Lectures 6 and 7

Site Characterization

Questions to be answered by site characterization

Nature and extent of contamination—
where is it?

What is future migration and control—
where is it going?

What are receptors and their risk—
what harm will it do?

What are technical options for remediation—
how do we fix it?

Data needed from site characterization

1. Contaminant sources – research history as well as collect samples
2. Extent of contamination – need to understand transport as well
3. Hydrogeologic setting – use to address items 1 and 2
4. Restoration potential

Stages of investigation

Stage 1 – scoping study

Is there a problem? How bad is it?

Stage 2 – prepare field study plan

Includes sampling and analysis, health and safety, and quality assurance plans

Stage 3 – conduct on-site sampling and analysis

Stage 4 – interpretation, assessment, modeling

(Stages 3 and 4 may be iterative)

Stage 5 – design remedial action

First steps in understanding a site

1. Get a USGS topo map!

   Understand geographic setting, topography, nearby water bodies

2. Get background geologic data

   Consult ground-water atlas of the U.S.

   Get reports on geology, hydrology, meteorology

   Check for reports from state and U.S. geological surveys

First steps in understanding a site

3. Understand site use and history

   Where were chemicals handled or disposed?

   What site structures or activities are potential sources?

   What chemicals are <u>and were</u> handled?

Background information is important

Regional geology helps you understand site geology and hydrology

Regional hydrogeology may have significant effect on contaminant movement

Prevents costly mistakes such as multi-aquifer wells

Health and safety Level A

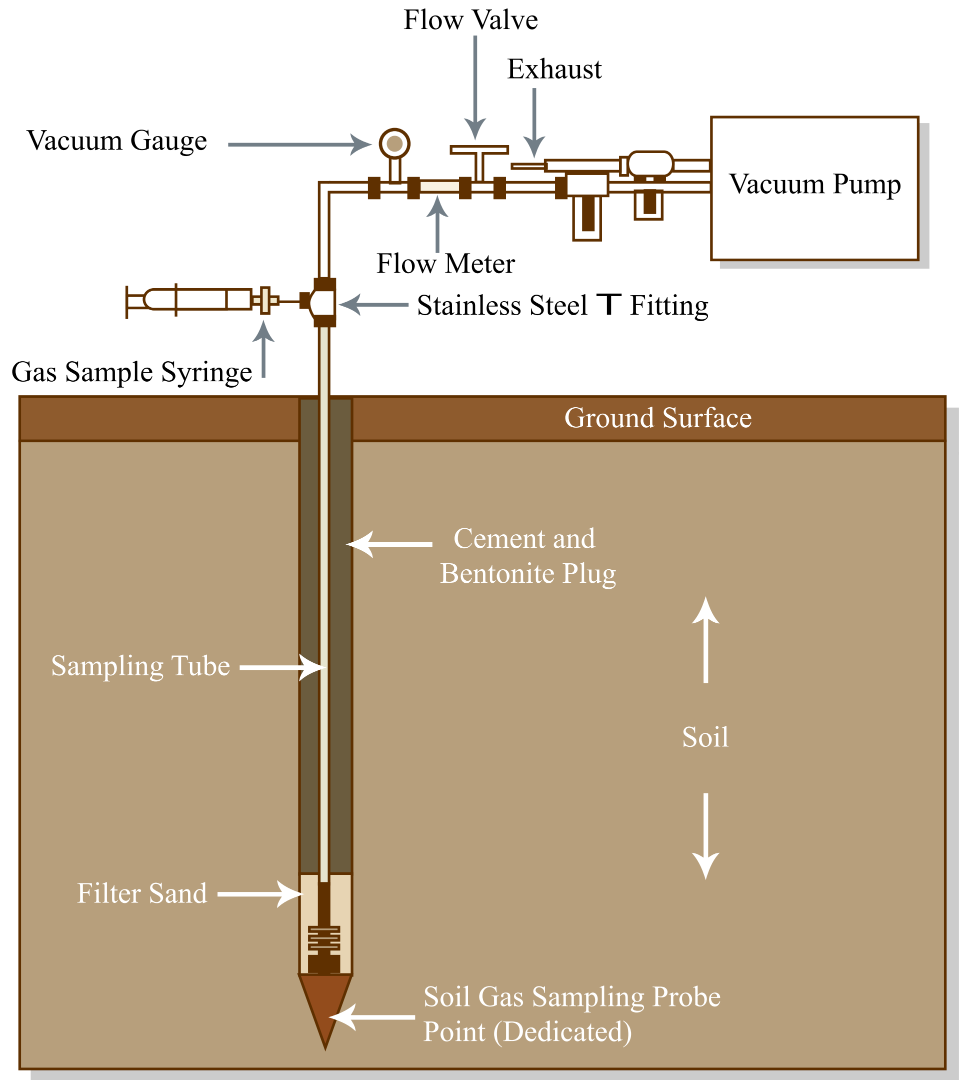
U.S. Environmental Protection Agency, September 30, 2002. Emergency Response Program. United States Environmental Protection Agency. Washington, D.C. http://www.epa.gov/superfund/programs/er/resource/photos1.htm. Accessed December 20, 2002.

Health and Safety Levels

Safety Level	Equipment	Labor Productivity	Equipment Productivity
A	"Moon suit"	37%	50%
B	SCUBA; facial mask	48%	60%
C	Respirator; Tyvec suit	55%	75%
D	Normal work protection	82%	100%
E	No personal protection equip.	100%	100%

Source: Rast, R. R., 1997. *Environmental Remediation Estimating Methods*. R.S. Means Company, Inc., Kingston, Massachusetts.

Soil gas sampling system



Adapted from: Environmental Support Technologies, Inc., undated. *Soil Gas Surveying*. Environmental Support Technologies, Inc. Irvine, CA. www.est-inc.com/soil-gas.htm. Accessed December 17, 2002.

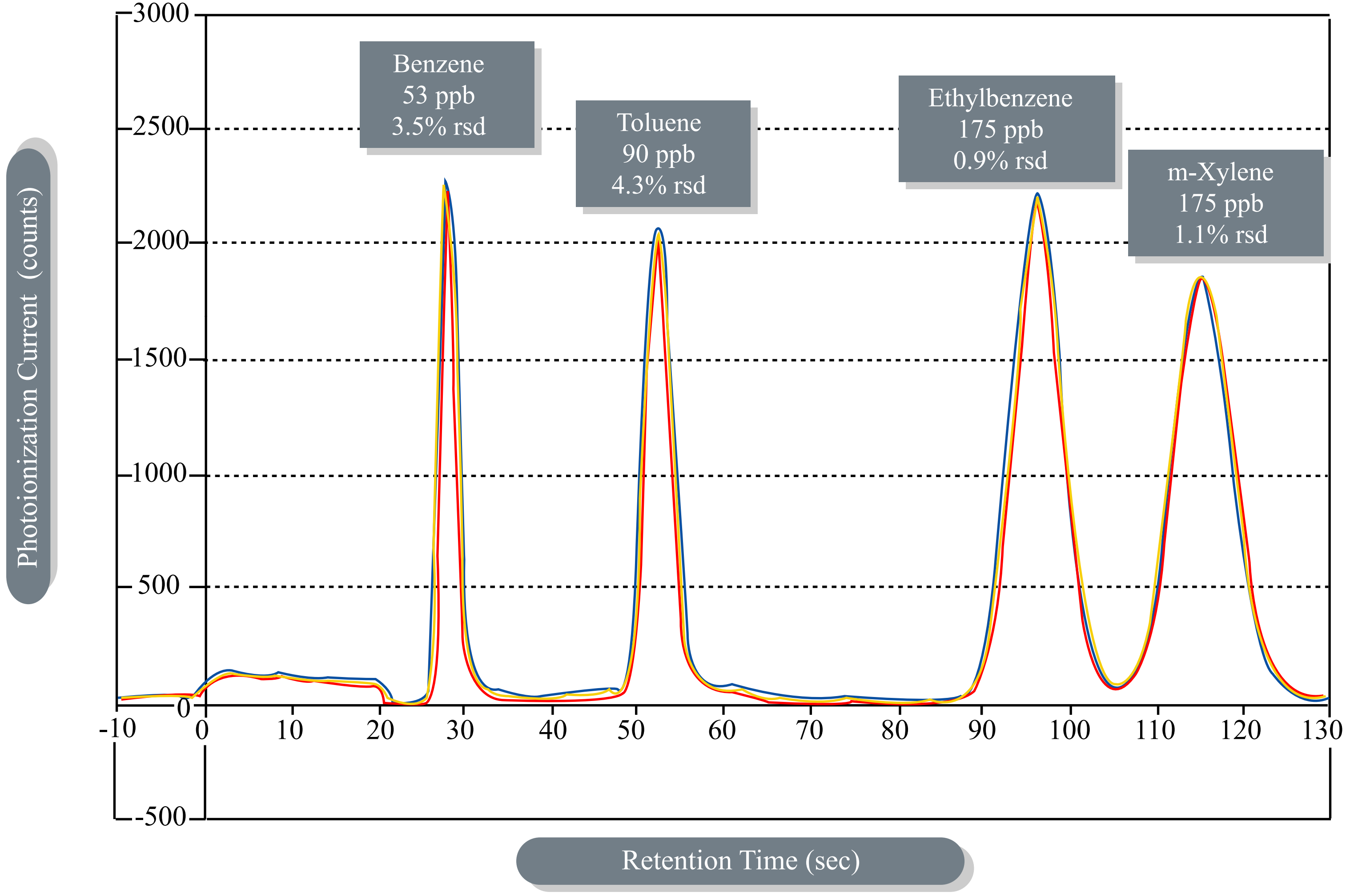
Soil gas survey is a good qualitative technique to assess areas on a site where contamination is likely. Output is an indication of the chemicals present and their relative concentrations.

Soil vapor sampling

See images of soil vapor sampling at the Web site of Environmental Support Technologies, Inc.,Irvine, CA:
http://www.est-inc.com/soil-gas.htm

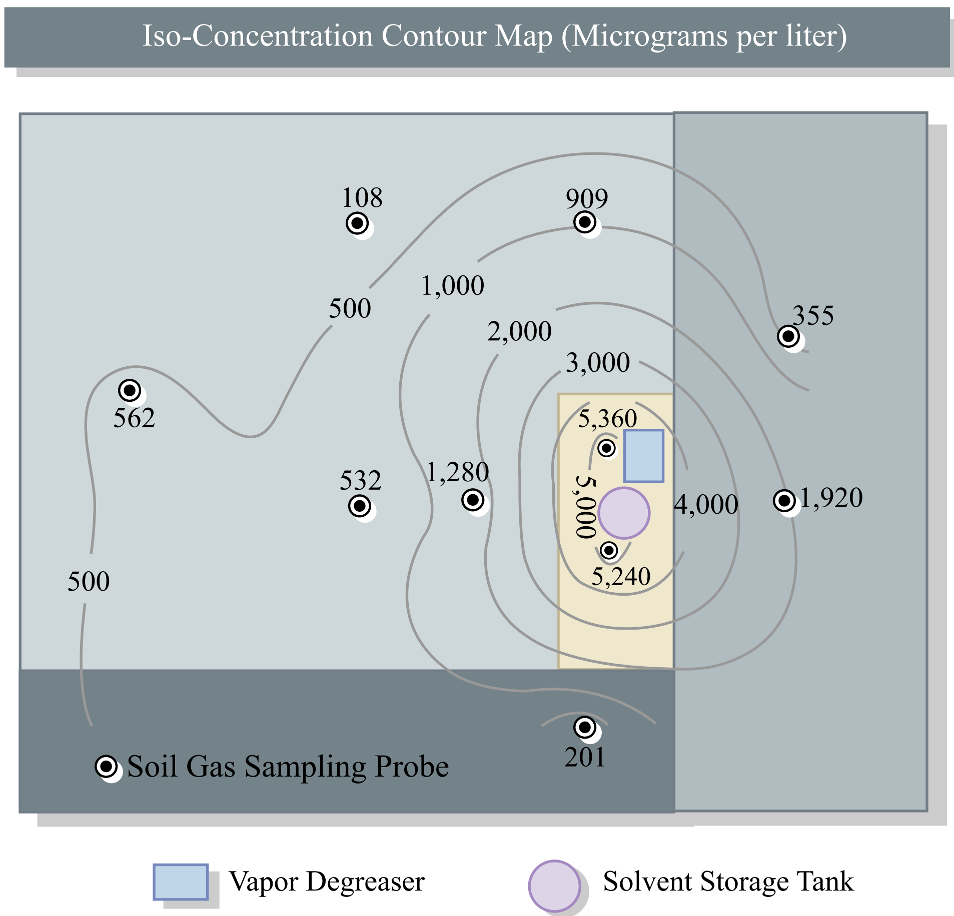
(Accessed December 17, 2002.)

