GAS MIGRATION PATHWAYS AND EXTENT

by

Missouri Department of Natural Resources
Division of Environmental Quality
Solid Waste Management Program

<u>Flood Grant Team</u>
Jim Hull, Program Director and Project Officer
Mike Potter, SWMP, Team Leader
Dr. Robert K. Ham, Team Advisor
Bill Duley, Division of Geology and Land Survey
Michele Boussad, SWMP
Frank Dolan, SWMP
Stuart Harlan, SWMP

<u>Field Services</u>
Jackson Bostic, Environmental Services Program
Ron Sheeley, Environmental Services Program
Doug Thompson, Environmental Services Program
Jim Fels, Division of Geology and Land Survey
Larry Pierce, Division of Geology and Land Survey

June 10 791050996

GAS MIGRATION PATHWAYS AND EXTENT

by

Missouri Department of Natural Resources

Flood Grant Team

INTRODUCTION

This study was conducted by the Missouri Department of Natural Resources through a grant provided by the U.S. Environmental Protection Agency to evaluate the impacts of the Great Flood of 1993 on Missouri landfills. The purpose of this portion of the overall project was to study the pathways that provide gas migration from sanitary landfills into surrounding areas. The ultimate goals are to gain a better understanding of gas migration pathways, and the extent of migration, to aid in the prediction, remediation and prevention of gas migration problems.

APPROACH

Six landfills were selected for this study. The primary selection criterion was hydrogeological setting, such that the different settings commonly found in Missouri would be represented. Access to each site and its surroundings was required. Additional criteria included a history of known gas migration or the likelihood of migration; surrounding land use and the potential for impacts should migration occur; and landfill size, construction and operation. Finally, one site was chosen where gas migration was not expected to be an issue because of the presence of shallow groundwater and low permeability clay, and because it is in an undeveloped area.

Each site was tested using a Membrane Interface Probe (MIP) as a screening device to determine the relative concentrations of methane in the surrounding area, the lateral extent of migration at different depths, and potential geological pathways for migration based on soil conductivity. Soil cores were then taken from nearby borings, advanced by either push-probe (Geoprobe) or auger drill rigs, and evaluated visually for gas migration characteristics based on grain size, apparent permeability, moisture content, fractures, and soil classification. These visual observations were checked against MIP results. Gas monitoring wells were then installed, using MIP and boring information as guidance for setting locations and screened intervals to best characterize gas migration. The resulting methane concentration readings, coupled with MIP, core and drilling information, provide the basis for this report.

BACKGROUND

Gas migration from landfills is dependent on a complex set of factors. These factors can be grouped under: (1) driving forces and hence the mechanism causing flow; (2) media or soil properties; (3) temporal changes including gas generation; and (4) landfill cover. The gas migration data, discussion and conclusions presented in this report are dependent on these factors; consequently, a short summary of their importance and interactions is useful at the outset.

(1) Driving forces and mechanisms.

Landfill gas migration is driven by the pressure gradient, in which case the flow is termed convective flow, and by the concentration gradient, giving diffusive flow. Most landfills under consideration here are at pressures close to the atmospheric pressure, because of a lack of cover and/or the permeability of the cover. As the barometric pressure changes, there may be times when the landfill pressure is the same as or even less than the barometric pressure. Landfill gas is typically 50-55% CH_4 and 45-50% CO_2 by volume, resulting in relatively constant concentration gradients to the atmosphere or in soils surrounding the landfill with distance from the landfill. The result is the relatively constant diffusive flow plus the more variable convective flow driving gas migration. Typically convective flow dominates; however, there are times and locations around a landfill when diffusion will be the principal mechanism driving flow.

(2) Medium and soil properties.

The hydraulic conductivity or permeability of soil is obviously important in determining gas migration through it. Gravel is more permeable than sand, which is more permeable than silt, clay, etc. This is a function of the void fraction within the soil, but also the size or effective cross-sectional area of these voids through which methane must pass. Of more importance than soil classification, however, at the landfills studied here are macropores (cracks, fissures, or other discrete pathways) that allow rapid gas migration through soil or rock. Missouri geology is often complex, with multiple layers of soils and rock, each of which provides characteristic pathways for gas migration. Consequently, it is important to look for pathways for migration not suggested by soil classification alone.

Moisture content in general, but specifically the depth to groundwater and the extent of saturated zones must be known. Landfill gas will not migrate through saturated zones and can be confined at depth by perched water, or by very wet conditions in surficial soils, resulting in extensive migration pathways.

(3) Gas generation and other temporal changes.

The effect of time must be superimposed on all of the other factors involved in gas migration. Gas generation will necessarily slow as a landfill decomposes; less substrate is available to the microorganisms generating the gas, and the substrate becomes more resistant. Once a landfill no longer receives incoming waste, the gas generation rate from the entire landfill will decrease, maybe within a few months, depending on the lag time to develop peak generation rates from the most recently placed refuse. Five of the landfills studied here have been closed to new refuse for several years, and the sixth (Southeast) is taking new waste only at high elevations (greater than 80 ft. above surroundings) or on the other side of the landfill and so would not be expected to contribute gas to the area tested. Gas generation rate decreases are expected at all six landfills, but probably are not significant over the relatively short monitoring period of this study.

Other factors changing over time are weather, climate and diurnal variations. Soil moisture changes, especially for surficial soils, result from changes in precipitation, temperature, humidity, sunlight and wind. Vegetation will also have an effect. Vegetation, sunlight and wind can dry soils; temperature and humidity also affect the rate of drying. Precipitation or dew may lower the permeability of soils to gas flow depending on the degree to which the moisture is held in a continuous layer. Freezing rain has been shown to be especially effective in sealing surficial soils, resulting in exceptionally long migration distances. Barometric pressure can have a short term effect on gas migration, as mentioned above.

(4) Landfill cover.

A low permeability landfill cap, such as required under subtitle D to minimize leachate formation, will drastically reduce the flow of landfill gas directly to the atmosphere compared to a sandy or granular cover, as is present on most of the landfills tested here. A low permeability cap can increase the pressure in the landfill and direct gas to the surrounding soils, increasing migration. The pressure gradient is increased, resulting in more convective flow.

All of the factors mentioned here can impact gas migration at the six landfills tested. The results will be interpreted in light of at least the more important factors operable at a given landfill.

METHODS

Each landfill was selected based on a thorough review of historical and geological data, site visits, and access to the site and to the surrounding area. Sites were also selected to be representative of Missouri geological settings and past (pre-subtitle D) landfill practice.

SOIL AND GAS SCREENING WITH MIP

A Membrane Interface Probe (MIP) was used with a Geoprobe push rod rig to provide screening information for soil characteristics and the presence of methane at depths up to 60 feet below ground surface (bgs). A total of 93 probe holes were drilled and tested at the six landfills. This device provides continuous readings for probe temperature, soil conductivity, rate of hole advance, and Photo Ionization Detector (PID) and Flame Ionization Detector (FID) output over the depth of the hole.

According to Geoprobe, the probing speed is generally related to the density of the soil, with rapid speed indicative of soft soils, and slow speed stiff clays, densely packed sands or larger grain sizes. Soil conductivity or resistivity are established tools to classify soils and geologic formations. Clays generally have high conductivity, silts intermediate conductivity, and sand and gravel low conductivity. Figure 1, taken from Geoprobe literature, illustrates the interpretation of a conductivity log. Probe temperature was not used in soil interpretation.

The MIP measures organic soil gases by bringing gas samples to the surface for measurement by detectors widely used in gas chromatography. The MIP has a thin film fluorocarbon polymer membrane mounted in the sidewall, which is in direct contact with the soil. Organic gases in the soil come into contact with the heated membrane, whereupon a portion of the gases will absorb onto and diffuse through the membrane. The concentrations on the internal side of the membrane are low because of continuous sweeping provided by carrier gas (nitrogen was used), which then transports the soil gases via Teflon tubing to the surface for readout by a Flame Ionization Detector (FID) and a Photo Ionization Detector (PID). The combination of a thin, heated membrane and carrier gas flow rate through small diameter tubing provides a quick response (approximately 45 seconds as set up here) from the time of probe advancement to organic gas readout. The PID responds to organic gases (such as volatile organic compounds or VOC's) excluding methane, while the FID responds to both VOC's and methane. Since methane is the dominant gas in a landfill environment, FID readings are used here as an indication of methane concentration. Figure 2, taken from Geoprobe literature, is an example of a MIP log showing the relationship and interpretation of FID, conductivity and speed plots for a 40 foot deep hole. The MIP data are shown on the screen and stored continuously in a portable computer.

Figure 1. Soil Conductivity Interpretation

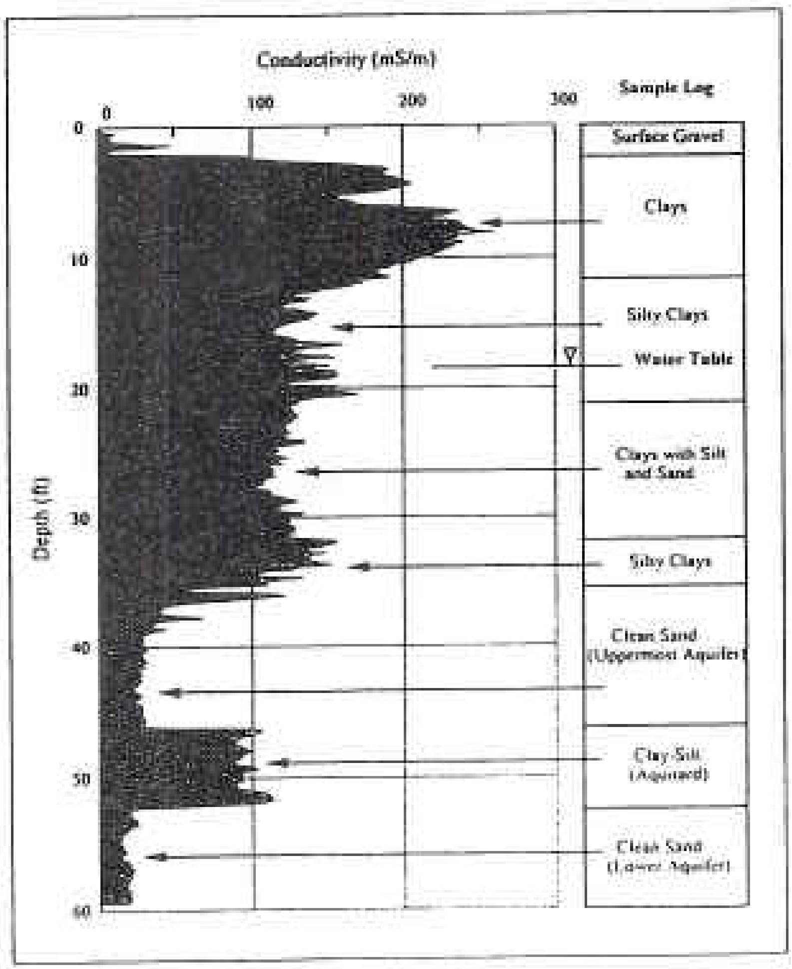
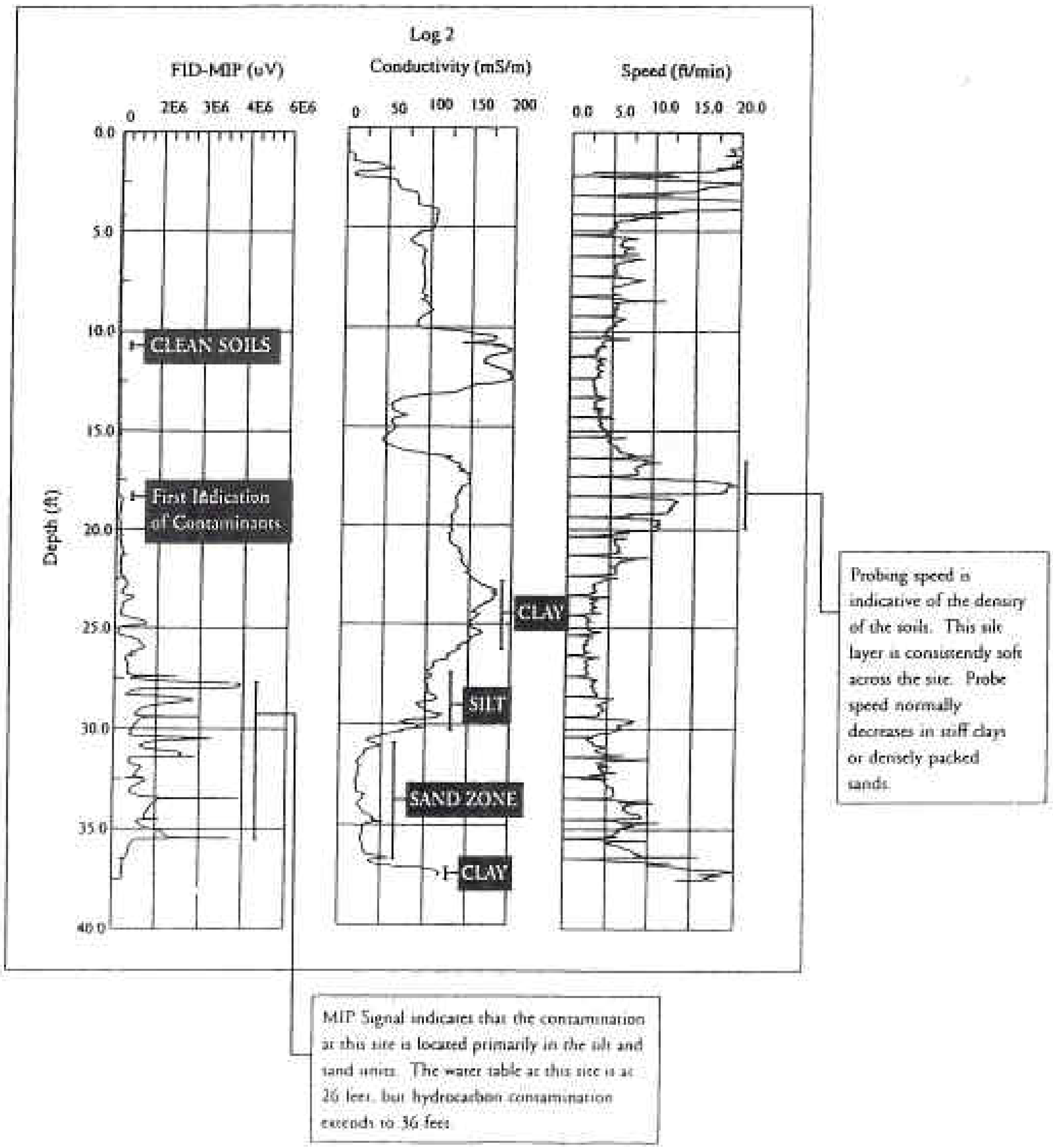


Figure 2. Example MIP Logs and Interpretation



The MIP manufacturer considers FID and PID output to be semi-quantitative with regard to organic soil gas concentrations. Variables that affect output include soil characteristics, soil organic carbon content, soil water content, the volatility of the soil gas constituents, as well as the actual gas concentration. VOC's may be gaseous in the soil, dissolved, or free product, but the readout will differ. Accordingly, MIP data are used here to indicate the presence of methane (FID) and VOC's (PID) primarily, and secondarily as a measure of actual soil gas concentrations.

Calibration tests were completed in a laboratory and in the field to better understand and possibly quantify the relationship between FID response and methane gas concentrations. Methane was used for calibration because it is volatile and not soluble or readily adsorbed onto soil. This lessens the effects of soil moisture, organic content and other soil characteristics. Further, methane is the gas of interest for this project.

A complication developed in this project regarding the use of FID data, except for the two calibration tests. During initial laboratory calibration attempts the MIP malfunctioned, with the FID readouts becoming increasingly unrealistic. Attempts to repair the probe and the FID failed, and finally the entire unit was returned to the manufacturer and replaced or repaired. It was determined that the FID readings that had been taken up to the laboratory calibration attempt were too high, so the lab calibration results given here cannot be applied directly to earlier field data. It is believed, however, that the field data are useful in a relative sense in that high readings do relate to higher concentrations of methane in the soil, etc. Accordingly, these field data will be used throughout this report in a relative sense (i.e. indicating high, medium and low concentrations of methane), with numerical values used only when gas wells were constructed and sampled for direct methane measurements. It is further believed that the MIP results were useful in guiding well locations and screened intervals to intercept desired methane migration pathways.

Calibration of the MIP in Laboratory Conditions

A steel test cell was assembled, into which the MIP was placed. The cell had inlet and outlet ports to allow gas flow through it. After sealing, air was pumped through the cell and the FID reading noted. The outlet gas was analyzed continuously with a Bachrach TLV Sniffer (up to 1% CH_4) and/or a Landtec GA-90 (greater than 1% CH_4). Controlled methane additions were made using standard calibration gas cylinders via the inlet port and the FID and outlet methane concentrations recorded, up to approximately 50% methane. The results are given in Table 1 and are plotted in Figure 3 (excluding test number 9). The plot also shows the results of a fit to the following second order polynomial:

$$\text{FID reading} = -333.587\ (\%\ CH_4)^2 + 35452.9\ (\%\ CH_4) + 33482.9$$

The coefficient of determination (R^2) value for this fit is 0.997.

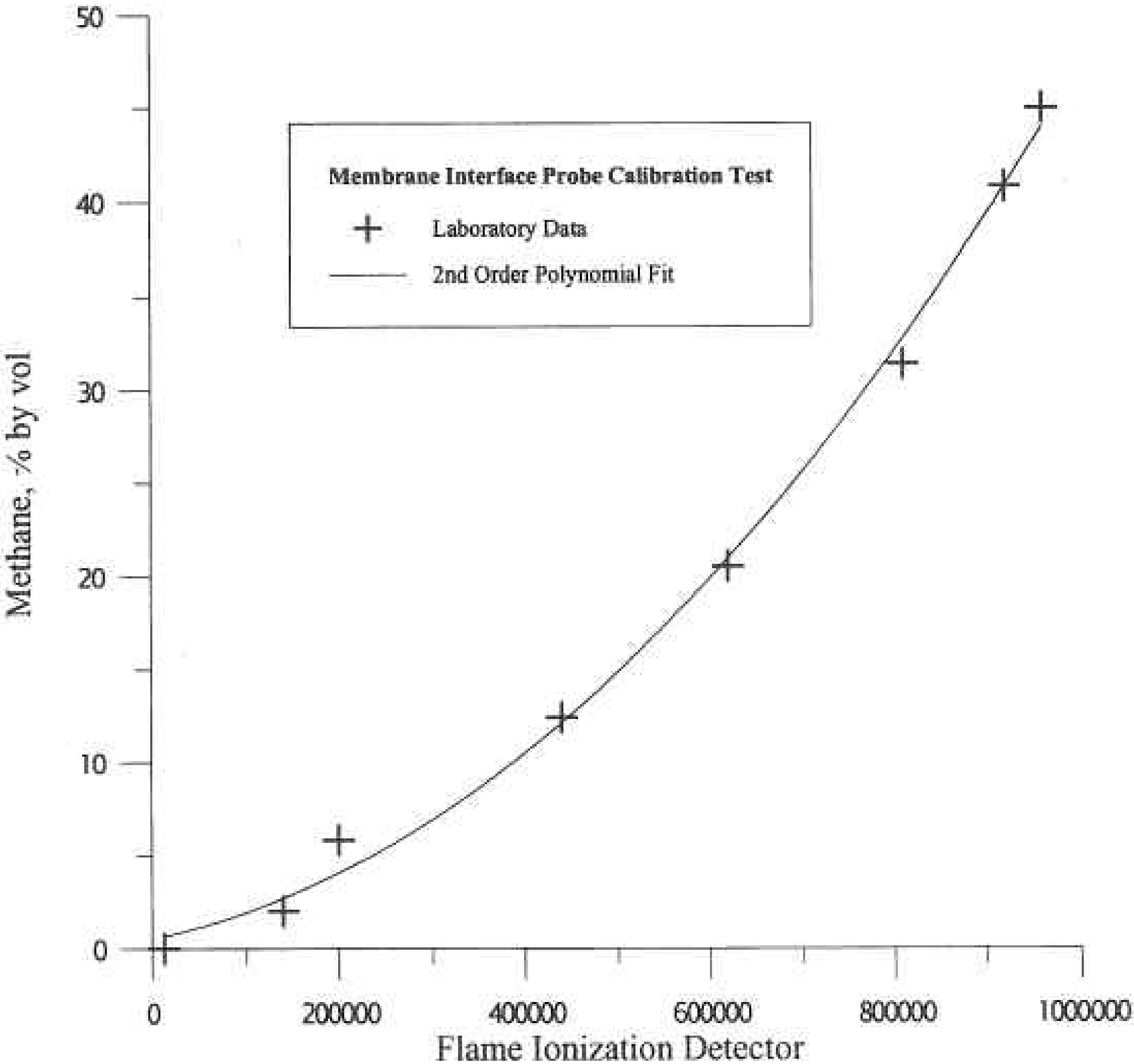
These data show a clear relationship between FID reading and the % CH_4 in an otherwise empty gas-filled container. Although promising, these results do not necessarily apply to real world soil gas testing, however, because of the various factors cited previously. Accordingly, a second calibration procedure was completed in the field.

Calibration of MIP in Field Conditions

A special test was run at JZ landfill to provide field calibration of the FID readings. The MIP was used adjacent to gas monitoring wells selected on the basis of the predicted range of

Table 1. Membrane Interface Probe Calibration Test, 2/2/98				
Test Number	Calibration Gas Methane Concentration	Average MIP FID Reading	Bachrach TLV Sniffer Reading, ppm †	Landtec GA-90 Reading, % by vol
1	1	1.3×10^4	250	0.0
2	2.5	1.4×10^5	n/a	2.0 ± 0.2
3	15	2.0×10^5	n/a	5.8 ± 0.1
4	15	4.4×10^5	n/a	12.4 ± 0.2
5	50	6.2×10^5	n/a	20.5 ± 0.3
6	50	8.1×10^5	n/a	31.4 ± 0.2
7	50	9.2×10^5	n/a	40.8 ± 0.5
8	50	9.6×10^5	n/a	45.0 ± 0.2
9	50	9.7×10^5 to 1.1×10^6	n/a	47.7 ± 0.3
† Bachrach TLV Sniffer has a range of 0 - 10,000 ppm				

Figure 3. MIP-FID
Laboratory Calibration



methane concentrations, accessibility and time constraints. (Well locations are shown in Figure 7, and construction specifics are given in Table 4.) Five probes were completed, with three of them having wells with two screened intervals for a total of eight wells. One well provided no gas sample because of water intrusion. The maximum FID readings over the screened intervals and the corresponding methane concentrations from the gas monitoring wells are given in Table 2 and plotted along with the laboratory calibration results presented in the previous section in Figure 4. The complete MIP logs are given in Appendix A.

The field results are not conclusive in that the FID readings and methane concentrations are clustered at low or high values; there are no points between these extremes. Nevertheless, a straight line fit is reasonable as shown, indicating that FID readings did increase at higher methane concentrations. More important, however, is the overlap or consistency with laboratory results. Given the variability inherent with field FID results because of varying methane concentrations, soils, soil moisture contents, etc., and the shape of the laboratory calibration curve with its relative lack of sensitivity of FID readings at higher methane concentrations, it is surprising the field and laboratory results are as consistent as they are. It is concluded that the laboratory calibration does relate to field results and, at least within the scope of this project, can be used as an indication of methane soil gas concentrations.

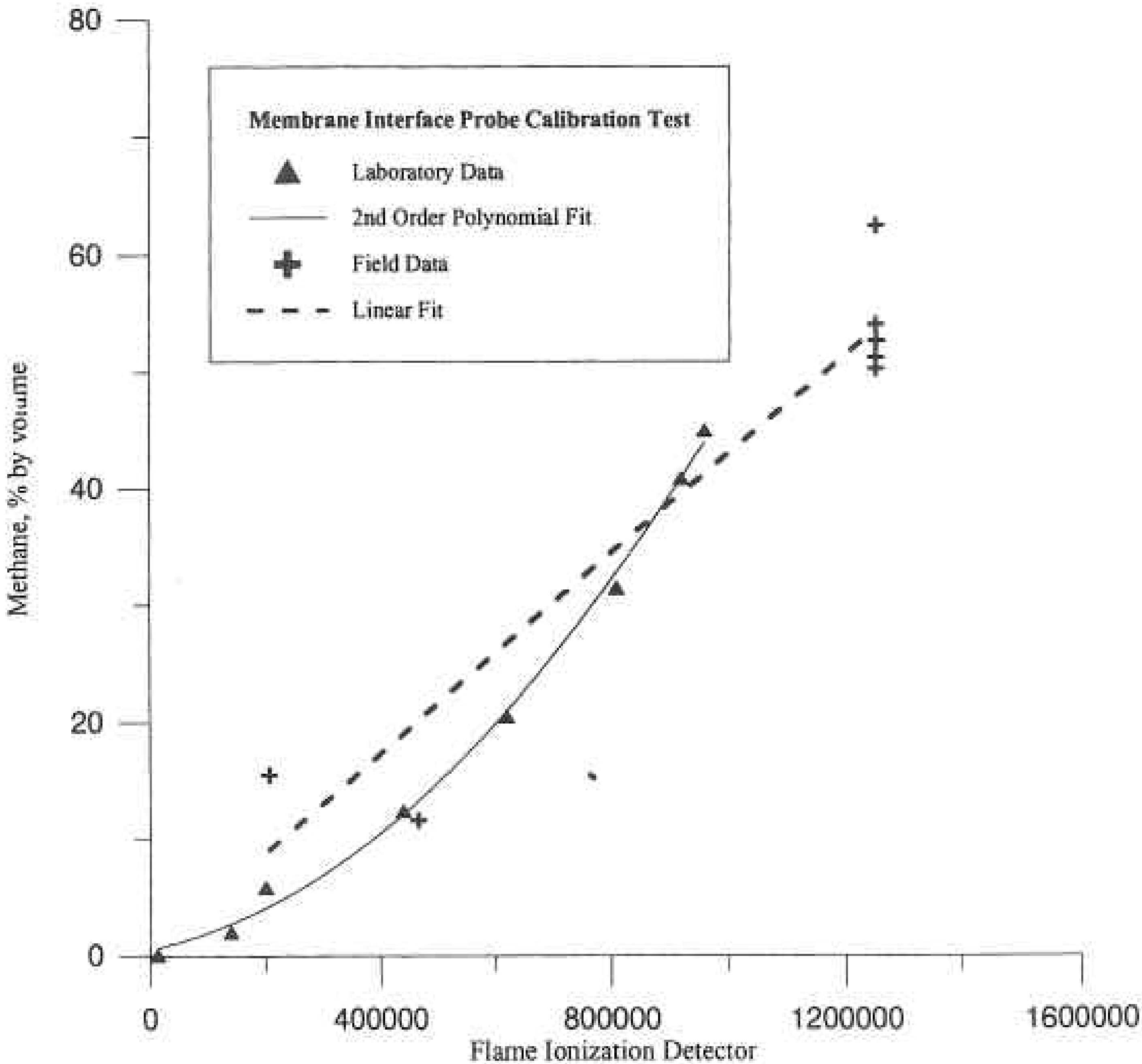
MIP Field Methods

The MIP was used to indicate the pathways for methane migration and the extent of migration from the six landfills. These indications were then confirmed by placing and sampling

Table 2. MIP-FID Field Calibration Data		
Well Number	FID Reading*	Methane Reading
JZ-11	1.25×10^6	62.5
JZ-12	1.25×10^6	54.1
JZ-13	1.25×10^6	51.3
JZ-14	1.25×10^6	50.3
JZ-15	1.25×10^6	52.7
JZ-23	2.06×10^5	15.5
JZ-24	4.66×10^5	11.6

*Maximum FID reading recorded over depth equivalent to screened interval of well

Figure 4. MIP-FID
Field and Laboratory Calibration



gas monitoring wells. Because of the expense and time required to install and test wells relative to MIP testing, more probe tests were conducted than wells installed.

The MIP survey generally started close to the landfill and worked outward until ideally no gas was found. Normally, the area tested was to only one side of a landfill, selected according to topography, known geology, land use, and ease of access. Once one round of MIP testing was completed and the results analyzed, some sites were revisited to fill in data gaps or reduce uncertainties.

SOIL GAS MONITORING WELLS

Gas monitoring wells were located based on MIP results to verify these results and to provide additional information over time at JZ, Modern Sanitation and Centropolis landfills. Wells were installed at Southeast and Mexico landfills prior to MIP use. At Renfro numerous wells had been installed and monitored in a built-up area of suspected gas migration and next to the landfill. No MIP work was done at Renfro because of this prior work; however, a set of three additional gas monitoring wells were installed between the built-up area and the landfill. The three screen intervals were selected to monitor surficial materials above bedrock.

Wells were installed with either a Geoprobe push probe rig or an auger rig. The push probe produced a 2 inch hole into which ½ inch screen and riser was placed; the auger rig used a 6 inch auger and a 2 inch screen and riser. Sand was placed around and 6 inches above the screen, and bentonite slurry topped by 12 to 18 inches of concrete was placed over the sand to the ground surface. The screened interval was set to cover zones of high FID readings if the MIP was done first.

Wells were sampled weekly for four months, September through December of 1997, using a Landtec GA-90 for gas analysis.

SOIL CORES

Soil cores were taken during gas monitoring well construction. Soil cores taken with the auger rig were to be analyzed by the Division of Geology and Land Surveying of the Missouri Department of Natural Resources (DGLS), but somehow were lost in transit and so were never analyzed. Cores taken with the push-probe rig were sent to a soil scientist for analysis, the results of which form the basis for most of the soil descriptions presented in this report. Soil core results will be compared to MIP logs to determine characteristics of gas bearing and non-gas bearing zones and to provide an absolute basis for interpretation of conductivity logs.

DATA ANALYSIS

The MIP probe provides a set of data every 1/20 of a foot while being driven into the ground. These data were then reduced to provide a representative value for every foot, using a BASIC computer program. The result was drive speed, soil conductivity, PID max (maximum), FID max, and temperature for each foot of depth. Each probe location was surveyed so accurate plots could be prepared compiling the results.

The FID max values were then plotted as 2 dimension plots to find areas where additional probing was needed at each site using the Environmental Visualization System (EVS) software uncertainty routine. This routine predicts gas levels over the study area based on the maximum gas levels at each probe location. It then creates a map of confidence in these gas levels, which ranges from high to low confidence, and in so doing indicates areas where more probing is needed. Sites were then revisited and additional MIP work performed to reduce this uncertainty.

Figures 5 and 6 illustrate this process of reducing uncertainty at JZ landfill. In Figure 5, the computer has examined the highest FID readings for each MIP log for locations 1 through 11, compared them, and indicated areas of relative confidence in predicting FID readings within the study area. Areas of highest uncertainty are areas where nearby probes gave contradictory FID readings, or where few or no probes were located. Emphasis is placed on areas of highest FID readings in this computer program, to emphasize areas likely to have high readings but with insufficient or contradictory data to provide confidence that the values are indeed high. Figure 6 shows the locations and resulting uncertainty after nine additional MIP tests were performed. This generally reduced the levels of uncertainty within the original study area. As would be expected, areas of high uncertainty tend to be along the side of the study area, where relatively few probes are located and where no probes are present outside of the study area. (Probes 16 and 19 were not completed and are not shown in the Figure.)

Table 3 gives the number of probes completed at each site during the initial and follow-up testing. All probe data will be used in this report.

In addition to the uncertainty plots, FID readings were compiled to create 3D plots over the study areas and depths, and cross-sections selected to help visualize gas presence as a function of depth and horizontal distance.

The EVS interpolates between data points to produce a complete picture of FID readings (methane concentrations) even if there are only a few data points. In some cases the EVS predicted areas where FID readings would be high even if no MIP probes were completed there.

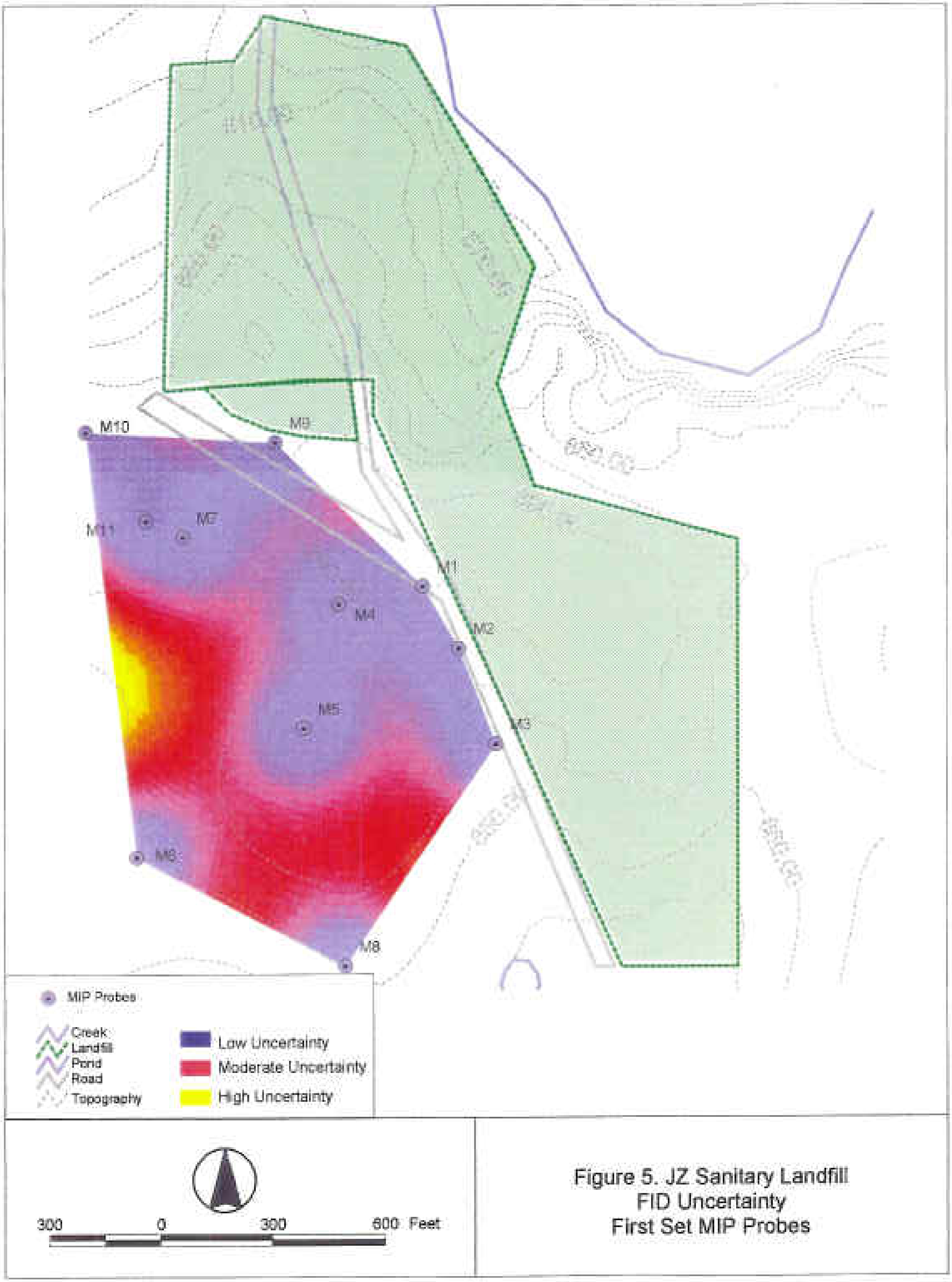


Figure 5. JZ Sanitary Landfill
FID Uncertainty
First Set MIP Probes

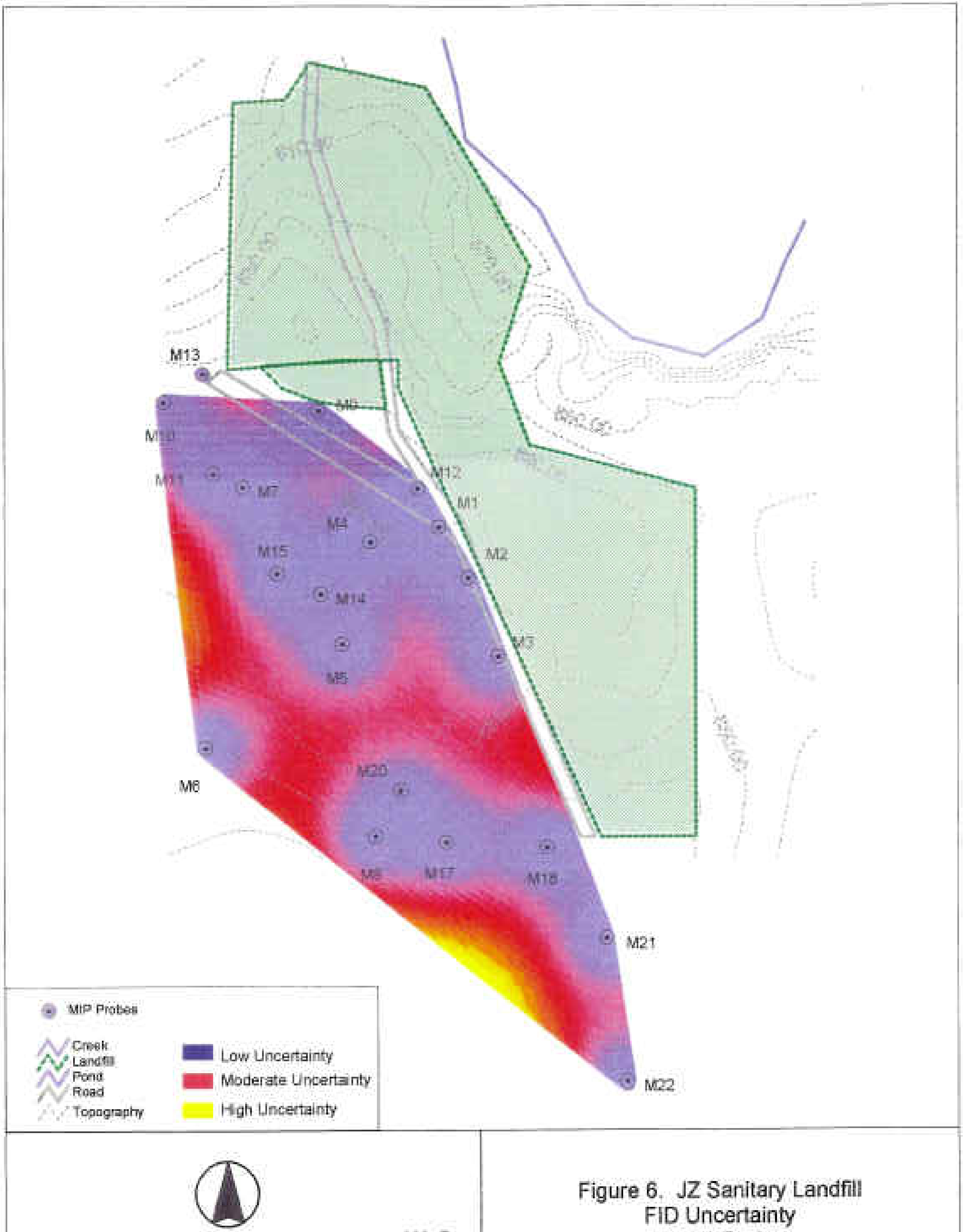


Figure 6. JZ Sanitary Landfill
FID Uncertainty
All MIP Probes

Table 3. Number of Probe Locations at Each Site		
Facility	First Site Visit	Second Site Visit
Centropolis SLF	9	6
JZ SLF	11	9
Mexico SLF	8	n/a†
Modern Sanitation SLF	10	13
Southeast SLF	9	n/a†
†Only one set of MIP probes was completed at these sites.		

In some cases, these predictions may be quite misleading. Attempts were made to fill in data gaps with more probes, but time and budget constraints did not allow for all gaps to be addressed. Accordingly, areas with few or no probe holes are areas where there is little confidence in the results.

In many cases the landfill was included in the study area, but no probing was done in or immediately adjacent to the landfill due to the certainty of landfill gas being there. This produced, in some cases, plots suggesting that the landfill has little or no methane gas, which of course is false.

Lastly, soil core results and soil conductivities from the MIP log will be presented on the same plot for selected probe locations, along with methane concentrations measured for any wells and their screened intervals. These figures provide the best integration of all the information gathered for this report and can be used to reinforce and supplement the 3D and 2D cross-section plots from FID data alone.

RESULTS AND DISCUSSION OF RESULTS AT EACH LANDFILL

JZ LANDFILL

JZ Sanitary Landfill, located near Wright City in Warren County, is bordered on the north-northwest by a demolition waste landfill. A second demolition waste landfill is within a few hundred feet to the northwest. To the north, east and south the topography drops within a few hundred feet to creeks (north and south) or a quarry (east) which are below the base grade of the landfill. To the west, which is the area of study, the surface elevation drops off more slowly. This area is close to 1000 feet (east to west) by approximately 2000 feet (north to south). This is the area of concern for gas migration. Landfill gas was discovered here several years ago when bubbles were observed in puddles of water. A grid of shallow gas probes was placed to define near-surface gas migration patterns, and high concentrations of methane were measured. The soil in the study area is derived from glacial drift and contains sand lenses from a preglacial stream channel at depth. These lenses and joints within the glacial till provide potential pathways for gas migration.

MIP and Soils

Figure 7 shows the locations of the 22 MIP probes and the 24 gas monitoring wells installed in the study area. Appendix B gives MIP and soil logs for the seven locations tied to gas monitoring wells and compiled in Figures 11 to 17; Appendix C gives additional MIP and soil logs. The only probes where high FID readings were not encountered (defined as greater than 1×10^5) were M10, M11 and M13 in the NW corner of the study area, and M17, M21 and M22 in the SE corner. These locations are lower (ground surface) than other parts of the study area, and in each location there is a pond nearby which may have an impact. Probe depths ranged from 10 to 50 feet.

Those probes with high FID readings had high readings throughout except near the surface and near the bottom. Refusal was not encountered; surficial material thickness is greater than 50 feet for most of the study area. Near-surface surficial materials are composed of silty, sandy clay till. A preglacial channel composed of silt, sand and gravel is present in much of the study area at greater depths and at probe locations with higher surface elevations. The thickness of the coarse-grained layer is unknown. Soil conductivity logs show fine-grained layers towards the

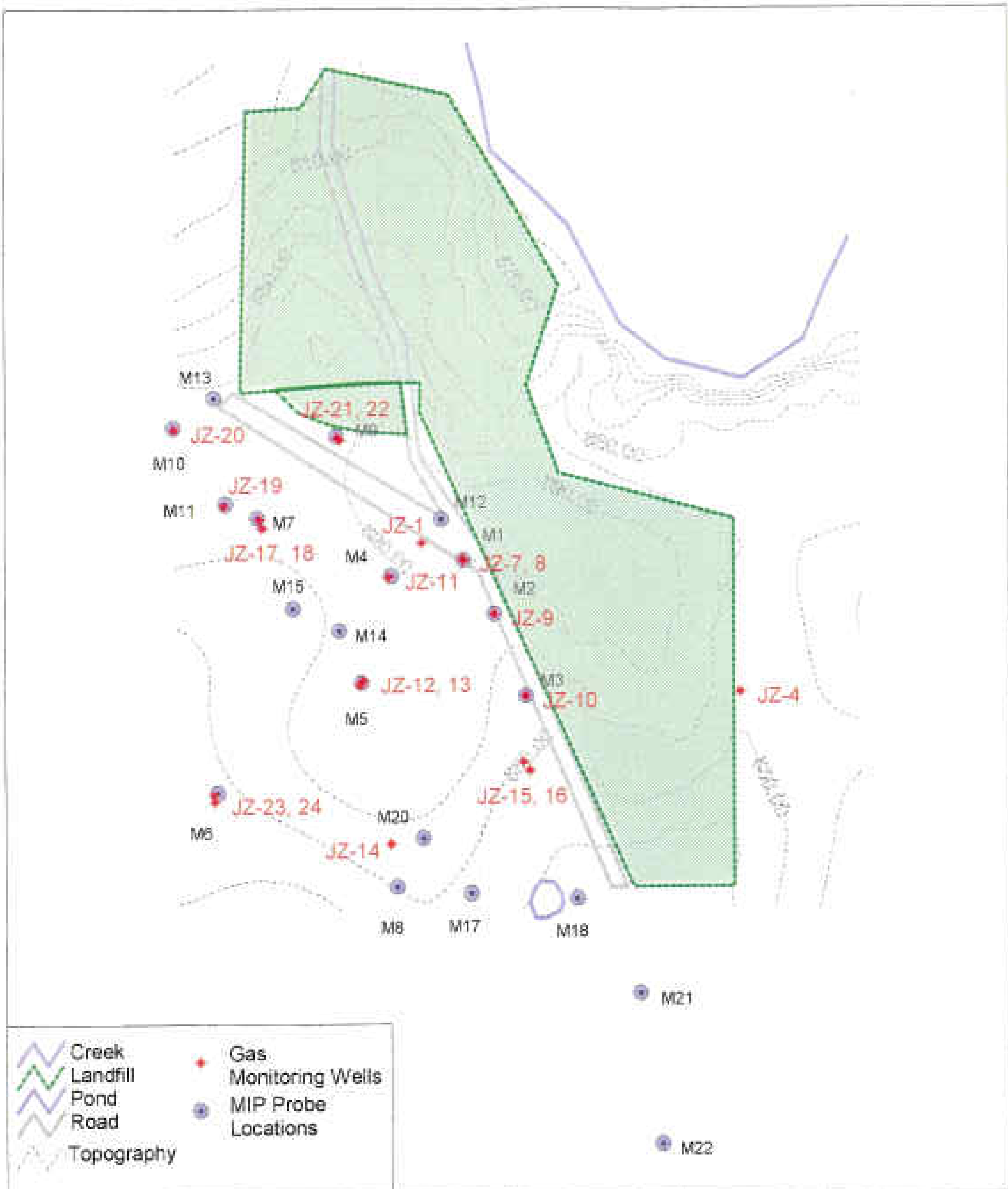


Figure 7
JZ Sanitary Landfill Study Area

surface, becoming progressively coarser with depth. Many of the logs and soil cores indicated a fine-grained layer (till) near the surface with low FID readings, suggesting this layer acts as a cap limiting gas migration to the surface and promoting migration laterally in deeper zones. (See MIP logs for M4, M6, M8, M9, M10, M12, M13, M14, M17 and M18).

Gas Monitoring Wells

Well descriptions, average corrected methane concentrations* and FID results are given in Table 4. Of the 20 wells involved in this task, only numbers 19 and 20 in the NW corner of the study area had basically no methane; excluding wells with little or no flow, the other wells had concentrations up to 50% methane by volume. Screened intervals ranged from 4 to 42.5 feet bgs, indicating methane present over the study area over a thick zone. The most distant wells from the landfill that contained methane are numbers 23 and 24. Number 23 is the deeper of the two, screened at 25-40 feet bgs, and had an average of 16.8% CH_4. Well 24 had 0.9% CH_4 over its 11-20 foot screen. These wells are approximately 1000 feet from the landfill.

Comparison of Soil Cores, MIP Logs, and Gas Monitoring Well Results

Figure 8 is MIP log number 4, which was used as guidance to construct gas monitoring well 11. Table 5 is the soil log report based on the corresponding cores and analysis. This soils information is plotted as Figure 9. The MIP log provides curves for probe advancement speed (top), soil conductivity, PID, FID and membrane temperature. Of interest here is the

---

* Corrected methane concentration refers to the adjustment of methane concentrations read by a meter to account for air intrusion. See Flood Grant Report titled "An Analysis of Landfill Gas Monitoring Well Design and Construction" for a detailed explanation of this calculation.

Table 4. Gas Monitoring Wells, JZ Sanitary Landfill					
Well Number	Screen, ft	MIP Log	Soil Log	Avg. Corrected CH_4†	FID Average
1	6 - 15	none	#2	19.4	N/A
4	6-15	none	#1	N/A	N/A
7	21 - 31	1	none	58.9	8.3×10^5
8	9 - 14	1	none	56.5	9.5×10^5
9	4 - 9	2	none	43.3	1.3×10^6
10	5 - 10	3b2	none	1.6‡	6.1×10^5
11	25 - 40	4	4	49.5	1.2×10^6
12	30.5 - 42.5	5	5	38.1	1.2×10^6
13	13 - 28	5	5	41.6	1.2×10^6
14	12 - 24	8	8	47.1	1.1×10^6
15	24-42	none	19	46.0	N/A
16	11 - 20	none	19	14.3††	6.1×10^5
17	21 - 30	7	7	25.5	8.0×10^5
18	13 - 16	7	7	4.9††	1.3×10^6
19	9 - 12	11	11	0.0	4.1×10^4
20	11.5 - 17.5	10r	10	1.5*	4.7×10^4
21	26 - 41	9	9	7.8††	1.1×10^6
22	11 - 20	9	9	26.3	1.1×10^6
23	25 - 40	6	6	16.8	3.8×10^5
24	11 - 20	6	6	0.9	4.1×10^3

† Average of readings from September through December 1997, corrected methane (% by volume)
‡ At some times well contains water covering screened interval
†† Pumping the well during sampling creates a vacuum indicating very little gas flow into the well
* All readings are zero except one reading which may be due to not purging sampling hose prior to sampling

Figure 8. Example MIP Data Log

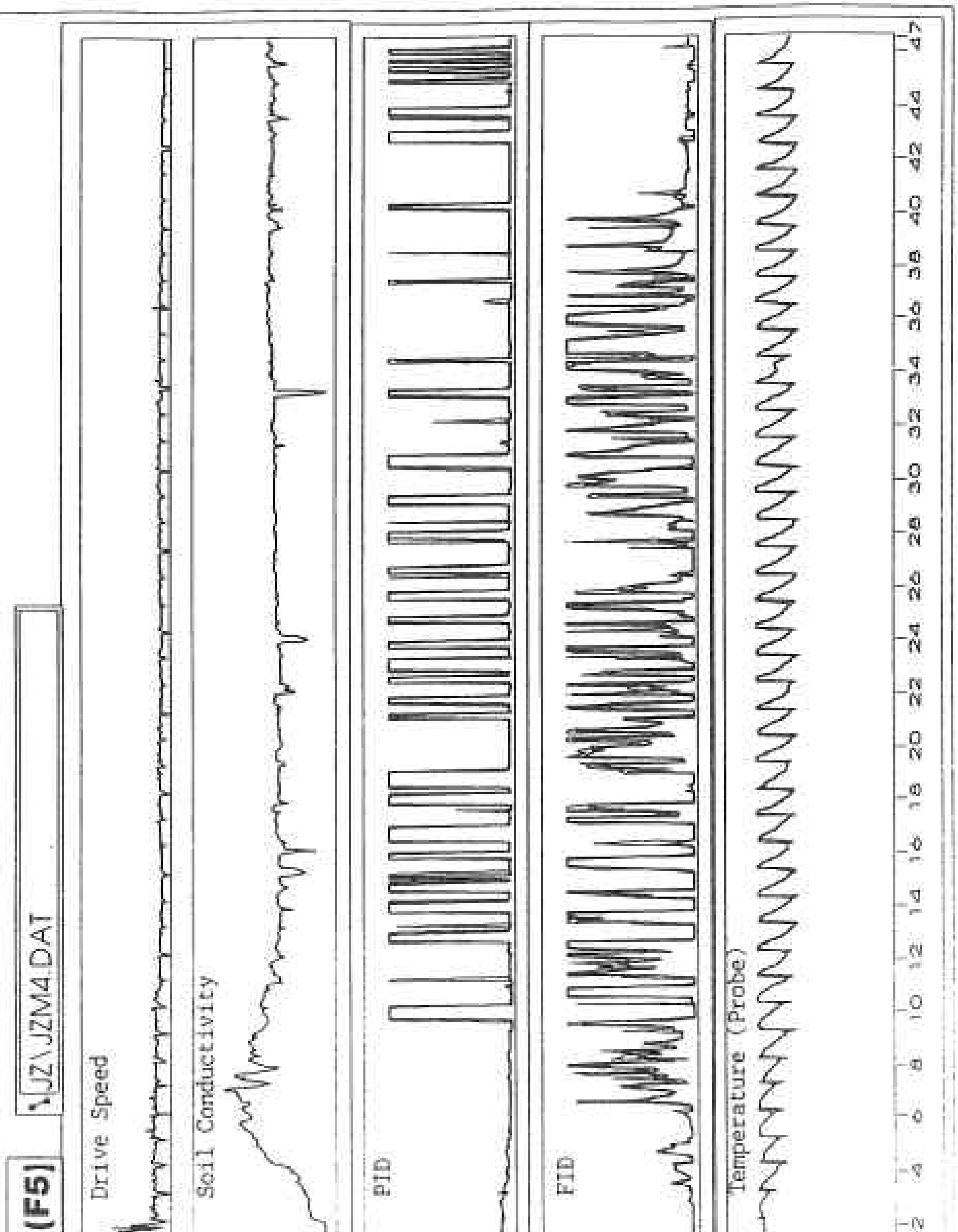


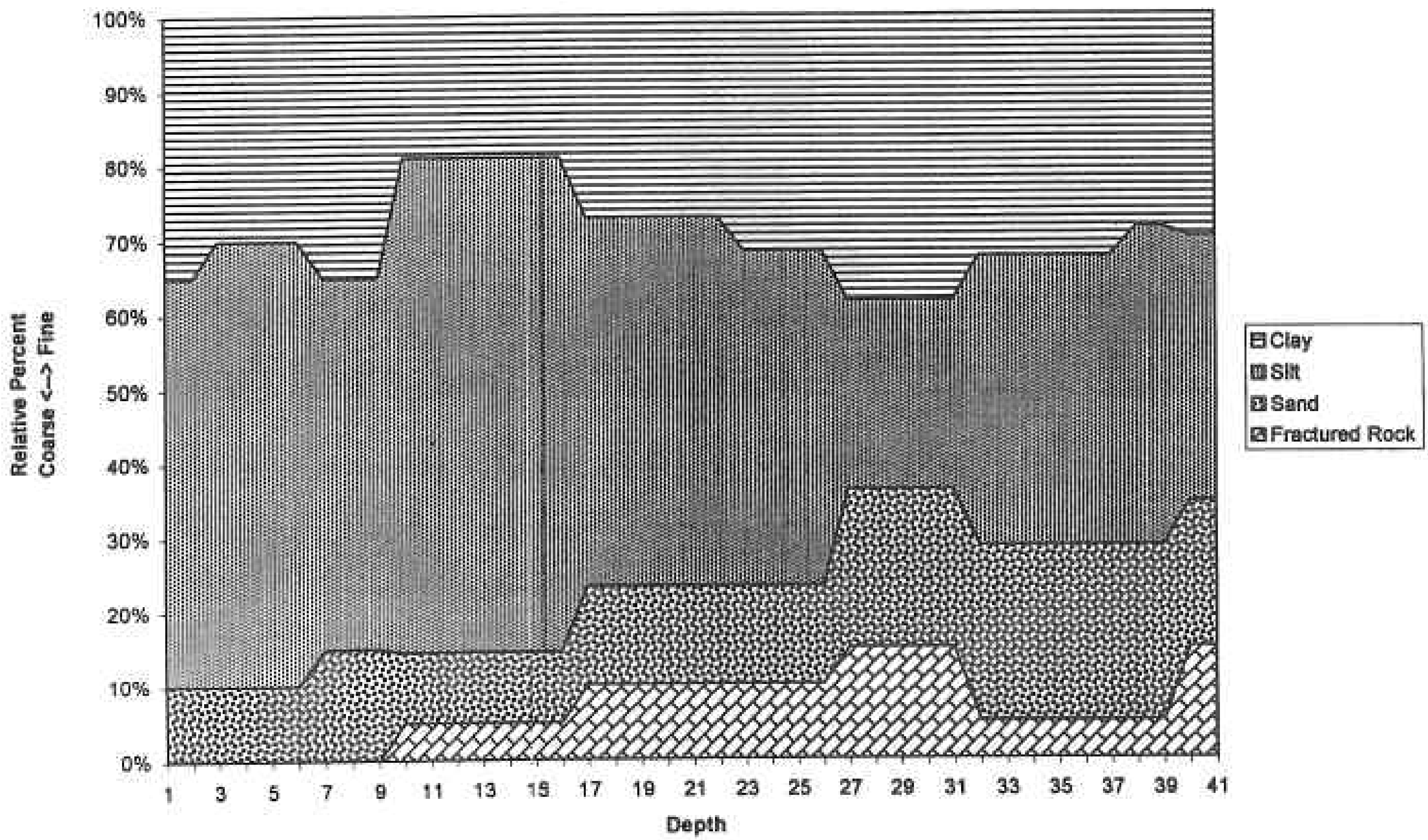
Table 5
SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-4
DATE July 23, 1997

DEPTH (Ft)	COLOR MATRIX	MOTTLES	SOIL TYPE % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES	H_2O CHANNELS
0-1.7	10YR4/3		<10	35		medium subangular blocky	few very fine; few fine	few medium interstiti-al; few fine tubular	
1.7-5.7	10YR6/6	10YR6/2	<10	30		weak subangular blocky	few very fine	many fine interstiti-al, few fine tubular	Fe/Mn stains; silt seams
5.7-9	10YR5/6	10YR6/2	15	35		medium subangular blocky	**many very fine; many fine**	few interstiti-al	clay seams; clay skins; **following roots**
9-16	10YR4/6 +5/6+4/4		10	20	5 ch		**many very fine; many fine**	many fine tubular	Fe/Mn stains; silt seams; **following roots**
16-22	10YR6/2 +6/6	10YR6/2	15	30	10 ch	weak subangular blocky	**many fine @ 19'**	many very fine interstiti al, few fine tubular	Fe/Mn nodules; silt coats
22-26.4	10YR6/2 +6/6	10YR6/2	15	35	10 ch	weak subangular blocky	few fine	many very fine interstiti -al, few fine tubular	silt seams
26.4-30	10YR4/4 +6/6		25	45	15	very weak subangular blocky--massive		very few fine interstiti -al	Fe/Mn stains & nodules; silt coats

30-31	weathered	rock							
31-37	10YR6/3		25	34	5 ch	weak subangular blocky		few fine interstiti-al; few fine tubular	Fe/Mn nodules; silt coats
37-38.7	10YR3/4		25	30	5 ch	medium subangular blocky		few fine interstiti-al; few medium interstiti-al	Fe/Mn stains
38.7-41	10YR5/4 +6/6		23	35	15 ch	medium subangular blocky		few fine interstiti-al; few medium interstiti-al	clay and silt seams
41-44	sample	lost due to	excessive	moisture	&	no soil structure			

Several factors make this soil very conducive for significant gas and liquid movement. A Massive root zone exists from 6-19' which allows movement in all directions. A weathered rock lense exists at 30-31' which could allow significant horizontal movement. Tubular pores exists from the surface to 37' which would allow significant vertical movement. The presence of Fe/Mn stains and silt/clay seams show significant water movement from the surface to 38'. Good soil structure and a high percentage of silt in these soils would allow significant movement through these soils when soil moisture conditions are dry.

Figure 9. JZ - MIP Soil Core Analysis at MIP Location M4



higher conductivity from approximately 4 to 10 feet, suggesting a tighter soil, with lower conductivities from 10 feet on, suggesting a less dense soil. Deeper than 20 feet the conductivity is gradually increasing. The soil log confirms that silt and clay range from approximately 90% over the top 7 feet, gradually reducing to 60% at 27 feet. Results from the soil log are plotted in Figure 9. The MIP log shows little organic gas (both FID and PID) over the first few feet, with a gradual increase in methane (FID) from 4 to 10 feet, followed by generally high levels of methane from 10 to 40 feet. The PID curve shows VOC presence from 10 feet downward. It is clear that gas presence is tied to soil characteristics, and that substantial levels of methane should be found at depths greater than 10 feet.

The soil conductivity and FID curves are plotted again in Figure 10, removing the noise, especially that caused by the FID sampling pattern of 20 data points per foot, by computer as mentioned previously. The percentages of sand and gravel from the soil logs are also plotted again and the screened interval and average corrected methane concentration (corrected for air intrusion) measured from gas monitoring well 11 is shown. The value of the MIP in indicating soil properties and presence of gas is obvious, as confirmed by the high concentration of methane measured over the screened interval of 25 to 40 feet. The presence of gas below the conductivity peak at approximately 8 feet relates to the presence of increasing amounts of sand and gravel from approximately this depth downward.

There are seven additional locations at JZ where MIP testing was performed at the same locations as gas monitoring wells. These are gas monitoring wells 12 and 13 (Figure 11), 14 (Figure 12), 17 and 18 (Figure 13), 19 (Figure 14), 20 (Figure 15), 21 and 22 (Figure 16), and 23 and 24 (Figure 17). The figures provide FID and conductivity curves from the MIP,

Figure 10. JZ Landfill
MIP Log #4, Soil Log#4, Well #JZ11

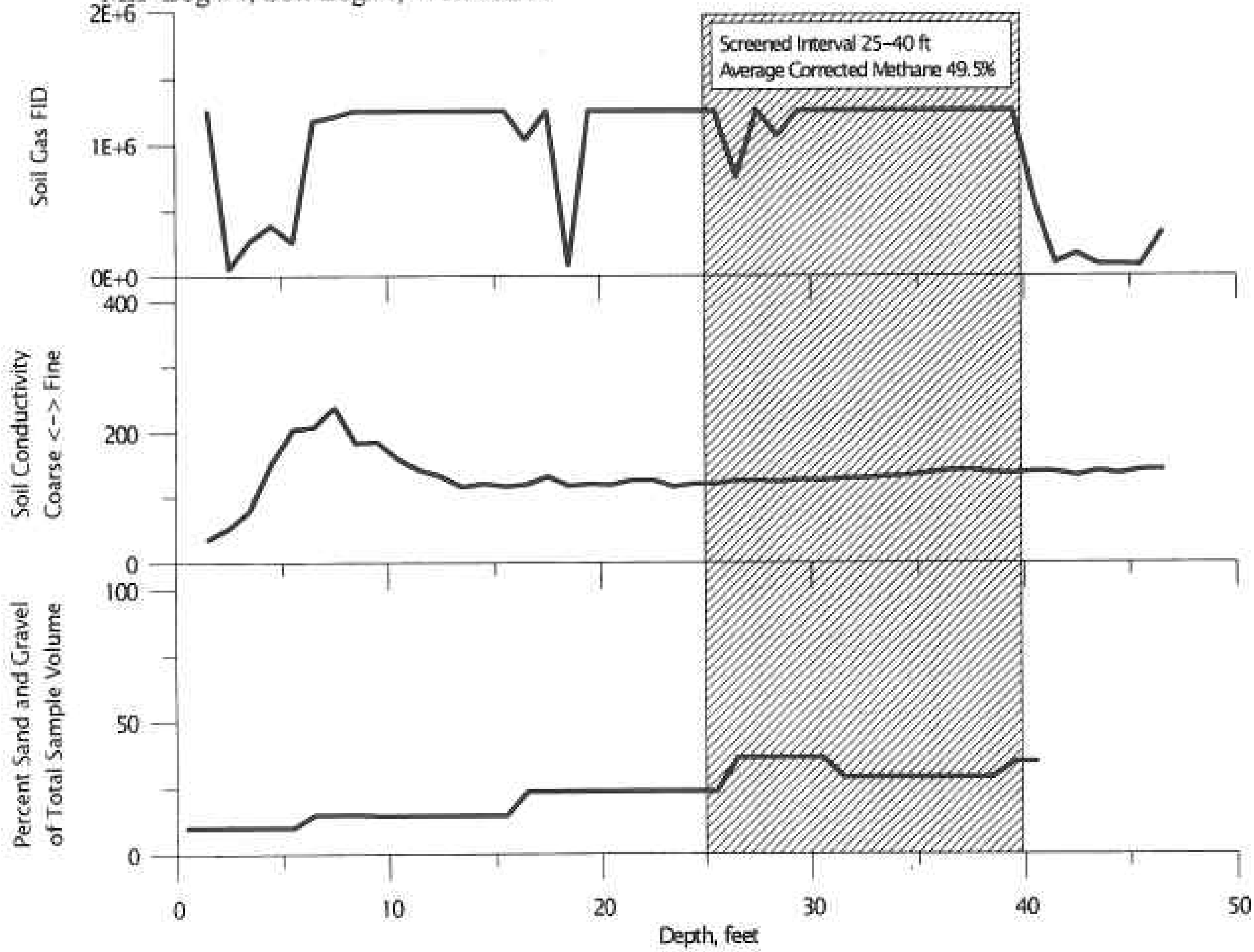


Figure 11. JZ Landfill
MIP Log #5, Soil Log#5, Well #JZ12, JZ13

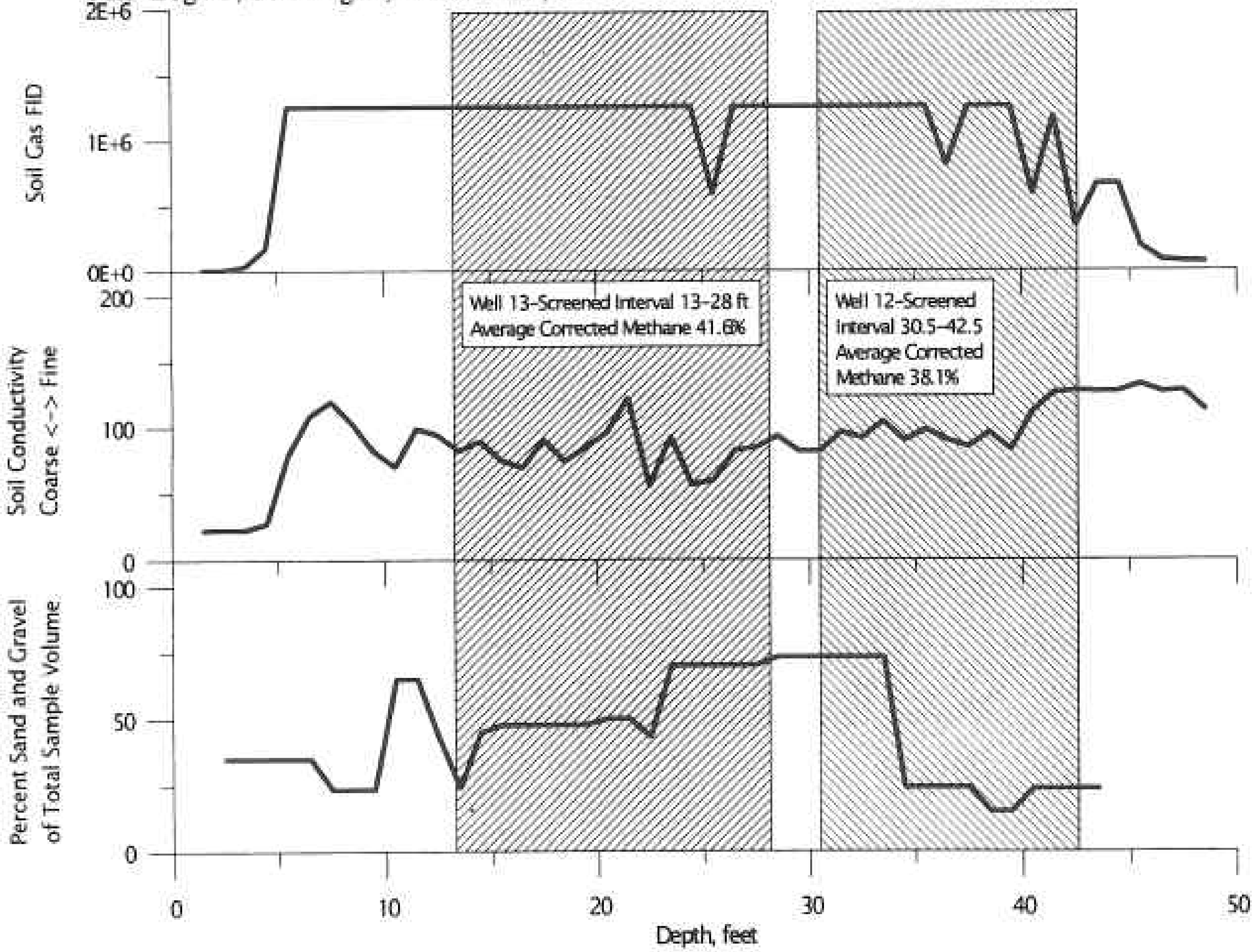


Figure 12. JZ Landfill
MIP Log #8, Soil Log#8, Well #JZ14

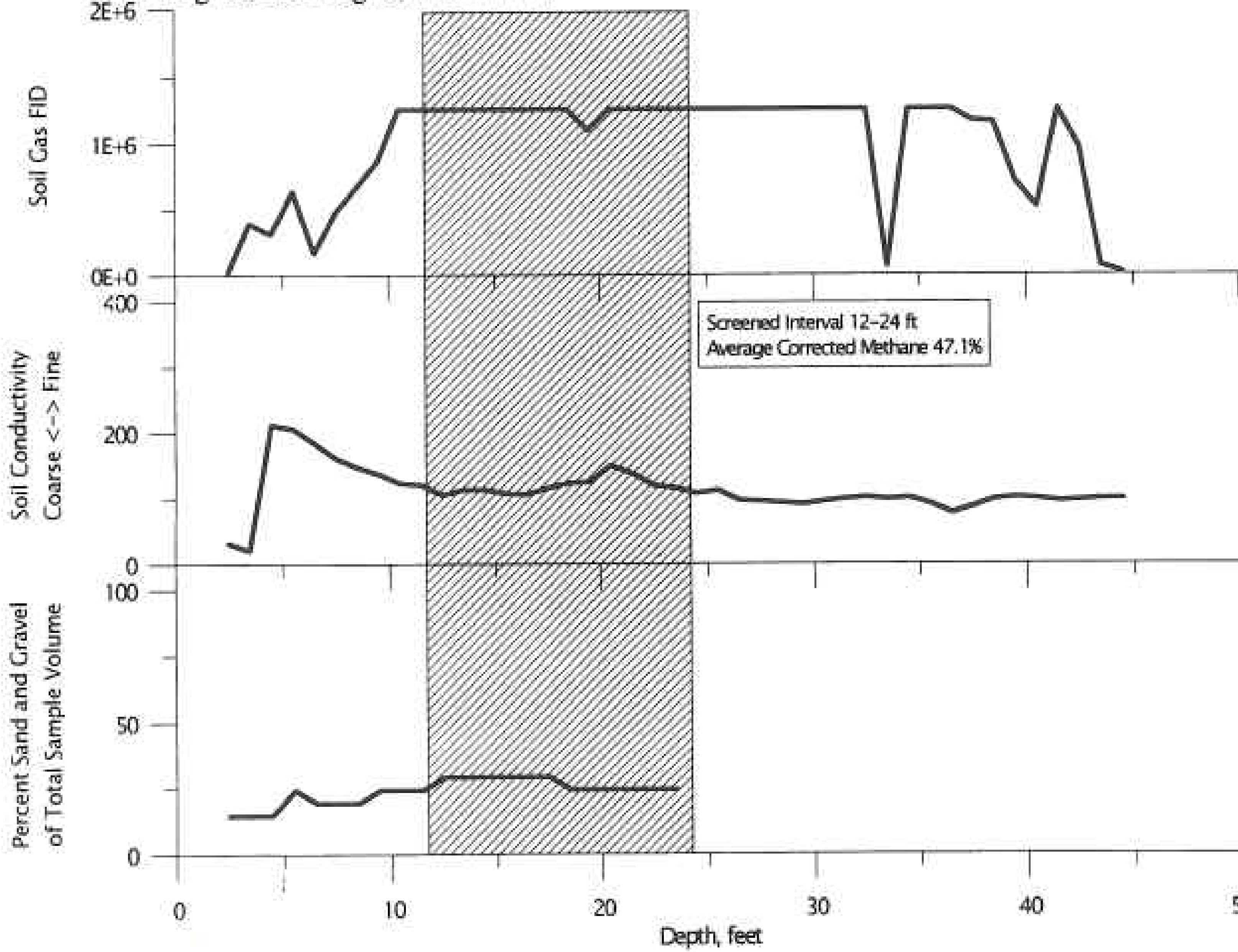


Figure 13. JZ Landfill
MIP Log #7, Soil Log#7, Well #JZ17, JZ18

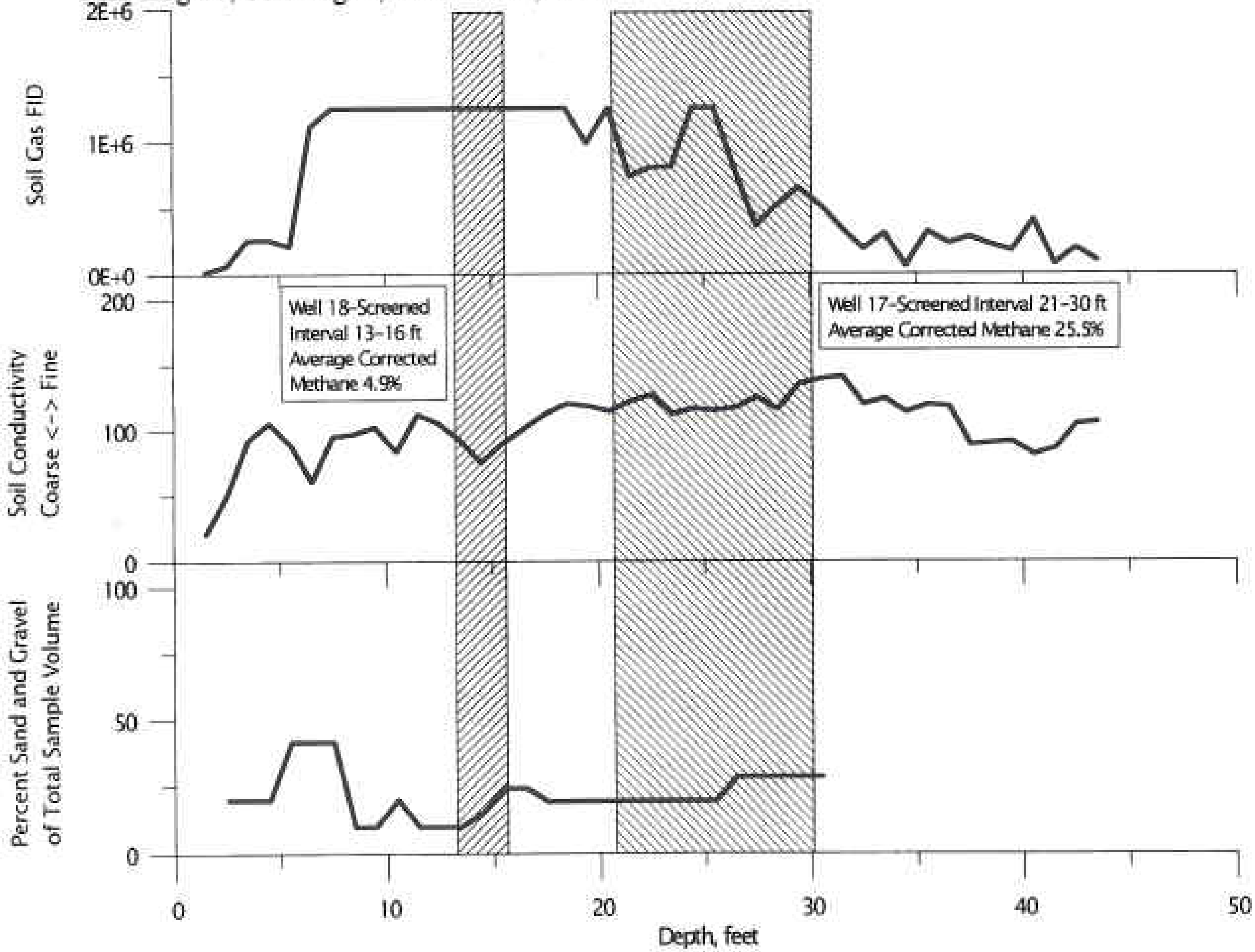


Figure 14. JZ Landfill
MIP Log #11, Soil Log#11, Well #JZ19

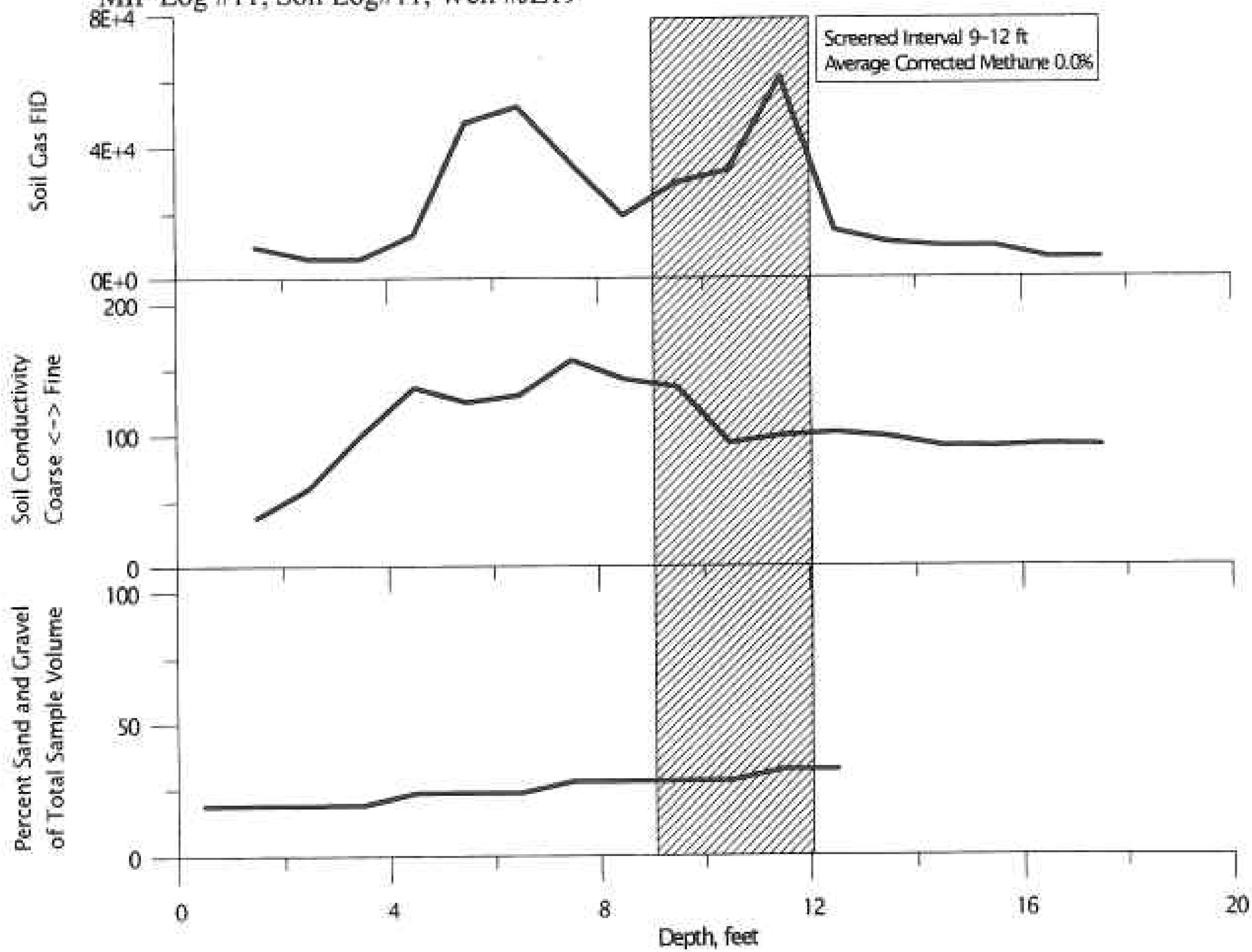


Figure 15. JZ Landfill
MIP Log #10, Soil Log#10, Well #JZ20

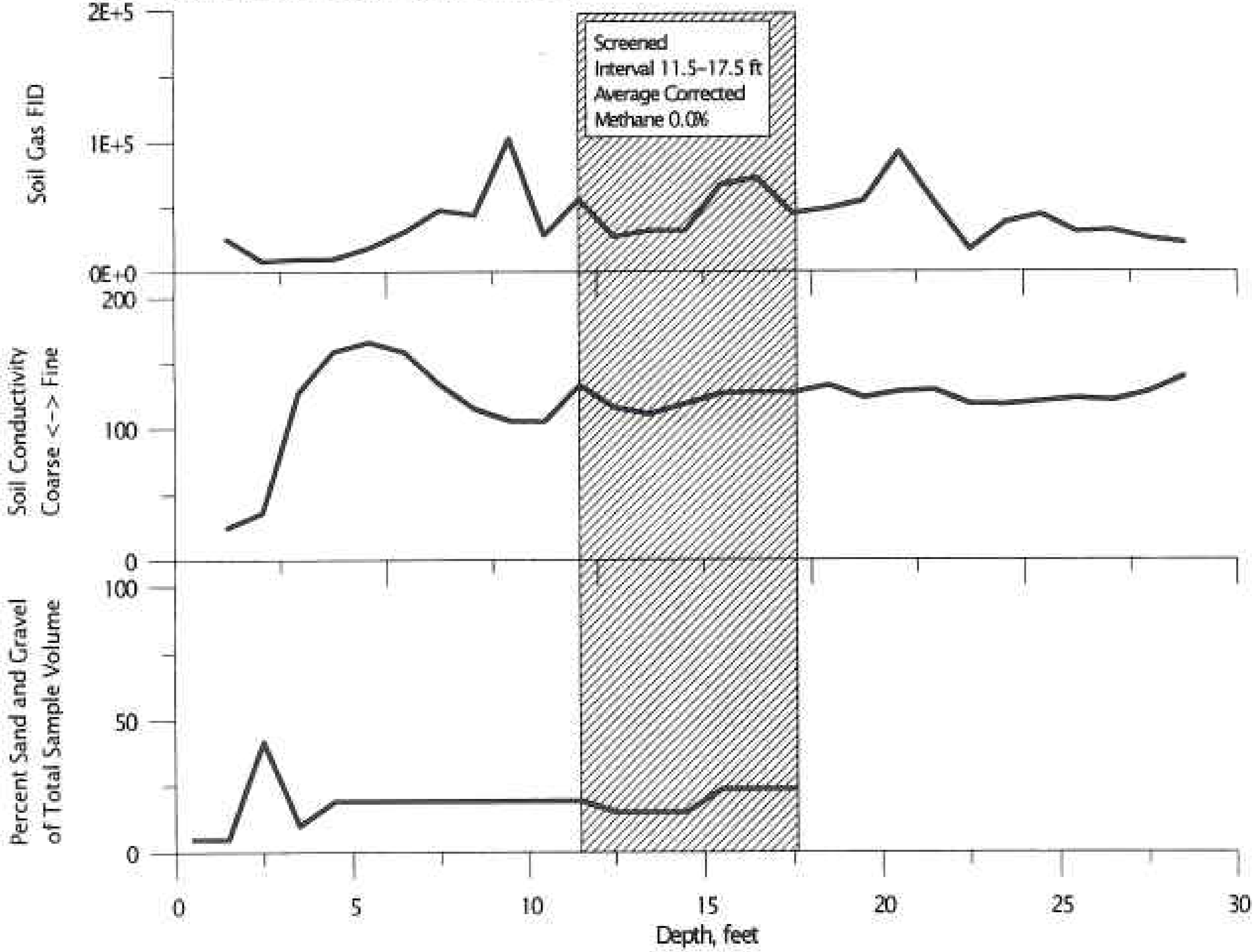


Figure 16. JZ Landfill
MIP Log #9, Soil Log#9, Well #JZ21, JZ22

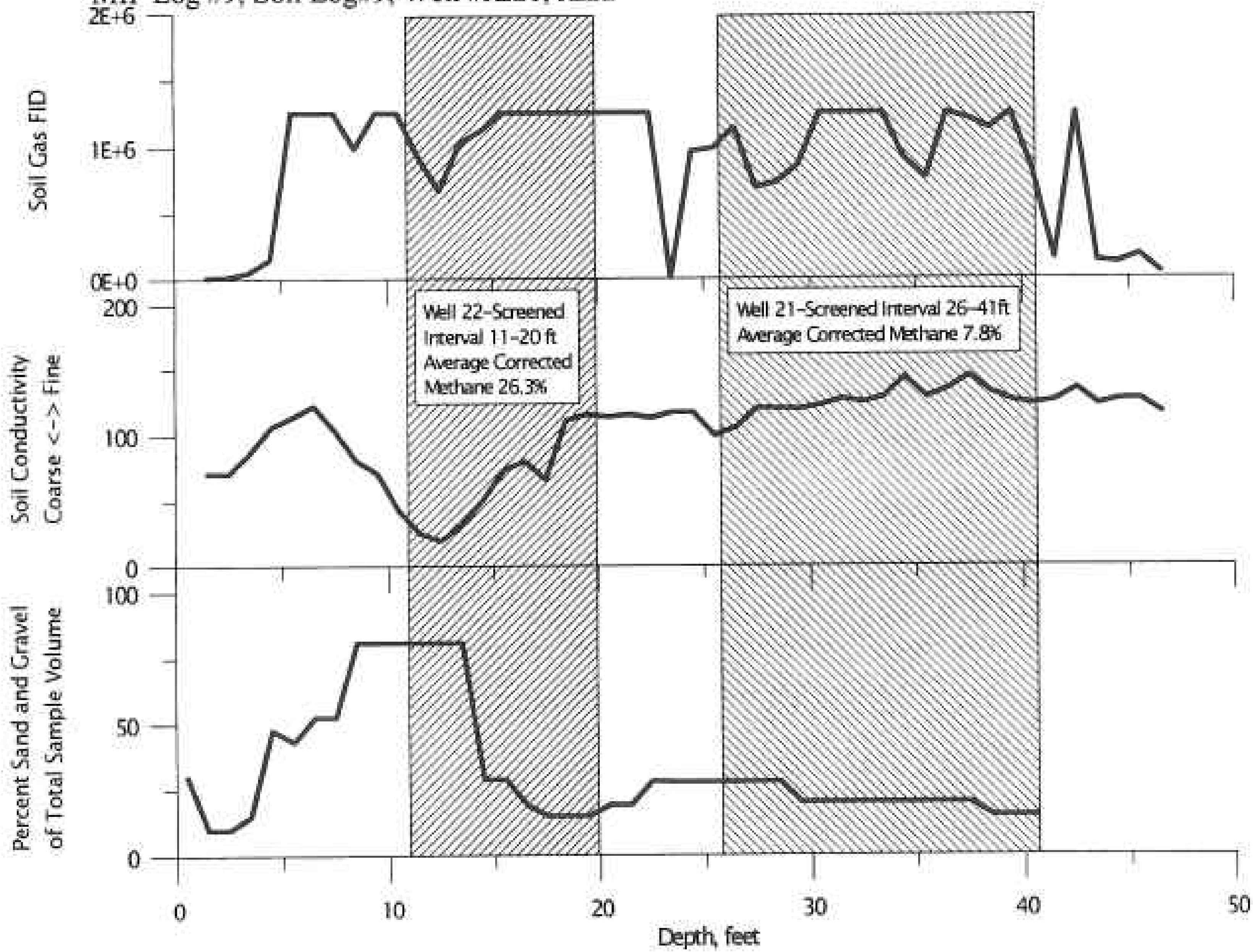
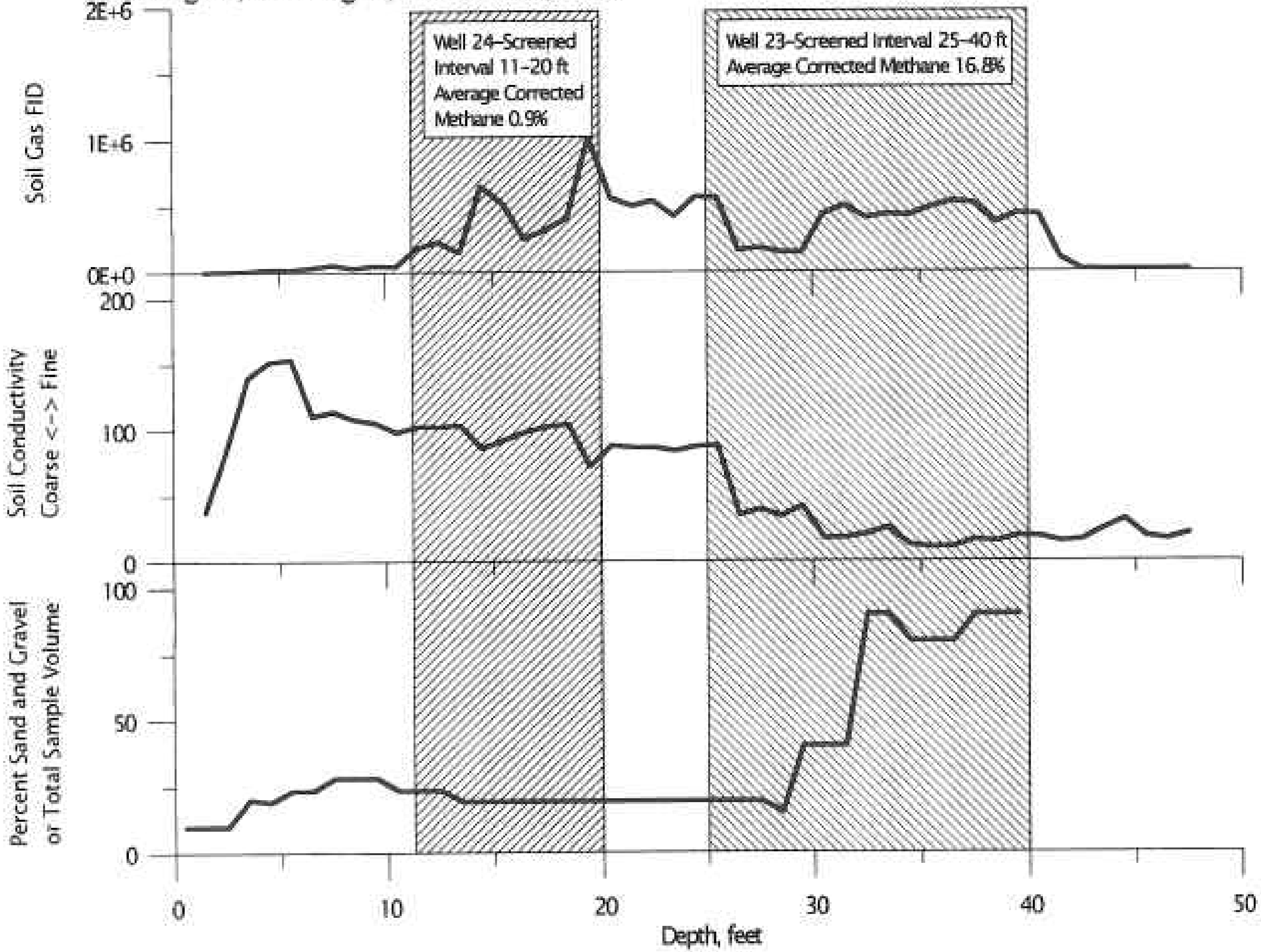


Figure 17. JZ Landfill
MIP Log #6, Soil Log#6, Well #JZ23, JZ24



percentages of sand and gravel from soil cores, and average corrected methane concentrations measured for monitoring wells over the given screened interval. These figures further illustrate the inverse relationship between sand and gravel content and soil conductivity; the higher FID readings related to soil intervals of high sand and gravel contents and lower conductivities; and the higher FID readings associated with higher percent methane values.

