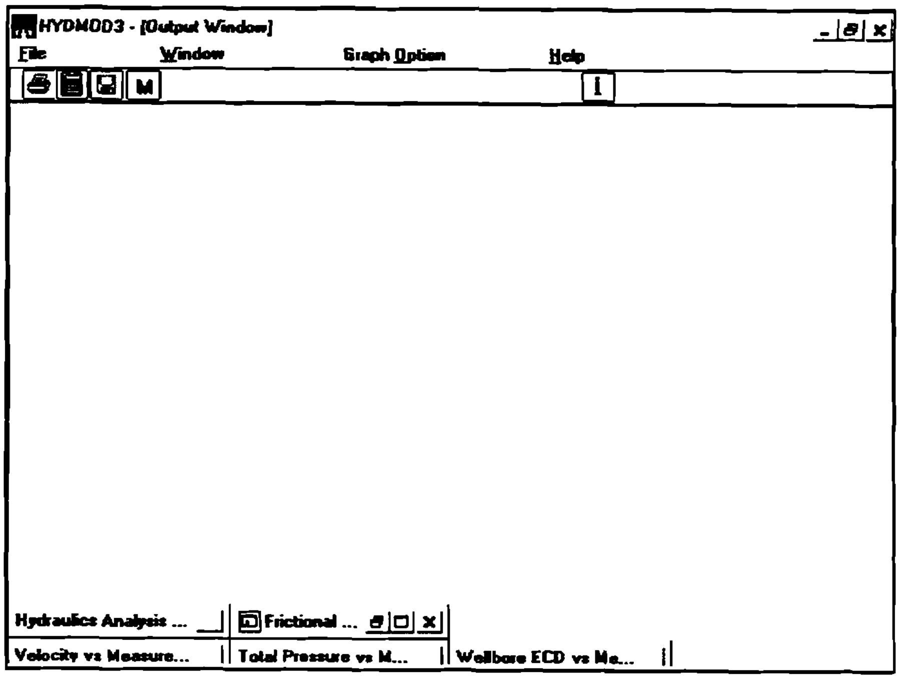


Figure 5-60. Arranged Window Icons

4. "1. Hydraulics Analysis" command opens the sub-level menu used to open or activate the six output child windows of Hydraulics Analysis shown in Section 5.1.3.1. Figure 5-61 displays the indented sub-menu of "Hydraulics Analysis."

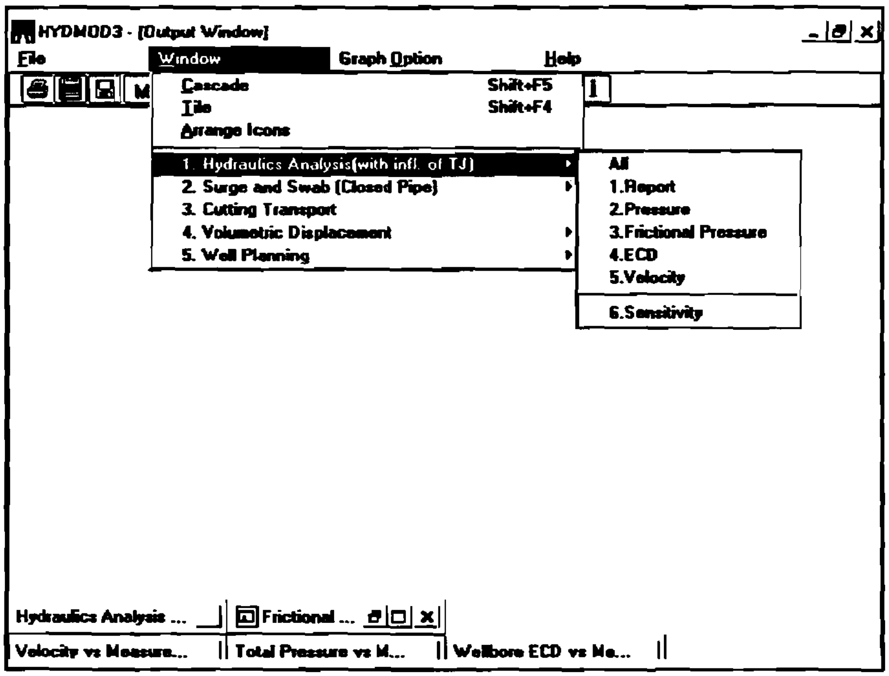


Figure 5-61. Sub-Level Menus of "Hydraulics Analysis"

5. "2. Surge and Swab (Closed Pipe)" command opens the sub-level menu used to view the six output child windows shown in Section 5.1.3.2. The indented sub-menu of "Surge and Swab (Closed Pipe)" is shown as follows:

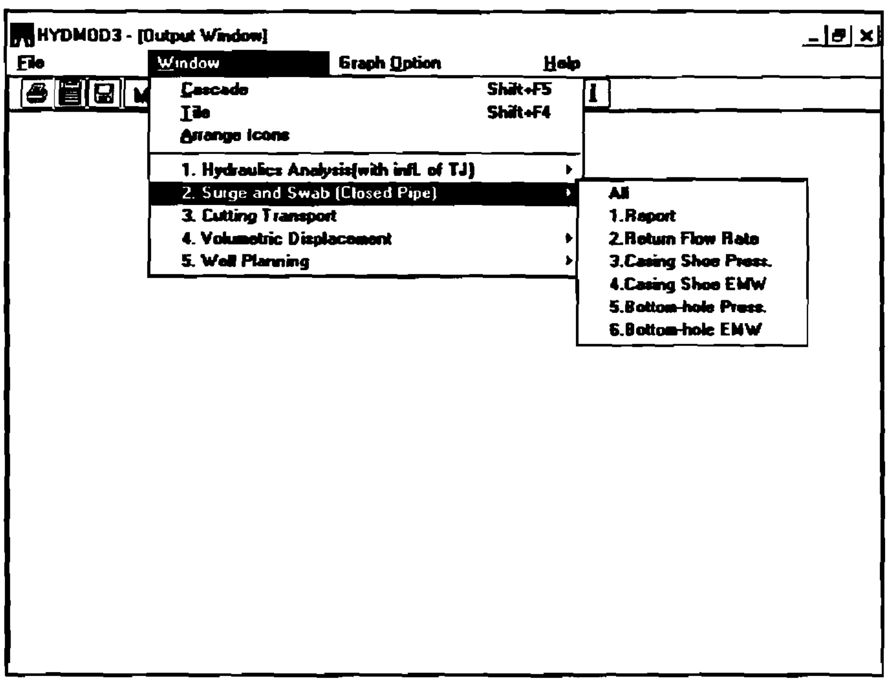


Figure 5-62. Sub-Level Menus of "Surge and Swab (Closed-Pipe)"

6. "3. Cuttings Transport" command does not have a sub-level menu. It directly opens the screen showing the slip velocity and cuttings transport. See Section 5.1.3.3 for details.

7. "4. Volumetric Displacement" command opens the sub-level menu which contains four items. The corresponding child windows are shown in Section 5.1.3.4. Figure 5-63 displays the indented submenu of "Volumetric Displacement."

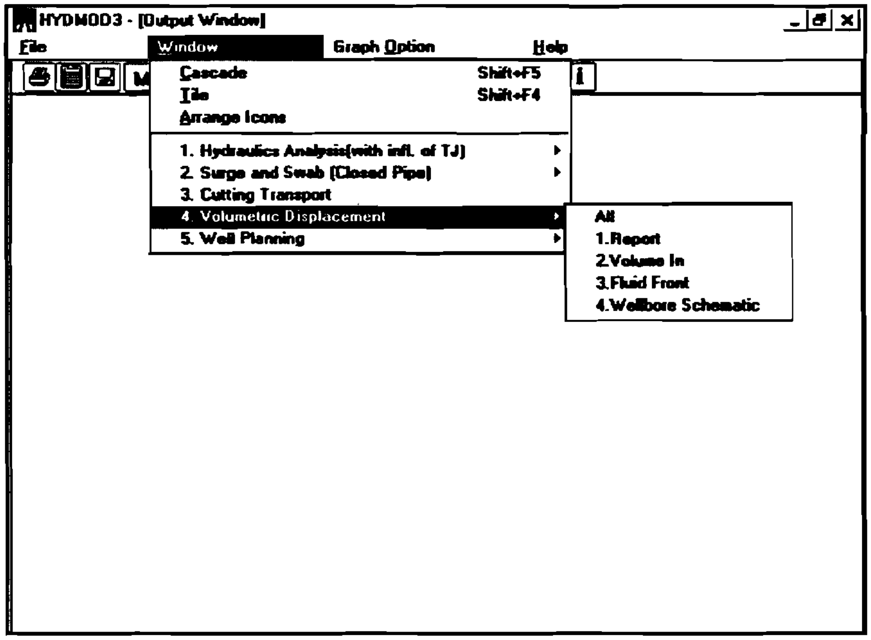


Figure 5-63. Sub-Level Menus of "Volumetric Displacement"

8. "5. Well Planning" opens the similar sub-level menu. Figure 5-64 displays the indented submenu.

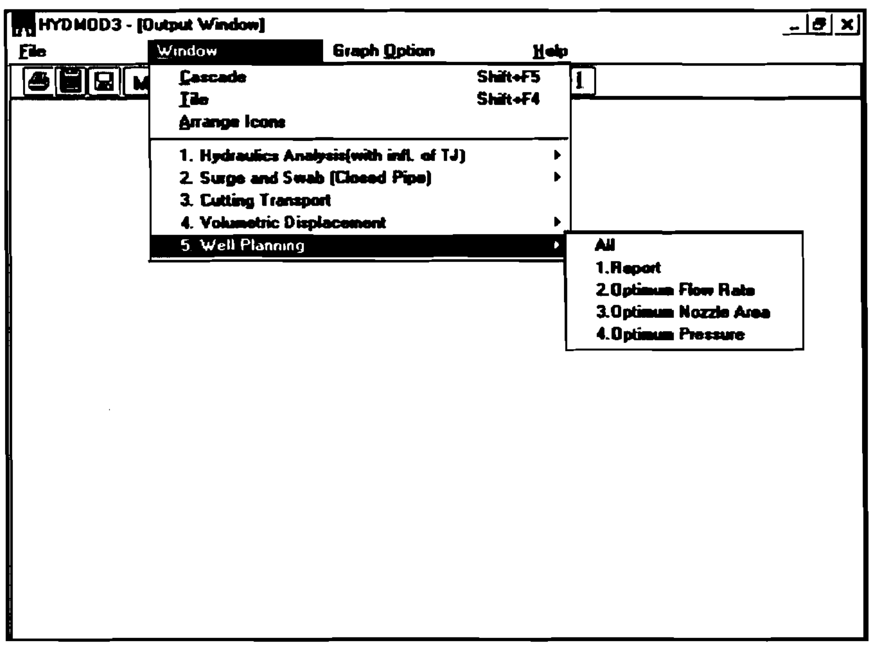


Figure 5-64. Sub-Level Menus of "Well Planning"

The user is advised to always minimize or close the child windows that are not presently needed. This gets them out of the way temporarily and helps the user maintain an orderly display.

The **Graph Option** menu contains commands that enable the user to design interactively using the following style options. The styles selected in the Graph Option will affect all graphs in child windows.

Figure 5-65 shows the pull-down Graph Option menu.

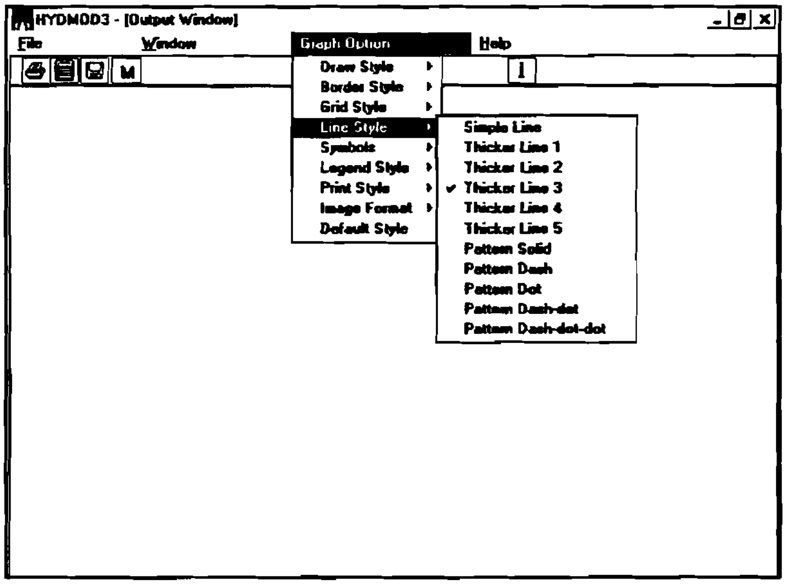


Figure 5-65. Graph Option Menu

1. "Draw Style" command enables the use to choose from "Monochrome" or "Color." "Monochrome" will set the background to white, and all other colors to black.

2. "Border Style" gives the user the option of using borders. This can only be seen in the printout of a graph.

3. "Grid Style" command enables the user to place grids on the graph axes as desired.

4. "Line Style" command enables the user to set the width or patterns of the lines drawn.

5. "Symbols" command enables the user to use default symbols for the graphs.

6. "Legend Style" command gives the user the option of using a legend (Color or B/W) for the graphs.

7. "Print Style" command enables the user to print the graph in color if the computer is equipped with a color printer.

8. "Image Format" command enables the user to save the graphical image in either bitmap or metafile format.

9. "Default Style" command sets all above styles to the default values, which are as follows:

Draw Style:	Color
Border Style:	Fixed
Grid Style:	Both
Line Style:	Thicker Line 3
Symbols:	None
Legend Style:	Color
Print Style:	Monochrome
Image Format:	Bitmap

The **Help** menu is exactly the same as the INPUT Window.

5.2.4 Toolbar in the Output Window

Figure 5-66 shows the toolbar in the Output Window.

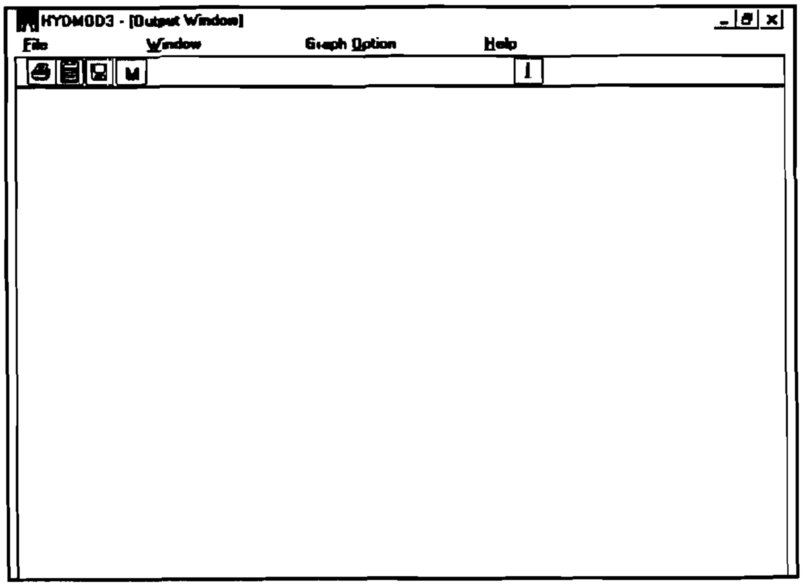


Figure 5-66. Menus in the Output Window

The buttons on the toolbar give the user access to several commands in the menu quickly and easily. The relationships between the button and menu bar commands are:

-  – [Print Report/Graph] in File menu
-  – [Copy Graph to Clipboard...] in File menu
-  – [Save Graph to File...] or [Save Report As...] in File menu
-  – [Return to Input] in File menu
-  – [About] in Help menu

5.3 HYDMOD3 DIALOG BOXES

There are five types of dialog boxes associated with menus: File Open dialog box, File Save dialog box, Color Dialog box, Assistance dialog box, and About dialog box.

