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LTV Steel Company

Revised Closure Plan
Clark Landfill

Volume I of II

Indiana Harbor Works
East Chicago, Indiana

REVISED CLOSURE PLAN
CLARK LANDFILL
INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

VOLUME I OF II

LTV STEEL COMPANY
3100 E. 45TH STREET
CLEVELAND, OHIO 44127

STS PROJECT NO. 08741-P

JULY 27, 1999

REVISED CLOSURE PLAN
CLARK LANDFILL
INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

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EXECUTIVE SUMMARY

This application summarizes the design and management plan for closure and post-closure care of the Clark Landfill at the Indiana Harbor Works of LTV Steel Company (LTV) in East Chicago, Indiana. The Clark Landfill is a steel mill waste disposal area within the Indiana Harbor Works. The landfill was operated as a non-hazardous waste landfill under an Interim Status Permit Application submitted in 1989. Type 1 Restricted Waste was disposed in the landfill.

The disposal facility is about 43 acres with a maximum fill height of approximately 100 feet above Lake Michigan. The steel mill wastes consist of slag, BOF dust and other steel mill waste. The landfill was filled to capacity and waste disposal ceased in March 1998. LTV has been in the process of preparing for and implementing closure of the Clark Landfill since about 1996. On August 6, 1997, a foundation and slope movement occurred along the south facing slope causing movements adjacent to and into the plant's water intake flume. Shortly after this movement, closure construction ceased and the flume was dredged to restore its hydraulic capacity. The flume conveys Lake Michigan water to the plant's No. 2 pumphouse.

Through subsequent geotechnical evaluations, it was determined that foundation and slope movements were caused by inadequate shear strength properties of glacial lake bed clay. Loading due to rapid filling to reconfigure the landfill slopes induced high pore water pressures in the natural glacial lake bed deposits. These pore water pressures limited the amount of shear strength gain in proportion to the additional vertical and horizontal stresses caused by landfill regrading. The movements observed on August 6, 1997 were due to overstressing the natural clays beyond their available shear strength.

This application proposes an amended closure plan which includes flume dredging, buttress installation in the flume along the toe of the south slope and landfill reconfiguration. The landfill reconfiguration will establish a stable landfill slope and

restore the required hydraulic capacity of the flume. A low permeability final cover is also proposed to limit infiltration of stormwater through the waste.

The permit application consists of a Ground Water Sampling and Analysis Plan prepared in general accordance with 329 IAC 10-29; a Closure Plan prepared in general accordance with 329 IAC 10-30; a Post-Closure Plan prepared in general accordance with 329 IAC 10-31, Construction Quality Assurance Plan prepared in general accordance with 329 IAC 10-17, a Dredge Disposal Plan and Closure and Post-Closure Cost Estimates. The above plans are included as Attachments 2, 3, 4, 5, 6 and 7, respectively, with a brief explanation of each plan presented below.

Ground Water Sampling and Analysis Plan

Four (4) monitoring wells are proposed around the perimeter of Clark Landfill. These wells are located on all sides of the landfill with general locations depicted on Drawing 589884 (Appendix B). These wells will be installed after the Phase II closure grading; probably in the year 2000. The wells are located in the uppermost aquifer and will be constructed in accordance with 329 IAC 10-21-4. Following well installation, the wells will be monitored in accordance with 329 IAC 10-21-1 to determine the direction of groundwater flow and to identify the upgradient and downgradient wells. One (1) upgradient and three (3) downgradient wells will be installed. All wells will be sampled quarterly the first year to establish the upgradient groundwater quality. Monitoring will continue on a semi-annual schedule in accordance with the Ground Water Sampling and Analysis Plan (GWSAP). Monitoring results will be reported in accordance with 329 IAC 10-21-6 and 329 IAC 10-21-1(t).

Closure Plan

An amended Closure Plan has been prepared to address the foundation and slope instability observed on August 6, 1997. The Closure Plan addresses the need to repair the foundation and slope movement which occurred on August 6, 1997 during closure construction grading and to achieve a factor of safety greater than or equal to 1.3 against significant future slope and foundation movements. The Closure Plan also addresses the need to maintain adequate hydraulic flow capacity of the intake flume from Lake Michigan to pumphouse No. 2. To achieve the above objectives, three design elements are proposed for the amended Closure Plan.

The first element involves minimal flume dredging to re-establish adequate hydraulic conveyance capacity. Secondly, a buttress fill is proposed in the intake flume to restabilize the south slope. Corps of Engineers 404, IDEM 401 Water Quality and IDNR Permit Applications were submitted on March 2, 1999 to dredge and partially fill about four acres of U.S. Waters in the flume. Thirdly, the landfill Closure Plan provides for regrading of the south exterior landfill slope to a less steep condition to achieve a factor of safety greater than or equal to 1.3. The landfill will be reconfigured to a less steep slope condition on the south side slope along the flume by transferring the excavated wastes to the north side of the landfill where the foundation stability is greater. The Closure Plan also proposes a geomembrane cover consisting of 40-mil LLDPE textured geomembrane with an aggregate cover and appropriate stormwater management structures.

These basic closure design concepts and performance criteria were discussed with IDEM on October 20, 1998. The Closure Plan attached in Appendix B outlines the proposed design in greater detail in general accordance with 329 IAC 10-30. A cost estimate and schedule to complete the Closure Plan are also included.

Post-Closure Plan

The Post-Closure Plan has been prepared in general accordance with 329 IAC 10-31 to minimize the need for further maintenance of the facility and to control the escape of solid waste and reduce leachate generation. The plan provides for regular inspections and ongoing monitoring of slope and foundation stability and groundwater quality. Inspections will check for erosion and final cover intactness on a quarterly basis the first two years, and semi-annually thereafter for the 30-year period of post-closure care. A cost estimate and schedule to complete the Post-Closure Care Plan is included.

Construction Quality Assurance Plan

The Construction Quality Assurance (CQA) Plan has been prepared in general accordance with 329 IAC 10-17. The CQA Plan addresses the site specific issues for all construction activities including, but not limited to, flume filling, waste regrading, landfill cover materials and installation, drainage structures, access roads and groundwater monitoring wells. A key component of the CQA Plan involves continued monitoring of the slope movements and pore water pressure during and between mobilizations of the various construction activities.

Dredge Disposal Plan

Approximately 4,000 cubic yards of material will be dredged from the No. 2 pump house intake flume and placed in a one- to two-acre area on the north side of the Clark Landfill. Prior to dredging, four sediment samples will be collected and analyzed for volatile organic compounds, semi-volatile organic compounds, target metals, and polychlorinated biphenyls to verify the environmental quality of the sediment. Previous analyses of the sediment indicate that the material has not been environmentally impacted. Laboratory

quality assurance/quality control procedures will be followed during the proposed analyses.

Closure and Post Closure Cost Estimate

A current cost estimate for closure and post-closure care has been prepared. The estimate was compiled from third party estimates with the exception of a cost estimate from exclusive trade practices at the Indiana Harbor Works facility . The cost estimates are presented on the attached spread sheets. The spread sheet information has been incorporated into IDEM Forms SWF-3 and SWF-4. The estimated total cost of closure is $18,791,510. The cost estimate for post-closure care is $1,802,932.

CLARK LANDFILL
LTV STEEL COMPANY, INC.
EAST CHICAGO, INDIANA

GROUND WATER SAMPLING AND ANALYSIS PLAN (GWSAP)

Prepared by

STS Consultants, Ltd.
July 1999

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1 INTRODUCTION

This Ground Water Sampling and Analysis Plan (GWSAP) has been prepared for the Clark Landfill site. The Clark Landfill is a Type 1 Restricted Waste Disposal Facility located at the LTV Steel Company, Indiana Harbor Works (LTV) located in East Chicago, Indiana. This plan describes routine sampling and analysis procedures in response to 329 Indiana Administrative Code 10-29.

The following plan covers the procedures for collecting representative samples from ground water monitoring wells and the basic laboratory requirements for obtaining valid, defensible data. The plan is limited to sampling and analysis requirements and does not include monitoring well placement, design and construction, or well development procedures. However, any well that becomes consistently dry or unserviceable may require replacement. Well replacements shall be installed in accordance with 329 IAC 10-21-4. All groundwater monitoring wells shall be easily visible and identified with the Agency monitoring point designation and a padlocked protective cover must be installed.

2 FIELD PROCEDURES

2.1 Basic Elements for a Field Sampling Health and Safety Plan

A health and safety plan is required for all ground water sampling events at the Clark Landfill. This GWSAP lists some general safety precautions which should be incorporated into the Ground Water Sampling Health and Safety Plan; however, this document in no way constitutes the actual plan. Prior to monitoring, well purging and sampling, a proper Ground Water Sampling Health and Safety Plan must be in place. The responsibility of designing the site Ground Water Sampling Health and Safety Plan will be the duty of the party performing the actual work and at a minimum, the plan should:

- Name key personnel and alternates responsible for site safety.
- Describe the risks associated with ground water sampling field operations.
- Confirm that field personnel are adequately trained to perform their job responsibilities and to handle the specific hazardous situations they may encounter.
- Describe the protective clothing and equipment to be worn by personnel during ground water sampling operations.
- Describe the field program for periodic air monitoring, any personnel monitoring, especially to address any potential landfill gas (see Section 2.1.4).
- Describe the actions to be taken to mitigate any existing field hazards.
- Define site and sampling point access measures and include a site map with sampling point locations marked.
- Establish any required field decontamination procedures for personnel and/or equipment.
- Set forth the field standard operating procedures utilized by the firm collecting the samples.
- Set forth a field contingency plan for safe and effective response to emergencies including maps of emergency routes on and off LTV property with location(s) of nearest hospitals.

This GWSAP lists some general safety precautions which must be met by a health and safety plan. This should not be construed as an exhaustive list of all such precautions.

A health and safety plan is developed to assist personnel in understanding and avoiding potential health and safety concerns that may be associated with ground water sampling at a landfill. This plan shall be reviewed by the sampling crew prior to each sampling event and each individual involved in the sample collection process should be knowledgeable in the contents and implementation of this plan.

In addition, each laboratory facility should have their own standard laboratory health and safety plan as required by current OSHA regulations.

2.1.1 Potential Dangers

Potential dangers associated with ground water sampling at a landfill consist of the following.

- Landfill equipment traffic
- Mill traffic
- Inhalation of airborne contaminants, including landfill gas
- Splash-hazard from handling ground water samples, resulting in skin contact with or ingestion of potentially contaminated water
- Explosion of landfill gases at the well head
- Snakes, insects, poison ivy, etc.
- Hornets or wasps nesting in well protector casings
- Exposure to extreme temperatures of heat and cold
- Loose footing in rockfill cover areas

2.1.2 Personal Protective Equipment

The following level of protection is anticipated for ground water sampling events. Levels of protection are as defined by OSHA. Higher levels of protection will be used as dictated by site conditions.

Level D Protection

- Coveralls
- Safety boots/shoes
- Safety glasses or chemical splash goggles
- Disposable gloves

2.1.3 Decontamination Procedures

Decontamination of ground water purging and sampling equipment is addressed in Section 2.2.4. Decontamination of personnel during ground water sampling events will consist of discarding disposable gloves and washing hands with soap and water after sampling procedures are completed at each well location. Thorough personnel decontamination should be conducted prior to eating and/or drinking.

2.1.4 Other

- A MSA Gascope Combustible Gas Indicator or equivalent device will be used to check each monitoring well for the presence of methane gas. Measurements are to be taken immediately after the well cap has been removed. All necessary calibrations and maintenance procedures found in the manufacturer's operation manual are to be followed. Calibration information and monitoring results are to be recorded on the LTV Field Information Log.

- Absolutely no smoking is allowed during ground water sampling procedures.

- Water should be made available on site for drinking and decontamination purposes.

- Equipment should be cleaned prior to storage or transportation offsite. Suitable storage is required for all equipment and supplies.

- A first-aid kit and fire extinguisher must be maintained and carried in each vehicle used during ground water sampling events.

2.1.5 Emergency Assistance Information

The following information is provided in case of an emergency.

Acute Exposure System(s):	First Aid:
· Eyes (slight to moderate irritation)	· Flush with water for 15 minutes
· Skin (irritation, redness, edema, drying)	· Wash with soap and water
· Respiratory (dizziness, irritation of eyes, nose, throat, vomiting, bluish skin, central nervous system (CNS) effects)	· Remove to fresh air
· Ingestion	· Do not induce vomiting (can cause chemical pneumonitis). Call physician.

Hospital:

7:00 A.M. to 5:00 P.M.	5:00 P.M. to 7:00 A.M.
· LTV Medical Hospital Phone (219) 392-2459	LTV Security Transport to St. Catharines Phone: (219) 391-2595

Emergency Transportation:

· Call LTV Ambulance (219) 391-2345

Emergency Route to Hospital:

· All transports via LTV Ambulance (219) 391-2345

2.1.6 Personnel Acknowledgement

A form should be provided so that it may be documented that all personnel associated with the project have read and are familiar with the Ground Water Sampling Health and Safety Plan document.

All ground water sampling personnel and project managers must sign the form, acknowledging that they have read and understand the document.

2.2 Sample Event Preparation and QA/QC

2.2.1 General Event Preparation

The laboratory performing the ground water analysis shall supply all necessary coolers, pre-cleaned containers, trip blanks, chemical preservatives, packaged refrigerant, labels, custody seals, chain-of-custody and shipping forms. All field data shall be entered on a Field Information Log (see Pages B.1 through B.6 in Appendix B). Adequate instructions to the laboratory must be given in advance of each monitoring event. Details concerning any changes to the monitoring plan and/or procedures need to be given to the laboratory in writing prior to the field sampling personnel arriving on the site. A specific contact person shall be established at both the facility and contract laboratory for communication between the two (2) parties.

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2.2.2 Sample Container Selection

Sample containers need to be constructed of a material compatible and non-reactive with the material it is to contain. Consult Page B.7 in Appendix B, *Containerization and Preservation of Samples*, to determine the number, type and volume of appropriate containers. As noted in Section 2.2.1, the contract laboratory performing the analysis shall supply all the required containers. In special circumstances when the facility must obtain its own containers, these containers will be purchased from local container distributors with the exception of the septum vials and PTFE (e.g. Teflon®) lined caps required for organic analyses which are available from laboratory supply companies. Metal lids shall not be utilized for any sample containers.

2.2.3 Sample Container Preparation

Sample containers will be purchased as a pre-cleaned product or cleaned in the laboratory in a manner consistent with EPA protocol. An example protocol is as follows:

- Bottles, vials, cubitainers, liners and caps hand washed in a laboratory-grade, non-phosphate detergent.
- Rinse three (3) times with distilled water.
- Rinse with a chemically pure or reagent grade 10% nitric acid solution.
- Rinse three (3) times with organic-free water.
- Oven-dried (air-dried for high-density polyethylene containers and caps).

After containers and caps are cool and dry, cap each container and store in a clean and dry environment.

2.2.4 Equipment Preparation Prior to Site Arrival

Dedicated pump purge and sample devices for the Clark Landfill are described in detail in Sections 2.3.3 and 2.4.3. This section outlines the equipment preparation prior to site arrival for a specific monitoring event. This equipment preparation includes minimum decontamination procedures for water level indicator(s), filter device, pH/temperature meter, specific conductivity meter and turbidity meter. Operation and calibration information for field instruments are contained in Appendix C.

- Water Level Indicator(s) - Water level indicator(s) will be decontaminated prior to initial site arrival by hand washing the sensor probe and entire length of tape in a laboratory grade non-phosphate detergent followed by a triple rinse with deionized water. While the tape is reeled back onto the carrying spool, the tape and probe will be wiped down with a clean dry paper towel.

- pH / Temperature Meter - Meters will be decontaminated by hand washing the sample cells in a laboratory grade non-phosphate detergent followed by a triple

rinse with deionized water. Meters will then be checked for proper calibration and operation as specified in Appendix C. Any malfunctioning meters will be replaced prior to packing.

- Specific Conductivity Meter - Meters will be decontaminated by hand washing the probes in a laboratory grade non-phosphate detergent followed by a triple rinse with deionized water. Meters will then be checked for proper calibration and operation as specified in Appendix C. Any malfunctioning meters will be replaced prior to packing.

- Turbidity Meter - The meter will be decontaminated by hand washing the sample cells in a laboratory grade non-phosphate detergent followed by a triple rinse with deionized water. Meters will then be checked for proper calibration and operation as specified in Appendix C. Any malfunctioning meters will be replaced prior to packing.

- Filtration Device - Filtering of ground water samples will be done with in-line disposable filtration cartridges requiring no decontamination. A sufficient number of disposable filtration cartridges will be taken to the site.

2.2.5 Field QA/QC Samples

Field QA/QC samples consist of two (2) primary areas of quality control. The first part is the quality control of sample contamination which may occur in the field and/or shipping procedures. This is monitored in the trip blank(s), field blank(s), and the equipment (rinsate) blank(s). A basic description of each is as follows:

- Trip Blank - These samples will be prepared in the laboratory by filling the appropriate clean sample containers with organic-free water and adding the applicable chemical preservative, if any, as indicated on Page B.7 for each type of sample. These containers are to be labeled "Trip Blank", the analyses to be performed on each container indicated, and then shipped in the typical transportation cooler to the field and back to the laboratory along with the other sample set containers for a given event. This blank is tested for any contamination that may occur as a result of the containers, sample coolers, cleaning procedures, or chemical preservatives used. Trip blanks shall be taken and analyzed at least one (1) for each sampling event or a minimum of a one (1) in twenty (20) sample point (monitor well) batch per monitoring event.

- Field Blank - Field blank containers will be prepared in the field at a routine sample collection point during a monitoring event by filling the appropriate sample containers from the field supply of deionized water. This field supply water shall be the same water used for cleaning and decontamination of all field purge and sample equipment. This blank is tested for any contamination that may occur as a result of site ambient air conditions and serves as an additional check for contamination in the containers, sample transport coolers, cleaning procedures, and any chemical preservatives. Field blanks shall be taken and analyzed at least one (1) for each sampling event or a minimum of a one (1) in twenty (20) sample point (monitor wells) batch per monitoring event.

- Equipment (Rinsate) Blank - These blanks will be prepared in the field immediately following decontamination cleaning procedures on any non-dedicated equipment used for purging, sampling or sample filtration. Following decontamination, field supply deionized water is passed through the non-dedicated equipment in the same procedure as a ground water sample. This blank confirms proper field decontamination procedures on non-dedicated equipment utilized in the field.

  Equipment blanks shall be taken and analyzed for all applicable parameters anytime non-dedicated equipment is used or new equipment is being dedicated to a well at a sample point (monitor well) batch minimum of one (1) in twenty (20) per monitoring event.

Other Field QA/QC Samples - A second area of standard field QA/QC samples are field duplicates, matrix spike and matrix spike duplicates.

- Field duplicates are an extra set of samples taken at a particular monitoring point and labeled "Field Duplicate".

  These are independent samples which are collected as close as possible to the same point in space and time. They are two (2) separate samples taken from the same source, stored in separate containers, and analyzed independently.

  Field duplicates are useful in documenting the precision of the sampling and analytical process. Samples shall be collected in proper alternating order for the sample point and field duplicate for each parameter (e.g. collect first VOC sample, then duplicate VOC sample; then collect first metals sample, then duplicate metals sample; and so on). Field duplicates shall be taken and analyzed at a sample point (monitor well) batch minimum of one (1) in twenty (20).

- Field samples for matrix spike and matrix spike duplicate analyses are taken in the same manner as field duplicates and allow sufficient volumes of sample to perform matrix spike and matrix spike duplicate analyses.

  Matrix spikes are those samples having a known amount of a target analyte added at the lab to the sample prior to sample preparation and analysis. The matrix spike is used to determine the bias of a method in a given sample matrix.

  Matrix spike duplicates are intralaboratory split samples spiked with identical concentrations of target analyte(s). The spiking occurs at the lab prior to sample preparation and analysis. They are used to document the precision and bias of a method in a given sample matrix. Appropriate field QA/QC documentation should be recorded in the field notes (e.g. location where field blank was collected).

2.3 Well Purge

2.3.1 General Well Purge Information

Purging a monitoring well is just as important as the subsequent sampling of the well. Water standing in a monitoring well over a certain period of time may become unrepresentative of formation water because of chemical and biochemical changes which may cause water quality alterations.

Prior to monitoring well purge, inspection of the monitoring well integrity will be performed utilizing the LTV Monitoring Well Condition Form (see Page B.12).

2.3.2 Water Level Measurement

Prior to any purge or sampling activity at any monitoring wells, water level measurements are required to be taken at all monitoring wells. Ground water elevations in wells which monitor the same waste management area must be measured within a twenty-four (24) hour period to avoid temporary variations in ground water flow which could preclude accurate determination of ground water flow rate and direction. Measurement of the static water level is important in determining the hydrogeologic characteristics of the subsurface (e.g. upgradient and downgradient). Also, as indicated on the LTV Field Information Log (Pages B.1 through B.6), several other water level measurements are to be taken during the course of purge and sampling.

Water level indicator equipment will be constructed of chemically inert materials. During mobilization preparation and following each monitoring point, the water level indicator will be decontaminated at each well with a non-phosphate detergent followed with multiple deionized water rinses. Decontamination water will be disposed of in each respective well's purge water containers. Water levels will be measured with a precision of ± 0.01 foot.

Each monitoring well shall have a reference point located and properly marked at the top of the riser casing/dedicated pump cap established by a licensed surveyor. This reference point elevation should be measured to an accuracy of ± 0.01 ft. Mean Sea Level (MSL) and will be noted on the LTV Field Information Log. Basic procedures for water level measurement are indicated on Page C.11.

2.3.3 Purge Equipment

Ground water wells will be purged with temporarily installed variable speed submersible pumps or hand (disposable or dedicated) bailers (preferably Teflon) with non-absorbent cord and bottom check valve. Parts of the pump contacting the ground water will be constructed of stainless steel and Teflon.

2.3.4 Purge Procedures

The sample crew will put on clean disposable gloves and an initial water level will be taken as described in Section 2.3.2.

Standard procedures for ground water monitor well purge is as follows:

1. Start the portable generator (or other power source compatible with the temporary pump), electrical voltage to the converter must always be ± 10% of the specified power supply. Generator should be in the downwind direction and as far as practical from the sample point. Check power supply with voltmeter for proper voltage range.

2. For bailer operation, support cord should be wrapped on a reel and drop cloth consisting of clean plastic shall be provided for all equipment laydown. Disposable or dedicated bailers are preferred.

3. For portable pump use, the rate of discharge and volume purged shall be checked periodically with a graduated bucket and timer or an in-line device. The preferred rate of discharge when purging is 1.0 gallons per minute.

2.3.5 Purge Volume

Low yield wells will be purged to dryness. Moderate to high yield wells will be purged a minimum of three (3) well volumes and to stabilization of field parameters temperature, conductivity, pH, and preferably turbidity values of 5 NTUs or less.

- Parameter stabilization is defined as:

  - Specific Conductivity = ± 10% for three (3) consecutive measurements at approximately five (5) minute increments.

  - pH = ± .10% standard pH units for three (3) consecutive measurements at approximately five (5) minute increments.

  - Temperature = ± 10% for three (3) consecutive measurements at approximately five (5) minute increments.

  - Turbidity = 5 NTUs or less.

Check water level after purge is complete.

Monitoring of temperature, pH, conductivity, and turbidity for stabilization will be recorded on each LTV Field Information Log (see Pages B.1 through B.6). Total purge volume will be monitored with a measurement bucket during purging.

2.3.6 Purge Water Management

If purge water is known to be historically contaminated or suspect due to prior analytical data, the water shall be stored in appropriate containers until analytical results are available. After review of these analyses, proper arrangements for disposal or treatment shall be made. Otherwise, purge water will be discarded on the ground away from the monitor well area.

2.4 Monitoring Well Sample Collection

2.4.1 General Sample Collection Information

Sampling should take place as soon as purging is complete if the well has sufficient recharge. The time interval between the completion of well purge and sample collection normally should not exceed twenty-four hours.

2.4.2 Sample Collection Order

Monitoring well sampling at each event shall proceed from upgradient wells to downgradient wells. Samples will be collected and containerized according of the volatility of the requested analyses. A specific collection order is as follows:

- Field Parameters (Temperature, Specific Conductivity, pH, Turbidity)
- Volatile Organics
- Semi-Volatile Organics
- Metals
- Inorganics

2.4.3 Sampling Equipment/Procedures

Ground water samples shall be collected with temporarily installed variable speed submersible pumps or bailers. Parts of the pump or bailer contacting the ground water sample will be constructed of stainless steel and Teflon. Standard procedures for collecting representative ground water samples after completion of purge is as follows:

<u>Pump Sampling</u>

a. Reduce flow from pump (if used) to approximately 100 ml/minute and flow at this rate for approximately five (5) minutes.
b. Sample field parameters (conductivity, temperature, pH and turbidity).
c. Sample for volatile organic compounds.
d. Sample for semi-volatile organics
e. Sample metals.
f. Sample general water chemistry parameters.

<u>Bailer Sampling</u>

a. Lower bailer slowly into water column unseating bottom discharge ball check valve and lowering up to length of bailer.
b. Retrieve sample slowly without aeration and agitation.
c. Unseat bottom discharge valve (tilt bailer if necessary) to fill decontaminated container and test for field parameter (conductivity, temperature, pH and turbidity).
d. Continue to retrieve additional samples if necessary and sample in order for:
    volatile organic compounds
    semi-volatile organic compounds
    metals
    general water quality parameters

(For dissolved analytical parameters, connect in-line filter cartridge to end of discharge

line or use paper filter and funnel for bailer.)

2.4.4 Sample Filtration

The primary reason for filtration of a sample is to remove sample turbidity resulting from a number of factors including natural formation fines. All efforts must be made to delete or minimize controllable factors to allow the collection of as representative and turbid-free sample as possible.

Ground water samples for any required dissolved constituents will be filtered at each respective monitor well during sample collection with an in-line .45 micron disposable filter cartridge. Ground water sample field filtering procedures are indicated on Page C.12 - C.13. When samples are filtered, any acid preservatives will be added after filtration to avoid breaking down clay molecules or placing adsorbed ions into solution, which could result in the generation of artificially high concentrations of metals. Sampling forms will indicate if the samples are filtered or unfiltered.

2.4.5 Sample Preservation

All samples will be containerized and preserved according to Pages B.7 and B.8, *Sample Containerization and Preservation.* To obtain the most representative sample possible, preserving the sample for transportation and storage to the laboratory is also important.

Methods of preservation are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Samples requiring refrigeration to four degrees Centigrade will be accomplished by placing the sample containers immediately into coolers containing wet ice or the equivalent and delivering to the analytical laboratory as soon as possible.

2.4.6 Field Measurements

Required field measurements include water levels, temperature, pH, specific conductivity, and turbidity. Water level measurement procedures are described in Section 2.3.2. Temperature should be measured immediately after collection of the sample. Specific conductance will be measured prior to pH to avoid any effect on the sample from salts due to the pH probe.

See Appendix C for pH/temperature, specific conductivity and turbidity procedures and schedule of calibration of these field instruments. Each of these measurements is important in the documentation of properly collected ground water samples.

All instruments shall be properly calibrated and checked with standards according to the manufacturer's instructions and the standard operating procedures outlined in Appendix

C. Any improper operating instruments must be replaced prior to continuing sample collection operations.

2.5 Record Keeping

2.5.1 Field Logs

All field notes must be completely and accurately documented to become part of the final report for a monitoring event. All field information will be entered on a standard LTV Field Information Log (see Pages B.1 through B.6). Included on Pages B.1 through B.6 is an explanation of each requested piece of information and the proper location to enter the data.

An individual field log page is shown on Page B.1 - B.2. All entries should be legible and made in black, indelible ink. Entry errors will be crossed out with a single line, dated, and initialed by the person making the corrections.

2.5.2 Chain-of-Custody

Proper chain of custody records are required to insure the integrity of the samples and the conditions of the samples upon receipt at the laboratory, including the temperature of the samples at the time of log in. The sample collector shall fill in all applicable sections and forward the original, with the respective sample(s), to the laboratory performing the analysis. Upon receipt of the samples at the laboratory, the sample coordinator is to complete the chain of custody, make a copy for his/her files, and make the original documents part of the final analytical report (see Page B.9).

All sample containers will be labeled to prevent misidentification. The following will be indicated on an adhesive label with a waterproof pen:

- Collector's name, date and time of sampling.
- Sample source.
- Sample Identification number.
- Sample preservatives.
- Test(s) to be performed on the sample.

If the sample shuttle kit (cooler) does not employ a tamper proof seal, the collector is to date, sign and identify each sample on a tamper proof seal and attach it to each individual sample container and lid.

2.5.3 Sample Summary Log

A quick reference summary sheet referred to as a Field Sample Summary Log (see Pages B.10 and B.11) presents a general overview of the field sampling program. This document is to be prepared prior to a specific sampling event and appropriately filled in with sampling dates each day. The field sample summary log shall be included with the final analytical report as part of the field note documentation section.

2.6 Sample Transport

Samples shall be shipped from the field back to the analytical laboratory either by hand delivery or utilizing an overnight courier service. Samples are to be shipped in sealed insulated shipping containers which maintain the samples at approximately 4°C. Standard shipping containers must be a sturdy water-proof design (ice chests are commonly used) equipped with bottle dividers and cushion material to prevent breakage during shipment.

The field crew shall contact the laboratory each time samples are sent to identify the samples being sent and the transportation carrier along with the shipping identification number.

3 LABORATORY PROCEDURES / PERFORMANCE STANDARDS

3.1 Deliverables (General and Supplemental QA/QC)

3.1.1 General Requirements

For general reporting of quantitative results for ground water monitoring projects, the following reporting requirements apply:

- Methodology Summary - a table will be required listing all the analytical test methods used in the analyses of the samples with a reference made for each to the method manual and the test method number to confirm compliance with Tables A and B.

- Summary of analytical results, indicating appropriate unit, and reporting PQL, and supervisor approval - concentrations units must be consistently applied throughout report. Data can not be method blank corrected. It must be appropriately flagged.

- Chain-of-Custody Form - a separate form for each sample is not required. Name and organization of person taking sample, time and date of sampling, all custody changes, and all appropriate signatures must be included. All entries must be legible.

- LTV Field Information Logs (see Pages B.1 through B.2).

3.1.2 Supplemental QA/QC Reporting Requirements

- Laboratory Chronicles - must include date of sampling, sample receipt, preservation, preparation, analysis, supervisor approval signature.

- The document should be three hole punched and paginated and shall contain a table of contents; set margins and binding appropriately so that the document is legible.

- Non-Conformance Summary for GC/MS Data Reports - must state if the following do not meet QA/QC requirements:

  GC/MS Tune Specifications
  GC/MS Tune Frequency

Calibration Frequency
Calibration Requirements - System Performance Check
Compounds, Calibration Check Compounds
Blank Contamination
Surrogate Recoveries
Sample Holding Times
Minimum Detection Limits

3.1.3 Requirements for Organics: Volatiles

- GC/MS Tune Summary.
- Calibration Time and Date Summary (Initial and Continuing).
- Quality Assurance (QA) Data Form - must include minimum detection limits, method blanks, field/trip blanks as specified in Sampling Plan, lab replicate. All blanks and replicates must be run once per batch, or once per 20 samples, whichever is more frequent. Quality Control (QC) samples may be other than project samples, but must be of same batch and similar matrix. A single QA Data Form should be used for a number of samples, however, pertinent sample numbers must be listed on the form.
- Surrogate Compound Recovery Summary - for samples and blanks - as per most recent version of applicable SW-846 method 8260.
- Total Ion Chromatogram (TIC) for sample with all peaks identified.

3.1.4 Requirements for Organics: Semi-Volatiles

- GC/MS Tune Summary.
- Calibration Time and Date Summary (Initial and Continuing).
- Quality Assurance (QA) Data Form - must include minimum detection limits, method blanks, field/trip blanks as specified in Sampling Plan, lab replicate. All blanks and replicates must be run once per batch, or once per 20 samples, whichever is more frequent. Quality Control (QC) samples may be other than project samples, but must be of same batch and similar matrix. A single QA Data Form should be used for a number of samples, however, pertinent sample numbers must be listed on the form.

- Surrogate Compound Recovery Summary - for samples and blanks - as per most recent version of applicable SW-846 method 8270.

- Total Ion Chromatogram (TIC) for sample with all peaks identified.

3.1.5 Requirements for Metals

At a minimum, analytical results, method detection limits must be established and method blank results are mandatory.

3.1.6 Requirements for Inorganics - General Chemistry

Quality Assurance (QA) Data Form - must include minimum detection limits, method blanks, field/trip blanks as specified in Sampling Plan, lab replicate. All blanks and replicates must be run once per batch, or once per 20 samples, whichever is more frequent. Quality Control (QC) samples may be other than project samples, but must be of same batch and similar matrix.

A single QA Data Form should be used for a number of samples, however, pertinent sample numbers must be listed on the form. In addition, spiked sample results must be included.

3.2 Data Quality Objectives

3.2.1 Required Reporting Limits

Data reported must be such that the method used shall achieve the nominal practical quantitation limits (PQLs) listed in Table A. This table is located in Appendix A.

3.2.2 Precision

Precision is a measure of the degree to which two or more measurements are in agreement. Precision refers to the reproducibility of method results when a second aliquot of the same sample undergoes duplicate analysis.

The degree of agreement is expressed as the Relative Percent Difference (RPD). The RPD for unspiked samples is calculated according to the following equation:

$$RPD = \frac{(D1 - D2)}{((D1 + D2)/2)} \times 100$$

where D1 = result of first sample
D2 = result of second sample (duplicate)

RPD will be calculated for spiked samples using the following equation:

$$RPD = \frac{2|MSR - MSDR|}{(MSR - MSDR)} \times 100$$

where MSR = Matrix Spike Recovery (%R)
MSDR = Matrix Spike Duplicate Recovery (%R)

Duplicates shall be run on five percent (5%) of all samples minimally. Table B and its attachment provide the matrix precision control criteria as provided by Heritage Environmental Services.

3.2.3 Accuracy

Accuracy refers to the agreement between an observed value and an accepted reference value. Accuracy is usually expressed as a percent Recovery (R). Recoveries will be calculated according to following equations:

Surrogate Spike Recovery = $\frac{SurrR \times 100}{SurrA}$

where SurrR = amount of surrogate found
and SurrA = amount of surrogate added

Matrix Spike Recovery = $\frac{(MSR - SR) \times 100}{SA}$

where MSR = Matrix Spiked Sample Result
SR = Sample Result
SA = Spike Added

Laboratory Control Sample = $\frac{LCS\ Found \times 100}{Recovery\ LCS\ True}$

Recommended surrogate standards must be added to each organic sample processed to monitor method performance. Spikes and/or Laboratory Control Samples are to be run of at least five percent (5%) of samples run. Surrogate Recovery limits are generally published in the applicable method. Table C and its attachment provide the matrix accuracy control criteria as provided by Heritage Environmental Services.

3.2.4 Completeness

Completeness is the percentage of valid data acquired from a measurement system compared to the amount of valid measurements that were planned to be collected. Projects shall meet a level of ninety percent (90%) completeness. A corrective action narrative may be required from a laboratory should a project completeness fall below ninety percent (90%).

Completeness = %C = 100 x V / N

where V = Number of measurements judged valid
N = Total number of measurements

3.3 Approved Analytical Methods

Methods and reporting limits will conform to Table A.

4 SAMPLING FREQUENCY - DETECTION/VERIFICATION MONITORING

4.1 Ground Water Monitoring Schedule

All monitoring wells shall be sampled semi-annually (quarterly the first year).

Sampling Round	Parameters to be Monitored
1st - April/May	Phase I detection monitoring parameters 329 IAC 10-29-6
2nd - Oct/Nov	Phase I detection monitoring parameters 329 IAC 10-29-6

[refer to Table A of Appendix A for Phase I monitoring parameters]

4.2 Evaluation of Ground Water Monitoring Data

Prior to analyzing the monitoring data, a brief data validation review will be conducted to verify that the data meets the data quality objectives. The validation will also assess data usability relative to USEPA data validation requirements USEPA 1985. Specifically, the data will be examined for blank contamination, poor matrix spike recoveries, etc. Data which does not meet validation requirements will be disqualified. Resampling and/or analysis of subsequent quarterly data will be conducted to corroborate analysis results.

The following section describes the evaluation procedures to be utilized at the facility downgradient wells at the monitoring boundary. For the following observed increases, the IDEM Commissioner shall be notified within fourteen (14) days.

4.2.1 Wells Within the Uppermost Aquifer Downgradient from the Landfill

For downgradient wells at the monitoring boundary, the following occurrences will constitute an observed increase:

- A statistically significant increase 95 percent level of confidence detected and confirmed above background levels in accordance with procedures outlined in 329 IAC 10-29-5(3) for two (2) or more parameters, or using ASTM PS64 (attached in Appendix B) as an interwell approach using prediction intervals and resampling verification based on power curve analysis.

- A detected exceedance above Groundwater Quality maximum contaminant levels (MCL) described in 329 IAC 10-29-10 unless background water quality has demonstrated to exceed the MCL in which case the background quality will govern.

If upgradient wells indicate any change in water quality, background concentrations may be recomputed.

4.3 Additional Monitoring

Additional monitoring will be implemented, as required in 329 IAC 10-29-6(2). This monitoring will include the following:

- Collection of additional samples within sixty (60) days of reporting an exceedance to the Commissioner. The IDEM will be notified of any confirmed exceedance at the close of the 60 day period.

- Determination of the source of any confirmed exceedance. Sources may include, but are not limited to: natural phenomena; sampling or analysis error, or an off-site source.

If Phase II detection monitoring confirms that a release has occurred, reports of these analyses will be provided to the IDEM Commissioner in accordance with schedules identified by 329 IAC 10-29-7. If an alternate source of contamination not attributable to the landfill is confirmed under 329 IAC 10-29-8, a report demonstrating the alternate source impact should be submitted to the IDEM Commissioner. If an exceedance is confirmed, plans for corrective action shall be provided to the IDEM Commissioner in accordance with 329 IAC 10-29-9.

4.4 Phase II Detection Monitoring Program

A Phase II detection monitoring program meeting the requirements of 329 IAC 10-29-7 shall be implemented if two (2) parameters have statistically significant increases of Phase I detection parameters over background. The Phase II monitoring shall also include the secondary standards described in 329 IAC 10-29-7(c), the protection standards in 329 IAC 10-29-10(a) and any constituents determined by the IDEM Commissioner based on analysis of the disposed waste. Phase II detection monitoring shall continue for at least a one (1) year period until no significant increase is shown.

4.5 Ground Water Analysis Result Submittals

Ground water analytical data results will be submitted to the IDEM Commissioner semi-annually after background water quality is established following the submittal schedule required by the IDEM permit.

5 REFERENCES

American Society of Testing and Materials (ASTM), 1986. *Standard Guide for Sampling Groundwater Monitoring Wells.* D 4448 - 850.

Martin, W.F., Lippitt, J.M., and Protherd, T.G. 1987. *Hazardous Waste Handbook For Health and Safety,* Butterworth Publishers, Stoneham, Massachusetts, pp. 28 - 30.

U.S. Environmental Protection Agency, 1986. *RCRA Groundwater Monitoring Technical Enforcement Guidance Document.* OSWER - 99550.1, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency, 1992. *RCRA Groundwater Monitoring: Draft Technical Guidance.* EPA/530-R-93-001, NTIC # PB93-139-350, Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency, 1991b. *Handbook - Groundwater, Volume II: Methodology.* EPA/625/6-90/0166.

U.S. Environmental Protection Agency, November 1986. *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, Third Edition (Revised),* SW-846. Office of Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency, 1985. *Laboratory Data Validation, Functional Guidelines for Evaluating Inorganics Analysis.* U.S. EPA Office of Emergency and Remedial Response, Washington, D.C.

U.S. Environmental Protection Agency, November 1993. *Solid Waste Disposal Facility Criteria Technical Manual.* EPA/530-R-93-017, NTIC #PB94-100-450, Office of Solid Waste and Emergency Response, Washington, D.C..

Indiana Administrative Code, Title 329 IAC 10, 11 and 12, Solid Waste Land Disposal Facilities Solid Waste Processing Facilities, and Solid Waste Management Activity Registration, Office of Solid and Hazardous Waste Management, Indiana Department of Environmental Management.

TABLE A

PROPOSED ANALYSIS METHODS AND STANDARDS
CLARK LANDFILL
LTV STEEL COMPANY
EAST CHICAGO, INDIANA

CLARK LANDFILL - PROPOSED ANALYSIS METHODS AND STANDARDS				
FIELD PARAMETERS	**CAS RN (1)**	**Method (2)**	**PQL (3)**	**Units**
PH	N/A	SW846-9040B		
SPECIFIC CONDUCTANCE	N/A	SW846-9050	1.0	umHOS/cm
TEMPERATURE	N/A	EPA 170.1	N/A	Degrees C
DEPTH TO WATER (FEET BELOW MEAS. PT.)	N/A	N/A	N/A	ft.
ELEVATION OF MEAS. PT. (TOP OF CASING FT MSL)	N/A	N/A	N/A	ft.
ELEVATION OF GROUNDWATER SURFACE	N/A	N/A	N/A	ft.
ELEVATION OF BOTTOM OF WELL	N/A	N/A	N/A	ft.
TURBIDITY	N/A	EPA 180.1	0.1	ntu
PHASE I PARAMETERS				
SPECIFIC CONDUCTANCE	N/A	SW846-9050	1.0	umHOS/cm
CHLORIDE	16887-00-6	SW846-9056	0.25	mg/L
BORON, DISSOLVED	7440-42-8	SW846-6010B	0.050	mg/L
AMMONIA, NITROGEN	7664-41-7	EPA 350.3	0.12	mL
SODIUM	7440-23-5	SW846-6010B	0.10	mg/L
CHEMICAL OXYGEN DEMAND	N/A	EPA 410.4	10	mg/L
TOTAL PHENOLICS	N/A	SW846-9065/9066	0.01	mg/L
METHYLENE CHLORIDE	75-09-2	SW846-8260B *	5	ug/L
1,1-DICHLOROETHANE	75-34-3	SW846-8260B *	1	ug/L
TOLUENE	108-88-3	SW846-8260B *	1	ug/L
BENZENE	71-43-2	SW846-8260B *	1	ug/L
1,2-DICHLOROETHENE, TOTAL	540-59-0	SW846-8260B *	5	ug/L
ETHYL BENZENE	100-41-4	SW846-8260B *	5	ug/L
2-BUTANONE, (METHYL ETHYL KETONE)	78-93-3	SW846-8260B *	5	ug/L
PHASE II SECONDARY PARAMETERS				
CHLORIDE	16887-00-6	SW846-9056	0.25	mg/L
COPPER	7440-50-8	SW846-6010B	0.020	mg/L
IRON	7439-89-6	SW846-6010B	0.025	mg/L
MANGANESE	7439-96-5	SW846-6010B	0.010	mg/L
SULFATE	7757-82-6	SW846-9056	0.25	mg/L
TOTAL DISSOLVED SOLIDS	N/A	EPA 160.1	10	mg/L
ZINC	7440-66-6	SW846-6010B	0.020	mg/L
GROUND WATER QUALITY STANDARDS				
INORGANICS:				
ARSENIC	7440-38-2	SW846-6010B	0.05 (4)	mg/L
BARIUM	7440-39-3	SW846-6010B	1.0 (4)	mg/L
CADMIUM	7440-43-9	SW846-6010B	0.01 (4)	mg/L
CHROMIUM	7440-47-3	SW846-6010B	0.010	mg/L

CLARK LANDFILL - PROPOSED ANALYSIS METHODS AND STANDARDS

FIELD PARAMETERS	CAS RN [1]	Method [2]	PQL [3]	Units
FLUORIDE	7681-49-4	EPA 340.2	0.1	mg/L
LEAD	7439-92-1	SW846-6010B	0.0050	mg/L
MERCURY	7439-97-6	SW846-7470A	0.00020	mg/L
NITRATE (AS NITROGEN)	N/A	SW846-9056	0.05	mg/L
SELENIUM	7782-49-2	SW846-6010B	0.01 [4]	mg/L
SILVER	7440-22-4	SW846-6010B	0.05 [4]	mg/L
VOLATILE ORGANIC COMPOUNDS:				
ACETONE	67-64-1	SW846-8260B *	10	ug/L
ACROLEIN	107-02-8	SW846-8260B *	25	ug/L
ACRYLONITRILE	107-13-1	SW846-8260B *	10	ug/L
BENZENE	71-43-2	SW846-8260B *	1	ug/L
BROMODICHLOROMETHANE	75-27-4	SW846-8260B *	1	ug/L
BROMOFORM	75-25-2	SW846-8260B *	1	ug/L
BROMOMETHANE	74-83-9	SW846-8260B *	1	ug/L
2-BUTANONE (METHYL ETHYL KETONE)	78-93-3	SW846-8260B *	5	ug/L
CARBON DISULFIDE	75-15-0	SW846-8260B *	1	ug/L
CARBON TETRACHLORIDE	56-23-5	SW846-8260B *	1	ug/L
CHLOROBENZENE	108-90-7	SW846-8260B *	1	ug/L
CHLOROETHANE	75-00-3	SW846-8260B *	1	ug/L
2-CHLOROETHYL VINYL ETHER	110-75-8	SW846-8260B *	5	ug/L
CHLOROFORM	67-66-3	SW846-8260B *	1	ug/L
CHLOROMETHANE	74-87-3	SW846-8260B *	5	ug/L
DIBROMOCHLOROMETHANE	124-48-1	SW846-8260B *	1	ug/l
DIBROMOMETHANE	106-93-4	SW846-8260B *	1	ug/L
DICHLORODIFLUOROMETHANE	75-71-8	SW846-8260B *	1	ug/L
1,1-DICHLOROETHANE	75-34-3	SW846-8260B *	1	ug/L
1,2-DICHLOROETHANE	107-06-2	SW846-8260B *	1	ug/L
1,2-DICHLOROETHENE (TOTAL)	540-59-0	SW846-8260B *	5	mg/L
CIS-1,3-DICHLOROPROPENE	10061-01-5	SW846-8260B *	1	ug/L
TRANS-1,3-DICHLOROPROPENE	10061-02-6	SW846-8260B *	1	ug/L
ETHYLBENZENE	100-41-4	SW846-8260B *	1	ug/L
ETHYL METHACRYLATE	97-63-2	SW846-8260B *	1	ug/L
2-HEXANONE	591-78-6	SW846-8260B *	5	ug/L
IODOMETHANE	74-88-4	SW846-8260B *	1	ug/L
METHYLENE CHLORIDE	75-09-2	SW846-8260B *	5	ug/L
4-METHYL-2-PENTANONE	108-10-1	SW846-8260B *	5	ug/L
STYRENE	100-42-5	SW846-8260B *	1	ug/L
1,1,2,2-TETRACHLOROETHANE	79-34-5	SW846-8260B *	1	ug/L
TOLUENE	108-88-3	SW846-8260B *	1	ug/L
1,1,1-TRICHLOROETHANE	71-55-6	SW846-8260B *	1	ug/L
1,1,2-TRICHLOROETHANE	79-00-5	SW846-8260B *	1	ug/L
TRICHLOROETHENE	79-01-6	SW846-8260B *	1	ug/L
TRICHLOROFLUOROMETHANE	75-69-4	SW846-8260B *	1	ug/L
1,2,3-TRICHLOROPROPANE	96-18-4	SW846-8260B *	1	ug/L
VINYL ACETATE	108-05-4	SW846-8260B *	5	ug/L
VINYL CHLORIDE	75-01-4	SW846-8260B *	2 [4]	ug/L
XYLENES (TOTAL)	1330-20-7	SW846-8260B *	1	ug/L

NOTES TO TABLE A

1. Chemical Abstracts Service registry number. Supplied by Heritage Environmental Services, May 1999.

2. Suggested Methods refer to analytical procedure numbers used in EPA Report SW-846 "Test Methods for Evaluating Solid Waste", third edition, November 1986, as revised, December 1987, or applicable updates (as of May 1999). All methods used that are not SW846 are used because there are no equivalent SW846 methods (provided by Heritage Environmental Services, May 1999).

3. Practical Quantitation Limits (PQLs) are the lowest concentrations of analytes in ground water that can be reliably determined within specified limits of precision and accuracy by the indicated methods under routine laboratory operating conditions. PQL's provided by Heritage Environmental Services, May 1999, except where noted.

4. PQL's have been set at the MCL published in 40 CFR 258.40.

In order to report the volatile organics at or below the MCL, a25 mL purge vessel will be used instead of the standard 5 mL purge vessel.

N/A = Not Applicable per Heritage Environmental Services

TABLE B

Matrix Precision (RPD) Control Criteria

ANALYTE GROUP	AQUEOUS	SOIL/SLUDGE/SED
Volatile Organics	20	30
Metals *	20	25
Inorganic Wet Chemistry	20	25
Organic Wet Chemistry	20	25
Base/Neutral Extractable Organics	25	30
Acid Extractable Organic	25	30
All Analytes with Concentrations less than 10 times the PQL	± PQL	± PQL

* Metals (ICP) criteria is per method 6010.

NOTE: GC/MS methods require lab generated limits, which change every time charts are updates. A copy of the current matrix precision limits for method 8260B is provided in Table B attachment.

Provided by Heritage Environmental Services, Indianapolis, Indiana, 1999.

TABLE C

Matrix Accuracy (% Recovery) Control Criteria

ANALYTE GROUP	AQUEOUS	SOIL/SLUDGE/SED
Volatile Organics	75 - 125	75 - 125
Metals *	80 - 120	75 - 125
Inorganic Wet Chemistry	75 - 125	75 - 125
Organic Wet Chemistry	75 - 125	75 - 125
Base/Neutral Extractable Organics	25 - 150	25 - 150
Acid Extractable Organic	10 - 100	10 - 100

* Metals (ICP) criteria is per method 6010.

NOTE: GC/MS methods require lab generated limits, which change every time charts are updates. A copy of the current matrix accuracy limits for method 8260B is provided in Table C attachment.

Provided by Heritage Environmental Services, Indianapolis, Indiana, 1999.

LTV FIELD INFORMATION LOG

Facility: _____ **Sample Point ID:** _____

Location: _____ Field Representative: _____

Sample Matrix: _____ Lab Sample #: _____

Gascope Calibration: % Gas: ____ % LEL: ___
Gascope Reading: % Gas: ____ % LEL: ___

PURGE INFORMATION:

Method of Well Purge: _____ Dedicated: Y / N

Date / Time Initiated: _____ One (1) Casing Volume, Gal: _____

Initial Water Level, Feet: _____ Total Volume Purged, Gal: _____

Ground Water Elevation, MSL: _____ Was Well Purged To Dryness: _____

Well Total Depth, Feet: _____ Water Level After Purge, Feet: _____

Casing Diameter, Inches: _____ Date / Time Completed: _____

PURGE DATA:

Time	Purge Rate (gpm)	Cumulative Volume	Temp. (°C)	pH (std units)	Conduct. (µmhos/cm)	Turb. (NTU)	Other ___ (___)

LTV FIELD INFORMATION LOG
(continued)

SAMPLING INFORMATION: Sample Point ID: _____

Method of Sampling: _____ : Y / N

Water Level @ Sampling, Feet: _____ Well Collection Sequence Number: _____

Parameters: Phase I ( ) Phase II ( ) GWQS ( )

SAMPLING DATA:

Date/Time	Sample Rate	Temp. (°C)	pH (Std. Units)	Conduct. (µmhos/cm)	Turb. (NTU)	Other ___ (___)
	VOA _____ Other _____					

INSTRUMENT CHECK DATA:

Turbidity Serial #: _____ ___ NTU std. = ___ NTU ___ NTU std. = ___ NTU

pH Serial #: _____ 4.0 std. = ___ 7.0 std. = ___ 10.0 std.= _____

Conductivity Serial #: _____ ___ umhos/cm = ____ ___ umhos/cm = _____

GENERAL INFORMATION:

Weather Conditions @ time of sampling: _____

Sample Characteristics: _____

ANALYTE COLLECTION ORDER, CONTAINERS, PRESERVATIVES AND TESTS PERFORMED:

_____

_____

COMMENTS AND OBSERVATIONS: _____

_____

I certify that sampling procedures were in accordance with all applicable EPA, State and E & E Hauling, Inc. protocols.

Date: __/__/__ By: _____ Company: _____

LTV FIELD INFORMATION LOG EXPLANATION
SEE ATTACHED NOTE REFERENCES

Facility: 1

Sample Point ID: 4

Location: 2

Field Representative: 5

Sample Matrix: 3

Lab Sample #: 6

Gascope Calibration: % Gas: 7 % LEL: ___
Gascope Reading: % Gas: 8 % LEL: ___

PURGE INFORMATION:

Method of Well Purge: 9

Dedicated: Y / N

Date / Time Initiated: 10

One (1) Casing Volume, Gal: 15

Initial Water Level, Feet: 11
Ground Water Elevation, MSL: 12
Well Total Depth, Feet: 13

Total Volume Purged, Gal: 16
Was Well Purged To Dryness: 17
Water Level After Purge, Feet: 18

Casing Diameter, Inches: 14

Date / Time Completed: 19

PURGE DATA:

Time	Purge Rate (gpm/htz)	Cumulative Volume	Temp. (°C)	pH (std units)	Conduct. (µmhos/cm)	Turb. (NTU)	Other ___ ( )
20	21	22	23	24	25	26	27

LTV FIELD INFORMATION LOG EXPLANATION (continued)

SAMPLING INFORMATION: Sample Point ID: 4

Method of Sampling: 28 Dedicated: Y / N

Water Level @ Sampling, Feet: 29 Well Collection Sequence Number: 30

Parameters: Annual ( ) Semi-Annual ( ) Quarterly ( ) Monthly ( ) Other ( ) 31

SAMPLING DATA:

Date/Time	Sample Rate	Temp. (°C)	pH (Std. Units)	Conduct. (µmhos/cm)	Turb. (NTU)	Other ___ (___)
32	VOA ___ Other 33	34	35	36	37	38

INSTRUMENT CHECK DATA:

Turbidity Serial #: 39 40 NTU std. = ___ NTU ___ NTU std. = ___ NTU

pH Serial #: 41 4.0 std. = 42 7.0 std. = ___ 10.0 std.= ___

Conductivity Serial #: 43 44 umhos/cm = ___ ___ umhos/cm = ___

GENERAL INFORMATION:

Weather Conditions @ time of sampling: 45

Sample Characteristics: 46

ANALYTE COLLECTION ORDER, CONTAINERS, PRESERVATIVES AND TESTS PERFORMED:

47

COMMENTS AND OBSERVATIONS: 48

I certify that sampling procedures were in accordance with all applicable EPA, State and E & E Hauling, Inc. protocols.

Date: __/__/__ By: 49 Company: ___

PAGE 2 OF 2

LTV FIELD INFORMATION LOG EXPLANATION

1. Name of facility to be sampled.
2. City, County, or Township in which the facility is located.
3. Type of sample collected (ground water, surface water, soil, etc.).
4. The official identification of the sample point (e.g. MW-1).
5. All representatives conducting the purging and/or sampling of the given well.
6. Identification number given to the set of samples. This number is generally assigned by the lab.
7. The gascope calibrations for % Gas and % LEL.
8. The gascope readings for % Gas and % LEL of methane.
9. The equipment used to purge (e.g. Rediflo 2®; QED air displacement purge pump, bailer).
10. Self explanatory.
11. Depth to water as measured with a water level indicator from the official point of reference. The official point of reference is usually from top of the inner casing (riser). This is to be included on the laboratory diskette.
12. The actual elevation of the water surface relative to sea level.
13. Measurement from the surveyed point at the top of the inner casing (riser) to the bottom of the well. To be measured to the nearest hundredth of a foot. To be measured every sampling event.
14. Measurement of the inner diameter of the inner casing. To be measured in inches.
15. The volume of water (in gallons) occupying the well prior to purging. Calculation:

    Volume (gallons) = $(3.14)\ r^2h/231$

    r = radius of the inner casing (in inches)

    h = height of the water column in the well (in inches). Height equals the well total depth minus the initial water level.

    [NOTE: UNITS IN INCHES]

16. The total volume purged from the well prior to sampling. Measured in gallons.
17. Yes or No.
18. Water level measurement taken at the end of purging. If a pump is used for purging, then take the measurement while the pump is on. If a well has been purged to dryness, then write N/A in this space.
19. Self explanatory.
20. Time of a given field data measurement during the purge process. If more than one day is used for purging, then write the new date in the margin next to the time.
21. Timed rate that the well is being purged when the purge field data is being collected. If a rate controlled, electric submersible pump is being used, then also include the Hertz reading on this line.
22. The total volume that has been purged each time the purge stabilization field data is being collected. Measured in gallons.
23. Temperature measured in celsius to the nearest tenth.
24. pH measured in standard units to the nearest hundredth.
25. Specific conductance measured in micro mhos per centimeter to three (3) or four (4) significant digits.
26. Turbidity measured in nephelometric turbidity units to three (3) significant digits.
27. Any other field parameter measured during the purge process (e.g. dissolved oxygen, eH).

LTV FIELD INFORMATION LOG EXPLANATION

28. Equipment used to sample (e.g. Rediflo2®, Well Wizard® bladder pump). Also indicate if device is dedicated.
29. Measurement of water level from the top of the inner casing measured immediately before sampling.
30. Note sequential number of well in monitor well sample collection order.
31. Type of parameter list used for the sampling event. If other, then record what list is being used.
32. Date and time that sampling begins. Sample field parameters are to be taken separate from purge field parameters. The sample field parameters are to be measured in one (1) replicate unless otherwise stated in state regulations or the site permit.
33. The rate that the sample water is filling the sample bottles (in milliliters per minute).
34. Temperature to be measured only in the field at the time of sampling. Record in degrees celsius to the nearest tenth.
35. The pH to be written on this line is to be measured only in the field at the time of sampling. Record in standard units to the nearest hundredth.
36. The Specific Conductance to be written on this line is to be measured only in the field at the time of sampling. Record in micro mhos per centimeter to three (3) or four (4) significant digits.
37. The turbidity to be written on this line is to be measured only in the field at the time of sampling. Record in nephelometric turbidity units to three (3) significant units.
38. Any other parameter that is to be measured in the field at the time of sampling.
39. Document turbidity meter manufacturer serial identification number.
40. Turbidity standard to be measured between wells. Record the theoretical standard value in the first line and the measured standard value in the second line. Two (2) different standards can be measured.
41. Document pH meter manufacturer serial identification number.
42. Measure each buffer solution and calibrate the pH meter at a minimum of once every 10 samples.
43. Document conductivity meter manufacturer serial identification number.
44. Measure each standard solution and calibrate the conductivity meter at a minimum frequency of once every 10 samples. Record the theoretical standard solution value in the first line and the measured standard solution value in the second line. Two (2) different standards can be measured.
45. Record any ambient weather conditions that might affect sample.
46. Record general physical characteristics of sample at time of sampling before preservation, filtration, or cooling (e.g. odor, visual turbidity, color, particulate matter).
47. Record the analytes to be tested as per container following the order noted in the sampling section of this SOP. The bottle size and material are also to be recorded along with any preservative. Filtration, if needed, shall also be recorded. Example:

    2 - 40 ml(G)/HCl = VOA
    1 - Liter (P)/Filt. & HNO3 = Diss. Metals

48. Any comments or observations that reflect anything not covered by this field log that may be important to the sampling event.
49. Record the date signed, the signature of the person who filled out the field log, and the company represented on this line. This line should be filled when the field log has been completed at the well.

CONTAINERIZATION AND PRESERVATION OF SAMPLES

Measurement	Volume Req., (mL)	Container[a]	Preservative	Max. HoldingTimes	Reference
Specific Cond. (Field)	100	P, G	None	Det. on Site	1
pH (Field)	50	P, G	None	Det. on Site	1, 2
Temperature (Field)	1000	P, G	None	Det. on Site	1
Turbidity (Field)	100	P,G	None	Det. on Site	1

Measurement	Volume Req., (mL)	Container[a]	Preservative	Max. Holding Times	Reference
Inorganics, Non-Metallics					
Ammonia	400	P, G	Cool, 4°C H_2SO_4 to pH <2	28 Days	1
Total Dissolved Solids	50	P, G	Cool, 4°C	7 Days	1
Chloride	200	P, G	Cool,4°C	28 Days	1, 2
Nitrate plus Nitrite	200	P, G	Cool, 4°C H_2SO_4 to pH <2	28 Days	1, 2
Oil & Grease (one replicate)	1000	G only	Cool, 4°C H_2SO_4, or HC1 to pH <2	28 Days	1, 2
Total Organic Carbon (TOC)	100	G only Teflon lined cap	Cool, 4°C H_2SO_4, or HC1 to pH <2	28 Days	1, 2
Phenolics	1000	G only	Cool, 4°C H_2SO_4 to pH <2	28 Days	1, 2
Sulfate	100	P, G	Cool, 4°C	28 Days	1, 2
TOX (2 Rep) (4 Rep)	500 1000	G only Teflon lined cap	Cool, 4°C H_2SO_4 to pH <2	28 Days	1, 2
Cyanides	500	P, G	Col, 4°C N_aOH to pH >12	14 Days	1, 2
Fluoride	50	P	Cool, 4°C	28 Days	1

CONTAINERIZATION AND PRESERVATION OF SAMPLES

Measurement	Volume Req., (mL)	Container[a]	Preservative	Max. Holding Times	Reference
Metals					
Total	500	P, G	HNO_3 to pH <2	6 Mos	1, 2
Dissolved	500	P, G	Filt. + HNO_3 to pH <2	28 Days	1, 2
Mercury - Dissolved	300	P, G	Filter on Site HNO_3 to pH <2	28 Days	1, 2
Mercury - Total	300	P, G	HNO_3 to pH <2	28 Days	1, 2

Measurement	Volume Req. (mL)	Container[a]	Preservative	Max. Holding Times	Reference
Organics					
Volatile Organics by GC/MS	100 (2 vials @ 40mL)	G, Teflon septum cap	Cool, 4°C HCl to pH <2	14 Days	2, 3
Semi-Volatiles Acid and Base/Neutral Compounds	2000	Glass only	Cool, 4°C	7 Days[b] 40 Days[c]	2, 3

NOTES:

a - Plastic (P) or Glass (G). For metals, polyethylene with an all polypropylene cap is preferred.

b - Maximum holding time from sampling to extraction.

c - Maximum holding time from extraction to analysis.

REFERENCES:

1 - Methods for Chemical Analysis of Water and Wastes, March, 1983, USEPA, 600/4-79-020 and additions thereto.

2 - Test Methods for Evaluating Solid Waste, Physical/Chemical Method, November, 1986, Third Edition, USEPA, SW-846 and additions thereto.

3 - "Guidelines Establishing Test Procedures for the Analysis of Pollutant Under the Clean Water Act", Environmental Protection Agency, Code of Federal Regulations (CFR), Title 40, Part 136.

LTV

FIELD SAMPLE SUMMARY LOG

Page __ of __

Facility: _____ Location: _____

Laboratory: _____ Sample Dates: _____

Monitoring Event: _____

Lab #	Sample Point	SAMPLE PARAMETERS/CONTAINER						

Comments: _____

Legend:

•	• DATE	• N/R	• INS.

•-Required Sample Parameter.
Date-Date of Sample Collection (Date/Month/Year)
N/R-Not Requested
INS.-Insufficient Water for Sample
(G)-Glass Container
(P)-Plastic Container

LTV

FIELD SAMPLE SUMMARY LOG

Page 1 of 1

Facility: Clark Landfill Location: _____

Laboratory: _____ Sample Dates: _____

Monitoring Event: _____

Lab #	Sample Point	SAMPLE PARAMETERS/CONTAINER						
		VOA	Metals	pH, Cond.				
		2-40 ml(G) Vials	1-Liter(P)	1-500 ml(P)				
0000	MW-1	• 2/14/93	• 2/14/93	• 2/14/93				
0001	Field Duplicate	• 2/14/93	• 2/14/93	• 2/14/93				
0002	Field Blk.	• 2/14/93	• 2/14/93	• 2/14/93				
0003	Trip Blk.	• 2/13/93	• 2/13/93	• 2/13/93				

Comments: _____

Legend:

•	• DATE	• N/R	• INS.

•-Required Sample Parameter
Date-Date of Sample Collection (Date/Month/Year)
N/R-Not Requested
INS.-Insufficient Water for Sample
(G)-Glass Container
(P)-Plastic Container

LTV GROUND WATER MONITORING WELL CONDITION REPORT

LTV Facility: Clark Landfill Well ID: _____ Date: _____

Access:

Accessibility: Good ___ Fair ___ Poor ___

Vicinity of well clear of weeds and/or debris: Yes ___ No ___

Remarks: _____

Concrete Pad:

Integrity of Concrete Pad: Good ___ Inadequate ___

Presence of depressions or standing water around well:
Yes ___ No ___

Remarks: _____

Protective Outer Casing: Material = _____

Condition of Protective Casing: Good ___ Damaged ___

Condition of Locking Cap: Good ___ Damaged ___

Condition of Lock: Good ___ Damaged ___

Condition of Weep Hole: Good ___ Damaged ___

Remarks: _____

Well Riser: Material = _____

Condition of Riser: Good ___ Damaged ___

Condition of Riser Cap: Good ___ Damaged ___

Measurement Reference Point: Yes ___ No ___

Remarks: _____

Dedicated Purging/Sampling Device: Type - _____

Condition: Good ___ Damaged ___ Missing ___

Remarks: _____

Field Certification: _____
Signed Title Date

pH METER CALIBRATION / OPERATION PROCEDURES

(reference EPA Method 9040)

The field pH meter will be calibrated each day water samples are collected. Calibration results will be recorded on the LTV Field Information Log.

pH CALIBRATION

Two-Buffer Calibration

This procedure is recommended for precise measurements using the Orion Model SA210 pH meter. pH meter calibration should be conducted once every 10 samples.

1. Select two buffers which bracket the expected sample pH. The first should be near the electrode isopotential point (pH 7) and the second near the expected sample pH (e.g. pH 4 or pH 10).

2. Rinse electrode first with distilled water and then with pH 7 buffer. Place the electrode in pH 7 buffer. Measure the temperature of the buffer solution and set temperature control.

3. Wait for stable display and compare pH value obtained with pH value vs. temperature shown on back of pH buffer solution bottle and adjust calibration accordingly.

4. Rinse electrode first with distilled water and then with the second buffer. Place the electrode in the second buffer and repeat step 3.

5. The meter is now calibrated for use.

This section will be revised as necessary to reflect the model of meter being used.

pH MEASUREMENT

1. Obtain a sample from collection device and place electrode directly into sample.

2. Allow reading to stabilize.

3. Record pH reading directly from meter and record on the LTV Field Information Log.

4. Probes are to be decontaminated by multiple rinses with distilled water.

If any of the above procedures does not work, refer to **Troubleshooting** section of instrument instruction manual.

Measuring Hints

1. Always use fresh buffers for calibration. Choose buffers that are no more than 3 pH units apart.

2. Check pH calibration daily by performing a two-buffer calibration.

3. Between measurements, rinse electrodes with distilled water and then with the next solution to be measured.

4. Stir all buffers and samples.

5. Avoid rubbing or wiping electrode bulb, to reduce chance of error due to polarization.

Interferences

Oil samples and salty samples may leave residues on the electrodes. The probe has to be rinsed thoroughly between all measurements using distilled water to remove salt residues. If oily residues need to be removed, rinse with acetone then distilled water. The electrodes need to be kept wet to ensure proper response.

CONDUCTIVITY / TEMPERATURE METER CALIBRATION / OPERATION PROCEDURES

(reference EPA Method 9050)

CALIBRATION PROCEDURES

Conductivity meters are factory calibrated. Most field models cannot be manually calibrated. Conductivity will be checked at a minimum of once per day using commercial traceable standards in the 1000 and 10,000 µmhos/cm range and recorded on the LTV Field Information Log. Calibration checks outside of a ± 10% range are not acceptable. Replace probe and re-check standards. If calibration check standards are still outside ± 10% range, use alternate meter. Do not proceed with sample collection without acceptable calibration checks.

Temperature measurement is also factory calibrated. Temperature will be checked for calibration by comparison prior to sample event with a laboratory thermometer and respond in a ± 10% range.

TEMPERATURE MEASUREMENT

(for YSI Model 33 Meter)

1. With instrument off, adjust meter mechanical zero, if necessary.
2. Switch to redline and adjust, if necessary.
3. Immerse the Conductivity Cell into the sample and allow to stabilize.
4. Turn Conductivity/Temperature Selector Knob to temperature readout mode.
5. Record temperature reading directly from meter and record on the LTV Field Information Log.

CONDUCTIVITY MEASUREMENT

The unit of measure is selected using the Conductivity Range Selector Knob (top knob, front panel) either mS/cm (mmhos/cm) or µS/cm (µmhos/cm). Report all values on the LTV Field Information Log in µmhos/cm (µS/cm).

1. Immerse the Conductivity Cell into the sample.
2. Select Conductivity measurement by turning meter Conductivity/Temperature Selector Knob to Conductivity Scale using the X1 scale.
3. If indicator is out of range, switch to X 10 scale. Switch to X100 scale, if necessary.

4. Note the conductivity reading and correct to 25° C using the following formula:

$$C_{CORR} = \frac{1 + 0.02\ (T\ measured - 25)}{C\ measured}$$

5. Record conductivity reading corrected to 25° C on the LTV Field Information Log.

6. Probes are to be decontaminated by multiple rinses with distilled water.

TURBIDITY METER CALIBRATION / OPERATION PROCEDURES

(Reference EPA Method 180.1)

Turbidity is the physical measurement of light scattered and absorbed verses transmitted through a sample. Turbidity is an indicator of water clarity (the amount of suspended matter found in a sample). Using a nephelometer, the results are expressed as NTU (nephelometer turbidity units).

TURBIDITY MEASUREMENT

1. Collect a representative sample in a clean container. Fill a clean sample cell to the top line, taking care to handle the sample cell by the top only. Cap the cell.

2. Wipe the cell with a soft, lint free cloth to remove water spots and fingerprints.

3. Make sure the instrument is on a flat, steady surface and turn the power on. Select measurement range and turn signal averaging on or off.

4. Place the sample cell in the instrument cell compartment.

5. Press read button.

6. Record turbidity value after lamp icon turns off.

TURBIDITY CALIBRATION

The Hach 2100P Portable Turbidimeter is calibrated with Formazin Primary Standard at the factory. The recommended recalibration time is once every three (3) months with purchased or prepared Formazin Standard.

Routine Calibration Check with Gelex Standards

The 2100P Turbidimeter does not require standardization before every measurement as some turbidimeters do. Periodically, as experience dictates, check the instrument calibration using the appropriate Gelex Secondary Standard. Be sure the Gelex standards are aligned correctly when inserting them (diamond aligns with orientation mark). If the reading is not within 5% of the previously established value, the instrument should be recalibrated with Formazin Primary Standard (see below).

Quarterly Calibration Procedure

1. Rinse a clean sample cell with dilution (deionized) water and fill to the mark with dilution water.

2. Place cell into cell compartment, align orientation marks, close lid and press I/O.

3. Press CAL, the "SO" icons appear and the "O" will flash. Press READ, the instrument will read the blank and calculate a correction factor. If the dilution water is less than or equal to 0.5 NTU, E 1 will appear when the calibration is calculated.

4. The "S1" display will show the value of the first turbidity standard. Using a clean sample cell, fill with the well mixed portion of 20 NTU standard. Insert the align the sample cell in the cell compartment, close the lid and press READ. When finished, the instrument will automatically move to the next standard.

5. Follow the instructions listed above for a 100 NTU and a 800 NTU standard.

6. Press CAL to accept the calibration, the instrument will return to measurement mode.

7. THIS PROCEDURE IS TO BE PERFORMED IN THE LABORATORY EVERY THREE (3) MONTHS, OR AS NEEDED (if not within ± 5% gelex standard checks).

MAINTENANCE

Keep the turbidimeter and accessories as clean as possible and store the instrument in the carrying case when not in use. Avoid prolonged exposure to sunlight and ultraviolet light. Wipe spills up promptly. Wash sample cells with non-abrasive laboratory detergent, rinse with distilled or demineralized water, and air dry. Avoid scratching the cells and wipe all moisture and fingerprints off the cells before inserting them into the instrument. Failure to do so can give inaccurate readings.

BASIC WATER LEVEL INDICATOR PROCEDURES

The following outlines standard procedure for taking monitor well water levels utilizing a Solinis Model 101 water level indicator:

1. Unlock and remove the monitor well protective casing cap. Note and document any problems with the locking cap or lock itself.

2. Put on a pair of clean new disposable gloves and remove the PVC well cap or well seal access port from the top of the PVC riser. Store the PVC well cap or access port in a clean location.

3. Check the on/off button and sensitivity switch with the test button located on the side of the water indicator. A audible beep and light indicate that the device is working properly. The sensitivity switch should be turned to the highest setting and then lowered if required due to highly conductive water (e.g. if the sensitivity is too high the water indicator buzzer will fail to turn off when removed from water column. On the other hand, if the sensitivity is too low the indicator will not detect the water column in a water with low conductivity).

4. Slowly lower the indicator probe into the well until the audible beep/light indicates the probe has contacted the water column. Carefully work the probe up and down to find the exact spot the probe senses the water level.

5. Read the tape measure numbers on the indicator line at the top of the well casing. These numbers are in 1/100 of a foot increments. Record the measurement to the closest 1/100 of a foot. This number reflects the distance from the top of the well casing down to the water column. A permanent point is notched in the well casing or etched on the permanent well head seal so that the same surveyed reference point is always used. To convert this number to water level relative to Mean Sea Level, subtract the measurement from the surveyed elevation of the monitor well riser reference point.

6. As the probe and line are pulled from the well, the line should be wiped with a fresh distilled/deionized saturated paper towel. The probe should then be washed with the non-phosphate detergent and rinsed with triple distilled/deionized rinse.

GROUND WATER SAMPLE FIELD FILTRATION PROCEDURES

Ground water monitor wells will have dedicated permanently installed variable speed submersible pumps which allow the use of .45 micron disposable in-line cartridge filters to be placed directly in the end of each respective wells discharge line.

The following outlines standard procedures for filtration of ground water monitor well samples:

Equipment:

1. Disposable .45 Micron Filters (High or Low Capacity) Cartridge Type

Decontamination:

No decontamination required.

Procedure:

1. Reduce flow from discharge line.

2. Tightly screw in disposable filter cartridge making sure flow direction arrow points away from the discharge line.

3. Increase pump rate until low flow rate is initiated from the discharge line and maintain this flow.

4. Precondition[1] Filter Cartridge - For high capacity cartridges with a surface area of 700 cm^2 or greater, rinse with approximately 0.5 liter of sample water. For low capacity cartridges with a typical surface area of 200 cm^2 or less, rinse with approximately 0.25 liter of sample water.

5. Fill appropriate sample containers.

6. Remove pressure in filter chamber or flow line. Remove and dispose of filter cartridge after complete.

Note on Field Log comment section filtration method used, cartridge size and make, and number of samples used per monitoring well.

[1] Filter Preconditioning:

The process of preparing a filter medium for filtration. A new, unused filter medium is rinsed with a defined volume of medium-specific solvent (e.g. water, acid etc.) prior to use to remove potential residuals resulting from filter manufacture, packaging and handling. Such residuals, if not removed, may bias sample integrity as a result of filtration. Filter preconditioning also creates a uniform wetting front across the filter surface to prevent channel flow through the filter and increase filter efficiency.

GAI CONSULTANTS

REPORT

DESIGN REPORT
CLOSURE OF CLARK LANDFILL
IDEM SOLID WASTE PERMIT APPLICATION
INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

Submitted to: LTV Steel Company, Inc.
Cleveland, Ohio

Project 97-481

April 1999

LTV STEEL COMPANY, INC.
CLEVELAND, OHIO

DESIGN REPORT
CLOSURE OF CLARK LANDFILL
IDEM SOLID WASTE PERMIT APPLICATION
INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

GAI Consultants, Inc.
570 Beatty Road
Monroeville, Pennsylvania 15146

Project 97-481-10

April, 1999

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589892	Details

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INTRODUCTION AND PROJECT BACKGROUND

This report summarizes the design of the closure of the Clark Landfill at the Indiana Harbor Works of LTV Steel Company in East Chicago, Indiana. The design drawings prepared for permit application are attached.

The Clark Landfill is a steel mill waste disposal fill within the Indiana Harbor Works located as shown on Drawing 589**880**. (The emboldened final two digits of the drawing number are intended to facilitate referencing.) The disposal area is about 43 acres and the 80-foot high fill is composed of slag, BOF dust, and other steel mill wastes. The landfill was filled to capacity and waste disposal ceased in early 1998. LTV Steel has been in the process of preparing for and implementing the closure of Clark Landfill since about 1996.

The intake flume for the No. 2 pumphouse of the Indiana Harbor Works is located along the south side of the Clark Landfill and is the major source of water for plant operations. A portion of the south slope of the landfill failed on August 6, 1997 as shown on Drawing 589**882** during the implementation of an earlier closure plan developed by others. The slope movement partially filled the intake flume and placed the steel plant's water supply source in jeopardy. The landfill slope must be reconstructed to provide a stable condition that both protects the ability of the intake flume to deliver water to the No. 2 pumphouse and meets the slope and foundation stability requirements set forth in the Indiana Landfill Closure Regulations. The only practicable alternative to stabilizing the landfill slope and keeping the landfill materials at the current landfill location requires modifications to the intake flume. These modifications include the placing of fill within a portion of the flume to create a buttress for the slope, regrading the waste to create a flatter slope, and dredging a small portion of the flume to maintain adequate flow capacity. These modifications are required to raise the existing factor of safety against slope failure from approximately 1 to $\geq$ 1.3.

Subsequent to the slope failure and geotechnical studies to determine how to repair the slope failure (Reference 1), LTV met with IDEM on March 5, 1998 and with IDEM and IDNR on October 20, 1998. The purpose of these meetings was to discuss ways to repair the failed slope and meet Indiana's requirements for closure without requiring removal of disposed materials from the Clark Landfill to another disposal area. During these meetings IDEM indicated general agreement with the following concepts that have been used to develop the current plan:

- Stability analyses of the landfill and cover systems should have minimum safety factors of 1.3 for current or temporary conditions and 1.5 for long-term conditions.

- Construction of an aggregate buttress in the flume is an acceptable approach to improving slope stability.
- Since a vegetated cap may not be necessary in an area surrounded by industrial facilities, IDEM will consider innovative capping systems such as a free draining aggregate layer over a low permeability geomembrane.
- A runoff detention pond for the south slope is not required if clean cover materials are used to limit sediment transport from the cap.
- The existing landfill can be reconfigured to flatten the south slopes and relocate the excavated materials along the more stable north slope to improve the overall stability of the landfill.
- The geotechnical evaluations of the slope failure indicated that high pore water pressures in the natural clay below the landfill were a factor in the failure. These pore pressures were induced by construction of the landfill and by landfill regrading in 1997. Pore water pressures are a function of the rate and magnitude of loading of the clay. Thus, the proposed grading for closure should be performed in a gradual fashion and pore pressures should be monitored so that the stability of the landfill is satisfactory throughout the completion of the closure plan.

LTV obtained emergency dredging permits in October, 1997 to restore adequate flow capacity to the flume in its most constricted area following the slope failure. Emergency dredging was done both in November 1997 and in December 1998. The currently proposed flume dredging, buttressing, and landfill reconfiguration will reestablish a stable configuration and restore the required capacity of the flume.

The following sections of this report summarize the key information used to design the final configuration of the landfill. Elevations in this report are referenced to the U.S. Coast and Geodetic Survey 1929 Mean Sea Level Datum, unless otherwise stated. Table 1 provides conversions to other systems.

DESCRIPTION OF SUBSURFACE CONDITIONS

Original Plant Grading

The LTV property that includes the Clark Landfill and the intake flume to the No. 2 pumphouse was originally created as fill in Lake Michigan. The fill progression is well documented on historical USGS Quadrangle maps, NOAA navigation maps, and LTV filling program drawings. The majority of fill that was placed to create over 300 acres of level ground for the LTV plant in the late 1960's and the early 1970's. The intake flume to the No. 2 pumphouse is an artificial waterway and was designed in 1971 and was constructed by filling on both sides before 1976. The flume is constructed of fill material consisting primarily of rubble, stone, and slag, and is not a natural stream or water course. It is merely the remnant of the lake that was not filled during the original site grading to provide a source of water for plant operations. Drawing 589880 provides an overview of the current LTV property, landfill and intake flume limits.

Geology

The Clark Landfill at the southern limit of Lake Michigan is within the limits of continental glaciation (Reference 2). This area of northern Indiana has been separated into three physiographic provinces based on the glacial deposits and landforms found within each province (Reference 3). The Clark Landfill site is located in the northern-most providence, the Calumet Lacustrine Plain. The plain is characterized by fine lake clay, silt, peat, beach sand and till inclusions. South of the site, are the Valparaiso Moraine and the Kankakee Outwash Plain physiographic providences. The Valparaiso Morainal area is a composite of several end moraines and is a topographic high area.

The soil deposited by the ice sheets is commonly referred to as glacial till, or hardpan. The till is clay silt loam with sand pockets and is generally very stiff to hard due to preconsolidation under the past weight of overlying glaciers. The top of the glacial till below the Clark Landfill is found approximately 75 feet below the current lake level, or about 45 feet below the base of the fill. The till is on the order of 60 feet thick and is underlain by in place bedrock.

When the ice sheet retreated northward, melt water lakes periodically formed between the margin of the retreating ice sheet and the glacial till deposits of the Valparasio moraine area. The lakes formed when the low level water outlets were blocked during minor glacial advances and later drained when a low level outlet was exposed. This episodic flooding and glacial advancement

resulted in successive layers of lake deposited soils of lake till clay, lake border moraines and reworked lake shore deposits. The layers could have erosion surfaces. The result is lake deposits with interbedded layers of clay and silt of variable soil properties and horizontal and vertical geometry. These layers of lake till clays overlie the very stiff till below the Clark Landfill and generally range from soft to stiff in consistency with strengths that vary accordingly.

More recent lake deposits that form the current bottom of Lake Michigan cover the glacial lake clays with a thin layer of fine sand and silt.

A generalized geologic profile for the Clark Landfill is shown in Figure 1.

Subsurface Explorations

Subsurface explorations at the Clark Landfill were made in the spring of 1996 for an earlier closure plan by others, in August 1997 immediately after the slope failure, and in the spring and fall of 1998. GAI used the data from these explorations as well as from explorations completed in 1964 for the filling of the northwest area of the plant for the design of this regrading and closure plan. A summary of information from borings used to prepare this design is presented in Table 2. The locations of these borings and the slope failure are presented on the existing features plan Drawing 589882 and are summarized in Table 3. The field classification sheets for the 1998 GAI borings are presented in Appendix A. The geotechnical data for the remaining borings are presented in References 4 through 8.

An exploration program was started in March of 1998 to better define soil parameters for design of closure of the landfill. Piezocone penetrometer tests were conducted adjacent to the 1997 borings LTV -1 ,-3, -4, -5, -7, and the 1996 boring B-4. The cone test locations were designated with the same boring numbers, followed by the letter "C". Prior to each test, an air rotary drill rig was used to predrill a hole through the fill and to install temporary PVC casing. The piezocones were pushed through the natural soils by a drill rig supplied by D& G Drilling Company. Pore pressure dissipation tests were also conducted near the top , middle and bottom of the glacial lake clay . Four borings were also drilled on the north side of the landfill, borings LTV98-8, -8c, LTV98-9 and -9c, for piezocone and vane shear testing. Pneumatic piezometers were installed in the vane shear borings to measure pore pressures in the clay below the north side of the landfill. The field installation records for the piezometers installed in the clay in borings LTV 98-8 and -9 are included in Appendix A.

Further explorations with borings B-100 through B-104 were drilled between April and June 1998 including soil samples for lab testing, in place soil tests, and installation of piezometers and

slope inclinometer casings. The data from of these investigations and the GAI investigations are presented in the Phase I Interim Geotechnical Data Report dated October 29,1998 (Reference 7).

The additional exploration program in the fall of 1998 was conducted primarily to better refine the soil strengths in the existing flume. These flume borings are numbered SB-201 through SB-211. STS performed vane shear tests of the clay in borings SB-201 to SB-205. Piezometers were installed in borings SB-202 through SB-205. Piezocone penetrometer tests were conducted in borings SB-206 through SB-210. Standard penetration tests were conducted in boring SB-211. The results of these explorations are summarized in Reference 8. Three piezometers were installed in boring SB-207 and inclinometer casing was installed in boring SB-210.

Inclinometer casings were installed in the 1997 borings LTV-1 ,-3, - 4, -5, -6 and -7 and in the 1998 borings SB-100 and SB-210. Through December 1997, Baker Environmental, Inc., obtained and recorded the data from the piezometers and inclinometers installed in the 1997 borings. GAI Consultants Inc. started to collect the data in January of 1998 for the 1997 LTV borings and also for the instrumentation installed in 1998. The inclinometer displacements for 1997 and in 1998 are small, as summarized in Table 4. The rates of lateral movement in the downslope, positive A-axis, direction have remained stable outside the failure zone and have decreased within the failed area. The cumulative displacement plots are presented in Appendix B.

A summary of the piezometer tip elevations is presented in Table 5 . The piezometer data obtained to date is presented in Appendix C. The piezometers installed at various levels within the lake clays below the fill indicate that excess pore pressures are present in the lake clays due to the weight of the landfill and the slow consolidation of the relatively low permeability clays. These excess porewater pressures are expected to take many years to dissipate based on piezometer records and one dimensional consolidation tests (References 1, 7 and 8). Piezometer B101B at 91-foot depth malfunctioned and has been replaced by B101C at 91 feet. The data for Piezometer B101B at 91-foot depth should be disregarded.

Data from the borings indicates that the highest groundwater level in the fills beneath the relatively permeable landfill is governed and fluctuates with the level of Lake Michigan between approximate elevations 577 and 583 feet.

Laboratory Testing

The results of laboratory tests of site soils are contained in References 6, 7, and 8. This testing was used in conjunction with the results of the field tests to assign parameters for the stability analyses.

Testing of potential capping materials has been completed and the results are presented in Appendix D. The results indicate satisfactory interface shear strength for the aggregate to geotextile interface and for the textured geomembrane to sand interface. However, the shear strength for the interface between the geotextile and the textured geomembrane is marginal for the steepest planned landfill closure slope of 3H:1V. Thus, supplemental geogrid reinforcement or possibly an alternate textured geomembrane will be necessary to achieve satisfactory cap stability for the 3H:1V slope.

Soil Properties

The location of the slope failure is shown on Drawing 589882. The material in the slope failure zone includes the upper half of the natural clay deposit and the fill above. The soft to stiff clay deposit upon which the landfill is founded is nominally 43.5 feet thick outside the failure zone and extends essentially from the base of the slag at approximate elevation 550 to the top of very stiff till at approximate elevation 506.5. The 1997 failure zone is within the clay deposit. The top of clay has heaved in the toe area of the landslide to about elevation 560± feet.

Regrading is intended to create loading conditions favorable to both the short term and the long term stability of the landfill. Since the drainage properties of the clay deposit are slow, regrading cannot be expected to produce an appreciable short term dissipation of induced pore pressures (or increase in effective stresses) within the clay deposit. The slow drainage properties of the clay dictate that the stability of the landfill be evaluated by means of undrained stability analyses both under existing (post-failure) conditions and under conditions that will prevail during and immediately after regrading. Although such analyses can be conducted on a total-stress or an effective-stress- with-pore-pressures basis with equal validity, the total stress approach has been adopted in the present work. This allows the shear strength of the clay deposit to be characterized in terms of a single parameter — the undrained strength, Su.

Prevailing vertical and lateral variations of Su within the clay deposit have been assessed through a series of fourteen piezocone (CPT) and twelve vane shear profiles made within the footprint of the landfill and the flume. The field investigation yielded nearly 3,000 values of undrained strength which have been used in the assessment of post-failure landfill stability —

approximately 2,700 from CPT profiles, where tests were typically made at 0.25 foot intervals of depth, and approximately 280 from vane shear tests, where tests were made variously at 2 to 5 foot intervals of depth, with one peak and one remolded value at each depth.

The body of field strength data has been synthesized as follows:

- The clay deposit has been divided into six horizontal layers based on a consideration of the depth-wise variations of Su exhibited by the strength profiles. The judicious delineation of layers, with thicknesses ranging from 4 to 16 feet, with upper and lower boundary elevations being listed in Table 6, has made it possible to use the same layers in all stability analyses, regardless of location inside or outside of the failure area.
- The Su profiles defined by the CPT and vane data have been separated into two groups — one group encompassing tests performed within the failure area, and the other encompassing tests performed throughout the remainder of the site.
- A series of design strength envelopes have been defined that characterize the prevailing depth-wise variation in Su within each sector of the site.
  - > There are four such envelopes. They are paired as shown in Appendix E and summarized in Table 6. One pair of envelopes pertains to areas of the site that were not involved in the slope failure and the other to the area within the slope failure.
  - > For the pair of strength envelopes pertaining to the non-failure zone, one envelope applies to "thin overburden" conditions (such as near the toe of the landfill or the flume, for example) and the other to "thick overburden" conditions (such as farther under the landfill). Specifically, the line of demarcation between thin and thick overburden conditions has been set at a total slag thickness of 65 feet, corresponding to approximately 35 feet of slag above normal lake level. [Note that, in the cross sections discussed in "stability analyses", thick overburden has been denoted by letter *"a"* and thin overburden by letter *"b"*.]
  - > For the pair of strength envelopes pertaining to the failed zone, one envelope applies to the disturbed clay located between the head scarp and the near (north) side of the flume, and the other to the disturbed, potentially heaved, clay beneath and immediately adjacent to the flume. [Note that, in the cross sections discussed in "stability analyses", the disturbed clay

between head scarp and flume has been denoted by letter *"b"* and the disturbed clay approximate to the flume by letter *"c"*.]

> For each of the four strength envelopes, the design value Su of the six clay layers is listed in Table 6. The strength envelopes are considered to be reasonable representations of the undrained strength of the clay deposit.

In the assessment of the long term stability of the landfill slopes for the future condition when the induced pore pressures have fully dissipated, the clay deposit has been assigned an effective friction angle of 16 degrees within the slope failure area (Reference 6, Table 3) and 20 degrees outside the failed area (Reference 2, pp. 37, and Reference 7, Appendix G), with zero cohesion in both cases.

EXISTING CONDITIONS SLOPE STABILITY

The stability of the existing south slope along the intake flume was evaluated during the fall of 1997 after the slope failure and was found to be marginally stable with a factor of safety near unity (1.0) (References 1 and 6). At the time of the slope failure in August 1997, the landfill was being regraded to prepare for ultimate closure of the facility. The failure occurred in the area shown on Drawing 989882. The stability of the area of the south slope that has not failed is still marginal and analyses indicate safety factors near unity (1.0) (Reference 6).

The slope inclinometer data indicates minor creep of the south slope and the piezometers indicate that excess pore pressures are either stable or dissipating slowly. Thus, the instruments confirm the marginal stability of the south slope of the landfill. Since the stability of the south slope is marginal, the first priority of the closure plan must be to restore the stability of the south slope.

PROPOSED CLOSURE PLAN

General Closure Objectives and Proposed Features

The objectives of the proposed closure plan are to restore the stability of the south slope of the landfill while maintaining adequate flow capacity in the intake flume and meeting Indiana's regulations for closure of a residual waste disposal area. The three major activities to accomplish these objectives are as follows:

- constructing an aggregate buttress in the flume;
- flattening the slopes on the south side of the landfill; and
- providing a durable low permeability cap to minimize long term infiltration into the closed landfill.

The proposed regrading of the south slope to a flatter configuration with overall slopes ranging from 3.5H:1V to 7H:1V in conjunction with the buttress fill in the flume improves the short term safety factor for stability of the south slope from the current value of about 1.0 to a value of 1.3. After years of further dissipation of the excess pore pressures in the clay, the safety factor against failure of the south slope is expected to be at least 1.5.

The north slope of the landfill will be graded to a maximum slope of 3H:1V. The safety factor for the north slope exceeds 1.3 for the short term stability and 1.5 for long term stability.

Slope Stability

Stability analyses were performed to define stable slopes using the computer program Slope/W (Reference 9) which is a software product that uses the limit equilibrium theory to solve for the factor of safety of slopes. The program creates a graphical output which is included herein. The factor of safety along circular and block specified slip surfaces was calculated using both Bishop's and Spencer's method of analysis (Reference 10). The Spencer method is more amenable to analysis of sliding block failure surfaces than the Bishop method while both are equally well suited for analyzing circular failure surfaces. The results from the Spencer method were therefore used in design since this method satisfies both force and moment equilibrium, and the results for circular failure surfaces are comparable to those of the Bishop method. Block specified slip surfaces were utilized to calculate the factor of safety of the overall landfill slope, and circular slip surfaces were utilized to determine the factor of safety approximate to the toe of the landfill at the flume. The factor of safety of a particular slope was taken to be the minimum value

of a series of stability analyses performed, for the block mode of failure, on one thousand and twenty (1,020) specified slip surfaces and, for the circular mode of failure, on 320 circular slip surfaces. The failure surface with the least factor of safety is presented on the enclosed graphical output in Appendix F.

Short term stability governs the geometry of the landfill. Short term stability analyses were performed using total stress undrained strength parameters for the clay soils . Long term stability analyses were performed using effective stress strength parameters and fully drained conditions. The static water level in fill for both sets of analyses was at a typical elevation 581.

In both sets of analyses, the clay was divided into six horizontally bedded strata labeled Clays 1 through 6 and subdivided into lateral segments as indicated on the output from the stability analyses (Appendix F) and as discussed under "Soil Properties". In stability analyses involving the landslide, the demarcation between undisturbed and disturbed clay beneath the landfill was established by projecting downward to the south from the head scarp visible at the ground surface at an inclination of 0.75H:1V.

Drawing 589884 shows the proposed finished grading developed on the basis of the stability analyses. Short term stability analyses were performed along nine cross sections: Sections at Stations 3, 6, 8, 10, 14, 16, 18, 22, and 26 along the flume side (south side) and Section 10 along the land side (north side) of the landfill. Long term stability analyses were performed along three sections: Sections 10 and 22 along the flume side of the landfill and Section 10 along the land side of the landfill. All sections were cut perpendicular to the regraded topography as shown on the plan in Appendix F. Sections 3 and 6, in order to be perpendicular to the topography gradient, were cut skewed to the baseline. Sections 6, 8, 10, and 14 were within the zone of slope failure. Sections 3, 16, 18, 22 and 26 were outside the slope failure.

The stability analyses indicate that the regraded landfill will have a short term factor of safety of at least 1.3 and a long term factor of safety of at least 1.5.

South Slope Buttress

Clean fill, consisting of crushed stone or other inert environmentally acceptable granular material that is not a by-product of the plant steel-making operations, will be used to create the buttress at the toe of the south landfill slope. This material is to be placed below elevation 585 (the highest anticipated lake level is elevation 583 feet). The screened gradation for this material consists of particles between 1/2 and 6 inches in diameter.

Flume Hydraulic Analysis

Current plant water intake demand at the No. 2 pumphouse is 120,000 gallons per minute (gpm). It is anticipated that future demands may require an additional 50,000 gpm, which would make the total demand 170,000 gpm. Due to the importance of maintaining a reliable supply of intake water for plant needs, and the potential duration of ice cover on the flume, the reconfigured intake flume has been designed to provide 340,000 gpm at the minimum monthly mean water level recorded from 1903 to 1998 at Calumet Harbor Station, Elevation 576.8. The reconfigured intake flume has been designed to deliver 340,000 gpm to the intake structure with less than 2 feet of head loss and a minimum hydraulic grade line elevation of 575 at the intake structure. The hydraulic analyses for the realigned intake flume are in Appendix G. Assumptions and limitations to these calculations are listed below:

- Assess as a "forebay" problem as described in Heyderson, F.M., Open-Channel Flow MacMillan Publishing, Co., New York, 1966.
- The calculations are based on a rectangular-shaped channel; therefore, for a trapezoidal shaped channel, the actual capacities will be somewhat greater than computed.
- Do not allow pumping to lower the water below the level of the supply pump intake.

Numerous configurations of channel invert vs channel widths were investigated. The minimum channel dimensions selected are as follows:

Channel Invert (ft)	Min. Channel Base Width (ft)
568	20

The calculations presented in Appendix G indicate that the proposed channel geometry has adequate capacity for the design flows.

Channel Backwater Analysis

To determine the steady state performance of the intake channel, a channel backwater analyses was performed. The Hydrologic Engineering Center - River Analysis System (HEC-RAS) method was used. As a conservative approximation, the proposed forebay water volume was ignored and the channel was assumed to be of constant section for 3,000 feet from the beginning of proposed flume filling at the north end of the reconfigured channel to the intake structure at the south end. The flume section was modeled as a flat (zero percent slope) trapezoidal channel with two horizontal to one vertical side slopes (2H:1V) and a bottom width of 20 feet at elevation 568. The calculations were performed using the record minimum monthly mean water level (elevation

576.86) and 340,000 gpm water intake rate. Using this input, the head loss thorough the channel is less than one foot. Velocities of the water in the channel under these conditions ranged from 2.7 to 3.2 feet per second. Therefore, the channel appears to have adequate capacity without excessive velocities.

Realigned Flume Wave Protection

The northeast end of the realigned flume which is closest to Lake Michigan will be protected against wave erosion by riprap. The size and thickness of this riprap will be determined as a part of the preparation of construction plans and specifications.

Landfill Cover Design

Cover Design and Characteristics. The proposed cap is 2 feet in total thickness. It will incorporate a low permeability barrier geomembrane textured on both sides. The base of the geomembrane will be protected by a 0.5 foot thick sand-sized cushion and gas collection layer. The upper surface of the geomembrane will be protected by a geotextile. A free draining durable aggregate is the finished surface for the cap. The thickness of the aggregate layer will generally be 1.5 feet. The stability of the cap is a function of the interface shear strength of the cap components and seepage forces developed during peak precipitation events. The cap is designed for a minimum safety factor against sliding of 1.3 for the design storm. The screened aggregate for the cap will consist of particles from 1/2 to 2-1/4 inch in diameter.

Stormwater Management. The LTV Clark landfill has been designed to convey storm water that lands on the cap in such a manner as to maintain cover stability while conveying the water away from the closed landfill. The storm water design incorporates the following features:

- The coarse aggregate cover is capable of handling the storm water from a 100-year, 24-hour storm event while maintaining all storm water flow within the coarse aggregate layer (no visible surface runoff).
- The storm drainage pipes on the North bench are designed to handle the 100-year, 24-hour storm event.
- The sedimentation/equalization pond at the toe along the north side of the landfill is designed to store the 25-year 24-hour storm event without overflow of the drainage channel. The stored water will discharge slowly to the plant storm drainage system within 10 days of being filled by a 25-year 24-hour storm.

- Storm water that lands on the South side of the landfill (flume side) will flow downslope in the coarse aggregate layer and discharge as sheet flow into the flume along the entire flume length. There will be no point source discharges.
- Storm water that lands on the North side of the landfill will be captured in pipes and the sedimendation/equalization pond and will be diverted into the existing plant area storm water drainage system. The connection to the existing storm water system will be made at existing manholes #23 and #46. The existing storm water system drains into the plant area North Lagoon from which the plant service water is obtained.