Output from field GC



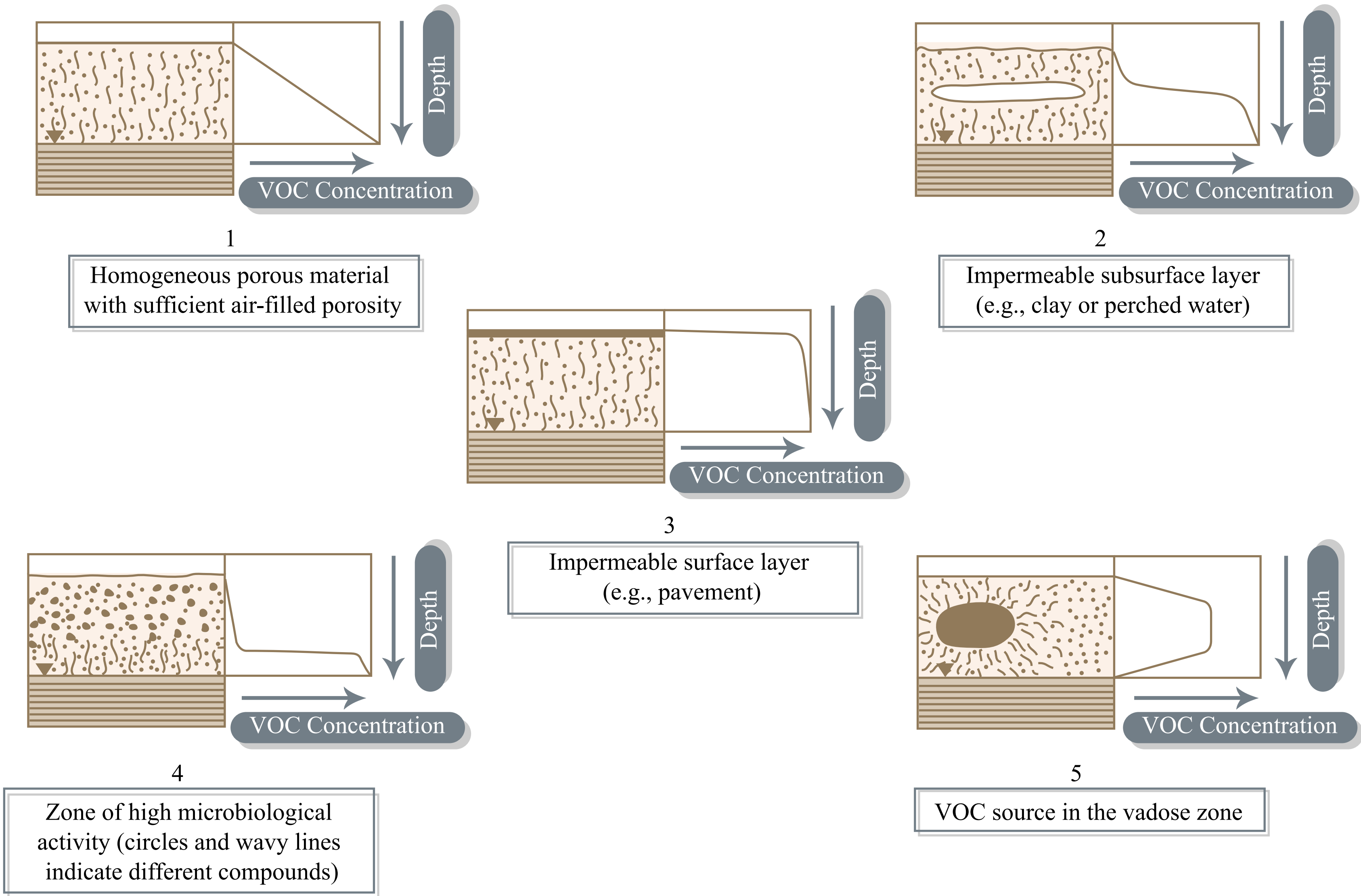
Adapted from: Ebersold, P. J. and N. Baker. "Having a Field Day." *Environmental Protection* 14, no. 3 (April 2003): 45-49.

Soil gas survey results



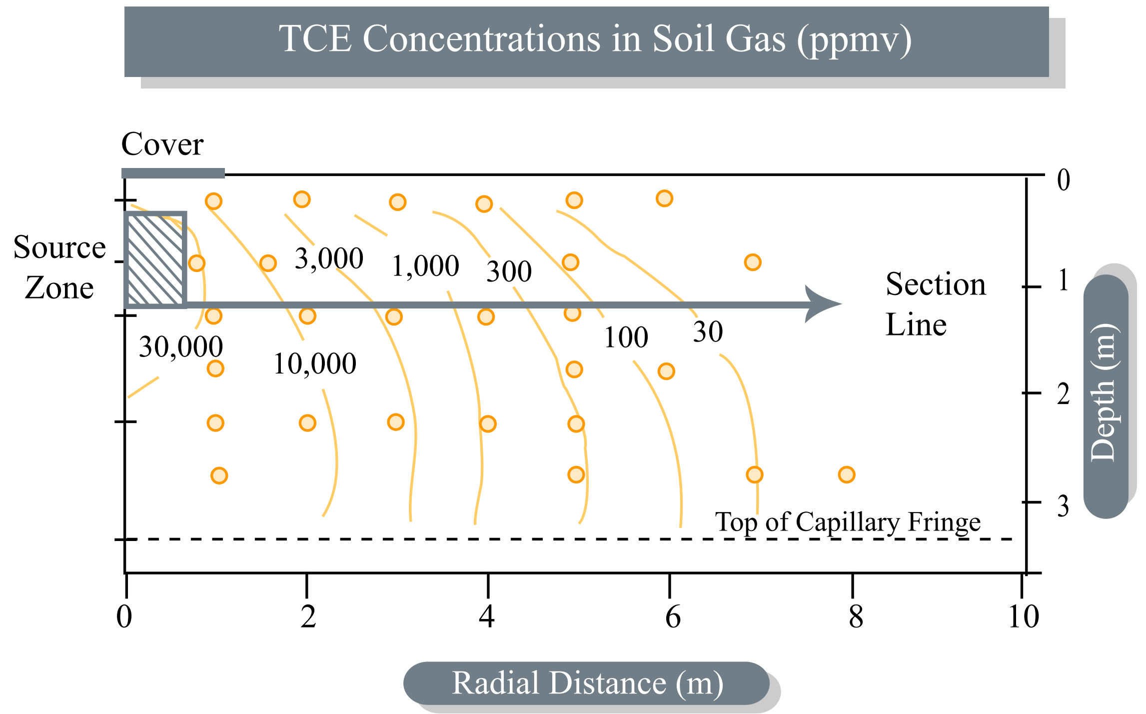
Adapted from: *Soil Gas Surveying*. Environmental Support Technologies, Inc. (undated) Irvine, CA. www.est-inc.com/soil-gas.htm. Accessed December 17, 2002.

Potential character of soil gas contamination



Adapted from: Cohen, R. M. and J. W. Mercer. *DNAPL Site Evaluation.* Boca Raton, Florida: C. K. Smoley, 1993, Figure 8-5, pp. 8-18.

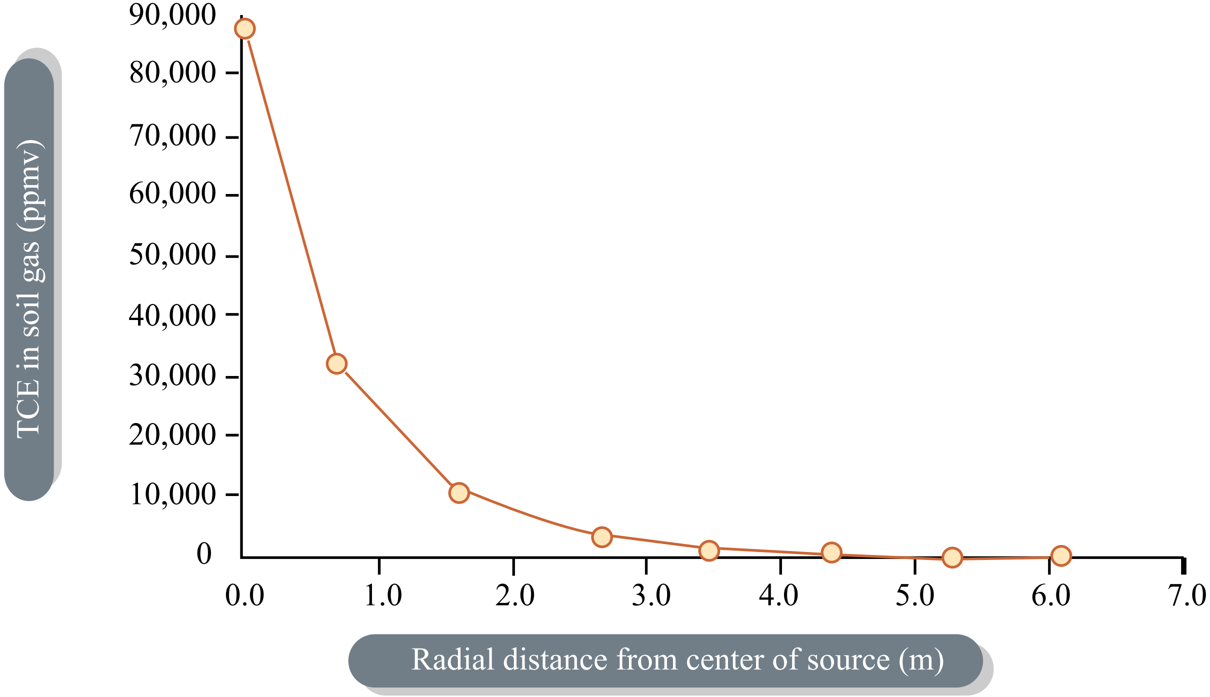
Observed soil gas contamination pattern



Example of lateral transport of TCE vapor in a sandy aquifer resulting from a experimental placement of a DNAPL source in the vadose zone. This vapor distribution developed 18 days after placement of a source zone that contained 42 L of TCE.

Adapted from: Pankow, J. F. and J. A. Cherry. *Dense Chlorinated Solvents and Other DNAPLS in Groundwater*. Portland, Oregon: Waterloo Press, 1996.

Results of experiment by University of Waterloo with emplaced source at Borden experimental aquifer.

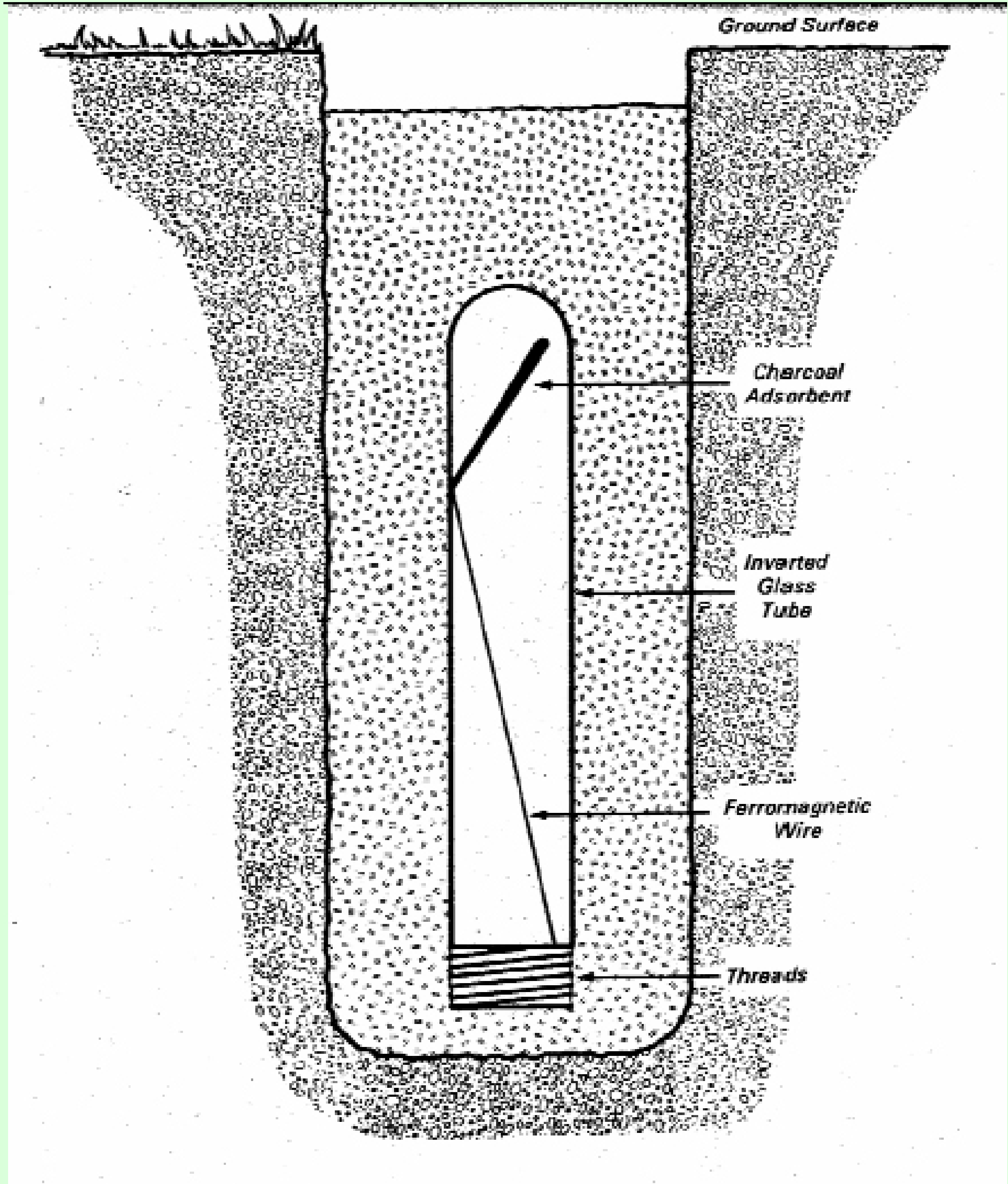


Example of the decline in TCE vapor concentrations with distance from the DNAPL source in the vadose zone. This profile corresponds to the section line shown in the figure on the previous slide.

Adapted from: Pankow, J. F. and J. A. Cherry. *Dense Chlorinated Solvents and Other DNAPLS in Groundwater*. Portland, Oregon: Waterloo Press, 1996.

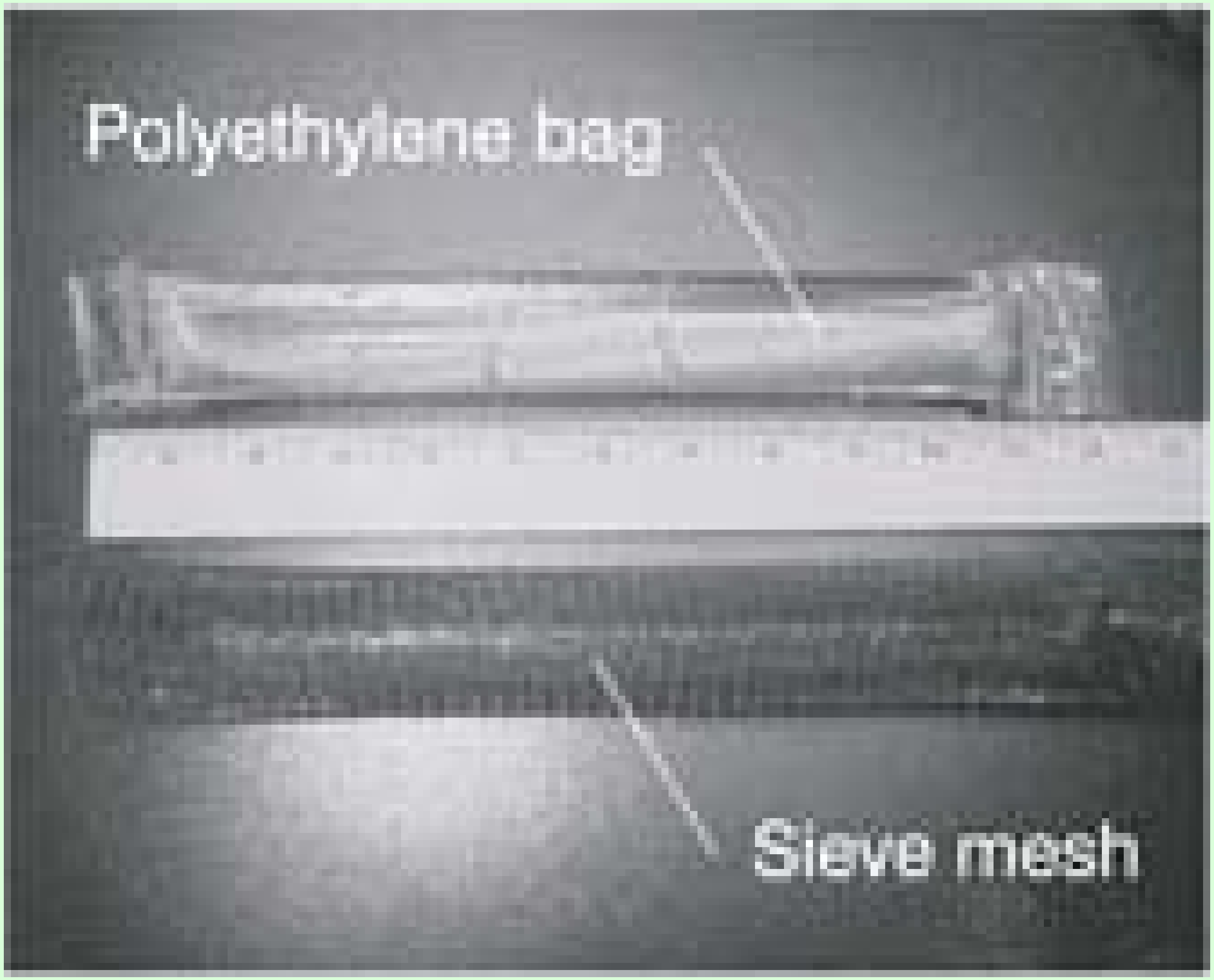
Note rapid decrease in soil gas concentration with distance from source.

