

Capacity Building of Academic Institutions (IIT Delhi)
to Support Remediation Initiatives

Advanced Equipment for Subsurface Characterization of Contaminated Sites



Sponsored by
Ministry of Environment, Forest and Climate Change
(2018-2020)



Geotechnical and Geoenvironment Group
Department of Civil Engineering
Indian Institute of Technology Delhi
Hauz Khas, New Delhi-110016

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1.0 Background

Under a sponsored research project awarded by the Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India, to the Geotechnical and Geoenvironment Group, Civil Engineering Department IIT Delhi, for the duration 2018-2020, titled “Capacity Building of Academic Institutions (IIT Delhi) to Support Remediation Initiatives” (RP03531G and RP03614G), the following Advanced Equipment have been procured for Subsurface Characterization of Contaminated Sites:

Geophysical (non-destructive testing) Equipment:

- Ground Penetrating Radar
- Electrical Resistivity Imaging System
- Multichannel Analysis of Surface Waves

Field Sampling and Penetration Testing:

- Shallow Depth Sampling Equipment
- Medium Depth Direct Push Sampling Equipment
- Optical Imaging (Visual & UV) and Hydraulic Profiling Tools
- Cone Penetration Equipment – Piezocone & Seismic Cone Samplers

Portable Field Analysers

- Landfill Gas Analyser
- VOC Detector
- Handheld XRF

Laboratory Testing Equipment

- Soil Digester
- TCLP Apparatus

Software

- Contaminant Transport Software

The above equipment helps in accurate characterization of the subsurface environment of contaminated sites as well as in delineating the spread of contaminants beneath the ground surface - in soil, ground water and unsaturated pore-space. A brief description of the advanced equipment along with photographs are presented in the following pages. Some of the photographs pertain to field demonstration testing performed from 17th to 21st Feb 2020 for 160 participants of the event “Geoenvironment-2020” held at IIT Delhi.

2.0 Ground Penetrating Radar

Manufacturer: Utsi Electronics Ltd., UK

Rep.: Avantech Engg. Consortium P. Ltd., New Delhi

Ground Penetrating Radar (GPR) is a geophysical method which sends electromagnetic pulses into the ground and detects the reflected signals to identify buried objects, pipes, cables, underground utilities, voids etc. It identifies boundaries between materials having different permittivities. Useful in soil, rock, ice and pavements. Suitable for detecting boundaries up to a few metres depth below the ground surface. Groundvue 3.0 from Utsi Electronics, UK, comprises of 8-channel controller (capable of 1600 scans per second) with antennas having frequency ranges of 250 MHz to 1 GHz and processing software (Reflex-W) along with a snake antenna of frequency 40 MHz.



(a) Ground Penetration Radar Assembly



(b) Standard Antenna (250 Mhz)



(c) Snake Antenna



(d) Demonstration of Equipment at Geoenvironment-2020



(e) Demonstration of Equipment at Geoenvironment-2020

3.0 Electrical Resistivity Imaging System

Manufacturer: IRIS Instruments, France

Rep.: Aimil Ltd., New Delhi

Electrical Resistivity Imaging (or Tomography) is a non-invasive geophysical subsurface imaging technique in which apparent electrical resistivity of the subsoil is measured by inducing current into the ground and measuring the potential drops along an array of electrodes. Vertical and lateral variations of electrical resistivity are obtained by placing electrodes in different linear configurations, resulting in a 2-D Tomographic image. Combining different 2-D sections, a 3-D Tomographic image can also be obtained. The variation or anomalies in resistivity help in finding soil lithology, groundwater, fracture zones, depth of bedrock, saltwater intrusion, groundwater contamination, and many more. Syscal system from IRIS Instruments is an automatic resistivity calculating unit with a multi-channel system (Syscal junior pro), cable (length of 360 m with 72 switches each at 5m spacing), 72 stainless electrodes, and jumpers to connect the electrode with the cable. This system works with three Softwares: Electre Pro (for Array configuration), Prosys II and RES2DINV/ RES3DINV (for data processing and inversion).