The surface drainage calculations are presented in Appendix H.

Selection of the final cover for the landfill was made based on material availability, the materials' ability to meet certain performance criteria, and cost. The objective of the cap is to provide a durable, stable, cost effective cover that limits waste leachate impacts to groundwater by limiting stormwater infiltration into the closed landfill wastes. The final cover consists of a very low permeability synthetic geomembrane which acts as an infiltration barrier covered by a washed coarse aggregate surface. The coarse aggregate surface acts as a combined drainage layer and protective cover. The coefficient of permeability of the cover aggregate will be greater than 20 cm/sec.

The coarse aggregate cover is designed such that the cover will remain stable in storms up to and including the 100-year 24-hour rainfall event, with all flow on the final cover within the interstitial spaces in the aggregate layer. Drainage structures on the periphery of the closed landfill are designed to store the landfill runoff during a 25-year 24-hour storm event. In storm events in excess of the 25-year event up to and including the 100-year event, the area immediately around the landfill may develop pockets of standing water, but the landfill cover will remain stable.

Drainage from the north side of the landfill is designed to provide subsurface flow to the bench and sedimentation/equalization pond at the toe of the landfill. This pond will slowly discharge the stormwater to the existing plant area stormwater collection system. The connection to the existing system will be made at existing storm water manholes #23 and #46. From here the stormwater is transported to the existing North Lagoon which receives stormwater runoff from the immediate plant area and acts as a sedimentation pond. Water from the North Lagoon is used within the plant complex as service water.

Stormwater runoff from the south side of the landfill is designed to sheet flow into the reconfigured intake flume. Stormwater which lands on the south side of the landfill will percolate into and flow within the washed coarse aggregate cover and discharge in a non point discharge into

the flume. Due to the durable, clean (washed crushed limestone aggregate) nature of the coarse aggregate cover and the lack of ongoing activity once the landfill is closed, no additional sedimentation control is proposed at this location.

Landfill Cover Stability

The LTV Clark Landfill cap has been designed to provide a stable, low permeability cover which will be non-erosive and will blend into the surrounding facility. The cap will provide ground water protection by greatly reducing the landfill storm water infiltration rate. Although no vegetative cover is proposed for the closure, the cover will provide a long term, low maintenance encapsulation of the waste. As proposed, the cap design from top to bottom, incorporates an 18-inch thick coarse aggregate layer, a 16-ounce nonwoven geotextile, a 40-mil textured geomembrane, a six-inch-thick sand aggregate cushion and gas vent layer, all placed on the prepared waste. Supplemental geogrid reinforcement will be provided for stability of the 3H:1V slopes. The following further describes the layers:

- An 18-inch deep coarse aggregate cover will be the top layer in the cap. This layer will function as a protective cover and non erosive surface for the low permeability liner located below this layer. The use of this layer will eliminate any storm water runoff since based on the design, all storm water will flow in the interstitial space between the individual aggregate pieces. The grain size of the aggregate has been selected such that the veneer stability of the aggregate remains satisfactory in storms up to and including the 100-year 24-hour storm.
- A 16-ounce nonwoven geotextile will be placed under the coarse aggregate as a cushion for the underlying geomembrane. This geotextile will be replaced with a geocomposite drainage net (Geonet bounded on both sides by nonwoven geotextiles) under maintenance road areas where located on the cap.
- A 40-mil textured geomembrane will be used as the low permeability barrier in the cap. The geomembrane will be located under the cushion geotextile. The geomembrane will provide a long term infiltration barrier which will not be adversely affected by freezing temperatures and frost heave like a clay barrier would. The geomembrane will be continuous over the entire landfill but will be periodically penetrated by gas vents strategically located across the site. The gas vents will be passed through the geomembrane with watertight boot connections.

- A six-inch-thick sand aggregate layer will be located immediately beneath the geomembrane. This layer will act as a cushion for the geomembrane as well as a gas vent layer. Any gas collected in this layer will be vented to the atmosphere through the periodically located gas vents.

The existing waste will be regraded to provide greater long term stability. The overall landfill slopes will be flattened, regraded and compacted. The finished surface of the waste will be fine graded to provide positive drainage and uniform slopes. Large materials that could endanger the integrity of the geomembrane will be removed from the waste final graded surface.

The stability of the cover was analyzed using the infinite slope method of analysis. Two slope inclinations were considered: the steepest face inclination of 3H:1V and a face inclination of 7H:1V. Water depths associated with the dry and the 100-year 24-hour rainfall conditions were analyzed. For the 3H:1V slope, the minimum interface friction value between dissimilar materials must be at least 24.5 degrees to achieve a factor of safety of 1.3 for the 100-year 24-hour rainfall event. This same slope has a factor of safety of 1.2 in the dry with the minimum tested interface friction angle of 22 degrees. Based upon laboratory test results completed to date, this minimum friction angle will occur at the geotextile/geomembrane interface. A geogrid veneer reinforcement layer will be installed above the geotextile on the 3H:1V slope to increase the factor of safety in the dry to 1.5. For the 7H:1V slope the factor of safety for the 100-year 24-hour rainfall event is 2.6 for a minimum interface friction angle of 22 degrees. The calculations are presented in Appendix I.

CONSTRUCTION

Overall Schedule

It may be theoretically possible to implement the closure plan in one construction season if this were strictly a regrading and capping project. However, the governing issue in this closure plan is the improvement of stability of the south (flume-side) slope. There are several piezometers and slope inclinometers at the project site. All of this instrumentation will be used to monitor the elevated pore pressures in the underlying clay layers and slope movements during the regrading operations for conformity with acceptable performance. It is anticipated that the rate of filling of the flume to buttress the south slope will require 1 to 2 construction seasons to complete in a sufficiently gradual fashion to prevent the development of unacceptably high pore pressures. Regrading of the landfill, which must be delayed until after the flume buttress has been completed, is anticipated to require one construction season. The cap should not be constructed until all regrading has been completed and the instrumentation indicates satisfactory performance of the regraded slopes. The capping will then require one construction season to complete. Therefore the closure should be completed in a proper sequence over the next 3 to 4 years.

Sequence

The anticipated sequence of construction is outlined on Drawing 589881. The Phase I activities will include:

- Installation of erosion and sedimentation controls;
- Road and utility relocations;
- Installation of new stormwater collection pipes and the sedimentation/equalization pond;
- Dredging shallow areas in the flume; and
- Constructing the buttress in the flume.

The buttress construction in the flume is subdivided into three stages and is controlled by elevation so that no portion of the flume receives a large concentrated load and the filling is conducted gradually along the length of the flume.

Once the Phase I activities have been completed, the Phase II activities can begin. This includes:

- Installation of additional erosion and sedimentation control measures;

- Excavating materials from the top and south face of the landfill and placing them as fill on the north and west sides of the landfill; and
- Fine grading the landfill to the finished subgrade configuration for the cap.

As with the Phase I buttress construction, the sequence of construction of the Phase II grading is controlled by elevation stages. The excavation will proceed from the highest elevation downward which reduces the load tending to cause slope instability. The filling will proceed in 5-foot increments from the lowest level up. Filling at the lowest level improves the buttressing of the slope which improves stability. All filling in a 5-foot elevation stage must be completed before filling can be initiated in the next higher 5-foot increment so that fill loads will be placed gradually and uniformly. This will reduce the risk of slope failures during construction due to large loads being placed too rapidly for the strength of the underlying clays.

The remaining portion of the Phase II construction will be the installation of the capping system including surface drainage features and gas vent piping. The sand cushion and gas vent layer will be installed first. It will be immediately protected from erosion by installation of the textured geomembrane followed by the geotextile and the geogrid layer (north slope only). The coarse aggregate cover will then be placed in a single 18-inch lift. The coarse aggregate will be stockpiled below the area where it is needed and then will be carried uphill for final placement. All placement will be undertaken using low ground pressure (less than 7 psi) equipment. Under no circumstance will equipment be allowed to travel directly on the geotextile or geomembrane. The contractor will be required to provide a detailed placement procedure for the entire capping system for approval prior to proceeding.

Throughout the entire construction process, the existing piezometers and slope inclinometers will be monitored and maintained to determine if the landfill is being adversely affected by the grading activities. If the inclinometer data indicate that ground movements are accelerating or if the piezometers indicate rises in pore pressures greater than the loading pressures being applied, the information will be evaluated and the grading sequence or rate will be modified to preclude a slope failure.

Sedimentation and Erosion Control Measures

Erosion and sedimentation control measures will be provided during and after the closure of the landfill. Proposed controls include silt fence, silt curtains in the flume, and the use of durable coarse aggregate fill materials. Control of erosion from stormwater runoff during landfill regrading will be achieved by the use of temporary silt fence installed around the periphery of the proposed

landfill prior to landfill grading. Permanent erosion and sedimentation control will be provided by the drainage collection system installed along the north side of the landfill, and the selection of the final cover material which will be a durable crushed limestone placed over the entire synthetic cover. Drainage from the south side of the landfill will continue to be sheet flow into the plant intake flume. At completion of the landfill closure, the silt curtains will be removed from the plant intake flume. The following describes the erosion and sedimentation control measures.

Initially two silt curtains will be installed in the existing intake flume. One will be installed near the existing plant intake structure, and the other will be placed to the north of the proposed flume filling area. Both of these curtains will be installed prior to any dredging and filling of the existing flume. The fill to be placed in the flume will consist of durable aggregate having particle sizes from 1/2" to 6".

The stormwater drainage system will then be installed along the north side of the landfill. Once installed, this stormwater pipe and ditch will collect water from the north side of the landfill and direct it to the existing North Lagoon. The North Lagoon currently receives stormwater from the rest of the immediate plant area and the water is recycled as plant service water. The installation of the stormwater piping will take place within the plant area on the virtually flat plant existing grade. The length of open trenching will be limited to a few hundred feet of ditch at any time.

Prior to regrading of the existing waste, silt fence will be installed around the periphery of the proposed landfill. It will be located along the newly constructed drainage ditch and pipe along the north side of the landfill and along the newly constructed access road along the relocated flume. This silt fence will remain in place until immediately before placement of the synthetic cover at which time it will be selectively removed to facilitate liner construction.

Groundwater Monitoring Wells

During the meeting on October 20, 1998, IDEM indicated that the permit for closure will probably require the installation of four groundwater monitoring wells around the perimeter of the facility. The proposed locations are shown on Drawing 589884. The wells to monitor ground water quality will be installed into the natural soils below the landfill as shown on Drawing 589891. The wells should be installed after completion of the Phase II grading to reduce the probability of damage during construction.

FUTURE ACTIVITIES

This report and design have been prepared to aid in the closure of the Clark Landfill of the Indiana Harbor Works of LTV Steel Company. Its scope is limited to the specific project and location described herein and represents our understanding of the significant aspects relative to soil and groundwater considerations. If there are differences in the locations of relevant facilities and/or design features from those described herein, GAI should be informed so we may, if necessary, modify or revise our recommendations and determine if additional exploration, testing and analyses are warranted prior to the planned construction. GAI should be permitted to complete any currently unresolved design issues before proceeding with construction. We should then be permitted to prepare the construction plans and specifications. GAI should monitor any additional exploration, instrumentation, subgrade preparation, and regrading and capping activities so that these aspects of the project are constructed according to the intent of our recommendations and so that any unanticipated geotechnical conditions might be recognized and properly reconciled.

Respectfully submitted,
GAI Consultants, Inc.

Robert W. Bruhn, P.E.
Staff Consultant

Joseph D. Phillips /TRG

Joseph D. Phillips, P.E.
Engineering Manager

F. Barry Newman

F. Barry Newman, P.E.
Project Manager

RWB:JDP:FBN/bab

REFERENCES

1. GAI Consultants, Inc., "Conclusions and Recommendations, Investigation of Landslide in Clark Landfill, LTV Steel Company Indiana Harbor Works, East Chicago, Indiana," Project 97-481-10, November 14, 1997.

2. Peck, R.B. and William C. Reed, "Engineering Properties of Chicago Subsoils," University of Illinois Engineering Experiment Station Bulletin No. 423, Urbana Illinois, 1954.

3. "Hartke, Edwin J., et al. , "Environmental Geology of Lake and Porter Counties, Indiana, An Aid to Planning", Bloomington, Indiana, 1975.

4. Elio D'Appolonia Associates, Inc. "Subsurface Investigation, Northwest Fill Area, Youngstown Sheet and Tube Company, Indiana Harbor Works," October, 1964.

5. Baker Environmental, Inc., "Geotechnical Report, Stability Analyses for Clark Landfill, LTV Steel Company, Indiana Harbor Works, East Chicago, Indiana," August 1996.

6. Baker Environmental, Inc., "Draft Report on Investigation of Slope Failure, Clark Landfill, LTV Steel Company, Indiana Harbor Works, East Chicago, Indiana" Volumes 1 and 2, November, 1977.

7. STS Consultants, Ltd,. Phase I Interim Geotechnical Data Report - Clark Landfill Slide Mass, LTV Steel Mill, East Chicago, Indiana, STS Project No. 8741-0, Task 8000, October 29, 1998.

8. STS Consultants, Ltd,. Interim Phase 2 Geotechnical Data Report - Flume Study and Clark Landfill Slide Mass, LTV Steel Mill, East Chicago, Indiana, STS Project No. 8741-Q, Task 8000, December 11, 1998.

9. SLOPE/W for Slope Stability Analysis, Version 3, Geo-Slope International, Ltd., Calgary, Alberta, Canada, 1995.

10. Spencer, E. " A Method of Analysis of the Stability of Embankments Assuming Parallel Interslice Forces," Geotechnique, 17, 11-26, 1967.

TABLES

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.

Table 1
LTV INDIANA HARBOR DATUM CONVERSIONS
Clark Landfill
LTV STeel Indiana Harbor Works

SELECTED ELEVATION	U.S.C.&G.S. 1929 DATUM		LTV PLANT DATUM		I.G.L.D. 1985 DATUM
GENERAL PLANT GRADE	**600.00**	=	21.14	=	599.09
LTV DATUM REFERENCE	578.86	=	**0.00**	=	577.95
MAX. RECORDED LAKE ELEV. *	583.26	=	4.40	=	**582.35**
MIN. RECORDED LAKE ELEV. **	576.86	=	-2.00	=	**575.95**
NEW FLUME BOTTOM	**568.00**	=	-10.86	=	567.10
I.G.L.D. DATUM REFERENCE ***	0.91	=	-577.95	=	**0.00**

* Maximum monthly mean water level recorded at Calumet Harbor Station, Oct 1986

** Minimum monthly mean water level recorded at Calumet Harbor Station, Feb 1964

*** Correction between 1929 U.S.C.&G.S. (NGVD) AND 1985 I.G.L.D. at Indiana Harbor Station, Bench Mark H 18

U.S.C.&G.S. - United States Cost & Geodetic Survey
I.G.L.D. - International Great Lakes Datum

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.

Table 2
Summary of Information from Borings
Clark Landfill
LTV Steel Indiana Harbor Works

	Elevations							
	Ground Surface	Top of Fill	Top of Sand/Silt	Top of Clay Soft to Stiff	Top of Very Stiff to Hard Silt/Till	Top of Bedrock	Bottom of Boring	Instruments Installed
1964 Borings								
Station A	552		552	550	505		496	
Station B	551		551	550	505		501.5	
Station C	555		555	552	506		504	
Station D	563	563	555	552	508		504	
Station AA	595	595		549	505		500	
Station BB	596	596		547	509		505	
1996 Borings								
B-1	600.2	600.2	553.2	548.2	498.2	447.2	439.2	
B-4	632.8	632.8	549.8	547.8	504.8	446.8	441.8	
1997 Borings								
LTV-1	599.9	599.9	551.9	548.9	506.9		503.9	Piez. Inclinometer
LTV -2	616.2	616.2	550.2	548.2	505.2		499.7	Piezometers.
LTV-3	595.5	595.5	547.5	545	506.5		498.1	Piez.,Inclinometer
LTV-4	618.1	618.1	646.1	544.6	506.5		498.1	Piez.,Inclinometer
LTV-5	588.6	551.8	551.8	548.1	500.3		492.6	Piez.,Inclinometer
LTV-6	675	675	552	548.5	503.2		492	Piez.,Inclinometer
LTV-7	629.6	629.6	552.9	548.9	503.4		484.9	Piez.,Inclinometer

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.

Table 2 (Continued)
Summary of Information from Borings
Clark Landfill
LTV Steel Indiana Harbor Works

	Elevations							
	Ground Surface	Top of Fill	Top of Sand/Silt	Top of Clay Soft to Stiff	Top of Very Stiff to Hard Silt/Till	Top of Bedrock	Bottom of Boring	Instruments Installed
1998 Borings								
LTV98-8	599.7	599.7	550.7	549.2			520.2	3 Piezometers
LTV98-9	616.1	616.1	548.6	546.1	504.6		502.6	3 Piezometers
LTV3P98	598.8	598.8	558.8	548.8			508.8	
LTV5P98	589.1	589.1	549.1	547.1	505.1		500.1	
B-100	616	616	548	543			511	Inclinometer to El. 490
B-101	617.9	617.9		540.9			501.9	Inclinometer
B-102	672.3	672.3	552.3	550.3			503.8	2 Piezometers
B102A	672.5	672.5	547.5	544.5			505	2 Piezometers
B-103	638.5	638.5	550.5	542.5			503.5	3 Piezometers
B-104	599.7	599.7	559.7	548.7			507.7	2 Piezometers
B-104A	599.7	599.7	553.7	549.7			511.7	
SB-201	559.5	559.5	553.5	548.5	507.5		498.5	
SB-202	575.4	575.4	548.4	546.4			497.9	Piezometers
SB-203	575.9	575.9	550.9	546.9			501.9	Piezometers
SB-204	569.5	569.5	556.5	551.5			501.5	Piezometers
SB-205	569	569	554	549			506	Piezometers
SB-206	553.3		553.3	548.3	505.3		494.3	
SB-207	574.8	574.8	561.6	558.6	507.6		499.1	3 Piezometers
SB-208	566.1		566.1	563.1	512.1		489.1	
SB-209	574.3	574.3	553.3	551.3	499.3		493.3	
SB-210	583.6	583.6	551.6	547.6	503.6		487.1	Inclinometer
SB-211	601.3	601.3	555.3	549.8			547.8	

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.
Table 3
Surveyed Locations of Borings and Instrumentation
Clark Landfill
LTV Steel Indiana Harbor Works

GAI HOLES LTV-CLARK LANDFILL WELL LOCATION CHART

DATE: 5/28/98

WELL NAME	LOCATED	PROGRAM USE	NORTHING	EASTING	STEEL CASING OR FLUSH MOUNT ELEV.	PVC RISER ELEV.	ROUND ELEV 1 FOOT FROM WELL BASE	
CPT/B-4C	X		1,521,534.45	400,529.63		635.185	634.1	PVC SHOT ON N. SIDE
CPT/B-101C	X		1,520,859.44	399,133.69		616.330	616.4	
CPT/LTV-1C	X		1,520,780.12	398,853.16		599.785	600.4	PVC SHOT ON S. SIDE
CPT/LTV-3C	X		1,520,776.38	399,224.23		596.560	596.2	PVC SHOT ON N. SIDE
CPT/LTV-4C	X		1,520,943.48	399,114.43		617.355	617.4	
CPT/LTV-5C	X		1,520,978.26	399,459.00		590.240	590.1	PVC SHOT ON E. SIDE
CPT/LTV-7C	X		1,521,394.28	400,100.49		629.755	629.5	
CPT/LTV98-8C	X		1,521,455.09	398,847.54		599.980	599.7	
CPT/LTV98-9C	X		1,521,713.30	399,706.43		616.600	616.0	PVC SHOT ON N. SIDE
LTV98-8	X		1,521,446.41	398,840.96		602.67 *	599.7	
LTV98-9	X		1,521,717.36	399,697.75		619.11 *	616.1	PVC SHOT ON N. SIDE

LTV_GAI1.WB2

* NO INNER PVC-SHOT TOP OF CASING

Table by Cole Associates Inc.

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.
Table 3A
Surveyed Locations of Borings and Instrumentation
Clark Landfill
LTV Steel Indiana Harbor Works

GAI HOLES LTV-CLARK LANDFILL WELL LOCATION CHART

DATE: 11/29/98

BORING NAME	LOCATED	PROGRAM USE	NORTHING	EASTING	STEEL CASING OR FLUSH MOUNT ELEV.	PVC RISER ELEV.	GROUND ELEV. 1 FOOT FROM WELL BASE
B-206	X	IN WATER	1,520,593.91	398,597.56			553.3
B-207	X	IN WATER	1,520,673.02	398,782.43			574.8
B-208	X	IN WATER	1,520,624.89	398,892.40			566.1
B-209	X	IN WATER	1,521,102.64	399,803.51			574.3
B-210	X		1,521,027.69	399,580.10	586.945	587.095	583.6
B-211	X		1,520,742.10	398,980.18		602.430	601.3
LIGHT POLE	X		1,521,250.00	398,299.17			607.1
LIGHTPOLE	X		1,521,584.71	398,411.96			605.9

LTV_GAI2.WB2

"TOP OF WATER AT 579.81"

Table by Cole Associates Inc.

GAI Consultants, Inc.

Table 4
Cummulative Inclinometer Downslope Displacements
Clark Landfill

Boring	Stickup Elevation	A Axis* Bearing	Aug.-Dec. 1997 Displacement Maximun	Jan.-Dec. 1998 Displacment Maximun	Maximum Lateral Displacment Sept 1997 - Dec. 1998 (Inches)
LTV - 1	602.6	N01W	0.2	0.2	0.4
LTV - 3	598.6	N11E	0.2	0.4	0.6
LTV-4	621.0	N40E	0.9	0.7	1.6
LTV - 5	591.8	N30E	0.5	0.4	0.9
LTV - 6	678.6	N24W	0.4	0.8	1.2
LTV-7	633.4	N06W	0.1	0.4	0.5
B-100	618.2	N25E	–	0.3	–
SB-210	587.1	N45W	–	0.1	–

*The A-axis is oriented in the downslope direction.

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.
Table 5
Piezometer Elevations
Clark Landfill
LTV Steel Indiana Harbor Works

Piezometer Name	Piezometer Elevation
LTV-1STP	543.4
LTV-2STP	539.7
LTV-3STP	540.4
LTV-4STP	531.8
LTV-4AP	527.5
LTV-5STP	534.4
LTV-6STP	528.9
LTV-7STP	522.9
LTV98-8 - Top	539.7
LTV98-8 - Middle	529.7
LTV98-8 - Bottom	521.2
LTV98-9 - Top	538.6
LTV98-9 - Middle	522.6
LTV98-9 - Bottom	503.6
B-102A @ 133 ft	539.3
B-102A @ 143 ft	529.3
B-102A @ 153 ft	519.5
B-102A @ 163 ft	509.5
B-103 @ 113 ft	525.5
B-103 @ 123 ft	515.5
B-103 @ 133 ft	505.5
B-104 @ 59 ft	540.7
B-104 @ 76 ft	523.7
LTV3P98 @ 64 ft	534.8
LTV3P98 @ 76 ft	522.8
LTV5P98 @ 72 ft	517.1
B-101C @ 91 ft	426
B-101C @ 102 ft	415
SB-202 @ 39 ft	545.5
SB-202 @ 60 ft	524.5
SB-203 @ 61 ft	522
SB-204 @ 43 ft	540
SB-204 @ 61 ft	522
SB-205 @ 39 ft	544
SB-205 @ 60 ft	523
SB-207 @ 33 ft	550.6
SB-207 @ 41 ft	542.6
SB-207 @ 58 ft	525.6

GAI Consultants, Inc.
Table 6
Design Values -- Undrained Strength of Clay Deposit
Clark Landfill
LTV Steel Indiana Harbor Works

		Undisturbed Clay Outside Landslide Zone		Disturbed Clay Inside Landslide Zone	
		Thick Overburden	Thin Overburden	Scarp-to-Toe	Flume
	Elevation	a	b	b	c
Clay Layer	(feet)	(Su, ksf)	(Su, ksf)	(Su, ksf)	(Su, ksf)
1	550-534*	1.5	1	0.7	0.5
2	534-530	1.4	1	0.5	---
3	530-525	1.4	1	0.6	---
4	525-520	1.4	1	0.6-0.9	---
5	520-514	1.25	1.25	0.9-1.1	---
6	514-506.5	1.25-1.7	1.25-1.7	1.1-1.7	---

Su refers to the undrained shear strength of a clay layer in units of kips (thousands of pounds) per square foot.

Thick Overburden pertains to the section of the undisturbed clay layer outside the landslide area that is overlain by slag whose thickness is 65 ft or more.
In stability analysis cross sections, Thick overburden is denoted by the letter a.

Thin Overburden pertains to the sections of the undisturbed clay layer that are overlain by slag whose thickness is less than 65 feet.
In stability analysis cross sections, Thin overburden is denoted by the letter b.

Scarp-to-Toe refers to the section of the disturbed clay layer within the landslide area that is located between the head scarp and the top of the slope.
In the stability analysis cross sections, this is denoted by the letter b.

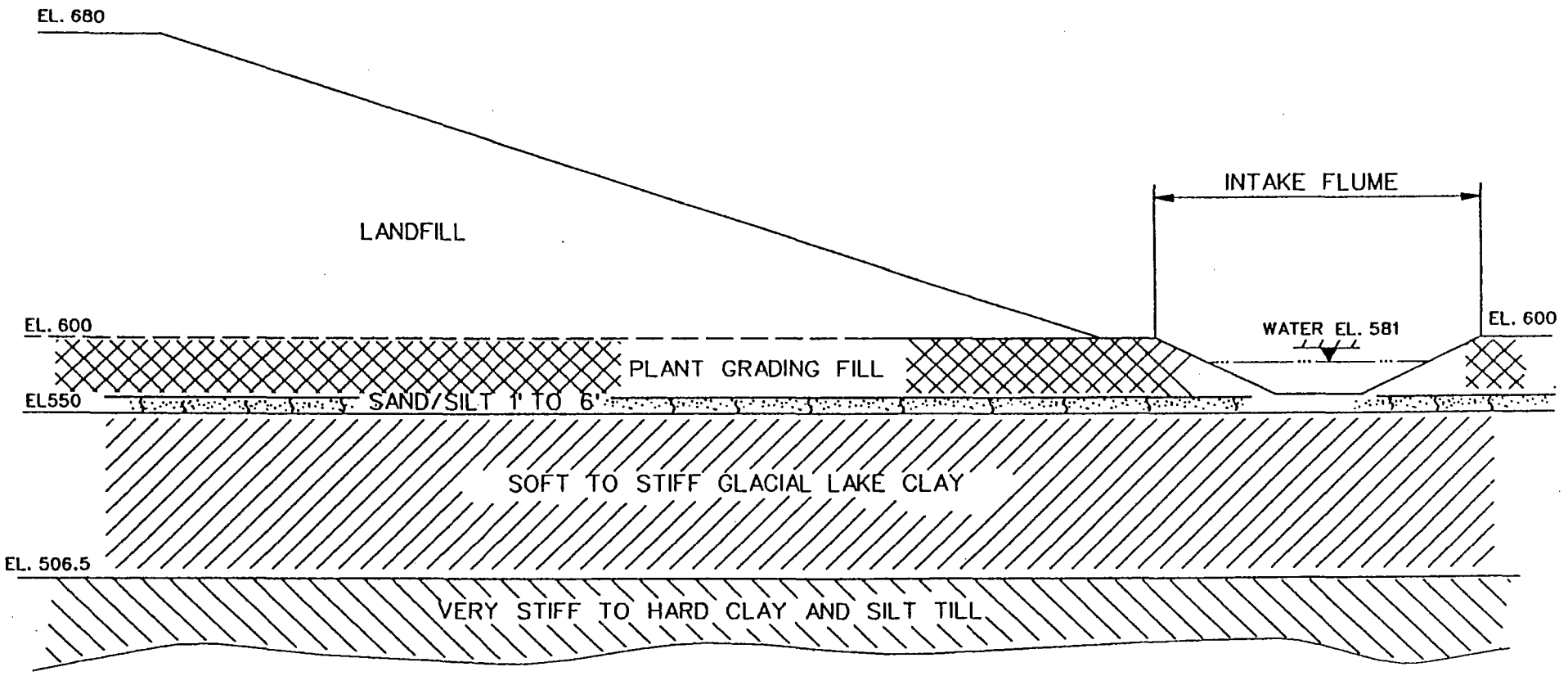
Flume refers to the section of the disturbed clay layer beneath and directly adjacent to the flume, which may have experienced heave. In the stability analyses cross sections, this is denoted by the letter c.

(*Note: For stability cross sections that pass through the landslide zone, the tops of Clay 1a and 1b are at Elevation 544 and the top of Clay 1c is heaved above elevation 544 as noted on the cross sections. Locations of soil layers are shown on individual stability sections in Appendix F.)

FIGURES

gai CONSULTANTS, INC.

DRAWN G.Y. CHECKED TAG APPROVED JRG DATE 1/6/98 DWG. NO. 97-481-A21



GENERALIZED GEOLOGIC CROSS SECTION

N.T.S.

FIGURE 1

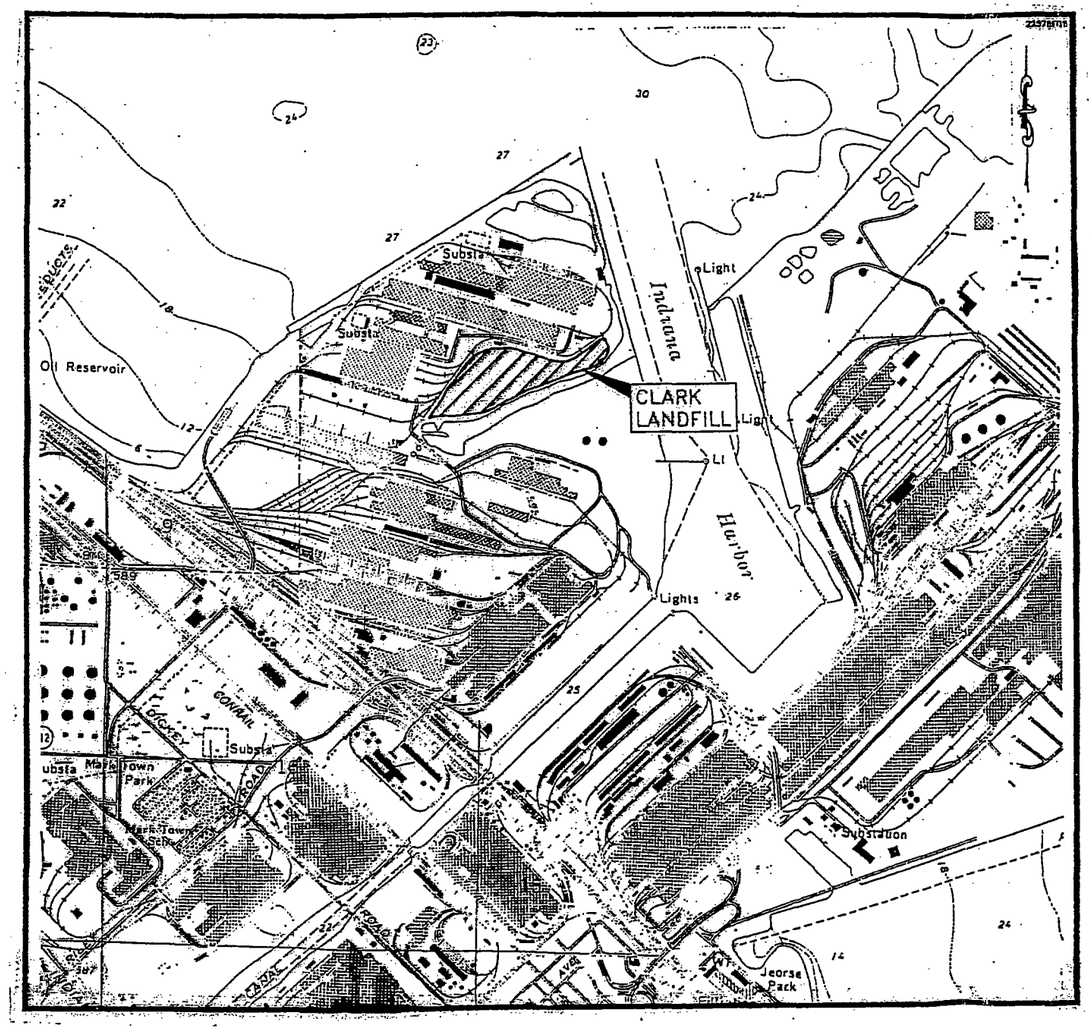
GENERALIZED GEOLOGIC CROSS SECTION

CLARK LANDFILL
INDIANA HARBOR WORKS
LTV STEEL COMPANY

DRAWINGS

589880

CLOSURE PLAN FOR CLARK LANDFILL
INDIANA HARBOR WORKS
LTV STEEL COMPANY
EAST CHICAGO, INDIANA



DRAWING SCHEDULE

DRAWING NO.	DRAWING TITLE
589880	TITLE SHEET-TITLE, LOCATION MAP AND SCHEDULE OF DRAWING
589881	NOTES
589882	EXISTING FEATURES
589883	PHASE I GRADING-FLUME FILL, ROADS, UTILITIES, PERIMETER DRAINAGE
589884	PHASE II GRADING-FINISHED CONFIGURATION
589885	SECTIONS AT STA. 2+00, 4+00 AND 6+00
589886	SECTIONS AT STA. 8+00, 10+00 AND 12+00
589887	SECTIONS AT STA. 14+00, 16+00 AND 18+00
589888	SECTIONS AT STA. 20+00, 22+00 AND 24+00
589889	SECTIONS AT STA. 26+00 AND 28+00
589890	DETAILS
589891	DETAILS
589892	DETAILS

E. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1	~~4/12/99~~		ADDED DWGS. 589891 AND 589892 TO DRAWING SCHEDULE
ORIG	1/5/99	TMS	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
TITLE SHEET-TITLE, LOCATION MAP, SCHEDULE OF DRAWINGS

SCALE NONE DR G.T. DATE 01/05/99 CK _____ DATE _____
APPROVED

589880

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION

REFERENCES REFERENCES REFERENCES

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

97-481-E40

Purpose of Closure Plan:

The purpose of this plan is to close the Clark Landfill according to Indiana's regulations, provide stable slopes and a low permeability cap, and maintain adequate plant water supply through the intake flume to the No. 2 pump house. The proposed regrading plan has adequate volume to accommodate the existing on-site materials plus the proposed cap and clean fill to be placed in the flume area.

Regrading of Slopes to Improve Stability:

On August 6, 1997, a landslide occurred on the south slope of the landfill adjacent to the intake flume to the No. 2 pump house. Subsequent geotechnical investigations and analyses determined that the existing south slope of the landfill is marginally stable. Excess porewater pressures are present in the lake clays below the landfill due to the weight of the landfill. These excess porewater pressures will dissipate with time which will improve the stability of the south slope. The proposed regrading of the south slope to a flatter configuration as shown in the plans is anticipated to improve the short term safety factor for stability of the south slope from the current value of about 1.0 to 1.3. After dissipation of the excess pore pressures in the clay, the safety factor against failure of the south slope is expected to exceed 1.5.

The north (land-side) slope of the landfill will be graded to a maximum slope of 3 horizontal to 1 vertical. The safety factor for the north slope exceeds 1.3 for the short term stability and 1.5 for long term stability.

Flume modifications:

Clean fill, consisting of crushed stone or other inert environmentally acceptable granular material that is not a by-product of the plant steel-making operations, will be used to buttress the south slope of the landfill. This material is to be placed below elevation 585. The highest anticipated lake level is elevation 583 feet. The screened gradation for this material consists of particles between ½ and 6 inch diameter.

Landfill Cover System:

This proposed cap is 2 feet in total thickness. It will incorporate a low permeability barrier geomembrane textured on both sides. The base of the geomembrane will be protected by a 0.5 foot thick sand-sized cushion and gas collection layer. The upper surface will be protected by a geotextile. A free draining durable aggregate is the finished surface for the cap. The thickness of the aggregate layer will generally be 1.5 feet with greater thicknesses near the toe of the slope. The stability of the cap is a function of the interface shear strength of the cap components and seepage forces developed during peak precipitation events. The cap is designed for a minimum safety factor against sliding of 1.3 for the design storm. The washed aggregate for the cap will consist of particles from ½ to 2-1/4 inch in diameter. The aggregate must have suitable leachate, stability, durability and flow characteristics. Geogrid reinforcement is required to provide adequate stability for 3H:1V slopes. Conversely, testing of alternate textured geomembranes may identify a system that has adequate interface friction without supplemental geogrid reinforcement.

Access Roads:

Two granular access roads are provided - one to the top of the fill and the other along the flume north bank.

Surface Drainage:

Surface drainage from the completed cap will be directed as follows. Most flow on the southerly slopes will be discharged as sheet flow into the flume. Runoff from the northerly slopes will be collected and discharged into the plant storm drainage system.

Design Criteria:

Maximum side slopes - 3H:1V
Short term slope stability - Minimum SF - 1.3
Long term slope stability - Minimum SF - 1.5
Cover slope stability - Minimum SF - 1.3 for design storm
Minimum thickness of coarse aggregate portion of cap - 18 inches
Design storm - peak discharge from 25-year 24-hour storm
Design storm for cap stability - peak discharge from 100-year 24-hour storm
Flume design flow - 340,000 gallons/minute (2 x (120,000+50,000) gallons/minute required)

Key Elevations:

Elevations are relative to the US Coast and Geodetic Survey 1929 mean sea level datum.
Normal lake level elevation - 581 feet
Maximum lake level elevation - 583 feet
Minimum lake level elevation - 577 feet
General plant grade elevation - 600 feet
Top of clean flume fill elevation - 585 feet
Bottom of modified flume elevation - 568 feet

Elevation Datum Conversions at Indiana Harbor Works:

Elevation 600.00 (USC&GS, 1929) - Elevation 599.09 (I.G.L.D., 1985)
Elevation 600.00 (USC&GS, 1929) - Elevation 21.14 (LTV IHW Plant Datum)

Estimated Quantities:

Existing volume of landfill - 1,960,000 cubic yards
Volume of dredging from flume - 4,000 cubic yards
Clean fill to construct buttress in existing flume - 185,000 cubic yards
Volume of aggregate for coarse aggregate portion of the cap - 105,000 cubic yards
Volume of Sand cushion below geosynthetic cap - 35,000 cubic yards
Finished volume of landfill with cap (minus clean fill in flume) - 2,100,000 cubic yards
Area of landfill - 43 acres
Area of flume filling at elevation 582.4 feet - 5 acres
Clean fill in flume below elevation 582.4 feet - 165,000 cubic yards

Overall Schedule:

It may be theoretically possible to implement the closure plan in one construction season if it were strictly a regrading and capping project. However, the governing issue in this closure plan is the improvement of stability of the south (flume-side) slope. There are several piezometers and slope inclinometers in the project site. All of this instrumentation will be used to monitor the elevated pore pressures in the underlying clay layers and slope movements during the regrading operations for conformity with acceptable performance. It is anticipated that the rate of filling of the flume to buttress the south slope will require 1 to 2 construction seasons to complete in a sufficiently gradual fashion to prevent the development of unacceptably high pore pressures. Regrading of the landfill, which must be delayed until after the flume buttress has been completed, is anticipated to require one construction season. The cap should not be constructed until all regrading has been completed and the instrumentation indicates satisfactory performance of the regraded slopes. The capping will then require one construction season to complete.

Material Specifications:

All material and substitutions of materials must be approved by LTV Steel Company and GAI Consultants, Inc. prior to use.

Clean Flume Fill - Durable aggregate (crushed stone, crushed concrete, sand and gravel) having particle sizes from 1/2- to 6-inches

Erosion Protection Aggregate Along Flume - 3-inch to 12-inch durable crushed stone

Erosion Protection Aggregate at Entrance of Flume - To be sized for wave protection by GAI

Coarse Aggregate for Cap - Durable crushed limestone having the following mean gradation:

Size	Percent Finer
2-1/4"	100
2"	97
1-3/4"	88
1-1/2"	46
1-1/4"	21
1"	8
¾"	1
½"	0.5

Sand Bedding for Cap - Durable sand from crushed limestone having the following mean gradation:

Size	Percent Finer
⅜"	99
No. 4 Mesh	85
No. 16 Mesh	40
No. 100 Mesh	15
No. 200 Mesh	<9

Geotextile for Cap - 16 oz Armco 4516 non-woven geotextile

Geomembrane for Cap - 40 mil National Seal LLDPE, textured both sides.

Geogrid reinforcement for Cap - Strata Grid 500, Strata Systems, Inc.

Composite Geonet - Minimum 7 oz nonwoven geotextile on both sides.

Pipe for storm drainage - HDPE, SDR 32.5 Pipe
Sizes shown on drawings are minimum inside diameter.
All joints to be full-strength butt fashion welds.

Construction Sequence:

1. Maintain access and monitor the piezometers and inclinometers through the entire closure plan and adjust the construction sequence as required to maintain the stability of the landfill. If the rates of slope movement increase or if increases in pore water pressures exceed the increases in applied loading pressure, the sequence or rate of site grading shall be modified to preclude a slope failure.

2. Relocate roads and utilities as shown on the Phase I grading plan.

3. Install storm water runoff drainage ditch and piping system around north side of landfill as shown on the Phase I grading plan.

4. Install silt curtains in existing intake flume at locations shown on drawing 589883.

5. The existing grade in the flume bottom between approximate stations 10 and 12 is higher than the finished grade, as shown on the Phase I grading plan. In addition, minor trimming of the south bank of the flume may be necessary near stations 14 and 22. Excavate the excess material to one foot below to the proposed finished configuration before beginning the flume filling.

6. Fill the flume to elevation 585 as shown on the Phase I grading plan. Perform this filling operation in three stages:
   - Stage FF1 - below elevation 568
   - Stage FF2 - elevation 568 to 578
   - Stage FF3 - elevation 578 to 585

   Complete each stage of flume filling before initiating the next phase. Install the access road on the flume bench in conjunction with the Stage FF3 flume filling.

7. Install silt fence around periphery of the landfill as shown on drawing 589883.

8. After completing all activities on the Phase I grading plan, proceed with the Phase II regrading. The Phase II regrading shall be accomplished in the following excavation and filling sequence:

Excavation Stage	Finished Subgrade Elevations
E1	Above 660
E2	640 to 660
E3	620 to 640
E4	585 to 620

Filling Stage	Finished Subgrade Elevations
F1	585 to 590
F2	590 to 595
F3	595 to 600
F4	600 to 605
F5	605 to 610
F6	610 to 615
F7	615 to 620
F8	620 to 625
F9	625 to 630
F10	630 to 635
F11	635 to 640
F12	640 to 645
F13	645 to 650
F14	650 to 655
F15	655 to 660
F16	660 to 665
F17	665 to 670
F18	670 to 675

   Deposit excavated materials into fill areas. Complete all required excavation in each stage before proceeding to the next excavation stage. Complete all required filling in each filling stage before proceeding to the next filling stage.

9. Fine grade the landfill to the subgrade configuration.

10. After completion of all Phase II fine grading and pending satisfactory instrumentation data, install the cap consisting of the sand subgrade layer, the geomembrane, the geotextile, gas vents, and the coarse aggregate finished surface. An installation, quality control, and testing plan will be required for the capping system. Geogrid reinforcement is required above the geotextile layer to assure a stable cap on the 3:1 slopes. Equipment shall not traffic on unprotected geotextiles.

11. Complete access roads in conjunction with the cover system.

Project Technical Specifications:

All work for this closure project is to be conducted in accordance with the project technical specifications.

F. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

F. Barry Newman
4·13·99

DRAWING CODE INDEX	1	2	3	4	5	6	7	8
LEVELS	2.	1.						

1 4/13/99	REVISED NOTES
Orig 1/5/99	FOR PERMIT APPLICATION
CHK'D BY	DESCRIPTION
* DENOTES NUMBER OF PLACES REVISION APPEARS	

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
NOTES

SCALE NONE DR G.Y. DATE 01/05/99 CK DATE
APPROVED

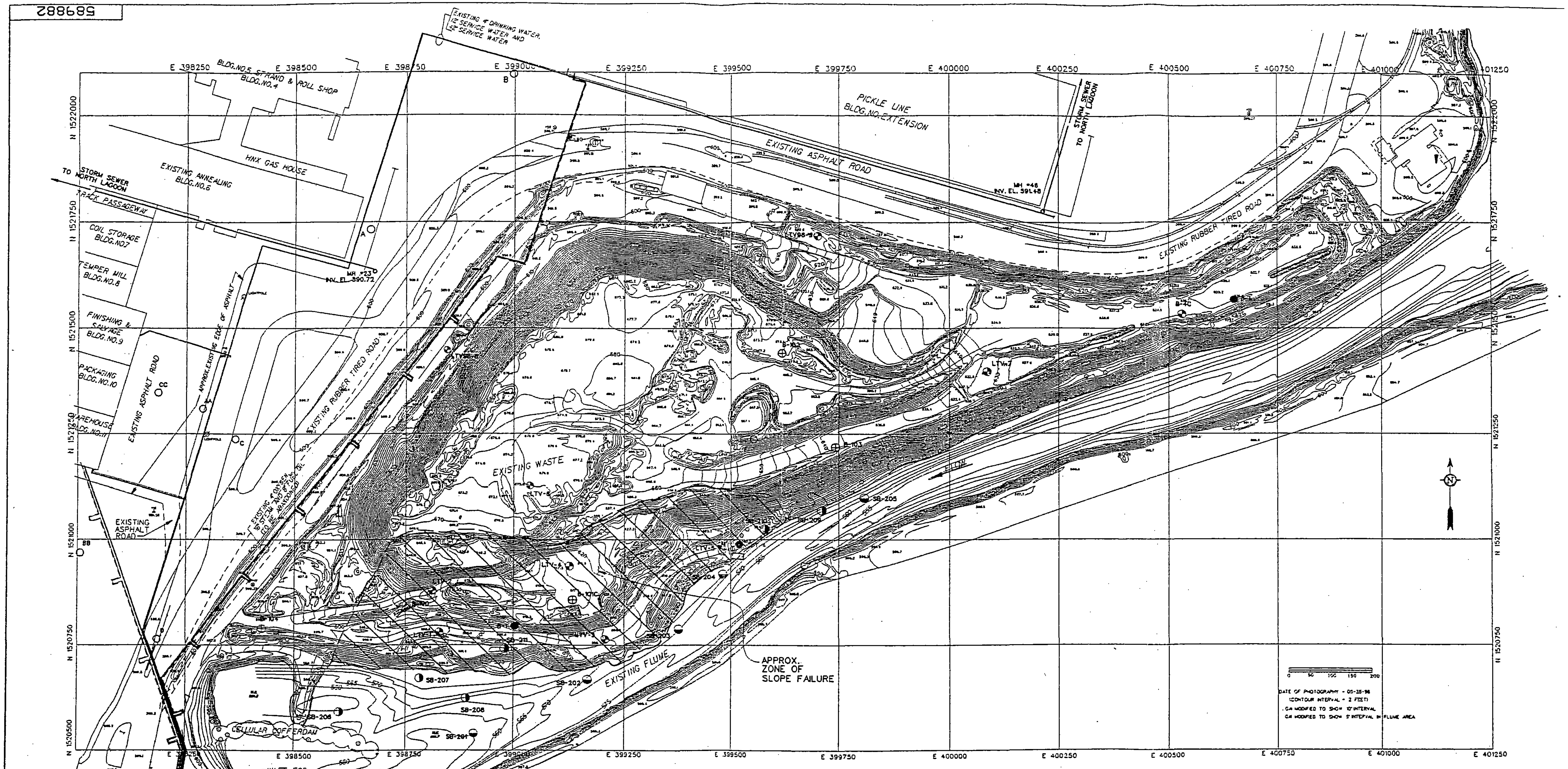
589881

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

97-481-E41

DESCRIPTION	DRAWING No.	DESCRIPTION	DRAWING No.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES



LEGEND

LTV-2	(EXISTING BORING LOCATION, 1997, 1998)
	EXISTING SITE ROADS
	5-26-98 TOPOGRAPHY
	APPROX ZONE OF SLOPE FAILURE
B-1	BORING LOCATION 1996
AA	STATION BORING LOCATION 1964
B-100	APPROXIMATE LOCATION OF STS BORINGS 1998
SB-206	APPROX. GAI BORING LOCATION
SB-201	STS BORING LOCATION

NOTES:

1. THE CONTOURS DEPICTED ON THIS MAP WERE COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY KUCERA INTERNATIONAL INC. WILLOUGHBY, OHIO, USING PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY TAKEN 05-26-98.
2. EXISTING 4" OXYGEN, 8" FUEL OIL AND 16" STEAM PIPES THAT WILL BE BURIED UNDER THE PROPOSED CLOSED LANDFILL WILL BE ABANDONED IN PLACE.
3. EXISTING 4" OXYGEN, AND 16" STEAM PIPES WILL BE RELOCATED SEE NOTES DRAWING 589883.
4. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.

MAPPING REFERENCES:
EXISTING TOPOGRAPHY PREPARED BY: KUCERA INTERNATIONAL - INC.
DENVER - CO: LAKELAND - FL: COLUMBUS - OH: PITTSBURGH - PA: ST. LOUIS - MO
HEADQUARTERS: WILLOUGHBY - OH

COLE ASSOCIATES, INC. DWG. NO. SHEET 1 OF 1
FILE NUMBER XSECT.DWG-LTV CLARKFILL-NO.2 INTAKE
TOPOGRAPHICAL AND SOUNDING SURVEY EXISTING
GROUND AS OF 5/29/98. LTV-INDIANA HARBOR WORKS
DATUM NGVD 1929 VERTICAL-NAD 1927 HORIZONTAL

F. BARRY NEUMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

F.B. Neuman
4.13.99

DRAWING CODE INDEX

LEVELS	1	2	3	4	5	6	7	8
	2	1						

REV	#	DATE	CHK'D BY	DESCRIPTION
4				
3				
2				
1		9-13-99		ADDED APPROX. ZONE OF SLOPE FAILURE
ORIG		1/5/99	TRS	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
EXISTING FEATURES

SCALE AS NOTED DR C.F. DATE 01/05/99 CK ____ DATE ____
APPROVED

589882

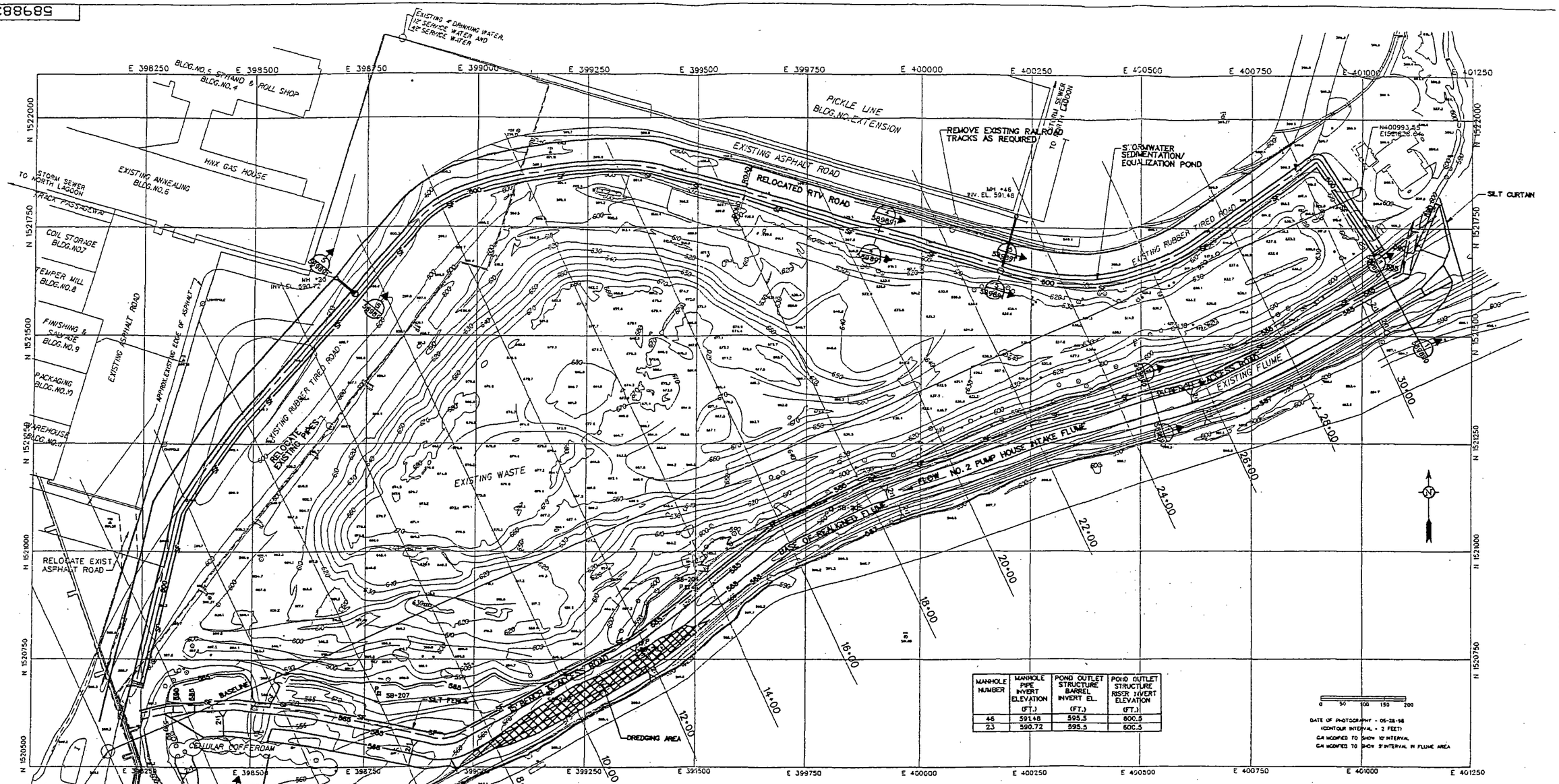
DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
	REFERENCES		REFERENCES		REFERENCES

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

GAI CONSULTANTS

97-481-E42

589883



MANHOLE NUMBER	MANHOLE PIPE INVERT ELEVATION (FT.)	POND OUTLET STRUCTURE BARREL INVERT EL. (FT.)	POND OUTLET STRUCTURE RISER INVERT ELEVATION (FT.)
46	591.48	595.5	600.5
23	590.72	595.5	600.5

0 50 100 150 200

DATE OF PHOTOGRAPHY - 05-28-98
HCONTOUR INTERVAL - 2 FEET
GA MODIFIED TO SHOW 10' INTERVAL
GA MODIFIED TO SHOW 5' INTERVAL IN FLUME AREA

MAPPING REFERENCES:
EXISTING TOPOGRAPHY PREPARED BY:
KUCERA INTERNATIONAL - INC.
DENVER - CO: LAKELAND - FL: COLUMBUS - OH: PITTSBURGH - PA: ST. LOUIS - MO
HEADQUARTERS: WILLOUGHBY - OH

COLE ASSOSIATES, INC. DWG. NO. SHEET 1 OF 1
FILE NUMBER XSECT.DWG-LTV CLARKFILL-NO.2 INTAKE
TOPOGRAPHICAL AND SOUNDING SURVEY EXISTING
GROUND AS OF 5/29/98, LTV-INDIANA HARBOR WORKS
DATUM NGVD 1929 VERTICAL-NAD 1927 HORIZONTAL

LEGEND

- EXISTING SITE ROADS
- 5-26-98 TOPOGRAPHY
- LTV-2 — PIEZOMETER LOCATION IN BORING
- INCLINOMETER LOCATION IN BORING
- POND OUTLET STRUCTURE
- SF — SILT FENCE (TO REMAIN IN-PLACE UNTIL LINER CONSTRUCTION)
- TOP OF PROPOSED SLOPE
- 2:1 — TOE OF PROPOSED SLOPE
- DREDGING AREA
- 565 — PROPOSED GRADING

NOTES:

1. THE CONTOURS DEPICTED ON THIS MAP WERE COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY KUCERA INTERNATIONAL INC. WILLOUGHBY, OHIO, USING PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY TAKEN 05-26-98.
2. EXISTING 4" OXYGEN, 8" FUEL OIL AND 16" STEAM PIPES THAT WILL BE BURIED UNDER THE PROPOSED CLOSED LANDFILL WILL BE ABANDONED IN PLACE.
3. EXISTING 4" OXYGEN, AND 16" STEAM PIPES WILL BE RELOCATED SEE NOTES DRAWING 589851.
4. PROPOSED CONTOURS DEPICT FINAL GRADING ELEVATIONS.
5. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
6. FOR SECTIONS SEE DRAWINGS 589885 THRU 589889.

L. BARRY NEWMAN REGISTERED No. 19300188 STATE OF INDIANA PROFESSIONAL ENGINEER

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1	4/18/99		ADDED PROPOSED SILT FENCE, SILT CURTAIN AND SCHEDULE 2
	1/13/99	TMC	ELEVATIONS FOR PERMIT APPLICATION, MODIFIED
ORIG			SECTION 22-30

* DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
PHASE I GRADING-FLUME FILL, ROADS, UTILITIES, PERIMETER DRAINAGE

SCALE AS NOTED DR G.T. DATE 01/05/99 CK DATE
APPROVED

589883

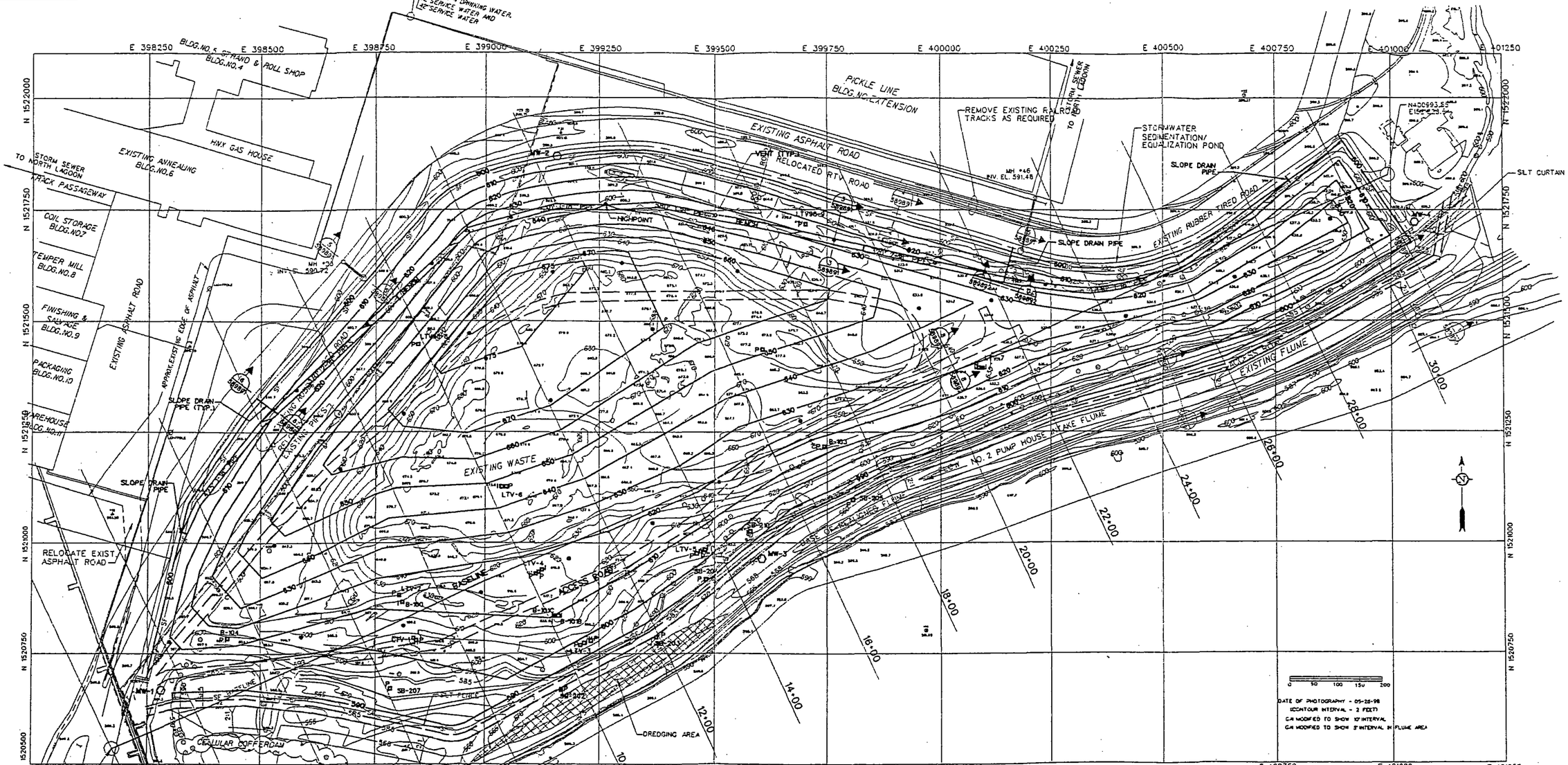
DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

97-481-E43

589884



MAPPING REFERENCES:
EXISTING TOPOGRAPHY PREPARED BY:
KUCERA INTERNATIONAL - INC.
DENVER - CO: LAKELAND - FL: COLUMBUS - OH: PITTSBURGH - PA: ST. LOUIS - MO
HEADQUARTERS: WILLOUGHBY - OH

COLE ASSOSIATES, INC. DWG. NO. SHEET 1 OF 1
FILE NUMBER XSECT.DWG-LTV CLARKFILL-NO.2 INTAKE
TOPOGRAPHICAL AND SOUNDING SURVEY EXISTING
GROUND AS OF 5/29/98, LTV-INDIANA HARBOR WORKS
DATUM NGVD 1929 VERTICAL-NAD 1927 HORIZONTAL

LEGEND

LTV-2 — PIEZOMETER LOCATION IN BORING
— INCLINOMETER LOCATION IN BORING
— EXISTING SITE ROADS
— 5-26-98 TOPOGRAPHY
— ACCESS ROAD
— 840 — FINISHED GRADE CONTOUR
— VENT LOCATION
— MONITORING WELL LOCATION SEE DETAIL 10/589831

NOTES:

1. THE CONTOURS DEPICTED ON THIS MAP WERE COMPILED TO NATIONAL MAP ACCURACY STANDARDS BY KUCERA INTERNATIONAL INC. WILLOUGHBY, OHIO, USING PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY TAKEN 05-26-98.
2. EXISTING 4" OXYGEN, 8" FUEL OIL AND 16" STEAM PIPES THAT WILL BE BURIED UNDER THE PROPOSED CLOSED LANDFILL WILL BE ABANDONED IN PLACE.
3. EXISTING 4" OXYGEN, AND 16" STEAM PIPES WILL BE RELOCATED SEE NOTES DRAWING 589881.
4. PROPOSED CONTOURS DEPICT FINAL GRADING ELEVATIONS.
5. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589821.
6. FOR SECTIONS SEE DRAWINGS 589885 THRU 589889.

E. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2	4-13-99		ADDED MONITORING WELL LOCATIONS, VENTS, AND DETAIL
1			SECTION NUMBERS, SECTION 6 - SLOPE DRAINS AND MODIFIED
			SECTION STA. 22+00
ORIG	1/9/99	TRC	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
PHASE II GRADING-FINISHED CONFIGURATION

SCALE AS NOTED DR C.Y. DATE 01/25/99 CK DATE
APPROVED

589884

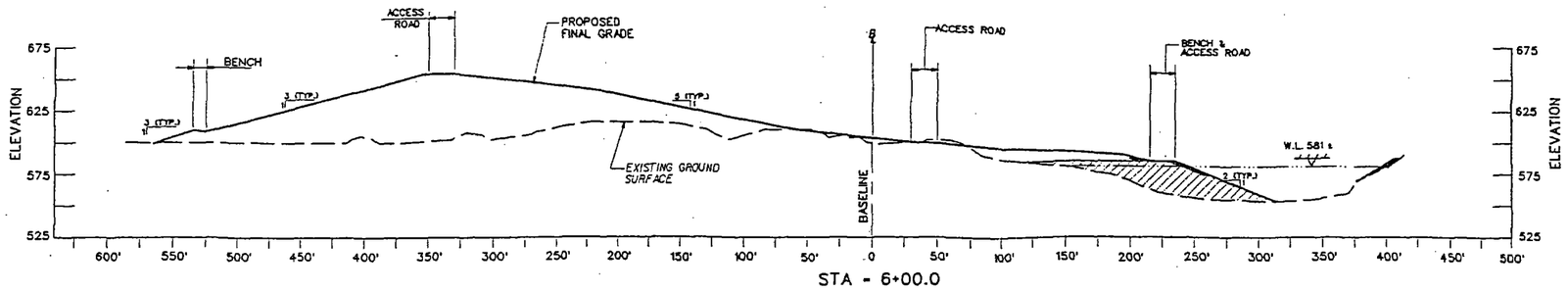
DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS
GAI CAD FILE: TASKEDMA.DGN 04/13/99

97-481-E44

589885



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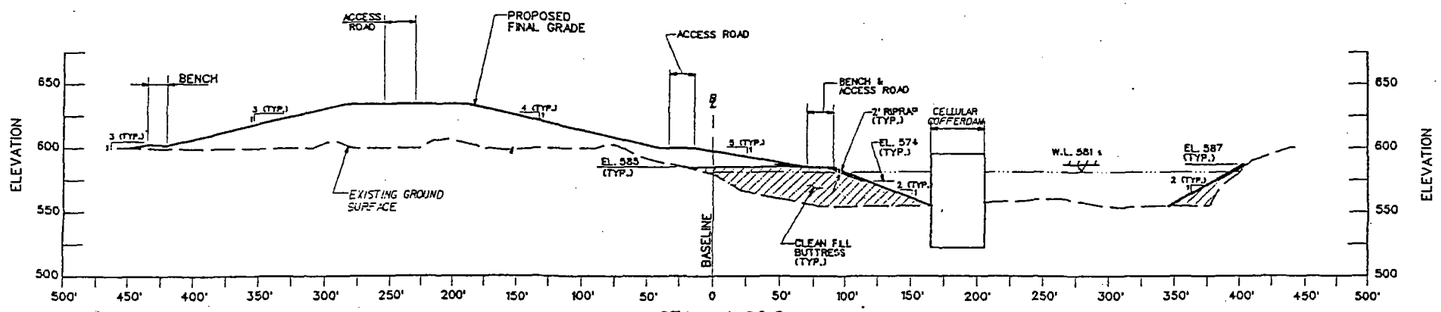

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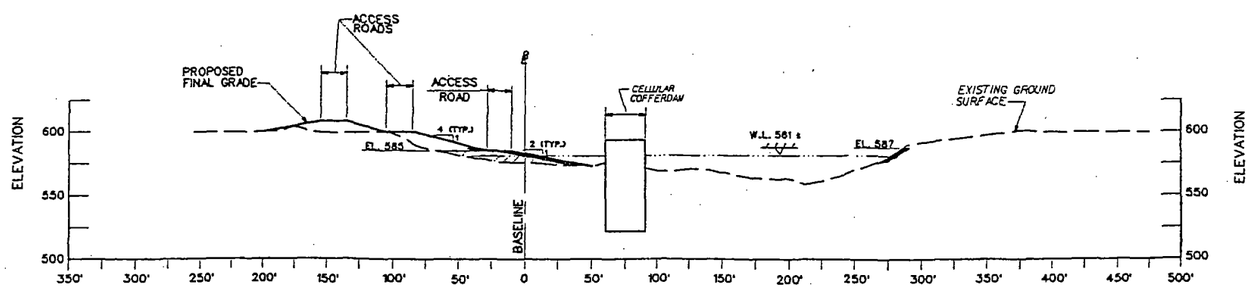


STA - 2+00.0

LEGEND

- CLEAN FILL
- 2' RIPRAP
- PROPOSED FINAL GRADE

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. FOR DETAILS SEE DRAWINGS 589890 AND 589891.
5. LINER, DRAINAGE DITCH AND PIPES NOT SHOWN.

50' 0' 50' 100'

L. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV	#	DATE	CHK'D BY	DESCRIPTION
4				
3				
2				
1		4-13-99		ADDED NOTE 5 AND CHANGED TO PROPOSED FINAL GRADE
DRAWN		1/13/99	TMG	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS

CLARK LANDFILL CLOSURE PLAN

SECTIONS AT STA. 2+00, 4+00 AND 6+00

SCALE AS NOTED DR G.T. DATE 01/05/99 CK DATE

APPROVED

589885

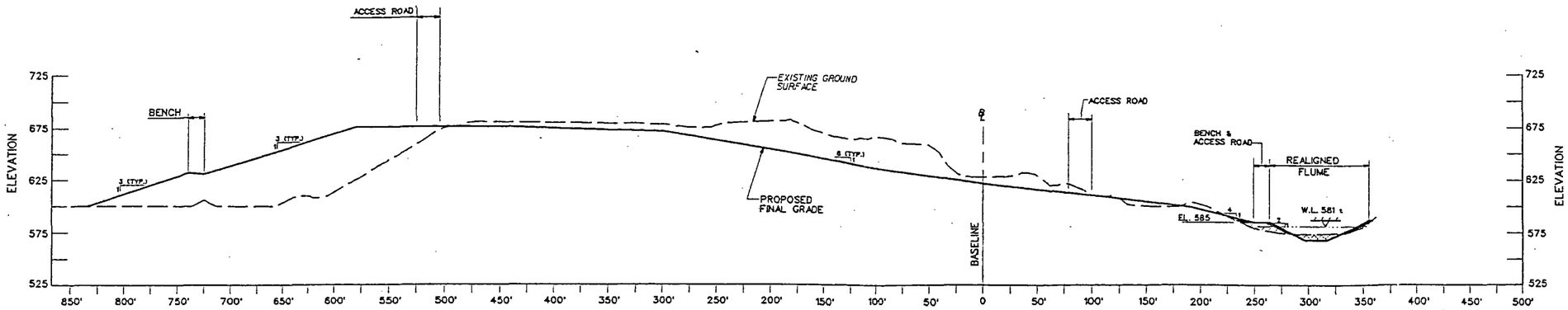
DRAWING No.	DESCRIPTION	DRAWING No.	DESCRIPTION	DRAWING No.	DESCRIPTION
	REFERENCES		REFERENCES		REFERENCES

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

97-481-E45

589886



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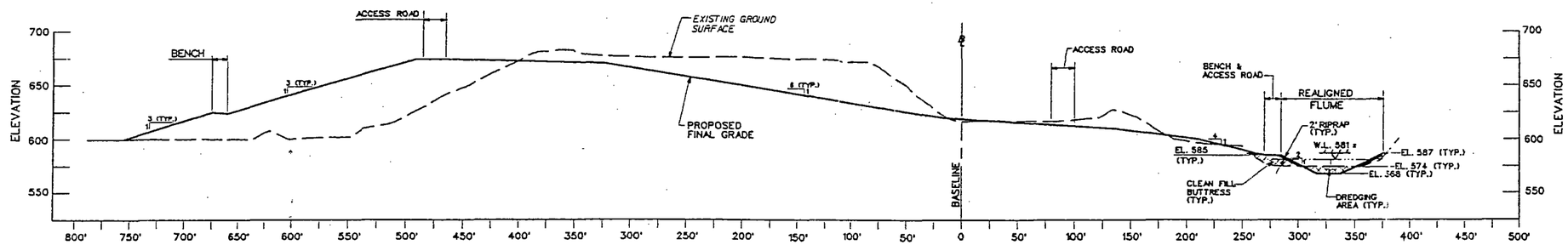

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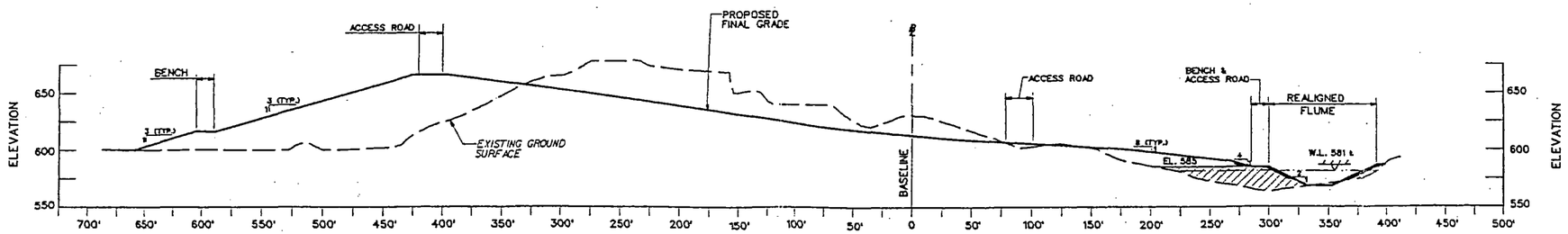


STA - 8+00.0

LEGEND

- CLEAN FILL
- DREDGING AREA
- 2' RIPRAP
- PROPOSED FINAL GRADE

50' 0' 50' 100'

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. FOR DETAILS SEE DRAWINGS 589890 AND 589891.
5. LINER, DRAINAGE DITCH AND PIPES NOT SHOWN.

T. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-17-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1	4-17-99		ADDED NOTE 5 AND CHANGED TO PROPOSED FINAL GRADE
ORIG	1-15-98	TFG	FOR PERMIT APPLICATION

GENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
SECTIONS AT STA. 8+00, 10+00 AND 12+00

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

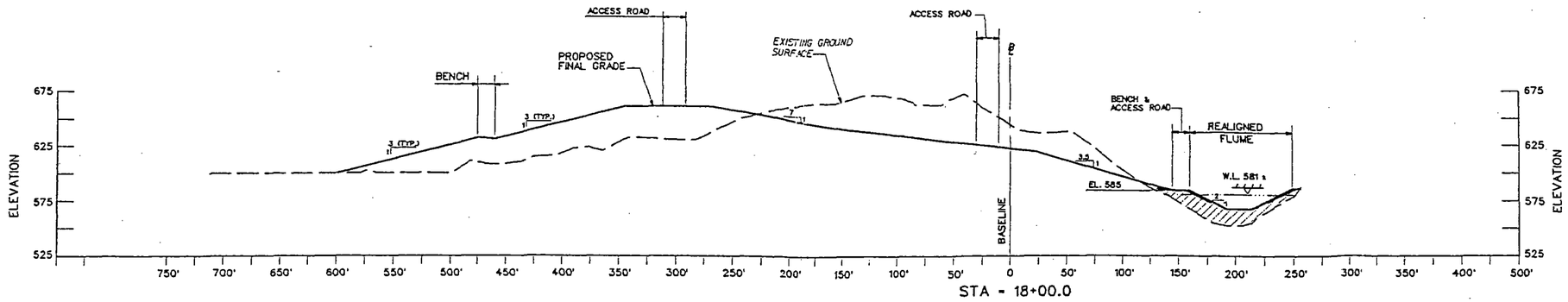
97-481-E46

SCALE AS NOTED DR G.Y. DATE 01/05/99 CK DATE

APPROVED

589886

589887



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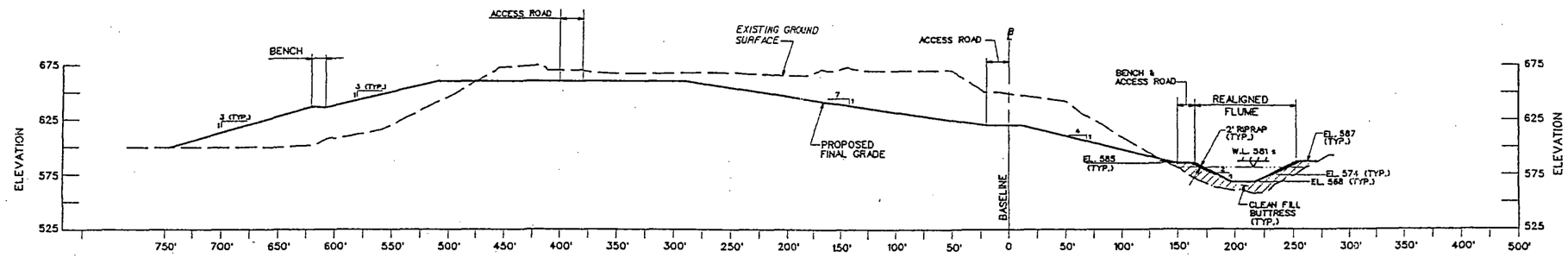

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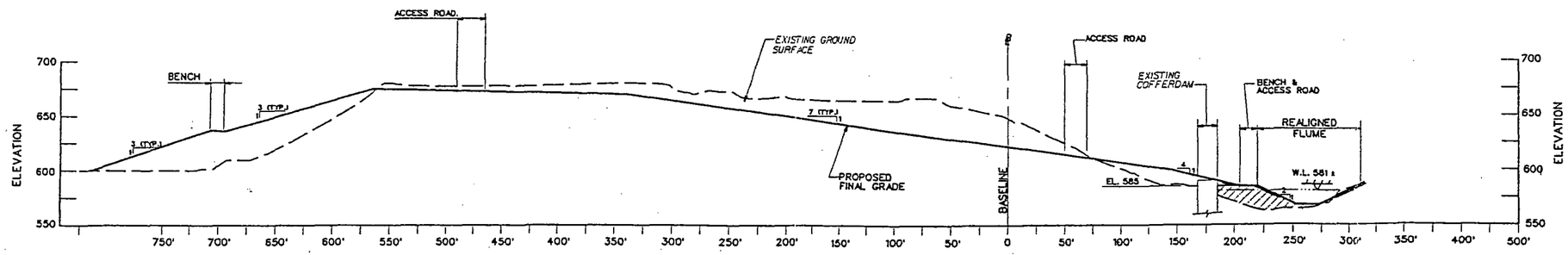


STA - 14+00.0

LEGEND

- CLEAN FILL
- 2' RIPRAP
- PROPOSED FINAL GRADE

50' 0' 50' 100'

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. FOR DETAILS SEE DRAWINGS 589890 AND 589891.
5. LINER, DRAINAGE DITCH AND PIPES NOT SHOWN.

E. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

REV. #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1	4-13-99		ADDED NOTE 5 AND CHANGED TO PROPOSED FINAL GRADE
ORIG	1-25-99	TAG	FOR PERMIT APPLICATION

- DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
SECTIONS AT STA. 14+00, 16+00 AND 18+00

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

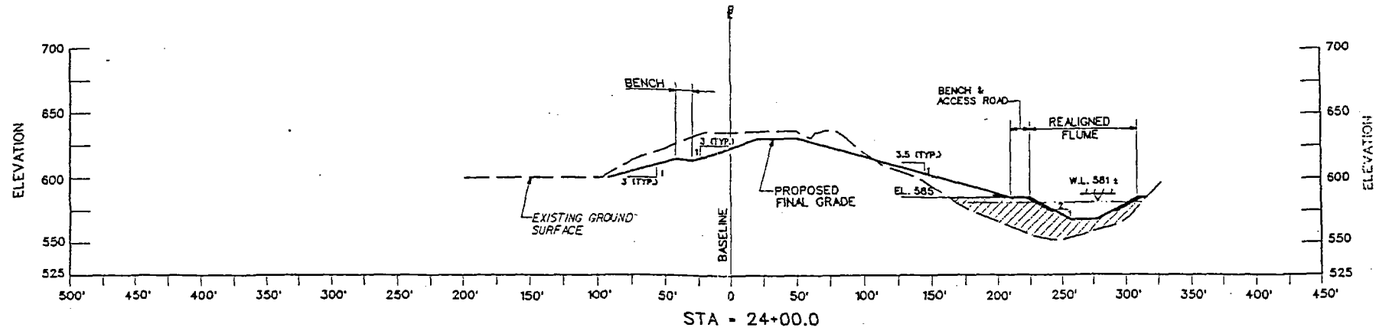
97-481-E47

SCALE AS NOTED DR G.Y. DATE 01/25/99 CK DATE

APPROVED

589887

589888



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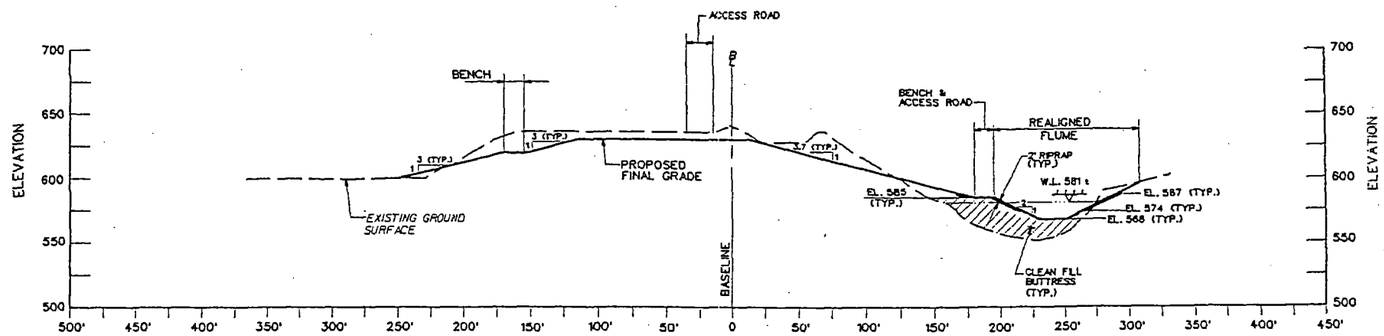

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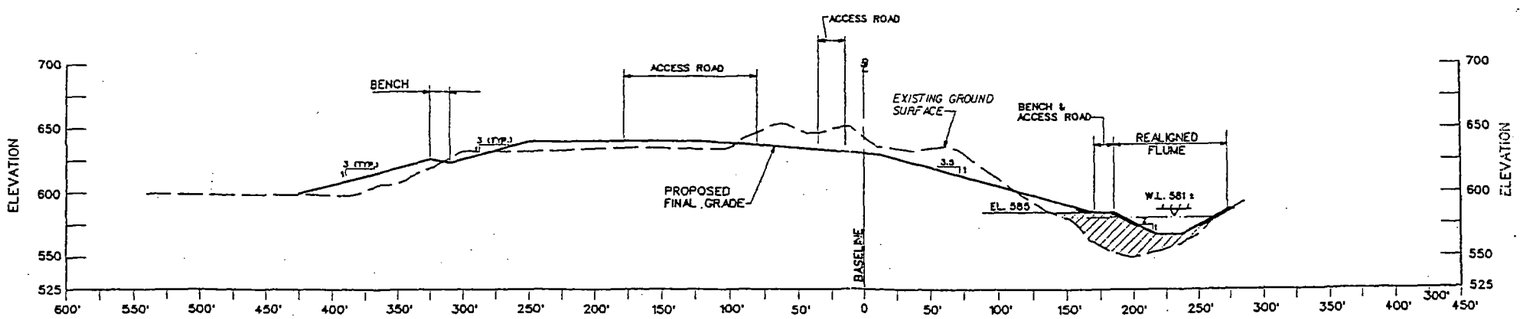


STA = 20+00.0

LEGEND

- CLEAN FILL
- 2' RIPRAP
- PROPOSED FINAL GRADE

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. FOR DETAILS SEE DRAWINGS 589890 AND 589891.
5. LINER, DRAINAGE DITCH AND PIPES NOT SHOWN.

50' 0' 50' 100'

F. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

F. B. Newman 4.13.99

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1	4-13-99		ADDED NOTE 5. CHANGED TO PROPOSED FINAL GRADE AND MODIFIED SECTION STA. 22+00
0	1/5/99	TRO	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
SECTIONS AT STA. 20+00, 22+00 AND 24+00

SCALE AS NOTED DR G.T. DATE 01/05/99 CK DATE
APPROVED

589888

DRAWING NO.	DESCRIPTION
REFERENCES	

DRAWING NO.	DESCRIPTION
REFERENCES	

DRAWING NO.	DESCRIPTION
REFERENCES	

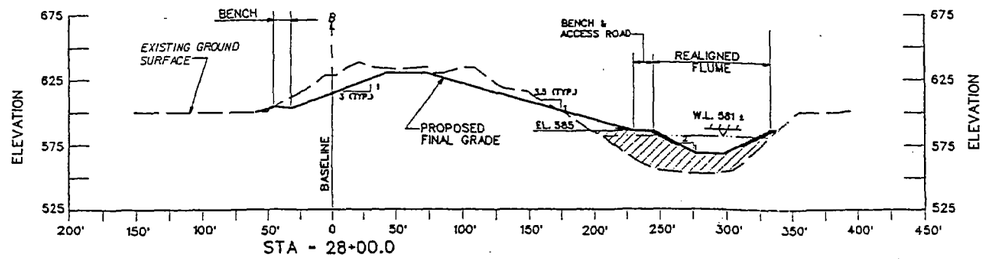
- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

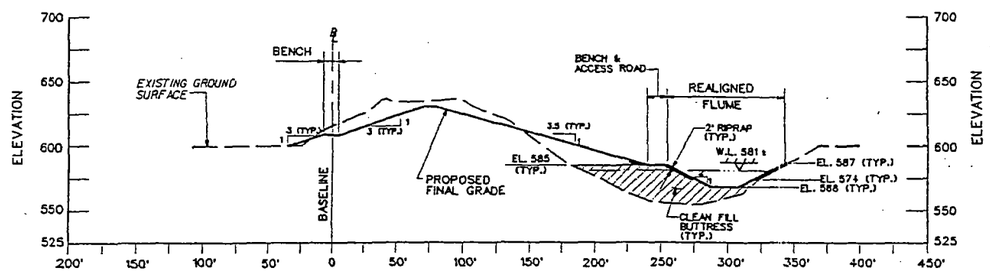
97-481-E48

C:\0001\1997\97481\cadd\w00\dg0\74 Apr 13 1999 11:20:18

589889



STA - 28+00.0



STA - 26+00.0

LEGEND

- CLEAN FILL
- 2' RIPRAP
- PROPOSED FINAL GRADE

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. FOR DETAILS SEE DRAWINGS 589890 AND 589891.
5. LINER, DRAINAGE DITCH AND PIPES NOT SHOWN.

50' 0' 50' 100'

E. BARRY McNAMEE REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

REV	#	DATE	CHK'D BY	DESCRIPTION
	4			
	3			
	2			
	1	4-13-99		ADDED NOTE 5 AND CHANGED TO PROPOSED FINAL GRADE
ORIG		1/5/99	TMS	FOR PERMIT APPLICATION

# DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
SECTIONS AT STA. 26+00 AND 28+00

SCALE AS NOTED DR G.F. DATE 01/05/99 CK DATE

APPROVED

589889

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -

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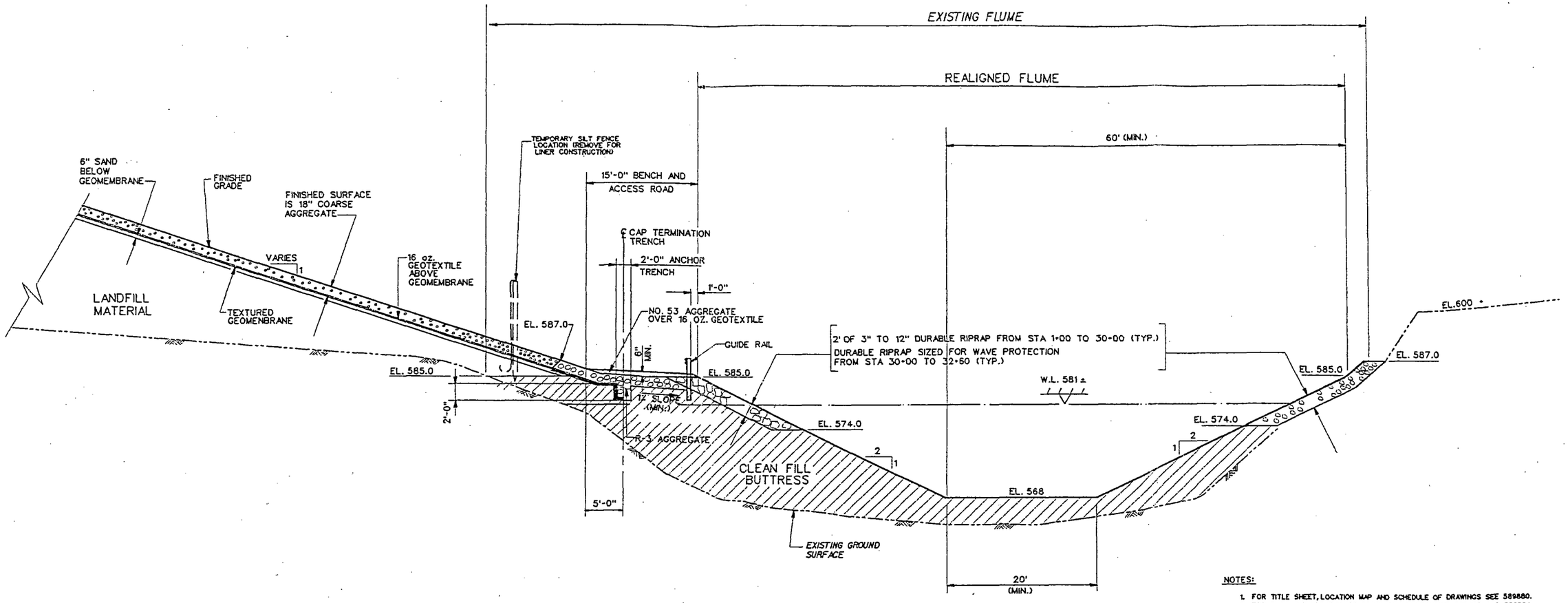
gai CONSULTANTS

97-481-E49

589890



DETAIL 1 / 589883

TYPICAL REALIGNED FLUME CHANNEL DETAIL

N.T.S.

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. ALL PERFORATED AND SOLID WALL DRAIN PIPE AND RISERS TO BE HIGH DENSITY POLYETHLENE PIPE. ALL JOINTS TO BE BUTT FUSED.
5. RIPRAP NATIONAL STONE ASSOCIATION STANDARDS.

F. HARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

4-13-99

REV #	DATE	CHK'D BY	DESCRIPTION
2			
1	4-13-99		MOVED DETAILS 2-6 TO DRAWING 589881. DELETED DETAIL
ORIG			

* DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
PROPOSED INTAKE FLUME
DETAILS

SCALE N.T.S. DR G.Y. DATE 01/05/99 CK ____ DATE ____

APPROVED

589890

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -

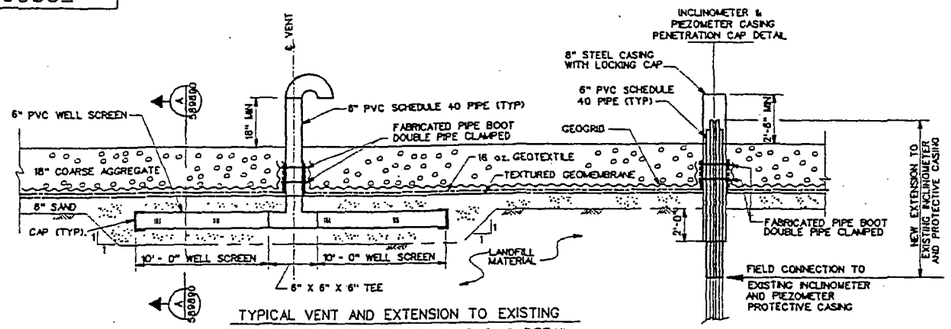
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

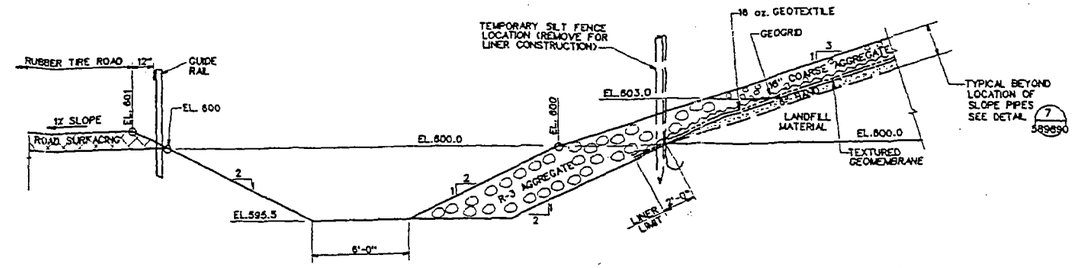
CAD FILE 7481E000 DGN 01/05/99

97-481-E50

589891

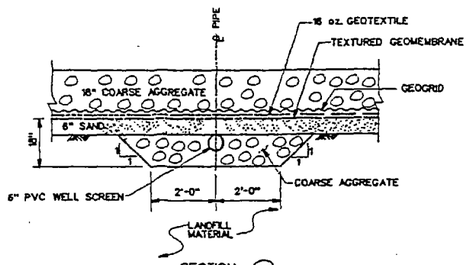


TYPICAL VENT AND EXTENSION TO EXISTING INCLINOMETER AND PROTECTIVE CASING DETAIL
N.T.S.



DETAIL 4 589883

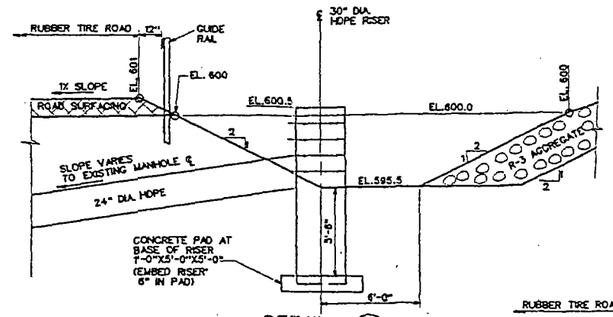
TYPICAL SEDIMENTATION/EQUALIZATION POND (NORTH SIDE)
N.T.S.



SECTION A

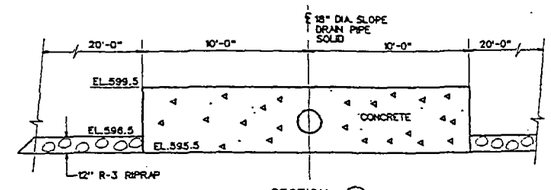
DETAIL 2 589884

TYPICAL VENT AND INCLINOMETER DETAIL
N.T.S.

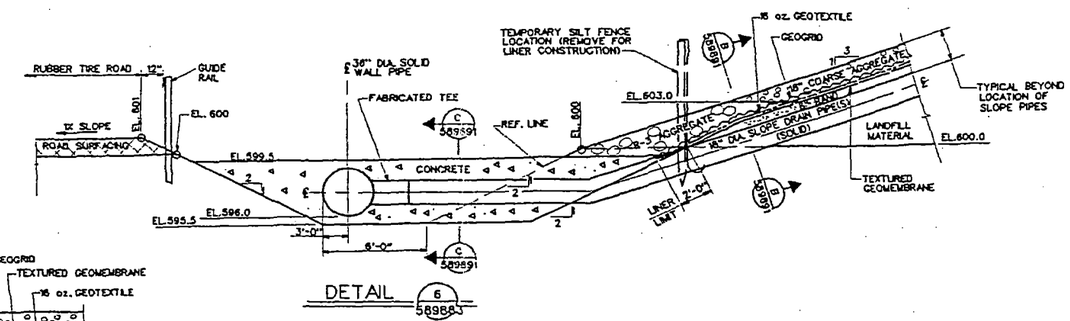


DETAIL 5 589884

TYPICAL SEDIMENTATION/RETENTION POND OUTLET STRUCTURE
N.T.S.

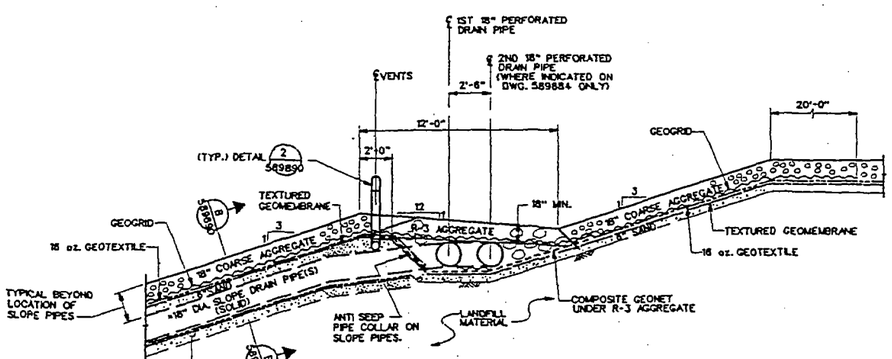


SECTION C



DETAIL 6 589883

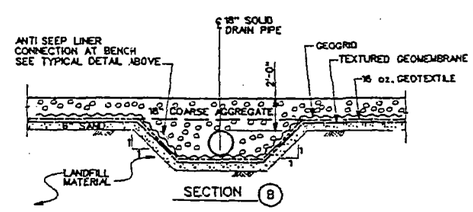
TYPICAL SLOPE DRAIN TOE DETAIL (NORTH SIDE)
N.T.S.



TYPICAL BENCH DETAIL
N.T.S.

DETAIL 3 589884

TYPICAL SLOPE DRAIN DETAIL
N.T.S.



SECTION B

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. THRUST BLOCKS BELOW EACH SLOPE DRAIN PIPE TO BE 3000 PSI CONCRETE, MINIMUM 24" THICK, 10 FEET LONG AND 4 FEET HIGH.
5. ALL PERFORATED AND SOLID WALL DRAIN PIPE AND RISERS TO BE HIGH DENSITY POLYETHLENE PIPE. ALL JOINTS TO BE BUTT FUSED.
6. FOR DETAIL 1 SEE DWG. 589890.

4-13-99

4			
3			
2			
1			
ORIG	4-13-99		FOR PERMIT APPLICATION
REV #	DATE	CHK'D BY	DESCRIPTION

* DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	2.	1.						

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
DETAILS

SCALE N.T.S. DR G.T. DATE 01/25/99 CK _____ DATE _____
APPROVED

589891

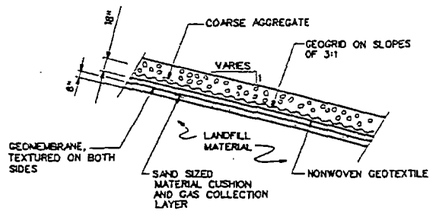
DRAWING No.	DESCRIPTION	DRAWING No.	DESCRIPTION	DRAWING No.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
ALL DRAWING REVISIONS MUST BE MADE USING APPROVED CAD SOFTWARE. THE MASTER DISK WILL BE ARCHIVED BY INDIANA HARBOR WORKS ENGINEERING DEPARTMENT.

gai CONSULTANTS

97-481-E51

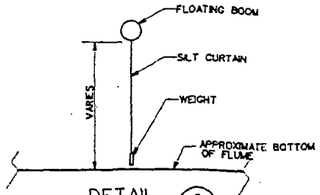
589892



DETAIL 7 / 589884

TYPICAL COVER DETAIL

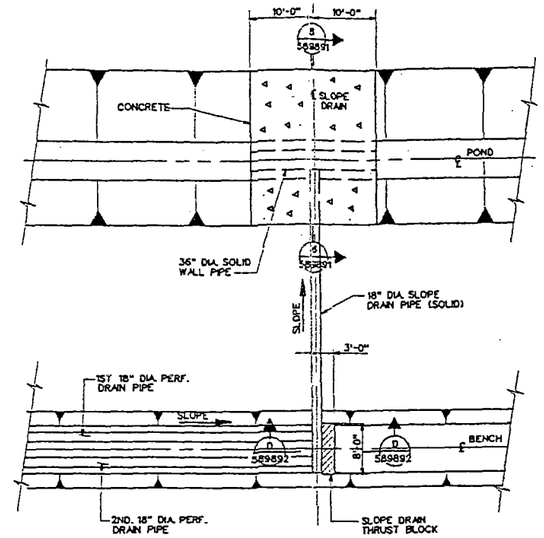
N.T.S.