Passive soil gas collector



Source: U.S. EPA, 1993. Subsurface characterization and monitoring techniques: A desk reference guide. Report Number EPA/625/R-93/003. Center for Environmental Research Information, U.S. Environmental Protection Agency, Cincinnati, Ohio. May 1993. Figure 9.4.1, pg. 9-39.

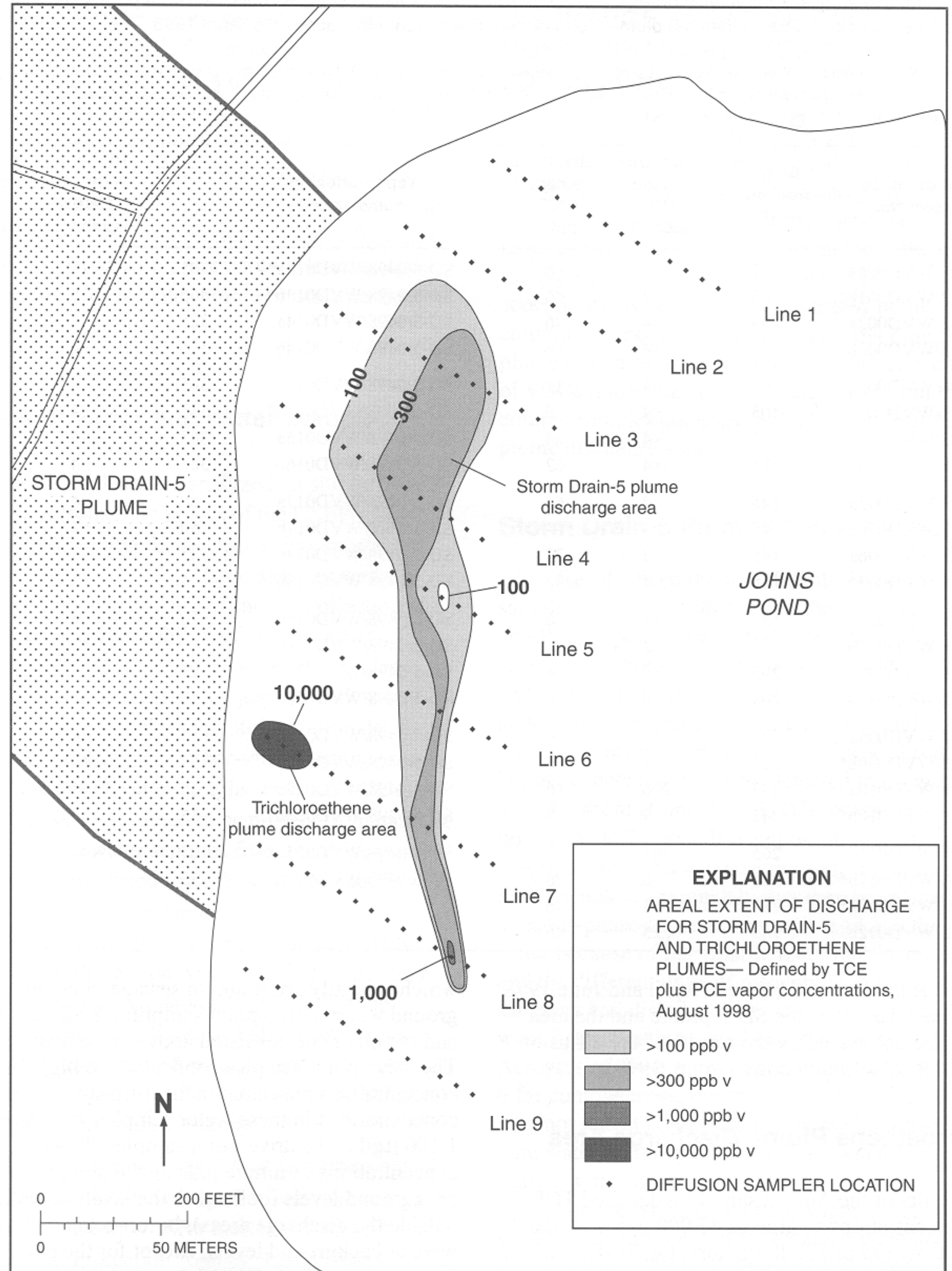
Passive diffusion sampler for water phase



Source: United Stated Geological Survey, August 23, 2001. Water Resources of New Hampshire and Vermont: New Contaminant Sampling Method Tested at Superfund Site in Milford, MA. U.S. Department of the Interior, U.S. Geological Survey, New Hampshire/Vermont District. Pembroke, NH. http://vt.water.usgs.gov/.../2001Newsletter/ contaminant.htm. Accessed January 11, 2002.

Diffusion sampler results for Ashumet Pond, Cape Cod

Source: Savoie, J. G., D. R. LeBlanc, D. S. Blackwood, T. D. McCobb, R. R. Rendigs, and S. Clifford, 2000. Delineation of Discharge Areas of Two Contaminant Plumes by Use of Diffusion Samplers, Johns Pond, Cape Cod, Massachusetts, 1998. Water-Resources Investigations Report 00-4017. U.S. Geological Survey, Northborough, Massachusetts.



Field vapor analyzers

OVA Flame Ionization Detector – aliphatics, aromatics, haloethanes, Halomethanes

HNu Photoionization Detector – aliphatics and aromatics

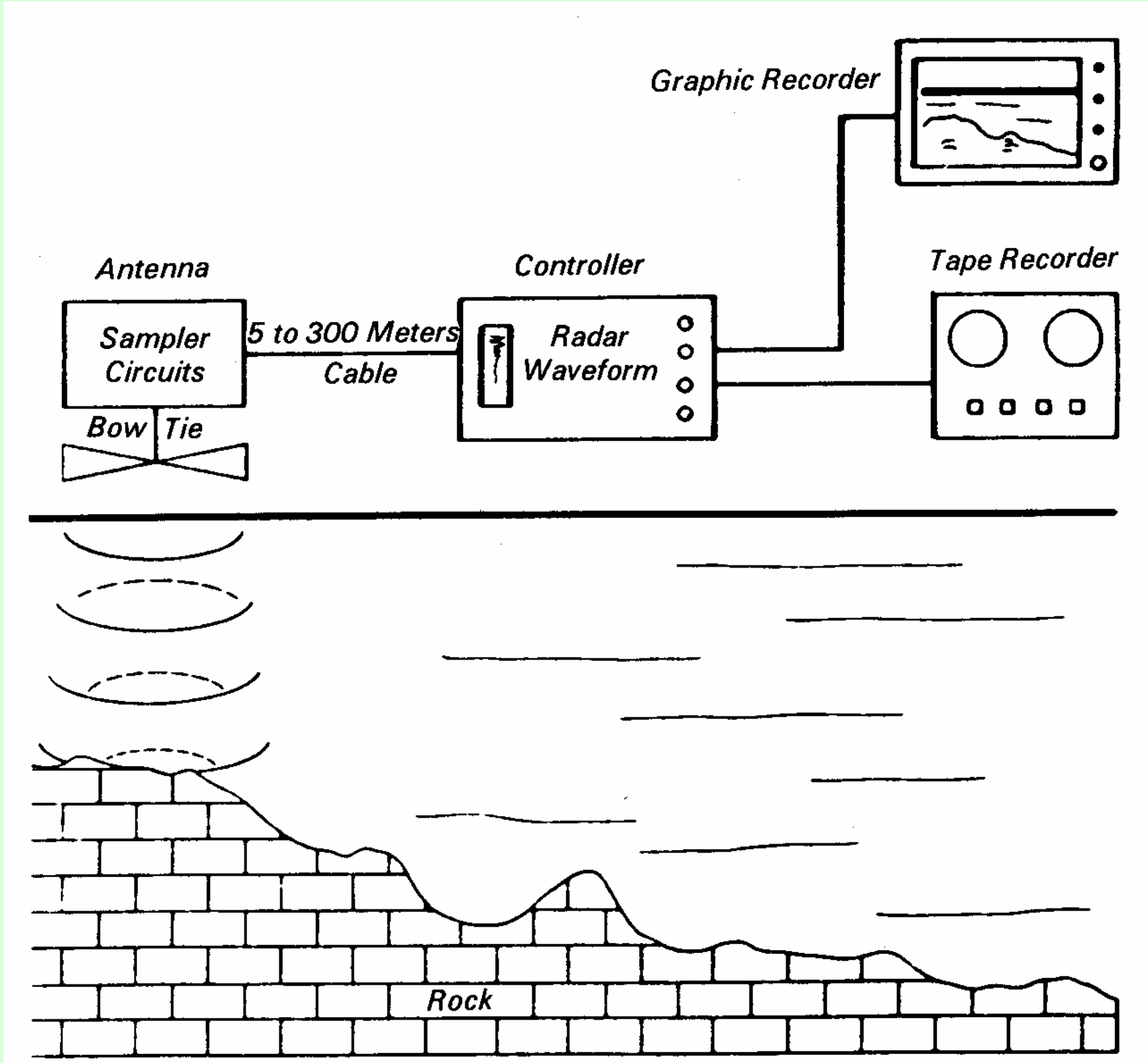
Field vapor analyzer in use

Source: Environmental Protection Agency, Region 10 Inspection Office. http://www.epa.gov/r10earth/offices/oea/ieu/manual/gallery.htm. Accessed May 11, 2004.

Geophysical Methods

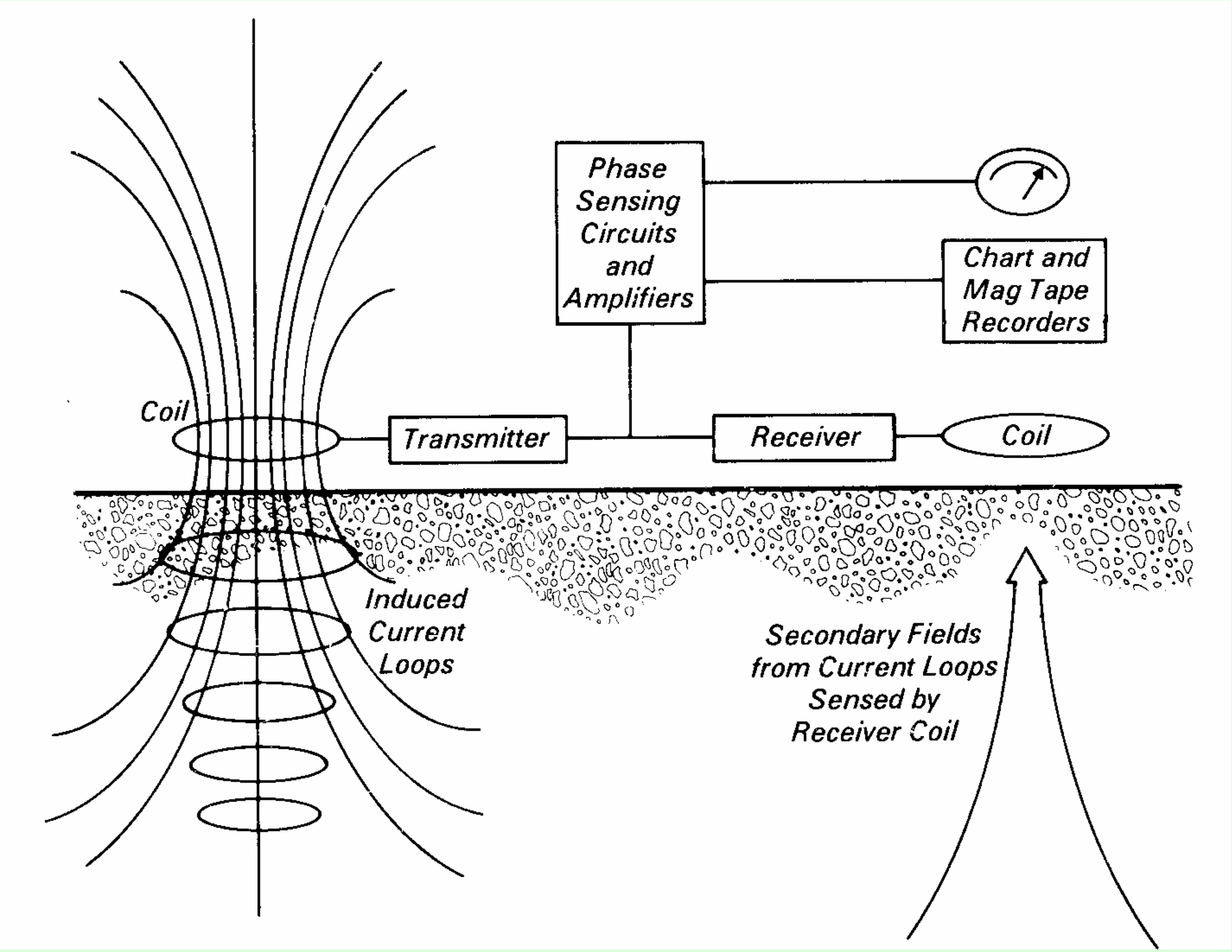
Method	Object
Electrical resistivity	Map conductive or nonconductive contaminants; stratigraphy
Electromagnetic induction	Map conductive or nonconductive contaminants; metal objects; stratigraphy
Seismic refraction	Stratigraphy (top of bedrock); depth to ground water
Seismic reflection	High resolution mapping of top of bedrock
Ground penetrating radar (GPR)	Buried objects (plastic and metal); stratigraphy; depth to ground water
Magnetometry	Buried metal objects
Gravity survey	Overburden thickness; landfill boundaries