5.3.1 "Open Project..."

When the user selects the "Open Project..." command from the File Menu in the INPUT Window, the following dialog box will appear (Figure 5-67).

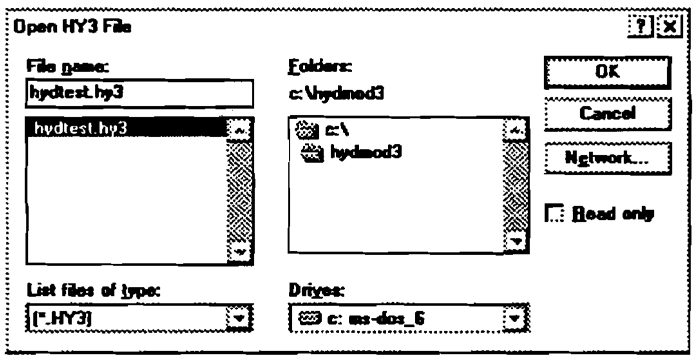


Figure 5-67. "Open Project..." Dialog Box

This dialog box enables the user to search the file system for the desired files with extension name ".HY3."

The user can move between sections of the dialog box by simply clicking on the desired section. Alternatively, the user can press the <TAB> key from keyboard until the focus moves to the desired section.

There are four list boxes: the drive list box, the directory list box, the file list box, and type list box. There is one text box and two command buttons: OK and CANCEL. Their functions are described below.

1. **The Drive List Box**

   On the lower right corner is the drop-down drive list box. In its normal state, it displays the current drive. When the user clicks the arrow at the right of the drive list box, it drops to list all valid drives. The user can activate a new drive by single-clicking the desired one.

2. **The Directory List Box**

   The directory list box displays the hierarchy of paths of the current drive. The current directory appears as a shaded open file folder; directions above it in the hierarchy appear as a nonshaded open file folder, and those immediately beneath the current directory are closed file folders. The user can change the directory by double-clicking the selected one. Note that in the directory list box, a single click only selects (highlights) the item; a double click is required for the command to be performed.

3. **The File List Box**

   The file list box displays the files in the current directory. The file names shown are those specified by their extension name "HY3." A single mouse click on an item makes it appear in the "File Name" text box. If the user chooses OK at this time, the data file is retrieved and all data related to the current calculation mode are displayed in appropriate entries. Double-clicking the selected file has the same effect as above.

   When the user selects a new drive, the directory list box is updated, which then causes the file list box contents to be updated. When a new directory is selected, the file list box is updated, but the drive remains the same.

   The path specification label always represents the current path information.

4. **The Type List Box**

   This list box is set by the program. The user cannot change it. It specifies the type of files that are to be displayed in the file list box. In this "Open Project.." dialog box, the type of file is "*.HY3."

5. **"File Name" Text Box**

   The application should also do the following when the user enters text in the "File Name" text box and then presses <ENTER>.

   - If a drive letter is entered, the drive, directory, and file list boxes should be updated.
   - If a directory path is entered (for example, "\HYDMOD3"), the directory list box and the file list box should be updated accordingly.
   - If the name of an existing file (with extension name ".HY3") is entered, the dialog will be completed and the files will be retrieved.

6. **Command Buttons**

If the existing file name is shown in the text box, pressing OK will complete the dialog and the data file will be retrieved and displayed.

If the CANCEL button is pressed, the dialog is canceled and no information is made available to the application.

For our example, select "C:" from drive list box. In the directory list box, find "HYDMOD3" under "C:\" and double-click it. Then the file list box should be updated and the file name "HYDTEST.HY3" will appear in the file list box providing the user set up "HYDMOD3" using the default subdirectory names. Double-click the "HYDTEST.HY3" in the file list box to complete the input data file selection.

5.3.2 "Open File..."

When the user selects the "Open File..." command from the File Menu in the INPUT Window, the following dialog box will appear (Figure 5-68).

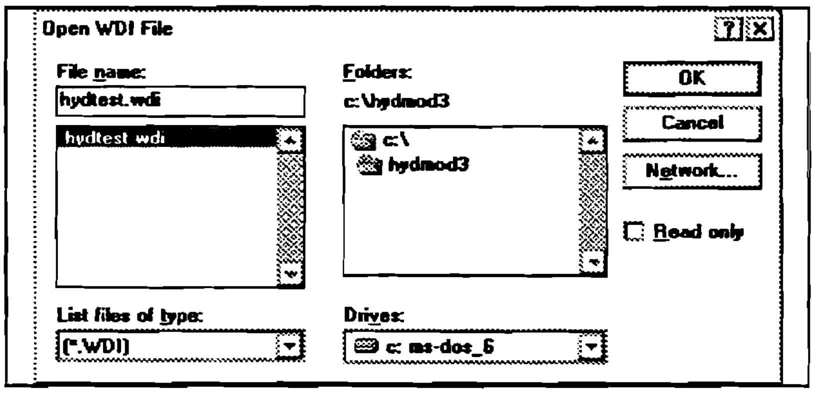


Figure 5-68. "Open File..." Dialog Box

This dialog box is almost identical to the "Open Project..." box in appearance; however, the filter in the type list box is different. Depending on the page from which the search was launched, the filter in the type list box will be one of the ".WDI," ".SDI," "FDI," ".HT3" or ".HP3" extensions.

5.3.3 "Save Project As..."

When the user selects the "Save Project As..." command from the **File** menu in the INPUT window, the following dialog box appears.

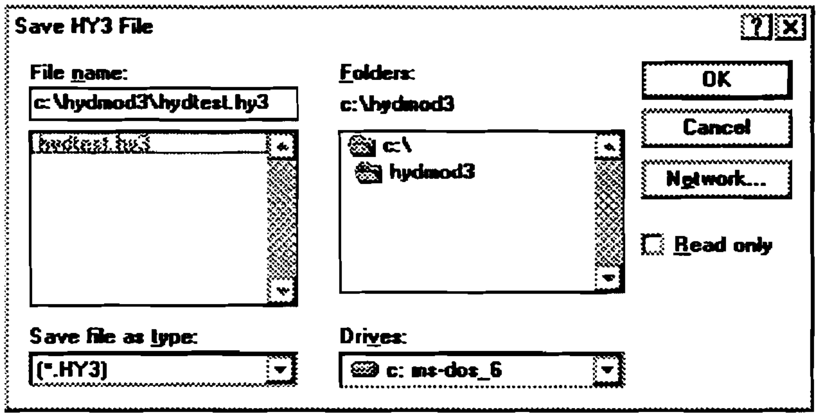


Figure 5-69. "Save Project As..." Dialog Box

It looks identical to the "Open Project..." dialog; however, it allows the user to specify a file to save rather than to open.

Note that the filter in the type list box is ".HY3."

5.3.4 "Save File As..."

When the user selects the "Save File As..." command from the **File** menu in the INPUT window, the following dialog box appears.

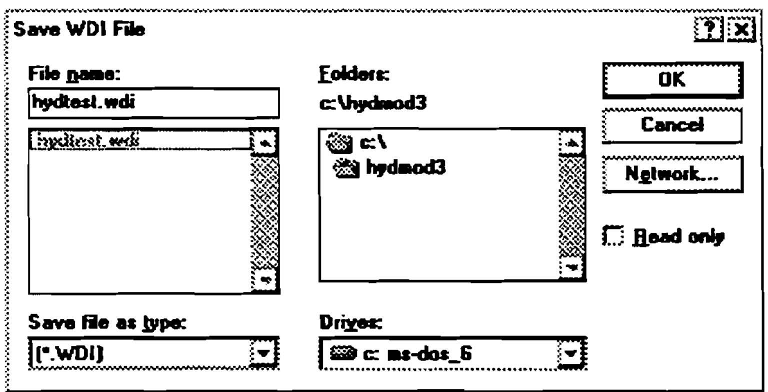


Figure 5-70. "Save File As..." Dialog Box

This dialog box is almost identical to the "Save Project As..." dialog box in appearance; however, the filter in the type list box is different. Depending on the page currently being used, the filter in the type list box will be one of the ".WDI," ".SDI," "FDI," ".HT3" or ".HP3" extensions.

5.3.5 "Save Graph to File..."

When the user selects the "Save Graph to File..." command from the File Menu in the Output Window, the following dialog box will appear (Figure 5-71).

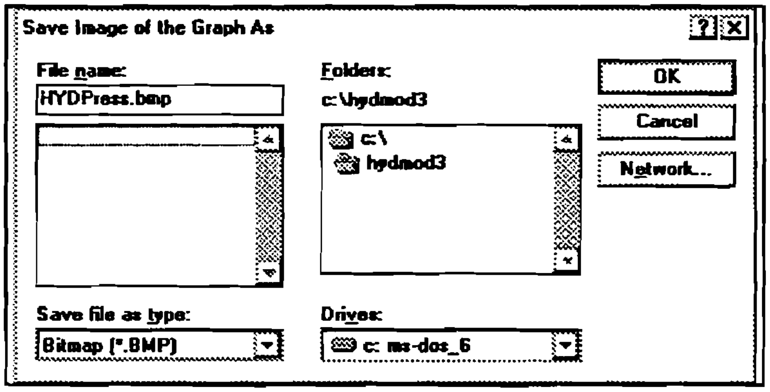


Figure 5-71. "Save Graph to File..." Dialog Box

Depending on how the image format is set, the filter in the type list box is either "*.BMP" (default) or "*.WMF." The difference between bitmaps and metafiles is that a metafile can be scaled proportionally while a bitmap cannot. A metafile is more suitable for copying via the Clipboard to a Word document. However, a bitmap can be edited in Paintbrush on a pixel-by-pixel basis.

5.3.6 "Assistance..."

When the user selects the "Assistance..." command from the Help menu in both INPUT and OUTPUT Windows, the following dialog box will appear (Figure 5-72).

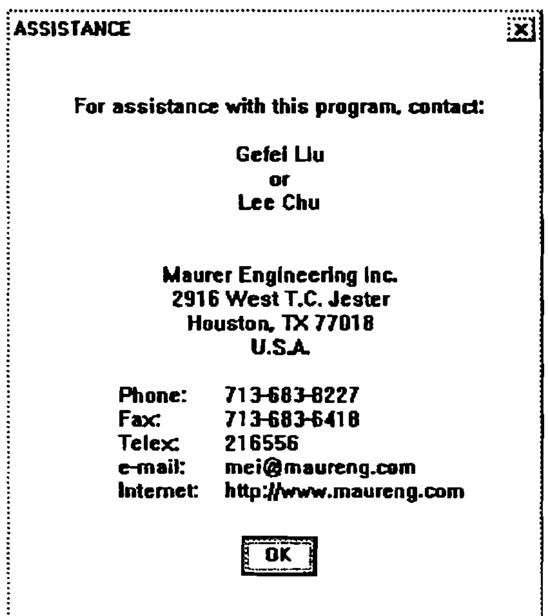


Figure 5-72. "Assistance..." Dialog Box

5.3.7 "About..."

When the user selects the "About..." command from the Help menu in both INPUT and OUTPUT Windows, the following dialog box will appear (Figure 5-73).

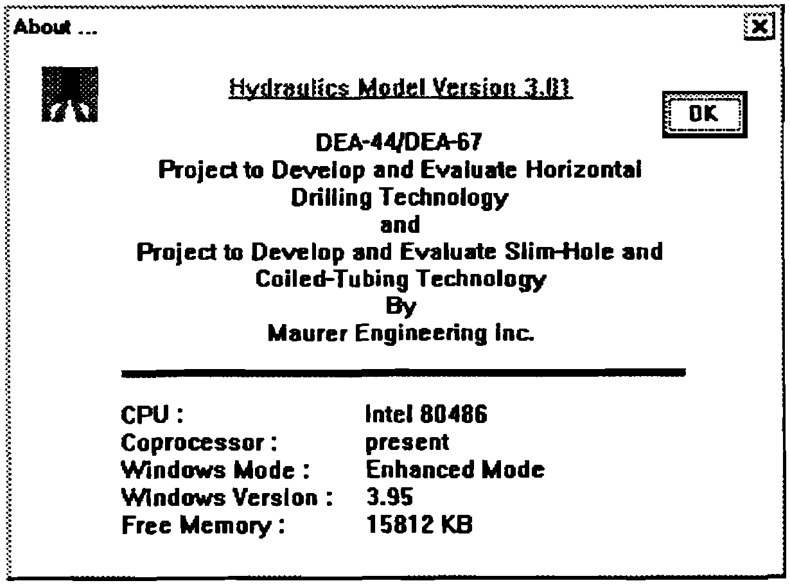


Figure 5-73. "About..." Dialog Box

5.4 HYDMOD3 ERROR HANDLING

When input data on a page are outside the appropriate range of values and the user tries to exit the page, HYDMOD3 error checking routines will locate the error. The application will then display an error message explaining why the data are not acceptable. The user can ignore the error message and leave the page even though the data on the page are in error. This ability enables the user to edit and view different input pages without having to complete one before going to another.

The user can start calculation from any page. If any invalid data are found at this time, the application will display an error message and force the user to go to the page with invalid data for editing. Figure 5-74 shows some of the error messages.

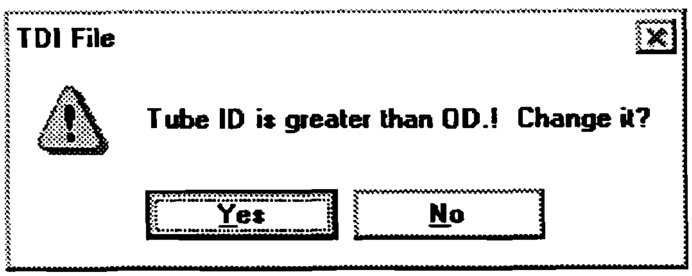


Figure 5-74. Error Messages

When an error message appears, click yes or press <ENTER> to return to the associated page in the INPUT window.

6. Example Run of HYDMOD3

6.1 OVERVIEW

This chapter presents a complete example run of HYDMOD3.

The input project file HYDTEST.HY3 will be run to familiarize the user with program operation. The user will become familiar with:

- Menu operation.
- Displaying and printing input data.
- Displaying and printing output data.