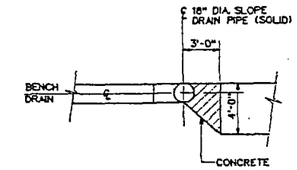
DETAIL 9 / 589883

FLOATING BOOM DETAIL

N.T.S.



PLAN

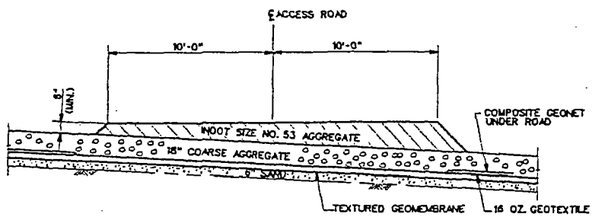


SECTION D

DETAIL 11 / 589884

TYPICAL THRUST BLOCK DETAILS

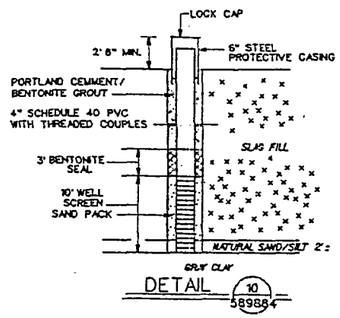
N.T.S.



DETAIL 8 / 589884

TYPICAL ACCESS ROAD OVER CAP

N.T.S.



DETAIL 10 / 589884

MONITORING WELL DETAIL

N.T.S.

NOTES:

1. FOR TITLE SHEET, LOCATION MAP AND SCHEDULE OF DRAWINGS SEE 589880.
2. FOR PLAN AND LOCATION OF SECTIONS SEE DRAWINGS 589883 AND 589884.
3. FOR GENERAL NOTES AND DESCRIPTION OF CLOSURE PLAN SEE DRAWING 589881.
4. THRUST BLOCKS BELOW EACH BENCH DRAIN PIPE TO BE 3000 PSI CONCRETE, MINIMUM 24" THICK, 8 FEET LONG AND 4 FEET WIDE.
5. ALL PERFORATED AND SOLID WALL DRAIN PIPE AND RISERS TO BE HIGH DENSITY POLYRTHLENE PIPE. ALL JOINTS TO BE BUTT FUSED.
6. FOR DETAIL 1 SEE DWG. 589890.

F. BARRY NEWMAN REGISTERED No. 19900188 STATE OF INDIANA PROFESSIONAL ENGINEER

F B Newman
4-13-99

DRAWING CODE INDEX								
LEVELS	1	2	3	4	5	6	7	8
	3.	1.						

REV #	DATE	CHK'D BY	DESCRIPTION
4			
3			
2			
1			
ORIG	4-13-99		FOR PERMIT APPLICATION

= DENOTES NUMBER OF PLACES REVISION APPEARS

REVISIONS

LTV Steel Company
Cleveland, Ohio

Works: INDIANA HARBOR WORKS
CLARK LANDFILL CLOSURE PLAN
DETAILS

SCALE N.T.S DR G.Y. DATE 01/05/99 CK _____ DATE _____

APPROVED

589892

DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION	DRAWING NO.	DESCRIPTION
REFERENCES		REFERENCES		REFERENCES	

- NOTE -
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gai CONSULTANTS

97-481-E52

APPENDIX A

FIELD CLASSIFICATION SHEETS AND INSTRUMENTATION INSTALLATION RECORDS

A-1

GAI CONSULTANTS, INC.

DEFINITION OF TERMS USED TO DESCRIBE SUBSURFACE MATERIALS

SOILS

DENSITY OF GRANULAR SOILS IS BASED ON STANDARD PENETRATION RESISTANCE

DESIGNATION	STANDARD PENETRATION RESISTANCE (BLOWS/FOOT)
VERY LOOSE	0 - 4
LOOSE	5 - 10
MEDIUM DENSE	11 - 30
DENSE	31 - 50
VERY DENSE	OVER 50

CONSISTENCY OF COHESIVE SOILS IS BASED ON FIELD AND/OR LABORATORY TESTS

CONSISTENCY	UNC. COMPRESSIVE STR. (TONS PER SQUARE FOOT)	FIELD IDENTIFICATION
VERY SOFT	LESS THAN 0.25	EASILY PENETRATED SEVERAL INCHES BY FIST
SOFT	0.25 TO 0.50	EASILY PENETRATED SEVERAL INCHES BY THUMB
MEDIUM STIFF	0.50 TO 1.0	CAN BE PENETRATED SEVERAL INCHES BY THUMB WITH MODERATE EFFORT
STIFF	1.0 TO 2.0	READILY INDENTED BY THUMB BUT PENETRATED ONLY WITH GREAT EFFORT
VERY STIFF	2.0 TO 4.0	READILY INDENTED BY THUMBNAIL
HARD	MORE THAN 4.0	INDENTED WITH DIFFICULTY BY THUMBNAIL

ADDITIONAL TERMS USED IN THE DESCRIPTION OF SOILS:

AND — INDICATES APPROXIMATELY EQUAL AMOUNTS OF MATERIALS, SUCH AS A SAND AND GRAVEL MIXTURE. IF THE MATERIALS OCCUR IN THIN SEPARATE SEAMS, IT IS NOTED IN THE DETAILED WORD CLASSIFICATION. THE THICKNESS IS GIVEN WHERE POSSIBLE
EXAMPLE: MEDIUM DENSE SAND AND GRAVEL, OR DENSE INTERBEDDED COARSE SAND AND GRAVEL (1/4" - 3/4") THICK

SOME — INDICATES A SIGNIFICANT AMOUNT OF THE ACCESSORY MATERIAL
EXAMPLE: MEDIUM DENSE SILTY SAND - SOME GRAVEL

TRACE — INDICATES A MINOR AMOUNT OF THE ACCESSORY MATERIAL
EXAMPLE LOOSE SILTY SAND - TRACE OF GRAVEL

INTERBEDDED — USED TO DESCRIBE THIN ALTERNATING SEAMS. THICKNESS IS GIVEN WHERE POSSIBLE
EXAMPLE: HARD INTERBEDDED SILT AND CLAY (APPROXIMATELY 1/16" THICK)

ROCK

TERM	DEFINITION
SEAM	THIN (12 INCHES OR LESS) PROBABLY CONTINUOUS LAYER
SOME	INDICATES SIGNIFICANT (15 to 40 PERCENT) AMOUNTS OF THE ACCESSORY MATERIAL EXAMPLE: ROCK COMPOSED OF SANDSTONE (70%) AND SEAMS OF SHALE (30%) WOULD BE: SANDSTONE – SOME SHALE SEAMS
FEW	INDICATES MINOR (0-15 PERCENT) AMOUNTS OF THE ACCESSORY MATERIAL EXAMPLE: ROCK COMPOSED OF SANDSTONE (90%) AND SEAMS OF SHALE (10%) WOULD BE: SANDSTONE - FEW SHALE SEAMS
INTERBEDDED	USED TO INDICATE THIN OR VERY THIN ALTERNATING SEAMS OF MATERIAL OCCURRING IN APPROXIMATELY EQUAL AMOUNTS EXAMPLE: ROCK COMPOSED OF SANDSTONE (50%) AND SHALE (50%) SEAMS WOULD BE.INTERBEDDED SANDSTONE AND SHALE

THE DEGREE OF BROKENNESS OF THE ROCK IS DESCRIBED BY ONE OF THE FOLLOWING TERMS:

DESCRIPTIVE TERMS	ABBREVIATION	SPACING
VERY BROKEN	(V. BR.)	LESS THAN 2 INCHES
BROKEN	(BR.)	2 INCHES - 1 FOOT
BLOCKY	(BL.)	1 FOOT - 3 FEET
MASSIVE	(M.)	3 FEET - 10 FEET

ROD-ROCK QUALITY DESIGNATION IS CUMULATIVE LENGTH OF PIECES OF CORE EQUAL TO OR GREATER THAN FOUR INCHES IN LENGTH DIVIDED BY THE TOTAL LENGTH OF CORE RUN, EXPRESSED AS A PERCENTAGE

THE FOLLOWING BASIC NAMES ARE APPLIED TO THE TYPE OF ROCK FOUND AT THE SITE:

ROCK TYPE	CHARACTERISTICS
SANDSTONE	MADE UP PREDOMINANTLY OF GRANULAR MATERIALS RANGING BETWEEN 1/16 AND 2MM IN DIAMETER
SILTSTONE	MADE UP OF GRANULAR MATERIALS LESS THAN 1/16MM IN DIAMETER. FRACTURES IRREGULARLY. MEDIUM THICK TO THICK BEDDED
CLAYSTONE	VERY FINE GRAINED ROCK MADE UP OF CLAY MATERIALS. FRACTURES IRREGULARLY. VERY SMOOTH TO TOUCH. GENERALLY HAS IRREGULARLY SPACED PITTING ON SURFACE OF DRILLED CORES.
SHALE	A FISSILE VERY FINE GRAINED ROCK. FRACTURES ALONG BEDDING PLANES
LIMESTONE	ROCK MADE UP PREDOMINANTLY OF CALCITE ($CA\ CO_3$) EFFERVESCES UPON THE APPLICATION OF HYDROCHLORIC ACID.
COAL	ROCK CONSISTING MAINLY OF ORGANIC REMAINS.

LEGEND

RESIDUAL SOIL	CLAYSTONE		2" O.D. SPLIT BARREL SAMPLE
GRAVEL	LIMESTONE		CASING SAMPLE
SAND OR ALLUVIUM	SILTSTONE	ST-1	SAMPLE NUMBER. 3" DIA. UNDISTURBED SAMPLE
SILT	SANDSTONE		
CLAY	SHALE	4.6 5.0	LENGTH OF CORE RECOVERED LENGTH OF DRILL RUN
ORGANIC MATERIAL	CONCRETE		
SLAG	COAL	3-10-66	GROUND WATER LEVEL AND DATE OF OBSERVATION
FILL	VOID	60/0.3'	INDICATES 60 BLOWS REQUIRED FOR SPLIT BARREL TO PENETRATE 0.3 FEET
			APPROXIMATE TOP OF ROCK

A-2

GAI CONSULTANTS INC

PROJECT LTV Steel Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 599.7 GWL 0 HRS ≈20ft. — BORING NO. LTV98-8

9 days ~~HRS~~ 18.5ft 4-2-98

DATE 3-24-98 FIELD ENGINEER T.R. Gower — PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Red-BK	Slag and Flyash Fill	GW-SM	Air. Rotary Tubex to 49 feet

REMARKS** Advanced 0 to 49' with Tubex air rotary drill by TCDI. D&G Drilling advanced boring 49' to 79.5' with roller bit and drilling fluid

PROJECT NO. 97-481-10

BORING NO. LTV98-8

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

GAI CONSULTANTS, INC

PROJECT LTV Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 599.7 GWL 0 HRS 27' 3-26-98 LTV98-8C — BORING NO. LTV 98-8

168 HRS 18.5 ft 4-2-98

DATE 4-6-98 FIELD ENGINEER T.R. Gower — PAGE NO. 2 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Red-BK	Slag Fill	GW-SM	
49.0				49.0					
	4 3	S-1 0		50.5	Loose	Gray	Fine Grain Sand	SP	
51.0	7 9	(1.5 ft)							
					V. Stiff	Gray	Silty Clay	CL	PP = 3.0 ¥
55.0									Push Vane 55 to 57.5
57.5 58.0		V-1			Stiff				Small Vane 11X5 cr Field Est 1.8 TSF

REMARKS** Boring advanced with roller bit and drilling mud between sample / test location 4" casing drove to 53 feet

PROJECT NO. 97-481-10

BORING NO. LTV98-8

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-T

gai CONSULTANTS, INC

PROJECT LTV Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 599.7 GWL 0 HRS ____ HRS — BORING NO. LTV98-8

DATE 4-6-98 FIELD ENGINEER TR Gower — PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	PROFILE	SOIL DENSITY–CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
					Stiff	Gray	Clay	CL-CH	
63.0									
	1.2/2.0	ST-1 Δ	X						PP = 1.25 to 1.75 TSF
65.0			X						
67.5 / 68.0		V-2			Med. Stiff				Small Vane 67.5-68 Est 0.8 TSF Vane pushed from 65' to 68 & then to 72.5'
72.0 / 72.5		V-3							Small Vane 72-72.5 Est 0.8 TSF
74.5									
	1.8/2.0	ST-2 Δ	X						PP = 0.75 TSF
76.5			X						
77.5 / 78.0		V-4							13 x 6.5 cm ; C=1.[illegible] Mid Size Vane, Est = 0.7[illegible]
79.5				79.5					

Bottom @ 79.5'

Piezometers installed 4-7-98 @ 60, 70, 78.5 feet.

REMARKS** Mobile B-57 Drill. Barry Tommason Driller w/D & C Drilling, 5" & NC is IES Drilling Co, 5886 South Lorraine Rd Pearl City, IL. 1-800-388-2906

PROJECT NO. 97-481-10

BORING NO. LTV98-8

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

SUBJECT LTV Steel Clark Landfill
LTV98-8 Piezometers

BY TRG DATE 4-7-98 PROJ. NO. 97-481-10
CHKD. BY AC DATE 1-4-99 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

Log. General Geology — LTV98-8 Piez. — Not to Scale

Depth of		Elevation		Depth
		599.7 ft.		0 ft.
	Slag & Flyash Fill			
		581.2'		18.5' W.L.
			Open Hole in Casing	
49.0'		550.7'		49.0
50.5'	Gray Fine Grain Sand	549.2'	Sand	50.5' PVC Casing 5" ϕ
		545.2'		54.5
			Bentonite	
	Gray Clay	541.7'		58.0
			Sand	
		539.7'		60.0 Piez # 50508
		538.7'		61.0
			Bentonite	
		535.7'		64.0
		534.7'	Sand	65.0
			Bentonite	
		531.7'		68.0
			Sand	
		529.7'		70.0', Piez # 50507
		528.7'		71.0
			Bentonite	
		523.2'		76.5'
			Sand	
		521.2'		78.5 Piez. # 50509
		520.2'		79.5 Bottom

gai CONSULTANTS, INC

PROJECT LTV Steel Clark landfill — PROJECT NO. 97-481-10

ELEVATION 616.1 — GWL 0 HRS ≈35.0' — BORING NO. LTV98-9

14 days ~~HRS~~ 34.8'

DATE 4-8-98 — FIELD ENGINEER T.R. Gower — PAGE NO. 1 OF 4

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Br-Red	Slag & Flyash Fill	GW-sm	

REMARKS** TCDI air rottary to 67.5 feet. D&G drilling 67.5' to 113.5' with roller bit and drilling fluid

PROJECT NO. 97-481-10

BORING NO. LTV98-9

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION 616.1 GWL 0 HRS BORING NO. LTV98-9

HRS

DATE 4-8-98 FIELD ENGINEER T. R. Gower PAGE NO. 2 OF 4

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Bk-Red	Slag & Flyash Fill	gw-sm	

REMARKS**

PROJECT NO. 97-481-10

BORING NO. LTV98-9

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

GAI CONSULTANTS, INC.

PROJECT LTV Steel Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 616.1 GWL 0 HRS ~35' — BORING NO. LTV98-9

HRS 34.8'

DATE 4-8-98 FIELD ENGINEER T. R Gower — PAGE NO. 3 OF 4

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Red-BK	Slag & Flyash Fill	gw-sm	
67.0									
	3 1	S-1 0		67.5					
68.5	4 1				V. Loose	DK Gray	Fine Grain Sand	sp	No Recovery S-1=
	5 9	S-2 0		70.0	Med-Dense				
	6	18"			V. Stiff	Bk-Gray	Clay	cl	PP = 3.5 TSF
									Push vane 75 to 77.5'
77.0									
77.5		V-1			Stiff				
86.0									
	1.7/2.0	ST-1 Δ	X						1.0 TSF
88.0									

REMARKS**

PROJECT NO. 97-481-10

BORING NO. LTV98-9

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS INC

PROJECT LTV Steel Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 616.1 GWL 0 HRS ____ HRS — BORING NO. LTV98-9

DATE 4-8-98 FIELD ENGINEER T. R. Gower — PAGE NO. 4 OF 4

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
90.5		V-2			Stiff	Gray	Clay	cl-ch	Small Vane 90'-90.5'
93.0									
	0 0	S-3 0			med Stiff				PP = 0.5 TSF
95.0	2 3	18"							
97.5 98.0		V-3							Small Vane 97.5 to 98.0'
99.0									
	0.2/2.0	ST-2 Δ	X				- trace 1/4-1/2" ϕ		Sample was loose in tube placed in jar. ST-2 Δ. Clean out to 101. Pushed 2nd tube no recovery.
101.0							shale gravel		
	0.0/2.0	ST-3 Δ	X						
103.0			X						
104.5 105.0		V-4							Medium Vane 104.5 to 105.0'
110.5	3								
	6 11	S-4 0		111.5					
112.5	12	22"			V. Stiff	Gray	Clayey Silt - Trace Sand	ml-cl	
113.5				113.5					
							Bottom @ 113.5		
							Piezometers installed @ 112.5', 93.5', 77.5'		

REMARKS** ____

PROJECT NO. 97-481-10

BORING NO. LTV98-9

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

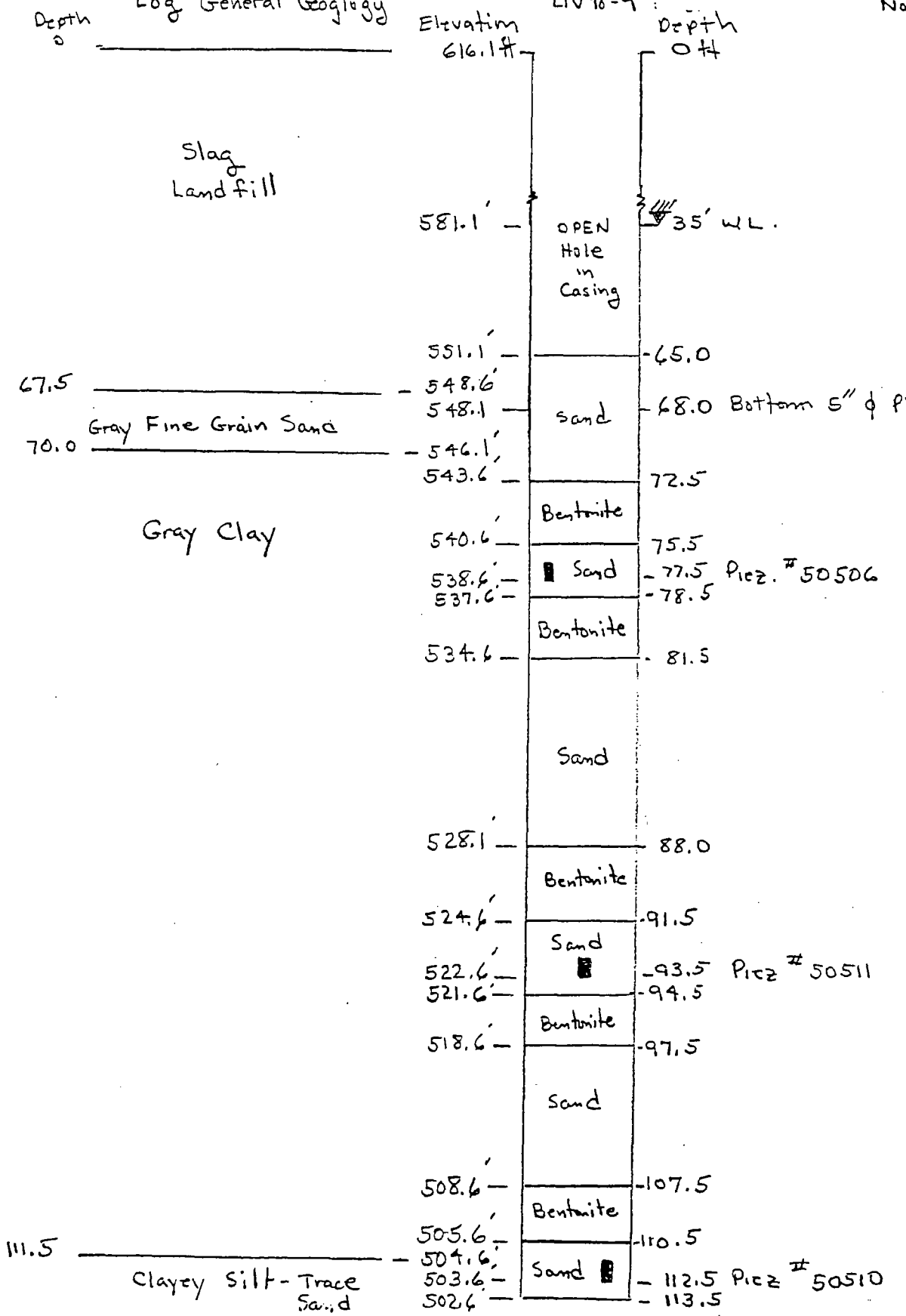
SUBJECT LTV Steel Clark Landfill
LTV 98-9 Piezometers

BY TRG DATE 4-9-98 PROJ. NO. 97-481-10
CHKD. BY AC DATE 1-4-99 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists

Log General Geology

Not To Scale



gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-206

HRS

DATE _____ FIELD ENGINEER TR Gower PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION ≈ 582.3 = 0' Top of Barge	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Barge		
				2.5					WL = 579.8'
							Water		26.5' of water
				29.0			↓		553.3' El.
							Slag to Sand		Bottom of flume

REMARKS** Mobile B-47 Drill Rig, 4" ϕ casing w/roller bit used to advance boring, Barry Tommison Driller, D&G Drilling Co.

PROJECT NO. 97-481-10

BORING NO. SB-206

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-12

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-206

HRS

DATE 10-26-98 FIELD ENGINEER T R Gauer PAGE NO. 2 OF 3

DEPTH 0 FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE 29.0	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Gray	Slag to sand to clay, 29.0 to 33.5'		
									Casing 33.5'
34.0				34.0					548.3' El.
						Gray	Clay		core @ 34' started
39.0	4								
40.0	4								
41.0	4								
42.0	5								
43.0	5								
44.0	4								
45.0	5								
	5								
48.0									
49.0	20								
50.0	16								
51.0	6								
52.0	6								
	7								
54.0									
55.0	9								
	13								
57.0									
58.0	5								
	6								
60.0	11								
	15								

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-206

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-206

HRS

DATE 10-26-98 FIELD ENGINEER TR Gower PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
61.0						Gray	Clay		
	16								
64.0									
	15								
67.0									
	18								
	18								
70.0	18								
	17								
				77.0					505.3 El.
							Silt		
				88.0					
							Bottom 88'		

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-206

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. B-207

HRS

DATE 10-27-98 FIELD ENGINEER T R Gower PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION (Top Barge = 583.6')	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
				2.8					W.L. ≈ 580.8' EL.
							Water		6' water
				8.8					574.8' EL.
						Red-Gray	Slag		Bottom of flume
				22.0					561.6' El.
						Gray	Sand & Silt		Casing to 23'
23.5	16								Start Core 23.5'
25.0	16			25.0					558.6' El
	3					Gray	Clay		
	3								
	3								
29.0	3								
	4								

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. B-207

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel — PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ HRS — BORING NO. SB-207

DATE 10-27-98 FIELD ENGINEER TR Gower — PAGE NO. 2 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
31.0	4						Clay - med-low strength		
	4								
	3								
	4								
	4								
	3								
37.0	3								
38.0	4			37.5					
	3						Low strength clay zone		
	3								
	3								
	3								
	3								
44.0	3			43.5					
	4						med to higher strength clay zone		
	4								
	4								
48.0	4								
	5								
	5								
	5								
52.0	5								
	6								
	6								
	6								
56.0	6								
	5								
58.0	5								
59.0	7								
	5								

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-207

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-16

gai CONSULTANTS, INC.

PROJECT LTV Steel PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-207

HRS

DATE 10-27-98 FIELD ENGINEER T R Gower PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
	5						Clay		
	5								
	5								
	5								
	5								
	5								
67.0	5								
	6								
	6								
	6								
71.0	6								
72.0	7			72					
	+10						Silt & Clay		
74.0									
75.0	10								
76.0	11			76.0					507.6' EL
77.0	34						Silt		
78.0	17								
79.0	32								
80.0	35								
81.0	21								
	30								
83.0									
	19								499.1' EL.
84.5				84.5					
							Bottom 84.5'		

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-207

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

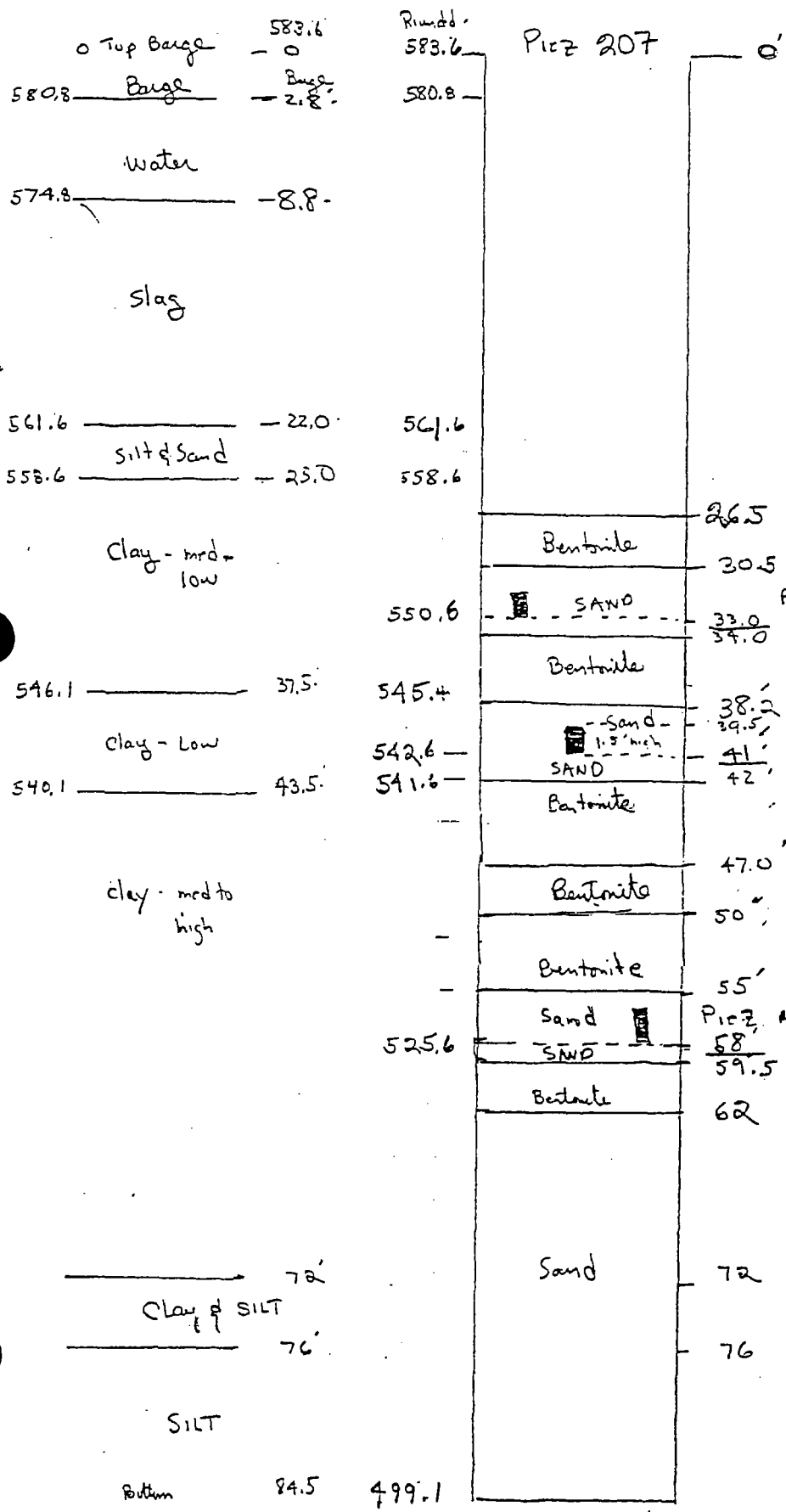
SUBJECT LTV Steel

Boring 207 Piezometers

BY TRG DATE 10-28-98 PROJ. NO. 97-481-10

CHKD. BY AC DATE 1-4-99 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists



water level - 3.0' Avg.
10-28-98 - 2.8-3.3 va.

squeeze 54' to 56'
Sand to 55
bentonite 53 then pulled
casing back from 53'

gai CONSULTANTS INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-208

HRS

DATE 10-26-98 FIELD ENGINEER T R Gower PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION (Top Barge ≈ 585.1' 0')	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Barge		
2.7				2.7					WL ≈ 582.4'
							Water		Erosion line east of 208, approx. 10' above present W.L. extends to 0' @ 207 and
19.0				19.0					≈566.1
						Gray	Slag-Sand		Bottom of flume
22.0				22.0					≈ 563.1' El.
						Gray	Clay		Top of clay ≈ 22' Casing to 23' Start core @ 24'

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-208

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-208

HRS

DATE 10-26-98 FIELD ENGINEER T R Gower PAGE NO. 2 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Clay		

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-208

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC.

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-208

HRS

DATE 10-26-98 FIELD ENGINEER TR Gower PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Clay		
				73.0					≈512.1' EL.
							Silt		
									Bottom @ 23.7 meters
77.0				77.0					
							Bottom ≈ 77'		

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-208

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-209

HRS

DATE 10-29-98 FIELD ENGINEER T R Gower PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION ≈584.3' El. top Barge	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Barge		Depths from top of Barge
									WL ≈ 580.8'
				3.5					
							Water		6.5' of water
				10.0					Bottom of flumes 574.3'
							Slag		

REMARKS** Approx 20' from shoreline, 240' east of LTU-5, El. 16+25

PROJECT NO. 97-481-10

BORING NO. SB-209

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-22

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ BORING NO. SB-209

HRS

DATE 10-29-98 FIELD ENGINEER T R Gower PAGE NO. 2 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
31.0				31.0			Slag		553.3' ↓
						DK	Sand - Sandy Silt		
				33.0		Gray	↓		551.3'
33.5	8					Gray	Clay		Start core @ 33.5'
35.0	9 10								SPT are
36.0	11								preliminary
37.0	10								
	9								
	8								
40.0	6								
	5								
	5								
	5								
	5								
	5								
46.0	5								
	6								
48.0	6								
	5								
	5								
	5								
	5								
	5								
	6								
55.0	7								
	7								
58.0	7								
	6								
	6								
60	6					↓	↓		
	5								

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-209

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel — PROJECT NO. 97-481-10

ELEVATION _____ GWL 0 HRS _____ HRS — BORING NO. SB-209

DATE 10-29-98 FIELD ENGINEER TRGower — PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
61.0	5						Clay		
62.0	4								
63.0	8								
64.0	6								
65.0	5								
66.0	6								
67.0	5								
68.0	6								
69.0	5								
70.0	7								
	5								
72.0	5								
73.0	6								
74.0	5								
75.0	6								
	7								
77.0	7								
78.0	8			78.0'					506.3' El.
79.0	12						Silt & Clay Transistion		
80.0	10								
	8								
	9								
83.0	9								
84.0	7								
	7			85.0'					499.3' El.
	12						Silt		
	13								
	14								
	12								
	12						Hard Silt 91'±		Bottom @ 27.8 meter
±91.0'	10 Bottom								

REMARKS** _____

PROJECT NO. 97-481-10

BORING NO. SB-209

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC.

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION 583.6 GWL 0 HRS BORING NO. SB-210

HRS

DATE 11-2-98 FIELD ENGINEER TR Gower PAGE NO. 1 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION ≈583.6 Ground Surface	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Slag		

REMARKS**

PROJECT NO. 97-481-10

BORING NO. SB-210

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-25

gai CONSULTANTS, INC.

PROJECT LTV Steel Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 583.6 GWL 0 HRS ____ HRS — BORING NO. SB-210

DATE 11-2-98 FIELD ENGINEER T R Gower — PAGE NO. 2 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
							Slag		
32.0				32.0			↓		551.6' El.
33.0							Sand		
34.0	19								drilled to 34'
35.0	8								start core @ ≈33.5
36.0	15			36.0			↓		547.6' EL.
	10						Clay		
	9								
	7								
40.0	6								
	5								
	5								
	4								
	4 5								
	4								
	4								
	4								
	5								
	5								
	5								
	5								
	5								
	5								
	6								
	6								
	5								
	5								
	5								
	6								
	4						↓		Pore Pressure up

REMARKS** ____

PROJECT NO. 97-481-10

BORING NO. SB-210

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

A-26

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION 583.6 GWL 0 HRS BORING NO. SB-210

HRS

DATE 11-2-98 FIELD ENGINEER T.R. Gower PAGE NO. 3 OF 3

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	DESCRIPTION: SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	DESCRIPTION: COLOR	DESCRIPTION: MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
	5						Clay		
	6								
	5								
	6								
65.0	5								
	6								
	6								
	6								
	5								
70.0	5								
	5								
	6								
	6								
	6								
75.0	6								
	6								
	6								
	9								
	8								
80.0	8			80.0					503.6' El.
	15						Silt		
	21								
	16								
	17								
	18								
≈ 85.6									96.23 water
									Inc. 10.5° slope=
									100' Slope Increment
									pipe installed 8.34"
									with 3.5' stick up

A0 - A18 axis N330°E. A0 toward flume

REMARKS**

PROJECT NO. 97-481-10

BORING NO. SB-210

*POCKET PENETROMETER READINGS

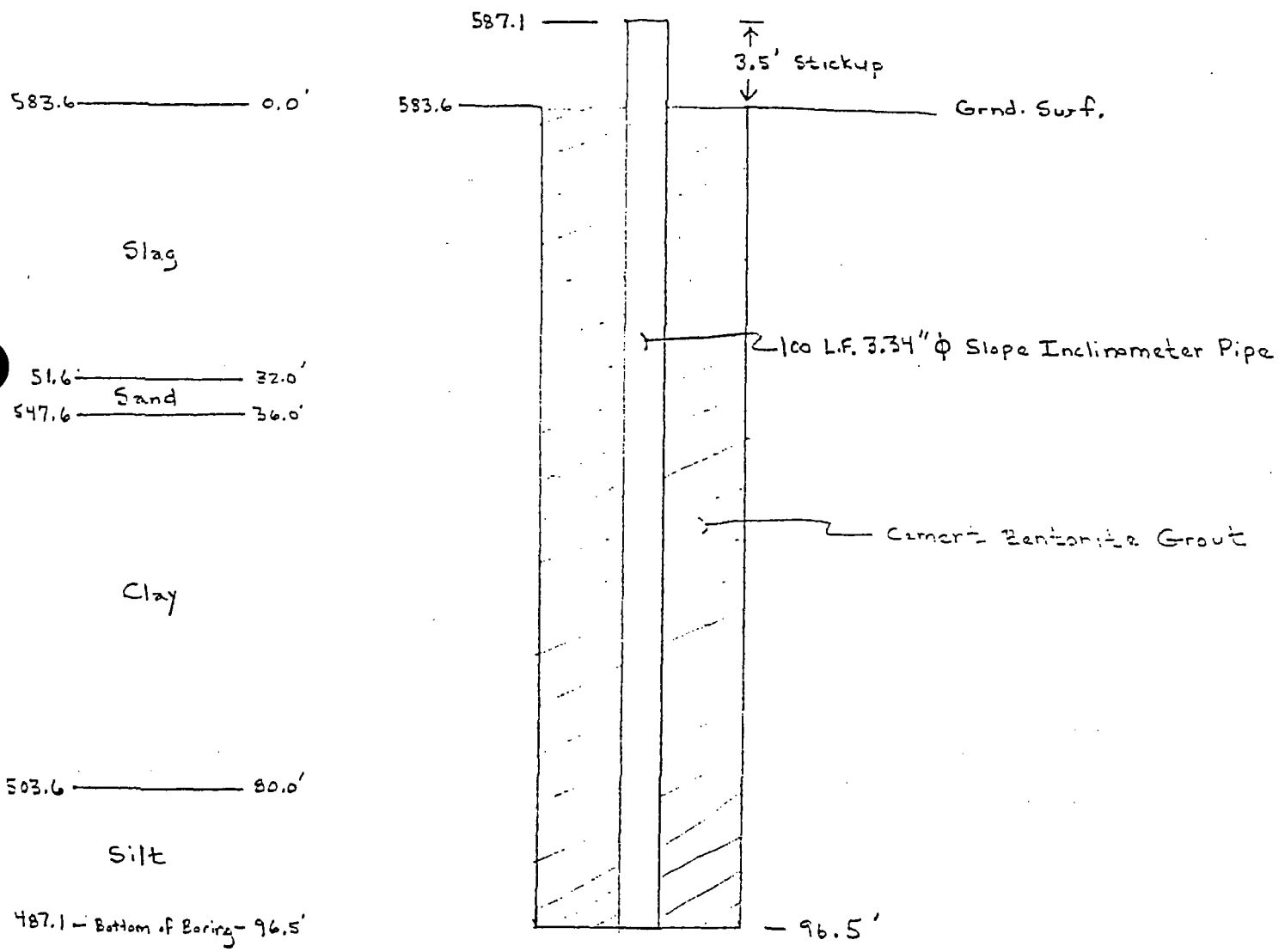
**METHOD OF ADVANCING AND CLEANING BORING

SUBJECT LTV Steel Clark Landfill
Boring 210 Slope Inclinometer

BY AC DATE 12-4-98 PROJ. NO. 97-481-10

CHKD. BY TRG DATE 12-31-98 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC
Engineers • Geologists • Planners
Environmental Specialists



gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill — PROJECT NO. 97-481-10

ELEVATION 601.3 GWL 0 HRS HRS — BORING NO. SB-211

DATE 11-5-98 FIELD ENGINEER TR Gower — PAGE NO. 1 OF 2

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION ≈ 601.3'	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Gray	Slag	GW	
6.0									
7.0		S-1							Cutting Sample

REMARKS** E 398985, N 1520745

PROJECT NO. 97-481-10

BORING NO. SB-211

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

gai CONSULTANTS, INC

PROJECT LTV Steel Clark Landfill PROJECT NO. 97-481-10

ELEVATION 601.3 GWL 0 HRS BORING NO. SB-211

HRS

DATE 11-5-98 FIELD ENGINEER T R Gower PAGE NO. 2 OF 2

DEPTH FEET	BLOWS PER SIX INCHES OR CORE RECOVERY/RUN	SAMPLE NO., TYPE & RECOVERY OR % ROCK RECOVERY	RQD (%)	DESCRIPTION: PROFILE	SOIL DENSITY—CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	USCS OR ROCK BROKENNESS	REMARKS*
1	2	3	4	5	6	7	8	9	10
						Gray	Slag	gw	
				46.0					
						Bk-BR	Sand	sw	
48.5	4				med Dense	Gray	Fine Sand		
50.0	11 7	S-2 0							
52.0				51.5					
	3 3	S-3 0			Stiff	Gray	Clay	cl	
53.5	4			53.5					
							Bottom @ 53.5'		

REMARKS**

PROJECT NO. 97-481-10

BORING NO. SB-211

*POCKET PENETROMETER READINGS

**METHOD OF ADVANCING AND CLEANING BORING

Monitoring Well Installation and Development Specification

Four (4) monitoring wells are proposed on the perimeter of the LTV Clark Landfill. These wells should be installed within 50 feet of the waste boundary and to depths allowing groundwater monitoring of the uppermost aquifer. The wells should be installed at least 10 feet into the uppermost aquifer (~+568 based on normal lake levels). The IDEM Commissioner shall be given ten (10) day notice prior to the installation of the well.

Drilling Requirements

It is expected that drilling will encounter relatively hard slag fill materials. Continuous split spoon sampling or rock coring is required the full depth of the hole. Drilling for sampling purposes may be smaller diameter ahead of reaming the hole for well installation. A sample of drill water should be collected and analyzed for Phase I parameters during drilling. All samples collected during drilling should be retained for a minimum of seven years following notification of the IDEM Commissioner. Representative samples from the hole shall also be tested for grain size analysis and cation exchange capacity. The hole shall be reamed to a minimum 8-inch diameter hole size using an air rotary rig to provide for a 4-inch diameter well casing and screen. The rig should provide a coalescing air filter to minimize contamination of the formation with air pressure.

All equipment and tools used between boreholes shall be decontaminated to prevent the transfer of contamination from one hole to another.

Well Installation

The well shall be installed so that the screen length ranges from 2 to 10 feet and is placed in the uppermost portion of the aquifer. A minimum 10 foot up to 20 foot depth of installation below the phreatic surface observed during drilling is recommended.

The wells should be installed with PVC casing and continuous wire round PVC screen. Both the casing and screen shall be free of printed labeling and other coatings or adhesives. Screen size should be appropriate to retain 90 to 100 percent of the formation material and matched to the filter pack. When the well is installed, it shall be centered with at least two standard centralizers a minimum of 5 feet above the top of the screen and at the bottom of the screen. Centralizers shall not interfere with other well installation activities. After the screen is placed it shall be backfilled with an annular inert filter pack sized to match the 50 percent retained size of the formation. This inert filter pack shall be placed by side discharge tremie up to 2 feet above the top of the well screen. In the event the formation is very coarse, a coarse filter pack may be utilized, but will also require a finer size fraction to retain the bentonite seal above the annular filter pack. The annular filter pack shall be surged gently holding the casing in place to seat the pack material. Above the annular filter pack, a 3 foot bentonite seal shall be placed consisting of bentonite chips or pellets having known hydration properties. The bentonite seal shall be allowed to substantially hydrate before the remaining annular fill is placed. Above the bentonite seal, a cement-bentonite grout extending up to 1 foot below the frost line (approximately 4 feet below grade) shall be placed. This shall also be placed by side discharge tremie similar to the filter pack sand and bentonite chips.

A steel protective casing shall be placed 4 feet below grade and extend at least 3 feet above grade immediately above the cement-bentonite grout. The remaining annular space around the casing shall be concrete and provide for a 6 foot square apron sloping 15 degrees or about 10 inches from the well to the apron edge.

The protective casing shall provide a vent hole at the top of the well casing. The annular space between the protective casing and the apron shall also be filled at least 1 inch above the apron where a small drain hole shall be provided through the protective casing. The remaining annular space between the protective casing and well casing shall be backfilled with a fine gravel. Embossed brass tags with permanent labels shall be provided on each protective casing hasp with an all-weather lock and key. Permanent signage is also

recommended. Each protective casing shall be protected by a minimum of three perimeter bollards offset 3 to 4 feet and painted bright yellow along with the protective casing. All painting shall be conducted off-site.

Well Development

After the seal and grout has an opportunity to set (approximately four days), development of the well should be completed using various surging and pumping techniques to remove any turbidity associated with the well. pH, specific conductance, redox potential and turbidity should be measured during all well development activities. A complete record of performance data and accumulative pumping volume shall be recorded up to the point where a 5 NTU or less turbidity level is achieved and/or all development parameters have stabilized. At the completion of the development, hydraulic conductivity tests using constant pumping or slug techniques shall be conducted.

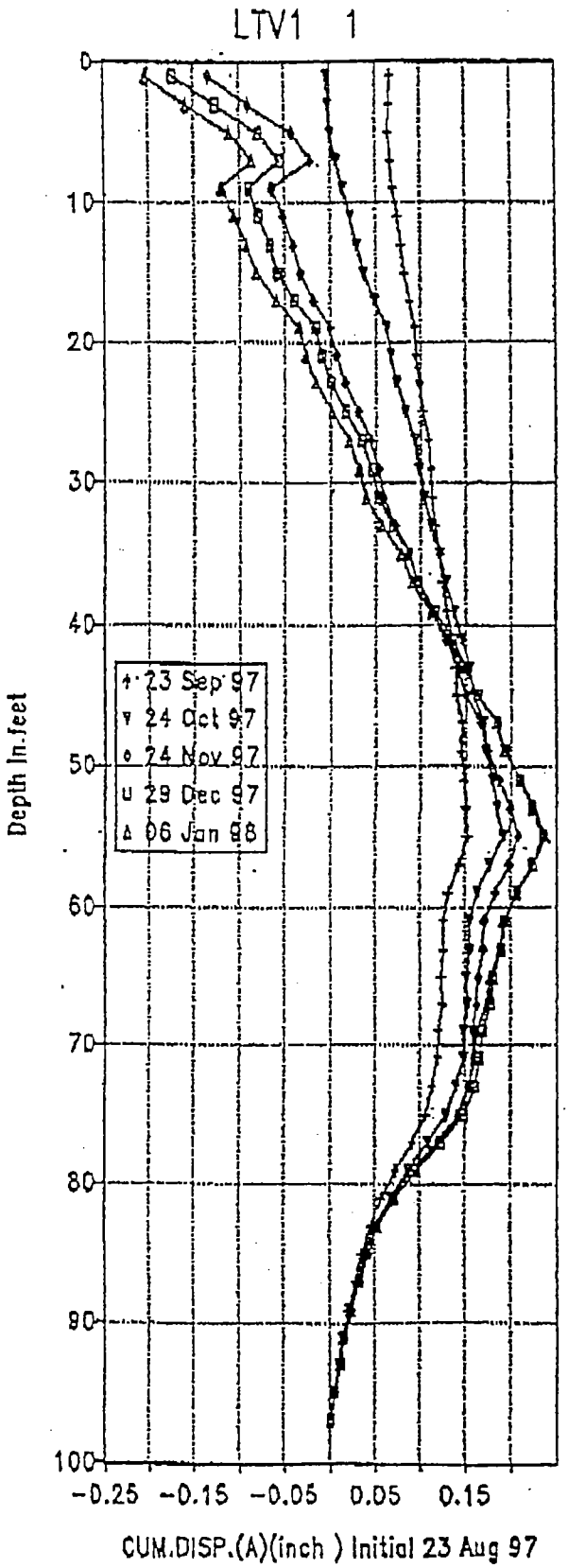
Well Documentation

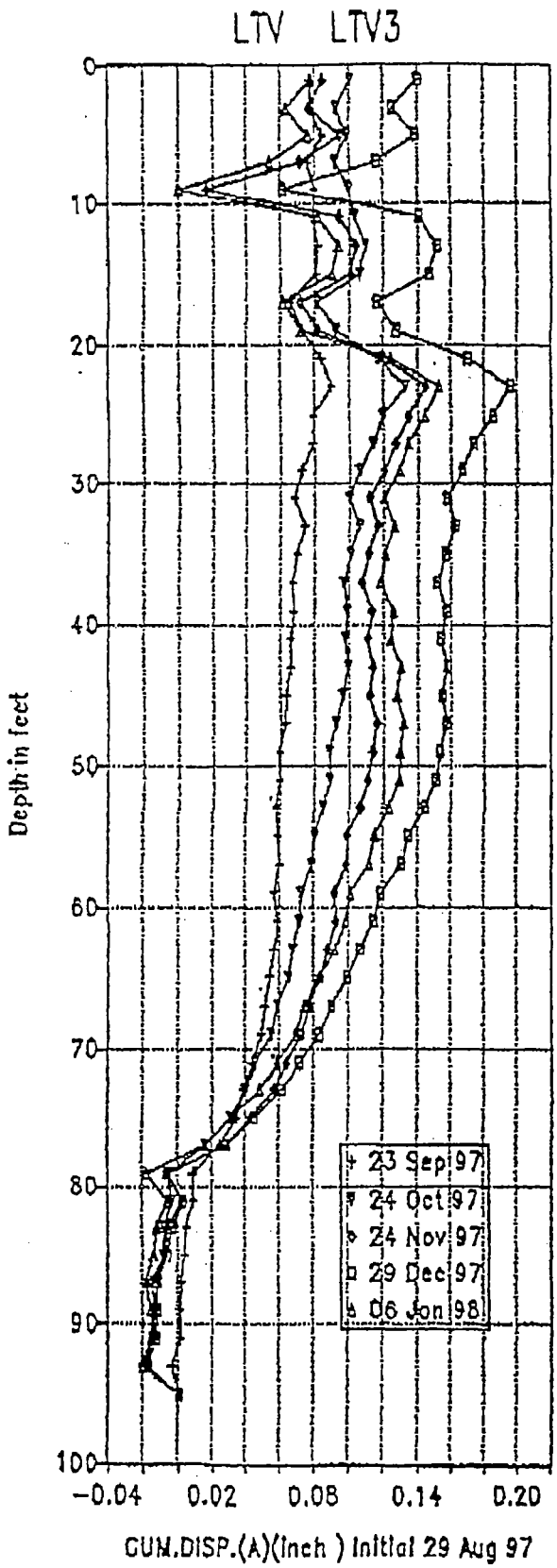
All of the observations and data collected during the well installation shall be prepared in a geologic log and diagrammatical construction and design log of the groundwater monitoring well. This documentation shall be conducted in general conformance with 329 IAC 10-21-4. All horizontal survey locations should be to the nearest foot, while all vertical elevation should be to the nearest 0.01 foot.

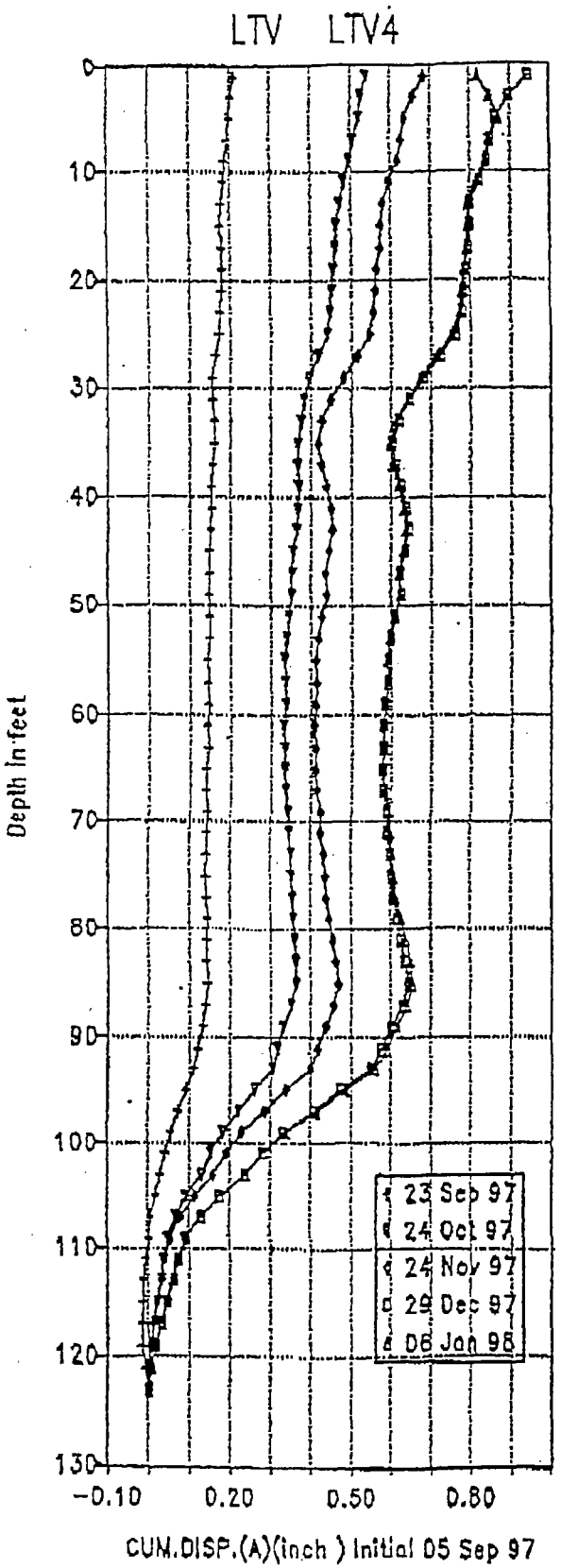
APPENDIX B

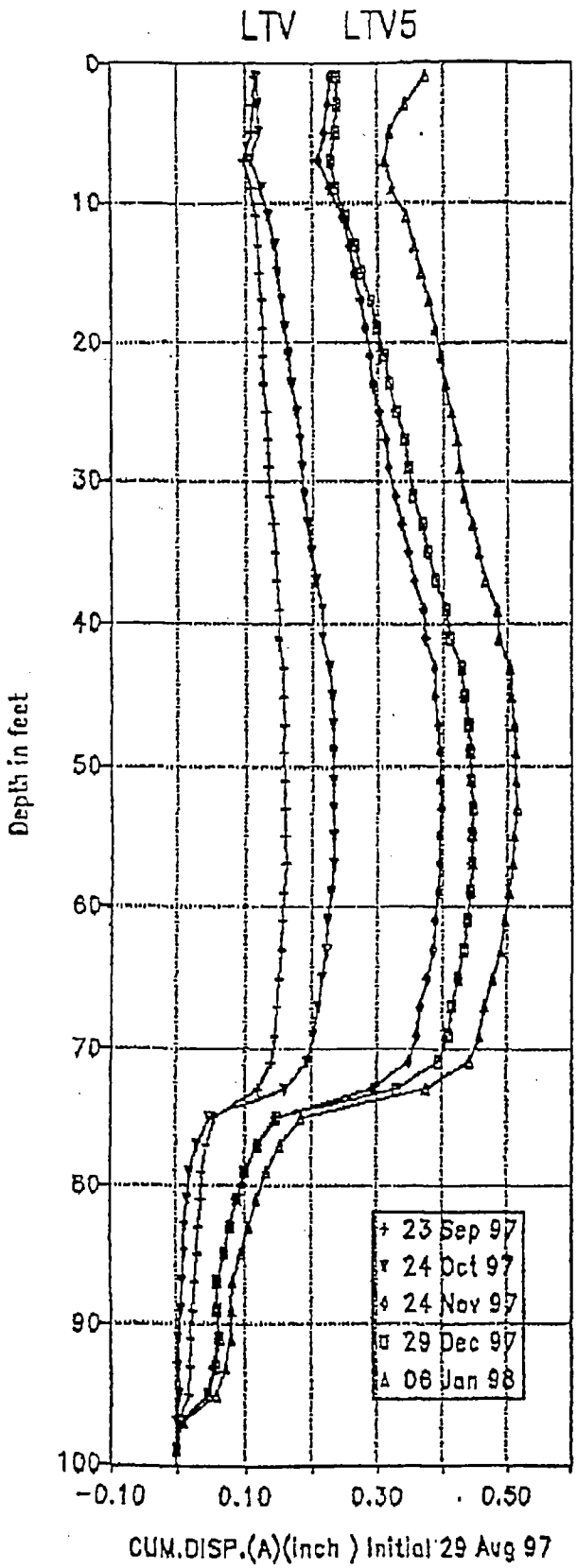
INCLINOMETER PLOTS 1997 AND 1998

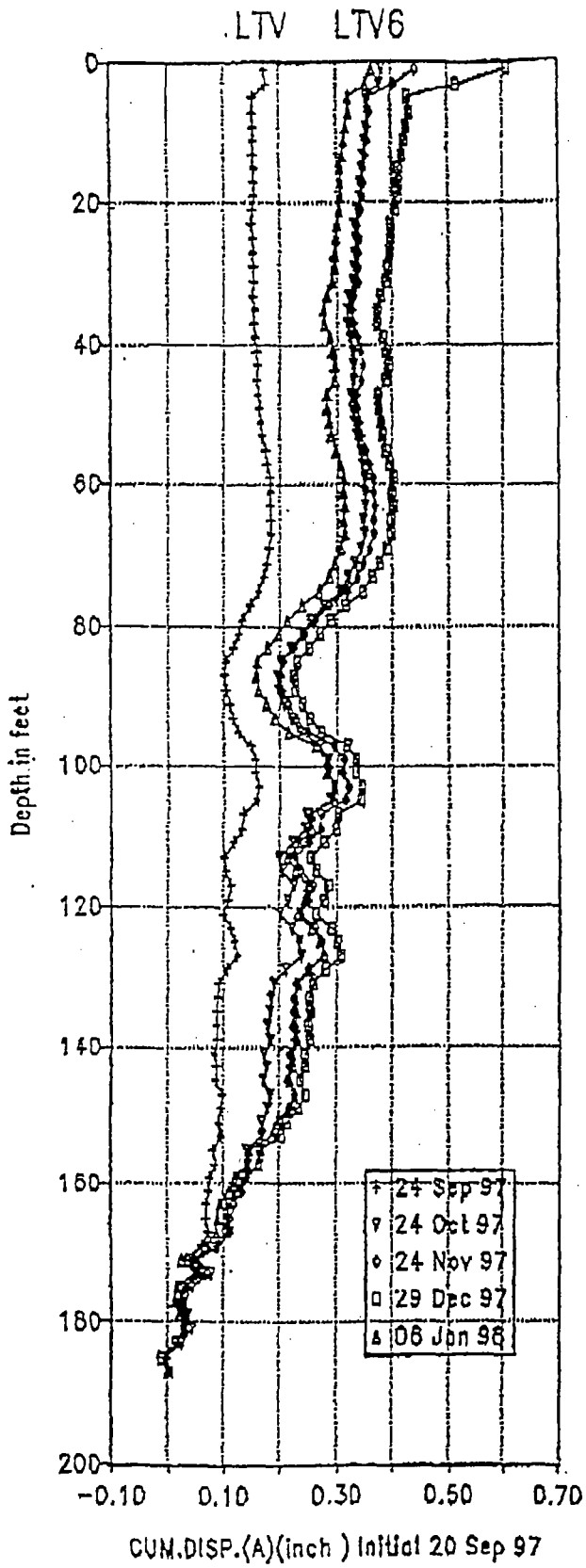
Inclinometer Graphs LTV-1 to LTV-7 August 23, 1997 by Baker Environmental, Inc.

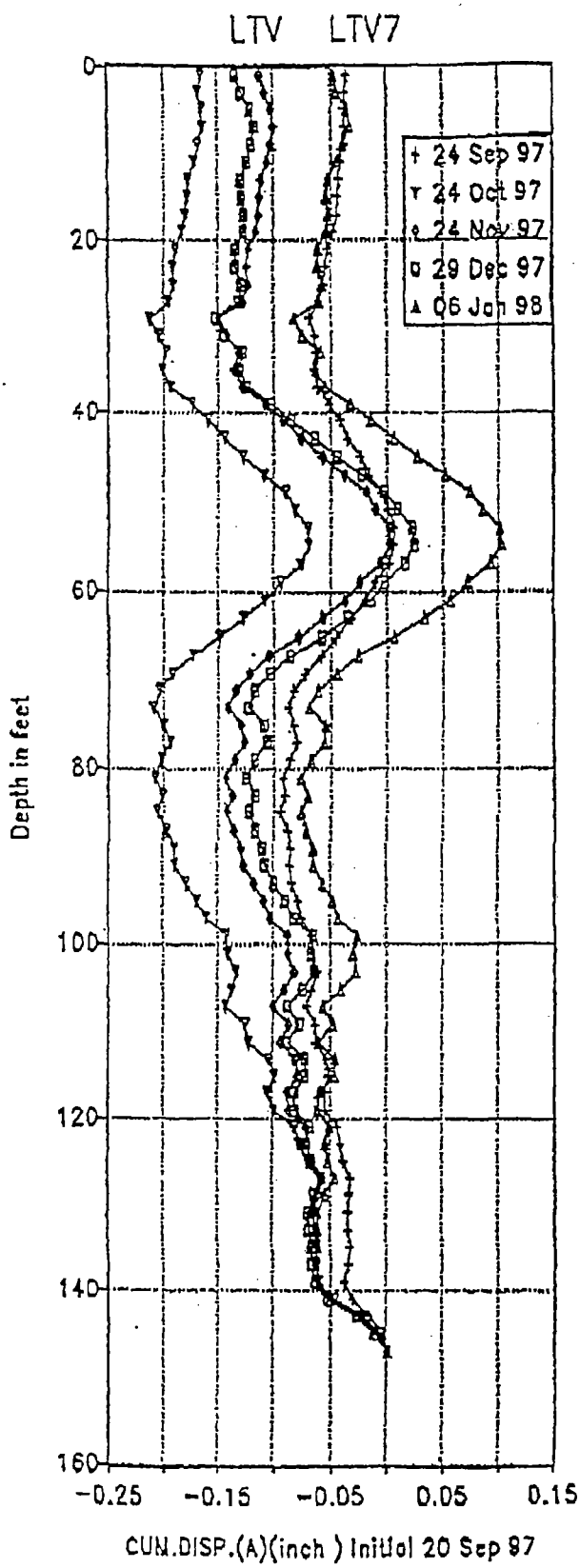

LTV1 1
Depth In.feet
0
10
20
30
40
50
60
70
80
90
100
-0.25
-0.15
-0.05
0.05
0.15
CUM.DISP.(A)(inch) Initial 23 Aug 97
23 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
06 Jan 98

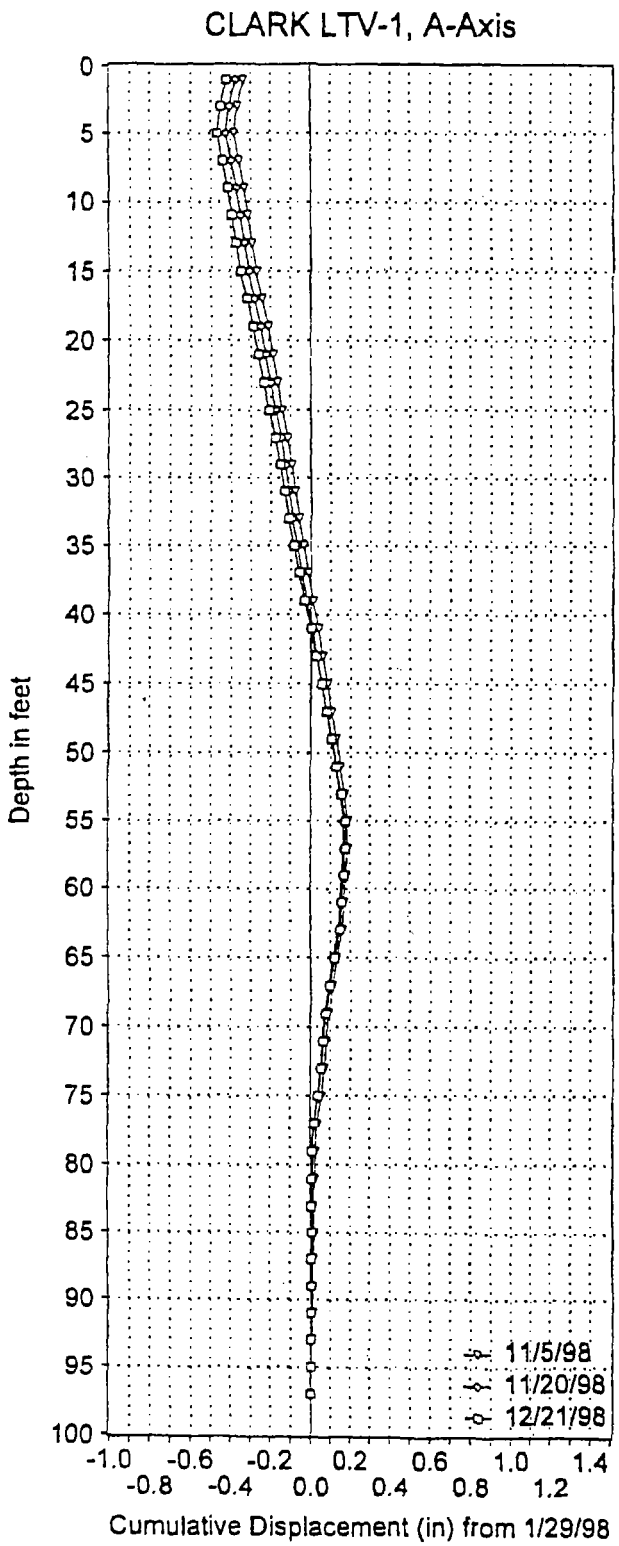

LTV LTV3
Depth in feet
0
10
20
30
40
50
60
70
80
90
100
-0.04
0.02
0.08
0.14
0.20
23 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
06 Jan 98
CUM.DISP.(A)(inch) Initial 29 Aug 97

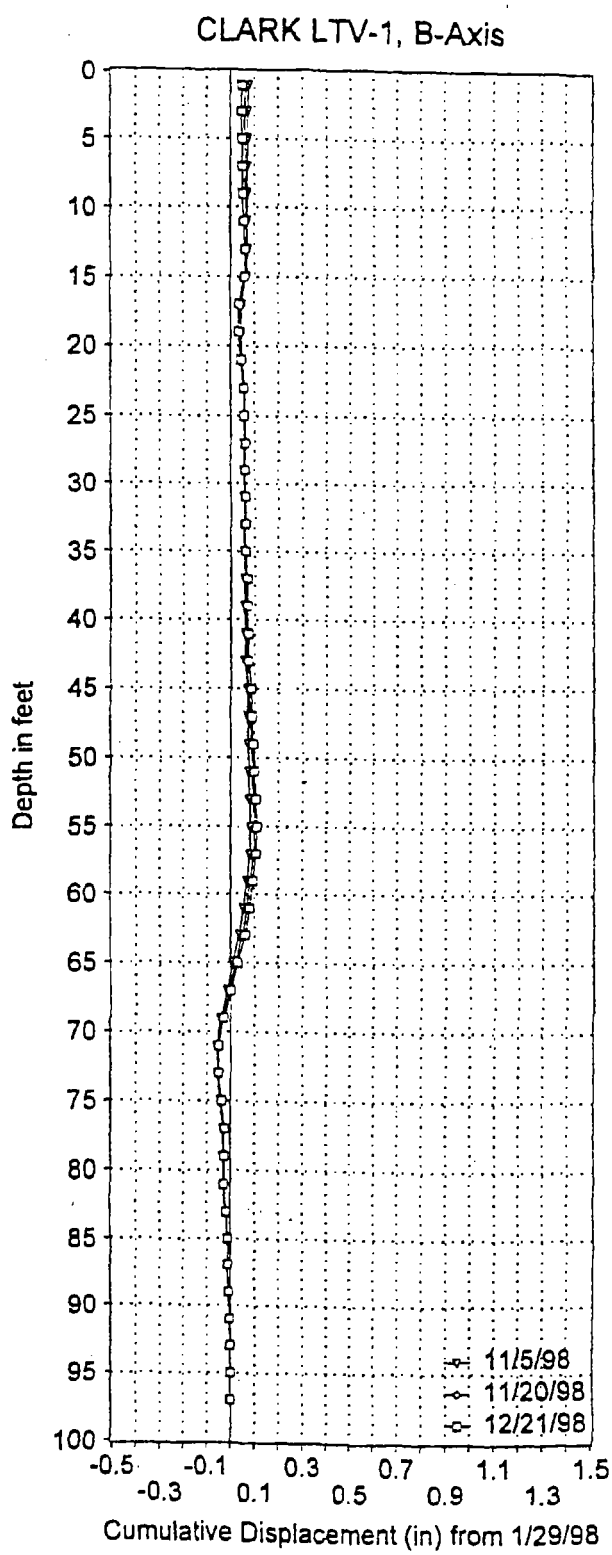

LTV LTV4
Depth in feet
0
10
20
30
40
50
60
70
80
90
100
110
120
130
-0.10
0.20
0.50
0.80
CUM.DISP.(A)(inch) Initial 05 Sep 97
23 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
08 Jan 98


LTV LTV5
Depth in feet
0
10
20
30
40
50
60
70
80
90
100
-0.10
0.10
0.30
0.50
CUM.DISP.(A)(inch) Initial 29 Aug 97
23 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
06 Jan 98


.LTV LTV6
Depth in feet
0
20
40
60
80
100
120
140
160
180
200
-0.10
0.10
0.30
0.50
0.70
CUM.DISP.(A)(inch) Initial 20 Sep 97
24 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
06 Jan 98


LTV LTV7
24 Sep 97
24 Oct 97
24 Nov 97
29 Dec 97
06 Jan 98
Depth in feet
0
20
40
60
80
100
120
140
160
-0.25
-0.15
-0.05
0.05
0.15
CUM.DISP.(A)(inch) Initial 20 Sep 97





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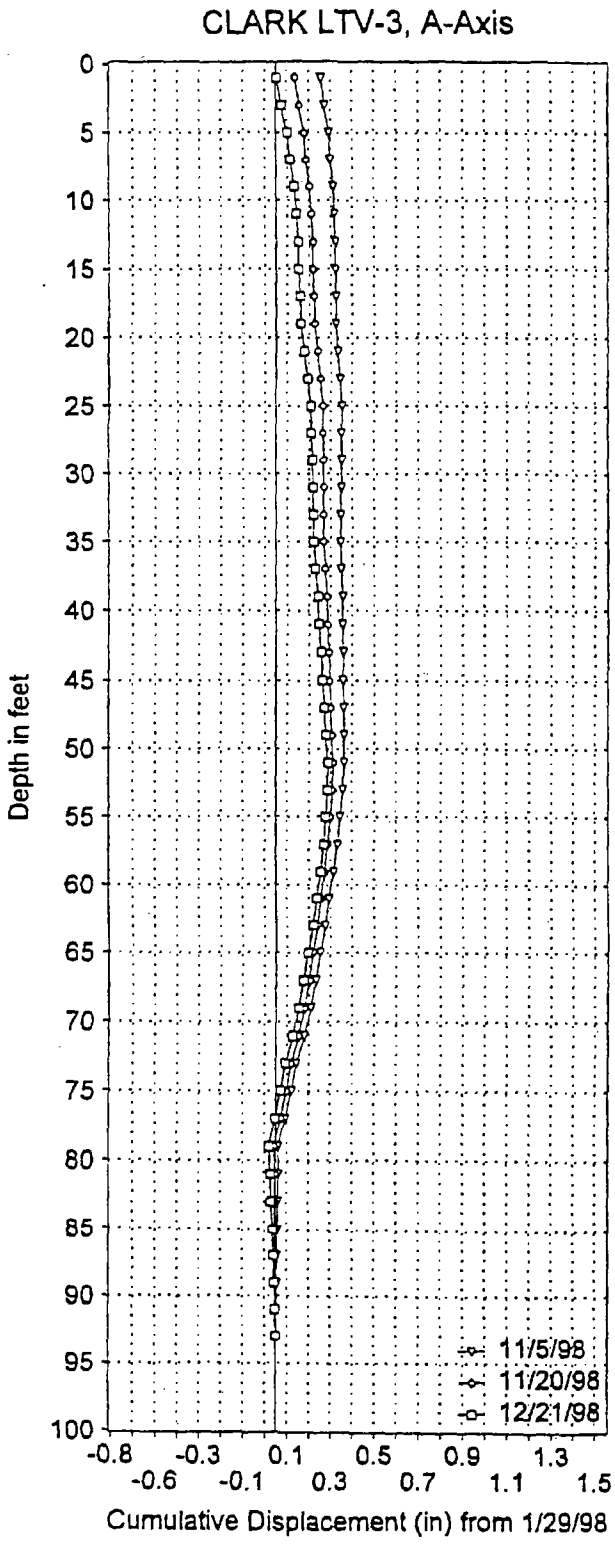
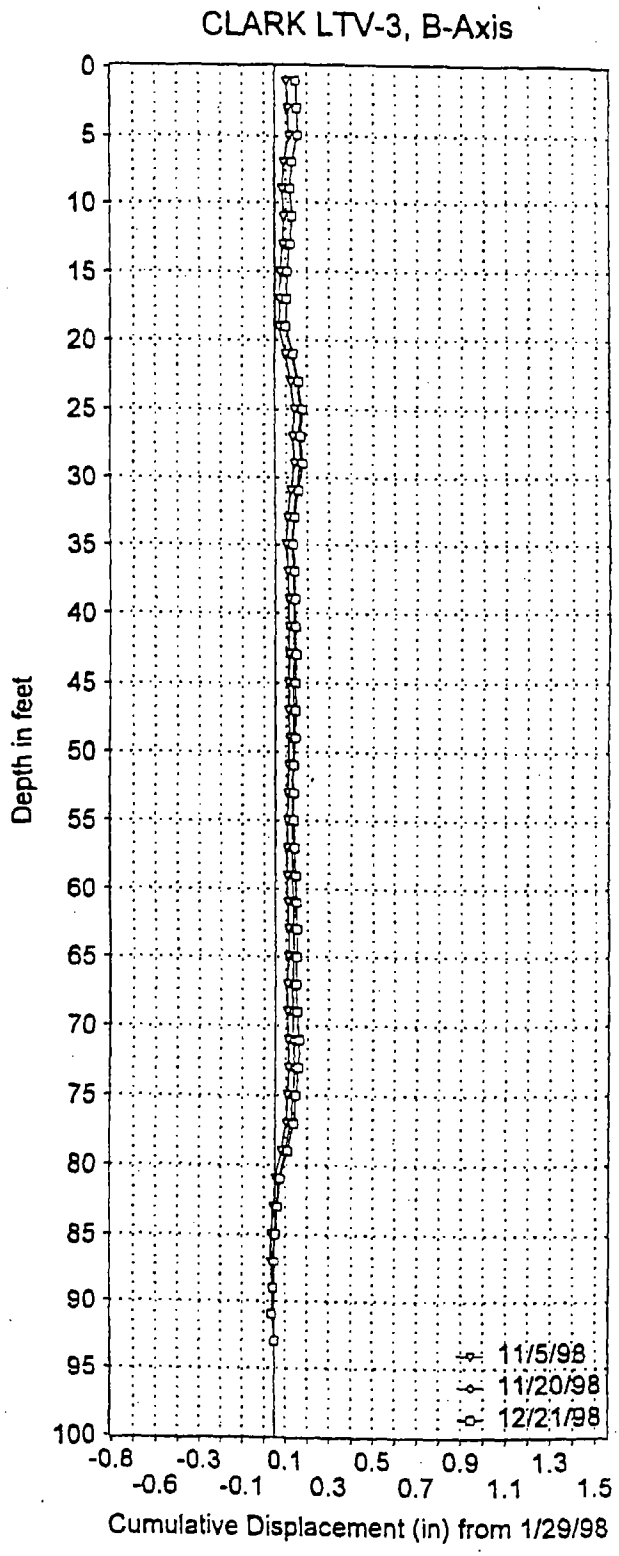
Fort Wayne, Indiana
Glen A. Howard

LTV Steel, Clark Landfill
3001 Dickey Road
East Chicago, Indiana
Initial Reading 01/29/98





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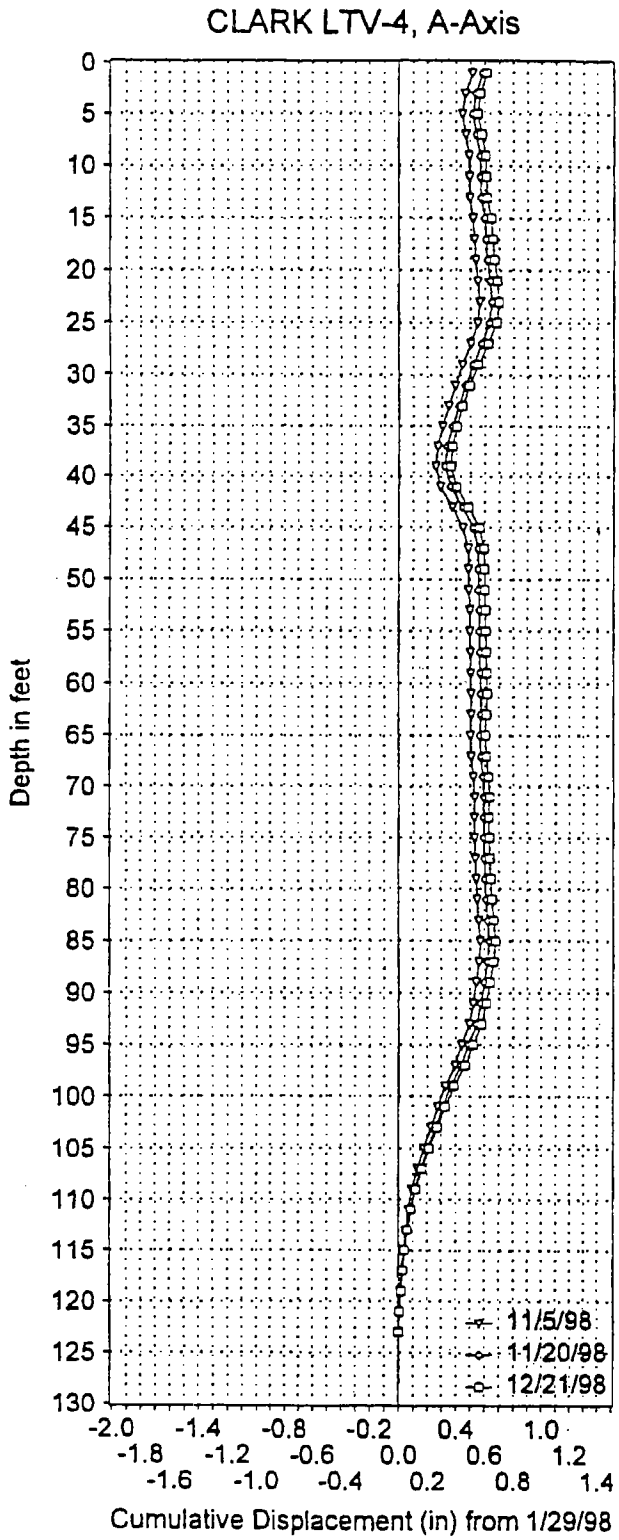

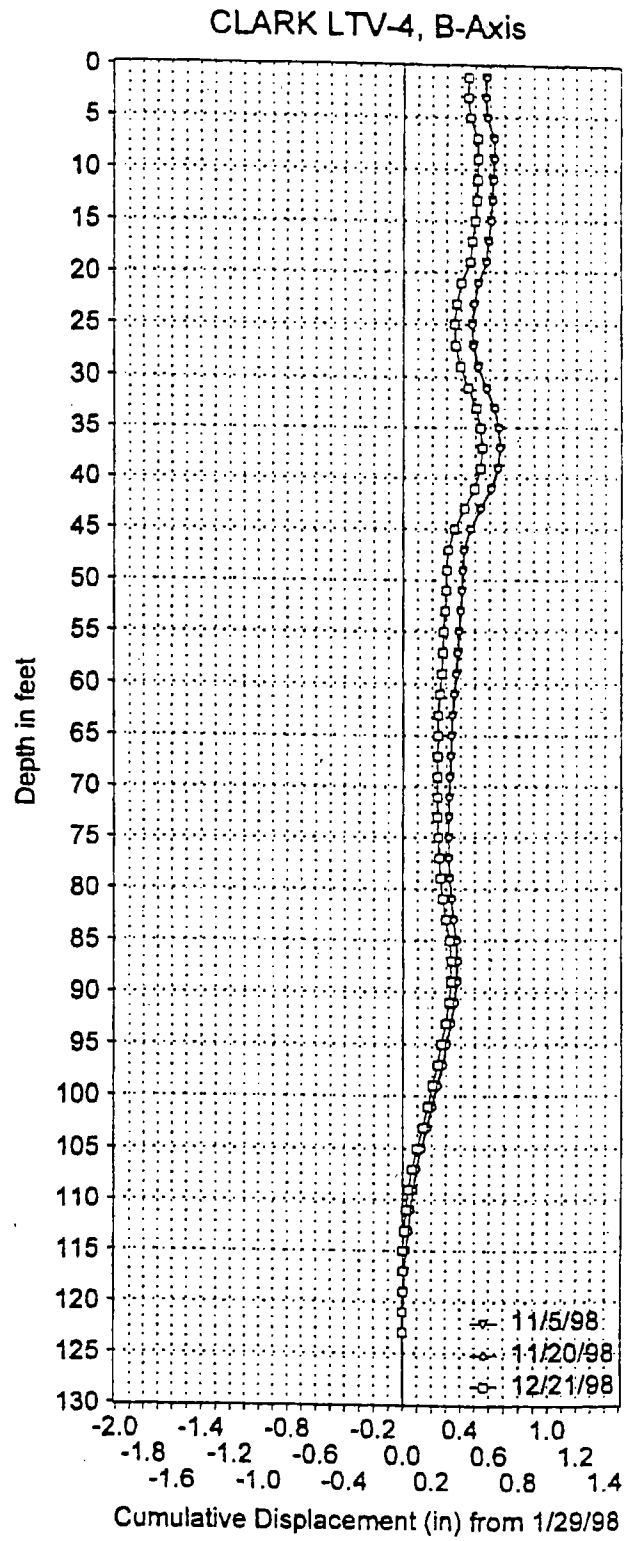

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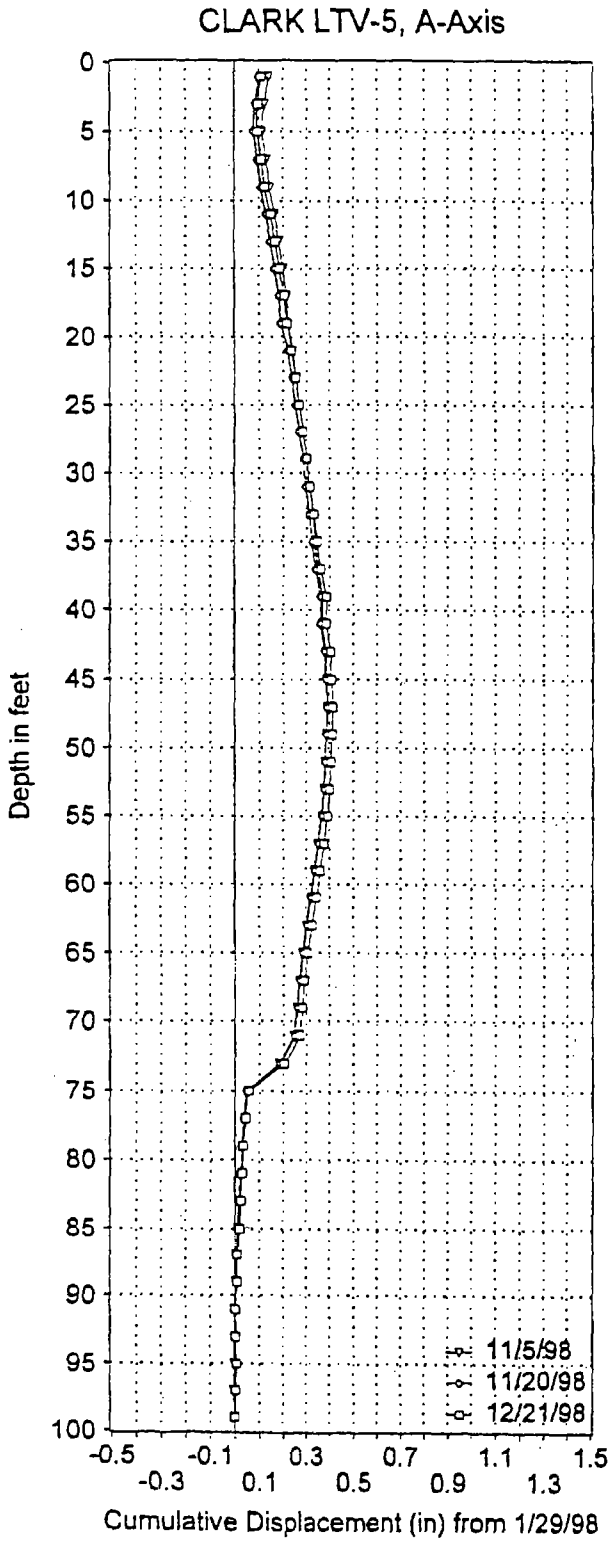

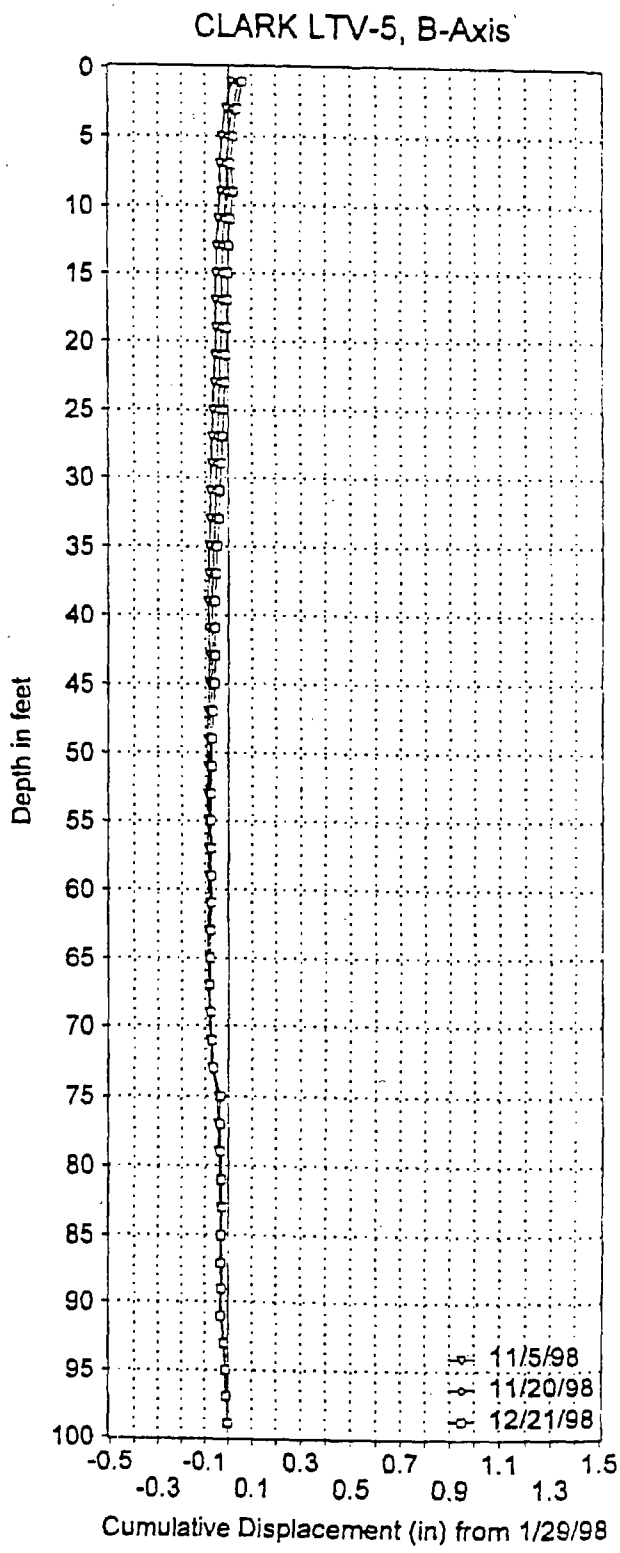

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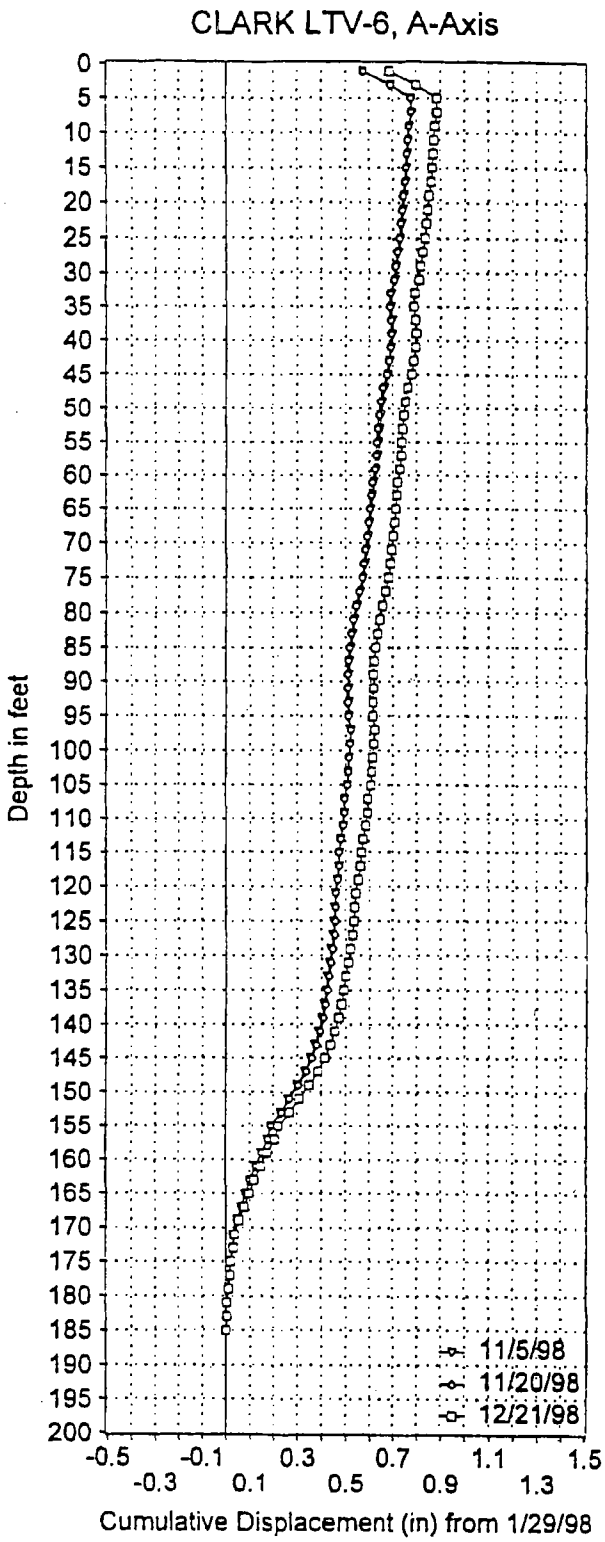

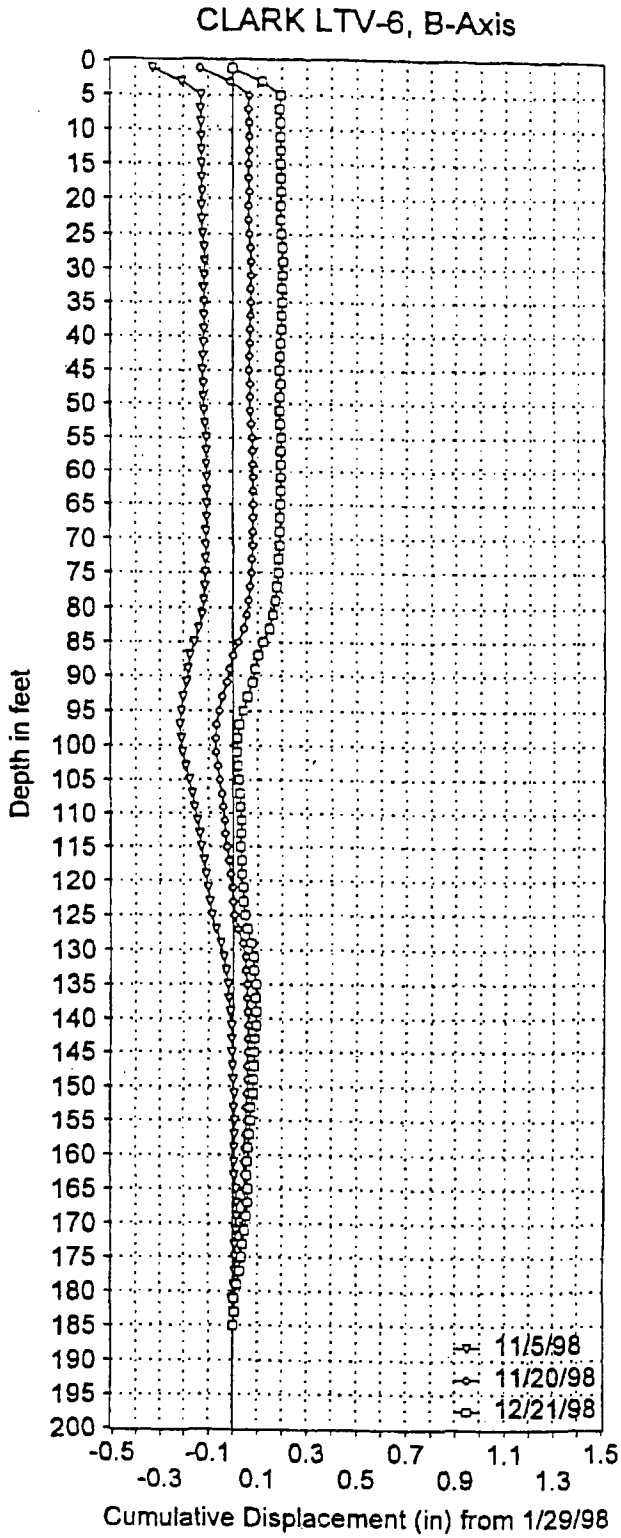

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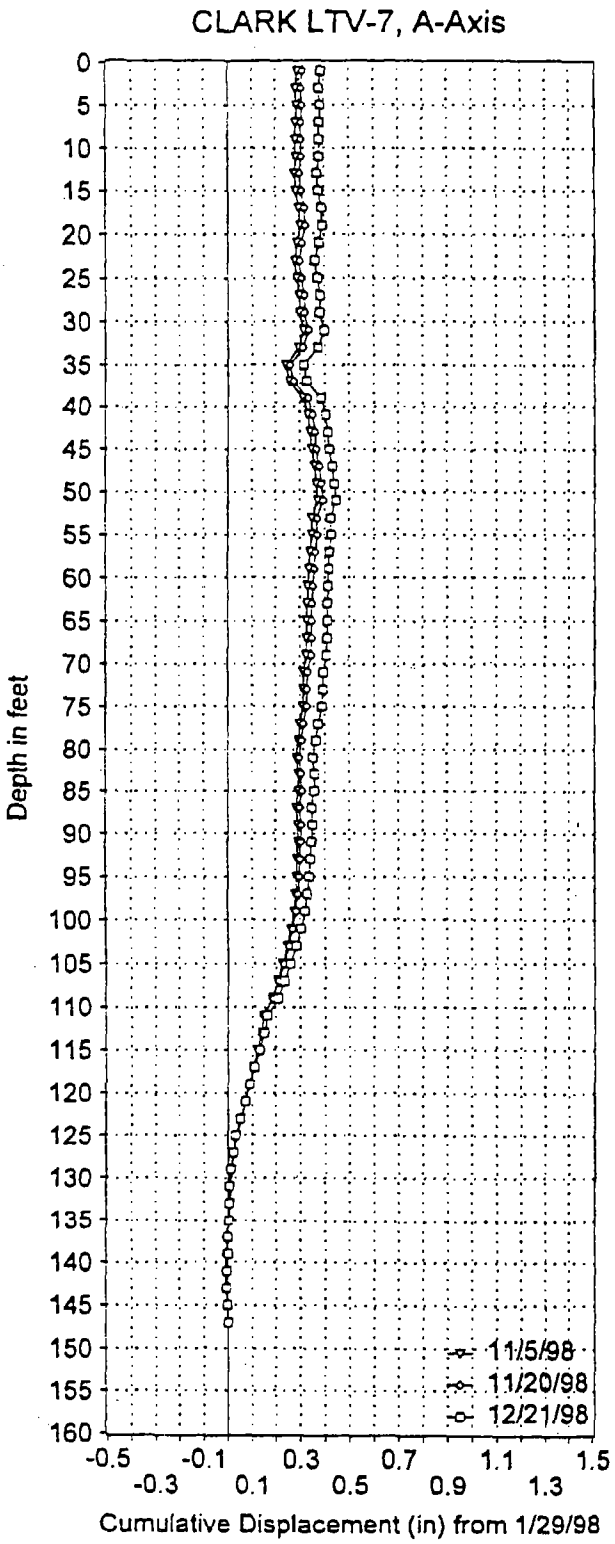
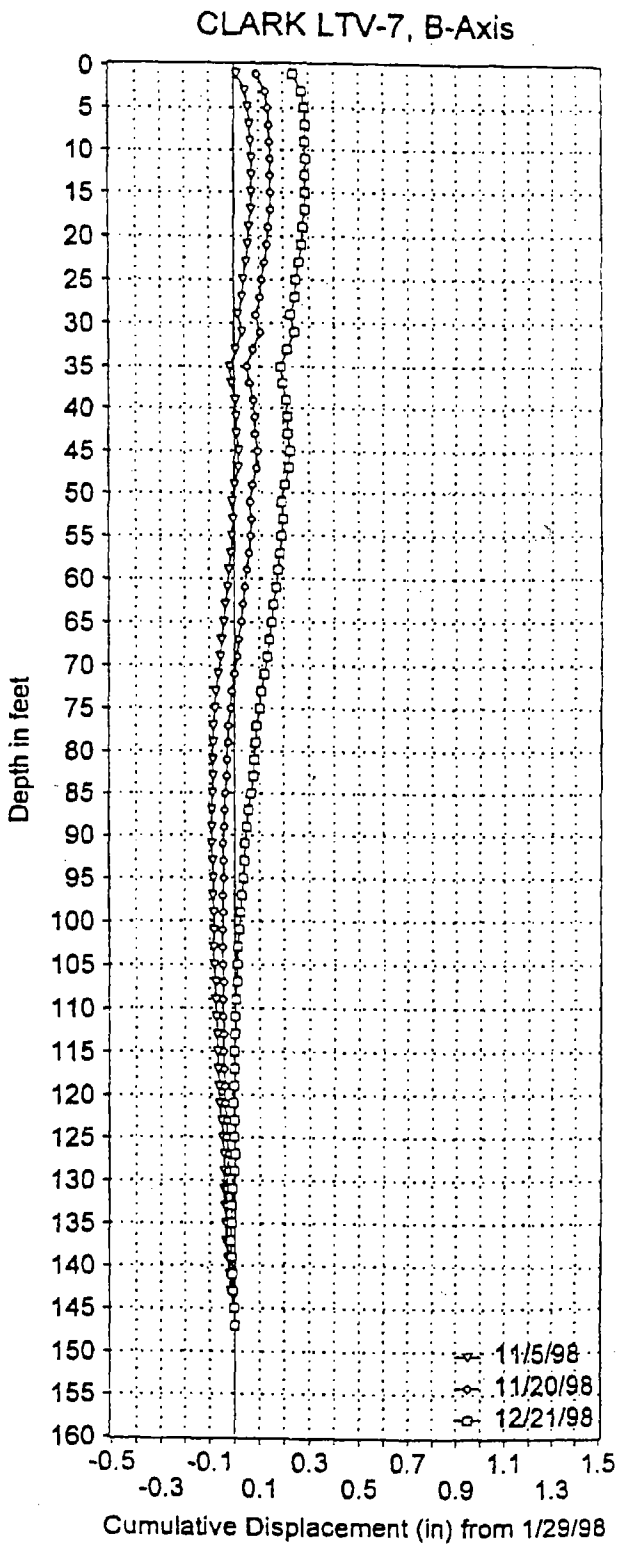
Initial Reading 01/29/98