Ground penetrating radar



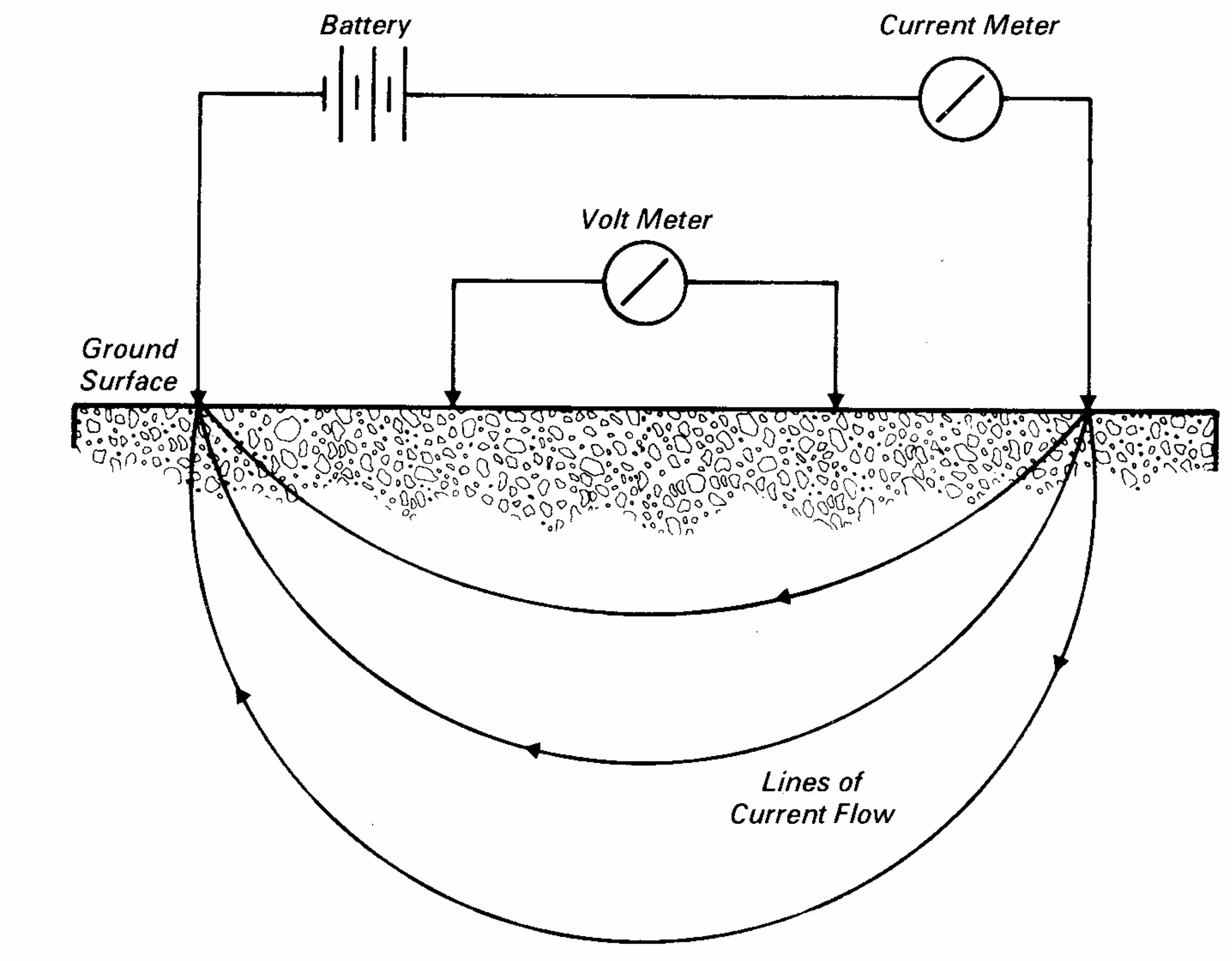
Source: van Ea, J. J., 1985. Project Summary: Geophysical Techniques for Sensing Buried Wastes and Waste Migration. Report Number EPA/600/S7-84/064. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada. May 1985.

Electromagnetic Induction



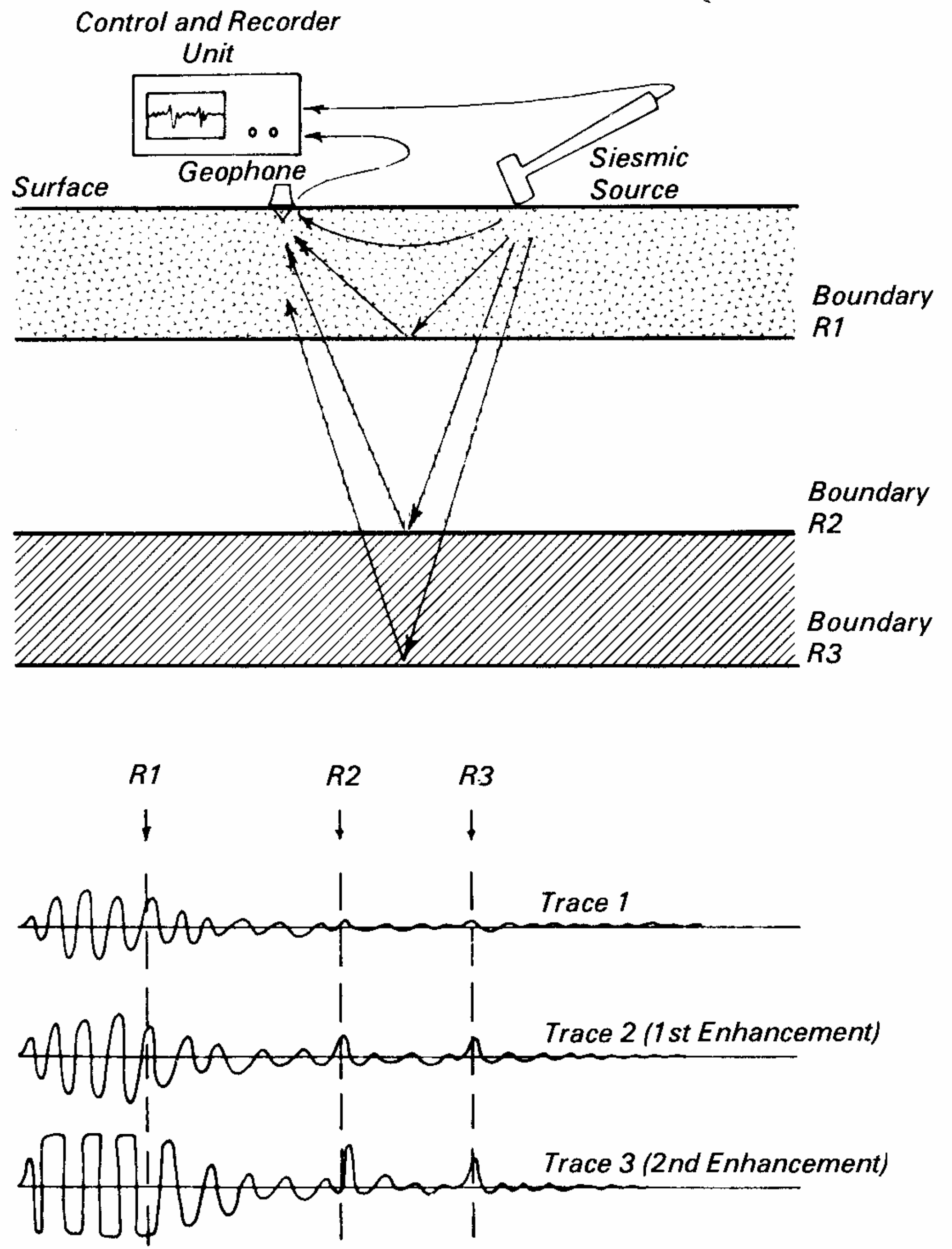
Source: van Ea, J. J., 1985. Project Summary: Geophysical Techniques for Sensing Buried Wastes and Waste Migration. Report Number EPA/600/S7-84/064. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada. May 1985.

Electrical resistivity



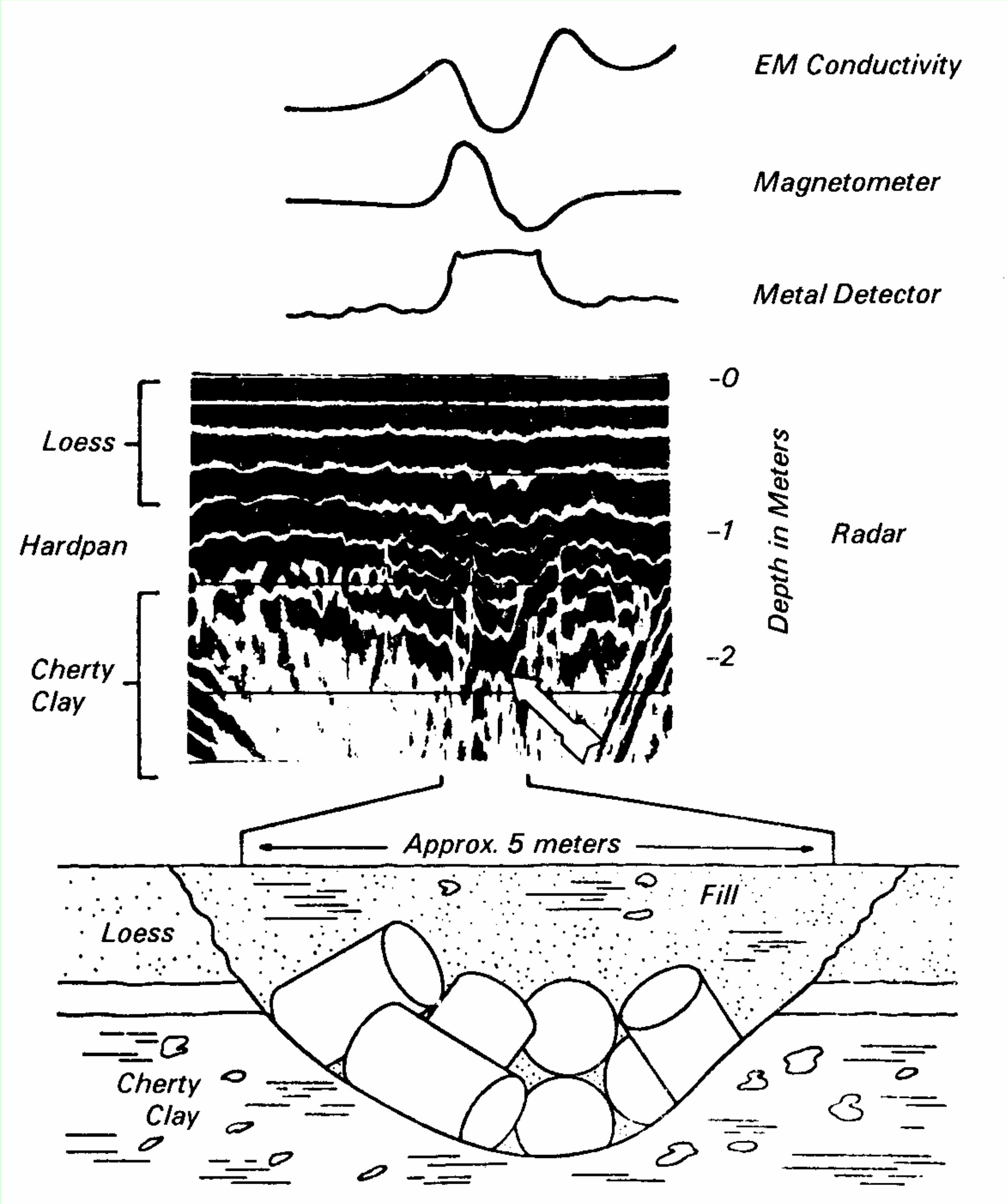
Source: van Ea, J. J., 1985. Project Summary: Geophysical Techniques for Sensing Buried Wastes and Waste Migration. Report Number EPA/600/S7-84/064. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada. May 1985.

Seismic reflection



Source: van Ea, J. J., 1985. Project Summary: Geophysical Techniques for Sensing Buried Wastes and Waste Migration. Report Number EPA/600/S7-84/064. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada. May 1985.

Geophysics suite

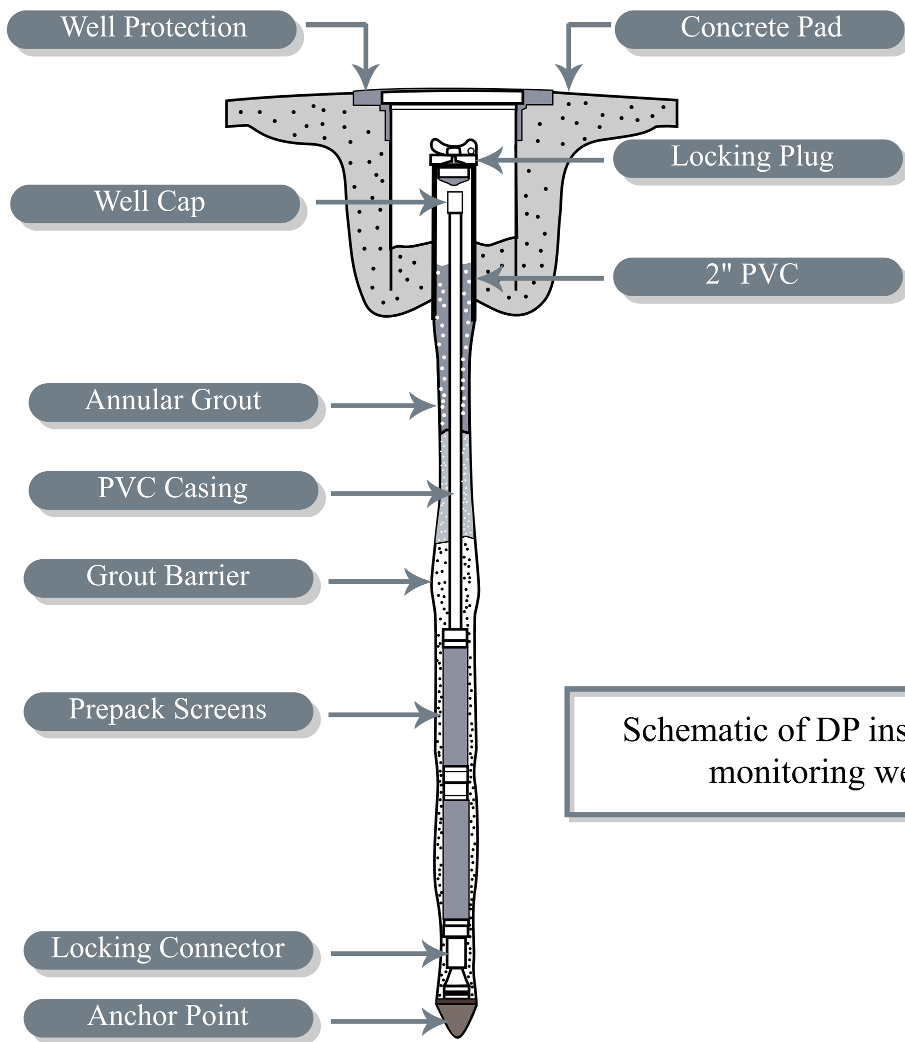


Source: van Ea, J. J., 1985. Project Summary: Geophysical Techniques for Sensing Buried Wastes and Waste Migration. Report Number EPA/600/S7-84/064. Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, Nevada. May 1985.