Environmental Visualization System (EVS)

EVS was applied to the FID data. In Figure 18, the highest relative FID reading obtained over the entire depth of each MIP borehole is compared to the highest readings for other probes, and the locations of highest to lowest readings plotted over the study area. Consequently, the color at a point relates to the highest FID reading the computer program expects at any depth up to approximately 40 feet (the limit of probe depths). The highest methane levels are expected to trend SW from the site, in the vicinity bordered by M12, M3, M6 and M8.

The indication that the highest concentration is 500 to 800 feet from the landfill likely results from the general increase in readings from M10 in the NW corner of the study area to the SE in the vicinity of M5 and M6, and a similar increase from M22 at the SE corner to the NW by M8 and M20. The computer extrapolated these increases to the area of high gas, assigning the highest concentrations in the study area to this location. Since there were no probes in this high concentration area, there are no data to justify capping the reading and the reading assigned is probably artificially high.

There are sufficient gas monitoring wells in the study area of JZ to allow an EVS plot of average corrected methane concentrations measured, Figure 19. This shows the same pattern as the

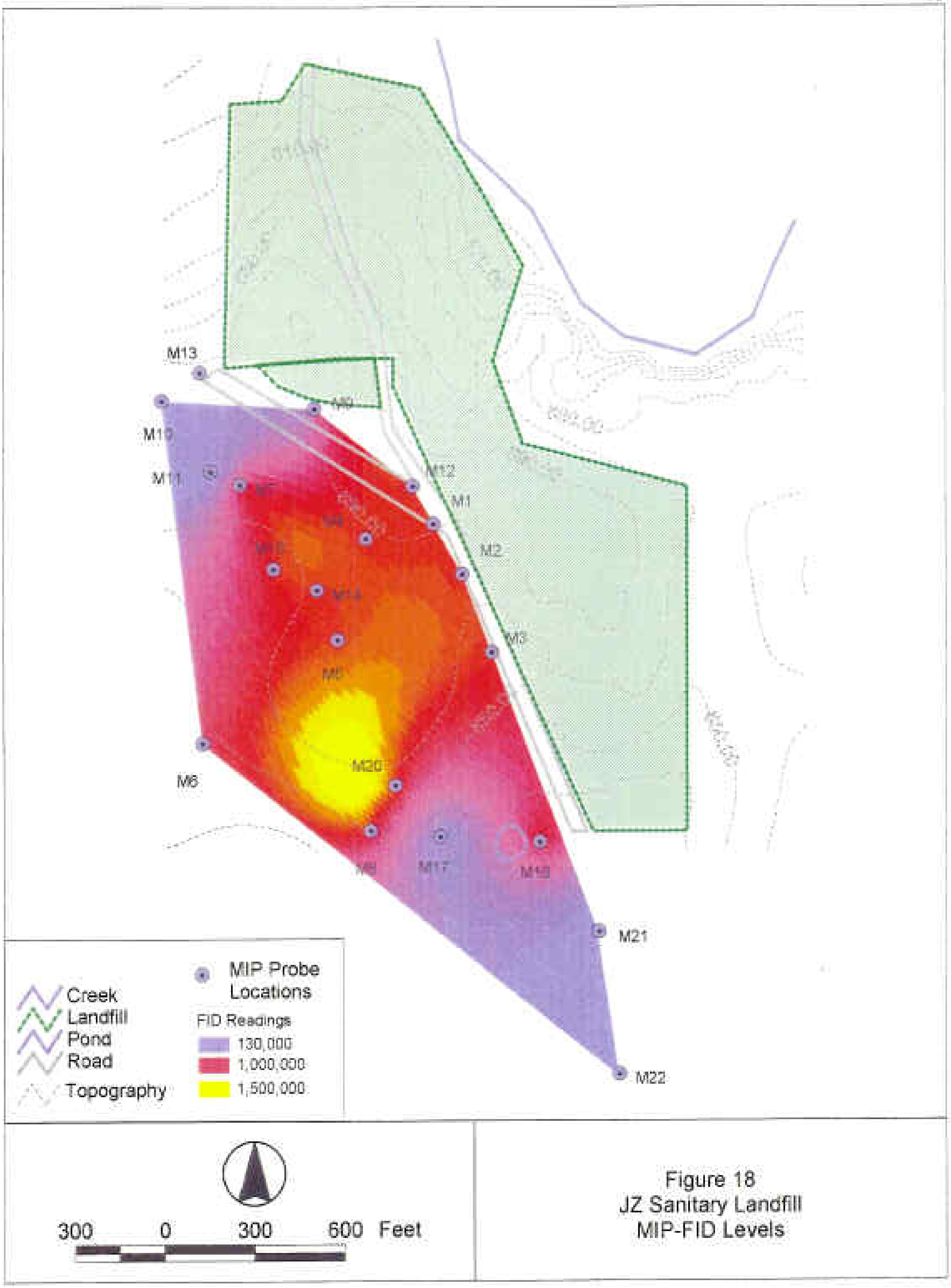


Figure 18
JZ Sanitary Landfill
MIP-FID Levels

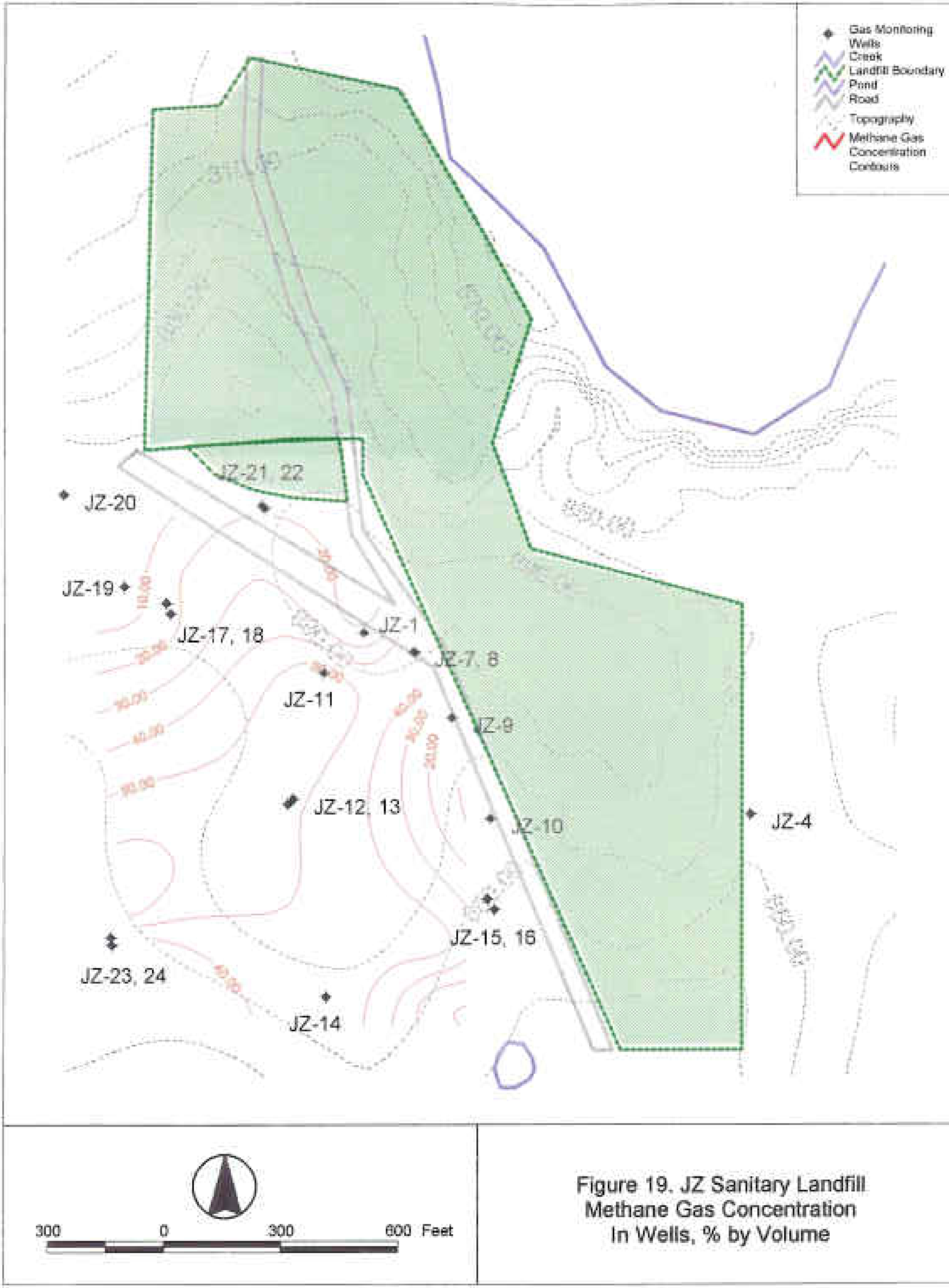


Figure 19. JZ Sanitary Landfill Methane Gas Concentration In Wells, % by Volume

FID plot, Figure 18, with the highest concentrations extending from the mid-east boundary of the landfill to the SE through the middle of the study area. Lower concentrations exist to the NE and SW.

Figure 20 is an EVS generated 3D plot of FID readings in the study area SE of the landfill. Although difficult to read, the figure shows wide distribution of methane in a layer, with the highest concentrations in the area highlighted in Figures 18 and 19. Since this is a 3D color plot, overlapping of colors obscures the color at a given point, making it difficult to locate a color zone on the 3D coordinates, and producing colors, such as brown, not on the scale. Brown results from multiple layers of discrete colors, each of which applies to different points in this 3D space, that are overlaid in this diagram. The 3D plot shows some, but not all probe locations, depending on whether they are located close to the near-side border of the study area.

Figure 21 presents two cross sections through the study area. Both cross-sections show clearly the zone of high FID readings at discrete depths. Section B-B' shows very high concentrations extending continuously in a layer approximately 1000 feet from the landfill, which is connected to a deeper layer in the area of M8, M17 and M20 which extends on another 600 feet. Section A-A' shows that this zone of high concentrations is confined to the middle portion of the study area, as identified previously, with some additional but seemingly smaller pockets of higher concentrations located on either side.

The EVS figures show clearly that high concentrations of methane gas extend over 1000 feet from the landfill and are confined to discrete layers. It is not surprising that gas measurements at a given location may show little or no gas, depending on the depth actually sampled. For this study

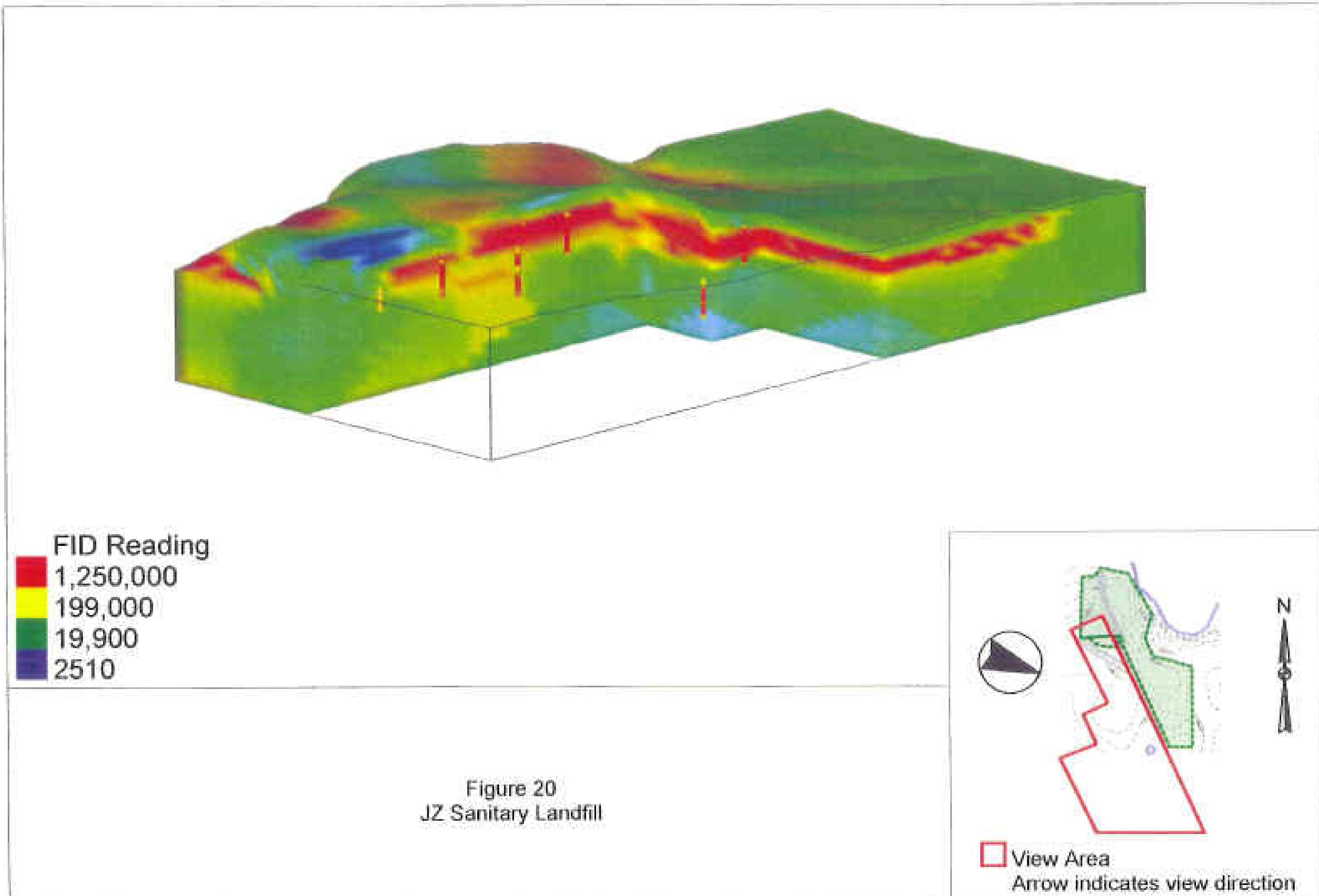
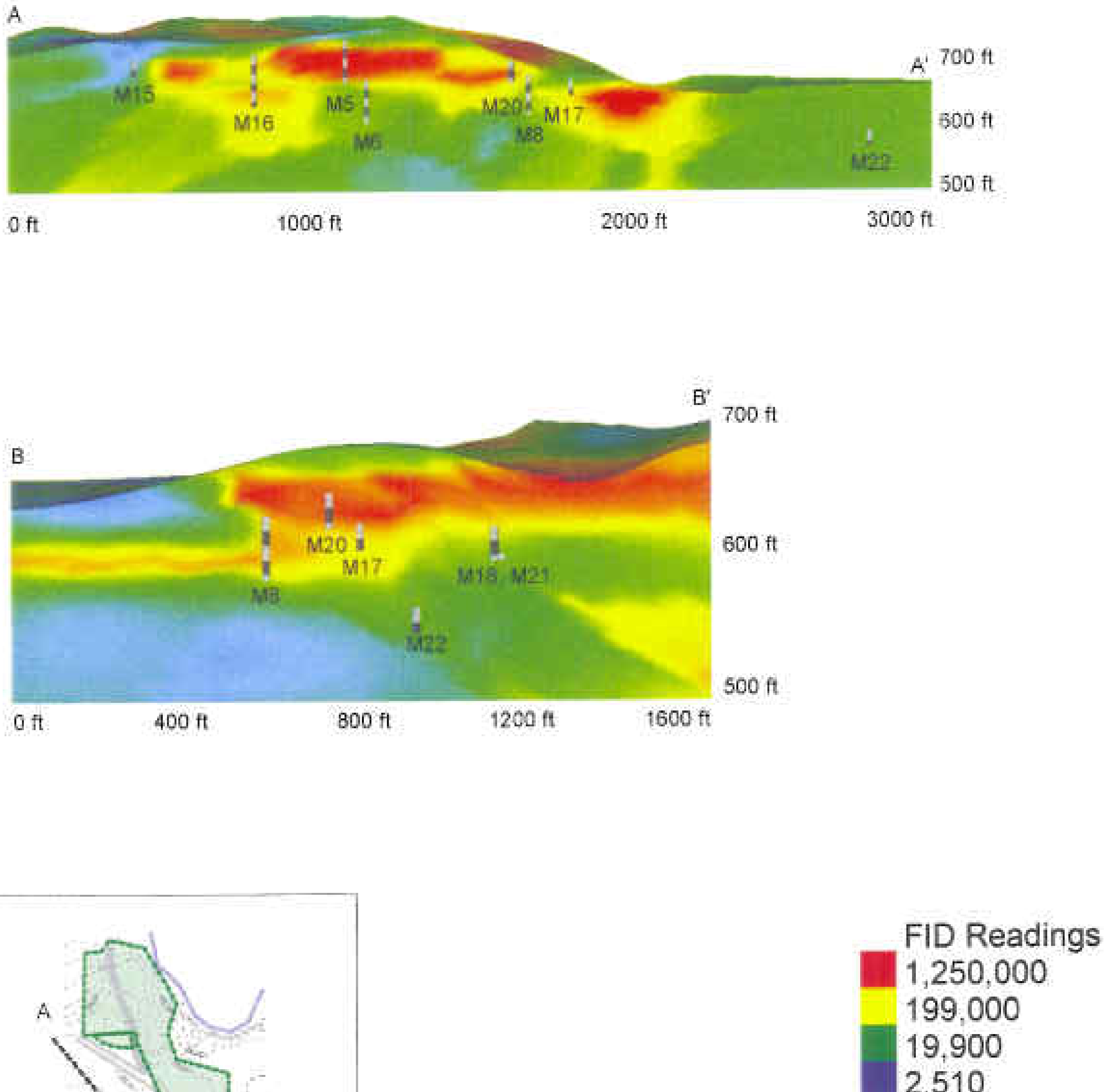


Figure 20
JZ Sanitary Landfill



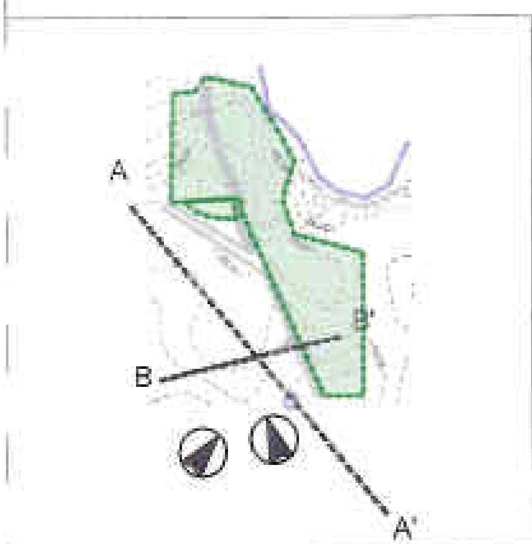


Figure 21
JZ Sanitary Landfill
FID Reading Cross Sections

area, near-surface measurements will seldom give high concentrations, and would give misleading information about the presence and extent of gas migration.

Summary for JZ

The soil in the study area is mostly silty and sandy clays near the surface, with silt, sand and gravel at depth. These soils likely retard gas flow to the surface and confine the highest concentrations, and probably flow, to lower elevations. Pathways for migration are provided by coarse grained sediments, root zones and joints in the till.

Gas was found approximately 1000 feet from the landfill and may extend further. Gas monitoring well 14 (Figure 7) had up to 40% methane, indicating the gas plume likely extends further to the southwest, beyond the study area. Additionally, the end of the plume extending to the west (section B-B' of Figure 21) was not defined.

Little or no gas was found in the NW and SE corners of the study area. In both areas this may be due to a shallow water table near a pond just beyond the area to the NW, and to a pond within the SE portion of the area and another pond to the SE outside of the study area. It may also be due to topography, as the surface slopes downward both to the NW and SE, bringing deep gas found in layers in the middle of the area closer to the surface for venting.

CENTROPOLIS LANDFILL

Gas migration was discovered off site during soil gas screening in late 1996. This screening was prompted by detecting explosive levels of gas near occupied buildings with an explosimeter at the ground surface adjacent to the landfill. The study area, shown in Figure 22, is bounded on the

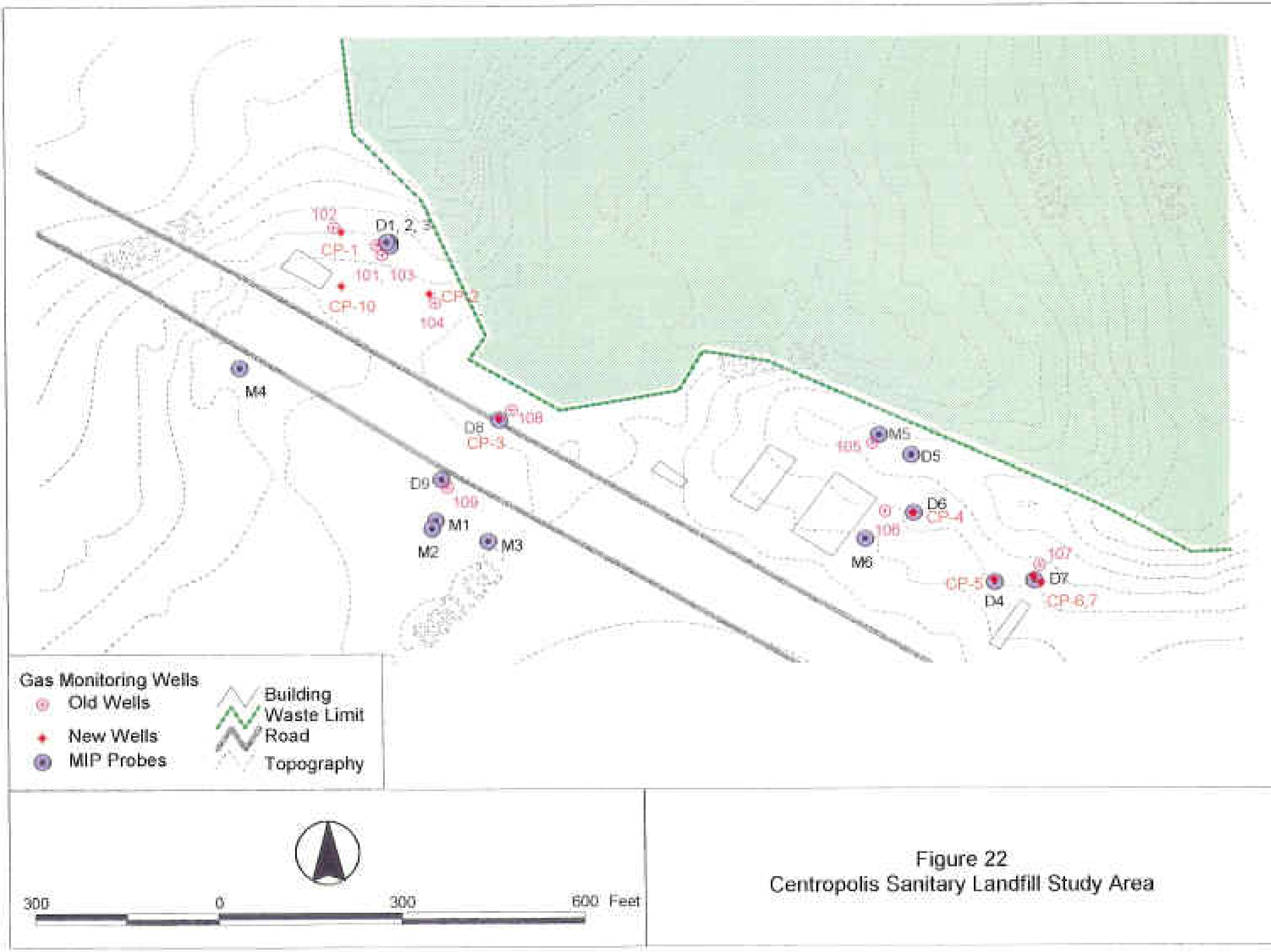


Figure 22
Centropolis Sanitary Landfill Study Area

north by the landfill and on the west and east by deep valleys which limit gas flow in these directions. To the south, the land is level for several hundred feet, beyond which it drops to another valley. The area of study is mostly commercial, with four such establishments likely to be in the immediate path of any migrating gases. The entire area, including the landfill, is underlain by a limestone mine, the roof of which has failed at several locations, allowing rock and waste into the mine. The soil is derived from windblown loess, limestone and shale. In some places fill has been placed to provide level areas for structures and for the major road which passes through the study area. Potential migration pathways are fill areas and permeable zones in the natural soils and rock.

MIP and Soils

Nine probes were completed in 1996, labeled D in Figure 22, and six in 1997 which are labeled M. MIP output is given in Appendix D for 15 probes, including most of these 15 plus some extra probes placed in the vicinity of the occupied building near D1,2,3. The highest FID readings were within 200 feet of the landfill, with readings dropping off quickly at greater distances. Probe depths ranged from 8 to 26 feet and were limited by refusal. Soil is typically coarse in the upper 3 to 11 feet, followed by silty clays 4 to 12 feet thick. In a few holes there appears to be FID spikes at refusal.

Gas Monitoring Wells

Nine wells were installed initially, within 200 feet of the landfill. The locations and general soil profiles and construction parameters are given in Figure 22 and Appendix D. These wells, labeled 101-109, revealed methane up to 40-50% by volume close to the landfill; those further away had no measurable methane. All but one of these wells were subsequently removed and a second set of seven wells was constructed generally near the same locations. These wells are shown in Figure 22 (labeled CP) and listed along with average results in Table 6. This second set of wells revealed much lower methane concentrations, which may be functions of construction details, screened intervals selected, or the different times of the year the two well sets were monitored.

Methane was found in wells close to the landfill and at depths where the MIP indicated the presence of methane. In the outer areas across the road, where the MIP indicated very low readings, no methane was found.

EVS

Figure 23 indicates the general levels of the highest FID readings at any depth for each probe. The highest concentrations are close to the landfill, especially near D1, 2 and 3, and M5 and D5. Concentrations drop off quickly and are basically undetectable across the road. This pattern is shown in a 3D plot in Figure 24, which, subject to the difficulty in interpretation mentioned previously, shows the higher concentrations close to the landfill and the rapid drop off moving away from the landfill.

Figure 25 shows these gas concentration patterns more clearly. Section B-B' indicates that the highest concentrations are in the upper zone, where fill is common, extending outward to the landfill side of the road (D8) but not to the other side of the road (D9 and M4). Note that this cross-section extends approximately 400 feet into the landfill (D8 is approximately 50 feet from

Table 6. Gas Monitoring Wells, Centropolis Sanitary Landfill (including data from previous wells 101-109 for gas concentration comparison)					
Well Number	Screen, ft	MIP Log	Soil Log	Avg CH_4†	FID Average
101	10 - 20	n/a	n/a	29.0	n/a
102-A‡	4 - 6	n/a	n/a	54.5	n/a
102-B‡	18 - 20	n/a	n/a	19.0	n/a
103	5 - 10	n/a	n/a	35.5	n/a
104	9 - 14	n/a	n/a	11.9	n/a
105-A‡	5 - 7	n/a	n/a	6.1	n/a
106-B‡	16 - 18	n/a	n/a	57.7	n/a
106-A‡	5 - 7	n/a	n/a	0.0	n/a
106-B‡	10 - 17	n/a	n/a	0.0	n/a
107	10 - 15	n/a	n/a	0.0	n/a
108-A‡	4.5 - 6.5	n/a	n/a	17.8	n/a
108-B‡	11 - 16	n/a	n/a	0.1	n/a
109	5 - 9	n/a	n/a	0.1	n/a
1	7 - 16	none	102	13.5	N/A
2	7 - 16	none	104	0.0	N/A
3	5 - 11	8	108	36.4	3.8×10^5
4	6 - 12	6	106	0.0	1.9×10^4
5	6 - 15.8	4	none	0.2	2.3×10^3
6	11 - 20	7	107	0.0	1.6×10^4
7	5 - 8	7	107	0.0	1.3×10^4
10	1.5 - 6	none	none	20.3	N/A

† Average of all gas readings, methane (% by volume)
‡ These wells were screened at multiple depths.

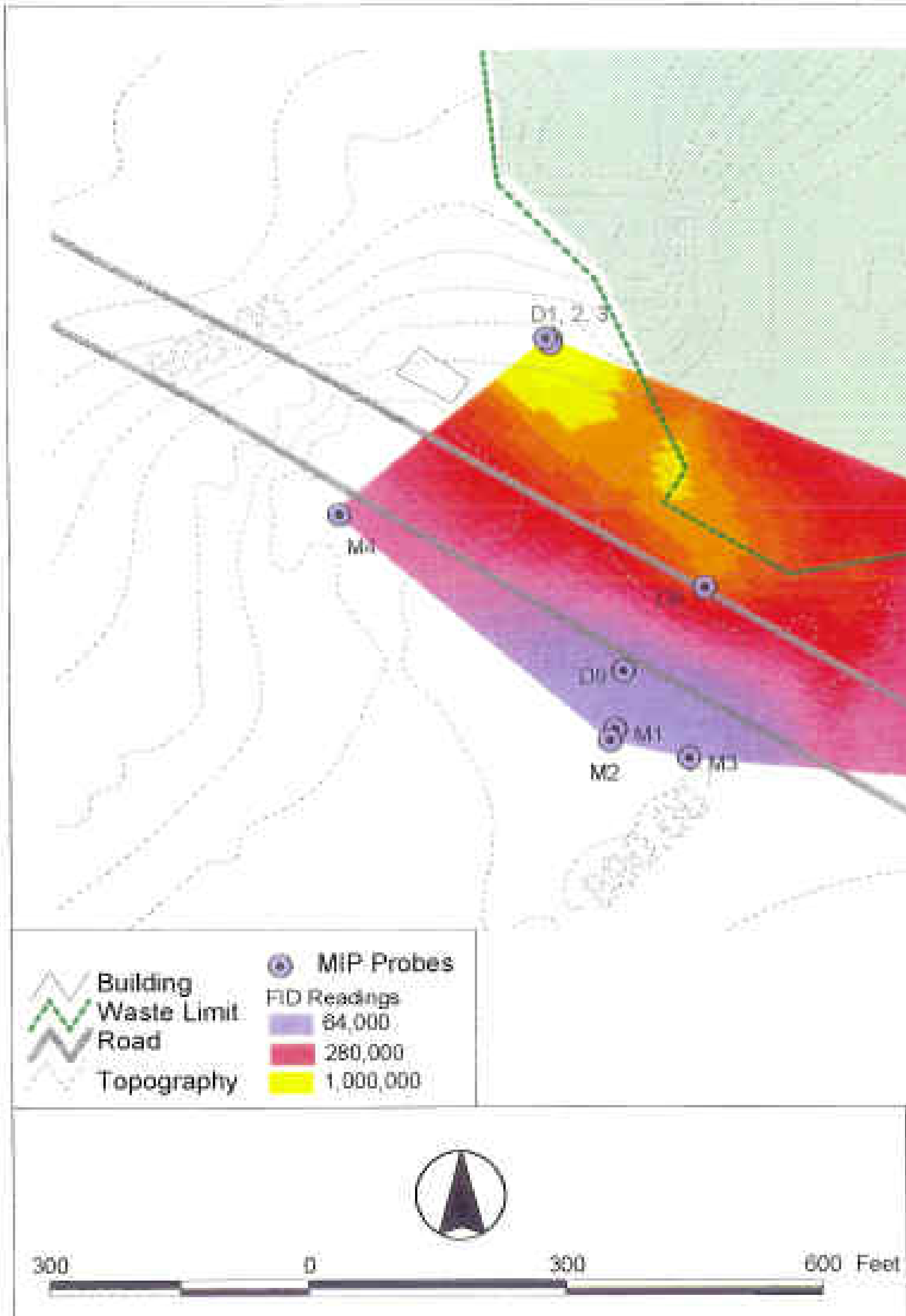


Figure 23
Centropolis Sanitary Landfill
MIP-FID Levels

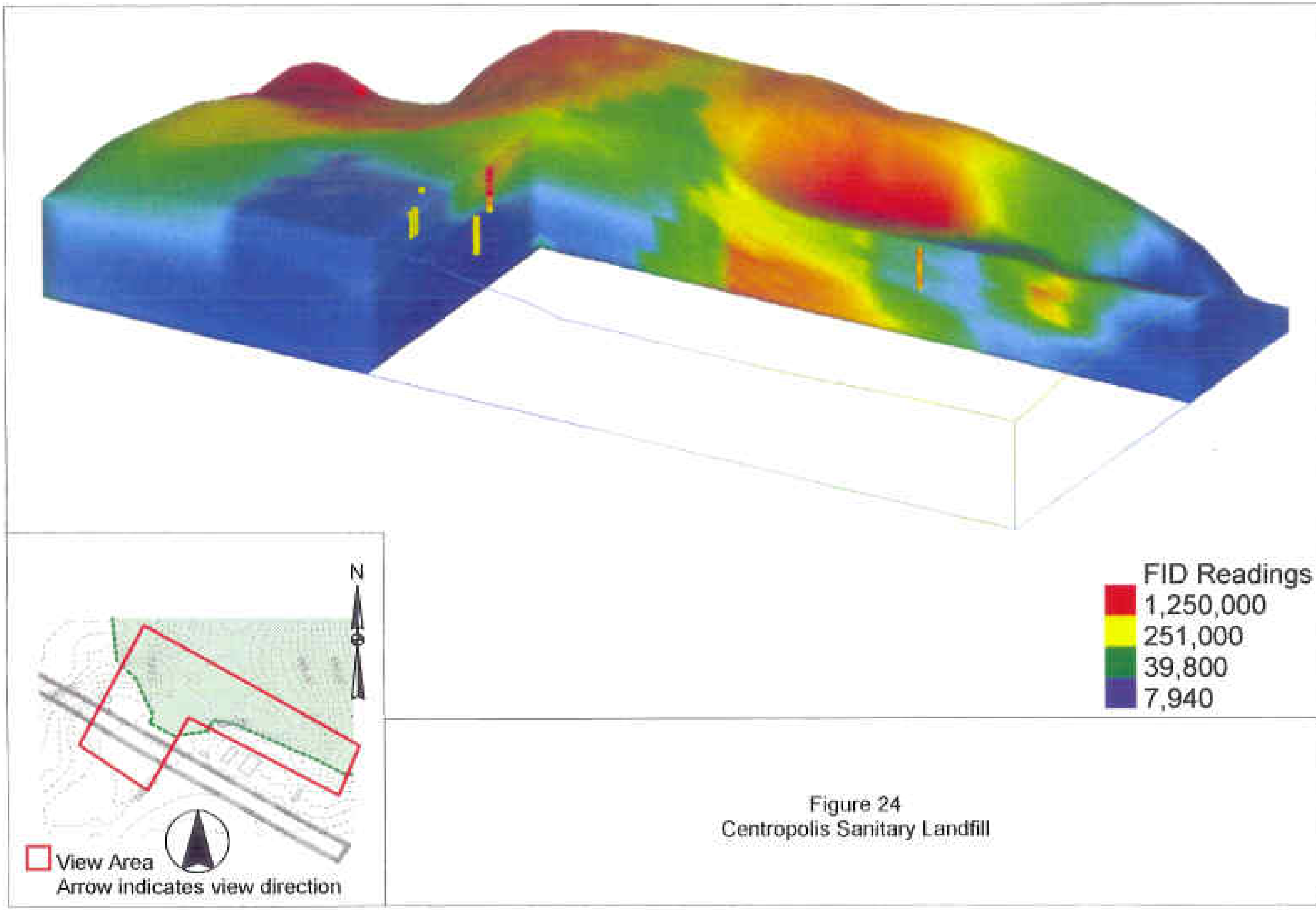
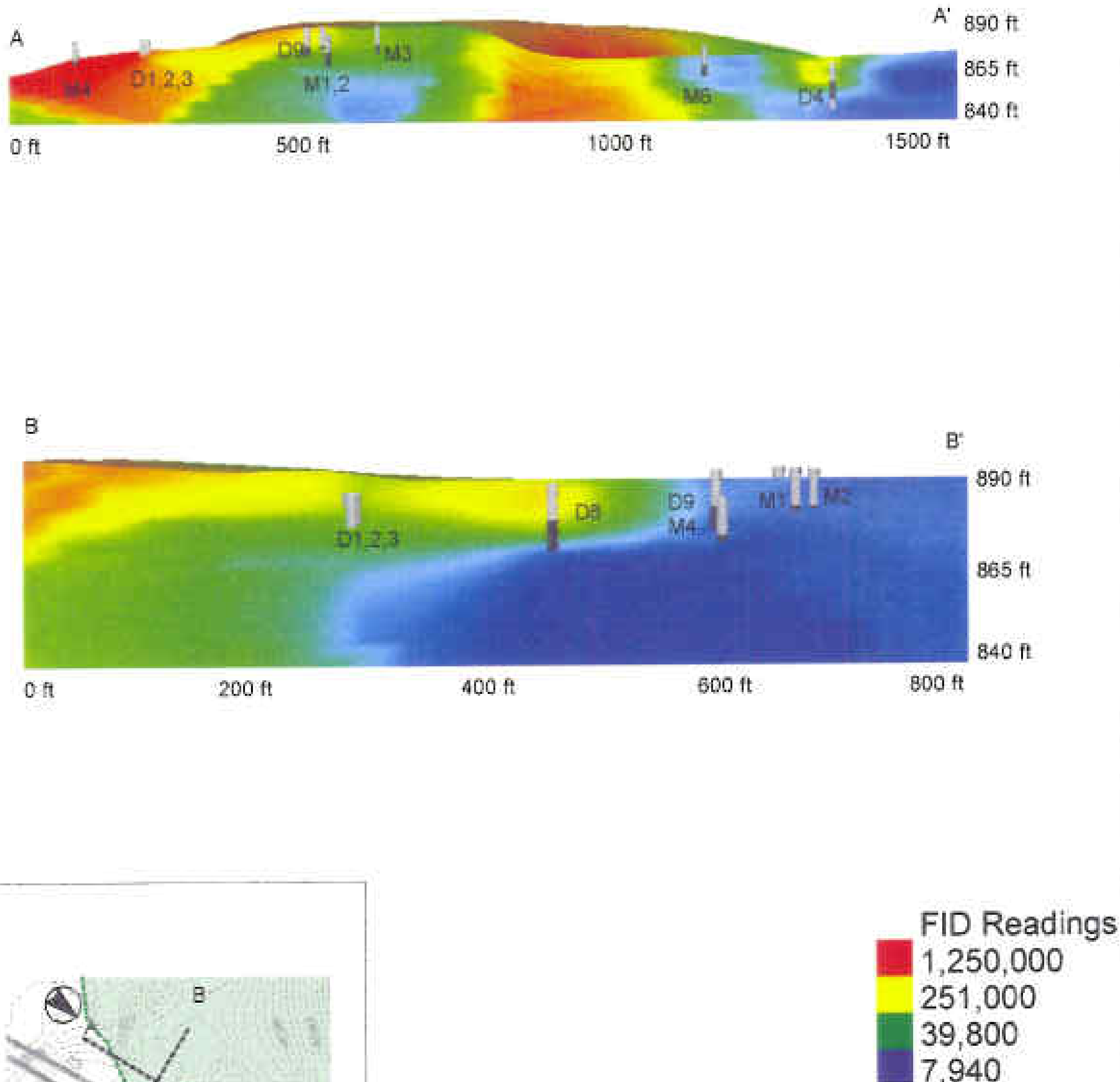


Figure 24
Centropolis Sanitary Landfill



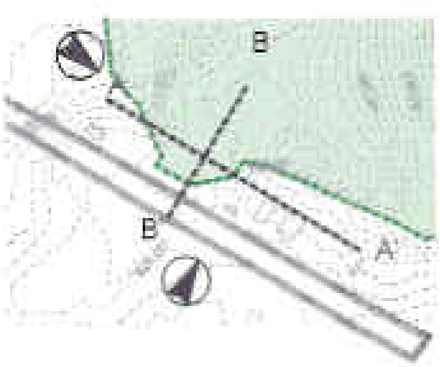


Figure 25
Centropolis Sanitary Landfill
FID Reading Cross Sections

the landfill boundary), but no testing was actually done in the landfill. The EVS is taking values from D1, 2 and 3 and superimposing them onto the B-B' section, thereby projecting high concentrations in an area appearing to be in the landfill. In this case the projection gives a logical result; in some other landfills and in section A-A' here the projection suggests illogically that the landfill has lower concentrations of methane than the surroundings.

Section A-A' cuts through the landfill and shows low methane concentrations within the landfill (generally where M3 is shown). The highest concentrations are in the vicinity of D1, 2 and 3, and between M3 and M6. The area by D1, 2 and 3 is consistent with gas well measurements taken in that area, and the depth extending to approximately 20 feet is also consistent with gas well results.

Summary for Centropolis

The soil in the study area is fine, silty clays overlain by clay mixed with clean fill material (rubble, bricks, concrete, etc.). The depth to bedrock is generally 20 to 30 feet, but refusal for a given probe or well may or may not be indicative of bedrock. The porous fill tends to transmit high concentrations of methane, but this extends only as far as the fill extends laterally. Methane is generally confined to within 100 feet of the landfill and up to 13 feet deep. There may be a zone near the bedrock where natural soils transmit low concentrations of methane.

MODERN SANITATION

Figure 26 shows the landfill and the study area, which is adjacent to the east boundary of the landfill. The area dimensions are close to 1000 feet in the E-W direction by 3500 feet N-S. An old highway (M175 is adjacent to it) forms a ridge along the east boundary of the landfill, extending to the north and south. Between the old road and the existing highway (M450 to M480 are adjacent to it) is a depression triangular in shape which could vent gas. To the north is a ridge extending from M1 to M6 and across the highway to M11. Buildings in the vicinity of M1 and M11 plus the topography make this ridge the primary area of concern. One building near M1 had methane seeping through floor cracks, prompting the level of study performed. (Note that the building is not an enclosed structure, and elevated methane levels were not detected within it.) As part of this study, an old abandoned dump was discovered near M1, so it is not clear whether the old dump provides methane, provides a pathway for methane generated in the main landfill, and/or if soil pathways from the main landfill circumvent the dump.

The soil is derived from dolomite and contains layers of fractured chert and sandstone. These layers and macropores are the most likely pathways for gas migration.

MIP and Soil Logs

Twenty-three MIP logs were completed and are given in Appendix E. The deepest was 40 feet, but many probes were terminated at refusal at much shallower depths. Soil conductivity is highly variable, with values from close to zero (very coarse, rock, gravel) to 200 and higher (very fine, clay) on almost every log. High FID readings were common but there is no consistent pattern with depth or lateral location. High FID readings were found on all logs but M3, 5 , 6, 7, 11, 465,

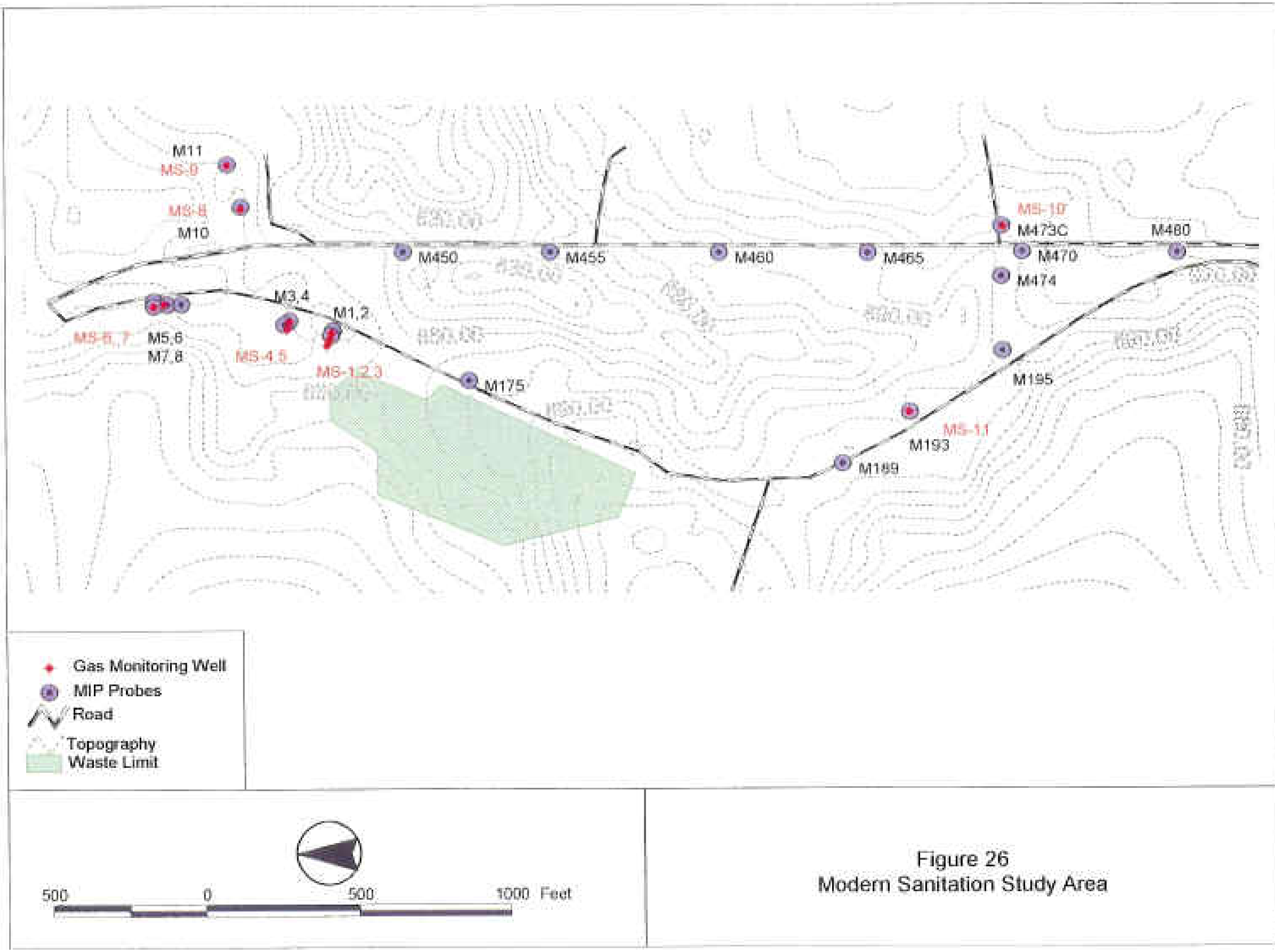


Figure 26
Modern Sanitation Study Area

470 and 480. Of these, M5, 6, 7, 465, 470 and 480 are shallow and would have missed deeper gas, and M465, 470 and 480 were installed near the highway where bedrock is near the surface. It is not known why M3 and 11 had low FID readings, especially since nearby gas monitoring wells 1 and 9 had significant methane concentrations. M3 is in an area prone to perched water, which might have had an effect.

Four soil logs were obtained, which are also given in Appendix E. Figures 27, 28, 29 and 30 are based on these four soil logs and the FID and soil conductivity results from the corresponding MIP logs. These figures show the erratic soil composition, with highly variable conductivity which is usually related to sand and gravel content. The FID readings are also erratic and less related to soil properties than at other landfills tested. The erratic soil characteristics correspond to field experience, which was that very hard layers would be hit, making probe advancement difficult, sometimes at seemingly random locations.

The soil is basically rocky clay with some sand. Permeability is very high. Refusal was hit at shallow depths in several cases, well before bedrock. Soil characteristics are highly variable, with hard layers of rock and permeable gravel near pockets of high clay and silt content. The erratic FID readings are not surprising given these soil conditions.

Gas Monitoring Wells

Eleven wells were installed, as shown in Figure 26 of which eight are summarized in Table 7. Wells 2 and 3 were installed at basically the same location and screened over the same interval as well 1. Of these three wells, well 1 was monitored, the results of which are given in the Table. Similarly, well 5 was a duplicate of well 4 which was monitored. All wells had high

Figure 27. Modern Sanitation
MIP Log #1b, Soil Log#101, Well #MS01

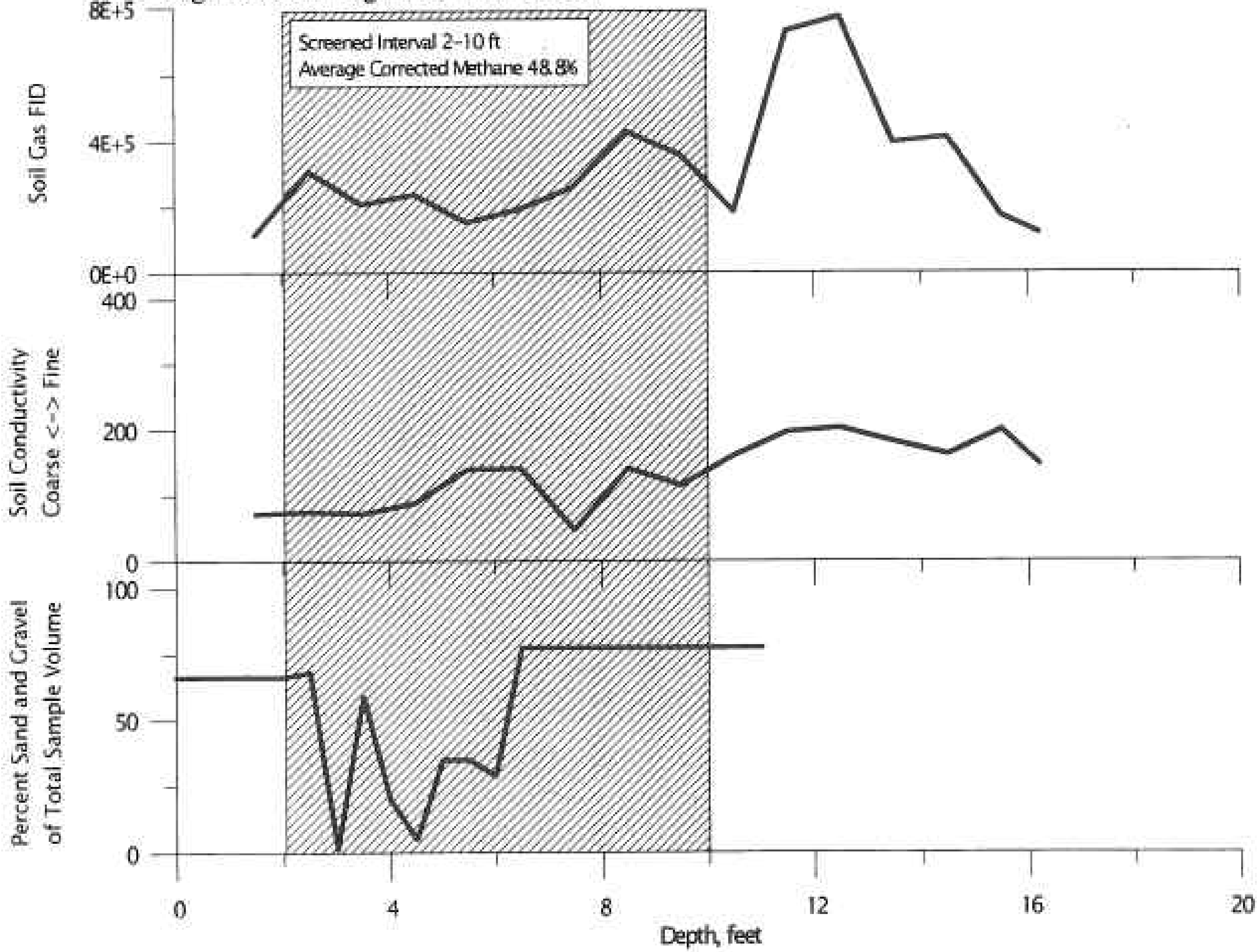


Figure 28. Modern Sanitation
MIP Log #4, Soil Log#104, Well #MS04

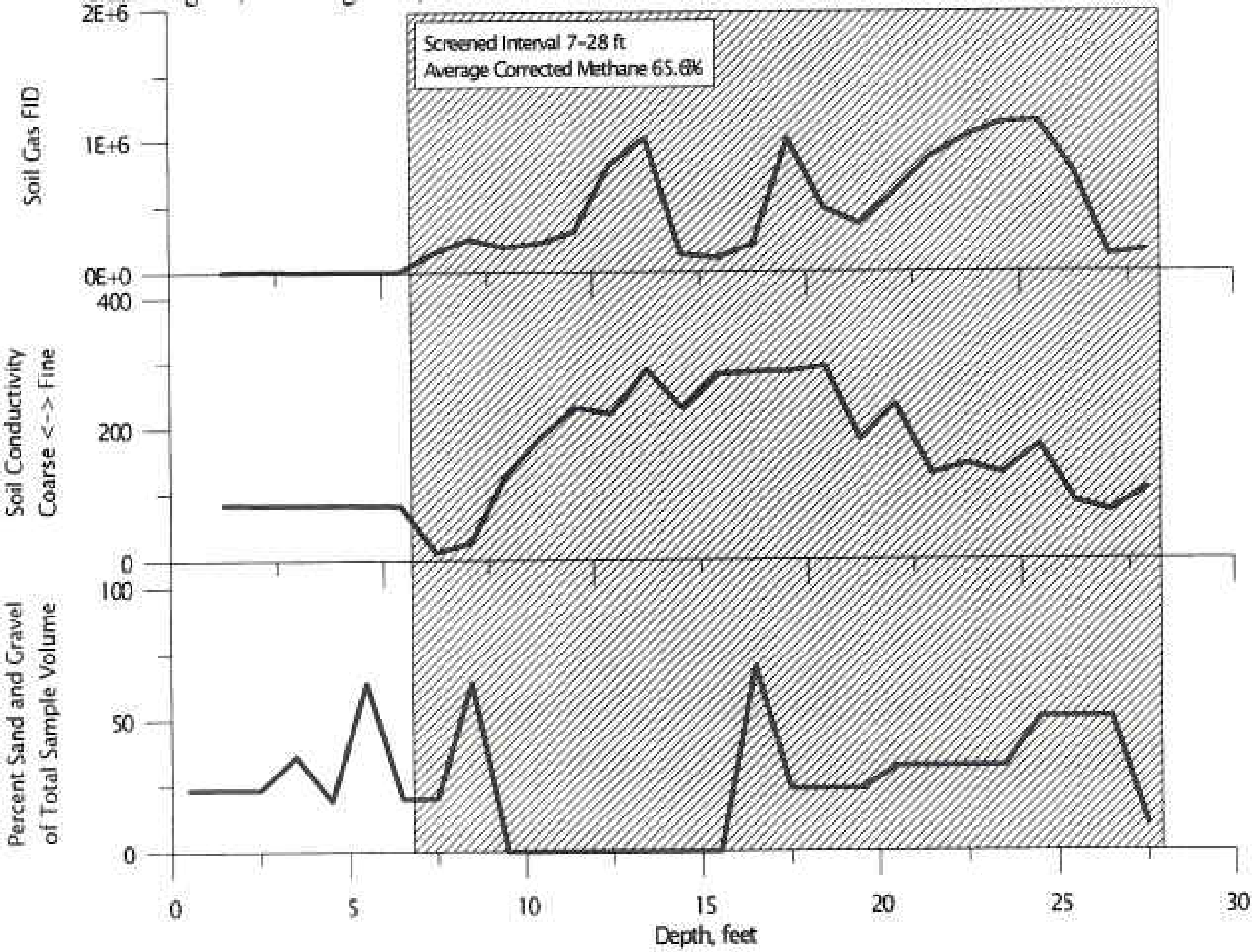


Figure 29. Modern Sanitation
MIP Log #473c, Soil Log#474, Well #MS10

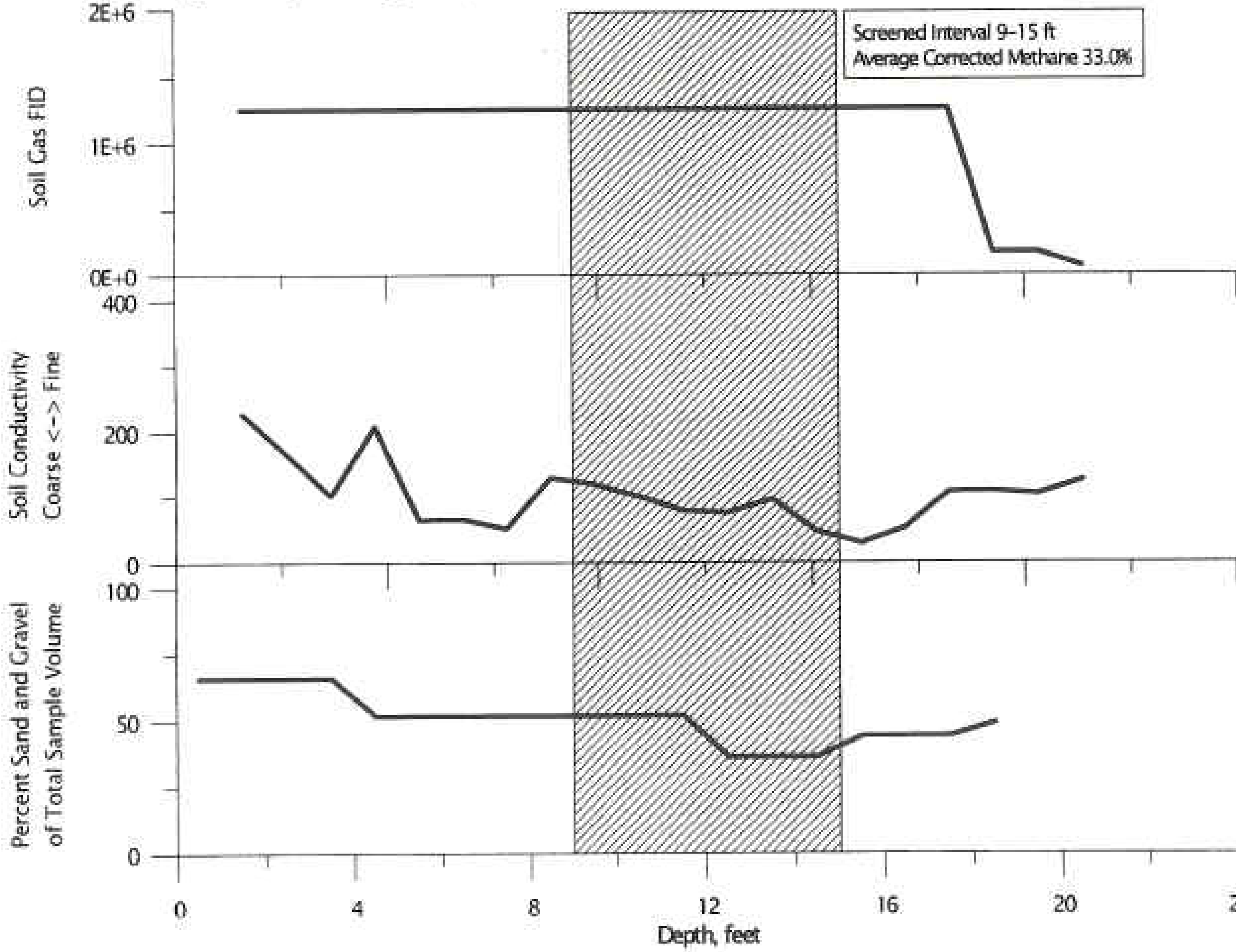


Figure 30. Modern Sanitation
MIP Log #193, Soil Log#193, Well #MS11

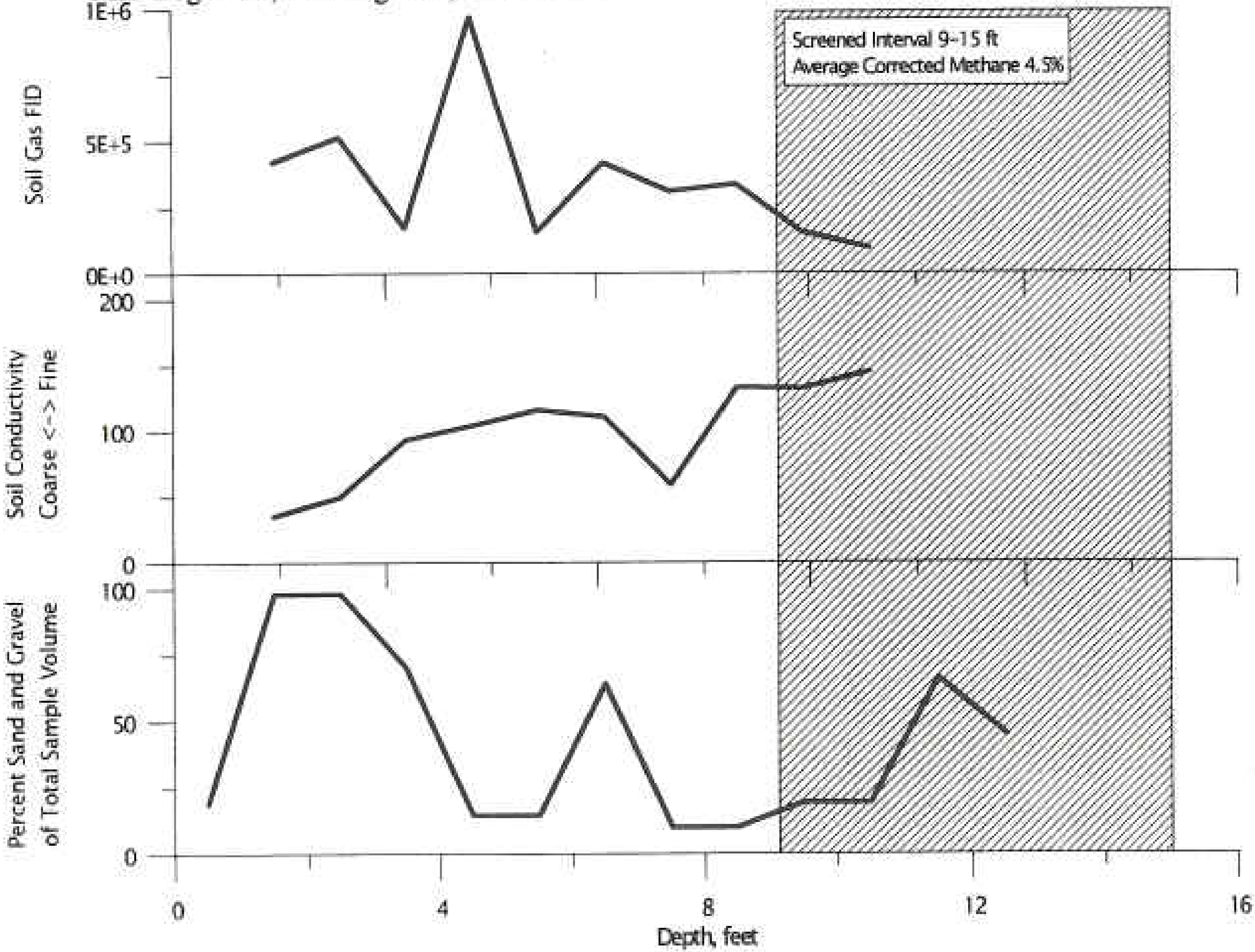


Table 7. Gas Monitoring Wells, Modern Sanitation Sanitary Landfill					
Well Number	Screen, ft	MIP Log	Soil Log	Avg Corrected CH_4†	FID Average
1	2 - 10	1B	101	48.8	2.7×10^5
4	7 - 28	4	104	65.6	5.3×10^5
6	9 - 15	8	none	60.4	8.9×10^5
7	25 - 40	7	none	34.4	8.9×10^5
8	8.5 - 11.5	10	none	26.1	1.1×10^6
9	10 - 16	11	none	7.8	6.2×10^4
10	9 - 15	473c	474	33.0	1.3×10^6
11	9 - 15	193	193	4.5	1.4×10^5

† Average of readings from September through December 1997, corrected methane (% by volume)

methane concentrations except well 11, which corresponds to the low FID readings at the upper end of the screened interval for MIP log 193 (see Figure 30). The most distant well is MS-10, which had an average corrected methane concentration of 33% and high FID readings over the screened interval (Figure 29). This well is 1500 feet from the landfill. Figures 27, 28, 29 and 30 allow a comparison of average corrected methane concentrations over the screened intervals to corresponding FID results. In general, the comparison is good in that elevated (above background) FID readings were obtained in the screened interval giving the methane, but the magnitude of the FID reading does not relate very well to the actual methane content of the gas. This is not surprising, however, given the highly variable FID readings and erratic soil conditions. A small highly permeable zone could provide most of a gas sample, which would hardly be noticed over the screened interval with the FID results. The lack of a quantitative correlation between average methane concentrations and FID results is further illustrated by the other gas monitoring wells as shown in Table 7.

EVS

Figure 31 provides interpolations for the highest FID value at each MIP probe over the study area. The result is not very helpful, plus it contradicts the results from the gas monitoring wells. Table 7 indicates the highest average methane concentrations at MW1, 4 and 6, corresponding to probes M1, 4 and 6 on Figure 31, which have low to moderate gas according to the EVS. Monitoring wells 7, 8 and 10 have lower concentrations at 26 to 35% methane, corresponding to probe locations M7, 10 and 473C on Figure 31, which are indicated at low to moderate gas levels according to EVS. Finally, wells 9 and 11 had low methane concentrations (4-8%), with their

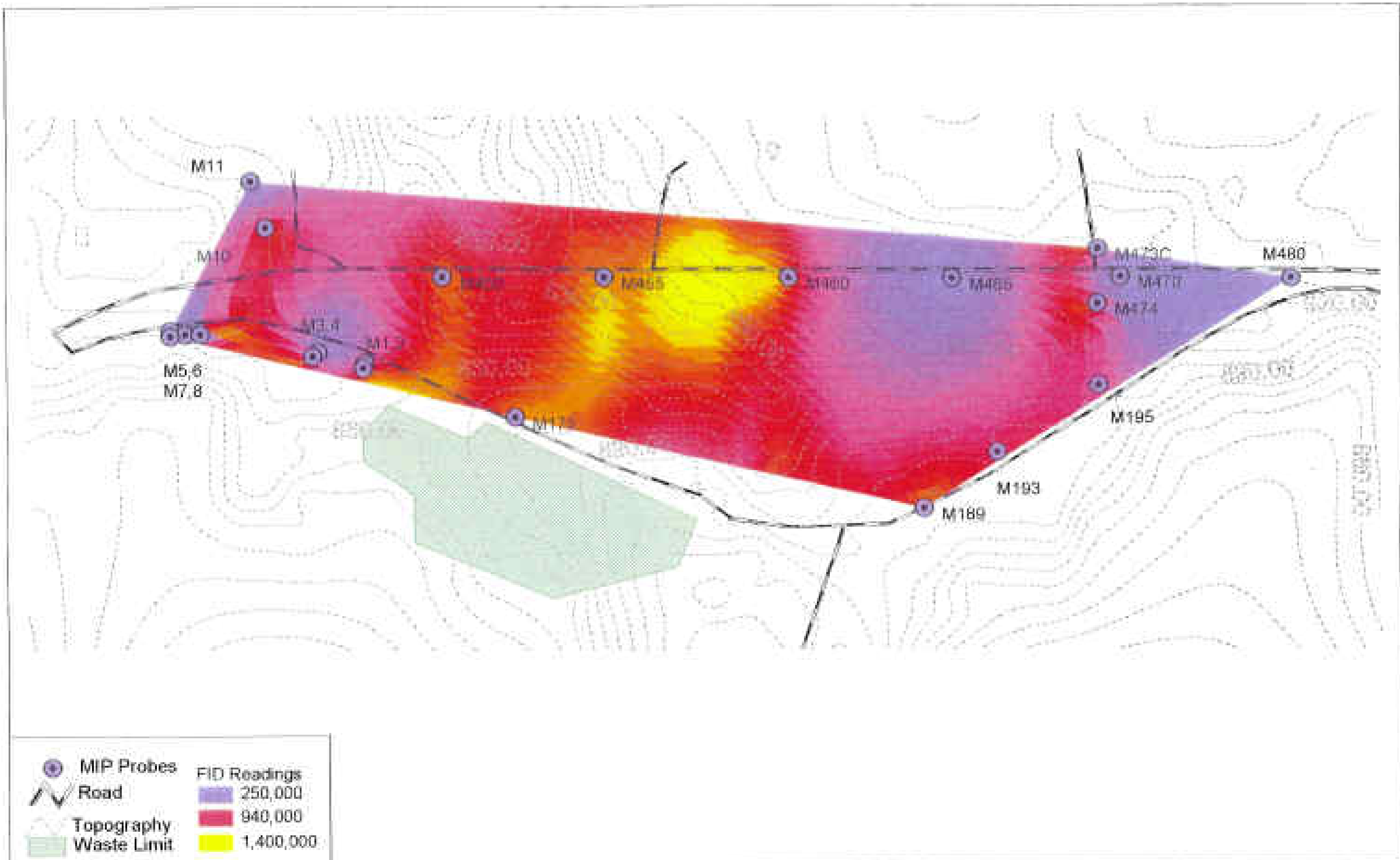


Figure 31
Modern Sanitation Sanitary Landfill
MIP-FID Levels

corresponding locations of M11 and 193 on Figure 31, respectively, showing correctly low gas in the first case but moderate gas for the second well.

The high gas areas between M455 and 460, and between 455 and 175 are also troublesome. Undoubtedly, the computer program considered the increased FID reading in going from M465 to M460 and projected a continued increase beyond M460, which had to plateau and then decrease to meet the reading at M465. The result is the unlikely area of high gas shown. There are no probes in the areas of highest projected gas concentrations (FID readings) to temper these projections. An additional complication is the valley between M175 (which was only 8 feet deep) and M455/460 (20 and 23 feet deep), making it even more unlikely the pathway suggested in the EVS plot is real. The EVS plot does correctly suggest more gas along the old road, near the landfill, and especially to the north in the vicinity of M1, 2, 3 and 4, extending but at lower concentrations east to M10.

The 3D plot, Figure 32, correctly shows higher concentrations close to the landfill and extending to the north. Three cross-sections are given in Figure 33. Section A-A' indicates gas at 1000 feet, which is consistent with FID results and the monitoring well (MS 10) results in this area. The elevated gas levels suggested at approximately 3000 feet (M450) are reasonable given the proximity to the landfill and the shallow valley between the landfill and M450. Finally, the gas at 4000 feet (M10 and 11) is reasonable and is backed up by monitoring well 8 results showing 26% methane. Note that the projections to lower elevations, especially around M450 and M10 and 11, should be treated with caution, as there are little to no data to back them up.

Section B-B' shows elevated gas concentrations only in the vicinity of M189 and near the surface. Monitoring well 11, screened from 9-15 feet, averaged 4.5% methane, backing up the cross-section projection to some degree. Section C-C' shows elevated methane near the landfill (M175),

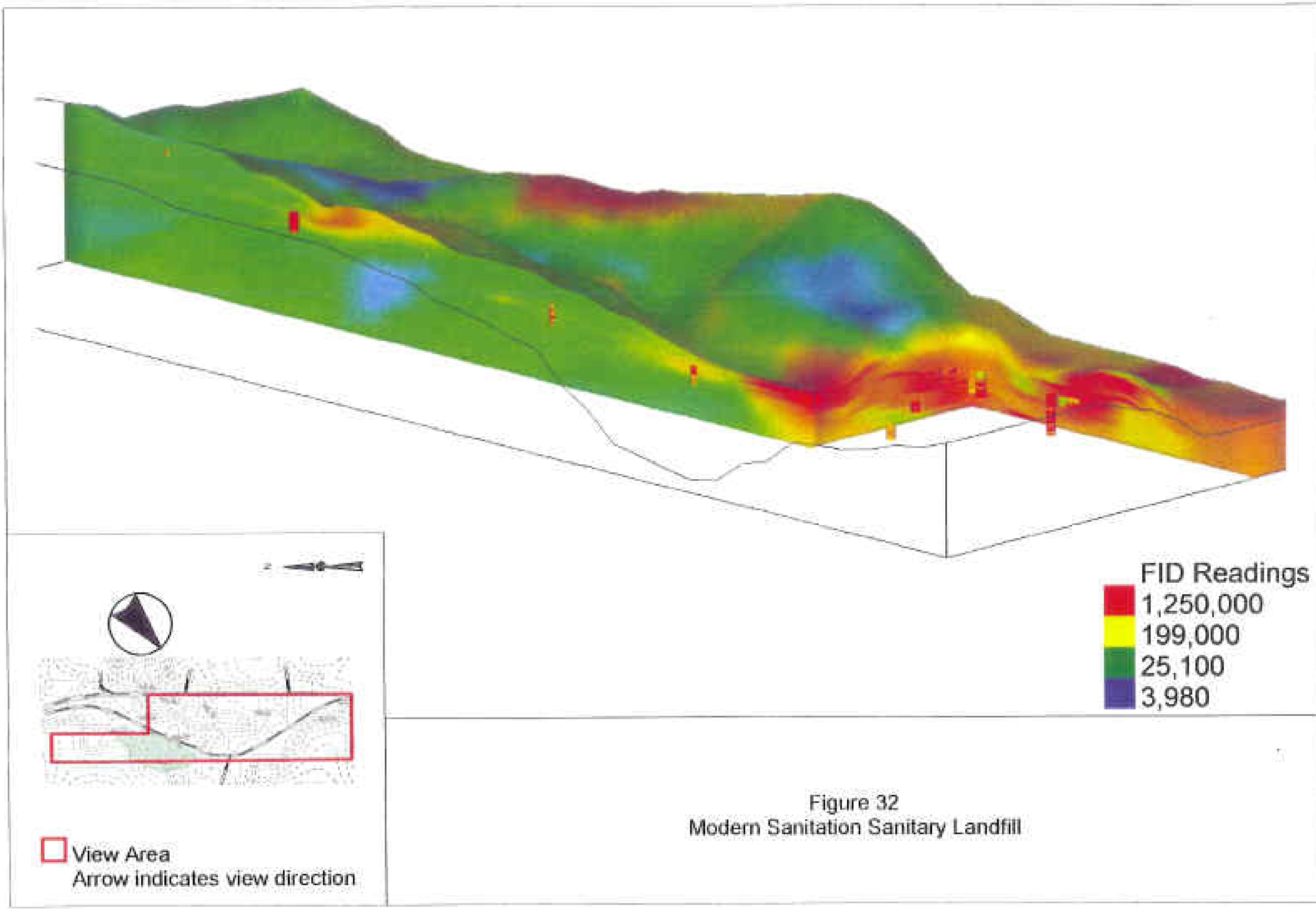
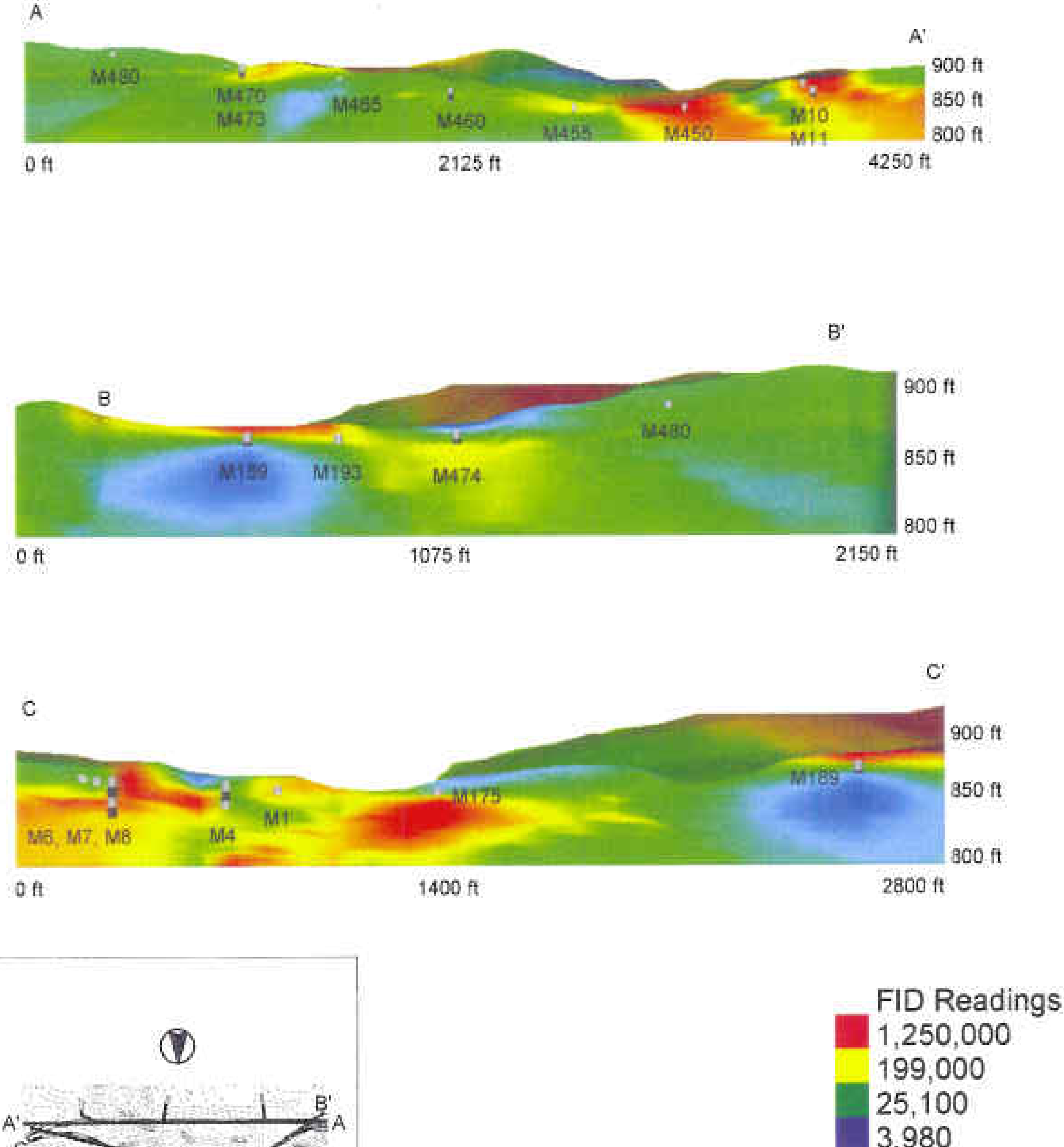


Figure 32
Modern Sanitation Sanitary Landfill



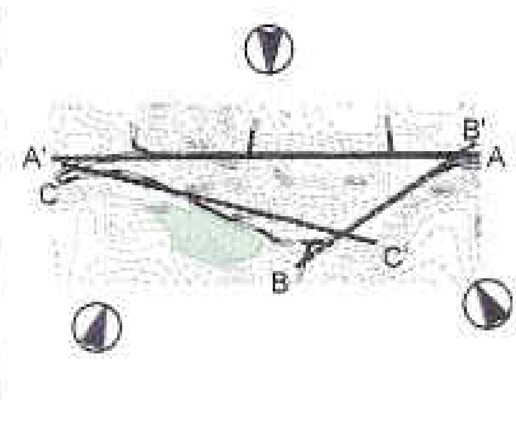


Figure 33
Modern Sanitation Sanitary Landfill
FID Reading Cross Sections

especially at depth, and again to the north from M4 on to M6, 7 and 8. The migration to the north is supported by monitoring well results (MW 1, 4, 6 and the deeper MW7). Once again, projections at deeper levels should be treated cautiously, as they are based on little to no data, the exception being in the area of M1 through 8, where deeper probes were possible and where wells of different screened interval depths were placed.

Summary for Modern Sanitation

The soil is very rocky. The parent material for this soil is dolomite bedrock, which contains an abundance of chert. There are also some sandstone layers. Clay is mixed with the rock along with small amounts of sand. Weathered rock lenses were observed in all soil cores taken. The soil is highly permeable and can readily transmit high concentrations of landfill gas long distances. These natural pathways are complex and enhanced by the old road and highway; the topography with valleys, ridges and hills; fill for road and building construction; and the old dump adjacent to the northern landfill boundary. Clean fill under the highway acts as a preferential pathway for gas migration along the highway, as suggested by the data.

Methane was found up to 1500 feet from the landfill and along the highway at concentrations exceeding 20% by volume. Gas is likely to migrate further, especially to the NE, but this was not determined in this study. Probe depth was limited by refusal, sometimes at less than 10 feet, limiting information at deeper locations. Since refusal was commonly a hard, rocky layer, gas transmission below refusal is likely. Projections based on available data indicate gas migration pathways at deeper levels, but the lack of data except in a few areas makes such projections unverified.

SOUTHEAST LANDFILL

The study area is shown in Figure 34. It is a flat area to the west of the landfill. The landfill is located on a large point bar for the Blue River near Kansas City. The soil is alluvium and contains clay, gravel and sand layers, of which the gravel and sand provide pathways for methane migration. Of special interest at this site is the gas flow in an unsaturated layer between two saturated zones.