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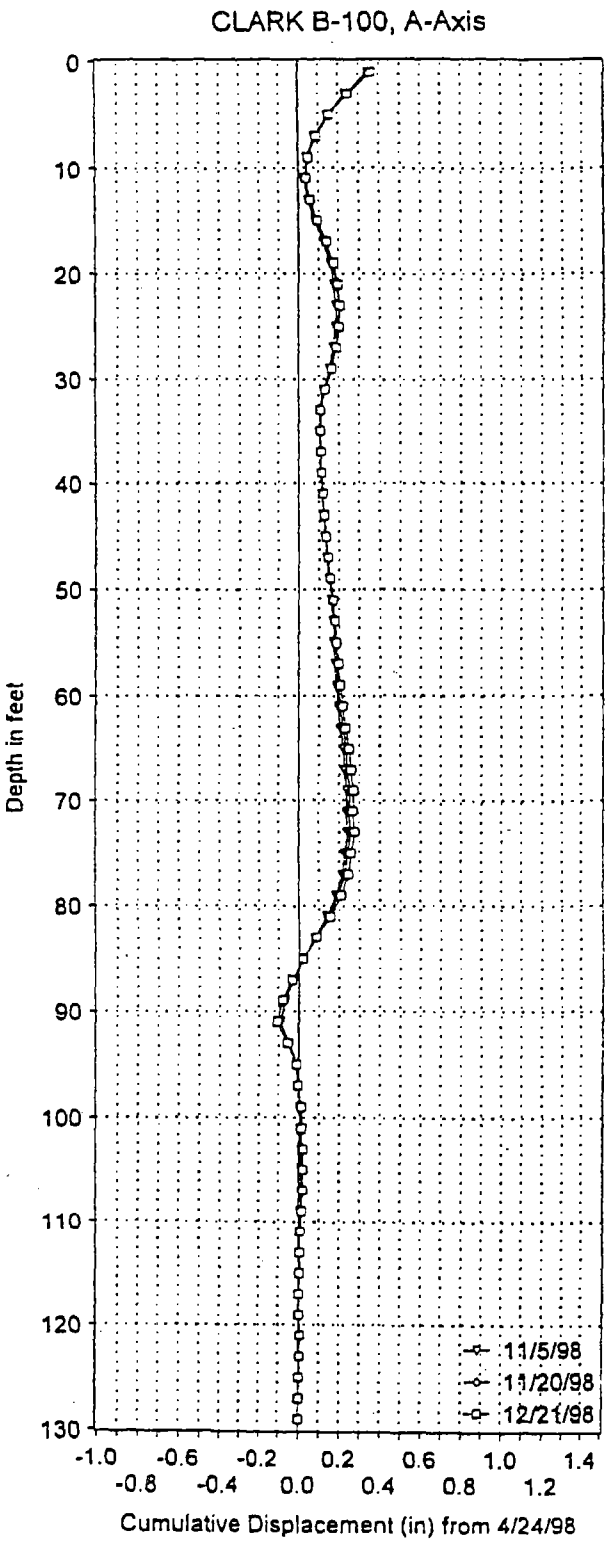

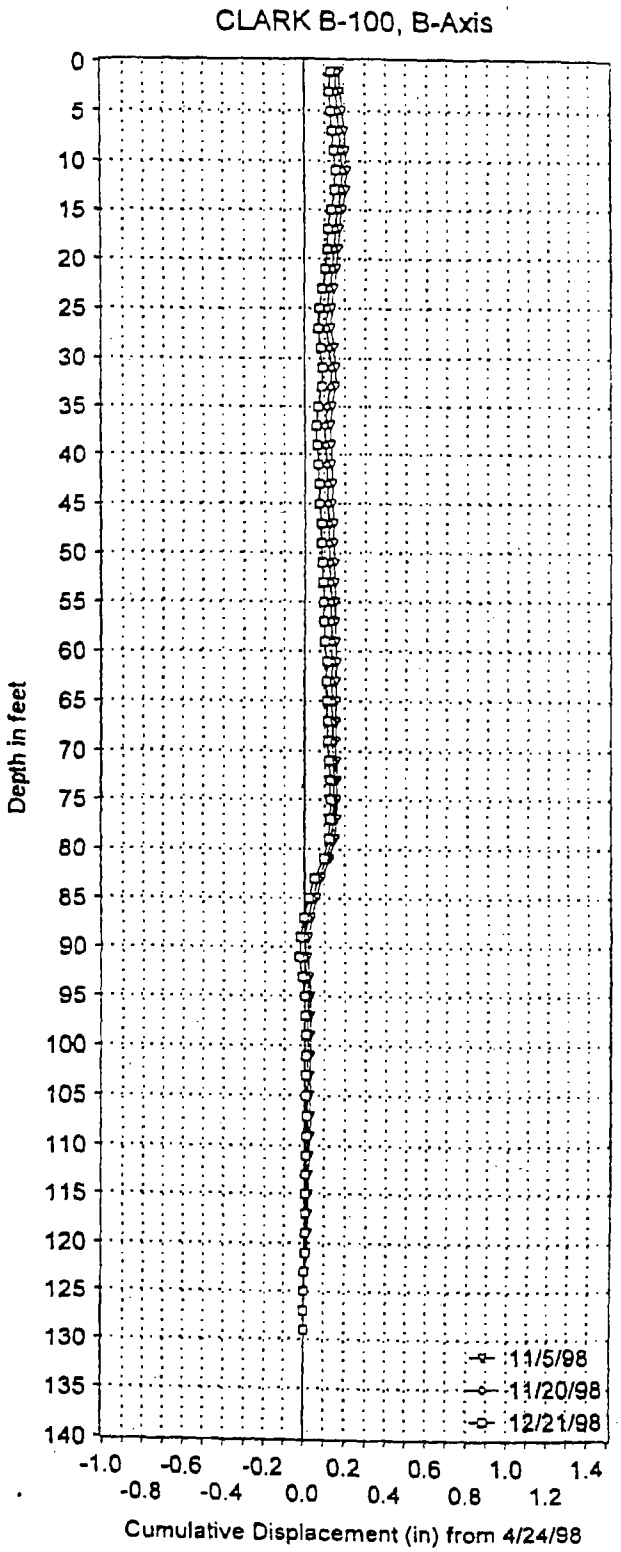

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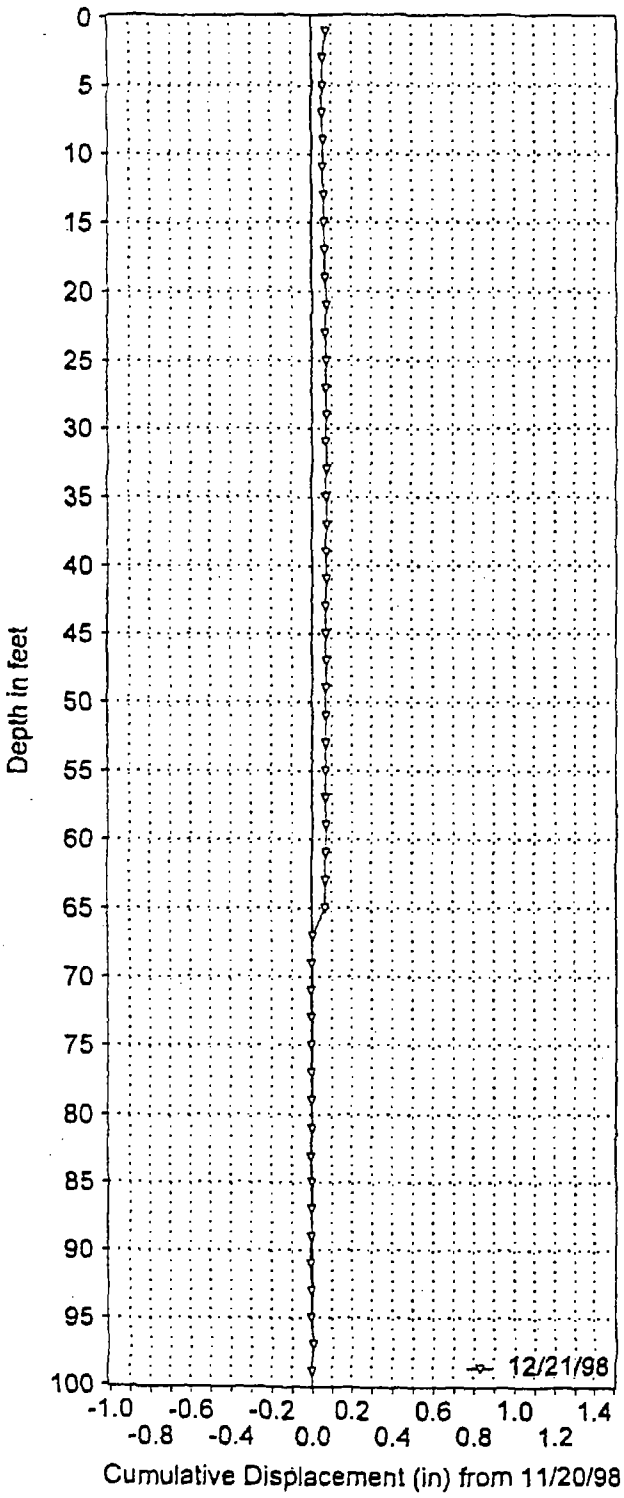
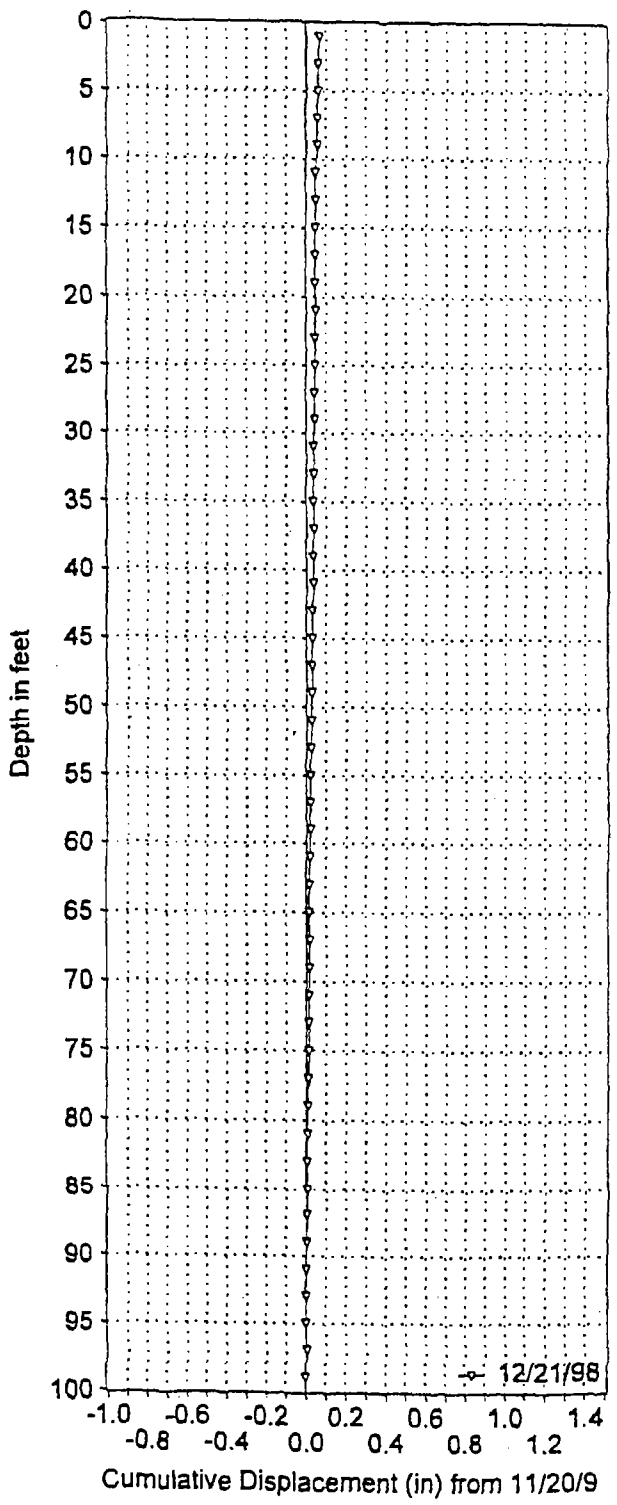
Initial Reading 04/24/98

CLARK ~~LTV~~ SB 210, A-Axis



CLARK ~~LTV~~ SB 210, B-Axis



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East Chicago, Indiana
Initial Reading 11/20/98

APPENDIX C

PIEZOMETER PORE PRESSURE PLOTS AND TABLES

Project 97-481-10

Table 1

Pneumatic Piezometer Pressure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana

Date Gauged	LTV-1STP	LTV-2STP	LTV-3STP	LTV-4STP	LTV-4AP	LTV-5STP	LTV-6STP	LTV-7STP	LTV98-8 TOP	LTV98-8 MIDDLE	LTV98-8 BOTTOM	LTV98-9 TOP	LTV98-9 MIDDLE	LTV98-9 BOTTOM
5-Sep-97	28.1		24	43.6		27.2								
8-Sep-97	24.3	41.3	23.6	41.8		26.9								
9-Sep-97	28.5	45.9	24.1	46.1	49.9	27								
10-Sep-97	17.3	38.8	16.8	45.5	49.1	26.8								
11-Sep-97	25.6	36.5	22.4	39.4	45	23.9								
12-Sep-97	27.7	45.7	23.7	46.7	53.3	27.2								
19-Sep-97	27.4	45.8	23.6	46.1	54.3	27.7								
23-Sep-97	27.2	35.5	23.5	35.3	41.6	27.4								
24-Sep-97								32.3						
25-Sep-97							29.4	35.4						
3-Oct-97	26.6	42.2	23.2	44.8	51.6	27.7	50.5	34.3						
9-Oct-97	26.3	43.7	23.1	47.1	54	28.2	51.9	34.6						
17-Oct-97	25.9	42.8	23	47	53.7	28	51.8	35.1						
24-Oct-97	25.8	42.3	22.6	47.3	53.9	28.1	52.2	35.7						
30-Oct-97	25.8	41.7	22.7	47	53.5	28.1	51.8	35.4						
10-Nov-97	25.7	41.5	22.7	46.8	53.2	28.4	51.5	35.6						
16-Nov-97	25		22.6			31								
19-Nov-97	24.8		22.3			31								
20-Nov-97	24.7		22.6			28.8								
21-Nov-97	24.7		22.5			28.8								
24-Nov-97	24.1	39.6	22.3	46.4	52.3	29.5	50.8	36.5						
3-Dec-97	12.7		22.1			24.4								
11-Dec-97	24.4	39.1	22.3	45.6	52.1	29.3	51.1	36.2						
19-Dec-97	24.4	35.7	22	45.1	51.8	29.5	36.4	35.1						
22-Dec-97	26.8	37.3	21.4	43.3	47.6	19.2	49.2	31.9						
6-Jan-98	24.1	37.7	22	44.6	51.5	30.3	50.9	36.6						
28-Jan-98	23.6					30.9		36.6						
29-Jan-98		36.6	21.8	44.5	50.9		50.5							
12-Feb-98	24.1	35.8	21.8	43.8	50.5	31.2	50.6	37.3						
27-Feb-98	24.0	35.6	21.6	43.7	49.9	31.7	50.6	36.0						
13-Mar-98	23.5	35.4	21.5	43.2	49.6	31.6	50.5	36.4						
27-Mar-98	23.5	35.2	21.5	43.5	49.2	31.2	50.4	36.4						
10-Apr-98	23.5	34.2	21.6	43.0	48.7	31.0	50.3	36.4	21.9	30.9	36.3	21.8	33.4	43.8
24-Apr-98	23.4	34.3	21.6	42.8	48.6	31.5	50.7	36.5	21.7	30.7	36.5	21.0	32.5	43.3
8-May-98	23.5	34.2	21.5	42.4	48.2	31.6	50.5	36.5	21.6	30.6	36.3	21.2	32.6	43.4
22-May-98	23.1	33.6	22.0	42.4	47.9	31.5	49.7	36.9	21.7	30.5	36.1	21.2	32.6	43.3
5-Jun-98	22.5	33.0	21.3	41.8	48.1	31.2	50.5	37.0	21.8	30.4	36.0	21.5	32.1	43.1

Note:
Values gauged in pounds per square inch (PSI).
Blank cells indicate pressure not gauged.
Some Piezometers were not gauged on August 28, 1998, due to equipment failure.
LTV-4STP, LTV-4AP, and B-101B, 8/28/98 data are suspect.

C-1

Table 1

Pneumatic Piezometer Pressure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana

Date Gauged	LTV-1STP	LTV-2STP	LTV-3STP	LTV-4STP	LTV-4AP	LTV-5STP	LTV-6STP	LTV-7STP	LTV98-8 TOP	LTV98-8 MIDDLE	LTV98-8 BOTTOM	LTV98-9 TOP	LTV98-9 MIDDLE	LTV98-9 BOTTOM
19-Jun-98	22.7	32.5	21.7	41.8	47.4	31.0	50.1	36.3	21.7	30.7	36.3	21.0	31.1	43.1
2-Jul-98	22.5	31.9	21.6	41.5	47.2	31.1	50.4	36.3	21.8	30.6	36.3	21.1	37.3	43.0
17-Jul-98	22.4	31.8	21.6	41.7	47.1	31.3	50.6	36.5	21.9	30.7	36.4	21.1	32.2	43.1
3-Aug-98	22.2	31.9	21.4	41.4	46.5	31.3	50.3	36.2	21.7	30.6	36.2	21.0	32.1	42.9
17-Aug-98	22.4	31.2	21.3	41.3	46.4	31.2	52.5	36.3	21.7	30.6	36.3	21.1	32.2	43.0
28-Aug-98		30.2		39.2	43.2		52.3	36.2	21.6	30.4	36.1	20.8	31.9	42.8
11-Sep-98	22.1	30.8	21.2	40.7	45.8	31.1	52.5	36.2	21.7	30.5	36.2	20.8	31.9	43.0
29-Sep-98	22.1	31.3	20.9	40.5	45.3	31.4	52.3	36.0	21.5	30.3	35.9	20.7	31.7	42.2
16-Oct-98	22.0	30.6	20.9	40.2	45.0	31.1	52.0	36.0	21.4	30.2	35.9	20.5	31.7	41.9
5-Nov-98	22.1	30.0	20.6	39.9	44.6	30.7	50.4	36.1	21.2	30.2	35.7	20.4	31.5	41.9
20-Nov-98	21.6	30.3	20.6	39.9	44.4	30.7	50.0	36.0	21.2	30.1	35.6	20.4	31.5	41.9
4-Dec-98			20.5	39.3	44.0	30.3	48.8	35.7	20.8	29.9	35.4	20.1	31.1	41.6

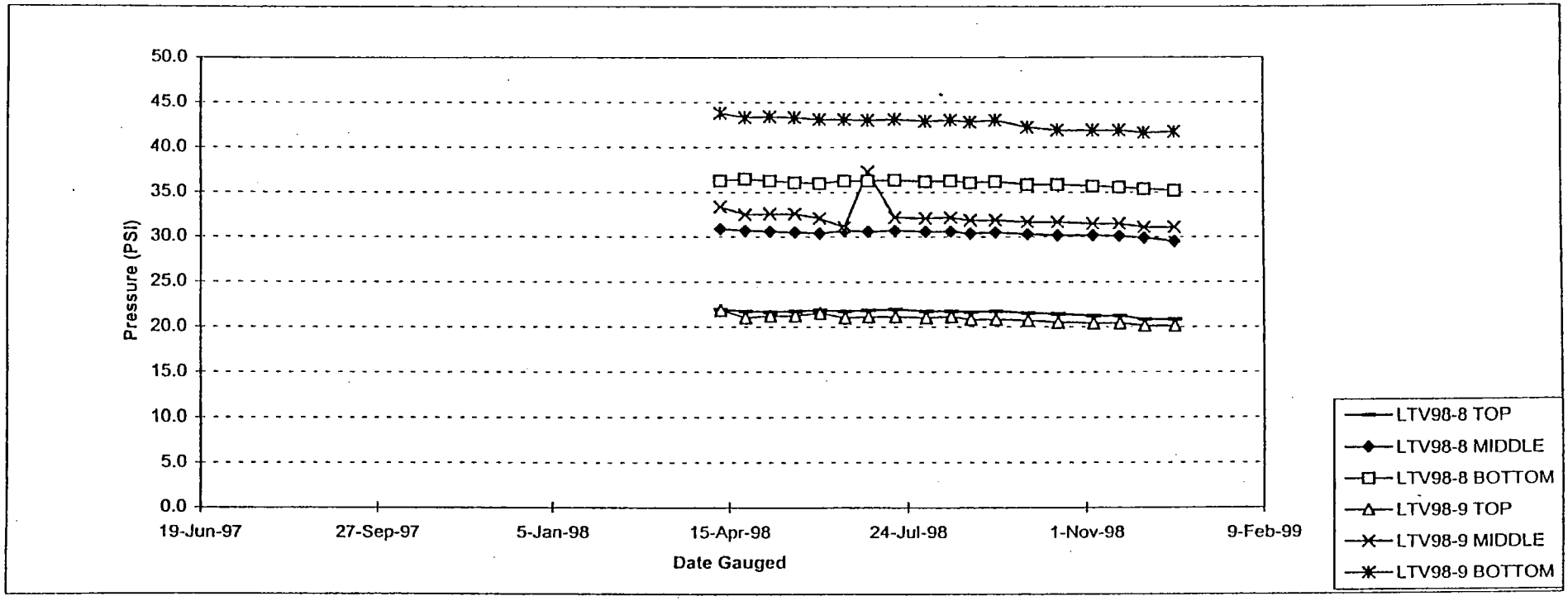
Note:
Values gauged in pounds per square inch (PSI).
Blank cells indicate pressure not gauged.
Some Piezometers were not gauged on August 28, 1998, due to equipment failure.
LTV-4STP, LTV-4AP, and B-101B, 8/28/98 data are suspect.

C-2

Project 97-481-10

Chart 2

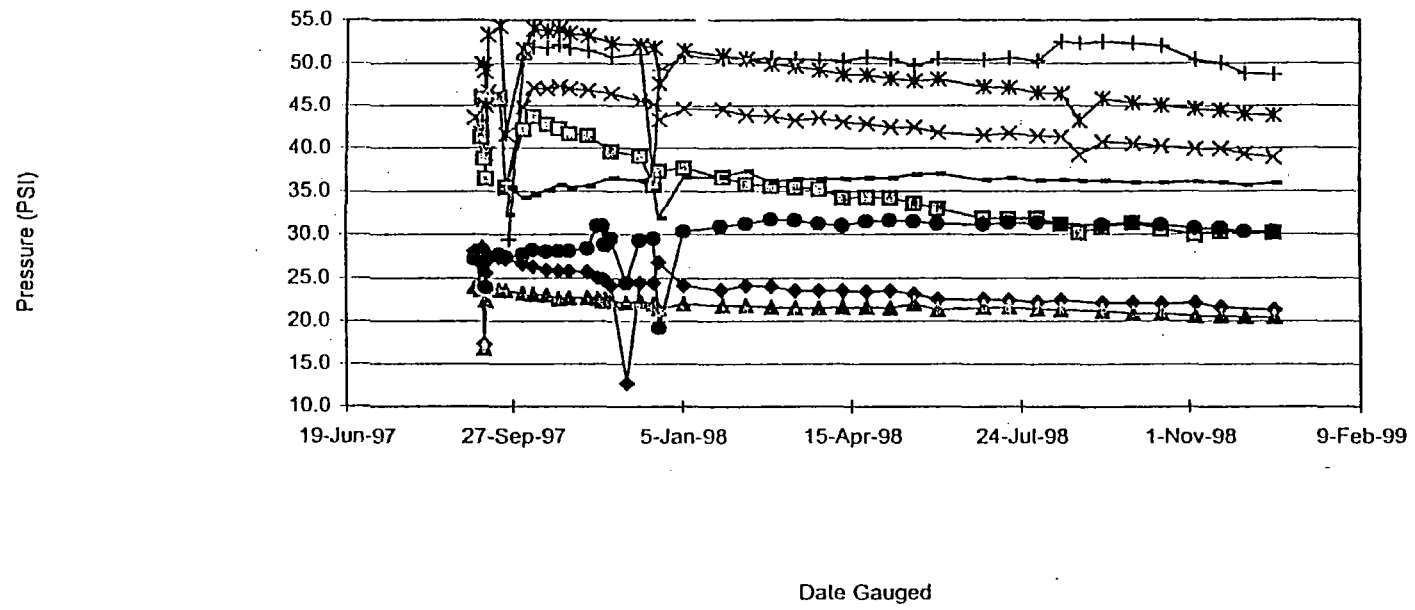
Pneumatic Piezometer Pressure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana



Project 97-481-10

Chart 1

Pneumatic Piezometer Pressure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana



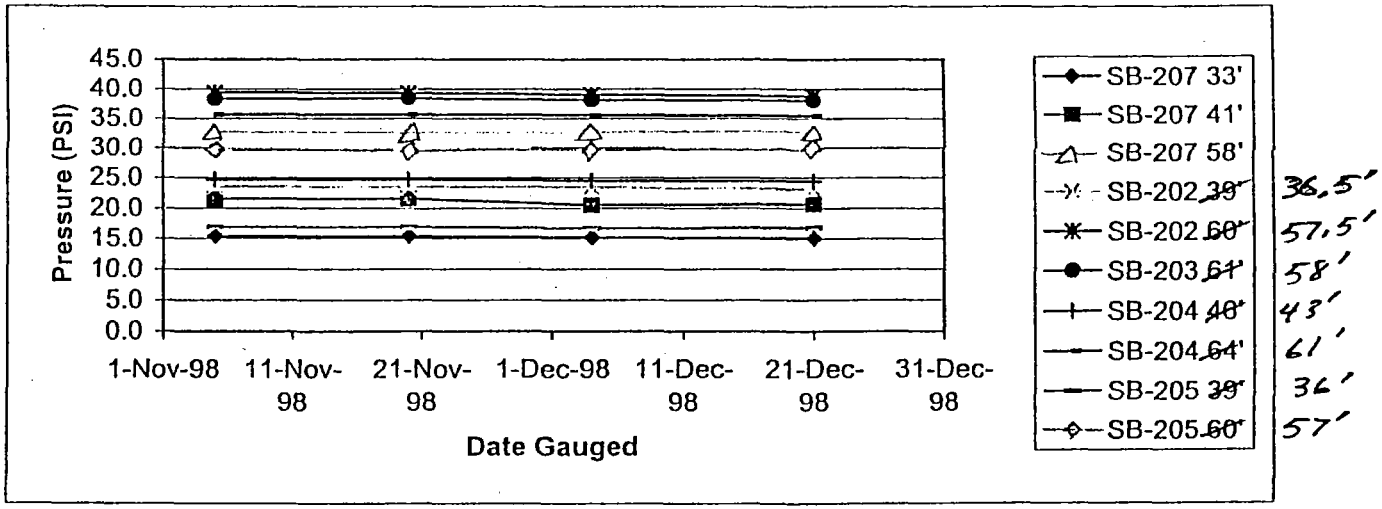
C-4

Project 97-481-10

Table 1

Pneumatic Piezometer Pressure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana

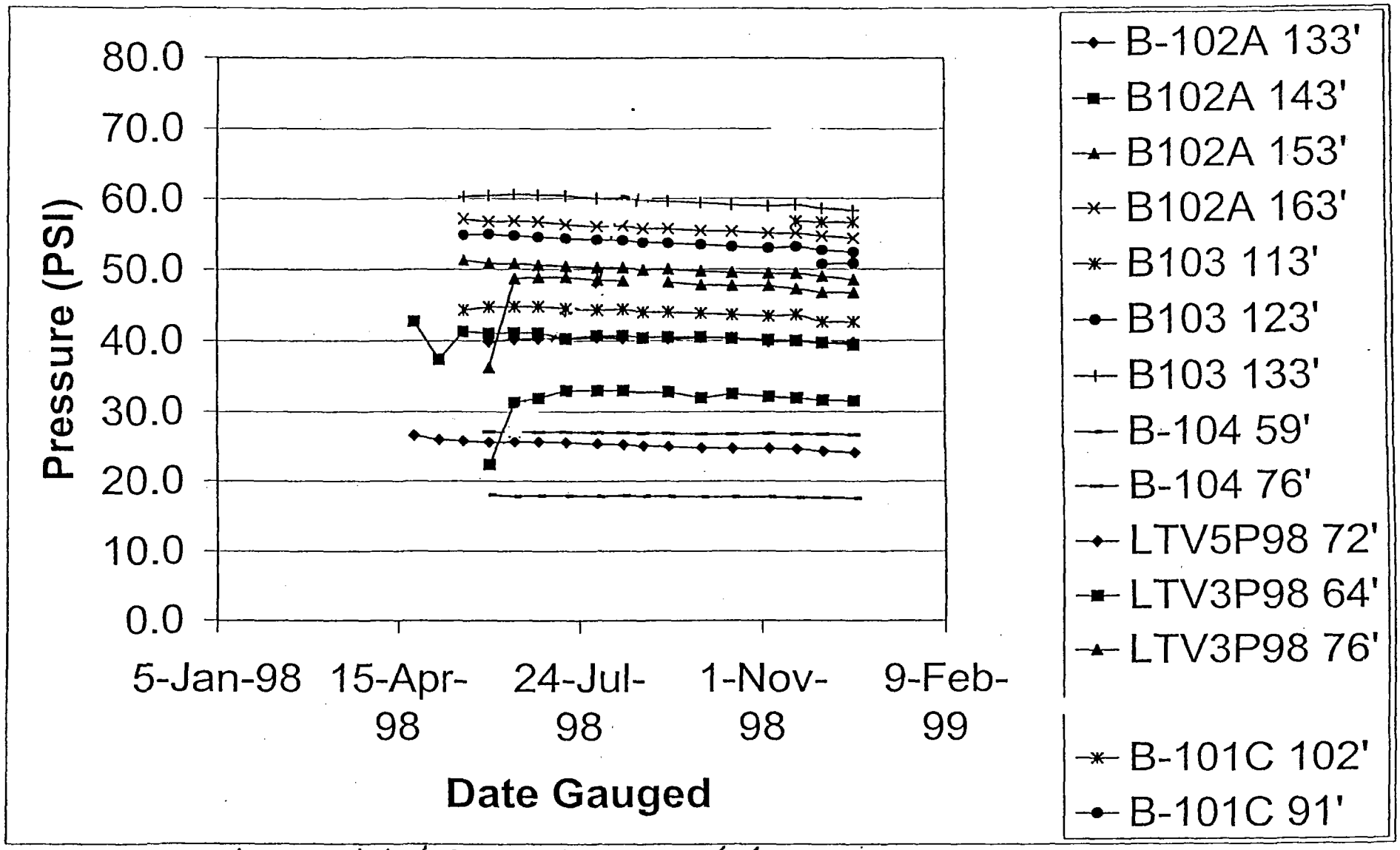
Date Gauged	LTV-1STP	LTV-2STP	LTV-3STP	LTV-4STP	LTV-4AP	LTV-5STP	LTV-6STP	LTV-7STP	LTV98-8 TOP	LTV98-8 MIDDLE	LTV98-8 BOTTOM
A-axis bearing	LTV-1STP N01W	B-100 N25E	LTV-3STP N11E	LTV-4STP N40E		LTV-5STP N30E	LTV-6STP N24W	LTV-7STP N06W			
	SB-207	SB-207	SB-207	SB-202	SB-202	SB-203	SB-204	SB-204	SB-205	SB-205	
Date Gauged	33'	41'	58'	~~39'~~ 36.5'	~~60'~~ 57.5'	~~64'~~ 58'	~~48'~~ 43'	~~64'~~ 61'	~~39'~~ 36'	~~60'~~ 57'	
5-Nov-98	15.4	21.5	32.7	23.6	39.4	38.3	24.7	35.7	16.9	29.8	
20-Nov-98	15.4	21.6	33.2	23.5	39.3	38.4	24.7	35.7	16.9	29.9	
4-Dec-98	15.2	20.5	33.0	23.4	39.0	38.1	24.5	35.6	16.7	29.7	
21-Dec-98	15.0	20.7	32.8	23.1	38.8	38.0	24.4	35.5	16.8	29.9	



Note:
Values gauged in pounds per square inch (PSI).
Blank cells indicate pressure not gauged.
Some Piezometers were not gauged on August 28, 1998, due to equipment failure.
LTV-4STP, LTV-4AP, and B-101B, 8/28/98 data are suspect.
Revised 7/15/99

Chart 2

Pneumatic Piezometer Presure Summary
LTV Steel, Clark Landfill
East Chicago, Indiana



Revised 7/15/99 - Deleted B-101B 91', erroneous data

APPENDIX D

LABORATORY TEST RESULTS

D-1

Presque Isle Corp.
P.O. Box 426, Alpena, MI 49707
Phone (517) 595-6862
Fax (517) 595-6228
Pager (517) 730-0113

HIGH MAG PRODUCT SIZES
AS LOADED ABOARD VESSEL - 1997

PRODUCT NAME		2 1/4	2	1 3/4	1 1/2	1 1/4	1	3/4	1/2
2 1/2 DRAIN STONE	Mean	100	97.0	78.9	45.3	21.3	7.9	1.3	0.4
HI MAG A	+2 Sigma	100	100.0	100.0	78.9	43.7	18.8	2.9	0.9
	-2 Sigma	100	86.8	44.7	13.6	0.0	0.0	0.0	0.0
1996-9	SD	0	5.065	17.08	16.306	11.217	5.44	0.809	0.274

		1 3/4	1 1/2	1 1/4	1	3/4	1/2	3/8	LBW
	SPEC	100	90/100		25/60	1/10	1/2	0/1	
1 1/2 DRAIN STONE	Mean	100	59.2	81.2	38.7	9.4	1.9	0.8	0.2
HI MAG B	+2 Sigma	100	100.0	100.0	64.2	21.8	5.3	2.1	0.4
	-2 Sigma	100	97.7	61.7	13.3	0.0	0.0	0.0	0.0
7	SD	0	0.758	9.782	12.73	6.2	1.692	0.652	0.101

		Si02	Fe203	Al203	Ca0	CaC03	Mg0	MgC03	Sulphur
HIGH MAG RKS	Mean	1.75	0.34	0.41	50.02	89.29	3.65	7.63	0.115
'PRODUCTION	+2 Sigma	2.78	0.43	0.56	52.99	94.58	6.28	13.14	0.129
CHEMICAL"	-2 Sigma	0.72	0.25	0.26	47.05	83.99	1.02	2.13	0.101
	SD	0.514	0.047	0.074	1.483	2.647	1.317	2.755	0.007

		3/8	1/4	4M	8M	16M	50M	100M	LBW
HIGH MAG SINTER	Mean	100	99.7	96.5	71.2	50.4	29.2	23.7	19.1
"WET ANALYSIS"	+2 Sigma	100	99.8	97.6	73.6	53.8	33.9	28.9	24.6
	-2 Sigma	100	99.6	95.4	68.8	47.0	24.6	18.5	13.6
	SD	0	0.043	0.543	1.184	1.721	2.325	2.601	2.726

		3/8	1/4	4M	8M	16M	50M	100M	200M	MOIST
HIGH MAG SINTER	Mean	100	99.3	94.6	66.5	44.7	18.8	12.7	9.8	4.0
"DRY ANALYSIS"	+2 Sigma	100	99.6	100.0	71.6	50.0	24.6	16.8	14.4	6.0
	-2 Sigma	100.0	99.0	89.2	61.4	39.4	13.0	8.6	5.2	2.0
	SD	0	0.159	2.684	2.568	2.626	2.877	2.041	2.314	0.986

		Si02	Fe203	Al203	Ca0	CaC03	Mg0	MgC03	Sulphur
HIGH MAG SINTER	Mean	2.45	0.45	0.65	49.48	88.32	3.86	8.07	0.174
'PRODUCTION	+2 Sigma	3.62	0.57	0.86	53.13	94.84	6.44	13.47	0.207
CHEMICAL"	-2 Sigma	1.28	0.33	0.44	45.83	81.80	1.28	2.68	0.141
	SD	0.584	0.058	0.104	1.827	3.261	1.290	2.698	0.017

Other --		3/8	1/4	4M	8M	16M	50M	100M	LBW	MOIST
WASHPOND SAND	Mean	99.3	96.5	85.0	56.4	40.2	21.8	14.9	9.4	5.2
	+2 Sigma	100	97.6	87.8	61.7	46.8	27.6	19.3	12.4	8.1
	-2 Sigma	98.7	95.4	82.2	51.1	33.5	15.9	10.5	6.5	2.4
	SD	0.3	0.551	1.38	2.627	3.339	2.905	2.21	1.464	1.436

Other --		37.5mm 1 1/2 100	25.0mm 1 95/100	19.0mm 3/4	12.5mm 1/2 30/60	9.5mm 3/8	4.75mm 4M 50M	75µ.m LBW 0/2
MI 6AA	Mean	100	99.6	86.4	49.6	28.2	4.0	0.5
"Cons Concrete"	+2 Sigma	100	100.0	92.5	60.5	37.7	7.1	0.7
	-2 Sigma	100.0	98.9	80.3	38.7	18.7	0.9	0.3
	SD	0	0.338	3.073	5.468	4.741	1.539	0.11

/PDS/1997/MAG97/ 2/1/98

DEC 18 1998 D-2
GAI CONSULTANTS INC.

geotechnics
..... GEOTECHNICAL, GEOENVIRONMENTAL, AND GEOSYNTHETIC LABORATORIES

LABORATORY TEST REPORT

December 16, 1998

Mr. Barry Newman
GAI Consultants, Inc.
570 Beatty Road
Monroeville, PA 15146-1300

Project No.: L98250-01

RE: INTERFACE FRICTION TEST RESULTS
LTV STEEL CLOSURE
PROJECT NO. 97-481-10

Transmitted herein are the results of the interface friction test performed for GAI Consultants, Inc. as directed by Mr. Newman. The soil samples were submitted by GAI while the NSC textured LLDPE and the Amoco geotextile were submitted by the manufacturers.

The interface friction testing was performed in accordance with the ASTM D 5321-92 as well as the project-specific details described on the attached Supplementary Test Report Information sheet.

The friction angles reported are based on mathematical regression using the points indicated on the data sheets. Other shear strength relationships may be more appropriate and are subject to the engineering judgement of the Client.

We are pleased to be of service and trust that our efforts have contributed to the success of your project. Should you have any questions or if we may be of any further assistance, please do not hesitate to call.

Respectfully submitted,

Richard S. Lacey

Richard S. Lacey, P.E.
Laboratory Director
attachments: 9 Data Pages

544 Braddock Avenue • East Pittsburgh, PA 15112 • Phone (412) 823-7600 • Fax (412) 823-8999

geotechnics

INTERFACE FRICTION (DIRECT SHEAR) TEST REPORT

Supplementary Test Report Information

Alphena High Mag A Limestone vs. Amoco Geotextile Test Specifics

The textured geomembrane was clamped to the shear box base as the substrate. The Amoco geotextile was then placed on the textured geomembrane. The limestone was placed in the 6-inch deep upper box on the geotextile. After placing the stone, the interface was immersed with water and sheared at a horizontal displacement rate of 0.04 in/min.

Amoco Geotextile vs. NSC Textured LLDPE Test Specifics

The textured geomembrane test specimens were clamped to the shear box base. The Amoco geotextile was then placed on the textured geomembrane and clamped to the upper box. The limestone was placed in the 6-inch deep upper box on the geotextile as a superstrate. The interface was immersed with water and sheared at a displacement rate of 0.04 in/min.

Alphena Wash Pond Sand vs. NSC Textured LLDPE Test Specifics

The textured geomembrane was clamped to the shear box base as the substrate. The Amoco geotextile was then placed on the textured geomembrane. The sand was then placed in 2-inch deep upper box on the geotextile. After placing the sand, the interface was immersed with water and sheared at a displacement rate of 0.04 in/min.

Direct Shear Device Description

The tests were performed using a dead weight apparatus with a twelve inch by twelve-inch shear area that bears against a proving ring. A six-inch deep upper box was used with the tests including the limestone sample. The shear box is driven with a gear motor.

Friction Angles Calculations

The friction angles were calculated by plotting the peak and, when appropriate, the "residual*" shear stresses with the corresponding normal stresses, then constructing mathematical linear best fit lines through the points.

*NOTE: Residual shear in ASTM D 5321-92 is defined as the shear resistance where "the applied shear force remains constant with increasing displacement".

CAVEAT

The tests were performed in general accordance with the procedures referenced on the data tables as well as industry practice on test specimens believed to be representative of the samples submitted. The test results are indicative only of the specimens that were actually evaluated. The sample remnants will be retained for ninety days unless otherwise directed by the Client.

Geotechnics has no direct knowledge of the origin of the samples submitted, implies no position with regard to the disposition of the test results, i.e. pass/fail, and makes no claims as to the suitability of the material for its intended end use.

The test data and all associated project information provided shall be held in confidence and disclosed to other parties not directly associated with the project only with the authorization of the Client and Geotechnics.

The test data transmitted herein is considered integral with this report and is not to be reproduced except in whole and only with the authorization of the Client and Geotechnics.

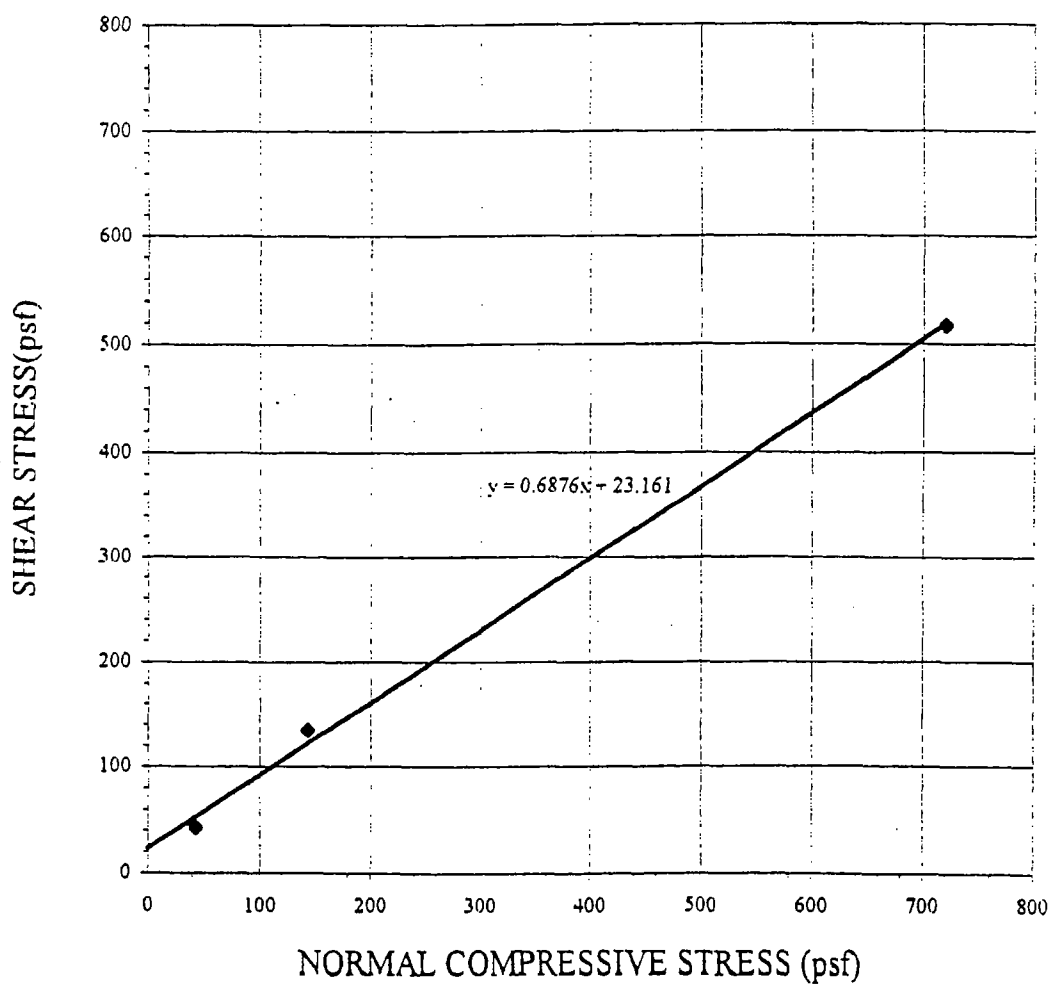
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT :	GAI CONSULTANTS, INC.
CLIENT PROJECT :	LTV STEEL CLOSURE
PROJECT NO. :	L98250-01
LAB I. D. NO.:	Alpena High Mag A Limestone (2.5"): L98250-01-01, AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03
INTERFACE :	**Alpena High Mag A Limestone VS. AMOCO 16oz. Geotextlie on NSC 40 mil LLDPE**

	PEAK SHEAR		RESIDUAL SHEAR	
FRICTION ANGLE (deg) :	Φ =	34.5	Φ =	n. a.
COEFFICIENT OF FRICTION :	=	0.69	=	n. a.
ADHESION [Calculated] (psf):	a =	23	a =	n. a.

NOTES:
1.)A component of the adhesion values reported may be an anomaly of the laboratory procedure and calculation algorithm.
2.)The friction angle was calculated using linear regression basing on original data.
3.)The displacement limit for the direct shear unit used is 2.3 inches.
4.)The interface tested "wet".



◆ PEAK SHEAR DATA

CHECKED BY: RH DATE: 12-10-98

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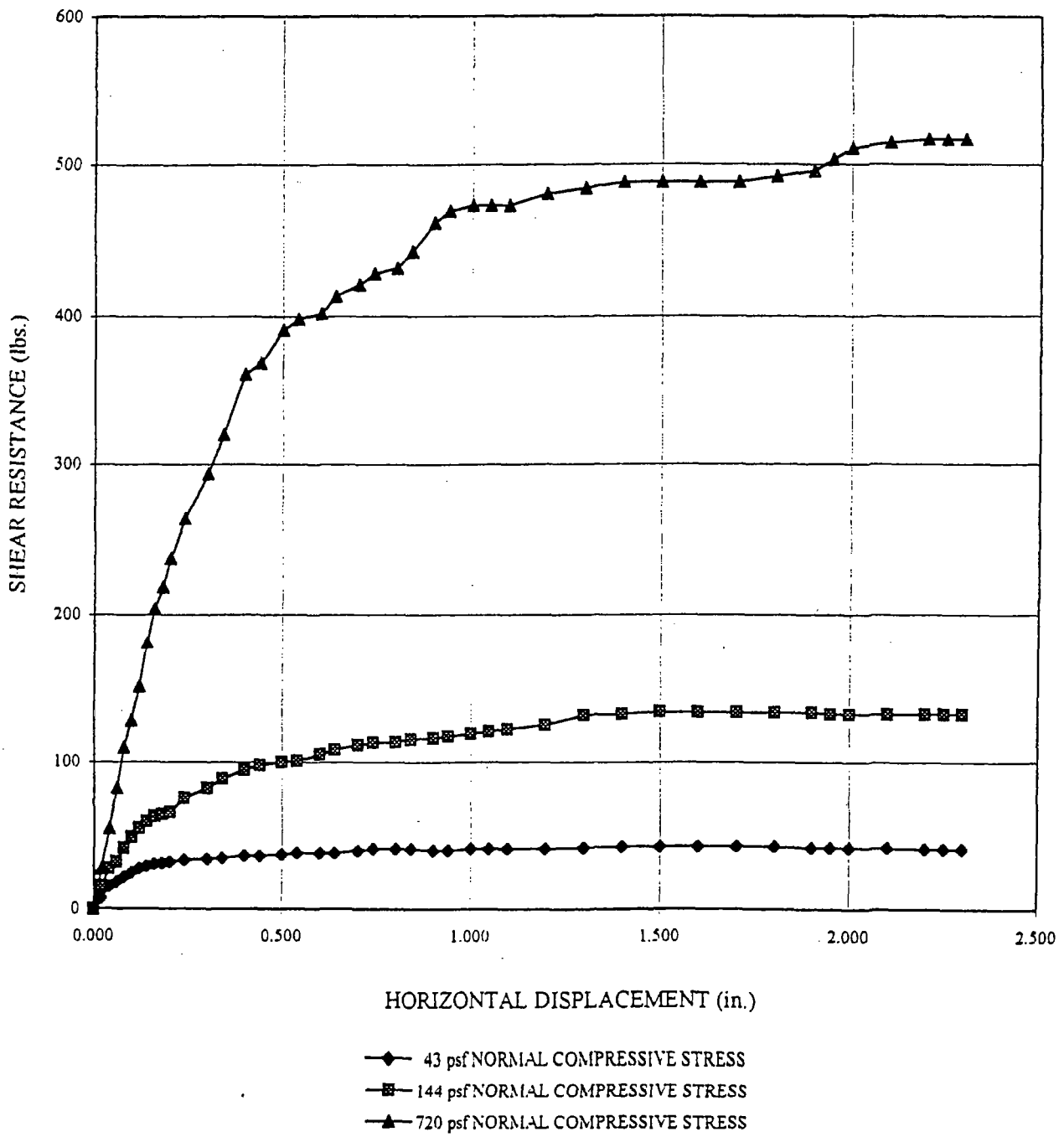
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT : GAI CONSULTANTS, INC.
CLIENT PROJECT : LTV STEEL CLOSURE
PROJECT NO. : L98250-01
LAB I. D. NO.: Alpena High Mag A Limestone (2.5"): L98250-01-01,
AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03

INTERFACE : **Alpena High Mag A Limestone VS. AMOCO 16oz. Geotextlie on NSC 40 mil LLDPE**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



CHECKED BY: RH DATE: 12-10-98

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INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT : GAI CONSULTANTS, INC.
CLIENT PROJECT : LTV STEEL CLOSURE
PROJECT NO. : L98250-01
LAB I. D. NO.: Alpena High Mag A Limestone (2.5"): L98250-01-01,
AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03

INTERFACE : **Alpena High Mag A Limestone VS. AMOCO 16oz. Geotextlie on NSC 40 mil LLDPE**

STRAIN RATE (in / min) : 0.04 NORMAL LOADING : DEAD LOAD

TEST DATA

NORMAL LOAD (psf)	43	NORMAL LOAD (psf)	144	NORMAL LOAD (psf)	720
NORMAL LOAD (psi)	0.3	NORMAL LOAD (psi)	1.0	NORMAL LOAD (psi)	5.0
PEAK SHEAR STRESS (psf)	42	PEAK SHEAR STRESS (psf)	134	PEAK SHEAR STRESS (psf)	516
RESIDUAL SHEAR (psf)	41	RESIDUAL SHEAR (psf)	133	RESIDUAL SHEAR (psf)	n. a.

HORIZONTAL			HORIZONTAL			HORIZONTAL		
DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)
0.000	0.0	0	0.000	0.0	0	0.000	0.0	0
0.020	2.5	7	0.020	5.0	15	0.020	9.0	27
0.040	5.0	15	0.040	9.0	27	0.040	18.0	55
0.060	6.0	18	0.060	10.5	32	0.060	27.0	82
0.080	7.0	21	0.080	13.5	41	0.080	36.0	110
0.100	8.0	24	0.100	16.0	49	0.100	42.0	128
0.120	9.0	27	0.120	18.0	55	0.120	49.0	151
0.140	9.5	29	0.140	19.5	59	0.140	53.0	181
0.160	10.0	30	0.160	20.5	62	0.160	56.0	204
0.180	10.2	31	0.180	21.0	64	0.180	58.0	219
0.200	10.5	32	0.200	21.5	65	0.200	60.5	237
0.240	11.0	33	0.240	24.8	75	0.240	64.0	263
0.300	11.2	34	0.300	27.0	82	0.300	68.0	293
0.340	11.5	35	0.340	29.0	88	0.340	71.5	320
0.400	12.0	36	0.400	31.0	94	0.400	77.0	361
0.440	12.0	36	0.440	32.0	98	0.440	78.0	368
0.500	12.2	37	0.500	32.8	100	0.500	81.0	391
0.540	12.5	38	0.540	33.0	101	0.540	82.0	398
0.600	12.5	38	0.600	34.5	105	0.600	82.5	402
0.640	12.5	38	0.640	35.5	108	0.640	84.0	413
0.700	13.0	39	0.700	36.5	111	0.700	85.0	421
0.740	13.5	41	0.740	37.0	113	0.740	86.0	428
0.800	13.5	41	0.800	37.2	113	0.800	86.5	432
0.840	13.5	41	0.840	37.8	115	0.840	88.0	443
0.900	13.2	40	0.900	38.0	116	0.900	90.5	462
0.940	13.2	40	0.940	38.4	117	0.940	91.5	469
1.000	13.5	41	1.000	39.0	119	1.000	92.0	473
1.050	13.5	41	1.050	39.5	120	1.050	92.0	473
1.100	13.5	41	1.100	40.0	122	1.100	92.0	473
1.200	13.5	41	1.200	41.0	125	1.200	93.0	480
1.300	13.8	42	1.300	43.2	132	1.300	93.5	484
1.400	14.0	42	1.400	43.5	133	1.400	94.0	488
1.500	14.0	42	1.500	44.0	134	1.500	94.0	488
1.600	14.0	42	1.600	43.8	134	1.600	94.0	488
1.700	14.0	42	1.700	43.8	134	1.700	94.0	488
1.800	14.0	42	1.800	43.8	134	1.800	94.5	492
1.900	13.8	42	1.900	43.8	134	1.900	95.0	495
1.950	13.8	42	1.950	43.5	133	1.950	96.0	503
2.000	13.8	42	2.000	43.5	133	2.000	97.0	510
2.100	13.8	42	2.100	43.5	133	2.100	97.5	514
2.200	13.5	41	2.200	43.5	133	2.200	97.8	516
2.250	13.5	41	2.250	43.5	133	2.250	97.8	516
2.300	13.5	41	2.300	43.5	133	2.300	97.8	516

 CHECKED BY : PC DATE : 12-10-98

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INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT :	GAI CONSULTANTS, INC.
CLIENT PROJECT :	LTV STEEL CLOSURE
PROJECT NO. :	L98250-01
LAB I. D. NO.:	Alpena High Mag A Limestone (2.5"): L98250-01-01, AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03
INTERFACE :	**Alpena High Mag A Limestone on AMOCO 16oz. Geotextlie VS. NSC 40 mil LLDPE**

	PEAK SHEAR		RESIDUAL SHEAR	
FRICTION ANGLE (deg) :	Φ =	23.2	Φ =	21.8
COEFFICIENT OF FRICTION :	=	0.43	=	0.40
ADHESION [Calculated] (psf):	a =	19	a =	20

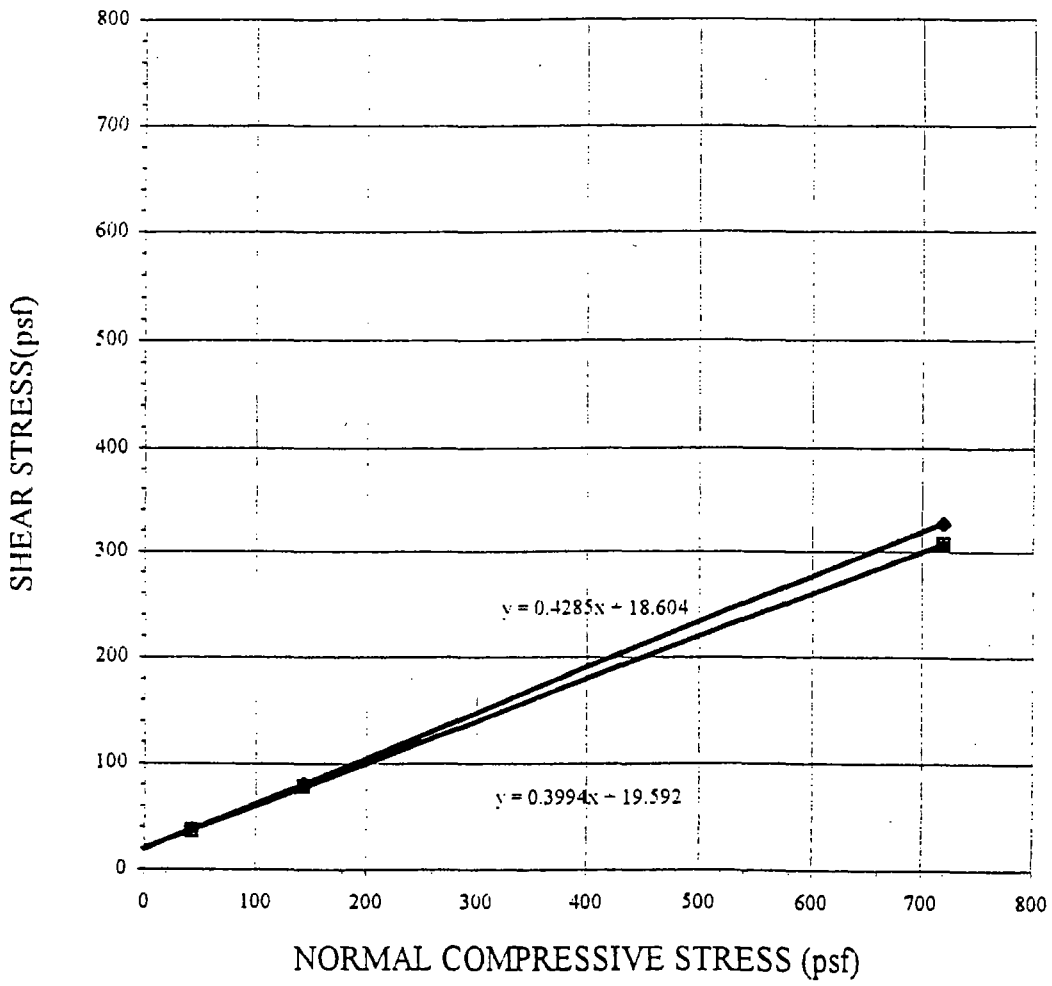
NOTES:

1.)A component of the adhesion values reported may be an anomaly of the laboratory procedure and calculation algorithm.

2.)The friction angle was calculated using linear regression basing on original data.

3.)The displacement limit for the direct shear unit used is 2.3 inches.

4.)The interface tested "wet".



◆ PEAK SHEAR DATA ■ RESIDUAL SHEAR DTAT

CHECKED BY : RM DATE : 12-11-98

C:\MSOFFICE\EXCEL\DIRSHEAR\[98250-1?.XLS]3 Points

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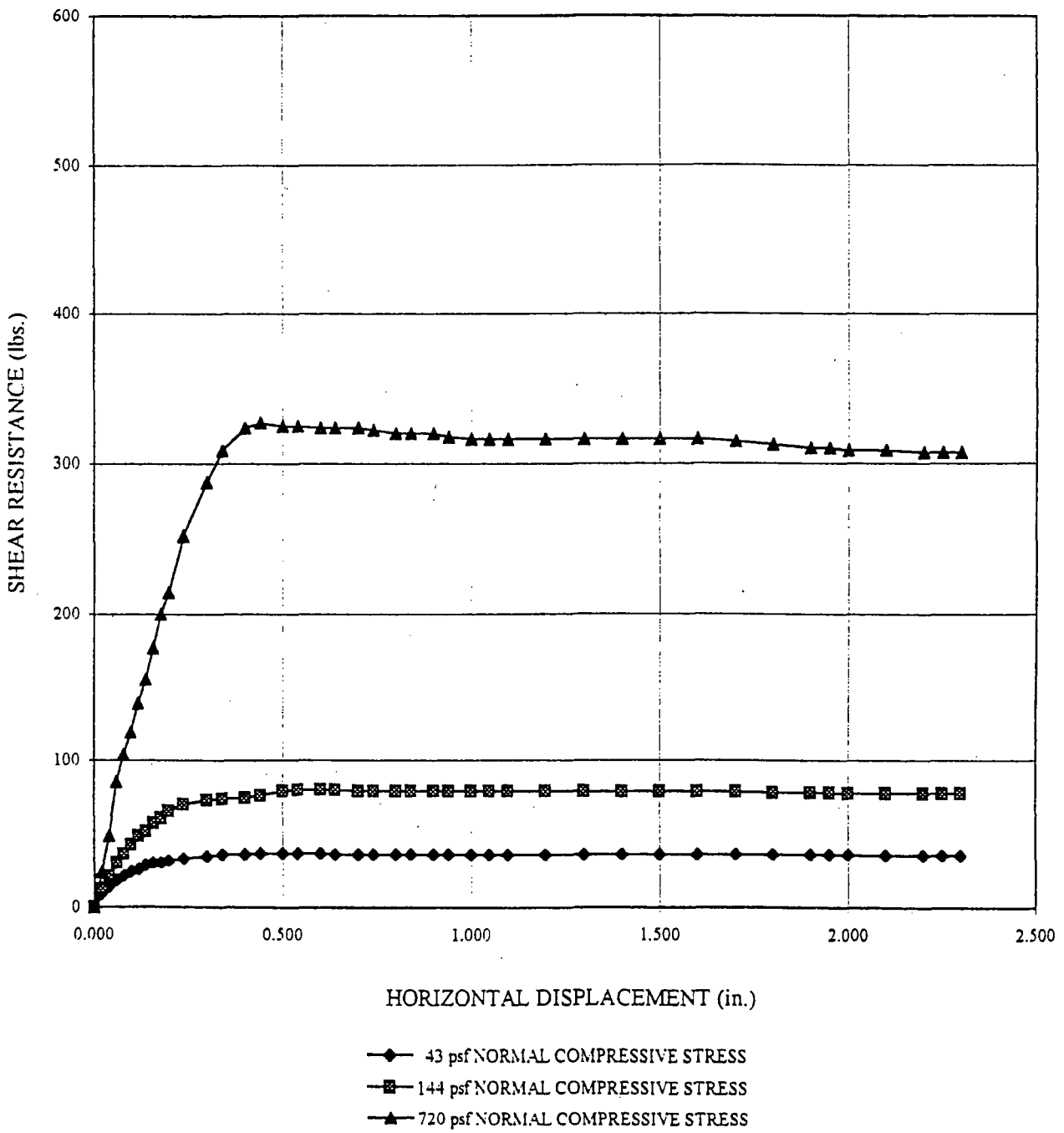
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnic

CLIENT :	GAI CONSULTANTS, INC.
CLIENT PROJECT :	LTV STEEL CLOSURE
PROJECT NO. :	L98250-01
LAB I. D. NO.:	Alpena High Mag A Limestone (2.5"): L98250-01-01, AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03
INTERFACE :	**Alpena High Mag A Limestone on AMOCO 16oz. Geotextlie VS. NSC 40 mil LLDPE**

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



CHECKED BY : RJH DATE : 12-11-98

C:\MSOFFICE\EXCEL\DIRSHEAR\[98250-12.XLS]3 Points

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D-1

INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

Geotechnic

CLIENT : GAI CONSULTANTS, INC.
CLIENT PROJECT : LTV STEEL CLOSURE
PROJECT NO. : L98250-01
LAB I. D. NO.: Alpena High Mag A Limestone (2.5"): L98250-01-01,
AMOCO 16oz. Geotextlie: L98250-01-02, NSC 40 mil Tex'd LLDPE: L98250-01-03

INTERFACE : **Alpena High Mag A Limestone on AMOCO 16oz. Geotextlie VS. NSC 40 mil LLDPE**

STRAIN RATE (in / min) : 0.04 NORMAL LOADING : DEAD LOAD

TEST DATA

NORMAL LOAD (psf)	43	NORMAL LOAD (psf)	144	NORMAL LOAD (psf)	720
NORMAL LOAD (psi)	0.3	NORMAL LOAD (psi)	1.0	NORMAL LOAD (psi)	5.0
PEAK SHEAR STRESS (psf)	37	PEAK SHEAR STRESS (psf)	80	PEAK SHEAR STRESS (psf)	327
RESIDUAL SHEAR (psf)	36	RESIDUAL SHEAR (psf)	78	RESIDUAL SHEAR (psf)	307

HORIZONTAL			HORIZONTAL			HORIZONTAL		
DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)
0.000	0.0	0	0.000	0.0	0	0.000	0.0	0
0.020	3.0	9	0.020	4.0	12	0.020	8.0	24
0.040	4.5	13	0.040	7.0	21	0.040	16.0	49
0.060	6.0	18	0.060	10.0	30	0.060	28.0	85
0.080	7.0	21	0.080	12.0	36	0.080	34.0	104
0.100	8.0	24	0.100	14.0	42	0.100	39.0	119
0.120	8.5	26	0.120	16.0	49	0.120	45.5	139
0.140	9.5	29	0.140	17.0	52	0.140	49.5	155
0.160	10.0	30	0.160	18.8	57	0.160	52.5	177
0.180	10.0	30	0.180	20.0	61	0.180	55.5	200
0.200	10.5	32	0.200	21.5	65	0.200	57.5	215
0.240	11.0	33	0.240	23.0	70	0.240	62.5	252
0.300	11.5	35	0.300	24.0	73	0.300	67.2	287
0.340	12.0	36	0.340	24.2	74	0.340	70.0	308
0.400	12.0	36	0.400	24.5	75	0.400	72.0	323
0.440	12.2	37	0.440	25.0	76	0.440	72.5	327
0.500	12.2	37	0.500	26.0	79	0.500	72.2	325
0.540	12.2	37	0.540	26.2	80	0.540	72.2	325
0.600	12.2	37	0.600	26.4	80	0.600	72.0	323
0.640	12.0	36	0.640	26.2	80	0.640	72.0	323
0.700	12.0	36	0.700	26.0	79	0.700	72.0	323
0.740	12.0	36	0.740	26.0	79	0.740	71.8	322
0.800	12.0	36	0.800	26.0	79	0.800	71.5	320
0.840	12.0	36	0.840	26.0	79	0.840	71.5	320
0.900	12.0	36	0.900	26.0	79	0.900	71.5	320
0.940	12.0	36	0.940	26.0	79	0.940	71.2	317
1.000	12.0	36	1.000	26.0	79	1.000	71.0	316
1.050	12.0	36	1.050	26.0	79	1.050	71.0	316
1.100	12.0	36	1.100	26.0	79	1.100	71.0	316
1.200	12.0	36	1.200	26.0	79	1.200	71.0	316
1.300	12.0	36	1.300	26.0	79	1.300	71.0	316
1.400	12.0	36	1.400	25.8	79	1.400	71.0	316
1.500	12.0	36	1.500	25.8	79	1.500	71.0	316
1.600	12.0	36	1.600	25.8	79	1.600	71.0	316
1.700	12.0	36	1.700	25.8	79	1.700	70.8	314
1.800	12.0	36	1.800	25.6	78	1.800	70.5	312
1.900	12.0	36	1.900	25.6	78	1.900	70.2	310
1.950	12.0	36	1.950	25.6	78	1.950	70.2	310
2.000	12.0	36	2.000	25.5	78	2.000	70.0	308
2.100	11.8	36	2.100	25.5	78	2.100	70.0	308
2.200	11.8	36	2.200	25.5	78	2.200	69.8	307
2.250	11.8	36	2.250	25.5	78	2.250	69.8	307
2.300	11.8	36	2.300	25.5	78	2.300	69.8	307

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C:\MSOFFICE\EXCEL\DIRSHEAR\[98250-12.XLS]3 Points

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INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnic

CLIENT :	GAI CONSULTANTS, INC.
CLIENT PROJECT :	LTV STEEL CLOSURE
PROJECT NO. :	L98250-01
LAB I. D. NO.:	Alpena wash pond sand: L98250-01-04, NSC 40 mil Tex'd LLDPE: L98250-01-03
INTERFACE :	**Alpena Wash Pond Sand* VS. NSC 40 mil LLDPE**

* Sand was placed at 101.38pcf @ 1% w. c. (as received moisture)

	PEAK SHEAR		RESIDUAL SHEAR	
FRICTION ANGLE (deg) :	Φ =	34.2	Φ =	n. a.
COEFFICIENT OF FRICTION :	=	0.68	=	n. a.
ADHESION [Calculated] (psf):	a =	23	a =	n. a.

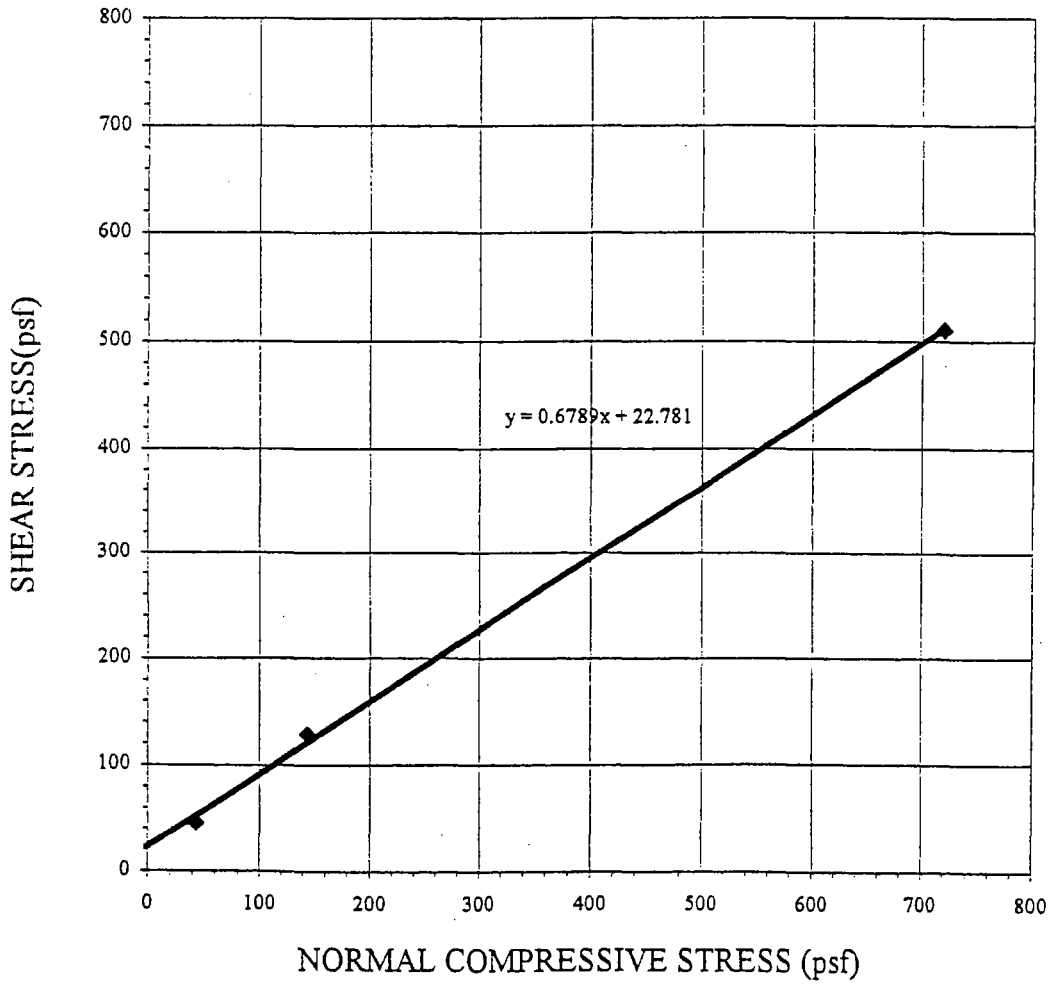
NOTES:

1.)A component of the adhesion values reported may be an anomaly of the laboratory procedure and calculation algorithm.

2.)The friction angle was calculated using linear regression basing on original data.

3.)The displacement limit for the direct shear unit used is 2.3 inches.

4.)The interface tested "wet".



◆PEAK SHEAR DATA

CHECKED BY: RM DATE: 12-15-98

A:\[98250-13.XLS]3 Points

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D-1

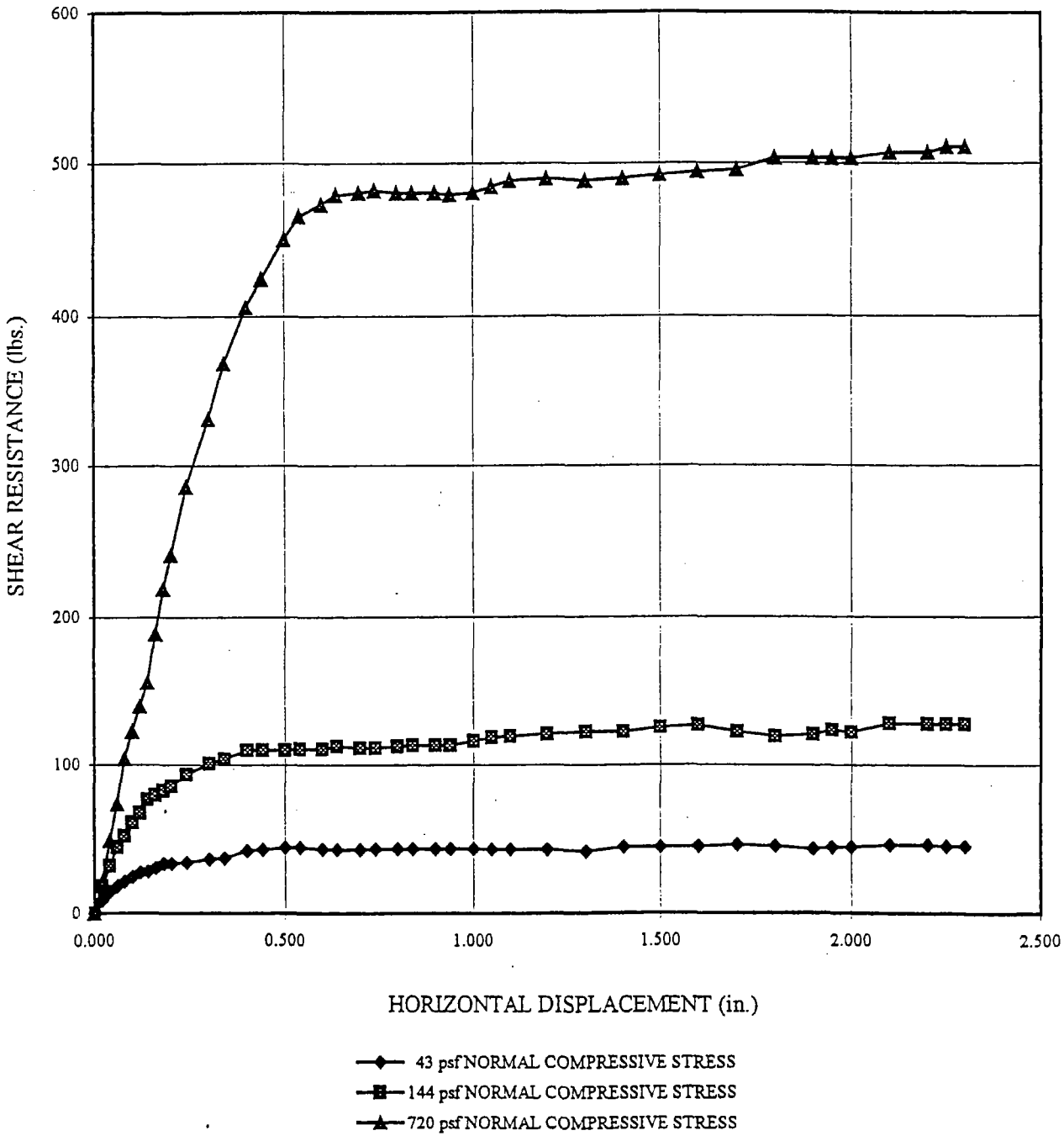
INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnic

CLIENT : GAI CONSULTANTS, INC.
CLIENT PROJECT : LTV STEEL CLOSURE
PROJECT NO. : L98250-01
LAB I. D. NO.: Alpena wash pond sand: L98250-01-04, NSC 40 mil Tex'd LLDPE: L98250-01-03

INTERFACE : **Alpena Wash Pond Sand* VS. NSC 40 mil LLDPE**
* Sand was placed at 101.38pcf @ 1% w. c. (as received moisture)

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



CHECKED BY: RAJ DATE: 12-15-98

A:\[98250-13.XLS]3 Points

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INTERFACE FRICTION TEST RESULTS
ASTM D 5321-92

geotechnics

CLIENT : GAI CONSULTANTS, INC.
CLIENT PROJECT : LTV STEEL CLOSURE
PROJECT NO. : L98250-01
LAB I. D. NO.: Alpena wash pond sand: L98250-01-04, NSC 40 mil Tex'd LLDPE: L98250-01-03

INTERFACE : **Alpena Wash Pond Sand* VS. NSC 40 mil LLDPE**

* Sand was placed at 101.38pcf @ 1% w. c. (as received moisture)

STRAIN RATE (in / min) : 0.04 NORMAL LOADING : DEAD LOAD

TEST DATA

NORMAL LOAD (psf)	43	NORMAL LOAD (psf)	144	NORMAL LOAD (psf)	720
NORMAL LOAD (psi)	0.3	NORMAL LOAD (psi)	1.0	NORMAL LOAD (psi)	5.0
PEAK SHEAR STRESS (psf)	46	PEAK SHEAR STRESS (psf)	128	PEAK SHEAR STRESS (psf)	510
RESIDUAL SHEAR (psf)	n. a.	RESIDUAL SHEAR (psf)	n. a.	RESIDUAL SHEAR (psf)	n. a.

HORIZONTAL			HORIZONTAL			HORIZONTAL		
DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)	DISPLACE. (in.)	FORCE (div.)	STRESS (psf)
0.000	0.0	0	0.000	0.0	0	0.000	0.0	0
0.020	3.0	9	0.020	6.0	18	0.020	7.0	21
0.040	4.8	14	0.040	10.5	32	0.040	16.0	49
0.060	6.0	18	0.060	14.5	44	0.060	24.0	73
0.080	7.0	21	0.080	17.0	52	0.080	34.0	104
0.100	8.0	24	0.100	20.0	61	0.100	40.0	122
0.120	9.0	27	0.120	22.0	67	0.120	45.5	139
0.140	9.2	28	0.140	25.0	76	0.140	49.5	155
0.160	10.0	30	0.160	26.0	79	0.160	54.0	189
0.180	11.0	33	0.180	27.0	82	0.180	58.0	219
0.200	11.0	33	0.200	28.0	85	0.200	61.0	241
0.240	11.2	34	0.240	30.5	93	0.240	67.0	286
0.300	12.0	36	0.300	33.0	101	0.300	73.0	331
0.340	12.2	37	0.340	34.0	104	0.340	78.0	368
0.400	13.8	42	0.400	36.0	110	0.400	83.0	406
0.440	14.0	42	0.440	36.0	110	0.440	85.5	424
0.500	14.5	44	0.500	36.0	110	0.500	89.0	451
0.540	14.5	44	0.540	36.2	110	0.540	91.0	466
0.600	14.2	43	0.600	36.2	110	0.600	92.0	473
0.640	14.0	42	0.640	36.8	112	0.640	92.8	479
0.700	14.0	42	0.700	36.5	111	0.700	93.0	480
0.740	14.2	43	0.740	36.5	111	0.740	93.2	482
0.800	14.2	43	0.800	36.8	112	0.800	93.0	480
0.840	14.2	43	0.840	37.0	113	0.840	93.0	480
0.900	14.2	43	0.900	37.0	113	0.900	93.0	480
0.940	14.2	43	0.940	37.0	113	0.940	92.8	479
1.000	14.2	43	1.000	38.0	116	1.000	93.0	480
1.050	14.0	42	1.050	38.8	118	1.050	93.5	484
1.100	14.0	42	1.100	39.0	119	1.100	94.0	488
1.200	14.0	42	1.200	39.5	120	1.200	94.2	489
1.300	13.5	41	1.300	40.0	122	1.300	94.0	488
1.400	14.5	44	1.400	40.0	122	1.400	94.2	489
1.500	14.5	44	1.500	41.0	125	1.500	94.5	492
1.600	14.6	44	1.600	41.5	127	1.600	94.8	494
1.700	15.0	46	1.700	40.0	122	1.700	95.0	495
1.800	14.8	45	1.800	39.0	119	1.800	96.0	503
1.900	14.2	43	1.900	39.5	120	1.900	96.0	503
1.950	14.5	44	1.950	40.5	124	1.950	96.0	503
2.000	14.5	44	2.000	40.0	122	2.000	96.0	503
2.100	15.0	46	2.100	42.0	128	2.100	96.5	507
2.200	15.0	46	2.200	41.8	128	2.200	96.5	507
2.250	14.8	45	2.250	41.8	128	2.250	97.0	510
2.300	14.8	45	2.300	41.8	128	2.300	97.0	510

CHECKED BY : PC DATE : 12-15-98

A:\[98250-13.XLS]3 Points

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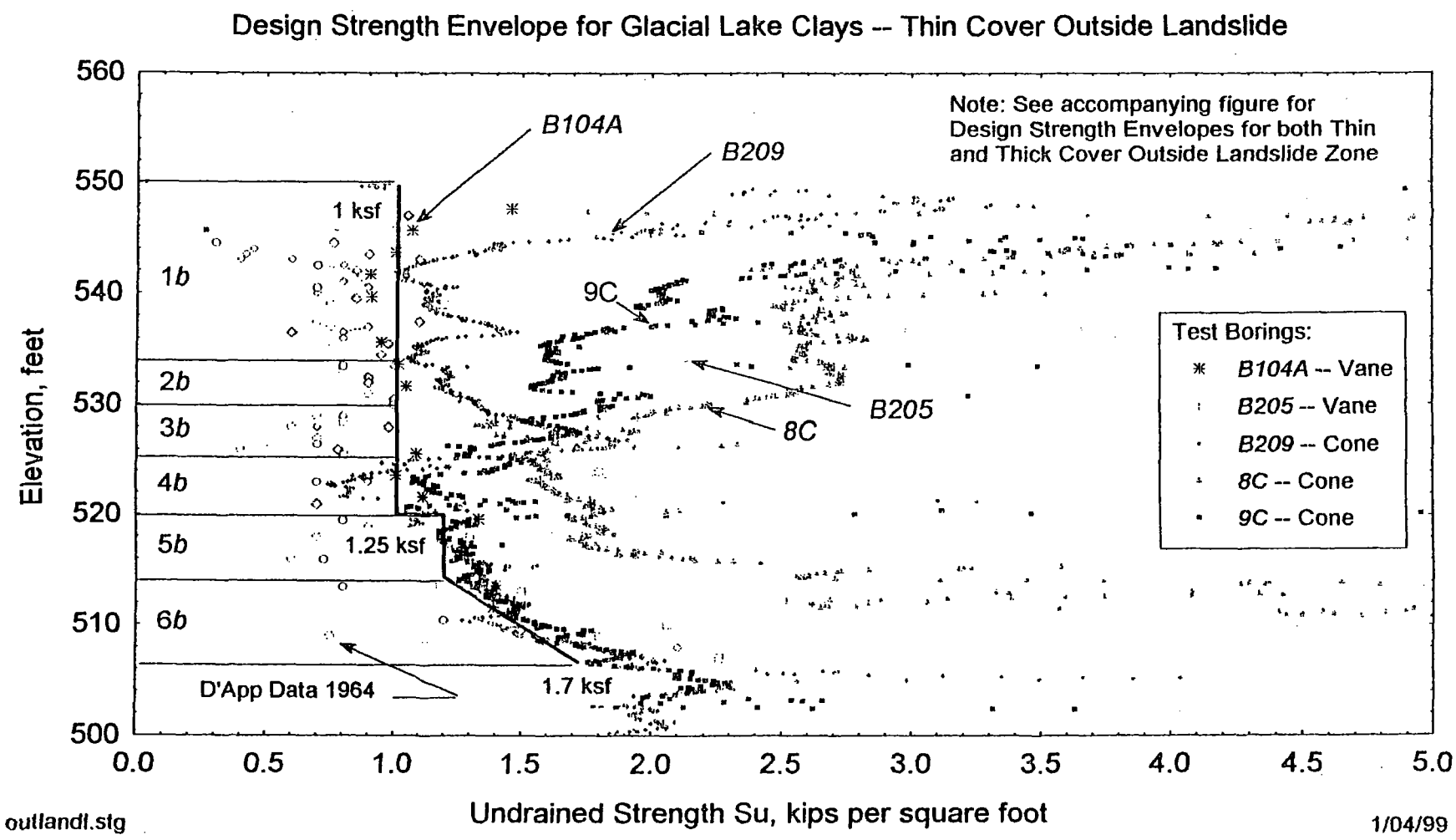
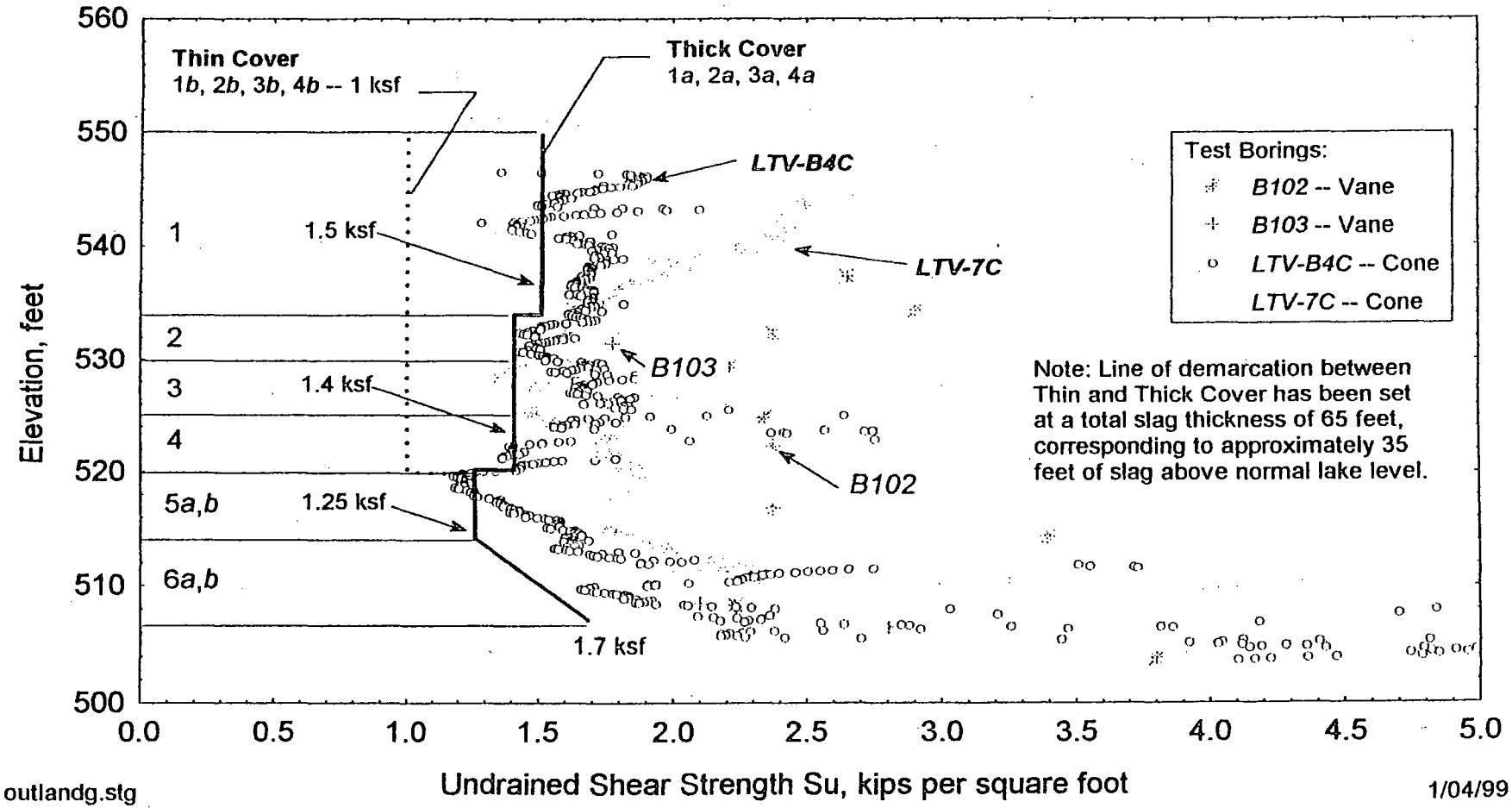
APPENDIX E

SUMMARY OF UNDRAINED STRENGTH DATA


Design Strength Envelope for Glacial Lake Clays -- Thin Cover Outside Landslide
Note: See accompanying figure for Design Strength Envelopes for both Thin and Thick Cover Outside Landslide Zone
B104A
B209
9C
B205
8C
1 ksf
1.25 ksf
1.7 ksf
1b
2b
3b
4b
5b
6b
D'App Data 1964
Test Borings:
B104A -- Vane
B205 -- Vane
B209 -- Cone
8C -- Cone
9C -- Cone
Elevation, feet
560
550
540
530
520
510
500
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Undrained Strength Su, kips per square foot
outlandl.stg
1/04/99

F-2

Design Strength Envelopes for Glacial Lake Clays -- Outside Landslide Zone



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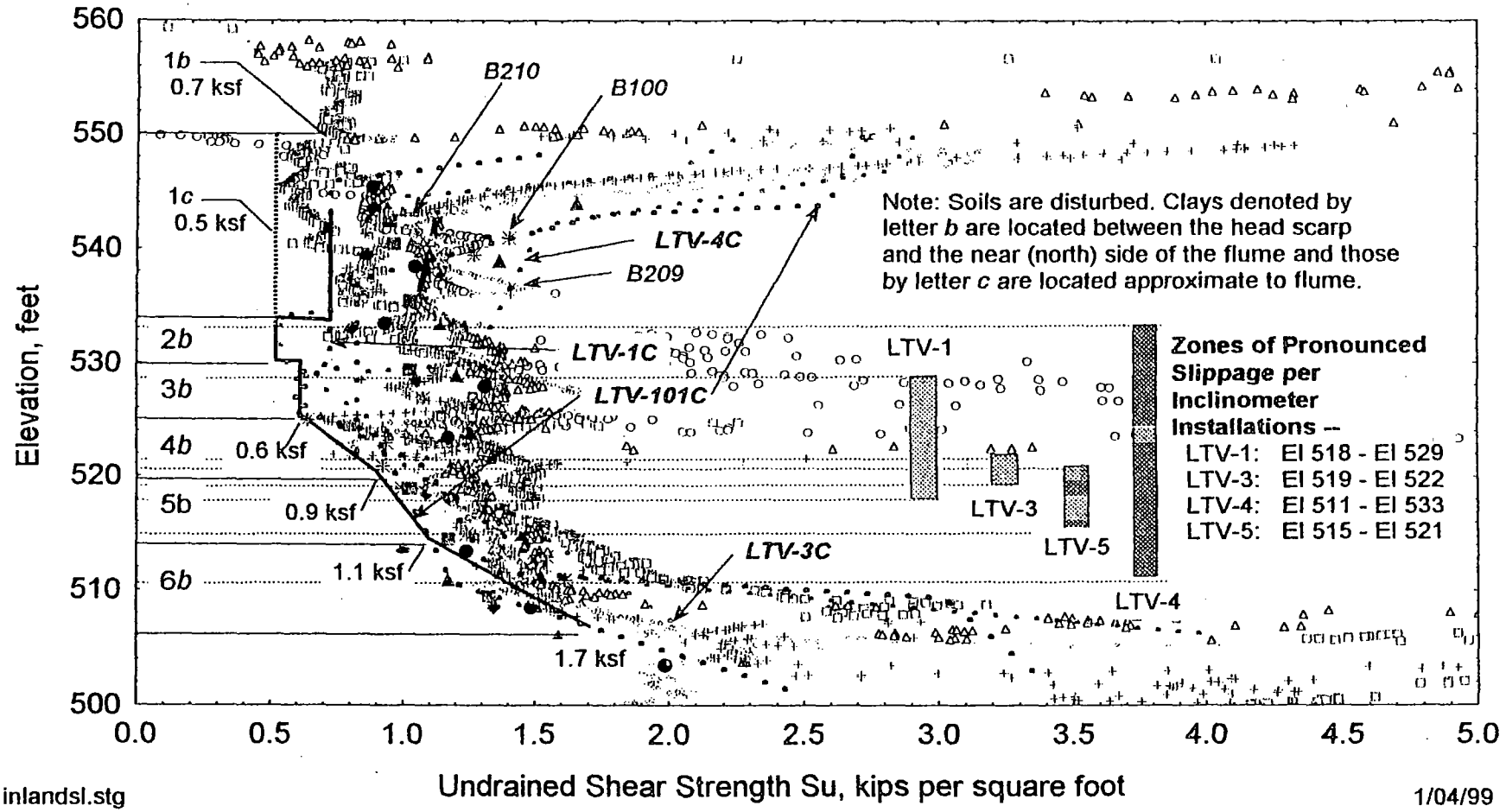
1/04/99

F-2

Design Strength Envelopes for Glacial Lake Clays -- Landslide Zone



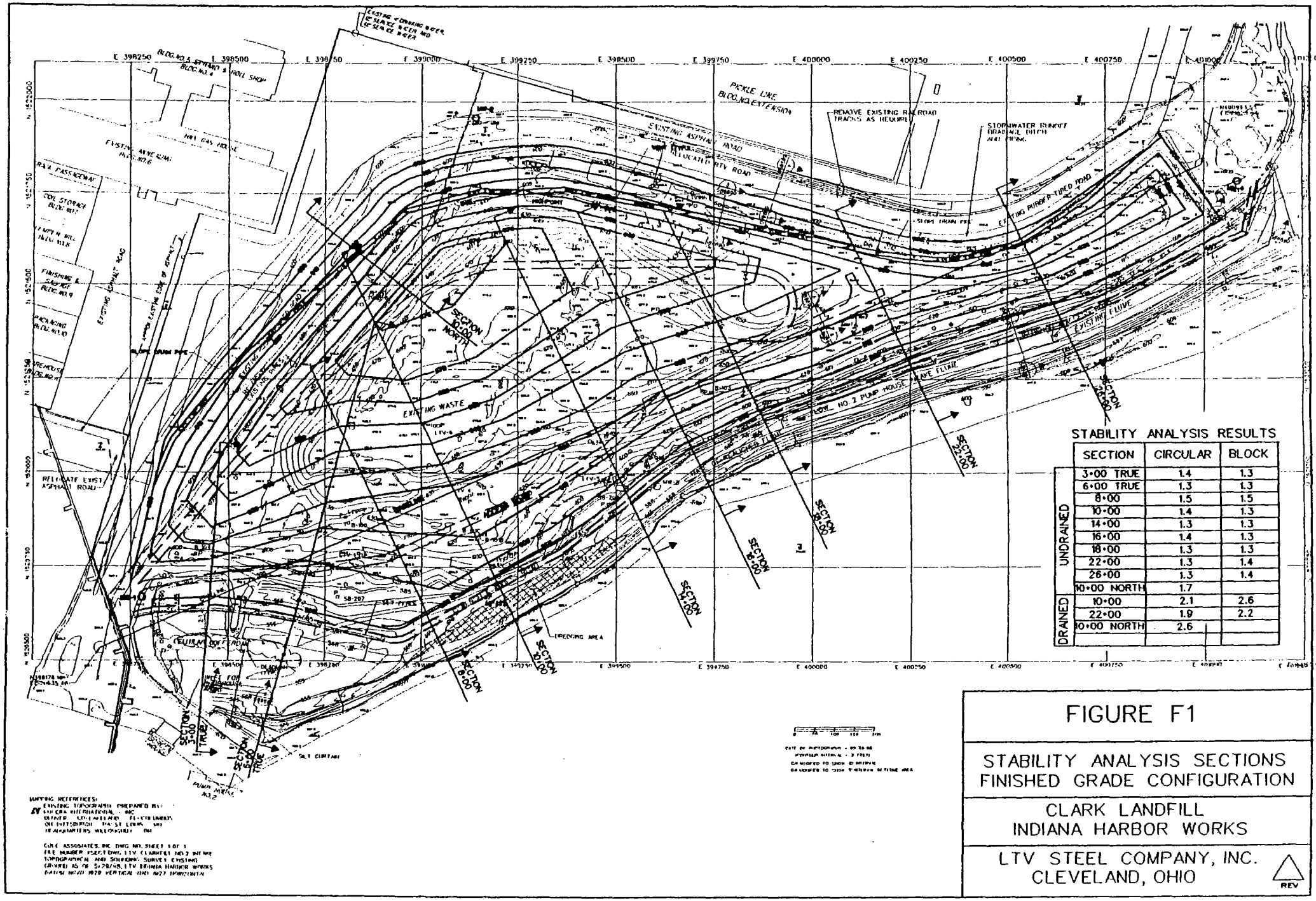
inlandsl.stg

1/04/99

APPENDIX F

RESULTS OF SLOPE STABILITY ANALYSES

DRAWN G.Y. CHECKED TRG APPROVED TRG DATE 2-17-99 DWG. NO. 97-481-A22



STABILITY ANALYSIS RESULTS

	SECTION	CIRCULAR	BLOCK
UNDRAINED	3+00 TRUE	1.4	1.3
	6+00 TRUE	1.3	1.3
	8+00	1.5	1.5
	10+00	1.4	1.3
	14+00	1.3	1.3
	16+00	1.4	1.3
	18+00	1.3	1.3
	22+00	1.3	1.4
	26+00	1.3	1.4
	10+00 NORTH	1.7	
DRAINED	10+00	2.1	2.6
	22+00	1.9	2.2
	10+00 NORTH	2.6	

FIGURE F1

STABILITY ANALYSIS SECTIONS
FINISHED GRADE CONFIGURATION

CLARK LANDFILL
INDIANA HARBOR WORKS

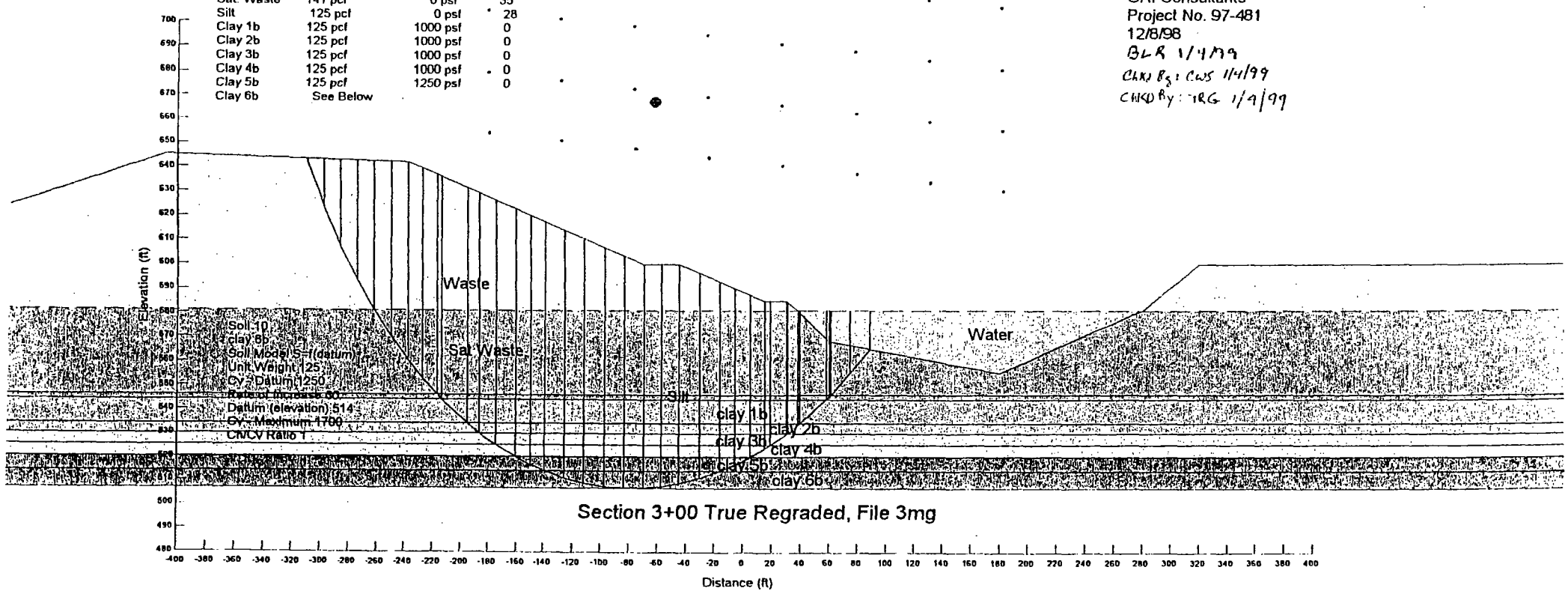
LTV STEEL COMPANY, INC.
CLEVELAND, OHIO

REV

F.S. = 1.4

SOIL	Unit Weight	COHESION	PHI(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1b	125 pcf	1000 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6b	See Below		