(a) Electrical Resistivity Imaging System: Resistivity meter, Electrodes, Cables and Connectors



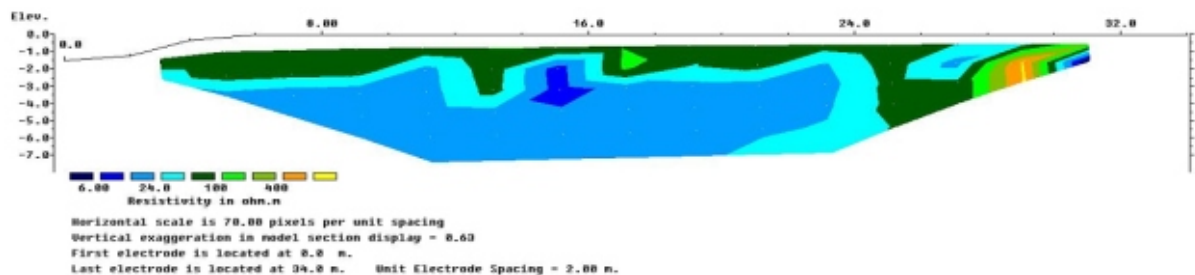
(b) Equipment Setup in Field



(c) Demonstration of Equipment at Geoenviroment-2020



(d) Demonstration of Equipment at Geoenviroment-2020



(e) Typical Output from the Electrical Resistivity Imaging Test

4.0 MASW (Multichannel Analysis of Surface Waves): Reflection and Refraction Survey

Manufacturer: OYO Corporation, Japan

Rep.: Aimil Ltd., New Delhi

The MASW equipment evaluates shear-wave velocity distribution with depth either in 1D (depth) or 2D (depth and surface distance) formats. It measures the dispersion of surface waves with depth and then estimates the shear wave velocity. The shear wave velocity can be used to estimate the shear modulus with depth. This is a non-destructive technique and can be used to detect the thickness of cover layer and intermediate layers. This equipment has also applications like: soil-bed rock mapping, seismic site characterization and liquefaction hazard assessment. Specifications are as follows: 24 Channel engineering seismograph (McSEIS-SW) with 4.5 Hz geophones and a drop hitter system (WEH -250).



(a) MASW Instrumentation



(b) 24 Channel Engineering Seismograph



(c) Drop Hitter, Hammer and Accessories



(d) Geophones

5.0 Shallow Depth Soil Coring/ Groundwater Sampling/ Soil-Gas-Vapour Sampling System

Manufacturer: AMS Inc., USA

Rep.: Complete Instrumentation Solutions P. Ltd., Gurgaon

The AMS kits are capable of environmental sampling of soil/ gas/ groundwater up to a shallow depth of 3m in different ground conditions. The environmental soil sampling kit has stainless-steel components (augers, rods, samplers) so that no contaminants are introduced during drilling and sampling. These can be decontaminated after sampling. Six types of kits include: environmental soil sampling kit, bulk density soil sampling kit, flighted auger kit, hollow stem auger kit, petrol powered core sampling kit and heavy-duty gas vapour probe kit along with various accessories and consumables. Automatic vacuum gas sampling chamber/ vacuum pump station and peristaltic pump are used for collecting gas and groundwater samples respectively.



(a) Environmental Soil Sampling Kit



(b) Bulk Density Soil Sampling Kit



(c) Flighted Auger Kit



(d) Hollow Stem Auger Kit with Peristaltic Pump



(e) Petrol Powered Core Sampling Kit with Hammer and Removal Foot Jack



(f) Heavy Duty Gas Vapour Probe Kit



(g) GVP Tip attached with Vacuum Gas Sampling Chamber(Left) and Peristaltic Pump for Groundwater Sampling (Right)