6.2 EXAMPLE CASE

Figure 6-1 (continued on pages 6-2, 6-3, and 6-4) presents a printout of input data for the example case. The data shown are from the supplied data files "HYDTEST.HY3," "HYDTEST.WDI," "HYDTEST.SDI," "HYDTEST.FDI," "HYDTEST.HT3," and "HYDTEST.HP3."

```
                    Hydraulics Model

                 [ Project Information ]
-----------------------------------------------------------

Project file:                C:\HYDMOD3\HYDTEST.HY3  (-)
Well Data Input file:        C:\HYDMOD3\HYDTEST.WDI  (+)
Survey Data Input file:      C:\HYDMOD3\HYDTEST.SDI  (+)
Tubular Data Input file:     C:\HYDMOD3\HYDTEST.HT3  (+)
Parameter Data Input file:   C:\HYDMOD3\HYDTEST.HP3  (+)

Unit System: English

Depth:          (ft)                Flow Rate:     (gpm)
Hole Size:      (in)                Nozzle Vel:    (ft/s)
Nozzle Size:    (1/32in)            Fluid Vel:     (ft/min)
Mud weight:     (ppg)               Pressure:      (psi)
Viscosity:      (cp)                Force:         (lbf)
Yield Point:    (lbf/100ft2)        Power:         (HP)
K:              (lbf.s^n/ft2)
-----------------------------------------------------------
Note: (+) = Saved,    (-) = Not saved
-----------------------------------------------------------

              ========== End of HYD file ==========
```

Hydraulics Model

[Well Data Input]

Company Name	:	Maurer Engineering Inc.
Project Name	:	DEA-44/67
Well Name	:	Well #1
Well Field	:	Austin
Well City / State	:	Texas
Date	:	10/10/96
Comments	:	Example

================ End of WDI File ================

HYDTEST.WDI

Hydraulics Model

[Survey Data Input]

Station	Meas. Depth (ft)	Inclination (Dec.)	Azimuth (Dec.)
1	0.0	.	.
2	500.0	.	.
3	1000.0	5.	.
4	1500.0	10.	2.
5	2000.0	15.	12.
6	2500.0	20.	12.
7	3000.0	25.	12.
8	3500.0	30.	12.
9	4000.0	35.	12.
10	4500.0	40.	12.
11	5000.0	50.	12.
12	5500.0	60.	12.
13	6000.0	70.	12.
14	6500.0	80.	12.
15	7000.0	90.	12.
16	7500.0	90.	12.
17	8000.0	90.	12.
18	9000.0	90.	12.

============= End of SDI File =============

====================================
Hydraulics Model
====================================

[Formation Data Input]

Trip margin(psi/ft) = 0.1
Kill margin(psi/ft) = 0.1

No. #	V. Depth (ft)	Pore (psi/ft)	Frac (psi/ft)
1	0.0	0.4	0.7
2	1000.0	0.4	0.8
3	2000.0	0.4	0.9
4	3000.0	0.4	0.9
5	4000.0	0.4	0.8
6	5206.3	0.4	0.85

======= End of FDI File =======

Hydraulics Model

[Tubular Data Input]

Bit depth(ft):	9000.0
Casing shoe depth(ft):	4000.0
Rig Type:	Case No. 1

Tube Geometry (from bit)

No.	BHA Sections	Length (ft)	O.D. (in)	P. Drop (psi)
1	BHA	100.0	4.0	50.0

No.	Drill Strings	Length (ft)	I.D. (in)	O.D. (in)
1	Drill Collar	500.0	2.75	7.5
2	Drill String	8400.0	3.83	5.0

Well Geometry (from surface)

No.	Components	From (ft)	I.D. (in)
1	Casing	0.0	11.0
2		4000.0	11.2
3	Shale	4950.0	12.5
4		5000.0	11.2
5	Depleted Int.	5150.0	11.0
6		5650.0	11.3
7	Water Zone	6400.0	11.0
8		6600.0	11.3
9	Shale Cap	7150.0	13.0
10	Major Pay Int.	7250.0	11.3
11		7800.0	11.3
12		8500.0	11.35

Nozzle Diameters (1/32in)

12.0 12.0 12.0 12.0 12.0

TFA (in2) 0.55

=============== End of TDI File ===============

Hydraulics Model

[Parameter Data Input]

Selected Options:	Hydraulics Analysis Surge and Swab Cutting Transport Volumetric Displacement Well Planning and Nozzle Selection	
Mud Properties:	Mud Weight(ppg): Plastic Viscosity(cp): Yield Point(lbf/100ft2):	13.0 30.0 12.0
Pump Properties:	Stroke Rate(stk/min): Stroke Displacement(gal/stk):	84 5.0
Surge/Swab Condition:	Pipe Running Speed(ft/min):	100.0
Cutting Properties:	Cutting Diameter(in): Cutting Density(ppg):	0.25 21.6

Volumetric Displacement Schedule:

Fluid Pumped	Pump Rate (gpm)	Elapsed Time (min)	Volume (bbl)
Spacer	210.0	16.0	80.0
	0.0	10.0	0.0
Lead Cement	340.0	21.0	170.0
Tail Cement	140.0	35.0	116.67
	0.0	5.0	0.0
Polymer	420.0	15.0	150.0
	252.0	5.0	30.0
	420.0	5.0	50.0
	150.0	3.0	10.71
	84.0	4.0	8.0

Well Planning:	Maxi. pump pressure(psi): Maxi. pump horsepower(HP): Pump efficiency: Flow rate index: Minimum flow rate(gpm): The flow rate(gpm):	3423.0 1600.0 .9 1.75 395.0 500.0

Mud Program

Bit Depth (ft)	Mud WT (ppg)	PV (cp)	YP (#)	N' (-)	K' (@)
5000.0	9.5	15.0	5.0		
6000.0	9.5	15.0	5.0		
7000.0	9.5	15.0	5.0		
8000.0	12.0	25.0	9.0		
9000.0	13.0	30.0	12.0		

Note: (#) = (lbf/100ft2) , (@) = (lbf.s^n/ft2)

End of PDI File

Figure 6-1. Input Data of the Example Case

Use of these data will generate the example results presented in this manual. The HYDTEST data are for illustration only and should not be taken as preferred values.

Start HYDMOD3 using the methods described in Section 3.3.

In the following sections, the procedure will be negotiated step by step.

6.3 INPUT WINDOW

Select "Open Project..." from the File menu (in the INPUT Window). Retrieve the project file HYDTEST.HY3 in C:\HYDMOD3. After the user completes the dialog, the Main Window is displayed as shown in Figure 5-3. Other data input windows are shown in Figures 5-4, 5-5, 5-6, 5-7 and 5-11. Please refer to them.

6.4 OUTPUT WINDOW AND PRINTOUTS

Selecting "Start" from the Run menu in the INPUT Window will start the calculation. A message window will be displayed showing the progress of the calculation.

The OUTPUT window and its child windows are shown in Figures 5-14 through 5-36. The figures displayed here are the printouts of corresponding windows. (For some test reports, only partial printouts are shown in order to save space.)

6.4.1 Hydraulics Analysis

1. "Report" (Figure 6-2, continued on the following page)

Hydraulics Analysis Report

Flow rate (gpm)	420.0
Pump output hydraulic power (HP)	562.03
Circ. system HP loss(w/o bit) (HP)	392.34
Bit hydraulic HP (HP)	169.68
Wellhead pressure (psi)	2293.6
Surface equipment press. loss (psi)	152.9
Circ. system pressure loss(w/o bit) (psi)	1601.13
Nozzle pressure loss (psi)	692.47
Jet impact force (lbf)	690.13
Impact force/hole area (psi)	6.82
Nozzle area (in2)	0.55
Nozzle velocity (ft/s)	243.98

Frictional Pressure Drop Inside the Drill Strings, etc.

Drill Strings	Press. Drop (psi)	Flow Type	Velocity (ft/min)
Surface	152.9	NA	NA
Drill Stri	1004.01	T	701.76
Drill Coll	288.87	T	1361.21
BHA	50.0	T	1143.79

Bit Pressure Drop

Bit	692.47	T	14638.85

Frictional Pressure Drop in the Annulus

Inner	Outer	P. Drop (psi)	Flow Type	Velocity (ft/min)
BHA		0.9	L	91.24
Drill Coll		8.16	L	141.85
Drill Coll		2.08	L	144.09
Drill Stri		6.5	L	100.24
Drill Stri	Major Pay	5.96	L	100.24
Drill Stri	Shale Cap	0.81	L	71.49
Drill Stri		5.96	L	100.24
Drill Stri	Water Zone	2.31	L	107.23
Drill Stri		8.13	L	100.24
Drill Stri	Depleted I	5.77	L	107.23
Drill Stri		1.66	L	102.49
Drill Stri	Shale	0.44	L	78.43
Drill Stri		10.51	L	102.49
Drill Stri	Casing	46.17	L	107.23

Hydraulics Details

No. M.D.	TVD	Press.	ECD	Velocity

	(ft)	(ft)	(psi)	(ppg)	(ft/min)
1	5158.25	4634.39	4657.01	19.32	701.76
2	5723.72	4926.67	4787.01	18.69	701.76
3	6674.73	5187.85	4849.89	17.98	701.76
4	7857.07	5206.3	4721.04	17.44	701.76
5	-9000.0	5206.3	3624.81	13.39	91.24
6	-8653.87	5206.3	3618.89	13.37	141.85
7	-8216.91	5206.3	3611.68	13.34	100.24
8	-7959.88	5206.3	3608.9	13.33	100.24
9	-7343.01	5206.3	3602.21	13.31	100.24
10	-6957.47	5205.98	3598.1	13.29	100.24
11	-5929.35	5008.55	3453.35	13.26	100.24
12	-5440.99	4792.46	3301.84	13.25	107.23
13	-4721.3	4346.83	2992.61	13.24	102.49
14	-3513.26	3376.32	2322.95	13.23	107.23
15	-2356.62	2324.36	1598.47	13.23	107.23
16	-1097.18	1096.1	753.63	13.22	107.23

=============== End of Hydraulics Report ===============

Figure 6-2. Text Report of Hydraulics Analysis

2. "Pressure" (Figure 6-3)

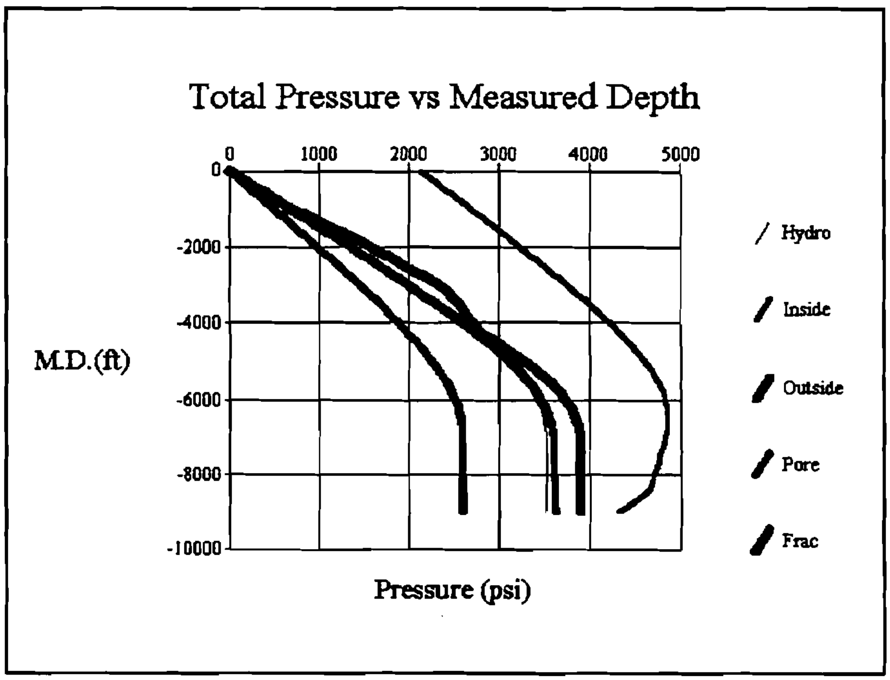


Figure 6-3. Total Pressure Vs. Measured Depth

3. "Frictional Pressure" (Figure 6-4)

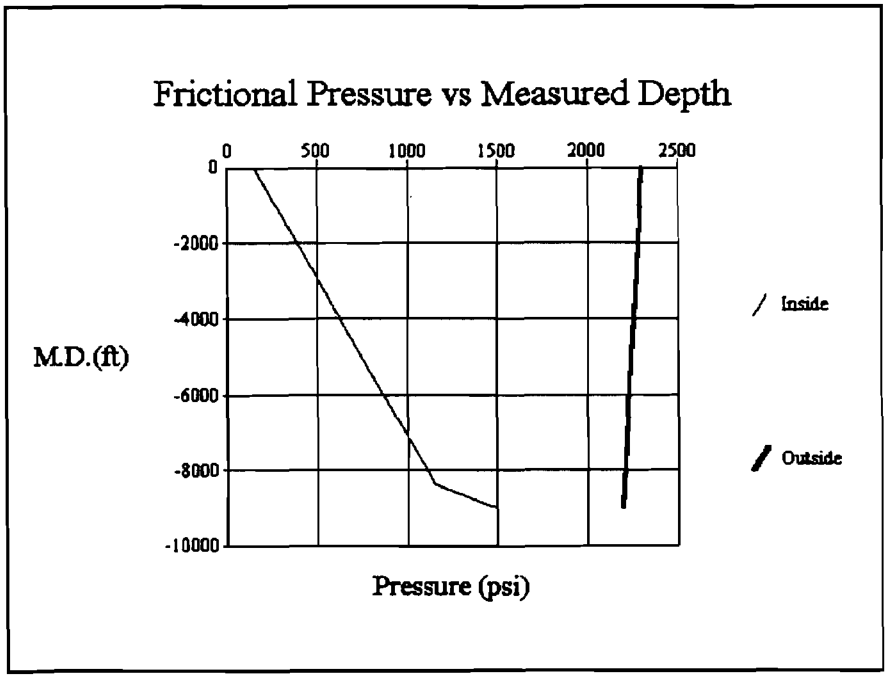


Figure 6-4. Frictional Pressure Vs. Measured Depth

4. "ECD" (Figure 6-5)

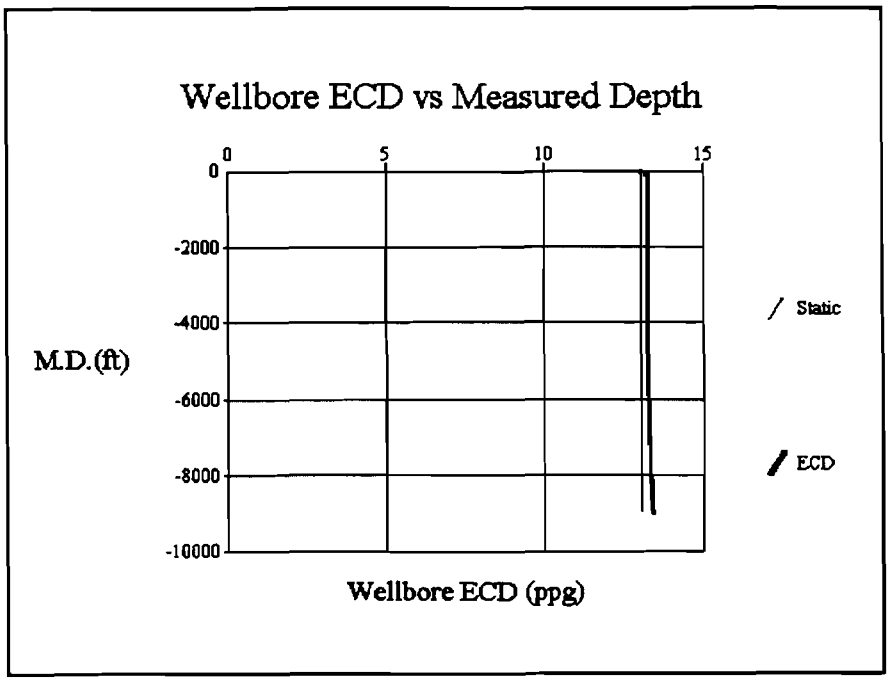


Figure 6-5. Wellbore ECD Vs. Measured Depth

5. "Velocity" (Figure 6-6)

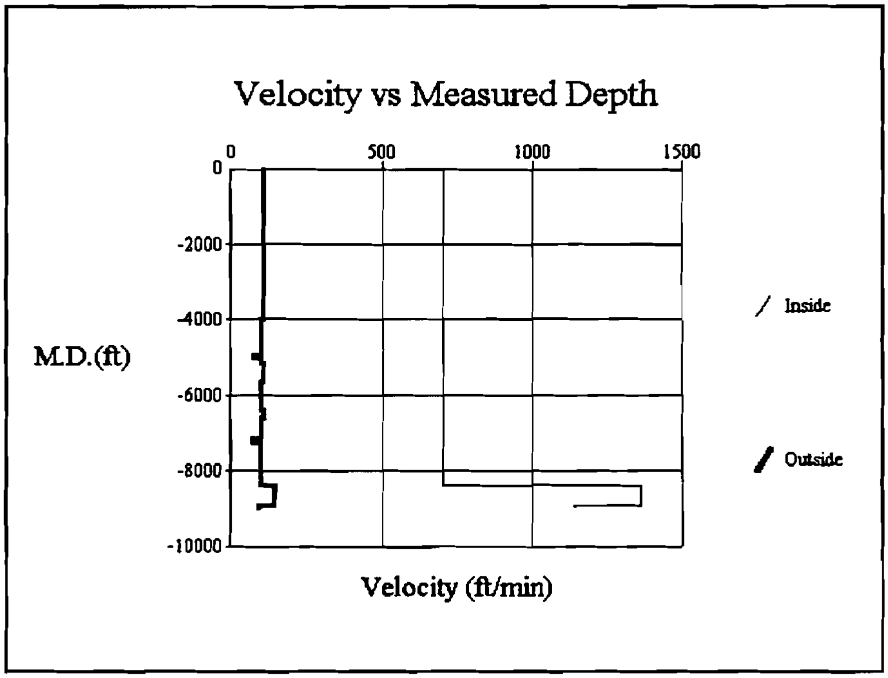


Figure 6-6. Velocity Profiles

6. "Sensitivity" (Figures 6-7 and 6-8)

A text report and one graph from this window are presented in Figures 6-7 and 6-8.