MIP and Soils

Nine probes were completed, supplemented by three soil cores of which two were associated with probes. The locations are shown on Figure 34. The MIP and soils results are in Appendix F and form the basis for Figures 35 and 36. The outermost probes M3, 4 and 5 showed very low FID responses; M2 had spotty but higher values at 35 to 40 feet deep. M6 also had a low response, within the top 10 feet or so, and is closer to the landfill. High FID values, found at M1, 7, 8 and 9, tended to be shallow at less than 6 feet, or deeper at 30 to 40 feet. Water was found at approximately 10 feet bgs, followed by an increasingly unsaturated zone from approximately 20 to 40 feet bgs. Methane was found, consequently, either in the shallow unsaturated layer, or below the perched groundwater zone.

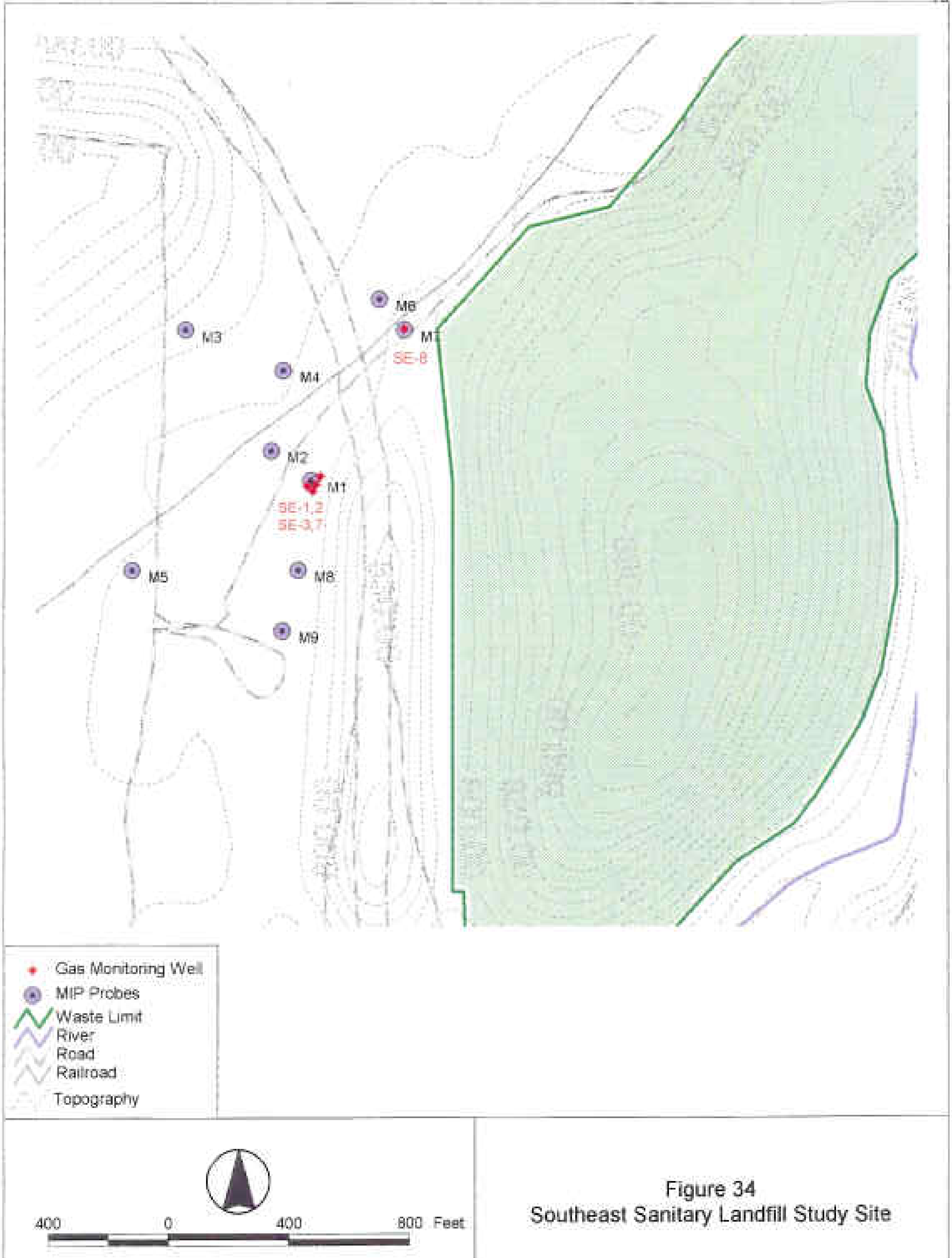


Figure 34
Southeast Sanitary Landfill Study Site

Figure 35. Southeast SLF
MIP Log #1r, Soil Log#1, Well #SE07

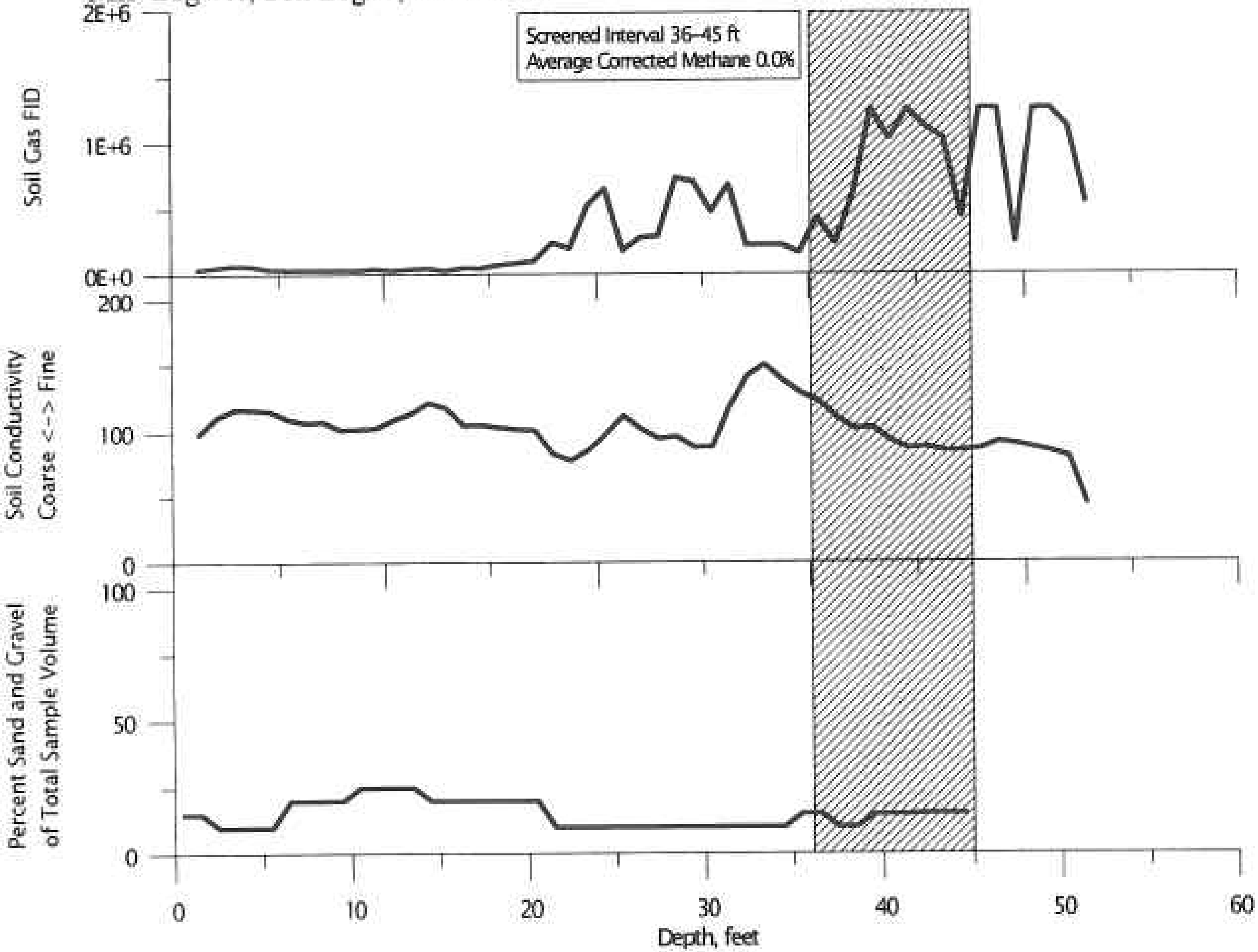
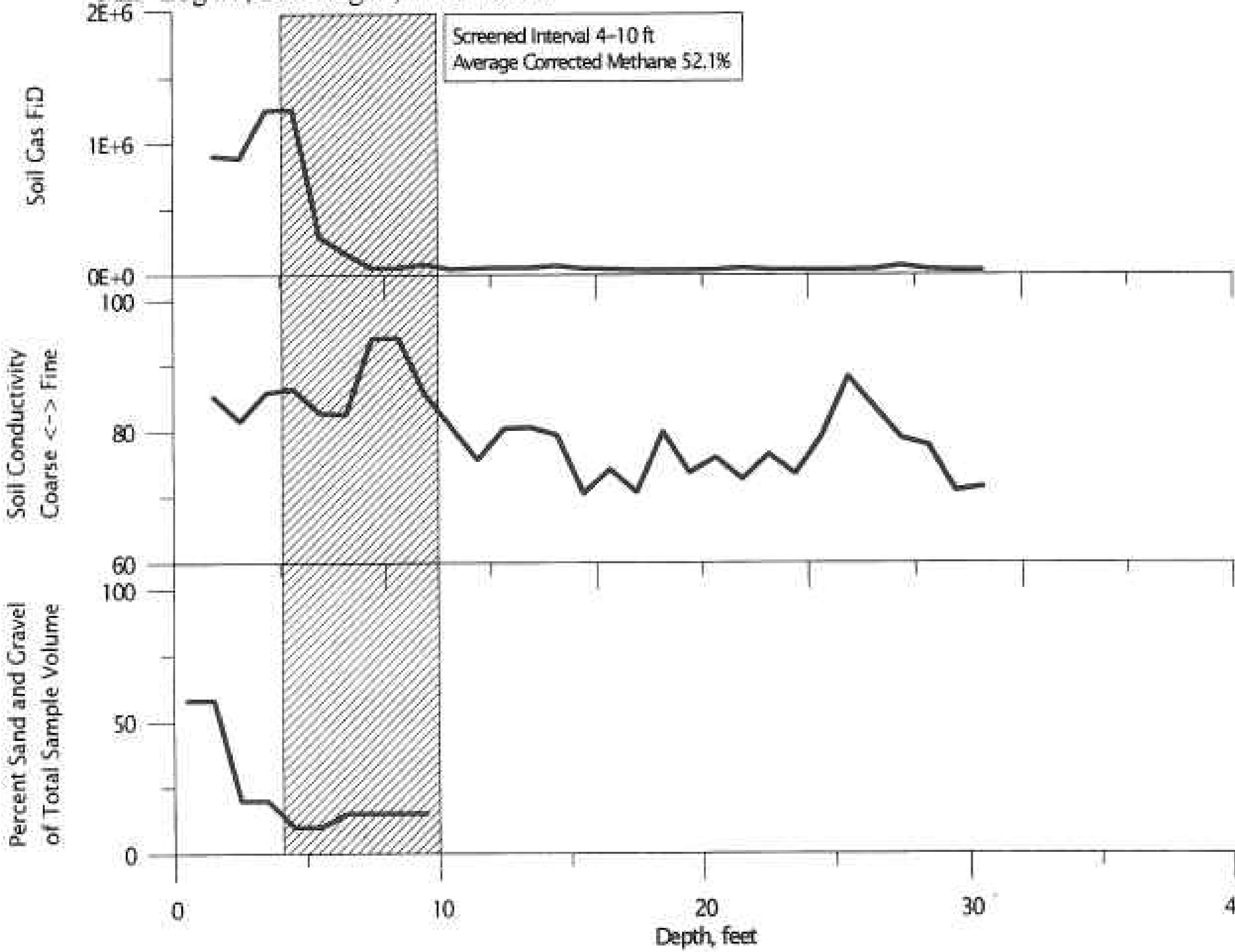


Figure 36. Southeast SLF
MIP Log #7, Soil Log#2, Well #SE08



The combined MIP and soil logs, Figures 35 and 36 show low amounts of sand and gravel which are reasonably mirrored by the medium soil conductivity values. High FID values were found in the top 10 feet for probe 7, and at 20 feet and deeper for probe 1r.

Gas Monitoring Wells

Thirteen wells were constructed prior to MIP tests. Since many of these were installed to meet other objectives, not pertinent to this report, they are not given here. The five pertinent wells are described in Table 8, of which Wells 7 and 8 are related to the probe and soils results in Figures 35 and 36. Well 7 has a screened interval that intersects elevated FID readings; however, it proved impossible to seal this and other wells through the perched water and the wells filled with water, precluding gas measurement. Well 1 was screened in the lower layer and did yield a gas sample during probing, but not after the well was installed. Well 8 was screened from 4 to 10 feet deep and did have a high average methane concentration of 52.1% that corresponded to the high FID readings. This well is close to the landfill, near M7; the other wells were further from the landfill and near M1. Wells 1, 2 and 3 had erratic methane concentrations, ranging from zero to over 40% methane, with averages given in Table 8. Given the variability within a given well, these averages must be considered with caution.

EVS

Figure 37 models the highest FID readings at each probe. It shows a logical progression of gas concentrations decreasing with distance from the landfill. The 3D plot, Figure 38, shows gas in two layers, which is better illustrated by the cross-sections in Figure 39. Section B-B'

Table 8. Gas Monitoring Wells Southeast and Mexico Sanitary Landfills					
Well Number	Screen, ft	MIP Log	Soil Log	Gas Corrected CH_4†	FID Average
Southeast Sanitary Landfill					
1	36 - 45	1r	none	27.7‡	n/a
2	7 - 10	1r	none	9.6‡	n/a
3	3 - 6	1r	none	20.8‡	n/a
7	36-45	1r	1	0.0	8.2×10^3
8	4 - 10	7	2	52.1	3.2×10^4
Mexico Sanitary Landfill					
1	7 - 19	1	1	1.7	5.5×10^5
4	7 - 19	1	2	1.3	5.5×10^5

† Average of all gas readings, methane (% by volume)
‡ Readings varied from 0% to greater than 40% methane

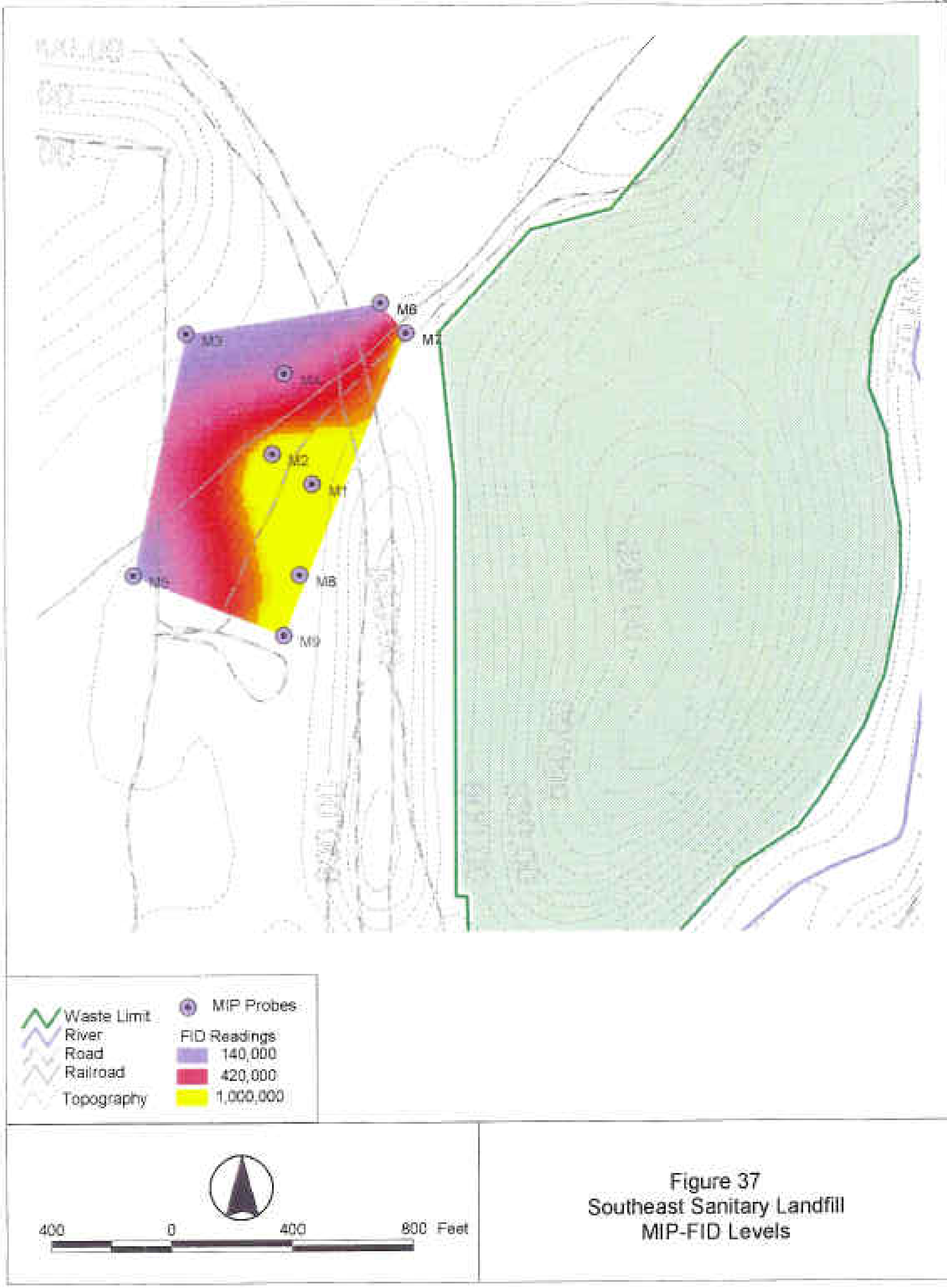
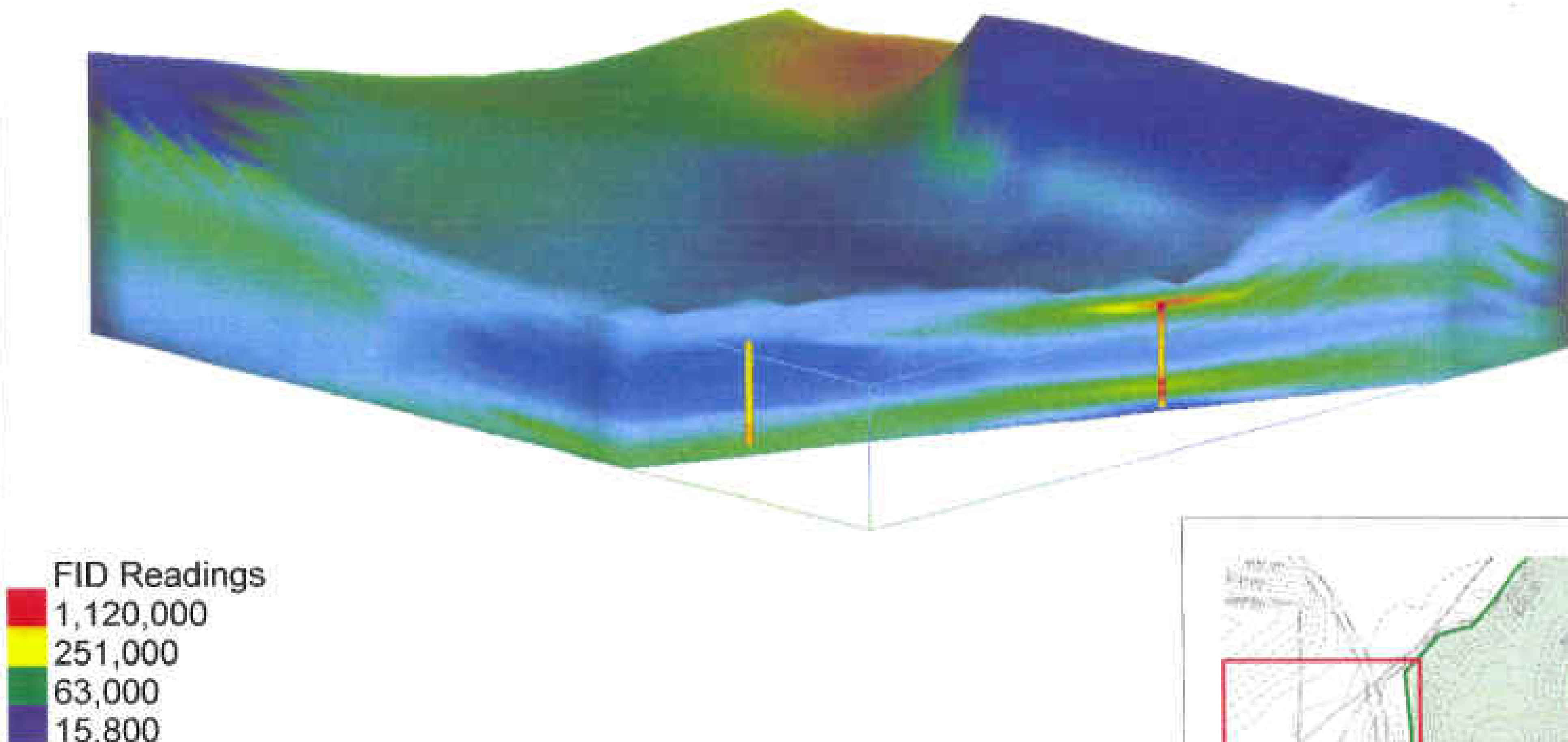


Figure 37
Southeast Sanitary Landfill
MIP-FID Levels



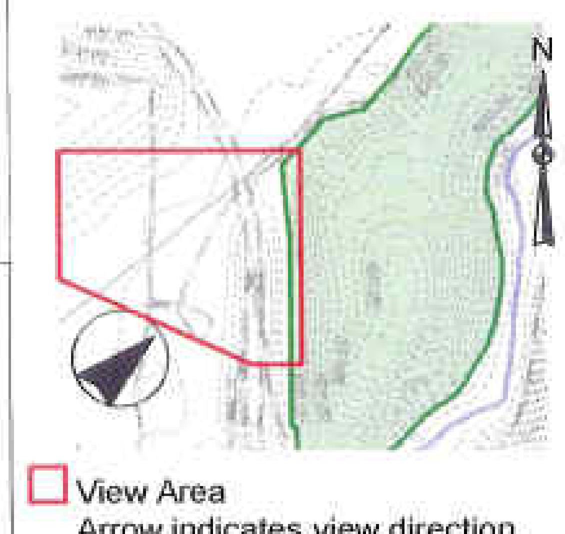
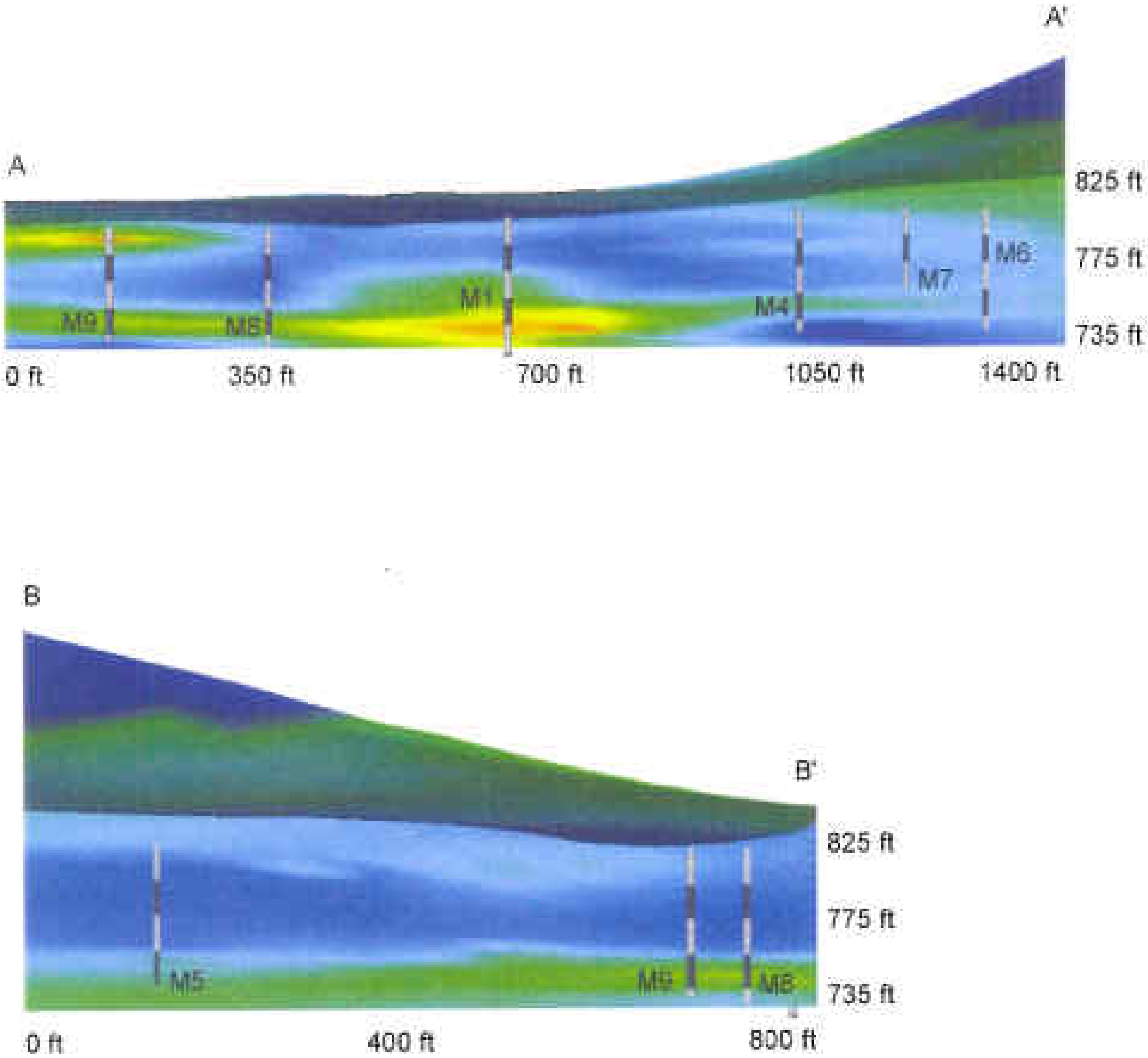
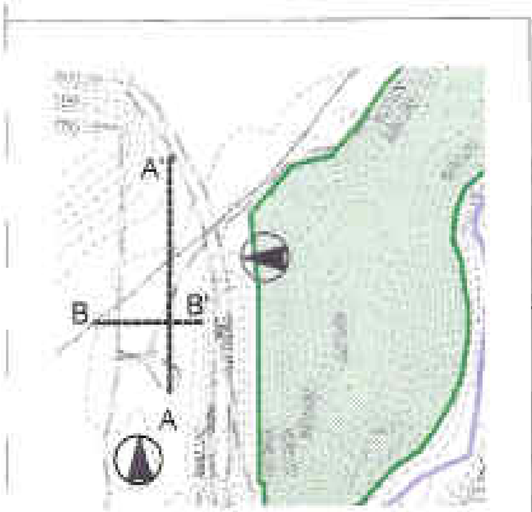


Figure 38
Southeast Sanitary Landfill





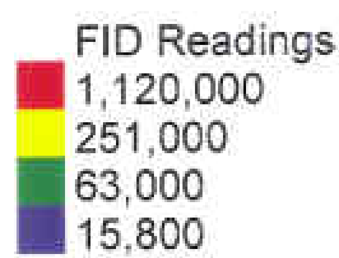


Figure 39
Southeast Sanitary Landfill
FID Reading Cross Sections

clearly shows the deeper gas migration pathway and hints that there may be shallow gas as well. This section suggests deep gas extending over 1000 feet to the west of the landfill. Section A-A' more clearly shows both layers of gas. The shallow gas drops off to the north (toward A'). The deeper gas zone is over 1000 feet long, dropping off beyond M4 but still showing an impact at M6 and beyond.

Summary for Southeast Landfill

Clays and silts are mixed with 5 to 10 foot thick sandy layers in this alluvial valley. Porosity is inter-granular according to soil type and is not controlled by fractures or rock layers. Methane was confirmed 500 feet from the landfill, and MIP results suggest deep migration of at least 1000 feet. The highway between the study area and the landfill boundary is above the elevation of the study area. It is not known if the highway has an effect on gas movement, but gas is migrating under the highway. There are reports that the depression between the highway and the landfill was filled with waste, which would in effect move the landfill boundary closer to the study area by 100 to 150 feet.

The near surface gas dissipates faster than does the deeper gas, most likely due to surface venting. Depending on surface conditions, the extent of shallow depth migration would be expected to contract or expand--a scenario not monitored here.

MEXICO LANDFILL

Methane was found at the property boundary during an investigation by a consultant on behalf of the landfill. The study area is adjacent to the southeast corner of the landfill. The area surrounding this portion of the landfill is used for agriculture, including the study area. The soil is a tight clay derived from glaciation containing micro-fractures and root zones, which constitute the most likely pathways for gas migration.

MIP and Soils

Eight probes were completed, as shown in Figure 40. Probe logs are included in Appendix G, along with two soil core results. Figures 41 and 42 were compiled from logs contained in the Appendix, to which were added average methane concentrations over the screened intervals for the gas monitoring wells constructed at MX1 and MX4. The two figures show low conductivities, indicating a layer of coarse surface soils, over the top 3 feet. Conductivity increases from 3 to 5 feet deep, beyond which it levels. This is consistent with the fine grained soils noted in the soil logs, which are summarized in Figures 43 and 44.

High FID readings occurred in M1, 3 and 6, which are at a topographic high. M7 also had high FID readings and is close to the landfill. Probes with low FID readings are M2, 4 and 8. Elevated FID readings occurred generally from 5 to 20 feet bgs if found at all. Clearly, in spite of the tight, clayey soils, the many root zones and fractures revealed in the soil cores are able to transmit methane. The deeper probes generally terminated 20 to 30 feet bgs because of low FID readings. Bedrock was not encountered.

Gas Monitoring Wells

Four wells were installed, prior to the MIP's, of which two failed and are not considered further. The remaining two provided low average corrected methane concentrations of 1.7 and 1.3%,

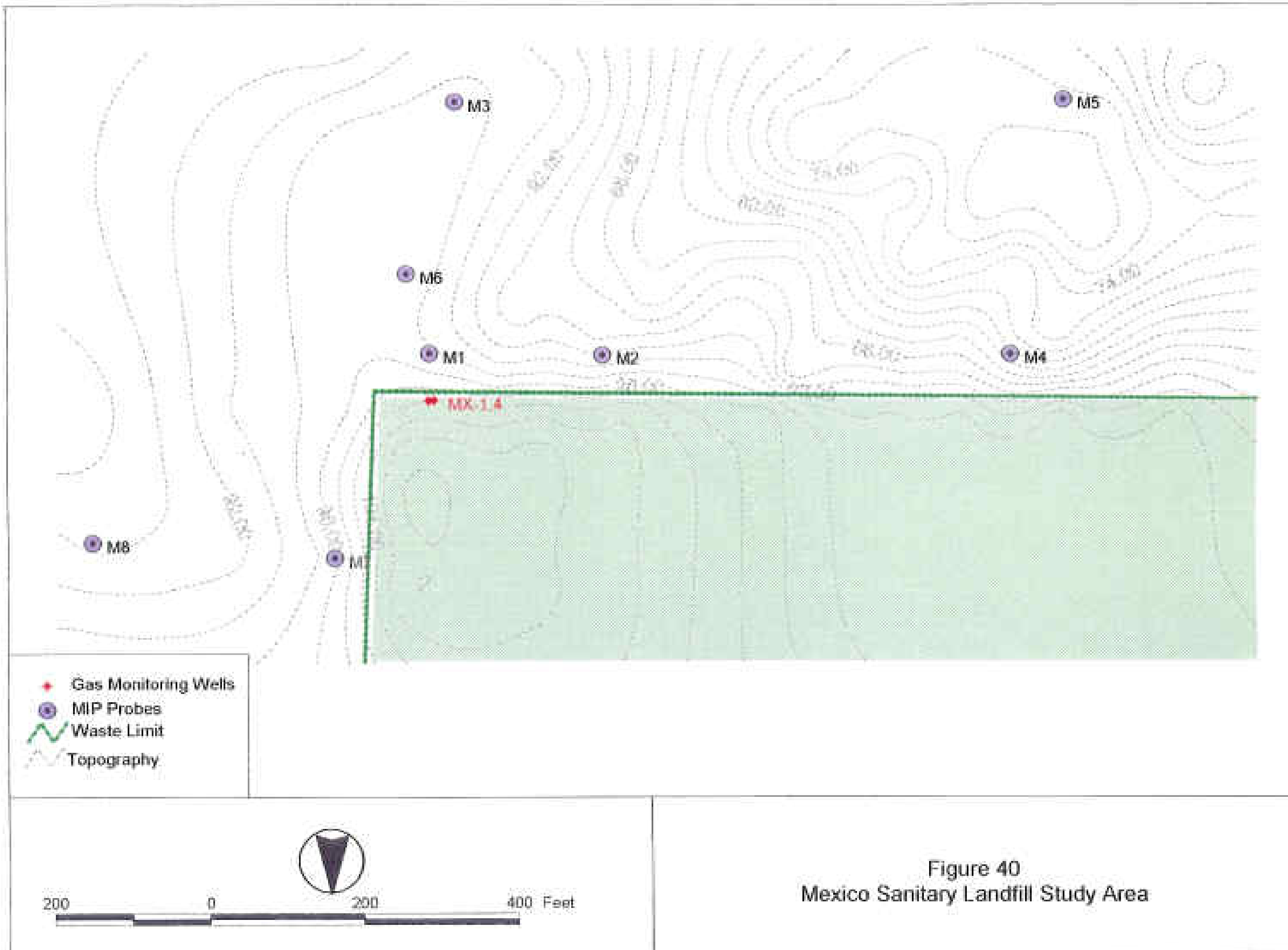


Figure 40
Mexico Sanitary Landfill Study Area

Figure 41. Mexico SLF
MIP Log #1, Soil Log#1, Well #MX01

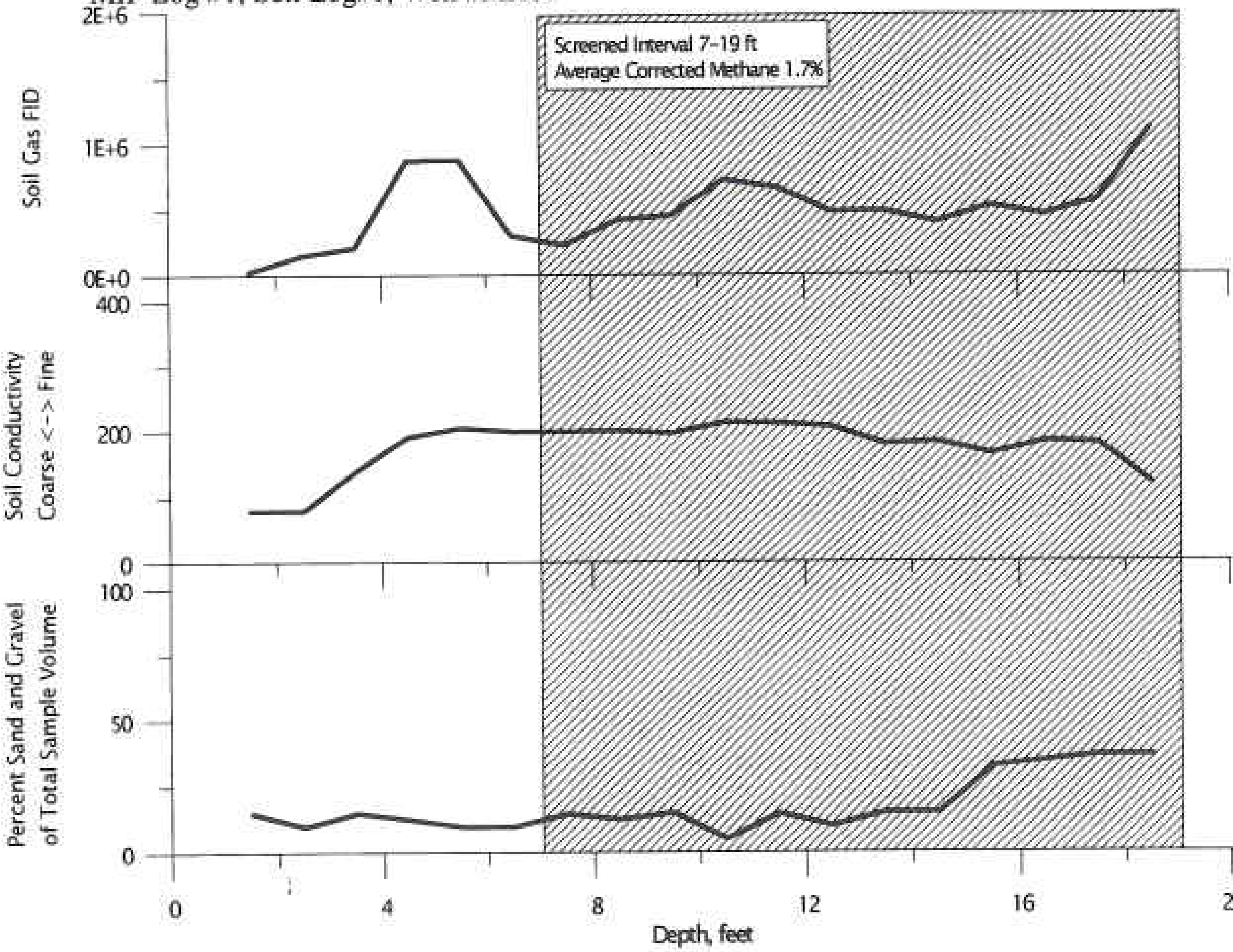


Figure 42. MexicoSLF
MIP Log #1, Soil Log#2, Well #MX04

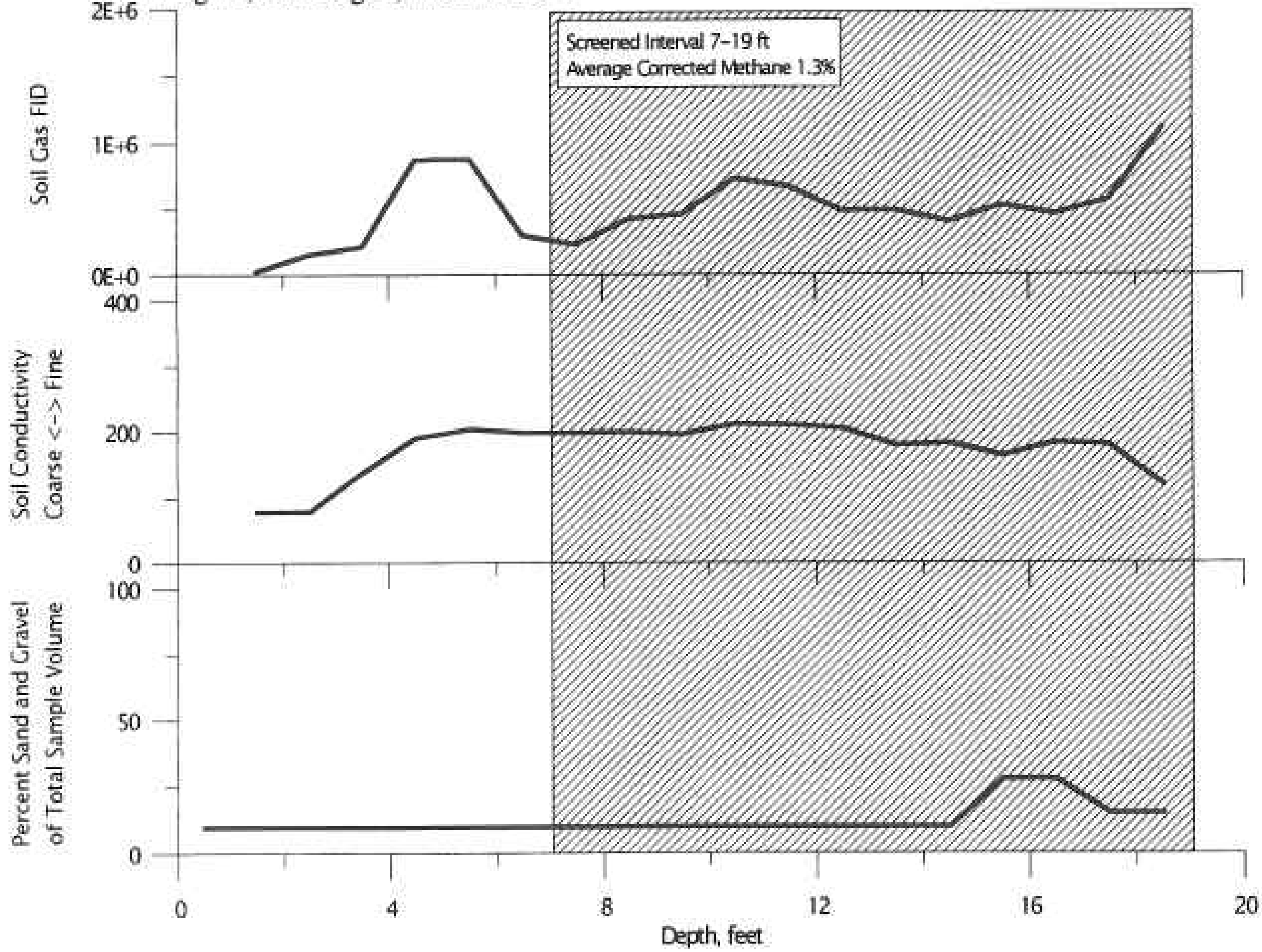


Figure 43. Mexico - MIP Soil Core Analysis Near MIP Location #1

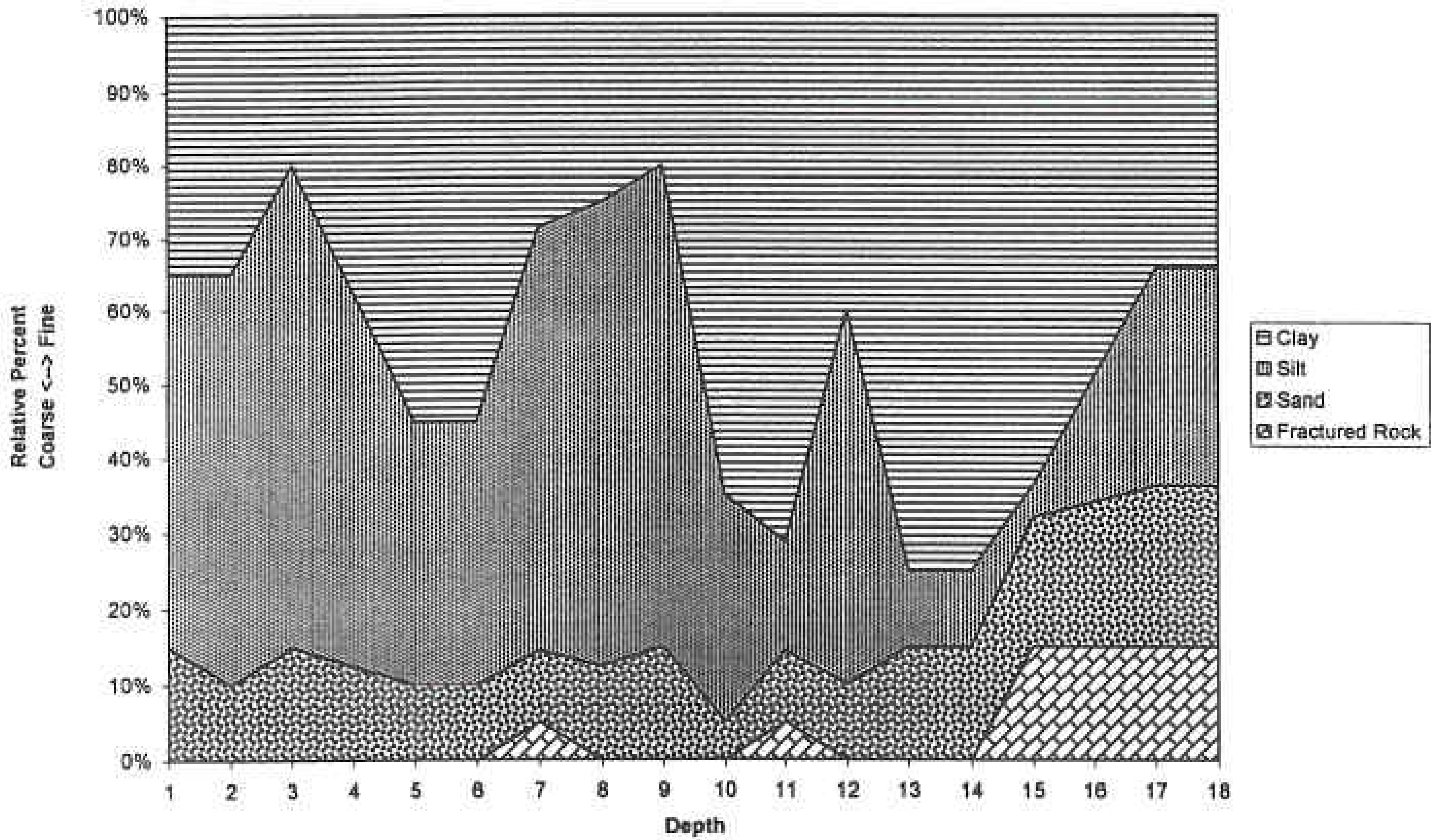
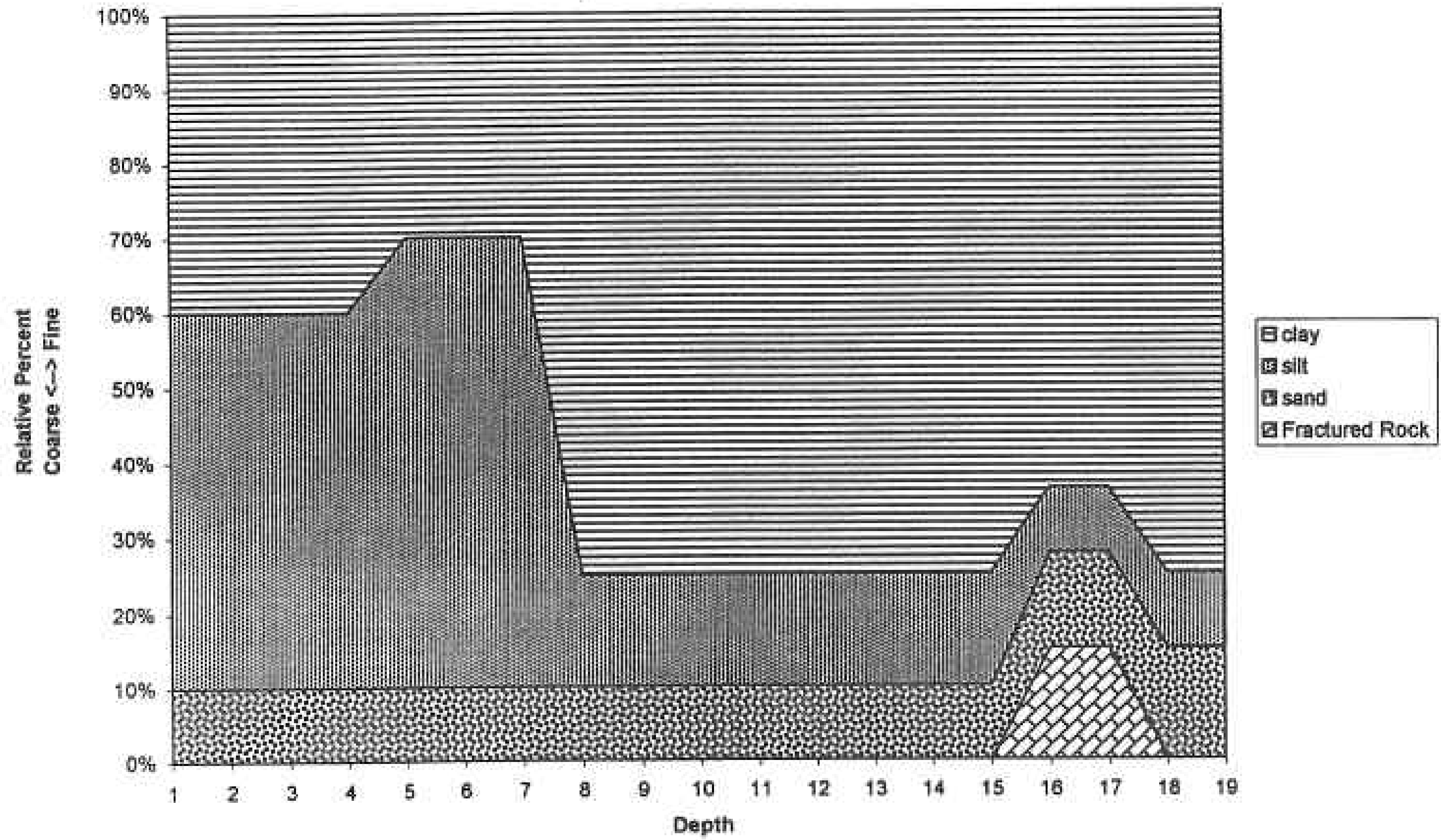


Figure 44. Mexico - MIP Soil Core Analysis at MIP Location #2



as shown on Figures 41 and 42 and Table 8. Both wells were installed within 5-10 feet of the landfill and were screened from 7 to 19 feet bgs.

EVS

Figure 45 is the EVS output resulting from the highest FID reading at each probe location. Note that the high gas concentration areas shown refer to the highest readings at this landfill. The numerical values for these high concentrations are not necessarily the same as those shown in similar areas for other landfills. The highest values are in a zone extending from along the east boundary of the landfill to the south, ranging from M7 through M1 and M6 to M3. The south border of the landfill has little gas, except for a relatively high and unexplained value at M5.

The 3D plot, Figure 46, shows clearly two layers of gas, with the improbable low gas concentrations in the landfill itself as noted for other EVS plots. The cross-sections, Figure 47, show the two layers of elevated FID readings more clearly, with the shallow gas extending along the eastern border of the landfill and to the south over 400 feet from the landfill. The deeper gas layer is shown along the southern border of the landfill and extending to the south over 400 feet from the landfill. Note, however, that this lower layer may or may not exist as widely as indicated, as it results from only M3 and M5 this far south of the landfill. Time and budget did not allow additional probing to determine the extent of this layer.

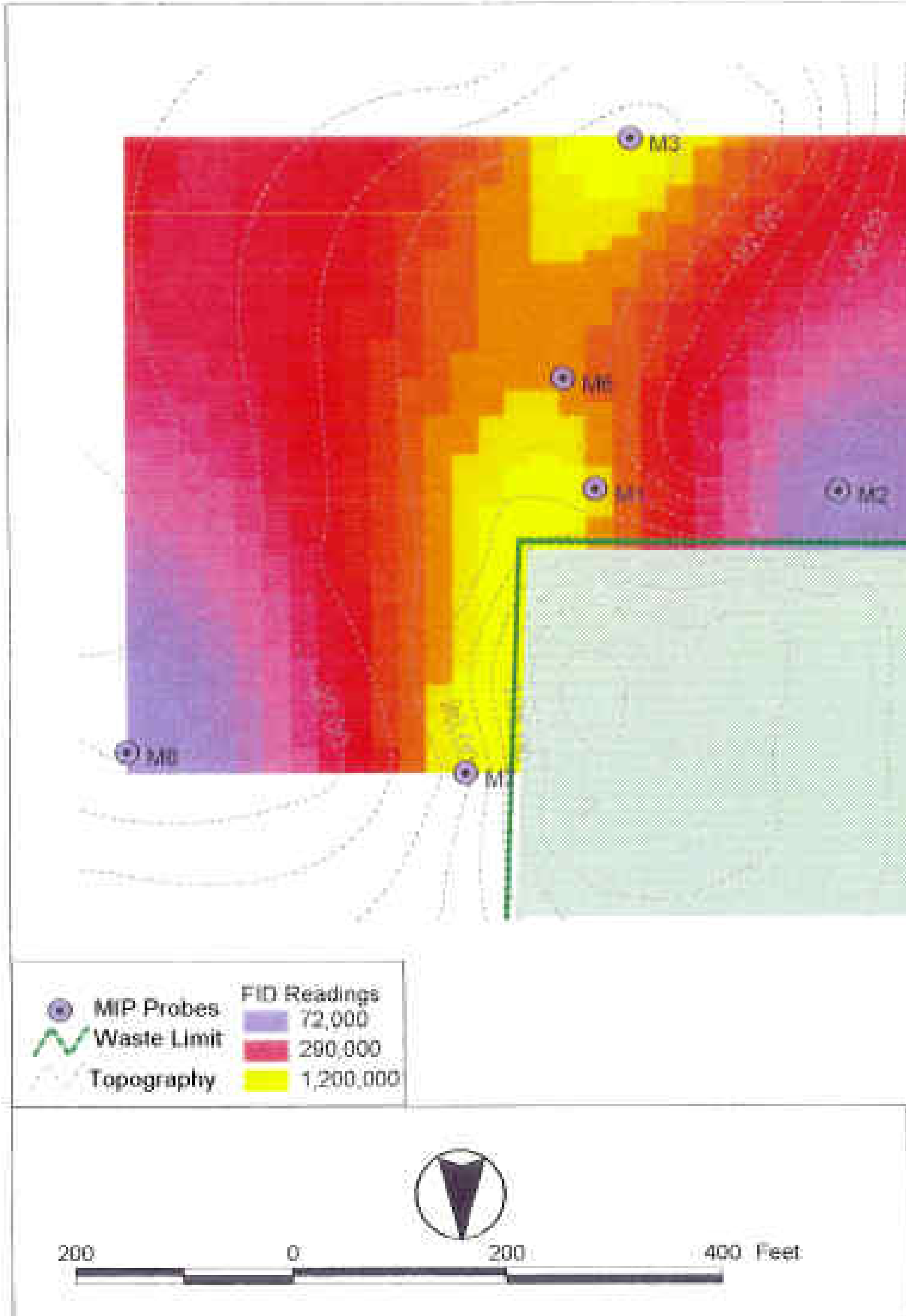
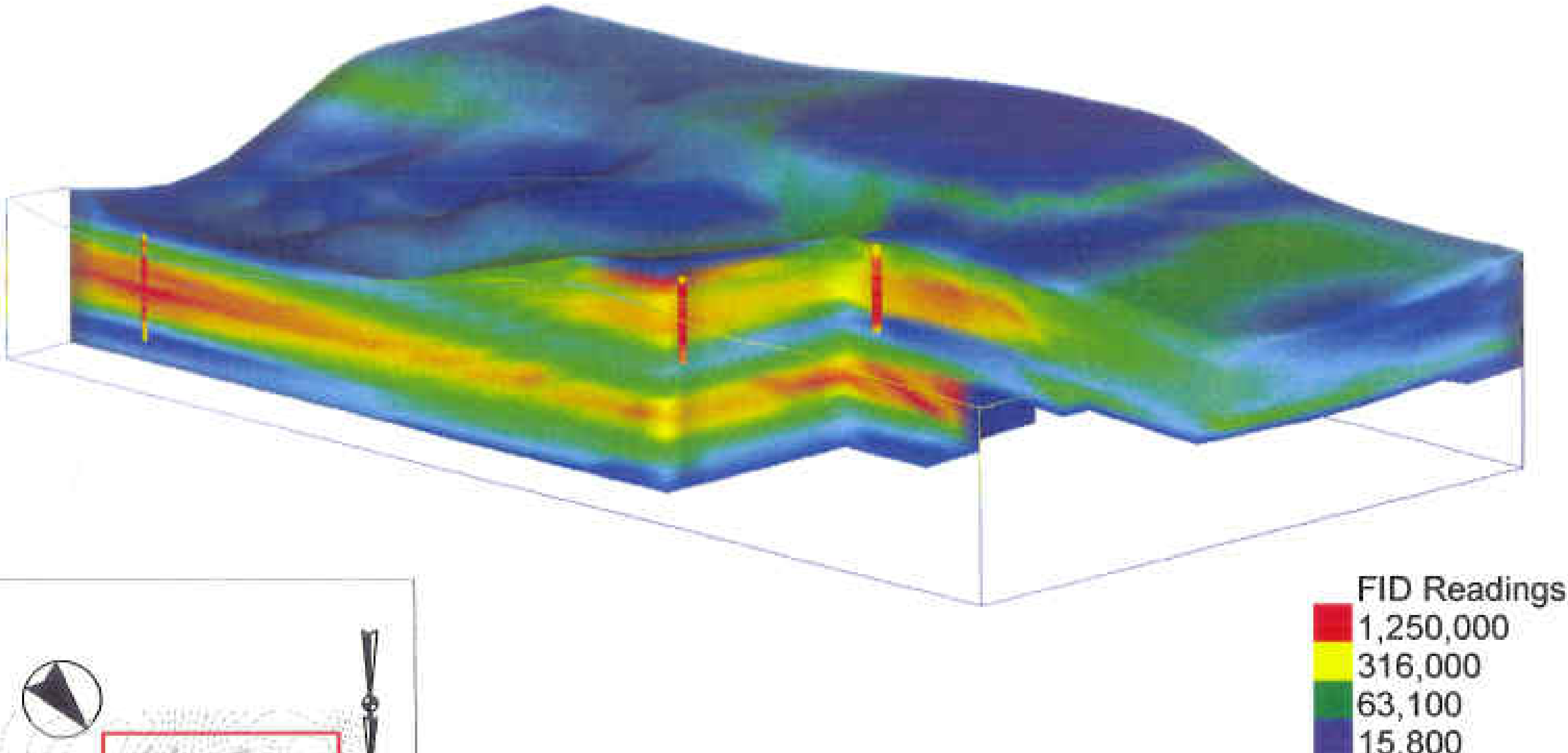


Figure 45
Mexico Sanitary Landfill
MIP-FID Levels



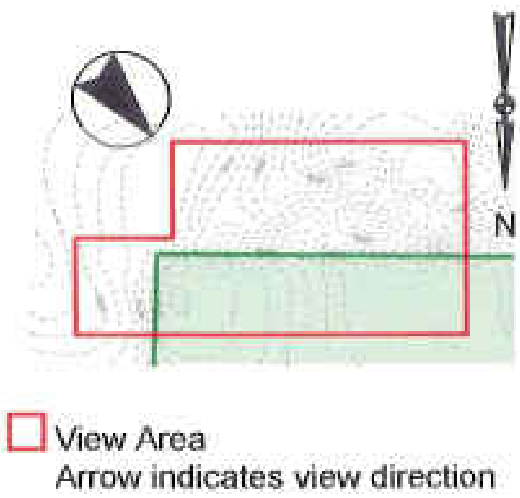


Figure 46
Mexico Sanitary Landfill

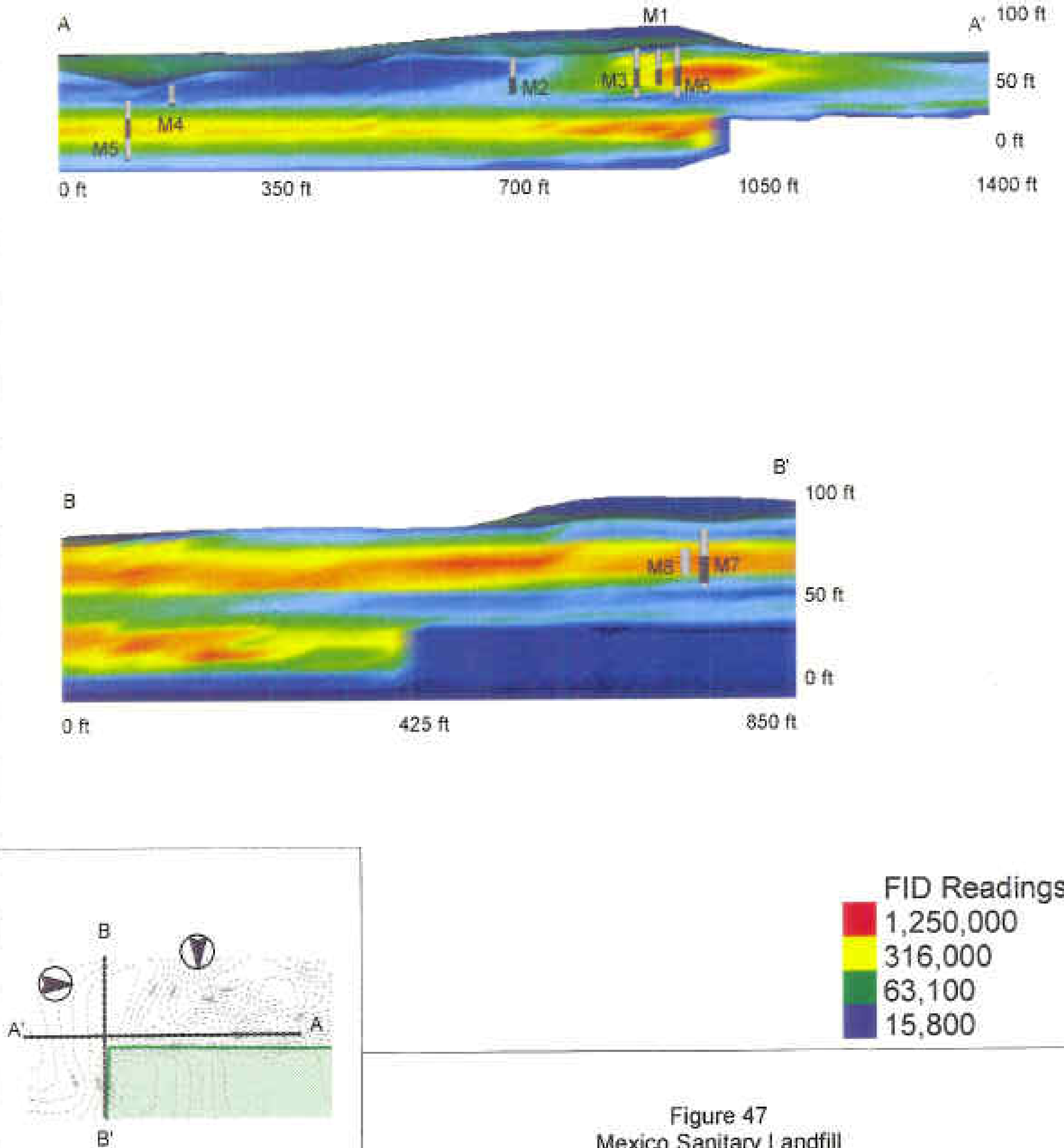


Figure 47
Mexico Sanitary Landfill
FID Reading Cross Sections

Summary for Mexico

The soil is predominately tight clays but with micro-fractures that likely provide the pathways for gas migration. There are very fine root structures near the surface, but only low FID readings were found this close to the surface. Relatively high FID readings were encountered up to 400 feet from the landfill, which was the limit of exploration. The high readings at distance were not verified by gas monitoring wells, but experience at other sites where such confirmation was performed suggests the elevated FID readings do correctly indicate the presence of landfill gas. The depth of the landfill may limit the depth of gas migration; however, soil fracture patterns may also be a limiting factor. These results are not conclusive in this regard.

It is notable that gas migration clearly occurs in an area known for its tight clays, and that near surface measurement will not discover this gas. The importance of layering and imperfections in the clay are obvious.

RENFRO LANDFILL

This landfill is in a karst region of Missouri. Limestone solution features are common in the area. The study area is north of the landfill and is bounded on the east, north and west by deep valleys. To the south, the study area is bounded partially by the landfill but also by a deep valley. Gas migration testing began approximately two years ago, which revealed migration into a small portion of the study area both at shallow and deeper levels. The soil contains large amounts of fractured chert, layers of which are likely pathways for gas migration.

Previous Investigations

Gas monitoring wells were installed in multiple sets over time at this landfill. Well and vent locations are shown in Figure 48.

Methane gas was initially found near the landfill during drilling for groundwater monitoring wells. Gas was released from zones near the bedrock/soil interface. Nine passive gas vents were drilled into the landfill in an attempt to reduce gas pressure and hence migration, and several gas monitoring wells were placed around the perimeter of the landfill. Results from these wells plus other information indicated methane may have been migrating into a nearby mobile home park, which is part of the study area. Seven shallow gas monitoring wells were then installed in the mobile home area, two of which showed high methane concentrations approaching 30%. This prompted installation of ten more shallow wells, of which three had high methane concentrations. Six more wells were then installed deep around the perimeter of the shallow wells, of which three had high concentrations. Finally, the on-site passive vents were converted to form an active gas extraction system in May 1997 in an attempt to stop gas migration.

Recent Investigations and Results

All gas monitoring wells in the mobile home park to the north of the landfill, which is across the road running east-west just north of the landfill, have had non-detectable methane concentrations since operation of the active gas system began. Gas wells 3 and 4, less than 1000 feet from the northern landfill boundary, have shown methane concentrations greater than 50% prior to the active system. Since the active system has been in operation, well 3 methane levels

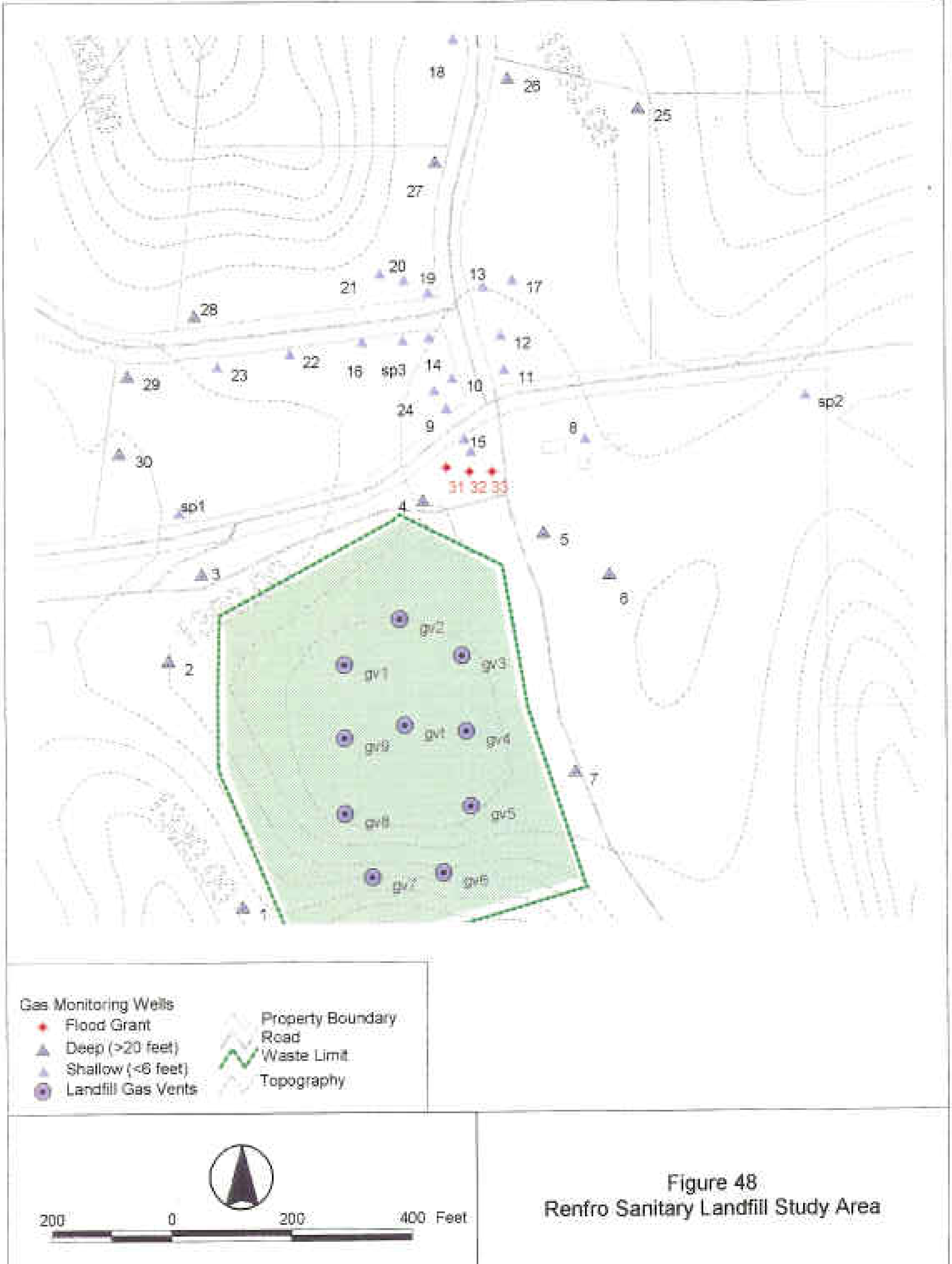


Figure 48
Renfro Sanitary Landfill Study Area

have been zero or very close to zero and well 4 concentrations have fallen but not reached zero (not detectable).

The last gas monitoring wells installed are numbers 31, 32 and 33, also shown in Figure 48, approximately 100 feet from the landfill boundary. Table 9 indicates well installation specifics, and Figure 49 gives the results over four months. Note the active system began in May of 1997. The curves show that the highest gas concentrations are at the medium and deep levels; shallow gas (8 to 18 feet deep) is less than 3% methane. The rising levels from September to November mirror increases measured during these months in previous years.

Methane constant concentration contours are given in Figure 50. These contours reflect average concentrations over August to November, 1997. Note that little methane migrates under the road and into the mobile home park. The only area projected to have measurable concentrations (ranging up to 10% methane) across the road is bounded by SP1 and wells 23, 24 and 9. There are no wells in this area except for two unnumbered wells between well 15 and wells 31, 32 and 33. The two unnumbered wells averaged 5 to 10% methane and are off to one side of the measurable methane area. Thus, there is a lack of actual measurements delineating methane migration across the road since operation of the active system; the area shown is based only on projections.

Summary for Renfro

The soil is derived from cherty limestone, which has weathered to a residual soil with as much as 50% chert. The chert is often found in fractured layers, which can be highly permeable for gas migration. Deep monitoring wells indicated, prior to operation of the active gas extraction system, methane concentrations up to 26%, 600 feet from the landfill. Shallow wells have shown up to 52%

Table 9. Renfro SLF Well Specifications		
Well	Total Depth, ft	Screened Interval, ft
#31	41	24-34
#32	36	8-18
#33	52	37-47

methane in the top 6 feet of soil, but this shallow gas is spotty with some areas at very low gas concentrations. The valleys bounding the study area act as cutoff trenches limiting gas migration. Since operation of the active system, the extent of migration has been reduced to within 100 to 200 feet of the landfill at all depths. The depth of gas migration is presumably limited by bedrock and waste depth. Note that there were no deep monitoring wells to measure the depth of migration.

GENERAL DISCUSSION

USE AND EFFECTIVENESS OF THE MIP

The MIP is an expensive tool, requiring expertise to operate and to interpret the data; however, it can provide much guidance in a short time regarding soil conditions and the presence of organic gases in soil. Table 10 provides probe operation statistics. At an average probing time of 46 minutes to achieve the average depth of 20.2 feet, the process of data generation is very efficient. Rig set up, take down and relocation time must be added, but even this is efficient with an average of 6.2 probes completed per working day. Probe depth was typically limited by refusal based on hard rocky layers or bedrock. The rig is capable of probing to 60 feet; the deepest probes achieved here were in the 40 to 45 foot range. Clearly, much information is obtained in a relatively short time by

Figure 49. Renfro Sanitary Landfill
Flood Grant Gas Wells, 1997 - 1998

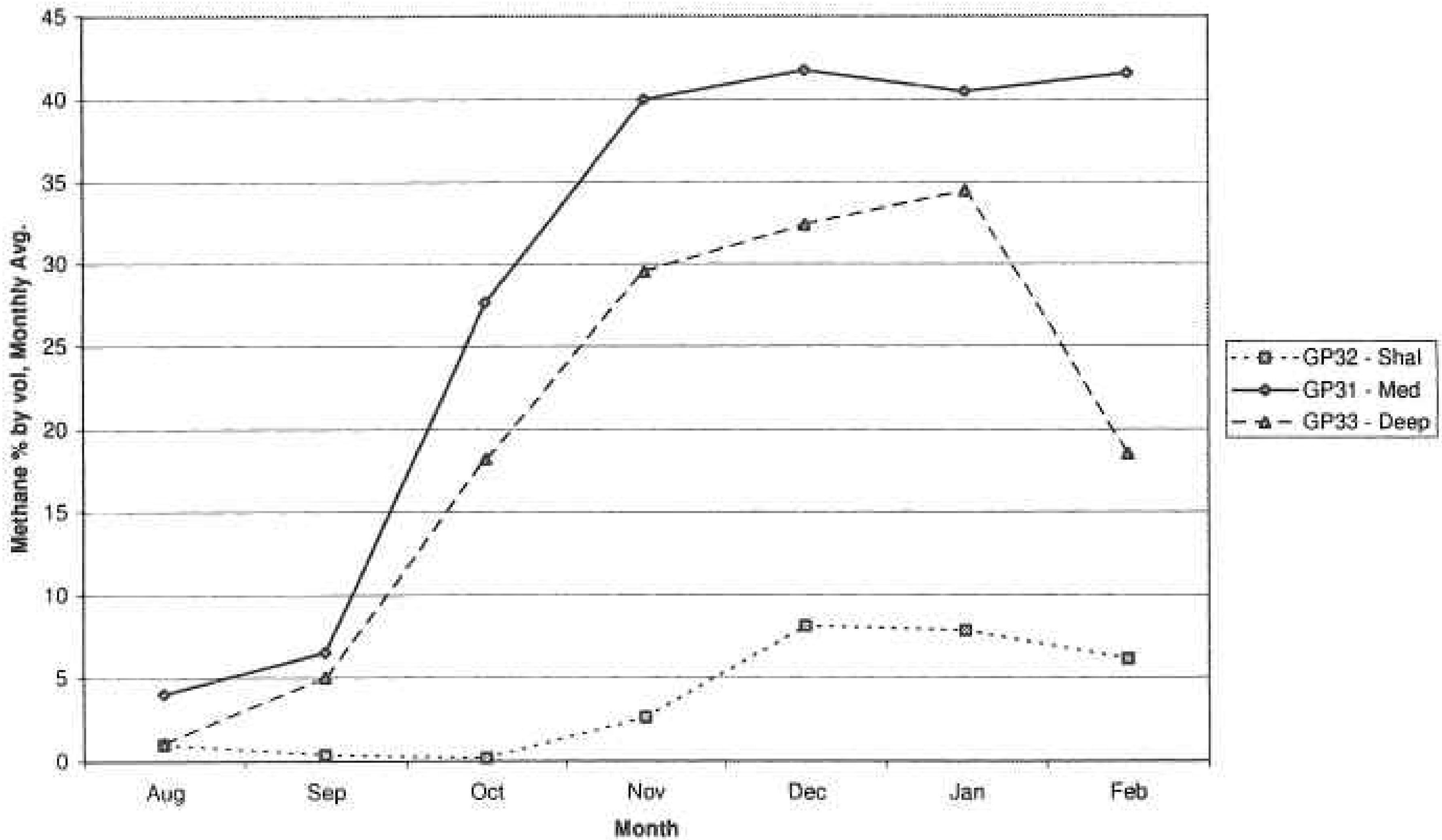


Figure 50
Renfro Sanitary Landfill
Projected Methane Gas Contours

Table 10. MIP Probing Statistics		
Statistic	Value	Comment
Average Time per Probe Hole	46 minutes	
Average Rate of Probing	0.48 ft/min	
Total Number Probes for this Project	93 probes	Including Non-completed Holes
Total Time Spent Probing	71.7 hrs	
Total Number of Days Probing	15 days	Includes Partial Probing Days
Average Hours per Day Probing	4.8 hrs	Rest of Time Is Travel, Setup and In-field Maintenance
Average Probes per Day	6.2 probes	Includes Partial Probing Days
Average Depth of Probes	20.2 ft	Including Non-completed Holes
Maximum Probes in One Day	10 probes	
Average Depth of Max Probes in One Day	16.2, 20.6 ft	Achieved at Two Sites

this technique. Conventional soil logging and soil gas sampling and measurement would take much longer and would not provide the detail, especially with regard to soil gas presence or concentrations.

The major difficulty with the MIP is the resulting data do not provide absolute information about soil characteristics or gas composition. The probe speed and soil conductivity logs must be interpreted and can be misleading. The only way to obtain solid, accurate soil information is to gather soil cores for logging and analysis. Similarly, the FID (and PID) log is in units other than gas concentration and so must also be interpreted and then typically confirmed by installation of gas monitoring wells to obtain and finally analyze gas samples.

There is a general relationship between FID readings during probing and gas compositions measured later with wells, as noted throughout this report, but it is neither direct nor exact. Calibration of the FID reading in the lab in a closed test vessel without soil provided a strong relationship between reading and methane concentration (Table 1 and Figure 3). Field calibration is less exact, with soil characteristics, moisture content, screened interval selection, and other factors complicating the relationship, but even so, field calibration gave results similar to the laboratory results (Figure 4). In all but two of the probe locations where wells were later installed, the MIP correctly indicated the presence of methane. At the first of these two locations, the probe predicted little to no methane, yet the well produced samples always greater than 5% methane. In the other case, the MIP predicted moderate methane concentrations, but the well samples had very low to undetectable concentrations. These disparities may be due to specific locations within the screened intervals controlling gas composition, well construction, or some other unknown factor.

The FID did in fact provide readings generally comparable to soil gas composition measured with wells. Certainly as a screening tool indicating presence or absence of methane, the FID was effective. Furthermore, higher FID readings were usually corroborated later by higher measured methane concentrations. Additional experience may improve the ability to predict soil gas concentrations under field conditions with the MIP, but it is unlikely to replace direct soil gas sampling and analysis, especially for legal or enforcement purposes.

USE AND EFFECTIVENESS OF EVS AS AN INVESTIGATIVE AND DATA VISUALIZATION TOOL

The plan view 2D plots using the highest FID readings for each probe to indicate areas of high to low relative FID readings (methane concentrations), and the confidence in the areas being accurate, were somewhat useful. Improbable results, especially those showing relatively high FID readings, occurred. They were usually attributable to the lack of information outside of the study area. These plots need to be treated with caution and need careful interpretation. At JZ the reliability plot after the first set of MIP's was used as guidance for a second set of MIP's with marginal results. The new probe locations did not greatly increase confidence in the results, and new probe locations could have just as well been decided without the uncertainty routine of the EVS.

The 3D plots are useful as a tool to visualize relative gas concentrations, but may be difficult to interpret. The reliability of the plot obviously depends on the amount and quality of data, over the three dimensions encompassing the study area. Table 11 gives the grid dimensions and node spacing for the six landfills. Generally, better results were obtained with smaller Kriging parameters. Visualization of the 3D plot is hampered by varying topography, with hills and valleys complicating the result such as to possibly obliterate gas pathways. Overlapping of pathways can shield some pathways from view or create apparent high or low gas zones that do not in fact exist. The lack of

Table 11. Kriging Parameters		
Facility	Grid Size, X x Y	Node Spacing, ft
Centropolis SLF	35 x 20	35
JZ SLF	24 x 30	60
Mexico SLF	36 x 20	40
Modern Sanitation	40 x 15	100
Southeast SLF	18 x 20	60
Renfro SLF	39 x 50	27

coordinates contributes to the difficulty in visualizing and interpreting the 3D plot. The 3D plot is more effective in an area with minimal topographic changes and more uniform soil and resulting pathways throughout the study area.

The 2D cross-section plots are more useful in showing relative gas concentrations and gas migration pathways. Used in conjunction with the 3D plots, two or so cross-sections sufficed; without the 3D plots, several cross-sections would be helpful to visualize gas presence and migration pathways. The 2D plots were especially useful to show the layering of gas presence or pathways. In most sites studied here, the higher gas concentrations at depth were easily documented and visualized, as was the migration distance away from the landfill.

With EVS it is possible to build rather misleading plots, showing unlikely gas presence, areas of high methane concentrations away from the landfill and areas of lower concentration adjacent to the landfill, and/or zones or layers of gas migration bordering on speculation. These situations arose here when there were little data with probes spaced far apart or not extending deep enough. Complex geology and significant topographic changes were also contributing factors. Less satisfactory models were created at Modern and Centropolis for these reasons. Other models were better but were limited by inconsistent soil conditions (such as at JZ) or by the lack of data (as at Mexico).

Given adequate data, properly interpreted, the EVS is a powerful tool compiling and then illustrating the results of hundreds to thousands of data points to show gas presence and migration pathways, and the extent of migration. There is no method other than the MIP known to provide the detailed albeit relative information regarding gas presence in soils, and no method better than EVS to compile and illustrate the results. The output is graphic evidence of gas migration pathways and zones of little to no migration, information unobtainable except at great cost and over a much longer time span by other methods. The ability to reveal gas migration under perched groundwater, and to deal with the complex soil conditions at these landfills is obvious and notable. The need for data sets to be as complete as possible, for careful interpretation of results, and for some confirming soil logs and gas samples and analyses is equally obvious in using and applying this information.

SUMMARY AND CONCLUSIONS

This study produced clear evidence of gas migration at each of the six landfills tested. Migration pathways were documented at shallow depths, but more importantly all sites had deeper pathways, usually with higher methane concentrations than found at the shallower depths. At Mexico, Southeast, JZ and Modern Sanitation, methane measured in shallow wells was not representative of deeper migrating gases. Furthermore, it is the deeper pathways that produced the greatest horizontal migration from the landfills, ranging from 100 to 200 feet at Renfro to well over 1000 feet at JZ. Investigation of gas presence at multiple depths is necessary to determine gas migration pathways and the extent of migration, and to develop an effective gas migration control plan.

Different geological settings characterize the sites tested: Southeast - river alluvium, Mexico - glacial till with tight clay, JZ - glacial till and drift with sand and clay, Renfro and Modern Sanitation - cherty clay from Mississippian limestone, and Centropolis - silty clay with windblown loess, Pennsylvanian shale and limestone with large areas of clean fill. These different geologic settings resulted in the following observations: (1) Tight clays can transmit methane gas, as observed at the Mexico site where high FID readings were found up to 400 feet from the landfill boundary. (2) Areas of clean fill (rock, dirt, concrete, etc.) over native soils will most likely be porous and readily transmit gas, as noted at the Centropolis landfill. (3) Methane gas will migrate under perched water zones, as observed at the Southeast landfill. (4) The JZ site illustrated that a given area may provide both distinctive pathway flow as well as more widespread flow through soils. (5) Complex soil structures will generally lead to more complex migration patterns as noted at both the Renfro and Modern Sanitation sites. (6) High methane concentrations can be found at the bedrock/soil interface, as found at the Renfro and Centropolis sites. Additional methane gas was distributed more generally within the surficial soils.

One major pattern of methane gas migration documented through the use of the MIP and the EVS software is the preference for horizontal gas migration as distinct from vertical migration. This is mainly a result of the horizontal nature of surficial material structures. This study showed that methane gas can move in excess of 1000 feet from a landfill and the extent is easy to underestimate without a full investigation. Defining the geology and hydrogeology of any site is of utmost importance in determining the pathways and extent of methane gas migration.

Topography is important. Renfro, Modern Sanitation, JZ and Centropolis landfills are all adjacent to deep valleys on one or more sides. These valleys seem to be instrumental in limiting the extent of the gas migration. However, caution should be exercised when characterizing a site because methane can move around (Modern Sanitation) or under a valley (Centropolis) depending on geological conditions. The depth of the waste must be considered relative to the depth of the valley.

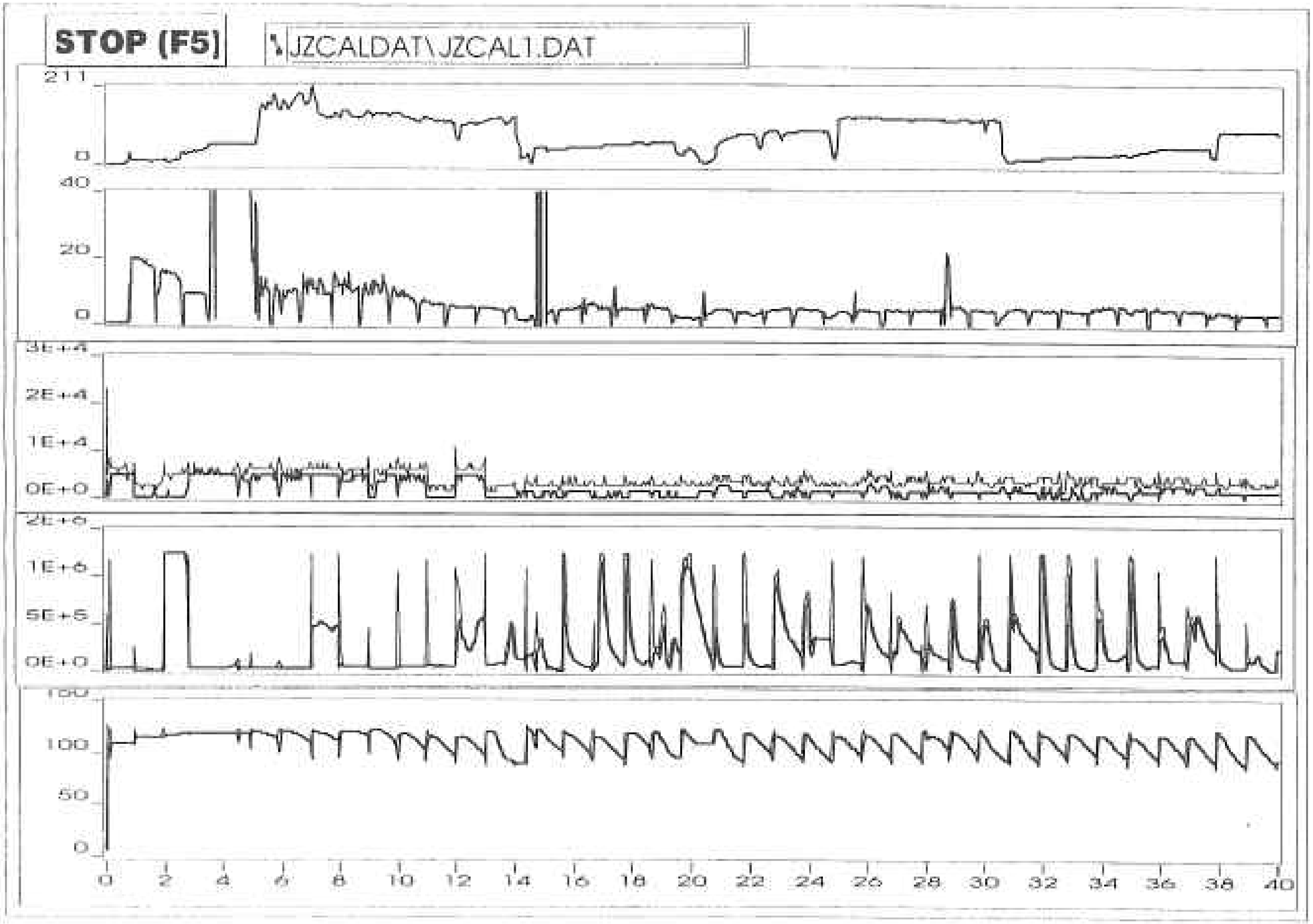
The on-site active gas withdrawal system at Renfro was found to not eliminate gas migration. Gas was attenuated at some depths, but others continued to contain high methane concentrations.