(h) Demonstration of Equipment at Geoenvironment-2020



(i) Demonstration of Equipment at Geoenvironment-2020

6.0 Medium Depth Direct Push Rig with Soil Sampling/ Ground Water Sampling/ Pore-Gas Kit (7822DT: Integrated 3-in-1)

Mfr: Geoprobe Systems, USA

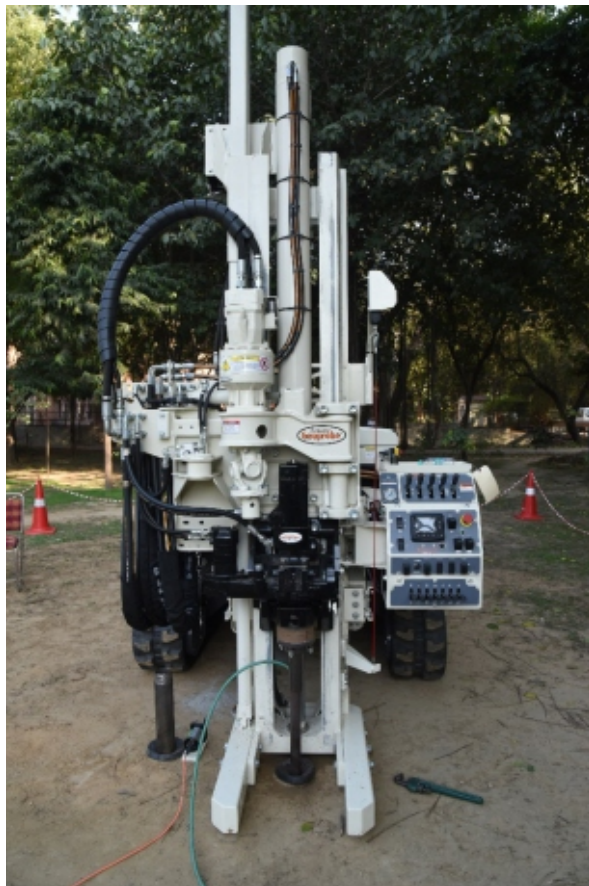
Rep.: Complete Instrumentation Solutions P. Ltd., Gurgaon

Geoprobe 7822DT: The 7822DT is a self-propelled, crawler-mounted, highly-mobile, compact rig which uses 3-in-1 integrated techniques i.e. direct push, rotary and percussion to drive a sampler/probe into the ground.

Direct Push Soil Sampling: The environmental soil sampling system DT 325 consists of a dual tube sampler with outer diameter of 3.25 inches. DT325 allows recovery of core samples in 1.5 m long plastic liners in single push down operation. The samples are untouched by hand and can be sealed using endcaps and transported to the lab for environmental analysis. Continuous soil cores can be recovered down to depths of 15 m without any cross-contamination and without generation of extra cuttings of soil during the push-down operation.

Groundwater Sampling: The Screen Point 16 (SP16) groundwater sampling tips are used to collect groundwater samples from different soil layers beneath the ground water table.

Pore-Gas Vapour Sampling: The Post Run Tubing System (PRT) allows the user to collect soil vapour samples quickly and easily at the desired sampling depth without the time-consuming complications associated with rod leakage and contamination.



(a) The Geoprobe 7822DT Drill Rig



(b) A Typical Dual Tube with Liner and Cutting Shoe



(c) Groundwater Sampling and Pore-Gas Vapour Sampling Units



(d) Demonstration of Equipment at Geoenvironment-2020



(e) Lifting of Dual Tube Assembly



(f) Pushing Dual Tube into the Sub-surface Soil



(g) Removing Liner from the Inner Tube



(h) Liners Containing Continuous Core Samples

7.0 In-situ Optical Imaging & Hydraulic Profiling Tool (OIHPT) for Soils (7822DT: Integrated 3-in-1)

Mfr: Geoprobe Systems, USA

Rep.: Complete Instrumentation Solutions P. Ltd., Gurgaon

The OIHPT (Optical Imaging & Hydraulic Profiling Tool) equipment comes with a probe tip on which an electric dipole, a light source (UV & visible), a camera and a flow screen are placed. The probe is driven by 7822DT rig. The electric dipole is used for measuring electrical conductivity of soil and camera along with the light source is used to measure visual images as well as fluorescence of the contaminants (hydrocarbons (NAPL)) present in the subsurface. The hydraulic profiling tool measures the flow and pressure required for water to out from the flow screen during penetration. This injection pressure log with depth is an excellent indicator of formation permeability. The in-situ measurements of electric conductivity, fluorescence and flow properties are logged using a computerized logging system. The log is presented in form of continuous depth plot of measured electric conductivity, fluorescence, flow pressure and flow volume. The OIHPT, along with continuous collection of samples using DT325, provide the necessary and sufficient information for High Resolution Site Characterization of contaminated sites.