Sensitivity Analysis

#	Rate (gpm)	Head P (psi)
1	100.0	367.95
2	170.0	557.82
3	240.0	917.76
4	310.0	1377.3
5	380.0	1933.41
6	450.0	2583.7
7	520.0	3326.29
8	590.0	4159.66
9	660.0	5082.53
10	730.0	6094.38
11	800.0	7194.79
12	870.0	8381.9
13	940.0	9656.03
14	1010.0	11023.11
15	1080.0	12478.74
16	1150.0	14019.36
17	1220.0	15644.12
18	1290.0	17352.61
19	1360.0	19144.43
20	1430.0	21019.08
21	1500.0	22976.19

End of Sensitivity Analysis Report

Figure 6-7. Text Report of Sensitivity Analysis

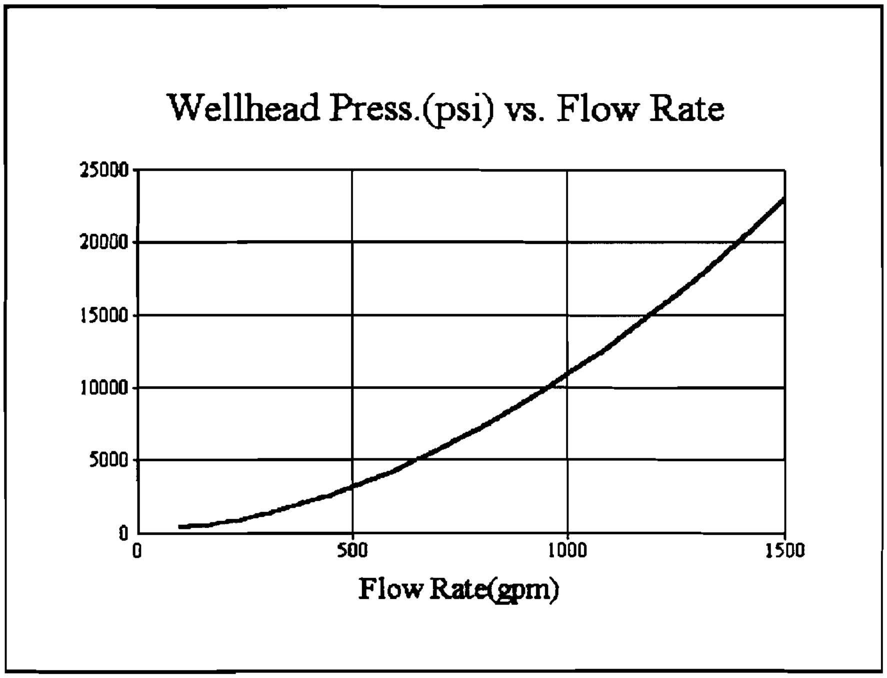


Figure 6-8. Graph Output of Sensitivity Analysis

6.4.2 Surge and Swab (Closed Pipe)

1. "Report" (Figure 6-9, which is a portion of the printout)

Surge and Swab Report

Surge History Analysis

#	Time (min)	M.D. (ft)	QOut (gpm)	Shoe P (psi)	Shoe ECD (ppg)	BH P (psi)	BH ECD (ppg)
1	0.0	0.0	387.09	2559.61	13.0	3519.46	13.0
2	0.9	90.0	387.09	2560.47	13.0	3520.31	13.0
3	1.8	180.0	522.57	2562.58	13.02	3522.42	13.01
4	2.7	270.0	522.57	2564.85	13.03	3524.7	13.02
5	3.6	360.0	522.57	2567.12	13.04	3526.97	13.03
6	4.5	450.0	522.57	2569.39	13.05	3529.24	13.04
7	5.4	540.0	522.57	2571.66	13.06	3531.51	13.04
8	6.3	630.0	417.38	2573.52	13.07	3533.37	13.05
9	7.2	720.0	417.38	2574.55	13.08	3534.4	13.06
10	8.1	810.0	417.38	2575.59	13.08	3535.43	13.06
11	9.0	900.0	417.38	2576.62	13.09	3536.47	13.06
12	9.9	990.0	417.38	2577.65	13.09	3537.5	13.07
13	10.8	1080.0	417.38	2578.69	13.1	3538.53	13.07
14	11.7	1170.0	417.38	2579.72	13.1	3539.57	13.07
15	12.6	1260.0	417.38	2580.75	13.11	3540.6	13.08
16	13.5	1350.0	417.38	2581.79	13.11	3541.63	13.08
17	14.4	1440.0	417.38	2582.82	13.12	3542.67	13.09
18	15.3	1530.0	417.38	2583.85	13.12	3543.7	13.09
19	16.2	1620.0	417.38	2584.89	13.13	3544.73	13.09
20	17.1	1710.0	417.38	2585.92	13.13	3545.77	13.1
21	18.0	1800.0	417.38	2586.96	13.14	3546.8	13.1
22	18.9	1890.0	417.38	2587.99	13.14	3547.83	13.1
23	19.8	1980.0	417.38	2589.02	13.15	3548.87	13.11
24	20.7	2070.0	417.38	2590.06	13.15	3549.9	13.11
25	21.6	2160.0	417.38	2591.09	13.16	3550.93	13.12
26	22.5	2250.0	417.38	2592.12	13.17	3551.97	13.12
27	23.4	2340.0	417.38	2593.16	13.17	3553.0	13.12
28	24.3	2430.0	417.38	2594.19	13.18	3554.03	13.13
29	25.2	2520.0	417.38	2595.22	13.18	3555.07	13.13
30	26.1	2610.0	417.38	2596.26	13.19	3556.1	13.14
31	27.0	2700.0	417.38	2597.29	13.19	3557.13	13.14
32	27.9	2790.0	417.38	2598.32	13.2	3558.17	13.14
33	28.8	2880.0	417.38	2599.36	13.2	3559.2	13.15
34	29.7	2970.0	417.38	2600.39	13.21	3560.23	13.15
35	30.6	3060.0	417.38	2601.42	13.21	3561.27	13.15
36	31.5	3150.0	417.38	2602.46	13.22	3562.3	13.16
37	32.4	3240.0	417.38	2603.49	13.22	3563.33	13.16
38	33.3	3330.0	417.38	2604.52	13.23	3564.37	13.17
39	34.2	3420.0	417.38	2605.56	13.23	3565.4	13.17
40	35.1	3510.0	417.38	2606.59	13.24	3566.44	13.17
41	36.0	3600.0	417.38	2607.62	13.24	3567.47	13.18
42	36.9	3690.0	417.38	2608.66	13.25	3568.5	13.18
43	37.8	3780.0	417.38	2609.69	13.25	3569.54	13.18
44	38.7	3870.0	417.38	2610.72	13.26	3570.57	13.19
45	39.6	3960.0	417.38	2611.76	13.26	3571.6	13.19
46	40.5	4050.0	417.38	2612.32	13.27	3572.62	13.2
47	41.4	4140.0	417.38	2611.87	13.27	3573.56	13.2
48	42.3	4230.0	417.38	2610.63	13.26	3574.4	13.2
49	43.2	4320.0	417.38	2609.39	13.25	3575.25	13.21
50	44.1	4410.0	417.38	2608.15	13.25	3576.09	13.21
51	45.0	4500.0	417.38	2606.92	13.24	3576.94	13.21
52	45.9	4590.0	417.38	2605.68	13.23	3577.79	13.22

53	46.8	4680.0	417.38	2605.54	13.23	3578.76	13.22
54	47.7	4770.0	417.38	2605.54	13.23	3579.76	13.22
55	48.6	4860.0	417.38	2605.54	13.23	3580.75	13.23
56	49.5	4950.0	417.38	2605.54	13.23	3581.75	13.23
57	50.4	5040.0	417.38	2605.54	13.23	3582.66	13.23
58	51.3	5130.0	417.38	2605.54	13.23	3583.33	13.24
59	52.2	5220.0	417.38	2605.54	13.23	3584.34	13.24
60	53.1	5310.0	417.38	2605.54	13.23	3585.47	13.24
61	54.0	5400.0	417.38	2605.54	13.23	3586.65	13.25
62	54.9	5490.0	417.38	2605.54	13.23	3587.83	13.25
63	55.8	5580.0	417.38	2605.54	13.23	3589.19	13.26
64	56.7	5670.0	417.38	2605.54	13.23	3590.48	13.26
65	57.6	5760.0	417.38	2605.54	13.23	3591.58	13.27
66	58.5	5850.0	417.38	2605.54	13.23	3592.35	13.27
67	59.4	5940.0	417.38	2605.54	13.23	3593.11	13.27
68	60.3	6030.0	417.38	2605.54	13.23	3593.87	13.27
69	61.2	6120.0	417.38	2605.54	13.23	3594.64	13.28
70	62.1	6210.0	417.38	2605.54	13.23	3595.4	13.28
71	63.0	6300.0	417.38	2605.54	13.23	3596.28	13.28
72	63.9	6390.0	417.38	2605.54	13.23	3597.25	13.29
73	64.8	6480.0	417.38	2605.54	13.23	3598.27	13.29
74	65.7	6570.0	417.38	2605.54	13.23	3599.46	13.3
75	66.6	6660.0	417.38	2605.54	13.23	3600.68	13.3
76	67.5	6750.0	417.38	2605.54	13.23	3601.76	13.3
77	68.4	6840.0	417.38	2605.54	13.23	3602.73	13.31
78	69.3	6930.0	417.38	2605.54	13.23	3603.71	13.31
79	70.2	7020.0	417.38	2605.54	13.23	3604.64	13.31
80	71.1	7110.0	417.38	2605.54	13.23	3605.4	13.32
81	72.0	7200.0	417.38	2605.54	13.23	3606.07	13.32
82	72.9	7290.0	417.38	2605.54	13.23	3606.67	13.32
83	73.8	7380.0	417.38	2605.54	13.23	3607.22	13.32
84	74.7	7470.0	417.38	2605.54	13.23	3608.19	13.33
85	75.6	7560.0	417.38	2605.54	13.23	3609.17	13.33
86	76.5	7650.0	417.38	2605.54	13.23	3610.14	13.33
87	77.4	7740.0	417.38	2605.54	13.23	3611.12	13.34
88	78.3	7830.0	417.38	2605.54	13.23	3612.6	13.34
89	79.2	7920.0	417.38	2605.54	13.23	3613.7	13.35
90	80.1	8010.0	417.38	2605.54	13.23	3614.68	13.35
91	81.0	8100.0	417.38	2605.54	13.23	3615.65	13.36
92	81.9	8190.0	417.38	2605.54	13.23	3616.63	13.36
93	82.8	8280.0	417.38	2605.54	13.23	3617.6	13.36
94	83.7	8370.0	417.38	2605.54	13.23	3618.58	13.37
95	84.6	8460.0	417.38	2605.54	13.23	3619.55	13.37
96	85.5	8550.0	417.38	2605.54	13.23	3620.53	13.37
97	86.4	8640.0	417.38	2605.54	13.23	3621.48	13.38
98	87.3	8730.0	417.38	2605.54	13.23	3622.42	13.38
99	88.2	8820.0	417.38	2605.54	13.23	3623.35	13.38
100	89.1	8910.0	417.38	2605.54	13.23	3624.29	13.39
101	90.0	9000.0	417.38	2605.54	13.23	3625.23	13.39