GAI Consultants
Project No. 97-481
12/8/98
BLR 1/4/99
CHKD By: CWS 1/4/99
CHKD By: JRG 1/4/99

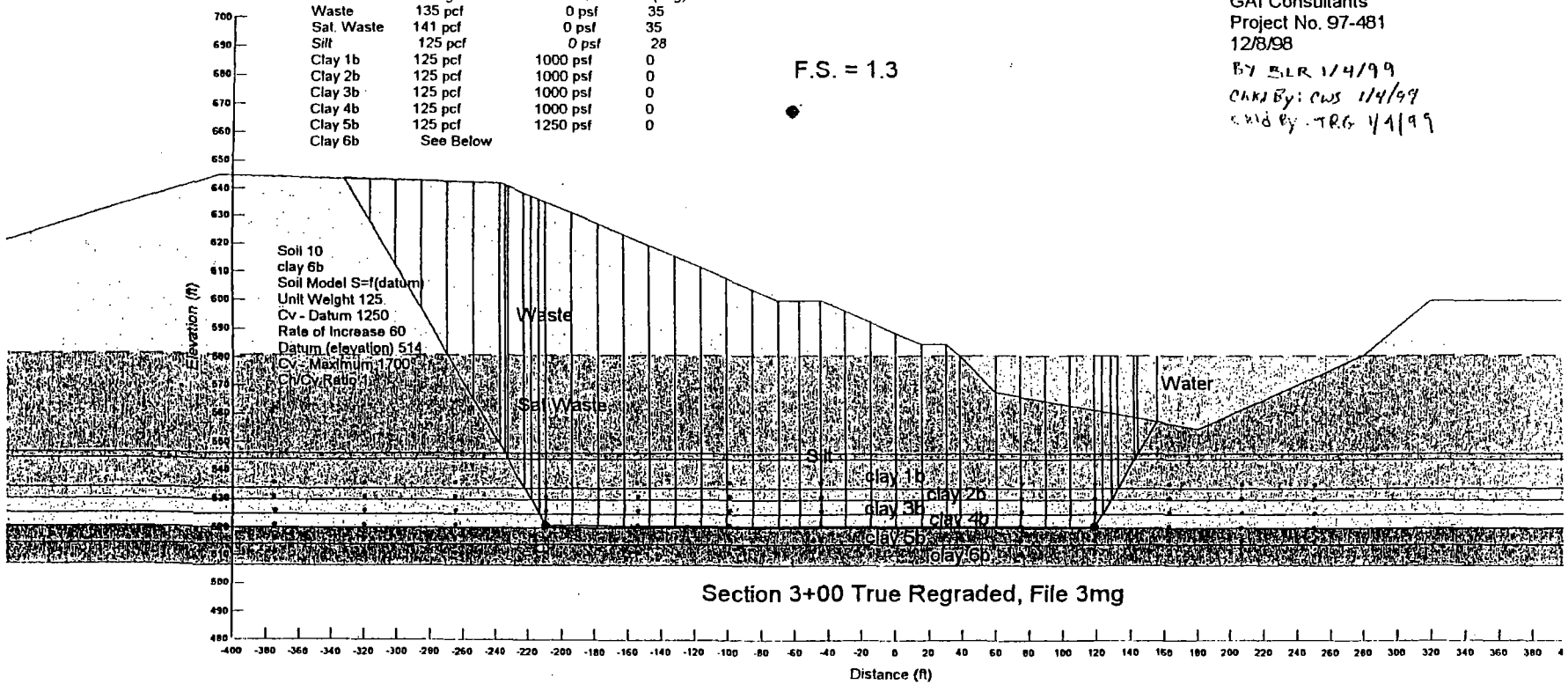


Section 3+00 True Regraded, File 3mg

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	*125 pcf*	*0 psf*	*28*
Clay 1b	125 pcf	1000 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6b	See Below		

F.S. = 1.3

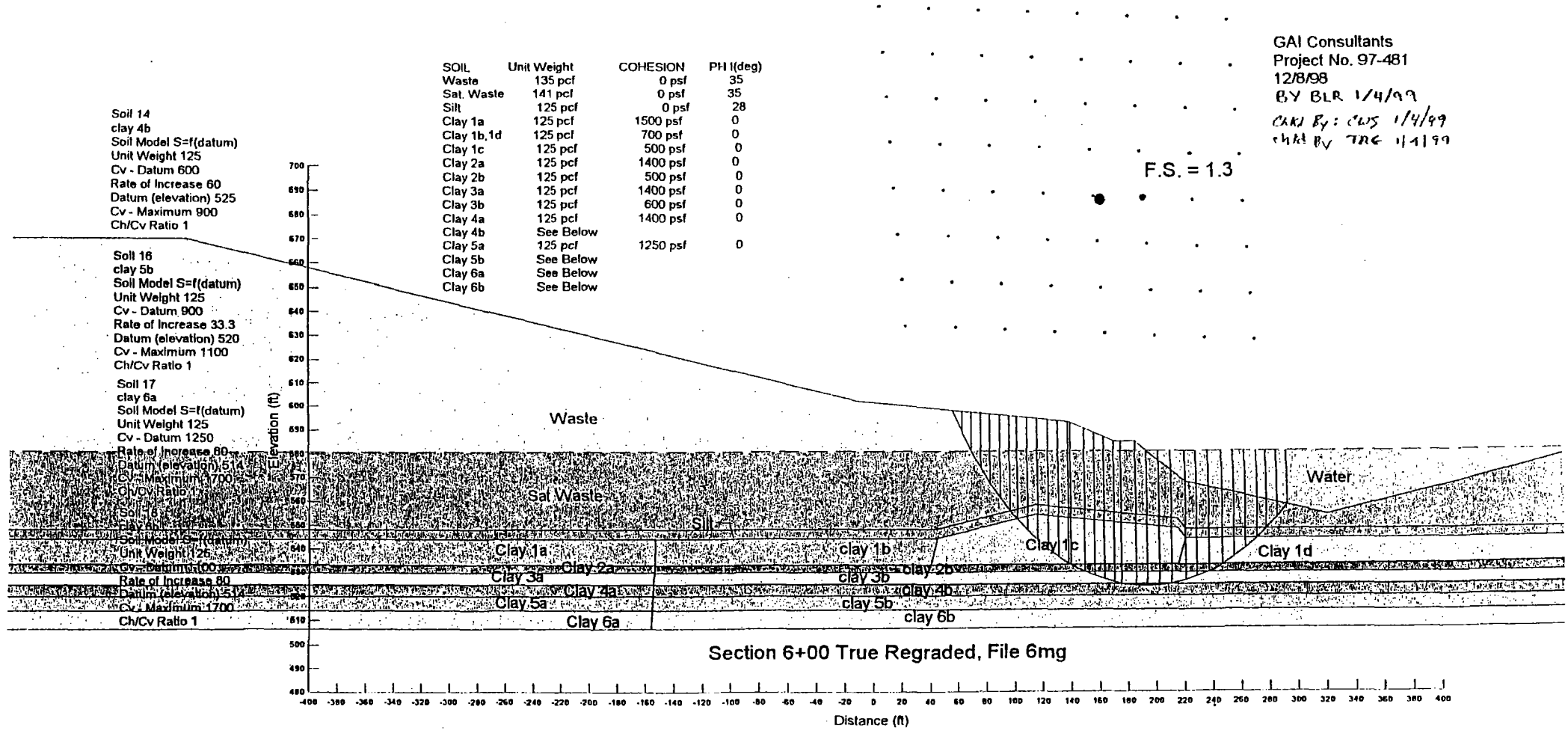
GAI Consultants
Project No. 97-481
12/8/98
BY BLR 1/4/99
CHKD By: CWS 1/4/99
CHKD By: TRG 1/4/99



Section 3+00 True Regraded, File 3mg

GAI Consultants
Project No. 97-481
12/8/98
BY BLR 1/4/99
CHKD BY: CWS 1/4/99
chkd BY TRG 1/4/99

SOIL	Unit Weight	COHESION	PHI(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		



Section 6+00 True Regraded, File 6mg

Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1

Soil 16
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1

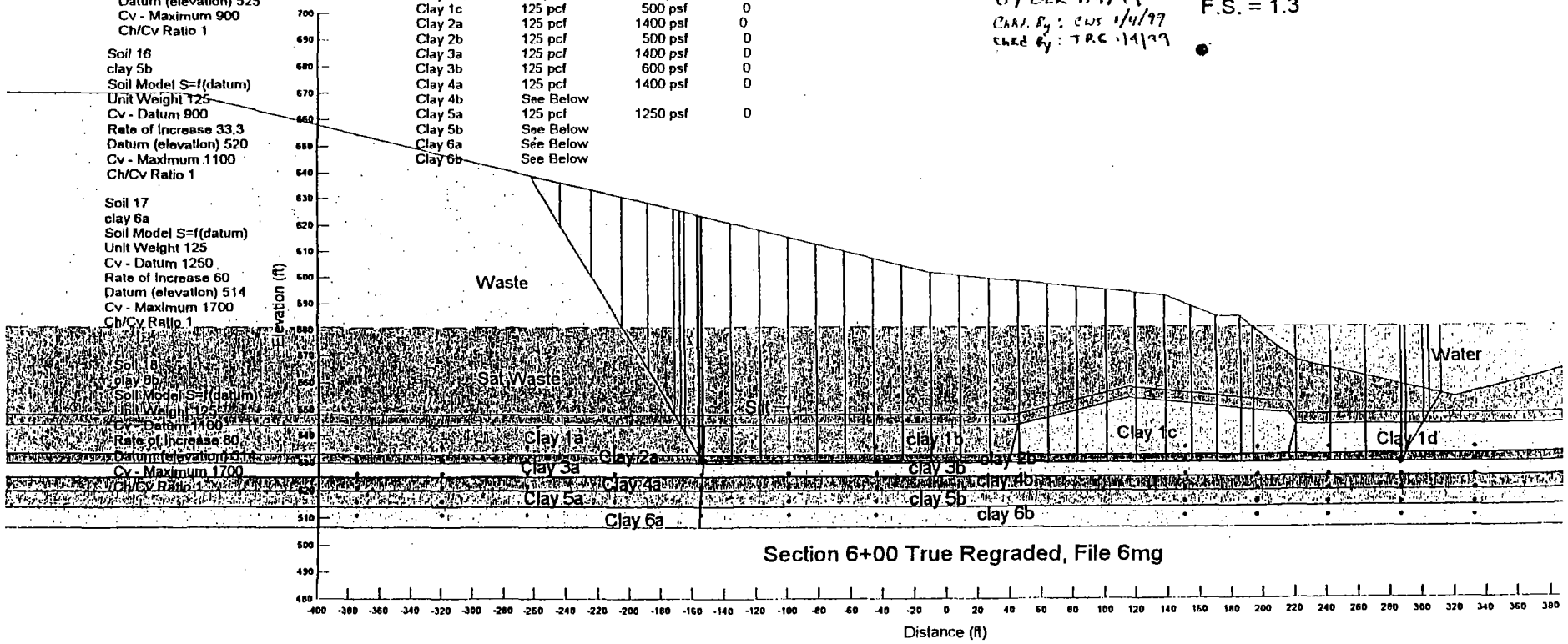
Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 18
clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1100
Rate of Increase 80
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

GAI Consultants
Project No. 97-481
12/8/98
BY BLR 1/4/99
CHKD. By: CWS 1/4/99
CHKD By: TRG 1/4/99

F.S. = 1.3



Section 6+00 True Regraded, File 6mg

GAI Consultants
Project No. 97-481
12/11/98

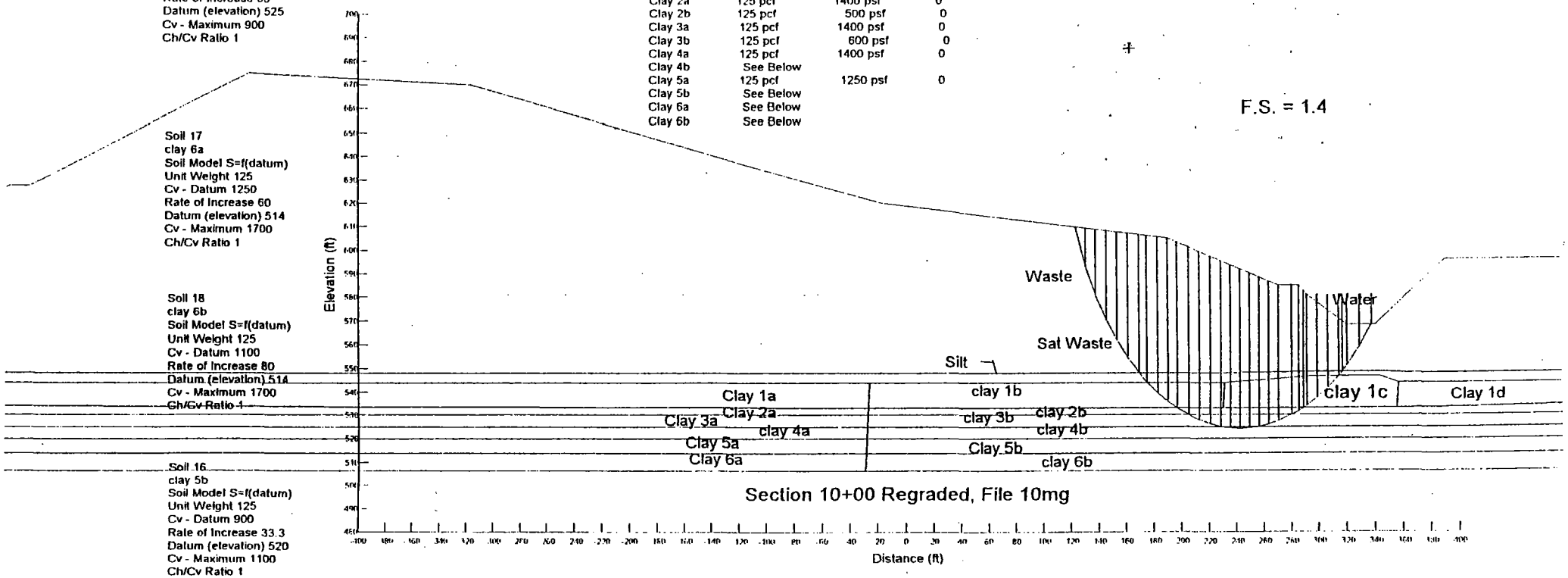
SOIL	Unit Weight	COHESION	PH f(deg)
Waste	135 pcf	0 psf	35
Sat Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b, 1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1

Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 18
clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1100
Rate of Increase 80
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 16
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1



Section 10+00 Regraded, File 10mg

GAI Consultants
Project No. 97-481
12/11/98
BLR 1/4/99
Chkd By: DWS 1/5/99
Chkd By: TRG 1/5/99

F.S. = 1.3

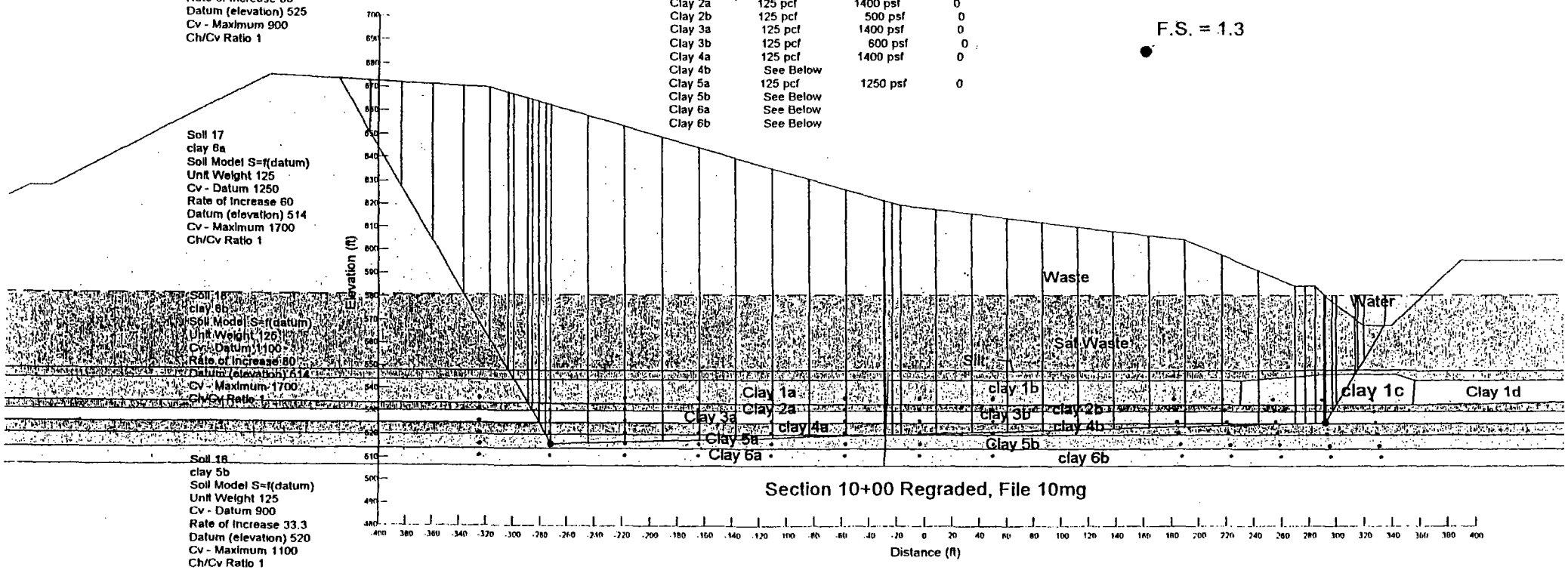
SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1

Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 15
clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1100
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 18
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1



Section 10+00 Regraded, File 10mg

Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

GAI Consultants
Project No. 97-481
12/8/98

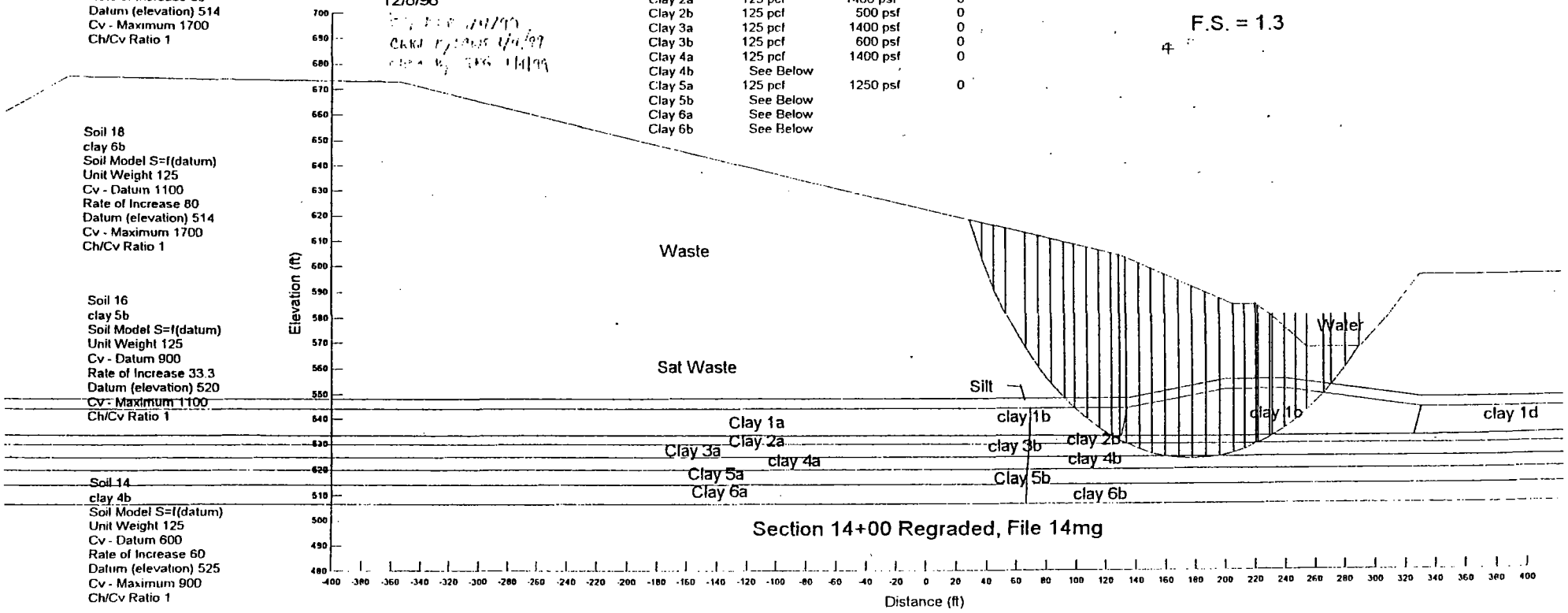
SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

F.S. = 1.3

Soil 18
clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1100
Rate of Increase 80
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 16
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1

Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1



GAI Consultants
Project No. 97-481
12/8/98

BY BLR 1/4/99
Chkd. By: CWS 1/4/99
Chkd By: TRG 1/4/99

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

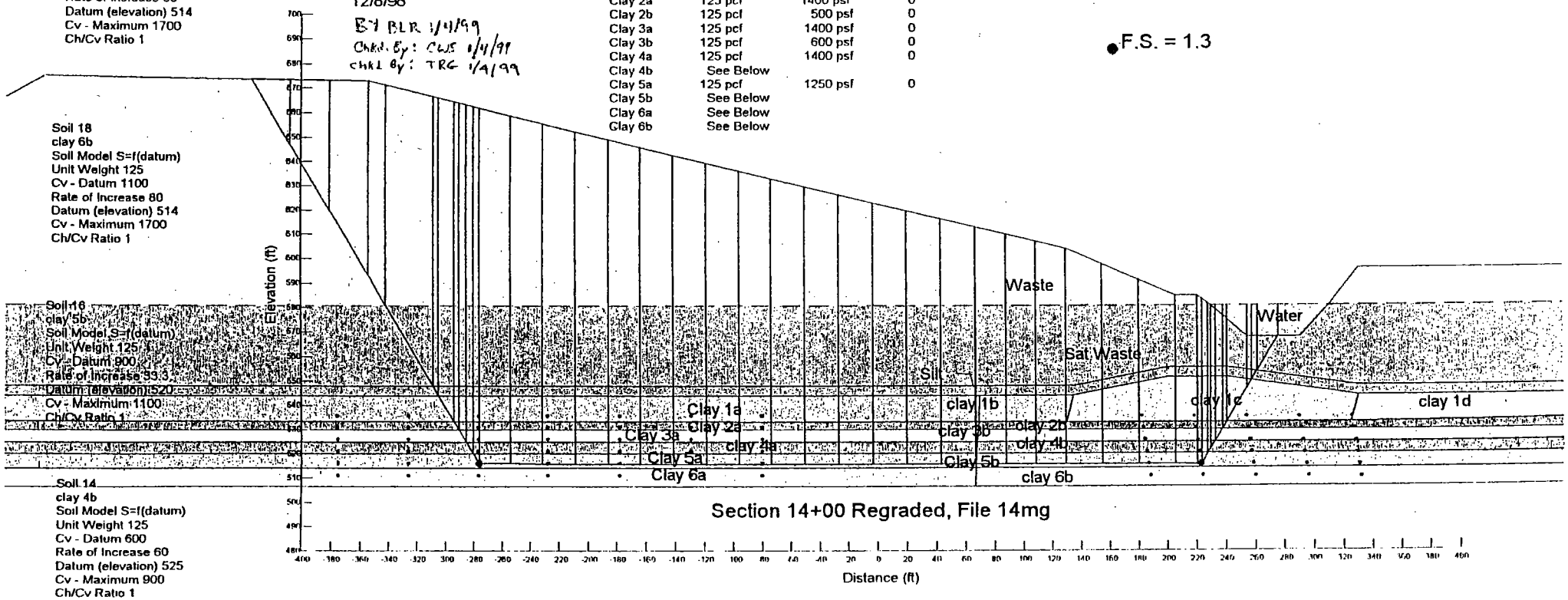
F.S. = 1.3

Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 18
clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1100
Rate of Increase 80
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 16
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1

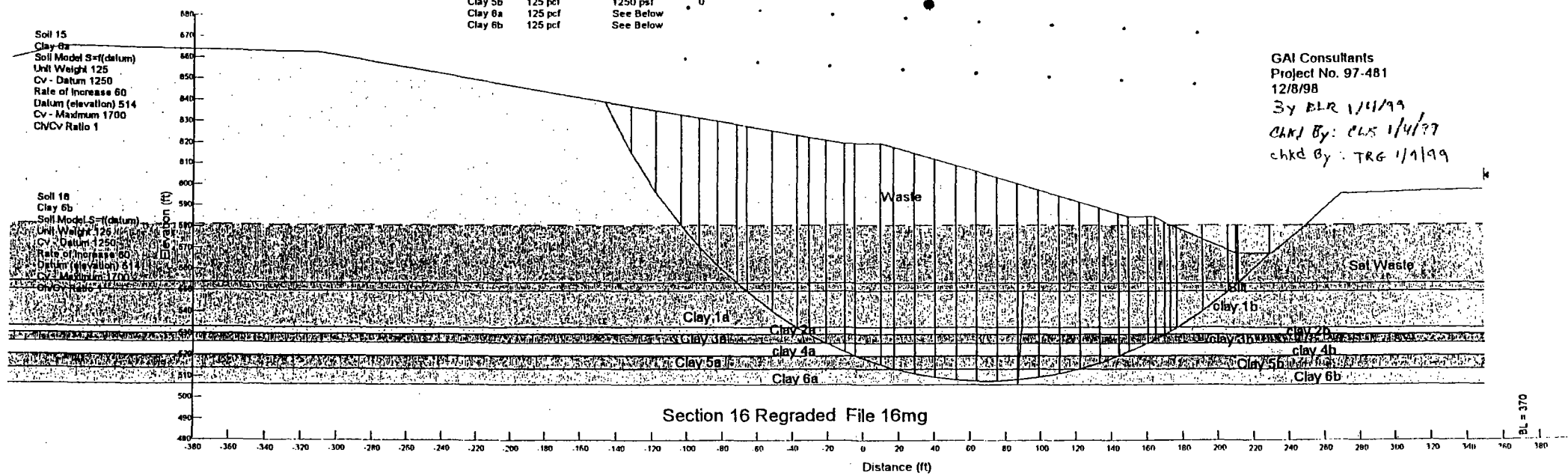
Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1



Section 14+00 Regraded, File 14mg

SOIL	Unit Weight	COHESION	PHI(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

F.S. = 1.4



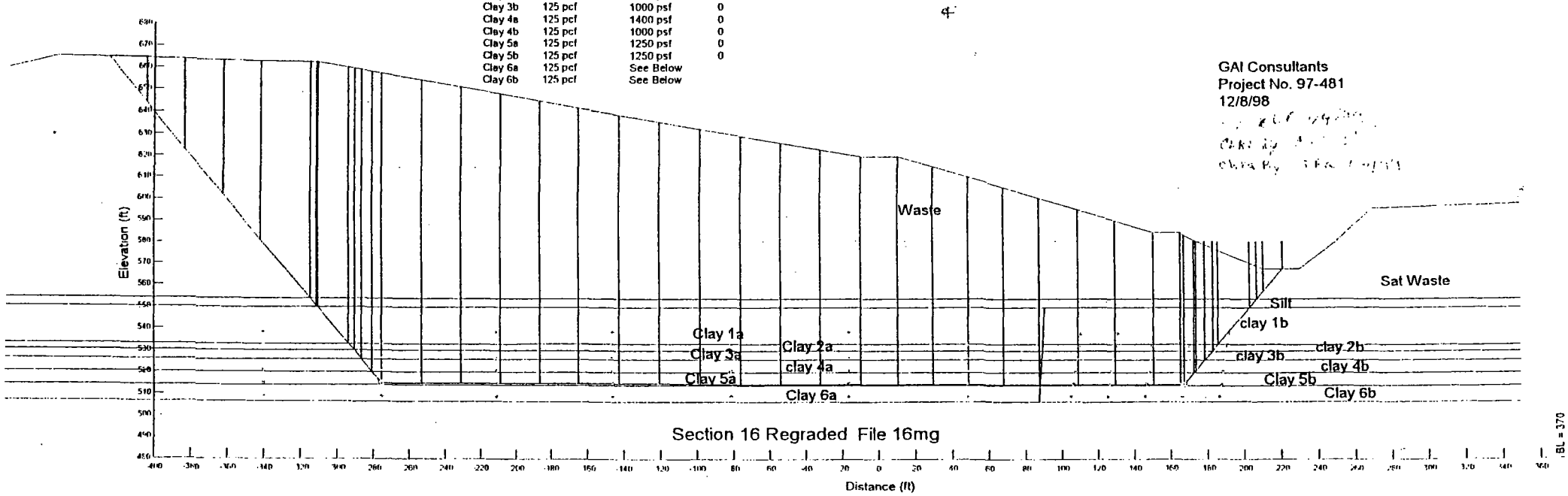
Section 16 Regraded File 16mg

GAI Consultants
Project No. 97-481
12/8/98
By BLR 1/4/99
Chkd By: CLS 1/4/99
chkd By: TRG 1/4/99

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

F.S. = 1.3

GAI Consultants
Project No. 97-481
12/8/98



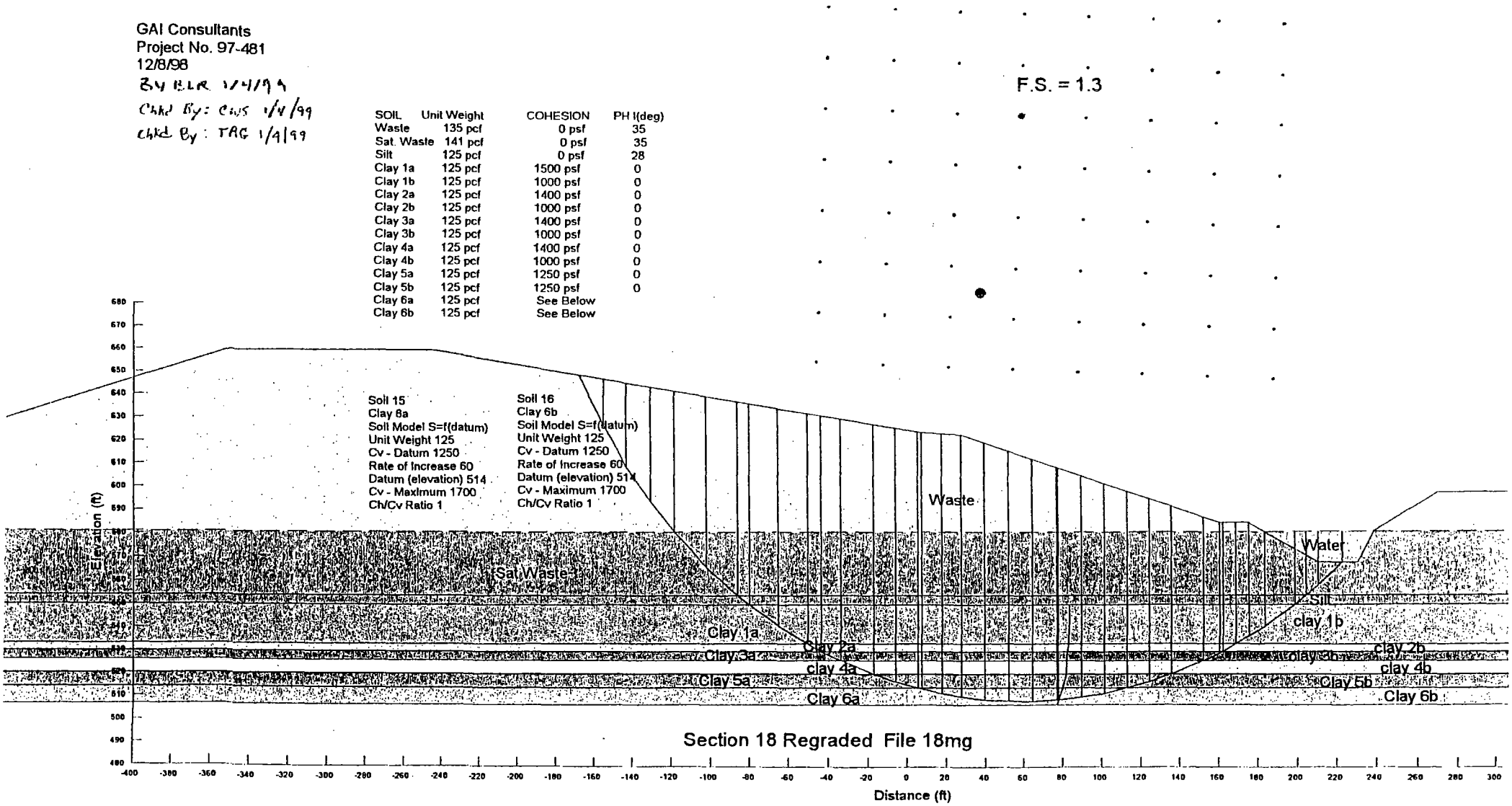
Section 16 Regraded File 16mg

Soil 16
Clay 6b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

Soil 15
Clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

GAI Consultants
Project No. 97-481
12/8/98
By BLR 1/4/99
Chkd By: CWS 1/4/99
Chkd By: TRG 1/4/99

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

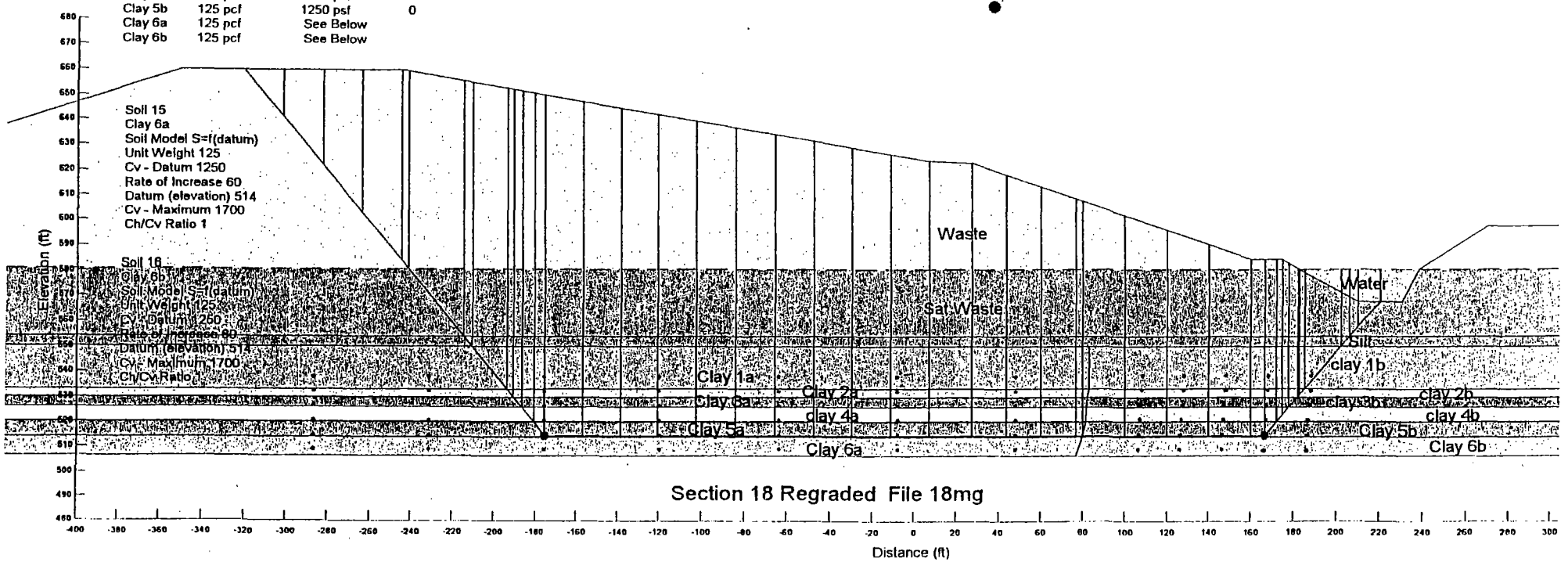


Section 18 Regraded File 18mg

SOIL	Unit Weight	COHESION	PH f(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

GAI Consultants
Project No. 97-481
12/8/98
BY BLR 1/4/99
CHKD BY: CAS 1/5/99
chkd By: TRG 1/4/99

F.S. = 1.3

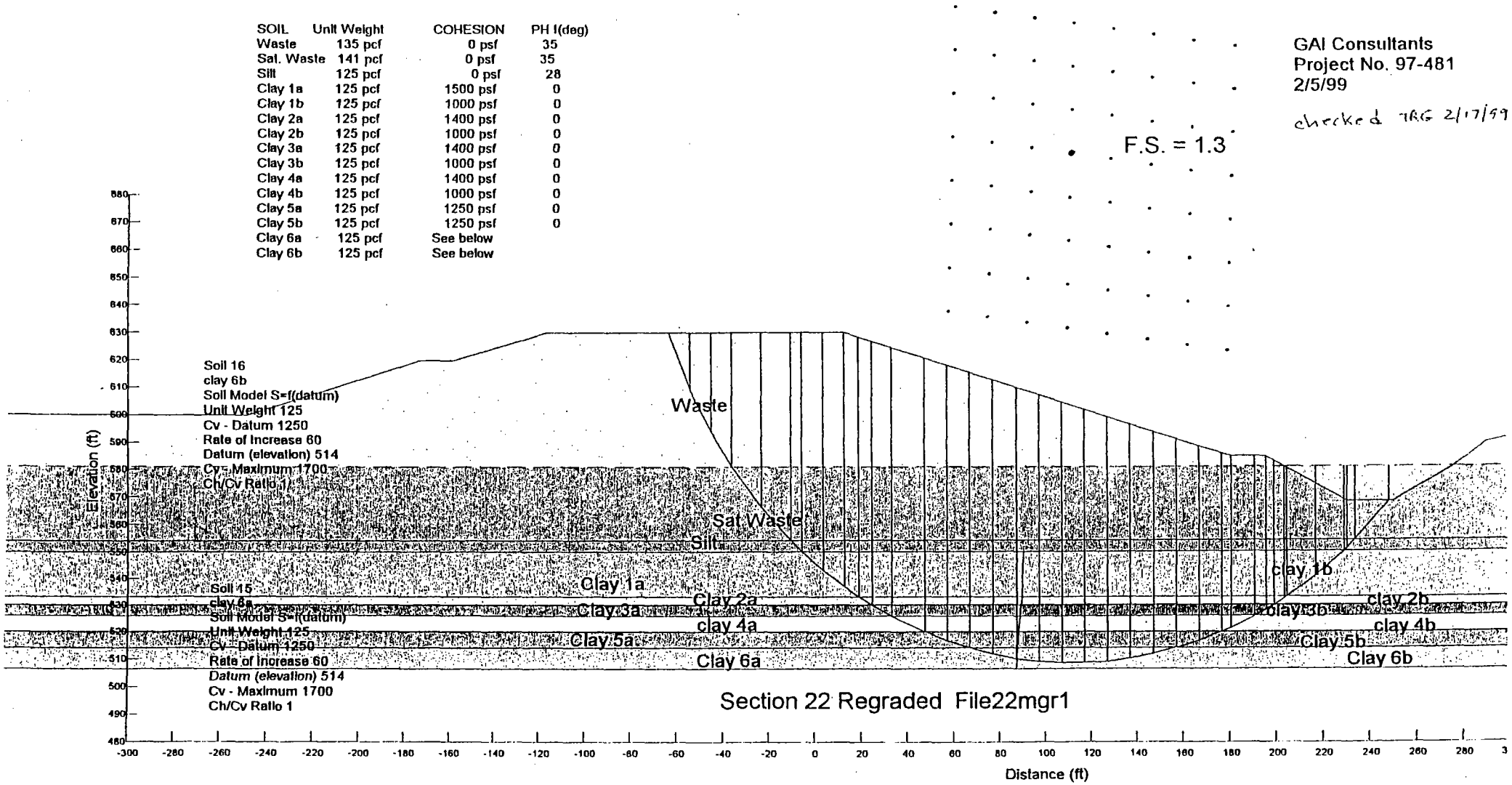


Section 18 Regraded File 18mg

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See below	
Clay 6b	125 pcf	See below	

GAI Consultants
Project No. 97-481
2/5/99

checked TRG 2/17/99

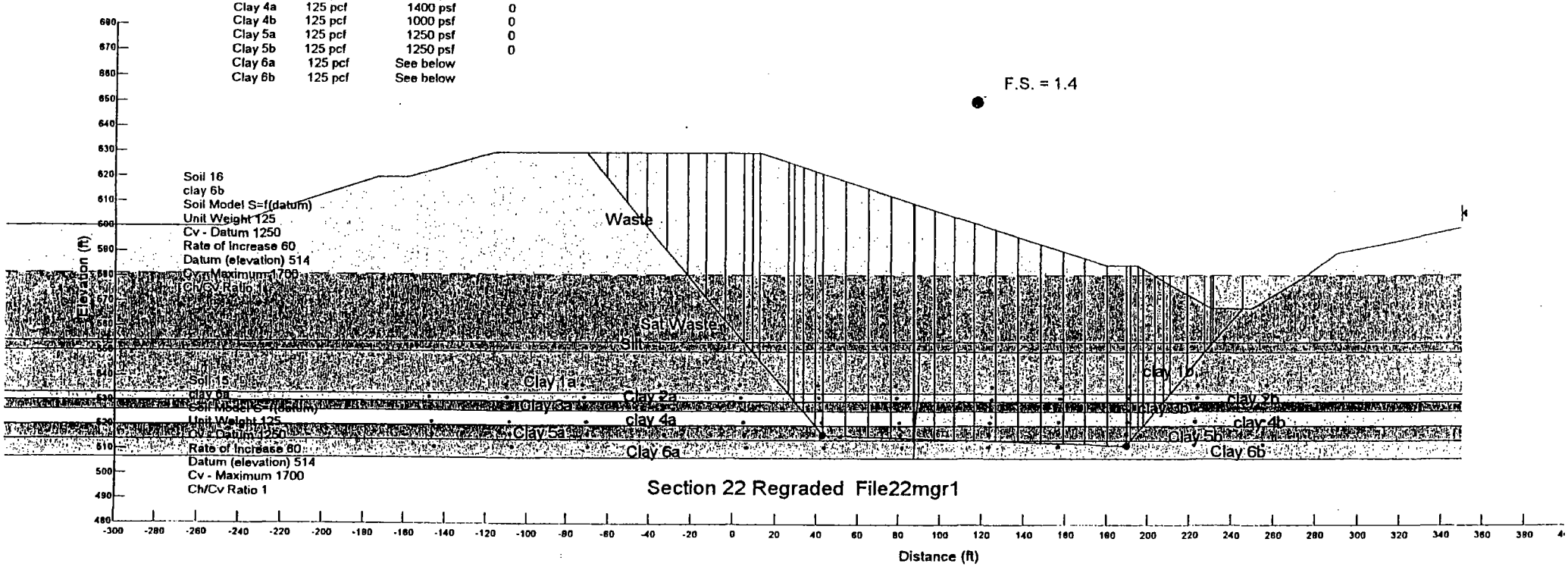


Section 22 Regraded File22mgr1

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See below	
Clay 6b	125 pcf	See below	

GAI Consultants
Project No. 97-481
2/5/99

Checked TRG 2-17-99

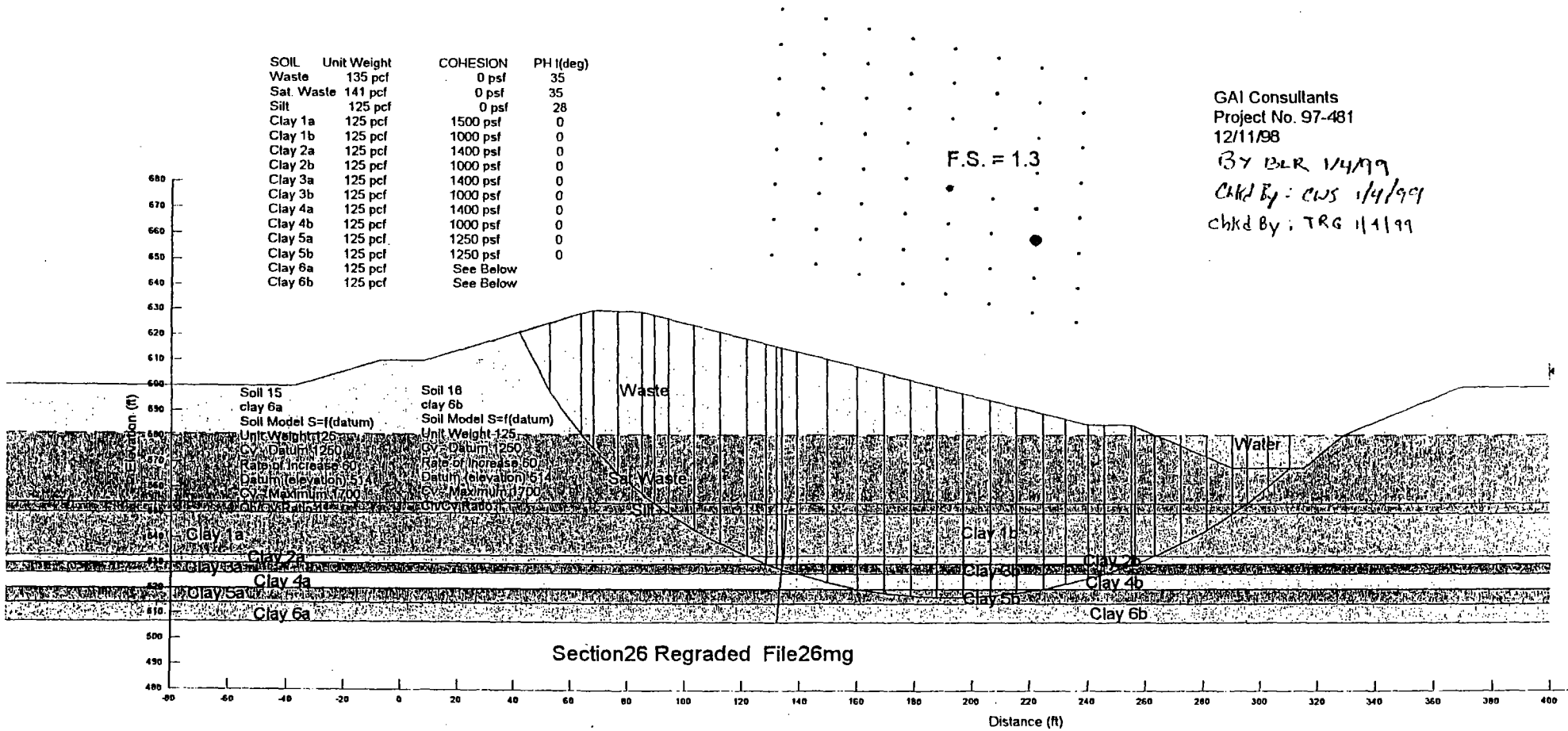


Section 22 Regraded File22mgr1

F-14

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

GAI Consultants
Project No. 97-481
12/11/98
BY BLR 1/4/99
Chkd By: CWS 1/4/99
chkd By: TRG 1/4/99

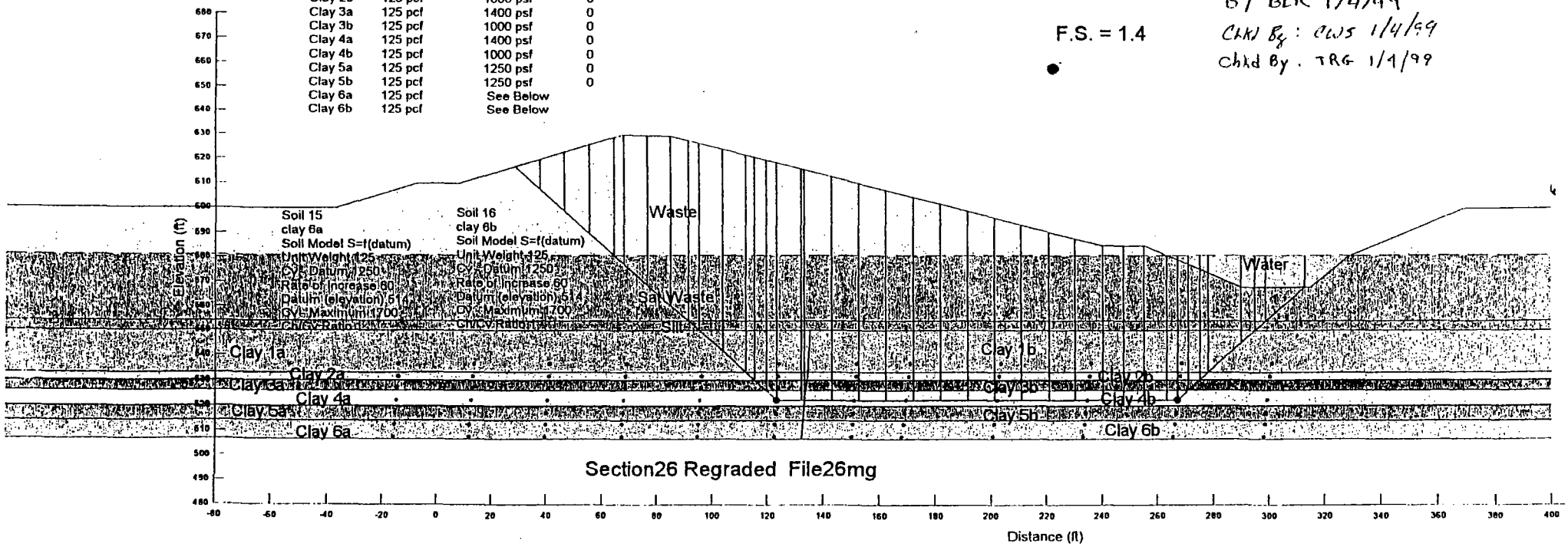


SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b	125 pcf	1000 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	1000 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	1000 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	125 pcf	1000 psf	0
Clay 5a	125 pcf	1250 psf	0
Clay 5b	125 pcf	1250 psf	0
Clay 6a	125 pcf	See Below	
Clay 6b	125 pcf	See Below	

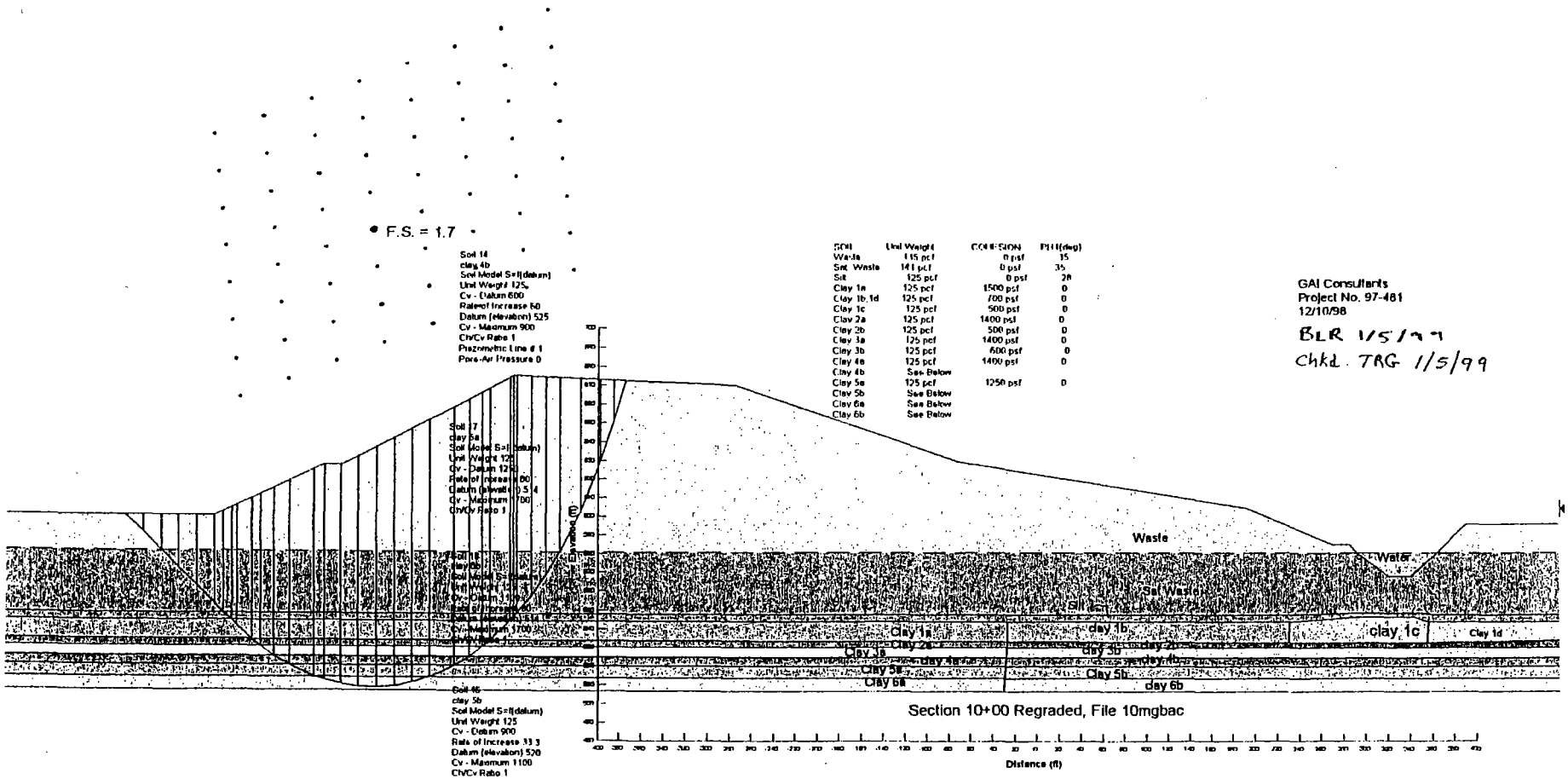
GAI Consultants
Project No. 97-481
12/11/98

By BLR 1/4/99
Chkd By: CWS 1/4/99
Chkd By. TRG 1/4/99

F.S. = 1.4



Section26 Regraded File26mg



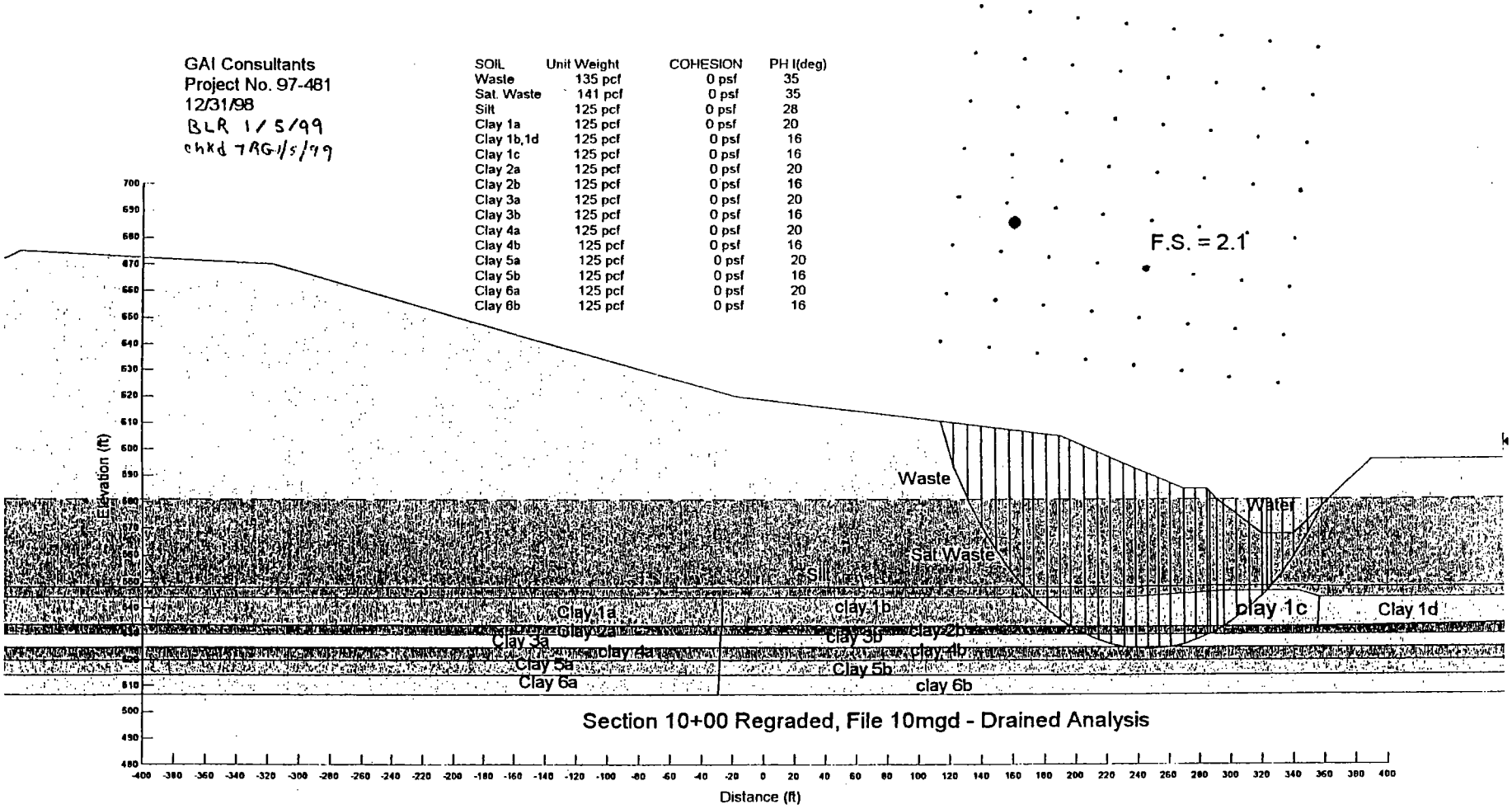
SOIL	Unit Weight	COHESION	PHI (deg)
Waste	115 pcf	0 psf	15
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

GAI Consultants
Project No. 97-481
12/10/98

BLR 1/5/99
Chkd. TRG 1/5/99

GAI Consultants
Project No. 97-481
12/31/98
BLR 1/5/99
chkd TRG 1/5/99

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	0 psf	20
Clay 1b,1d	125 pcf	0 psf	16
Clay 1c	125 pcf	0 psf	16
Clay 2a	125 pcf	0 psf	20
Clay 2b	125 pcf	0 psf	16
Clay 3a	125 pcf	0 psf	20
Clay 3b	125 pcf	0 psf	16
Clay 4a	125 pcf	0 psf	20
Clay 4b	125 pcf	0 psf	16
Clay 5a	125 pcf	0 psf	20
Clay 5b	125 pcf	0 psf	16
Clay 6a	125 pcf	0 psf	20
Clay 6b	125 pcf	0 psf	16



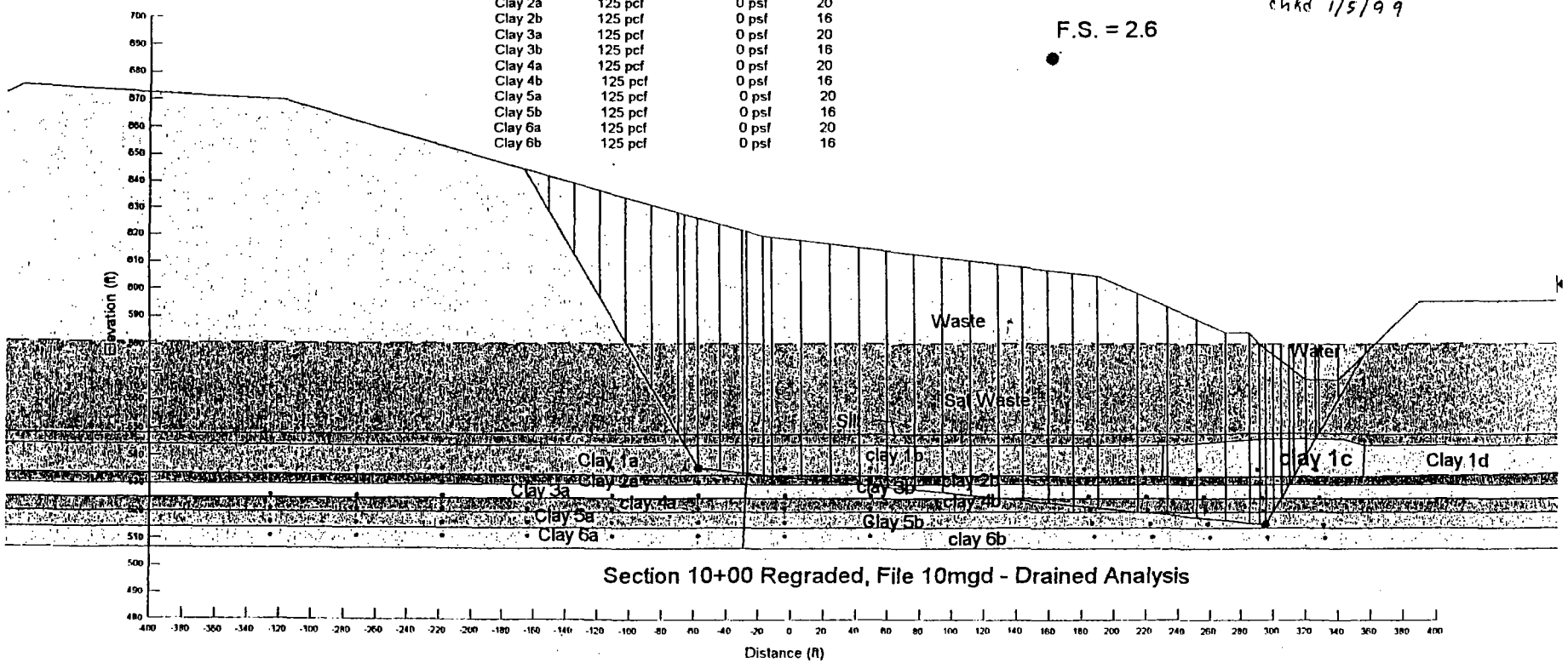
Section 10+00 Regraded, File 10mgd - Drained Analysis

T-10

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	0 psf	20
Clay 1b,1d	125 pcf	0 psf	16
Clay 1c	125 pcf	0 psf	16
Clay 2a	125 pcf	0 psf	20
Clay 2b	125 pcf	0 psf	16
Clay 3a	125 pcf	0 psf	20
Clay 3b	125 pcf	0 psf	16
Clay 4a	125 pcf	0 psf	20
Clay 4b	125 pcf	0 psf	16
Clay 5a	125 pcf	0 psf	20
Clay 5b	125 pcf	0 psf	16
Clay 6a	125 pcf	0 psf	20
Clay 6b	125 pcf	0 psf	16

GAI Consultants
Project No. 97-481
12/31/98
BLR 1/5/99
chkd 1/5/99

F.S. = 2.6

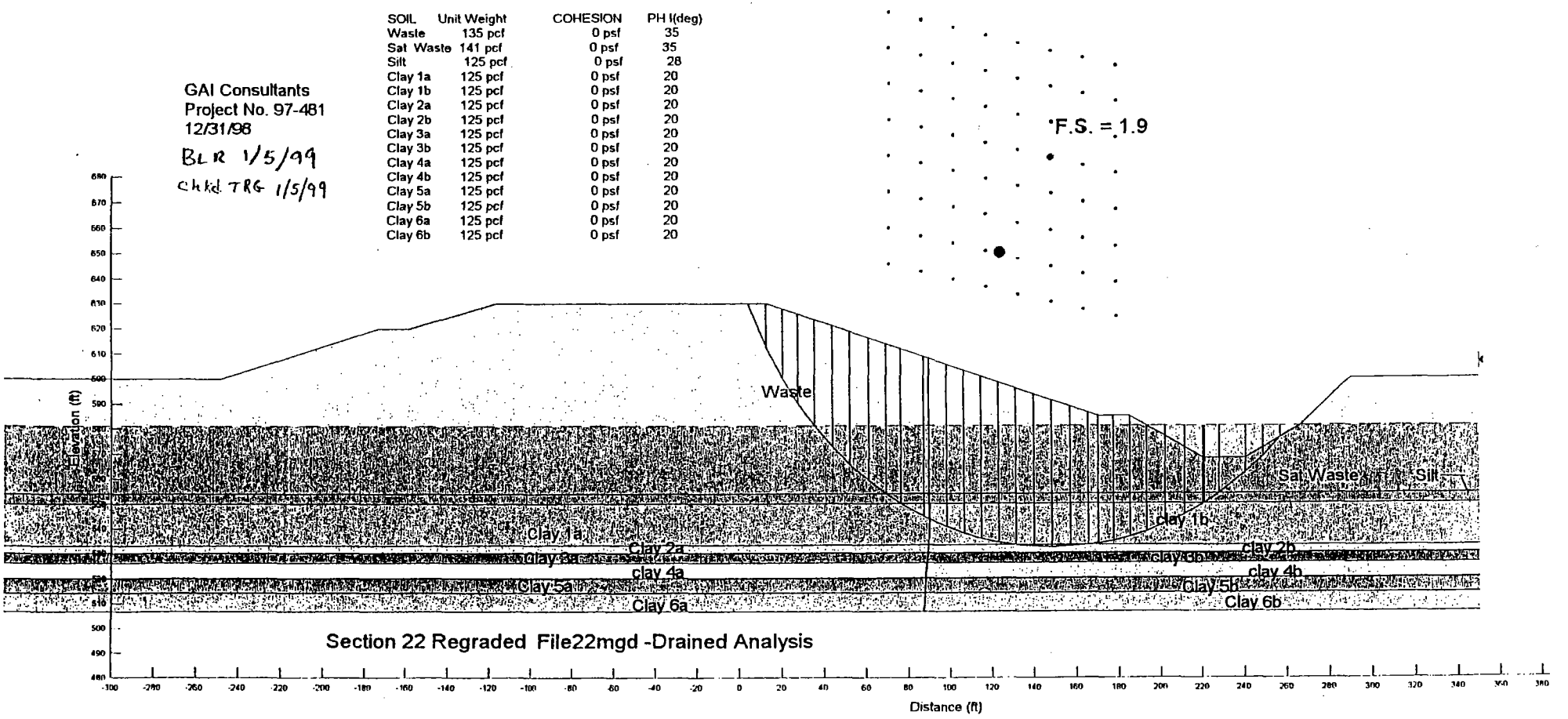


Section 10+00 Regraded, File 10mgd - Drained Analysis

GAI Consultants
Project No. 97-481
12/31/98

BLR 1/5/99
chkd TRG 1/5/99

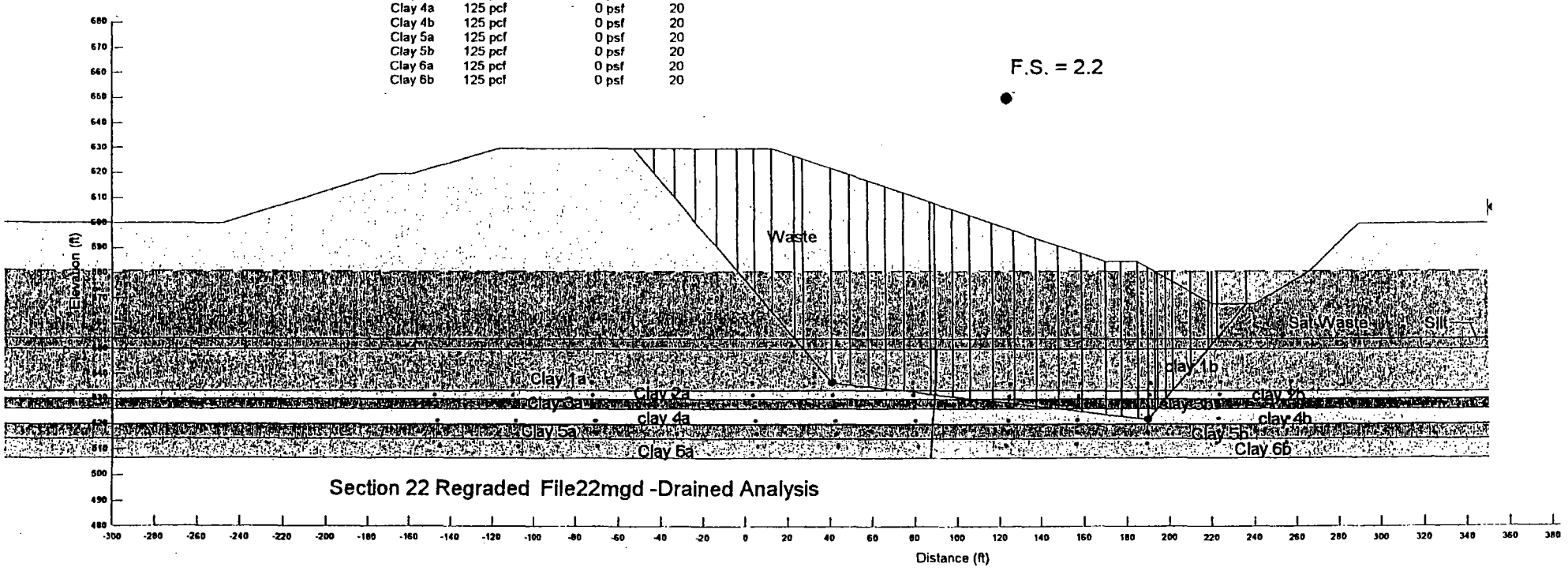
SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	0 psf	20
Clay 1b	125 pcf	0 psf	20
Clay 2a	125 pcf	0 psf	20
Clay 2b	125 pcf	0 psf	20
Clay 3a	125 pcf	0 psf	20
Clay 3b	125 pcf	0 psf	20
Clay 4a	125 pcf	0 psf	20
Clay 4b	125 pcf	0 psf	20
Clay 5a	125 pcf	0 psf	20
Clay 5b	125 pcf	0 psf	20
Clay 6a	125 pcf	0 psf	20
Clay 6b	125 pcf	0 psf	20



Section 22 Regraded File22mgd -Drained Analysis

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	0 psf	20
Clay 1b	125 pcf	0 psf	20
Clay 2a	125 pcf	0 psf	20
Clay 2b	125 pcf	0 psf	20
Clay 3a	125 pcf	0 psf	20
Clay 3b	125 pcf	0 psf	20
Clay 4a	125 pcf	0 psf	20
Clay 4b	125 pcf	0 psf	20
Clay 5a	125 pcf	0 psf	20
Clay 5b	125 pcf	0 psf	20
Clay 6a	125 pcf	0 psf	20
Clay 6b	125 pcf	0 psf	20

GAI Consultants
Project No. 97-481
12/31/98
BLR 1/5/99
CHKD. TRG 1/5/99

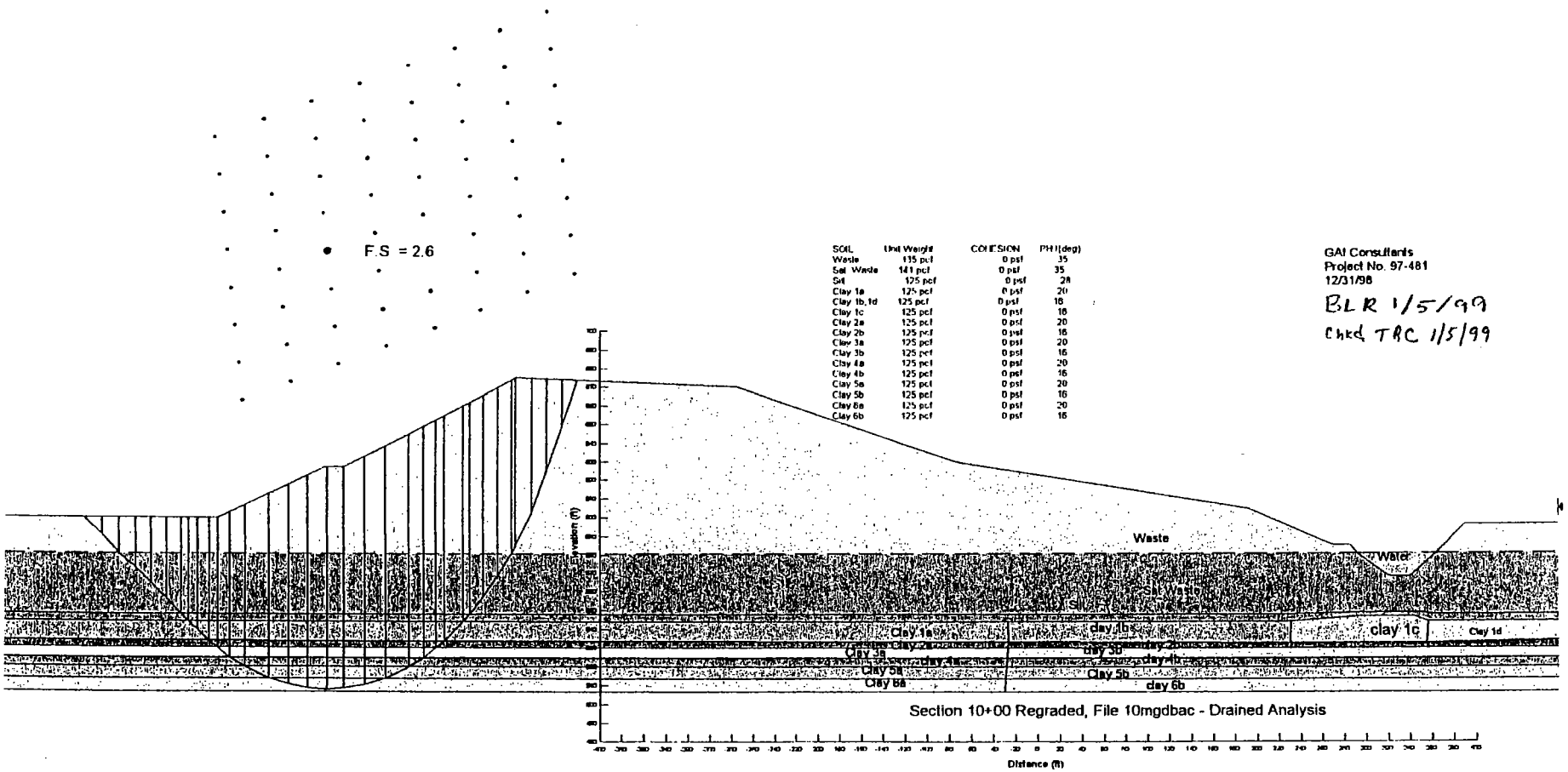


Section 22 Regraded File22mgd -Drained Analysis

F-21

SOIL	Unit Weight	COHESION	PHI (deg)
Waste	115 pcf	0 psf	35
Sat Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	0 psf	20
Clay 1b, 1d	125 pcf	0 psf	18
Clay 1c	125 pcf	0 psf	18
Clay 2a	125 pcf	0 psf	20
Clay 2b	125 pcf	0 psf	18
Clay 3a	125 pcf	0 psf	20
Clay 3b	125 pcf	0 psf	18
Clay 4a	125 pcf	0 psf	20
Clay 4b	125 pcf	0 psf	18
Clay 5a	125 pcf	0 psf	20
Clay 5b	125 pcf	0 psf	18
Clay 6a	125 pcf	0 psf	20
Clay 6b	125 pcf	0 psf	18

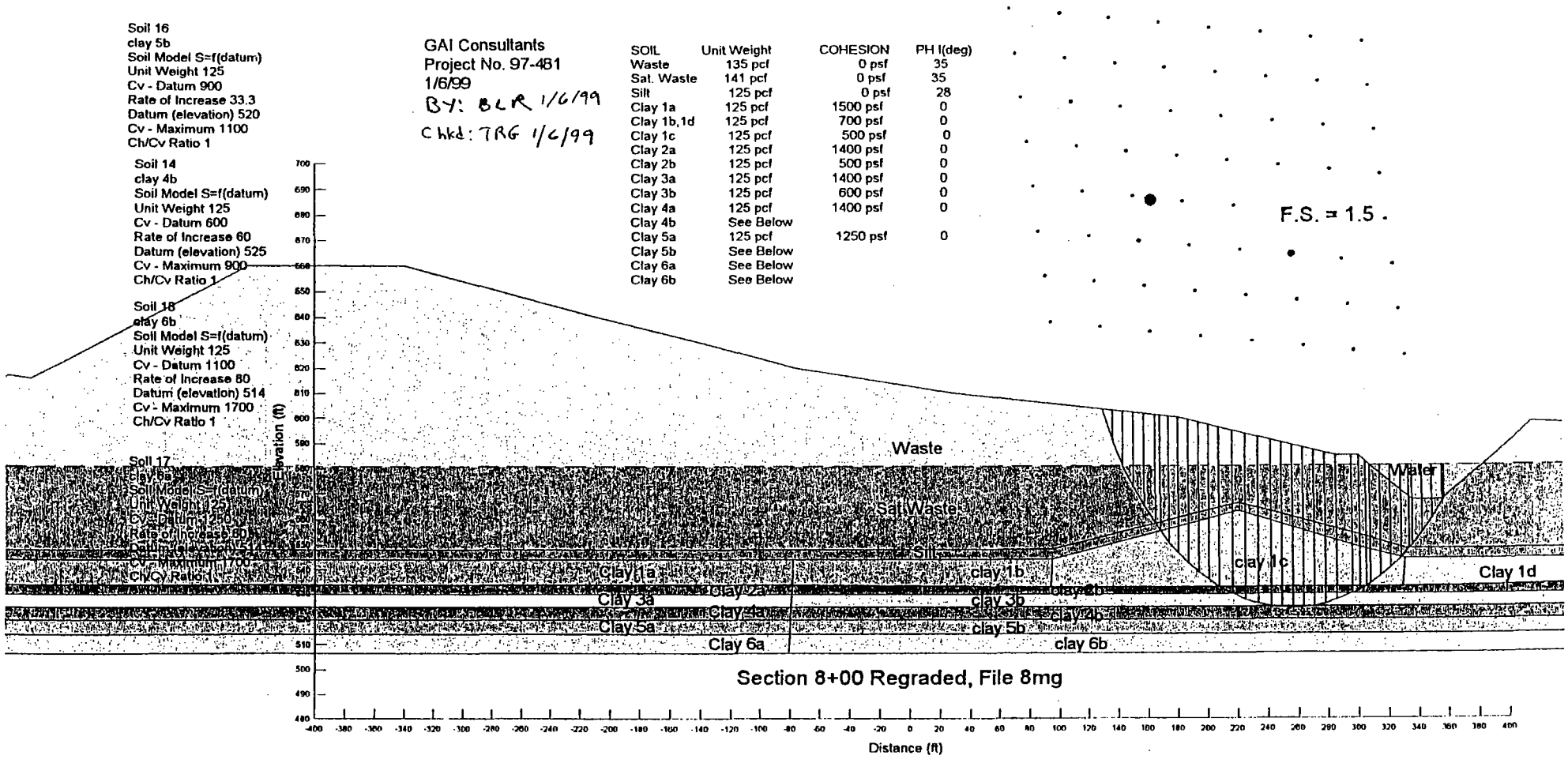
GAI Consultants
Project No. 97-481
12/31/98
BLR 1/5/99
Chkd TRC 1/5/99



Section 10+00 Regraded, File 10mgdbac - Drained Analysis

GAI Consultants
Project No. 97-481
1/6/99
BY: BLR 1/6/99
Chkd: TRG 1/6/99

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		



Soil 14
clay 4b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 600
Rate of Increase 60
Datum (elevation) 525
Cv - Maximum 900
Ch/Cv Ratio 1

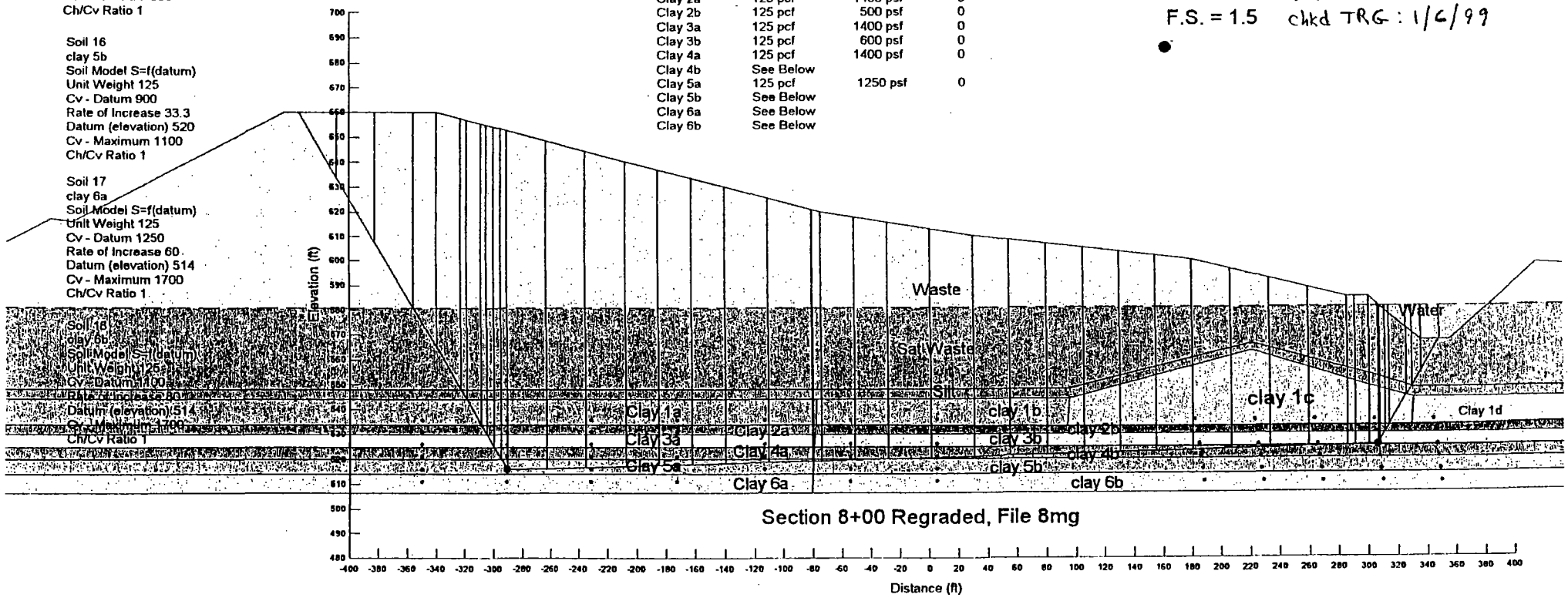
Soil 16
clay 5b
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 900
Rate of Increase 33.3
Datum (elevation) 520
Cv - Maximum 1100
Ch/Cv Ratio 1

Soil 17
clay 6a
Soil Model S=f(datum)
Unit Weight 125
Cv - Datum 1250
Rate of Increase 60
Datum (elevation) 514
Cv - Maximum 1700
Ch/Cv Ratio 1

SOIL	Unit Weight	COHESION	PH I(deg)
Waste	135 pcf	0 psf	35
Sat. Waste	141 pcf	0 psf	35
Silt	125 pcf	0 psf	28
Clay 1a	125 pcf	1500 psf	0
Clay 1b,1d	125 pcf	700 psf	0
Clay 1c	125 pcf	500 psf	0
Clay 2a	125 pcf	1400 psf	0
Clay 2b	125 pcf	500 psf	0
Clay 3a	125 pcf	1400 psf	0
Clay 3b	125 pcf	600 psf	0
Clay 4a	125 pcf	1400 psf	0
Clay 4b	See Below		
Clay 5a	125 pcf	1250 psf	0
Clay 5b	See Below		
Clay 6a	See Below		
Clay 6b	See Below		

GAI Consultants
Project No. 97-481
1/6/99
By BLK: 1/6/99
chkd TRG: 1/6/99

F.S. = 1.5



F-24

APPENDIX G

FLUME CALCULATIONS

Note: The calculations in Appendix G are based on the IGLD datum and show that the base of the intake flume should be no higher than elevation 568 feet (IGLD). The design drawings show the base of the flume to be elevation 568 feet (U.S.C. & G.S. datum) which equals 567.10 feet (IGLD). Therefore, the base of the flume shown on the drawings is 0.9 feet lower than required, and the channel has greater flow capacity than the calculations in Appendix G indicate.

SUBJECT LTV Steel Indiana Harbor Works
Clark Landfill Closure - Pumphouse No. 1 Channel

BY TNK DATE 6/24/98 PROJ. NO. 97-481-10
CHKD. BY KLC DATE 9.24.98 SHEET NO. 1 OF 8

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Determine: (1) Minimum channel dimensions to allow for the capability to withdraw 2 times design flow of 120,000 gpm, or 240,000 gpm.
(2) elevation limits for waste placement

References: (1) U.S. Army Corps of Engineers, Waterways Experiment Station, Monitoring Completed Navigation Projects Program, Burns Harbor, Indiana, Monitoring study, Volume 1: Overview of Approach and Results, by McGehee, D., et al Technical Report CHL-97-5, March 1997.

(2) Henderson, F.M., Open Channel Flow, MacMillan Publishing Co., New York, 1966.

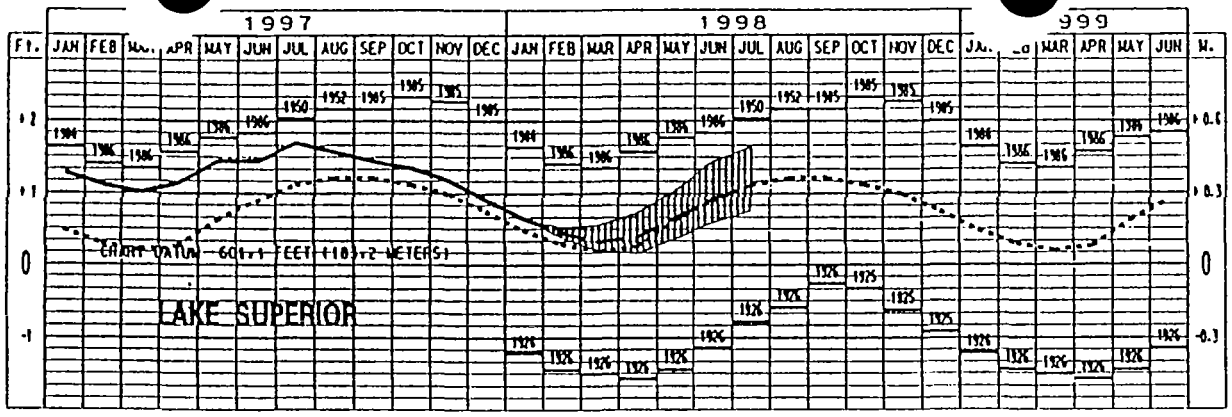
Lake Levels: from sheet 2, max. recorded level ~ +4.9' MLW (582.4)

min. recorded level ~ -1.3' MLW (576.2)

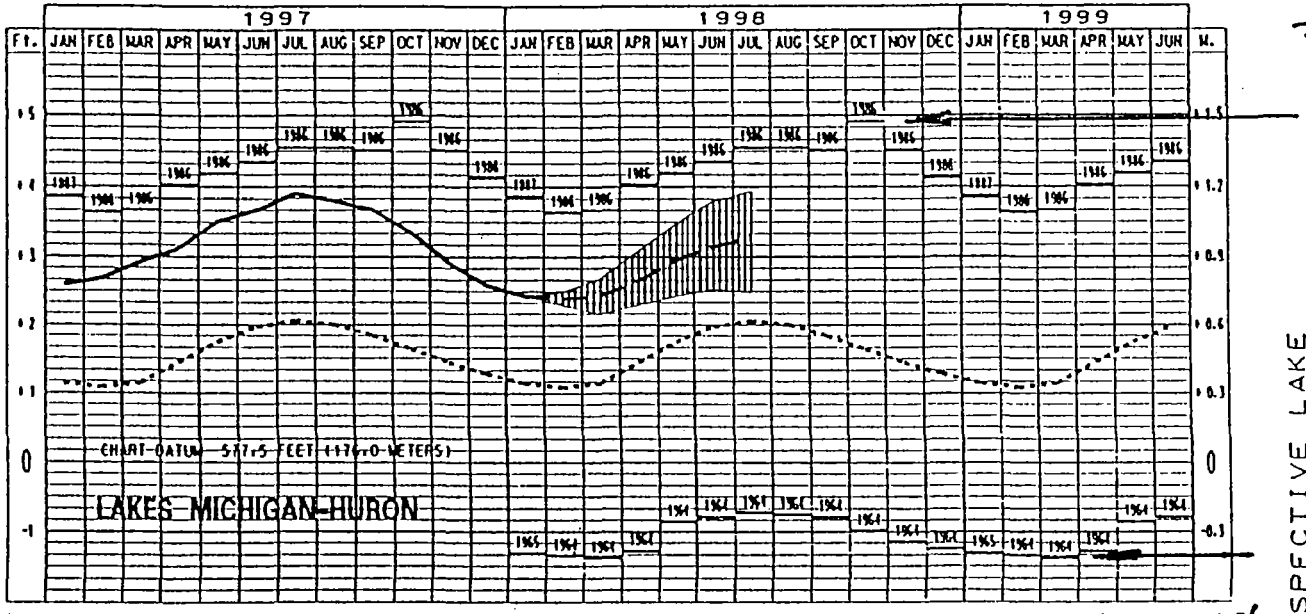
from sheet 3, 10-yr lake level ~ +5.2 MLW (582.7)

100-yr lake level ~ +6.7' MLW (584.2)

LWD = 0.0 = 577.5' (IGLD 1985)



MAX. RECORDED LAKE LEVEL ~ +4.9' MLW



MIN. RECORDED LAKE LEVEL ~ -1.3' MLW

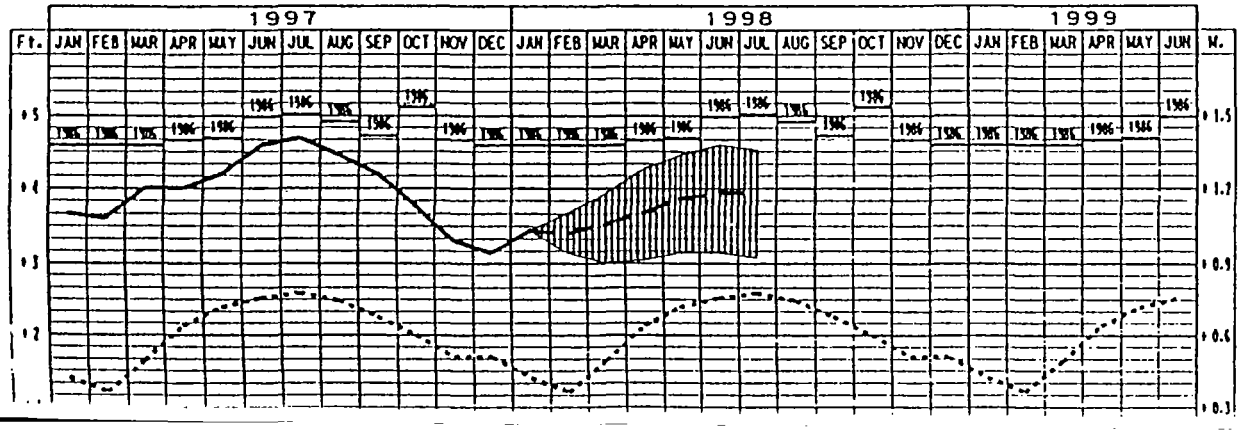


CHART DATUM OF EACH RESPECTIVE LAKE

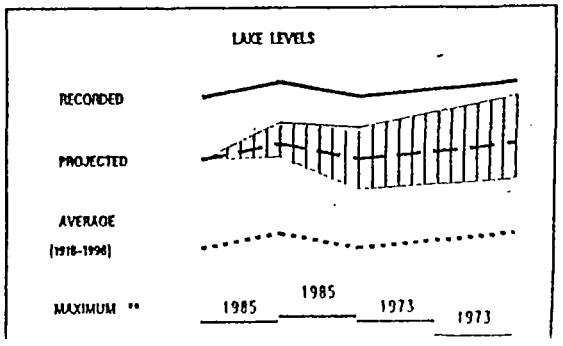
US Army Corps of Engineers
Detroit District

MONTHLY BULLETIN OF LAKE LEVELS FOR THE GREAT LAKES

FEBRUARY 1998

Water levels for the previous year and the current year to date are shown as a solid line on the lake hydrographs. A level projection for the next six months is given as a dashed line. This projection is based on the present condition of the lake basin and anticipated future weather conditions. In addition, the shaded area shows a range of levels that might occur over the next six months dependent upon weather variations. The current and projected levels (solid and dashed lines) can be compared with the 1918–1996 average levels (dotted line) and extreme levels (shown as bars with their year of occurrence). The legend below further identifies the information on the hydrographs.

LEGEND



LTY Steel - Indiana Harbor

Feb. 11 - 20, 10

TNK 6/24/98

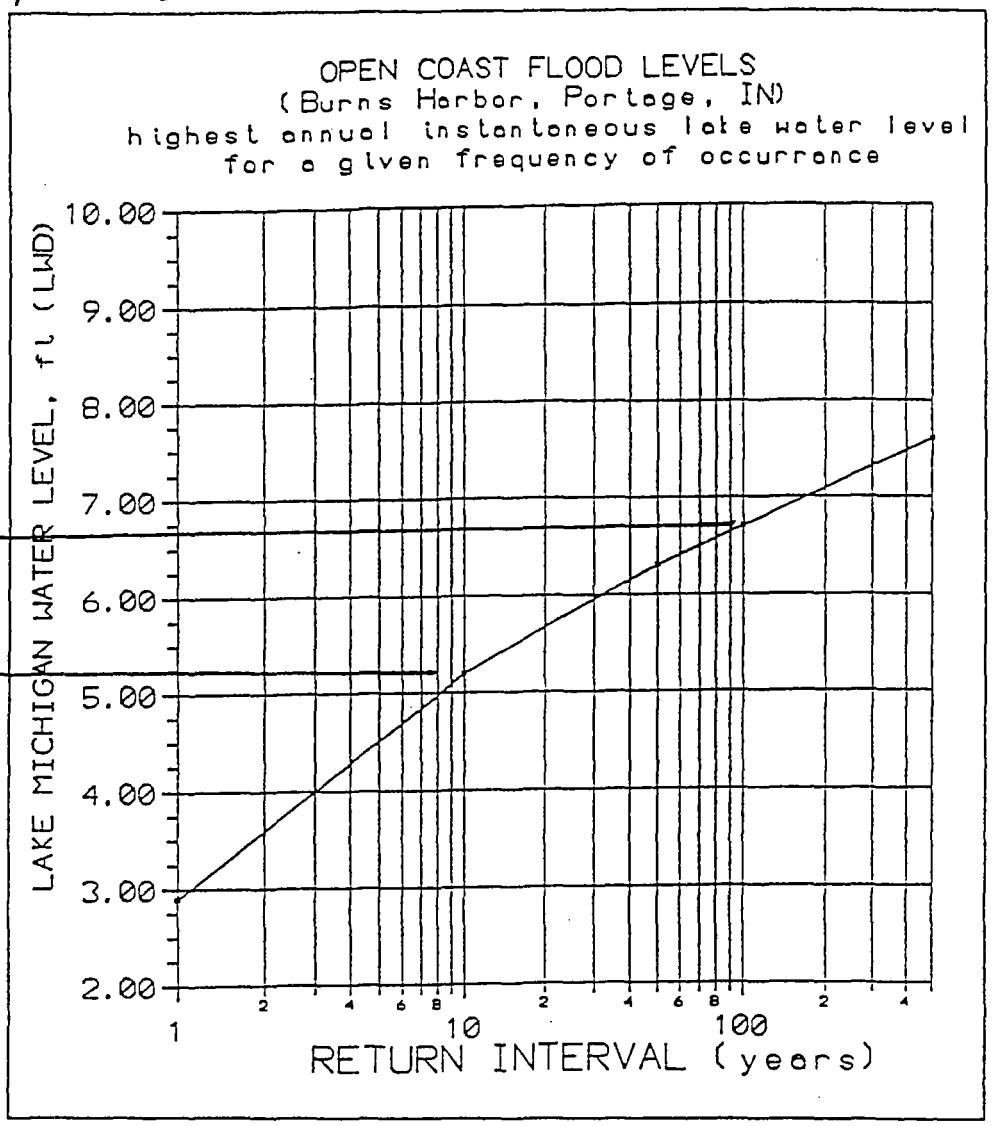
Sheet 2 of 18

G-2

LTV Steel - Indiana Harbor Proj. 97-481-10 G-3

THK 6/24/98 sheet 3 of 8

from: Reference (1)



100 YR ~ +6.7'

FOR 10-YR Elev ~ +5.2'

Figure 36. Return interval versus water level

SUBJECT LTV Steel Indiana Harbor Works
Clark Landfill

BY TNK DATE 6/25/98 PROJ. NO. 97-481-10
CHKD. BY KLF DATE 9-24-98 SHEET NO. 4 OF 8

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wave heights : Because of the location (the landfill is in an area protected by a breakwater, jetties, previously filled areas, existing buildings, etc.)*, the landfill would not be subject to direct attack from large wind waves from Lake Michigan. Relatively smaller waves (probably less than 1 foot wind waves and boat wakes) would reach the shoreline however.

* see following sheet

- If the regulations require 'waste' material to be above the 100-yr level, the limiting elevation would be ~ 585 feet
(100-yr lake level of 584.2 plus a small allowance for wave runup, boat wakes, etc.)