(a) OIHPT Instrumentation



(b) Demonstration of Equipment at Geoenvironment-2020



(c) Setting up the Equipment



(d) Field Check



(e) Field Check



(f) Performing OIHPT test



(g) Output on screen



(h) Output on screen

8.0 Cone Penetrometer: Piezocone and Seismic Cone (7822DT: Integrated 3-in-1)

Mfr: Geoprobe Systems, USA

Rep.: Complete Instrumentation Solutions P. Ltd., Gurgaon

The Geoprobe Cone Penetration Testing equipment can apply a downward force of 200 kN to push an electrical piezocone and measure tip resistance, skin friction, pore water pressure, depth and inclination of the cone during penetration. A seismic adaptor above the piezocone allows measurement of shear wave velocities when seismic pulses are generated by hitting a shear plate placed on the ground. The data helps in determination of the subsurface stratigraphy in-situ and estimation of geotechnical parameters of the materials from the cone data generated by static pushing at a controlled rate of 2 cm/sec. The seismic cone data is useful for assessment of liquefaction risk and earthquake generated ground surface movements.



(a) The CPT Cone



(b) Saturating the Piezocone



(c) Setting up the Cone



(d) Attaching the Cables



(e) Attaching Cone to Rod



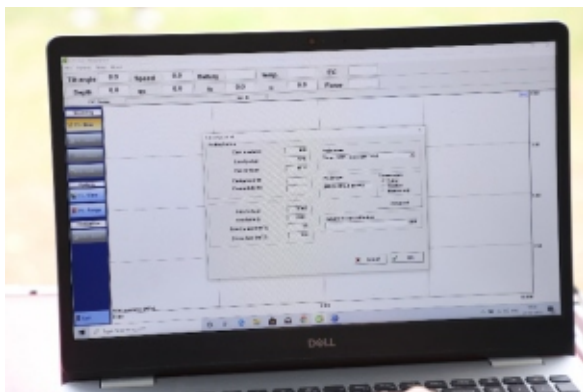
(f) Installation of Anchors



(g) Connecting Cone, CPT Controller and Laptop



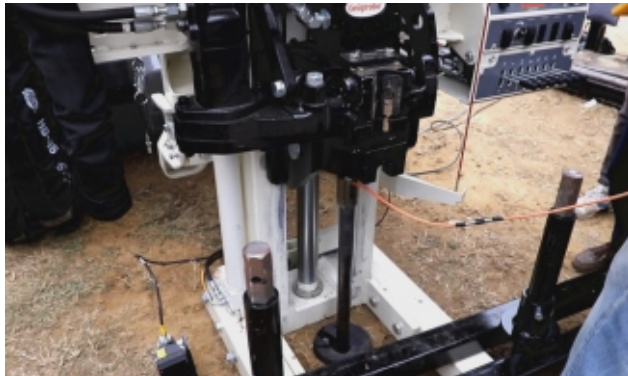
(h) Connecting Cone, CPT Controller and Laptop



(i) Initialising Data Acquisition on Laptop



(j) Alignment Check



(k) Cone Penetration



(l) Output on screen



(m) Pulling Out Rods and Cone



(n) Removing Anchors

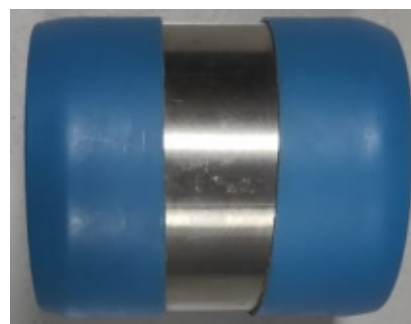
9.0 Samplers

Manufacturer: AMS Inc. (USA); CEL Scientific Corp. (USA); Rep.: Complete Instrumentation Solutions
Geotech Env. Equip. (USA), others P. Ltd., Gurgaon

Plastic and stainless-steel liners with end caps and swatches for safe transportation of environmental soil samples. Core catchers to minimize the sample loss when sampling dry, loose soils and wet, unconsolidated soils. Tedlar bags for collecting gas samples. Automatic vacuum gas sampling chamber for sampling gas to Tedlar bags at a contaminated site. Peristaltic pump for taking groundwater samples. Environmental soil sampling and head-space gas sampling syringes for easy sampling in a small quantity from already sampled soil (in liners) and gas (in Tedlar bags).