Direct-push technology (Geoprobe)

Source: Environmental Protection Agency, Region 9, Charnock MTBE Cleanup Project. http://www.epa.gov/region09/cross_pr/mtbe/charnock/site23.html. Accessed May 11, 2004.

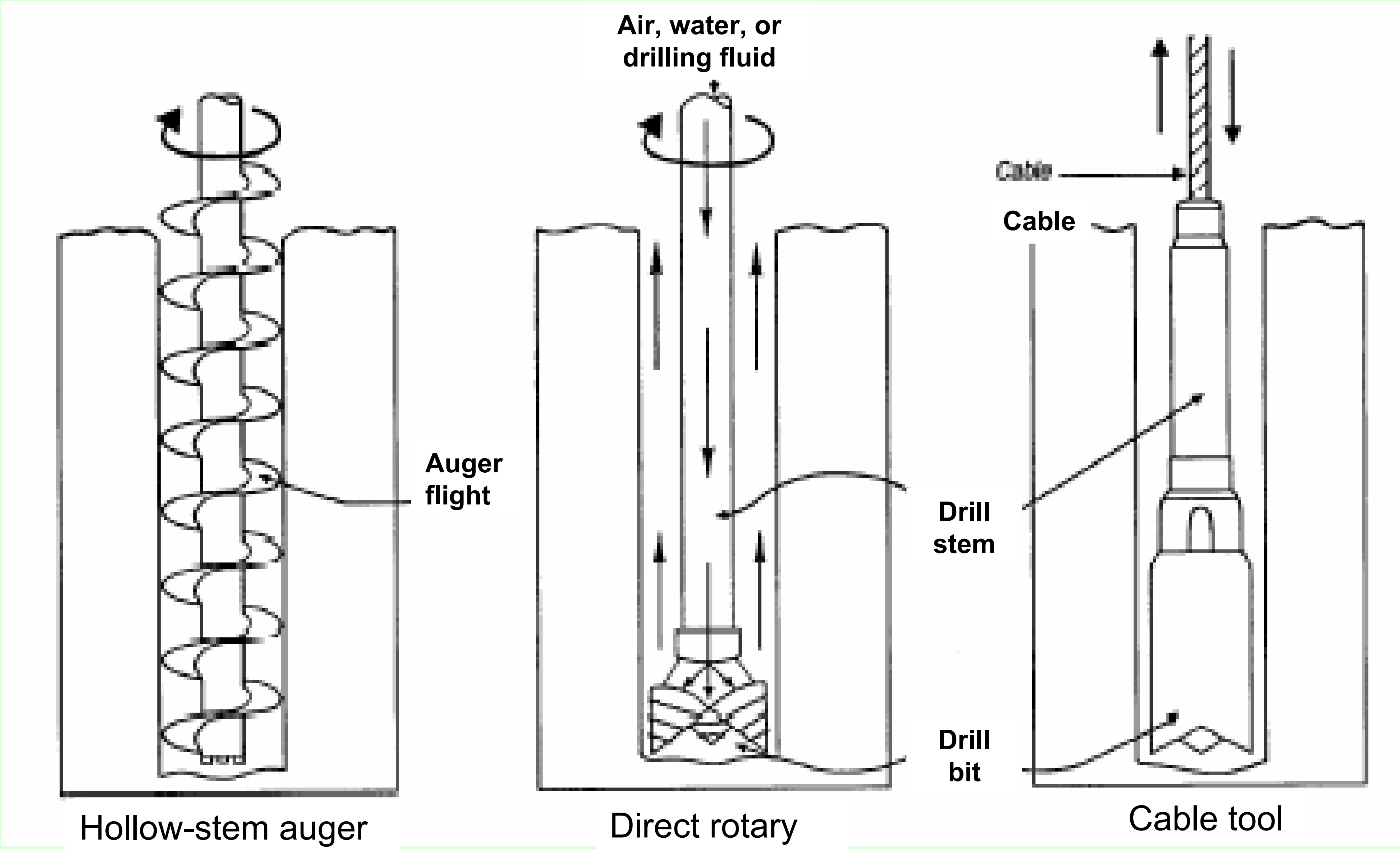
Direct-push monitoring well



Schematic of DP installed small diameter monitoring well construction.

Adapted from: McCall, W. "Getting a Direct Push." *Environmental Protection* 13, no. 7 (September 2002): 49-53.

Drilling techniques



Note: hollow-stem augering can cause smearing of well wall.
Cable-tool also called percussion drilling. Drive-and-wash is similar, but circulates water to wash cuttings out of hole.
Also Barber rig: spins in a pipe fitted with cutting bits.
Ultrasonic and vibratory – vibrates casing into soft formations.

Hollow Stem Auger

Source: Environmental Protection Agency, Underground Storage Tanks Office.
http://www.epa.gov/swerust1/graphics/miscpix1.htm. Accessed May 11, 2004.

Dual-rotary drilling technique

(Dual-rotary or Barber rig)

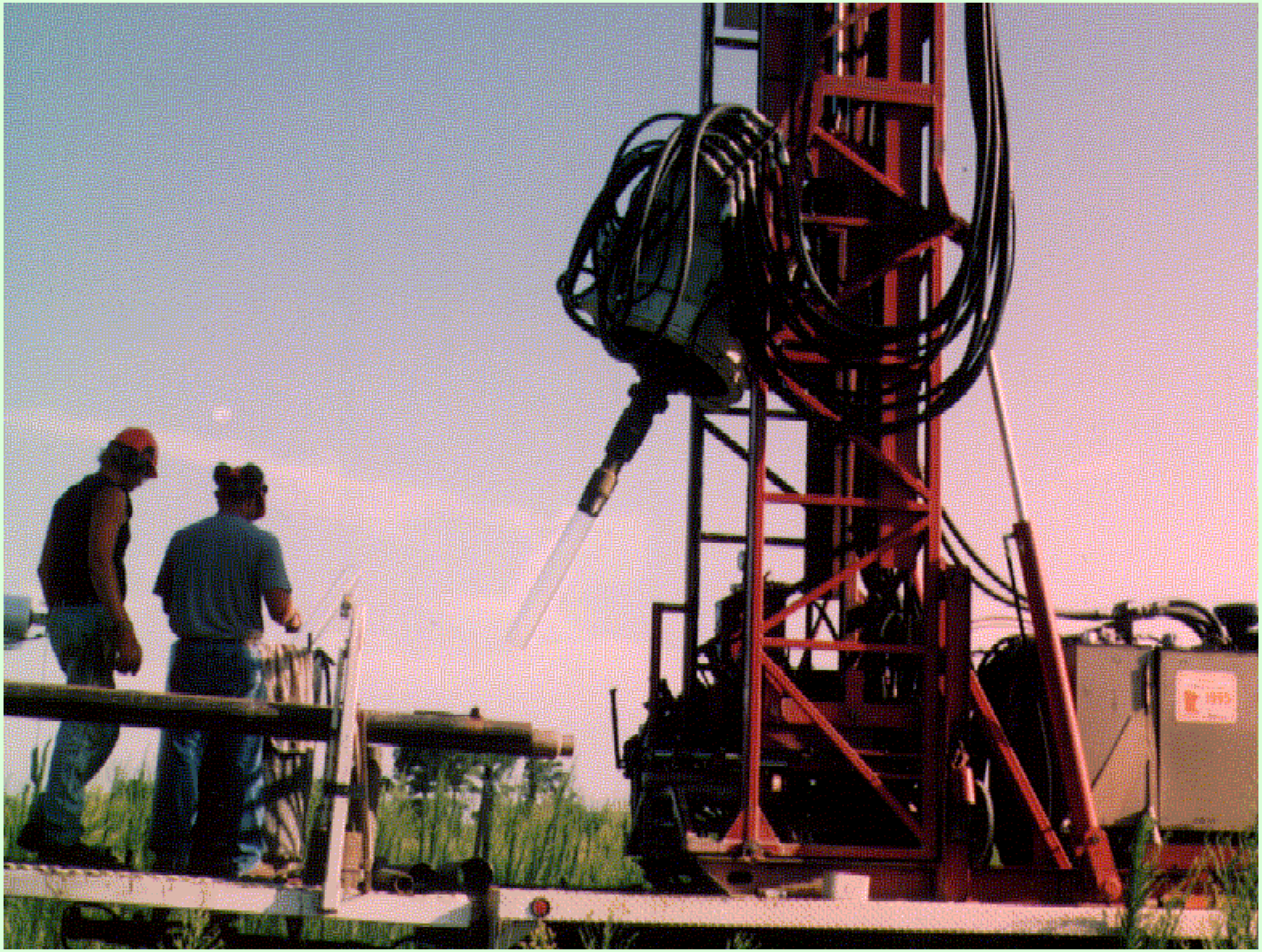
See images of the dual-rotary drilling technique at the Web site of Hanjin Drilling Company Ltd.: http://www.hjdrilling.com/dual_rotary_drill.htm

and the Web site of Foremost Industries L.P.: http://www.foremost.ca/gallery/dr/dr12w01.jpg

(Accessed May 11, 2004.)

Sonic drilling

The drill stem and sampler barrel are vibrated vertically at frequencies between about 50 and 180 Hz such that the sampler barrel normally advances by slicing through the soil.



Source: Oak Ridge National Laboratory, Environmental Sciences Division. http://www.esd.ornl.gov/programs/microbes/currproj.html. Accessed May 11, 2004.

Truck-mounted drill rig

Note safety concerns in drilling:
- Overhead power lines
- Buried utility lines
- Dangerous equipment

Source: Warwick, Peter D., Geologic Assessment of Coal in the Gulf Coastal Plain, U.S. Geological Survey, http://energy.er.usgs.gov/NCRA/Gulf_Coast_A.htm. Accessed May 11, 2004.

Core barrel sampler

Source: M.L. Beutner, August 1988, U.S. Geological Survey, http://nevada.usgs.gov/adrs/pg_soil7.html. Accessed May 11, 2004.

Split-spoon sampler and sample cores

Source: Nevada Division of Environmental Protection, Nellis Air Force Base site, http://ndep.nv.gov/boff/nellis02.htm. Accessed May 11, 2004.