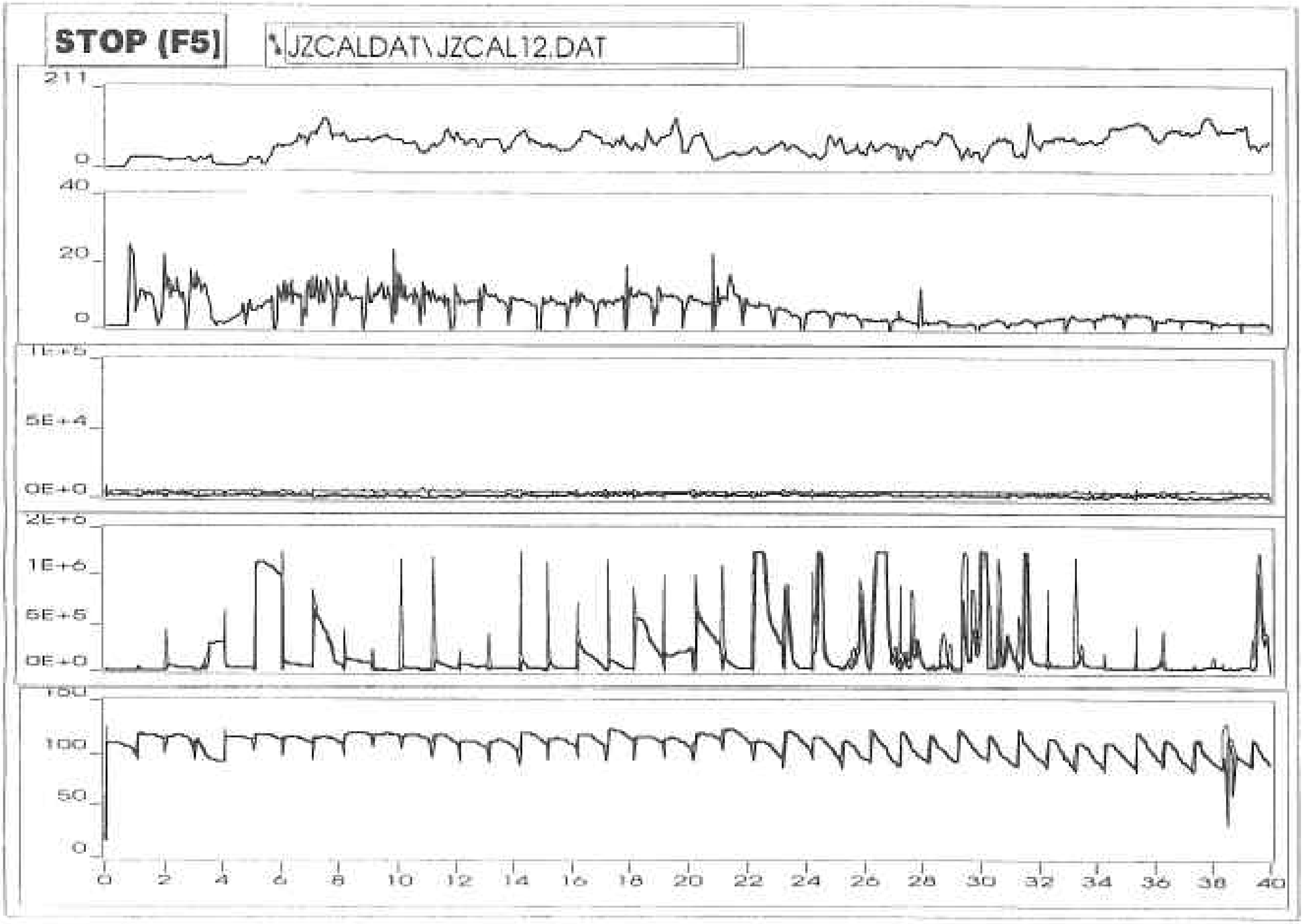
Finally, the location of all buried waste should be defined. Unknown areas of buried waste may occur near older landfills where dumps were operated before regulations were in place. These will produce methane gas and can provide pathways for flow of gas generated elsewhere.

Appendix A

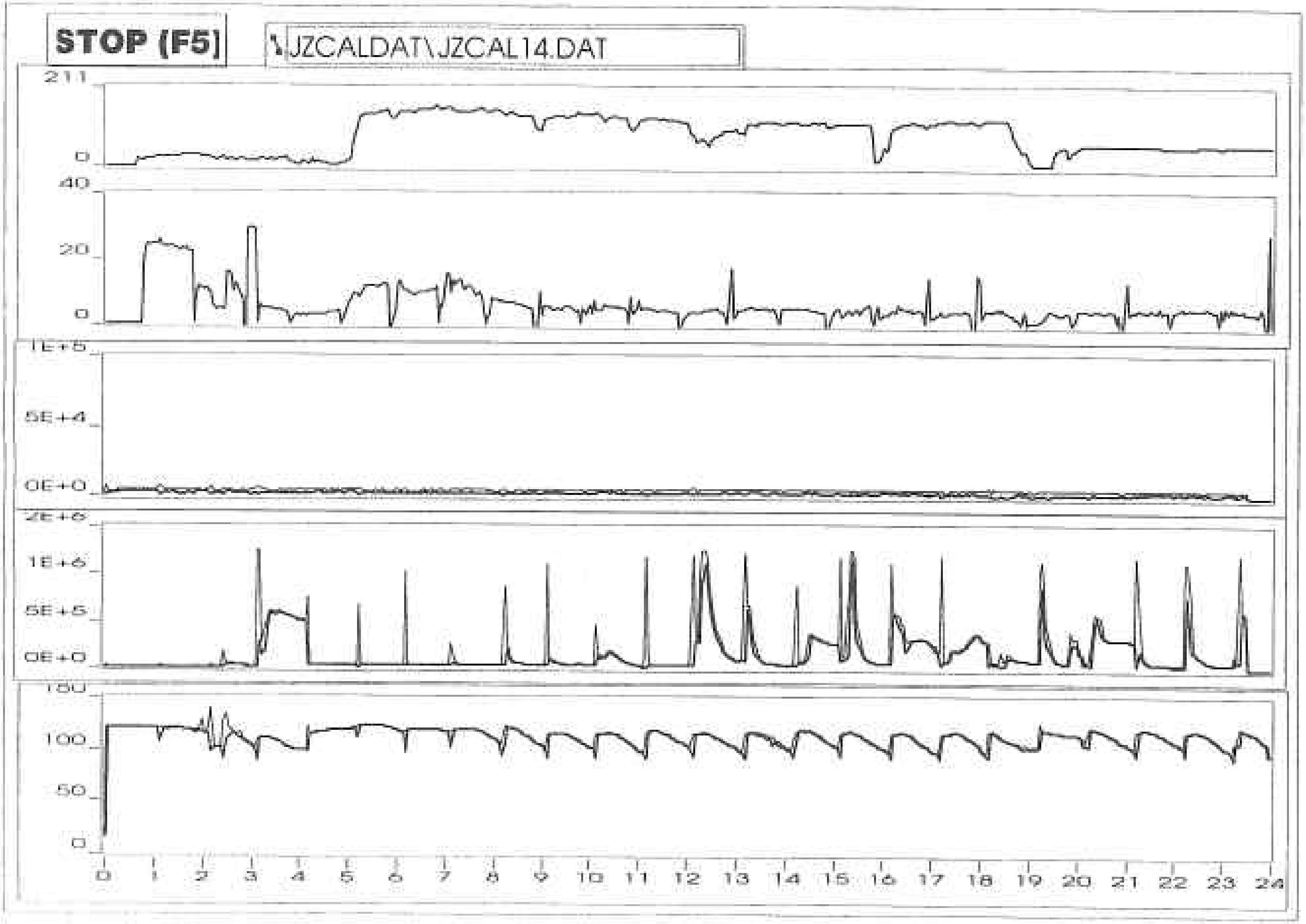
Field MIP Calibration Logs

JZ Landfill

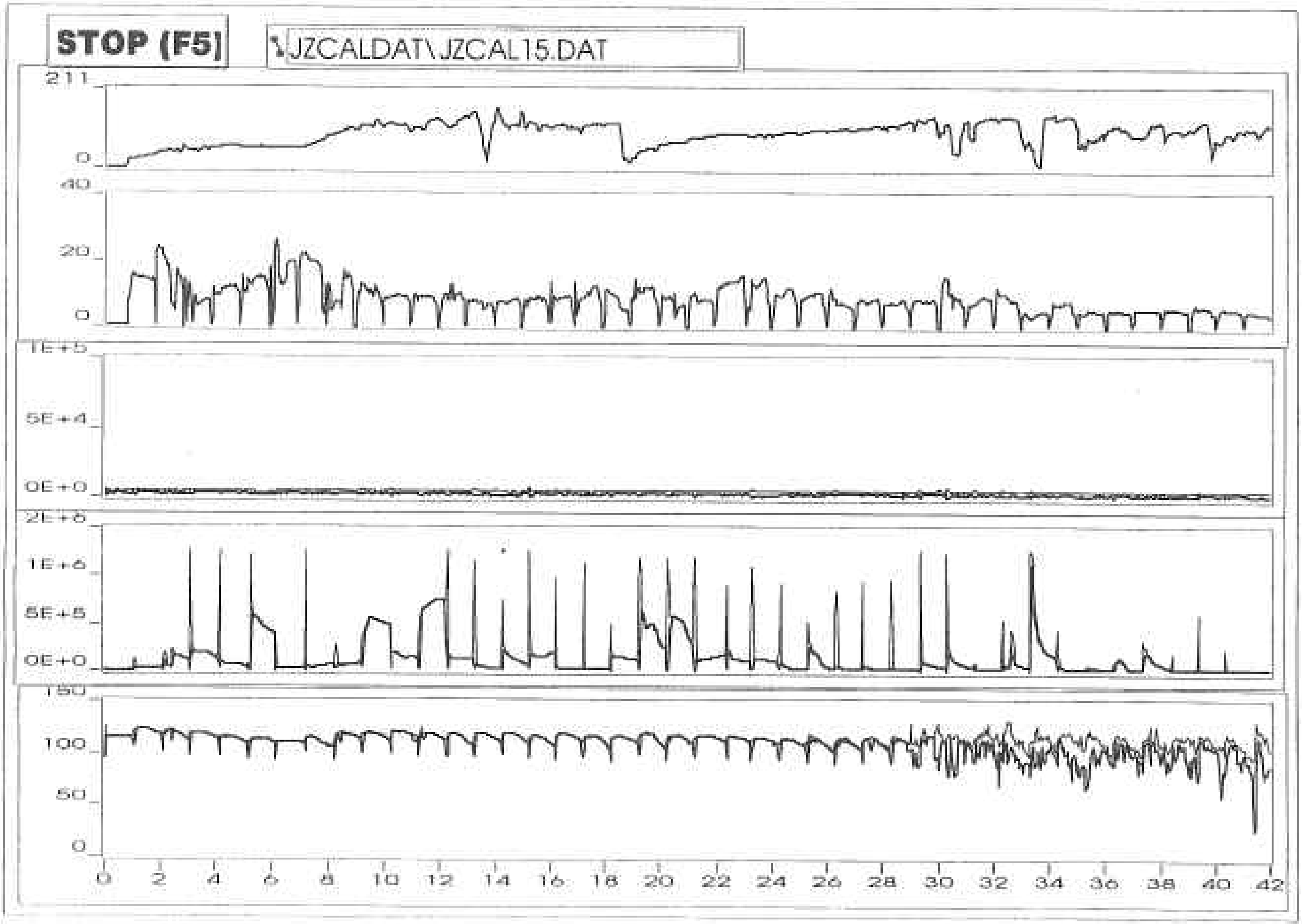

STOP (F5)
JZCALDAT\JZCAL1.DAT
211
0
40
20
0
3E+4
2E+4
1E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40



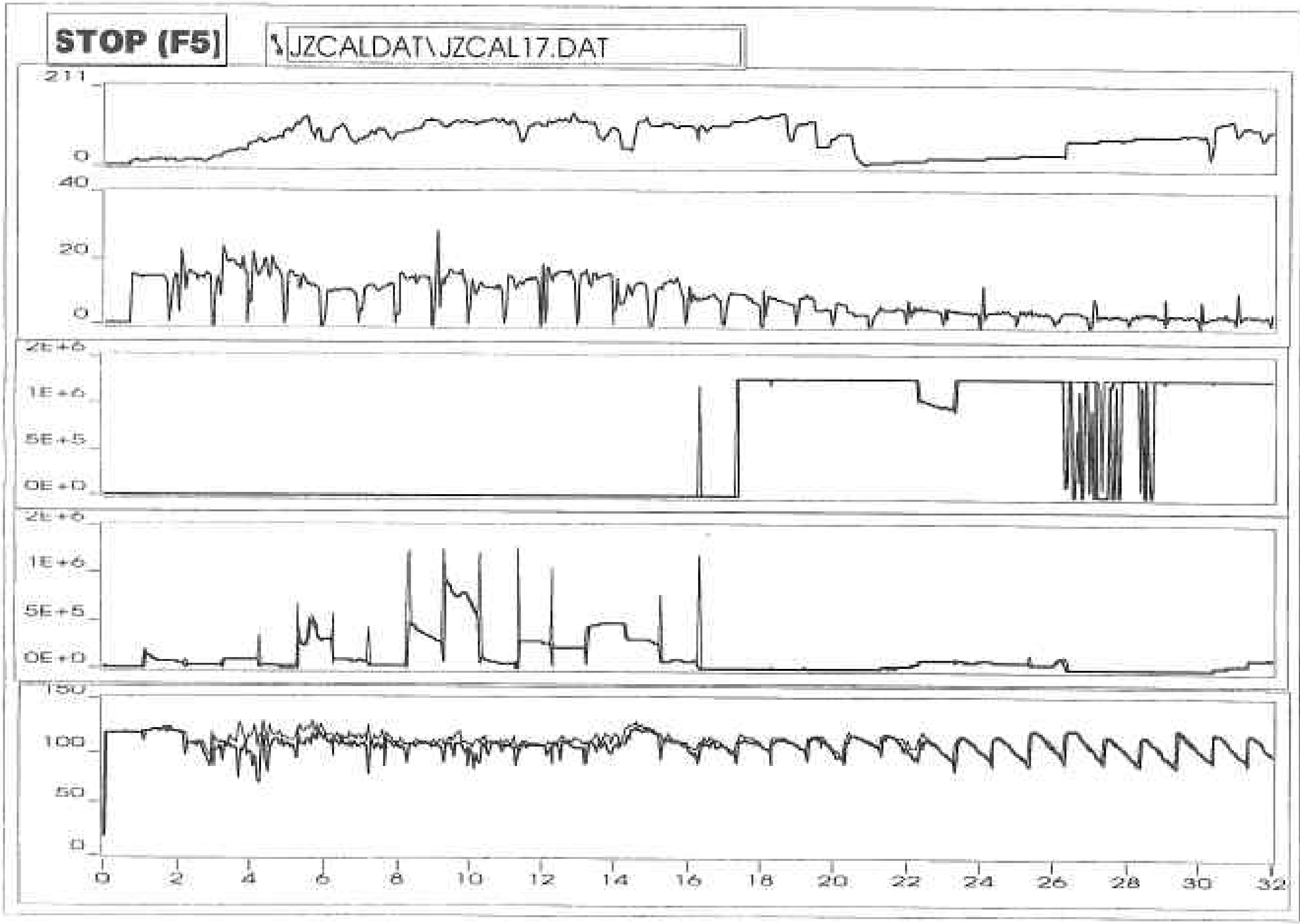
STOP (F5)
JZCALDAT\JZCAL12.DAT
211
0
40
20
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

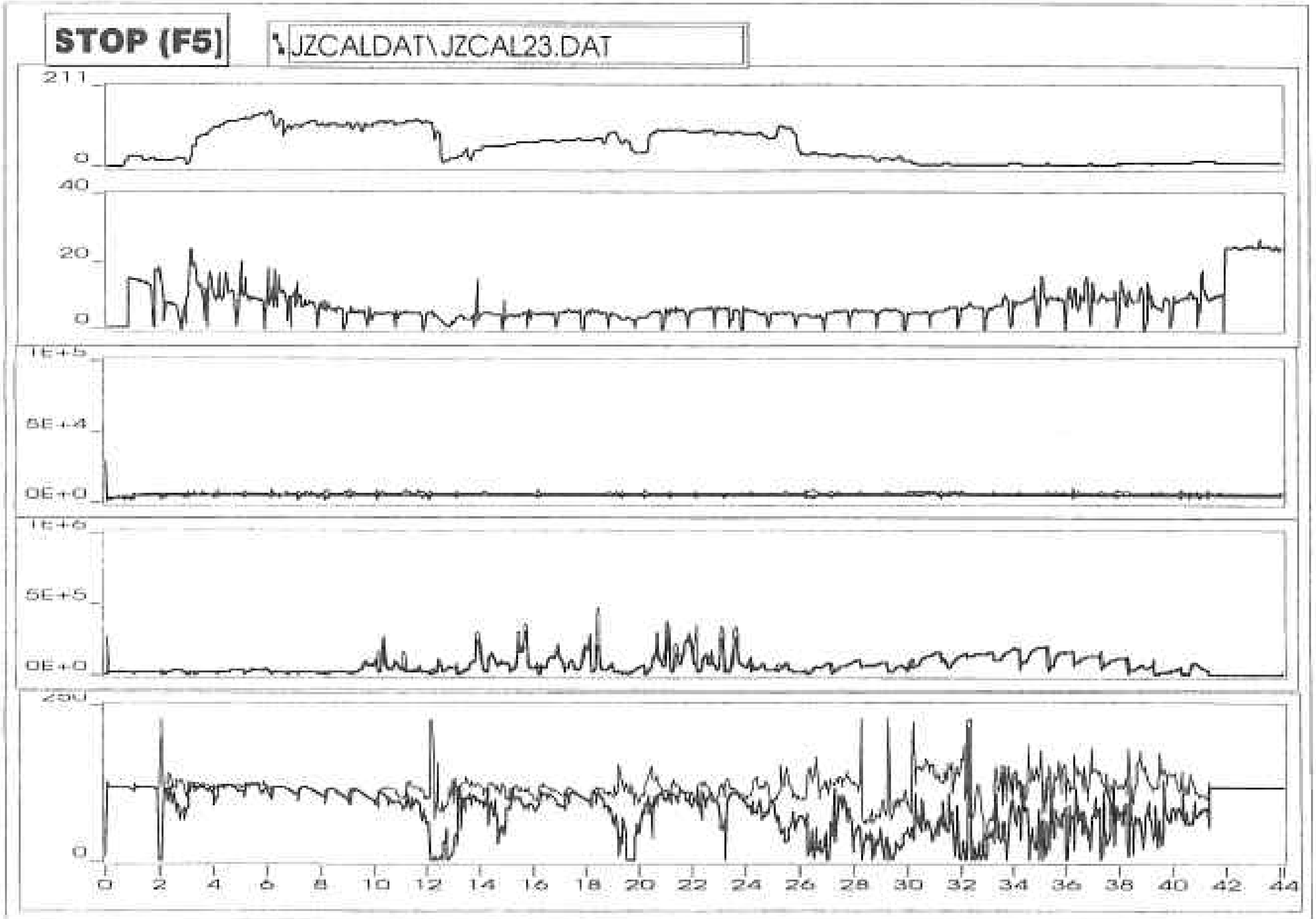


STOP (F5)
\JZCALDAT\JZCAL14.DAT
211
0
40
20
0
1E+5
5E+4
0E+0
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24



STOP (F5)
JZCALDAT\JZCAL15.DAT
211
0
40
20
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42


STOP (F5)
JZCALDAT\JZCAL17.DAT
211
0
40
20
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32


STOP (F5)
JZCALDAT\JZCAL23.DAT
211
0
40
20
0
1E+5
5E+4
0E+0
1E+6
5E+5
0E+0
250
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44

Appendix B

MIP and Soil Logs tied to Gas Monitoring Locations, JZ Landfill and Compiled in Text as Figures [p16B] to [p16H]

Key:

MIP Number	Gas Well Number
M5	JZ 12, 13
M6	JZ 23, 24
M7	JZ 17, 18
M8	JZ 14
M9	JZ 21, 22
M10	JZ 20
M11	JZ 19

Note: For MIP logs, top curve is rate of advance, then soil conductivity, PID, FID and last is probe temperature.

RECEIVED
NOV 1997
SWMP

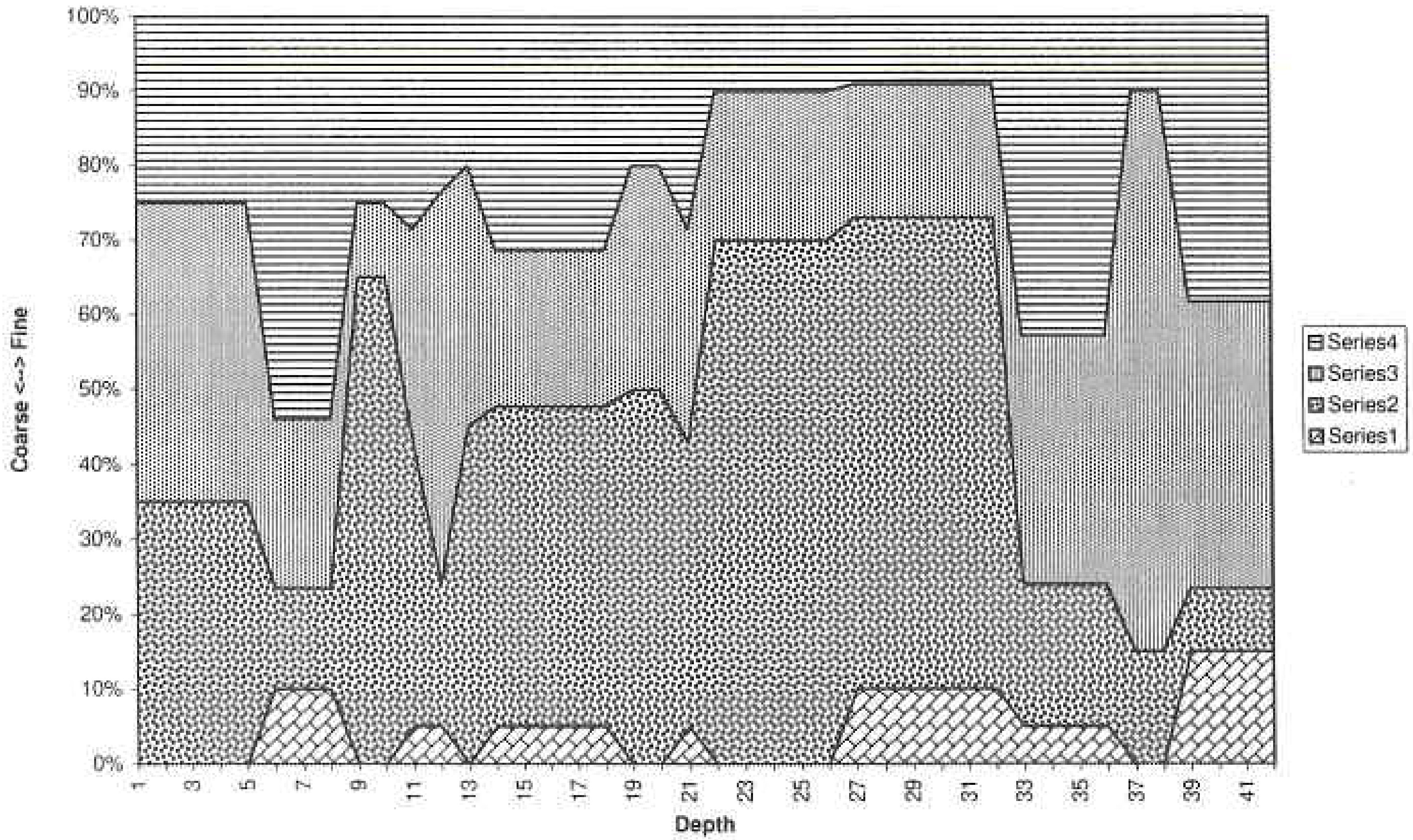
SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-5
DATE July 21, 1997

DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-2	excavated	for spider	wells						
2-7	10YR4/3	10YR6/1 (5%)	35	25		medium subangular blocky	few fine; few medium	few fine Interstiti-al; few medium interstiti-al; few fine tubular	silt coats
7-9.8	10YR6/6	2.5YR4/6	15	60	10 ch	weak subangular blocky	few very fine	many medium interstiti-al; few fine tubular	clay skins
9.8-11.5	10YR5/6	2.5YR4/6	65	25		massive			
11.5-12	10YR6/6	2.5YR4/6	40	30	5 ch	weak subangular blocky	few very fine	few medium interstiti-al; few very fine interstiti-al	Fe/Mn nodules
12-12.5							massive		
12-13.5	10YR6/6	10YR6/2 + 2.5YR4/6	20	25	5 ch	medium subangular blocky	few fine; few medium	few fine interstiti-al	Fe/Mn stain
13.5-15	10YR6/6		45	20		weak subangular blocky			silt coats; Fe/Mn nodules; calcite deposit

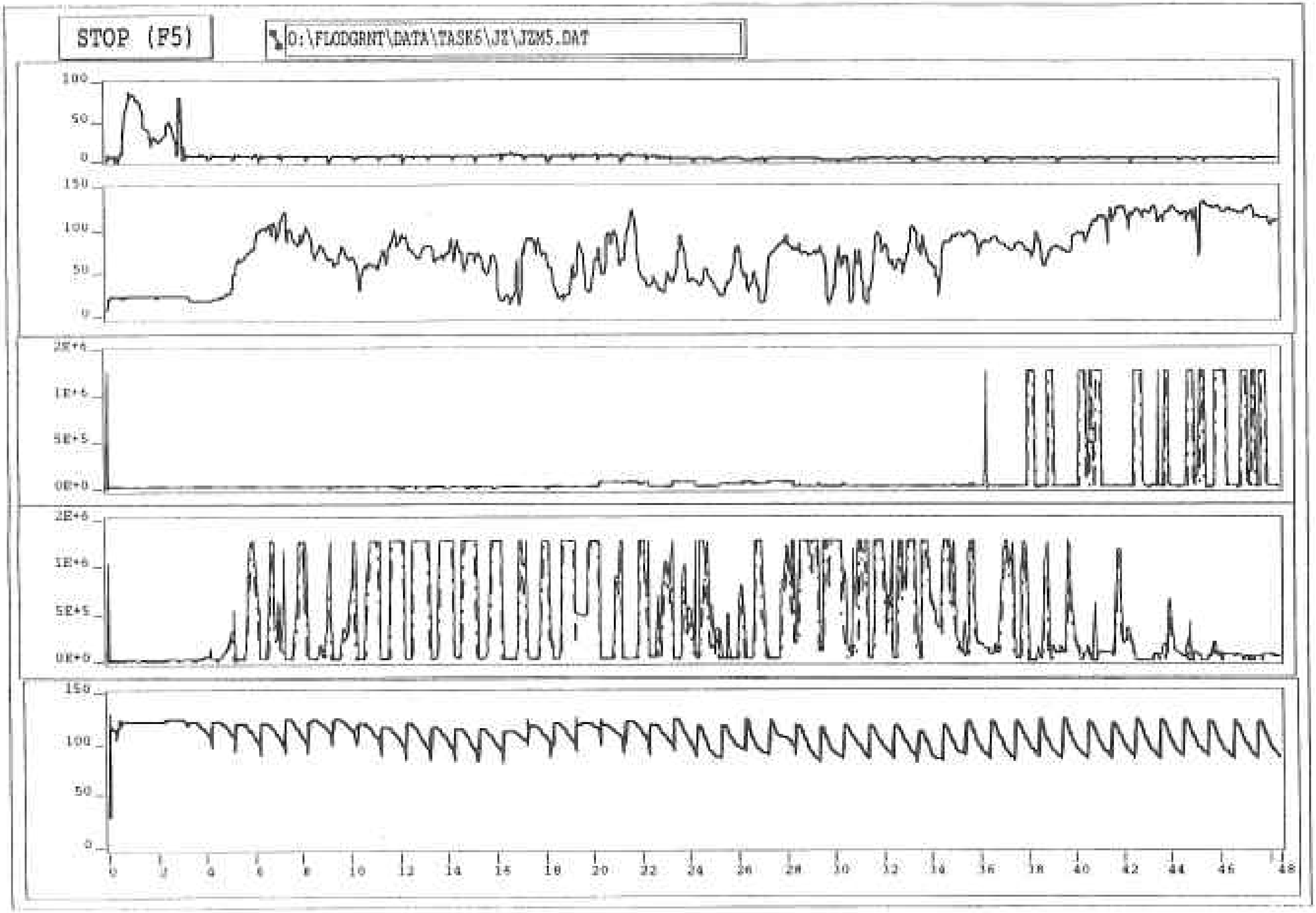
15-20.4	10YR6/6	10YR5/2 + 2.5YR4/6	45	33	5 ch	weak subangular blocky	few fine; few medium	Many very fine tubular; few fine interstiti-al	Fe/Mn stains
20.4-21.8	10YR6/6 +4/4	2.5YR4/6	50	20		weak subangular blocky		many very fine tubular; few fine interstiti-al	
21.8-22.8	10YR6/6	10YR6/1 (30%)	40	30	5 ch	weak subangular blocky		few medium interstiti-al; few fine interstiti-al	
22.8-28	10YR5/6 +6/2		70	10		medium subangular blocky		few fine interstiti-al	Fe/Mn nodules
28-31	10YR5/6 +6/2		70	10	10	medium subangular blocky		few fine interstiti-al	Fe/Mn nodules
31-34	2.5YR4/6	10YR6/1 (20%)	70	10	10	weak subangular blocky		few fine interstiti-al	Fe/Mn nodules
34-38	10YR6/6 +6/4+6/1		20	45	5	weak subangular blocky		few medium interstiti-al; few fine interstiti-al	Fe/Mn stains & nodules; calcite deposit
38-40	10YR6/6 +5/4+4/4		15	10		weak subangular blocky			Fe/Mn stains
40-42.5	10YR3/1		10	45	15 ch	massive		many fine interstiti-al; many medium interstiti-al	

Several factors make this soil very conducive for significant gas and liquid movement. Roots were found from surface to 20'; a root wad was found at 12-12.5'. These root channels would allow rapid migration in all directions. Several weathered chert beds were found (11-12', 13.5-15', 28-31' and 38-40') which could allow significant horizontal movement. High percentages of sand were found from 9-34' which could allow movement in all directions. The presence of alternating Fe/Mn stains and silt/clay seams show significant water movement from the surface to 40'. The presence of alternating Fe/Mn nodules and calcite crystals at various places in the profile shows layers of soils which impeded water movement and contained conditions conducive for chemical precipitation (e.g. low pH). Good soil structure and a high percentage of silt in these soils would allow significant movement through these soils when soil moisture conditions are dry. The sudden change in soil color at 40-42.5 indicated the presence of leachate contaminants or long term submersion under water. The soil had a moderate "landfill odor" and did not seem to be excessively wet, thus lending credence to the presence of leachate theory.

JZ Boring#M5



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
Depth
Series4
Series3
Series2
Series1


STOP (F5)
O:\FLODGRNT\DATA\TASK6\JZ\JZM5.DAT
100
50
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48

SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-6
DATE July 24, 1997

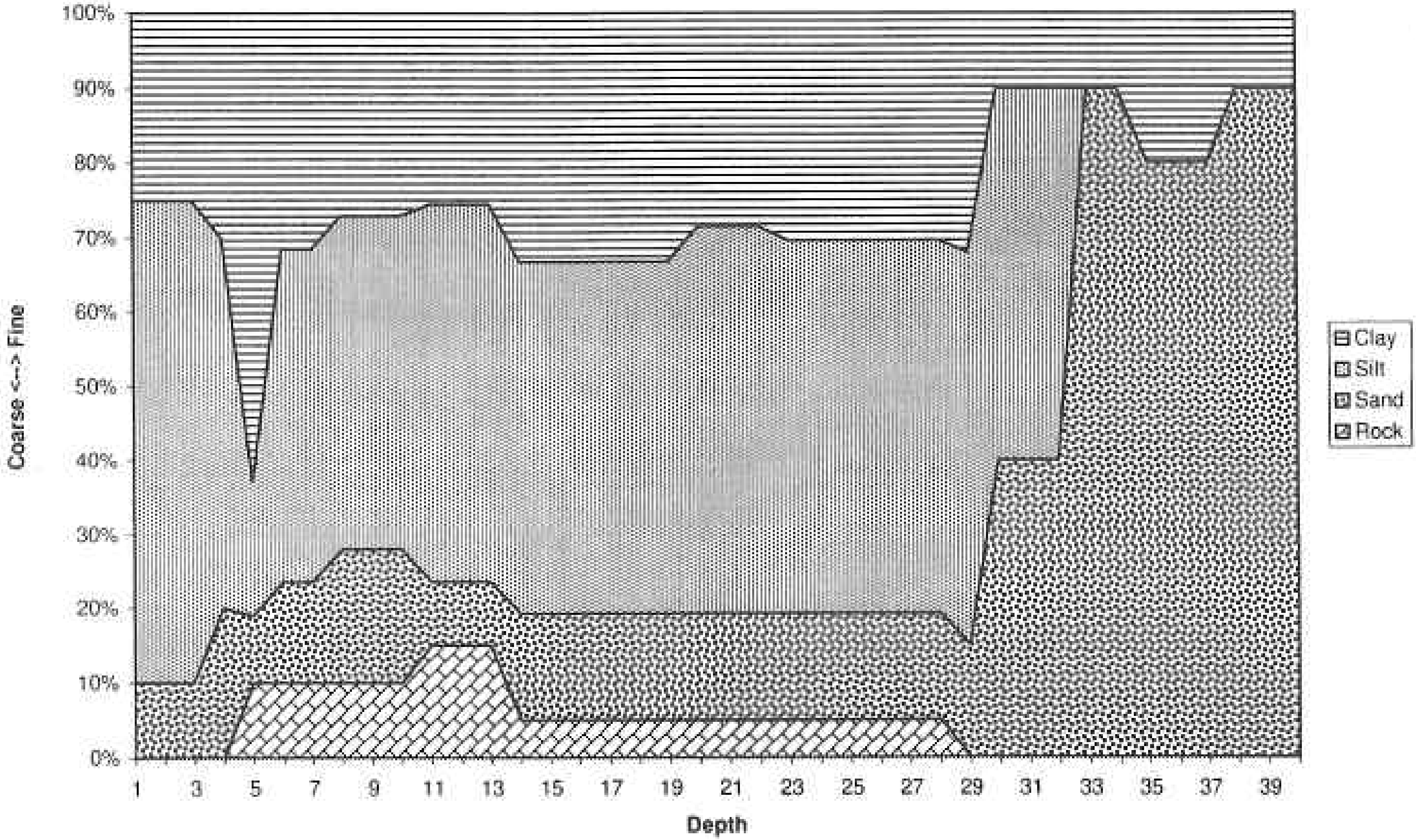
DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES	H_2O CHANNELS
0-2.5	10YR4/4 +5/2		10	25		weak subangular blocky	many very fine; few fine; few medium	few fine interstiti-al; few fine tubular	silt seams
2.5-3.2	10YR6/6	10YR5/3	20	30		weak subangular blocky	few fine	few medium interstiti-al; few fine interstiti-al	Fe/Mn stains
3.2-4	10YR4/3	2.5YR4/6 (20%)	10	70	10 ch	weak subangular blocky	few fine	few fine interstiti-al	Fe/Mn nodules; clay skins
4-7	10YR5/4	10YR5/2 (5%)	15	35	10 ch	weak subangular blocky	many very fine; many fine; many course	few fine interstiti-al; few medium interstiti-al	
7-10	10YR6/6	10YR6/2 seams	20	30	10 ch	weak subangular blocky	few fine	few medium interstiti-al; few fine interstiti-al; few fine tubular	

10-13	10YR6/8	10YR6/2 seams	10	30	15 ch	weak subangular blocky	few medium	few medium interstiti-al; few fine interstiti-al; few fine tubular	Fe/Mn stains & nodules; silt seams
13-17	10YR6/8	10YR6/2 seams	15	35	< 5	weak subangular blocky	few fine	few medium interstiti-al; few fine interstiti-al; few fine tubular	Fe/Mn nodules; silt seams
17-19	10YR6/8		15	35	< 5	weak subangular blocky		few fine interstiti-al; few medium interstiti-al	Fe/Mn channels
19-22	10YR5/6	10YR6/1	15	30	5	medium subangular blocky		few fine interstiti-al; few medium interstiti-al	Fe/Mn nodules; silt seams
22-27.5	10YR5/6	10YR6/1+ 6/2 seams	15	32	5	medium subangular blocky	few fine	few fine interstiti-al; few fine tubular	Fe/Mn nodules; silt seams
27.5-28.5	10YR6/6	10YR6/1+ 6/2 seams	15	32		weak subangular blocky			
28.5-30.9	10YR6/6		40	10		massive			
30.9-31	10YR6/6		40	10		medium subangular blocky			
31-34	10YR6/4		90	10 silt		massive			
34-37	10YR6/4		80	20 silt		massive			
37-40	10YR6/4 +5/4+4/4	7.5YR5/6 (5%)	90	10		massive		few fine tubular	Fe/Mn stains

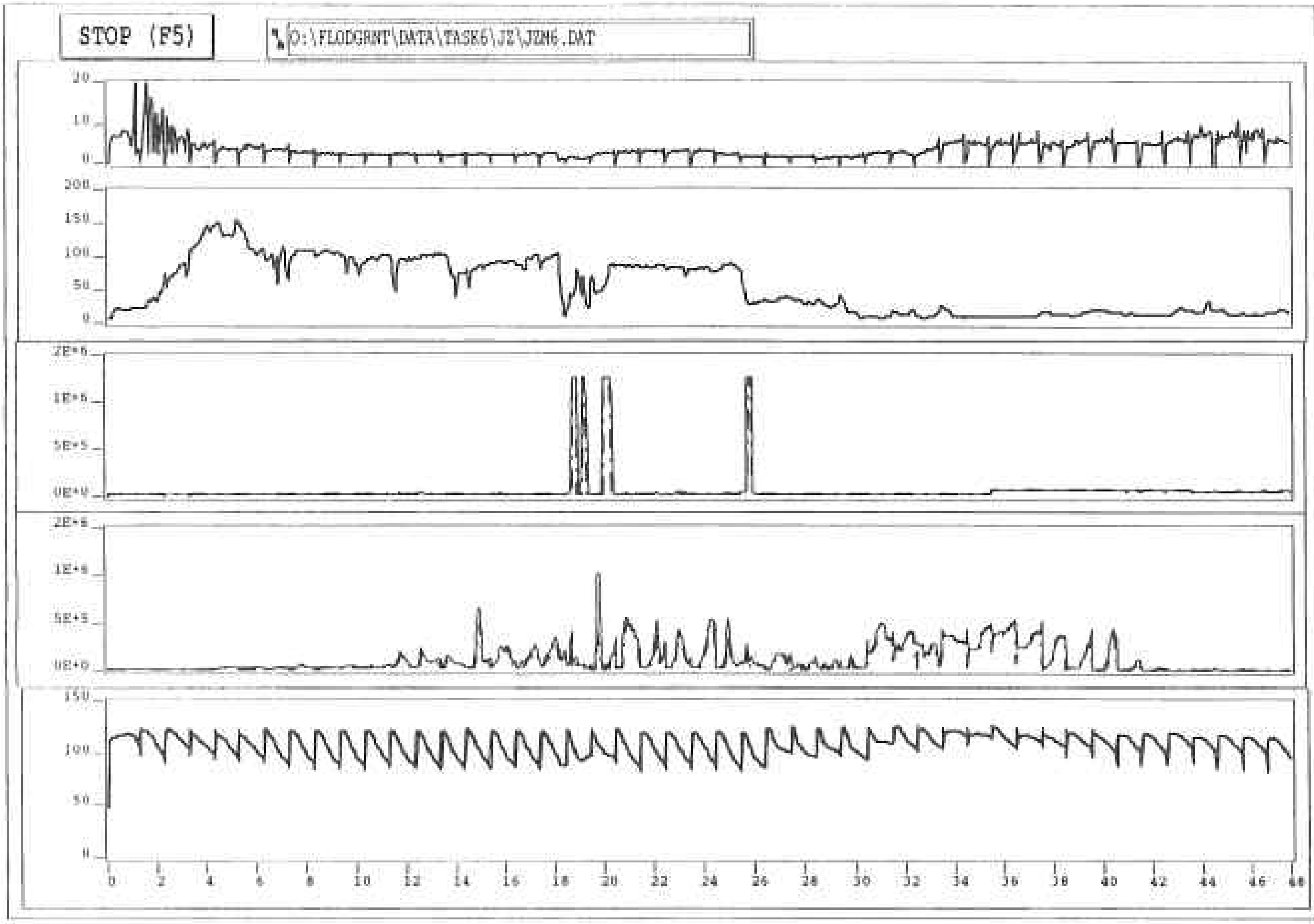
Several factors make this soil conducive for significant gas and liquid movement. Roots were found from surface to 28'. These root channels would allow rapid migration in all directions. High percentages of sand were found from 28-40' which could allow movement in all directions.

The presence of alternating Fe/Mn stains show significant water movement from the surface to 28'. The presence of alternating Fe/Mn nodules at various places in the profile shows layers of soils which impeded water movement under certain conditions. Good soil structure and a high percentage of silt in these soils would allow significant movement through these soils when soil moisture conditions are dry.

JZ Boring#M6



Coarse <--> Fine
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
Depth
Clay
Silt
Sand
Rock



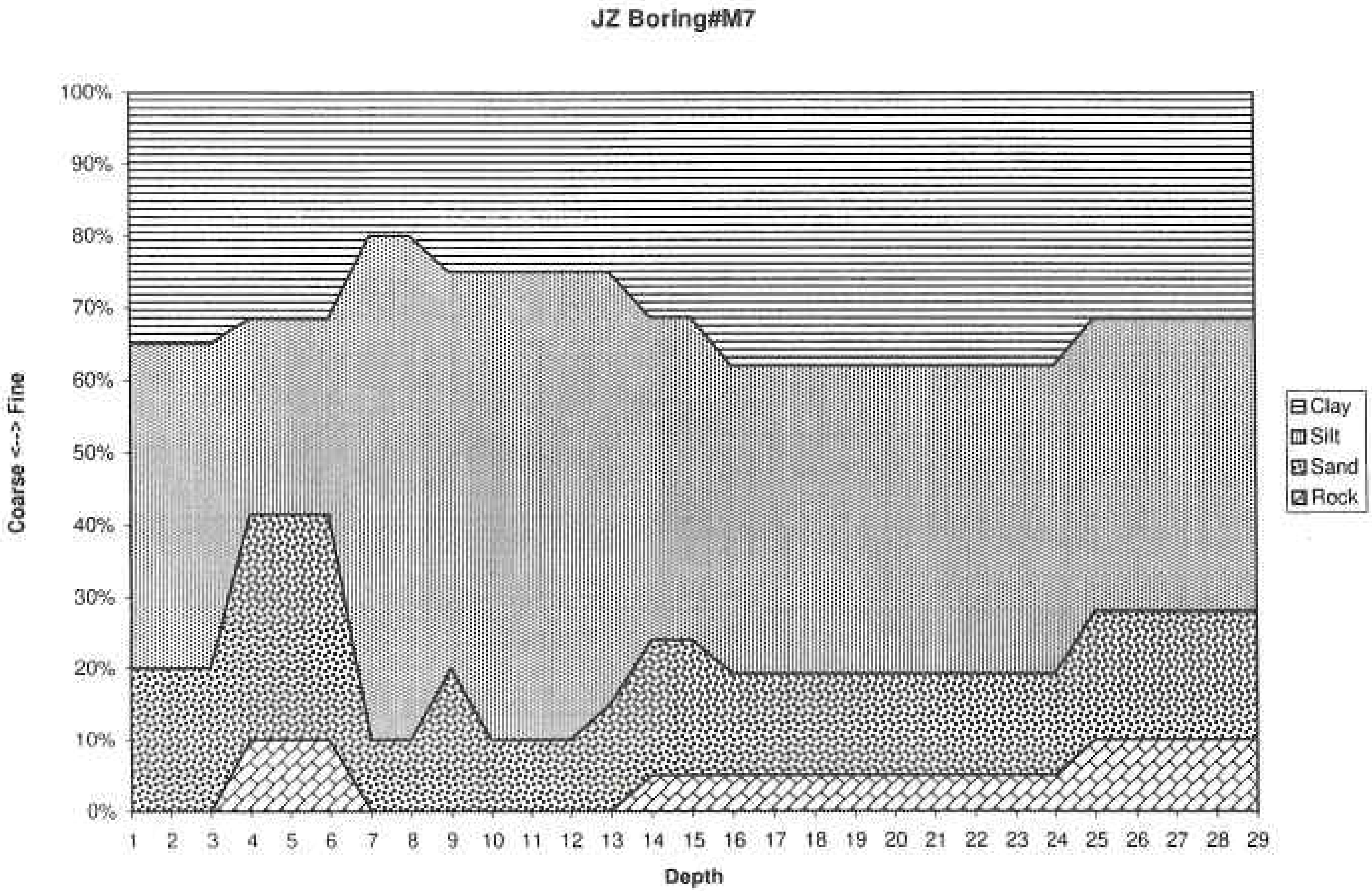
STOP (F5)
D:\FLODGRNT\DATA\TASK6\JZ\JZN6.DAT
20
10
0
200
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-7
DATE July 24, 1997

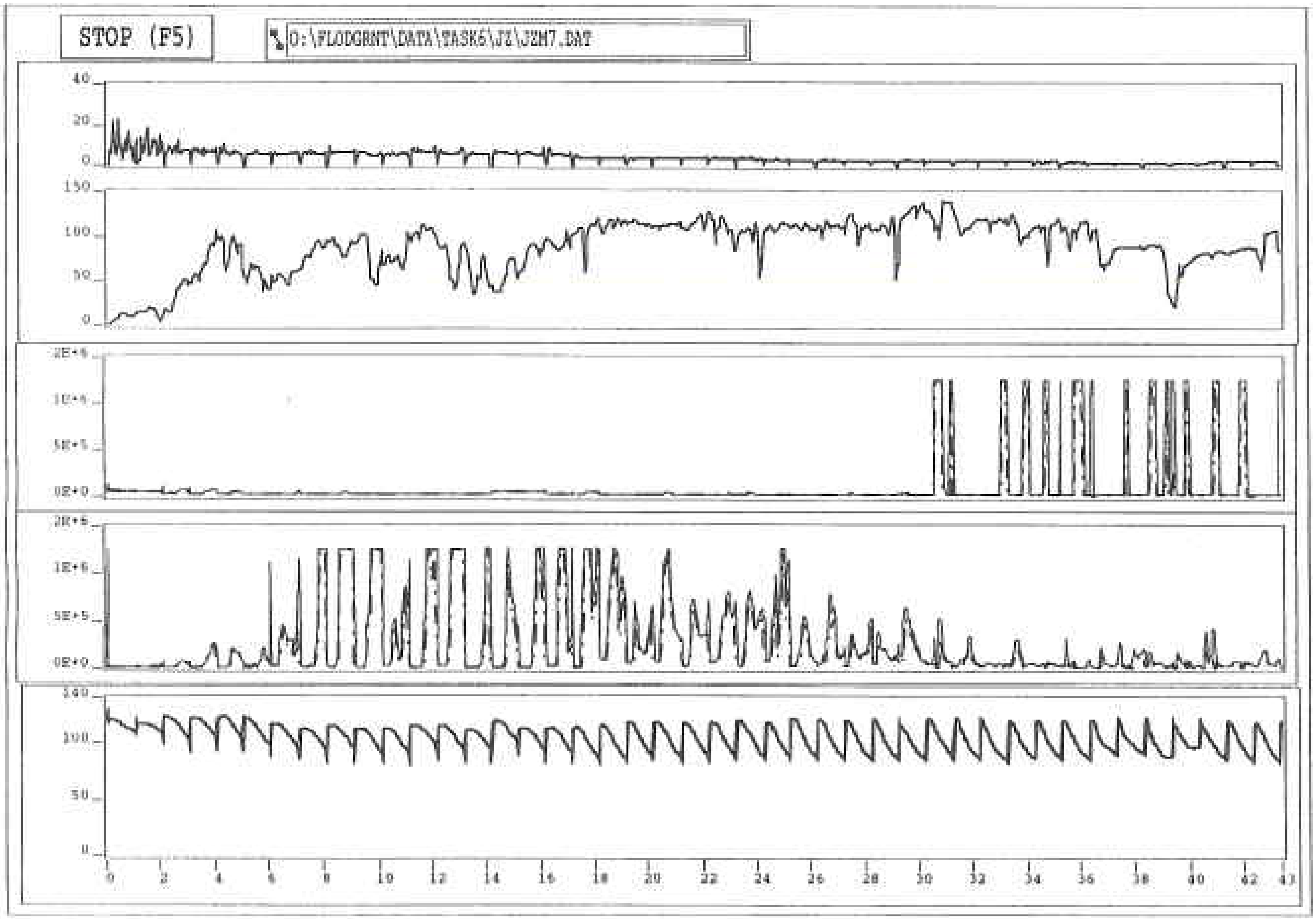
DEPTH (Ft)	COLOR MATRIX	MOTTLES	SOIL TYPE % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES	H_2O CHANNELS
0-2.5	excavation	for spider	wells						
2.5-5.1	10YR6/4	2.5YR4/6	20	35		medium subangular blocky	few fine	few fine interstitial; few fine tubular	clay seams
5.1-6.5	10YR6/4	2.5YR4/6	35	35	10	weak subangular blocky		few fine interstitial:few fine tubular	
6.5-7.9	10YR64	2.5YR4/6	35	35	10	weak subangular blocky	few fine	few fine interstitial; few fine tubular	clay seams
7.9-10	10YR5/6	5YR4/6	10	20		weak subangular blocky	few fine, few medium	few fine interstitial; few fine tubular	silt seams; Fe/Mn
10-11	10YR5/6		20	25		weak subangular blocky	few fine; few medium	few fine interstitial; few fine tubular	silt seams
11-14	10YR5/4		10	25		weak subangular blocky	few fine	few fine interstitial; few medium tubular	Fe/Mn ; silt seams
14-14.7	10YR5/6	10YR6/1 seam	15	25		medium subangular blocky	many fine, few medium	few fine interstitial; few fine tubular	Fe/Mn stains

14.7-17	10YR5/6	10YR6/1	20	33	5	medium subangular blocky		few fine interstiti-al; few fine tubular	Fe/Mn stains & nodules
17-22	10YR5/4	10YR6/1 seams	15	40	5	weak subangular blocky	few fine	few fine interstiti-al; few medium tubular	Fe/Mn nodules; silt seams
22-26	10YR5/4	10YR6/1 seams	15	40	5	weak subangular blocky	few fine; few medium	few fine tubular; few medium tubular	Fe/Mn nodules; silt seams
26-31	10YR5/3 +4/3		20	35	10	medium subangular blocky			Fe/Mn nodules

Several factors make this soil conducive for gas and liquid movement. Roots were found from surface to 28'. These root channels would allow rapid migration in all directions. The presence of alternating Fe/Mn stains and nodules and silt and clay seams show water movement from the surface to 31'. These soils show less rapid movement than those in M-4-M-6. Good soil structure, good soil pore percentage and a high percentage of silt in these soils would allow significant movement through these soils when soil moisture conditions are dry.



JZ Boring#M7
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Depth
Clay
Silt
Sand
Rock

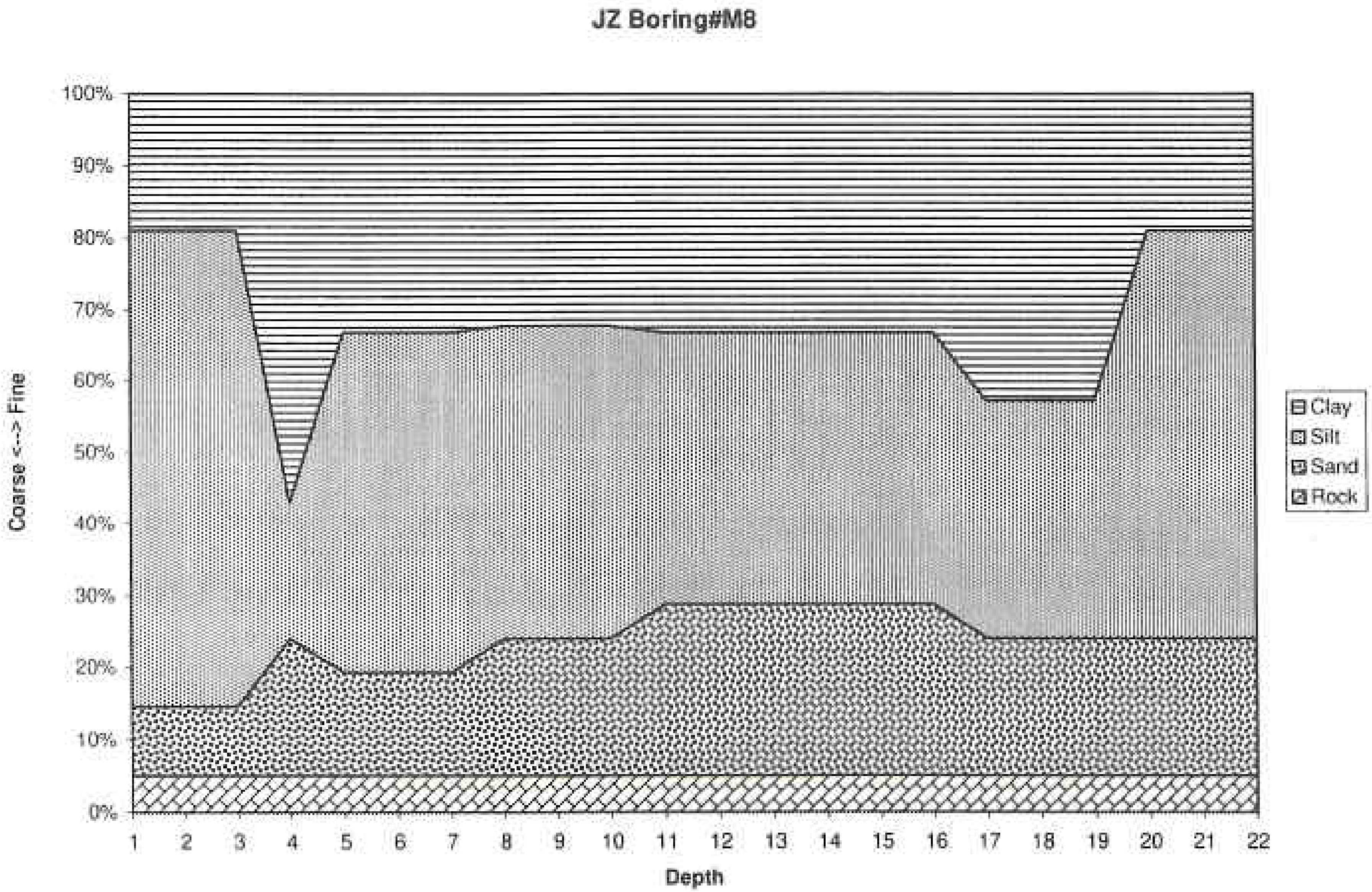

STOP (F5)
40
20
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
140
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 43

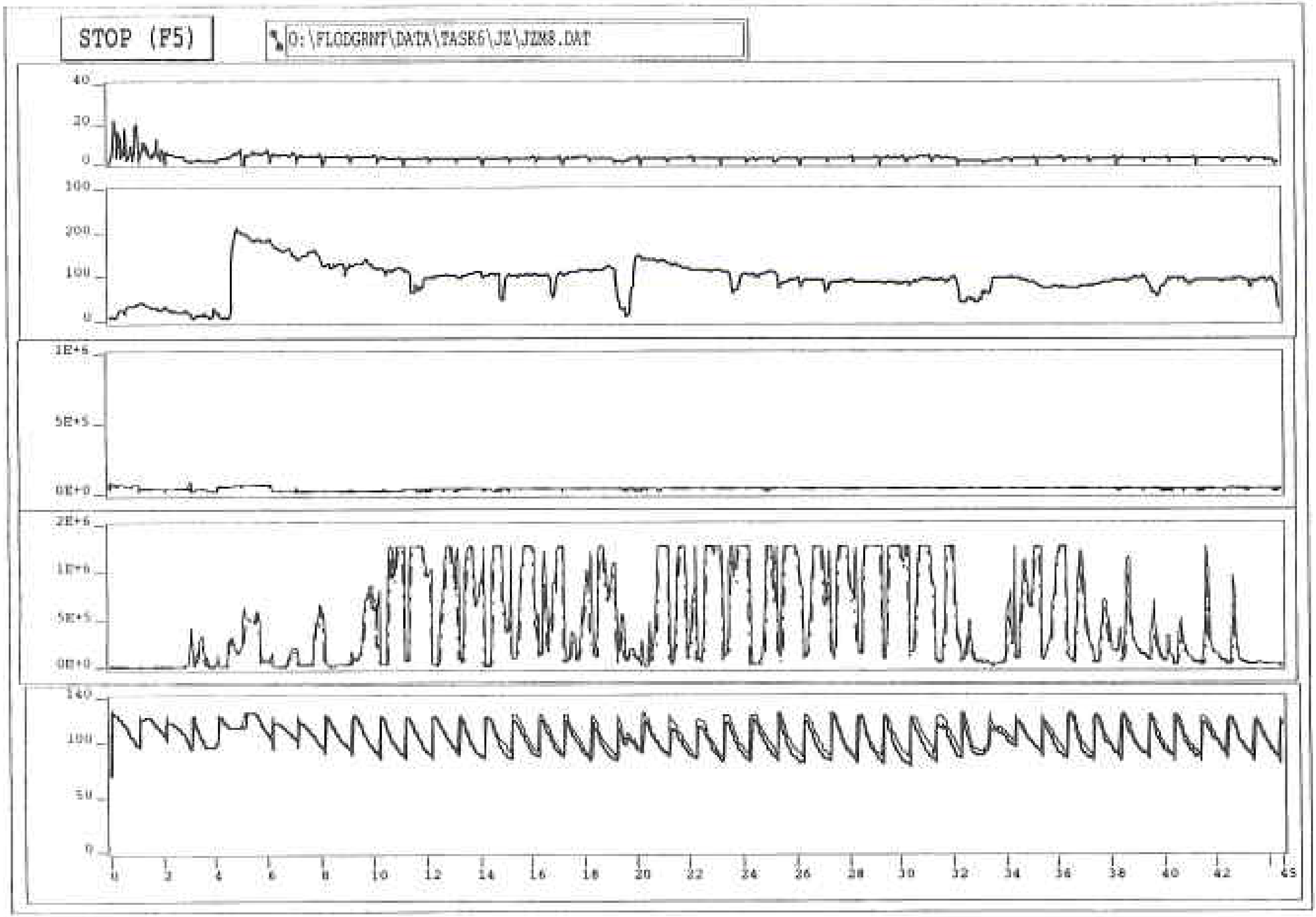
SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-8
DATE July 24, 1997

DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-2	excavation	for spider	wells						
2-5	10YR5/4 +4/4		10	20	5 ch	medium subangular blocky		few fine interstit i-al; few fine tubular	
5-6	10YR5/4	2.5YR4/6	20	60	< 5 ch	medium subangular blocky		few medium interstiti -al	Fe/Mn channels; clay skins
6-9	10YR5/6	2.5YR4/6	15	35	5 ch	medium subangular blocky		many very fine interstiti -al	Fe/Mn channels; silt coats
9-12	10YR5/6 +4/4 + 5YR4/4	10YR6/1 seams	20	34	< 5	weak subangular blocky	few very fine	few fine interstiti -al	Fe/Mn channels; silt seams
12-18	10YR5/6 +4/4 + 5YR4/4	10YR6/1 seams	25	35	5 ch	weak subangular blocky	few fine@ 13.4'	few very fine interstiti -al; few medium interstiti -al	silt seams
18-21	10YR4/4	2.5YR4/6	20	45	5 ch	very weak subangular blocky	few very fine	many fine interstiti -al; few fine tubular	Fe/Mn stains & nodules
21-24	10YR6/6 + 2.5YR4/6	10YR6/1	20	20	< 5	medium subangular blocky		few fine tubular	

Several factors make this soil conducive for gas and liquid movement. Roots were found from 9-21'. These root channels would allow rapid migration in all directions. The presence of

Fe/Mn channels show rapid water movement from 5-12'. Fe/Mn stains from 21-24' show rapid water movement in this zone enhanced by the presence of tubular soil pores. Silt seams and clay skins from 5-18' show slower water movement through preferential pathways in that zone. A high percentage of silt in the profile from 9-24' would allow significant movement through these soils when soil moisture conditions are dry.


JZ Boring#M8
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Depth
Clay
Silt
Sand
Rock



STOP (F5)
O:\FLODGRNT\DATA\TASK6\JZ\JZN8.DAT
40
20
0
300
200
100
0
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
140
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
45

RECEIVED

SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-9
DATE July, 1997

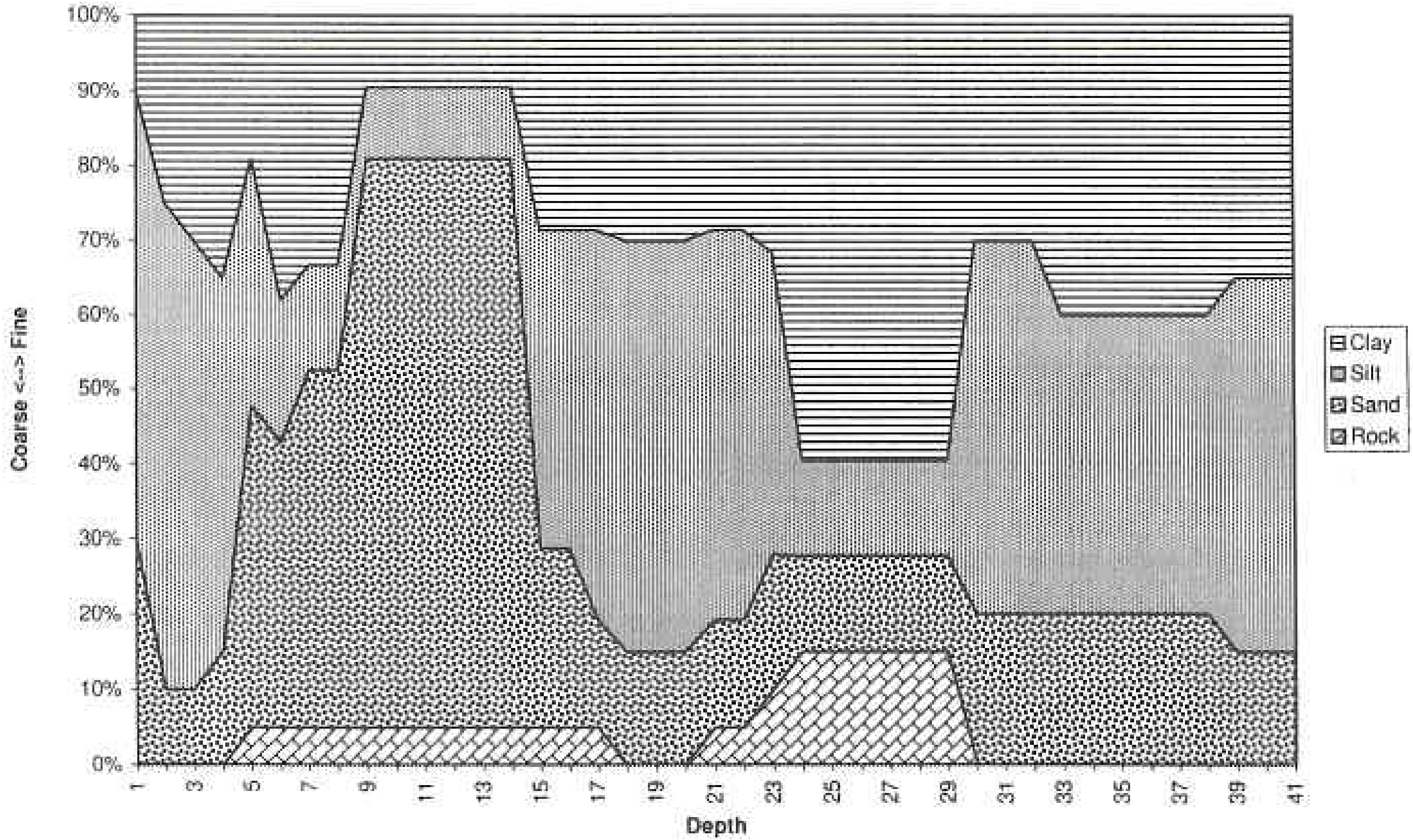
DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-0.6	2.5YR5/4		30	10		granular	many very fine		
0.6-1.2	10YR4/4		<10	25		medium subangular blocky	few fine; few medium	few medium tubular	
1.2-2.4	10YR5/4	2.5YR6/2	10	30		medium subangular blocky	few fine; few medium	few fine tubular; few medium tubular	Fe/Mn nodules
2.4-3.5	10YR3/3 +4/6		15	35		weak subangular blocky	few medium ;few fine	few fine interstiti-al; few very fine tubular	Fe/Mn stains
3.5-4	10YR5/4 + 5YR4/6		45	20	5 ch	weak subangular blocky	few very fine; few fine	few fine interstiti-al; few very fine tubular	Fe/Mn stains
4-5.6	10YR5/2 + 2.5YR4/6	10YR4/4	40	40	5 ch	medium subangular blocky	few very fine; few fine; few coarse	few fine tubular; many very fine tubular	Fe/Mn nodules

5.6-6.6	10YR5/6 + 2.5YR4/6		50	35	5 ch	weak subangular blocky	many very fine; many fine; few coarse	few medium interstiti-al; few very fine interstiti-al; few very fine tubular	clay skins
6.6-8	10YR5/6	10YR5/2 (10%)	50	35	5 ch	weak subangular blocky	many very fine; many fine; few coarse	few fine interstiti-al; few very fine tubular	root channels; clay skins
8-14	10YR5/6		80	10	5 ch	massive			Fe/Mn nodules
14-16.1	10YR5/4 +4/3		25	30	5 ch	weak subangular blocky	few fine; few very fine	few medium interstiti-al; few very fine tubular	Fe/Mn stains; root channels; silt seams
16.1-17	10YR6/6		15	30	5 ch	weak subangular blocky	few fine; few very fine	few medium interstiti-al; few very fine tubular	Fe/Mn stains; root channels; silt seams
17-20	10YR6/4	10YR5/2 silt	15	30		medium subangular blocky	few very fine; few medium	few medium interstiti-al; few very fine interstiti-al; few very fine tubular	Fe/Mn nodules; worm channels; silt seams
20-22.1	2.5YR6/6		15	30	5 ch	weak subangular blocky		few fine interstiti-al	Fe/Mn stains & nodules; silt seams
22.1-23	10YR6/6		20	35	10 ch	weak subangular blocky -- platy		few fine interstiti-al	Fe/Mn stains; silt seams

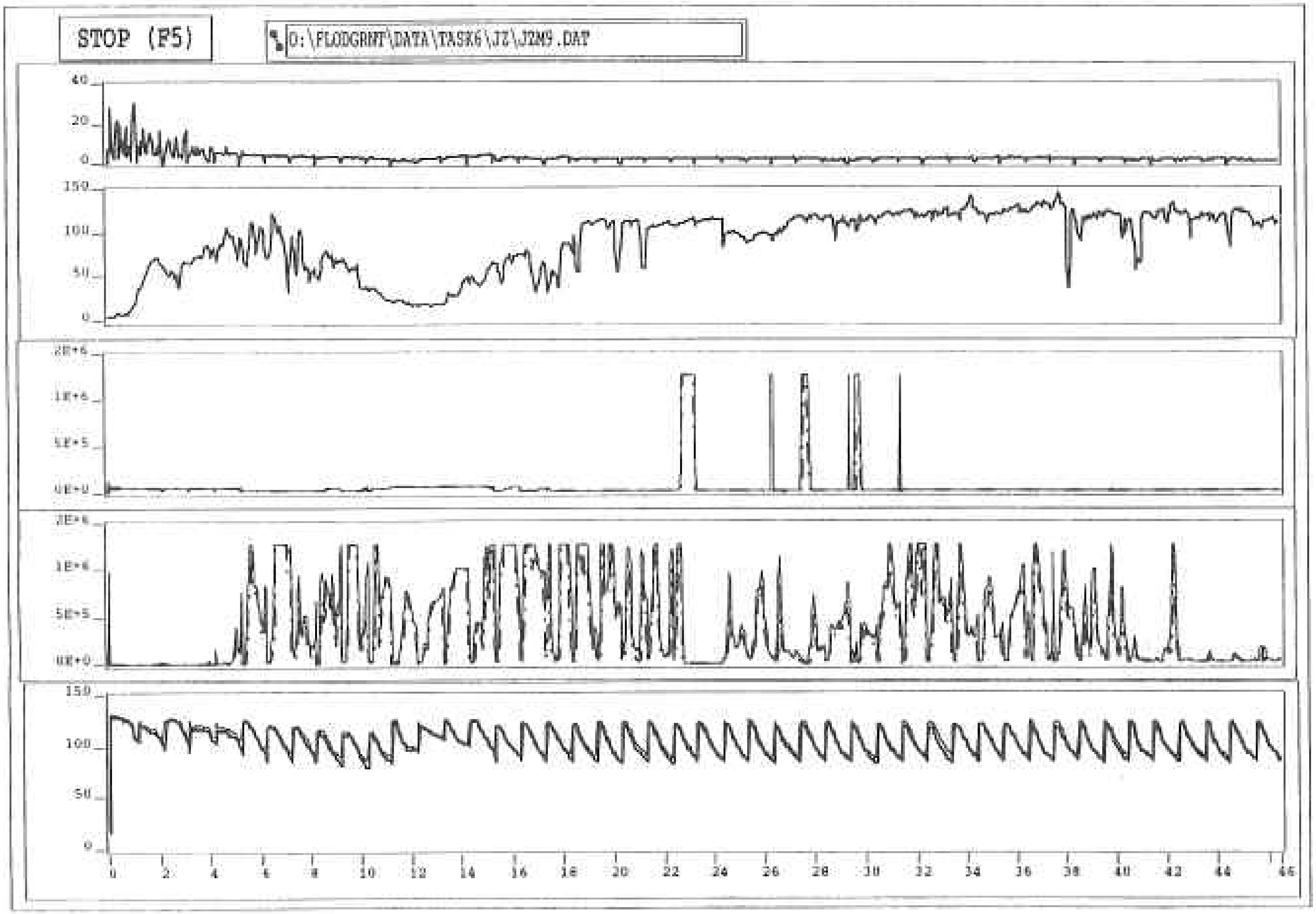
23-26	10YR4/4 +5/2		15	70	15 ch	weak subangular blocky		few very fine interstiti -al; few very fine tubular	Fe/Mn nodules, silt seams
26-29	10YR4/4 +5/2		15	70	15 ch	weak subangular blocky		few very fine interstiti -al; few very fine tubular	Fe/Mn nodules
29-32	10YR5/6	10YR6/1 seams	20	30		medium subangular blocky		few fine intersti-tial; Few fine tubular	silt seams
32-38	10YR5/4	10YR6/1 seams	20	40		medium subangular blocky		few fine intersti-tial; Few fine tubular	Fe/mn; silt seams
38-41	10YR3/4		15	35		weak subangular blocky		few fine intersti-tial	Fe/Mn nodules & stains

Several factors make this soil conducive for significant gas and liquid movement. Roots were found from surface to 20'. These root channels would allow rapid migration in all directions. High percentages of sand were found from 4-16' which could allow movement in all directions. Root channels at 6-20 feet provide an area for significant water/gas movement. The presence of alternating Fe/Mn stains and nodules show significant water movement from the surface to 41'. The presence of alternating Fe/Mn nodules at various places in the profile shows layers of soils which impeded water movement under certain conditions. Good soil structure and a high percentage of silt in these soils would allow more significant movement through these soils when soil moisture conditions are dry. Four layers of decomposing chert beds which could form zones for significant horizontal movement were noted from 3.5-38'. Two buried A-horizons were found at 2.4-3.5' and 38-41' which shows the amount of lithological activity which has occured in the formation of these soils.

JZ Boring#M9



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
Depth
Clay
Silt
Sand
Rock


STOP (F5)
D:\FLODGRNT\DATA\TASK6\JZ\J2M9.DAT
40
20
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46

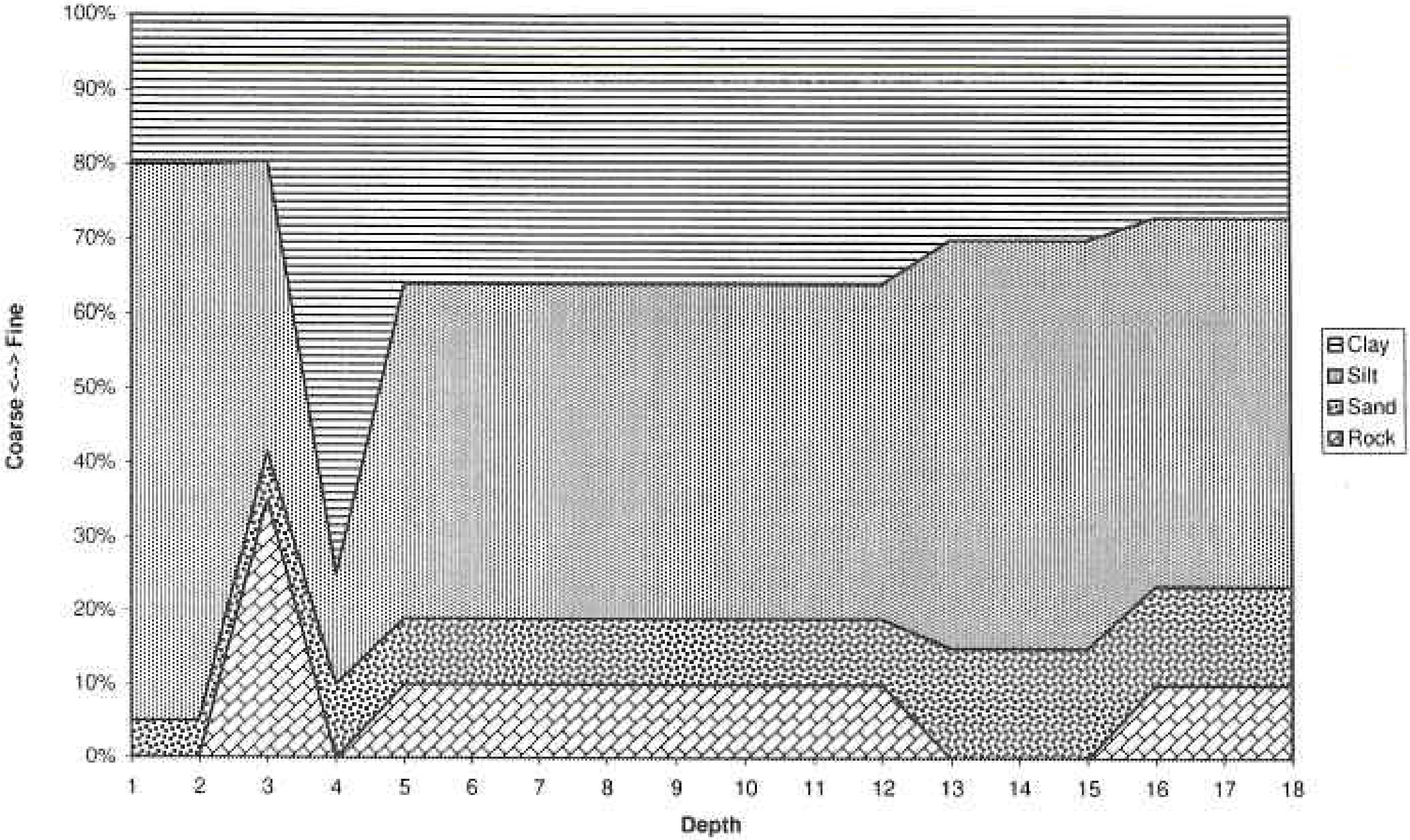
RECEIVED
NOV
SWMP

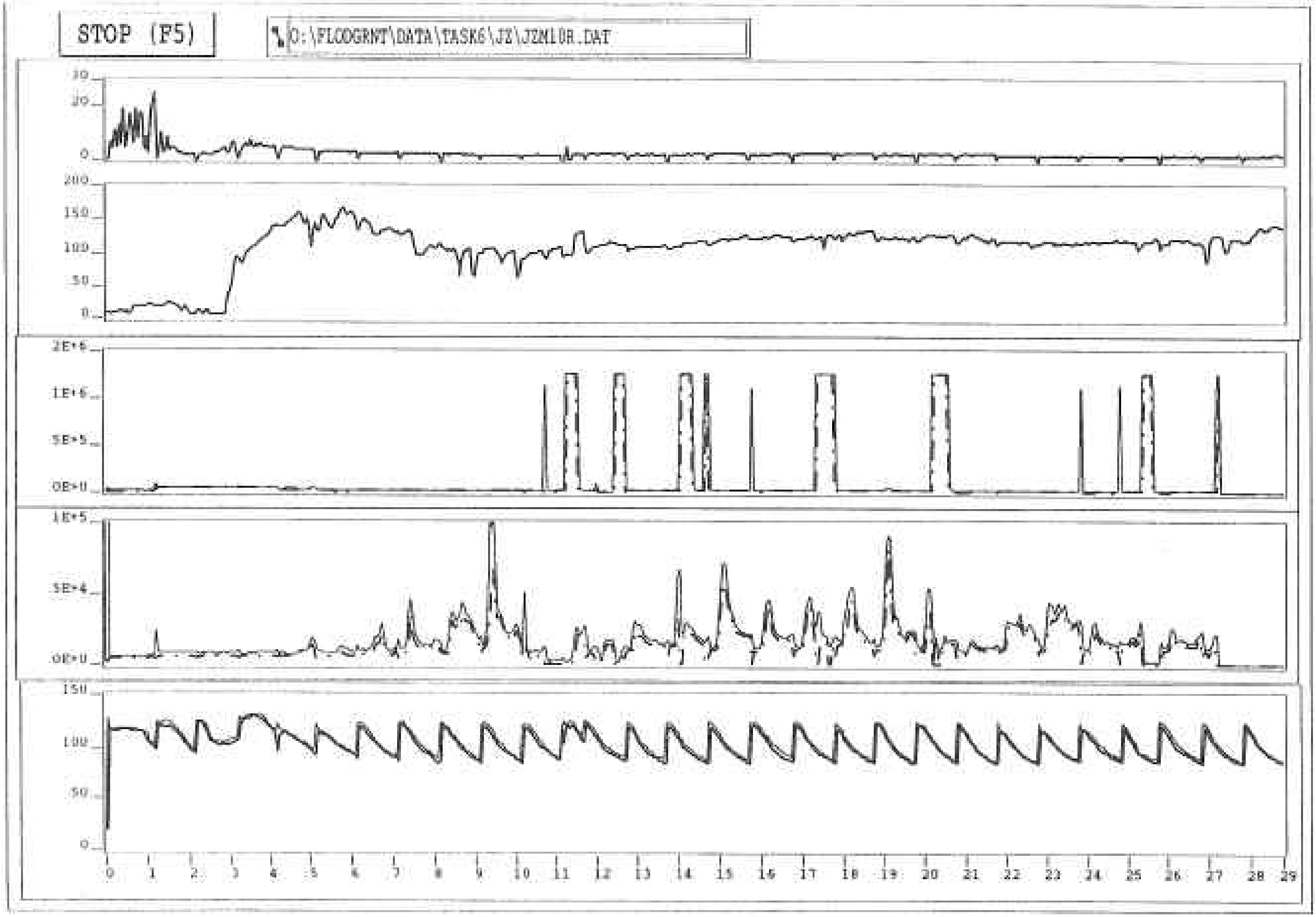
SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-10
DATE July 23, 1997

DEPTH (Ft)	COLOR MATRIX	MOTTLES	SOIL TYPE % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES	H_2O CHANNELS
0-1.8	2.5YR4/6		5	20		medium subangular blocky	few very fine; few fine	many very fine tubular; few fine tubular	
1.8-3.2	10YR6/6 + 5YR4/6		10	30	35 ch	medium subangular blocky	few very fine; few fine	many very fine interstiti-al; few fine tubular	Fe/Mn stains
3.2-4	10YR4/4 + 2.5YR4/6		10	75		weak subangular blocky	few very fine, few fine, few coarse		Fe/Mn stains
4-11.7	10YR6/6	10YR4/6 (15%)	10	40	10 ch	medium subangular blocky	few very fine, few medium; few coarse	few medium interstiti-al	massive root channels; silt coats
11.7-15	10YR6/6		15	30		medium subangular blocky -- platy			Fe/Mn stains; silt seams
15-18	10YR6/6		15	30	10 ch	medium subangular blocky -- platy			Fe/Mn stains

Several factors make this soil conducive for gas and liquid movement. Massive roots were found from 1-12'. These root channels would allow rapid migration in all directions. The presence of Fe/Mn stains show rapid water movement from 1-18'. A high percentage of silt in the profile from 9-24' could allow some movement through these soils when soil moisture conditions are dry but would be possibly restricted vertically by the presence of dense clay layers. However, the soils have good structure and could allow vertical movement when soil moisture conditions are dry. Weathered chert beds were detected from 2-18' which could allow horizontal migration.