(a) Plastic Liners with End Caps



(b) Stainless Steel Liners with End Caps



(c) Environmental Soil Sampling Syringes



(d) Demonstration of Environmental Soil Syringes



(e) Automatic Vacuum Gas Sampling Box



(f) Gas Sampling in a Tedlar Bag in the Sampling Box

10.0 Landfill Gas Analyzer

Manufacturer: Geotech, UK

Rep.: Neetel Ltd., Mumbai

Geotech GA5000 is a portable gas analyser for landfills and contaminated sites. It is used to measure the concentration of landfill gases (CH_4 , CO_2 , O_2 , H_2S , and CO). It measures CO_2 and CH_4 by dual wavelength infrared sensor while CO , O_2 , and H_2S are measured by an internal electrochemical sensor. It has a wide range applicability in landfill gas monitoring, waste to energy plants, investigation of contaminated sites. It has the facilities of measurement of temperature from -10°C to $+75^\circ\text{C}$ and barometric / relative pressure measurement with an optional probe for gas flow measurement from boreholes / pipes in a range of 0-20 l/hr.



(a) Installing Gas Vapour Probe at MSW Dumpsite



(b) Recording Concentrations of Landfill Gas Constituents

11.0 VOC Detector

Manufacturer: Ion Science Ltd., UK

Rep.: Ion Science India P. Ltd.

Volatile Organic Compound (VOC) Detector from Ion Science is a field screening tool with the help of which presence of VOCs at any site can be rapidly identified. The instrument works on the principle of photoionization detector (PID) technology. The molecules of VOC gas sucked into the instrument are broken by high energy UV photons emitted by a 10.6eV PID lamp inside and the electric current produced is detected by patented fence electrode technology to report the concentration in ppm or ppb. Over 700 gases can be detected in the range from 0 to 5000 ppm with minimum sensitivity of 0.1 ppm. To prevent the entry of any debris into the equipment, it is always used with a 0.5 micron polytetrafluorethylene (PTFE) filter disc. For calibration, the equipment uses isobutylene gas with a response factor of 1.0. Data can be stored in the instrument and also downloaded on to the laptop.



(a) VOC Analyzer Kit



(b) Demonstration at Geonevironment-2020



(c) Samples being checked for VOCs



(d) VOC reading from the sample

12.0 Handheld XRF

Manufacturer: Thermo Fisher Scientific Inc., USA

Rep.: Multitech Enviro Analytical, Delhi

The Niton XL3t handheld X-ray fluorescence (XRF) analyzer from Thermo Fisher Scientific allows rapid assessment of heavy metals and other contaminants for in-situ screening of soils at contaminated sites. It yields rapid, qualitative and semi-quantitative results allowing similar samples to be sent to the laboratory for confirmatory testing. The portable (handheld) XRF works on the principle of X-ray emission from individual atoms after excitation by an external energy source. It is a qualitative tool to detect metal concentrations in dry solid samples. The X-rays can only penetrate upto 0.5 mm and hence the results are for the surface of the samples only. It can be used to delineate the areas of potential concern. The XL3t Niton XRF analyzer comprises of X-ray tube power (50 kV - 2 W) for heavy element detection, Si-SDD detector technology, and tilt screen display and the elemental range covered is magnesium to uranium.



(a) Hand Held XRF Kit



(b) Detection of Constituents in Various Samples



(c) Onsite Display of Readings



(d) Demonstration at Geoenvironment-2020

13.0 Soil Digester

Manufacturer: Anton Paar, Austria

Rep.: Anton Paar India Pvt. Ltd., Gurgaon

Multiwave GO from Anton Paar is a microwave digestion system used for digestion of soil, water, food or biological samples. It is suitable for analysis of total heavy metals in soils. After digestion, the samples can be analysed by techniques such as inductive coupled plasma, atomic absorption emission etc. Digestion of 12 samples (up to 3 g each) simultaneously is feasible within a small footprint. This is accomplished by exposing a sample to a strong acid in a closed vessel and raising the pressure and temperature through microwave radiation. The digester provides efficient turbo heating using directed microwaves to one or more samples and has a turbo system for rapid cooling. The Smart Vent Technology and HF resistant vessels allow for reliable and safe digestion.