Issues in Field Sampling

Safety

DIG-SAFE

Cross contamination

Artifacts

QA/QC

Field Screening

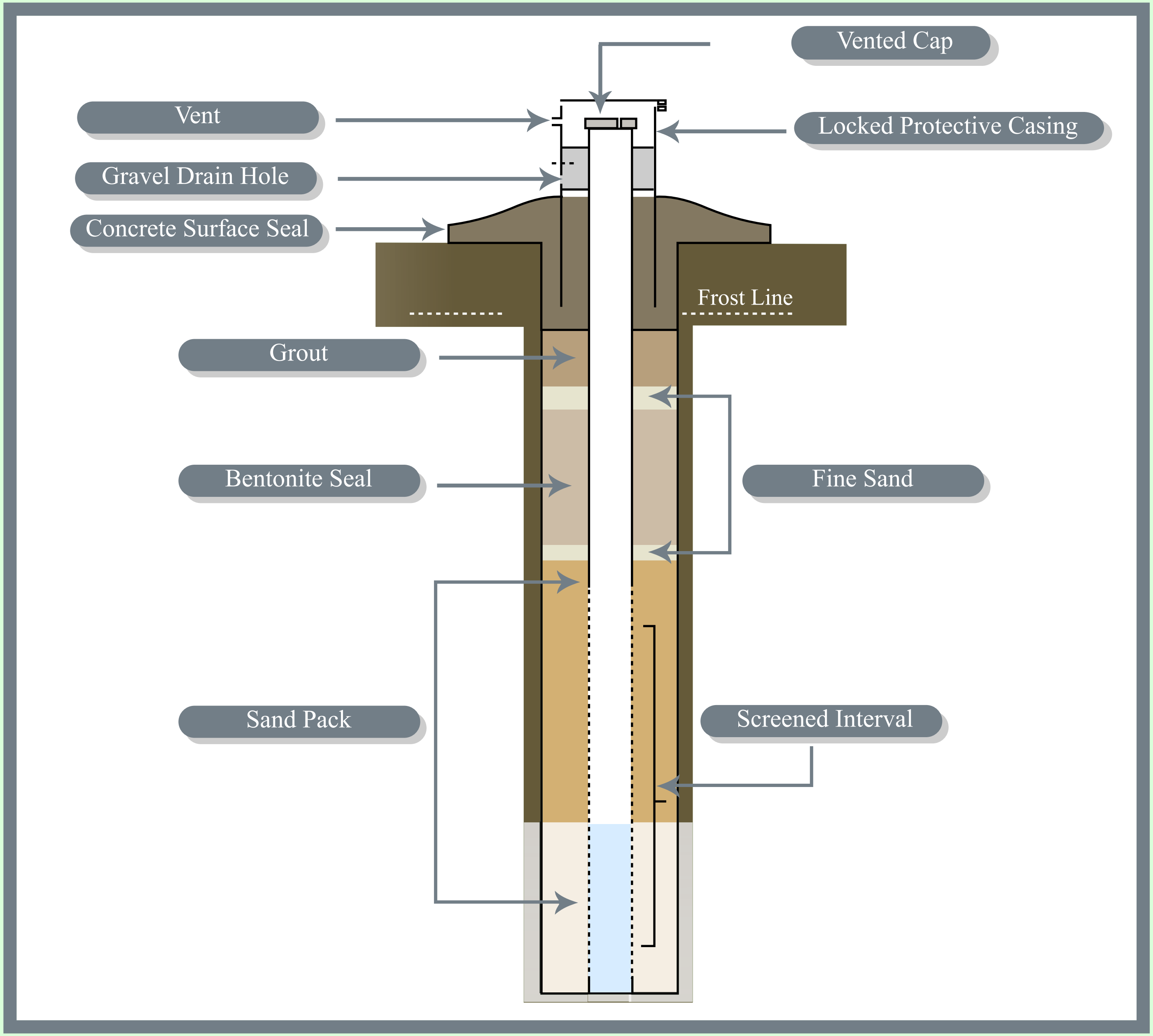
Sampling Handling

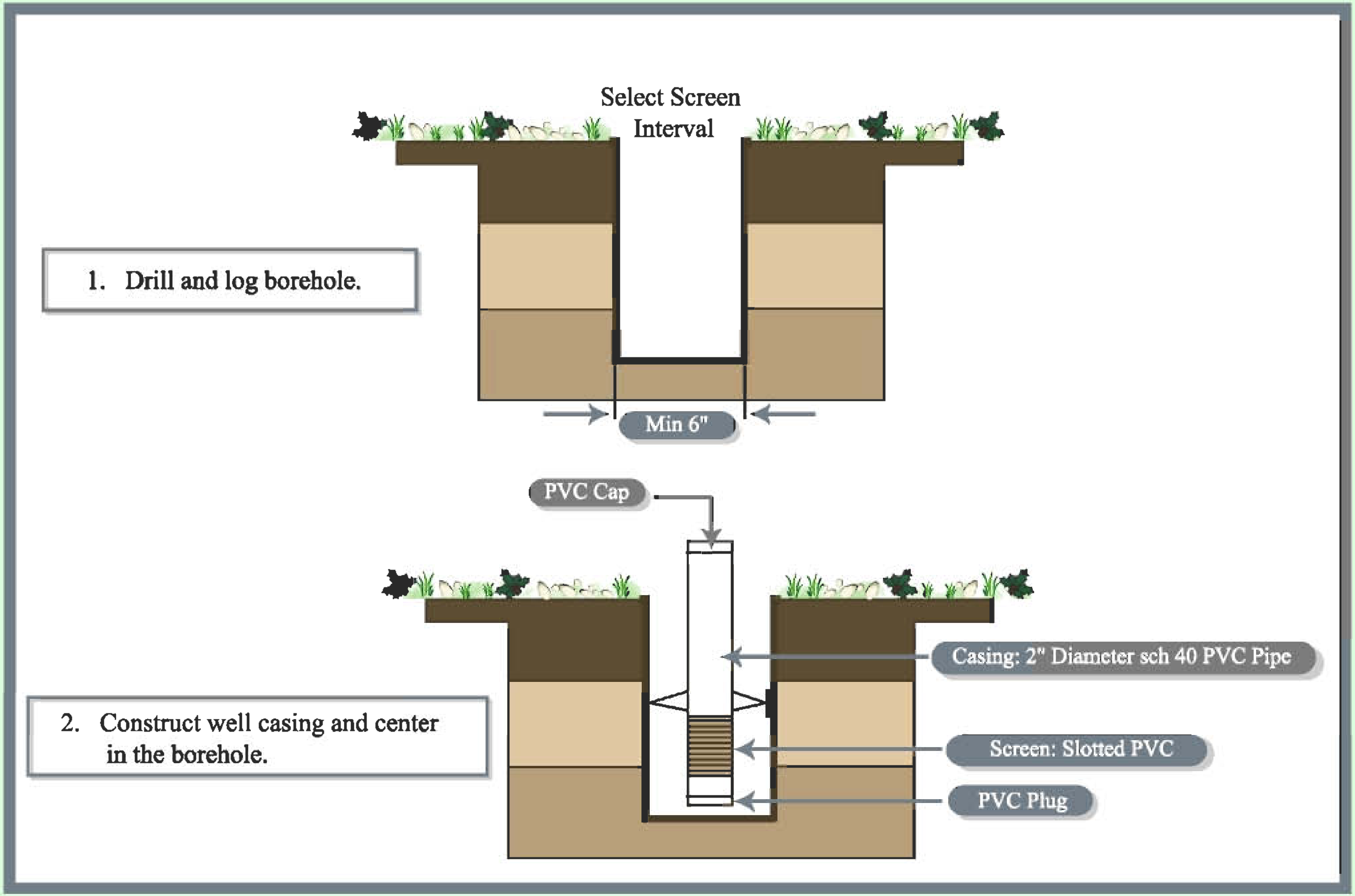
Potential Artifacts

Methylene chloride, MEK, chloroform, carbon tet.	Laboratory solvents
Phthalates	Plasticizers in tubing
Trihalomethanes (chloroform)	Domestic water
Acetone, isopropyl alcohol, hexane	Field decontaminants
Barium, high pH	Drilling fluid, grout
Carbon disulfide, methyl chloride	Natural chemicals
MEK	Duct tape

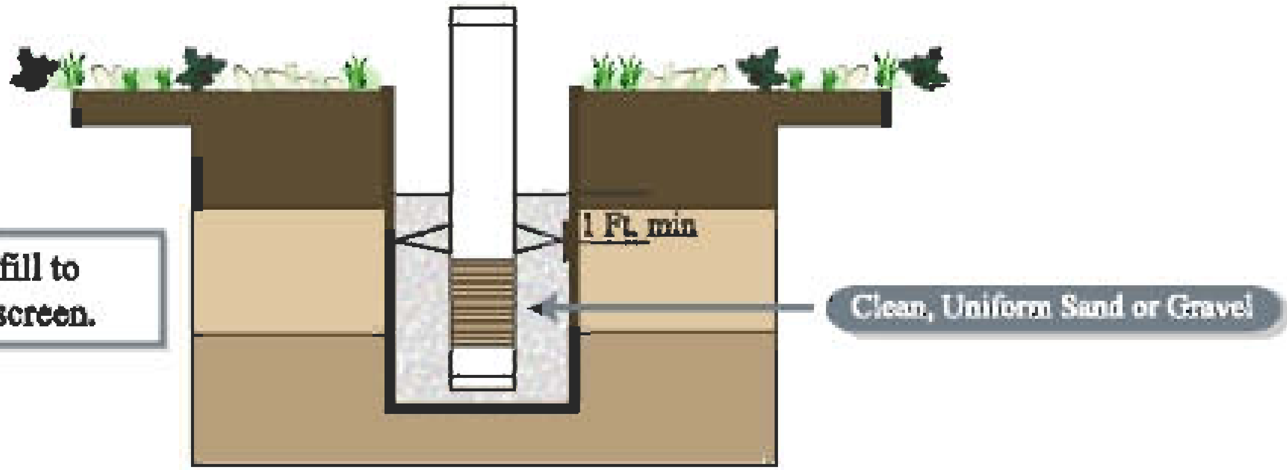
Source: Morrison, R. D., 1999. *Environmental Forensics: Principles and Applications*. CRC Press, Boca Raton, Florida.

Components of monitoring well

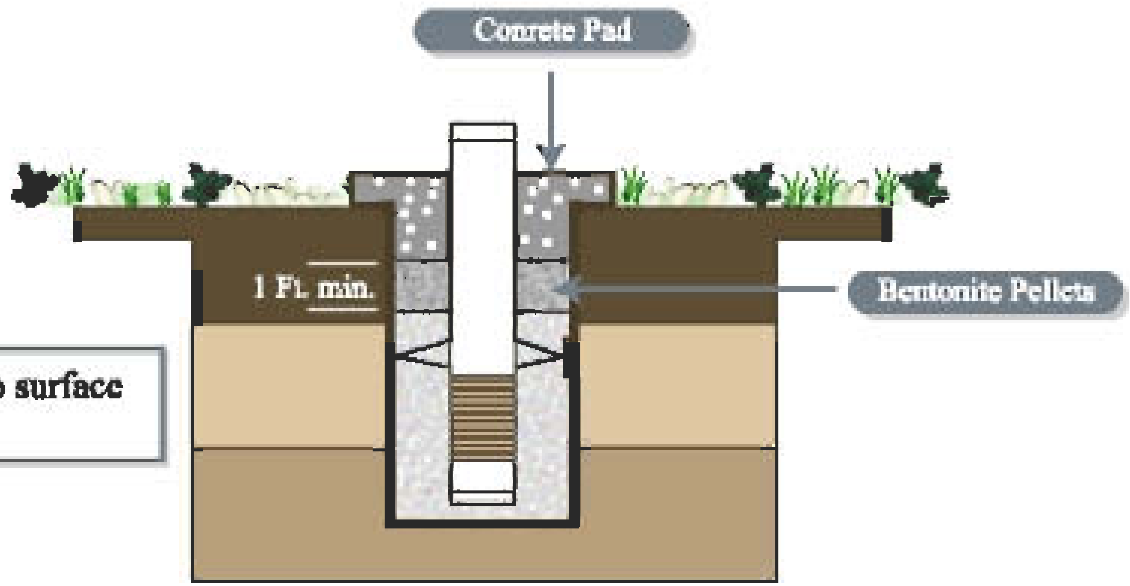



Select Screen Interval
1. Drill and log borehole.
Min 6"
PVC Cap
Casing: 2" Diameter sch 40 PVC Pipe
2. Construct well casing and center in the borehole.
Screen: Slotted PVC
PVC Plug

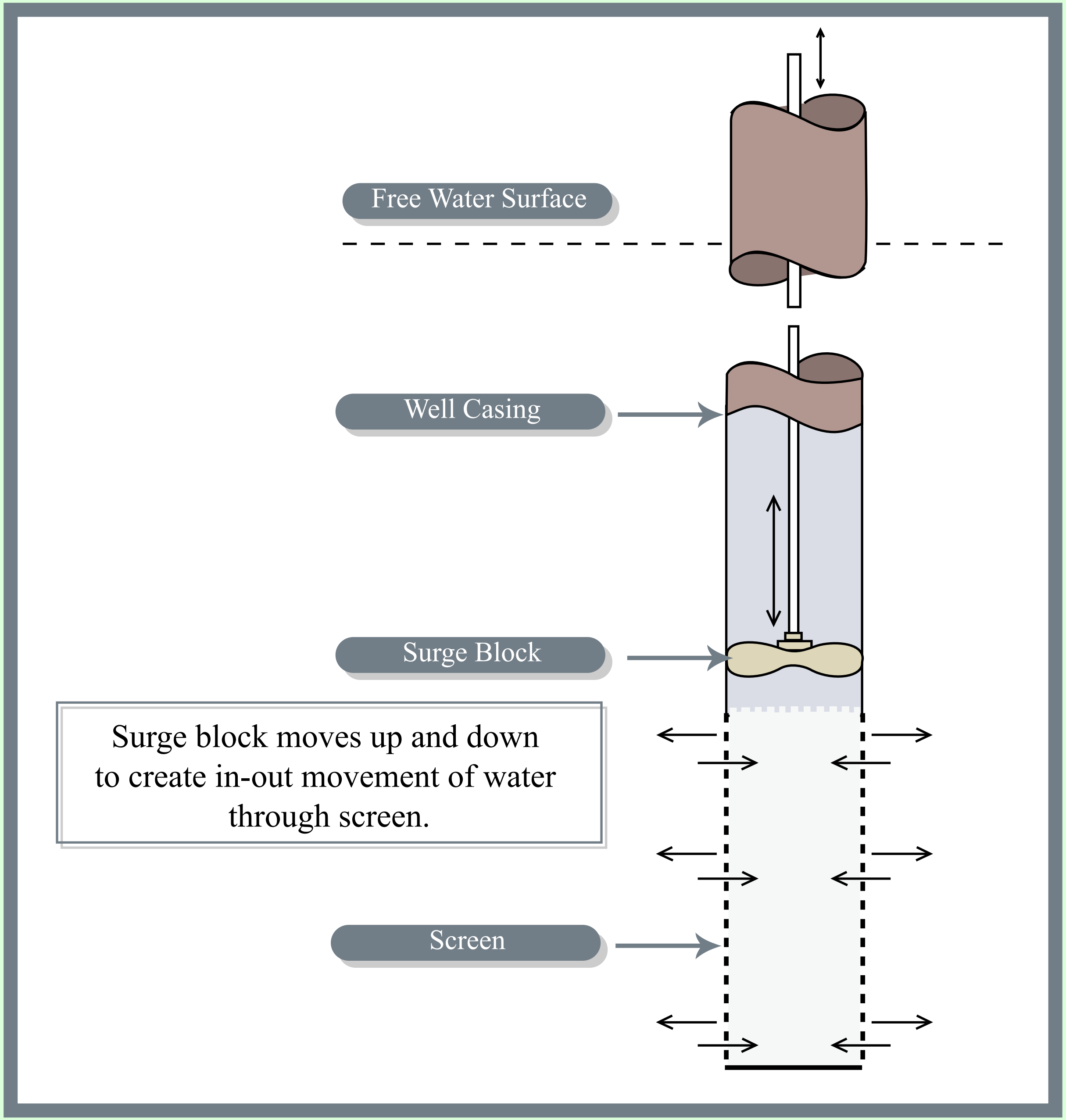
3. Install clean, coarse backfill to 1 ft. height above top of screen.