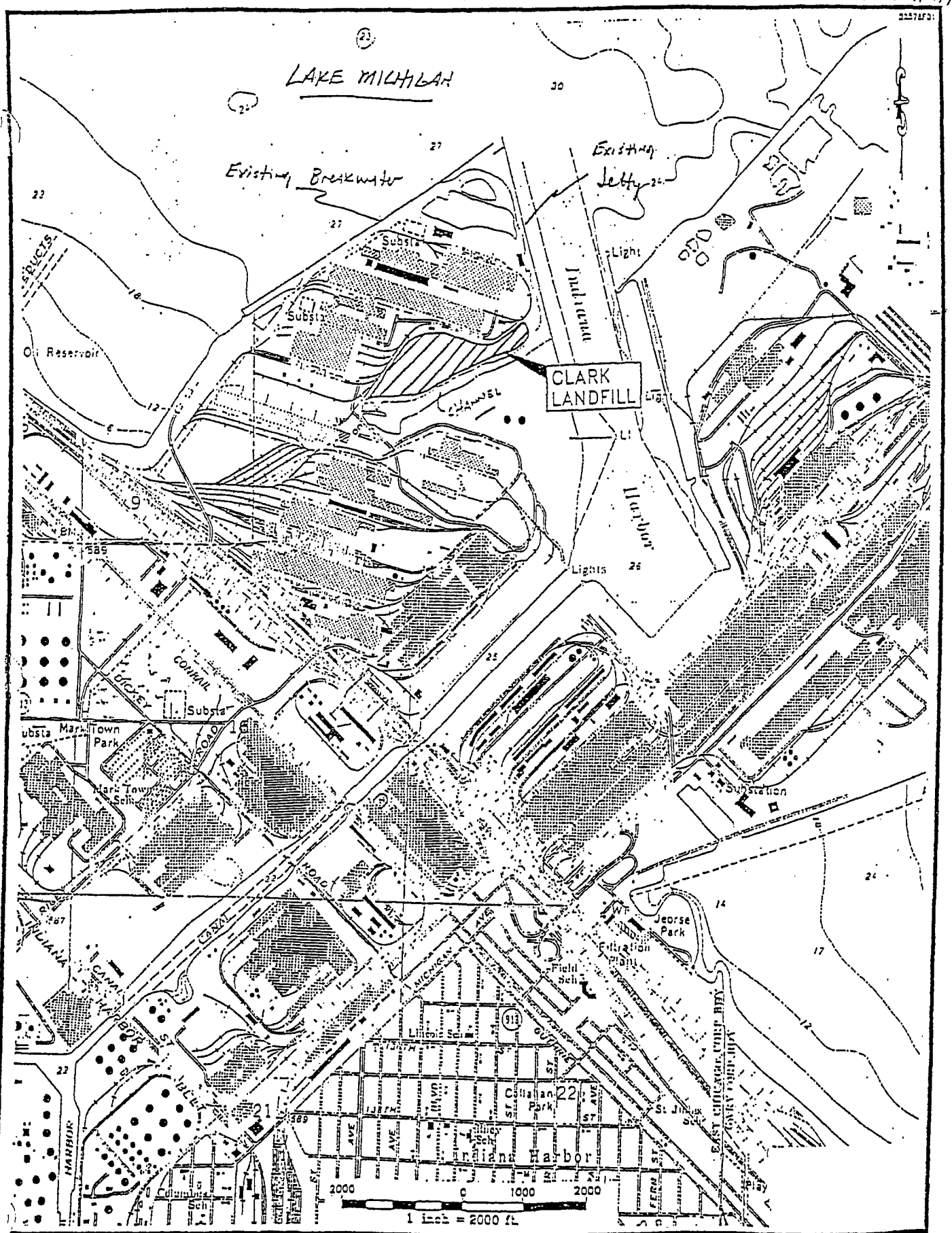
Intake Channel

- Assess as a 'forebay' problem, pp 321-323 of ref. (2)

for a simplified, rectangular channel:

$$Q_m = (8/27)\, b\, y_0 \sqrt{g y_0}$$

Q_m = max. rate (cfs) at which negative wave can withdraw water from delivery channel, without the need for storage
b = channel width (ft)
y_0 = initial channel depth (ft)



LTV STEEL COMPANY
CLARK LANDFILL

FIGURE 1
SITE LOCATION PLAN

SUBJECT LTV Steel Indiana Harbor Works
Clark Landfill

BY TMK DATE 9/17/98 PROJ. NO. 97-481-10
CHKD. BY KLF DATE 9.24.98 SHEET NO. 6 OF 8

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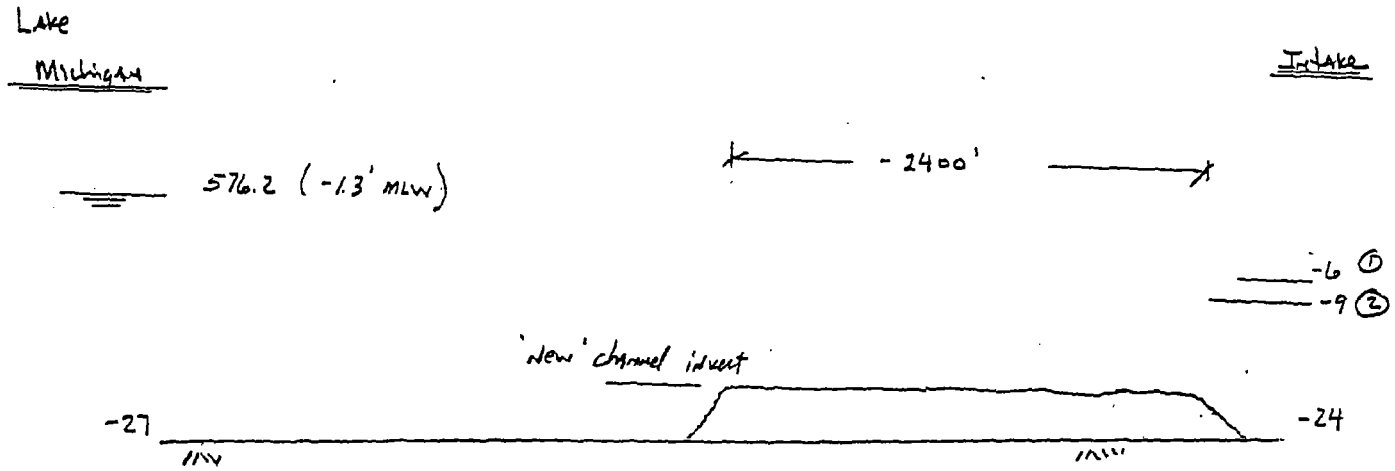
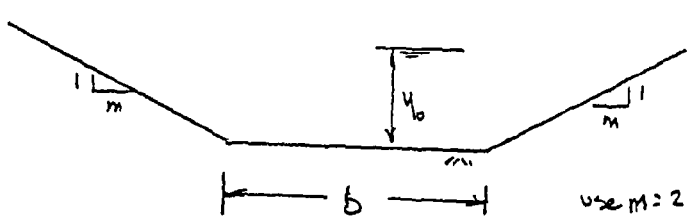
to assess minimum channel dimensions, perform a series of calculations using assumed channel dimensions → calculate capacities → then select appropriate channel dimensions

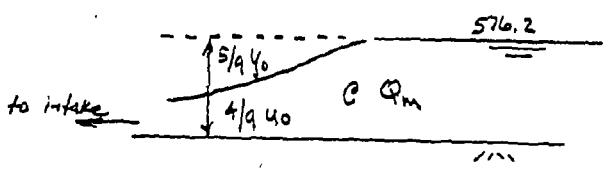
- use min. recorded lake level of 576.2 as lake level
- use Q_{design} = (2)(120,000 gpm) = 240,000 gpm = 535 cfs
- ref. dwg. 269855 supplied by LTV Steel
- schematic is shown below:



Schematic Profile
(N.T.S.)

From dwg 269855
① intake elev. for screen spray pump (-571.5)
② intake elev. for supply pumps (-568.5)





SUBJECT LTV Steel Indiana Harbor Works
Clark Landfill

BY THK DATE 9/17/98 PROJ. NO. 97-481-10
CHKD. BY KCC DATE 9.24.98 SHEET NO. 7 OF 8

576.2 - water level

> intake elev → Y
< intake elev → N

Channel Invert 570	y_o (ft)	channel invert + 4/9 y_o drawdown elev. (ft)	drawdown Acceptable?	Q_m (cfs)	(@ 535 cfs) Velocities (fps) 4/9 y_o	y_o
bottom width, b (ft)						
15	6.2	572.8	Y	389 < 535	∴ No good	
20	6.2	572.8	Y	519 < 535	∴ No good	
25	6.2	572.8	Y	649 > 535	∴ O.K. min. width at 570 is 25'	
			(for trapezoidal section)		6.4*	2.3

Channel Invert 568						
15	8.2	571.6	would be close for smaller pump - o.k. for larger	592 > 535	∴ O.K.	
					6.6*	2.1
20	8.2	571.6	"	790 > 535	∴ O.K.	
					5.4*	1.8

Channel Invert 566						
15	10.2	570.5	N - small pump Y - larger pump	821 > 535	∴ O.K.	
					4.9*	1.5

* Velocities would actually be somewhat lower since calculation is for 535 cfs at 4/9 y_o, with y_o corresponding to Q_m > 535 cfs

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G-7

SUBJECT LTV Steel Indiana Harbor Works
Clark Landfill

BY THIC DATE 9/22/98 PROJ. NO. 97-481-10

CHKD. BY KLF DATE 9.24.98 SHEET NO. 8 OF 8

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Summary

- the previous calculations were performed assuming a rectangular channel section, the min. recorded lake level, and a flowrate of two (2) times the pump capacity. Maintaining this level of reliability, we suggest the following min. channel sections:

channel invert	min. channel bottom width (ft) (trap. section)
570	25
568	20
566	15

SUBJECT LTV Steel - Indiana Harbor Works
Pumphouse No. 2 Channel

BY THK DATE 12/31/98 PROJ. NO. 97-481-10
CHKD. BY JDP DATE 1/5/99 SHEET NO. 1 OF 1

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- Will proposed channel dimensions allow for an additional 50,000 gpm withdrawal for a co-gen plant?

  - discharge = 120,000 + 50,000 = 170,000 gpm
  - trap.-shaped channel (2H:1V ss)

	invert elev (ft)	bottom width (ft), b	Q_m (cfs)	F.S.
(see previous THK calculations dated 9/11/98)	570	25	649	1.7
	568	20	790	2.1

$$Q_m = (8/27)(b)\, y_0 \sqrt{g\, y_0}$$

y_0 = initial channel depth (Assume min. new-det lake level of 576.2)

$$F.S. = \frac{Q_m}{(120{,}000) + (50{,}000)} = \frac{Q_m}{379 \text{ cfs}}$$

- Considering that the above calculations are for a rectangular channel section (a trapezoidal-shaped section would have more capacity), an additional withdrawal of 50,000 gpm would not adversely affect the capability of the proposed flume (min. dimensions as above) to deliver water. Would still have a F.S. approaching 2

SUBJECT: LTV
INDIANA HARBOR WORKS

BY: VAB DATE: 2/11/99 PROJ. NO. 97-431-10
CHKD. BY: SE DATE: 2/12/99 SHEET NO. 1 OF 10

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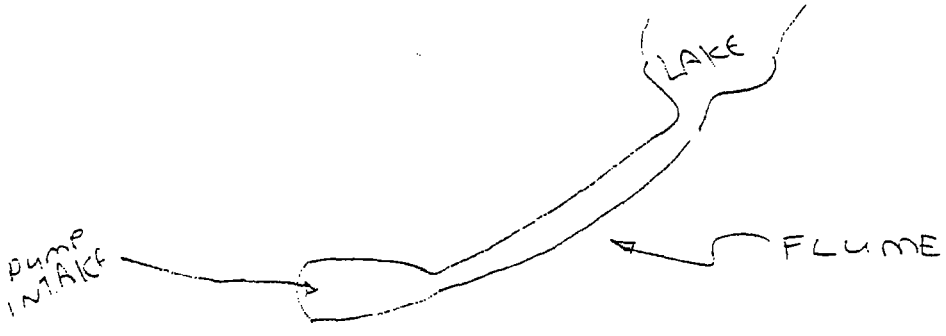
FLUME

A FLUME IS LOCATED BETWEEN THE PUMPHOUSE INTAKE AND INDIANA HARBOR OF LAKE MICHIGAN, AND WILL SUPPLY WATER TO THE INTAKE FROM THE LAKE. THE FLUME WILL BE REDUCED IN CROSS SECTION TO THAT SHOWN ON SHEET 3.

PROVIDE A WATER SURFACE PROFILE FOR THE FLUME.



THE TOTAL LENGTH FROM THE LAKE TO THE PUMP IS ≈ 3000' (LENGTH TO FOREBAY, OR INTAKE BASIN, IS ≈ 2450')
[REFERENCE DRAWING 559 883]

THE DESIGN FLOW TO BE PASSED BY THE FLUME IS 340,000 gpm (760 cfs). THE WATER SURFACE ELEVATION WILL BE CONTROLLED BY THE LAKE. THE MINIMUM RECORDED LAKE ELEVATION WILL BE USED — THIS YIELDS THE MOST CONSERVATIVE ANALYSIS

STARTING LAKE WATER SURFACE ELEVATION = 575.95
(SEE NEXT PAGE)

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.

Table 1
LTV INDIANA HARBOR DATUM CONVERSIONS
Clark Landfill
LTV STeel Indiana Harbor Works

SELECTED ELEVATION	U.S.C.&G.S. 1929 DATUM		LTV PLANT DATUM		I.G.L.D. 1985 DATUM
GENERAL PLANT GRADE	**600.00**	=	21.14	=	599.09
LTV DATUM REFERENCE	578.86	=	**0.00**	=	577.95
MAX. RECORDED LAKE ELEV. *	583.26	=	4.40	=	**582.35**
MIN. RECORDED LAKE ELEV. **	576.86	=	-2.00	=	**575.95**
NEW FLUME BOTTOM	**568.00**	=	-10.86	=	567.10
I.G.L.D. DATUM REFERENCE ***	0.91	=	-577.95	=	**0.00**

* Maximum monthly mean water level recorded at Calumet Harbor Station, Oct 1986

** Minimum monthly mean water level recorded at Calumet Harbor Station, Feb 1964

*** Correction between 1929 U.S.C.&G.S. (NGVD) AND 1985 I.G.L.D. at Indiana Harbor Station, Bench Mark H 18

U.S.C.&G.S. - United States Cost & Geodetic Survey
I.G.L.D. - International Great Lakes Datum

SUBJECT LTV
INDIANA HARBOR WORKS
BY KMR DATE 2/11/99 PROJ. NO. 97-481-10
CHKD. BY SFR DATE 2/16/99 SHEET NO. 3 OF 10

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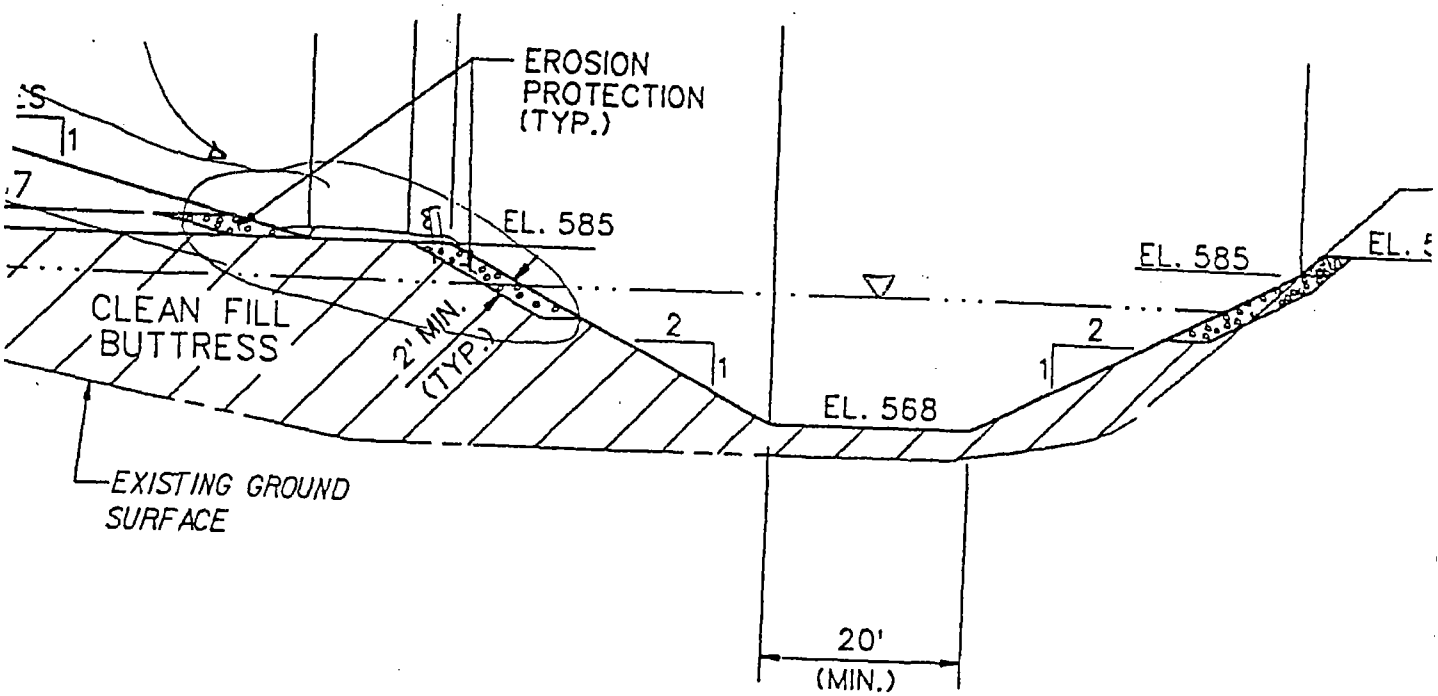
FLUME CONTINUED

THE FLUME GEOMETRY WILL BE CONSTANT FROM THE LAKE UNTIL THE FOREBAY. DO NOT CONSIDER THE FOREBAY IN THE ANALYSIS — USE 3000 FEET OF FLUME CHANNEL (THIS WILL PRODUCE A MORE CONSERVATIVE ANALYSIS). THE GEOMETRY IS SHOWN BELOW:



HEC-RAS WILL BE USED TO ANALYZE THE WATER SURFACE PROFILE. FOR THE COMPUTER MODELLING, USE THE FOLLOWING COORDINATES

POINT	HORIZONTAL	VERTICAL
LEFT EDGE	0	585
LEFT INVERT	34	568
RIGHT INVERT	54	568
RIGHT EDGE	88	585

SUBJECT LTV
INDIANA HARBOR WORKS

BY KMR DATE 2/11/99 PROJ. NO. 97-43-10
CHKD. BY [illegible] DATE 3/16/99 SHEET NO. 4 OF 10

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FLUME CONTINUED

SINCE THE FLUME GEOMETRY DOES NOT CHANGE (THERE IS NO SLOPE) USE THE SAME SECTION DATA THROUGHOUT THE REACH.

MANNING'S n

THE FLUME IS COMPOSED OF / LINED WITH CRUSHER RUN WHICH CONSISTS OF STONES OF 6" DIAMETER OR SMALLER. FOR THIS STONE SIZE, IN CONJUNCTION WITH ≈ 8' DEEP WATER AND A VERY WIDE (20' BOTTOM WIDTH) CHANNEL, USE A MANNING'S n VALUE OF 0.025

CHKD BY JTR 2/16/99

```
                    HEC-RAS Version 1.1 January 1996
                      U.S. Army Corp of Engineers
                     Hydrologic Engineering Center
                       609 Second Street, Suite D
                      Davis, California 95616-4687
                            (916) 756-1104

          X     X  XXXXXX    XXXX        XXXX        XX      XXXX
          X     X  X        X    X       X   X      X  X    X
          X     X  X        X            X   X     X    X   X
          XXXXXXX  XXXX     X       XXX  XXXX      XXXXXX    XXXX
          X     X  X        X            X  X      X    X        X
          X     X  X        X    X       X   X     X    X        X
          X     X  XXXXXX    XXXX        X    X    X    X   XXXXX

*****************************************************************************

PROJECT DATA
Project Title: LTV Indiana Harbor Works
Project File : ltvinhbr.prj
Run Date and Time: 2/11/99 3:53:14 PM

Project in English units

*****************************************************************************

PLAN DATA

Plan Title: Plan 01
Plan File : c:\hec\ras\ltvinhbr.p01

          Geometry Title: Plan 01
          Geometry File : c:\hec\ras\ltvinhbr.p01

          Flow Title    : Plan 01
          Flow File     : c:\hec\ras\ltvinhbr.p01

Plan Summary Information:
Number of:  Cross Sections =    3    Mulitple Openings =    0
            Culverts       =    0    Inline Weirs      =    0
            Bridges        =    0

Computational Information
    Water surface calculation tolerance =  .01
    Critical depth calculaton tolerance =  .01
    Maximum number of interations       =  20
    Maximum difference tolerance        =  .3
    Flow tolerance factor               =  .001
```

5/5 G-14

Computational Flow Regime: Subcritical Flow

Encroachment Data: None

Flow Distribution Locations: None

****

FLOW DATA

Flow Title: LTV Indiana Harbor Works
Flow File : c:\hec\ras\ltvinhbr.f01

Flow Data (cfs)

Reach	Riv Sta	PF#1
Flume	3	760

Boundary Conditions

Reach	Profile	Upstream	Downstream
Flume	1		Known WS = 575

****

GEOMETRY DATA

Geometry Title: LTV Indiana Harbor Works
Geometry File : c:\hec\ras\ltvinhbr.g01

CROSS SECTION INPUT Reach: Flume River Station: 3
Description: Lake Michigan (Elevation Data is IGLD)

Station Elevation Data, num = 4

Sta.	Elev.	Sta.	Elev.	Sta.	Elev.	Sta.	Elev.
0	585	34	568	54	568	88	585

Manning's n Values, num = 3

Sta.	Value	Sta.	Value	Sta.	Value
0	.025	0	.025	88	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	88	3000	3000	3000	.1	.3

CROSS SECTION INPUT Reach: Flume River Station: 1
Description: Pump Intake (Elevation Data is IGLD)

Station Elevation Data, num = 4

Sta.	Elev.	Sta.	Elev.	Sta.	Elev.	Sta.	Elev.
0	585	34	568	54	568	88	585

Manning's n Values, num = 3

Sta.	Value	Sta.	Value	Sta.	Value
0	.025	0	.025	88	.025

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
0	88	0	0	0	.1	.3

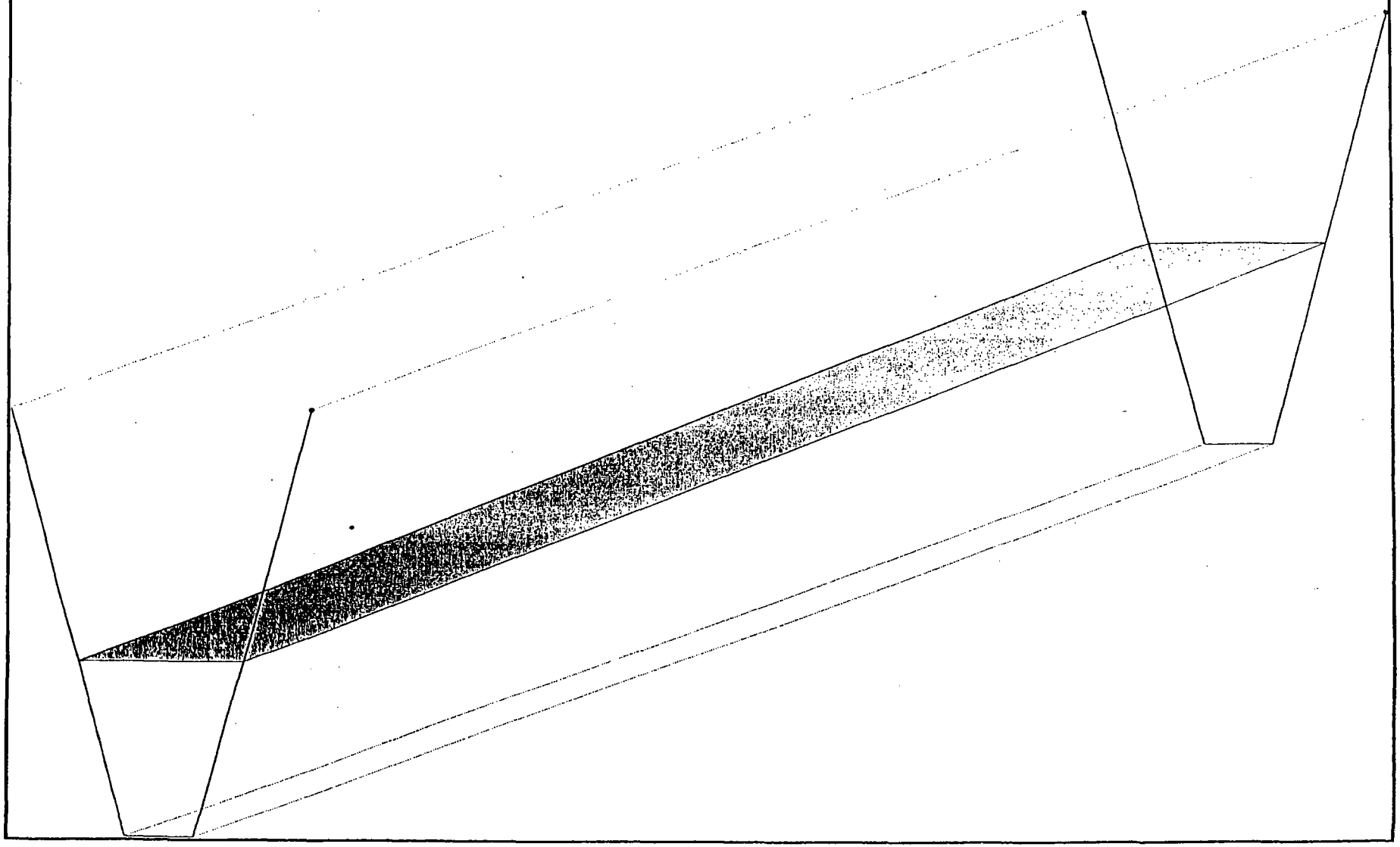
Profile Output Table - Standard Table 1

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	760.00	568.00	575.92		576.03	0.000230	2.68	283.77	51.67	0.20
1	760.00	568.00	575.00	571.17	575.16	0.000373	3.19	238.00	48.00	0.25

Profile Output Table - Standard Table 2

River Sta.	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
3	576.03	575.92	0.11	0.87	0.00		760.00		51.67
1	575.16	575.00	0.16	0.00	0.00		760.00		48.00

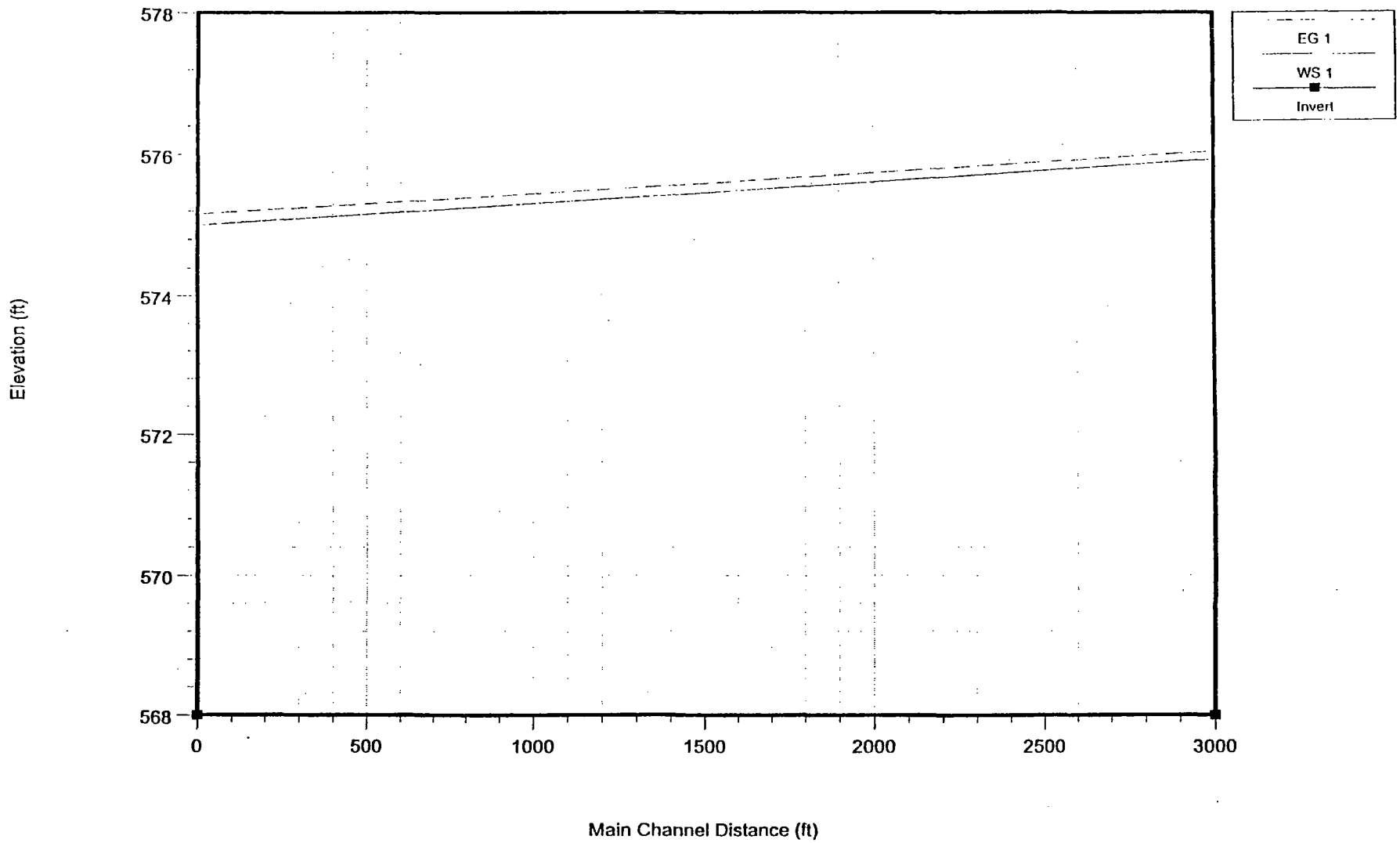
LTV Indiana Harbor Works
Riv Sta = 3 to 1 PF#: 1 Revised Project-Profile



HEC-RAS Plan: Plan 01 Reach: Flume 2/11/99

River Sta.	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
3	760.00	568.00	575.92		576.03	0.000230	2.68	283.77	51.67	0.20
1	760.00	568.00	575.00	571.17	575.16	0.000373	3.19	238.00	48.00	0.25

LTV Indiana Harbor Works
Revised Project-Profile



APPENDIX H

SURFACE DRAINAGE CALCULATIONS

SUBJECT

BY DATE PROJ. NO.

CHKD. BY DATE SHEET NO. 2 OF

GSI CONSULTANTS, INC.
Engineers • Geologists • Planners
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SURFACE DRAINAGE CALCULATIONS

DESCRIPTION	SHEET
HYDROLOGY AND HYDRAULICS	H-1
HYDROLOGY (PIPES)	H-1
HYDRAULICS (PIPES)	H-10
DEPTHS OF FLOW IN STONE	H-12
FLOW IN R-3 RIPRAP AT EDGE OF FLUME	H-15
POND HYDROLOGY	H-16
POND HYDRAULICS (DEWATERING)	H-17
HYDROLOGY SCHEMATIC	H-25
REFERENCES	H-26
HYDROLOGY AND HYDRAULICS WORKSHEET	H-37
THRUST BLOCK FORCE	H-38
THRUST BLOCK DESIGN	H-41
RISER BOUYANCY	H-43

SUBJECT LTV STEEL EAST CHICAGO
CLARK LANDFILL

BY SER DATE 12/11/98 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 1/4/99 SHEET NO. 1 OF 24

REV. BY SER 2/17/99 REV. BY SER 7/21/99
V KMB 4/8/99

GAI CONSULTANTS, INC.
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HYDROLOGY AND HYDRAULICS

PURPOSE:

DESIGN DRAINAGE FOR PROPOSED REGRADED AND CAPPED CLARK LANDFILL. SEE ATTACHED DRAWINGS FOR PLAN AND DETAILS.

HYDROLOGY

ESTIMATE PEAK FLOWS USING THE RATIONAL FORMULA. RATIONAL METHOD IS A GENERALLY ACCEPTED METHOD FOR SMALL WATERSHEDS ($< 2\ MI^2$)

$Q = CiA$

C = COEFFICIENT OF RUNOFF = 0.95 ASSUMED SIMILAR TO WATERTIGHT ROOF SEE SHEET 2

i = INTENSITY (INCHES/HOUR)
USE IDF CHART FOR CHICAGO SEE SH. 8

A = DRAINAGE AREA, ACRES

Q = PEAK FLOW, CFS

INTENSITY IS DEPENDENT ON DURATION
ASSUME DURATION = TIME-OF-CONCENTRATION = t_c

ESTIMATE t_c

FOR FLOW THROUGH STONE COVER OF CAP AND FLOW IN PIPE NETWORK

USE TR-55 METHODS FOR ESTIMATING TIME-OF-CONCENTRATION/TIME-OF-TRAVEL IN PIPES

Appendix A: Rational Method Runoff Coefficients

categorized by surface	
forested	0.059–0.2
asphalt	0.7–0.95
brick	0.7–0.85
concrete	0.8–0.95
shingle roof	0.75–0.95
lawns, well drained (sandy soil)	
up to 2% slope	0.05–0.1
2% to 7% slope	0.10–0.15
over 7% slope	0.15–0.2
lawns, poor drainage (clay soil)	
up to 2% slope	0.13–0.17
2% to 7% slope	0.18–0.22
over 7% slope	0.25–0.35
driveways, walkways	0.75–0.85

categorized by use	
farmland	0.05–0.3
pasture	0.05–0.3
unimproved	0.1–0.3
parks	0.1–0.25
cemeteries	0.1–0.25
railroad yard	0.2–0.40
playgrounds (except asphalt or concrete)	0.2–0.35
business districts	
neighborhood	0.5–0.7
city (downtown)	0.7–0.95
residential	
single family	0.3–0.5
multi-plexes, detached	0.4–0.6
multi-plexes, attached	0.6–0.75
suburban	0.25–0.4
apartments, condominiums	0.5–0.7
industrial	
light	0.5–0.8
heavy	0.6–0.9

SUBJECT LTV STEEL EAST CHICAGO

BY SER DATE 12/11/98 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 1/4/99 SHEET NO. 3 OF 24

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t_c IN STONE

REF ARTICLE BY ABT, ROFF AND WITTLER ATTACHED

$$V_i = 0.23 \sqrt{g D_{10} S}$$

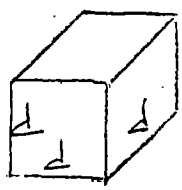
V_i = INTERSTITIAL VELOCITY, FPS

D_{10} ~ DIA. OF STONE 10% PASSES THIS SIZE SCREEN (INCHES)

S = SLOPE FT/FT

ESTIMATE V_A = AVERAGE VELOCITY

FOR A CUBE WITH SIDE EQUAL TO d



V_T = TOTAL VOLUME = d^3

$V_V + V_S = V_T$

$e = V_V / V_S$ = VOLUME OF VOIDS / VOLUME OF SOLIDS

$V_V = e V_S$

$V_S = \frac{V_V}{e}$

$V_T = d^3 = V_V + \frac{V_V}{e} = \left(1 + \frac{1}{e}\right) V_V$

$d^3 = \left(1 + \frac{1}{e}\right) V_V$

$V_V \approx A_V \cdot d$ WITH A_V = CROSS SECTIONAL AREA OF VOIDS (⊥ TO FLOW)

$d^3 = \left(1 + \frac{1}{e}\right) A_V d$

$d^2 = \left(1 + \frac{1}{e}\right) A_V$

SUBJECT LTV STEEL EAST CHICAGO

BY SER DATE 12/11/98 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 1/4/99 SHEET NO. 4 OF 24

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$Q = A_V \cdot V_i$ V_i = INTERSTITIAL VELOCITY

$Q = A_T \cdot V_A$ V_A = AVERAGE VELOCITY
A_T = TOTAL AREA = d^2

$$Q = d^2 \cdot V_A = A_V \cdot V_i$$

$$V_A = \frac{A_V \cdot V_i}{d^2}$$

$$A_V = \frac{d^2}{(1 + 1/e)}$$

$$V_A = \frac{V_i}{(1 + 1/e)}$$

ASSUME $e \doteq 0.85$ FROM FBN LOOSE $e = 1.0$
COMPACT $e = 0.7$
USE AVERAGE

$$V_A = \frac{V_i}{1 + 1/0.85} = 0.46 \cdot V_i$$

$$V_i = 0.23 \sqrt{g \, D_{10} \cdot S}$$

$D_{10} = 25$ mm FROM FBN

$$D_{10} = 25 \text{ mm} \cdot \frac{\text{cm}}{10 \text{ mm}} \cdot \frac{\text{in}}{2.54 \text{ cm}} = 1.0 \text{ in.}$$

$S = 0.\overline{3}$

$$V_i = 0.23 \sqrt{32.17 \cdot 1.0 \cdot 0.\overline{3}} = 0.75 \text{ FPS}$$

$$V_A = 0.46 \cdot 0.75 = 0.35 \text{ FPS}$$

SUBJECT LTV STEEL EAST CHICAGO

BY SER DATE 12/11/98 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 1/4/99 SHEET NO. 5 OF 24

REV BY SER 3/31/99

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t_c IN PIPES

ADD t_c FROM ABOVE AREAS

BENCH PIPES SEE DRAWINGS ATTACHED

USE AVERAGE SLOPE ON BENCHES

$$S = \left(\frac{640-610}{1230} + \frac{640-610}{915}\right)/2 = 0.028$$

ASSUME AN 18" ϕ HDPE PIPE OR 2-18" ϕ HDPE PIPES BELOW BENCHES

ASSUME FULL FLOW CONDITION

$R = D/4 = 1.5'/4 = 0.375'$

$n = 0.011$ HDPE

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$ MANNING'S EQUATION

$$V = \frac{1.49}{0.011} 0.375^{2/3} \; 0.028^{1/2} = 12 \text{ FPS}$$

SUBJECT LTV STEEL - EAST CHICAGO

BY SEB DATE 12/11/98 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 1/4/99 SHEET NO. 6 OF 24

REV. BY SEB 3/31/99

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t_c'S ARE ESTIMATED ON SHEET 7.

INTENSITIES FROM CHART ON SHEET 8 ARE LISTED ON SHEET 9 ALSO ESTIMATES OF INTENSITIES FOR DURATION (t_c'S < 5 MIN SHOWN ON SHEET 9

AREAS ARE ESTIMATED USING TRAPEZOIDAL APPROXIMATIONS FOR AREAS ABOVE THE BENCH.

FLOWS ARE ESTIMATED USING $Q = CIA$, RATIONAL FORMULA.

LTV - E... CHICAGO
PROJ. B7-481
BY: SER ~~12/14/98~~ 3/31/99
CHKD BY:_____

C = 0.95
AVERAGE VELOCITY IN STONE COVER (FPS) = 0.35

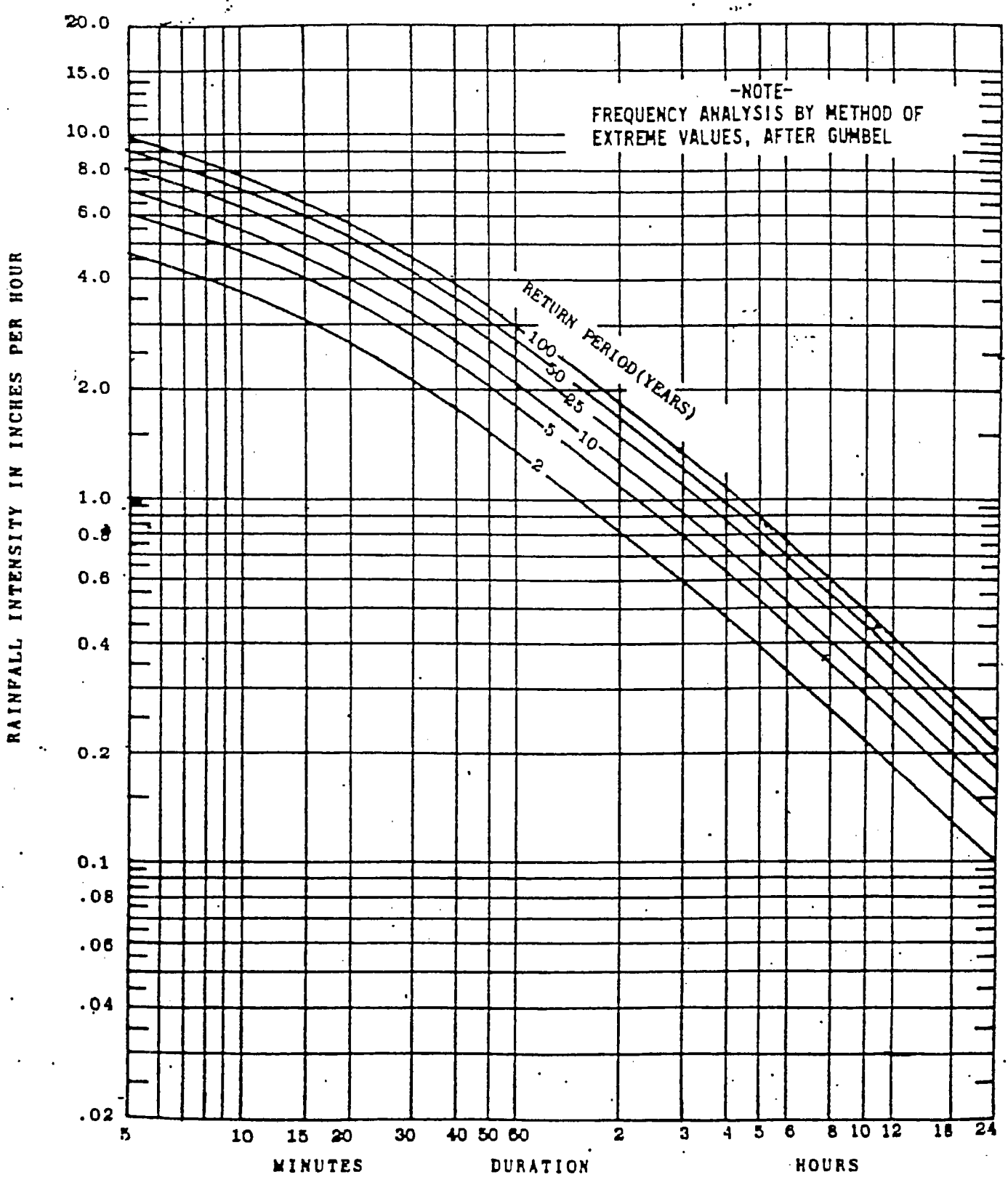
AREA	POINT NO.	RUN	SLOPE FLOW LENGTH	SLOPE H:1V	ABOVE BENCH OR DITCH T_c (ROUNDED) AT POINT (MIN)	100-YEAR INTENSITY (INCHES/ HOUR)	100 - YEAR FLOW PER UNIT WIDTH (CFS/FOOT)	INCREMENTAL ABOVE BENCH OR DITCH DRAINAGE AREA AT POINT (ACRE)	CUMULATIVE ABOVE BENCH OR DITCH DRAINAGE AREA AT POINT (ACRE)	PIPE LENGTH	CUMULATIVE LENGTH (FEET)	APPROX. VELOCITY (FPS)	TOTAL T_c TO POINT (MIN)	TOTAL T_c (ROUNDED) TO POINT (MIN)	10-YEAR INTENSITY (INCHES/ HOUR)	25-YEAR INTENSITY (INCHES/ HOUR)	100-YEAR INTENSITY (INCHES/ HOUR)	CUMULATIVE (ON BENCH OR DITCH) DRAINAGE AREA AT POINT (ACRES)	TOTAL CUMULATIVE DRAINAGE AREA AT POINT (ACRES)	10-YEAR FLOW	25-YEAR FLOW	100-YEAR FLOW	
A																							
	1	120	126	3	6	9.3	0.0257				0	12	6	6	6.6	7.6	9.3						
	2	125	132	3	6	9.3	0.0287	0.5674	0.5674	200	200	12	0.3	6	6.6	7.6	9.3	0.0551	0.6175	3.9	4.5	5.5	
	3	110	116	3	6	9.3	0.0235	0.5305	1.1010	200	400	12	6.0	7	6.3	7.2	8.9	0.1102	1.2121	7.4	8.5	10.5	
	4	90	95	3	5	9.6	0.0203	0.4591	1.5610	200	600	12	6.8	7	6.3	7.2	8.9	0.1653	1.7263	10.3	11.8	14.6	
	5	55	58	3	3	11.3	0.0143	0.3329	1.8939	200	800	12	7.1	7	6.3	7.2	8.9	0.2204	2.1143	12.7	14.5	17.9	
	5B	55						0.1515	2.0454	120	920	12	7.3	7	6.3	7.2	8.9	0.2534	2.2988	13.8	15.7	19.4	TOWARD SLOPE PIPE
	5B	55											3	3	8.0	9.2	11.3						
	6	55	58	3	3	11.3	0.0143	0.1010	0.1010	80	80	12	3.1	3	8.0	9.2	11.3	0.0220	0.1230	0.9	1.1	1.3	
	7	55	58	3	3	11.3	0.0143	0.2525	0.3535	200	280	12	3.3	3	8.0	9.2	11.3	0.0771	0.4306	3.3	3.8	4.6	
	8	70	74	3	4	10.4	0.0167	0.2870	0.6405	200	480	12	4.0	4	7.4	8.5	10.4	0.1322	0.7727	5.7	6.5	8.0	
	9	80	84	3	4	10.4	0.0191	0.3444	0.9849	200	680	12	4.3	4	7.4	8.5	10.4	0.1873	1.1722	8.2	9.5	11.6	
	10	0						0.1102	1.0951	120	800	12	4.4	4	7.4	8.5	10.4	0.2204	1.3155	9.2	10.6	13.0	
B																							
	1	120	126	3	6	9.3	0.0257				0	12	6	6	6.6	7.6	9.3						
	2	160	169	3	8	8.4	0.0309	1.2856	1.2856	400	400	12	8	8	6.0	6.9	8.4	0.1102	1.3958	8.4	9.6	11.7	
	3	150	158	3	8	8.4	0.0290	1.4233	2.7089	400	800	12	8.6	9	5.8	6.6	8.0	0.2204	2.9293	16.4	18.8	22.8	
	3B	150						0.4132	3.1221	120	920	12	8.7	9	5.8	6.6	8.0	0.2534	3.3755	18.6	21.2	25.7	TOWARD SLOPE PIPE
	3B	150											8	8	6.0	6.9	8.4						
	4	150	158	3	8	8.4	0.0290	0.9042	0.9042	280	280	12	8.4	8	6.0	6.9	8.4	0.0771	1.0413	5.9	6.8	8.3	
	5	120	126	3	6	9.3	0.0257	0.3719	1.3361	120	400	12	8.6	9	5.8	6.6	8.0	0.1102	1.4463	8.1	9.3	11.3	
AREAS DRAINING DIRECTLY TO POND																							
B																			0.34				
C																			5.22				
D																			0.40				
																		TOTAL TO POND =	14.4				

LTVECH16.XLS

U.S. DEPARTMENT OF COMMERCE WEATHER BUREAU COOPERATIVE STUDIES SECTION

RAINFALL INTENSITY - DURATION - FREQUENCY CURVES

CHICAGO, ILLINOIS
1905-1912, 1926-1951

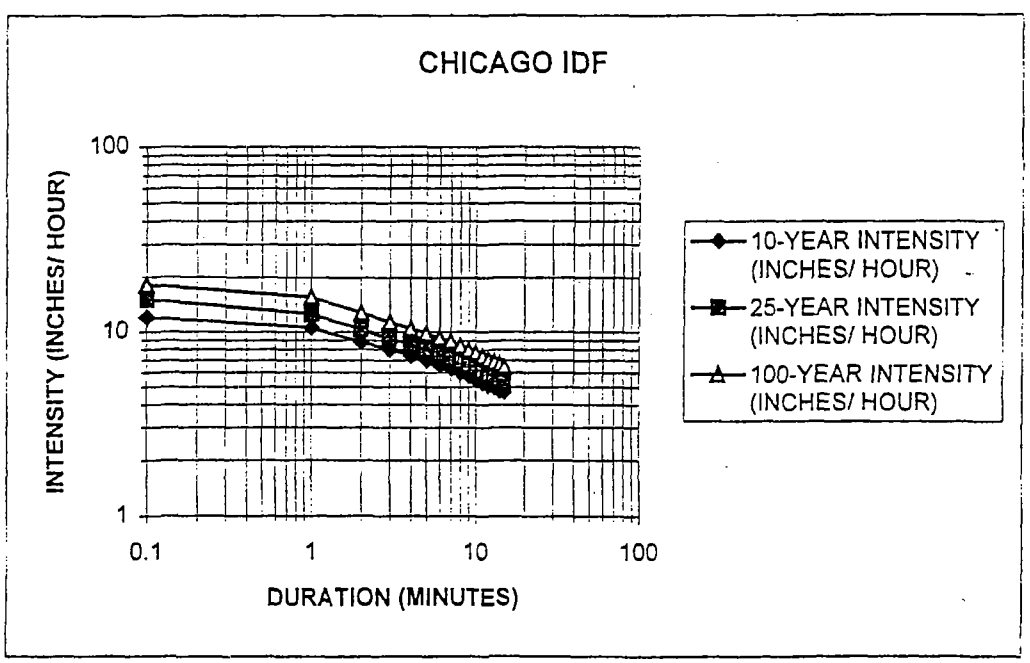


REF: "CHANNEL DESIGN" INDIANA DEPARTMENT OF HIGHWAYS APRIL 1988

FIGURE 12

LTV - EAST CHICAGO
PROJ. 97-481
BY: SER 12/11/98
CHKD BY: KMB 1/4/99

DURATION OR Tc (MINUTES)	10-YEAR INTENSITY (INCHES/ HOUR)	25-YEAR INTENSITY (INCHES/ HOUR)	100-YEAR INTENSITY (INCHES/ HOUR)
0.10	12	15	18
1	10.5	12.5	15.5
2	8.8	10.3	12.7
3	8.0	9.2	11.3
4	7.4	8.5	10.4
5	7.0	8.0	9.8
6	6.6	7.6	9.3
7	6.3	7.2	8.9
8	6.0	6.9	8.4
9	5.8	6.6	8.0
10	5.5	6.4	7.7
11	5.3	6.1	7.4
12	5.1	5.9	7.1
13	5.0	5.7	6.9
14	4.8	5.5	6.7
15	4.7	5.3	6.5



SUBJECT LTV STEEL

BY SER DATE 12/11/98 PROJ. NO. 97-481

CHKD. BY KMB DATE 1/5/99 SHEET NO. 10 OF 24

REV BY SER 3/31/99

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HYDRAULICS

PIPE 1. TO 3 BEDCH PIPES DESIGN EVENT 100 YR

PIPE 1 DRAINAGE POINTS A1 TO A5 B

$S = 5/375 = 0.013$

$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$

1 OR 2 - 18" ϕ

$A = 1.77 FT^2$ EACH

$R = 0.375$ FT EACH

$n = 0.011$

$Q = \frac{1.49}{0.011} 1.77 \cdot 0.375^{2/3} 0.013^{1/2} = 14.2$ CFS/PIPE

$Q_{TOTAL} = 28.4$ CFS FOR 2 PIPES

ONE PIPE CAN BE USED UNTIL FLOW IS > 14.2 CFS

FIND DISTANCE OF 1 PIPE BETWEEN POINTS A3 & A4

A3	10.5 CFS	Δ DISTANCE = 200'
A4	14.6 CFS	

USE 180 FT + 400 FT = 580 FT

AT POINT A-5B USE A SLOPE PIPE

$Q = 19.4$ CFS < 28.4 CFS

SUBJECT LTV STEEL

BY SER DATE 12/11/98 PROJ. NO. 97-481

CHKD. BY KMB DATE 1/5/99 SHEET NO. 11 OF 24

REV BY SER 3/31/99

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PIPE 2 POINT A5B TO A10

$S = 5/430 = 0.012$

$Q = \left(\frac{0.012}{0.013}\right)^{1/2} 14.2 \text{ CFS} = 13.6 \text{ CFS/PIPE}$

ONE PIPE IS SUFFICIENT FLOW @ A10 = 13.0 CFS

PIPE 3. POINT D1 TO D3B AND D3B TO D5

$S = 5/330 = 0.015$

$Q = \left(\frac{0.015}{0.013}\right)^{1/2} \cdot 14.2 \text{ CFS} = 15.3 \text{ CFS/PIPE}$

$Q_{TOTAL} = 30.6 \text{ CFS}$

ONE PIPE CAN BE USED UNTIL FLOW > 15.3 CFS

FIND DISTANCE OF 1 PIPE
BETWEEN POINTS D2 AND D3
D2 11.7 CFS
D3 22.8 CFS
Δ DISTANCE = 400'

USE 130 FT + 400 FT = 530 FT

AT POINT D-3B USE A SLOPE PIPE

Q = 25.7 CFS @ D-3B < 30.6 CFS ∴ OK

USE 1-18" ON D BENCH BELOW SLOPE PIPE

SUBJECT LTV STEEL

BY SER DATE 12/11/98 PROJ. NO. 97-481

CHKD. BY KMB DATE 1/5/99 SHEET NO. 12 OF 24

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ESTIMATE DEPTHS OF FLOW IN STONE

ESTIMATE FLOW DEPTHS IN STONE FOR
3:1 SLOPES;
4:1 SLOPES;
7:1 SLOPES; AND
30:1 SLOPES.

THE MAXIMUM FLOW RATE IN THE 3:1 SLOPE AREA IS 0.0309 CFS/FT FOR THE 100-YEAR STORM (FROM SHEET 7)
AVERAGE VELOCITY = 0.35 FPS (FROM SHEET 3).

$$\therefore \text{DEPTH OF FLOW} = \frac{0.0309 \text{ CFS}}{0.35 \text{ FPS}} = 0.10 \text{ FT}$$

USE C = 1 (RATIONAL FORMULA COEFF) FOR CONSERVATIVE ESTIMATES BELOW

ESTIMATE THE LONGEST FLOW LENGTHS FOR EACH OF THE OTHER SLOPES

SLOPE	LENGTH
30:1	255'
7:1	490'
4:1	80'

FIND V_C AND V_A FOR EACH SLOPE

$$V_C = 0.23\sqrt{g D_{10} S} \qquad V_A = 0.46 \cdot V_C$$

$D_{10} = 1.0$ IN

SLOPE		V_C	V_A
30:1	0.033	0.238 FPS	0.11 FPS
7:1	0.143	0.493	0.23
4:1	0.25	0.652	0.30

SUBJECT LTV STEEL

BY SER DATE 12/11/98 PROJ. NO. 97-481

CHKD. BY KMB DATE 1/5/99 SHEET NO. 13 OF 24

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ESTIMATE TIME-OF-CONCENTRATIONS AND INTENSITIES FOR THE FOLLOWING SLOPES AND LENGTHS

SLOPE	V_A	LENGTH	SLOPE LENGTH	t_c	100 YR i IN/HR	Q
30:1	0.11 FPS	255'	255'	39 MIN	4.0	0.0234 CFS
		130'	130'	20	5.8	0.0173
		1'	1'	0	18	0.0004
7:1	0.23	490	495	36 MIN	4.2	0.0477
		245	247	18 MIN	6.0	0.0340
		1'	1	0	18	0.0004
4:1	0.30	130'	134	7 MIN	8.9	0.0274
		65'	67	4 MIN	10.4	0.0160
		1'	1	0	18	0.0004

MAXIMUM DEPTHS FOR EACH SLOPE NOT CONSIDERING FLOW FROM SLOPES ABOVE

SLOPE	Q_{MAX}	V_A	D_{MAX}
30:1	0.0234 CFS	0.11 FPS	0.21 FT
7:1	0.0477	0.23 FPS	0.21 FT
4:1	0.0274	0.30	0.10 FT

NEXT CONSIDER COMBINATIONS OF SLOPES AND LENGTHS

30:1 FOR 255' + 7:1 FOR 350' + 7.5:1 FOR 150' + 4:1 FOR 80

SLOPE LENGTHS	255'	353'	151'	82
V_A (FPS)	0.11	0.23	0.22	0.3
t_c (MIN)	39	26+39 = 65	11+65 = 76	5+76 = 8
i (IN/HR)	4.0	2.9	2.6	2
TOTAL L	255'	608'	759'	84
Q (CFS)	0.0234	0.040	0.045	0.04
D	0.21'	0.17	USE → 0.20 (FOR 7:1 ALSO)	0.16

SUBJECT LTV STEEL

BY STR DATE 12/11/98 PROJ. NO. 97-481

CHKD. BY KMB DATE 1/5/99 SHEET NO. 14 OF 24

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TRY ALONG STA 16+00

30:1 FOR 170' + 7:1 FOR 300' + 4:1 FOR 140'

SLOPE LENGTHS	170'	303'	144'
V_A (FPS)	0.11	0.23	0.30
t_c (MIN)	26	26+22 = 48	48+8 = 56
i (IN/HR)	5.0	3.4	3.2
TOTAL L	170	473	617
Q (CFS)	0.0195	0.0369	0.0453
D (FT)	0.18	0.16'	0.15

TRY ALONG STA 10+00

30:1 FOR 210' + 6:1 FOR 300' + 15:1 FOR 150' + 5:1 FOR 130'

SLOPE LENGTHS	210'	304'	150'	132'
V_A (FPS)	0.11	0.24	0.16	0.26
t_c (MIN)	32	32+21=53	53+16=69	69+8=77
i (IN/HR)	4.5	3.3	2.7	2.6
TOTAL L	210'	514'	664'	796'
Q (CFS)	0.0217	0.0389	0.0412	0.0475
D (FT)	0.20	0.16	0.16	0.18

MAXIMUM FOR EACH SLOPE

30:1	MAX(0.21, 0.18, 0.20)	= 0.21'
7.5:1	MAX(0.20)	= 0.20'
7:1	MAX(0.21, 0.20, 0.16)	= 0.21'
4:1	MAX(0.10, 0.16, 0.15)	= 0.16'
3:1	MAX(0.10)	= 0.10'

SUBJECT LTV - EAST CHICAGO

BY SER DATE 2/16/99 PROJ. NO. 97-481-10

CHKD. BY KMB DATE 2/18/99 SHEET NO. 15 OF 24

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FLOW IN R-3 RIPRAP AT EDGE OF FLUME

DETERMINE MIN SLOPE REQUIRED TO PASS DESIGN STORM FLOW THROUGH R-3 RIPRAP AT TOE OF LANDFILL ALONG FLUME

$Q = 0.048$ CFS/FT ESTIMATED MAXIMUM FLOW FROM SHEET 17

ASSUME $D_{10} = 2''$ MIN. SIZE PENNDOT PUBLICATION 408 GRNSA DEFINITION OF R-3

ASSUME $\phi = 0.85$ CONSERVATIVE ASSUMPTION = ϕ OF COVER MATERIAL
ACTUAL ϕ OF R-3 $\gg 0.85$

$\therefore V_A = 0.46\, V_i$ FROM SHEET 4

$V_i = 0.23 \sqrt{g D_{10} S}$ FROM SHEET 4

$V_i = 0.23 \sqrt{32.17 \cdot 2 \cdot S}$

$V_i = 1.84\, S^{1/2}$

$V_A = 0.46\, V_i = 0.85\, S^{1/2}$

DEPTH $= Q/V_A = 18'' = 1.5'$

$\therefore V_A = Q/1.5' = 0.048/1.5 = 0.032$ FPS $= 0.85 \cdot S^{1/2}$

$\therefore S^{1/2} = 0.0376$

$S = 0.0014$ FT/FT OR GREATER TO KEEP FLOW IN 18" R-3 LAYER ON 1V-0H SLOPE

SUBJECT LTV STEEL - EAST CHICAGO

BY SER DATE 3/31/99 PROJ. NO. 97-481-10

CHKD. BY KLE DATE 4.1.99 SHEET NO. 16 OF 24

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POND HYDROLOGY

PURPOSE: STORE 25-YEAR, 24-HOUR RUNOFF VOLUME FROM LANDFILL

LANDFILL DRAINAGE AREA TO POND = 14.4 AC, SEE SH. 7

RAINFALL FOR 25 YEAR 24 HOUR STORM = 4.7"
FROM TR-55

USE CN = 98

$$\therefore S = \frac{1000}{CN} - 10 = \frac{1000}{98} - 10 = 0.2''$$

$$Q = \frac{(P - 0.2 \cdot S)^2}{P + 0.8 \cdot S} = \frac{(4.7 - 0.2 \cdot 0.2)^2}{4.7 + 0.8 \cdot 0.2} = 4.5''$$

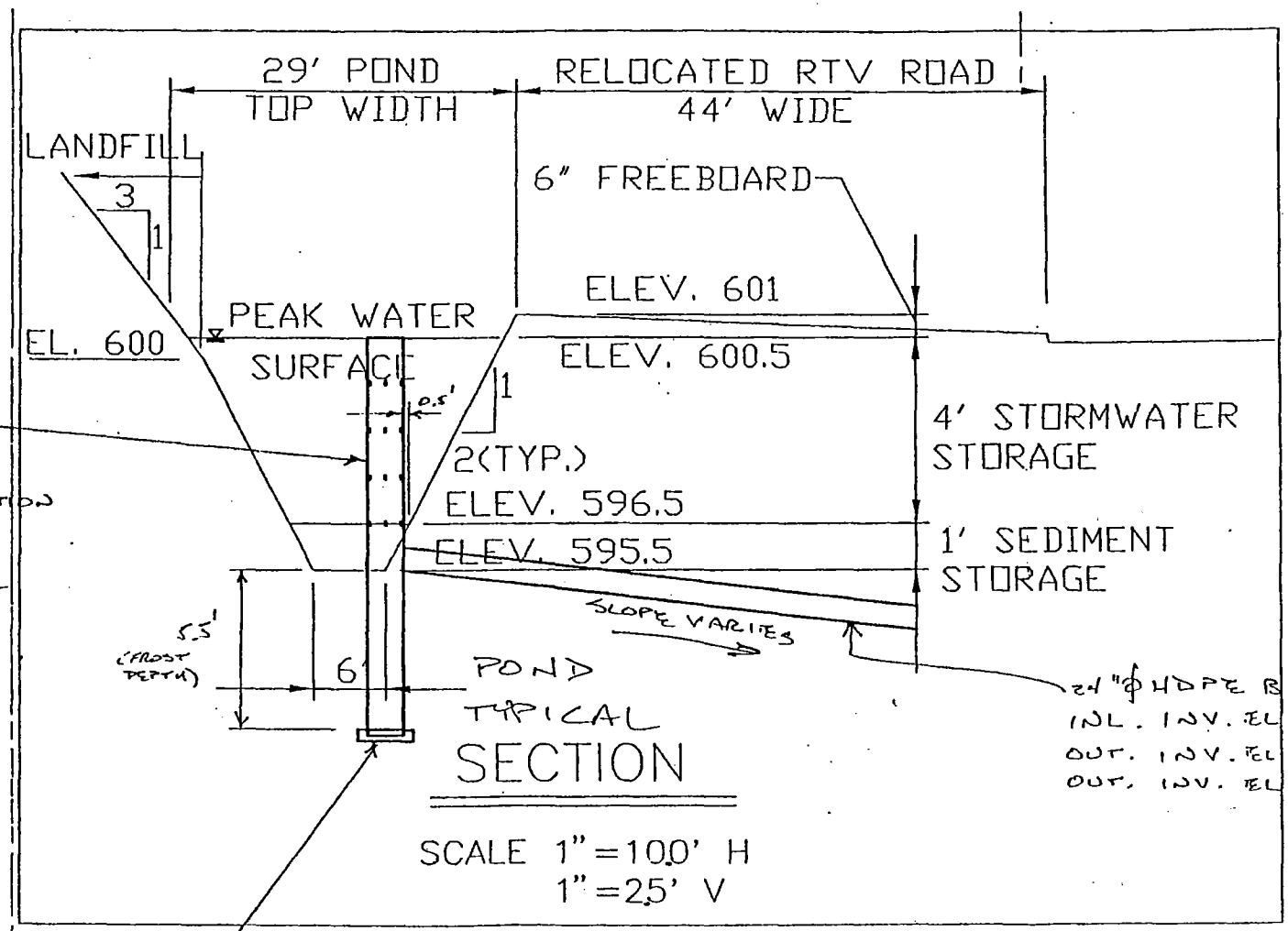
FROM TR-55

RUNOFF VOLUME = 4.5" · 14.4 AC = 5.4 AC·FT

NEGLECT ROUTING OF OUTFLOW OF POND THROUGH HOLES IN RISER, STORE ENTIRE EVENT BELOW CREST OF RISER.

SEE SHEET 17 FOR SKETCH OF POND CROSS SECTION AND RISER.

POND VOLUME AVAILABLE = 5.64 AC·FT ∴ OK
SEE SHEET 20



36"ϕ HDPE RISER
CREST EL. 600.5
BOTTOM EL 590.0
PROVIDE 6 — 1" ϕ HOLES/ELEVATION EQUALLY SPACED AT 4 ℄ ELEVATIONS, EL 596.5, EL. 597.5, EL 598.5, & 599.5

CONCRETE PAD AT BASE OF RISER
5'x5'x1' (L x W x H)
EMBED RISER 0.5' IN PAD

24"ϕ HDPE BARREL
INL. INV. EL. 595.5
OUT. INV. EL 590.72 @ MH2
OUT. INV. EL 591.48 @ MH4

PROJ. No. 97-481-10
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SUBJECT LTV STEEL - EAST CHICAGO

BY SER DATE 3/31/99 PROJ. NO. 97-481-10

CHKD. BY KWE DATE 4.1.99 SHEET NO. 18 OF 24

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POND
HYDRAULICS

PURPOSE: DESIGN OUTLET STRUCTURE TO DRAIN POND IN 10 DAYS

ASSUME EXISTING SYSTEM WILL DRAIN WITHIN 1 DAY - THEREBY ALLOWING FOR NO TAILWATER ON POND OUTLET STRUCTURES AFTER 1 DAY.

CHECK ASSUMPTION

TOTAL AREA DRAINING TO NORTH LAGOON = 54.2 AC
FROM CALC BY SER "HYDROLOGY AND HYDRAULICS - NORTH LAGOON STORM SEWER SYSTEM" 3/12/99 SHEET 4
DOES NOT INCLUDE LANDFILL, WHICH IS STORED IN POND

ASSUME Q = 4.5" FOR 25 YR 24 HOUR STORM

VOLUME OF RUNOFF = 54.2 AC · 4.5" = 20.3 AC·FT
= 884,000 CF

AVERAGE FLOW IN 1 DAY = $\frac{884{,}000 \text{ CF}}{24 \text{ HR}} \cdot \frac{\text{HR}}{60 \text{ MIN}} \cdot \frac{\text{MIN}}{60 \text{ S}}$

= 10 CFS

OUTLET PIPE OF NORTH LAGOON IS A 72" ϕ RCP WHICH CAN PASS THIS AVERAGE FLOW AND THE PLANT SERVICE WATER WHICH DISCHARGES TO THE NORTH LAGOON, WITH MINIMAL TAILWATER.

THERFORE DESIGN POND OUTLET STRUCTURE TO DRAIN POND IN 9 DAYS WITH NO TAILWATER

SUBJECT LTV STEEL - EAST CHICAGO

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SHEET 20 SHOWS A STAGE-STORAGE RATING FOR THE PROPOSED POND

SHEET 21 SHOWS A STAGE-DISCHARGE RATING FOR PERFORATIONS IN A RISER AS FOLLOWS

6 HOLES AT EACH ELEV., ELEV'S 596.5, 597.5, 598.5 & 599.5
1" ϕ HOLES

MAXIMUM FLOW THROUGH HOLES = 1.0 CFS / RISER

BARRELS WILL BE 24" ϕ HDPE PIPES

ONE WILL CONNECT TO MH NO 23 AT INV EL 590.72 AND WILL BE APPROX. 57' LONG

THE ANOTHER WILL CONNECT TO MH NO 46 AT INV. EL. 591.48 AND WILL BE APPROX. 123 FT LONG

EACH BARREL WILL HAVE AN INLET INV EL = 595.5

SLOPES

$$S_1 = \frac{595.5 - 590.72}{57} = 0.084 \text{ FT/FT}$$

$$S_2 = \frac{595.5 - 591.48}{123} = 0.033 \text{ FT/FT}$$

ESTIMATE DEPTH OF FLOW IN BARREL WITH MILDEST SLOPE

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

ASSUME $n = 0.011$ HDPE PIPE

LTV STEEL - EAST CHICAGO
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H-20/24

STAGE- STORAGE RATING PROPOSED POND

POND LENGTH = 3400 FEET
POND BOTTOM WIDTH AT TOP OF SEDIMENT STORAGE = 10 FEET

ELEVATION (FEET, MSL)	BOTTOM WIDTH (FEET)	BOTTOM LENGTH (FEET)	AREA (SQUARE FEET)	AVERAGE AREA (SQUARE FEET)	INCREMENTAL VOLUME (CUBIC FEET)	CUMULATIVE VOLUME (CUBIC FEET)	CUMULATIVE VOLUME (ACRE FEET)
596.5	10	3400	34000				
597	12	3402	40824	37412	18706	18706	0.43
598	16	3406	54496	47660	47660	66366	1.52
599	20	3410	68200	61348	61348	127714	2.93
600	24	3414	81936	75068	75068	202782	4.66
600.5	26	3416	88816	85376	42688	245470	5.64

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ALTERNATIVE 3

STAGE- DISCHARGE RATING PROPOSED POND

TOP OF RISER ELEVATION =	600.5	FEET, MSL
NUMBER OF HOLES PER ELEVATION =	6	
DIAMETER OF HOLES =	1	INCH
AREA OF HOLES AT EACH ELEVATION =	0.032725	SQUARE FEET
ORIFICE EQUATION DISCHARGE COEFFICIENT =	0.6	
ORIFICE EQUATION Q=CA*(2gh)^0.5		

ORIFICE FLOW THOUGH RISER HOLES

ELEVATION (FEET, MSL)	HEAD ON HOLES AT ELEVATION 596.5	FLOW (CFS) THROUGH HOLES AT ELEVATION 596.5	HEAD ON HOLES AT ELEVATION 597.5	FLOW (CFS) THROUGH HOLES AT ELEVATION 597.5	HEAD ON HOLES AT ELEVATION 598.5	FLOW (CFS) THROUGH HOLES AT ELEVATION 598.5	HEAD ON HOLES AT ELEVATION 599.5	FLOW (CFS) THROUGH HOLES AT ELEVATION 599.5	TOTAL FLOW (CFS) THROUGH HOLES/ RISER	TOTAL FLOW (CFS) THROUGH HOLES FOR TWO RISERS
596.5	0	0							0	0.0
597	0.5	0.1	0	0					0.1	0.2
598	1.5	0.2	0.5	0.1	0	0			0.3	0.6
599	2.5	0.2	1.5	0.2	0.5	0.1	0	0	0.5	1.0
600	3.5	0.3	2.5	0.2	1.5	0.2	0.5	0.1	0.8	1.6
600.5	4	0.3	3	0.3	2	0.2	1	0.2	1.0	2.0

H-2(2)

LTV STEEL - EAST CHICAGO
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DEWATERING CALCULATION

ELEVATION (FEET, MSL)	TOTAL FLOW (CFS) THROUGH HOLES	AVERAGE FLOW (CFS) IN INTERVAL	VOLUME IN INTERVAL (CUBIC FEET)	TIME TO DEWATER INTERVAL (DAYS)	
596.5	0				
		0.1	18706	2.2	
597	0.2				
		0.4	47660	1.4	
598	0.6				
		0.8	61348	0.9	
599	1				
		1.3	75068	0.7	
600	1.6				
		1.8	42688	0.3	
600.5	2				
		TOTAL TIME TO DEWATER =		5.5	DAYS

H-22/24

SUBJECT LTV STEEL - EAST CHICAGO

BY SER DATE 3/31/99 PROJ. NO. 97-481-10

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$Q = 1 cfs$
$S = 0.033$
$D = 2'$

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

$$1 = \frac{1.49}{0.011} AR^{2/3} \, 0.033^{1/2}$$

$$AR^{2/3} = 0.0464$$

$$AR^{2/3}/D^{8/3} = 0.0464/2^{8/3} = 0.0064$$

$y/D = 0.10$ FROM CHOW "OPEN CHANNEL HYDRAULICS" APP A p 625

$y = 0.2$ FEET

∴ FLOW HEAD-WATER (BY OUTLET CONTROL) AT INLET TO BARREL
$= 595.5 + 0.2 = 595.7 < 596.5$
ELEV OF FIRST SET OF HOLES

CHECK INLET CONTROL

USE UNSUBMERGED EQUATION FROM HDS No 5

FOR M(2) $$\frac{HW}{D} = K \left[\frac{Q}{AD^{0.5}}\right]^M$$

USE $K = 0.0098$ AND $M = 2$ FROM HDS No 5 ASSUME CONDITION IS EQUIVALENT TO A CIRC. CONC. PIPE WITH A SQ. EDGED HEADWALL

SUBJECT LTV STEEL - EAST CHICAGO

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$$A = \frac{\pi D^2}{4} = \pi$$

$$\frac{HW}{D} = K \left[\frac{Q}{A D^{0.5}} \right]^M$$

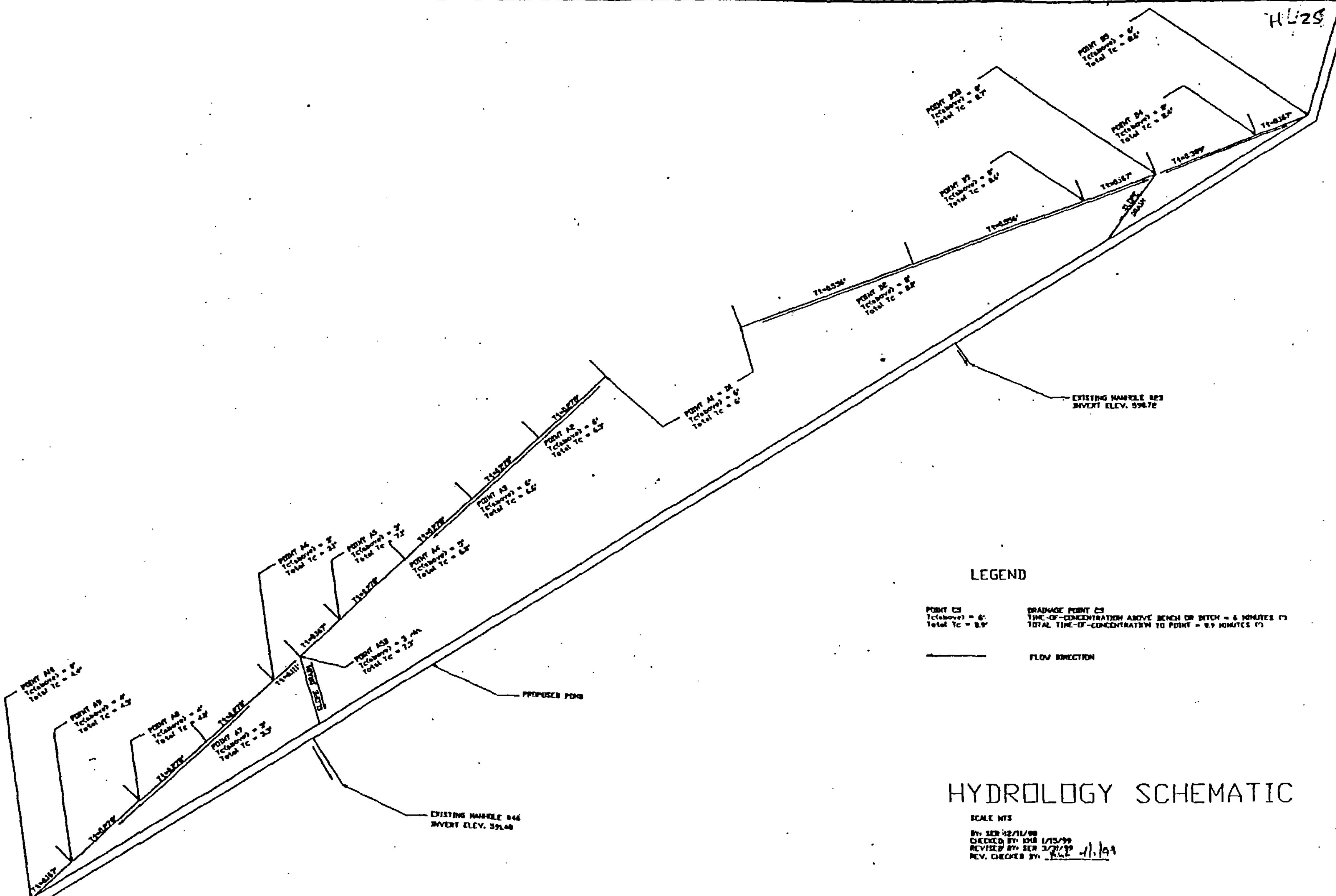
$$HW = 2 \cdot 0.0098 \left[\frac{1}{\pi \cdot 2^{0.5}} \right]^2 = 0.001 \text{ FT}$$

$$\therefore HW_{EL} = 595.5 + 0.001 = 595.5 < 596.5$$

∴ NO TAILWATERS WILL AFFECT FLOW THROUGH HOLES

POND WILL DRAIN IN A MAXIMUM OF 6.8 DAYS (=5.8 + 1)

HL25



HYDROLOGY SCHEMATIC

SCALE NTS

BY: SER 12/11/98
CHECKED BY: KMB 1/15/99
REVISED BY: SER 3/31/99
REV. CHECKED BY: KMB 4/1/99

SUBJECT

BY DATE PROJ. NO.

CHKD. BY DATE SHEET NO. OF

H-26

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REFERENCES

K_b = p[illegible]-loss coefficient for barrier-screen plates = $2g\Delta h_b/v_2^2$;
K_b' = $K_b(v_2/u_2)^2$;
K_s = gate-well pressure-loss coefficient associated with entrance, exit, friction, and barrier-screen support structure;
p = fraction of screen blocked by structural support members;
u_1 = local velocity parallel to barrier screen;
u_2 = local velocity normal to barrier screen;
v_1 = Q_1/A_1;
v_2 = Q_2/A_2;
v_b = Q_2/A_b;
v_b' = $v_b/(1-p)$;
v_s = Q_s/A_s;
v_s' = $v_s/(1-p)$;
Q = intake flow rate;
Q_1 = flow through and under diversion screen;
Q_2 = flow through gate well;
Q_3 = flow under diversion screen;
Q_s = flow through diversion screen;
β = angle of diversion-screen approach velocity with normal to screen;
β_0 = value of β with no diversion screen in place;
Δh = piezometric-head difference; and
Δh_b = piezometric-head difference across barrier screen.

Subscripts

b = barrier screen;
s = diversion screen;
1 = intake channel; and
2 = gate well.

Head Losses in Storm Sewer Manholes Submerged Jet Theory

By Flemming Bo Pedersen[1] and Ole Mark[2]

Abstract: The design of storm sewers especially suffers from lack of knowledge of the head losses in manholes. A submerged jet theory for the flow in manholes with straight throughflow has been outlined. The entrance head loss has been related to the kinetic energy transformation associated with the entrainment/detrainment in the jet. The exit head loss is calculated as a Carnot-loss in connection with the vena contracta in the exit pipe. The jet theory and the experiments have shown that the only governing parameter for a specific manhole shape is the ratio of manhole diameter to pipe diameter. The theory has been compared to laboratory experiments. The head loss in storm sewer manholes is shown to be considerably smaller than the values calculated by traditional formulas.

Introduction

Head losses in sanitary sewers consist partly of friction losses in the straight pipes, and partly of entrance and exit losses in connection with the manholes. While the friction losses can be estimated quite accurately, there seems to be very little experimental and theoretical support for calculating the single losses in the manholes. Especially in the design of storm sewers, i.e., for fully submerged exit to the manhole, the head loss in manholes is considerably smaller than the value calculated by traditional formulas, and hence one can improve the design by a more accurate theory. A submerged jet theory for the flow in manholes has been outlined. The theory has been compared with laboratory measurements in a specially designed manhole. Further, the theory has been extended to cover more realistically designed manholes, where it has been compared with laboratory measurements performed by Lindvall (1986).

Entrance and Exit Losses in Manholes

To put the importance of the single losses in manholes in perspective relative to the total losses in sanitary sewers we may estimate the so-called equivalent length L_E of a manhole.

By definition, the friction loss ΔH_F for a straight pipe of length L, hydraulic radius R (a quarter of the diameter), and mean velocity V is

$$\Delta H_F = \frac{fL}{4R}\frac{V^2}{2g} \quad (1)$$

where g = the acceleration of gravity; and f = the friction factor. The latter may be estimated by use of the Colebrook and White formula or a similar well-documented empirical formula.

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H-27

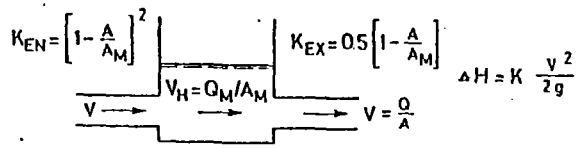


FIG. 1. Entrance (K_{EN}) and Exit (K_{EX}) Loss Coefficients in Manhole: Q = Discharge; A = Area

The head losses in a manhole ΔH_t amount to

$$\Delta H_t = K\frac{V^2}{2g} \quad (2)$$

where the coefficient K contains two contributions, one from the entrance K_{EN} and one from the exit K_{EX}. It is common practice to relate these coefficients to the Carnot loss, as illustrated in Fig. 1.

The major problem is that the effective flow area in the manhole A_M is unknown. By taking a conservative estimate of A_M (the cross-sectional area of the manhole) one quite often ends near the limiting values for K_{EN} (1.0) and K_{EX} (0.5), respectively, while experiments for large manholes with straight through flow give values, which might be an order-of-magnitude less than the maximum value 1.5, provided the outflow is submerged (storm sewers) (see Fig. 2).

The difference in head loss between the values calculated and the value

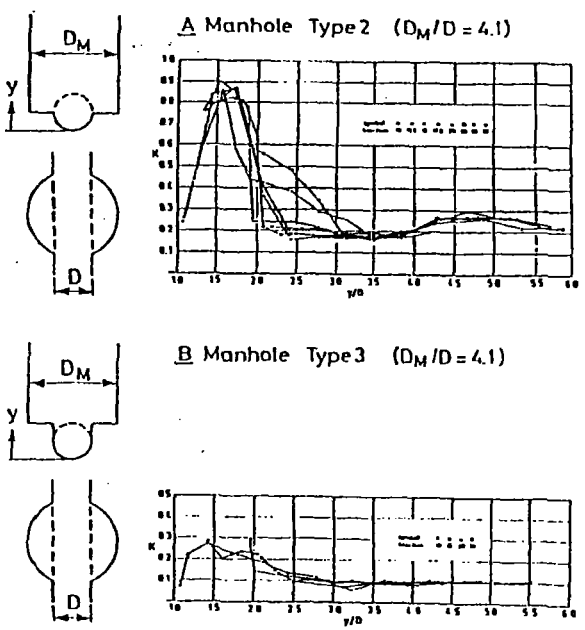


FIG. 2. Head Loss Coefficient K as Function of Degree of Submergence as Measured by Lindvall (1986): (a) Type 2 Manhole; (b) Type 3 Manhole

measured may be evaluated in terms of the difference in the equ pipe length L_E:

$$K = 1.5 \text{ yields } L_E = 1.5\frac{4R}{f} = 1.5\frac{1.0}{2\cdot 10^{-2}} = 75 \text{ m} \quad (3a)$$

$$K = 0.15 \text{ yields } L_E = 7.5 \text{ m} \quad (3b)$$

for a 1-m-diameter pipe with a reasonable friction factor. Hence, in the design of storm sewers, one may gain the equivalent of, say, nearly 70 times the diameter length of friction loss per manhole.

Flow in Manholes

Entrance

Inspection of the flow pattern in a circular manhole has revealed that the inflowing water behaves like a submerged jet, which entrains water from the ambient fluid and increases the streamwise discharge through the manhole (see Fig. 3). During steady state conditions, the outflow from the manhole equals the inflow, and hence the surplus discharge is rejected from the main flow before it leaves the manhole. The entrained water is accelerated on account of the kinetic energy of the through-flowing water, and similarly is the energy of the surplus discharge lost in the manhole as well. The energy transformation in this persistent pumping mechanism is directly related to the entrance head loss in the manhole. By use of a simple jet theory for submerged jets we have evaluated this entrance head loss.

The Exit

At the outlet from the manhole, the water is accelerated through a vena contracta in the outlet pipe, and hence an ordinary expansion loss is encountered downstream the vena contracta. This head loss is calculated by use of the Carnot-formula combined with an experimentally determined contraction coefficient ψ. Coefficient ψ is nearly a constant (around 0.6–0.7) with a weak dependency on the effective flow area in the manhole. The latter

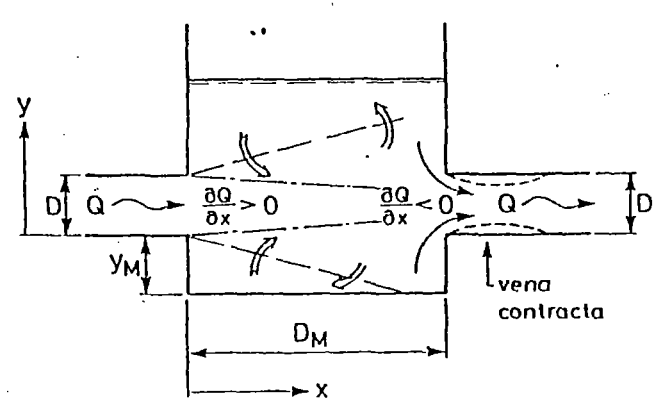


FIG. 3. Sketch of Flow Circulation in Circular Manhole Type 1 (Not in Scale): Q = Discharge

has been determined as the area in the jet that has an integrated discharge of Q.

Determination of Head Losses in Manholes

Entrance Head Loss, Type 1 Manhole

First we consider a laboratory manhole with a bottom depression relative to the pipes (see Fig. 3), i.e., a fully submerged jet. Hydrostatic pressure distribution is assumed. We apply the experimentally determined velocity distribution for a free jet (see Fig. 4), which means that the logarithmic velocity profile in the pipe has been approximated with a constant velocity profile.

For convenience we have chosen to substitute the weak nonlinear core variation with a linear function extending to the end of the zone of flow establishment [$X = 6.2D$, see Albertson et al. (1950)].

As long as the extent of the zone of flow establishment is less than the manhole diameter D_M, we may calculate the discharge and energy flux in the jet as the sum of two contributions:

Core

The discharge in the core Q_c may be found by integrating the velocity profile to yield

$$\frac{Q_c}{Q} = 1 - 4\left(\frac{C_2X}{D}\right) + 4\left(\frac{C_2X}{D}\right)^2 \quad \text{(4)}$$

where Q = the initial discharge.

The flux of kinetic energy in the core E_c is simply the discharge times the velocity head, since the velocity is constant

$$\frac{E_c}{E} = 1 - 4\left(\frac{C_2X}{D}\right) + 4\left(\frac{C_2X}{D}\right)^2 \quad \text{(5)}$$

where E = the initial energy flux measured as $Q(V^2/2g)$.

Diffusion Region: $X/D \leq 6.2$

Integrating the Gaussian velocity distribution outside the core yields the

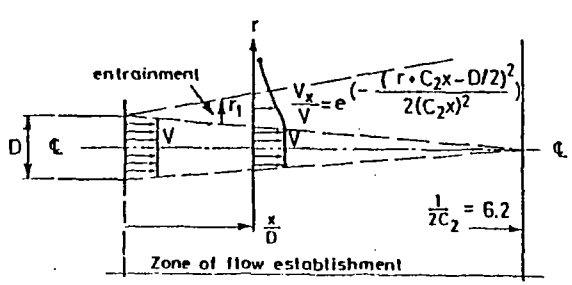


FIG. 4. Velocity Distribution in Circular Free Jet. In Core Velocity Is Constant = V. In Diffusion Region Velocity Profile Is Gaussian Normal Probability Function: $r_1 = r + C_2X - D/2$

diffusion region contribution Q_D as a function of the lateral integ[illegible] distance $r(\geq D/2 - C_2X)$

$$\frac{Q_D}{Q} = 8\left(\frac{C_2X}{D}\right)^2 [1 - e^{-(r_1/\sqrt{2}C_2X)^2}]$$

$$+ 2\sqrt{2\pi}\left[\frac{C_2X}{D} - 2\left(\frac{C_2X}{D}\right)^2\right] \operatorname{erf}\left(\frac{r_1}{\sqrt{2}\,C_2X}\right) \quad \text{(6)}$$

where erf = the error function; and r_1 = shown in Fig. 4. Performing the integration of the kinetic energy flux in the diffusion region yields E_D:

$$\frac{E_D}{E} = \frac{8}{3}\left(\frac{C_2X}{D}\right)^2 [1 - e^{-(r_1/\sqrt{2/3}C_2X)^2}]$$

$$+ 2\sqrt{\frac{2\pi}{3}}\left[\frac{C_2X}{D} - 2\left(\frac{C_2X}{D}\right)^2\right] \operatorname{erf}\left(\frac{r_1}{\sqrt{\frac{2}{3}}\,C_2X}\right) \quad \text{(7)}$$

Total for Zone of Flow Establishment: $X/D \leq 6.2$

The total discharge Q_M and kinetic energy flux E_M in the manhole as a function of the distance X may then be expressed by

$$\frac{Q_M}{Q} = \frac{Q_C}{Q} + \frac{Q_D}{Q} \quad \text{(8a)}$$

$$\frac{E_M}{E} = \frac{E_C}{E} + \frac{E_D}{E} \quad \text{(8b)}$$

where Q_C, Q_D and E_C, E_D are previously outlined.

Total for Zone of Established Flow: $X/D > 6.2$

Normally, the dimension of a manhole will be restricted to be less than 6.2 times the inlet/outlet diameter, and hence the established flow region has no practical importance.

Entrance Head Loss Coefficient

The energy loss in the manhole is calculated as the difference per unit discharge between the original energy flux into the manhole E and the energy flux out of the manhole E_0, both associated with the through-flowing discharge Q

$$\Delta H_{EN} = K_{EN}\frac{V^2}{2g} \quad \text{(9a)}$$

$$K_{EN} = \frac{E - E_0}{Q} \quad \text{(9b)}$$

The discharge Q_M in the main flow direction in the manhole exceeds the inflow/outflow discharge Q due to entrainment. Hence the energy flux in

the rejected discharge $(Q_M - Q)$ shall not be taken into account in calculating the outflow energy flux E_0. As the transition from the jet to the exit pipe is too complicated to model, we have tried different approaches, the most successful one was to calculate E_0 as the energy flux contained in that part of the central region of the manhole jet where the discharge is Q, which implies that the energy contained at the exit of the discharge Q is fully recovered (a reasonable assumption since the transition to the exit pipe is associated with convergence of the streamlines and is known to have negligible head loss).

During the experiments it was observed that the jet was oscillating, even when a rigid lid replaced the free water surface. The experimentally determined angle of oscillation [5.7°, see Bo Pedersen (1986)] has been used in the final numerical calculations of the oscillating Lagrangian velocity profile, which means, that the wider Eulerian (the time-average Lagrangian) velocity profile has been used for type 1 manholes.

Entrance Head Loss, Type 2 Manholes

Manholes of type 2, see Fig. 2(*a*), were investigated in the laboratory by Lindvall (1986). It is quite easy to adjust our jet theory to this type of manholes since the guide walls at the bottom reduce the entrainment/detrainment zone of the jet to approximately half the value of a type 1 manhole. This means that the head loss must be approximately half the value of a nonoscillating jet in a type 1 manhole.

Entrance Head Loss, Type 3 Manholes

Manholes of type 3, see Fig. 2(*b*), were also investigated by Lindvall (1986). This type differs a little from the manholes mentioned previously, because the entrainment is further restricted here due to the more hydraulically shaped bottom. By approximating the flow with a plane jet of width D, the discharge and the energy flux E_M can be calculated in the same manner as just mentioned to yield

$$\frac{Q_M}{Q} = 1 - \frac{\sqrt{\pi}\, C_1 X}{D} + \frac{\sqrt{2\pi}\, C_1 X}{D} \operatorname{erf}\left(\frac{y + \sqrt{\pi}\, C_1 \frac{X}{2} - \frac{D}{2}}{\sqrt{2}\, C_1 X}\right) \quad (10)$$

and

$$\frac{E_M}{E} = 1 - \frac{\sqrt{\pi}\, C_1 X}{D} + \frac{\sqrt{\frac{2\pi}{3}}\, C_1 X}{D} \operatorname{erf}\left(\frac{y + \sqrt{\pi}\, C_1 \frac{X}{2} - \frac{D}{2}}{\sqrt{\frac{2}{3}}\, C_1 X}\right) \quad (11)$$

respectively, where the first two terms are the core region contributions, and C_1 given later. The term y is measured from the centerline level.

No oscillations are expected in these guided flows.

The zone of established flow $[X/D > 1/\sqrt{\pi}\, C_1 \approx 5.2$, Albertson et al. (1950)] has not been treated, as it is beyond the length in the experimental set-up.

Exit Head Loss

As mentioned, the exit head loss is associated with the expansion downstream of the vena contracta in the outlet pipe, plus a minor contribution from the friction:

$$K_{EX} = \left(\frac{1}{\psi} - 1\right)^2 + c \quad (12)$$

where $\psi = A/A_M$ = the area contraction coefficient (a weakly varying function of A/A_M); and the friction contribution coefficient c = a dimensionless parameter ($c \approx 0.1$, weakly dependent on the Reynolds number, the wall roughness, and the A/A_M ratio). In the numerical calculations we have used the experimentally determined values of ψ, but for practical purposes, the empirical formula in Fig. 1 may be used as well

$$K_{EX} \approx 0.5\left(1 - \frac{A}{A_M}\right) \quad (13)$$

where A_M = the cross-sectional area in the manhole jet, which has a discharge equal to the inlet/outlet discharge Q.

Experimental Verification

Type 1 Manholes

To verify the basic jet theory we designed a special manhole with a depressed bottom, see Fig. 3, to ensure that a nearly free jet was present.

Fig. 5 gives a view of the experimental setup in the laboratory of the Institute of Hydrodynamics and Hydraulic Engineering (ISVA). The inlet and outlet pipes were of transparent perspex with an internal diameter D = 90 mm. The inlet section was 7.67 m long (85 times the diameter), and the outlet section was 2.74 m long (30 times the diameter). The pressure head was measured by three piezometer tubes located 50 mm upstream and 330 mm (and 50 mm) downstream of the manhole, respectively. The pressure head was measured with an accuracy of 1 mm, ensuring a maximum error of 5% on the energy loss coefficient for the smallest discharge used in the experiments.

FIG. 5. View of Experimental Setup with Manhole Type 1

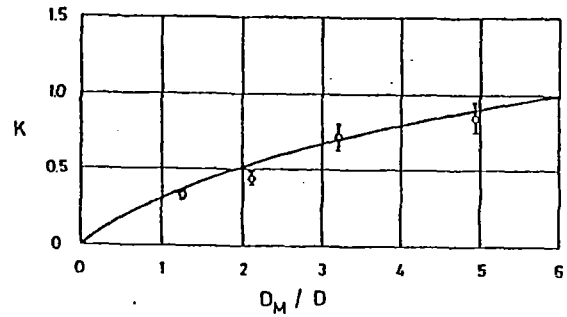


FIG. 6. Head Loss Coefficient for Type 1 Manhole (Fig. 3). Experimental Data Based on 184 Measurements. Theoretical Curve Based on Jet Theory (With Oscillation, i.e., Eulerian Velocity Profile)

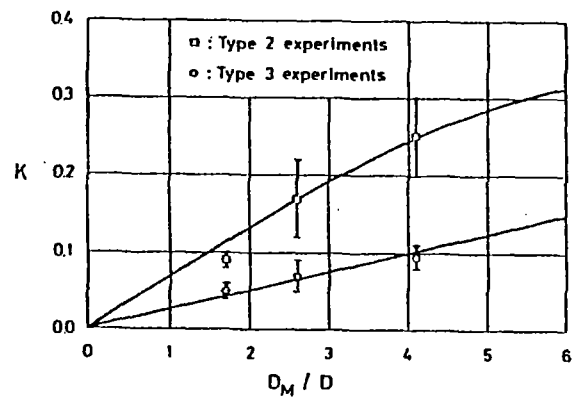


FIG. 7. Head Loss Coefficients for Manholes of Type 2 and Type 3 (See Fig. 2). Measurements Performed by Lindvall (1986). Theoretical Curves Based on Present Jet Theory (Without Oscillation)

The water depth ratios y/D (see Fig. 3) were varied from approximately 1 to 6. The range of discharges used was from 4 liter/s to 8 liter/s, yielding a minimum Reynolds number based on the diameter of 53,490 (18° C).

Four different sizes of manholes were investigated D_M/D = 1.22; 2.11; 3.20; and 4.94 with manhole bottom depressions of y_M/D = 1.22; 1.39; 1.38; and 1.33.

Detailed information on all the 184 experiments are reported in Mark (1989). In Fig. 6 are shown the statistically treated data in the form of mean values and standard deviations of the head loss coefficients measured for the four different sizes of manholes. At the same graph is shown the theoretically determined head loss coefficient.

It is noticed that the head loss coefficient is rather large compared with the values presented in Fig. 2 ($y/D > 2$). This is of course a consequence of the manhole layout, which is not very practical, but is ideal for testing the jet theory. Although the head loss coefficient is large, it is remarkable

that even at a manhole diameter equal to nearly five times the inl[illegible]eter the head loss is considerably smaller than the maximum value 1.5. With this strong evidence we feel confident that the proposed jet theory reflects the physics of the energy transformation in a manhole.

Type 2 and Type 3 Manholes

To test the theory with more realistic manholes it has been compared to the measurements performed by Lindvall (1986) (see Fig. 2).

We have adopted the data from the range of high y/D values, where the head loss coefficients are stabilized on a constant value.

As mentioned in the theoretical part, the type 2 manhole is from an entraining jet point of view just half a type 1 manhole with the exception that no oscillation takes place in the guided jet. This lack of oscillation is the reason that the theoretical curve for type 2 manholes in Fig. 7 is not half the value of the theoretical curve for type 1 manholes in Fig. 6, but a little less.

In the same manner, the dependency of the head loss coefficient on the relative manhole diameter is reflected in the measurements and the theory. Taking the absolute values of the coefficients into account—which are very low in the present types of well-shaped manholes—the agreement between the theory and the measurements is satisfactory.