JZ Boring#M10



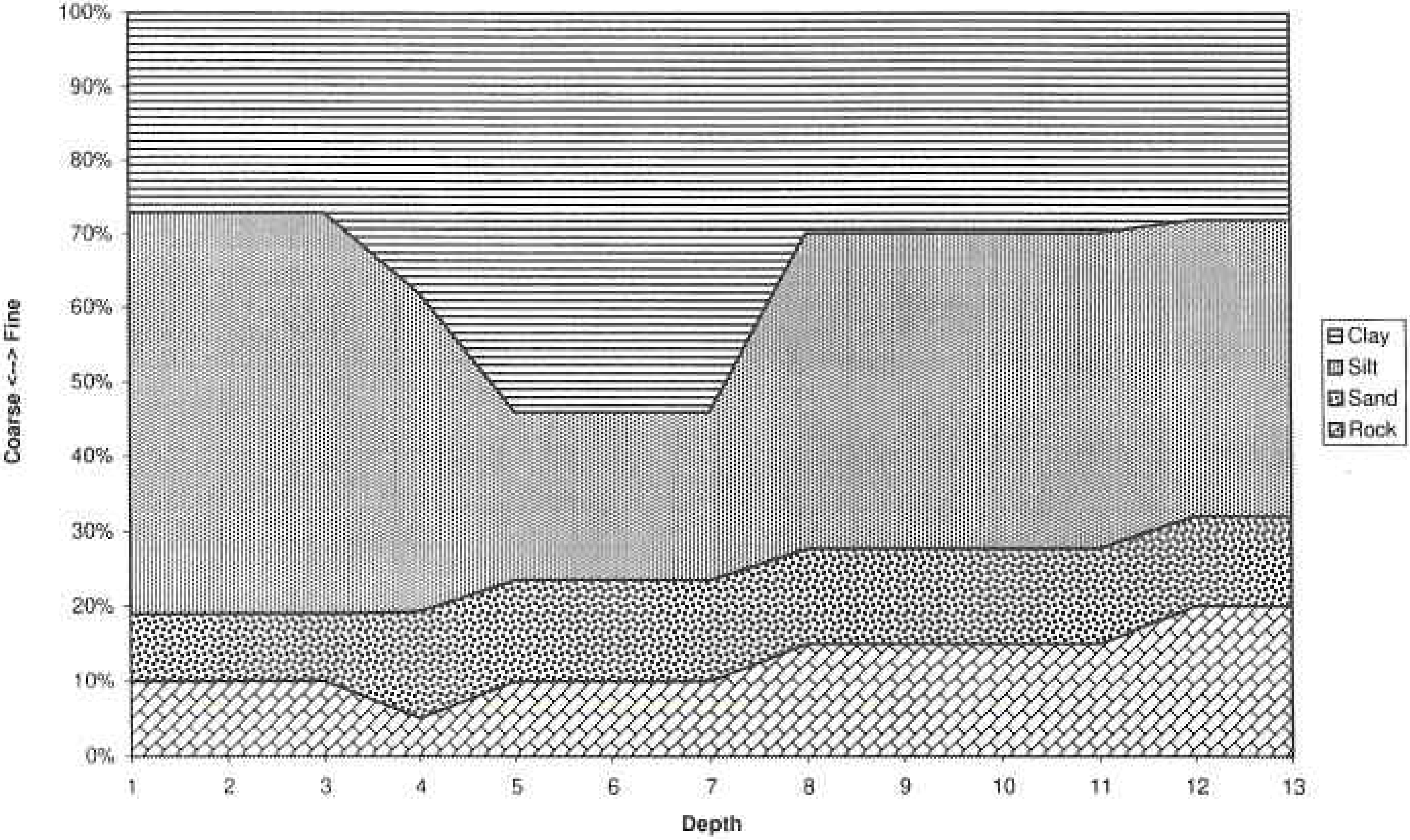

STOP (F5)
O:\FLOOGRNT\DATA\TASK6\JZ\JZM10R.DAT
30
20
0
200
150
100
50
0
2E+6
1E+6
5E+5
0E+0
1E+5
5E+4
0E+0
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

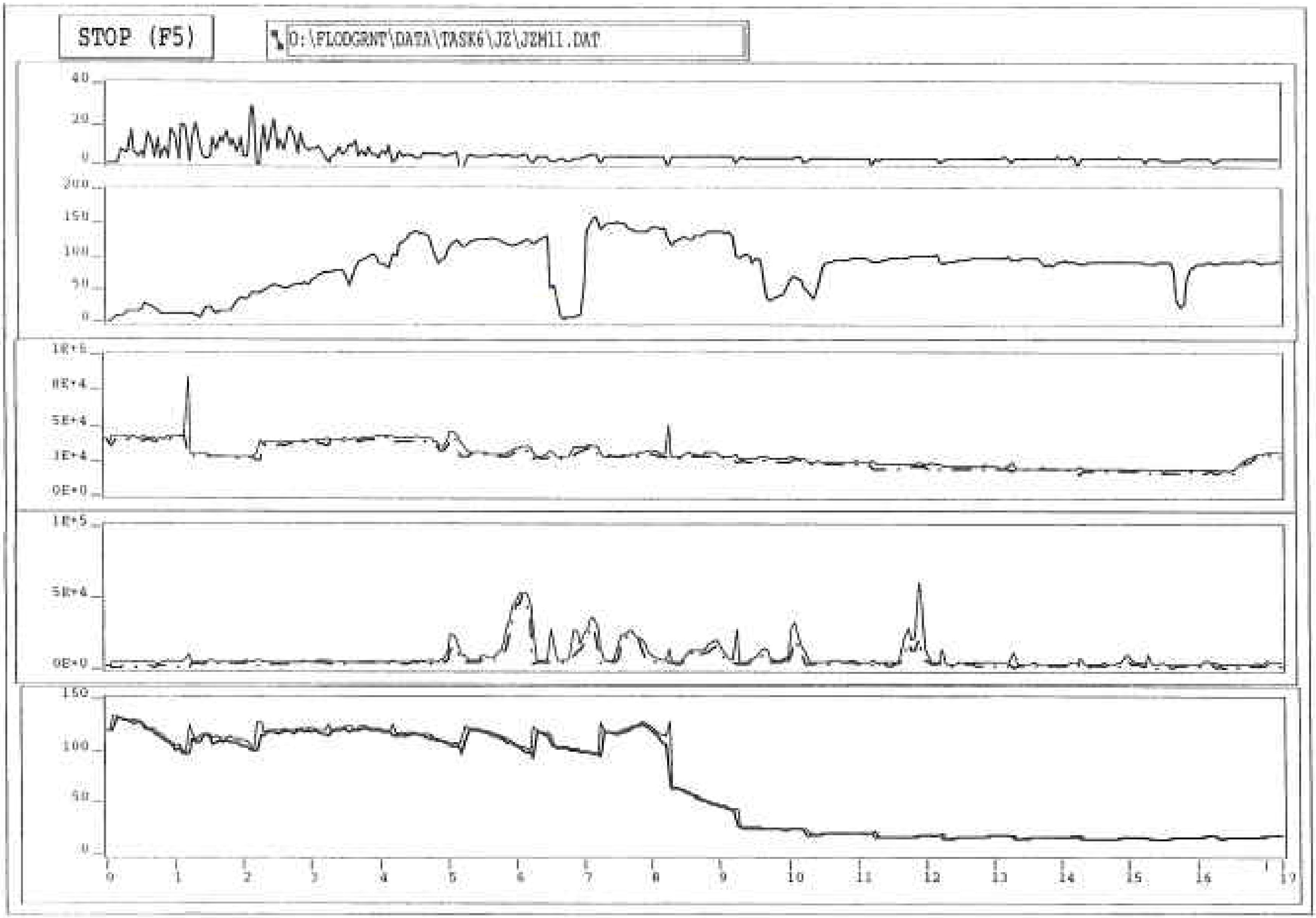
SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-11
DATE July 24, 1997

DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-2.6	7.5YR4/4		10	30	10 ch	weak subangular blocky	many very fine; many fine	few fine tubular; few medium tubular	Fe/Mn nodules
2.6-4	10YR4/4	2.5YR4/6 (60%)	15	40	5	weak subangular blocky	many very fine; many fine	few fine interstiti-al; few medium interstiti-al	
4-7	10YR4/2	10YR6/8	15	60	10	weak subangular blocky	few fine	few very fine interstiti-al; few medium interstiti-al	Fe/Mn stains
7-10	10YR5/6	10YR6/2 seams	15	35	15	medium subangular blocky	few fine; few medium	few very fine interstiti-al; few medium interstiti-al	Fe/Mn stains; silt seams
10-12	10YR6/2 +4/4+4/2	10YR6/2 seams	15	35	20	medium subangular blocky	few fine	few fine interstiti-al	Fe/Mn stains; silt seams

Several factors make this soil somewhat conducive for gas and liquid movement. Roots were found from 0-12'. These root channels would allow rapid migration in all directions. The presence of Fe/Mn stains show rapid water movement from 4-12'. A moderate percentage of silt in the profile from 7-12' could allow some movement through these soils when soil moisture conditions are dry but would be possibly restricted vertically by the presence of dense clay layers. However, the soils have good structure at 7-10' and could allow vertical movement when soil moisture conditions are dry. Weathered chert beds were detected along the length of this profile which could allow horizontal migration.

JZ Boring#M11





STOP (F5)
D:\FLODGRNT\DATA\TASK6\JZ\JZM11.DAT
40
20
0
200
150
100
50
0
1E+5
8E+4
5E+4
3E+4
0E+0
1E+5
5E+4
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Appendix C

Additional MIP and Soil Logs at JZ Landfill

(not given in Appendix B)

(See Appendix B cover page for MIP curve identification.)

SOIL CHARACTERIZATION FOR JZ SANITARY LANDFILL
DNR MONITORING WELL # 1

02/25/97

DEPTH (Ft)	MUNSELL COLOR		SOIL TYPE		% ROCK	STRUCTURE	PORES	
	MATRIX	MOTTLES	% SAND	%CLAY			ROOTS	SOILPORES
0- 1.1	boring compaction							
1.1- 2.6	mixed 10YR4/6+ 4/3		10 very fine	25	5 chert	weak subangular blocky	few very fine, few fine	many fine tubular; few interstitial
2.6- 3.3	10YR5/6		15	30	5 chert	medium subangular blocky	few very fine, few fine	few fine tubular; few very fine interstitial
3.3- 4.0	10YR5/6		10	40	5 chert	weak, very fine subangular blocky	few very fine, few fine	few fine tubular; few very fine interstitial
4.0- 5.8	10YR5/3 10%	40% 7.5YR5/4+ 5/6 10YR5/2 silt coats[2)]	15	40	10 chert	medium subangular blocky	few fine	many very fine tubular; few interstitial
5.8- 7.0	mixed 10YR5/6+ 5/3; Fe/Mn + organic stains[1)]	clay skins[2)]	5	50	10 chert + weathered rock	medium subangular blocky	few very fine, 1 medium	few very fine tubular
7.0- 7.5	mixed 10YR5/6+ 5/3; Mn channels[2)]		5	50	10 chert	weak subangular blocky - massive	few very fine+ few fine	few medium + few very fine tubular

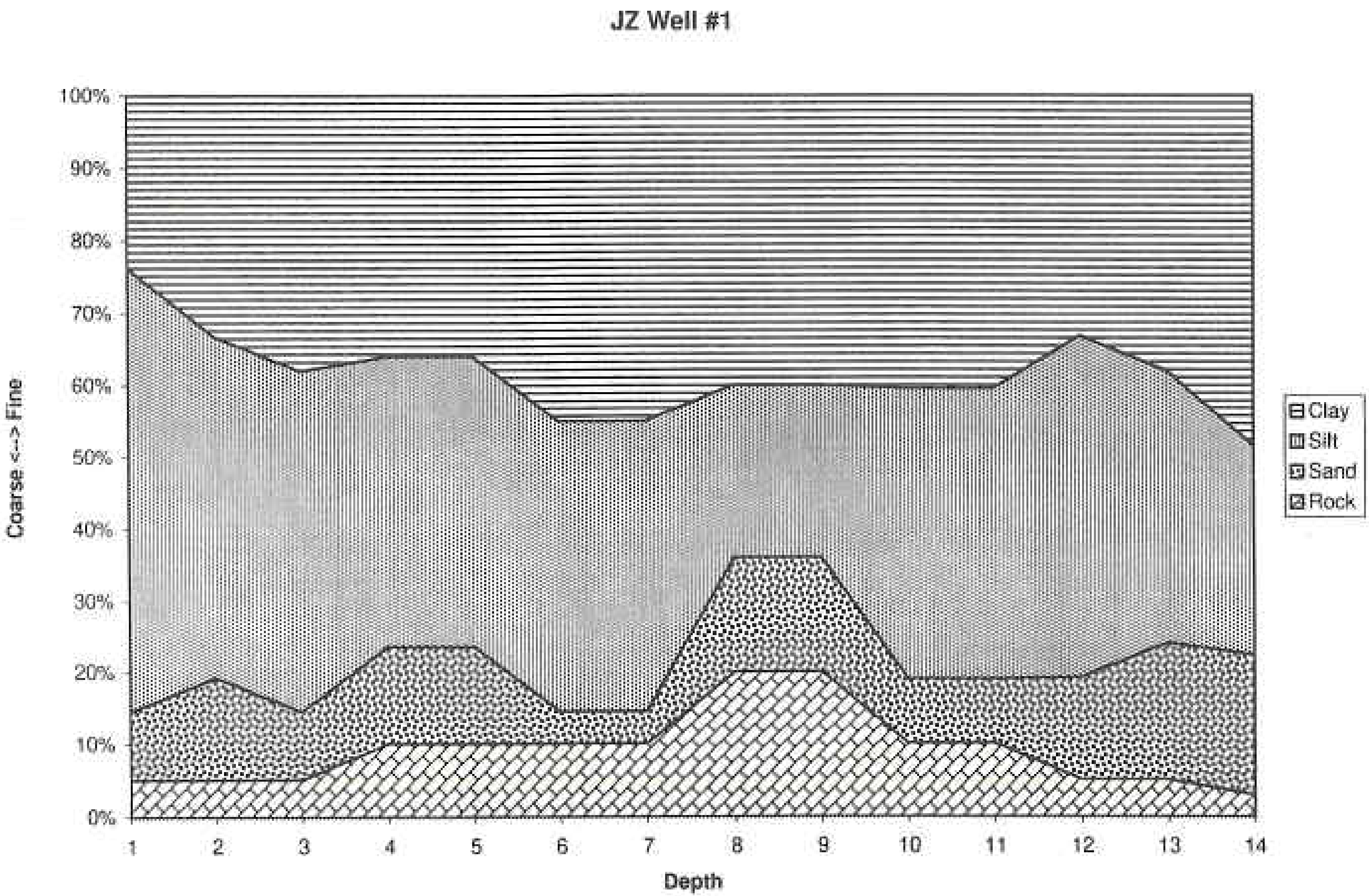
7.5-10.0	10YR5/6+ 5/3; 25% Fe/Mn stains[1] + wood		20	50	20 chert	weak platy - massive	few very fine	few fine tubular, few fine tubular
10.0-12.5	10YR5/6	10YR5/2 clay seams[2]	10	45	10 chert; fossils	weak subangular blocky	many fine & very fine	few fine tubular; few very fine interstitial
12.5-12.8	mixed 10YR5/2+ 5/4+4/3	10YR5/2 clay seams[2]	15	35	5	very weak subangular blocky	few fine & many very fine	many fine & very fine tubular
12.8-13.0	decomposed dolomite							
13.0-14.5	10YR5/6		20	40	5	very weak subangular blocky	very few fine	few very fine tubular, very few very fine interstitial
14.5-15	10YR5/4		20	50	3	very weak subangular blocky		few fine tubular; few very fine interstitial

1) Stain= iron and/or manganese formed by historic water movement.
2) Soil structure pathways formed by historic water movement.

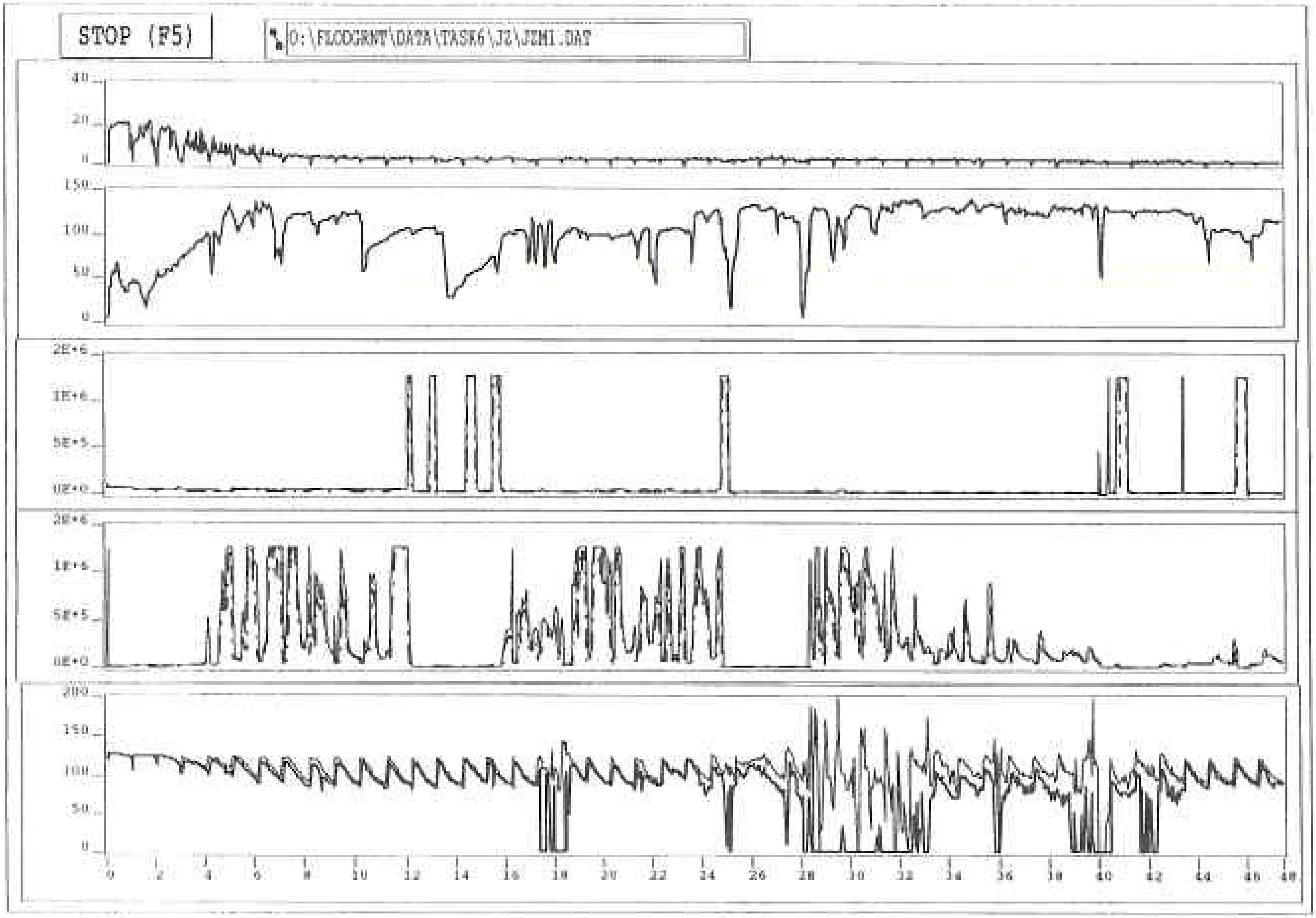
Permeability was not consistent throughout this stratified profile. Chert fragments were consistent throughout the profile. Rock fragments, clay and silt skins, soil pores and various layers of ancient root remnants which provide pathways were encountered at various depths. These structures could act as aqua-ducts or gas-ducts depending upon water retention within the soil profile. Vertical movement throughout the profile could be inhibited by clay and silt layers in the profile. The predominance of silt and clay in this soil would also inhibit rapid vertical movement of gases and liquids when saturated. The weathered dolomite layer at ~13' would allow very rapid gas movement laterally.

The high clay content and the thin, delicate structure of the transmissive features of this soil would be easily disturbed and destroyed by excessive radial forces applied in well installation. The push probe installation process should cause minimal damage to the overall soil profile. Also since the sand screening bridged though the silty clay zone, perched water could easily follow this artificial vertical sand lense created by the screening interval.

See attached registration for well construction details.



JZ Well #1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Depth
Clay
Silt
Sand
Rock



STOP (F5)
D:\FLODGRNT\DATA\TASK6\J2\J2M1.DAT
40
20
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
200
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48

SOIL CHARACTERIZATION FOR JZ SANITARY LANDFILL
DNR MONITORING WELL # 2 (Pasture)

02/25/97

DEPTH (Ft)	MUNSELL COLOR		SOIL TYPE		% ROCK	STRUCTURE	PORES	
	MATRIX	MOTTLES	% SAND	%CLAY			ROOTS	SOILPORES
0- 1.6	boring compaction							
1.6- 2.0	10YR4/3		20	15		weak subangular blocky	many fine, many very fine, few medium	many very fine tubular
2.0- 2.8	7.5YR5/6		5	20		medium subangular blocky	few fine	many very fine, few fine & few moderate tubular
2.8- 4.0	10YR5/6	5YR5/6 20%	10	33		medium subangular blocky	few very fine, few fine	many very fine & few fine tubular, few fine interstitial
4.0- 5.5	mixed 10YR5/3+ 5/8+ 4/6	10% 10YR5/2	20	55	15 chert	medium subangular blocky	few very fine, many fine	many very fine & few fine tubular, few fine interstitial
5.5- 8.0	mixed 10YR5/3+ 5/8+ 4/6	10% 10YR5/2	20	55	5 chert	medium subangular blocky	few very fine	many very fine tubular
8.0- 9.6	10YR5/6		20	20- 35	10 chert	massive	few very fine	many very fine tubular
9.6- 10.6	10YR4/6		20	10	15- 30 chert	weak, medium subangular blocky	few very fine	few fine tubular; few fine tubular
10.6- 14.6	mixed 10YR4/6+ 5/2+ 5/4	Fe/Mn[1)] & clay seams[2)]	20	40	10 chert; fossils	massive	few very fine	many very fine, many fine & few moderate tubular

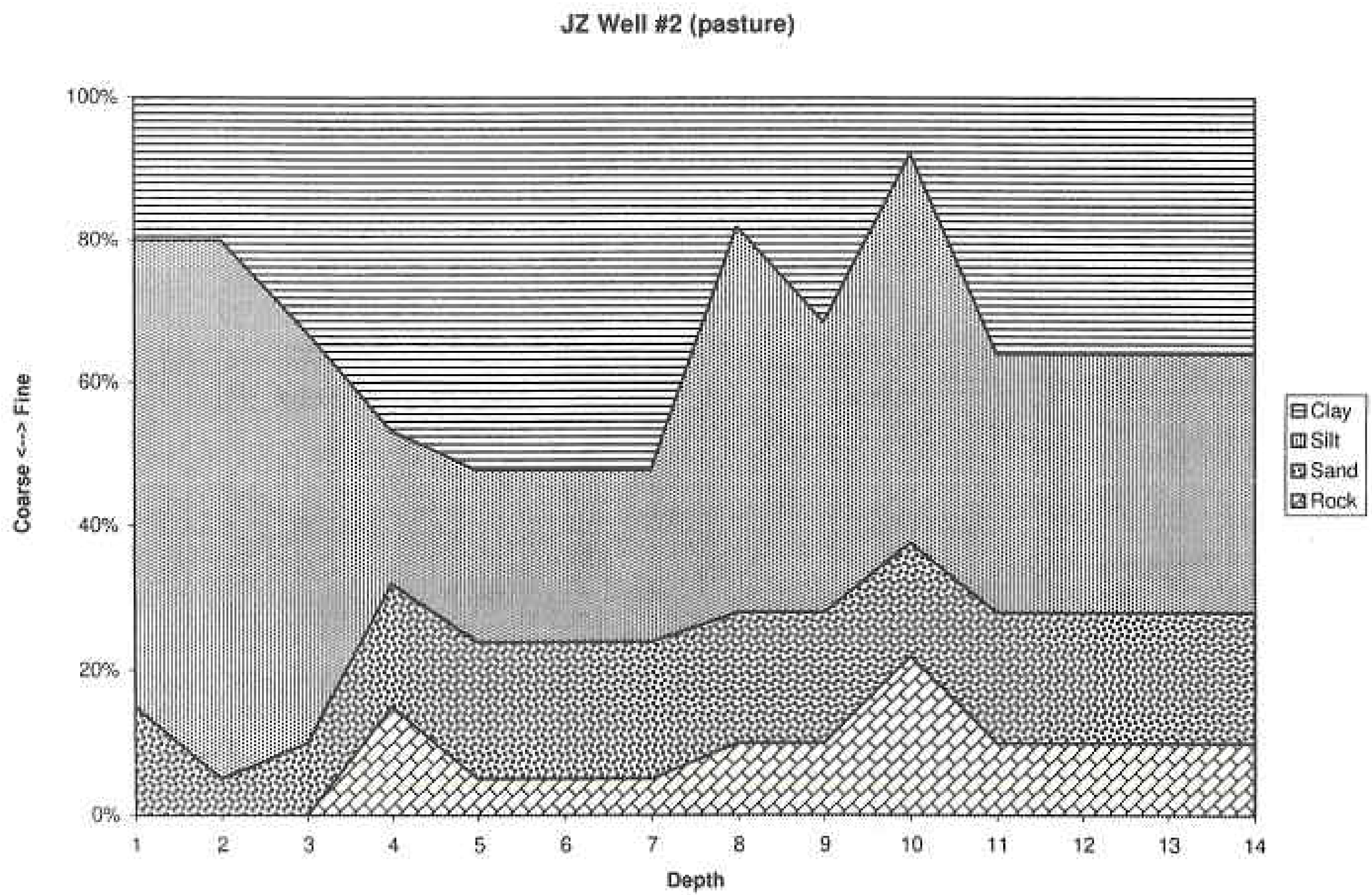
14.6-15.0	weathered chert bed							

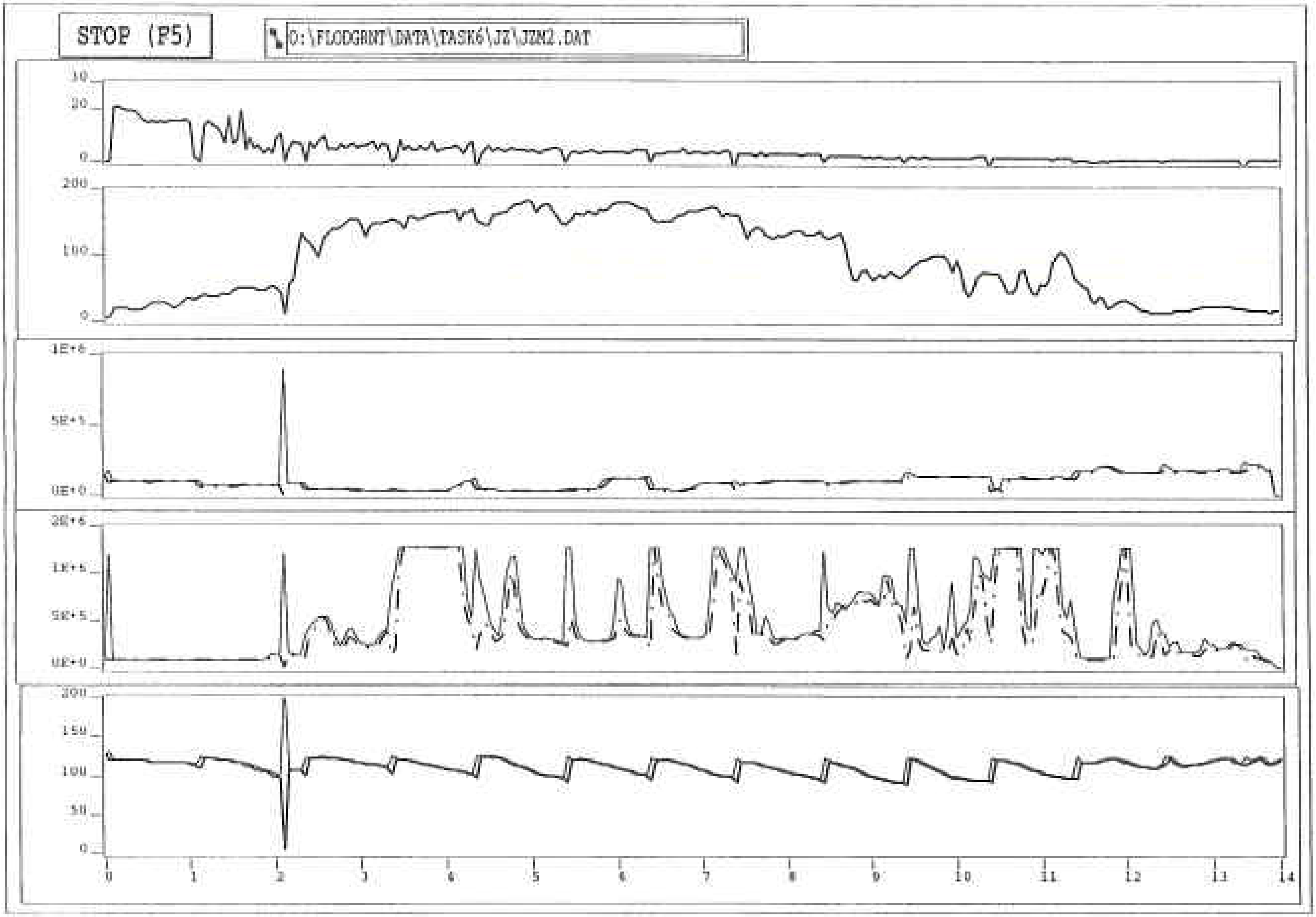
1) Iron and/or manganese staining formed by historic water movement
2) Soil structure pathways formed by historic water movement.

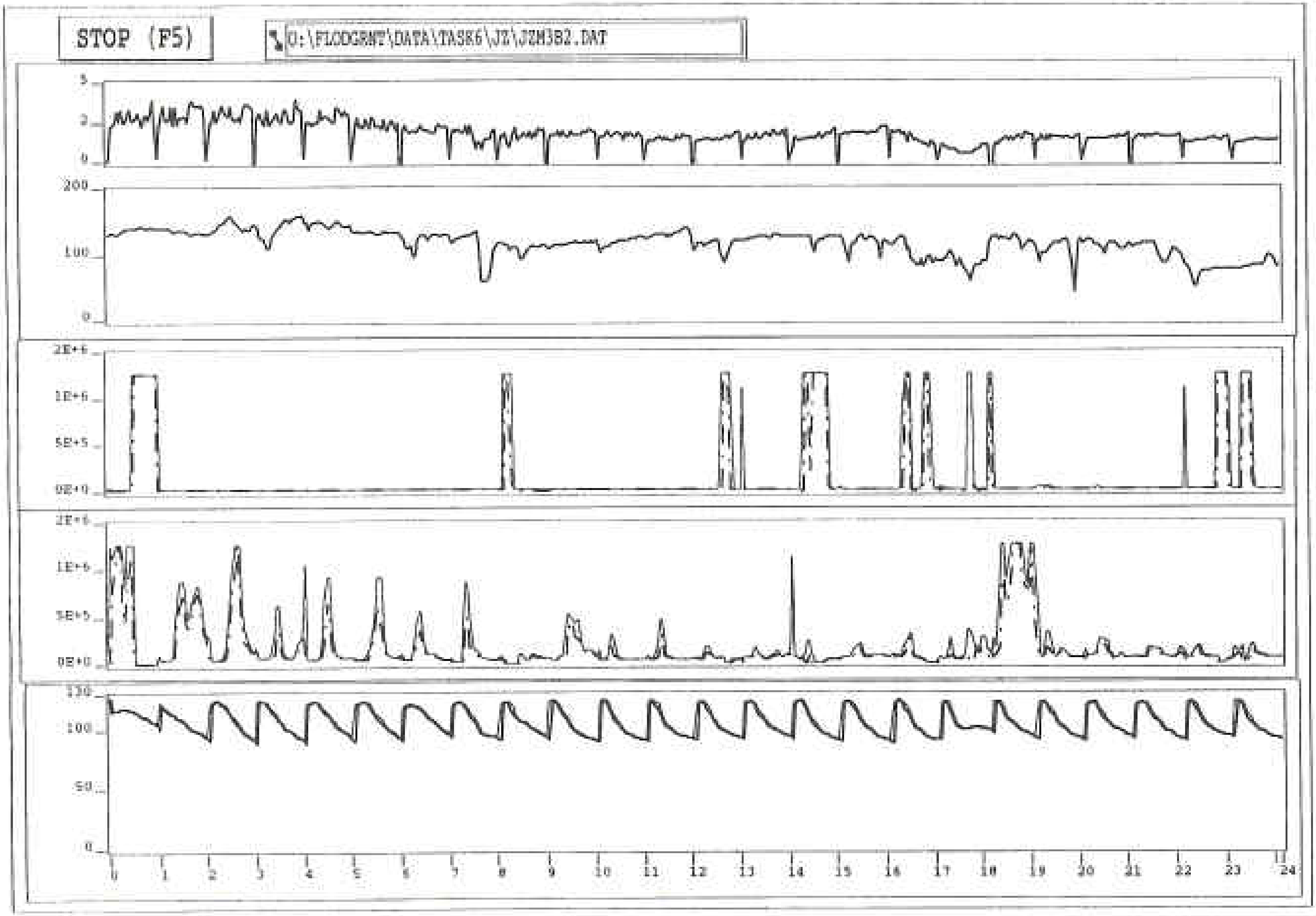
Permeability was not consistent throughout this stratified profile but many similarities existed with the soils from monitoring well #1. Chert fragments were consistent throughout the profile. Rock fragments, clay and silt skins, roots, soil pores and various layers of ancient root remnants which provide pathways were encountered at various depths. These structures could act as aqua-ducts or gas-ducts depending upon water retention within the soil profile. Vertical movement throughout the profile could be inhibited by clay and silt layers in the profile. The clay layer from 2-8' bgs was very wet The predominance of silt and clay in this soil would also inhibit rapid vertical movement of gases and liquids when saturated with water. The weathered dolomite layer at ~13' would allow very rapid gas movement laterally and could connect with the landfill to rapidly transmit landfill gases. The weathered chert bed at 15' had a strong landfill gas odor even after weeks in a refrigerated container.

The high clay content and the thin, delicate structure of the transmissive features of this soil would be easily disturbed and destroyed by excessive radial forces applied in well installation. The push probe installation process should cause minimal damage to the overall soil profile. Also since the sand screening bridged though the silty clay zone, perched water could easily follow this artificial vertical sand lense created by the screening interval.

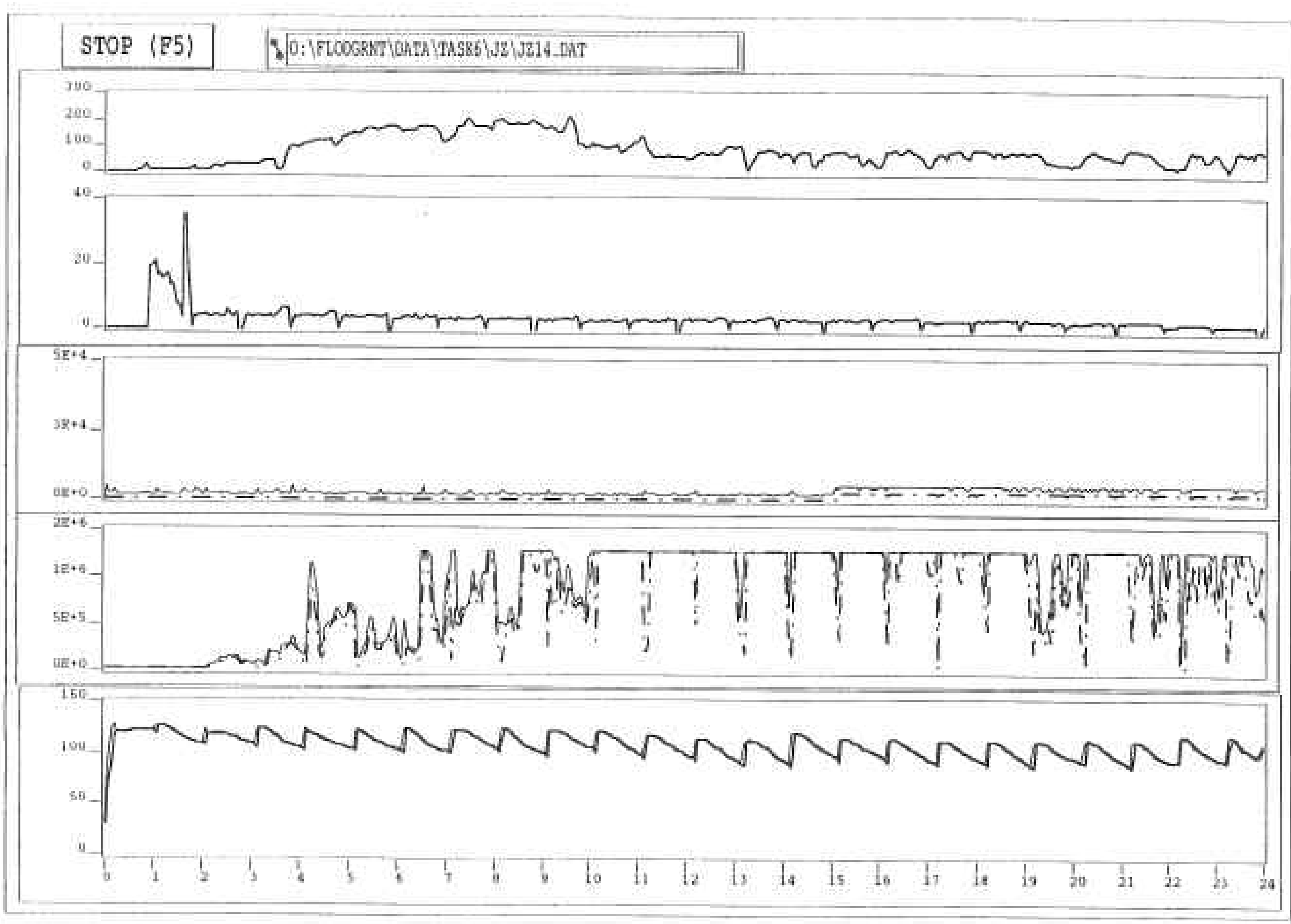
See attached registration for well construction details.


JZ Well #2 (pasture)
100%
80%
60%
40%
20%
0%
Coarse <--> Fine
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Depth
Clay
Silt
Sand
Rock

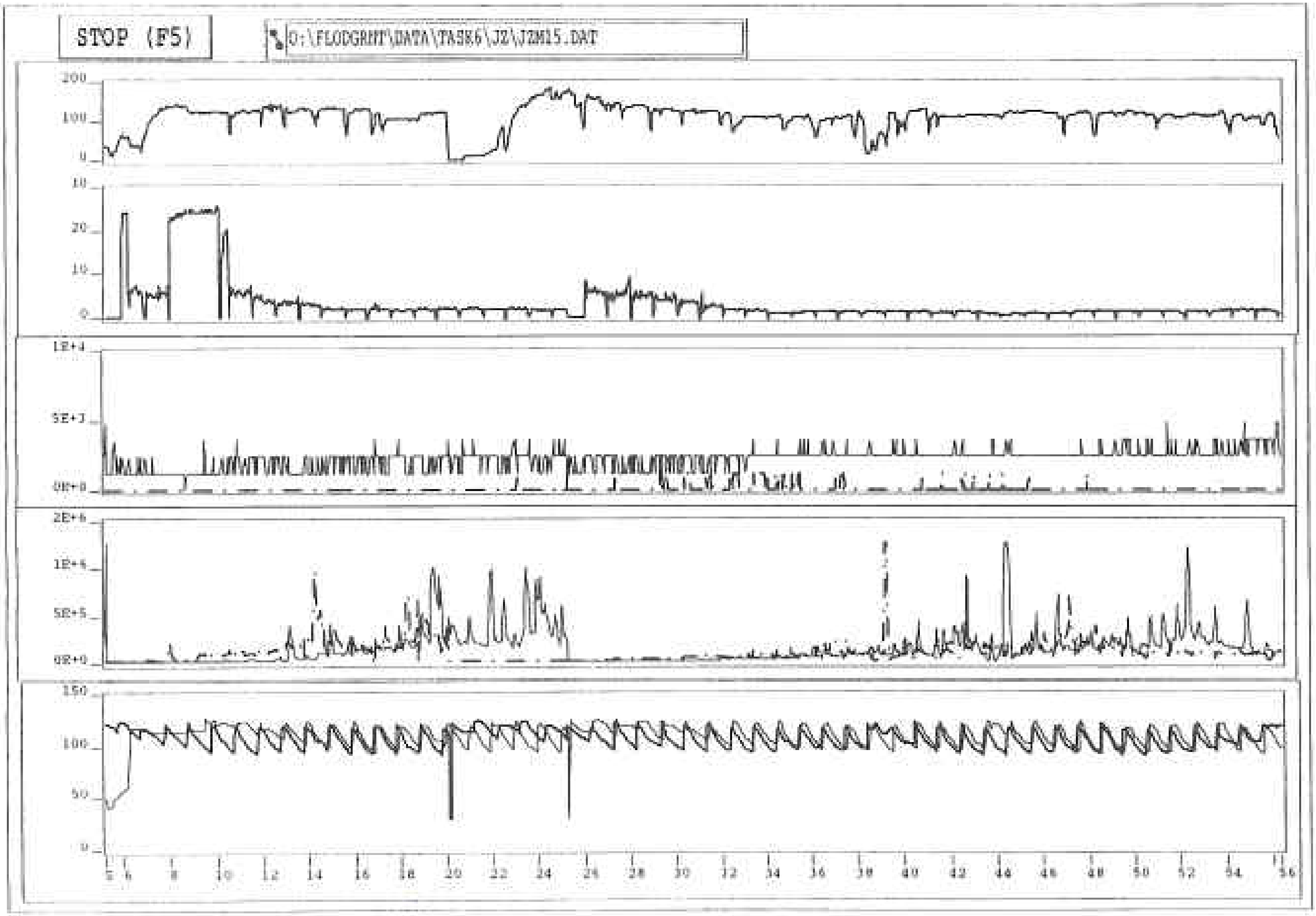

STOP (P5)
D:\FLODGRNT\DATA\TASK6\JZ\JZM2.DAT
30
20
0
200
100
0
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14



STOP (F5)
O:\FLODGRNT\DATA\TASK6\JZ\JZM3B2.DAT
5
2
0
200
100
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
120
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24



STOP (F5)
O:\FLOOGRNT\DATA\TASK6\JZ\JZ14.DAT
300
200
100
0
40
20
0
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

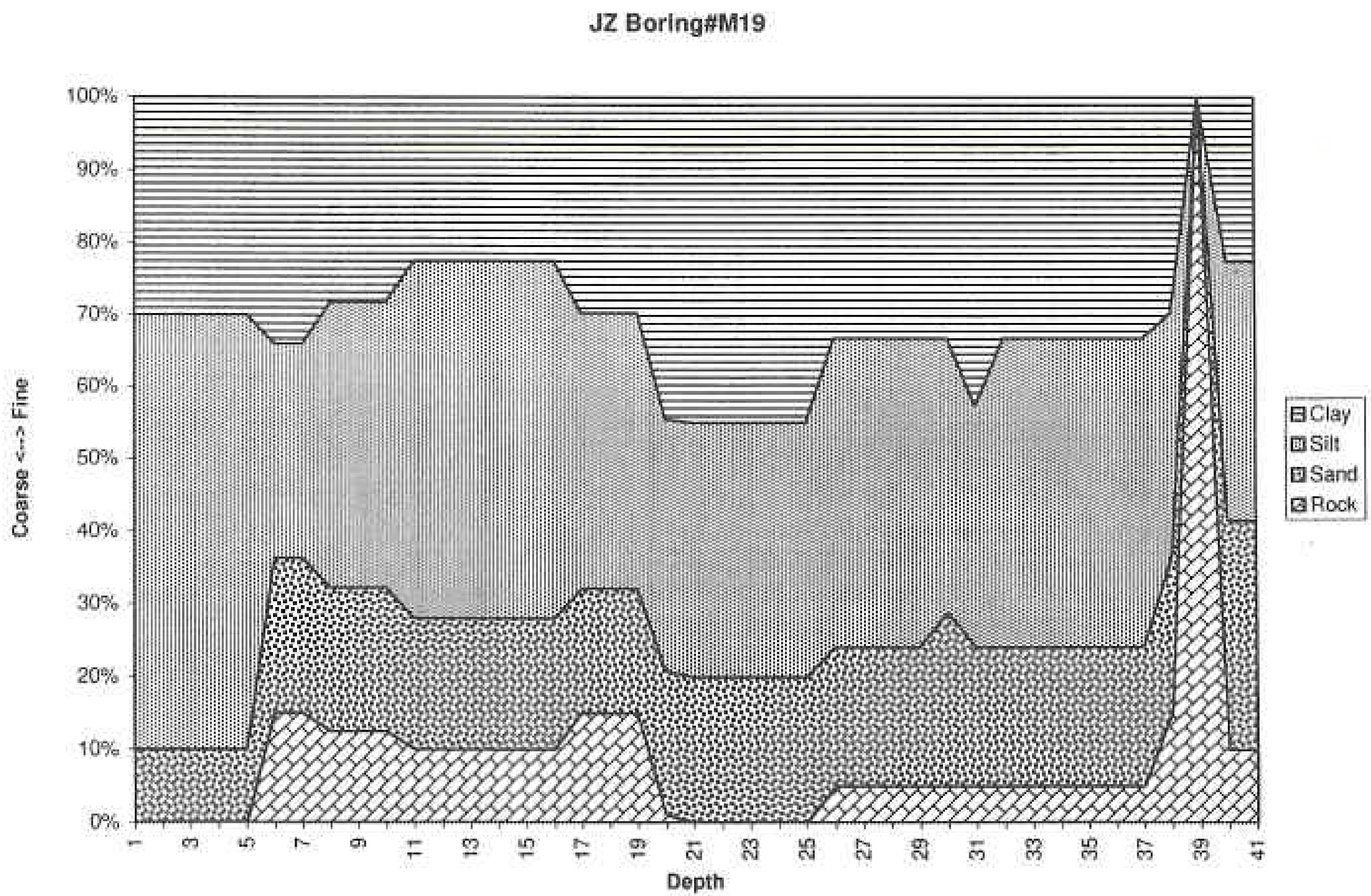

STOP (F5)
D:\FLODGRHT\DATA\TASK6\J2\J2M15.DAT
200
100
0
30
20
10
0
1E+J
5E+J
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
5 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56

SOIL CHARACTERIZATION FOR JZ LANDFILL
BORING # M-19
DATE July 24, 1997

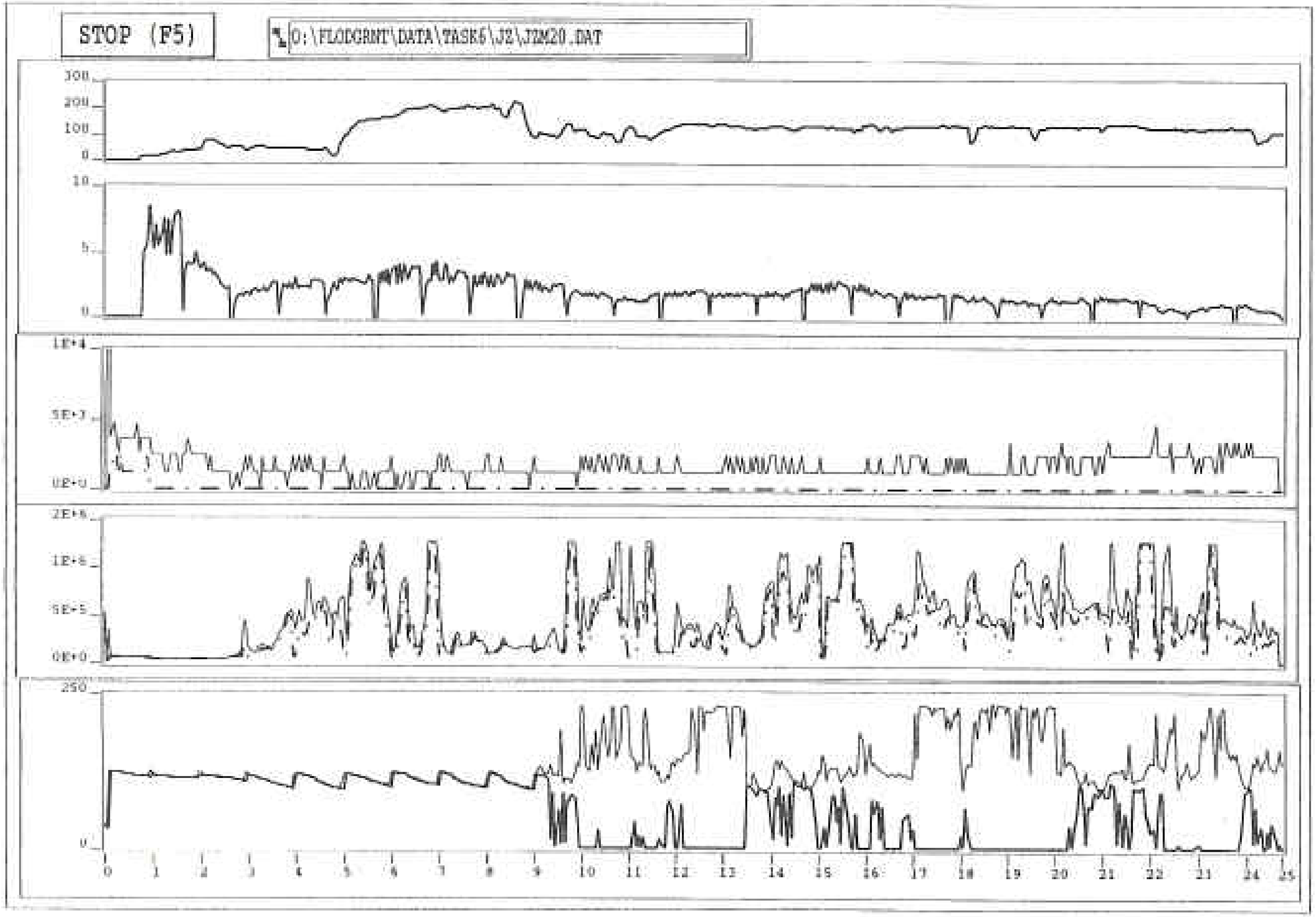
DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-2	excavation	for spider	wells						
2-7	10YR4/4 +5/2		<10	30		weak subangular blocky	few fine; few medium	many fine interstiti-al	Fe/Mn stains
7-9	10YR4/3	2.5YR6/2	25	40	15	medium subangular blocky	few fine, few coarse	few fine interstiti-al; few fine tubular	massive Fe/Mn channels
9-12	sample	lost							
12-18	10YR6/6	10YR 5/2 seams	20	25	10	weak subangular blocky	few very fine, few fine	few medium interstiti-al; few fine tubular	Fe/Mn stains & nodules; silt/clay seams
12-12.5	10YR4/4 +5/4		15	20	15	weak subangular blocky	few very fine; few fine;		inclusion of clay & silt
18-21	10YR5/4	10YR6/2 seams	20	35	15	weak subangular blocky	few fine	few fine interstiti-al; few fine tubular	Fe/Mn stains; clay seams; silt coats
21-26.4	10YR5/4	10YR6/2 seams	20	45		weak subangular blocky	few fine	few fine interstiti-al; few fine tubular	Fe/Mn stains; clay seams; silt coats
26.4-30	10YR6/8	10YR6/1 clay seams	20	35	5	medium subangular blocky	few very fine	few fine interstiti-al	Fe/Mn stains

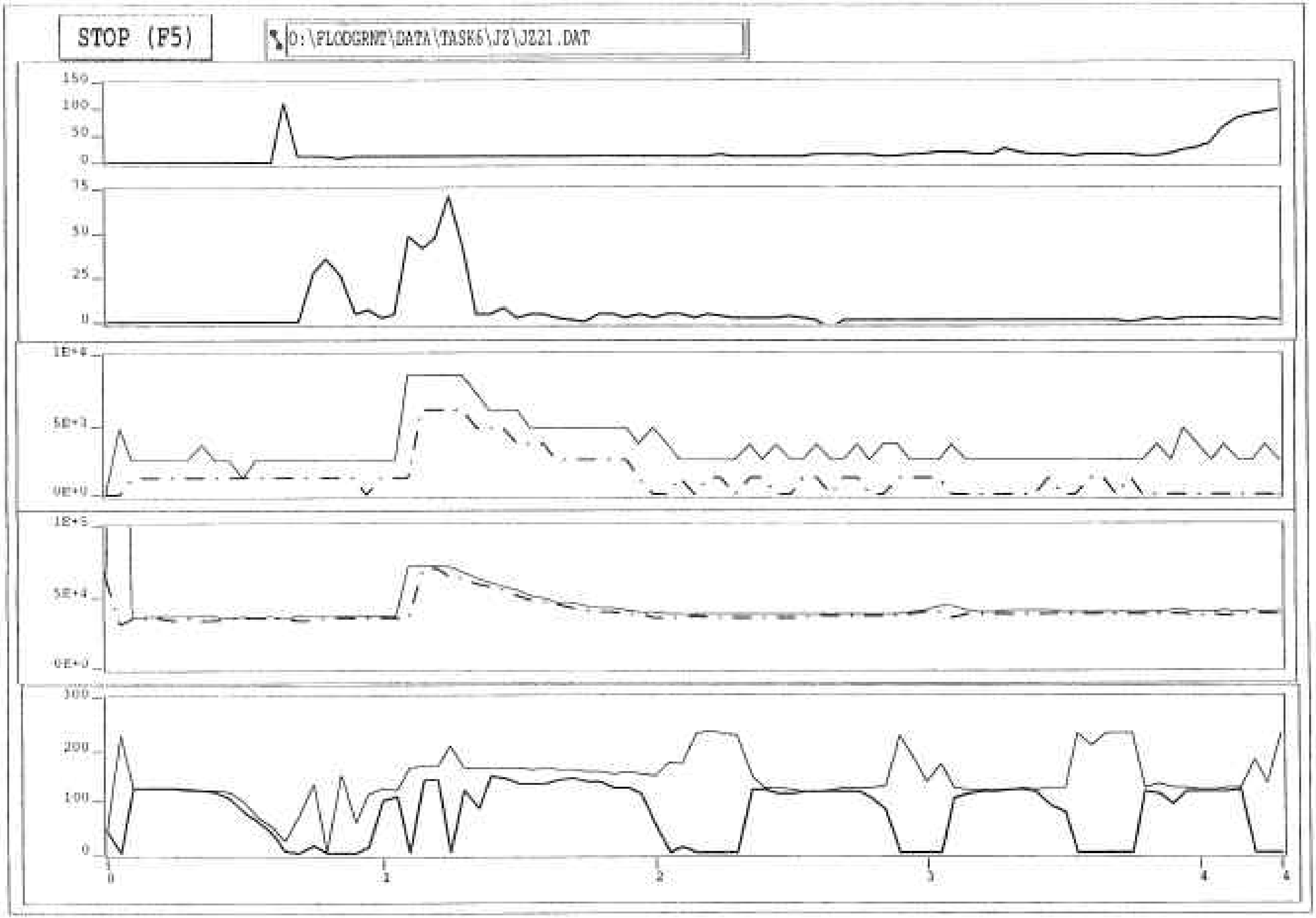
30-30.8	crushed	decomposed	sandstone						
30.8-31.8	10YR5/4 +6/6		25	35	5	weak subangular blocky	few fine	few very fine interstiti-al; few fine tubular	Fe/Mn stains; & nodules
31.8-33	10YR6/2	10YR4/6	20	45	5	medium subangular blocky		few fine interstiti-al	
33-39	2.5YR5/3		20	35	5	medium subangular blocky		many very fine interstiti-al; few fine interstiti-al	Fe/Mn stains & nodules
34	massive	calcite	deposit						
39-40	5YR2.5/1		25	35	15 ch	medium subangular blocky		few medium interstiti-al	
40-41	decompos-ing	chert bed							strong landfill odor
41-42	10YR4/4		35	25	10	medium subangular blocky		few medium interstiti-al	Fe/Mn nodules, silt coats

Several factors make this soil conducive for significant gas and liquid movement. Roots were found from surface to 30'. These root channels would allow rapid migration in all directions. The presence of Fe/Mn stains show significant water movement from the surface to 39'. The presence of alternating Fe/Mn nodules at various places in the profile shows layers of soils which impeded water movement under certain conditions; massive deposits of calcite crystals at 34' shows one of these zones. Good soil structure and a moderate percentages of silt in these soils would allow more significant movement through these soils when soil moisture conditions are dry. Layers of decomposing chert beds which could form zones for significant horizontal movement were noted from 7-42'. The residual chert bed at 37-41' had strong landfill odor confirming its capacity to transmit liquids and gases. Leachate may have been responsible for the marked color change at 37-40'.

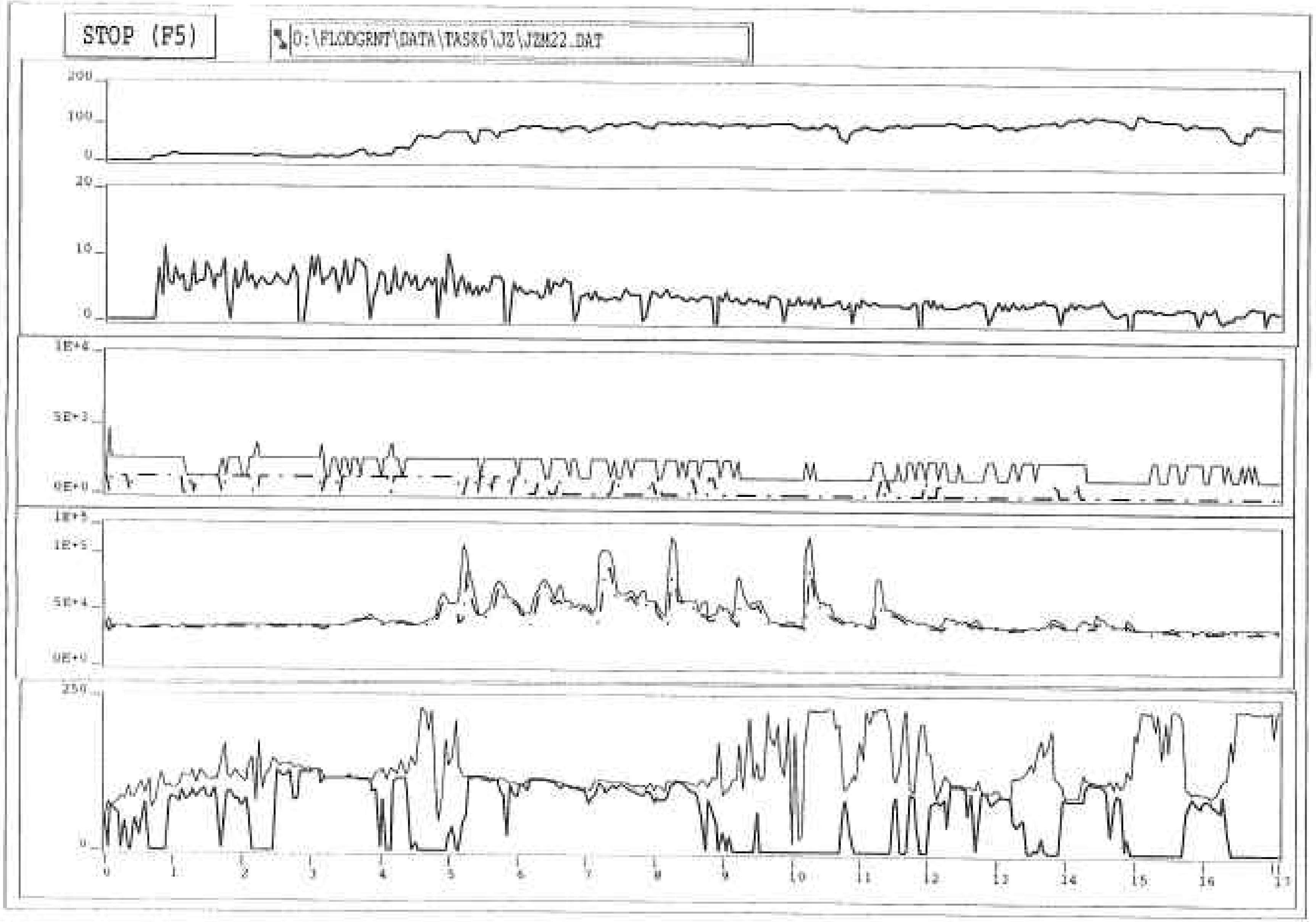


JZ Boring#M19
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Coarse <--> Fine
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39
41
Depth
Clay
Silt
Sand
Rock


STOP (F5)
O:\FLODGRNT\DATA\TASK6\J2\J2M20.DAT
300
200
100
0
10
5
0
1E+4
5E+3
0E+0
2E+6
1E+6
5E+5
0E+0
250
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



STOP (F5)
D:\FLODGRNT\DATA\TASK6\JZ\JZ21.DAT
150
100
50
0
75
50
25
0
1E+4
5E+3
0E+0
1E+5
5E+4
0E+0
300
200
100
0
0
1
2
3
4
4

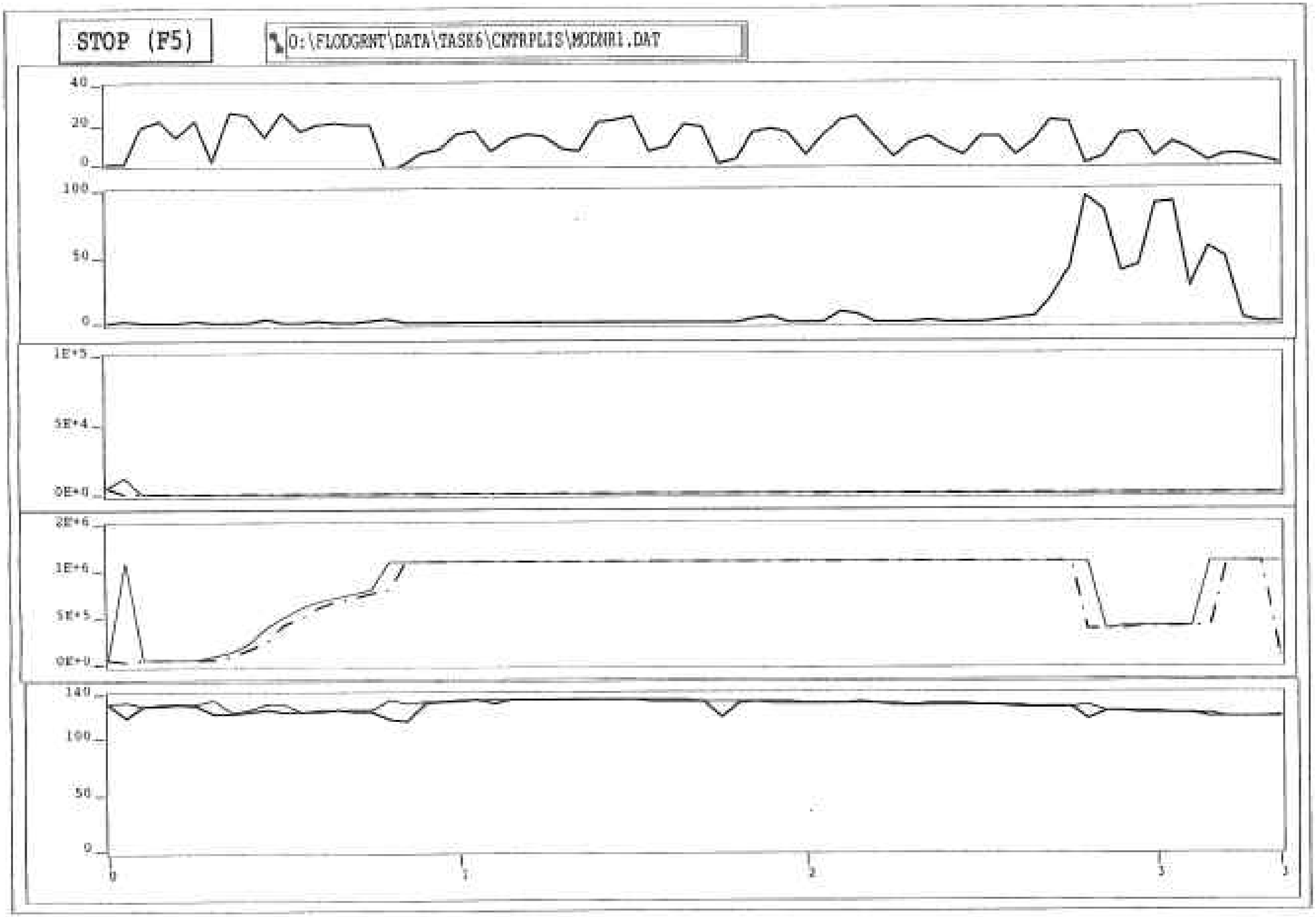

STOP (F5)
O:\FLODGRNT\DATA\TASK6\JZ\JZM22.DAT
200
100
0
20
10
0
1E+4
5E+3
0E+0
1E+5
1E+5
5E+4
0E+0
250
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

Appendix D

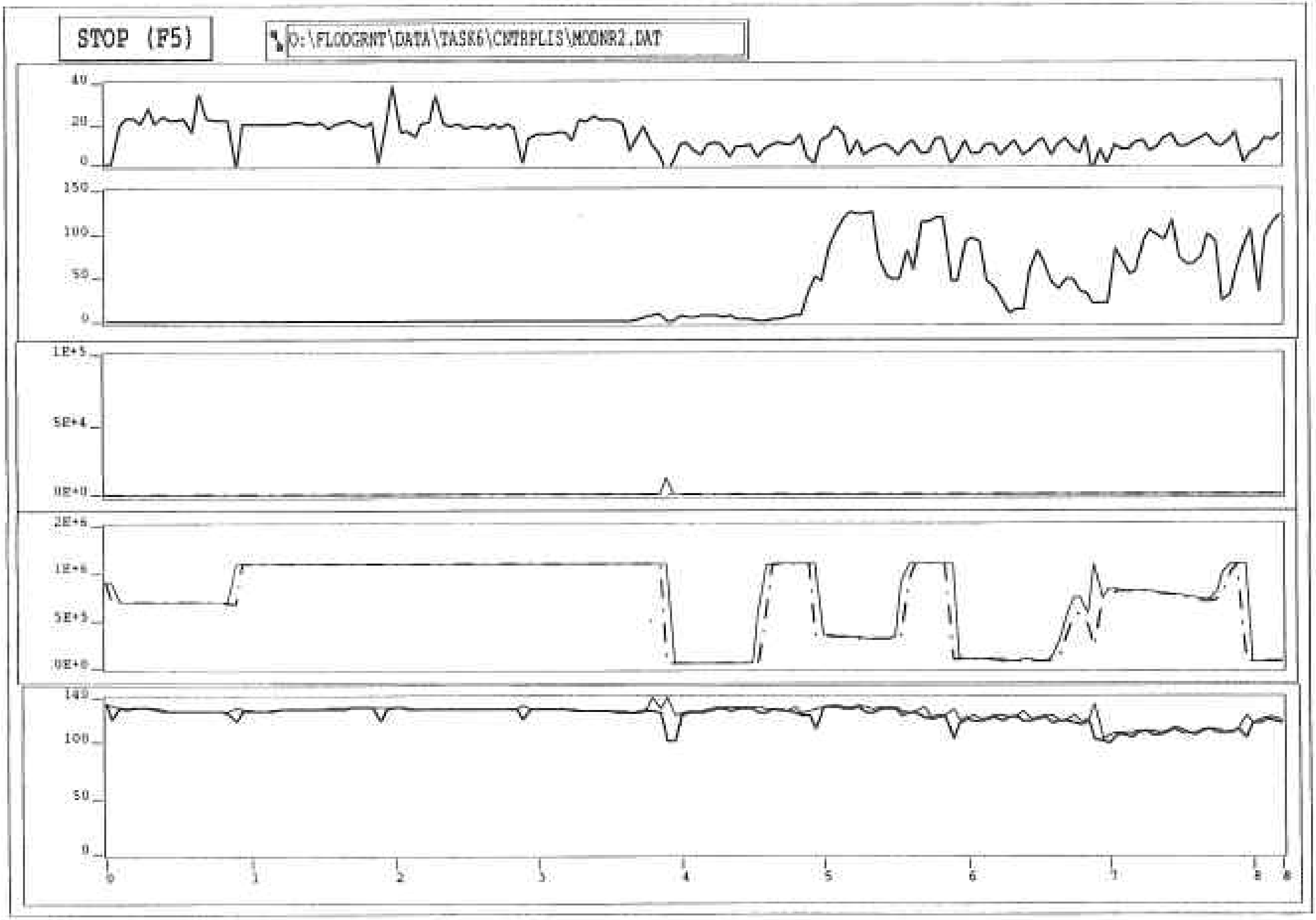
Centropolis Landfill

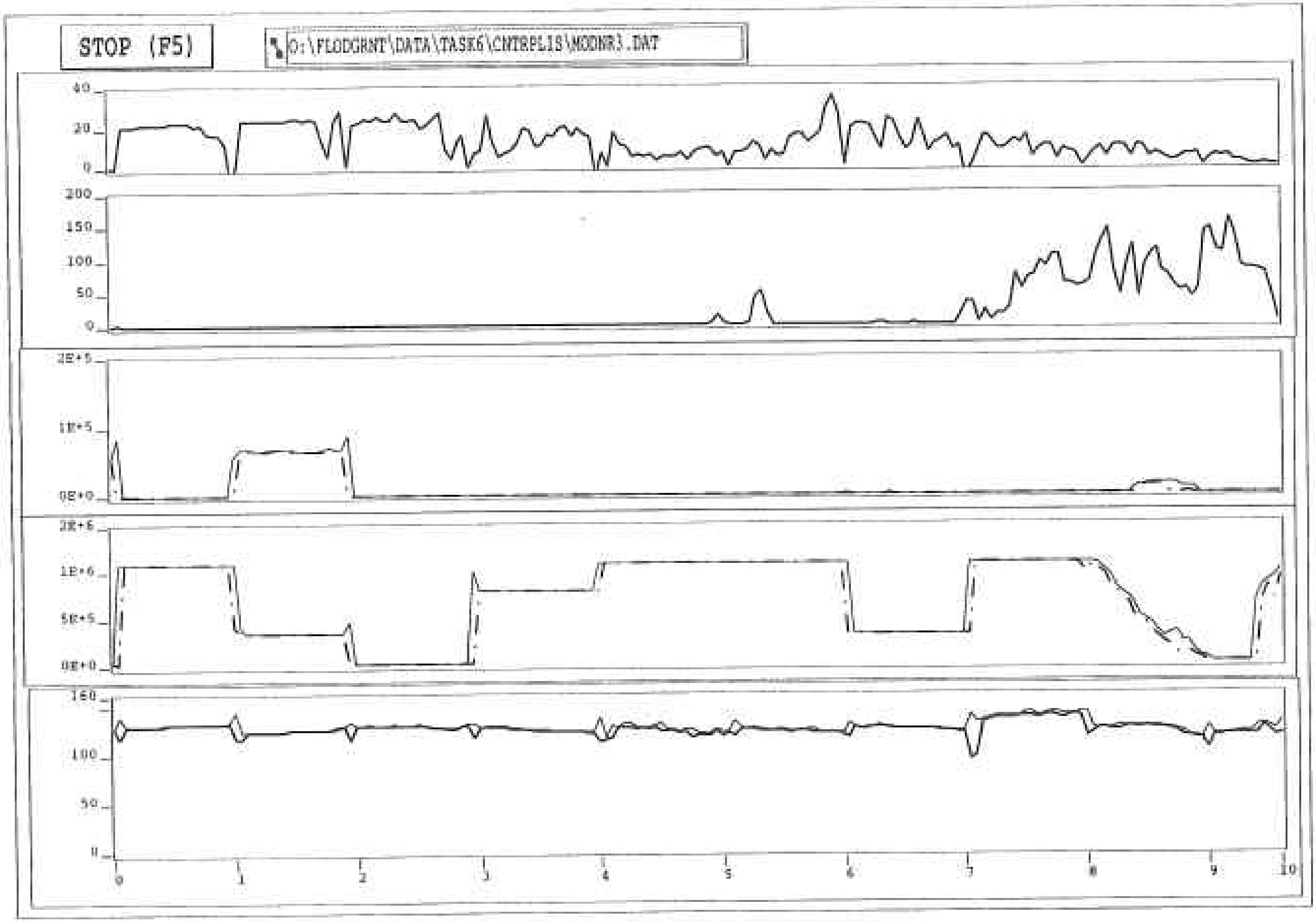
MIP Logs and Additional Gas Well Logs

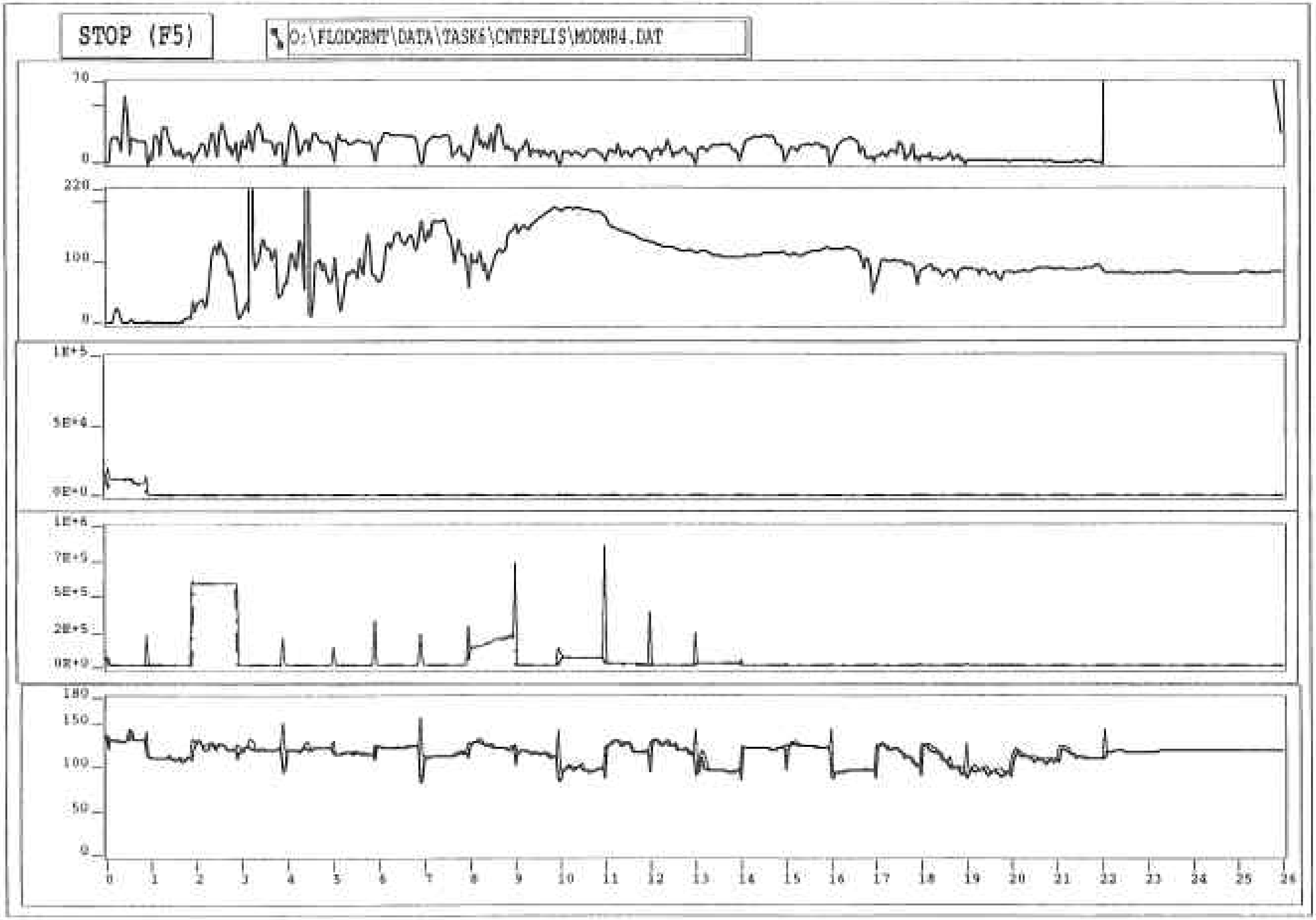
(See Appendix B cover page for MIP curve identification.)