Swab History Analysis

#	Time (min)	M.D. (ft)	QOut (gpm)	Shoe P (psi)	Shoe ECD (ppg)	BH P (psi)	BH ECD (ppg)
1	0.0	9000.0	417.38	2513.68	12.77	3413.69	12.61
2	0.9	8910.0	417.38	2513.68	12.77	3414.62	12.61
3	1.8	8820.0	417.38	2513.68	12.77	3415.56	12.62
4	2.7	8730.0	417.38	2513.68	12.77	3416.5	12.62
5	3.6	8640.0	417.38	2513.68	12.77	3417.43	12.62
6	4.5	8550.0	417.38	2513.68	12.77	3418.39	12.63
7	5.4	8460.0	417.38	2513.68	12.77	3419.36	12.63
8	6.3	8370.0	417.38	2513.68	12.77	3420.33	12.63
9	7.2	8280.0	417.38	2513.68	12.77	3421.31	12.64
10	8.1	8190.0	417.38	2513.68	12.77	3422.28	12.64
11	9.0	8100.0	417.38	2513.68	12.77	3423.26	12.64
12	9.9	8010.0	417.38	2513.68	12.77	3424.23	12.65
13	10.8	7920.0	417.38	2513.68	12.77	3425.21	12.65
14	11.7	7830.0	417.38	2513.68	12.77	3426.31	12.66
15	12.6	7740.0	417.38	2513.68	12.77	3427.8	12.66
16	13.5	7650.0	417.38	2513.68	12.77	3428.77	12.67
17	14.4	7560.0	417.38	2513.68	12.77	3429.75	12.67
18	15.3	7470.0	417.38	2513.68	12.77	3430.72	12.67
19	16.2	7380.0	417.38	2513.68	12.77	3431.7	12.68
20	17.1	7290.0	417.38	2513.68	12.77	3432.25	12.68
21	18.0	7200.0	417.38	2513.68	12.77	3432.84	12.68
22	18.9	7110.0	417.38	2513.68	12.77	3433.51	12.68
23	19.8	7020.0	417.38	2513.68	12.77	3434.28	12.69
24	20.7	6930.0	417.38	2513.68	12.77	3435.21	12.69
25	21.6	6840.0	417.38	2513.68	12.77	3436.18	12.69
26	22.5	6750.0	417.38	2513.68	12.77	3437.16	12.7
27	23.4	6660.0	417.38	2513.68	12.77	3438.23	12.7
28	24.3	6570.0	417.38	2513.68	12.77	3439.45	12.7
29	25.2	6480.0	417.38	2513.68	12.77	3440.65	12.71
30	26.1	6390.0	417.38	2513.68	12.77	3441.66	12.71
31	27.0	6300.0	417.38	2513.68	12.77	3442.63	12.72
32	27.9	6210.0	417.38	2513.68	12.77	3443.51	12.72
33	28.8	6120.0	417.38	2513.68	12.77	3444.28	12.72
34	29.7	6030.0	417.38	2513.68	12.77	3445.04	12.73
35	30.6	5940.0	417.38	2513.68	12.77	3445.8	12.73
36	31.5	5850.0	417.38	2513.68	12.77	3446.57	12.73
37	32.4	5760.0	417.38	2513.68	12.77	3447.33	12.73
38	33.3	5670.0	417.38	2513.68	12.77	3448.43	12.74
39	34.2	5580.0	417.38	2513.68	12.77	3449.72	12.74
40	35.1	5490.0	417.38	2513.68	12.77	3451.08	12.75
41	36.0	5400.0	417.38	2513.68	12.77	3452.26	12.75
42	36.9	5310.0	417.38	2513.68	12.77	3453.44	12.76
43	37.8	5220.0	417.38	2513.68	12.77	3454.57	12.76
44	38.7	5130.0	417.38	2513.68	12.77	3455.58	12.76
45	39.6	5040.0	417.38	2513.68	12.77	3456.25	12.77
46	40.5	4950.0	417.38	2513.68	12.77	3457.17	12.77
47	41.4	4860.0	417.38	2513.68	12.77	3458.16	12.77
48	42.3	4770.0	417.38	2513.68	12.77	3459.16	12.78
49	43.2	4680.0	417.38	2513.68	12.77	3460.15	12.78
50	44.1	4590.0	417.38	2513.54	12.77	3461.13	12.78
51	45.0	4500.0	417.38	2512.31	12.76	3461.97	12.79
52	45.9	4410.0	417.38	2511.07	12.75	3462.82	12.79
53	46.8	4320.0	417.38	2509.83	12.75	3463.66	12.79
54	47.7	4230.0	417.38	2508.59	12.74	3464.51	12.8
55	48.6	4140.0	417.38	2507.36	12.73	3465.36	12.8
56	49.5	4050.0	417.38	2506.91	12.73	3466.29	12.8

57	50.4	3960.0	417.38	2507.47	12.74	3467.31	12.81
58	51.3	3870.0	417.38	2508.5	12.74	3468.34	12.81
59	52.2	3780.0	417.38	2509.53	12.75	3469.38	12.82
60	53.1	3690.0	417.38	2510.57	12.75	3470.41	12.82
61	54.0	3600.0	417.38	2511.6	12.76	3471.44	12.82
62	54.9	3510.0	417.38	2512.63	12.76	3472.48	12.83
63	55.8	3420.0	417.38	2513.67	12.77	3473.51	12.83
64	56.7	3330.0	417.38	2514.7	12.77	3474.54	12.83
65	57.6	3240.0	417.38	2515.73	12.78	3475.58	12.84
66	58.5	3150.0	417.38	2516.77	12.78	3476.61	12.84
67	59.4	3060.0	417.38	2517.8	12.79	3477.64	12.85
68	60.3	2970.0	417.38	2518.83	12.79	3478.68	12.85
69	61.2	2880.0	417.38	2519.87	12.8	3479.71	12.85
70	62.1	2790.0	417.38	2520.9	12.8	3480.74	12.86
71	63.0	2700.0	417.38	2521.93	12.81	3481.78	12.86
72	63.9	2610.0	417.38	2522.97	12.81	3482.81	12.86
73	64.8	2520.0	417.38	2524.0	12.82	3483.84	12.87
74	65.7	2430.0	417.38	2525.03	12.82	3484.88	12.87
75	66.6	2340.0	417.38	2526.07	12.83	3485.91	12.88
76	67.5	2250.0	417.38	2527.1	12.83	3486.95	12.88
77	68.4	2160.0	417.38	2528.13	12.84	3487.98	12.88
78	69.3	2070.0	417.38	2529.17	12.85	3489.01	12.89
79	70.2	1980.0	417.38	2530.2	12.85	3490.05	12.89
80	71.1	1890.0	417.38	2531.23	12.86	3491.08	12.9
81	72.0	1800.0	417.38	2532.27	12.86	3492.11	12.9
82	72.9	1710.0	417.38	2533.3	12.87	3493.15	12.9
83	73.8	1620.0	417.38	2534.33	12.87	3494.18	12.91
84	74.7	1530.0	417.38	2535.37	12.88	3495.21	12.91
85	75.6	1440.0	417.38	2536.4	12.88	3496.25	12.91
86	76.5	1350.0	417.38	2537.43	12.89	3497.28	12.92
87	77.4	1260.0	417.38	2538.47	12.89	3498.31	12.92
88	78.3	1170.0	417.38	2539.5	12.9	3499.35	12.93
89	79.2	1080.0	417.38	2540.54	12.9	3500.38	12.93
90	80.1	990.0	417.38	2541.57	12.91	3501.41	12.93
91	81.0	900.0	417.38	2542.6	12.91	3502.45	12.94
92	81.9	810.0	417.38	2543.64	12.92	3503.48	12.94
93	82.8	720.0	417.38	2544.67	12.92	3504.51	12.94
94	83.7	630.0	417.38	2545.7	12.93	3505.55	12.95
95	84.6	540.0	522.57	2547.56	12.94	3507.41	12.96
96	85.5	450.0	522.57	2549.83	12.95	3509.68	12.96
97	86.4	360.0	522.57	2552.1	12.96	3511.95	12.97
98	87.3	270.0	522.57	2554.37	12.97	3514.22	12.98
99	88.2	180.0	522.57	2556.64	12.98	3516.49	12.99
100	89.1	90.0	387.09	2558.76	13.0	3518.6	13.0
101	90.0	0.0	387.09	2559.61	13.0	3519.46	13.0

============ End of Surge/Swab Report ============

Figure 6-9. Text Report of Surge and Swab (Closed-Pipe)

2. "Return Flow Rate" (Figure 6-10)

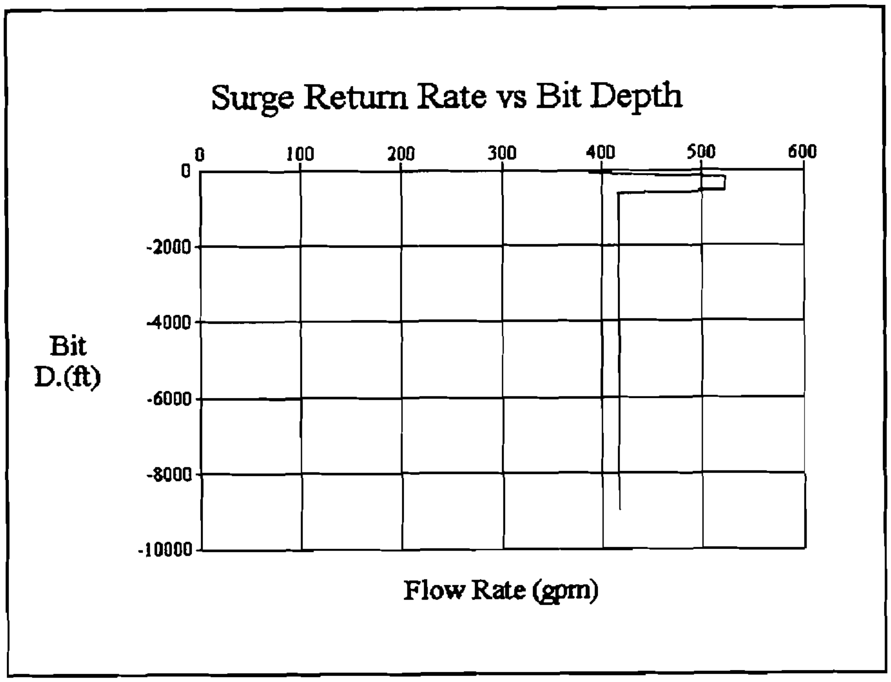


Figure 6-10. Surge Return Rate Vs. Bit Depth

3. "Casing Shoe Pressure" (Figure 6-11)

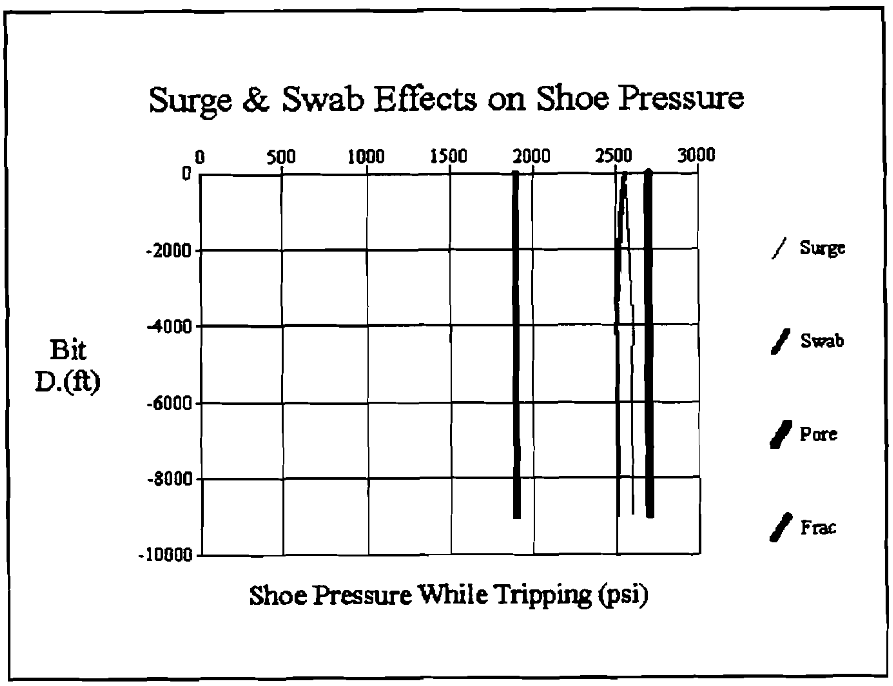


Figure 6-11. Surge and Swab Effects on Shoe Pressure

4. "Casing Shoe EMW" (Figure 6-12)

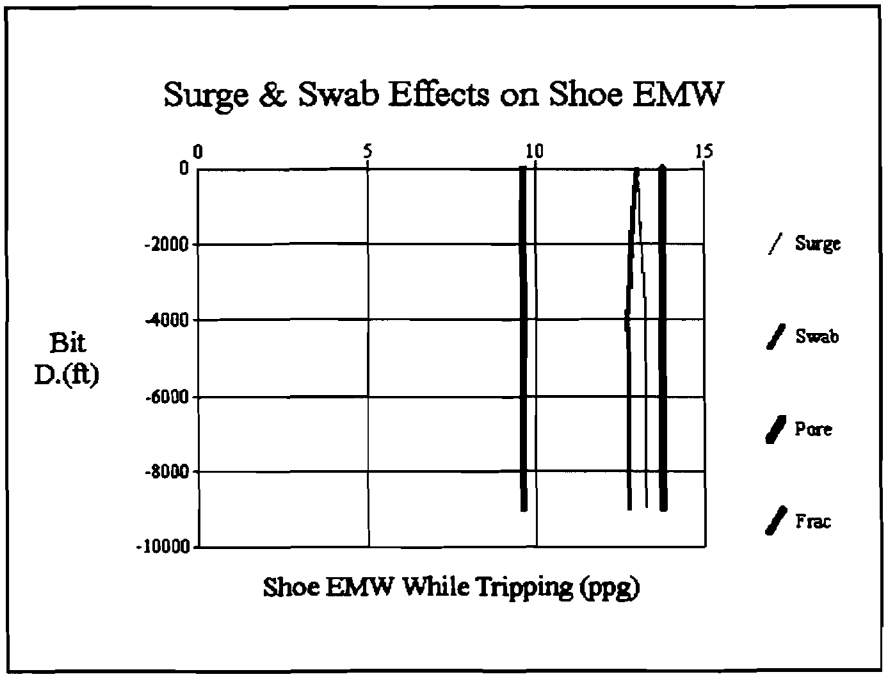


Figure 6-12. Surge and Swab Effects on Shoe EMW

5. "Bottom-hole Pressure" (Figure 6-13)

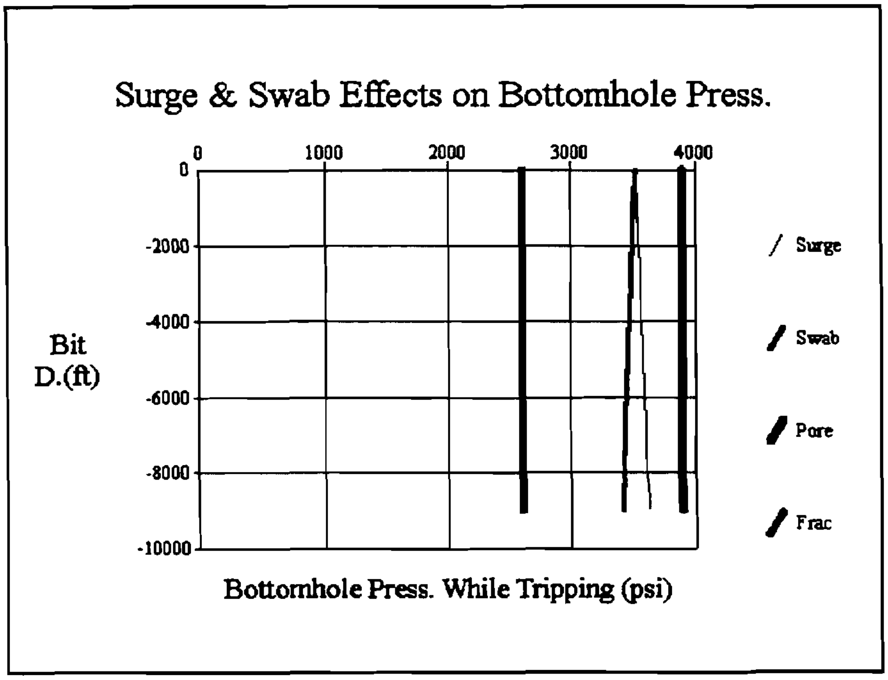


Figure 6-13. Surge and Swab Effects on Bottom-Hole Pressure

6. "Bottom-Hole EMW" (Figure 6-14)