Practical Application

For a given design of the junction manhole, the theory and the experiments

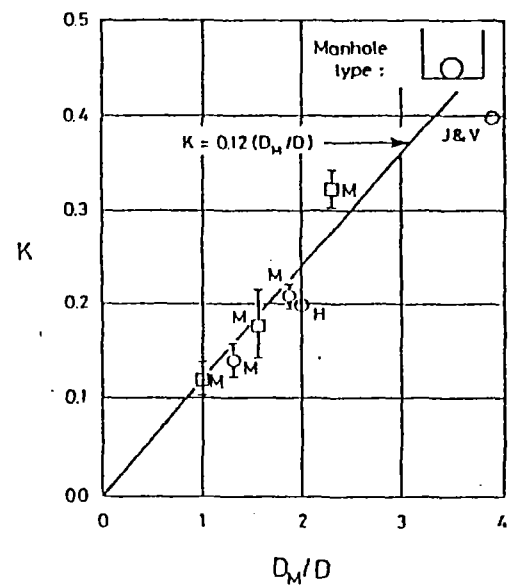
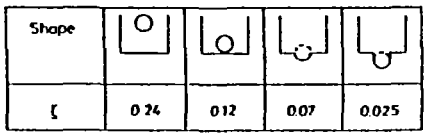


FIG. 8. Head Loss Coefficients for Manholes Without Moulding. Measurements Performed by Hare, Johnston, and Volker (Johnson and Volker 1990), Marsalek (1984). Circles: Circular Manholes; Squares: Square Manholes

Shape				
ζ	0.24	0.12	0.07	0.025

$\frac{D_M}{D} \leq 4$

FIG. 9. Shape Factor ζ (Eqs. 14 and 15) Estimated from Measurements with Diameter Ratio Up to 4

have shown that a unique relationship exists between the head loss coefficient K and the diameter ratio (D_M/D)

$$\Delta H = K\frac{V^2}{2g} \quad (14)$$

where K is a function of shape, (D_M/D).

A practical approach is therefore to approximate the experimentally obtained results to a simple function containing the diameter ratio and the shape factor ζ. The most simple function is

$$K = \zeta\left(\frac{D_M}{D}\right) \quad (15)$$

which from an engineering point of view fit the data satisfactory, confer with Figs. 6 and 7. Further support for the applicability of Eq. 15 is given in Fig. 8, where the measurements performed by Hare, Johnston, and Volker (Johnston and Volker 1990) and Marsalek (1984) are shown. The manhole represents the simple through flow without any flow guidance provided, where the bottom of the inlet/outlet pipe is located at or just above the bottom in the manhole.

In summary, the shape factor ζ in Eq. 15 can, for engineering purposes, be estimated from measurements. Based on the measurements dealt with, an estimate for the shape factor is given in Fig. 9.

Conclusion

In the design of storm sewer networks the major uncertainty is connected with the estimate of the head losses in the junction manholes. The commonly used empirical relations normally yield head losses that are an order-of-magnitude larger than the values encountered in laboratory experiments. To take advantage of the experiments, a theoretical model is needed, which is founded on a physical understanding of the energy transfer processes taking place in the manhole. Such a model has been outlined and verified for three different types of manholes. Being a basic theory, it may be extended to other types of manholes. From a practical point of view, the theory itself is too complicated to be incorporated in a numerical model of sewer networks, but the results of the theory can be used quite easily because the jet theory and the experiments have shown that the only governing parameter for a specific shape of a manhole is the ratio of the diameter of the manhole to the diameter of the pipe (D_M/D). This has been illustrated for a fourth type of manhole.

The present investigations have been restricted to a few different types of manholes, all with a straight through flow and with fully submerged inlet

and outlet pipes (of equal diameter). Taking the variability of des .nc-tion manholes into account, there remain many further cases to be investigated. It is believed that the jet theory outlined may serve as a guideline for interpreting this future research on head losses in manholes.

Appendix I. References

Albertson, M. L., et al. (1950). "Diffusion of submerged jets." *Trans.*, ASCE, 115, 617–639.

Bo Pedersen, F. (1986). "Environmental hydraulics: Stratified flows." *Lecture notes on coastal and estuarine studies 18*. Springer Verlag, Berlin, West Germany.

Johnston, A. J., and Volker, R. E. (1990). "Head losses at junction boxes." *J. Hydr. Engrg.*, ASCE, 116(3), 326–341.

Lindvall, G. (1986). "Energiförluster i ledningsbrunnar, laboratoriemätningar." Geohydrologiska forskningsgruppen, Meddelande nr.81, Chalmars Tekniska Högskola, Sweden (in Swedish).

Marsalek, J. (1984). "Head losses at sewer junction manholes." *J. Hydr. Engrg.*, ASCE, 110(8), 1150–1154.

Mark, O. (1989). "En matematisk model for energitab i brønde," thesis presented to the Institute of Hydrodynamics and Hydraulic Engineering, Technical University of Denmark, at Lyngby, Denmark, in partial fulfillment of the requirements for the degree of Master of Science (in Danish).

Appendix II. Notation

The following symbols are used in this paper:

A = area;
A_M = effective flow area in the manhole;
C_1, C_2 = dimensionless constants;
c = friction contribution coefficient;
D = pipe diameter;
D_M = manhole diameter;
E = flux of kinetic energy in the pipe;
E_C = flux of kinetic energy in the jet core;
E_D = flux of kinetic energy in the jet diffusion region;
E_M = flux of kinetic energy in the manhole;
E_0 = flux of kinetic energy out of the manhole;
EN = entrance;
EX = exit;
f = dimensionless friction factor;
g = acceleration of gravity;
K = dimensionless head loss coefficient (see Fig. 1);
L = length;
L_E = equivalent length of manhole;
Q = discharge in the pipe;
Q_c = discharge in the jet core;
Q_D = discharge in the jet diffusion region;
Q_M = discharge in the manhole;
R = hydraulic radius;
r = lateral distance from centerline (see Fig. 4);
r_1 = lateral distance from the jet core (see Fig. 4);
V = mean velocity;

X = coordinate in the flow direction (see Fig. 3);
y = vertical coordinate (see Fig. 3);
y_M = bottom depression in the manhole (see Fig. 3);
ΔH_F = friction loss;
ΔH_s = single head loss; and
ψ = A/A_M = area contraction coefficient.

Explicit Calculation of Pipe-Netwo Parameters

By Paul F. Boulos,[1] Associate Member, ASCE, and Don J. Wood,[2] Member, ASCE

Abstract: An explicit algorithm is presented for directly determining a variety of design, operating, and calibration parameters for pipe networks. The problem solution is based on the reformulation of the steady-state network equilibrium equations in terms of specified pipe-system parameters. Since these equations are nonlinear, the incremental Newton-Raphson method is used as the basic solution procedure. A continuous variable space is assumed for the various parameters, which are selected to exactly satisfy stated pressure and flow requirements at critical nodes and pipes throughout the pipeline systems for a range of operating conditions. This approach offers a basis for determining the optimum values for the various design, operating, and calibration parameters in the sense that the parameters can be calculated to exactly meet the specified pressure and flow constraints. All types of pipe distribution systems can be considered. The solution space is secured through a well-arranged interaction between network topology, boundary constraints, and network parameters. The feasibility and flexibility of the proposed approach are demonstrated using an example network.

Introduction

An iterative solution of the full set of continuity and energy equations provides a powerful technique for the determination of steady-state pressure and flow conditions in pipe networks. The number of independent continuity and energy equations equals the number of pipe sections for all network configurations. The resulting equation set is quasi-linear and is expressed in terms of the unknown flow rates in the pipe sections. The solution is obtained by applying the Newton-Raphson procedure to linearize nonlinear terms and solving the resulting system of linear simultaneous equations. Since the Newton-Raphson linearization is based on the solution vector, several trials are required to obtain an accurate solution. This approach has been compared to a number of alternative techniques for pipe network analysis and has been shown to exhibit superior convergence characteristics (Wood and Rayes 1981; Nielsen 1989).

This full-equation approach to network analysis is expanded in the present paper to include the specification of additional continuity and energy equations for the piping system and the use of additional equations for the direct determination of a wide variety of designated pipe-system parameters. The added continuity equations describe specified flow rates in designated critical pipe sections, e.g., the required flow into or out of a storage facility or supply. The added energy equations describe specified pressure requirements at designated nodes, such as the minimum pressure required at a designated junction node for a particular application. Parameters that can be explicitly determined include design parameters such as pipe diameter, operating pa-

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Estimating Flow through Riprap

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Introduction

Estimating flow through rockfill and protective rock covers can be a useful procedure for designing or evaluating flood control, waste repository, and waterways structures. Often, a knowledge of rockfill and rock cover transmissibility and the effect of through-flow forces on the stone are needed for structural stability analyses. Through-flow velocity is defined as the average velocity of water flow through rock voids. An understanding of turbulent flow in a rock medium is needed for through-flow analyses.

Numerous investigators have analyzed turbulent through flow, including Weiss (1951), Escande (1953), Olivier (1967), and Stephenson (1979). Wilkins (1956, 1963) performed laboratory transmissivity tests on cylindrical specimens, resulting in the relation

$$V_v = 32.9 m^{0.5} i^{0.54} \quad (1)$$

where V_v = the average velocity of water through rock voids in inches per second; i = the hydraulic gradient; and m = the hydraulic mean radius of rock voids in inches (volume of voids divided by total surface area of the particles).

Parkin (1963; Parkin et al. 1966) performed tests on clean, angular gravel (3/8–3/4 in.). Parkin derived the expression

$$i = 1.86 V_v^{1.86} \quad (2)$$

where i = the hydraulic gradient and V_v = the average velocity of flow through the rock voids in feet per second.

Leps (1973) consolidated the concepts of Escande, Wilkins, and Parkin and presented an expression for the average flow through rockfill for turbulent conditions as

$$V_v = W m^{0.5} i^{0.54} \quad (3)$$

where V_v = the average velocity of water in rockfill voids in inches per second; W = an empirical constant; m = the hydraulic mean radius in inches; and i = the hydraulic gradient. The average through-flow velocity is estimated by obtaining the appropriate value from Table 1 and inserting it into Eq. 3. Leps' relation is applicable to uniformly sized rock with a specific gravity of 2.87.

Wilkins (1956, 1963), Olivier (1967), and Stephenson (1979) reported that

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TABLE 1. Coefficients for Estimating Through Flow (for Eq. 3)

Rock Size in. (1)	Rock Size cm (2)	$Wm^{0.5}$ (3)
0.75	1.9	10
2	5.1	16
6	15.2	28
8	20.3	32
24	61.0	58
48	121.9	84

Note: Adapted from Leps (1971).

the average interstitial, or through-flow, velocity was a function of the riprap properties and the gradient. However, in the preliminary design process, the engineer must assume a representative stone size and gradation before extensive material testing or analysis of a rock source is done. Therefore, a procedure that predicts the average through-flow velocity for riprap and rockfill would be helpful. This note presents a method.

Experimental Program

An experimental program was conducted by Abt et al. (1987, 1988) at Colorado State University in which embankments with slopes ranging from 1–20% were constructed in recirculating flumes. These model embankments were similar to those designed for waste repositories. The embankments consisted of a compacted sand material covered with a geotextile. A 6-in. (0.15-m) sand-gravel bed was placed atop the geotextile. Riprap was placed on top of the bedding material in uniform layer thicknesses ranging from 3 in. (7.6 cm) to 12 in. (30.5 cm). The embankments were constructed horizontally upstream of the crest and transitioned to the desired downstream slope. Water overtopped the embankment crest and flowed through the riprap.

The riprap was obtained from a limestone quarry. Median stone sizes D_{50}, ranged from 1.02 in. (2.6 cm) to 6.2 in. (15.8 cm), as presented in Table 2. The rock specific gravity was 2.65, the gradation d_{84}/d_{16}, ranged from 1.80 to 2.72, and the stones were angular.

A tracer injection and recording system was developed to document the flow velocities through the riprap layer. The system consisted of a pressure-operated tracer injector, tracer-sensitive probes, a multichannel selector, and a multichannel strip chart recorder. Each tracer-sensitive probe was fabricated with three tracer-sensitive elements placed in the lower 8 in. (20.3 cm) of the probe. The tracer injector was fabricated with three injection ports. The injector port spacing was similar to the spacing of the tracer-sensitive elements in the probe; the spacing was 3 in. Fig. 1 shows a schematic of the injector and sensor in the rock layer. A salt solution was used as the tracer.

The injector ports were approximately aligned in the riprap layer with the elements in the tracer-sensitive probe. The lowest injector was approximately 1 in. (2.54 cm) above the riprap bedding interface. The injector was placed

TABLE 2. Interstitial Velocity Summary

Test number (1)	Median Stone Size, D_{50} in. (2)	cm (3)	D_{10} in. (4)	cm (5)	Riprap Layer Thickness in. (6)	cm (7)	Embankment slope (8)	Average Interstitial Velocity V_i fps (9)	cm/s (10)
61	1.02	2.6	0.6	1.5	3	7.6	0.01	0.10	3.0
71	1.02	2.6	0.6	1.5	3	7.6	0.02	0.13	4.0
91	1.02	2.6	0.6	1.5	3	7.6	0.10	0.24	7.3
41	2.2	5.6	1.1	2.8	6	15.2	0.01	0.15	4.6
31	2.2	5.6	1.1	2.8	6	15.2	0.02	0.23	7.0
101	2.2	5.6	1.1	2.8	6	15.2	0.10	0.36	11.0
111	2.2	5.6	1.1	2.8	6	15.2	0.10	0.37	11.3
3	4.1	10.4	2.0	5.1	12	30.5	0.20	0.72	21.9
4	4.1	10.4	2.0	5.1	12	30.5	0.20	0.97	29.6
8	5.1	13.0	3.45	8.8	12	30.5	0.20	1.04	31.7
9	5.1	13.0	3.45	8.8	12	30.5	0.20	0.86	26.2
14	6.2	15.7	3.8	9.7	12	30.5	0.20	1.47	44.8
26	2.0	5.1	1.03	2.6	3	7.6	0.10	0.46	14.0
28	2.0	5.1	1.03	2.6	4	10.2	0.10	0.50	15.2
30	2.0	5.1	1.03	2.6	6	15.2	0.10	0.54	16.5
39	4.0	10.2	2.0	5.1	6	15.2	0.10	0.62	18.9
41	4.0	10.2	2.0	5.1	8	20.3	0.10	0.66	20.1
47	4.0	10.2	1.2	3.0	12	30.5	0.10	0.48	14.6
50	4.0	10.2	2.38	6.0	12	30.5	0.10	0.66	20.1

The second probe was 20–24 in. (50.3–61.0 cm) downstream from the injector. Velocity measurements were taken in the upper third and lower third segments of the embankment slope.

In each of the 19 tests, flow was established in the flume with the water surface stabilized at a point just above the riprap surface. The tracer was then injected into the rock layer. An event marker on the strip chart recorder indicated when the injector was triggered. Output from the tracer-sensitive probe elements also was recorded on the strip chart so that tracer concentration versus time could be observed and documented. A tracer concentration curve was recorded for each injector port. The peak of the concentration curve was used to estimate the interstitial velocity. Knowing the time of injection, travel time between injector and tracer ports, and the distance between ports, one could compute the average interstitial velocity for each test condition in the rock layer. Each velocity reported in Table 2 represents the average value of one-to-five velocity measurement locations in each profile. The number of velocity measurements taken was a function of the layer thickness; a 3-in. (7.62 cm) layer allowed space for a single velocity measurement.

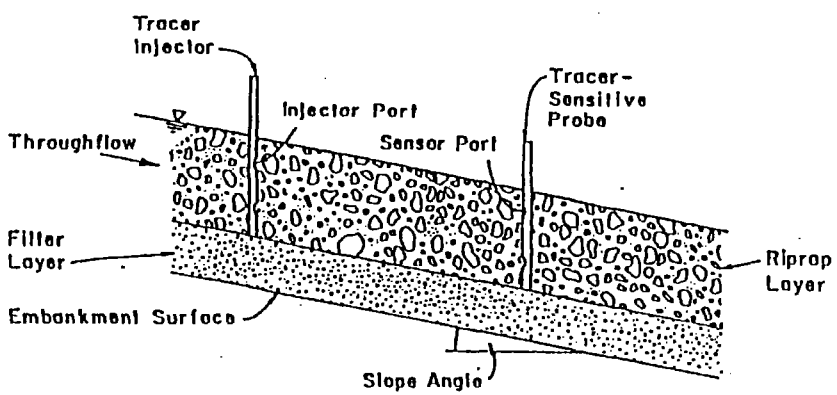

FIG. 1. Schematic of Tracer Injector and Sensor in Rock Layer

Results

The average interstitial velocities V_i that resulted from the 19 flume tests are presented in Table 2. Velocities through the rock layers ranged from 3–44.8 cm/s for embankment slopes of 1–20%, respectively. At a constant slope of 10%, average interstitial velocities ranged from 7.3–20.1 cm/s for median stone sizes of 2.6–10.2 cm, respectively.

A sensitivity analysis was performed, relating the rock size and embankment gradient to the average interstitial velocity. Representative stone sizes of D_{50}, D_{40}, D_{30}, D_{20}, D_{15}, and D_{10}, in conjunction with the slope, were correlated with the measured interstitial velocity. The analysis indicated that

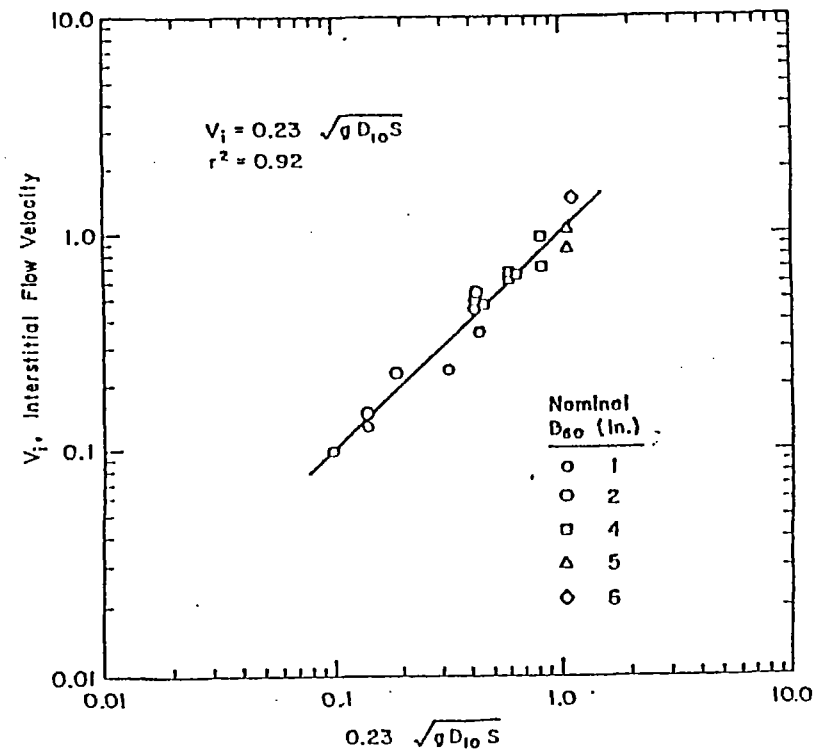

FIG. 2. Average Interstitial Velocity through Riprap as Function of D_{10} and Gradient

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this is not hydraulic gradient.

the D_{10} stone diameter (at which 10% of the weight is finer) provided the highest coefficient of correlation of the stone sizes tested. The interstitial velocities are shown in Fig. 2, as a function of the rock size D_{10} and the slope. A linear regression analysis yielded the expression

$$V_i = 0.23(gD_{10}S)^{1/2} \quad (4)$$ (SAE)

where V_i = the average interstitial velocity in feet per second; g = the acceleration of gravity in ft/sec^2, D_{10} is in inches, and S = the gradient expressed in decimal form. The correlation coefficient for Eq. 4 is $r^2 = 0.92$. It appears that the D_{10} stone size controls the rate of flow through the stone layer void space. Eq. 4 can be expressed in SI units as

$$V_i = 0.79(gD_{10}S)^{1/2} \quad (5)$$ (SI)

The flow distance between the injector port and the sensor port was dependent on the probe placement in the rock layer. In some instances, the injector discharged directly into a large stone, resulting in immediate tracer dilution and the tracer taking a sinuous path toward the sensor. In other cases, the injector discharged into a void between the stones, resulting in a shortened path between injector and sensor. Because of the high variability in flow distance, the average interstitial velocities through the rock layer varied ± 40%. Velocity variability was dependent on stone size.

Conclusions

A series of 19 flume tests was conducted, in which flow was routed through a riprap layer, and the average interstitial, or through-flow, velocity was measured and recorded. Flow measurements varied ±40% about the average velocity. A predictive relationship was developed in which the average interstitial velocity was determined to be a function of the embankment slope and rock size D_{10}, as presented in Eq. 4. The predictive relationship provides the designer with a method for estimating through flow based upon a representative stone size, gradation, and embankment slope. The relationship was developed for stone sizes with a D_{50} ranging from 2.6 cm to 15.7 cm, (1.0 – 6.2 in.) and D_{10} ranging from 1.5 cm to 9.7 cm. (0.6 in. – 3.8 in.)

Acknowledgment

This research was sponsored by the Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission.

Appendix. References

Abt, S. R., Khattak, M. S., Nelson, J. D., Ruff, J. F., Shaikh, A., Wittler, R. J., Lee, D. W., and Hinkle, N. E. (1987). "Development of riprap design criteria by riprap testing in flumes: Phase I." *NUREG/CR-4651*, U.S. Nuclear Regulatory Commission, Vol. 1, 48–53.

Abt, S. R., Wittler, R. J., Ruff, J. F., LaGrone, D. L., Khattak, M. S., Nelson, J. D., Hinkle, N. E., and Lee, D. W. (1988). "Development of riprap design criteria by riprap testing in flumes: Phase II." *NUREG/CR-4651*, U.S. Nuclear Regulatory Commission, Vol. 2, 57–65.

Escande, L. (1953). "Experiments concerning the infiltration of water through a rock mass." *Proc., Minnesota Int. Hydrology Convention.*

Leps, T. M. (1973). "Flow through rockfill." *Embankment dam engineering*, John Wiley and Sons, 87–107.

Olivier, H. (1967). "Through and overflow rockfill dams—New design techniques." *J. Inst. of Civ. Engrg.*, 36, 433–471.

Parkin, A. K. (1963). "Rockfill Dams with Inbuilt spillway." *Bulletin No. 6*, Water Resources Edn. Australia, Melbourne, Australia.

Parkin, A. K., Trollope, D. H., and Lawson, J. D. (1966). "Rockfill structures subject to water flow." *J. Soil Mech. Found. Div.*, ASCE, (6), 135.

Stephenson, D. (1979). *Rockfill in hydraulic engineering: Developments in geotechnical engineering 27*, Elsevier Scientific Publishing Company, Amsterdam, the Netherlands, 38–60.

Weiss, A. (1951). "Construction technique of passing floods over earth dams." *Trans. ASCE*, 116, 1158–1173.

Wilkins, J. K. (1956). "Flow of water through rockfill and its application to the design of dams." *Proc., Second Australian—New Zealand Soil Conf.*, Mechanics and Foundation Engrg., Christchurch, New Zealand.

Wilkins, J. K. (1963). "The stability of overtopped rockfill dams." *Proc. Fourth Australian Conf. on Soil Mech. Found. Engrg.*, Adelaide, Australia, 1–7.

NOTE: V_i is the average velocity of water through the rock voids. Q would equal $V_i A_v$. To determine A_v, the total area and void ratio (e) are required.

24/24

H-26

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DRAWN G.Y. CHECKED TRG APPROVED TRG DATE 4-2-99 DWG. NO. 97-481-

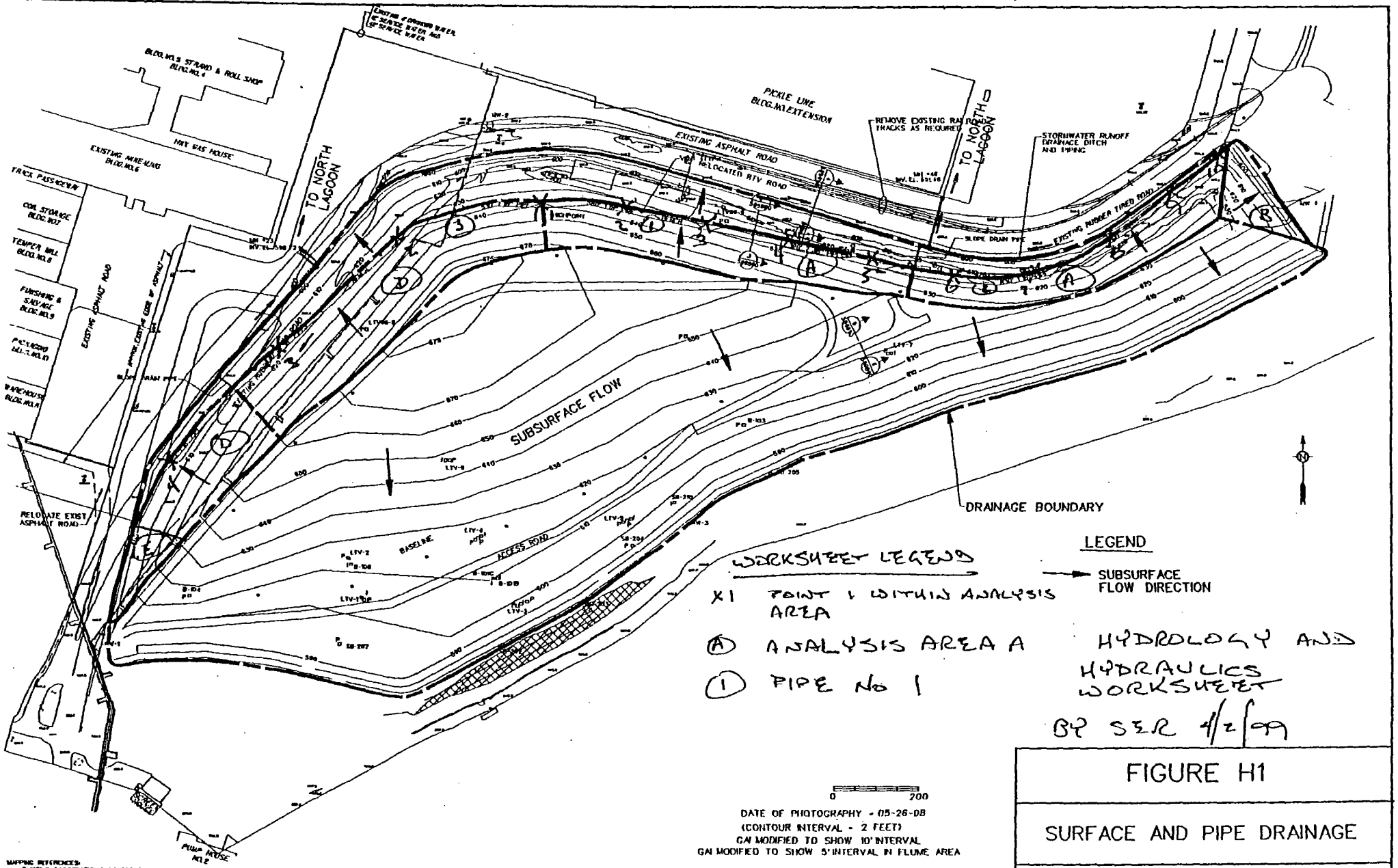

FIGURE H1

SURFACE AND PIPE DRAINAGE

CLARK LANDFILL
INDIANA HARBOR WORKS

LTV STEEL COMPANY, INC.
CLEVELAND, OHIO

1 REV

I-3

SUBJECT LTV
INDIANA HARBOR WORKS
BY [illegible] DATE 2/16/99 PROJ. NO. 97-481-10
CHKD. BY SER DATE 2/17/99 SHEET NO. 1 OF 3

GAI CONSULTANTS, INC.
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THRUST BLOCK FORCE

TWO 18" PIPES ACT AS SLOPE DRAINS AND TRANSPORT FLOW FROM BENCHES TO A MANHOLE. THIS SLOPE IS 3H : 1V.

ESTIMATE FORCE IMPACTED BY THE SLOPE DRAINS ON THE MANHOLE.

FROM HYDRAULIC CALCULATIONS BY SER, THE MAXIMUM FLOW IN SLOPE PIPES IS 25.7 cfs (SHEET 7 OF 17 OF SER CALCS) FOR A 100-YEAR EVENT. ANALYZE TO SEE IF THIS IS A FULL-FLOW CONDITION OR NOT. USE ONE PIPE.

PIPE IS HDPE USE $n = 0.011$

$S = 1/3 = 0.33$

FROM MANNING'S EQUATION

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \Rightarrow A R^{2/3} = \frac{Q n}{1.49 S^{1/2}} = \frac{(25.7)(0.011)}{(1.49)(0.33)^{1/2}}$$

$$A R^{2/3} = 0.3303$$

$$\frac{A R^{2/3}}{d_0^{8/3}} = \frac{0.3303}{1.5^{8/3}} = 0.1120$$

FROM THE ATTACHED TABLE, $\frac{y}{d_0} = 0.41 \Rightarrow y = 0.41 \times 1.5 = 0.62'$

$$\frac{A}{d_0^2} = 0.3032 \Rightarrow A = 0.3032 \times 1.5^2 = 0.68 \text{ ft}^2$$

VELOCITY IS $\frac{25.7}{0.68} = 37.8$ ft/s

SUBJECT LTV
INDIANA HARBOR WORKS
BY KMB DATE 2/16/99 PROJ. NO. 97-481-10
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H-39

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APPENDIX A. GEOMETRIC ELEMENTS FOR CIRCULAR CHANNEL SECTIONS (*continued*)

$\frac{y}{d_0}$	$\frac{A}{d_0^2}$	$\frac{P}{d_0}$	$\frac{R}{d_0}$	$\frac{T}{d_0}$	$\frac{D}{d_0}$	$\frac{Z}{d_0^{2.5}}$	$\frac{AR^{2/3}}{d_0^{8/3}}$
0.31	0.2074	1.1810	0.1755	0.9250	0.2242	0.0981	0.0650
0.32	0.2167	1.2025	0.1801	0.9330	0.2322	0.1044	0.0690
0.33	0.2260	1.2239	0.1848	0.9404	0.2404	0.1107	0.0736
0.34	0.2355	1.2451	0.1891	0.9474	0.2486	0.1172	0.0776
0.35	0.2450	1.2661	0.1935	0.9539	0.2568	0.1241	0.0820
0.36	0.2546	1.2870	0.1978	0.9600	0.2652	0.1310	0.0864
0.37	0.2642	1.3078	0.2020	0.9656	0.2736	0.1381	0.0909
0.38	0.2739	1.3284	0.2061	0.9708	0.2822	0.1453	0.0955
0.39	0.2836	1.3490	0.2102	0.9755	0.2908	0.1528	0.1020
0.40	0.2934	1.3694	0.2142	0.9798	0.2994	0.1603	0.1050
0.41	0.3032	1.3898	0.2181	0.9837	0.3082	0.1682	0.1100
0.42	0.3132	1.4101	0.2220	0.9871	0.3172	0.1761	0.1147
0.43	0.3229	1.4303	0.2257	0.9902	0.3262	0.1844	0.1196
0.44	0.3328	1.4505	0.2294	0.9928	0.3352	0.1927	0.1245
0.45	0.3428	1.4706	0.2331	0.9950	0.3446	0.2011	0.1298
0.46	0.3527	1.4907	0.2366	0.9968	0.3538	0.2098	0.1348
0.47	0.3627	1.5108	0.2400	0.9982	0.3634	0.2186	0.1401
0.48	0.3727	1.5308	0.2434	0.9992	0.3730	0.2275	0.1452
0.49	0.3827	1.5508	0.2467	0.9998	0.3828	0.2366	0.1505
0.50	0.3927	1.5708	0.2500	1.0000	0.3928	0.2459	0.1558
0.51	0.4027	1.5908	0.2531	0.9998	0.4028	0.2553	0.1610
0.52	0.4127	1.6108	0.2561	0.9992	0.4130	0.2650	0.1664
0.53	0.4227	1.6308	0.2591	0.9982	0.4234	0.2748	0.1715
0.54	0.4327	1.6509	0.2620	0.9968	0.4340	0.2848	0.1772
0.55	0.4426	1.6710	0.2649	0.9950	0.4448	0.2949	0.1825
0.56	0.4526	1.6911	0.2676	0.9928	0.4558	0.3051	0.1878
0.57	0.4625	1.7113	0.2703	0.9902	0.4670	0.3158	0.1933
0.58	0.4723	1.7315	0.2728	0.9871	0.4786	0.3263	0.1987
0.59	0.4822	1.7518	0.2753	0.9837	0.4902	0.3373	0.2041
0.60	0.4920	1.7722	0.2776	0.9798	0.5022	0.3484	0.2092
0.61	0.5018	1.7926	0.2797	0.9755	0.5144	0.3560	0.2146
0.62	0.5115	1.8132	0.2818	0.9708	0.5270	0.3710	0.2199
0.63	0.5212	1.8338	0.2839	0.9656	0.5398	0.3830	0.2252
0.64	0.5308	1.8546	0.2860	0.9600	0.5530	0.3945	0.2302
0.65	0.5404	1.8755	0.2881	0.9539	0.5666	0.4066	0.2358

FROM CHOW "OPEN CHANNEL HYDRAULICS"

SUBJECT LTV
INDIANA HARBOR WORKS
BY LMB DATE 2/16/99 PROJ. NO. 97-481-10
CHKD. BY SER DATE 2/17/99 SHEET NO. 3 OF 3

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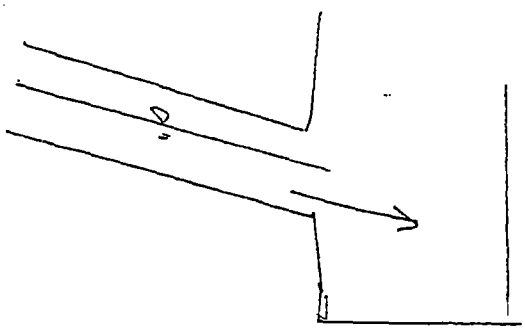
THE SITUATION IS



ASSUME THAT THE VELOCITY IN THE MANHOLE IS 0.

IN THE DIRECTION OF FLOW, $F = \frac{Q \gamma v}{g}$ (MOMENTUM EQUATION)

$$= \frac{(25.7\ \frac{ft^3}{s})(62.4\ \frac{lb}{ft^3})(37.8\ \frac{ft}{s})}{32.2\ ft/s^2} = 1900\ lb$$

USE 2000 lb AS A DESIGN VALUE.
NOTE THAT THIS FORCE ACTS IN THE DIRECTION OF FLOW.

H-41

SUBJECT LTV
PIPE THRUST BLOCK

BY EDS DATE 2/17/99 PROJ. NO. 97-481-10

CHKD. BY _____ DATE _____ SHEET NO. 1 OF 2

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The force on the pipe (see attached note) is 2000 lb, with slope 3 horizontal, 1 vertical *

proposed dimensions are (see Dwg 589890)

4' x 8'

Area = 32 ft.

stress = $\frac{2000}{32}$ = 62.5 lb/ft² very small

From AASHTO chapter 4 - Foundations the bearing capacity of an inclined footing is

65 lb/ft² (allowable)
(see spreadsheet in the next page)

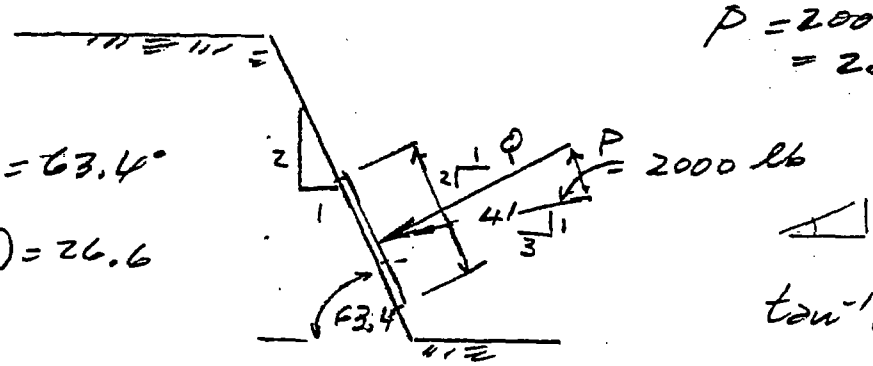
$\theta = 26.6 - 18.4 = 8.2°$

$Q = 2000 \cos 8.2$
$= 1980$ lbs

$P = 2000 \sin 8.2$
$= 285$ lbs

$\tan^{-1}(2) = 63.4°$

$\tan^{-1}(0.5) = 26.6$



$\tan^{-1}(\frac{1}{3}) = 18.4$

---

* As provided by Kevin Bortz

LTV - Pipe Thrust Block Sheet# 2/2 H-42

FEB 2/18/99 Prj No 97-481-10

ALLOWABLE BEARING CAPACITY OF SOILS								
INPUT:								
	c =	0			D =	0	ft	
	ϕ =	30	degrees		B =	4	ft	
	=	0.5236	radians		L =	8	ft	
	γ =	60	lb/ft^3					
	P =	285.00	lbs	α =	63.4	degrees	base inclination	
	Q =	1980.00	lbs	=	1.1065	radians	angle	
	M_B =	0		θ =	8.2	degrees		
	M_L =	0		=	0.1431	radians		
CALCULATE:								
	e_B =	0		N_q =	18.40			
	e_L =	0		N_c =	30.14			
shape				N_γ =	22.40			
	s_c =	1.31						
	s_q =	1.29						
	s_γ =	0.80						
inclined load				inclined base				
	n =	1.34						
	i_q =	0.81			b_q =	0.13		
	i_γ =	0.70			b_γ =	0.13		
	i_c =	0.80			b_c =	0.08		
	q =	0.00						
q_u =	from c =	0	lbs/ft^2					
	from γ =	195	lbs/ft^2					
	from q =	0	lbs/ft^2					
	total =	195	lbs/ft^2					
FS =	3							
q_{all} =	65	lbs/ft^2						
q_{actual} =	61.88	lbs/ft^2						

SUBJECT LTV STEEL

BY SER DATE 4/1/99 PROJ. NO. 97-481-10

CHKD. BY _____ DATE _____ SHEET NO. 1 OF 1

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RISER
BOUYANCY

DISPLACED WATER VOLUME $= 5' \times \frac{\pi 3^2}{4} = 35.3\,cf$

DISPLACED WATER WEIGHT $= 35.3\,cf \cdot 62.4\,pcf$
$= 2200$ lbs

UNIT WEIGHT OF CONCRETE $= 150\,pcf$

VOLUME OF CONCRETE $= \frac{2200}{150} = 15\,cf$

A $5' \times 5' \times 1'$ PAD HAS A VOLUME $= 25\,cf$

FACTOR OF SAFETY, $F_S = \frac{25}{15} = 1.7$ ∴ OK

APPENDIX I

COVER STABILITY CALCULATIONS

SUBJECT INFINITE SLOPE ANALYSIS
CLARK LANDFILL COVER

BY BLR DATE 11/4/98 Rev. 11/14/99 PROJ. NO. 97-481
CHKD. BY CWS DATE 1/5/99 SHEET NO. 1 OF 2

GSI CONSULTANTS, INC.
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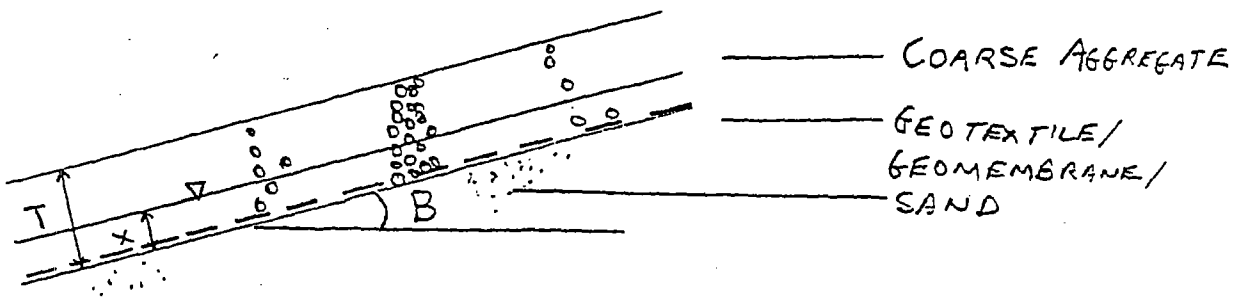
PURPOSE

CALCULATE THE FS FOR VARIOUS CASES OF WATER IN THE COARSE AGGREGATE COVER MATERIAL.

CALCULATION



$$r_u = \frac{X}{T}\frac{\gamma_w}{\gamma}\cos^2\beta$$

$$F = A\frac{\tan\phi'}{\tan\beta} + B\frac{c'}{\gamma H}$$

WITH:

$T = 18''$ (1.5')
X = VARIES - SEE ATTACHED MEMO
$\beta = 18.4°$ Max (3H:1V)
$\gamma_w = 62.4$ pcf
$\gamma = 90$ pcf
$c = 0$ psf
ϕ = SAY = 22° OR 26°
A FROM FIG 13-8 (ATTACHED)

	X	r_u	A	F (ϕ = 22°)	F (ϕ = 26°)	F (ϕ = 24°
	0	0	1	1.21	1.47	1.37
	1"	.035	.96	1.17	1.41	1.32
100 yr.	1.2"	.042	.95	1.15	1.39	1.30

SUBJECT INFINITE SLOPE

BY _____ DATE 1/4/99 PROJ. NO. 97-481

CHKD. BY CWS DATE 1/5/99 SHEET NO. 2 OF 2

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WITH $\beta = 8°$ (7H:1V)

	X	r_u	A	F ($\phi = 22°$)
	0	0	1	2.87
	1"	.038	.96	2.75
100 yr.	2.5"	.094	.90	2.58

I-3

5.4 Infinite Slope Analyses

Conditions are sometimes encountered in which a layer of firm soil or rock lies parallel to the surface of the slope at shallow depth. In such conditions the slip surface is constrained to parallel the slope, as shown in Figure 13-8. When such slip surfaces are long compared with their depth, they can be approximated accurately by infinite slope analyses. Such analyses ignore the driving force at the upper end of the slide mass and the resisting force at the lower end. The resisting force is ordinarily greater, and infinite slope analyses are therefore somewhat conservative.

The factor of safety for infinite slope analyses can be expressed as

$$F = A\frac{\tan\phi'}{\tan\beta} + B\frac{c'}{\gamma H} \qquad (13.15)$$

where

A, B = dimensionless stability coefficients given in Figure 13-8,
ϕ', c' = effective stress strength parameters for slip surface,
β = slope angle,
γ = unit weight of sliding mass (force per length cubed), and

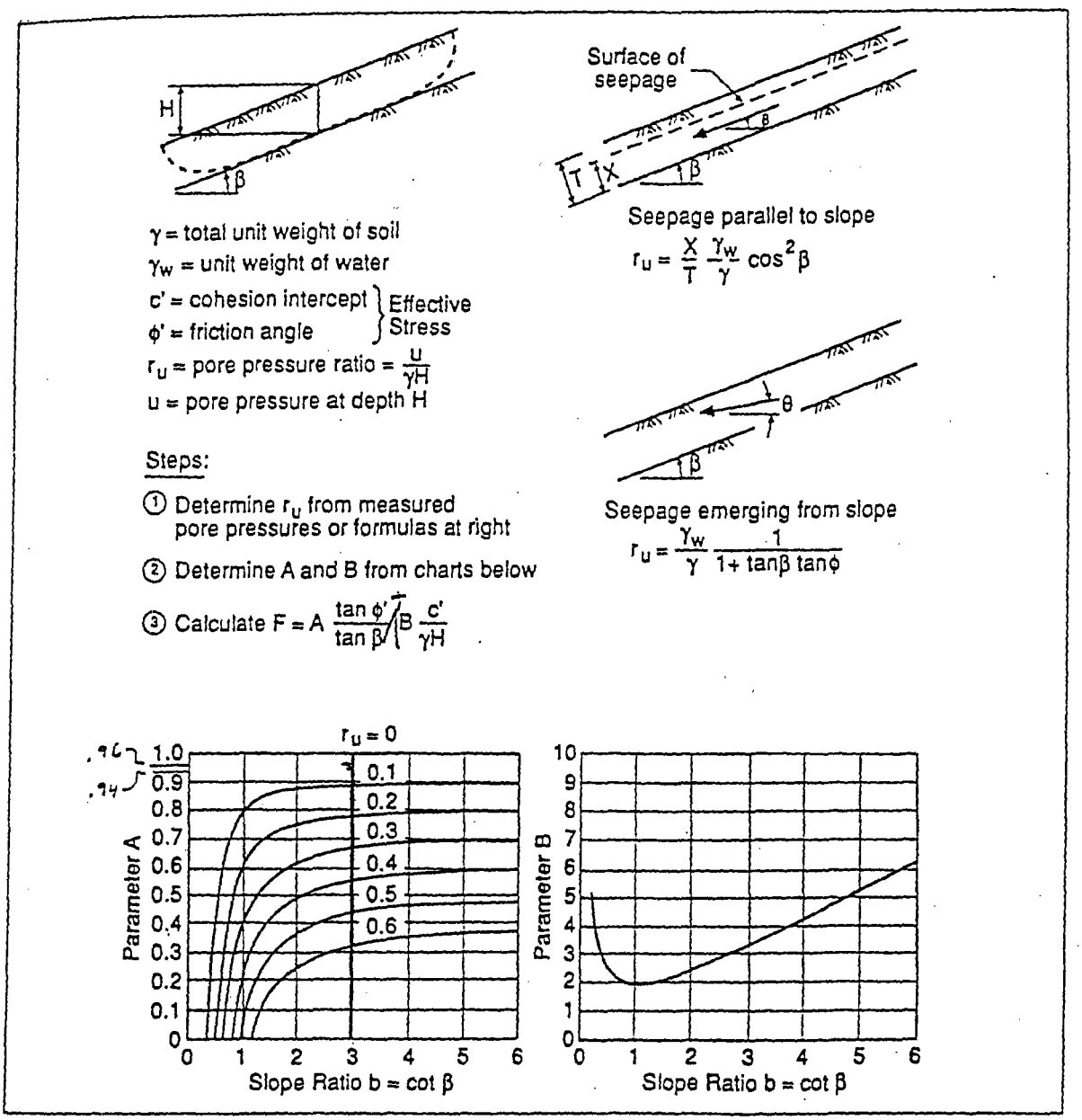

FIGURE 13-8
Stability char
infinite slope
(modified fr
Duncan et a

I-4

INTRA-OFFICE MEMO

GAI CONSULTANTS, INC.
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Environmental Specialists

To: BRUCE ROTH

From: SE RUST

Subject: LTV

Project No. 97-481-10 ☐ For Information Only ☐ For Your Action

Date: 12/29/98 ☐ For Review and Reply ☐ Non-Project File No.

TO GIVE YOU OUR MOST UP TO DATE ESTIMATE OF WATER DEPTHS (100 YEAR STORM EVENT) VS. SLOPE OF CAP I AM SENDING THIS MEMO

SLOPE (H:V)	WATER DEPTH 100 YEAR EVENT (FEET)
30:1	0.21
15:1	0.26
7.5:1	0.20
~~5~~7:1	0.21
4:1	0.16
3:1	0.10

Distribution: FBN, JDP, KMB

SUBJECT VENEER STABILITY
LTV CLARK LANDFILL

BY BLR DATE 2/15/99 PROJ. NO. 97-481-10

CHKD. BY EB DATE 2/16/99 SHEET NO. 1 OF 5

GAI CONSULTANTS, INC.
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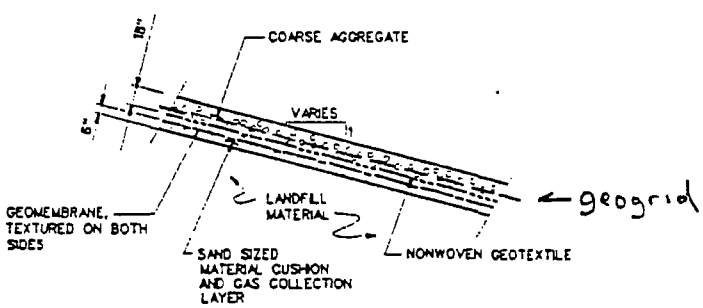
PURPOSE

THE STABILITY OF THE COVER RELATIVE TO VENEER INSTABILITY HAS PREVIOUSLY BEEN CONSIDERED IN THE CALCULATION DATED 11/4/98 BY BLR. BASED UPON THE INTERFACE FRICTION LABORATORY TEST RESULTS PERFORMED FOR THIS WORK (GEOTECHNICS, 12/16/98) THE MINIMUM FRICTION ANGLE OCCURS AT THE GEOTEXTILE / TEXTURED GEOMEMBRANE INTERFACE AND IS EQUAL TO 22°. THE TYPICAL COVER DETAIL IS SHOWN BELOW.



DETAIL 5 / 589884

TYPICAL COVER DETAIL

N.T.S.

THE PURPOSE OF THIS CALCULATION IS TO ACHIEVE A FACTOR OF SAFETY EQUAL TO 1.5 FOR THE DRY CASE AND 1.3 FOR THE 100 YR RAINFALL EVENT CASE.

CALCULATION

USING THE METHOD OF GIROUD AND BEECH, 1989, FOR THE DRY CASE AS SHOWN IN THE FIG. BELOW (FIG 6 (b) FROM ABOVE REF.) THE EQUATION TO SOLVE FOR THE GEOGRID REINFORCEMENT IS:

$$\alpha = \frac{\gamma_c T_c^2}{\sin 2B}\left[\left(\frac{2H\cos B}{T_c} - 1\right)\frac{\sin(B-\phi_i)}{\cos\phi_i} - \frac{\sin\phi_c}{\cos(B+\phi_c)}\right]$$

SUBJECT VENEER STABILITY
LTV CLARK LANDFILL

BY BLR DATE 2/15/99 PROJ. NO. 97-481-10
CHKD. BY EB DATE 2/16/99 SHEET NO. 2 OF 5

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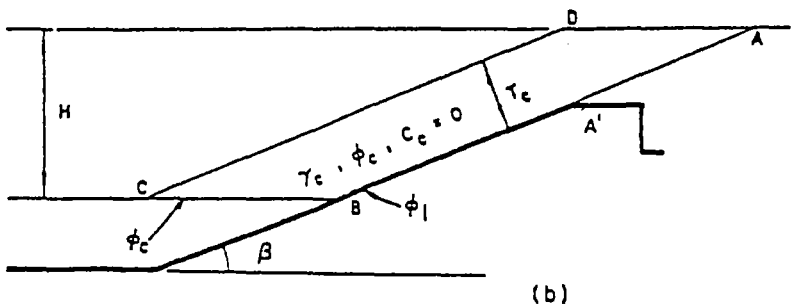

Figure 6. *Geometry of the Soil Cover for the Simplified Method:* (a) partial soil cover; and (b) complete soil cover. The relevant parameters are: H = height of the slope; β = slope angle; T_c = soil cover thickness; γ_c = unit weight of soil; ϕ_c = friction angle of soil; ϕ_i = minimum interface friction angle in the lining system. The cohesion of the soil is assumed to be zero (c_c = 0).

IN WHICH:

γ_c = 90 pcf
T_c = 18" = 1.5'
β = 18.4° (3H:1V)
H = 50' MAX AT STA 10+00 (675-625)
ϕ_i = 22° ; ϕ_{im} = 15.1°
ϕ_c = SAY = 33° ; ϕ_{cm} = 23.4°
($\tan\phi_{im} = \tan\phi_i / 1.5$; $\tan\phi_{cm} = \tan\phi_c / 1.5$)

$$\alpha = \frac{90 \times 1.5^2}{\sin(2 \cdot 18.4)} \left[\left(\frac{2 \cdot 50 \cdot \cos 18.4}{1.5} - 1 \right) \frac{\sin(18.4 - 15.1)}{\cos 15.1} - \frac{\sin 23.4}{\cos(18.4 + 23.4)} \right]$$

$$\alpha = 338 \left[(62.3)(.06) - .533 \right]$$

$$\alpha = 1083 \text{ lbs/ft}$$

PRODUCTS

HUESKER FORTRAC 55/30-20 LTDS = 1520 lbs/ft
MIRAGRID 5T LTDS = 1050 lbs/ft ; 10T = 2600 lbs/ft

SUBJECT VENEER STABILITY

BY BLR DATE 2/15/99 PROJ. NO. 97-481-10

CHKD. BY E.R. DATE 2/16/99 SHEET NO. 3 OF 5

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ANCHOR TRENCH AND RUNOUT

FROM KOERNER, 1994 PG 500

$$T_{ALLOW} = F_U + F_L + 2F_{AT}$$

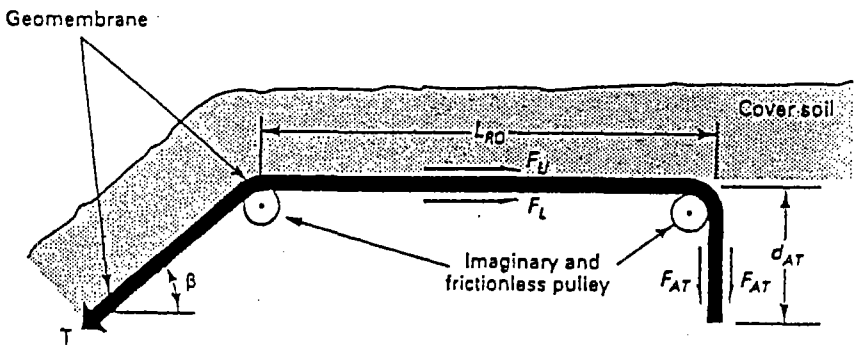

Figure 5.31 Cross section of geomembrane runout section with anchor trench and related stresses and forces involved.

ASSUME $F_L = 0$ SINCE GEOGRID WILL BE ON THE GEOTEXTILE:

$$F_{AT} = 2 K_o \sigma_{v\,avg} \tan\delta \, d_{AT}$$

IN WHICH:

$K_o = 1 - \sin\phi = 1 - \sin 33° = 0.46$

$d_{AT} = 3'$

$\sigma_{v\,avg} = 1/2(4.5)(90\text{ pcf}) = 202.5$

$\delta = 0.8(\phi) = 26.4°$ (FHWA MSE WALLS & RSS DESIGN 10/96)

$$F_{AT} = 2(0.46)(202.5)\tan(26.4)(3')$$
$$= 277.4 \text{ lbs}$$

$$F_U = q \tan\delta \, (L_{RO})$$

SUBJECT VENEER STABILITY
LTV CLARK

BY BLR DATE 2/15/99 PROJ. NO. 97-481-10
CHKD. BY RJB DATE 2/16/99 SHEET NO. 4 OF 5

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Engineers • Geologists • Planners
Environmental Specialists

$$F_{UREQ} = \alpha - F_{AT} = 1083 - 277 = 806 \text{ lbs}$$

$$L_{RO} = \frac{F_{UREQ}}{q \tan\delta}$$

$$L_{RO} = \frac{806 \text{ lbs}}{1.5 \times 90 \tan 26.4} = 12 \text{ FT}$$

WITH NO ANCHOR TRENCH:

$$L_{RO} = \frac{1083}{1.5 \times 90 \tan 26.4} = 16.2 \text{ FT}$$

SUBJECT LTV CLARK LANDFILL
VENEER STABILITY

BY BLR DATE 3/3/99 PROJ. NO. 97-481-10

CHKD. BY EB DATE 3/3/99 SHEET NO. 5 OF 5

GAI CONSULTANTS, INC

Engineers • Geologists • Planners
Environmental Specialists

- CALCULATE REQUIRED RUNOUT FOR $H = 40'$:

$$\alpha = \frac{90\,(1.5)^2}{\sin(2\cdot 18.4)}\left[\left(\frac{2\cdot 40'\cdot\cos(18.4)}{1.5} - 1\right)\frac{\sin(18.4-15.1)}{\cos(15.1)} - \frac{\sin(23.4)}{\cos(18.4+23.4)}\right]$$

$$\alpha = 338\left[(49.6)(0.06) - 0.533\right]$$

$$\alpha = 825.7 \text{ lbs/ft}$$

$$L_{RO} = \frac{F_{UREQ}}{q \tan\delta} \qquad , F_{AT} = 0$$

$$= \frac{826}{(1.5)(90)\tan 26.4}$$

$L_{RO} = 12.3$ FT = LENGTH OF RUNOUT WITH 40' HIGH BENCH

SUBJECT VENEER STABILITY - SUPPLEMENTAL CALC

BY BLR DATE 3/26/99 PROJ. NO. 97-481-10

CHKD. BY EVB DATE 3/26/99 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC.

Engineers • Geologists • Planners
Environmental Specialists

PURPOSE

CONSIDER THE RUNOUT LENGTH FOR THE GRID ASSUMING THE COVER SOIL, GRID & GEOMEMBRANE SLIDE AS A UNIT ON THE UNDERLYING GEOTEXTILE.

CALCULATION

FROM CALC DATED 2/15/99;

$X = 1083$ - WHICH INCLUDES THE $FS = 1.5$

δ_i (GEOMEMBRANE / GEOTEXTILE) $= 22°$

WHERE: 22° IS THE MINIMUM INTERFACE SHEAR AMOCO 16oz ON NSC 40 MIL LLDPE

$$L_{RO} = \frac{F_{UREQ}}{q \tan\delta}$$

$$= \frac{1083}{(1.5)90 \tan 22°}$$

$L_{RO} = 19.9$ ft SAY 20 ft

APPENDIX J

GRADING QUANTITY ESTIMATES

Project 97-481-10

LTV Steel, Clark Landfill
1998 - Existing Pile Quantity

	Contour Elevation (FT)	Area (SF)	Average Area (SF)	Elevation Difference (FT)	Volume (CY)
Berm	600	39,864			
			19,932	8	5,906
	608	0			
Pile	600	1,330,000			
			1,225,000	10	453,704
	610	1,120,000			
			1,022,945	10	378,869
	620	925,890			
			863,258	10	319,725
	630	800,626			
			686,437	10	254,236
	640	572,248			
			526,807	10	195,114
	650	481,366			
			449,433	10	166,457
	660	417,500			
			344,515	10	127,598
	670	271,530			
			150,512	10	55,745
	680	29,494			
			14,747	5	2,731
	685	0			
				Total	1,960,084 CY
				Say -	1,960,000 Cubic Yards

Done By: TRG Date: 8/11/98
Checked By: AC Date: 12/15/98

Project 97-481-10

LTV Steel, Clark Landfill
Regraded Pile - mg

	Contour Elevation (FT)	Area (SF)	Average Area (SF)	Elevation Difference (FT)	Volume (CY)
Below 600'	585	147,343			
			132,428	5	24,524
	590	117,512			
			84,346	10	31,239
	600	51,180			
Above 600'	600	1,650,000			
			1,510,000	10	559,259
	610	1,370,000			
			1,230,000	10	455,556
	620	1,090,000			
			959,300	10	355,296
	630	828,600			
			709,600	10	262,815
	640	590,600			
			506,100	10	187,444
	650	421,600			
			349,550	10	129,463
	660	277,500			
			209,100	10	77,444
	670	140,700			
			86,850	5	16,083
	675	33,000			

Total Volume of Propose Pile	**2,099,124**	CY
* 2' Soil Cover	**137,800**	
Total Volume of Proposed Pile Less Soil Cover	**1,961,324**	
Existing 1998 Pile Volume	**1,960,000**	
Excess Capacity of Regraded Pile	**1,324**	

*** 2' of Soil Cover over 42.7 Acres:**

(42.7 Acres) X (43,560 SF/Acre) X (2 FT) X (1 CY/27 CF) = **137,800** CY

Done By: TRG Date: 12/12/98
Checked By: AC Date: 12/19/98

Project 97-481-10
April 2, 1999

GAI Consultants, Inc.

LTV Steel, Clark Landfill
Clean Fill Buttress

Station	Area (SF)	Average Area (SF)	Distance Between Stations (FT)	Volume (CY)
0+00	0			
		340.0	200	2,519
2+00	680			
		2272.5	200	16,833
4+00	3,865			
		3252.5	200	24,093
6+00	2,640			
		2188.0	200	16,207
8+00	1,736			
		1055.5	200	7,819
10+00	375			
		367.5	200	2,722
12+00	360			
		795.0	200	5,889
14+00	1,230			
		1237.0	200	9,163
16+00	1,244			
		1377.5	200	10,204
18+00	1,511			
		1705.5	200	12,633
20+00	1,900			
		1973.0	200	14,615
22+00	2,046			
		2195.5	200	16,263
24+00	2,345			
		2307.5	200	17,093
26+00	2,270			
		2225.0	200	16,481
28+00	2,180			
		1090.0	300	12,111
31+00	0			

Total **184,644** CY
Say **185,000** CY

Done By: TRG Date: 12/12/98
Checked By: AC Date: 12/19/98

Project 97-481-10

LTV Steel, Clark Landfill
Clean Fill Buttress Above 581'

Station	Area (SF)	Average Area (SF)	Distance Between Stations (FT)	Volume (CY)
0+00	0			
		160	200	1,185
2+00	320			
		424	200	3,141
4+00	528			
		530	200	3,926
6+00	532			
		490	200	3,630
8+00	448			
		293	200	2,167
10+00	137			
		156	200	1,156
12+00	175			
		236	200	1,744
14+00	296			
		263	200	1,944
16+00	229			
		218	200	1,611
18+00	206			
		220	200	1,630
20+00	234			
		256	200	1,893
22+00	277			
		289	200	2,141
24+00	301			
		328	200	2,430
26+00	355			
		315	200	2,333
28+00	275			
		138	300	1,528
31+00	0			
			Total	32,457 CY

Done By: TRG Date: 12/12/98
Checked By: AC Date: 12/19/98

Project 97-481-10

LTV Steel, Clark Landfill
Clean Fill Buttress 581' to 585'

Clean Fill Below 581'

Total Clean Fill	184,644
Clean Fill +585'	32,457
	152,187

Say **153,000** CY of Clean Fill Below 581' Water Line

Area @ Elevation 581' between existing shoreline and new flume

Planimeter Readings:

1.	Area 1	0.3	
	Area 2	4.1	
	Area 3	0.6	
		5.0	Acres

Done By: TRG Date: 1/5/99
Checked By: AC Date: 1/5/99

gai

Project 97-481-10

LTV Steel, Clark Landfill
Flume Dreding Quantity

Station	Area Sq. Ft.	Avg Area Sq. Ft	Distance Ft.	Volume Yards
6+00	0			
		27.5	200	204
8+00	55			
		145	200	1070
10+00	245			
		230	200	1704
12+00	215			
		108	200	796
14+00	0			
				3774 Total
			Say	4000 Yards

Done by: TRG 12/29/98
Checked AC 12/31/98

SUBJECT LTJ Clark Landfill

BY TRG DATE 3-2-99 PROJ. NO. 97-981-10

CHKD. BY DRS DATE 3-8-99 SHEET NO. 1 OF 1

GAI CONSULTANTS, INC

Engineers • Geologists • Planners
Environmental Specialists

Determine quantity of clean buttress fill below IGLD Elev of 581.5'

From previous estimates 153,000 yds of clean fill below 581.0 USC&GS.

581' USC&GS = 580.1 IGLD

therefore there is 581.5' − 580.1' = 1.4 feet of additional fill between the 581' USC&GS quantity and the 581.5 IGLD Elev

The surface area of the flume previously determined is 5 Acres

∴ 1.4' (vert) × 5 Acres (area) = 11,300 yds of additional fill

12,000 yds

153,000 yds of fill to 581 + 12,000 yds fill to 582.4' USC&GS or 581.5' IG

= 165,000 yards of clean buttress fill required to fill existing flume to 581.5' IGLD El. of Realigned Flume

STS Consultants, Ltd.
Solutions through Science & Engineering

July 30, 1999

Mr. Jeff Sewell
Solid Waste Permit Management Section
Indiana Department of Environmental Management
100 N. Senate Avenue
Indianapolis, IN 46206-6015

RE: Closure of the LTV Steel Indiana Harbor Works-Clark Landfill, Lake County, Indiana - STS Project No. 08741-P

Dear Mr. Sewell:

On behalf of LTV Steel, we are forwarding three copies of an amended permit application for closure of the Clark Landfill. A copy has also been forwarded to IDEM's northwest regional office in Gary. The following attachments are included:

1. Executive Summary
2. A Groundwater Sampling and Analysis Plan prepared by STS Consultants, Ltd. (STS);
3. A Closure Plan prepared by GAI Consultants, which includes a schedule for completing closure with significant milestones indicated;
4. A Post-Closure Plan prepared by STS;
5. A Construction Quality Assurance (CQA) Plan for closure prepared by STS;
6. A proposal to dispose of dredge spoil in the Clark Landfill prepared by STS; and
7. Closure and post-closure cost estimates prepared by STS.

If you have any questions or comments about this application for closure permit amendment, please feel free to contact us at your convenience.

Very truly yours,

STS CONSULTANTS, LTD.

Douglas J. Hermann, P.E.
Principal Engineer

cc: Ralph McCullers, IDEM, Northwest Reg. Office, 504 N. Broadway, Ste. 418, Gary, IN 46402 (1 copy)
Keith Nagel, LTV Steel Company, 3100 East 45th Street, Cleveland, OH 44127 (4 copies)
Dale Papajcik, LTV Steel Company, 200 Public Square, Cleveland, OH 44114-2308 (2 copies)
Barry Newman, GAI Consultants, 570 Beatty Road, Monroeville, PA 15146-1300 (1 copy)

K:08741/P/Clark/C141P001.doc.nls

750 Corporate Woods Parkway • Vernon Hills, IL 60061-3153 • (847) 279-2500 • (847) 279-2510 Fax

POST-CLOSURE PLAN
CLARK LANDFILL
LTV STEEL COMPANY
EAST CHICAGO, INDIANA

1.0 Introduction

The Post-Closure Plan was developed to minimize the need for further maintenance at the Clark Landfill. The plan controls against the escape of waste and reduces leachate generation by maintaining the landfill cover improvements constructed during closure. The Post-Closure Plan provides for regular inspections and ongoing monitoring of slope stability and groundwater quality. Inspections will check for erosion in final cover intactness on a quarterly basis the first two years, and semi-annually thereafter for the 30-year period of post-closure care. Relevant requirements from the current regulations were reviewed and incorporated as necessary into the Post-Closure Plan and post-closure care cost estimate.

Cost estimates for post-closure care were prepared on the assumption that LTV Steel Company (LTV) will contract with a third party to implement the Post-Closure Care Plan.

Post-closure care will begin following closure construction certification and acceptance by IDEM. LTV will provide a minimum post-closure care period of 30 years following closure certification. The post-closure care period and/or frequency of monitoring may be decreased by IDEM upon demonstration by LTV that the reduced period and/or the frequency is sufficient to protect human health and the environment.

The post-closure care duties are outlined below.

Groundwater Monitoring

Groundwater monitoring shall be conducted in general accordance with the GWSAP. Since no groundwater monitoring has been initiated at the site and groundwater monitoring wells installation is not scheduled until landfill regrading is complete, it will be necessary to make interpretations of the groundwater flow system shortly after well installation. These interpretations will involve characterizing the following groundwater conditions:

- Determine the direction of groundwater flow
- Determine the upgradient and downgradient monitoring wells; a minimum of one (1) upgradient and three (3) downgradient wells will be required.
- Sufficient water level information shall be obtained to characterize the seasonal variations of groundwater flow as it may affect the interpretation of upgradient and downgradient wells.

All groundwater wells shall be installed in general accordance with 329 IAC 10-21-4. The wells will be installed in the uppermost aquifer, which consists of slag fill over the former lakebed. Well screens shall be installed to intersect the phreatic surface of the uppermost aquifer and extend to the base of the aquifer. The casing and screen materials shall consist of 4-inch diameter PVC.

Groundwater wells shall be monitored in general accordance with 329 IAC 10-21-1, following the general guidelines of the GWSAP which is included as Attachment 2.

The statistical evaluation and report for all groundwater monitoring events shall be prepared in general accordance with 329 IAC 10-21-6 and 329 IAC 10-21-1(t).

2.0 Geotechnical Instrumentation Monitoring

Continued monitoring of the existing geotechnical instrumentation at the site shall be continued for the first ten years of post-closure care. The monitoring frequency for this instrumentation shall be quarterly the first two years and semi-annually for the period three through ten years. The geotechnical instrumentation list for monitoring includes:

- Inclinometers LTV-1 through LTV-7 plus Clark B-100 and Clark SB-210; and

- Pneumatic piezometers LTV-1STP through LTV-7STP plus LTV-98-8 (top, middle, and bottom) and LTV-98-9 (top, middle, and bottom).

The results of all instrumentation shall be summarized in graphical format and an opinion shall be provided by a Professional Engineer as to the consistency and performance of the instrumentation with respect to landfill stability and instrumentation performance. If any instruments fail or become questionable as to their reliability, an evaluation shall be made by a Professional Engineer to replace and/or delete that instrumentation from interpretation. The deletion of instrumentation shall be based upon the availability of similar test results from other instrumentation which may also corroborate slope stability performance and the overall historical performance of the facility.

3.0 Site Inspections

Site inspections shall be completed on a quarterly basis the first two years, and on a semi-annual basis thereafter. The inspections shall check for:

- Access control roads and benchmarks;
- Cover thickness and intactness;
- Odor and dust emissions;

- Erosion features, particularly in areas of surface water management structures and flume shoreline rip-rap;
- Visual slope movements;
- Geotechnical instrumentation; and
- Monitoring well conditions as compared to 329 IAC 10-21-1, and gas vents.

A report shall be prepared and submitted to the IDEM Commissioner. This report shall include photo documentation and comparison against any prior observations. Recommendations for routine and planned maintenance shall be included in the report.

4.0 Planned Maintenance

Planned maintenance shall be scheduled and arranged in accordance with site inspection observations. Maintenance activities may include the following:

- Surface water erosion and flume rip-rap repair;
- Well replacement;
- Geotechnical instrumentation replacement;
- Gas vent repairs;
- Stormwater management structures; and
- Landfill cover repair.

5.0 Post-Closure Care Contact Person

All communications through the post-closure care period regarding post-closure care responsibilities shall be directed to:

Corporate Office Contact	Mill Contact
Mr. Keith Nagel Manager, Waste Management LTV Steel Company Corporate Environmental 3100 East 45th Street Cleveland, OH 44127	Mr. Michael Thomas Area Manager of Environmental LTV Steel Company Indiana Harbor Works 3001 Dickey Road East Chicago, IN 46312

6.0 Post-Closure Certification

Following completion of the 30-year post-closure care period, the Owner and a Professional Engineer shall review the historical data. The Owner may then certify that the post-closure care requirements have been met through a written statement submitted to the IDEM Commissioner. Similarly, a Professional Engineer shall provide the certification that the post-closure care requirements have been met. Written certification shall be provided to the IDEM Commissioner.

7.0 End Use of Property

The planned end use of the property is open land. No permanent structures are planned to be built on the closed landfill. The final cover will complement and blend with the surrounding industrial setting.

8.0 Closure and Post-Closure Cost Estimates

Closure and post-closure care cost estimates are summarized in Attachment 7. These cost estimates have been prepared in general accordance with 329 IAC 10-30-4 and 329 IAC 10-31-3, respectively. The cost estimates are supported by third party quotations. Please note that the planned maintenance costs for post-closure care have been assumed at ten percent

of the closure costs as provided for under 329 IAC 10-31-3(b)(4). Closure and post-closure cost estimates may be revised when a change in the closure or post-closure plan increases the cost estimates. LTV will review the closure and post-closure care plans prior to filing a revised cost estimate in order to determine whether they are consistent with the operating plans. Cost estimates may also be adjusted for inflation on an annual basis.

The above current cost estimates may be used to set appropriate financial assurance levels as required under 329 IAC 10-39.

QUALITY ASSURANCE PLAN - CLARK LANDFILL
CLOSURE CONSTRUCTION
LTV INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

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CONSTRUCTION QUALITY ASSURANCE PLAN
CLOSURE CONSTRUCTION
CLARK LANDFILL
LTV INDIANA HARBOR WORKS
EAST CHICAGO, INDIANA

1.0 GENERAL

1.1 Purpose

This purpose of this site-specific Construction Quality Assurance (CQA) Plan is to provide an organizational framework for testing, observation and monitoring activities which will be performed during the closure construction of the LTV-Clark Landfill over failed foundation clays to document that the landfill closure is constructed in substantial conformance with the design plans and specifications. The intent of this CQA plan is not to detail every aspect of the quality monitoring program but rather to provide a framework for which a thorough construction monitoring program can be implemented.

1.2 Scope

This CQA Plan addresses the quality assurance of the closure construction activities for Clark Landfill. Both care and detailed documentation are required to close waste containment facilities in accordance with Indiana Department of Environmental Management 329 IAC 10, 11, and 12 regulations. In particular, the Clark Landfill will be closed as a Type I Restricted Waste Landfill in accordance with 329 IAC 10-30.

This plan addresses quality assurance not quality control. Quality assurance refers to the means and actions employed by the Owner to assure conformity of the closure construction with the project-specific CQA Plan, drawings, specifications, and contractual and regulatory requirements. CQA is provided by a party independent from material production and construction/installation participants. Quality control refers only to those

actions taken to ensure that the materials and workmanship exercised by vendors and contractors meet the requirements of the drawings and specifications.

At a minimum, the CQA Plan shall consist of the following:

1. This CQA plan
2. Project-specific design drawings and specifications
3. Various testing standards provided by industry associations
4. Regulatory permit approvals

The scope of this CQA Plan applies to manufacturing, shipment, handling, construction and monitoring of the landfill closure design.

The plan addresses the test methods, test frequencies and documentation necessary to adhere to the construction specifications during each landfill closure construction phase. Protocol for reporting test results, correcting construction deficiencies, documenting construction activities, and preparing documentation reports are provided. A Professional Engineer registered in the State of Indiana shall certify completion of the landfill closure construction. The landfill closure construction components include:

1. Flume dredging;
2. Groundwater monitoring well installation, preservation and monitoring geotechnical instrumentation installations;
3. Flume fill placement;
4. Rubber tired vehicle (RTV) road relocation;
5. Utilities relocation (oxygen and steam piping);
6. Landfill waste regrading;
7. Landfill cover system construction;
8. Gas vents;

9. Access roads; and
10. Stormwater structures.

1.3 Definitions and Testing Standards

1.3.1 Definitions

Agency - The Indiana Department of Environmental Management (IDEM)

Coarse Protection Aggregate - A layer of coarse aggregate placed over a geosynthetic cover to protect the cover against erosion and damage.

Compaction - The process of increasing the density of unit weight of soil or waste by rolling, tamping, vibrating or other mechanical means.

Construction Quality Assurance (CQA) Engineer/Officer - Individual(s) providing monitoring of landfill closure construction and associated work. This shall be an independent consulting engineering firm, an individual hired by LTV Steel, or an employee of LTV Steel under the direction of a Professional Engineer licensed in the State of Indiana. The CQA Engineer is responsible for the certification of the landfill closure construction according to the technical specifications, drawings, and documents as approved by the Indiana Department of Environmental Management.

Construction Quality Assurance Plan - The CQAP is this document.

Contractor - The individual, firm, partnership, corporation or joint venture responsible for the construction of the Clark Landfill closure and related activities.

Density - The mass density of the soil and its weight per unit volume, usually reported in pounds per cubic foot.

Design Engineer - Person or firm retained by the Owner to design the landfill closure.

Engineer - A term used synonymously with the CQA Engineer/Officer in this document. A person having sufficient education, technical administrative experience to perform the required responsibilities. This person shall have the demonstrated knowledge and experience of engineering aspects of construction related to landfills and shall be a Professional Engineer registered in the State of Indiana. Either the Engineer or their designee having the same authority will be on site to provide the inspection of the work and act as the CQA Officer. If the Engineer is not personally on site at all times, visits to the site shall take place on a regular basis. In the absence of the Engineer, duties may be delegated to his designee.

Flume Fill - Natural rock aggregate materials proposed to be placed both above and below the Lake Michigan water level along the water intake flume for pump house No. 2.

Gas Vents - Passive vents located around the landfill to relieve internal gas pressures that may be produced below the landfill cover system.

Geocomposite Drainage Layer - A geosynthetic drainage net sandwiched between two geotextiles to enhance drainage and subsurface water flow.

Geogrid - A geosynthetic material manufactured in a grid pattern for purposes of reinforcing the tensile performance properties of a material.

Geomembrane - A geosynthetic material manufactured for the purposes of reducing water infiltration and installed as an integral cover component with fabricated seams.

Geotextile - A relatively porous construction or reinforcement fabric used in civil engineering projects. The fabric is available as a knit, woven, non-woven (spun-bonded,

etc.) mat or net. Geotextiles are frequently used as filter, cushion or segregation media but may also be used as drainage media.

Grain Size Distribution - Distribution of particle sizes within a soil. Applicable method for fine grained soils is ASTM D 422, and applicable method for rip rap is ASTM C 136.

Hydraulic Conductivity - A property that reflects the ability of pore fluid to travel through soil mass by flowing through interconnected voids. Rates of hydraulic conductivity are generally reported in centimeters per second (cm/sec).

Inclinometer - These are vertical plastic casings installed through the landfill into foundation soils used to perform precision survey of horizontal ground movement. They are to be preserved during construction.

In-Situ - Term used synonymously with in-place "as is" or at depth "as it exists in place naturally".

Laboratory - Testing facility meeting the requirements of ASTM D 3740 as applicable, additionally submitting evidence documenting the participation in a nationally recognized laboratory inspection program as applicable. All laboratory equipment shall be in good working order and shall conform to the requirements of applicable test method standards. Devices for measuring weights or forces (scales, load cells, test machines) shall be calibrated as per applicable standards and shall be labeled with the data and firm/person having performed the last calibration. In the event no standard calibration interval is specified, calibration shall be as recommended by the equipment manufacturer. Current standard test methods shall be kept available in the testing laboratory for reference by personnel.

Optimum Water Content and Maximum Laboratory Density - Water content corresponding to the laboratory maximum dry density as determined by ASTM D 698 or ASTM D 1557.

Overexcavation - The mechanical removal of all in-situ soils deemed unacceptable as foundation or subbase support or otherwise unsuitable for the intended purpose.

Owner - LTV Steel Company.

Permittivity - The volumetric flow rate of water per unit cross-sectional area per unit head under flow conditions in the normal direction through a geotextile (ASTM D 4491).

Piezometers - These are pneumatic pore water pressure transducers installed in the foundation soils to measure excess head or water pressure in the soils beneath the fill. They are to be preserved and protected during construction.

Quality Assurance (QA) - The formal organization and procedures utilized by the Owner for documenting that work performed by contractors, vendors and field/laboratory testing personnel meets the project requirements. The QA program will include a comprehensive and continuous review by the CQA Engineer/Officer as well as independent verification results accomplished through inspection and material testing.

Quality Control (QC) - The formal procedures utilized by project contractors, engineers, and inspection testing personnel and vendors to ensure conformance of their products to the plans, specifications, methods and other criteria established for the project. Note that while vendors, inspectors and testing personnel or contractors may have multiple levels in their product verification programs, for purposes of this plan the entire effort shall be considered quality control. Vendor, contractor and engineering quality control programs are not a part of this plan although they will be reviewed by the CQA Engineer/Officer and approved by the same to ensure general conformance with the project objectives.

Responsible Party - Individual(s) or their designee having responsibility for assuring quality control for specific manufacturing products designated in the technical specifications, drawings and this plan.

Rip Rap - A coarse stone aggregate proposed to be placed in areas of high velocity water flow along stormwater channels or along the flume shoreline to resist the dynamic forces of water.

Sand Bedding - A granular bedding material included as part of the landfill cover component.

Surveyor - Person having sufficient education and technical administrative experience to perform the required surveying responsibilities. The surveyor will have demonstrated knowledge and experience of all surveying aspects of specific construction practices related to landfills and will be a Land Surveyor registered in the State of Indiana.

Test Methods - Required testing in accordance with applicable ASTM method or other nationally recognized trade group method.

Unified Soil Classification System - Standard test method for classification of soils for engineering purposes by ASTM D 2487.

Water Content - The ratio of quantity of water in the soil (by weight) to the weight of the soil solids (dry soil) expressed in percentage, also referred to as moisture content.

1.3.2 Testing Standards

AASHTO - American Association of State Highway and Transportation Officials.

ASTM - American Society for Testing and Materials.

GRI - The Geosynthetics Research Institute.

NSF - The National Sanitation Foundation.

INDOT - The Indiana Department of Transportation.

1.4 CQA/CQC Organization

The CQA Engineer is responsible for the conformance of the closure construction to the technical specifications and drawings approved by IDEM for the Clark Landfill. The CQA Engineer will be supported directly by a technical staff of engineers or technicians and directly or indirectly by a materials testing laboratory.

1.5 Project Team Responsibilities and Qualifications

The parties discussed in this section are associated with the ownership, design, manufacture, transportation, construction, and quality assurance of the landfill closure. The definitions, qualifications and responsibilities of these parties are outlined in the following subsections.

1.5.1 Permitting Agency (IDEM)

IDEM has the regulatory authority for the approval of the closure plan for the LTV Clark Landfill. IDEM will have the responsibility and authority to review all CQA program documentation prior to, during, and after construction to confirm that the construction was completed in substantial conformance with the design plans and specifications.

1.5.2 Project Manager/Owner

LTV Steel Company (LTV) as the Owner is responsible for closure, design and construction of the LTV Clark Landfill. LTV has the authority to select and dismiss organizations charged with closure, design, QA and construction responsibilities. LTV also has the authority to accept or reject design drawings and specifications, CQA program activities and the materials and/or workmanship of the construction contractor. The Owner shall designate a Project Manager who will serve as the communications coordinator for the project initiating the resolution, preconstruction, and construction meetings outlined in this plan. As communications coordinator, the Project Manager shall serve as liaison between all parties involved in the project to ensure that communications are maintained. The Project Manager shall also be responsible for the proper resolution of quality assurance issues that arise during construction and/or designate an Owner's agent to fulfill this duty. The Project Manager shall be familiar with the following:

1. The company policies and procedures for project management;
2. The CQA Plan;
3. The approved design drawings and specifications;
4. All applicable regulatory requirements;
5. General familiarity with earthwork activity and landfill construction; and
6. Understand the foundation stability and the history of instability at the site.

1.5.3 Design Engineer

The Design Engineer has the primary responsibility for the preparation of the design, including drawings and project-specific technical specifications for the landfill closure. The Design Engineer is responsible for approving all closure and design specification changes requested and approved by IDEM and making the design clarifications necessary during construction of the landfill closure. The Design Engineer may attend resolution or

preconstruction meetings outlined in the CQA Plan as requested by the Project Manager. The Design Engineer shall be a qualified engineer, certified or licensed as required by regulation in the State of Indiana. The Design Engineer shall be familiar with landfill closure design and construction procedures and applicable regulatory requirements. Prior to construction the Design Engineer shall submit the project design drawings and specifications to the Project Manager. The Design Engineer shall submit completed design clarification forms to the Project Manager in a timely manner upon request.

1.5.4 CQA Engineer/Officer

The CQA Engineer/Officer shall be a firm or person independent from the Project Manager/Owner, material vendor(s), and construction contractor. The CQA Engineer shall be responsible for observing and documenting activities related to quality assurance of the production and construction of the landfill closure construction on behalf of LTV. The CQA Engineer shall supervise and be responsible for observations, testing and other activities required to be implemented as part of the CQA Plan. The CQA Engineer shall be a Professional Engineer registered in the State of Indiana. The CQA Engineer is responsible for the implementation of the CQA Plan. The CQA Engineer is also responsible for preparing the Construction Certification Report (CCR) sealed by a Registered Professional Engineer. The specific duties of the CQA Engineer are as follows:

1. Review design drawings and specifications;
2. Review other site-specific documentation, including proposed layouts and manufacturer's and contractor's literature;
3. Review landfill foundation stability analysis reports;
4. Review permit approvals and associated conditions of approval;
5. Administer the CQA Plan and manage CQA personnel, review field reports, and provide engineering review of quality assurance related issues;
6. Review changes to design drawings and specifications as issued by the Design Engineer;

7. Act as an on-site resident representative for CQA activities during construction;
8. Familiarize CQA personnel with the CQA Plan;
9. Attend quality assurance related meetings, such as progress, preconstruction, and resolution;
10. Review manufacturer's and contractor's certifications and documentation and make appropriate recommendations;
11. Review contractor's personnel qualifications for conformance with qualifications approved for work at the site;
12. Manage the preparation of as-built drawings;
13. Review instrumentation readings and compare readings with action levels;
14. Review calibration certification of all field testing equipment;
15. Review CQA personnel daily reports, logs and photographs;
16. Note any site activities that may result in damage to construction components;
17. Report to the Project Manager/Owner on a daily basis and report any relevant observations reported by the CQA personnel;
18. Prepare a personal daily report;
19. Prepare a daily summary of work activities and completed quantities;
20. Prepare a weekly summary of CQA activities;
21. Oversee the marking, packing and shipping of all field and laboratory test specimens;
22. Review the results of field and laboratory testing and make appropriate recommendations;
23. Designate a CQA representative when absent from the site;
24. Report any unapproved deviations from the CQA Plan to the Project Manager;
25. Prepare the Construction Certification Report.

The CQA Engineer shall be qualified by the Project Manager/Owner.

The CQA Engineer shall be experienced in landfill closure construction with a thorough understanding of geosynthetic engineering, geotechnical engineering, foundation

engineering, geosynthetic landfill cover construction, and landfill regulatory requirements. The CQA Engineer shall be registered as a Professional Engineer in the State of Indiana. CQA personnel working with the CQA Engineer shall have specific training in the quality assurance of geosynthetics and have at least one person on site having a minimum of 1 million square feet of field experience of prior landfill closure construction using geosynthetics. The Project Manager/Owner shall review the corporate background and capabilities, personnel and qualifications of eligible firms before selection of the CQA Engineer is completed.

1.5.5 CQA Officer-in-Absentia

In the event that the CQA Officer is unable to be present to perform the requirements of this CQA Plan, the CQA Officer will designate a person to fulfill the duties of the CQA Officer and exercise professional judgment in the role of CQA Officer-in-Absentia.

1.5.6 CQA Laboratory

The CQA laboratory shall be a firm independent from the Project Manager/Owner, manufacturers, and contractors and be responsible for conducting tests on the samples of materials used for landfill closure construction. The CQA laboratory will be responsible for conducting the appropriate laboratory tests as directed by the CQA Engineer. The test procedures shall be done in accordance with the test methods in the CQA Plan. The CQA laboratory shall have experience in testing construction materials and be familiar with the appropriate testing standards published by trade groups in Section 1.3.2. The CQA laboratory shall be capable of providing verbal results of destructive geosynthetic seam tests within 24 hours of receipt of samples and shall maintain that service standard throughout the construction period. The CQA laboratory shall submit all destructive seam test results to the CQA Engineer in written form within 48 hours of receipt of test samples, unless otherwise specified by the CQA Engineer. Verbal test results shall typically be

provided within 24 hours of receipt of samples. Written test results shall be in easily readable format and include references to standard test procedures.

1.5.7 Material/Manufacturer Vendors

The manufacturer/material vendor is responsible for the production of any materials associated with the landfill closure construction. Each manufacturer/material vendor shall provide a consistent product meeting the project specifications. Each manufacturer shall also provide quality control documentation for its product as specified in the CQA Plan. The manufacturer shall be responsible for the condition of all materials until the material is accepted by the Project Manager upon delivery. Each manufacturer/material vendor shall be pre-qualified by the Project Manager. The manufacturer/material vendor shall also provide sufficient production capacity and qualified personnel to meet the demands of the project schedule. Each manufacturer shall have an internal quality control program for its product that meets the requirements presented in this CQA Plan. Each manufacturer/material vendor shall provide corporate background information and capabilities including production capacity, material properties, and at least ten completed landfill projects totaling a minimum of 10 million square feet. Project references shall be supplied to the Project Manager as a demonstration of capabilities. The manufacturer/material vendor shall also provide a Quality Control Manual including a description of the quality control laboratory facilities and procedures. Any background tests on aggregate, methodology, resin chemistry, etc. shall be provided as part of the background information.

1.5.8 Construction Contractor

The construction contractor will be responsible for the landfill closure construction. The contractor may be affiliated with the manufacturer/material vendor. The contractor shall be responsible for all construction activities including the handling, storing, deploying, servicing, protecting, securing and administration of all construction activities. The

contractor may also be responsible for the transportation of materials to the site. The contractor shall be pre-qualified and approved by the Project Manager/Owner. The contractor shall be able to provide qualified personnel to meet the demands of the project. At the minimum, the contractor shall provide a superintendent. The superintendent is responsible for all contract activities. The superintendent shall represent the contractor at all meetings and shall be responsible for acting as the contractor spokesman on the project.

To be considered for pre-qualification, the contractor shall submit corporate background information including capabilities and strategies to provide all the construction components associated with the landfill closure. The corporate resume shall include a minimum of five completed projects having a minimum of 5 million square feet of geosynthetic installation experience. Project references shall be provided. The contractor shall also include his quality control manual and a copy of recommendation letters supplied by the manufacturer/material vendor. The contractor shall also provide a resume of the superintendent and key support personnel along with a construction schedule and shop drawings for various temporary structures or layout procedures.

1.5.9 Geosynthetics Installer

The geosynthetics installer will be affiliated with the construction contractor or will be a subcontractor of the construction contractor. The geosynthetics installer shall be responsible for all construction activities including the handling, storing, deploying, servicing, protecting, securing and administration of all geosynthetic activities. The geosynthetics installer shall be pre-qualified and approved by the Project Manager/Owner. The geosynthetics installer shall be able to provide qualified personnel to meet the demands of the project. The geosynthetics installer shall also provide a master seamer for geosynthetics having previous experience with geosynthetics and having managed a minimum of two completed projects and the installation experience of at least 5 million square feet of geosynthetics.

2.0 COMMUNICATION AND DOCUMENT CONTROL

To ensure a high degree of quality during construction and assure a final product that meets all project specifications, clear and open channels of communication are essential. This section discusses the appropriate lines of communication and describes the necessary meetings.

An effective CQA Plan depends on the identification of all construction activities that shall be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Engineer shall document that all requirements in the CQA Plan have been addressed and satisfied. The CQA Engineer shall also provide the Project Manager with a documentation report including data sheets and checklists to verify that all monitoring activities have been carried out. The CQA Engineer shall also maintain a complete file of all documents which comprise the CQA Plan, including drawings and specifications, CQA Manuals, permits, checklists, test procedures, daily logs, and other pertinent documents.

2.1 Chain of Command

The chain of command for the LTV Clark Landfill closure construction is illustrated in Exhibit A. The CQA Engineer shall be capable of direct communication with the Project Manager/Owner at all times. The Project Manager will be responsible for directing all project activities including direct control and administration of the CQA Engineer, contractor and all LTV trades.

2.2 Line of Communications

The lines of communication necessary to execute the landfill closure project are similar to the chain of command. Most communications will be exchanged between the Project

Manager/Owner, CQA Engineer and landfill contractor. The landfill contractor communications will be directed to the superintendent. Periodic communications may also be delivered to IDEM to satisfy regulatory requirements.

Meetings will be held at regularly scheduled intervals during the course of the project to enhance communication between the organizations and to strengthen the understanding, responsibilities and authority of each organization. Various key communication events are further described below.

2.2.1 Resolution Meeting

Following permit approval and completion of the construction drawings and specifications for the project, a resolution meeting may be held. If a resolution meeting is required, it is recommended that the meeting be held prior to bidding the construction work and include all parties then involved typically including the Project Manager/Owner, Design Engineer, CQA Engineer, and CQA laboratory. If necessary, this meeting can be held in conjunction with the preconstruction meeting.

The purpose of this meeting is to establish lines of communication, review construction drawings and specifications for completeness and clarity, begin planning for coordination of tasks, identify any problems which might cause difficulties and delays in construction, and update the CQA Plan. All aspects of the design shall be reviewed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding CQA testing and problem resolution must be known and accepted by all.

A recommended agenda for the resolution meeting is presented in Exhibit B. The meeting shall be documented by a person designated at the beginning of the meeting and the minutes shall be transmitted to all parties.

EXHIBIT B

RESOLUTION MEETING AGENDA

1. Introductions

    a. Assign minute taker
    b. Identify parties
        i. Project Manager/Owner
        ii. Design Engineer
        iii CQA Engineer
        iv. CQA Laboratory
        iv. Others

2. Distribution of Documents

    a. Design and construction drawings
    b. Specifications
    c. Construction Quality Assurance Plan
    d. Permit documents

3. Review Construction Drawings and Specifications

    a. Tour project site

4. Complete Construction Quality Assurance Plan

    a. Amend CQA Plan
    b. Amend drawings
    c. Amend specifications

5. Construction Contract Administration and Construction Issues

6. Define Lines of Communication

7. Project Deliverables

8. Schedule

2.2.2 Preconstruction Meetings

A preconstruction meeting shall be held at the site prior to beginning closure construction activities. Typically, the meeting shall be attended by the Project Manager, Design Engineer, Contractor, CQA Engineer, and IDEM if requested by IDEM. IDEM shall be notified of the preconstruction meeting seven days in advance.

Specific topics considered at this meeting shall include a review of the project CQA Plan for any problems or additions. In addition, the responsibilities of each party should be reviewed and understood clearly. A recommended agenda with specific topics for the preconstruction meeting is presented in Exhibit C. The meeting shall be documented by a person designated at the beginning of the meeting and the minutes shall be transmitted to all parties.

EXHIBIT C
PRECONSTRUCTION MEETING AGENDA

1. Introductions

    a. Assign Minute Taker
    b. Identify parties
        i. Project Manager/Owner
        ii. Contractor and Designated Superintendent
        iii. CQA Engineer
        iv. Surveyor
        v. Design Engineer
        vi. CQA Laboratory
        vii. Others, including LTV trade, IDEM, etc.

2. Distribution of Documents

    a. Design and Construction Drawings and Specifications
    b. Temporary Structure Shop Drawings and Layout Drawings
    c. Proposed Contractor Schedule
    d. Project Quality Assurance Plan

3. Lines of Communication

    a. Lines of Communication
    b. Test Data Distribution
    c. Progress Meetings
    d. Procedures for Approving Design Clarifications and Changes During Construction

4. Tour of Project Site

5. Site Requirements

    a. Safety rules
    b. Site rules
    c. Work schedule
    d. Storage of materials
    e. Available facilities

6. Construction Issues

    a. Scope of Work
    b. Review Design
        i. Design and construction drawings and specifications
        ii. Require shop drawings and temporary structures
        iii. Construction planning and layout
    c. Construction Procedures
        i. Proposed construction sequence
        ii. Equipment scheduling and coordination
    d. Construction Schedule
    e. Procedures for Preparing and Approving Change Orders

7. Construction Quality Assurance Plan

    a. Soils and Aggregates
    b. Geosynthetics
    c. Structures

8. Project Deliverables

    a. Responsibilities
        i. Design Engineer
        ii. Contractor
        iii. CQA Engineer
        iv. CQA Laboratory
        v. Project Manager
    b. Distribution of Deliverables
    c. Approval Procedures

2.2.3 Project/Progress Meetings

A periodic progress meeting shall be held between the CQA Engineer, Contractor Superintendent, Project Manager, and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, work locations and conflicts, contractor personnel and equipment assignments, issues requiring resolution, and any other new business or revisions to the work. The CQA Engineer shall record any problems, decisions, or questions arising from this meeting in the weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager shall be responsible for the resolution of the matter and communication of the decision to the appropriate parties, preferably before the next progress meeting.

2.2.4 Daily Progress Meetings

Informal daily progress meetings may also be held near the work area just prior to commencement or following completion of any work activity. At a minimum, this meeting should be attended by the construction contractor and the CQA personnel. The purpose of these meetings are to coordinate the construction activity and work location and to assist with contractor and CQA coordination. Any potential construction problems or safety issues may be discussed and referred to the periodic progress meeting.

2.2.5 Problem or Work Deficiency Meetings

A special meeting may be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting shall be attended by the construction contractor and CQA personnel. This meeting shall be documented by a member of the CQA team. The purpose of the meeting is to define and resolve a problem or recurring work deficiency as soon as possible. At a minimum, this meeting should:

- Define and discuss the problem or deficiency;
- Review alternative solutions; and
- Implement a plan to resolve the problem or deficiency.

2.3 Document Control

The CQA Engineer will be responsible for the overall administration and control of the project documentation. He will verify that a CQA filing system is implemented that will include at a minimum:

- Survey measurements;
- Results of CQA field and laboratory tests;
- QC and QA laboratory tests of manufactured products;
- Daily field reports;
- Contractor submittals;
- Design Engineer responses; and
- Material certifications

Documentation of failed test results, descriptions of procedures used to correct the improperly installed or damaged material and statements of retests performed also shall be maintained in a file. A file index shall be prepared to expedite retrieval of documents. As the testing work is performed by the CQA Engineer, test results shall be provided in a timely manner to the Project Manager and contractor superintendent.

The CQA personnel will be required to update the filing system weekly with new data, test results, certifications, etc. All documents generated by the CQA site personnel must be filed with the CQA Engineer, as well as in the file system of the originator. These

documents, when supplied by the CQA Engineer, will be reviewed for compliance with the CQA Plan by the CQA Engineer and accepted or rejected.

A Construction Certification Report (CCR) documenting the results of the CQA testing (locations, frequencies, procedures, results, failures, corrections and retesting) will be compiled concurrent with the construction activities. Also included in the CCR will be:

- As-built drawings;
- Laboratory data;
- Color photos of different stages of construction;
- A narrative describing the work completed; and
- Daily summary reports.

The CCR will be assembled and certified by the CQA Engineer and delivered to the Project Manager/Owner.

2.3.1 Daily Records

A summary report shall be prepared daily by or under the direct supervision of the CQA Engineer or designated CQA Engineer-in-Absentia. This report shall provide the framework for identifying and recording all other reports as well as provide a chronological reference of activities. The report will be supported by other daily reports provided by CQA personnel.

2.3.1.1 Daily Summary Report

The CQA Engineer shall review the daily reports submitted by the CQA personnel and incorporate a summary report of the reports into the CQA Daily Summary Report. Any matters requiring action by the Project Manager/Owner shall be identified. The report

shall include a summary of the quantities of all completed construction components installed that day. This report must be completed daily, summarizing the previous day's activities, and a copy submitted to the Project Manager at the beginning of the work day following the report date. The report should be identified by number for cross-referencing and document control. The report should include the following items:

- Date, project name, location and other identifiers;
- Data on weather conditions;
- Reports and any meetings held and their results and required action items;
- Equipment personnel being used in each unit process, including subcontractors;
- Descriptions of areas or units of work being monitored and documented;
- Description of materials received, including any quality verification, vendor certification and documentation;
- Calibration or recalibrations of test equipment including actions taken as a result of recalibration;
- Decisions made regarding approval of units of material or of work;
- Identifying sheet numbers of test results used to substantiate the decision to approve work;
- Daily reports from CQA personnel; and
- Signature of the CQA Engineer or CQA Engineer-in-Absentia.

2.3.1.2 Daily CQA Personnel Reports

Each CQA person shall complete a daily report and/or logs on prescribed forms outlining the monitoring activities for that day. The precise work areas (identified by grid location or panel and seam numbers) shall be identified. All completed work should be identified. Measures taken to protect unfinished areas overnight shall also be identified. Deficient work and products requiring corrective action shall be identified with regard to the nature of the action, required repair, and precise locations. Repairs completed must also be

identified. Any problems or concerns with regard to operations on-site should also be noted. This report must be completed at the end of each person's shift prior to leaving the site and submitted to the CQA Engineer. Each report should be signed by the CQA person.