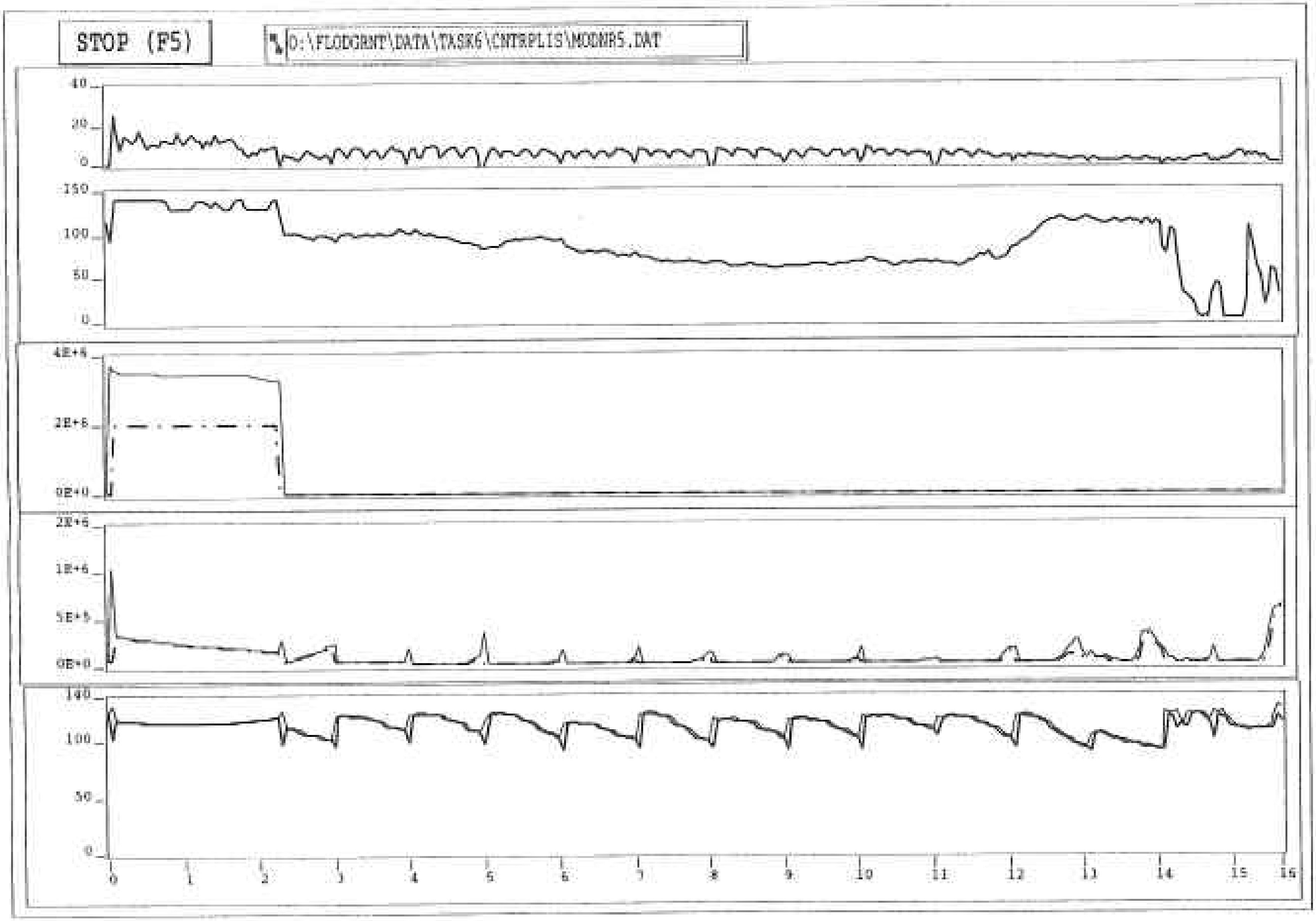


STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR1.DAT
40
20
0
100
50
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
140
100
50
0
0
1
2
3

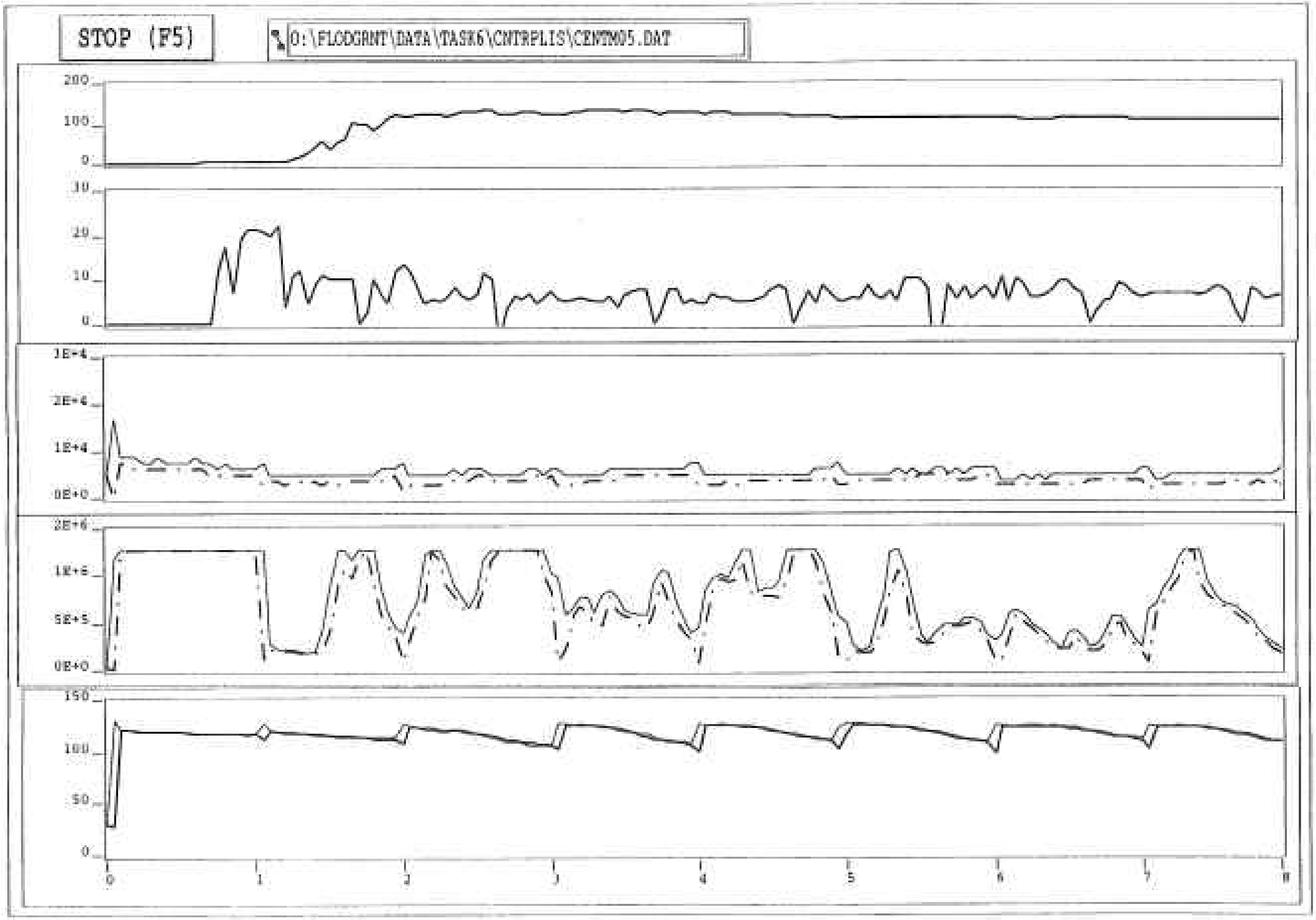

STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR2.DAT
40
20
0
150
100
50
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
140
100
50
0
0
1
2
3
4
5
6
7
8
8

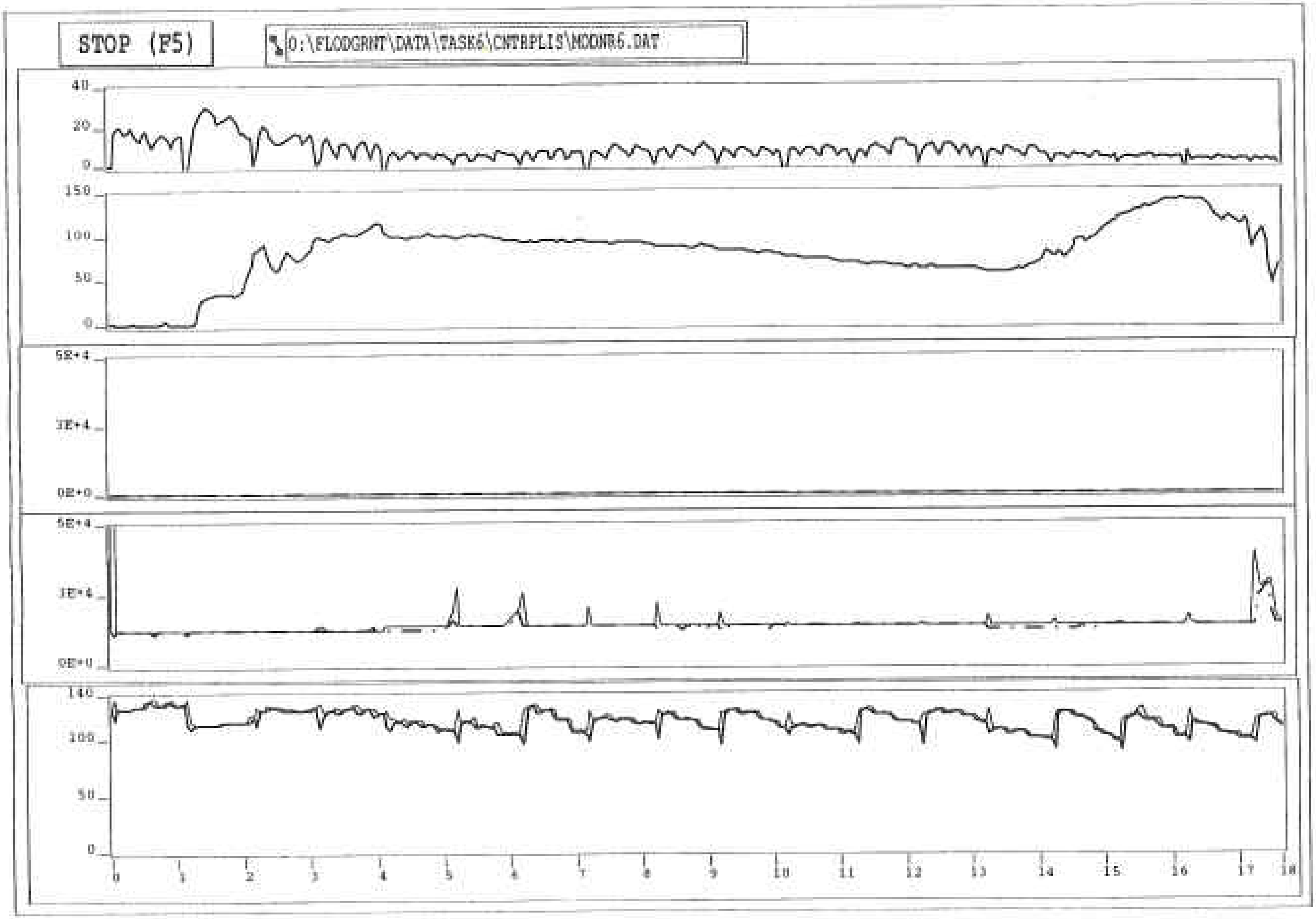

STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR3.DAT
40
20
0
200
150
100
50
0
2E+5
1E+5
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10

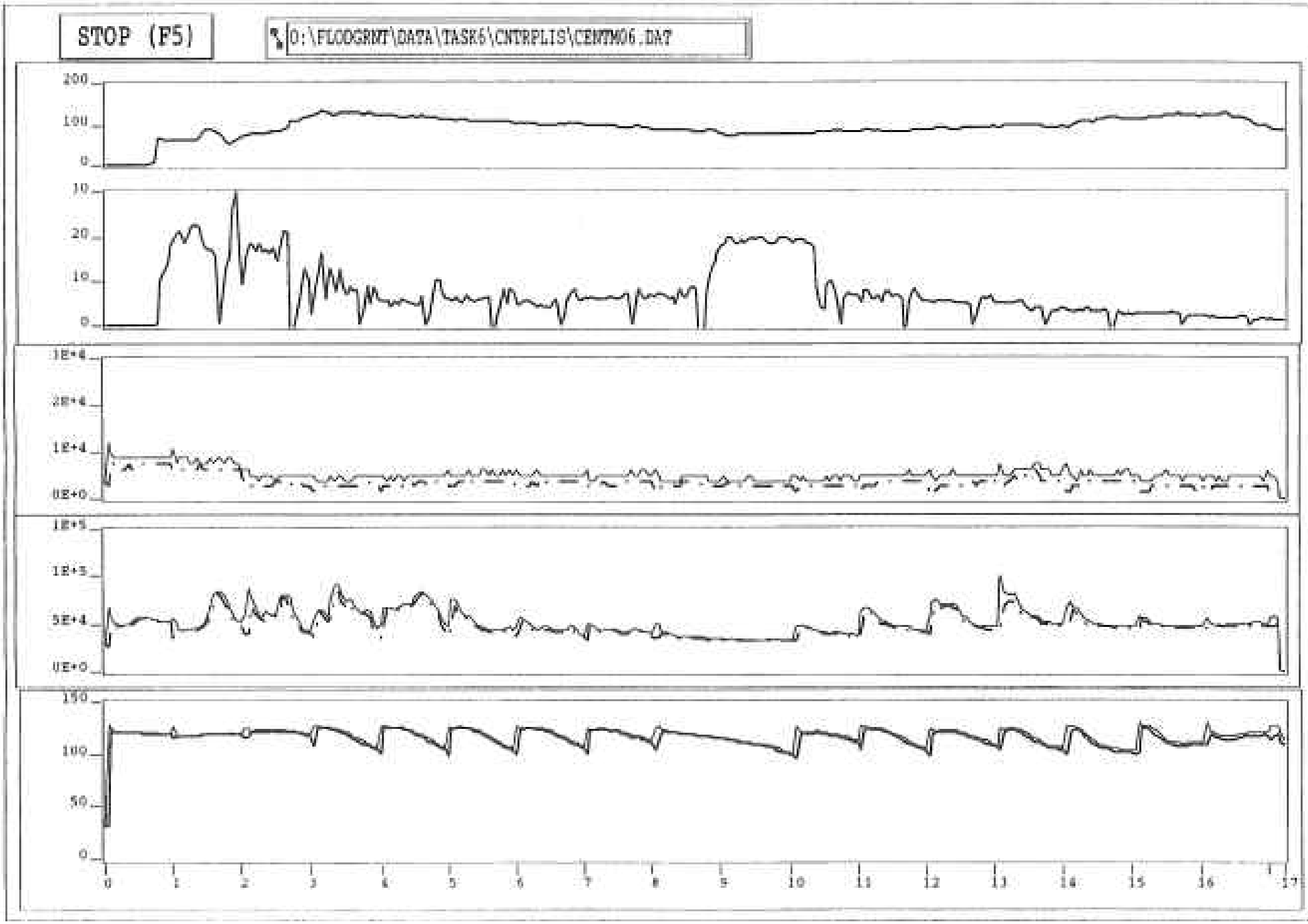

STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR4.DAT
70
0
220
100
0
1E+5
5E+4
0E+0
1E+6
7E+5
5E+5
2E+5
0E+0
180
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26



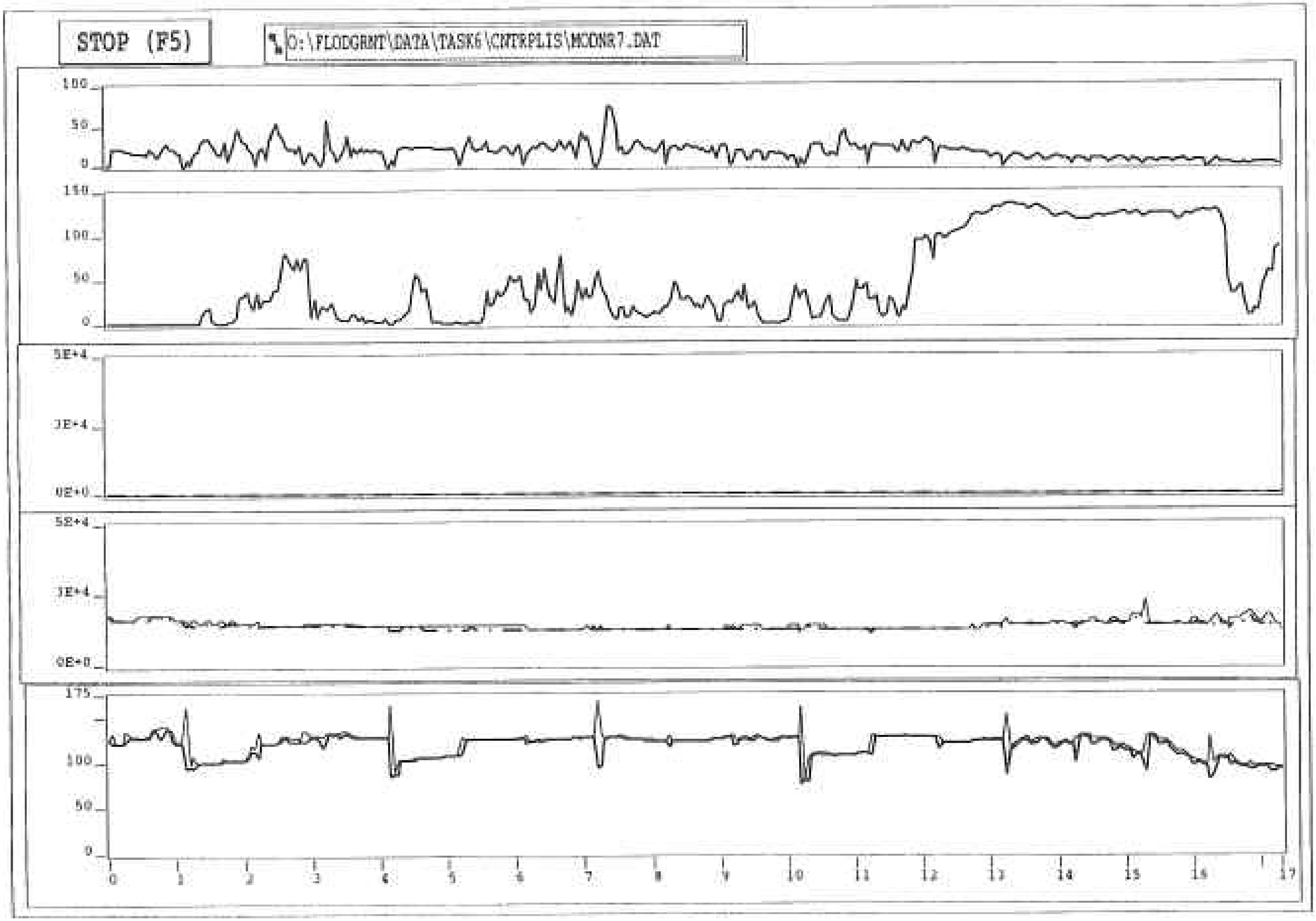
STOP (F5)
D:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR5.DAT
40
20
0
150
100
50
0
4E+6
2E+6
0E+0
2E+6
1E+6
5E+5
0E+0
140
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16


STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\CENTM05.DAT
200
100
0
30
20
10
0
3E+4
2E+4
1E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8

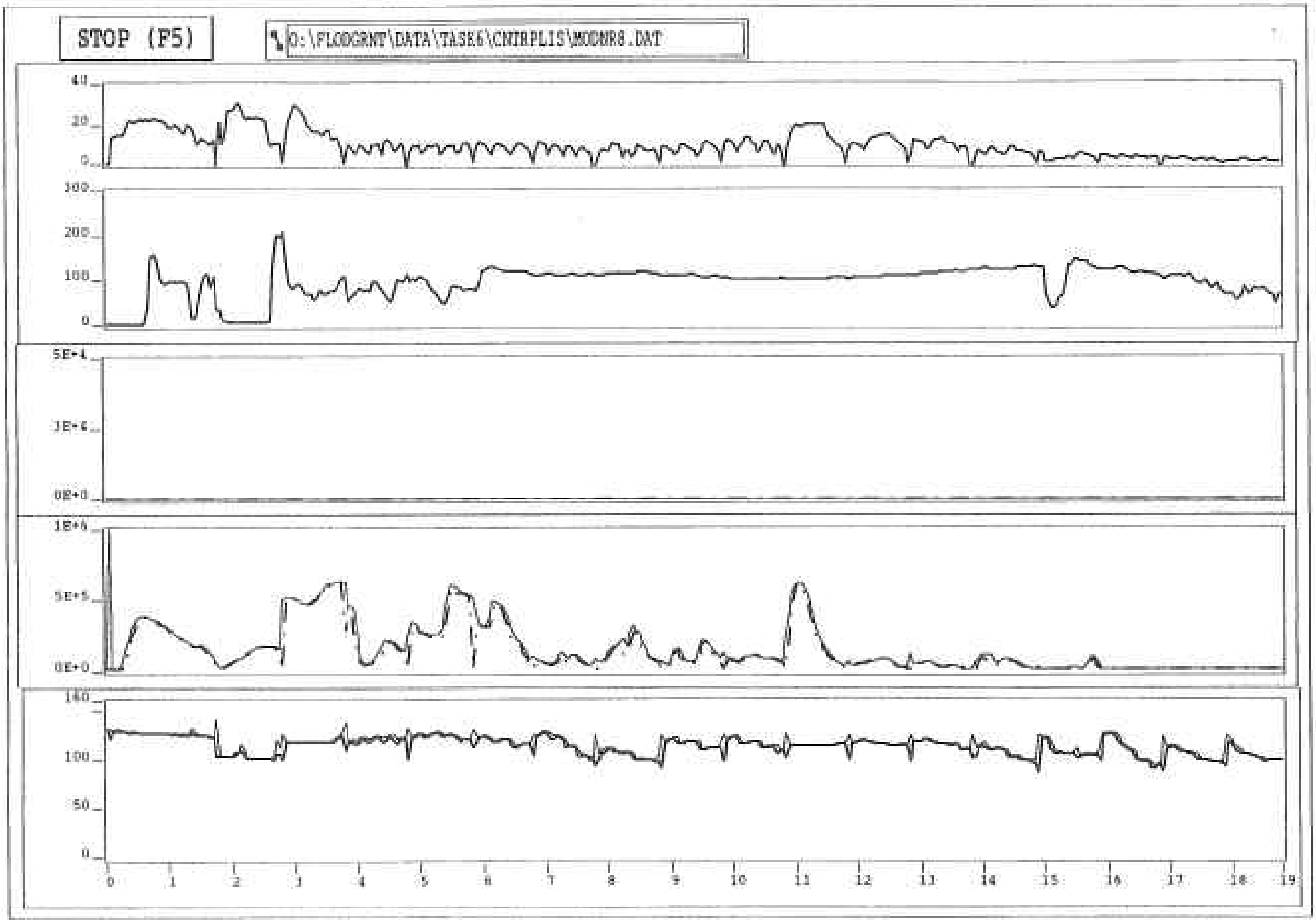

STOP (F5)
0:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR6.DAT
40
20
0
150
100
50
0
5E+4
3E+4
0E+0
5E+4
3E+4
0E+0
140
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18



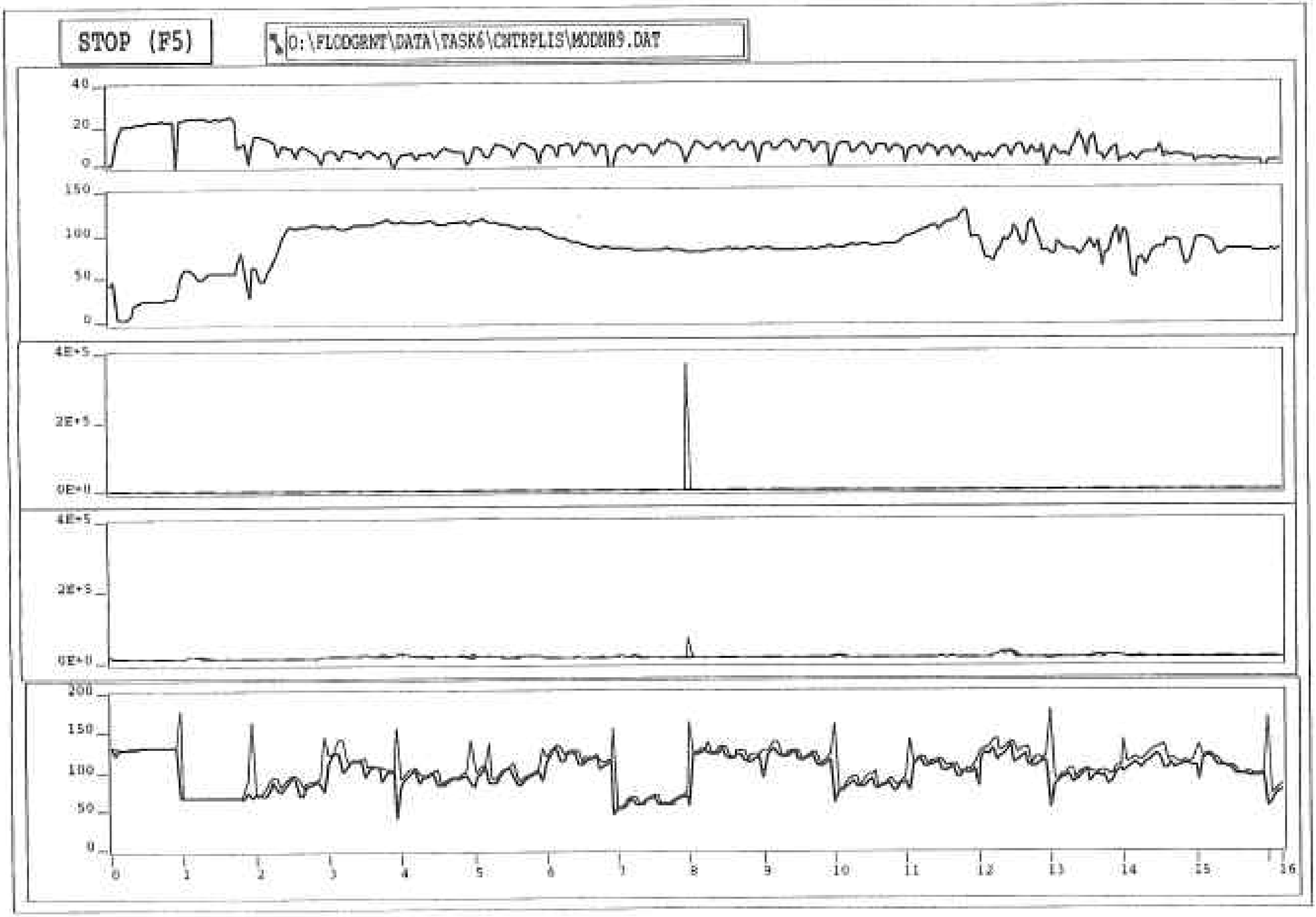
STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\CENTM06.DAT
200
100
0
30
20
10
0
3E+4
2E+4
1E+4
0E+0
1E+5
1E+5
5E+4
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17



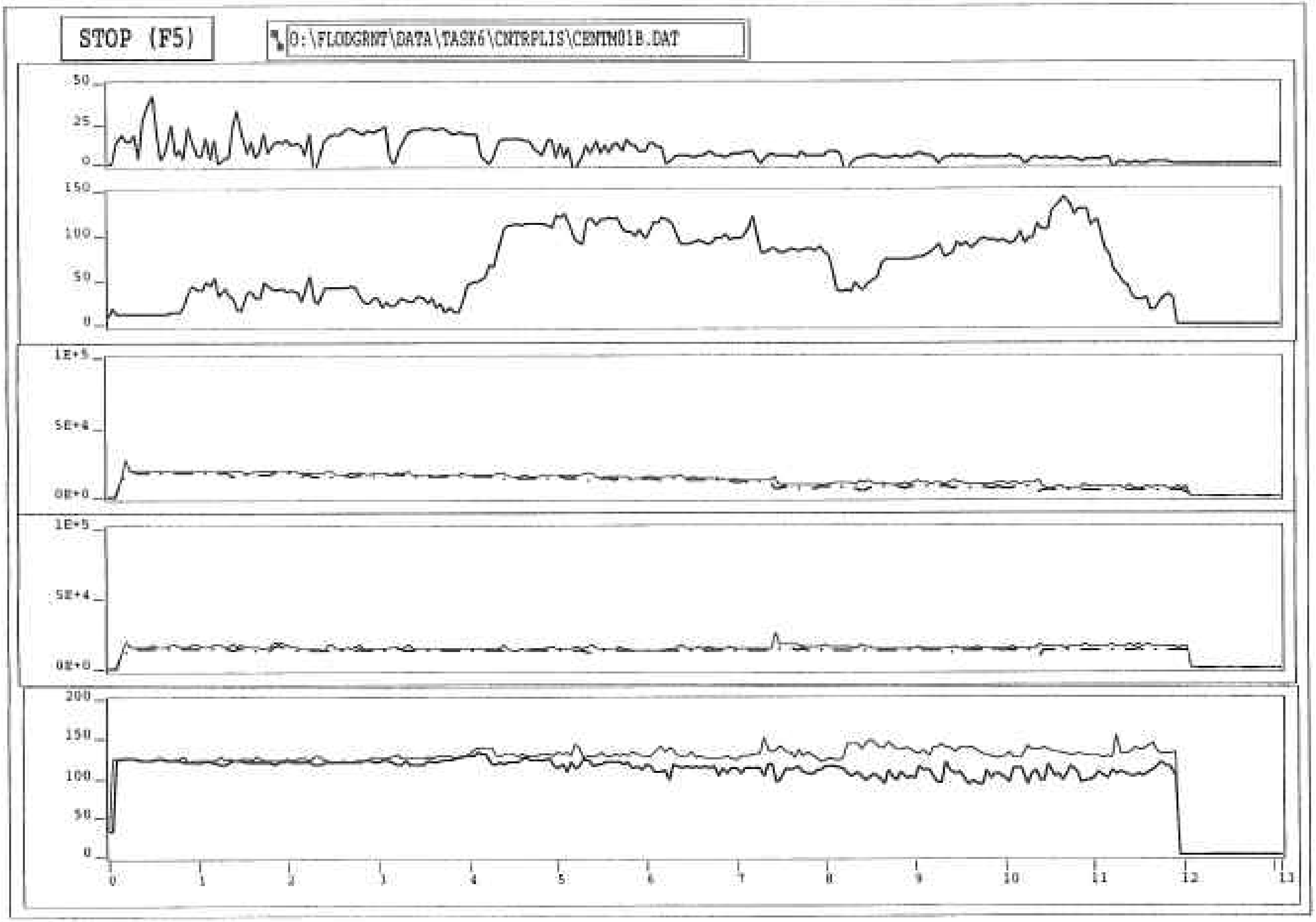
STOP (F5)
O:\FLODGRMT\DATA\TASK6\CNTRPLIS\MODNR7.DAT
100
50
0
150
100
50
0
5E+4
3E+4
0E+0
5E+4
3E+4
0E+0
175
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17



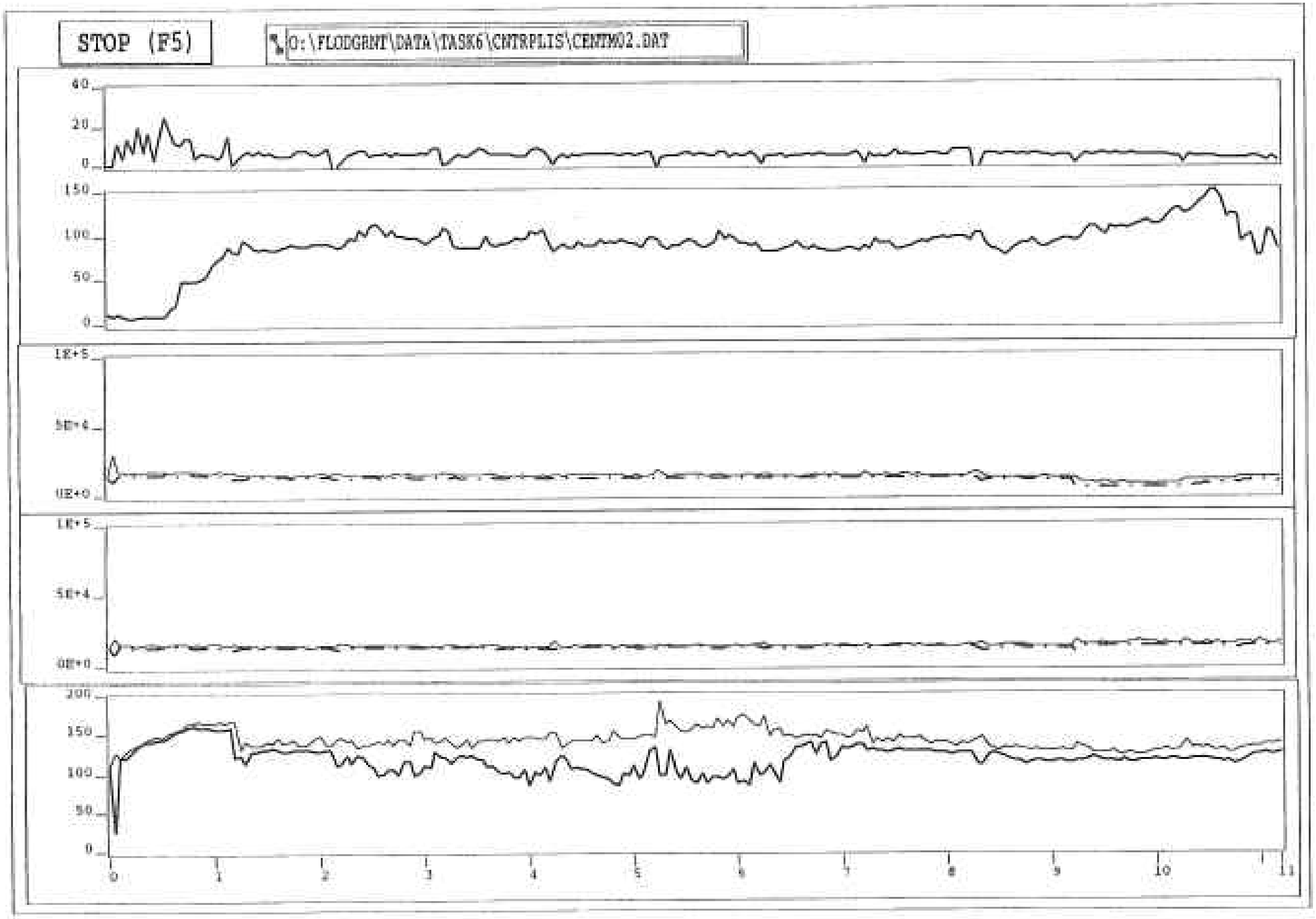
STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR8.DAT
40
20
0
300
200
100
0
5E+4
3E+4
0E+0
1E+6
5E+5
0E+0
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

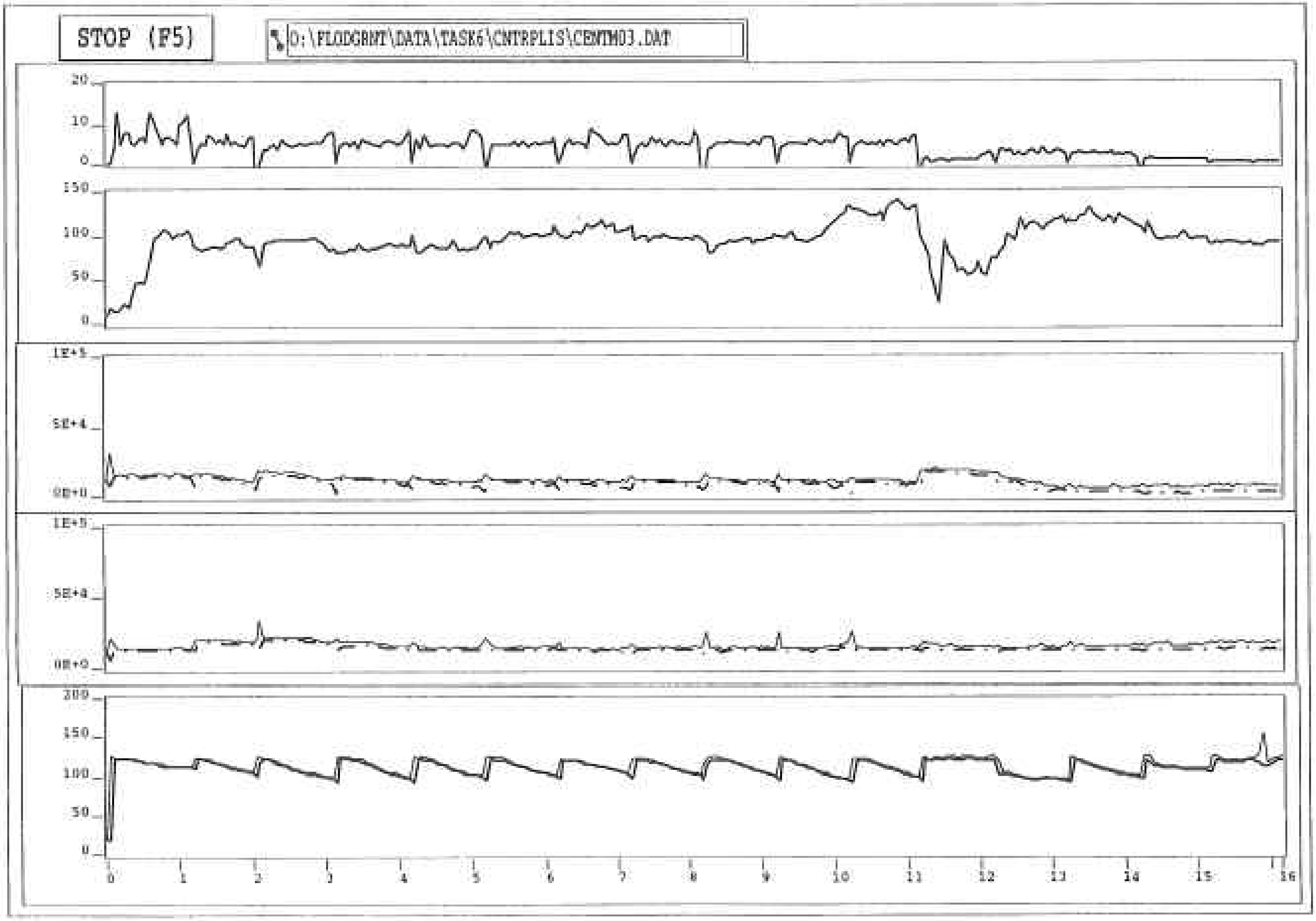


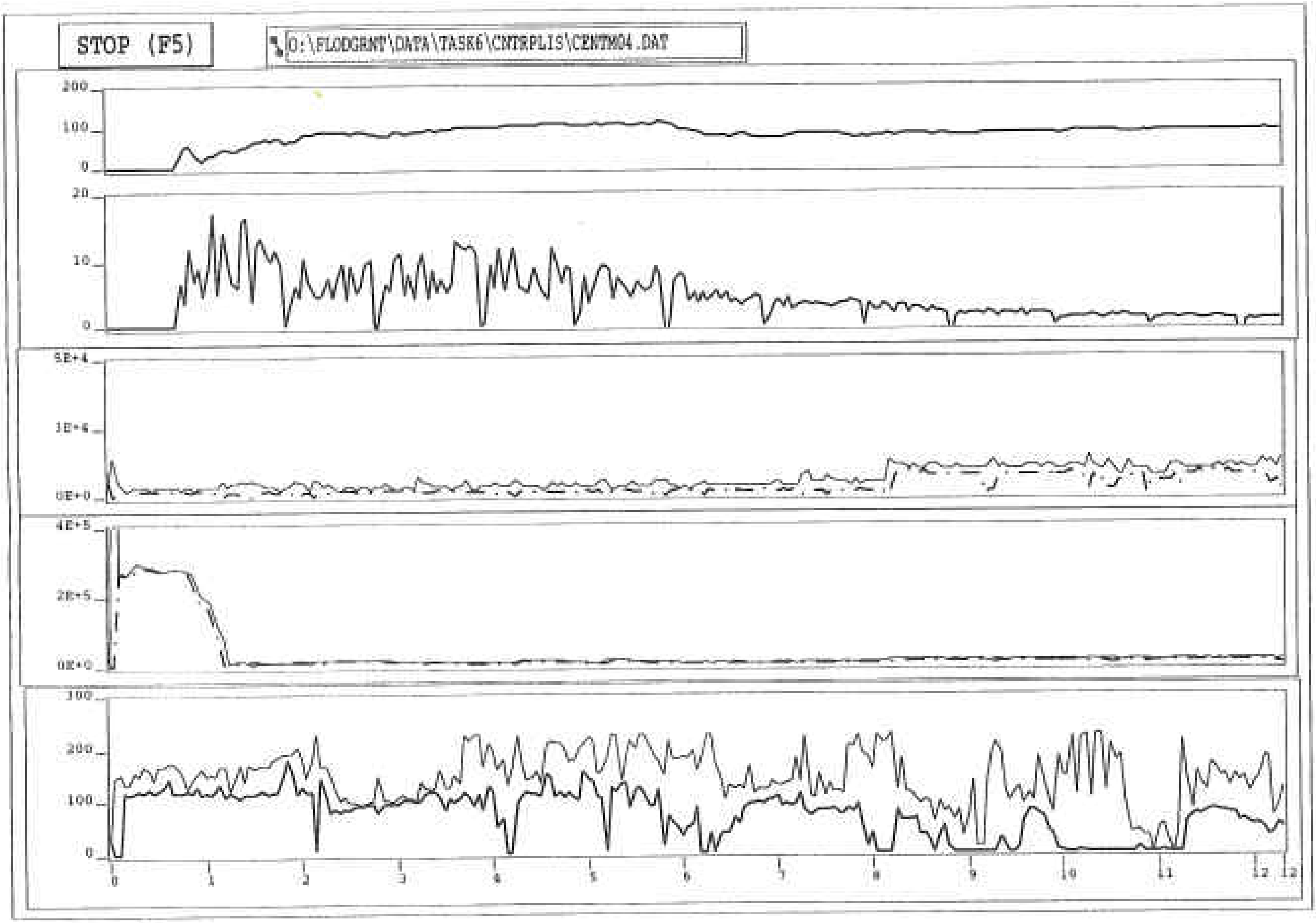
STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\MODNR9.DAT
40
20
0
150
100
50
0
4E+5
2E+5
0E+0
4E+5
2E+5
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16



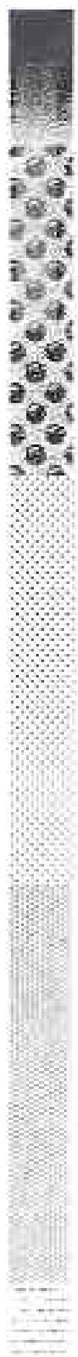
STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\CENTM01B.DAT
50
25
0
150
100
50
0
1E+5
5E+4
0E+0
1E+5
5E+4
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13


STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\CENTM02.DAT
40
20
0
150
100
50
0
1E+5
5E+4
0E+0
1E+5
5E+4
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11


STOP (F5)
D:\FLODGRNT\DATA\TASK6\CNTRPLIS\CEMTM03.DAT
20
10
0
150
100
50
0
1E+5
5E+4
0E+0
1E+5
5E+4
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16


STOP (F5)
O:\FLODGRNT\DATA\TASK6\CNTRPLIS\CENTM04.DAT
200
100
0
20
10
0
5E+4
1E+4
0E+0
4E+5
2E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
12

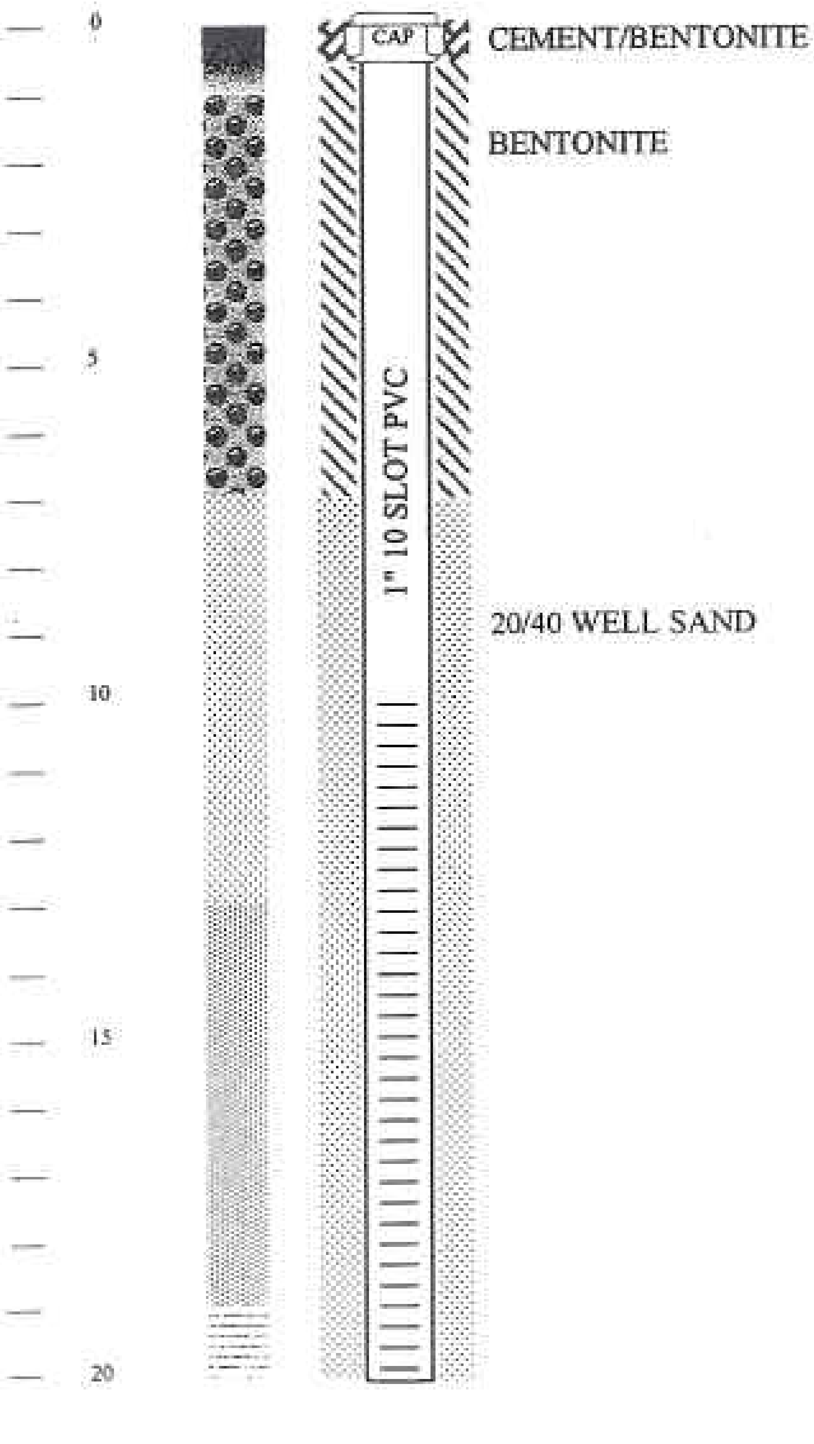
SOIL BORING LOG
BORING # 101
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996



DEPTH (FT.)	GROSS SOIL PROFILE	OBSERVATIONS
0		
		BR-GR LOAMY CL-SLT
5		GN-GR CL-SLT WITH WOOD & CONCRETE FILL DEBRIS
10		GN-GR CL-SLT WITH PLANT ROOTS
15		
		RD-BN SLT-CL WITH PLANT ROOTS
		YL FISSILE CL
20		

WELL CONSTRUCTION LOG
BORING # 101
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996

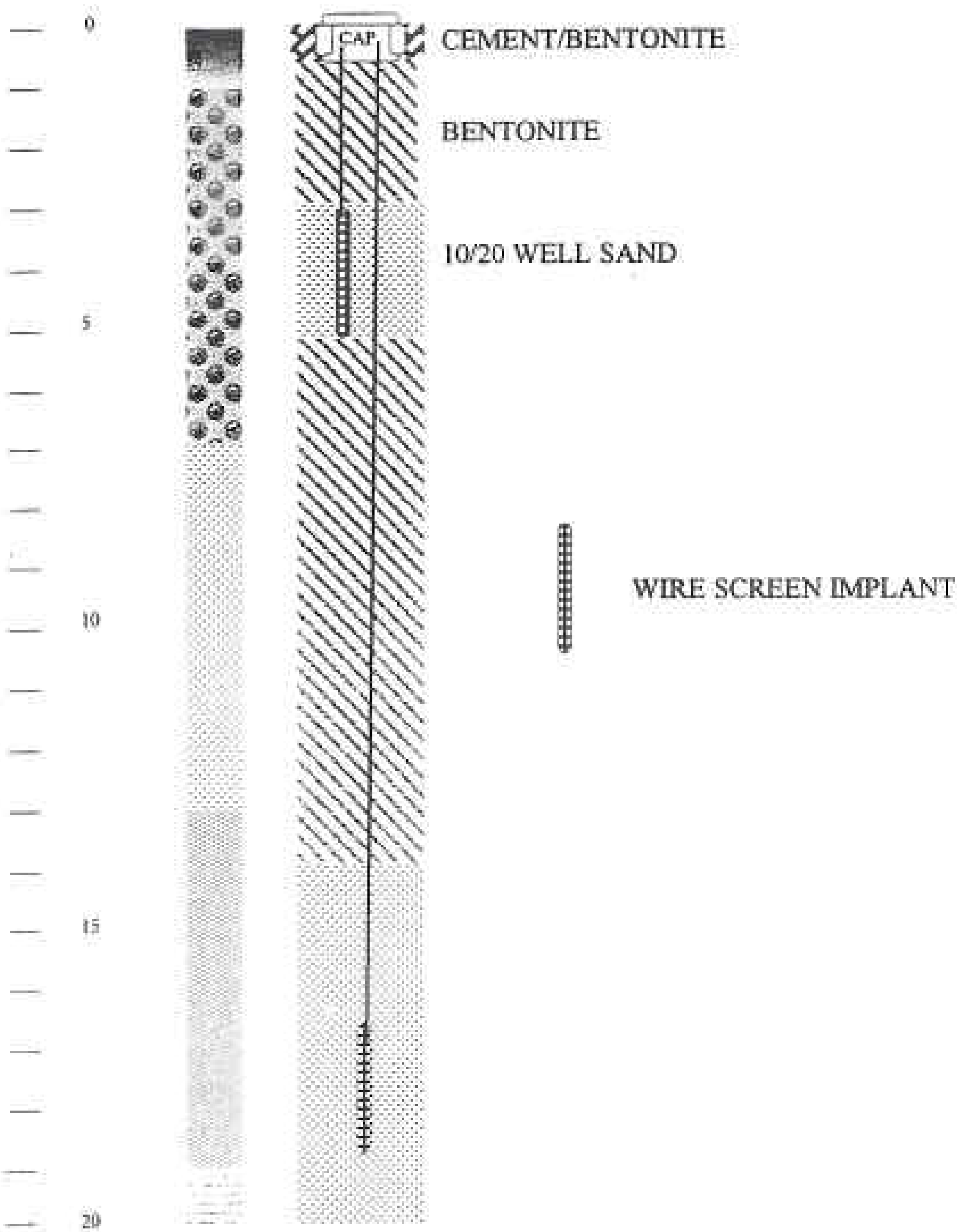
DEPTH (FT.)	SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



WELL CONSTRUCTION LOG
BORING # 102

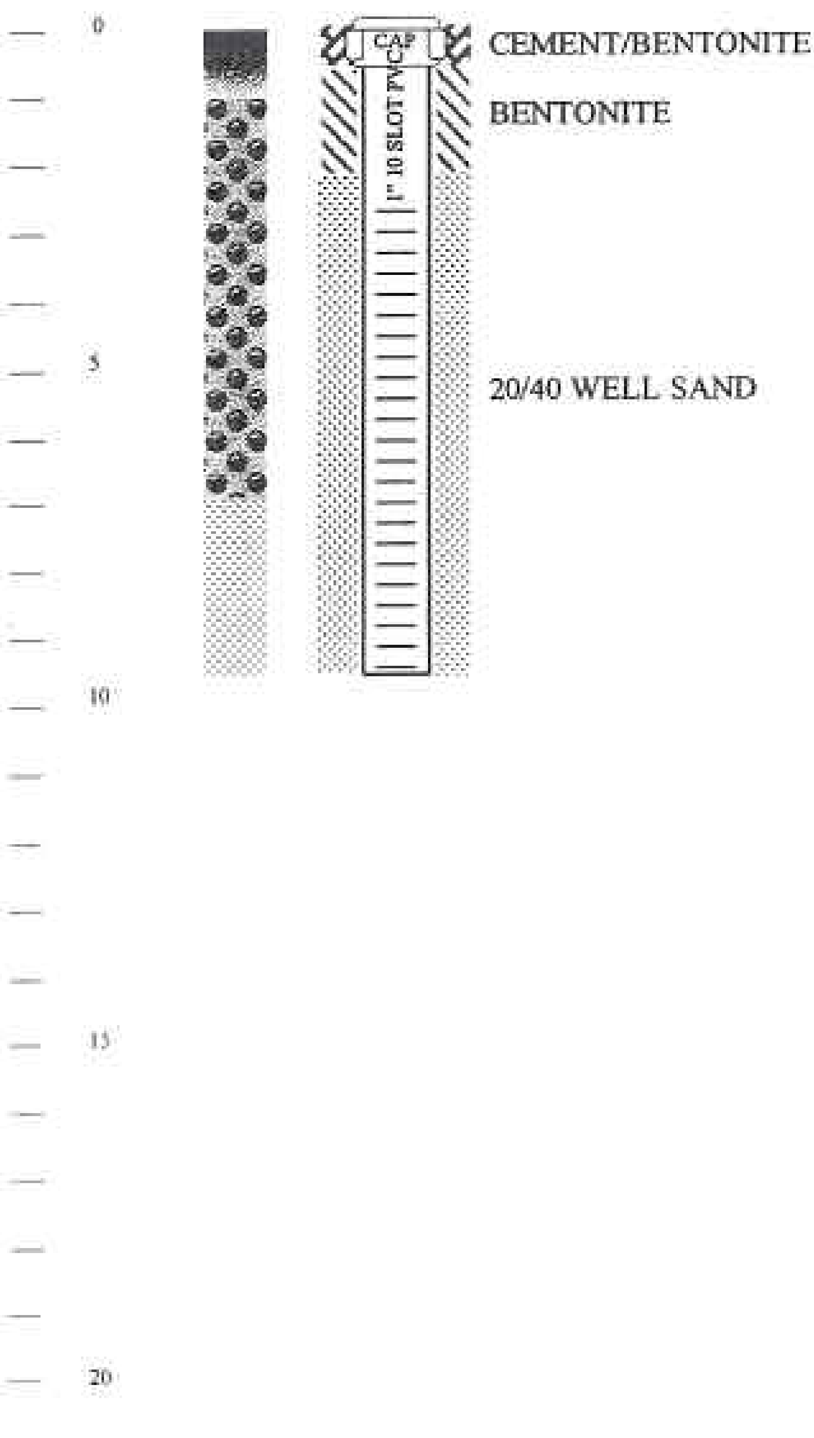
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996

DEPTH (FT.)	GEN SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



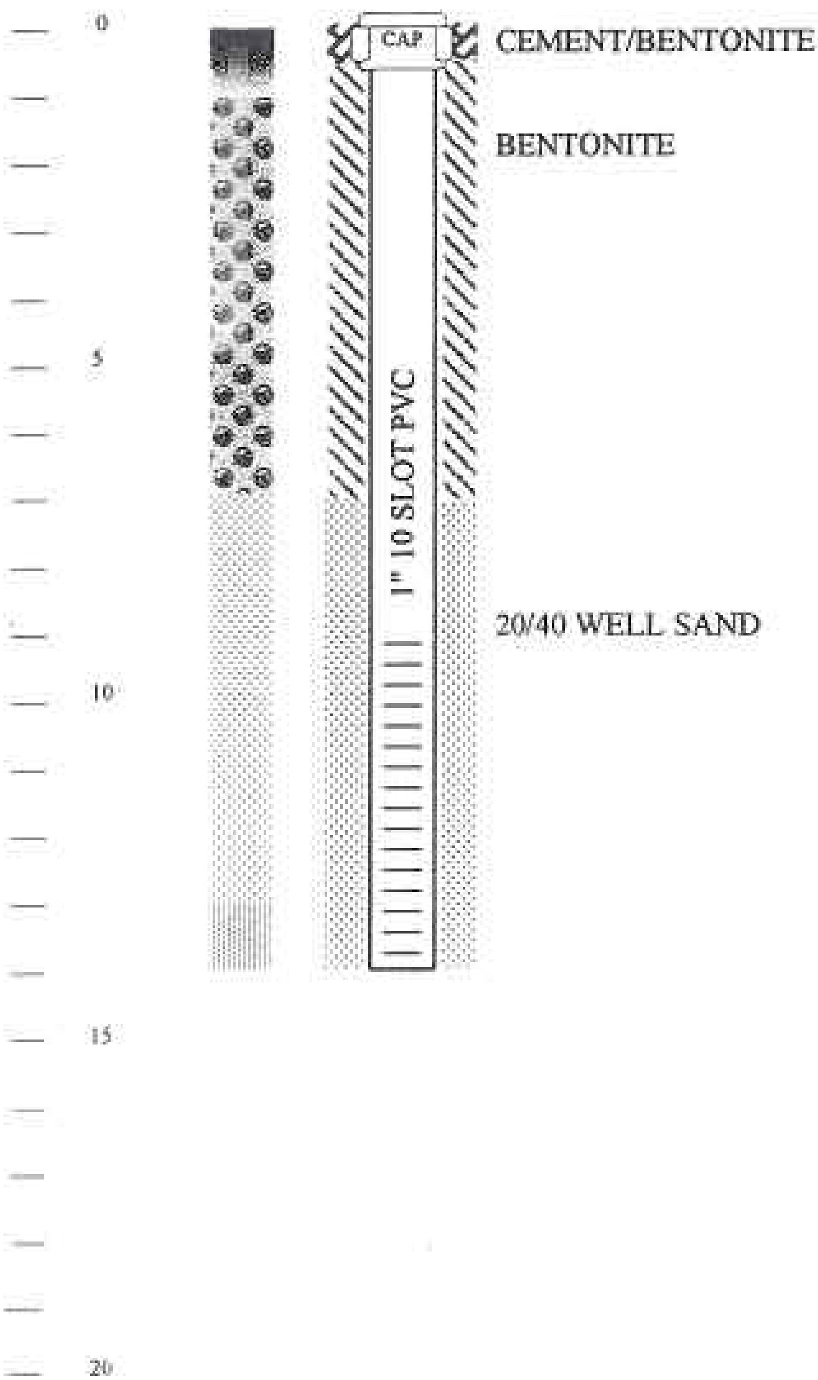
WELL CONSTRUCTION LOG
BORING # 103
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996

DEPTH (FT.)	GEN. SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



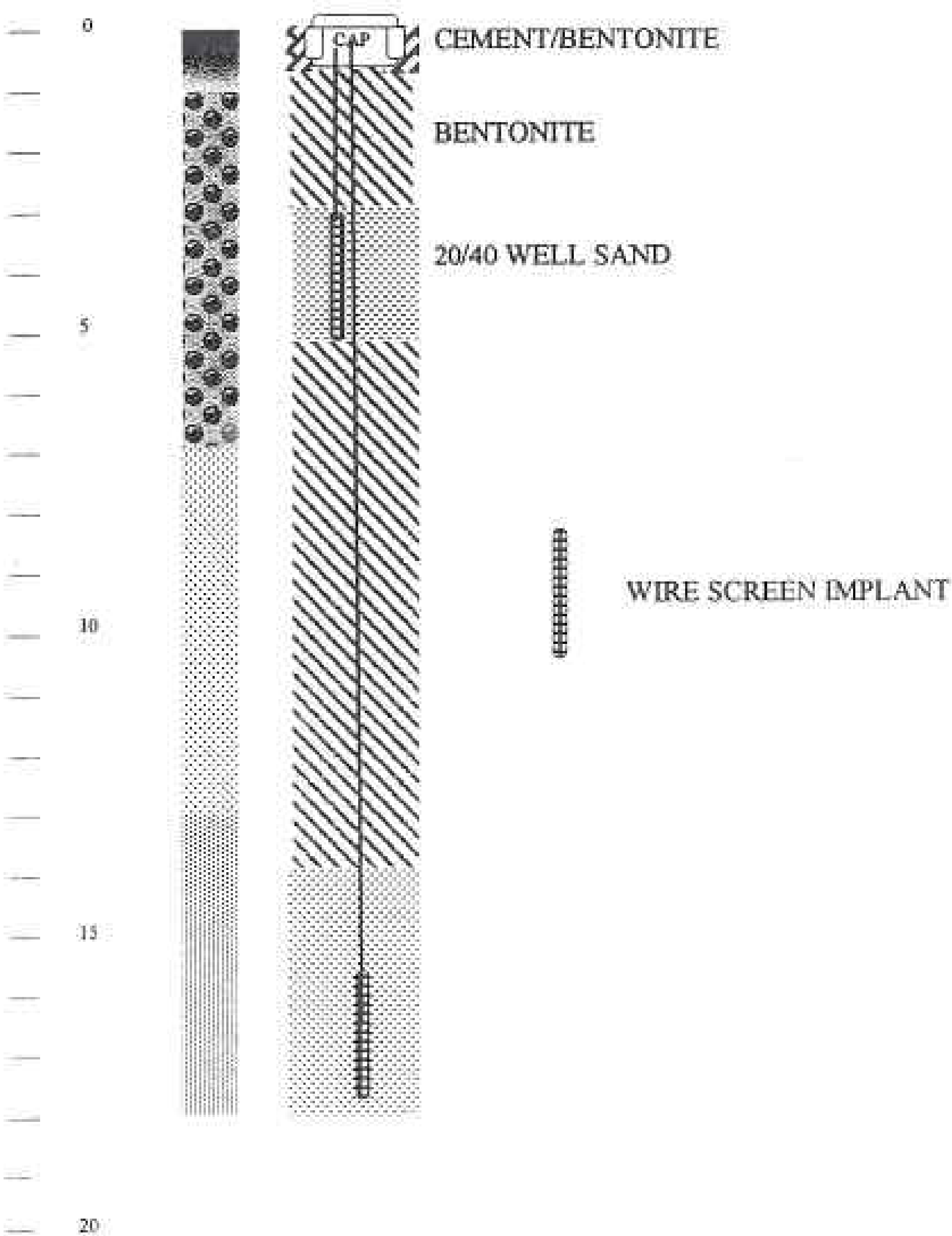
WELL CONSTRUCTION LOG
BORING # 104
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996

DEPTH (FT.)	GEN. SOIL PROFILE	WELL CONSTRUCTION	COMMENTS

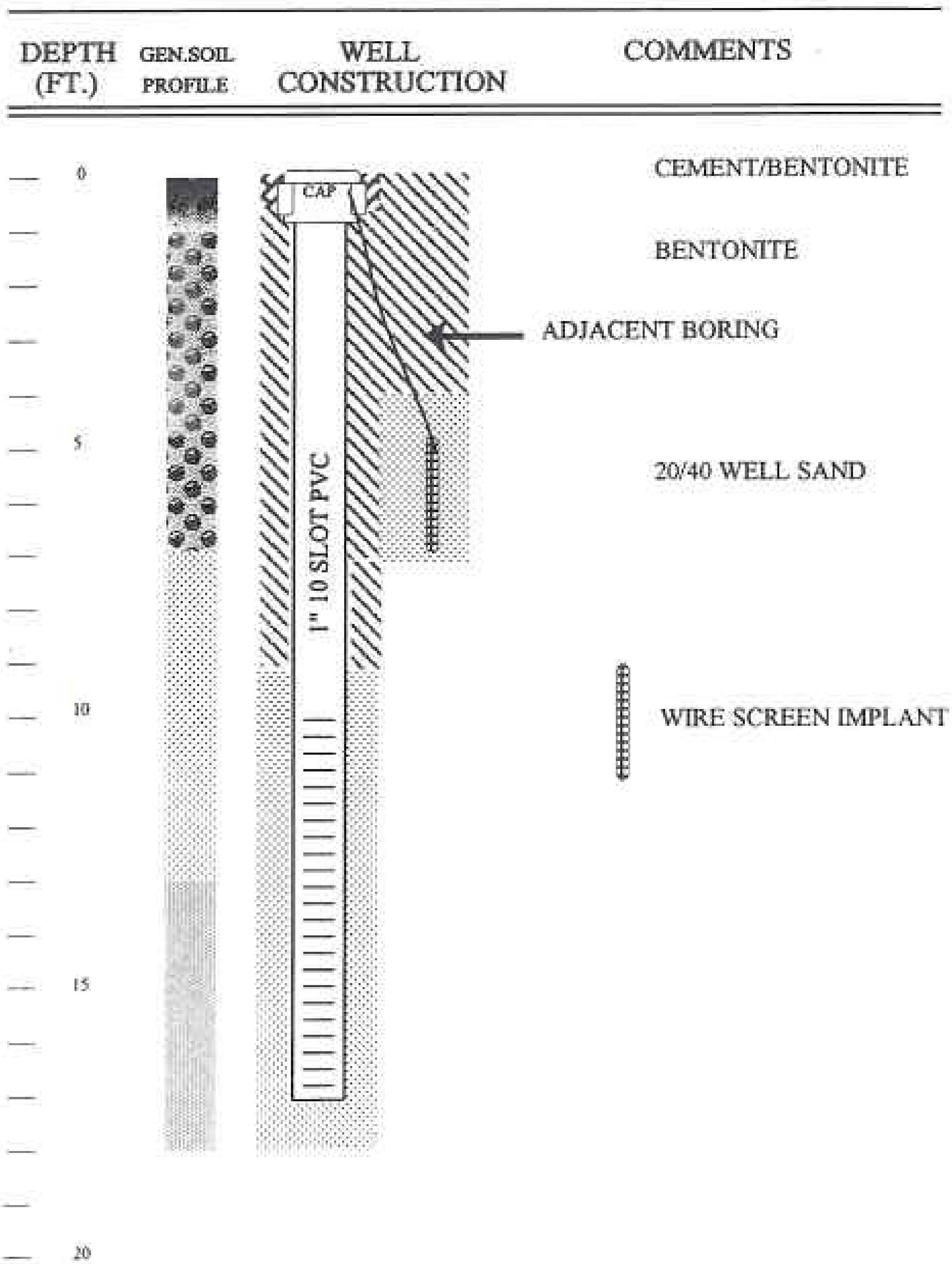


WELL CONSTRUCTION LOG
BORING # 105
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996

DEPTH (FT.)	GEN SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



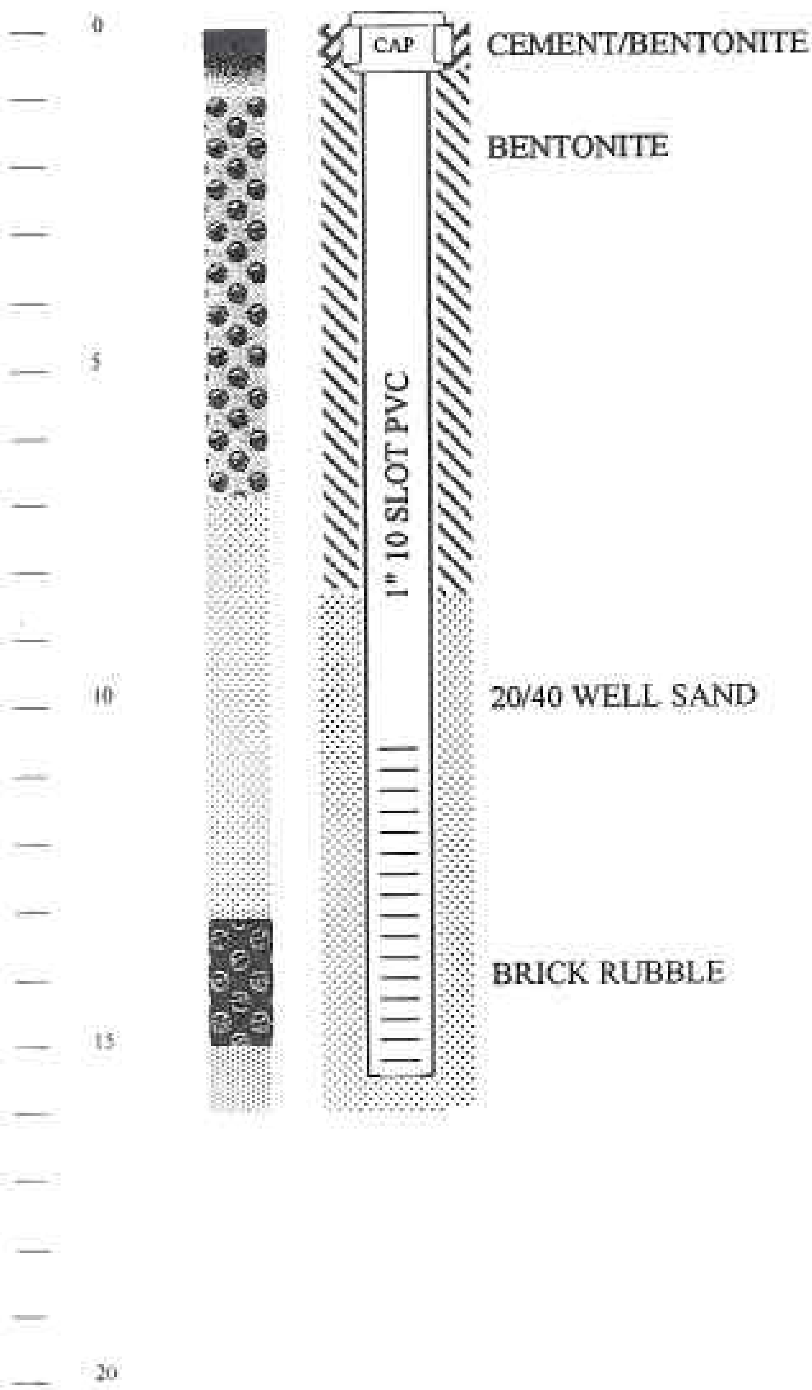
WELL CONSTRUCTION LOG
BORING # 106
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 28, 1996



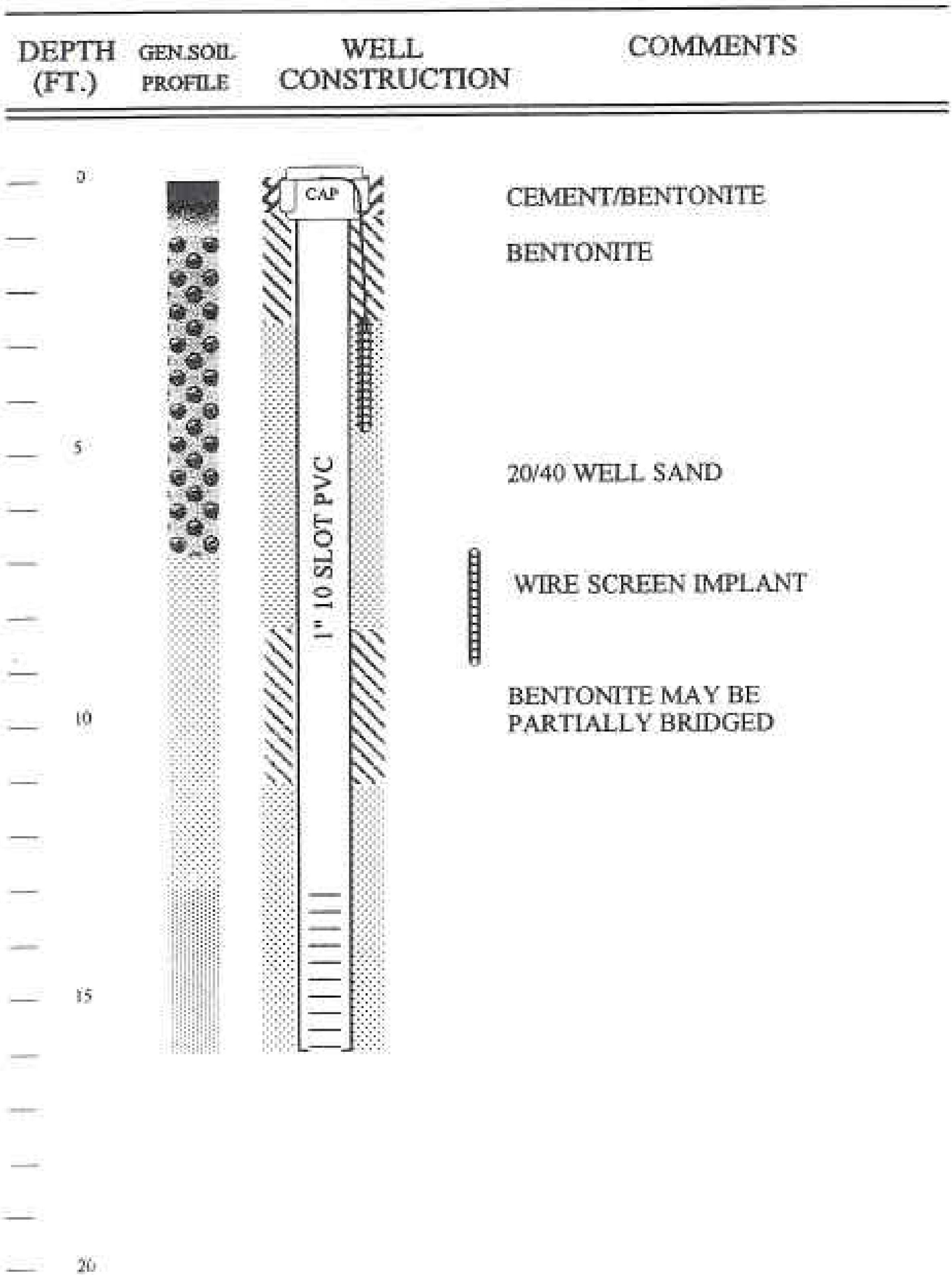
WELL CONSTRUCTION LOG
BORING # 107

CENTROPOLIS LANDFILL
Kansas City, Missouri
August 29, 1996

DEPTH (FT.)	GEN. SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



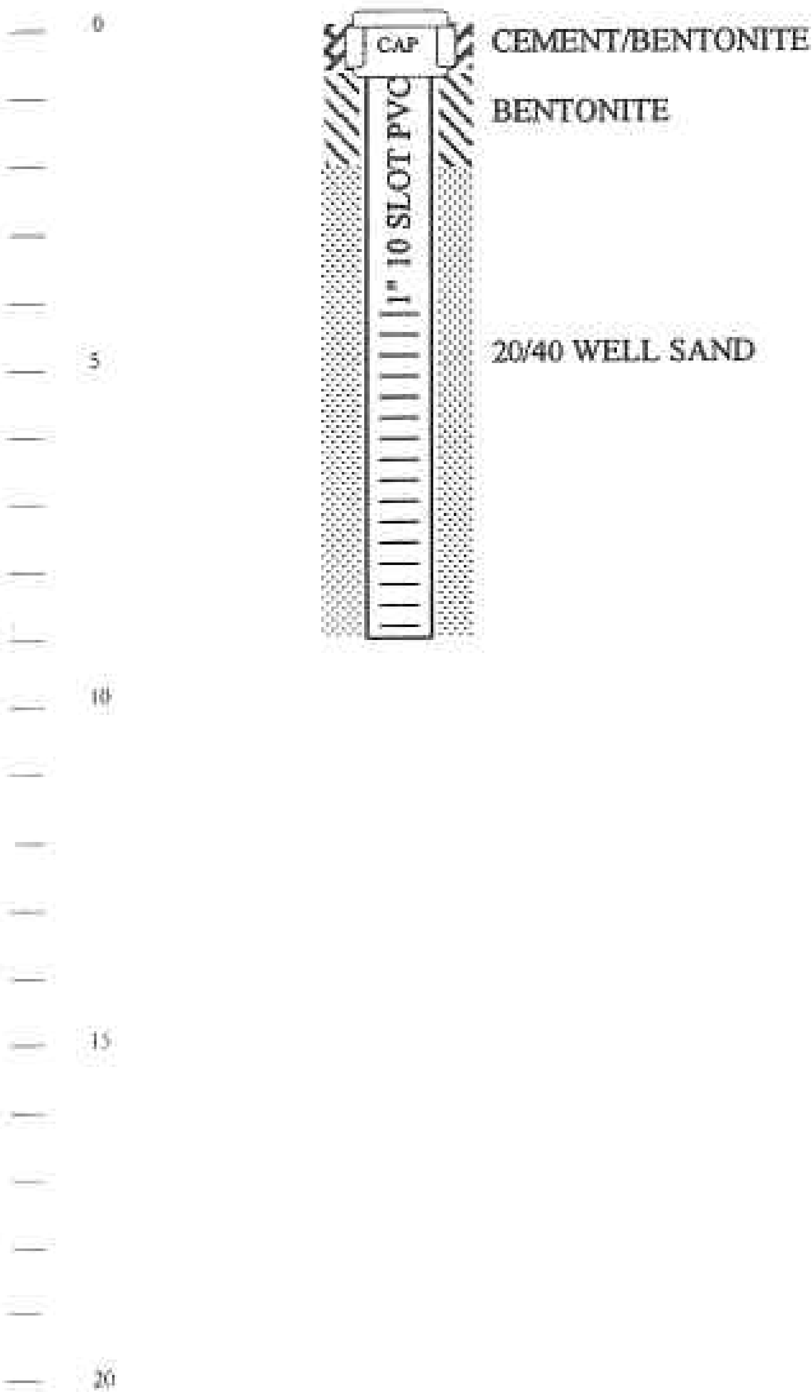
WELL CONSTRUCTION LOG
BORING # 108
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 29, 1996



WELL CONSTRUCTION LOG
BORING # 109

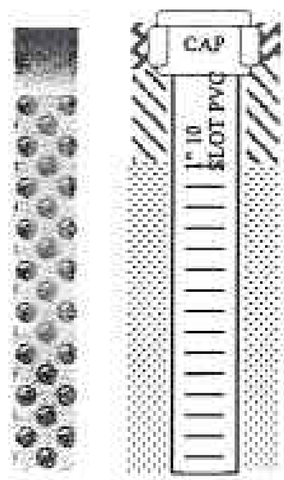
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 29, 1996

DEPTH (FT.)	WELL CONSTRUCTION	COMMENTS



WELL CONSTRUCTION LOG
BORING # 110
CENTROPOLIS LANDFILL
Kansas City, Missouri
August 29, 1996

DEPTH (FT.)	GEN. SOIL PROFILE	WELL CONSTRUCTION	COMMENTS



CEMENT/BENTONITE

BENTONITE

20/40 WELL SAND

Depth: 0, 5, 10, 15, 20

Appendix E

Modern Sanitation Landfill

MIP Logs and Soil Logs

(See Appendix B cover page for MIP curve identification.)

SOIL CHARACTERIZATION FOR MODERN SANITATION LANDFILL

BORING #101

01/06/97

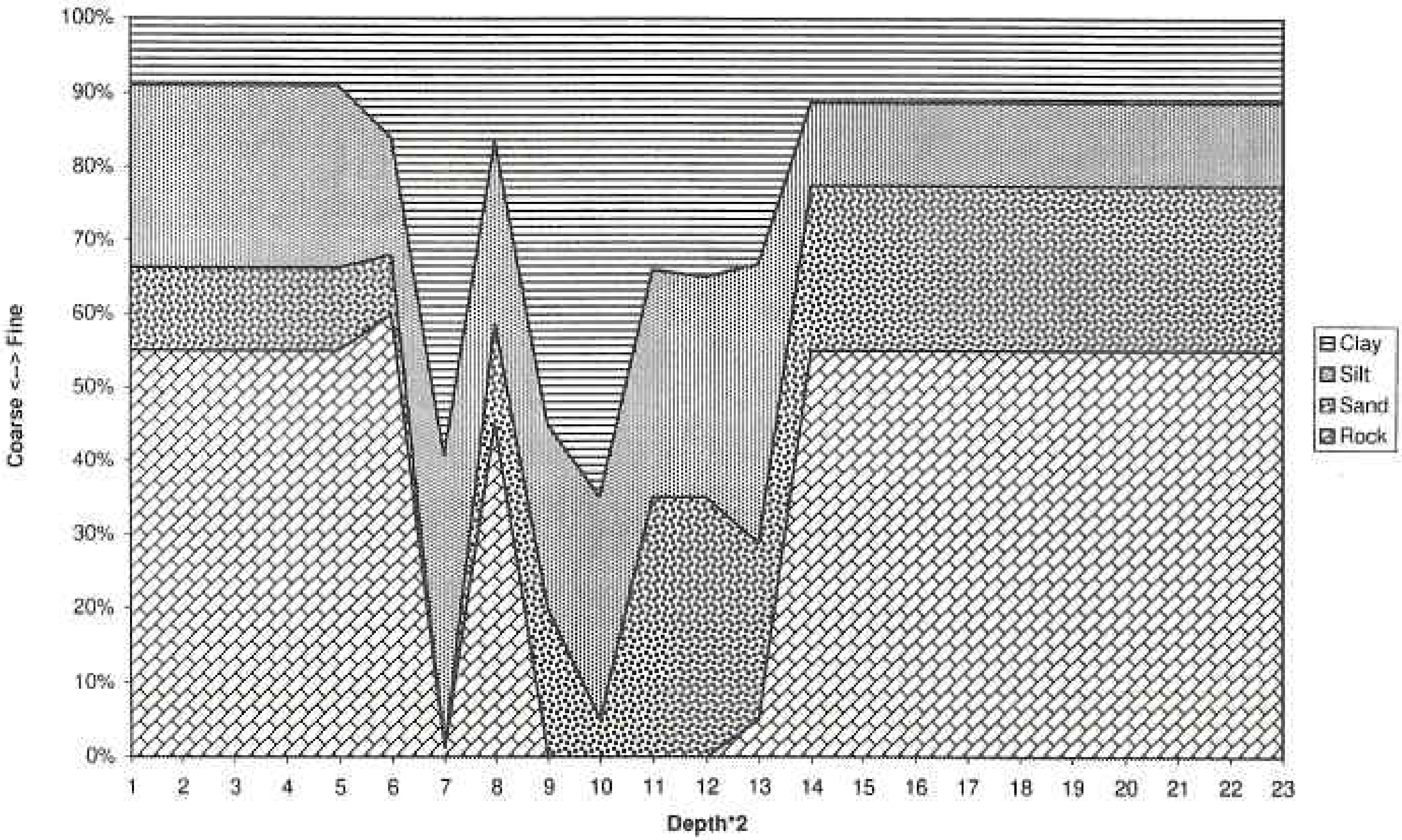
DEPTH (Ft)	MUNSELL COLOR		SOIL COMPOSITION[1]		% ROCK	STRUCTURE	PORES	
	MATRIX	MOTTLES	% SAND	%CLAY			ROOTS	SOILPORES
0-2.5 [2]	mixed 10YR6/2 +10YR6/4	mixed	25	20	55	weak subangular blocky	few fine, few very fine	weak fine tubular
2.5-3.0	mixed 10YR5/4 + 5YR4/6	mixed	20	40	60	weak subangular blocky		few weak tubular
3.0-3.6	mixed 5YR5/8 + 5YR5/6	10YR5/2		60	1	weak subangular blocky	few medium	few fine tubular, few fine interstitial
3.6-4.0	mixed 10YR6/8 + 5YR5/6	mixed	25	30	45	subangular blocky		many fine tubular
4.0-4.1	mixed 7.5YR4/6 + 5YR6/2	mixed	20	55		medium subangular blocky		
4.1-5.1	5YR4/6	10YR6/8	5	65		medium subangular blocky - weak fine subangular blocky	few coarse, few very fine	few very fine interstitial
5.1-5.2	mixed 7.5YR4/6	10YR6/8	35	34		very weak subangular blocky - platy inclusions	few fine	few fine tubular, few fine interstitial
5.2-6.0	mixed 7.5YR4/6	mixed	35	35	[illegible]	weak fine subangular blocky	few fine	few fine tubular
6.0-6.5	mixed 5YR5/1+ 7.5YR4/6; shale- 5YR6/2	5YR5/1	25	35	5	weak fine subangular blocky - weak fine platy	few fine	

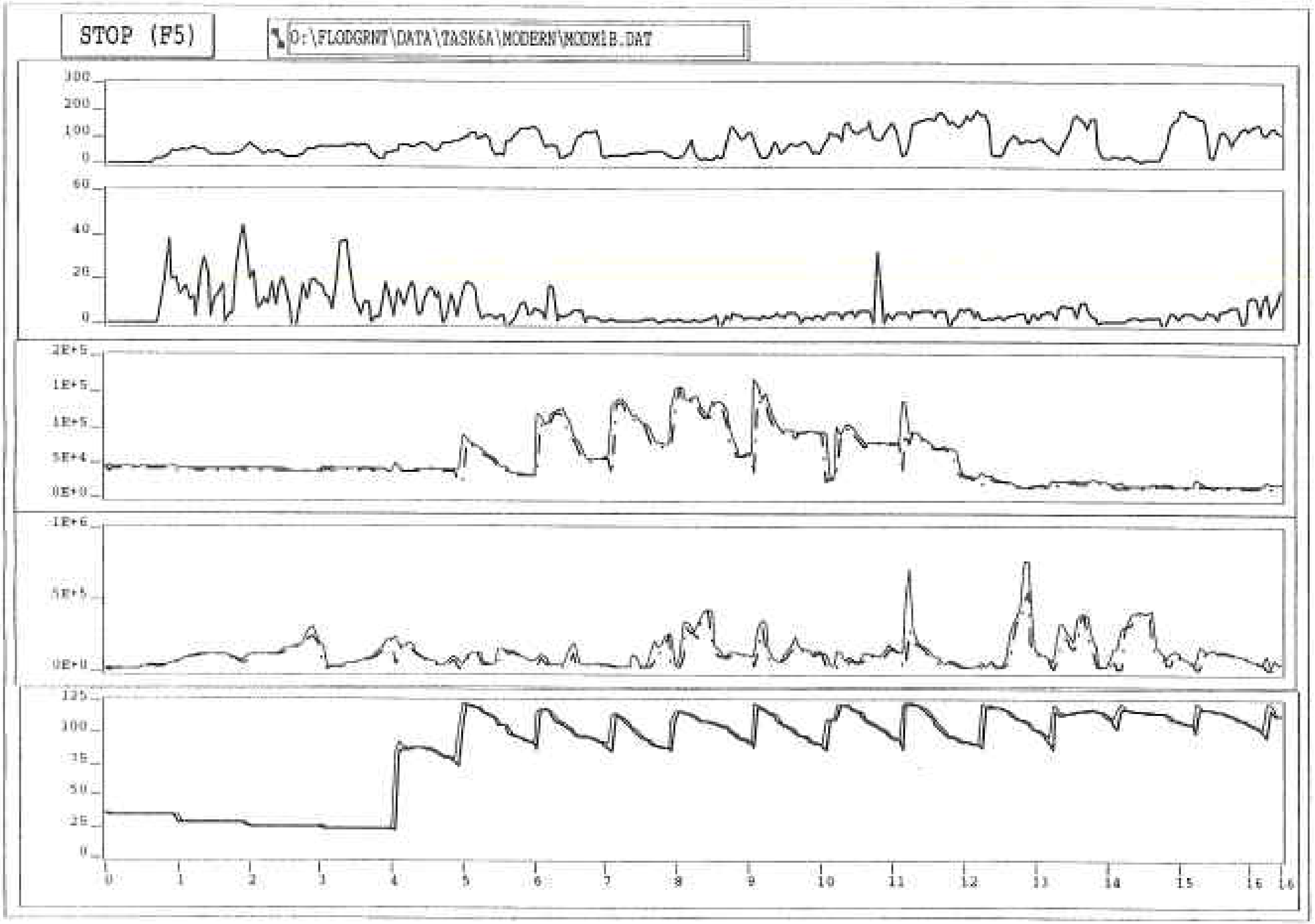
BORING 101 (cont.)

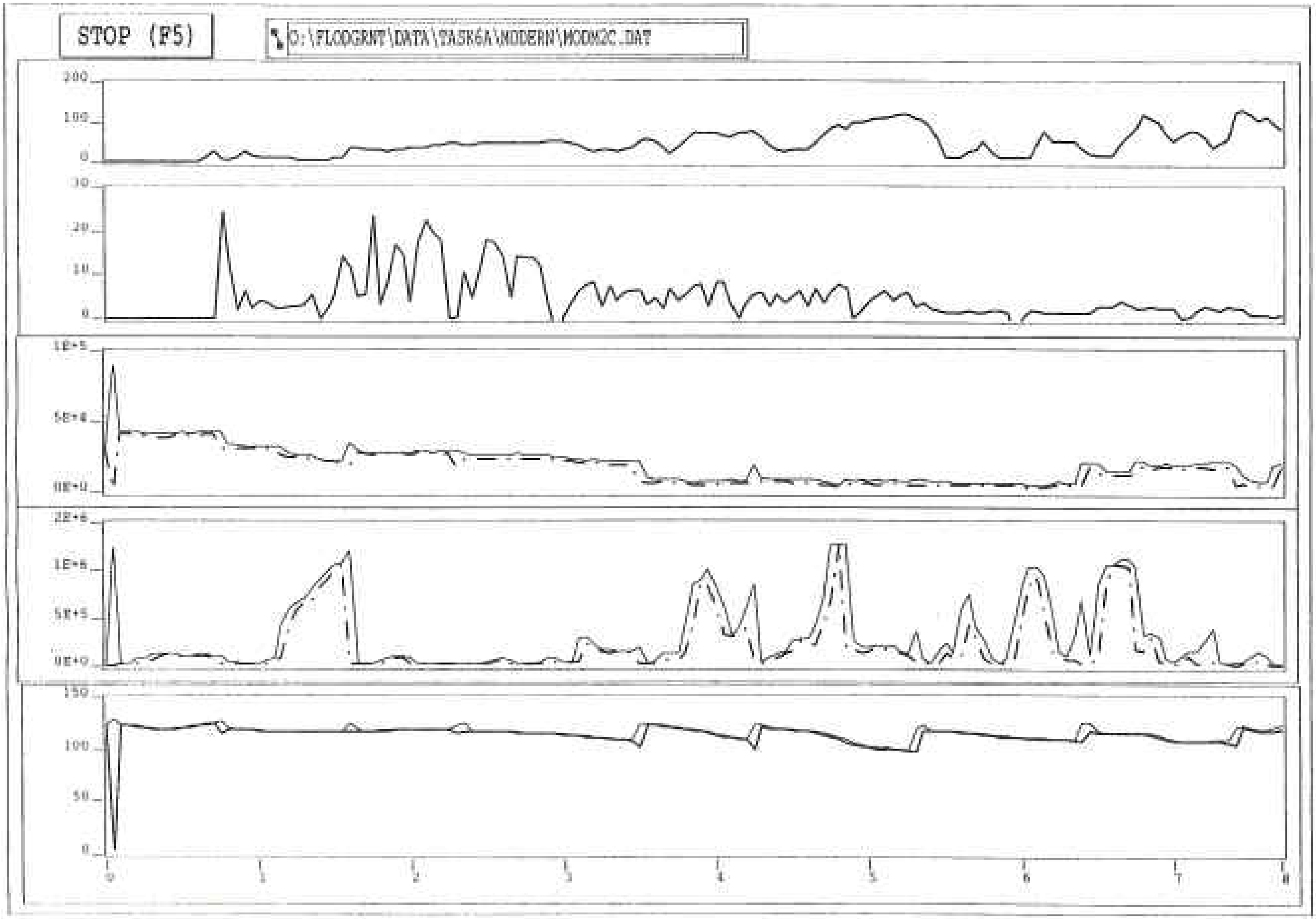
6.5-10.5	mixed 2.5YR6/3 +2.5YR6/6	2.5YR6/1	50	25	55	weak, fine sub-angular blocky grading to granular		

1) % silt= 100-%sand + %clay.
2) Upper 2' of soil compressed during sample acquisition.