(a) Microwave Soil Digesting system



(b) Fume Hood

14.0 TCLP Apparatus

Manufacturer: Cole-Parmer, USA

Rep.: Cole-Parmer India P. Ltd., Mumbai

Toxicity characteristics leaching procedure (TCLP) is a leachate extraction method from solid waste / contaminated soil to simulate leaching through a landfill. It is used to determine if a waste is hazardous or not. The Cole-Palmer TCLP apparatus comprises of a heavy duty TCLP Rotator (max. speed 30 rpm), 12 borosilicate extraction bottles (2.2 L capacity) and extraction pads, maxfil pressure filtration device & TCLP filters and PVF sampling bags.



(a) TCLP Apparatus



(b) Inside View



(c) 2.2 Litre Bottles for TCLP Apparatus

15.0 Modular Shelter/ Container for Field Rig

Manufacturer: Local Fabricator

Description: A field shelter/ container has been fabricated for housing the rig and a separate field container has been acquired for storing the accessories.



(a) Field Shelter/ Container for Rig



(b) Rig Inside the Shelter/ Container



(c) Field Container for Rig Accessories



(d) Accessories Inside the Container

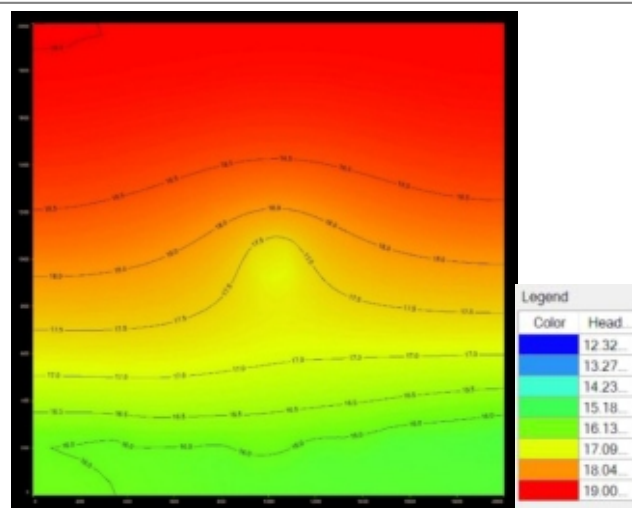
16.0 Contaminant Transport Software

Software: **GMS** by Aquaveo, USA; **HYDRUS** by PC-PESD, Czech Republic; Rep.: LaGa Systems Pvt. Ltd.,
MODFLOW by Waterloo Hydrogeologic, Canada Hyderabad

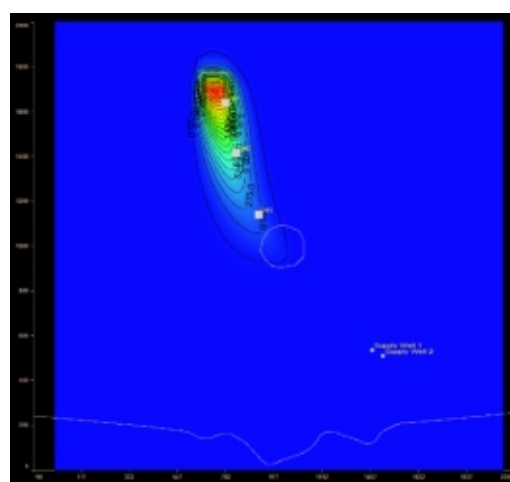
Groundwater Modelling System (GMS) is a groundwater and subsurface simulation software developed by Aquaveo, USA for performing groundwater simulations in a 3D environment. It supports a variety of ground water flow models with structured or unstructured grid options, native MODFLOW files and spreadsheet. The simulation results can be visualized in 2D plan, sectional and 3D views.

HYDRUS 2D/3D is a software package for simulating water, heat, and solute movement in two- and three-dimensional variably saturated media. It is developed by PC-Progress Engineering Software Developer, Prague, Czech Republic. It uses the Finite Element Method (FEM) for solving advection-dispersion equations, for modelling water & solute movement in partially or fully saturated homogenous or layered media.

Visual MODFLOW Flex is a groundwater flow & contaminant transport modelling software from Waterloo Hydrogeologic, Canada. This program has tools necessary for addressing water quality, groundwater supply, and source water protection initiatives. This program can model ground water flow in saturated/unsaturated subsurface and multi-species reactive contaminant transport simulations



(a) Typical Output of Groundwater Model



(b) Typical Output of Contaminant Plume



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