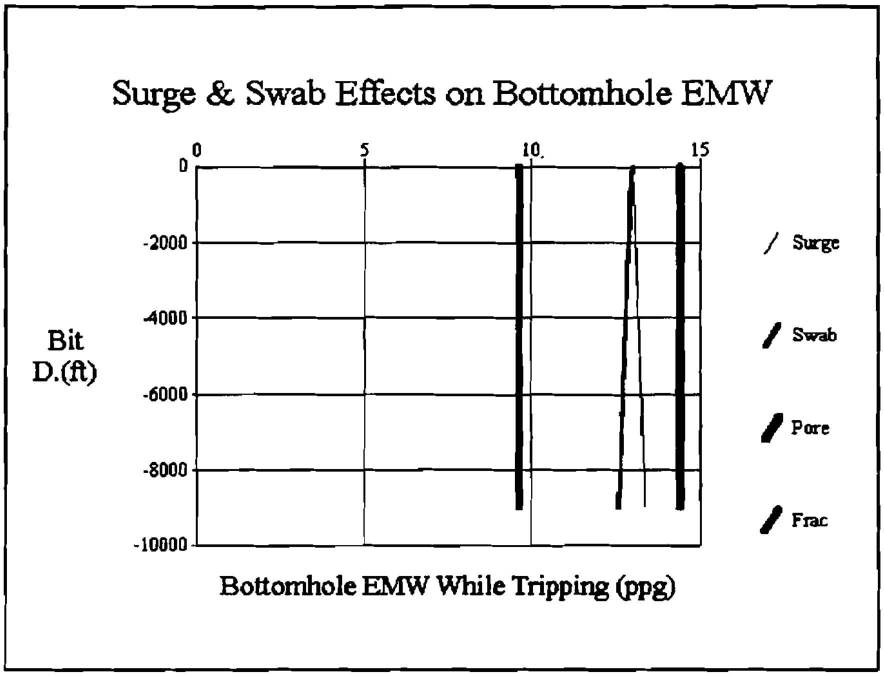


Figure 6-14. Surge and Swab Effects on Bottom-Hole EMW

6.4.3 Cuttings Transport

The only printout of this option is shown in Figure 6-15.

```
                 ========================
                 Cutting Transport Report
                 ========================

              ------------------------------
              Valid For Vertical Section Only
              ------------------------------

------------------------------------------------------------
Flow Rate(gpm):                                     420.0
Measured Depth(ft):                                 6894.26
Tube Outer Diameter(in):                            5.0
Hole Diameter(in):                                  11.3
Cutting Density(ppg):                               21.6
Cutting Chip Size(in):                              0.25

Annular Fluid Velocity(ft/min):                     100.24

Slip Velocity (Moore Correlation)(ft/min):          18.06
Cutting Transport Ratio(1-Vsl/Va) (Moore):          82.%

Slip Velocity (Chien Correlation)(ft/min):          30.12
Cutting Transport Ratio(1-Vsl/Va) (Chien):          70.%
------------------------------------------------------------

       ====== End of Cutting Transport Report ======
```

Figure 6-15. Text Report of Cuttings Transport

6.4.4 Volumetric Displacement

1. "Report" (Figure 6-16, which is a portion of the printout)

Volumetric Displacement Report

Summary

Volume	(bbl)	Time (min)		Strokes Required
Pipes:	124.25	Pump from surface to bit:	12.42	1044
Annulus:	856.51	Pump from bottom to surface:	85.65	7195
Total:	980.76	Pump one full circulation:	98.08	8238

Volumetric Displacement

#	Time (min)	Pump Stks	Pump Rate (gpm)	Fl. In	Fl. Out	Fl. Vol.In (bbl)	Fl.-2 Front (ft)	Fl.-3 Front (ft)	Fl.-4 Front (ft)	Fl.-5 Front (ft)
1	0.0		210.0	2	1	0.0	0.0	0.0	0.0	0.0
2	0.99	42	210.0	2	1	4.96	347.95	0.0	0.0	0.0
3	1.98	83	210.0	2	1	9.92	695.91	0.0	0.0	0.0
4	2.97	125	210.0	2	1	14.88	1043.86	0.0	0.0	0.0
5	3.97	167	210.0	2	1	19.83	1391.82	0.0	0.0	0.0
6	4.96	208	210.0	2	1	24.79	1739.77	0.0	0.0	0.0
7	5.95	250	210.0	2	1	29.75	2087.73	0.0	0.0	0.0
8	6.94	292	210.0	2	1	34.71	2435.68	0.0	0.0	0.0
9	7.93	333	210.0	2	1	39.67	2783.64	0.0	0.0	0.0
10	8.93	375	210.0	2	1	44.63	3131.59	0.0	0.0	0.0
11	9.92	417	210.0	2	1	49.58	3479.55	0.0	0.0	0.0
12	10.91	458	210.0	2	1	54.54	3827.5	0.0	0.0	0.0
13	11.9	500	210.0	2	1	59.5	4175.46	0.0	0.0	0.0
14	12.89	541	210.0	2	1	64.46	4523.41	0.0	0.0	0.0
15	13.88	583	210.0	2	1	69.42	4871.37	0.0	0.0	0.0
16	14.88	625	210.0	2	1	74.38	5219.32	0.0	0.0	0.0
17	15.87	666	210.0	2	1	79.33	5567.27	0.0	0.0	0.0
18	16.86	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
19	17.85	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
20	18.84	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
21	19.83	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
22	20.83	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
23	21.82	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
24	22.81	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
25	23.8	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
26	24.79	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
27	25.78	672	0.0	2	1	80.0	5614.06	0.0	0.0	0.0
28	26.77	725	340.0	3	1	86.27	6054.33	440.27	0.0	0.0
29	27.77	792	340.0	3	1	94.3	6617.68	1003.62	0.0	0.0
30	28.76	860	340.0	3	1	102.33	7181.04	1566.98	0.0	0.0
31	29.75	927	340.0	3	1	110.36	7744.39	2130.33	0.0	0.0
32	30.74	994	340.0	3	1	118.38	8307.75	2693.69	0.0	0.0
33	31.73	1062	340.0	3	1	126.41	-8980.24	3257.04	0.0	0.0
34	32.72	1129	340.0	3	1	134.44	-8906.99	3820.4	0.0	0.0
35	33.72	1197	340.0	3	1	142.47	-8797.01	4383.75	0.0	0.0
36	34.71	1264	340.0	3	1	150.5	-8683.13	4947.11	0.0	0.0
37	35.7	1332	340.0	3	1	158.52	-8569.26	5510.47	0.0	0.0
38	36.69	1399	340.0	3	1	166.55	-8454.69	6073.82	0.0	0.0
39	37.68	1466	340.0	3	1	174.58	-8357.57	6637.18	0.0	0.0
40	38.67	1534	340.0	3	1	182.61	-8277.1	7200.53	0.0	0.0

41	39.67	1601	340.0	3	1	190.63	-8196.63	7763.89	0.0	0.0
42	40.66	1669	340.0	3	1	198.66	-8116.15	8327.24	0.0	0.0
43	41.65	1736	340.0	3	1	206.69	-8035.68	-8977.71	0.0	0.0
44	42.64	1804	340.0	3	1	214.72	-7955.21	-8904.46	0.0	0.0
45	43.63	1871	340.0	3	1	222.75	-7874.73	-8793.06	0.0	0.0
46	44.63	1939	340.0	3	1	230.77	-7794.26	-8679.19	0.0	0.0
47	45.62	2006	340.0	3	1	238.8	-7713.78	-8565.32	0.0	0.0
48	46.61	2073	340.0	3	1	246.83	-7633.32	-8450.69	0.0	0.0
49	47.6	2117	140.0	4	1	252.0	-7581.48	-8383.43	140.35	0.0
50	48.59	2145	140.0	4	1	255.31	-7548.34	-8350.29	372.32	0.0
51	49.58	2172	140.0	4	1	258.61	-7515.21	-8317.16	604.29	0.0
52	50.58	2200	140.0	4	1	261.92	-7482.07	-8284.02	836.26	0.0
53	51.57	2228	140.0	4	1	265.22	-7448.94	-8250.89	1068.23	0.0
54	52.56	2256	140.0	4	1	268.53	-7415.8	-8217.75	1300.2	0.0
55	53.55	2283	140.0	4	1	271.83	-7382.66	-8184.61	1532.17	0.0
56	54.54	2311	140.0	4	1	275.14	-7349.53	-8151.48	1764.14	0.0
57	55.53	2339	140.0	4	1	278.44	-7316.39	-8118.34	1996.11	0.0
58	56.53	2367	140.0	4	1	281.75	-7283.25	-8085.2	2228.08	0.0
59	57.52	2394	140.0	4	1	285.06	-7250.12	-8052.07	2460.05	0.0
60	58.51	2422	140.0	4	1	288.36	-7226.45	-8018.93	2692.02	0.0
61	59.5	2450	140.0	4	1	291.67	-7202.83	-7985.8	2923.99	0.0
62	60.49	2478	140.0	4	1	294.97	-7179.2	-7952.66	3155.96	0.0
63	61.48	2506	140.0	4	1	298.28	-7155.56	-7919.52	3387.93	0.0
64	62.47	2533	140.0	4	1	301.58	-7124.67	-7886.39	3619.9	0.0
65	63.47	2561	140.0	4	1	304.89	-7091.53	-7853.25	3851.87	0.0
66	64.46	2589	140.0	4	1	308.19	-7058.4	-7820.12	4083.84	0.0
67	65.45	2617	140.0	4	1	311.5	-7025.26	-7786.98	4315.81	0.0
68	66.44	2644	140.0	4	1	314.81	-6992.12	-7753.84	4547.78	0.0
69	67.43	2672	140.0	4	1	318.11	-6958.99	-7720.71	4779.75	0.0
70	68.43	2700	140.0	4	1	321.42	-6925.85	-7687.57	5011.72	0.0
71	69.42	2728	140.0	4	1	324.72	-6892.72	-7654.44	5243.69	0.0
72	70.41	2755	140.0	4	1	328.03	-6859.58	-7621.3	5475.66	0.0
73	71.4	2783	140.0	4	1	331.33	-6826.44	-7588.16	5707.63	0.0
74	72.39	2811	140.0	4	1	334.64	-6793.31	-7555.03	5939.6	0.0
75	73.38	2839	140.0	4	1	337.94	-6760.17	-7521.89	6171.57	0.0
76	74.38	2867	140.0	4	1	341.25	-6727.04	-7488.76	6403.54	0.0
77	75.37	2894	140.0	4	1	344.56	-6693.9	-7455.62	6635.5	0.0
78	76.36	2922	140.0	4	1	347.86	-6660.76	-7422.48	6867.48	0.0
79	77.35	2950	140.0	4	1	351.17	-6627.63	-7389.35	7099.44	0.0
80	78.34	2978	140.0	4	1	354.47	-6594.11	-7356.21	7331.41	0.0
81	79.33	3005	140.0	4	1	357.78	-6558.67	-7323.08	7563.38	0.0
82	80.32	3033	140.0	4	1	361.08	-6523.22	-7289.94	7795.35	0.0
83	81.32	3061	140.0	4	1	364.39	-6487.77	-7256.8	8027.32	0.0
84	82.31	3080	0.0	4	1	366.67	-6463.35	-7238.57	8187.17	0.0
85	83.3	3080	0.0	4	1	366.67	-6463.35	-7238.57	8187.17	0.0
86	84.29	3080	0.0	4	1	366.67	-6463.35	-7238.57	8187.17	0.0
87	85.28	3080	0.0	4	1	366.67	-6463.35	-7238.57	8187.17	0.0
88	86.28	3080	0.0	4	1	366.67	-6463.35	-7238.57	8187.17	0.0
89	87.27	3102	420.0	5	1	369.33	-6434.76	-7219.51	8374.3	187.13
90	88.26	3186	420.0	5	1	379.25	-6333.07	-7148.05	-8954.35	883.05
91	89.25	3269	420.0	5	1	389.17	-6233.67	-7048.65	-8843.84	1578.95
92	90.24	3352	420.0	5	1	399.08	-6134.26	-6949.24	-8703.17	2274.86
93	91.23	3436	420.0	5	1	409.0	-6034.85	-6849.83	-8562.51	2970.77
94	92.22	3519	420.0	5	1	418.92	-5935.45	-6750.43	-8420.61	3666.68
95	93.22	3602	420.0	5	1	428.83	-5836.04	-6651.02	-8314.93	4362.59
96	94.21	3686	420.0	5	1	438.75	-5736.63	-6548.24	-8215.52	5058.5
97	95.2	3769	420.0	5	1	448.67	-5636.33	-6441.9	-8116.11	5754.41
98	96.19	3852	420.0	5	1	458.58	-5529.99	-6339.76	-8016.7	6450.32
99	97.18	3935	420.0	5	1	468.5	-5423.67	-6240.36	-7917.3	7146.23
100	98.18	4019	420.0	5	1	478.42	-5317.33	-6140.95	-7817.89	7842.14
101	99.17	4102	420.0	5	1	488.33	-5210.99	-6041.54	-7718.48	8667.77
102	100.16	4185	420.0	5	1	498.25	-5106.66	-5942.13	-7619.07	-8933.06
103	101.15	4269	420.0	5	1	508.17	-5005.03	-5842.73	-7519.67	-8810.74

104	102.14	4347	252.0	5	1	517.52	-4924.53	-5748.99	-7425.93	-8678.11
105	103.13	4397	252.0	5	1	523.47	-4863.55	-5689.35	-7366.29	-8593.72
106	104.13	4447	252.0	5	1	529.42	-4802.57	-5628.29	-7306.65	-8509.32
107	105.12	4497	252.0	5	1	535.37	-4741.59	-5564.49	-7247.86	-8423.73
108	106.11	4547	252.0	5	1	541.32	-4680.6	-5500.68	-7205.32	-8356.86
109	107.1	4600	420.0	5	1	547.67	-4615.52	-5432.59	-7159.93	-8293.21
110	108.09	4684	420.0	5	1	557.58	-4513.89	-5326.26	-7064.52	-8193.8
111	109.08	4767	420.0	5	1	567.5	-4412.25	-5219.92	-6965.11	-8094.39
112	110.07	4850	420.0	5	1	577.42	-4310.62	-5115.2	-6865.71	-7994.99
113	111.07	4934	420.0	5	1	587.33	-4208.99	-5013.57	-6766.3	-7895.58
114	112.06	5014	150.0	5	1	596.87	-4111.2	-4931.11	-6670.65	-7799.93
115	113.05	5043	150.0	5	1	600.42	-4074.91	-4894.82	-6635.15	-7764.43
116	114.04	5073	150.0	5	1	603.96	-4038.6	-4858.51	-6599.61	-7728.92
117	115.03	5103	84.0	5	1	607.45	-4002.85	-4822.76	-6562.21	-7693.95
118	116.03	5119	84.0	5	1	609.43	-3981.7	-4802.42	-6540.93	-7674.06
119	117.02	5136	84.0	5	1	611.41	-3960.44	-4782.1	-6519.67	-7654.18
120	118.01	5153	84.0	5	1	613.4	-3939.17	-4761.77	-6498.4	-7634.3
121	119.0	5169	84.0	5	1	615.38	-3917.91	-4741.45	-6477.14	-7614.42

======= End of Volumetric Displacement Report =======

Figure 6-16. Text Report of Volumetric Displacement

2. "Volume In" (Figure 6-17)