2.3.2 Design Changes Construction Documentation

Construction associated with design changes shall be documented by the CQA Engineer in the Daily Summary Report. All materials, quantities and construction methods required for the design change shall be documented.

2.3.3 Photographic Reports

Photographs may be taken to assist in the documentation of the construction period. The photographs will serve as a pictorial record of the work progress, problems, and corrective measures. They will be kept in a permanent, protective file in chronological order in which they were taken. The file will contain color prints. Negatives will be stored in chronological order in a separate file. Photographic reports shall include the following information:

- Identifying number on data sheets and photographs for cross-referencing and document control;
- The date, time and location and direction where the photograph was taken; and
- The name and signature of the photographer and concurrence of the CQA Engineer;

2.3.4 As-Built Record Drawings

Details of the completed facility will be recorded using as-built record drawings. A set of design drawings will be maintained at the site with as-built revisions. Revisions will be

made by CQA personnel as work is completed and the acceptance of the completed components report are filed. All as-built revisions will be dated, checked and initialed by the CQA Engineer. The as-built drawings shall include at a minimum the following information on completed components:

1. Dimensions of all completed components
2. Location as accurate as possible of each completed component;
3. Identification of all field fabrication seams and panels with appropriate numbers for identification codes;
4. Location of all repairs and corrective measures; and
5. Location of all destructive testing samples.

2.3.5 Construction Certification Report

The Construction Certification Report (CCR) shall be submitted upon completion of the work. This report shall summarize the activities of the project and document all aspects of the CQA Plan activities. This report will include all of the daily summary reports, field test data sheets, problem identification and corrective measures report, photographic report data sheets, acceptance of completed components reports, accepted design change reports, and as-built drawings.

The final certification report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project;
2. Scope of work;
3. Outline of project;
4. Quality assurance methods;
5. Test results (conformance and destructive and non-destructive, including laboratory tests); and

6. Certification sealed and signed by Registered Professional Engineer.

The CQA Engineer shall certify in the report that the construction has been completed in general accordance with the CQA Plan and in substantial conformance with the plans and specifications, except as noted in the CCR and communicated to the Project Manager. A recommended outline for the CCR is presented in Exhibit D.

EXHIBIT D
FINAL CONSTRUCTION QUALITY ASSURANCE CONSTRUCTION CERTIFICATION REPORT GENERAL OUTLINE

1. Introduction
   a. Purpose
   b. Scope
   c. Unit Description

2. Project Specifications
   a. Scope
   b. Design Changes

3. Quality Assurance Plan
   a. Scope
   b. Project specific amendments

4. Quality Assurance Completed
   a. Weather constraints
   b. Conformance testing
   c. Visual monitoring
   d. Non-destructive testing
   e. Destructive testing
   f. Repairs
   g. Geotechnical Instrumentation Monitoring

5. Summary and Conclusions

6. Project Certification

7. Appendices
   a. CQA Personnel
   b. Contractor personnel
   c. Quality Assurance Plan and specification modifications
   d. Design change forms
   e. Earthwork testing records
   f. Conformance testing records
   g. Manufacturer quality control records
   h. Quality assurance reports
   i. Subgrade acceptance certificates
   j. Panel placement records
   k. Non-destructive seam testing records
   l. Destructive seam testing records
   m. Repairs

n. As-built drawings
o. Geotechnical instrumentation monitoring results and history

2.3.6 Cover System Acceptance

Upon written recommendation by the CQA Engineer, the Project Manager/Owner shall consider accepting the landfill closure construction. The conditions of acceptance are described below. The contractor and the manufacturer/material vendor will retain all ownership and responsibility for the products associated with the construction until acceptance by the Project Manager/Owner. At the Project Manager/Owner's discretion, construction components may be accepted in sections or at stages of substantial completion.

The closure construction will be accepted by the Project Manager/Owner when:

1. The installation of the cover system or a portion thereof is finished.
2. Verification that all construction components and associated testing is completed.
3. All documentation of construction is completed.
4. The CQA Engineer is able to recommend acceptance of all construction components.

The CQA Engineer shall certify that construction has proceeded in accordance with the CQA Plan except at noted to the Project Manager. This certification shall be provided in the CCR.

3.0 MATERIAL CONTROL

This section of the plan describes material control which involves the test methods and minimum testing frequencies for conformance testing by manufacturer/material vendors. The testing is to ensure that the materials meet the requirements of the technical specifications. The CQA Engineer will review the test results and may specify additional testing if necessary.

3.1 Quality Control Documentation

Quality control documentation in support of all materials delivered to the site shall be approved in advance before delivery. The manufacturer/material vendor shall provide the CQA Engineer with the following information:

1. Premanufactured process materials shall provide origin information (i.e., source, rock lithology for aggregates and resin manufacturer and production date for geosynthetics).

2. Copies of quality control certificates issued by material supplier.

3. Reports on tests conducted by the manufacturer/material vendor to verify that the quality of the material meets all technical specifications.

4. Reports on quality control tests conducted by the manufacturer/material vendor to verify that the product manufactured or processed for the project meets the project specifications. The CQA Engineer will review the data provided and visually inspect the item to ensure compliance. The CQA Engineer has the authority to reject the item, require additional information keeping within the limits of specifications, or conduct additional testing as may be required.

5. A written certification that the minimum value given in the specifications is guaranteed by the manufacturer/material vendor.

Should the testing and/or certification establish that the material, item or workmanship is not in conformance with or does not meet the requirements of the plans and specifications the following actions will be required:

- Manufactured Items: Any manufactured item which does not meet the requirements or intent of the drawings or specifications will be rejected and not used in the construction of the facility.

- Construction Materials: Any materials which do not meet the requirements or intent of the drawings and specifications will be rejected and not used in the construction of the facility.

- Workmanship: Any workmanship which does not meet the requirements or intent of the drawings and specifications or acceptable construction practice will be repaired, redone, or removed.

3.2 Conformance Testing

Conformance testing shall be conducted in accordance with the technical specifications and this CQA Plan using the sampling procedures and test procedures described in Table 1. Conformance tests shall be provided in advance for acceptance by the CQA Engineer before shipment occurs.

3.2.1 Sampling Procedures

All conformance test specimens shall be sampled from whole lots, batches or stockpiles processed with similar raw materials. Sampling procedures should be in accordance with ASTM or alternative trade industry standard and so documented on the test result. Samples shall be randomly taken at the frequency prescribed in Table 1.

3.2.2 QC Test Results

QC test results shall be reported to the CQA Engineer or the Project Manager/Owner before shipment. Test results shall conform to the project specifications. Test results shall also be accompanied by a written certification that minimum values given in the specifications are guaranteed by the manufacturer/material vendor. Any manufacturing or processing adjustments between sampling intervals shall be so noted and brought to the attention of the CQA Engineer or Project Manager/Owner.

3.3 Flume Fill

Flume fill shall be processed from natural rock formations providing the petrographic analysis and aggregate grain size distribution required by the specifications. Test results demonstrating conformance to these specifications shall be provided to the CQA Engineer at sampling intervals of 20,000 cu. yd., change in material type or source, or more frequently for dissimilarly processed materials. Conformance tests should be forwarded to the CQA Engineer or the Project Manager/Owner before shipment.

3.4 Waste Excavation and Placement

Significant quantities of waste will be excavated and redisposed in designated areas as provided by the technical specifications. The waste excavation and fill placement locations

and volumes are provided in the technical specifications. During excavation, miscellaneous large objects will likely be encountered along with slightly cemented waste. All waste materials shall be broken down to maximum 1 ft. particle size and all large objects shall be excavated and handled separately so that these large objects are placed in independent areas and not nested together allowing uniform fill placement around the large objects in new fill areas.

During excavation it is expected that most materials will be excavated with hydraulic equipment, however, any use of impact hammers to break down cemented materials shall be so noted by the CQA Engineer and Project Manager/Owner. The degree of breakdown shall be sufficient in the opinion of the CQA Engineer to allow compaction of fine grained waste material around larger objects or cemented materials. All waste materials handled similar to soils which are excavated and redisposed shall be compacted in accordance with the compaction specifications in Table 1.

3.5 Sand Bedding

Natural sand bedding or processed natural rock shall be tested in accordance with the specifications in Table 1. Test results shall conform to the specification and be forwarded to the CQA Engineer or Project Manager/Owner before shipment.

3.6 Coarse Protection Aggregate

The coarse protection aggregate shall be processed from natural rock formations providing the petrographic analysis and aggregate grain size distribution required by the specifications. The coarse protection aggregate shall be of durable quality with conformance testing completed in accordance with the technical specifications. Conformance tests shall be forwarded to the CQA Engineer or the Project Manager/Owner before shipment.

3.7 Rip Rap

Rip rap shall be processed from natural rock formations providing the petrographic analysis and aggregate grain size distribution required by the specifications. The rip rap shall be of durable quality with conformance testing completed in accordance with the technical specifications. Conformance test results shall be forwarded to the CQA Engineer or the Project Manager/Owner before shipment.

3.8 INDOT #53 Aggregate

The INDOT #53 aggregate shall be of durable quality with conformance testing completed in accordance with the technical specifications. Conformance tests shall be in accordance with the technical specifications and accepted by the CQA Engineer or the Project Manager/Owner before shipment.

3.9 Geomembrane

The geomembrane manufacturer/material vendor shall provide the CQA Engineer with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and the production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the manufacturer/material vendor to verify that the quality of the resin used to manufacture the geomembrane meets the project specifications.
4. Reports on quality control tests conducted by the manufacturer/material vendor to verify that the geomembrane manufactured for the project meets the project specifications.

5. A statement indicating that the amount of reclaimed polymer added to the resin during the manufacturing was done with appropriate cleanliness and does not exceed 2 percent by weight.
6. A list of the materials which comprise the geomembrane expressed in the following categories as percent by weight: polyethylene, carbon black, and other additives.
7. Specifications for the geomembrane which includes all properties contained in the project specifications measured using the appropriate test methods.
8. Written certification that the minimum values given in the specifications are guaranteed by the manufacturer/material vendor.
9. Quality control certificates signed by responsible party employed by the manufacturer. Each quality control certificate shall include: roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for:

    a. Density
    b. Carbon black content
    c. Carbon black dispersion
    d. Thickness
    e. Tensile properties

These quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 50,000 sq. ft. of geomembrane produced. The manufacturer shall identify all rolls of geomembranes with the following:

1. Manufacturer's name
2. Product identification
3. Thickness
4. Roll number

5. Roll dimensions

The CQA Engineer shall review the CQ documents and shall report any discrepancies with the above requirements to the Project Manager/Owner. The CQA Engineer shall verify that:

1. The property values certified by the manufacturer meet all of its guaranteed specifications;

2. Measurements of properties by the manufacturer are properly documented and that the test methods used are acceptable;

3. Quality control certificates have been provided at the specified frequency for all rolls and that each certificate identifies the roll related to it;

4. The rolls are appropriately labeled;

5. Certified minimum properties meet the project specifications.

Upon delivery of the rolls of geomembrane, the CQA Engineer shall ensure that conformance test samples are obtained for the geomembrane. These samples shall then be forwarded to the CQA laboratory for testing to ensure conformance to the project specifications.

If the Project Manager/Owner desires, the CQA Engineer can perform the conformance testing sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The following conformance tests shall be conducted:

1. Density
2. Carbon black content
3. Carbon black dispersion
4. Thickness
5. Tensile characteristics
6. Melt index
7. Interface friction angle
8. Asperity height

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Conformance test samples shall be taken across the entire width of the roll and shall not include the first 3 feet. Unless otherwise specified, samples shall be 3 feet long by the roll width. The CQA Engineer shall mark the machine direction on the samples with an arrow.

The lot shall be defined as the group of consecutively numbered rolls from the same manufacturing line and the same resin material. Alternatively, a lot may be designated by the CQA Engineer based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot or one conformance sample per 50,000 sq. ft. of geomembrane.

All conformance test results shall be reviewed and accepted or rejected by the CQA Engineer before deployment of the geomembrane. The CQA Engineer shall examine all results from the laboratory conformance testing and shall report any nonconformance to the Project Manager. The CQA Engineer shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the manufacturer has reason to believe that failing tests may be the result of the CQA laboratory incorrectly conducting the test, the manufacturer may request that the sample in question be retested by the CQA laboratory with a technical representative of the manufacturer present during the testing. This retesting may be done at the expense of the manufacturer. Alternatively, the manufacturer may have the sample retested at two different CQA laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original CQA laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the CQA Engineer.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the CQA Engineer, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when rolls in the lot are consecutively produced and numbered from one manufacturing line and kept in storage as a group). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that "bracket" a greater number of rolls within the lot.

3.10 Geotextile

Prior to the installation of any geotextile, the manufacturer/material vendor or contractor shall provide the CQA Engineer with the following information:

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.

2. Copies of the quality control certificates issued by the resin supplier.

3. Reports on tests conducted by the manufacturer/material vendor to verify that the quality of the resin used to manufacturer the geotextile meets the manufacturer's resin specifications.

4. Reports on quality control tests conducted by the manufacturer to verify that the geotextile manufactured for the project meets the project specifications.

5. A statement indicating the reclaimed polymer added to the resin during the manufacturing was done with appropriate cleanliness.

6. A list of the materials which comprise the geotextile expressed in the following categories as a percent by weight:

   Base polymer;
   Carbon black; and
   Other additives.

7. Specification for the geotextile which includes all properties contained in the project specifications measured using the appropriate test methods.

8. Written certification that minimum average roll values given in the specification are guaranteed by the manufacturer.

9. For non-woven geotextiles, written certification that the manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.

10. Quality control certificates signed by a responsible party employed by the manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, the results shall be given for:

    Mass per unit area;
    Grab strength;
    Trapezoidal tear strength; and
    Puncture strength.

Quality control tests shall be performed in accordance with the test methods specified in the project specifications for at least every 50,000 sq. ft. of geotextile produced.

Manufacturers shall identify all rolls of geotextiles with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The CQA Engineer shall review the above documents and shall report any discrepancies with the above requirements to the Project Manager. The CQA Engineer shall verify that:

1. Property values certified by the manufacturer meet all of its guaranteed specifications.

2. Measurements and properties by the manufacturer are properly documented and the test methods used are acceptable.

3. Quality control certificates have been provided at the specified frequency for all rolls and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum average roll properties meet the project specifications.

Upon delivery of the rolls of geotextile, the CQA Engineer shall insure that conformance test samples are obtained for the geotextile. These samples shall then be forwarded to the CQA laboratory for testing to insure conformance to the project specifications.

At a minimum, the following conformance tests shall generally be performed on geotextiles:

1. Mass per unit area
2. Grab strength
3. Trapezoidal tear strength
4. Puncture resistance
5. Ultraviolet degradation
6. Abrasion
7. pH resistance
8. Interface friction angle

These conformance tests shall be performed in accordance with the test methods specified in the project specifications and Table 1. Other conformance tests may be required by the project specifications.

The rolls to be sampled shall be selected by the CQA Engineer. Samples shall be taken across the entire width of the roll and shall not include the first complete revolution of fabric on the roll. Samples shall not be taken from any portion of the roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 feet long by the roll width. The CQA Engineer shall mark the machine direction of the samples with an arrow. All lots of the material and the particular test sample that represents each lot shall be defined before the samples are taken.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line and resin. Alternatively, a lot may be designed by the CQA Engineer based on a review of all roll information, including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at the rate of one per lot or one conformance test per unit volume specified in Table 1.

All conformance test results shall be reviewed and accepted or rejected by the CQA Engineer prior to deployment of the geotextile.

The CQA Engineer shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The CQA Engineer shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications. If the manufacturer has reason to believe that the failing test may be the result of the CQA laboratory incorrectly conducting the test, the manufacturer may request that the sample in question be retested by the CQA laboratory with a technical representative of the manufacturer present during the testing. This retesting shall be done at the expense of the manufacturer. Alternatively, the manufacturer may have the sample retested at two different approved CQA laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both

laboratories do not produce passing results, then the original CQA laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the CQA Engineer.

If a test result is in nonconformance, all material from the lot presented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line and stored together). To isolate the out of specification material, additional samples must be taken from the rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and roll manufactured immediately after that roll (next largest roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that "bracket" a greater number of rolls within the lot.

3.11 Geocomposite Drain

Prior to the installation of any geocomposite drain the manufacturer or contractor shall provide the CQA Engineer with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number) and the production date of the resin. Information on resins from both the geonet and the geotextile shall be provided.

2. Copies of the quality control certificates issued by the resin suppliers

3. Reports on tests conducted by the manufacturer to verify that the quality of the resin used to manufacture the geocomposite drain components meets the project specifications.

4. Reports on quality control tests conducted by the manufacturer to verify that the geocomposite drain manufactured for the project meets the project specifications.

5. A statement indicating that the reclaimed polymer added to the resin during manufacturing, if any, was done with appropriate cleanliness.

6. A list of the materials which comprise the geocomposite drain components (i.e., geotextile and geonet), expressed in the following categories as percent by weight:

   Base polymer;
   Carbon black; and
   Other additives.

7. A specification for the geocomposite drain which includes all properties contained in the project specifications measured during the appropriate test methods.

8. Written certification that the minimum values given in the specification are guaranteed by the manufacturer.

9. Quality control certificates signed by the responsible party employed by the manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum the results shall be given for:

Geonet	Geotextile	Geocomposite
a. Density	a. Mass per unit area	a. Tensile Strength
b. Carbon black content	b. Grab strength	b. Ply adhesion
	c. Trapezoidal tear strength	c. Mass per unit area
	d. Puncture resistance	

Quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 50,000 sq. ft. of geocomposite produced.

The manufacturer shall identify all rolls of geocomposite drain with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The CQA Engineer shall review these documents and shall report any discrepancies with the above requirements to the Project Manager/Owner. The CQA Engineer shall verify that:

1. Property values certified by the manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the manufacturer are properly documented and that the test methods used are applicable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the project specifications.

Upon delivery of the rolls of geocomposite drain, the CQA Engineer shall insure that conformance samples are obtained for the geocomposite drain. These samples shall then be forwarded to the CQA laboratory for testing to insure conformance to the project specifications.

At a minimum, the following tests shall be performed:

Geonet	Geotextile	Geocomposite
a. Density	a. Mass per unit area	a. Mass per unit area
b. Carbon black	b. Grab tensile strength	b. Tensile strength
	c. Trapezoidal tear strength	c. Hydraulic conductivity
	d. Puncture resistance	d. Ply adhesion

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

The rolls to be sampled shall be selected by the CQA Engineer. Samples shall be taken across the entire width of the roll and shall not include the first wrap. Unless otherwise specified, samples shall be a minimum of 3 feet long by the roll width. The CQA Engineer shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the CQA Engineer based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot not to exceed one conformance test per 50,000 sq. ft. of geocomposite drain.

All conformance test result shall be reviewed and accepted or rejected by the CQA Engineer prior to deployment of the geocomposite drain.

The CQA Engineer shall examine all results from the laboratory conformance testing and shall report any nonconformance to the Project Manager. The CQA Engineer shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the manufacturer has reason to believe that the failing test may be the result of the CQA laboratory incorrectly conducting the test, the manufacturer may request that the sample in question be retested by the CQA laboratory with a technical representative of the manufacturer present during testing. This retesting shall be done at the expense of the manufacturer. Alternatively, the manufacturer may have the sample retested at two different approved CQA laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original CQA laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the CQA Engineer.

If a test result is in nonconformance, all material from the lots represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the CQA Engineer, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is only valid when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples may be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured

immediately after that roll (next largest roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that "bracket" a greater number of rolls within the lot.

3.12 Geogrid

Prior to the installation of any geogrid, the manufacturer or contractor shall provide the CQA Engineer with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number) and the production date of the resin.

2. Copies of the quality control certifies issued by the resin suppliers

3. Reports on tests conducted by the manufacturer to verify that the quality of the resin used to manufacture the geogrid meets the project specifications.

4. Reports on quality control tests conducted by the manufacturer to verify that the geogrid manufactured for the project meets the project specifications.

5. A statement indicating that any reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 1 percent by weight.

6. A list of the materials which comprise the geogrid, expressed in the following categories as percent by weight:

   Base polymer; Carbon black;
   Carbon black PVC coating; and

Other additives.

7. A specification for the geogrid which includes all properties contained in the project specifications measured during the appropriate test methods.

8. Written certification that the minimum values given in the specification are guaranteed by the manufacturer.

9. Quality control certificates signed by the responsible party employed by the manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum the results shall be given for:

    a. Mass per unit area, PE only and PVC carbon black coating
    b. Wide width tensile strength
    c. Creep
    d. UV performance
    e. Abrasion performance

Quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 50,000 sq. ft. of geogrid produced.

The manufacturer shall identify all rolls of geogrid with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The CQA Engineer shall review these documents and shall report any discrepancies with the above requirements to the Project Manager/Owner. The CQA Engineer shall verify that:

1. Property values certified by the manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the manufacturer are properly documented and that the test methods used are applicable.

3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.

4. Roll packages are appropriately labeled.

5. Certified minimum properties meet the project specifications.

Upon delivery of the rolls of geogrid, the CQA Engineer shall insure that conformance samples are obtained for the geogrid. These samples shall then be forwarded to the CQA laboratory for testing to insure conformance to the project specifications.

At a minimum, the following tests shall be performed:

1. Mass per unit area, PE only and PVC carbon black coating
2. Wide width tensile strength
3. Measurement of rib/strand count, aperture and thickness
4. UV degradation
5. Abrasion test

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

The rolls to be sampled shall be selected by the CQA Engineer. Samples shall be taken across the entire width of the roll and shall not include the first wrap. Unless otherwise specified, samples shall be a minimum of 3 feet long by the roll width. The CQA Engineer shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the CQA Engineer based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot or one conformance test per 50,000 sq. ft. of geogrid.

All conformance test result shall be reviewed and accepted or rejected by the CQA Engineer prior to deployment of the geogrid.

The CQA Engineer shall examine all results from the laboratory conformance testing and shall report any nonconformance to the Project Manager/Owner. The CQA Engineer shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the manufacturer has reason to believe that the failing test may be the result of the CQA laboratory incorrectly conducting the test, the manufacturer may request that the sample in question be retested by the CQA laboratory with a technical representative of the manufacturer present during testing. This retesting shall be done at the expense of the manufacturer. Alternatively, the manufacturer may have the sample retested at two

different approved CQA laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original CQA laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the CQA Engineer.

If a test result is in nonconformance, all material from the lots represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the CQA Engineer, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is only valid when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples may be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next largest roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that "bracket" a greater number of rolls within the lot.

3.13 Polyethylene Pipe (Solid and Perforated)

Prior to the installation of any polyethylene pipe the manufacturer or contractor shall provide the CQA Engineer with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number) and the production date of the resin.

2. Copies of the quality control certifies issued by the resin supplier.

3. Reports on tests conducted by the manufacturer to verify that the quality of the resin used to manufacture the polyethylene pipe meets the project specifications.

4. Reports on quality control tests conducted by the manufacturer to verify that the polyethylene pipe manufactured for the project meets the project specifications.

5. A statement indicating that any reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 1 percent by weight.

6. A list of the materials which comprise the polyethylene pipe, expressed in the following categories as percent by weight:

   Polyethylene;
   Carbon black; and
   Other additives.

7. A specification for the polyethylene pipe which includes all properties contained in the project specifications measured during the appropriate test methods.

8. Written certification that the minimum values given in the specification are guaranteed by the manufacturer.

9. Quality control certificates signed by the responsible party employed by the manufacturer. The quality control certificates shall include bundle identification numbers, sampling procedures and results of quality control tests. At a minimum the results shall be given for:

   a. Density
   b. Melt flow index
   c. Flexural Modulus

d. Tensile strength
e. Carbon black content
f. Carbon black dispersion

Quality control tests shall be performed in accordance with the test methods specified in the project specifications for every 50,000 lbs. of resin.

The manufacturer shall identify all bundles of polyethylene pipe with the following:

1. Manufacturer's name
2. ASTM D 2513 product specification
3. Product identification
4. Batch or lot number
5. Pipe diameter (ID)
6. Pipe SDR (standard dimension ratio)

The CQA Engineer shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The CQA Engineer shall verify that:

1. Property values certified by the manufacturer meet all of its guaranteed specifications.

2. Measurements of properties by the manufacturer are properly documented and that the test methods used are applicable.

3. Quality control certificates have been provided at the specified frequency for all pipe bundles, and that each certificate identifies the bundles related to it.

4. Pipe bundles are appropriately labeled.

5. Certified minimum properties meet the project specifications.

Upon delivery of polyethylene pipe, the CQA Engineer shall insure that conformance samples are obtained for the polyethylene pipe. These samples shall then be forwarded to the CQA laboratory for testing to insure conformance to the project specifications.

At a minimum, the following tests shall be performed:

1. Density
2. Melt flow index

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

The pipe bundles to be sampled shall be selected by the CQA Engineer.

A lot shall be defined as a group of consecutively numbered pipe bundles from the same manufacturing line. Alternatively, a lot may be designated by the CQA Engineer based on a review of all pipe bundle information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot not to exceed one conformance test per 25 bundles of polyethylene pipe. The sample shall consist of a three (3) foot long by pipe diameter SP.

All conformance test results shall be reviewed and accepted or rejected by the CQA Engineer prior to deployment of the polyethylene pipe.

The CQA Engineer shall examine all results from the laboratory conformance testing and shall report any nonconformance to the Project Manager. The CQA Engineer shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the manufacturer has reason to believe that the failing test may be the result of the CQA laboratory incorrectly conducting the test, the manufacturer may request that the sample in question be retested by the CQA laboratory with a technical representative of the manufacturer present during testing. This retesting shall be done at the expense of the manufacturer. Alternatively, the manufacturer may have the sample retested at two different approved CQA laboratories at the expense of the manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original CQA laboratory test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the CQA Engineer.

If a test result is in nonconformance, all material from the lots represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the CQA Engineer, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is only valid when all pallets in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples may be taken from pipe/pallets that have pipe/pallet numbers immediately adjacent to the pipe/pallet that was sampled and failed. If both additional tests pass, the pipe/pallet that represents the initial failed test and the pipe/pallet manufactured immediately after that pipe/pallet (next largest pipe/pallet number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that "bracket" a greater number of pipe/pallets within the lot.

3.14 Precast Concrete Structures

Immediately following delivery of precast concrete sections, the CQA Engineer shall observe and measure the dimensions of the structures, including the concrete cylinder strength and thickness, to verify that structure components are in conformance with the design drawings and specifications. The CQA Engineer shall also obtain the supplier's documentation that reinforcing steel was placed in accordance with the specifications. The CQA Engineer shall also direct his personnel to check for damage from shipment and handling and to document damaged structures. Any damaged materials shall be rejected.

Any damage that occurs during material storage and construction should also be documented. Any damaged material shall be rejected.

3.15 Guard Rail

The CQA Engineer shall observe and measure that the dimensions and thickness of guard rails are in conformance with the design plans and specifications. The CQA Engineer shall also obtain documentation that the guard rail was manufactured from the specified steel grade and was coated for corrosion protection in accordance with the specifications. Any damage from shipment and handling shall be cause to reject the damaged material. Engineers shall also check for damage that occurs during material storage and construction and reject any damaged material.

4.0 SURVEY CONTROL

4.1 Vertical and Horizontal Control Points

Vertical and horizontal survey control points are provided on the design plans. These control points shall be utilized for all construction activities. Each control point shall be suitably protected to prevent damage from construction activities. All horizontal control points shall be referenced to the Indiana State Plane Coordinate System and all vertical control points shall be referenced to United States Coast and Geodetic Survey (USCGS).

4.1.1 Dredging Survey Control

Survey control for dredging activities along the intake flume will be necessary. Survey controls should be provided on a daily basis to confirm that dredging is conducted to the prescribed dimensions on the design plans. Any excess dredging (beyond dredge dimensions) shall be immediately reported to the CQA Engineer. All dredge surveying shall consist of soundings at the toe of slope points at each trapezoidal section along the flume.

4.1.2 Flume Fill Survey Control

Flume fill will be placed on both sides of the flume with the majority of the volume placed along the north side of the flume. Surveying control shall be provided during construction to establish the original line and grade of the flume using soundings before fill is placed. Flume fill shall then be placed in horizontal lifts approximately 5 feet thickness below the water line each on both sides of the flume as provided in the design plans. Surveying control should be provided throughout the filling activity and lifts shall be placed in sublifts on the order of 3 to 4 feet each. Sounding shall be provided on a daily basis in the active filling area so as to produce an as-built drawing which provides the fill date and thickness of flume fill at each station along the flume alignment.

4.1.3 Waste Regrading Survey Control

Regrading of the landfill waste to the new configuration shall occur in accordance with the design drawings and specifications. Essentially, waste will be excavated from the top down on the south slope and placed and compacted from the bottom up on the north slope. The details for the excavation and fill areas are provided in the design drawings. To monitor this regrading operation, a GPS survey control scheme (mapping level accuracy) shall be developed. The GPS control shall provide for minimum weekly grade shots to establish the excavation and filling progress. Generally the GPS points shall be a minimum of 100 feet on center grid spacing near pre-established station points along the south and north slopes. Survey notes from this weekly surveying shall be used to provide progress topography of the excavation and filling activity in order that conformance to the design plans and specifications is confirmed and for purposes of interpreting geotechnical instrumentation.

The surveying activities shall also direct the placement of large objects so that nesting of these objects is not vertically overlain but rather staggered at varied locations so as not to induce significant fill settlement along any one particular slope section.

Near the completion of waste regrading, fine grading of the perimeter slopes and crests shall be provided to carefully contour the site to the proposed design grades. Any excess material encountered in the course of this regrading activity shall be disposed in areas designated by the CQA Engineer with consultation from the design engineer. Final waste subgrades shall be completed to survey level accuracy.

4.1.4 Cover System Survey Control

The cover system will essentially consist of a sand bedding and cover aggregate and geosynthetic materials on the regraded waste subgrade. This survey activity shall focus on

establishing the proper lift thicknesses and placement of layers associated with the cover system. The surveying activity may establish tell-tale survey grade staking as necessary to monitor lift thicknesses for all fill placement. All field seams for the geomembrane shall also be surveyed at the top and bottom of each slope and referenced to the as-built drawing section. Final cover grades shall be surveyed to survey level accuracy.

4.1.5 Gas Vent and Stormwater Management Structure Survey Control

The grade and location of all gas vent and stormwater structures shall be established with a survey along with construction staking and appropriate offsets. All stakes shall be appropriately marked to provide a clear understanding of survey control to all parties. Gas vents shall be surveyed to mapping level accuracy while stormwater structures shall be surveyed to survey level accuracy.

4.1.6 RTV and Access Road Survey Control

The centerline grades and alignment and appropriate offsets for all stations along the RTV roadway and access roadway shall be provided. All roadway construction shall be controlled from this staking system. Survey level accuracy shall be provided.

4.2 Geotechnical Instrumentation

Numerous geotechnical instruments have been installed at the site including pneumatic piezometers and vertical inclinometers. These instruments have been used to monitor slope movements and will be used to monitor subsurface conditions during construction. These instruments are positioned at critical locations and should be protected during construction. Some instruments are established at grades where extensive waste excavation is proposed. These instruments will be reestablished both during construction and following regrading so that the instrument performance is maintained throughout the construction activity. Periodic surveying of the instruments to confirm their location and to

assist with recalibration may be necessary. All geotechnical instrumentation points shall be protected by jersey barriers or precast concrete pipe sections during construction. All geotechnical instruments will be permanently established for post-closure monitoring. The permanent locations should also be referenced to the vertical and horizontal control system.

4.3 Monitoring Well Installations Survey Control

Four (4) monitoring well installations are proposed at the perimeter of the site. Horizontal and vertical survey controls should be provided at each location. Upon completion of the wells, the inner PVC casing shall be surveyed as a reference datum for all future groundwater levels. The survey information shall accompany the drilling and well installation documentation.

4.4 Final Survey Standards

A final survey of the site grades, roadways and drainage structures shall be completed to survey level accuracy. The survey shall be conducted under the direction of the CQA Engineer. Any slight variations from the proposed design grades or locations shall be discussed with the Project Manager to determine the functionality of the structures at the slightly varied grades.

5.0 CONSTRUCTION FIELD AND LABORATORY TESTING

5.1 Conformance Testing

Conformance testing for all field construction activities will generally include subgrade preparation, compaction control, verification of field fabrication, completed work protection, identification and characterization of damage and defects, and corrective measures to repair any substandard workmanship. Various field sampling strategies and field test equipment shall be used by CQA personnel in conformance testing. Sampling strategies and test equipment calibration are discussed below.

5.1.1 Sampling Strategies

The sampling program for each construction component will be based on accepted engineering practices. Table 1 summarizes the CQA sampling and testing proposed in this plan. Changes to the sampling program may be warranted during construction for appropriate evaluation of particular components. The need for and the extent of any such change will be determined by the CQA Engineer responsible for the work in question in cooperation with the Design Engineer. Documentation of the accepted program change of any sampling strategies shall be provided. Generally, sampling strategies shall be random and regular for each construction component.

5.1.2 Test Equipment Calibration

Both field and laboratory test equipment shall be calibrated throughout the testing program. Calibration should be noted on each test equipment and each test equipment shall be calibrated at least once before construction begins. Any test equipment that may fall out of calibration as a result of mishandling or environmental conditions shall be recalibrated on a regular basis during construction. Regular calibration between the sand

cone or rubber balloon methods and nuclear field moisture density testing shall be completed weekly with a daily check recalibration of the nuclear test equipment.

5.2 Dredging

Dredging along the flume intake between stations 7+00 and 14+00 is proposed. Generally, this dredging is shallow. Dredging shall be conducted with minimum sediment resuspension and preferably using mechanical means. Suspended dredge sediments shall be controlled with silt curtains draped around the dredge equipment or across the intake flume. Water quality samples shall be collected at the prescribed frequency in Table 1 both upstream and downstream of the dredging activity. Dredge sediment results shall be reported to the Project Manager and the CQA Engineer. Survey soundings shall be completed on a daily basis or as needed to direct the dredging operation.

Dredge solids shall be redisposed in thin lifts near the top of the landfill as provided in the project specifications. Diked and bermed areas shall be provided where necessary to limit off-site runoff and to provide dewatering opportunities for the dredge solids.

5.2.1 Geotechnical Instrumentation

During the dredging activity, regular geotechnical instrumentation measurements shall be collected and reported to the CQA Engineer at the frequencies noted in Table 1. The test results shall be reviewed regularly and reported to all parties.

5.3 Utility Relocation

An oxygen and steam line relocation is proposed along the west and north sides of the Clark Landfill. The relocated utility will involve both underground and overhead construction. Appropriate testing of bedding material compaction and backfill compaction

associated with the underground utility shall be provided. All tests shall be in accordance with standard engineering procedures as provided in the design plans and specifications.

5.4 RTV Roadway Relocation

The RTV roadway will be located slightly west and north of its current alignment to provide for a stormwater management structure (also referred to as the north ditch). The RTV roadway serves heavy rubber-tired vehicles transporting hot slabs of steel. A thick pavement section is required to accommodate these heavy vehicles. The RTV roadway grades will be established using excavated materials from the north ditch (stormwater structure). These materials will be placed, graded and compacted to establish a subbase for this pavement section. The subbase will be overlain with a full depth asphalt concrete pavement. A guard rail will be provided between the roadway and the stormwater ditch section.

5.4.1 Roadway Grading

RTV roadway grading shall be accomplished with excavated materials from the north ditch. The excavation of these materials may be difficult and the materials may be cemented. Any cemented materials shall be mechanically degraded to a maximum particle size of two-thirds the compacted lift thickness. Before any excavated materials are placed, the roadway alignment shall be established with centerline staking with appropriate offsets. Deleterious subgrade materials shall be removed before any compacted fill is placed.

5.4.2 Subbase Preparation

The subgrade preparation for the asphaltic concrete pavement section shall be compacted in accordance with the design drawings and specifications and at the frequencies provided

in Table 1. Any materials not satisfying the compaction specification shall be removed and replaced with suitably compacted materials.

5.4.3 Asphalt Pavement

The asphalt pavement section shall be placed in general accordance with the asphalt mix design and the compaction specifications provided in the design drawings and specifications. The appropriate tests and frequencies to confirm satisfaction of the design plans specifications are provided in Table 1.

5.4.4 Guard Rail Installation

A Class B Type I zinc coated "W" type beam shape is proposed. This guard rail should be checked for conformance with the design plans and specifications. Gauge thickness corrosion coating and dimensions should be confirmed.

5.5 Stormwater Management Structures

Various stormwater management structures are proposed to collect and convey stormwater while producing minimum sediment transport. The stormwater from the north side of the landfill will be collected in the north ditch and conveyed to the existing plant stormwater system. Water on the south facing landfill slope will sheet flow into the flume. The various stormwater management structures include precast concrete structures, flexible piping, and rip rap for ditch and mid-slope swale erosion protection. These structures are described further below.

5.5.1 Precast Concrete Structures

All precast structures shall be constructed to the lines and grades proposed in the design drawings and specifications. All locations shall be surveyed before construction with

appropriate offsets. Precast sections shall be connected with specified mastic materials. Precast structures shall also be placed with appropriate thrust block stabilization as provided for in the design drawings and specifications.

5.5.2 Polyethylene Piping

Both solid and perforated polyethylene piping are specified for the stormwater management structures. Pipe sections shall be joined in general accordance with the design plans and specifications. CQA personnel shall observe these joining methods and confirm that all connection systems meet the technical specifications. All pipe alignments shall be built to the proposed lines and grades as provided for in the plans and specifications.

5.5.3 Rip Rap Materials for Ditch and Mid-Slope Swales

Rip rap is proposed to protect against erosive forces of stormwater along the ditch and mid-slope swales. The test procedures and frequencies for rip rap placement and construction are presented in Table 1.

5.6 Flume Filling

The filling of the flume is proposed to buttress the toe of the existing Clark Landfill south slope against movement and to achieve a factor of safety ≥1.3 for static slope stability. The buttress will be placed on both the east and north sides of the flume leaving a prescribed trapezoidal section for the flume intake cross-section. Flume fill shall be placed in several separate 5 to 7-foot thick lift thicknesses in a uniform manner along the full length of the flume.

The flume filling shall be accomplished with minimum disturbance of the bottom sediments. Silt curtains shall be provided within the intake flume during fill placement to minimize transport of fines toward the Pumphouse No. 2 water intake structure.

During flume filling activity, geotechnical instrumentation will be monitored to check for any subsurface movements that may be triggered by flume filling activities. These results will be reviewed on a regular basis to direct the filling operation.

5.6.1 Flume Fill Aggregate

The flume fill aggregate will consist of a natural crushed stone meeting the technical specifications and placed at the proposed design grades. The flume fill aggregate shall be tested in accordance with Table 1 at the frequencies prescribed. During placement of the aggregate, staging stockpiles may be limited in size and shall be positioned at or near the flume causing minimal additional stress on the existing south slope. The CQA Engineer in consultation with the Design Engineer shall designate stockpile areas and the extent of stockpile height.

5.6.2 Lift Placement

The flume fill aggregate shall be placed in relatively equally thick lifts from the bottom up. Each lift shall be 5 to 7 feet thick and placed in a uniform manner, preferably in smaller sublifts throughout the length of the flume. Survey soundings shall be taken at the frequencies prescribed in Table 1.

5.6.3 Rip Rap Placement

Rip rap placement along the flume shoreline on both the north and south sides is proposed. The rip rap shall be placed to the lines and grades described on the design plans and specifications. All rip rap materials shall be tested in accordance with Table 1 at the frequencies prescribed.

5.6.4 Geotechnical Instrumentation Monitoring

Geotechnical instrumentation monitoring will be conducted throughout the flume filling activities. Survey data and instrumentation results will be utilized to characterize the influence of flume fill on the subsurface conditions. The geotechnical instrumentation and survey data shall be reviewed on a regular basis in accordance with Table 1. All results and conclusions shall be reported to all parties.

5.7 Waste Regrading

Extensive regrading of the landfill waste materials is proposed. This regrading activity shall be sequenced in accordance with the design plans and specifications. Generally, materials on the south slope will be excavated and filled on the north slope. Surveying shall be completed on a regular basis to direct the regrading operation. This surveying shall be accomplished with GPS survey equipment. The regrading activity will likely encounter numerous oversize materials which will require sorting and placement with special compaction. Both dust and surface water erosion controls are included in the design plans and specifications. The regrading activities are further described below.

5.7.1 Sequencing of Excavation and Filling

The design plans and specifications provide for a detailed sequencing of excavation and filling generally excavating from the top down along the south slope and filling from the bottom up along the north slope. All sequencing shall be accomplished within the boundaries prescribed in the design plans and specifications. Surveying, using GPS methods, shall be used to assist in monitoring the sequencing of excavation and filling activities.

5.7.2 Oversize Material Sorting and Placement

Numerous large objects within the waste materials will require excavation and sorting and redisposal along the north slope. All oversize materials shall be loaded and dumped in CQA Engineer prescribed locations to avoid nesting of these materials together. Fill should be placed around the materials so as to avoid settlement associated with nesting these materials at a particular slope section. Generally, the oversize material shall be uniformly distributed throughout the fill.

5.7.3 Compaction Near Oversize Materials

Generally, oversize materials shall be laid flat on their longest side and finer materials compacted around these large objects. These objects may also be pushed into the subgrade to bed them more firmly. Compaction may be accomplished with hand or smaller compactors to minimize the settlement and fill movements around these large objects. Alternatively, excavations may be made in the fill placement area where large objects are buried. Flowable fills may also be placed around these objects. The compaction near the oversize materials shall generally meet the compaction specifications for the waste materials.

5.7.4 General Fill Placement and Compaction

Waste materials shall be excavated and redisposed to the lines and grades proposed in the design plans and specifications. The sequences for this activity are prescribed in the design plans and specifications. All fill materials shall be compacted in accordance with the technical specifications and tested in accordance with the procedures and frequencies described in Table 1. Appropriate dust control measures and erosion control measures shall be provided during this excavation and fill activity. Various structures shall also be protected during the work activities associated with this construction component.

5.7.5 Geotechnical Instrumentation Monitoring and Reconstruction

Through the fill excavation and placement, geotechnical instruments will be monitored at the frequency described in Table 1. The monitoring results, along with the survey results, shall be released to the CQA Engineer.

Excavation and fill placement around existing geotechnical instruments shall be protected with jersey barriers or reinforced concrete pipe and the geotechnical instruments shall be reconfigured to the new regrading plan. Before major adjustments in geotechnical instrumentation, it may be appropriate to take a before and after reading associated with these adjustments.

5.7.6 Dust Control

Dust control measures shall be maintained throughout the waste regrading activity to protect workers and wind transport of waste materials. Where necessary, workers shall be suitably protected with personnel protection equipment. Dust control measures shall be approved by the CQA Engineer and maintained throughout the regrading activities.

5.7.7 Silt Fence Placement

A silt fence is proposed on the perimeter of the regrading area to protect against erosion transport of waste materials. The silt fence shall be installed in accordance with the design plans and specifications. Any damage to the silt fence or breakthrough should be observed by the CQA Engineer and noted to the Contractor for repair.

5.8 Sand Bedding

A 6-inch sand bedding layer is proposed over the waste material as a protective cushion and to provide a predictable interface friction angle on the textured geomembrane. The sand bedding material shall be compacted in accordance with the design plans and specifications and placed at the prescribed lift thickness. Appropriate survey control measures shall be provided to control the lift thickness.

5.8.1 Subgrade Preparation

Any large objects or pointed sharp objects present within the subgrade at the waste/sand bedding interface should be overexcavated and removed. Both the lines and grades of the subgrade should be approved by the CQA Engineer before sand cushion placement and the subgrade should be proofrolled with a smooth drum roller to limit the undulations of this surface.

5.8.2 Lift Thickness and Placement Techniques

The sand bedding shall be placed to the thickness prescribed in the design plans and specifications.

5.8.3 Grain Size Distribution

The sand bedding grain size distribution shall be tested in accordance with the procedures and frequencies prescribed in Table 1.

5.8.4 Compaction Control

The sand bedding materials shall be compacted in general accordance with the design plans and specifications and tested in accordance with the procedures and frequencies prescribed in Table 1.

5.9 Geomembrane (Textured)

A 40-mil LLDPE textured geomembrane will be installed above the sand bedding layer. This material shall be fabricated into an integral uniform sheet covering the entire landfill. The geomembrane sheet acts as a relatively impermeable barrier to surface water infiltration. The construction procedures associated with placing and testing the installation of this barrier are described below.

5.9.1 Subgrade Preparation

The Contractor shall be responsible for preparing the supporting soil for the geomembrane placement. The CQA Engineer shall coordinate the work of the earthwork contractor and geomembrane installer so that the requirements of the specifications in the Construction Quality Assurance Plan are met. Before geomembrane installation begins, the CQA Engineer shall verify that:

1. A qualified land surveyor has verified all lines and grades using a second order survey.

2. The CQA Engineer has verified that the supporting soil meets the density specified in the project specifications.

3. The surface to be lined has been rolled and compacted or hand-worked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.

4. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.

5. There is no area excessively softened by high water content.

6. There is no area where the surface of the area contains desiccation or erosion cracks with dimensions exceeding those allowed by the project specifications.

The installer/contractor shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance shall be executed by the installer and given to the CQA Engineer prior to commencement of the geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the CQA Engineer.

After the supporting soil has been accepted by the installer, it is the installer's responsibility to bring to the attention of the CQA Engineer any change in the supporting soil conditions that may require repair work. The Project Manager may consult with the CQA Engineer regarding the need for repairs. If the CQA Engineer concurs with the installer, the Contractor shall insure that the supporting soil is repaired. At any time before or during the geomembrane installation, the CQA Engineer shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

5.9.2 Anchor Trench

The CQA Engineer shall verify that the anchor trench has been constructed according to the design plans and specifications. Slightly rounded corners shall be provided in the trench so

as to avoid sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed to underlie the geomembrane in the anchor trench.

The anchor trench shall be adequately drained to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted as outlined in the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics. The CQA Engineer shall observe the backfilling operation and advise the Project Manage/Owner of any problems. Any problems shall be documented by the CQA Engineer in his daily report.

5.9.3 Geomembrane Deployment

A field panel is defined as a unit of geomembrane which is seamed in the field (i.e., a field seam is a roll or a portion of a roll cut in the field). It shall be the responsibility of the CQA Engineer to ensure that each field panel is given an identification code (number or letter number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, installer, and CQA Engineer. This field panel identification code shall be as simple and logical as possible. In general, it is not appropriate to identify panels using roll numbers, since roll numbers established in the manufacturing plant are usually cumbersome and are not related to location in the field. The CQA Engineer shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code shall be used for all quality assurance records.

The CQA Engineer shall verify that the field panel was installed at the locations indicated on the installer's layout plan as approved by the Project Manager.

The CQA Engineer shall review the panel deployment progress of the installer (keeping in mind issues related to wind, rain and other site-specific conditions) and advise the Project

Manager on installer compliance with the approved panel layout drawings and its suitability to actual field conditions. Once approved, only the Project Manager in consultation with the CQA Engineer can authorize changes to the panel deployment procedure. The CQA Engineer shall verify that the condition of the supporting soil does not change detrimentally during installation.

The CQA Engineer shall record the identification code, location and date of installation of each field panel.

Geomembrane deployment shall not proceed at an ambient temperature below 32°F (0°C) or above 104°F (40°C) unless otherwise authorized in writing by the Project Manager. Geomembrane placement shall not be performed during any precipitation. In the presence of excess moisture (such as fog and dew) in an area of ponded water or in the presence of excessive winds. Geomembrane deployment shall not be undertaken if weather conditions will preclude material seaming following deployment.

The CQA Engineer shall verify that the above conditions are fulfilled. Ambient temperatures shall be measured by the CQA Engineer in the area in which the panels are to be deployed. The CQA Engineer shall inform the Project Manager of any weather related problems which may not allow geomembrane placement to proceed.

Before the geomembrane is handled on site, the CQA Engineer shall verify that the handling equipment to be used on the site is adequate and does not pose a risk of damage to the geomembrane. During handling, the CQA Engineer shall observe and verify that the installer's personnel handled the geomembrane with care.

The CQA Engineer shall verify the following:

1. Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means.

2. The prepared surface underlying the geomembrane has not deteriorated since previous acceptance and is still acceptable immediately prior to geomembrane placement.

3. All personnel do not smoke or wear damaging hard sole shoes while working on the geomembrane, or engage in other activities which could damage the geomembrane.

4. The method used to unroll the panels does not cause excessive scratches or crimps in the membrane and does not damage the supporting soil.

5. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels).

6. Adequate temporary loading and/or anchoring (such as sand bags, tires, etc.) are not likely to damage the geomembrane and have been placed to prevent uplift by wind. In case of high winds, continuous loading (such as by sandbags) is recommended along edges of panels to minimize risk of wind flow under the panels.

7. Direct contact with the geomembrane is minimized, and the geomembrane is protected by geotextiles, extra geomembrane (rub sheets), or other suitable materials in areas where excess traffic may be expected.

The CQA Engineer shall inform the Project Manager if the above conditions are not fulfilled.

Upon delivery to the site, the CQA Engineer shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling the rolls unless defects or damages are found or suspected. The CQA Engineer shall advise the Project Manager in writing of any rolls or portions of rolls which should be rejected and removed from the site because they have severe flaws and/or minor repairable flaws.

The CQA Engineer shall inspect each panel after placement and prior to seaming for damage and for defects. The CQA Engineer shall advise the Project Manager which panels or portions of panels should be rejected, repaired or accepted. Damaged panels or portions of damaged panels which have been rejected shall be marked and their removal from the work area recorded by the CQA Engineer. Repairs shall be made using procedures described later.

To avoid confusion, the installer and the CQA Engineer shall each use different color markers that are readily visible for writing on the geomembrane. The markers must be semi-permanent and compatible with the geomembrane.

5.9.4 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify the conditions are adequate for production seaming. Such trial seams shall be made at the beginning of each seaming period, and at least once each four hours for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams.

The trial seam samples shall be at least 5 feet long by 1 feet wide after seaming with the seam centered lengthwise. Seam overlap shall meet the technical specifications.

Two specimens shall be cut from the sample with a 1-inch (25 mm) wide die. The specimen shall be cut by the installer at locations selected randomly along the trial seams sampled by the CQA Engineer. The specimen shall be tested in peel using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of 2 inches per minute. The sample should not fail along the seam. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved. The CQA Engineer shall observe all trial seam procedures. The remainder of the successful trial seam samples shall be cut into three pieces; one to be retained in the Project Manager's archives, one to be given to the installer, and one to be retained by the CQA Engineer for possible laboratory testing. Each portion of the sample shall be assigned a number and marked accordingly by the CQA Engineer who shall also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description.

If agreed upon between the Project Manager and the CQA Engineer, and documented by the CQA Engineer in his daily report, the remaining portion of the trial seam sample can be subjected to destructive testing. If a trial seam sample fails a test conducted by the CQA laboratory, then a destructive seam test sample shall be taken from each of the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be reported to the CQA laboratory and if they fail the test, destructive test failure procedures shall be followed. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been taken.

5.9.5 Field Seaming

Before installation begins, the installer must provide the Project Manager and the CQA Engineer with a panel layout drawing (i.e., a drawing of the facility to be covered showing all expected seams). The CQA Engineer shall review the panel layout drawing and verify that it is consistent with accepted standard of practice. No panel shall be seamed without the written approval of the panel layout drawing by the CQA Engineer. In addition, panels not specifically shown on the panel layout drawing may not be used without the CQA Engineer's prior approval.

In general, seams should be oriented parallel to the line of maximum slope gradient (i.e., oriented along, not across the slope). In corners and odd shaped geometrical locations, the number of seams should be minimized. No horizontal seams should be higher than 5 feet (1.5 meters) from the toe of the slope or areas of potential stress concentrations unless otherwise authorized by the CQA Engineer.

A seam numbering system compatible with the panel numbering system shall be used by the CQA Engineer.

Approved processes for field seaming are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted by the installer to the Project Manager for approval. Only apparatus which have been specifically approved by make and model shall be used. The Project Manager shall submit all documentation regarding seaming methods to be used to the CQA Engineer for review.

The CQA Engineer shall log ambient temperatures, seaming apparatus and geomembrane surface temperatures at appropriate intervals and report any non-compliances to the Project Manager.

For extrusion welding, the CQA Engineer shall verify that:

1. The installer maintains on-site number of spare operable seaming apparatus decided upon at the pre-construction meeting.

2. Equipment used for seaming is not likely to damage the geomembrane.

3. Prior to beginning a seam, an extruder is purged until all heat degraded extrudate has been removed from the barrel.

4. Clean and dry welding rods or extrudate pellets are used.

5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

6. Grinding shall be completed no more than one hour prior to seaming.

7. A smooth insulating layer of fabric is placed beneath the hot welding apparatus after usage.

8. The geomembrane is protected from damage in heavily trafficked areas.

9. The exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than one-quarter inch from the seamed area.

10. In general, the geomembrane panels are lined to have a nominal overlap of 3 inches for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the scene.

11. No solvent or adhesive is used unless the product is approved in writing by the CQA Engineer prior to use (samples shall be submitted to the CQA Engineer for testing and evaluation).

12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged or degraded.

For the fusion process, the CQA Engineer shall verify that:

1. The installer maintains on-site spare number of operable seaming apparatus decided upon at the pre-construction meeting.

2. The equipment used for seaming is not likely to damage the geomembrane.

3. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.

4. The smooth insulating layer of fabric or sheet is placed beneath the hot welding apparatus after usage.

5. The geomembrane is protected from damage in heavily trafficked areas.

6. A movable protective layer is used as required by the installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and to prevent debris from collecting around the pressure rollers.

7. In general, the geomembrane panels are lined up to have a nominal overlap of 5 inches for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on site.

8. No solvent or adhesive is used unless the product is approved in writing by the CQA Engineer prior to use (sample shall be submitted to the CQA Engineer for testing and evaluation).

The CQA Engineer shall verify that prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris or foreign materials of any kind. If seam overlap grinding is required, the CQA Engineer must ensure that the process is completed according to the manufacturer's instruction within one hour of the seaming operation and in a way that does not damage the geomembrane. The CQA Engineer shall verify that seams are lined up with as few as possible number of wrinkles and "fish mouths ".

During general seaming, the CQA Engineer shall be cognizant of the following:

1. For fusion welding, it may be necessary to place a movable protective layer of plastic directly below each overlap of the geomembrane that is to be seamed. This is to prevent any moisture buildup between the sheets to be welded and prevent debris from collecting around the pressure rollers.

2. If required, a firm substrate shall be provided by using a flat board, a conveyor belt or similar hard surface directly under the seam overlap to achieve proper support.

3. "Fish mouths" or wrinkles at the seam overlap shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut "fish mouths" or wrinkles shall be seamed and any portion where the overlap is inadequate shall be

patched with an oval or round patch of the same geomembrane extending a minimum of 6 inches beyond the cut in all directions.

4. If seaming operations are carried out at night, adequate illumination shall be provided.

5. Seaming shall be extended to the outside edge of panels placed on the anchor trench.

6. All cross-seam tee shall be extrusion welded to a minimum distance of 4 inches on each side of the tee.

7. No field seaming shall take place without the master seamer being present.

The CQA Engineer shall verify that the above seaming procedures (or any other procedures agreed upon and indicated in the CQA Plan) are followed and shall inform the Project Manager of any non-conformance.

The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32°F and 104°F.

2. Dry conditions, i.e., no precipitation or excessive moisture such as fog or dew.

3. No excessive winds.

The CQA Engineer shall verify that these weather conditions are fulfilled and notify the Project Manager in writing if they are not. The ambient temperature shall be measured by the CQA Engineer in the area where the panels are to be placed. The Project Manager will then decide if the installation is to be stopped or special procedures used.

To ensure a quality installation if seaming is conducted when the ambient temperature is below 32°F, the following conditions must be met:

1. The geomembrane surface temperature shall be determined by the CQA Engineer at intervals of at least once per 100 foot of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32°F.

2. Preheating may be waived by the CQA Engineer if the installer demonstrates to the CQA Engineer's satisfaction that the welds of equivalent quality may be obtained without preheating to achieve expected minimum temperature of installation.

3. If preheating is required, the CQA Engineer shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming to ensure that they have not been overheated. Care should be taken to confirm that the surface temperatures are not lowered below the minimum surface temperature specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for preheated seam areas.

4. All preheating devices shall be approved prior to use by the CQA Engineer.

5. Additional destructive tests shall be taken at an interval of 300 feet of seam length rather than 500 feet unless advised otherwise at the discretion of the CQA Engineer.

6. Sheet grinding may be performed before preheating if applicable.

7. Trial seaming as described above shall be conducted under the same ambient temperature and preheating conditions at the actual seams. Under cold weather conditions, new trial seams may be conducted if the ambient temperature drops by more than 5°F from the initial trial seam test conditions.

8. At ambient temperatures above 104°F, no seaming of the geomembrane shall be permitted unless the installer can demonstrate to the satisfaction of the CQA Engineer that the geomembrane seam quality is not compromised.

9. Trial seaming as described shall be conducted at the same ambient temperature conditions as the actual seams.

10. At the option of the CQA Engineer, additional destructive tests may be required for any suspect areas.

5.9.6 Non-Destructive Seam Testing

The installer shall non-destructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only) or other approved method. Vacuum testing and air pressure testing are described below. The purpose of non-destructive tests is to check the continuity of seams. It does not provide quantitative information on the seam strength. Non-destructive testing shall be carried out as the seam work progresses, not at the completion of all field seaming.

For all seams, the CQA Engineer shall:

1. Observe non-destructive testing procedures.

2. Record location data, test unit number, name of tester, and outcome of all testing.

3. Inform the installer and Project Manager of any required repairs.

Any seams that cannot be destructively tested shall be cap-stripped with the same geomembrane. The cap-stripping operation shall be observed by the CQA Engineer.

The following procedures are applicable to vacuum testing:

1. The equipment shall consist of the following:
   a. A vacuum box assembly consisting of a rigid housing, transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly and a vacuum gauge.
   b. A pump assembly equipped with a vacuum pressure regulator and pipe connections.
   c. A rubber pressure/vacuum hose with fittings and connections.
   d. A soapy solution.
   e. A bucket and wide paint brush are the means of applying the soapy solution.

2. The following procedures shall be followed:
   a. Energize the vacuum pump and reduce the tank pressure to approximately 5 psi gauge pressure.
   b. Wet a strip of geomembrane approximately 12 inches by 48 inches with the soapy solution.
   c. Place the box over the wetted area.
   d. Close the bleed valve and open the vacuum valve.
   e. Ensure that a leak-tight seal is created.
   f. For a period of not less than 10 seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.

g. If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over to the next adjoining area with a minimum 3 inch overlap, and repeat the process.
h. All areas where soap bubbles appear shall be marked and repaired in accordance with repair procedures.

The following air pressure test procedures are applicable to double fusion welding which produces a double seam with an enclosed air space.

1. The equipment shall consist of the following:
   a. An air pump (manual or motor-driven), equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi, and mounted on a cushion to protect the geomembrane.
   b. A rubber hose with fitting and connections.
   c. A sharp hollow needle or other approved pressure feed device.

2. The following procedures shall be followed:
   a. Seal both ends of the seam to be tested.
   b. Insert a needle or other approved pressure feed device into the air channel created by the fusion weld.
   c. Insert a protective cushion between the air pump and the geomembrane.
   d. Energize the air pump to a pressure between 25 and 30 psi, close valve, allow two minutes for pressure to stabilize and sustain pressure for at least five minutes.
   e. If loss of pressure exceeds 4 psi or does not stabilize, locate faulty area and repair in accordance with repair procedures.
   f. Cut opposite end of tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seal the cut end of the air channel.

g. Remove the needle or other approved pressure feed device and seal.

For test failure procedures, the installer shall complete any required repairs in accordance with repair procedures below. For repairs, the CQA Engineer shall:

1. Observe the repair and testing of the repair.

2. Mark on the geomembrane that the repair has been made.

3. Document the repair procedures and test results.

5.9.7 Destructive Seam Testing

Destructive seam tests shall be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

The CQA Engineer shall select locations where seam samples will be cut out for laboratory testing. These locations shall be established as follows:

1. A minimum frequency of one test per 500 feet of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility and not necessarily every 500 feet.

2. The test location shall be determined during seaming at the CQA Engineer's discretion. The selection of such locations shall be prompted by suspicion of overheating, contamination, offset wells or any other potential cause of imperfect welding.

The installer shall not be informed in advance of the locations where seam samples will be taken.

Samples shall be cut by the installer at locations chosen by the CQA Engineer as the seaming progresses so that the laboratory test results are available before the geomembrane is covered by any of the material. The CQA Engineer shall:

1. Observe sample cutting.

2. Assign a number of each sample, and mark it accordingly.

3. Record sample location on layout drawing.

4. Record reason for taking the sample at this location (such as statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described below. The continuity of the new seams in the repaired area shall be tested according to vacuum test procedures.

At a given sampling location, two types of samples shall be taken by the installer. First, two samples for field testing shall be taken. Each of these samples shall be cut with a 1-inch wide die with a seam center parallel to the width. The distance between these two samples shall be 42 inches. If both samples pass the field test described in field testing procedures (below), a sample for the laboratory testing shall be taken.

The sample for laboratory testing shall be located between the samples for field testing. The sample for laboratory testing shall be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

1. One portion to the installer for optional laboratory testing (12 inches by 12 inches).

2. One portion for the CQA laboratory testing (12 inches by 18 inches).

3. One portion to the Project Manager for archive storage (12 inches by 12 inches).

Final determination of sample sizes shall be made at the pre-construction meeting.

The two field testing samples discussed above shall be tested in the field using a tensiometer for peel and shall not fail according to the criteria in Table 1. The tensiometer shall be capable of maintaining a constant jaw separation rate of 2 inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam shall be repaired in accordance with test failure procedures. Final judgment regarding the seam acceptability, based on the failure criteria, rests with the CQA Engineer.

The CQA Engineer shall witness all field tests and mark all samples and portions with their number. The CQA Engineer shall also log the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures and pass or fail description and attach a copy of each sample portion.

Destructive test samples shall be packaged and shipped if necessary to the CQA laboratory under the control of the CQA Engineer in a manner which will not damage the test sample. The Project Manager shall be responsible for storing the archive samples. Test samples shall be tested by the CQA laboratory.

Testing shall include "seam strength" and "peel adhesion". These terms are defined in the specifications. The minimum acceptable values to be obtained in these tests are indicated

in the project specifications. At least five specimens shall be tested in each shear and peel. Specimens shall be selected alternatively by tests from the samples (i.e., "peel/shear - peel/shear). A passing test shall meet the minimum acceptable values in at least four of the five specimens tested for each method.

The CQA laboratory shall provide verbal results no more than 24 hours after they receive the samples. The CQA Engineer shall review the laboratory test results as soon as they become available and make appropriate recommendations to the Project Manager/Owner.

The following procedures shall apply whenever a sample fails a destructive test whether that test is conducted by the CQA laboratory or by the field tensiometer. The installer has two options:

1. The installer shall repair the seam between any two passing test locations.

2. The installer can trace the welding path to an intermediate location (at 10 feet minimum from the point of the failed test in each direction) and take a sample with a 1-inch wide die for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the test, then the seam is repaired between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be repaired.

All acceptable repaired seams shall be bound by two locations from which the samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as indicated above shall be used as a boundary for the failing seam. In cases exceeding 150 feet of repaired seam, a sample taken from the zone in which the seam has been repaired, must pass destructive testing. Repairs shall be made in accordance with repair procedures outlined below.

The CQA Engineer shall document all actions taken in conjunction with destructive test failures.

5.9.8 Defects and Repairs

All seams and non-seamed areas of the geomembrane shall be examined by the CQA Engineer for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of the examination. The geomembrane surface shall be cleaned by the installer if the amount of dust or mud prevents examination.

Each suspect location both in seam and non-seam areas shall be non-destructively tested using methods described above as appropriate. Each location which fails the non-destructive testing shall be marked by the CQA Engineer and repaired by the installer. Work shall not proceed with any materials which will cover locations which have been repaired until appropriate non-destructive and laboratory test results with passing values are available.

Any portion of the geomembrane exhibiting a flaw or failing a destructive or non-destructive test shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedures shall be agreed upon between the Project Manager, installer and CQA Engineer.

1. The repair procedures available include:

    a. Patching used to repair large holes, tears, undispersed raw materials, and contamination from foreign matter.

b. Spot welding or seaming used to repair small tears, pinholes, or other minor or localized flaws.
c. Capping used to repair large lengths of failed seams.
d. Extrusion welding the flap used to repair areas of inadequate fusion seams which have an exposed edge. Repairs of this type shall be approved by the CQA Engineer and shall not exceed 50 feet in length.
e. Removing bad seam and replacing with a strip of new material welded into place.

2. For any repair method, the following provisions shall be satisfied:

a. Seams of the geomembrane which are to be repaired using extrusion methods shall be abraded not more than one hour prior to repair.
b. All surfaces shall be clean and dry at the time of repair.
c. All seaming equipment used in repairing procedures shall meet the requirements of the CQA Plan.
d. Patches or caps shall extend at least 6 inches beyond the edge of the defect and all corners or patches shall be round with a radius of approximately 3 inches.

Each repair shall be numbered and logged. Each repair shall be non-destructively tested using the methods described above for vacuum testing. Repairs which pass the non-destructive test shall be taken as an indication of an adequate repair. Repairs more than 150 feet long may be of sufficient extent to require destructive test sampling at the discretion of the CQA Engineer. Failed tests indicate that the repair shall be redone and retested until a passing test results. The CQA Engineer shall observe all non-destructive testing on repairs and shall record the number of each repair, date, and test outcome.

Large wrinkles may develop following seaming. When seaming of the geomembrane is completed and prior to placing overlying materials, the CQA Engineer shall indicate to the

Project Manager which wrinkles should be cut and reseamed by the installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles shall be located during the coldest part of the installation process with keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over onto itself. This is generally the case where a wrinkle that extends 12 inches from the subgrade. Seams produced while repairing wrinkles shall be tested as outlined above.

When placing overlying cover material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover material should be placed during the coldest weather available. In addition, small wrinkles shall be isolated and covered as quickly as possible to prevent their growth. Placement of cover materials shall be observed by the CQA Engineer to ensure that wrinkle formation is minimized.

5.9.9 Geomembrane Protection

The quality assurance procedures outlined in this section are intended only to assure that the installation of the adjacent materials does not damage the geomembrane. The quality assurance of the adjacent materials themselves should be covered in separate section of this CQA Plan as necessary.

A copy of the specifications prepared by the Design Engineer for placement of soils shall be given to the CQA Engineer by the Project Manager. The CQA Engineer shall verify that these specifications are consistent with the state of the practice such as:

1. Placement of soils on the geomembrane shall not proceed at an ambient temperature below 32°F or above 104°F unless otherwise specified.

2. Placement of soil on the geomembrane shall be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.

3. A geotextile or other cushion approved by the Design Engineer is generally required between aggregate and the geomembrane.

4. Equipment used for placing soils should not be driven directly on the geomembrane.

5. A minimum thickness of 1 foot of soil is specified between a light dozer (ground pressure 7 psi) and the geomembrane.

6. In any areas traversed by any vehicles other than low ground pressure vehicles approved by the CQA Engineer, the soil layer shall have a minimum thickness of 3 feet. This requirement may be waived if provisions are made to protect the geomembrane with a cushion geotextile. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires or sharp turns. Dozer operators should also avoid turns where tracks are motivated in opposite directions for sharp turns.

The CQA Engineer shall measure soil thickness and verify that the required thicknesses are present. The CQA Engineer must also verify that final thicknesses are consistent with the design and verify the placement of the soil is done in such a manner that the geomembrane damage is unlikely. The CQA Engineer shall inform the Project Manager if the above conditions are not fulfilled.

5.10 Geotextiles

A cushion geotextile consisting of a 16 ounce non-woven needle-punch geotextile is proposed to protect the geomembrane against damage from aggregate placement. The deployment, seam fabrication and defects and repairs of the geotextile are further described below.

5.10.1 Geotextile Deployment

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud or dust, puncture, cutting or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and water tight wrappings. Wrappings shall be removed shortly before deployment.

The CQA Engineer shall observe rolls upon delivery at the site and any deviation for the above requirements shall be reported to the Project Manager.

The installer shall handle all geotextiles in such a manner to ensure that they are not damaged in any way and the following procedures shall be complied with:

1. On slopes, geotextile shall be securely anchored and then pulled/rolled down the slope in such a manner to continually keep the geotextile sheet in tension.

2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geotextile shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage which can be caused by the cutting of geotextiles.

4. The installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

5. During placement of geotextiles, care should be taken not to entrap, in or beneath the geotextile, stones, excessive dust or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.

6. A visual examination of geotextiles shall be carried out over all seams after installation to ensure that no potentially harmful foreign objects such as needles are present.

The CQA Engineer shall note any non-compliance and report it to the Project Manager.

5.10.2 Seaming Procedures and Overlap

On slopes steeper than 10 (horizontal):1 (vertical), all geotextiles shall be continuously sewn (i.e., spot sewn is not allowed). Geotextiles shall be overlapped a minimum of 3 inches prior to seaming. In general, no horizontal seams shall be allowed on side slopes (i.e., seams shall be along, not across the slope gradient) except as part of a patch.

On flat areas and slopes shallower than 10 (horizontal):1 (vertical), geotextiles shall be seamed as indicated above (preferred) or thermally bonded with the written approval of the Project Manager.

The installer shall pay particular attention at seams to ensure that no earth cover materials shall be inadvertently inserted beneath the geotextile and between the geotextile and geomembrane.

Any sewing shall be done using polymeric thread with chemical and ultraviolet light resistant properties equal to or exceeding those of the geotextile. Sewing shall be done using machinery and stitch-types specified in the project specifications or as approved in writing by the Project Manager and the CQA Engineer.

5.10.3 Defects and Repairs

Any holes or tears in the geotextile shall be repaired as follows:

1. On slopes, a patch made from the same geotextile shall be sewn into place in accordance with the project specifications. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

2. Care should be taken to remove any soil or other material which may have penetrated the torn geotextile.

3. The CQA Engineer shall observe any repair and report any non-compliance of the above requirements in writing to the Project Manager.

5.10.4 Geotextile Protection

All soil materials located on top of the geotextile shall be deployed in such a manner as to ensure:

1. The geotextile and underlying liner materials are not damaged.

2. Minimal slippage of the geotextile on underlying layers occurs.

3. No excess tensile stresses occur in the geotextile.

Unless otherwise specified by the Design Engineer, all cover soil material shall be in conformance with the technical specifications.

Any non-compliance shall be noted by the CQA Engineer and reported to the Project Manager.

If portions of the geotextile are exposed, the CQA Engineer may periodically place (at his discretion) marks on the geotextile 10 feet apart along the slope and measure the elongation of the geotextile during placement of the soil. This data should be reported to the Project Manager.

5.11 Geocomposite Drain

A geocomposite drain is proposed below all road areas and below the rip rap aggregate. The geocomposite drain will generally act as a durable separation fabric.

5.11.1 Geocomposite Deployment

During shipment and storage, the geocomposite drain should be protected from ultraviolet light exposure, precipitation, or other inundation, mud, dirt, dust, puncture, cutting or any other damage or deleterious conditions. The geocomposite roll shall be shipped and stored in relatively opaque and water tight wrappings. Wrappings shall be removed shortly before deployment.

The CQA Engineer shall examine rolls upon delivery and any deviations from the above requirements shall be reported to the Project Manager. Installers shall handle all geocomposite drain in such a manner as to ensure that it is not damaged in any way and the following shall be complied with:

1. On slopes, the geocomposite drain shall be secured and rolled down the slope in such a manner as to continually keep the geocomposite sheet in tension. If necessary, the geocomposite shall be positioned by hand after being unrolled to minimize wrinkles.

2. In the presence of wind, all geosynthetics shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Unless otherwise specified, geocomposite drain shall not be welded to geomembrane.

4. The geocomposite drain shall be cut using scissors or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care should be taken not to leave tools on the geocomposite drain.

5. The installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geocomposite.

6. During placement of the geocomposite, care should be taken not to entrap in the geocomposite dirt or excessive dust that could cause clogging of the drainage system and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geocomposite drain, it should be hosed clean prior to placement of the next material on top of it. In this regard, care should be taken with the handling of sandbags to prevent rupture or damage of the sandbag.

The CQA Engineer shall note any non-compliance and report it to the Project Manager.

5.11.2 Seams and Overlaps

The adjacent geocomposite shall be joined according to the design plans and specifications. The following requirements shall be met:

1. Adjacent rolls shall be overlapped at least 4 inches.

2. Overlap shall be secured by tying.

3. Tying shall be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic tying devices are not allowed.

4. Tying shall be every 5 feet along the slope, every 6 inches in the anchor trench, and every 6 inches along end to end seams on roll ends along the roadway.

5. In general, no horizontal seams shall be allowed on side slopes.

6. When more than one layer of geocomposite is installed, joints shall be staggered.

7. Geocomposite drains are preferably seamed by removing the adhesion geotextiles and overlapping the geonets and then connecting through the geonets and geotextile with plastic fasteners.

5.11.3 Defects and Repairs

Any holes or tears in the geocomposite drain shall be repaired by placing a patch extending 1 foot beyond the edges of the hole or the tear. The patch shall be secured to the original geonet by tying every 6 inches. Tying devices shall be as described above. If the hole or the tear with the geocomposite drain is more than 50 percent of the width of the roll, the damaged area shall be repaired as follows:

1. In roadway separation fabrics, the patch will be placed over any defect removing the geotextile adhesive layer as appropriate and tying in the water transmissive geonets as appropriate.

The CQA Engineer shall observe any repair and report any non-compliance with the above requirements in writing to the Project Manager/Owner.

5.11.4 Geocomposite Protection

Soil materials should first be placed on the edges of the geocomposite drain along the roadway alignment to anchor the edges. Soil materials may then be placed in the mid-sections of the geocomposite. Soil materials near the geocomposite shall be placed in such a manner to ensure:

1. The geocomposite and underlying materials are not damaged.

2. Minimal slippage of the geocomposite on underlying layers occurs.

3. No excess tensile stresses occur in the geocomposite.

Any non-compliance shall be noted by the CQA Engineer and reported to the Project Manager/Owner.

5.12 Geogrid

A geogrid is proposed on all landfill cover slopes at or near 3 (horizontal):1 (vertical). The geogrid is included to relieve stresses that would otherwise impinge on the geotextile and geomembrane in steeper-sloped areas. The geogrid is designed to interlock with the proposed aggregate protection cover. The geogrid shall also have a higher elastic modulus

to preferentially relieve stress that would otherwise occur on the geomembrane and geotextile.

5.12.1 Geogrid Deployment

The installer shall handle all geogrid in such manner to ensure that it is not damaged in any way and that the following shall be complied with:

1. On slopes, the geogrid shall be secured and rolled down the slope in such a manner to continually keep the geogrid in tension. A suitable length of runout should be provided at the top of the slope to anchor the geogrid. The length of runout shall be installed in accordance with the design plans and specifications.

2. In the presence of wind, all geogrid shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geogrid shall be cut using scissors or shears only. If in place, special care should be taken to protect other materials from damage which would be caused by the cutting of the geogrid.

4. Geogrid should be ordered to length where possible so that roll end seams can be avoided where possible. No roll end seams shall be positioned any higher than the lower 1/3 of each slope. Roll end seams shall be connected with Bodkin connectors.

5. The installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geogrid.

The CQA Engineer shall note any non-compliance and report it to the Project Manager.

5.12.2 Seams and Overlaps

The geogrid where used shall be placed in continuous pieces down slope. No lateral joining is required. Where geogrid is joined end to end, splicing approved by the manufacturer shall be used. This splice will not have any metallic components.

5.12.3 Repairs

Any damaged geogrid shall be discarded. No repairs shall be allowed.

5.12.4 Soil Materials Placement

All soil materials located on top of the geogrid shall be deployed in such a manner as to ensure:

1. The geogrid and underlying materials are not damaged.

2. Minimum slippage of the geogrid on the underlying layers occurs.

5.13 Gas Vent System

The gas vent system consists of a series of goose-neck vents connected to underlying vented (perforated) pipes installed below the geomembrane cover. The purpose of the gas vents is to relieve any gas pressures that may exist. Generally, only limited decomposition gases are expected to be relieved from the gas vent piping. Gases below the cover that are thermally-heated and expanded will also be relieved.

5.13.1 Goose-Neck Gas Vents

Goose-neck gas vents are provided above the gas vent piping. The goose-neck vents shall protrude at least 18 inches above the protection aggregate cover. These vents shall protrude through the cover with a fabricated pipe boot bonded to the geomembrane and double clamped to the vent.

5.13.2 Gas Piping

The goose-neck vent will connect to underground gas piping consisting of perforated polyethylene pipe extending at least 10 feet in each direction from the vent tee. Piping shall be embedded in coarse aggregate just below the bedding sand.

Any non-compliance with the design plans and specifications shall be noted by the CQA Engineer and reported to the Project Manager.

5.14 Coarse Protection Aggregate

The coarse protection aggregate is to be placed over and on the geomembrane and cushion geotextile (and the geogrid on steep slopes). The aggregate will protect the geosynthetics from damage due to wind and ultraviolet radiation. The coarse aggregate will absorb considerable moisture during significant rain events and also act as an erosion armor protection.

5.14.1 Lift Thickness

The coarse protection aggregate shall be placed in a minimum 18-inch lift thickness on all cover areas except those designated differently on the design plans and specifications. The lift shall be placed in a single motion using a low ground pressure (5 psi) bulldozer working off a thicker lift thickness on the order of 3 to 4 feet and pushing only short

distances preferably up the slope. Alternatively, the cover may be placed with a hydraulic excavator or conveyor where placement is not accomplished by thinning a thick layer with a bulldozer onto the cover.

5.14.2 Placement Techniques

The coarse protection aggregate on the steeper 3H:1V slopes shall first be placed over the length of runout for geogrid in these areas at the top of the slope. Following this placement, the coarse protection aggregate may be placed from the bottom of the slope over a taught geogrid pushing upward with a bulldozer operating off of a 3 or 4 foot lift thickness grading to a thinner lift. Any pushing action with bulldozers shall be directly up and down the slope and not transverse to the slope.

The Contractor's method to place a uniform single lift of coarse protection aggregate over the geosynthetic cover system shall be approved in advance by the CQA Engineer and Project Manager. The installer's method of placement shall provide a uniform single lift thickness using survey techniques where the lift thickness can be confirmed after placement.

5.15 Rip Rap

Rip rap is generally placed in flat areas where erosion forces are significant or in areas where shoreline protection is required.

5.15.1 Prequalification Testing

The prequalification testing procedures and frequencies are described in Table 1. Any materials not conforming to these technical specifications shall be rejected by the CQA Engineer and reported to the Project Manager.

5.15.2 Lift Thickness

The placement of rip rap in roadway, mid-slope swales, and shoreline areas shall provide the appropriate lift thickness and the appropriate line and grade. Delivered loads of the rip rap shall be graded into position with no required compaction control. In shoreline applications, it shall be bucket dragged up the slope to promote interlock of the material. Similarly, in mid-slope swales, it should be bucket dragged or bulldozed in the direction of water flow to promote interlock.

5.15.3 Placement Techniques

The method used in placement shall be such that any soft and organic materials on the flume floor will be displaced to the east and west of the slide mass towards the extreme toes of the required section of the structure. The material shall be handled or placed in a manner so as to minimize segregation and provide for a well-graded mass. If the materials are placed by clam shell, dragline or other conveyance equipment, the stone shall not be dropped from a height exceeding 2 feet above the existing flume bottom or previously placed material. Placement shall begin at the bottom of slope and proceed upward. Casting or dropping stone over 2 feet or moving by drifting or manipulating down the slope will not be permitted.

The finished surface and rip rap stone layer thicknesses shall not be less than two stones thick and not deviate from the line and grade shown on the drawings. A tolerance of 6 inches above the neatline and 2 inches below neatline will be required. The tolerances are measured perpendicular to the indicated neatlines.

5.16 Roadway Base Coarse

INDOT No. 53 aggregate is proposed on all roadway surfaces where traffic is allowed. This aggregate shall be graded in a single lift thickness and compacted with a smooth drum roller. The compaction control should be in accordance with the design plans and specifications. Any test results not conforming with the compaction specification shall be recompacted.

5.17 Guard Rail Installation

Guard rail along roadways near water hazards has been provided in the design plans and specifications. A Class B Type 1 W section having a base metal nominal thickness of 0.135 inches has been specified. This guard rail section shall be zinc coated for corrosion protection. The guard rail shall be fastened in accordance with AASHTO Designation M180-79. Posts supporting the guard rail shall be driven into the flume fill or if loose, post holes shall be provided and the posts shall be cast in concrete. Stable posts at the specified depths shall be achieved.

5.18 Geotechnical Instrumentation

A series of geotechnical instruments have been installed at the site to monitor slope movements and excess pore water pressure. These instruments are critical to the monitoring of the construction activities while excavating or filling activities are underway. These instruments will be monitored at various frequencies depending on the type of earthwork activity underway. The instrument locations, monitoring, testing and performance evaluation for these instruments is further described below.

5.18.1 Instrument List

The current active instrument list is attached on Tables 2 and 3 for inclinometer and piezometers, respectively. The status of each instrument is also noted. Please note that the piezometer in SB-203-61′ was destroyed during December 1998 dredging.

5.18.2 Monitoring and Reporting Procedures

The monitoring and reporting procedures for the geotechnical instruments will be under the supervision of the CQA Engineer in conjunction with the Design Engineer. The purpose of the monitoring is to compare the movements and pore pressures against historical and predicted performance. The monitoring and reporting procedures for various stages and levels of construction activity are described in Table 1. All test reports shall be provided to the Project Manager, CQA Engineer and Design Engineer.

5.18.3 Monitoring Schedule

The monitoring schedule for all instruments will vary in accordance with the then current construction activity. Between construction intervals, a reduced testing schedule shall be proposed by the CQA Engineer and adopted by the Project Manager.

5.18.4 Performance Evaluation

Regular performance evaluations of the geotechnical instrumentation shall be prepared and reported to the Project Manager and contractor by the CQA Engineer. The evaluation is to inform the contractor of his work activities and the slope stability performance with respect to these activities.

5.18.5 Instrument Protection and Maintenance

Several of the geotechnical instruments must be re-established at new grades in accordance with the landfill regrading plan. The Contractor shall protect these instruments throughout his work activities and provide for various temporary setups so that instruments may be monitored. Jersey barriers or precast concrete pipe sections shall be provided around the instruments to prevent rolling equipment from inadvertently damaging the instruments. Contractor damage to the instruments should be replaced by the Contractor at no cost to the CQA Engineer, Design Engineer or Owner. The procedure for re-establishing the instruments at the proposed final grades is further described in the design plans and specifications.

5.19 Groundwater Monitoring Well Installations

Four groundwater monitoring wells are proposed on the perimeter of the landfill to monitor landfill in accordance with regulatory standards. The procedures for installing these wells is further described below.

5.19.1 Location Survey

Horizontal and vertical survey controls should be provided at each well location before drilling begins. The survey control should be maintained on a temporary benchmark for later transfer of the benchmark to the top of casing datum for water measurement reference.

5.19.2 Drilling and Sampling

The drilling and sampling techniques used to log and stratify geologic conditions shall be initially appropriate for sample collection. The hole may be later reamed to a larger

diameter to accommodate the large diameter well installation. The specifications for drilling and sampling are included in the design plans and specifications.

5.19.3 Well Installation

Well installations shall be conducted in accordance with the Indiana 329 Administrative Code primarily referencing Sections 329 IAC 10-29 and 10-15-4. Both the drilling and well installation procedures shall be supervised by a qualified hydrogeologist under the direction of the CQA Engineer.

5.19.4 Equipment Decontamination

Between drilling each monitoring well, decontamination procedures shall be practiced to clean equipment to avoid cross-contamination of geologic materials and groundwater samples.

5.19.5 Well Development

Following the completion of each monitoring well installation, the well shall be developed to achieve stabilized field parameters in accordance with the design plans and specifications.

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
Flume Dredging	Batholith/Survey Soundings	Visual and sounding survey control (2nd order)	Every day in dredge area or as directed by CQA Engineer
	Dredge Sediment Quality	SW 846	One analysis
	Water Quality	Standard Methods	Before and after dredging and once per week during dredging
	Geotechnical Instrumentation (Inclinometers and Piezometers)	Continuation of historical measurements	Twice per week along flume during dredging. After dredging, every other week until flume filling begins
Dredge Disposal	Fill Lift Thickness	Visual	Every day during disposal
Flume Fill Placement	Lift Thickness	Visual and soundings/survey control (2nd order)	Every day during filling or as directed by the CQA Engineer
	Grain Size Distribution	ASTM D 422	Every 20,000 cu. yd.
	Water Quality	Standard Methods	Every week during filling
	Geotechnical Instrumentation (Inclinometers and Piezometers)	Continuation of historical measurements	Twice per week during filling or every 10,000 cu. yd. of fill placement, whichever is greater frequency and every 2nd week after filling or as directed by CQA Engineer
RTV Roadway	Subbase Lift Thickness	Visual	One per station per lift
	Subbase Moisture Density Proctor	ASTM D 698 or D 1557	One per 3,000 cu. yd. or at visually apparent changes in material
	Subbase Compaction	ASTM D 1566 and D 2216	One per station per lift
	Asphalt Marshall Density	ASTM D 5581	First day of paving, then one per week
	Asphalt Extraction	ASTM D 2172	Every 1,500 tons or one sample per day
	Asphalt Gradation	ASTM D 5444	Every 1,500 tons or one sample per day
	Asphalt Lift Thickness	Visual	One per station per lift
	Asphalt Mat Density	ASTM D 2950	Five tests per 1,000 ft. per lift across full paver width

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
Waste Excavation and Fill Placement	Large Object Excavation and Disposal	Visual and survey control to avoid nesting of large objects	Daily
	Excavation Difficulty	Visual and volume measurement	Daily
	Fill Placement	Visual and survey control using GPS instrumentation	Grade surveying every week
	Moisture Density (Proctor)	ASTM D 698 (Standard) or ASTM D 1557 (Modified)	One per 50,000 cu. yd. or at visually apparent changes in waste material
	Grain Size Distribution	ASTM D 422	One per 50,000 cu. yd. or at visually apparent changes in soil
	Fill Compaction and Density	ASTM D 2922 (Nuclear) or D 1566 (Sand Cone) or D-2167 (Balloon) and ASTM D 3017 (Nuclear) or D 4643/2216	One per acre per lift 10 feet below the proposed finished subgrade and every 5,000 cu. yd. at depths greater than 10 feet below the finished subgrade
	Loose Lift Thickness	Visual	One per acre per lift
	Geotechnical Instrumentation (Inclinometers and Piezometers)	Continuation of historical measurements	Weekly in new fill areas below elevation 620 and twice per week in new fill areas above 620
Interim Geotechnical Monitoring	Geotechnical Instrumentation (Inclinometers and Piezometers)	Continuation of historical measurements	Every second week or as directed by CQA Engineer
Groundwater Monitoring Wells	Hydrogeologist Supervision	ASTM D 5521 or 329 IAC 10-29 and 10-21-4	Daily
Sand Bedding for Geomembrane	Loose Lift Thickness	Visual	Five per acre per lift
	Moisture Density (Proctor)	ASTM D 698 or ASTM D 1557	One per 5,000 cu. yd. or at visually apparent changes in soil with a minimum of 3 tests per borrow source
	Grain Size Distribution	ASTM D 422	One per 5,000 cu. yd. (with Proctor)
	In-Situ Density	ASTM D 2922 if feasible	Five per acre per compacted lift

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
	In-Situ Moisture	ASTM D 2922	Five per acre per compacted lift
	In-Situ Density Correlation	ASTM D 1556 (Sand Cone)	One per week
	In-Situ Moisture Correlation	ASTM D 2216 (Sand Cone)	One per week
	Hydraulic Conductivity	ASTM D 2434	One per 10,000 cu. yd.
Coarse Protection Aggregate	Petrographic Examination	ASTM C 295	One representative sample from each borrow source
	Grain Size Distribution	ASTM C 136	One per 5,000 cu. yd. or at visually apparent changes in aggregate
	Freeze/Thaw Degradation	ASTM C 682	One representative sample from each borrow source
Stormwater Management Rip-Rap	Petrographic Examination	ASTM C 295	One representative sample from each borrow source
	Grain Size Distribution	ASTM C 136	One per 3,000 cu. yd.
	Freeze/Thaw Degradation	ASTM C 682	One representative sample from each borrow source
INDOT No. 53 Base Coarse Aggregate	Loose Lift Thickness	Visual	One per station per lift
	Moisture Density Proctor	ASTM D 698 or ASTM D 1557	One per 3,000 cu. yd.
	Grain Size Distribution	ASTM D 422	One per 3,000 cu. yd. (with Proctor)
	In-Situ Density	ASTM D 2922 (Nuclear) or ASTM D 1556 (Sand Cone)	One per station per lift and at least 10 percent by sand cone
Stormwater Management Precast Concrete Structures Backfill/Bedding	Loose Lift Thickness	Visual	One per 500 cu. yd. placed
	Moisture Density (Proctor)	ASTM D 698 or ASTM D 1557	One per 3,000 cu. yd. or at visually apparent changes in aggregate
	In-Situ Density	ASTM D 2922 (Nuclear) or ASTM D 1556 (Sand Cone)	One per 100 cu. yd. or at least 10 percent by sand cone

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
Stormwater Management Pipe Bedding Component	Loose Lift Thickness	Visual	One per 500 cu. yd. placed
	Moisture Density (Proctor)	ASTM D 698 or ASTM D 1557	One per 3,000 cu. yd. or at visually apparent changes in aggregate
	In-Situ Density	ASTM D 2922 (Nuclear) or ASTM D 1556 (Sand Cone)	One per 100 cu. yd. or at least 10 percent by sand cone
Stormwater Management Cast In-Place Concrete	Compressive Strength	ASTM C 172 Sampling and ASTM C 31	Four cylinders per 50 cu. yd.
	Temperature	ASTM C 172 Sampling and ASTM C 1064	One per cylinder set
	Air Content	ASTM C 172 Sampling and ASTM C 231	One per cylinder set
	Slump	ASTM C 172 Sampling and ASTM C 143	One per cylinder set
Stormwater Management Earthwork	Loose Lift Thickness	Visual	One per acre per lift
	Moisture Density (Proctor)	ASTM D 698 MC or ASTM D 1557 MC	One per 5,000 cu. yd. or at visually apparent changes in material
	Grain Size Distribution	ASTM D 422	One per 5,000 cu. yd. (with Proctor)
	In-Situ Density	ASTM D 2922 (Nuclear) or ASTM D 1556 (Sand Cone)	One per 1,000 cu. yd. or at least 10 percent by sand cone
Stormwater Management Piping (polyethylene pipe)	Density	ASTM D 1505	One per 50,000 lbs. resin
	Melt Flow Index	ASTM D 1238	One per 50,000 lbs. resin
Geomembrane (40 mil VFPE Textured Two Sides)	Thickness	ASTM D 5994	Five measurements per roll
	Density	ASTM D 1505 or ASTM D 792	One per lot or one per 50,000 sq. ft.
	Melt Index	ASTM D 1238 with 2.16 kg load @ 190°C	One per lot or one per 50,000 sq. ft

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
	Carbon Black Content	ASTM D 1603	One per lot or one per 50,000 sq. ft.
	Carbon Black Dispersion	ASTM D 5596	One per lot or one per 50,000 sq. ft.
	Tensile Properties including Yield Strength, Break Strength, Elongation at Yield, and Elongation at Break	ASTM D 638 Type IV specimen @ 2"/min	One per lot or one per 50,000 sq. ft.
	Asperity Height	GRI GM12	One per lot or one per 50,000 sq. ft.
	Interface Friction Angle with Sand Bedding	ASTM D 5321	One test per each sand bedding material
	Non-Destructive Seam Testing	Various D 5641 or D 5820	100 percent of field seams
	Destructive Seam Testing-Field, Shear Strength and Peel Strength	ASTM D 4437 (NSF 54 Modified)	One test per 500 feet of seam length; one per 300 feet if air temperature is less than 32°F, 400 feet for extra seam welds
	Destructive Seam Testing QA Laboratory-Shear Strength and Peel Strength	ASTM D 4437 (NSF 54 Modified)	One test per 500 feet of seam length; one per 300 feet if air temperature is less than 32°F, 400 feet for extra seam weld
Geotextile	Mass per Unit Area	ASTM D 5261	One test per lot or one per 50,000 sq. ft.
	Grab Elongation and Tensile Strength	ASTM D 4362	One test per lot or one per 50,000 sq. ft.
	Puncture Resistance	ASTM D 4833	One test per lot or one per 50,000 sq. ft.
	Trapezoidal Tear	ASTM D 4533	One test per lot or one per 50,000 sq. ft.
	Ultraviolet Degradation	ASTM D 4355	One test per lot or one per 2,000,000 sq. ft.
	Abrasion Test	ASTM D 4886	One test per lot or one per 500,000 sq. ft.
	pH Resistance of Geotextile	ASTM D 5322	One test per lot or one per 2,000,000 sq. ft.
	Interface Friction Angle with Textured Geomembrane	ASTM D 5321	One test per 250,000 sq. ft. or at significant change in geomembrane texturing asperity height.

TABLE 1
CONSTRUCTION QUALITY ASSURANCE SUMMARY
LTV - CLARK LANDFILL

CONSTRUCTION COMPONENT OR ACTIVITY	TEST OR CQA DOCUMENTATION	TEST METHOD	FREQUENCY
	Seam Strength	ASTM D 4884	One test per 500 feet of the first startup seams up to 5 tests total (maximum number) unless visual observations suggest additional testing or seaming procedures and modified by the CQA Engineer.
Geocomposite Drain	Tensile Strength	ASTM D 4632	One test per lot or one per 50,000 sq. ft.
	Mass per Unit Area	ASTM D 3776	One test per lot or one per 50,000 sq. ft.
	Hydraulic Conductivity	ASTM D 4716	One test per lot or one per 50,000 sq. ft.
	Ply Adhesion	ASTM D 413	One test per lot or one per 50,000 sq. ft.
Geogrid	Mass per Unit Area (coated GG)	ASTM C 3776	One test per lot or one per 50,000 sq. ft.
	Mass per Unit Area (uncoated GG)	ASTM C 3776	One test per lot or one per 50,000 sq. ft.
	Measurement of Rib/Strand Count Aperture and Thickness	Caliper and ASTM D 1777	One test per lot or one per 50,000 sq. ft.
	Wide Width Tensile Strength	ASTM D 4595	One test per lot or one per 50,000 sq. ft.
	Ultraviolet Degradation	ASTM D 4355	One test per lot or one per 2,000,000 sq. ft.
	Abrasion	ASTM D 4886	One test per lot or one per 50,000 sq. ft.
CQA Line and Grade Surveying	Two-man GPS Survey	2nd Order Survey	Project Completion

TABLE 2
INCLINOMETER INSTRUMENTS
CLARK LANDFILL

BORING	HORIZONTAL COORDINATES		STICKUP ELEVATION	A AXIS* BEARING
	NORTHING	EASTING		
LTV-1	1,520,784.44	398,836.20	602.6	N01W
LTV-3	1,520,770.50	399,208.35	598.6	N11E
LTV-4	1,520,940.83	399,125.30	621.0	N40E
LTV-5	1,520,985.60	399,477.94	591.8	N30E
LTV-6	1,521,128.56	399,036.05	678.6	N24W
LTV-7	1,521,395.40	400,092.60	633.4	N06W
B-100	1,520,865.89	398,810.23	618.2	N25E
SB-210	1,521,027.69	399,580.10	587.1	N45W
B-105	1,521,115.50	399,748.95	± 591.5	***
TDR** B101B	1,520,836.28	399,161.19	619.5	NA
TDR** LTV-3C	1,520,776.38	399,224.23	587.0	NA

* The A-axis is oriented in the downslope direction.
** TDR Cable Inclinometer by Northwestern University.
*** Survey ongoing; ground surface elevation of B-105 = El. 589.

TABLE 3
PNEUMATIC PIEZOMETER INSTRUMENTS
CLARK LANDFILL

Piezometer Name	Horizontal Coordinates		Piezometer Elevation (Transducer)
	NORTHING	*EASTING*	
LTV-1BSTP	1,520,780.31	398,842.39	543.4
LTV-2STP	1,520,881.37	398,802.82	539.7
LTV-3STP	1,520,770.50	399,208.35	540.4
LTV-4STP	1,520,935.93	399,117.80	531.8
LTV-4AP	1,520,931.52	399,110.98	527.5
LTV-5STP	1,520,981.72	399,468.28	534.4
LTV-6STP	1,521,131.93	399,029.21	529.4
LTV-7ASTP	1,521,395.64	400,084.40	522.9
LTV98-8 - Top @ 60'	1,521,446.41	398,840.96	539.7
LTV98-8 - Middle @ 70'	1,521,446.41	398,840.96	529.7
LTV98-8 - Bottom @ 78.5'	1,521,446.41	398,840.96	521.2
LTV98-9 - Top	1,521,717.36	399,697.75	538.6
LTV98-9 - Middle	1,521,717.36	399,697.75	522.6
LTV98-9 - Bottom	1,521,717.36	399,697.75	503.6
B-102A @ 133 ft	1,521,436.34	399,605.97	539.5
B-102A @ 143 ft	1,521,436.34	399,605.97	529.5
B102A @ 153 ft	1,521,436.34	399,605.97	519.5
B102A @ 163 ft	1,521,436.34	399,605.97	509.5
B-103 @ 113 ft	1,521,218.45	399,744.11	525.5
B-103 @ 123 ft	1,521,218.45	399,744.11	515.5
B-103 @ 133 ft	1,521,218.45	399,744.11	505.5
B-104 @ 59 ft	1,520,789.29	398,427.17	540.7
B-104 @ 76 ft	1,520,789.29	398,427.17	523.7
LTV3P98 @ 64ft	1,520,780.33	399,231.45	534.8
LTV3P98 @ 76 ft	1,520,780.33	399,231.45	522.8
LTV5P98 @ 72 ft	1,520,969.00	399,470.70	517.1
B-101C @ 91 ft	1,520,859.44	399,133.69	526.0
B-101C @ 102 ft	1,520,859.44	399,133.69	515.0
SB-202 @ 36.5 ft BGS	1,520,668.160827	399,167.576308	538.9
SB-202 @ 57.5 ft	1,520,668.160827	399,167.576308	517.9
SB-203 @ 58 ft (Destroyed)	1,520,787.866876	399,371.645519	524.9
SB-204 @ 43 ft	1,520,917.147445	399,477.940385	540.0
SB-204 @ 61 ft	1,520,917.147445	399,477.940385	522.0
SB-205 @ 36 ft	1,521,098.371442	399,808.693839	533.0
SB-205 @ 57 ft	1,521,098.371442	399,808.693839	512.0
SB-207 @ 33 ft	1,520,673.020000	398,782.430000	541.8
SB-207 @ 41 ft	1,520,673.020000	398,782.430000	533.8
SB-207 @ 58 ft	1,520,673.020000	398,782.430000	516.8