4. Add bentonite seal. Grout to surface pad. Wait 24 hr to develop.



Well development by surge block

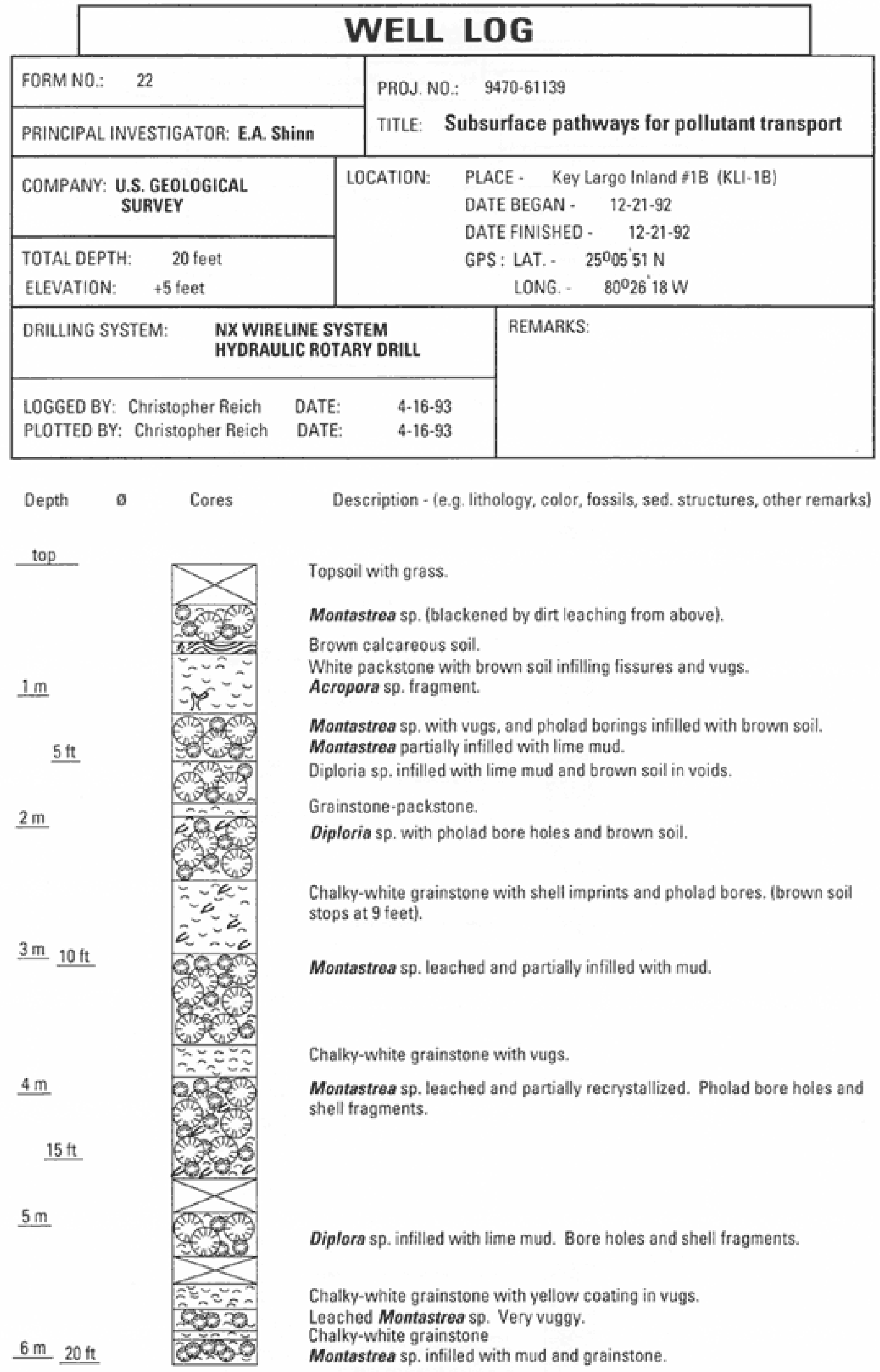


Surge block

See image at the Web site of Robertson GeoConsultants, Inc., RGC Image Library, Technology Themes, Hydrogeology and Hydrology: http://www.robertsongeoconsultants.com/RGC_Images/pages/RGC_Technical_ThemesHydrogeologyHYFU_rgc027101.asp .
Accessed May 11, 2004.

Well Logs

Source: Shinn, E., R. Reese, and C. Reich. "Fate and Pathways of Injection-Well Effluent in the Florida Keys." US Geological Survey Report OFR 94-276. http://sofia.usgs.gov/publications/ofr/94-276/appendixb.html. Accessed May 11, 2004.



WELL LOG

FORM NO.: 22	PROJ. NO.: 9470-61139
PRINCIPAL INVESTIGATOR: **E.A. Shinn**	TITLE: **Subsurface pathways for pollutant transport**
COMPANY: **U.S. GEOLOGICAL SURVEY**	LOCATION: PLACE - Key Largo Inland #1B (KLI-1B); DATE BEGAN - 12-21-92; DATE FINISHED - 12-21-92; GPS: LAT. - 25°05'51 N; LONG. - 80°26'18 W
TOTAL DEPTH: 20 feet; ELEVATION: +5 feet	
DRILLING SYSTEM: **NX WIRELINE SYSTEM HYDRAULIC ROTARY DRILL**	REMARKS:
LOGGED BY: Christopher Reich DATE: 4-16-93; PLOTTED BY: Christopher Reich DATE: 4-16-93	

Depth | ø | Cores | Description - (e.g. lithology, color, fossils, sed. structures, other remarks)

top

Topsoil with grass.

Montastrea sp. (blackened by dirt leaching from above).

Brown calcareous soil.

White packstone with brown soil infilling fissures and vugs.

Acropora sp. fragment.

1 m

Montastrea sp. with vugs, and pholad borings infilled with brown soil.

Montastrea partially infilled with lime mud.

5 ft

Diploria sp. infilled with lime mud and brown soil in voids.

Grainstone-packstone.

2 m

Diploria sp. with pholad bore holes and brown soil.

Chalky-white grainstone with shell imprints and pholad bores. (brown soil stops at 9 feet).

3 m 10 ft

Montastrea sp. leached and partially infilled with mud.

Chalky-white grainstone with vugs.

4 m

Montastrea sp. leached and partially recrystallized. Pholad bore holes and shell fragments.

15 ft

5 m

Diplora sp. infilled with lime mud. Bore holes and shell fragments.

Chalky-white grainstone with yellow coating in vugs.

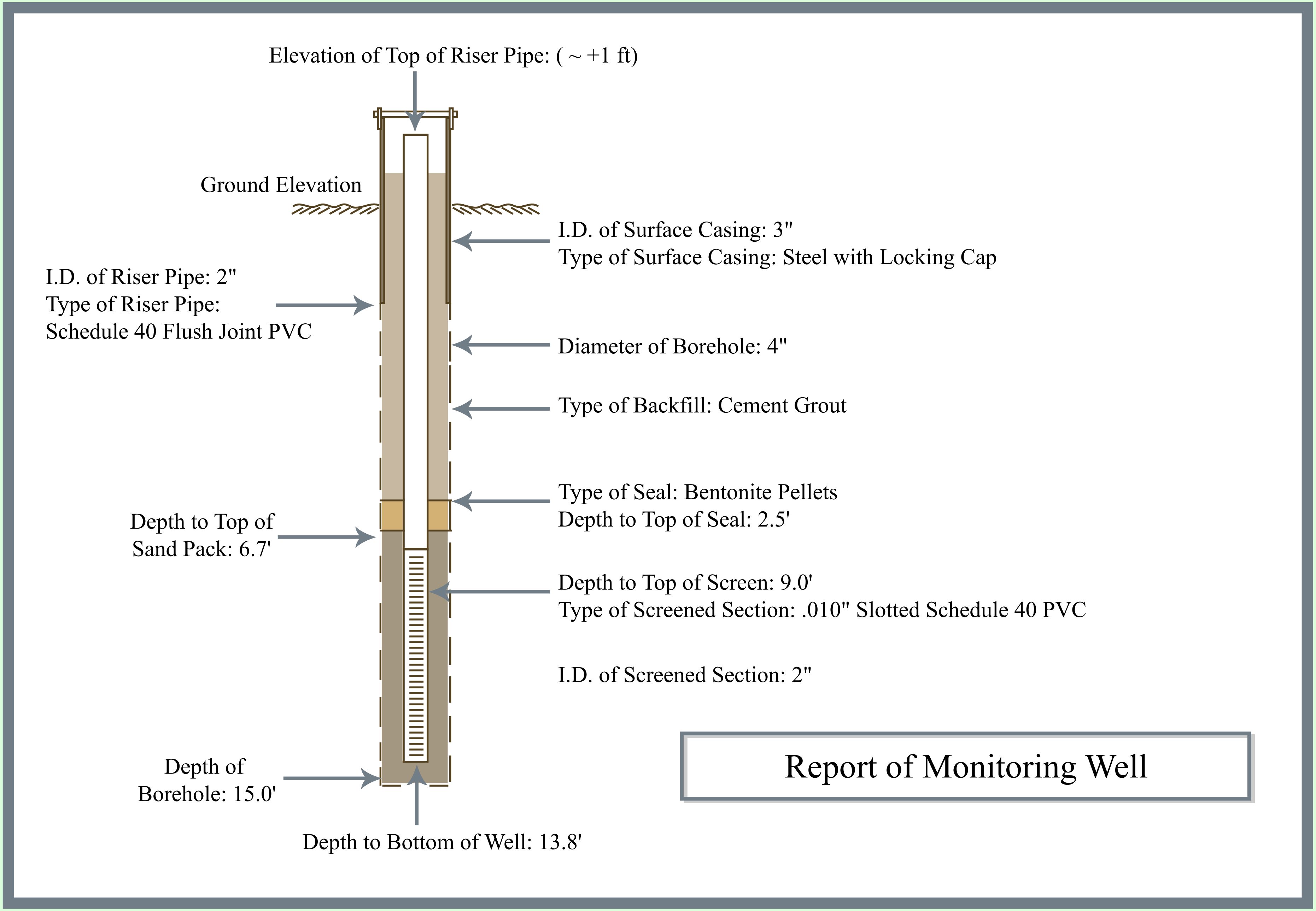
Leached ***Montastrea*** sp. Very vuggy.

Chalky-white grainstone

6 m 20 ft

Montastrea sp. infilled with mud and grainstone.

Well installation Diagram ("Well cartoon")



Driller's Log

March 5, 1945

John J. Riley Co.
228 Salem Street
Woburn, MA.

Gentlemen:

We are submitting herewith a log of test and observation wells as driven by us recently on your property near your present pumphouse.

Test Well #1

0 - 2'	Loam
2' - 15'	Brown medium sand
15' - 20'	Gray fine sand to rock
	Tight - did not pump freely.

Test Well #2

0 - 3'	Mud and loam
3' - 18'	Medium sand and gravel
18' - 23'	Coarse gravel
23' - 38'	Sand and gravel to rock
	Pumped free - 60 G.P.M.
	Observation Well at 37'
	This well tested for both capacity and drawdown.

It is in our opinion that at location #2 we could develop you, with one of our large diameter gravel filter wells, 500 G.P.M. with a safe drawdown and would run a preliminary test on this well at the above rated capacity for a period of forty-eight hours to determine the actual drawdown on this well.

Example cross sections

Source: Bemidji Crude-Oil Research Project, US Geological Survey, http://mn.water.usgs.gov/bemidji/maps.html. Accessed May 11, 2004.