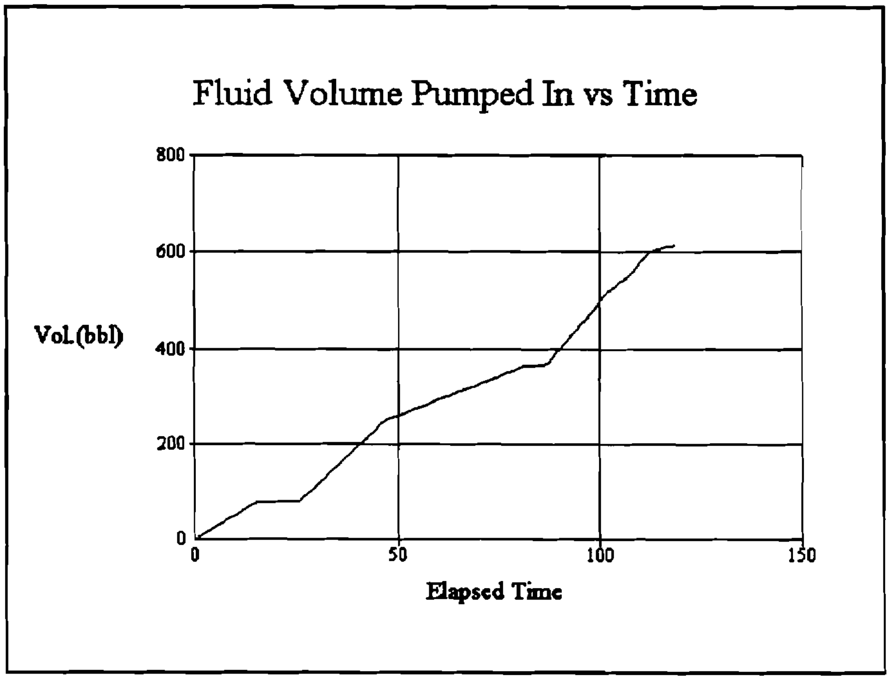


Figure 6-17. Fluid Volume Pumped in Vs. Time

3. "Fluid Fronts" (Figure 6-18)

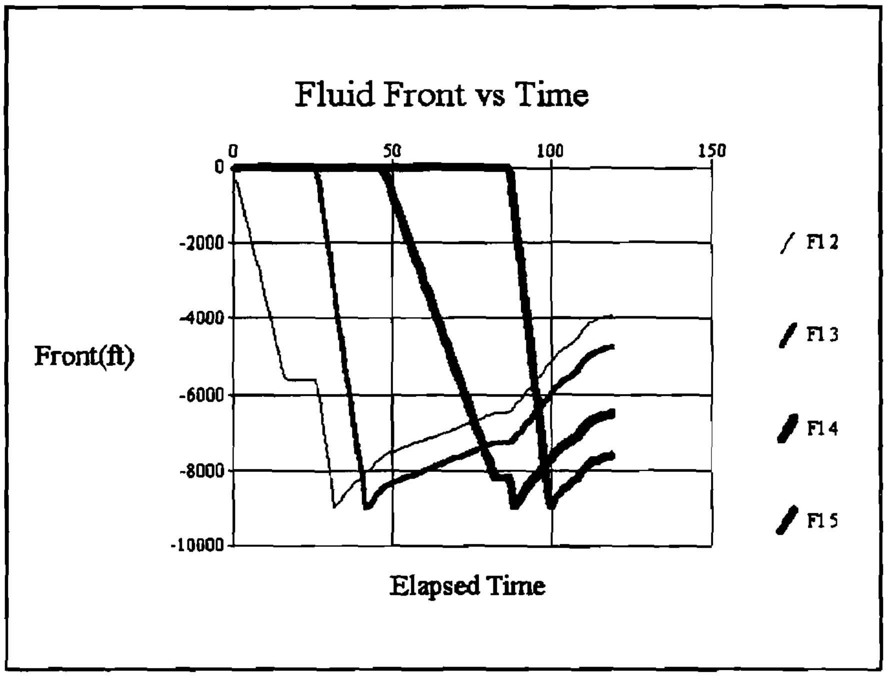


Figure 6-18. Fluid Fronts Vs. Time

4. "Wellbore Schematic"

The printout for this window is not available for this version.

6.4.5 Well Planning/Nozzle Selection

1. "Report" (Figure 6-19)

Well Planning and Nozzle Selection Report

Max. Jet Impact Force

#	Meas. Depth (ft)	Opti. Rate (gpm)	Opti. TFA (in2)	Opti. Sys. P (psi)	Opti. Bit P (psi)	Bit HP (HP)	Bit Vel. (ft/s)	Impact Force (lbf)	F/Hole S (psi)
1	5000.0	694.81	0.514	1825.6	1597.4	647.54	433.48	1482.33	37.95
2	6000.0	654.39	0.484	1825.6	1597.4	609.87	433.48	1396.09	21.87
3	7000.0	619.97	0.459	1825.6	1597.4	577.8	433.48	1322.67	13.81
4	8000.0	509.14	0.423	1825.6	1597.4	474.5	385.7	1220.8	9.56
5	9000.0	458.69	0.397	1825.6	1597.4	427.49	370.56	1144.75	7.11

Optimum Nozzle Selection Variance Analysis

Assumed Optimum Total Nozzle Area(in2) = 0.51

Two Noz. (1/32in)	Area Vari. (%)	Five Noz. (1/32in)	Area Vari. (%)
17.0+19.0	-2.2	11.0+11.0+12.0+12.0+12.0	1.4
18.0+18.0	-2.5	11.0+11.0+11.0+12.0+12.0	-2.1
19.0+19.0	8.6	11.0+12.0+12.0+12.0+12.0	4.8
		11.0+11.0+11.0+11.0+12.0	-5.6
		12.0+12.0+12.0+12.0+12.0	8.3
		10.0+10.0+11.0+12.0+12.0	-8.4
		10.0+11.0+11.0+11.0+12.0	-8.7
		11.0+11.0+11.0+11.0+11.0	-9.0

Three Noz. (1/32in)	Area Vari. (%)	Four Noz. (1/32in)	Area Vari. (%)
15.0+15.0+15.0	1.5	13.0+13.0+13.0+13.0	1.7
14.0+15.0+15.0	-2.8	12.0+13.0+13.0+13.0	-2.1
14.0+14.0+15.0	-7.2	12.0+12.0+13.0+13.0	-5.9
13.0+14.0+15.0	-11.3	12.0+12.0+12.0+13.0	-9.6
14.0+14.0+14.0	-11.6	11.0+11.0+13.0+13.0	-12.8
		11.0+12.0+12.0+13.0	-13.1
		12.0+12.0+12.0+12.0	-13.4

======== End of Well Planning Report ========

Figure 6-19. Text Report of Well Planning

2. "Optimum Flow Rate" (Figure 6-20)

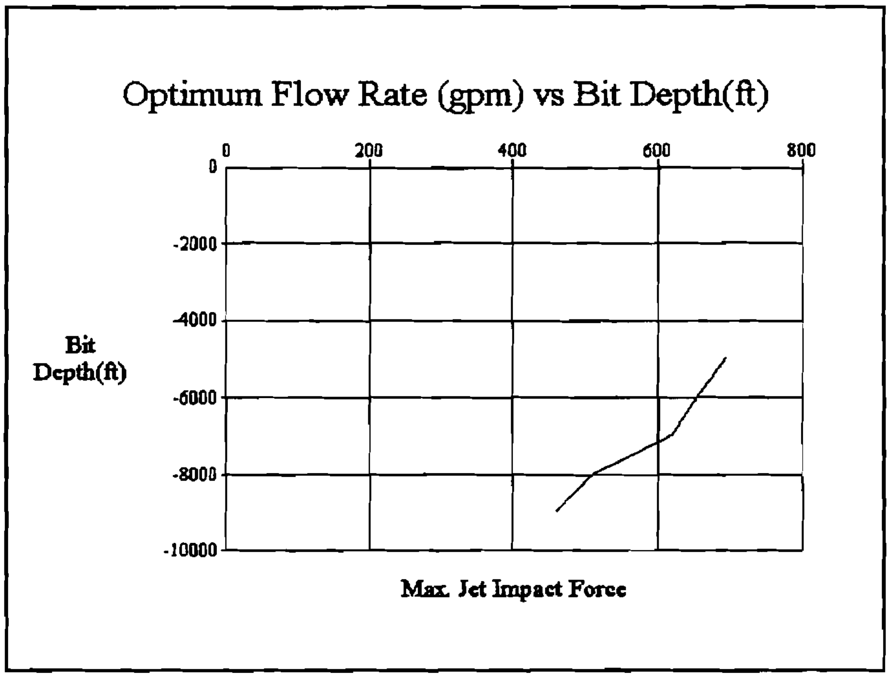


Figure 6-20. Optimum Flow Rate Vs. Bit Depth

3. "Optimum Nozzle Area" (Figure 6-21)

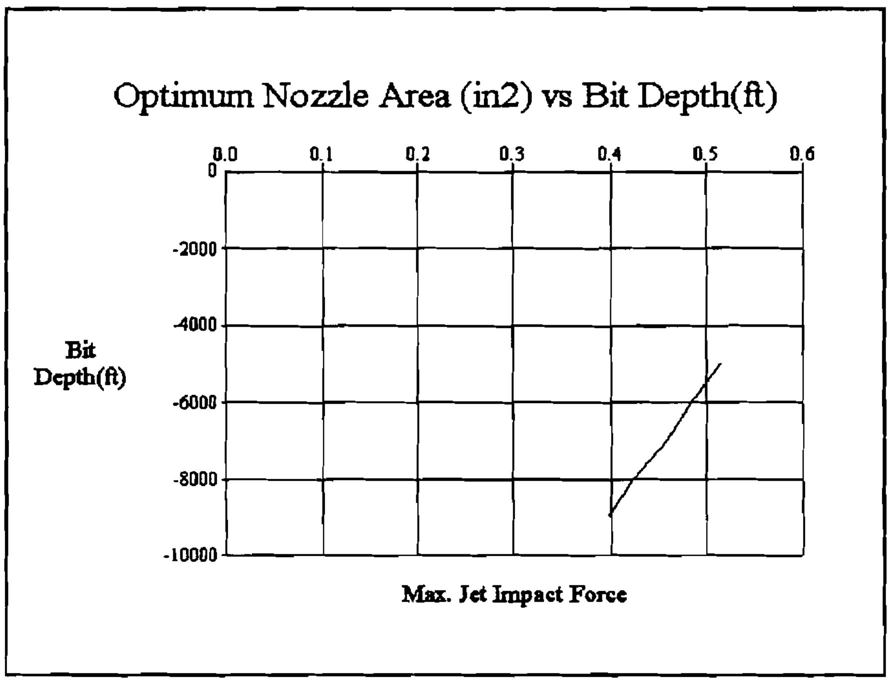


Figure 6-21. Optimum Nozzle Area Vs. Bit Depth

4. "Optimum Pressure" (Figure 6-22)

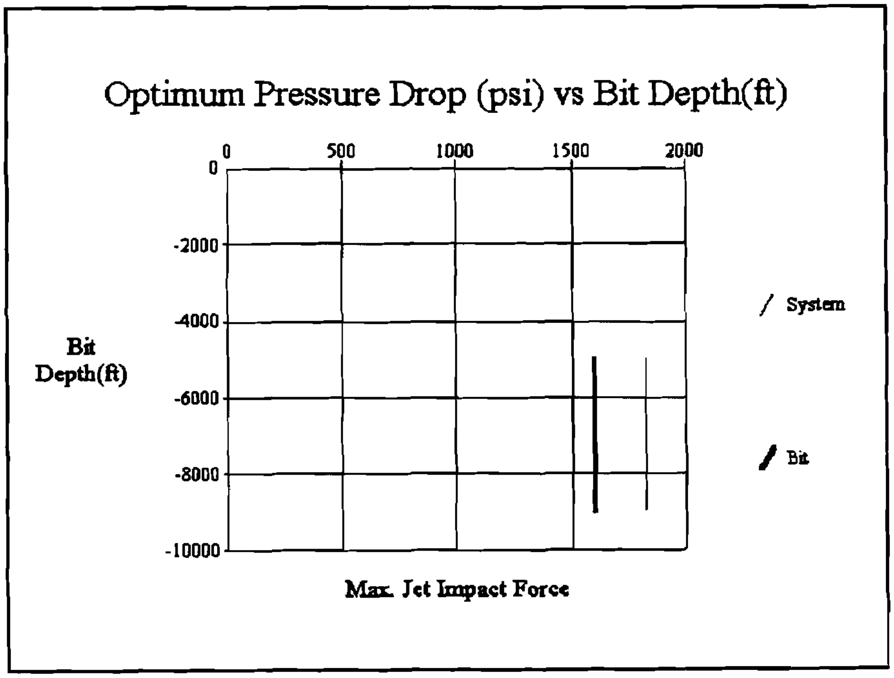


Figure 6-22. Optimum Pressure Drop Vs. Bit Depth

6.5 HYDMOD3 QUICK START

Use the following procedure to rapidly start the HYDMOD3 program.

Install:

1. Start Windows (3.0 or later version).
2. Insert Disk 1 in drive A:.
3. In the File Manager, choose Run from the File menu.
4. Type **A:setup** and press Enter.
5. Follow on-screen instructions. (Please use the default subdirectory).

Run:

6. Double-click the HYDMOD3 icon.
7. In the first window (Introductory Window), click "OK" after it becomes responsive.
8. In the INPUT Window, choose "Open Project..." from the File menu.

9. From the "Open HY3 File" dialog box, click the drive C: in the drive list box, double-click the "HYDMOD3" subdirectory, click the "HYDTEST.HY3" in the file list box, and then click OK.

10. Click "Next" from the Page menu to view other pages of input data (WDI, SDI, FDI, HT3, HP3).

11. Click the "Start" from the Run menu.

12. In the OUTPUT Window that follows, select the text report or graph windows of interest under the desired category to view the output.

13. To print the text report or graph, make the corresponding child window active, select "print report graph" from the File menu.

14. Choose "Return to Main Window" from File menu to return to the Main Window or choose "Exit" to terminate the application.

7. References

1. Bourgoyne, A.T., Jr., et al., 1986: *Applied Drilling Engineering,* Richardson, Texas, Society of Petroleum Engineers.

2. Specification for Materials and Testing for Well Cements API SPECIFICATION 10 (SPEC 10) FIFTH EDITION, July 1, 1990.

3. Leitão, H.C.F. et al., 1990: "General Computerized Well Control Kill Sheet for Drilling Operations with Graphical Display Capabilities," SPE 20327 presented at the Fifth SPE Petroleum Computer Conference held in Denver, Colorado, June 25-28.