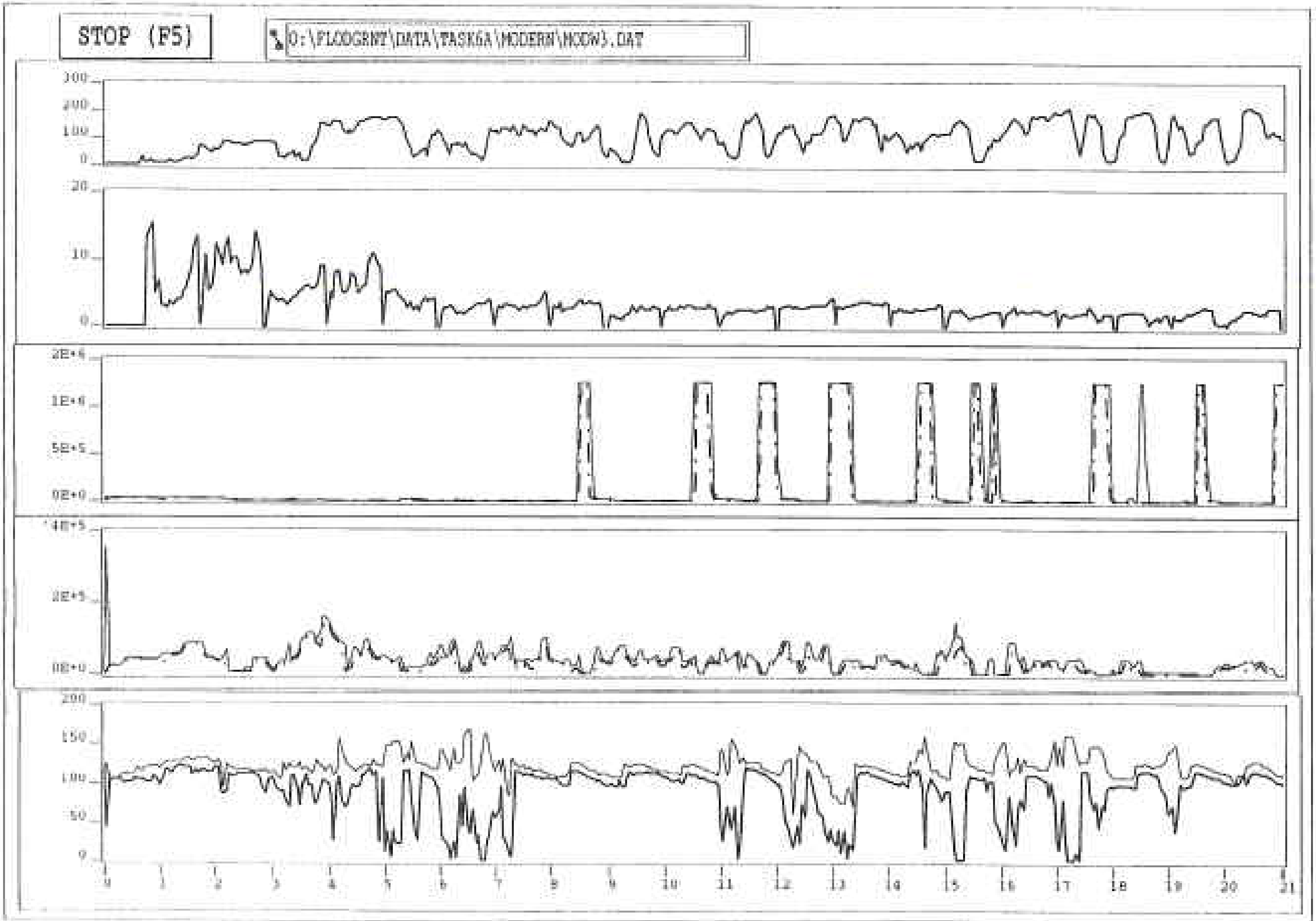
Modern Sanitation #101




STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM1B.DAT
300
200
100
0
60
40
20
0
2E+5
1E+5
1E+5
5E+4
0E+0
1E+6
5E+5
0E+0
125
100
75
50
25
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 16



STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM2C.DAT
200
100
0
30
20
10
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODW3.DAT
300
200
100
0
20
10
0
2E+6
1E+6
5E+5
0E+0
4E+5
2E+5
0E+0
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

SOIL CHARACTERIZATION FOR MODERN SANITATION LANDFILL

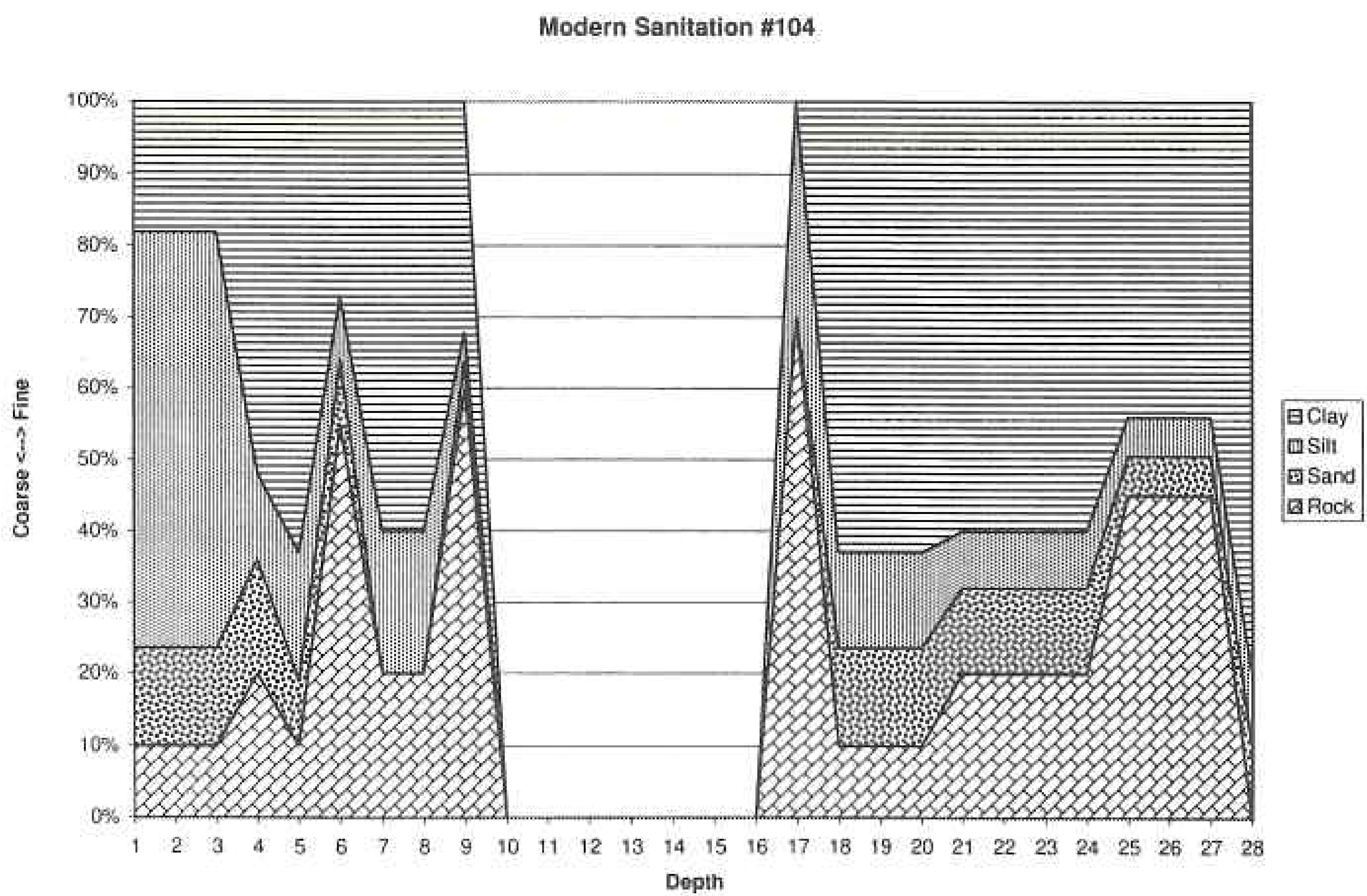
BORING #104

01/06/97

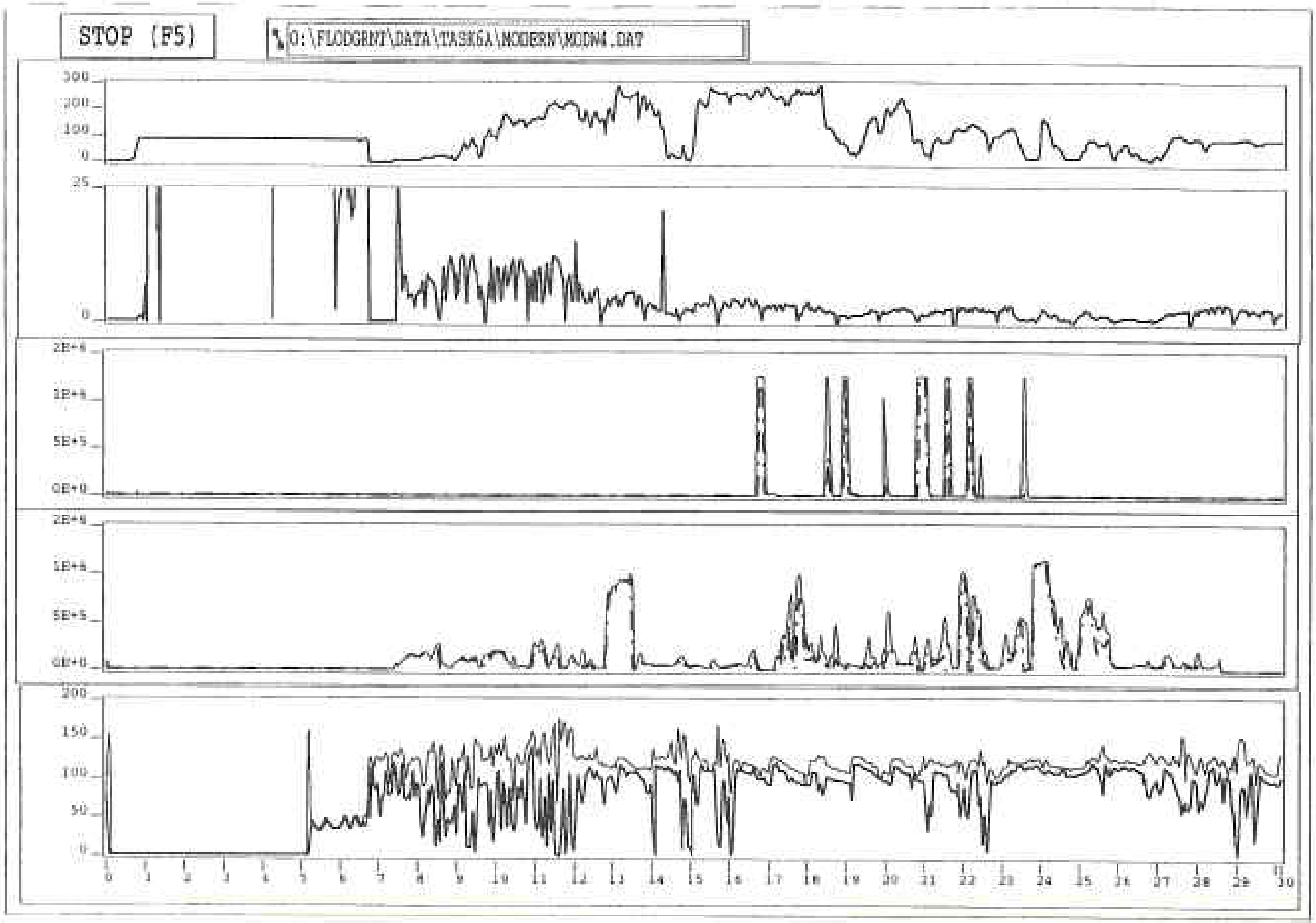
DEPTH (Ft)	MUNSELL COLOR MATRIX	MOTTLES	SOIL TYPE [1] % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES
0-3.6 [2]	10YR5/3	5YR4/6	15	20	10	weak subangular blocky	many very fine	few very fine tubular; few very fine interstitial
3.6-4.0	2.5YR4/6	10YR5/2 + 10YR5/3	20	65	20	weak subangular blocky	few fine, few coarse	few fine tubular; few fine interstitial
4-4.8	7.5YR6/4	2.5YR4/6	10	70	10	weak subangular blocky	few coarse, few very fine	
4.8-6.1	mixed 5YR5/6+5 YR4/4+5 YR4/3		20	60	55	weak subangular blocky	few coarse	few tubular; few interstitial
6.1-8.0	mixed 5YR5/6+5 YR4/4+5 YR4/3	massive Fe/Mn staining		75	20	weak subangular blocky	few coarse	few tubular, many interstitial
8.0-8.7	7.5YR4/6		10	80	60	weak, subangular blocky	many fine, many very fine	very few tubular, few fine interstitial
8.7-12.0	buried A horizon							
12.0-16.0	NO RECOVERY							
16.0-16.1					70			

16.1-20.0	7.5YR4/6	10YR6/8	15	70	10	medium subangular blocky		many fine tubular
20.0-24.3	2.5YR4/6	10YR6/8	15	75	20	weak subangular blocky		many fine tubular
24.3-27.0	7.5YR4/6	10YR6/8	10	80	45	weak subangular blocky		few fine tubular
27.1-27.2					sand & shale lenses	granular - platy		
27.2-28.0			10	80	decomposing shale	platy		

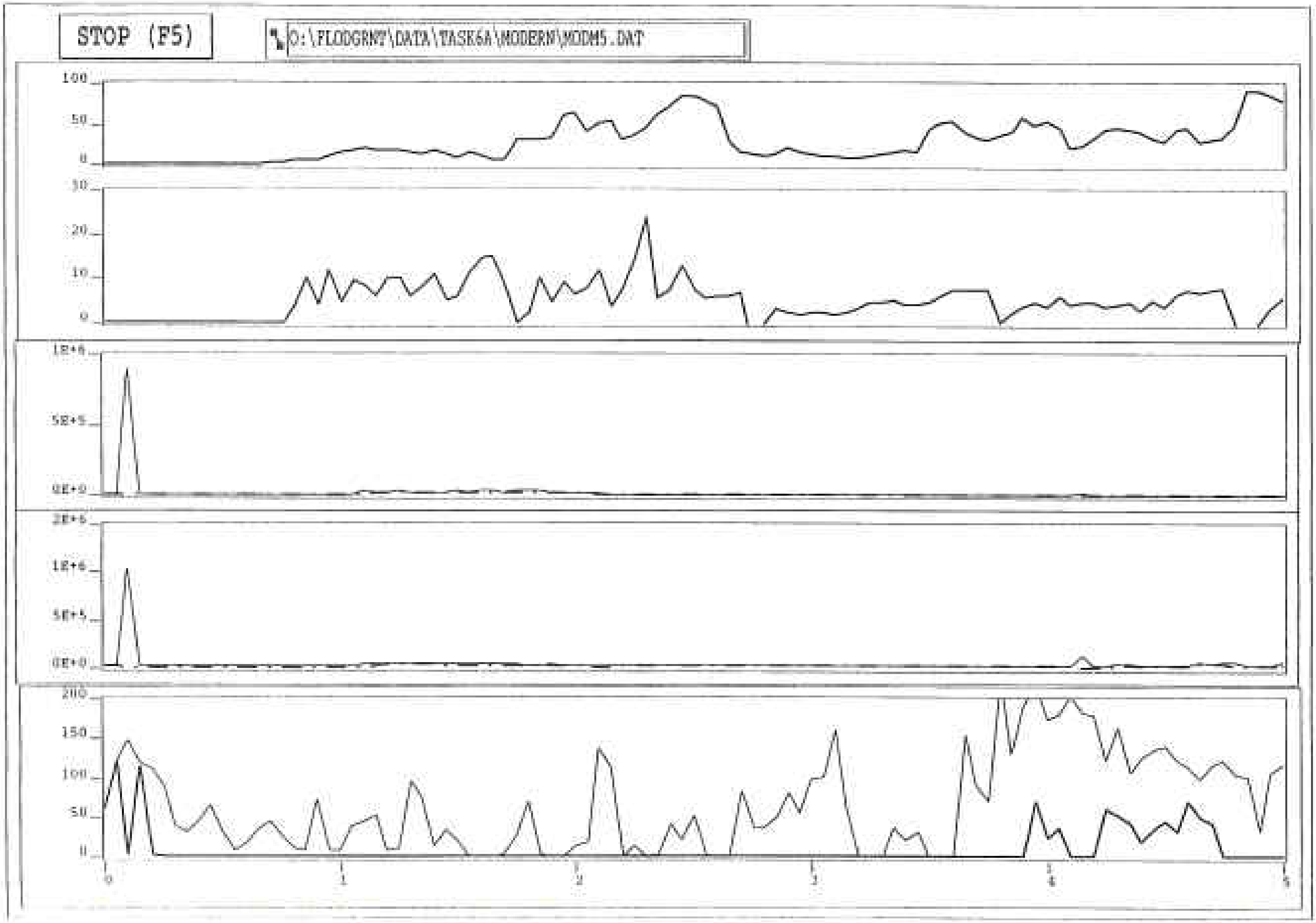
1) % silt= 100-%sand + %clay.
2) Upper 2' of soil compressed during sample acquisition.

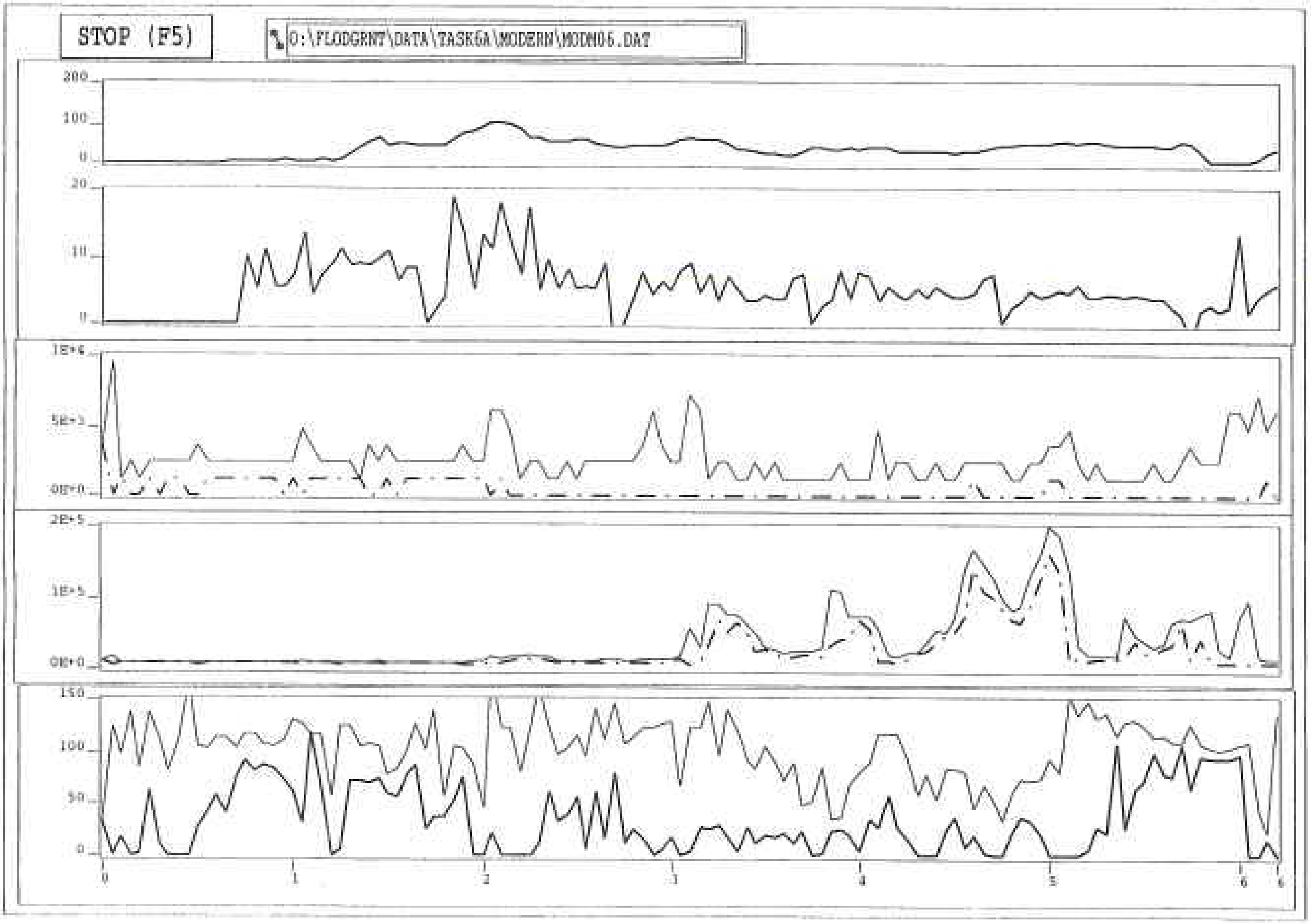


Modern Sanitation #104
Coarse <--> Fine
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Depth
Clay
Silt
Sand
Rock

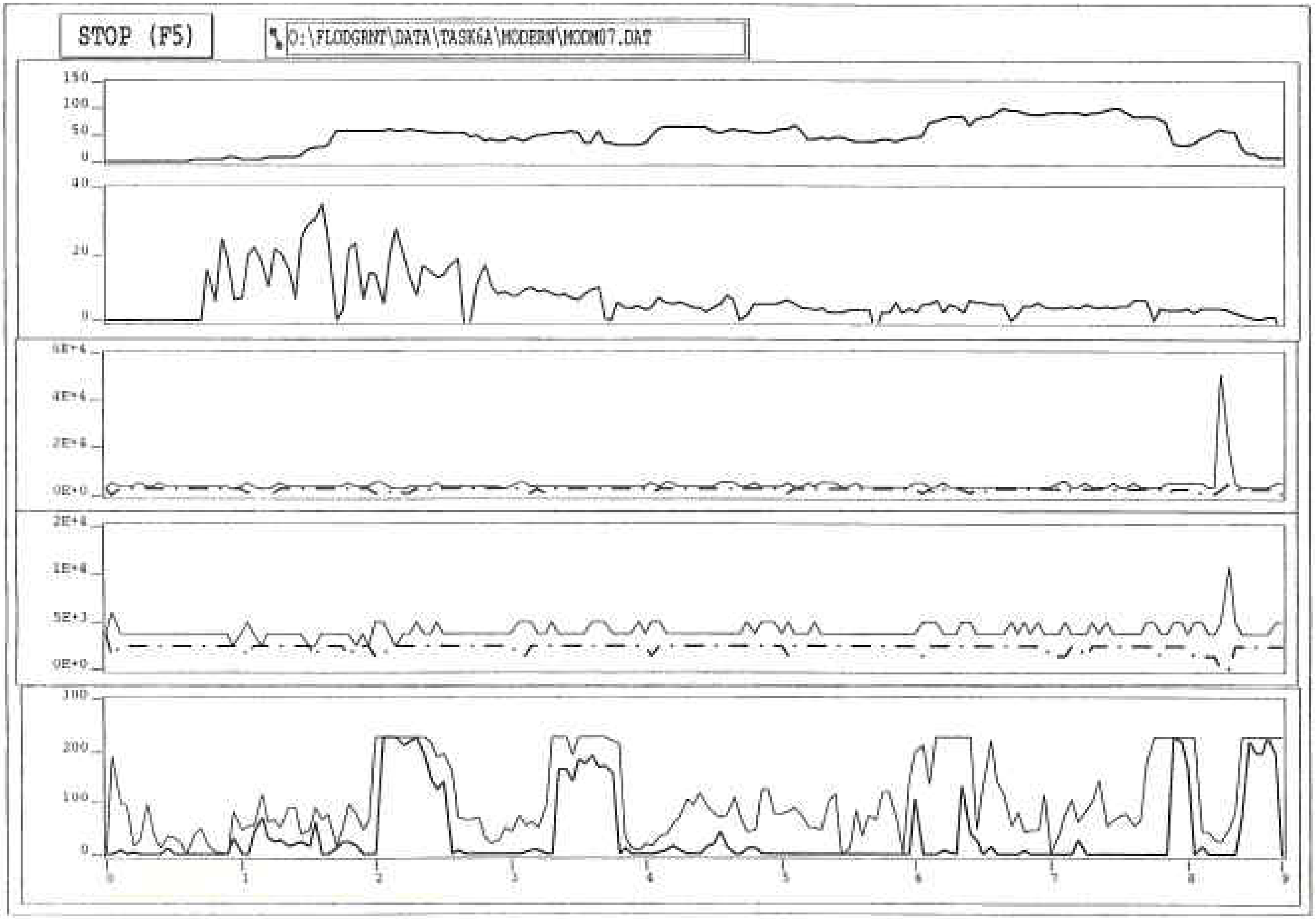


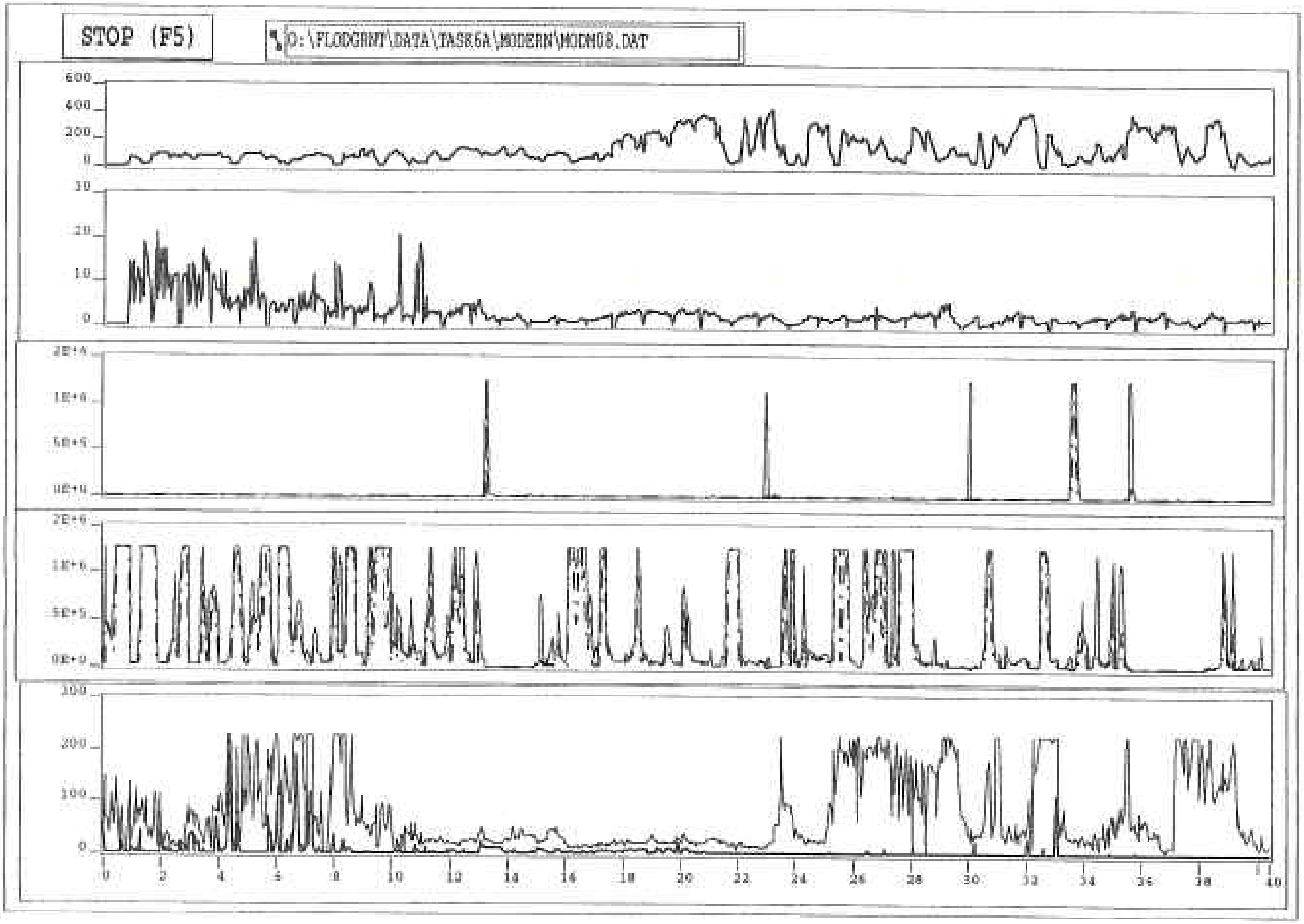
STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODN4.DAT
300
200
100
0
25
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM5.DAT
100
50
0
30
20
10
0
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
200
150
100
50
0
0
1
2
3
4
5

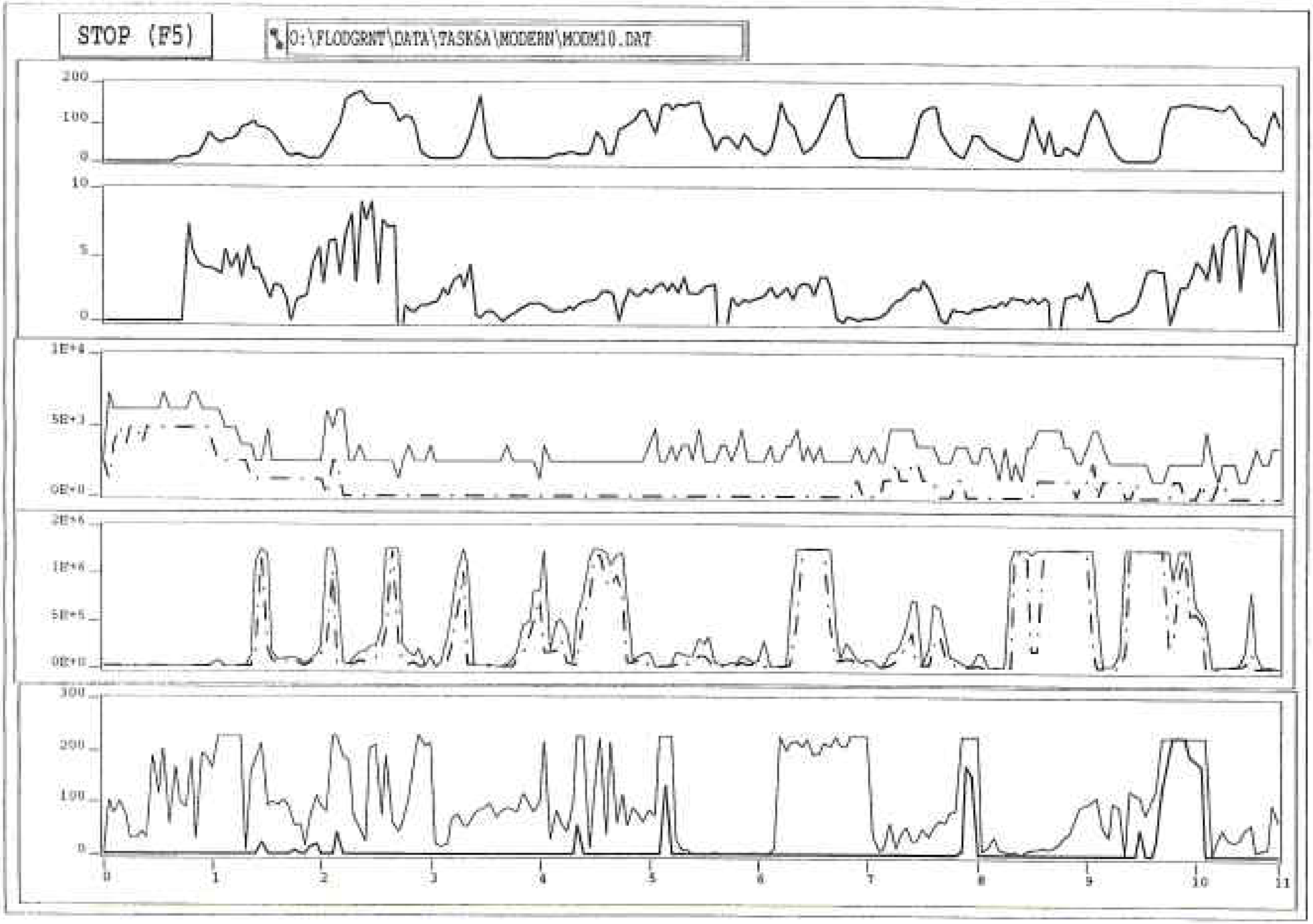


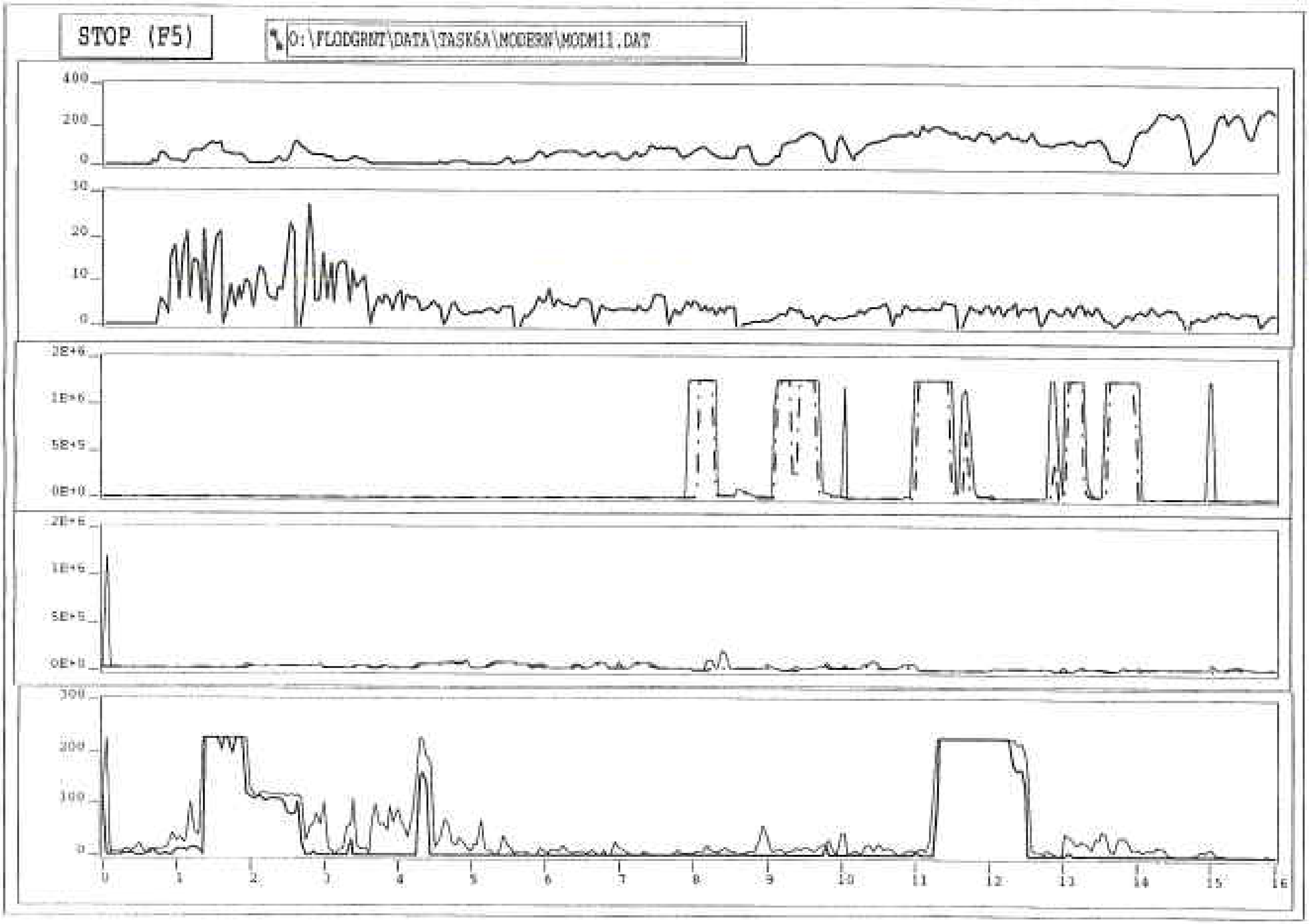
STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODN05.DAT
200
100
0
20
10
0
1E+4
5E+3
0E+0
2E+5
1E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
6

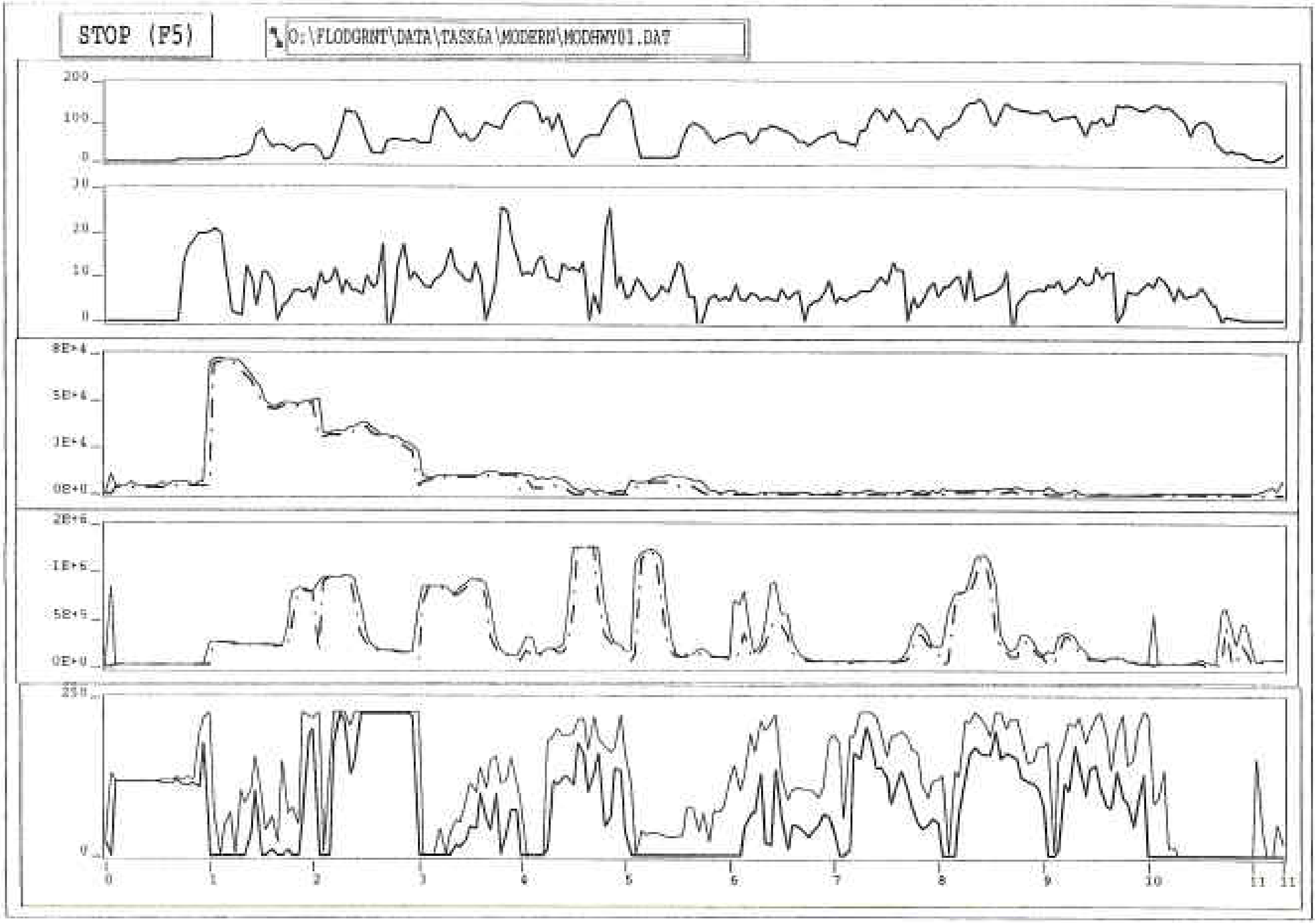

STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM07.DAT
150
100
50
0
40
20
0
6E+4
4E+4
2E+4
0E+0
2E+4
1E+4
5E+3
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9



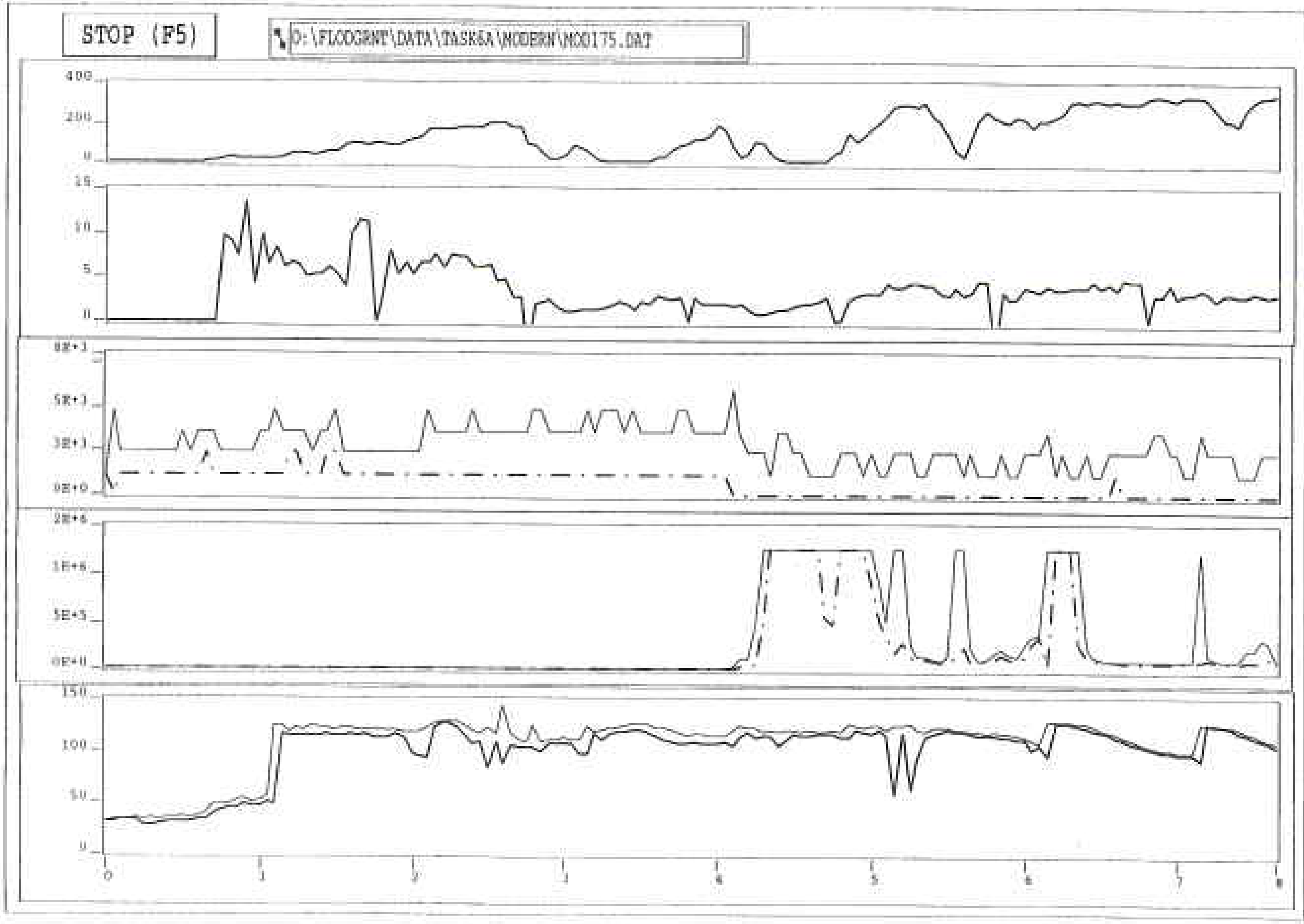
STOP (F5)
O:\FLODGRNT\DATA\TAS86A\MODERN\MODM08.DAT
600
400
200
0
30
20
10
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

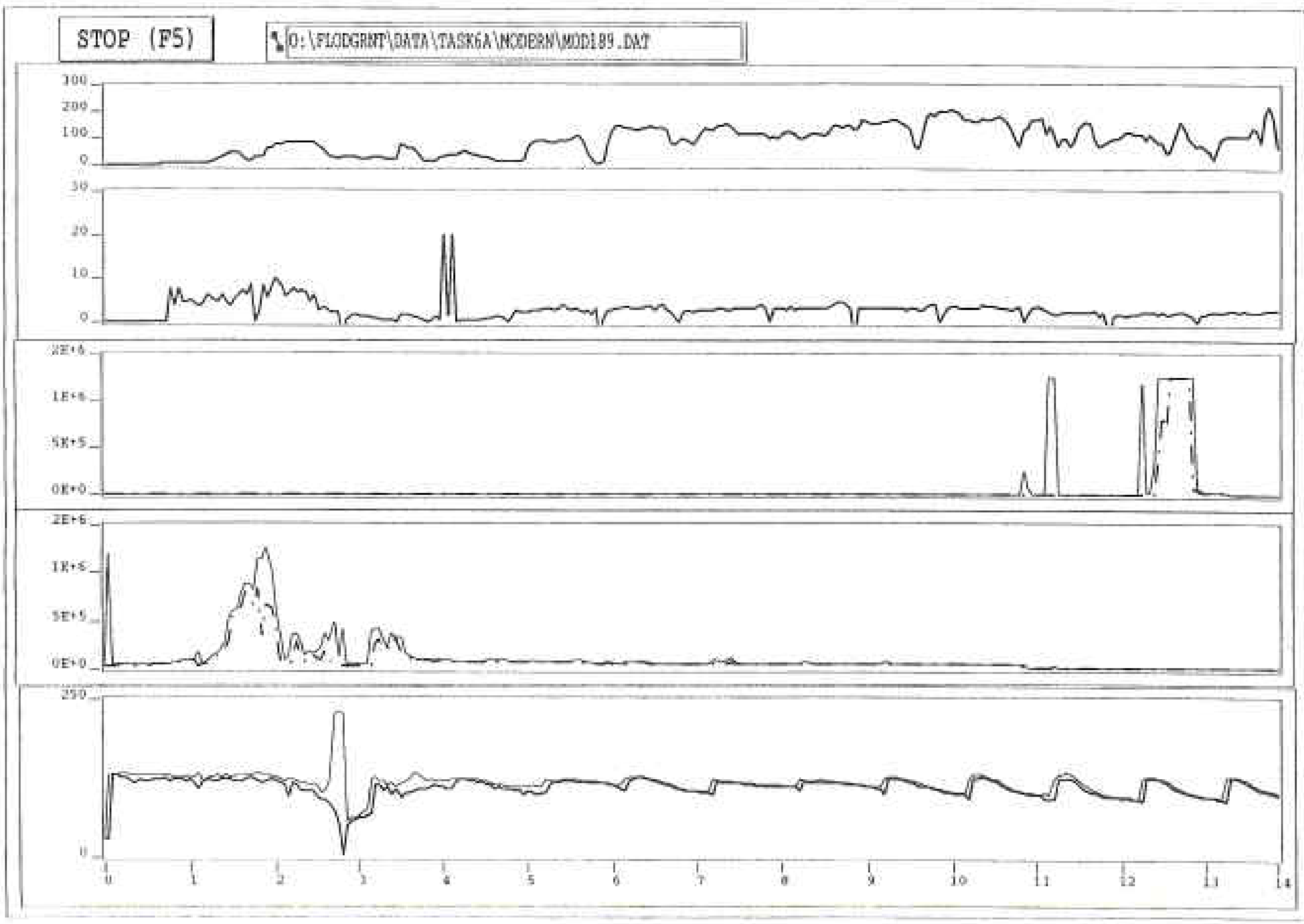

STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM10.DAT
200
100
0
10
5
0
1E+4
5E+3
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM11.DAT
400
200
0
30
20
10
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16



STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODHWY01.DAT
200
100
0
30
20
10
0
8E+4
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
250
0
0
1
2
3
4
5
6
7
8
9
10
11
11


STOP (F5)
D:\FLODGRNT\DATA\TASK6A\MODERN\MOD175.DAT
400
200
0
15
10
5
0
8E+3
5E+3
3E+3
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8



STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MOD189.DAT
300
200
100
0
30
20
10
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
250
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

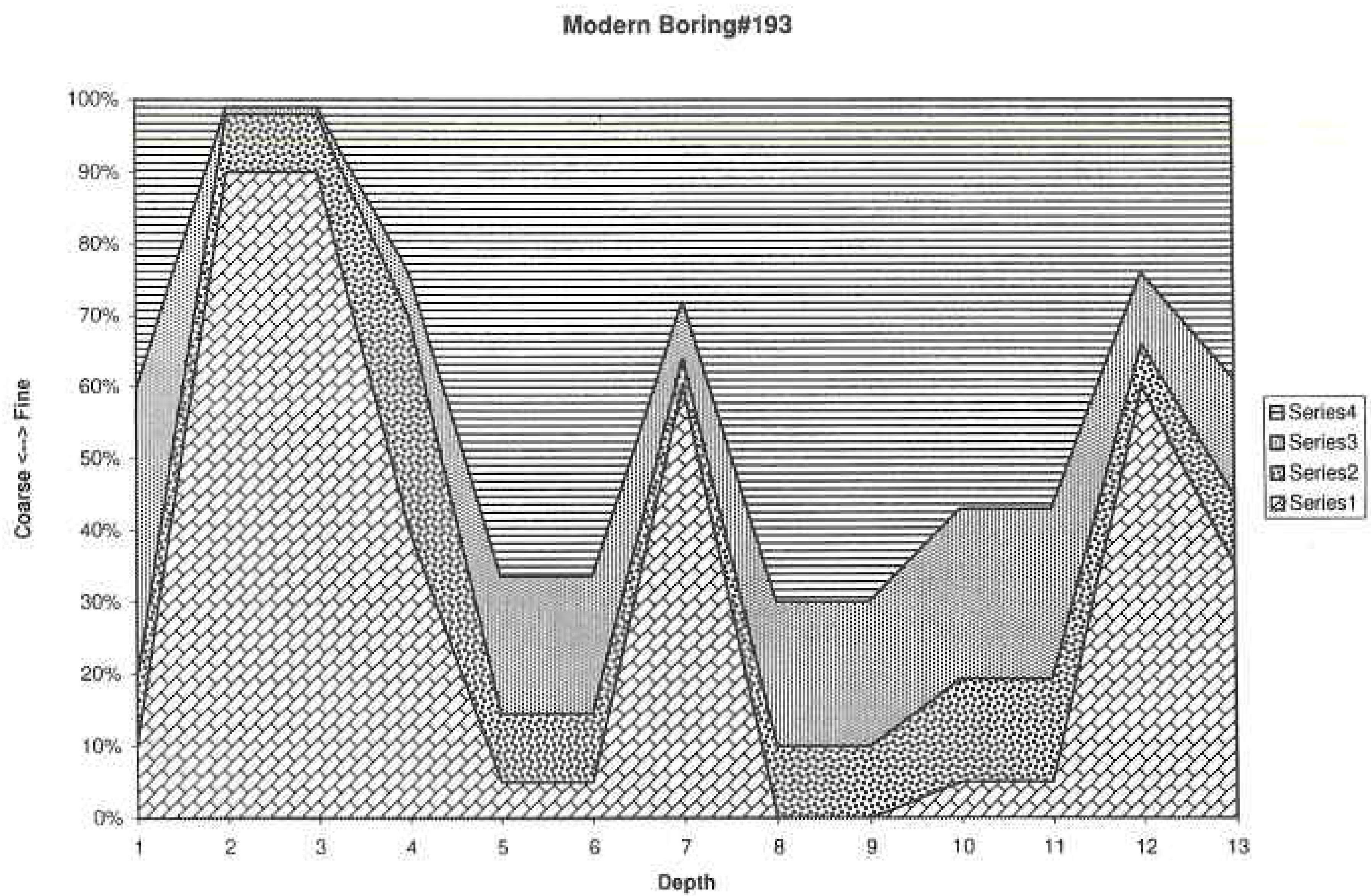
RECEIVED
NOV [illegible] 1997
SWMP

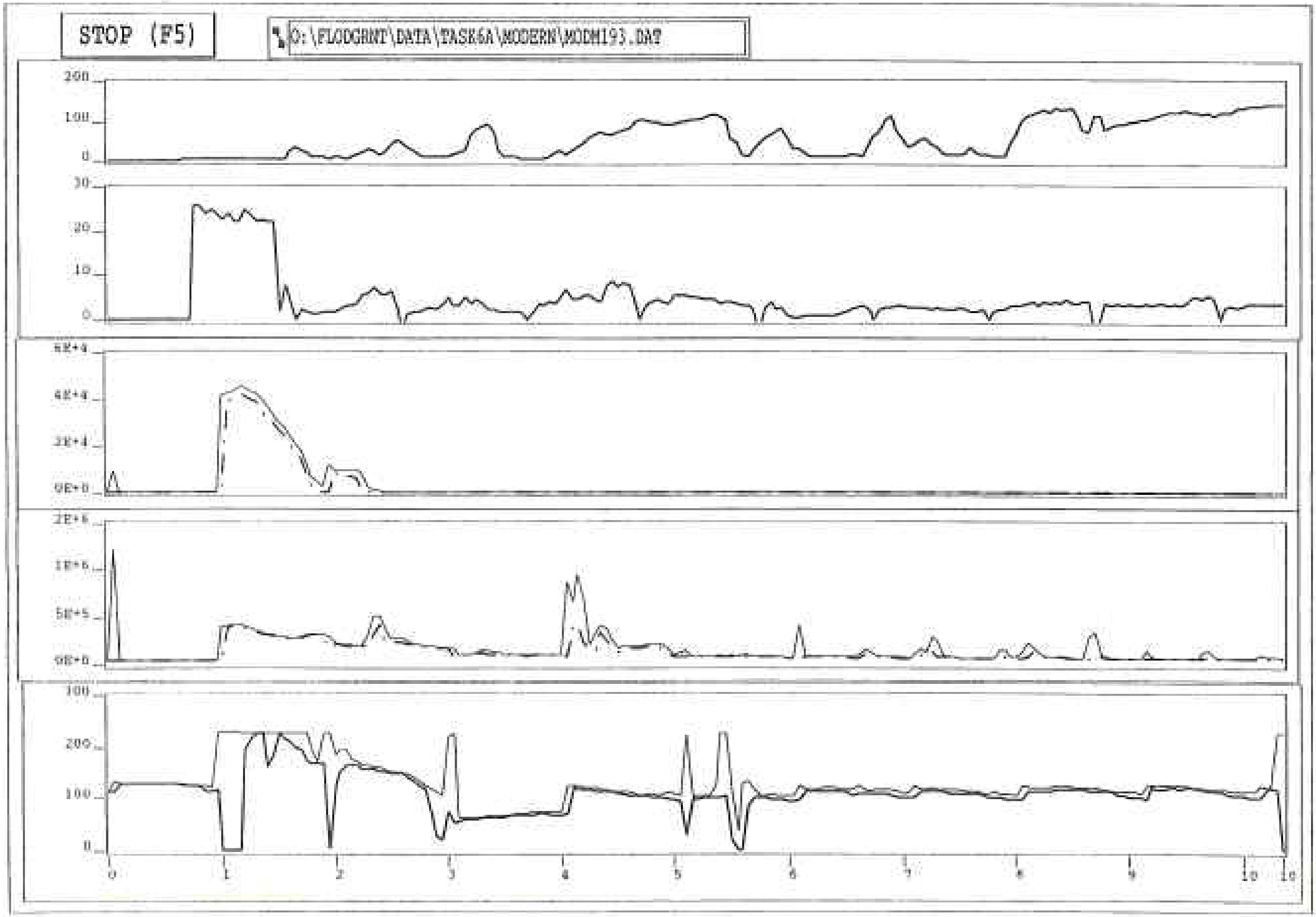
SOIL CHARACTERIZATION FOR MODERN LANDFILL
BORING # 193
DATE July 11, 1997

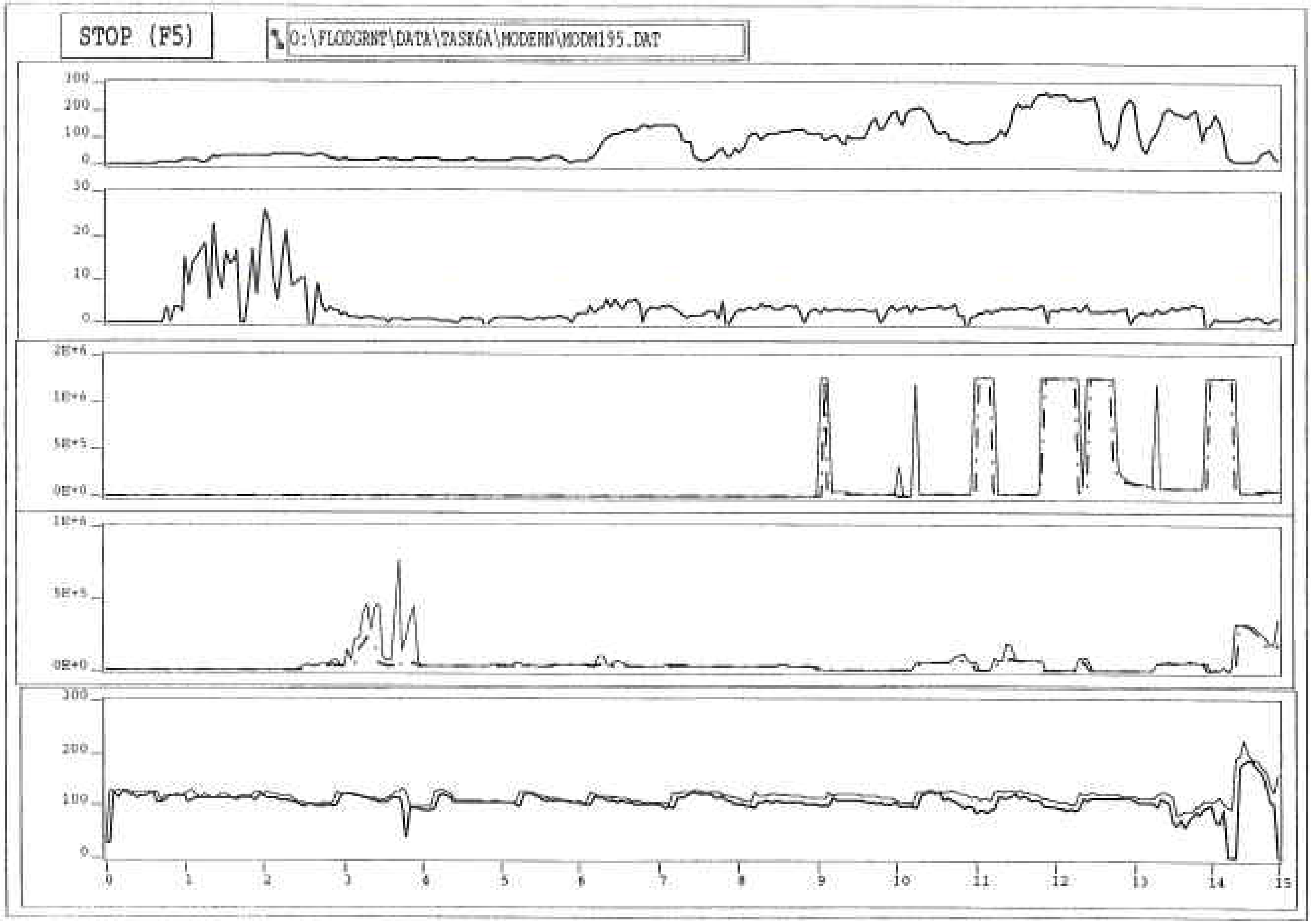
DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-0.5	7.5YR4/4		10	45	10	very weak subangular blocky	many fine; few medium	few fine intersiti-al; few fine tubular	
0.5-2.4	10YR6/4	10YR6/3 silt coats	80	<10	90	very weak subangular blocky			
2.4-3.1	decompos-ing	sandstone							
3.1-4	2.5YR4/6 +4/4	10YR6/2 silt coats	50	40	40	medium subangular blocky		few medium intersiti-al; few fine intersiti-al	
4-6.2	2.5YR3/6	10YR5/4 (10%)	10	70	< 5	weak subangular blocky	few fine; few medium	few fine intersiti-al	clay skins
6.2-7	2.5YR3/6	10YR5/4 (10%)	10	70	60 ch	weak subangular blocky			clay seams
7-8.6	2.5YR3/6	10YR5/4 (10%)	10	70		weak subangular blocky	few fine; few medium	few fine intersiti-al	clay seams
8.6-10	2.5YR3/6	10YR5/4 (10%)	15	60	< 5	weak subangular blocky	few fine; few medium	few fine intersiti-al	clay seams; Fe/Mn stains
10-11.2	2.5YR3/6	10YR5/4 (10%)	15	60	< 5	weak subangular blocky	few very fine	few fine intersiti-al	clay seams; Fe/Mn stains

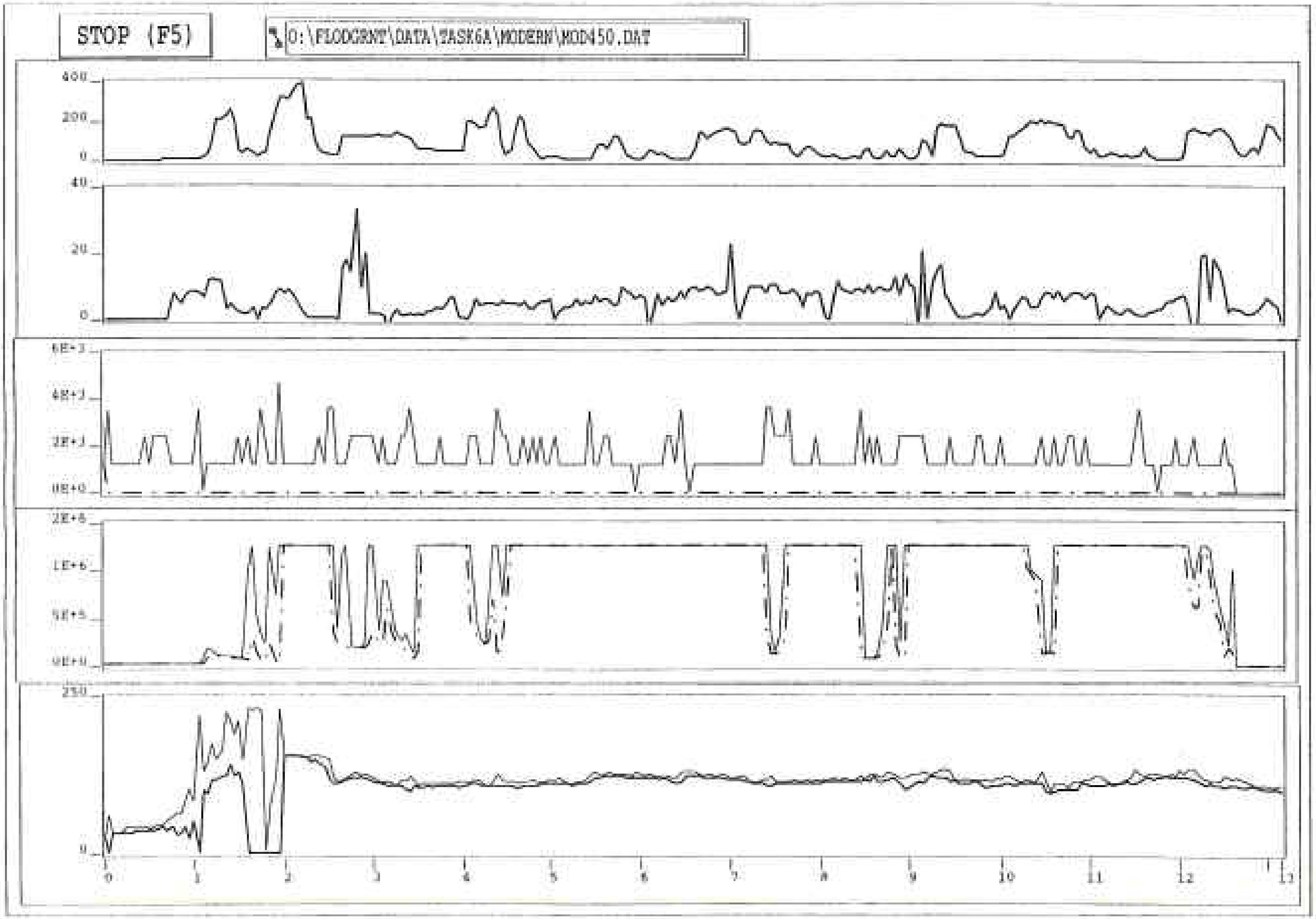
11.2-11.7	2.5YR3/6	10YR5/4 (10%)	15	60	60	weak subangular blocky	few very fine	few fine interstiti-al	Fe/Mn stains
11.7-13	2.5YR3/6	10YR5/4 (10%)	15	60	35	weak subangular blocky	few very fine	few fine interstiti-al	clay skins; Fe/Mn stains

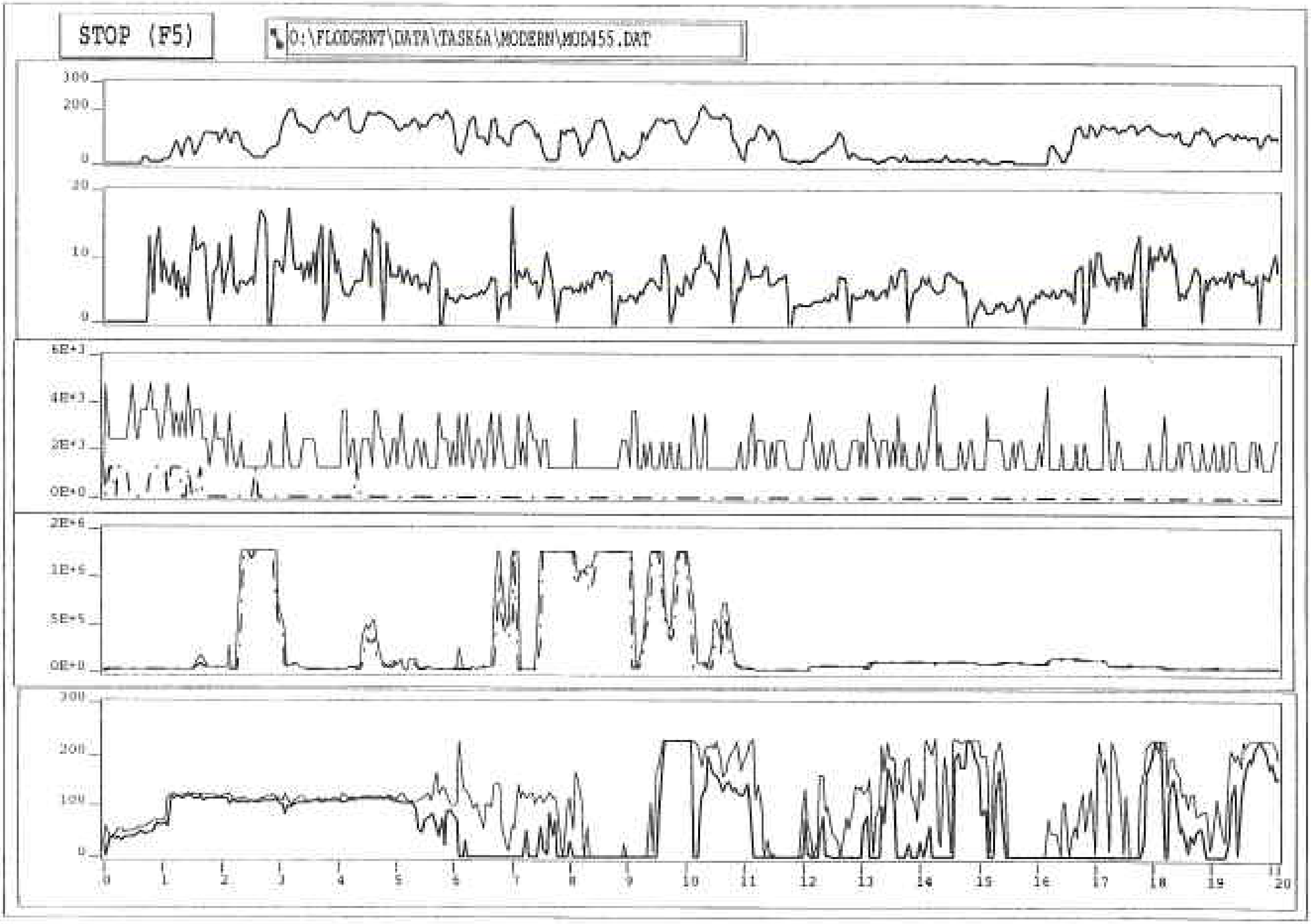
The most noticeable characteristics of this soil are the weathered rock lenses providing large and rapid horizontal as well as vertical gas movement. Roots and water channels are also present most of the length of these soils providing rapid movement of water and gases vertically. Fe/Mn stains indicate rapid vertical water movement

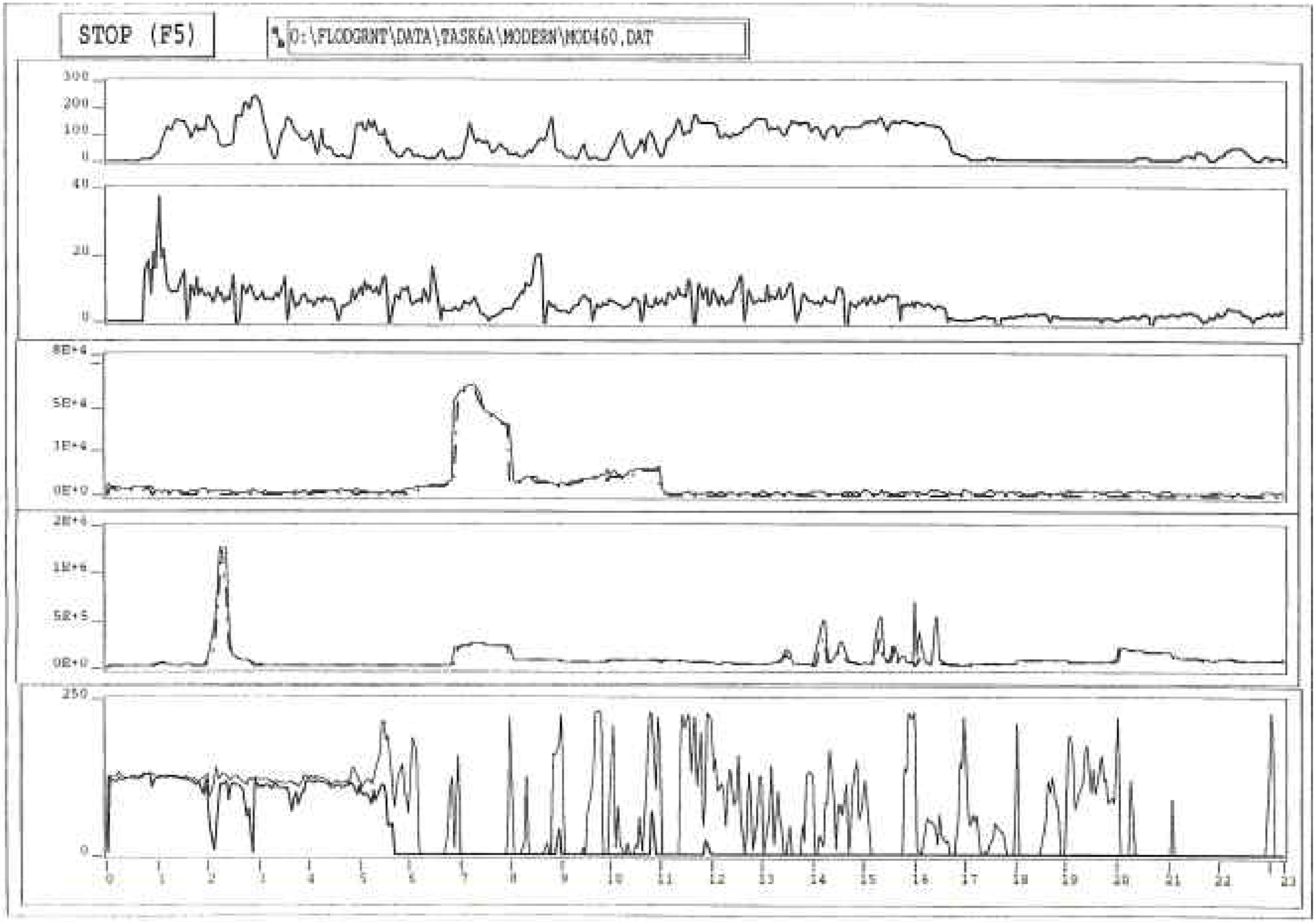

Modern Boring#193
Coarse <--> Fine
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
9
10
11
12
13
Depth
Series4
Series3
Series2
Series1

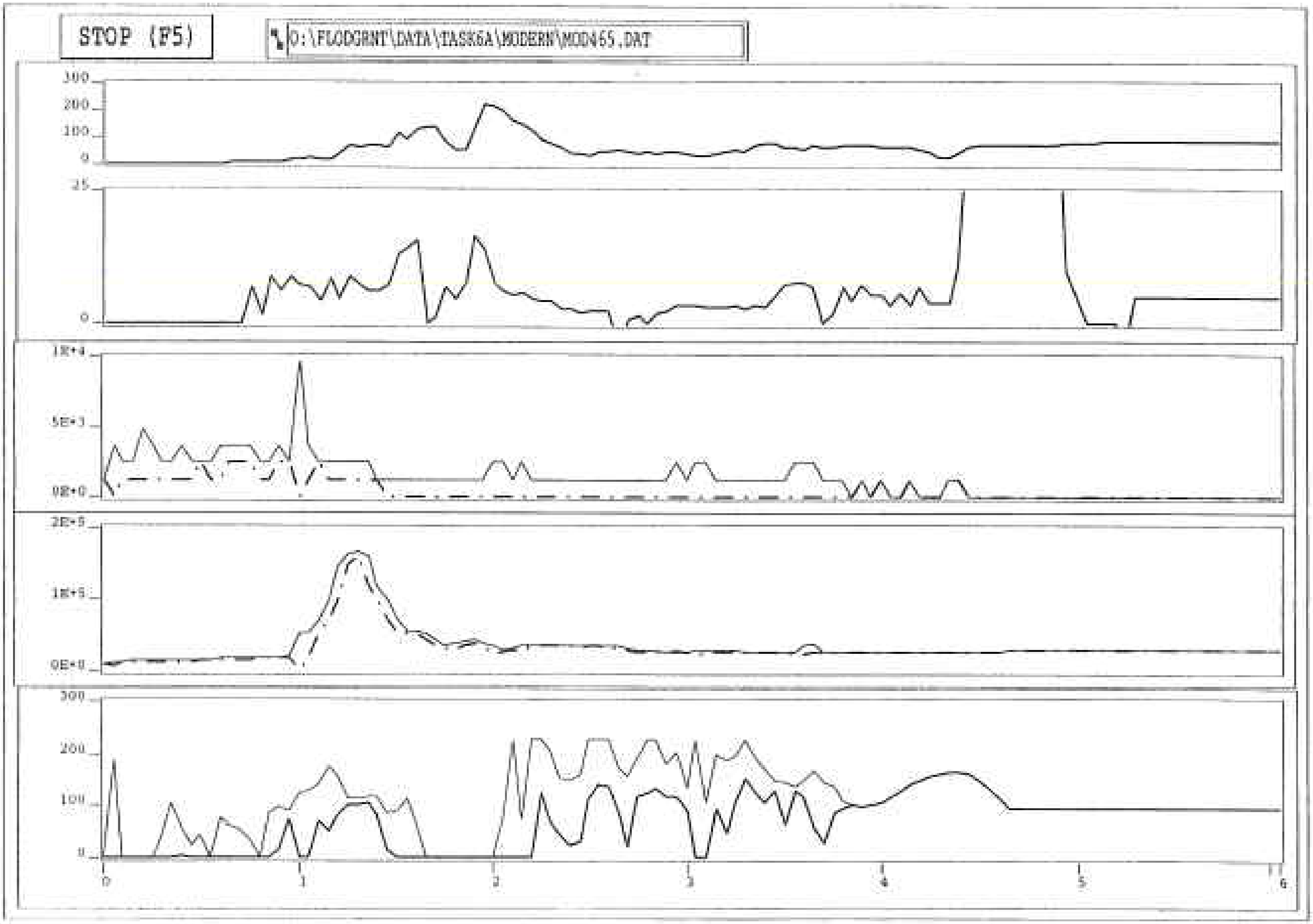

STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM193.DAT
200
100
0
30
20
10
0
6E+4
4E+4
2E+4
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
10

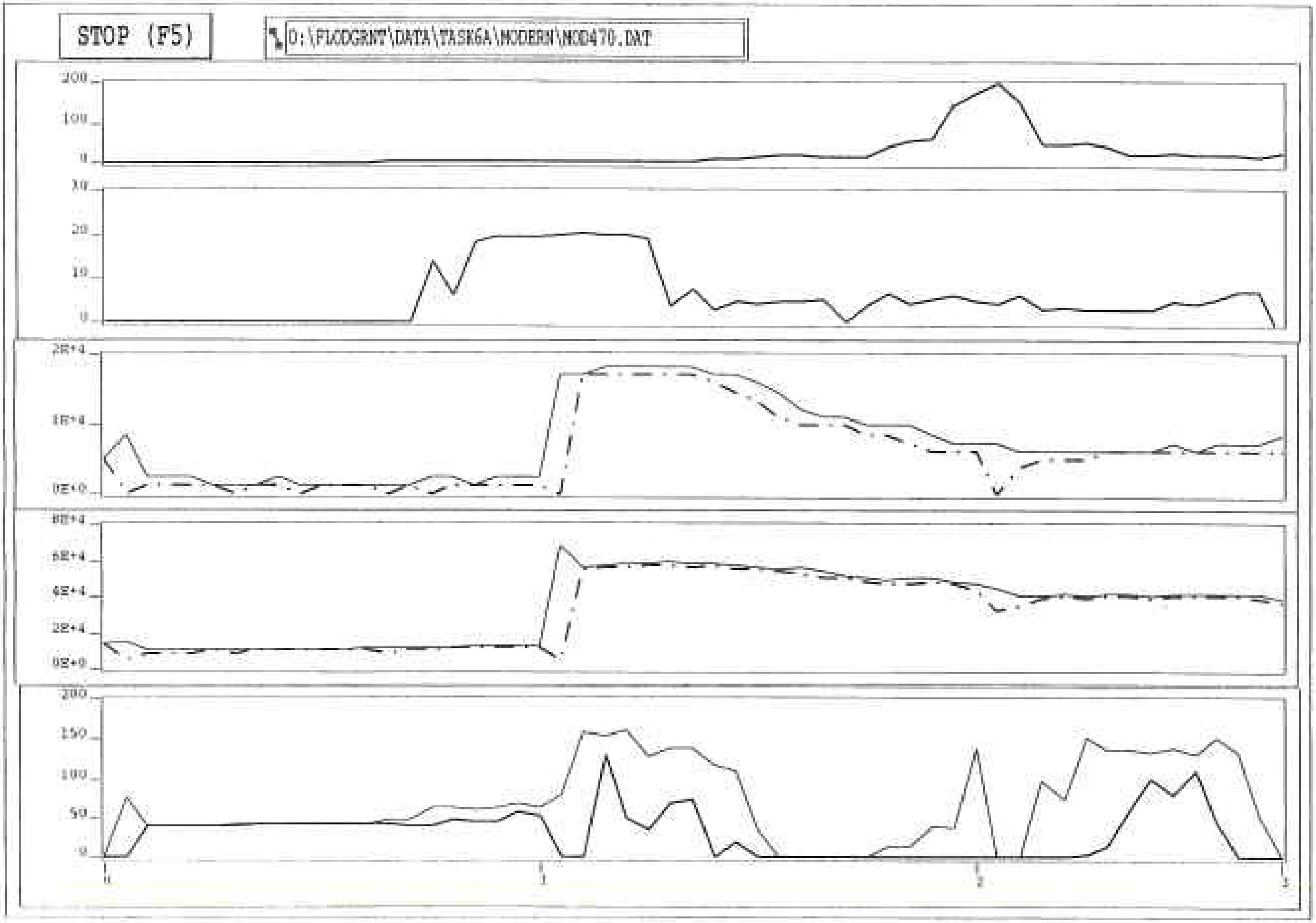

STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM195.DAT
300
200
100
0
30
20
10
0
2E+6
1E+6
5E+5
0E+0
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

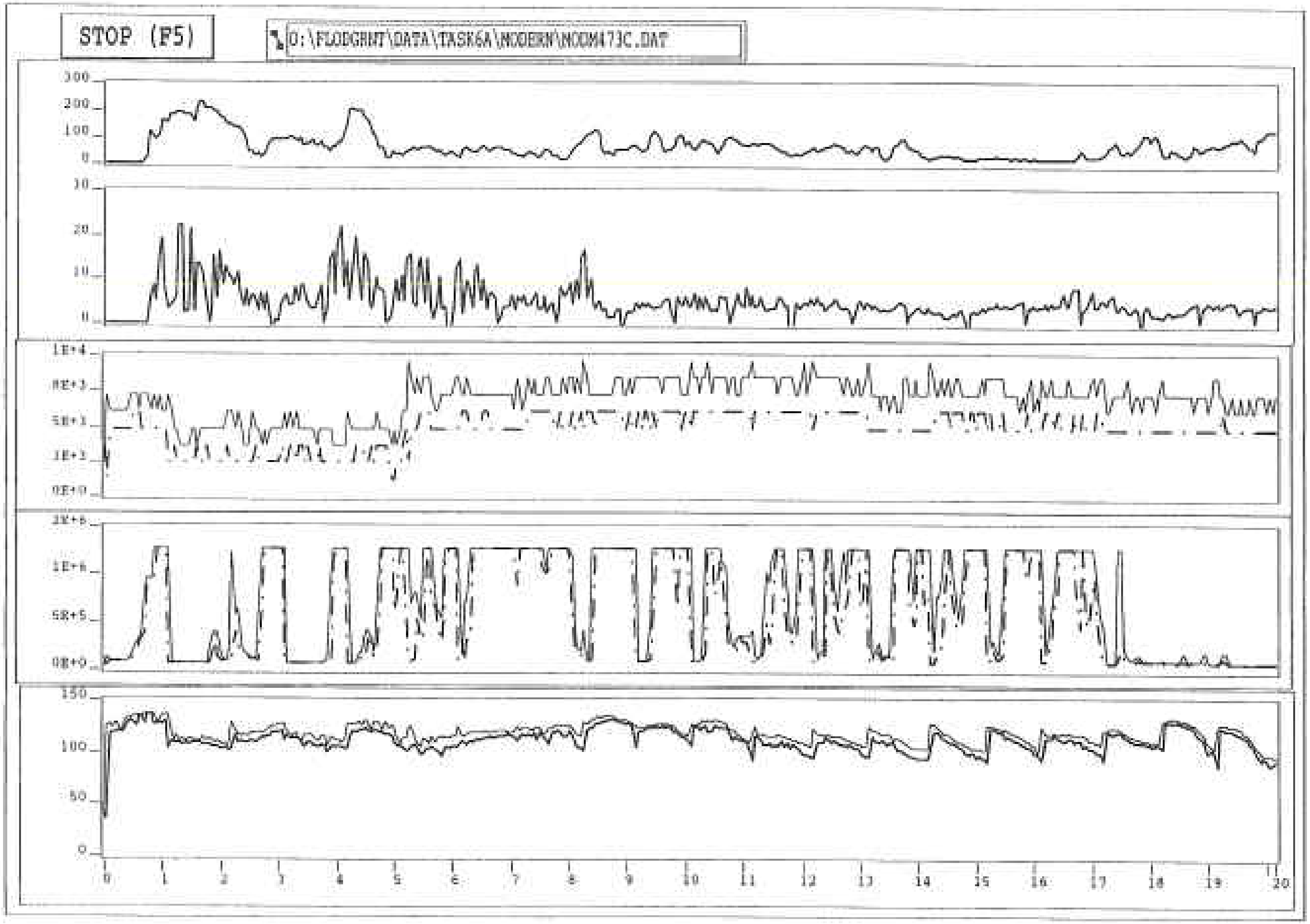

STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MOD450.DAT
400
200
0
40
20
0
6E+3
4E+3
2E+3
0E+0
2E+6
1E+6
5E+5
0E+0
250
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13


STOP (F5)
D:\FLODGRNT\DATA\TASK6A\MODERN\MOD455.DAT
300
200
0
20
10
0
6E+3
4E+3
2E+3
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MOD460.DAT
300
200
100
0
40
20
0
8E+4
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
250
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MOD465.DAT
300
200
100
0
25
0
1E+4
5E+3
0E+0
2E+5
1E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6


STOP (F5)
D:\FLODGRNT\DATA\TASK6A\MODERN\MOD470.DAT
200
100
0
30
20
10
0
2E+4
1E+4
0E+0
8E+4
6E+4
4E+4
2E+4
0E+0
200
150
100
50
0
0
1
2
3

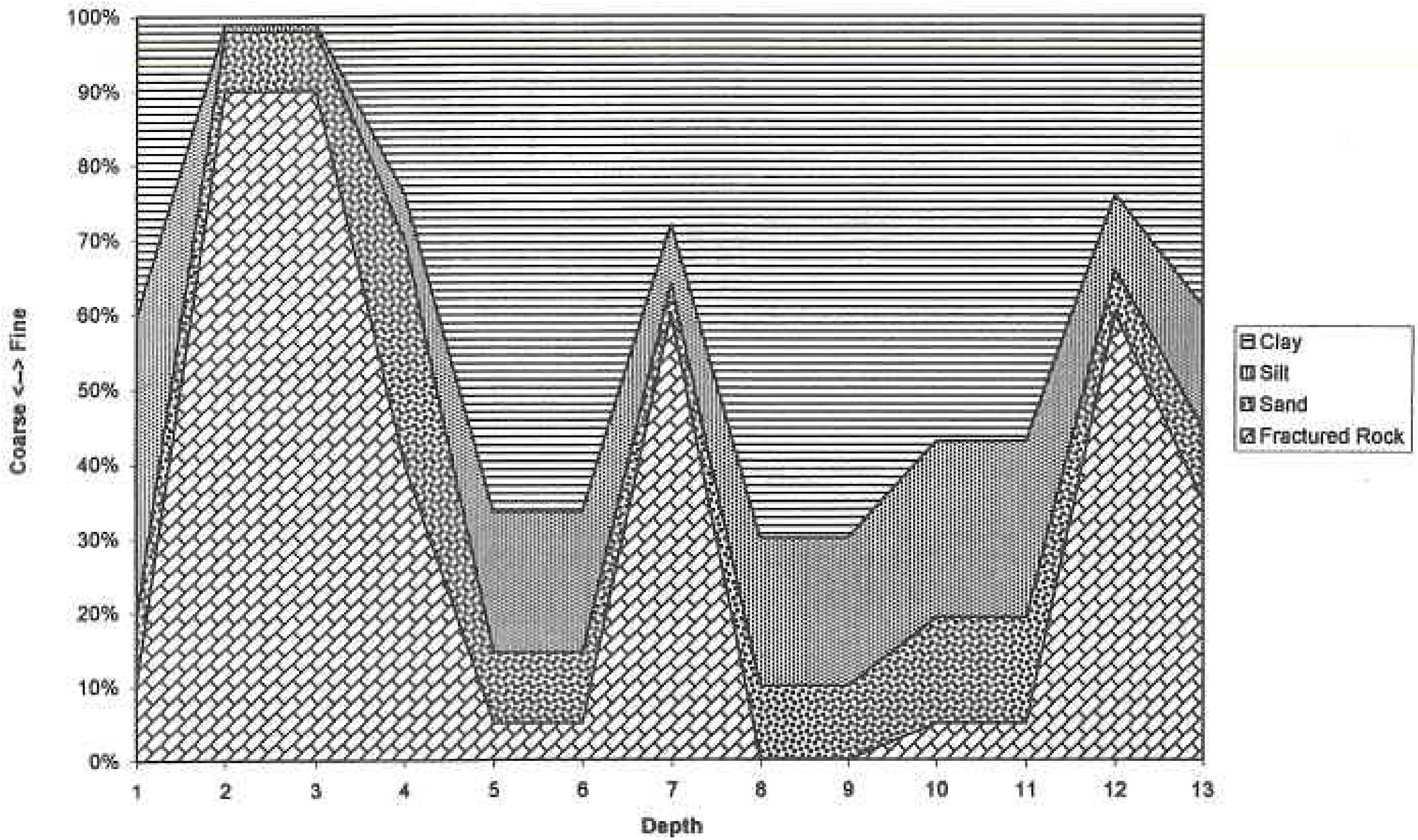

STOP (F5)
D:\FLODGRNT\DATA\TASK6A\MODERN\MODM473C.DAT
300
200
100
0
30
20
10
0
1E+4
8E+3
5E+3
3E+3
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

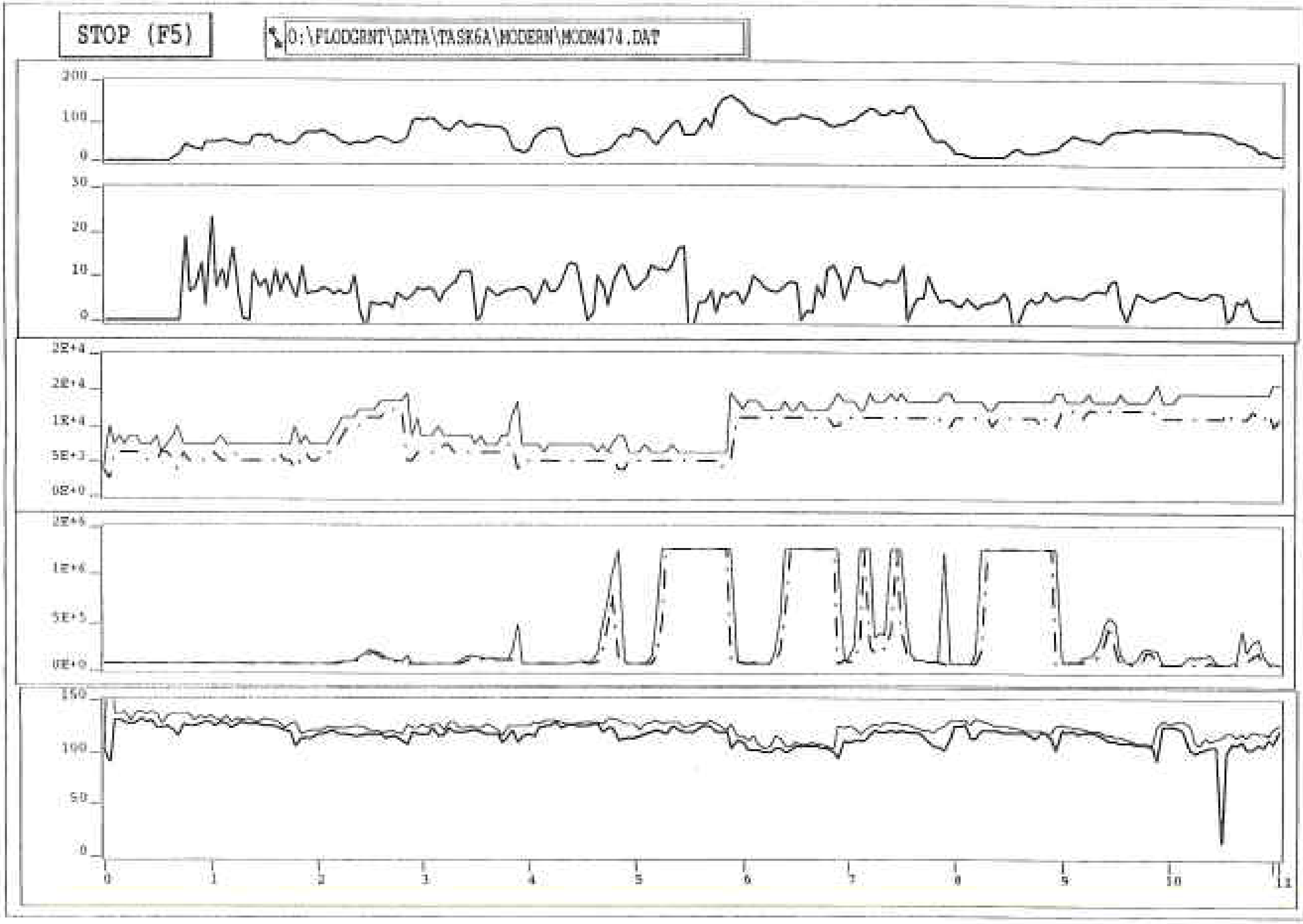
SOIL CHARACTERIZATION FOR MODERN LANDFILL
BORING # 474
DATE July 11, 1997

DEPTH (Ft)	COLOR MATRIX	MOTTLES	SOIL TYPE % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES	H_2O CHANNELS
0-4	2.5YR4/6 + 10YR4/6	10YR5/2	15	40	60	weak subangular blocky	few medium	few medium interstiti-al; few fine tubular	clay skins
4-12	10YR4/4 + 5/1		20	30	40	weak subangular blocky	few fine; few medium	few fine interstiti-al; few medium interstiti-al	clay skins
12-15	10YR4/4 + 5/1		20	30	20	weak subangular blocky	few fine; few medium	few fine interstiti-al; few medium interstiti-al	clay skins
15-18	10YR4/4 + 5/1		20	30	30	weak subangular blocky	few fine; few medium	few fine interstiti-al; few medium interstiti-al	clay skins
18-19	2.5YR3/6 + 10YR5/4 + 5/1		15	65	40	weak subangular blocky	few medium	few medium interstiti-al; few fine interstiti-al	clay skins

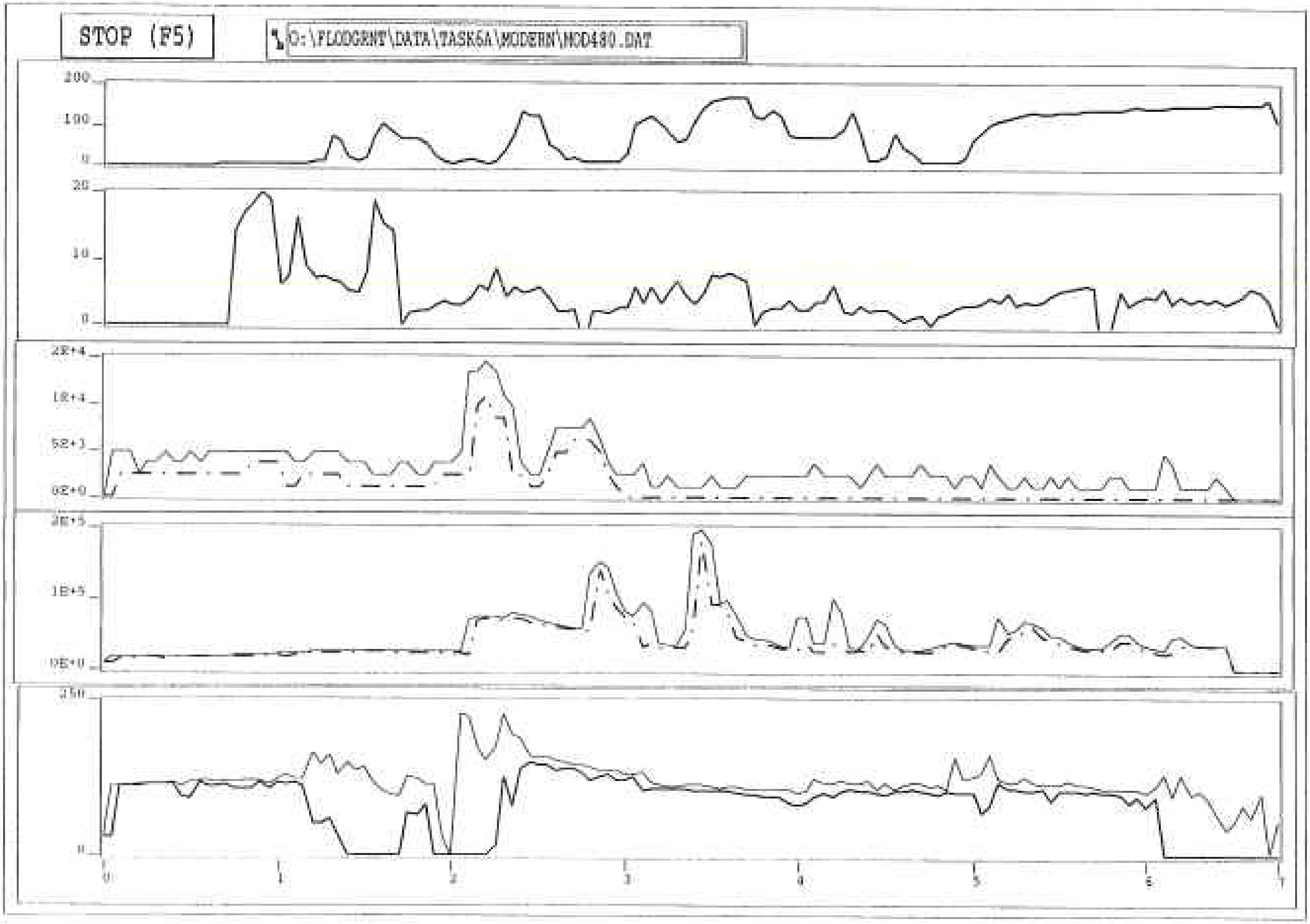
The most noticeable characteristics of this soil are the weathered rock lenses providing large and rapid horizontal as well as vertical gas movement. Roots and water channels (clay skins) are also present most of the length of these soils providing rapid movement conduits vertically.