4. Security Drill String Systems: *Hydraulics Manual.*

5. Moore, Preston, 1974: *Drilling Practices Manual*, The Petroleum Publishing Company, Tulsa. Oklahoma.

8. Bug Report or Enhancement Suggestion Form

Name: ______________________ Company: ______________________

Address: ______________________ City: ______________ State: ________

Phone No.: ______________________ Fax No.: ______________________

E-Mail: ______________________ Date: ______________________

☐ Bug/Problem Report ☐ Enhancement Suggestion

Program Name and Version Number: ______________________________

____

Bug/Problem Description or Enhancement Suggestion: ______________

____

____

____

____

____

____

____

Other Comments: ____

____

____

____

Data/Parameters Causing Bug

☐ Will be mailed on diskette ☐ Will be faxed ☐ Attached ☐ None

Operating System

MS-DOS Version No.: __________ MS-Windows Version No.:________ (Win 3.1/Win 95)

OS2 ______________ MS-Windows NT Version No.: __________

Other ______________

Please mail, fax, or e-mail to:

Lee Chu
MAURER ENGINEERING INC.
2916 West T.C. Jester
Houston, TX 77018-7098
Ph: 713/683-8227 • Fax: 713/683-6418
E-Mail: mei@maureng.com

Appendix A

Appendix A
Common Conversion Factors in HYDMOD3

Property	Traditional Unit (English)	Other Units	Conv. Factor	Example
Depth	ft	m	0.3048	10,000 ft = 3048 m
Hole Diameter	in.	mm	25.4	12-1/4 in. = 311 mm
Nozzle Size	1/32 in.	mm	0.79	10/32 in. = 7.9 mm
Flow Rate	gpm	m^3/min	0.003785	357 gpm = 1.35 m^3/min
		liter/min	3.785	357 gpm = 1351 lpm
		barrel/min	0.0238	357 gpm = 8.5 bpm
		ft^3/min	0.1337	357 gpm = 47.7 ft^3/min
		(Imp) gpm	0.833	357 gpm = 297 (Imp) gpm
Fluid Velocity	ft/min	m/min	0.3048	100 ft/min = 30.48 m/min
Nozzle Velocity	ft/sec	m/sec	0.3048	300 ft/sec 91.44 m/sec
Mud Weight	ppg	kg/m^3	119.83	10 ppg = 1198.3 kg/m^3
		Spec gravity	0.11983	10 ppg = 1.1983 S.G.
		kPa/m	1.1756	10 ppg = 11.756 kPa/m
		psi/100 ft	5.197	10 ppg = 51.97 psi/100ft
		lb/ft^3	7.481	10 ppg = 74.81 lb/ft^3
Viscosity	cp	lbf-s/ft^2	2.088×10^{-5}	30 cp = 6.26×10^{-4} lbf-s/ft^2
		dyne-s/cm^2	0.01	30 cp = 0.3 dyne-s/cm^2
Yield Point	lbf/100 ft^2	Pa	0.479	15 lbf/100 ft^2 = 7.2 Pa
		dyne/cm^2	4.79	15 lbf/100 ft^2 = 71.9 dyne/cm^2
Power Law Constant K	lbf.s^n/ft^2	Pa-s^n	47.9	0.002 lbf-s^n/ft = 0.0958 Pa-s^n
		dyne-s^n/cm^2	479	0.002 lbf-s^n/ft^2 = 0.958 dyne-s^n/cm^2
		eq cp	47900	0.002 lbf-s^n/ft^2 = 95.8 eq cp
Pressure	psi	kPa	6.895	4000 psi = 27,580 kPa
		atm	0.06804	4000 psi = 272.2 atm
		Bars	0.06895	4000 psi = 275.8 Bars
		kg/cm^2	0.0703	4000 psi = 281.2 kg/cm^2
Force	lbf	N	4.448	600 lbf = 2669 N
		daN	0.4448	600 lbf = 266.9 daN
		tonnes	0.0004536	600 lbf = 0.272 tonnes
		kg	0.4536	600 lbf = 272. kg
ower	HHP	HKW	0.7457	400 HHP = 298.3 HKW

Appendix B

Appendix B

HYDMOD3 Questionnaire

Name: ______________________ Company: ______________________

Address: ______________________ Fax No.: ______________________

This is Version 3.0 of the HYDMOD program. We would appreciate your input and suggestions on this program.

1. Have you had any problems installing and running HYDMOD3? ______________________

2. What do you like best about the program? ______________________

3. What do you like least about the program? ______________________

4. How do you like the input format? ______________________

5. How do you like the graphics presentation? ______________________

6. Is it important for you to have a program listing that you can modify? Yes ___ No ___

7. How can we improve the program? ______________________

Send To: Lee Chu
MAURER ENGINEERING INC.
2916 West T.C. Jester
Houston, Texas 77018-7098
PH: 713/683-8227 • FAX: 713/683-6418

Appendix C

Appendix C
International Keyboard

All DEA computer programs developed at Maurer Engineering Inc. are written using the "U.S." Keyboard. Under this keyboard, the "1000 separator" is a comma, and the "decimal separator" is a period. Thus, the number **one thousand, two hundred and thirty-four and twenty-two/100** is written

1,234.22

Numbers input into the programs are filed in this format.

Problems have occurred for some of our Participants who use the "International Keyboard," as is common in Europe and South America. Here, the same number would be written

1.234,22

Here, the "1000 separator" is a period, and the decimal separator is a comma.

European and South American users find that their computers garble input data being loaded into our DEA programs.

This problem can be readily solved by changing the Windows "numbers format" from the International to the U.S. format. This is accomplished as follows:

1. From the DOS prompt, type

   WIN <ENTER>

   to open WINDOWS.

2. From the Menu bar, choose "Window"either by clicking on "Window" or keying in

   <ALT> W

   This brings down the "Select Window" menu screen, as shown in Figure C-1.

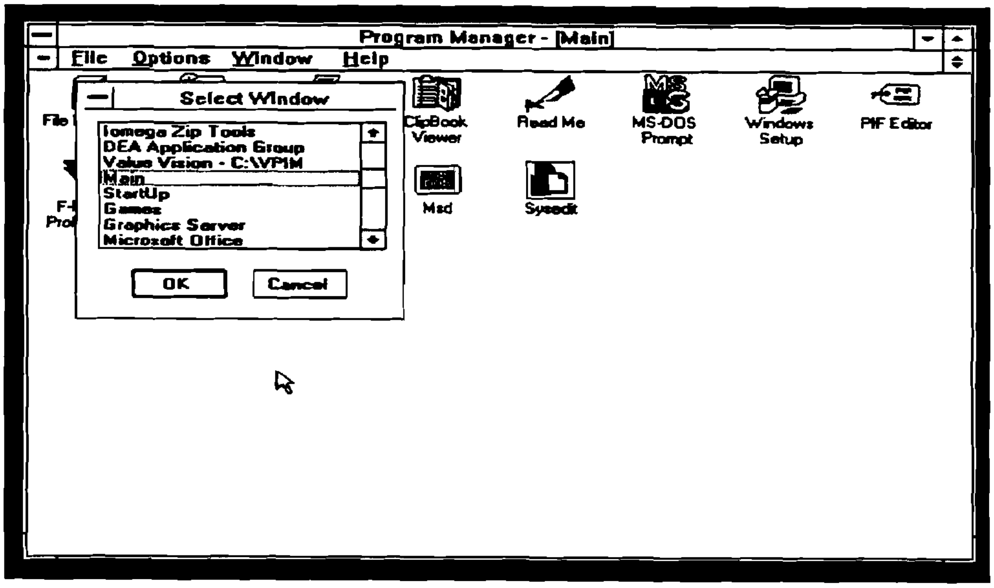


Figure C-1. Windows Menu Bar

3. Select "Main" by clicking on "Main" and then clicking on the "OK" button. This brings down the "Main" menu screen as shown in Figure C-2.

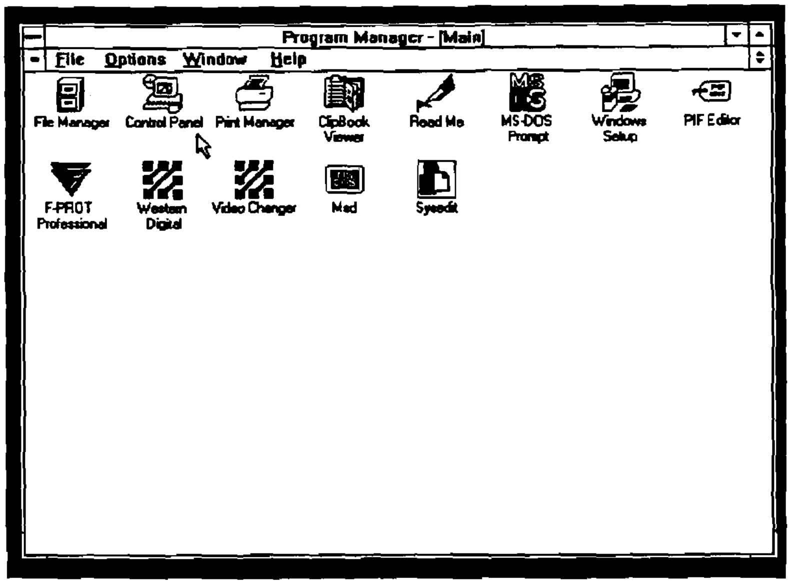


Figure C-2. Main Menu Screen

4. Select the "Control Panel" icon from the "Main" menu screen. This is done by pointing the mouse to this icon and double clicking. This brings up the "Control Panel" menu screen, as shown in Figure C-3.

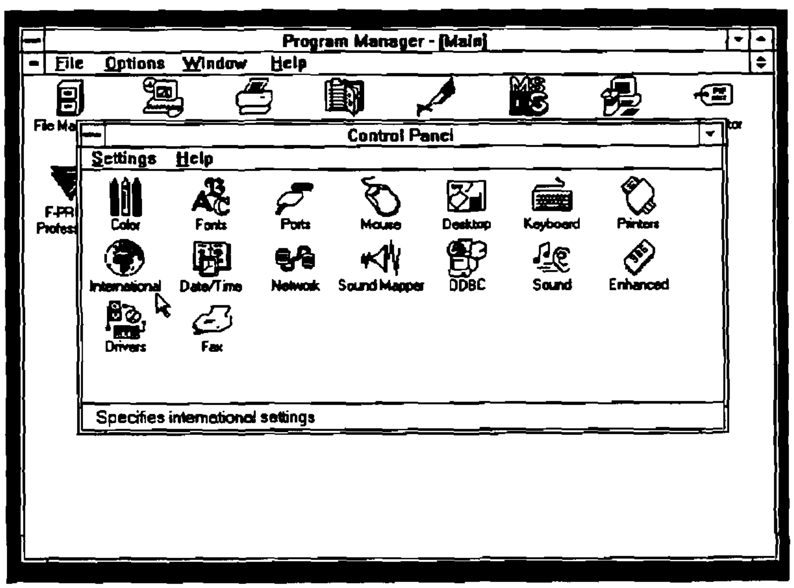


Figure C-3. Control Panel Menu Screen

5. Select the "International" icon from this menu screen by pointing to it with the mouse and double clicking. This brings up the "International" Menu screen, as shown in Figure C-4.

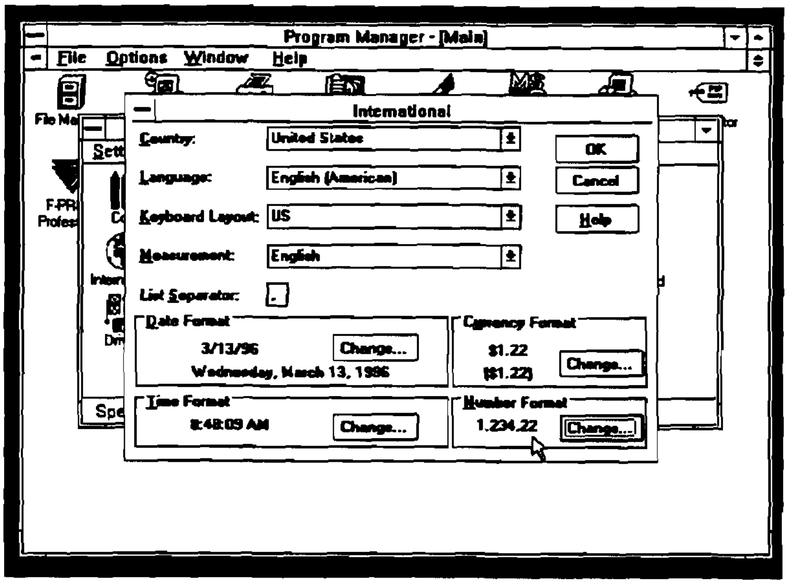


Figure C-4. International Menu Screen

6. In the lower right hand corner of the "International" menu screen is the "Number Format." If the number under the words "Number Format" is

1,234.22

The DEA programs will run. Click on the "Cancel" button in the upper right of this screen and back out to the "Windows"menu screen to run your program.

If the number under the words "Number Format" is

1.234,22

it must be changed before a DEA program will run successfully.

7. To change "Number Format," click on the "Change" button in the "Number Format" box on the screen. This will bring up the "International - Number Format" screen. The "1000 Separator" box will be highlighted, as shown in Figure C-5. Key in

<DEL> ,

This will erase the period from the "1000 separator" box and replace it with a comma.

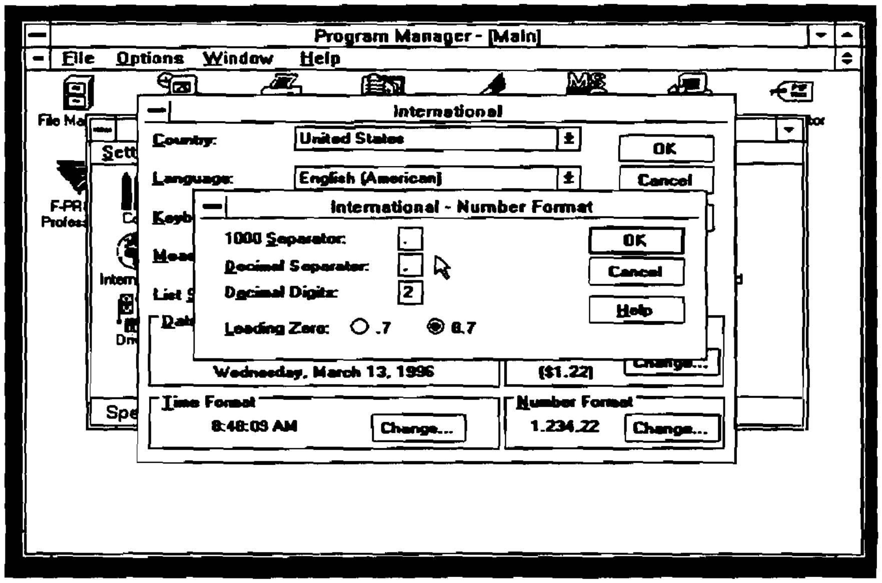


Figure C-5. International — Number Format Screen

8. Either point the mouse to the box labeled "Decimal Separator" and click, or key in

<TAB>

This will highlight the "Decimal Separator" box.

9. Key in

<DEL> .

This will erase the comma from the box and replace it with a period.

10. Either key in

<ENTER>

or point the mouse to the "OK"button in the "International – Number Format" box and click. This will return you to the "International" menu screen, as shown in Figure C-6.

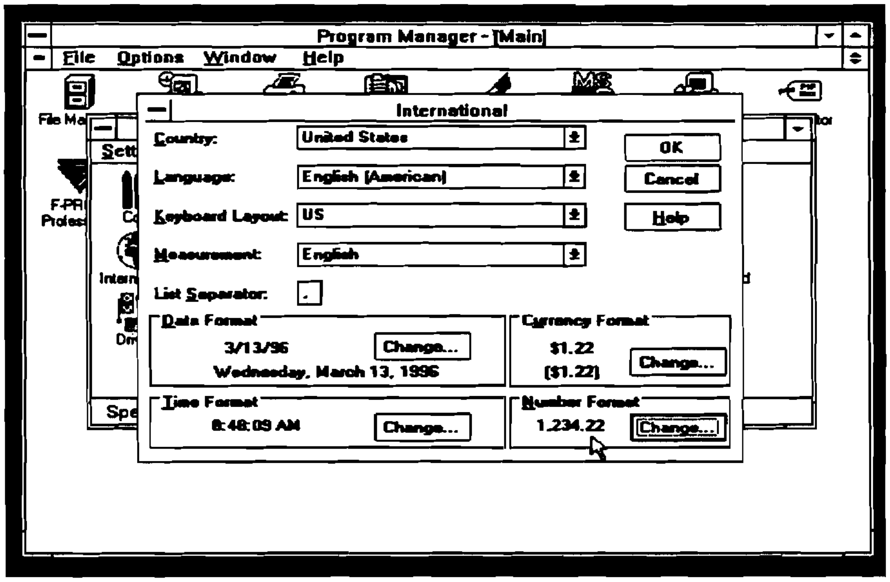


Figure C-6. International Menu Screen, with Correct Number Format