Modern Boring#474





STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MODM474.DAT
200
100
0
30
20
10
0
2E+4
2E+4
1E+4
5E+3
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11


STOP (F5)
O:\FLODGRNT\DATA\TASK6A\MODERN\MOD480.DAT
200
100
0
20
10
0
2E+4
1E+4
5E+3
0E+0
2E+5
1E+5
0E+0
250
0
0
1
2
3
4
5
6
7

Appendix F

Southeast Landfill

MIP and Soil Logs

(See Appendix B cover page for MIP curve identification.)

SOIL CHARACTERIZATION FOR SOUTHEAST SANITARY LANDFILL

DNR MONITORING WELL # 1

MIP Probe 1r

02/13/97 - 02/14/97

RECEIVED
DEC 0? 1997

DEPTH (Ft)	MUNSELL COLOR		SOIL TYPE		% ROCK	STRUCTURE	PORES	
	MATRIX	MOTTLES	% SAND	%CLAY			ROOTS	SOILPORES
0- 1.3	mixed 10YR5/2+ 2/1	5% Fe/Mn nodules[1)]	15 very fine	18		massive	many fine	few interstitial
1.3- 2.0	mixed 10YR3/2+ 2/1	<5% Fe/Mn nodules[1)]	15 very fine	30		weak subangular blocky	few fine	many fine tubular, few fine interstitial
2.0- 4.0	mixed 10YR3/1+ 4/3	5% Fe/Mn nodules[1)]; many water channels[2)]	10 very fine	35		weak subangular blocky	few fine, few very fine	few fine tubular, many fine interstitial
4.0- 4.7	boring compaction							
4.7- 5.8	10YR3/1	10YR5/2 silt coats[2)]	<10 very fine	35		weak - medium subangular blocky with sand & silt pockets	few very fine	many fine tubular
5.8- 9.8	mixed 10YR5/2+ 4/3	10YR5/1+ 7.5YR4/6; <10% Fe/Mn staining & nodules[1)]; many water channels[2)]	20	30		medium subangular blocky with silt pockets	few very fine	few very fine and few fine tubular
9.8- 11.4	10YR4/2	10YR5/2 + 2% 5/8, 20% Fe/Mn staining & nodules[1)], many water channels[2)]	25	35		weak subangular with silt pockets		few medium + few very fine tubular

11.4-14.2	10YR4/2	10YR5/2 + 2% 5/8; 20% Fe/Mn staining & nodules[1]; many plugged water channels[2]	25	35		weak subangular		few medium + few very fine tubular
14.2-15.1	10YR4/2	<5% 10YR5/2; 60% Fe/Mn staining & nodules[1]	20	30		very fine subangular blocky		many fine tubular
15.1-21.0	10YR4/1	30% 10YR4/1; 30% Fe/Mn staining & nodules[1]	20	30		weak subangular blocky with sand pockets		few very fine tubular; few very fine interstitial
21.0-25.0	5YR2.5/1	30% Fe/Mn staining & nodules[1]	10	35		very fine subangular blocky		few fine tubular; many fine interstitial
25.0-30.0	5YR2.5/1 septic odor	<1% 10YR5/2; 20% Fe/Mn nodules[1]	10	35		weak subangular blocky		many very fine tubular; few fine interstitial
30.0-32.5	5YR2.5/1		10	35		massive		few fine interstitial
32.5-34.3	5YR2.5/1	20% GLEY-2 5/PB	10	35		very weak subangular blocky		few fine interstitial
34.3-37.0	mixed 5YR2.5/1 + GLEY-2 5/PB	<5% Fe/Mn staining & nodules[1]	15	45		weak subangular blocky		few very fine interstitial
37.0-39.0	GLEY-2 5/10G	<10% 2.5YR4/1; decomposed wood fragment	10	45		weak subangular ablocky		few fine tubular; few fine interstitial
39.0-42.0	GLEY-2 5/10G	<2% Fe/Mn staining & nodules[1]; decomposed wood fragment	10	35	<5%	weak subangular blocky		very few fine tubular; very few fine interstitial

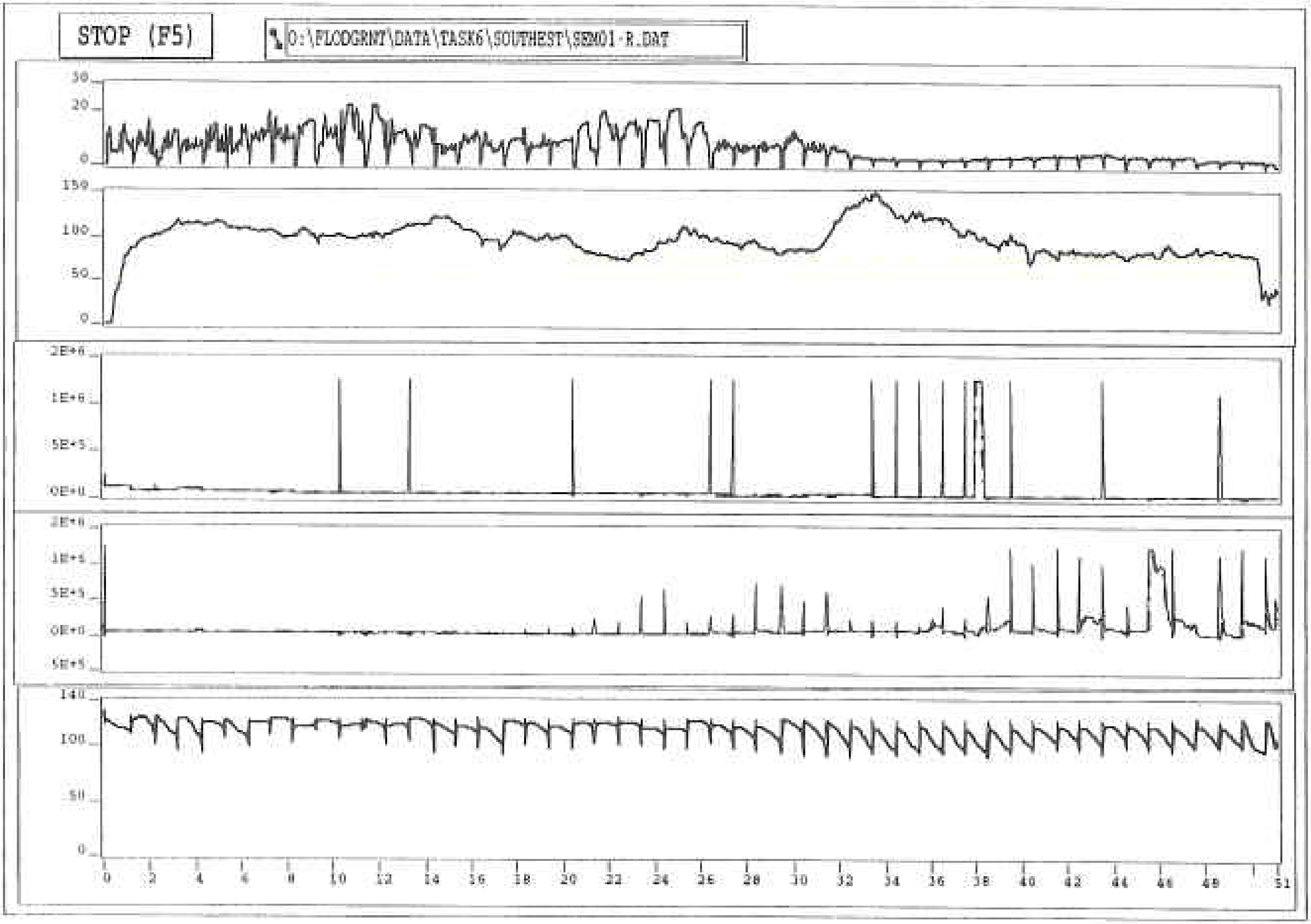
42.0-45.0	GLEY-2 5/10G	Fe/Mn staining[1]	15 very fine	45		massive		

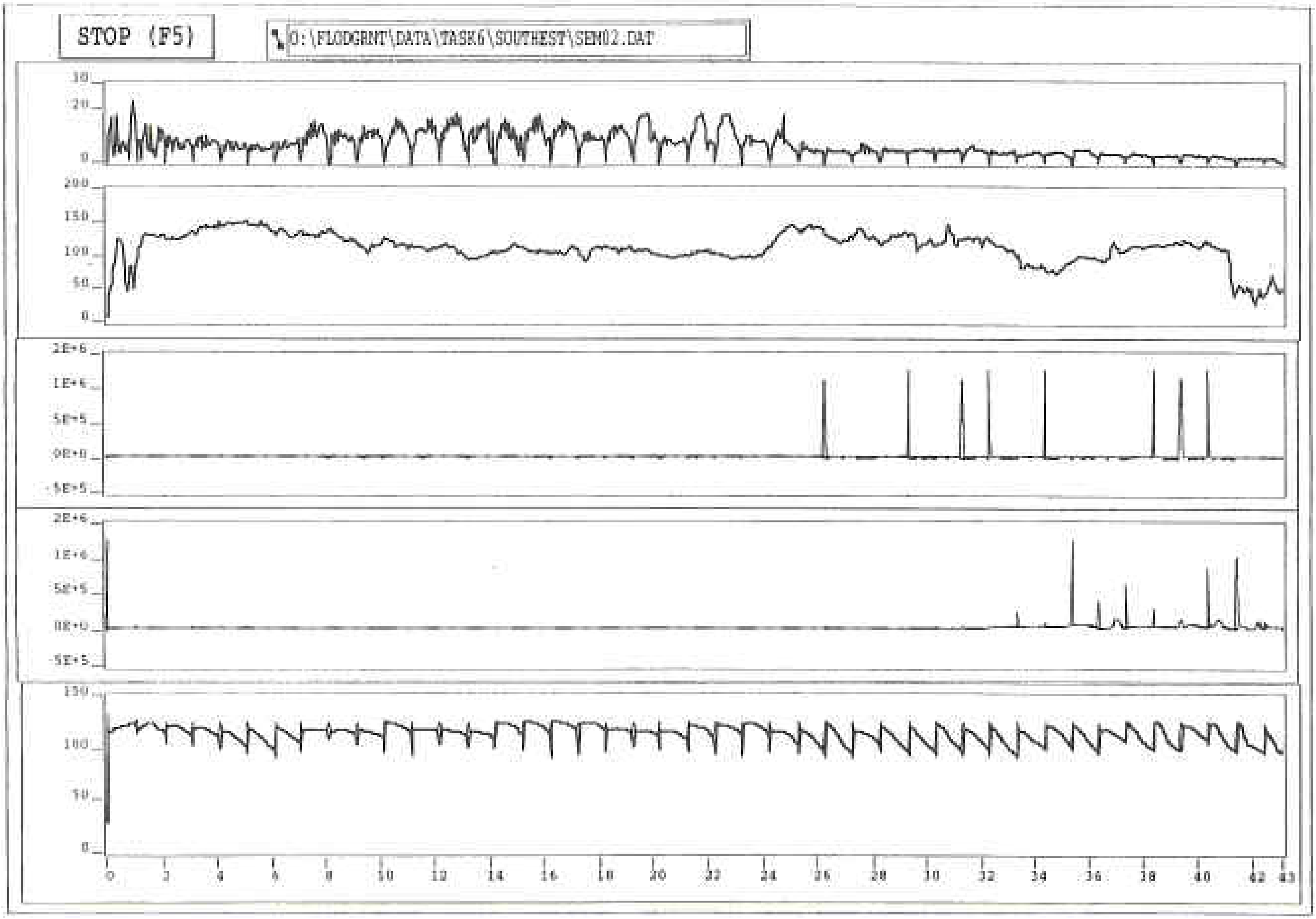
1) Stain= iron and/or manganese formed by historic water movement.
2) Soil structure pathways formed by historic water movement.

Permeability was not consistant throughout this profile. The profile with its FE/Mn staing from 0-37' showed evidence of long term water retention along this length. Roots provided vertical pathways from 0-9.8' bgs. The first water saturated zone was evident at the end of the root zone at ~10'; the soil was noticeably dryer after ~11-14'. Water channels, silt coats and sand-silt pockets were incountered from 0-21' bgs the latter being signs of a heaving formation. Most sand and silt pockets were found from ~5-11'; most water channels were found from ~10-14' at which point they were plugged by silt and clay. Massive soil structure was observed at 0-2' (mechanical compaction). Massive soil structure was also found at ~30-32' where it combined with the absence of tubular soil pores from 30-37' which could also serve as a aqua-tard and/or a gas-tard. These phenomena could help to retard vertical migration of soil gases as may have been evidenced by the presence of septic odor at the 21-30' zone resting on the massive soil structure layer beneath it. The predominance of silt and water in this soil could also inhibit rapid vertical movement of gases and liquids especially in regions where tubular soil pores are minimal when normal moisture conditions exist. Should a drought occur and water be drained from the formation rapid soil gas migration could occur through many of these soil structures.

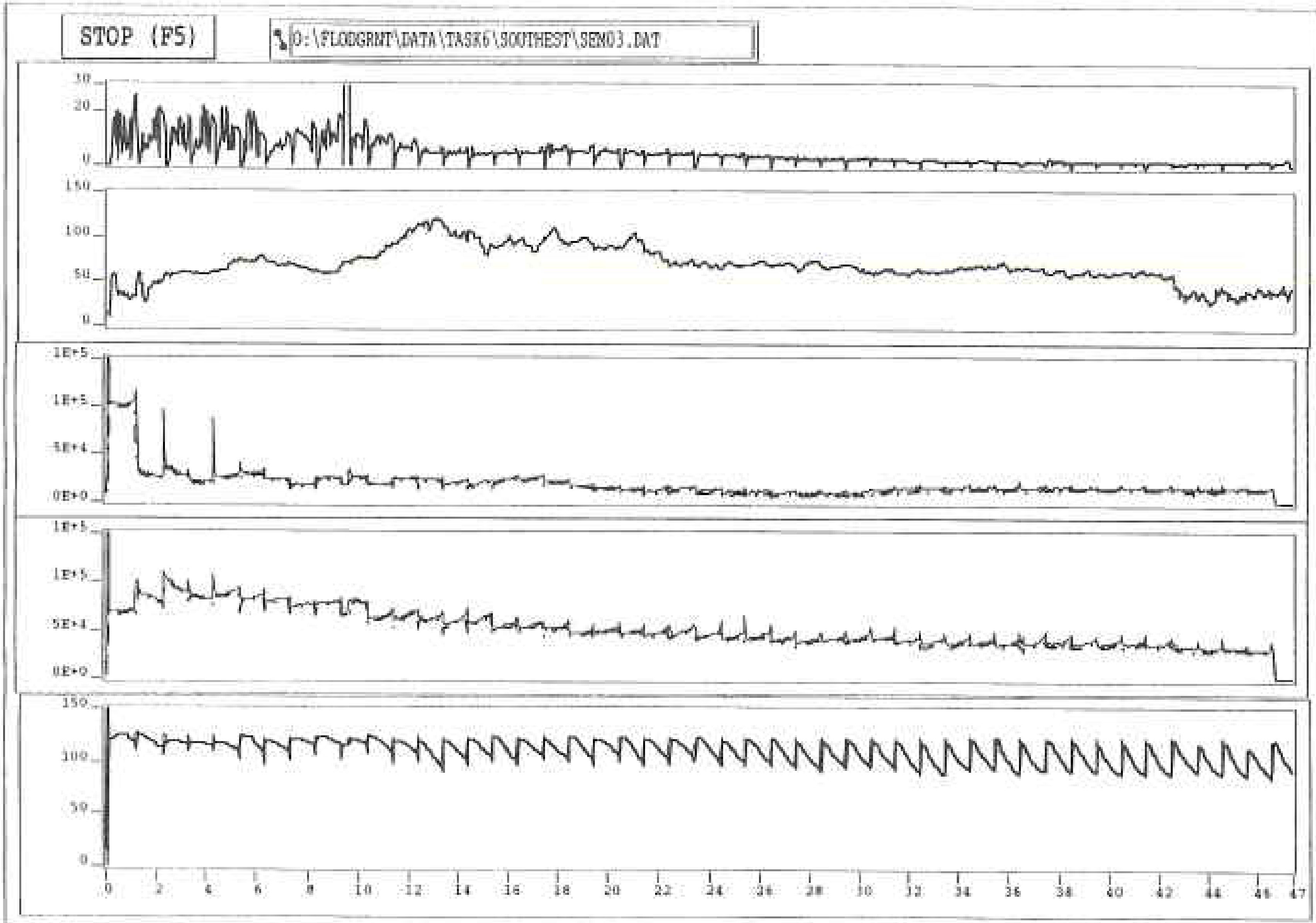
The high water content, moderate clay percentages and more massive structure of the transmissive features of this soil may be less easily disturbed and destroyed by excessive radial forces of a hollow stem augar applied during well installation. The push probe installation process which causes less damage to the overall soil profile also provides a more ready mechanism for rapid infiltration of water and consequent heaving of the sand pack (as occurred during this installation). Should future push probe wells be installed at this site great care must be taken to perform all operations in a very gradual manner to prevent water heaving phenomena.

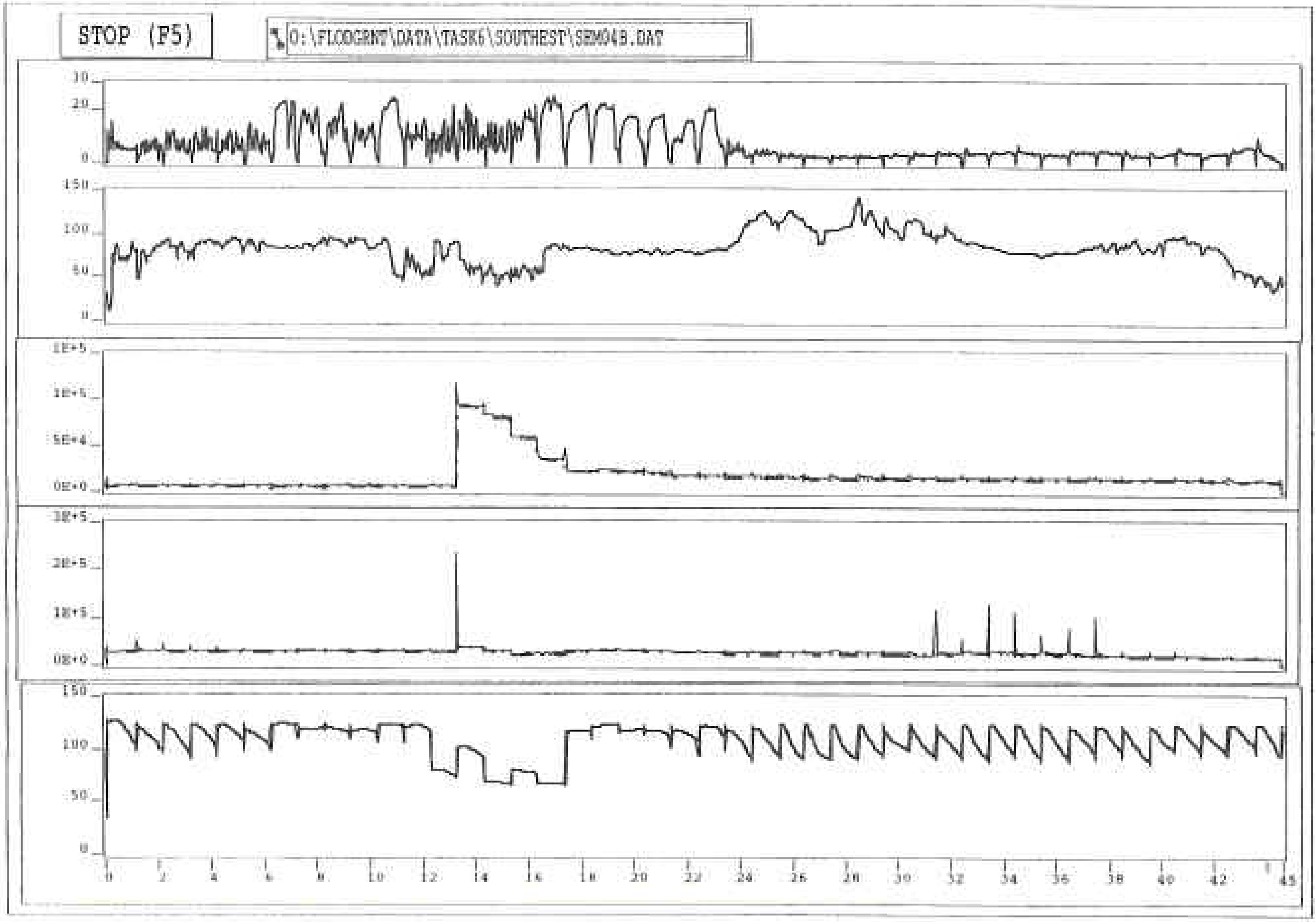
See attached registration for well construction details.

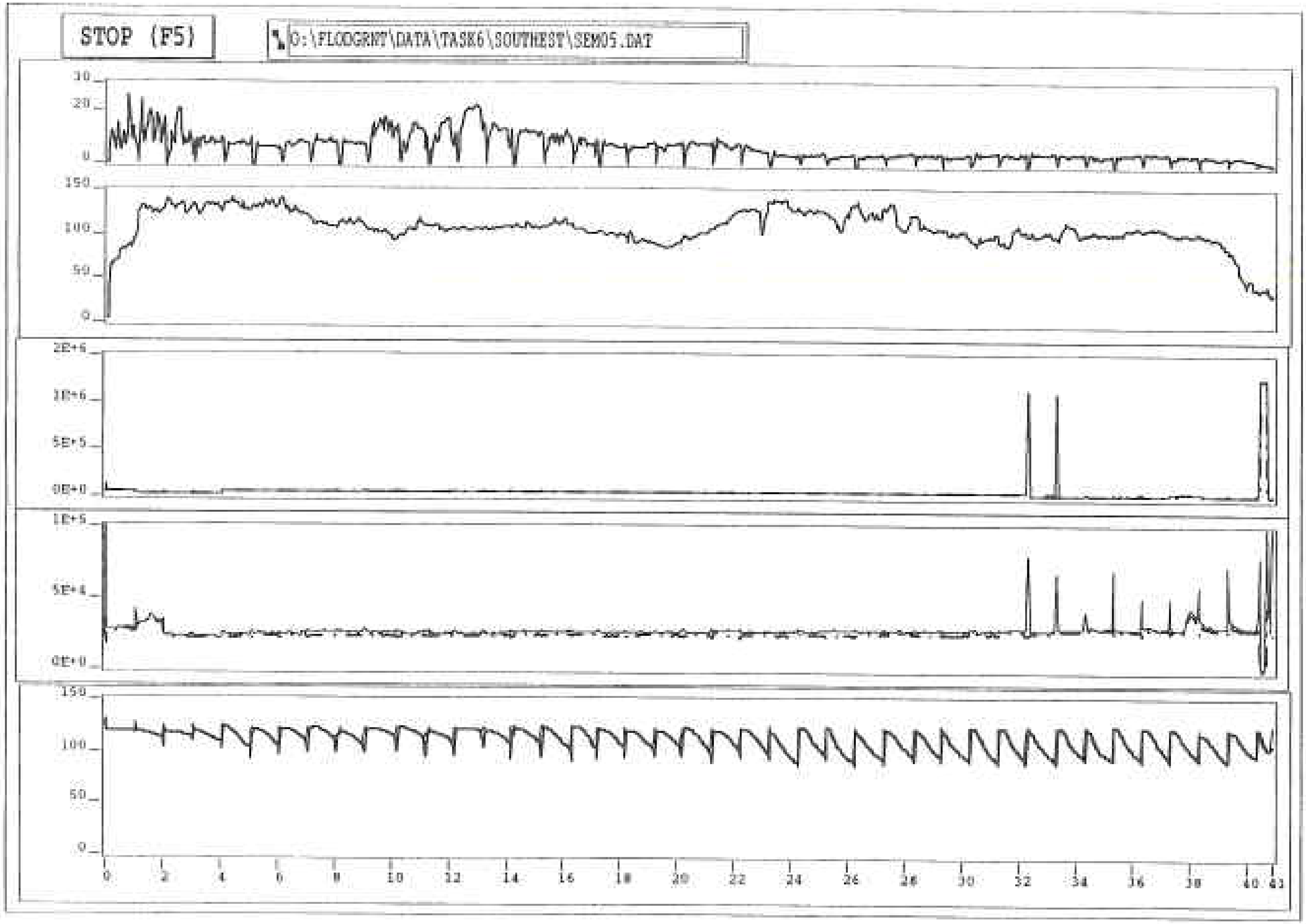

STOP (F5)
O:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM01-R.DAT
30
20
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
2E+6
1E+6
5E+5
0E+0
5E+5
140
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 51

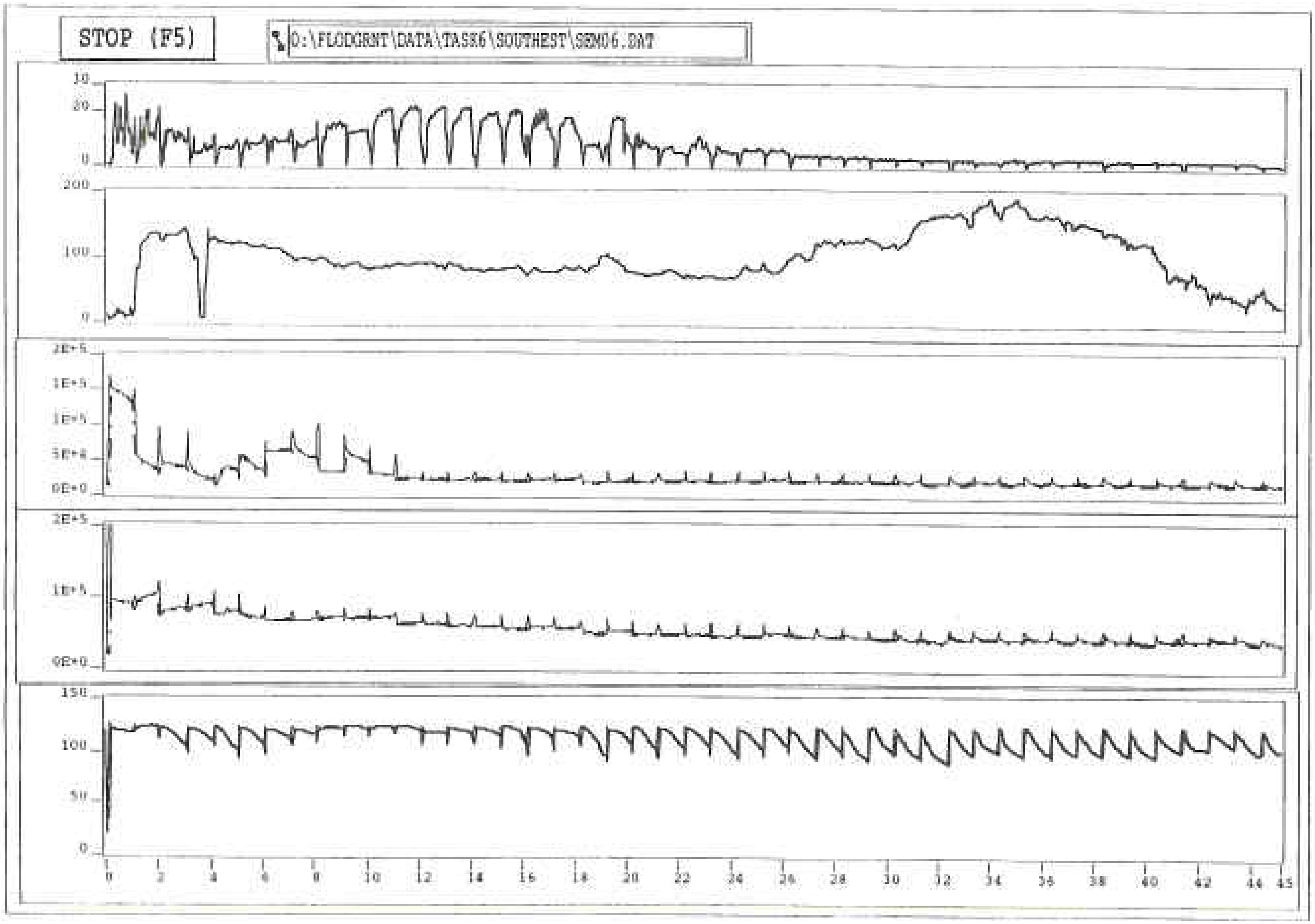


STOP (F5)
O:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM02.DAT
30
20
0
200
150
100
50
0
2E+6
1E+6
5E+5
0E+0
-5E+5
2E+6
1E+6
5E+5
0E+0
-5E+5
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 43


STOP (F5)
D:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM03.DAT
30
20
0
150
100
50
0
1E+5
1E+5
5E+4
0E+0
1E+5
1E+5
5E+4
0E+0
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
47


STOP (F5)
O:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM04B.DAT
30
20
0
150
100
50
0
1E+5
5E+4
0E+0
3E+5
2E+5
1E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 45


STOP (F5)
O:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM05.DAT
30
20
0
150
100
50
0
2E+6
1E+6
5E+5
0E+0
1E+5
5E+4
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 41



STOP (F5)
D:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM06.DAT
30
20
0
200
100
0
2E+5
1E+5
1E+5
5E+4
0E+0
2E+5
1E+5
0E+0
150
100
50
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 45

SOIL CHARACTERIZATION FOR SOUTHEAST SANITARY LANDFILL

RECEIVED
DEC 0 5 199

DNR MONITORING WELL # 2

MIP Probe 7

02/13/97 - 02/14/97

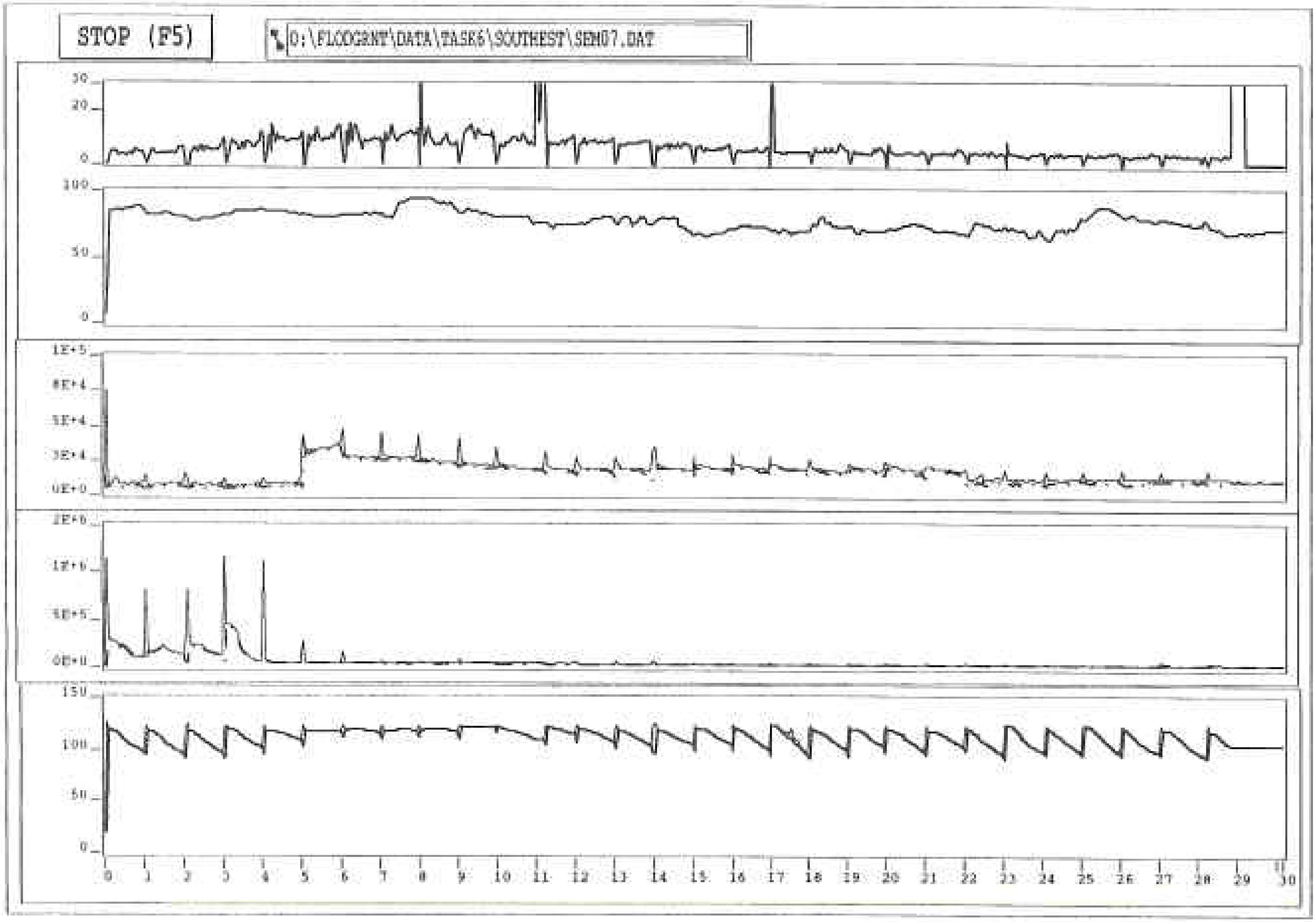
DEPTH (Ft)	MUNSELL COLOR MATRIX	MOTTLES	SOIL TYPE % SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES
0-2.0	mixed 10YR4/2		30	35	40	weak subangular blocky		
2.0-2.3	asphalt					massive		few fine tubular
2.3-4.0	10YR3/2		20 very fine	30		massive		few fine tubular
4.0-6.0	2.5Y4/1	5% 2.5Y5/1 mottles; 5% Fe/Mn staining[1]	10 very fine	30		weak subangular blocky		many fine & few fine tubular; few fine interstitial
6.0-10.0	2.5Y4/2	10YR5/2 silt coats[2] 10% Fe/Mn staining[1]; few water channels[2]	15	35		medium subangular blocky		many fine & many coarse tubular

1) Stain= iron and/or manganese formed by historic water movement.
2) Soil structure pathways formed by historic water movement.

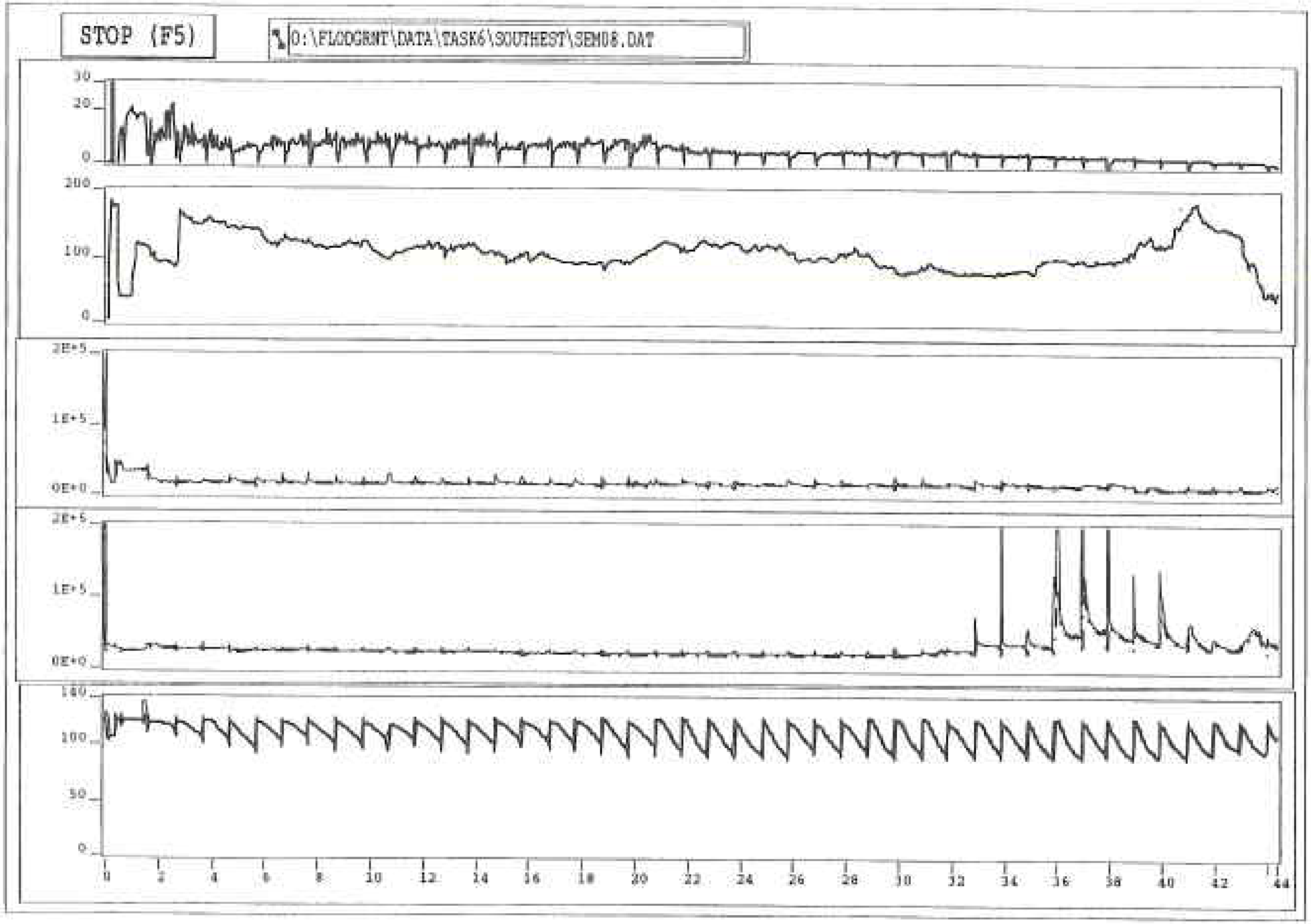
Permeability was not consistant throughout this profile. A layer of asphalt at ~2' sealed the profile off from the surface which consisted of compacted soils. Porous soil structures and evidence of historic water presence increased with depth. Most soil porosity appeared to be from tubular soil pores and water channels at the 10' depth. The asphalt seal serves as an aqui-tard & gas-tard from the surface thus providing an horizon for rapid vertical and horizontal soil gas movement.

The high clay content and the thin, delicate structure of the transmissive features of this soil would be easily disturbed and destroyed by excessive radial forces applied in well installation. The push probe installation process should causes less damage to the overall soil profile.

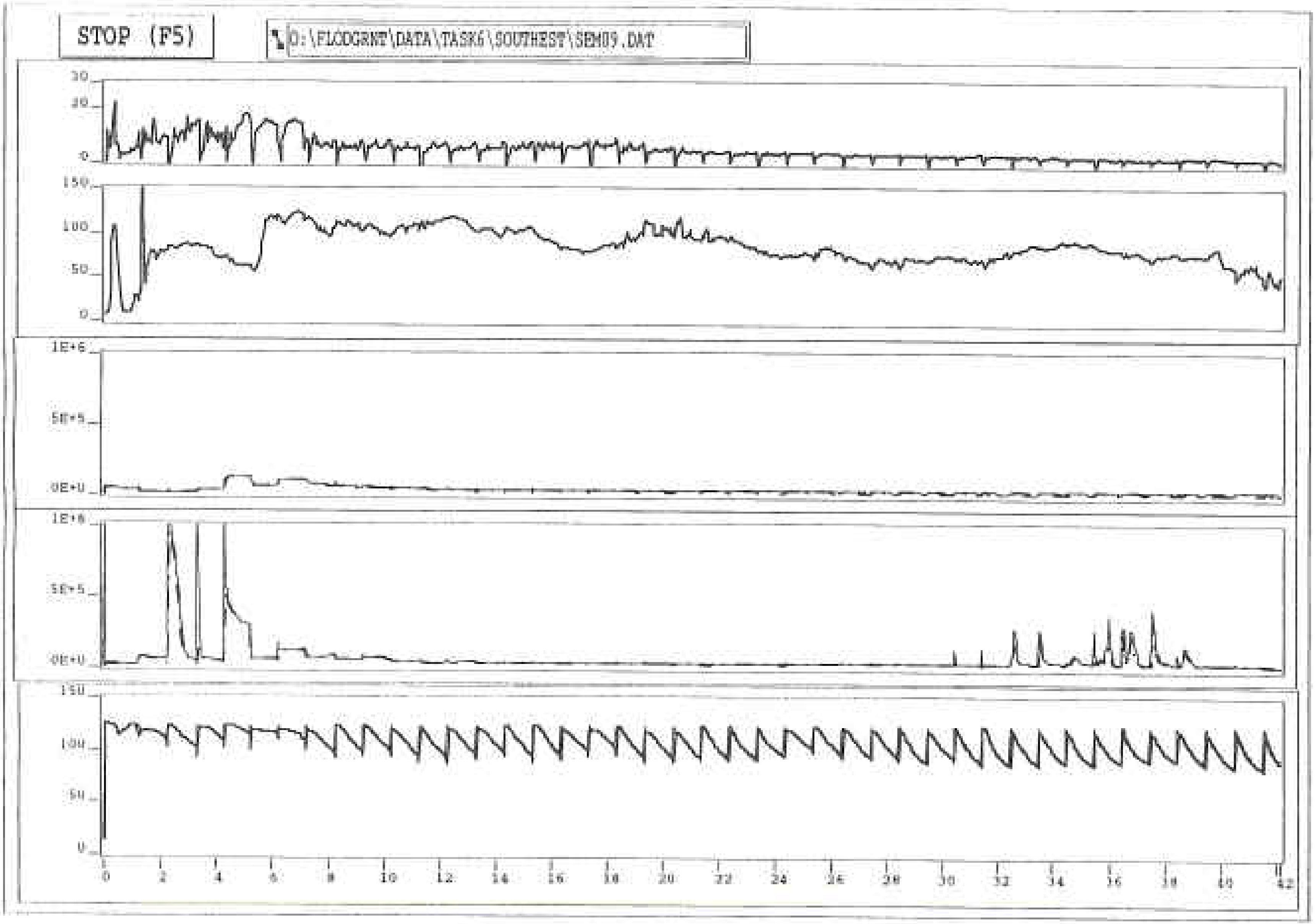
See attached registration for well construction details.



STOP (F5)
D:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM07.DAT
30
20
0
100
50
0
1E+5
8E+4
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30



STOP (F5)
O:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM08.DAT
30
20
0
200
100
0
2E+5
1E+5
0E+0
2E+5
1E+5
0E+0
140
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44



STOP (F5)
D:\FLODGRNT\DATA\TASK6\SOUTHEST\SEM09.DAT
30
20
0
150
100
50
0
1E+6
5E+5
0E+0
1E+6
5E+5
0E+0
150
100
50
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42

Appendix G

Mexico Landfill

MIP and Soil Logs

(See Appendix B cover page for MIP curve identification.)

SOIL CHARACTERIZATION FOR MEXICO SANITARY LANDFILL

DNR MONITORING WELL # 1

02/06/97

DEPTH (Ft)	MUNSELL COLOR MATRIX	MOTTLES	SOIL TYPE %SAND	%CLAY	% ROCK	STRUCTURE	PORES ROOTS	SOILPORES
0- 1.1	boring compaction							
1.1-2.5	mixed 10YR4/4+ 4/2		15	35		granular - weak subangular blocky	few medium, few fine	few very fine tubular
2.5-3.5	10YR4/4	10YR4/2 clay seams2), 20%Fe/Mn stains1)	10	35		few very fine subangular blocky	many fine	few very fine tubular
3.5-4.0	10YR3/1	<20% 10YR4/1	15	20		few very fine subangular blocky	few fine	few very fine tubular
4.0-5.4	boring compaction							
5.4-6.5	mixed 10YR4/2+ 5/1 Fe/Mn stains1)	<20% 10YR4/6+ 5/8; weak clay skins2)	<10	55		weak fine subangular blocky	few very fine+ 1 coarse	few fine tubular; few very fine interstitial
6.5-8.0	2.5Y5/5	55% 10YR5/6+ 5YR5/6; 5% Fe/Mn stains1); weak silt coats & clay skins2)	10	30	5 chert	medium fine subangular blocky		few fine tubular
8.0-9.2	boring compaction							

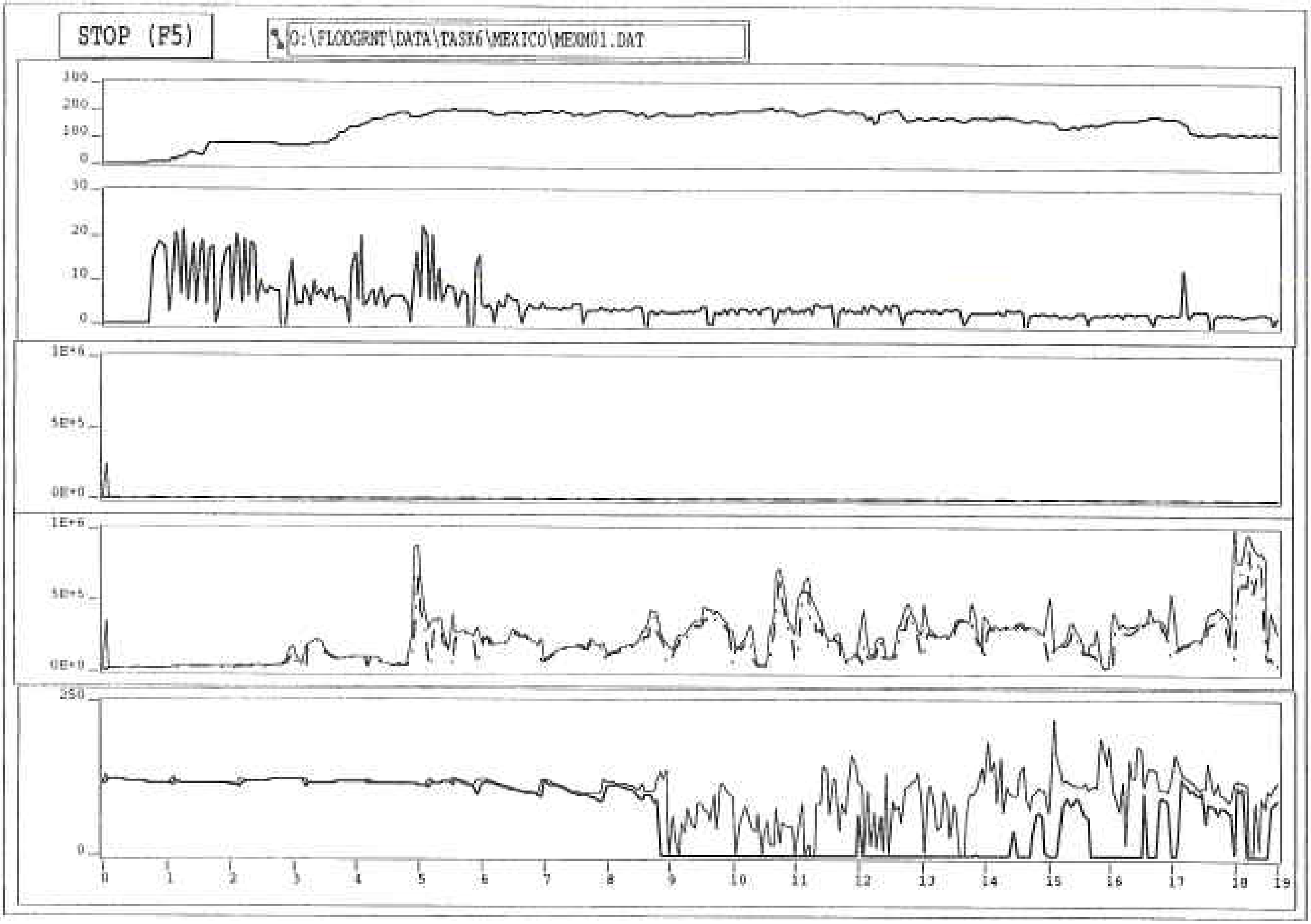
9.2-10.4	mixed 10YR5/3+ 4/2, earthworm		15	20		medium subangular blocky	few very fine, few coarse	few fine tubular
10.4-11.0	10YR4/2	<20% 10YR4/6; <1% Fe/Mn stains[1], clay skins[2]	5	65		medium subangular blocky	few fine, few very fine	very fine tubular
11.0-12.0	10YR5/2	20% 10YR5/8; 30%Fe/Mn stains[1], clay skins[2]	<10	75	5 chert	weak fine subangular blocky	few very fine	many very fine tubular
12.0-13.0	10YR4/3	<5% 10YR5/2	<10	40		medium subangular blocky, pragmatic	few fine	few fine tubular
13.0-15.0	10YR5/2	<25% 10YR5/6+ 5/8, <20% Fe/Mn stains[1]; 10YR4/2 clay skins[2]	15	75		very weak subangular blocky - massive; pragmatic	few fine	few very fine interstitial
15.0-16.0	10YR5/2	<25% 10YR5/6+ 5/8; <20% Fe/Mn stains[1]; 10YR4/2 clay skins[2]	20	75	15 chert	very weak subangular blocky - massive		
16.0-17.0	boring compaction							
17.0-19.0	10YR5/2	<10% Fe/Mn stains[1]; few weak clay skins[2]	25	40	15 chert	very weak subangular blocky - massive	few fine	many very fine tubular; few fine interstitial

1) Stain= iron and/or manganese formed by historic water movement.
2) Soil structure pathways formed by historic water movement.

Permeability was not consistent throughout this stratified profile although all horizons showed some degree of permeability. The upper 5' showed signs of manmade mixing. The soils from 5-10' were very plastic with a high degree of shrink/swell potential. The horizons from 10-16' were very dense due to increased clay content. The horizon between 12-15' showed pragmatic, oblique angled fracturing at the following intervals: 13.5, 13.8, 14.0, 14.5, 14.9 & 15.1'. Soils between 15 & 19' evolved from a decomposing chert bed. Roots and soil pores were found throughout the profile. These structures could act as aqua-ducts or gas-ducts depending upon water retention and shrink/swell cycling within the soil profile. Vertical movement throughout the profile could be inhibited by clay and silt layers in the profile. The predominance of silt and clay in this soil would also inhibit rapid vertical movement of gases and liquids when saturated. The weathered chert layer at 15-19' and the large pragmatic fractures at 12-15' would allow very rapid gas movement laterally especially during dry conditions.

The high clay content and the thin, delicate structure of the transmissive features of this soil would be easily disturbed and destroyed by excessive radial forces applied in well installation. The push probe installation process should cause minimal damage to the overall soil profile.

See attached registration for well construction details.

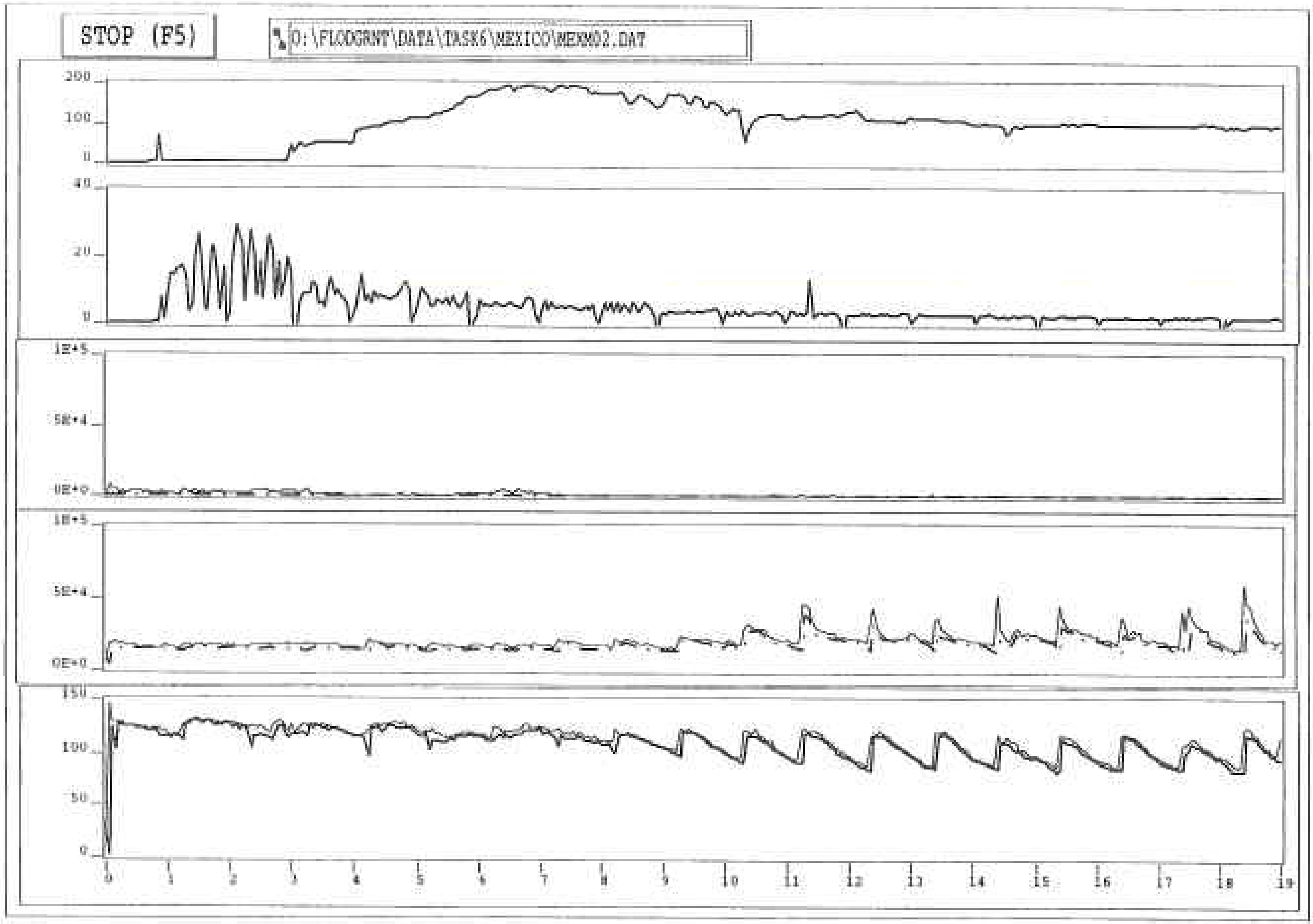

STOP (F5)
O:\FLODGRNT\DATA\TASK6\MEXICO\MEXM01.DAT
300
200
100
0
30
20
10
0
1E+6
5E+5
0E+0
1E+6
5E+5
0E+0
250
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

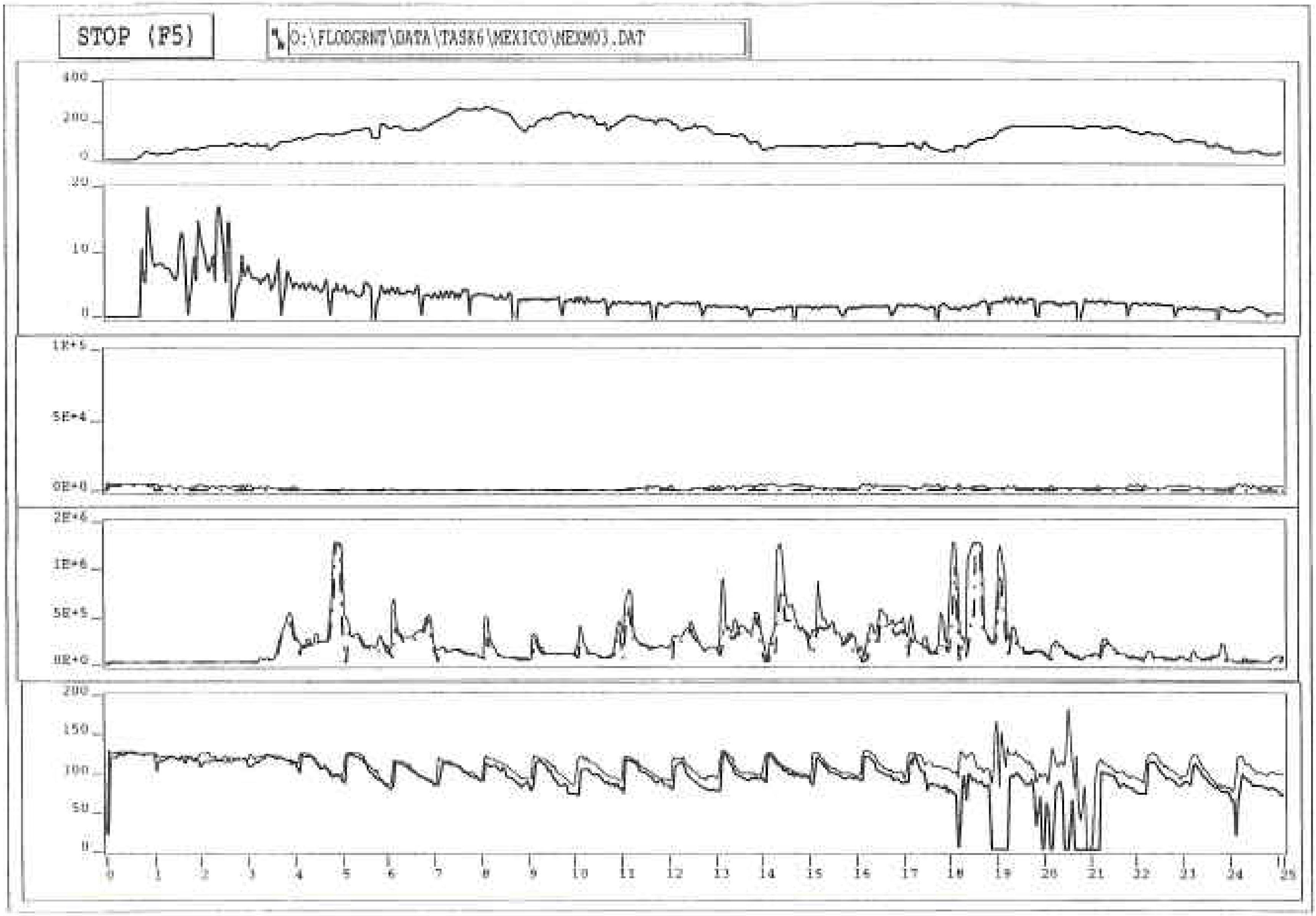
RECEIVED
NOV [illegible] 1997
SWMP

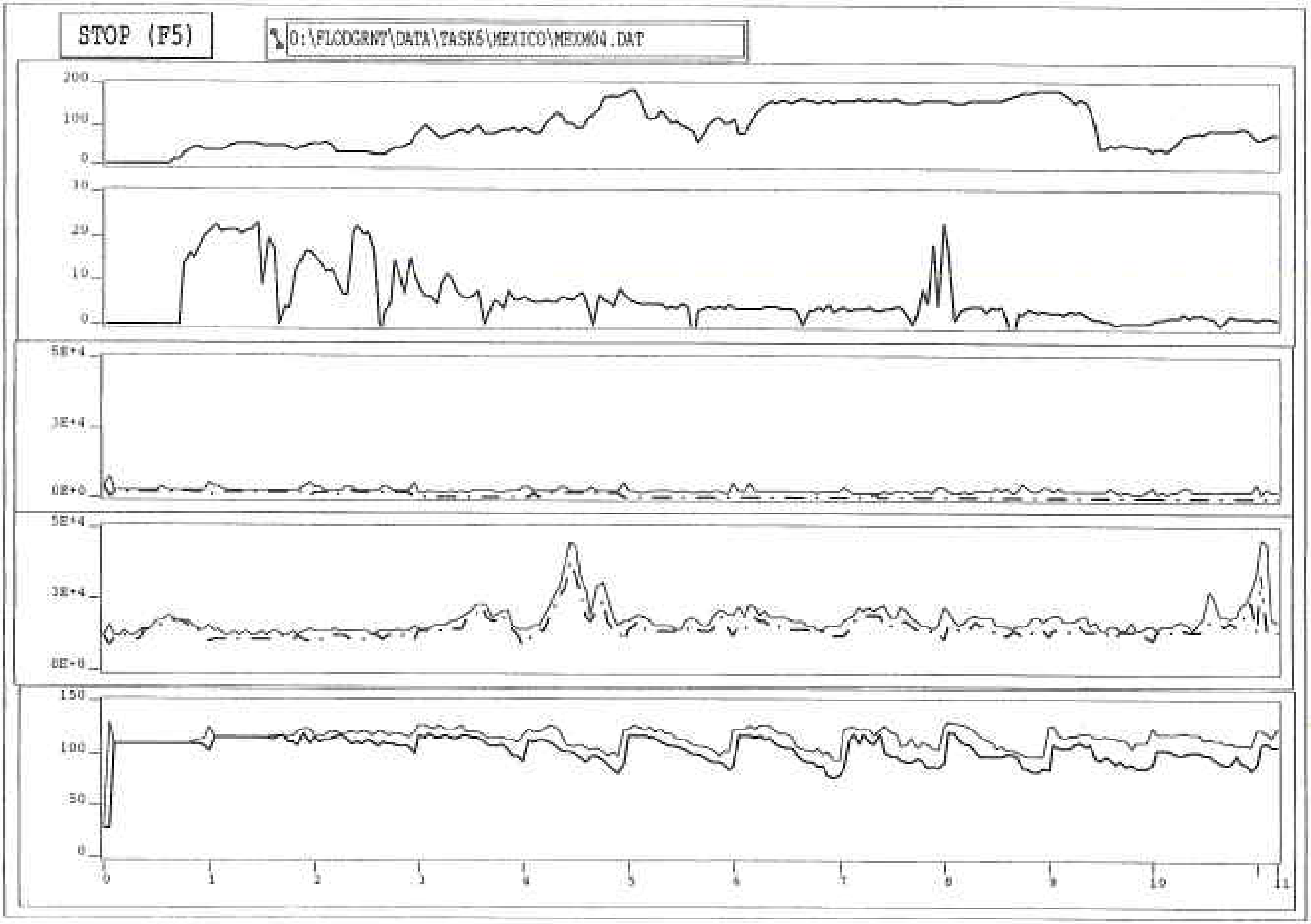
SOIL CHARACTERIZATION FOR MEXICO LANDFILL
BORING # 02
DATE July 8, 1997

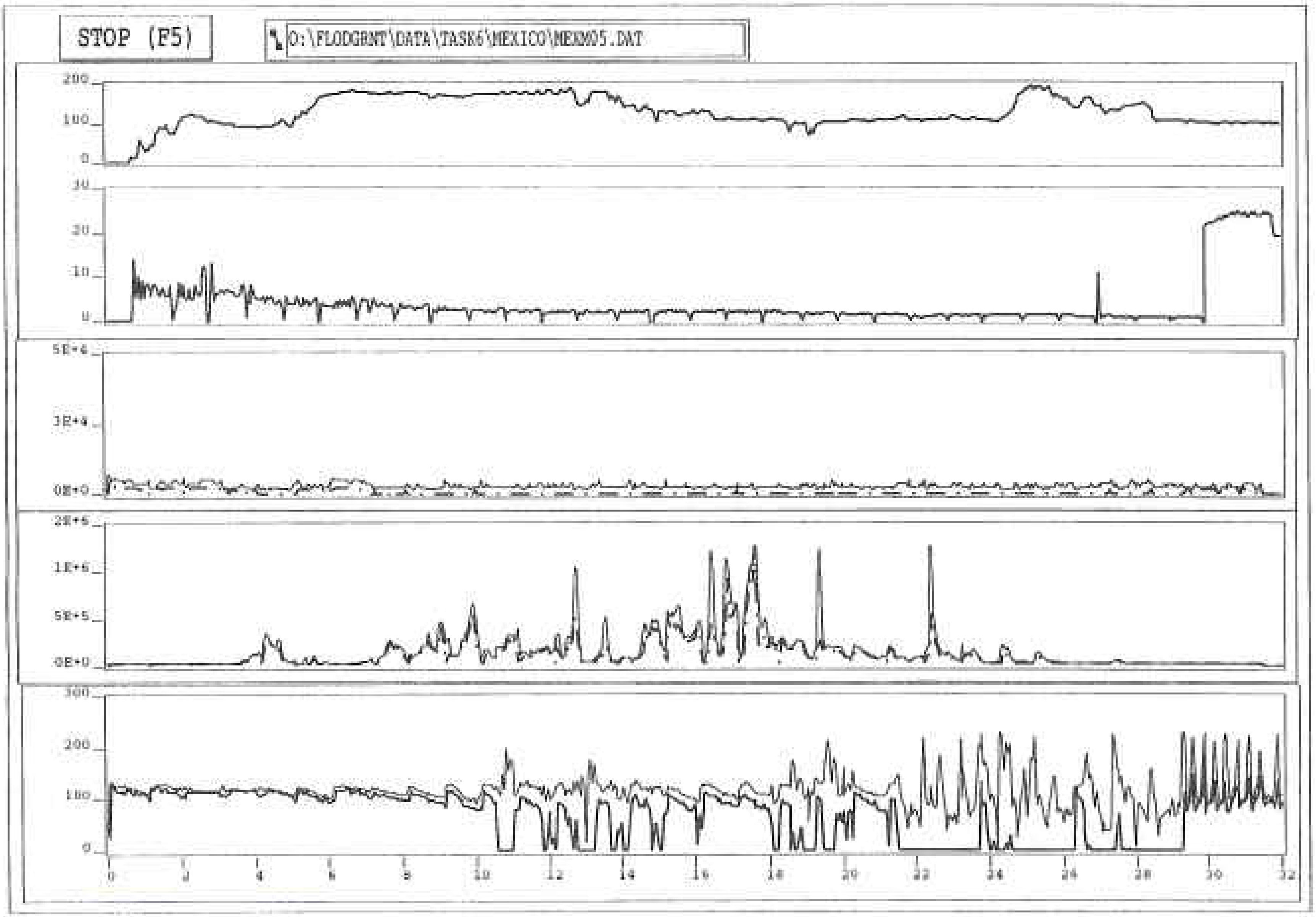
DEPTH (Ft)	COLOR MATRIX	COLOR MOTTLES	SOIL TYPE % SAND	SOIL TYPE %CLAY	% ROCK	STRUCTURE	PORES ROOTS	PORES SOILPORES	H_2O CHANNELS
0-4	(FILL)		<10	40			many fine, many very fine		Fe/Mn stains & nodules
4-7	10YR4/4 +4/2	10YR5/2 (20%)	<10	30		weak subangular blocky	many fine, many very fine	few medium interstiti-al	Fe/Mn stains & nodules
7-10	10YR3/2	10YR5/2 (15%)	<10	75		weak subangular blocky	few fine (followin-g cracks)	many fine intersti-tial	Fe/Mn stains
8.8-17	**pragmatiac**	**fractures @**	**~6" interval**						
10-15	10YR6/1	2.5YR4/6 + 5/8	<10	75		weak subangular blocky	few fine	few fine intersti-tial	Fe/Mn stains
15-17	10YR6/1	2.5YR4/6 + 5/8	15	75	15 ch	weak subangular blocky		few fine intersti-tial	Fe/Mn stains
17-19	10YR6/1	2.5YR4/6 + 5/8	15	75		weak subangular blocky		few fine intersti-tial	

The most striking feature of this soil is the presence of pragmatic fracturing from 8-17' at 6" intervals which would allow rapid movement of soil gases. The soil also exhibits high shrink swell potential which may influence the rate of gas movement based on soil moisture conditions.

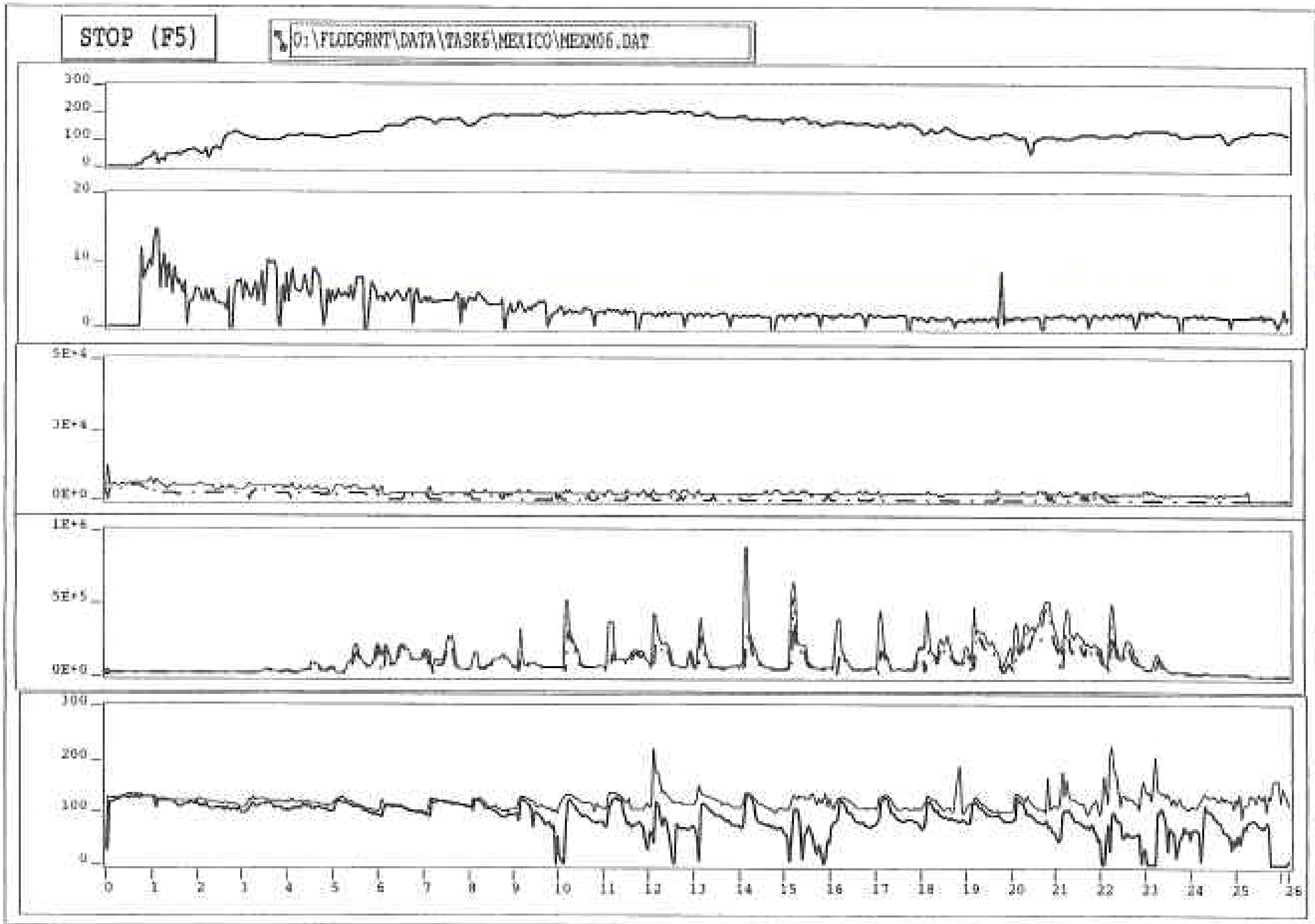

STOP (F5)
D:\FLODGRNT\DATA\TASK6\MEXICO\MEXM02.DAT
200
100
0
40
20
0
1E+5
5E+4
0E+0
1E+5
5E+4
0E+0
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

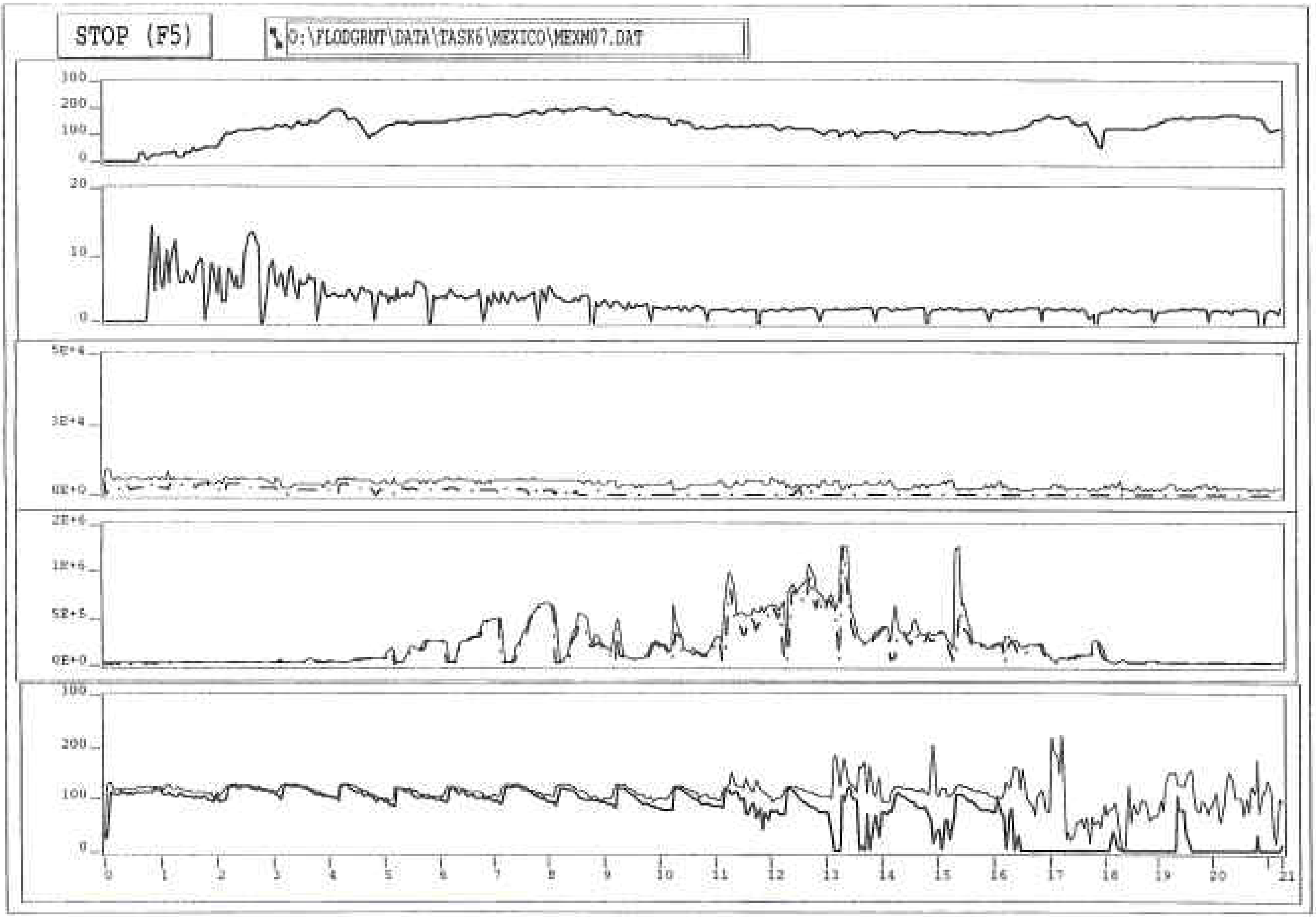

STOP (F5)
O:\FLODGRNT\DATA\TASK6\MEXICO\MEXM03.DAT
400
200
0
20
10
0
1E+5
5E+4
0E+0
2E+6
1E+6
5E+5
0E+0
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

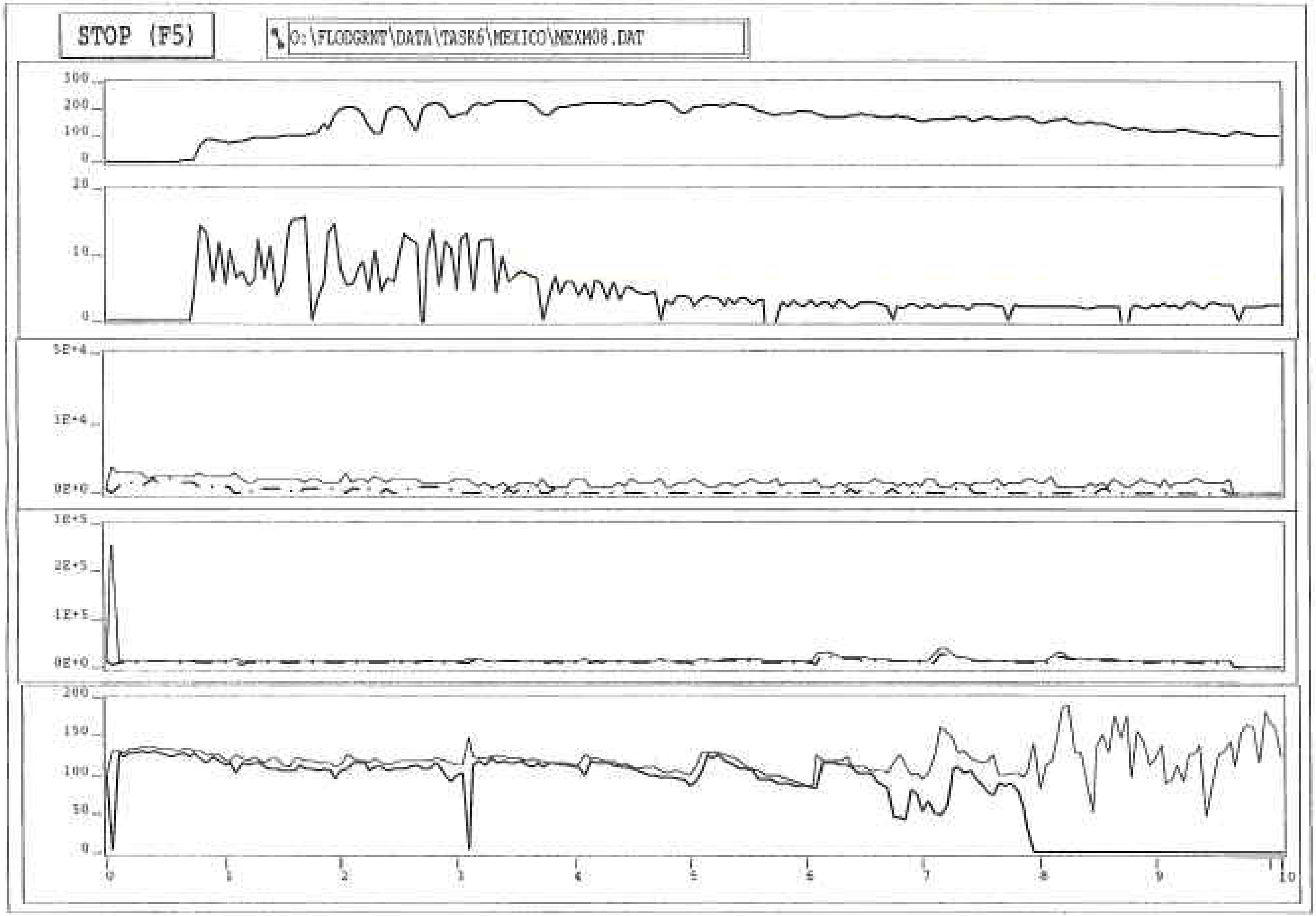

STOP (F5)
O:\FLODGRNT\DATA\TASK6\MEXICO\MEXM04.DAT
200
100
0
30
20
10
0
5E+4
3E+4
0E+0
5E+4
3E+4
0E+0
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10
11



STOP (F5)
O:\FLODGRMT\DATA\TASK6\MEXICO\MEXM05.DAT
200
100
0
30
20
10
0
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


STOP (F5)
O:\FLODGRNT\DATA\TA3R6\MEXICO\MEXM06.DAT
300
200
100
0
20
10
0
5E+4
0E+0
1E+6
5E+5
0E+0
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26


STOP (F5)
O:\FLODGRNT\DATA\TASK6\MEXICO\MEXM07.DAT
300
200
100
0
20
10
0
5E+4
3E+4
0E+0
2E+6
1E+6
5E+5
0E+0
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21


STOP (F5)
O:\FLODGRNT\DATA\TASK6\MEXICO\MEXM08.DAT
300
200
100
0
20
10
0
1E+4
0E+0
3E+5
2E+5
1E+5
0E+0
200
150
100
50
0
0
1
2
3
4
5
6
7
8
9
10