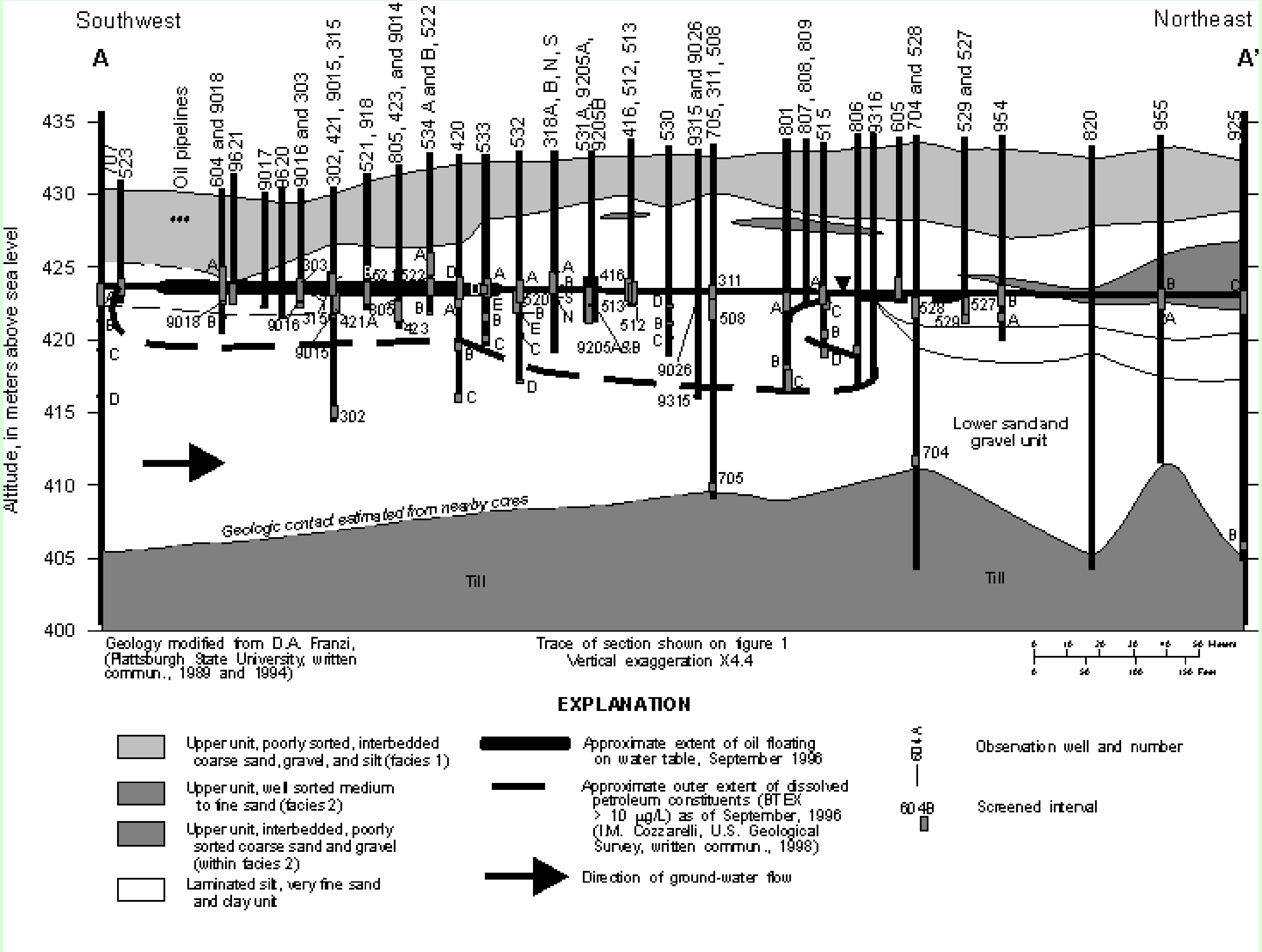
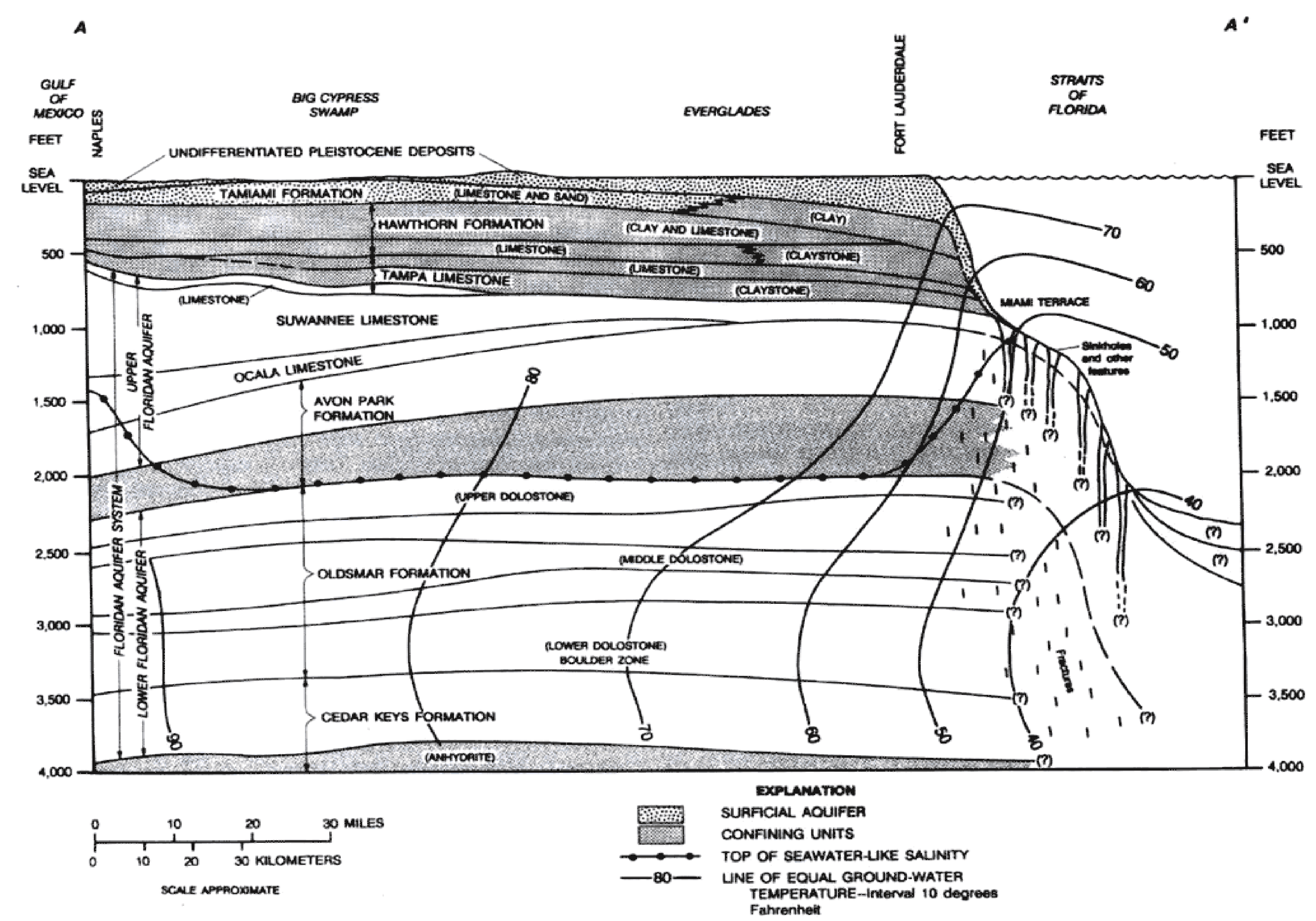
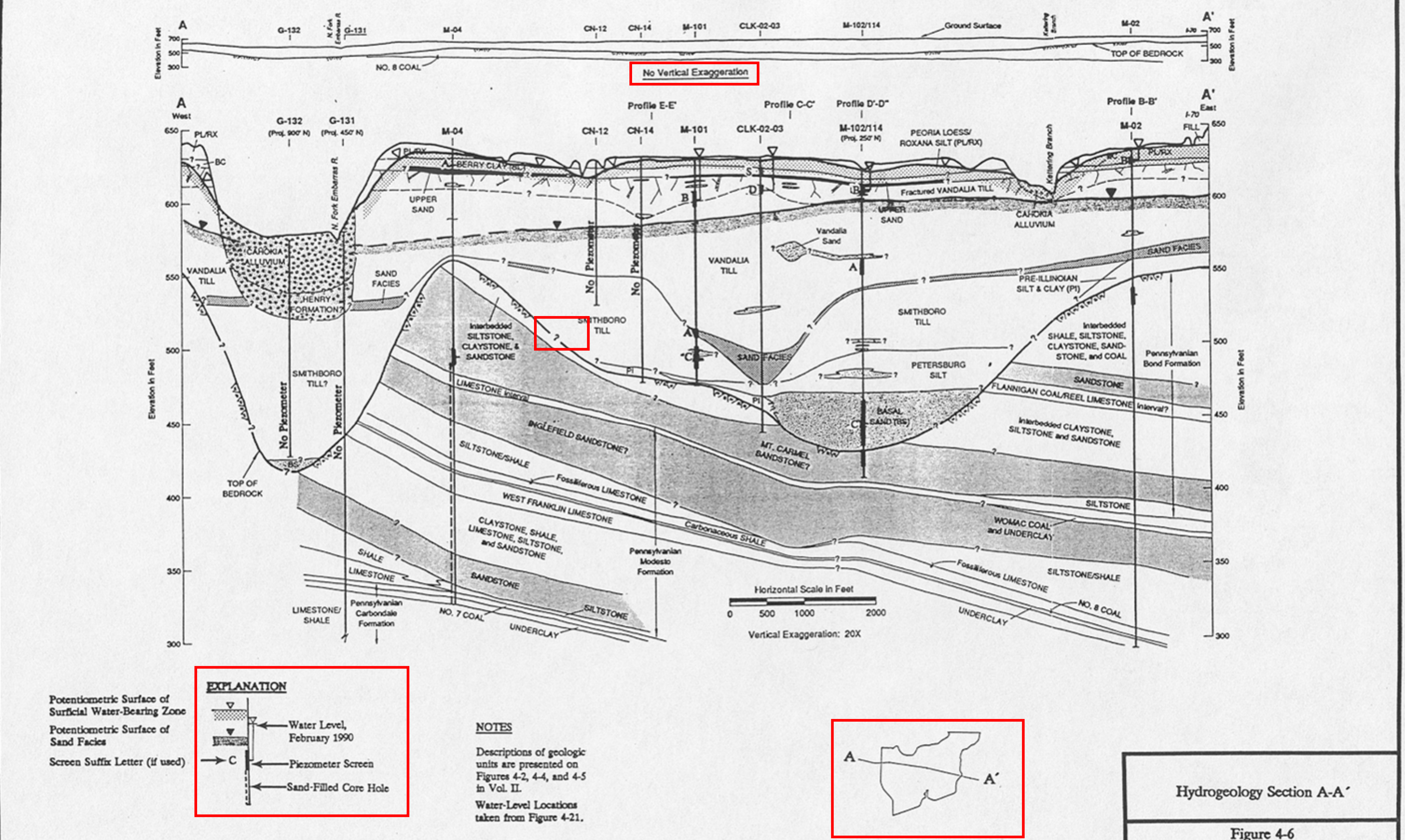


Figure _. Well locations and geology along cross section A-A' in relation to the approximate extent of the plumes of oil and dissolved petroleum constituents, September 1996.

Note vertical exaggeration!

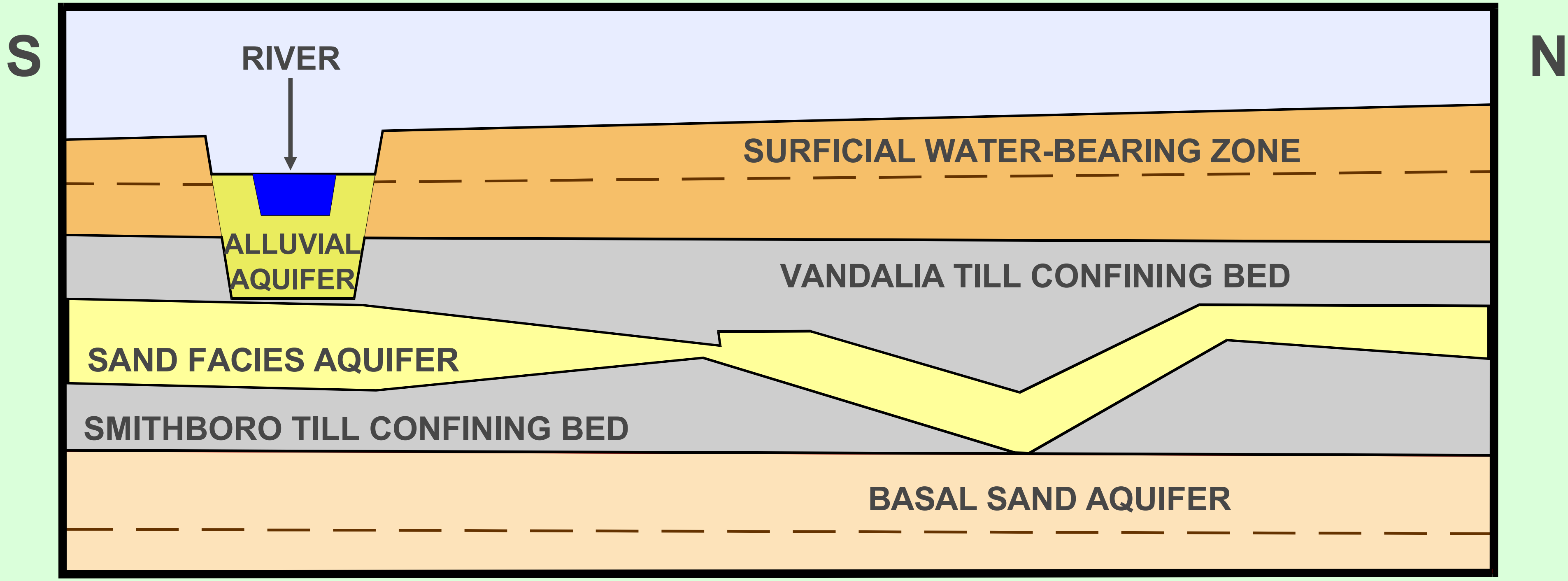


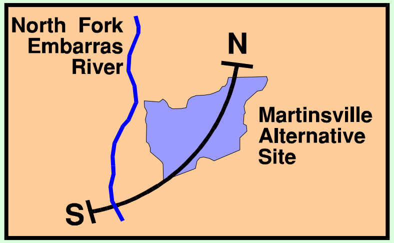
Source: Meyer, F.W. "Hydrogeology of Southern Florida: Floridan Aquifer System." US Geological Survey, http://sofia.usgs.gov/publications/papers/pp1403g/flaqsys.html. Accessed May 11, 2004.



This is a good example of a well-done cross section, particularly for its inclusion of an unexaggerated profile along with the exaggerated.

Martinsville Alternative Site Hydrostratigraphy





Well construction

Flush-mounted well

Source: Johnson Creek Basin Monitoring, US Geological Survey, http://oregon.usgs.gov/projs_dir/or175/htmls_dir/holgate.html. Accessed May 11, 2004.

“Stick-up” well and protective cover

Source: Acadian Pontchartrain (ACAD) Groundwater Studies, US Geological Survey, http://la.water.usgs.gov/nawqa/liaison/gwgeneral.htm. Accessed May 11, 2004.

Water-level meter

See images at the Web site of Solinst Canada Ltd. http://www.solinst.com/Prod/101/101an.html Accessed May 11, 2004.

Bailer for sample collection from wells

See images at the Web site of Solinst Canada Ltd. http://www.solinst.com/Prod/428/428.html Accessed May 11, 2004.

Collection of volatile organics samples

Source: Berndt, M.P., Hatzell, H.H., Crandall, C.A., Turtora, M., Pittman, J.R., and Oaksford, E.T., 1998, "Water Quality in the Georgia-Florida Coastal Plain, Georgia and Florida, 1992-96: U.S. Geological Survey Circular 1151", http://water.usgs.gov/pubs/circ/circ1151/nawqa91.2.html. Accessed May 11, 2004.

Soil sample collection

Stainless steel sampling trowel

Source: Region 10 Superfund: Boomsnub/AIRCO site, US Environmental Protection Agency, http://yosemite.epa.gov/R10/CLEANUP.NSF/0/d4f7133deabb8eea88256a1700634f74?OpenDocument. Accessed May 11, 2004.

Drum Thief or Coliwasa

See image at the Web site of GENEQ Inc.
http://www.geneq.com/catalog/en/coliwasa_liquid_waste.html
Accessed May 11, 2004.

CHAIN OF CUSTODY RECORD

PROJ. NO.	PROJECT NAME	NO. OF CONTAINERS	ANALYSIS	REMARKS
SAMPLERS: (Signature)				

STA. NO.	DATE	TIME	COMP	GRAB	STATION LOCATION	NO. OF CONTAINERS	ANALYSIS						REMARKS

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

Source: "Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. -- Testing Manual," US Environmental Protection Agency, http://www.epa.gov/waterscience/itm/ITM/appxg.htm. Accessed May 11, 2004.

Laboratory Analysis

Full analysis - $1100

(volatiles, semivolatiles, RCRA Appendix 8, pesticides, herbicides)

Volatile organics - $185

Semivolatile organics - $360

RCRA Appendix 8 metals - $110

(As, Ba, Cd, Cr, Pb, Hg, Se, Ag)

TAL metals - $240

(Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Ag, Na, Tl, V, Zn)

Pesticides - $145

Herbicides - $250

Source: Alpha Analytical Labs, Westborough, MA. April 2001 price list

Peristaltic (suction-lift) pump

See images at the Web site of the Georgia Tech course on Environmental Field Methods: http://hydrate.eas.gatech.edu/eas4420/water.htm Accessed May 11, 2004.

Maximum sampling depth ≈ 25 feet ≈ 8 meters

Submersible Pump

See images at the Web site of Noor Scientific and Trade. http://www.noor-scientific.com/survey_groundwater_instruments.htm. Accessed May 11, 2004.

WaTerra Positive Displacement Pump

See images at the Web site of Noor Scientific and Trade. http://www.noor-scientific.com/survey_groundwater_instruments.htm. Accessed May 11, 2004.

Bladder Pump

See images at the Web site of Solinst Canada Ltd. http://www.solinst.com/Prod/407/407d5.html. Accessed May 11, 2004.

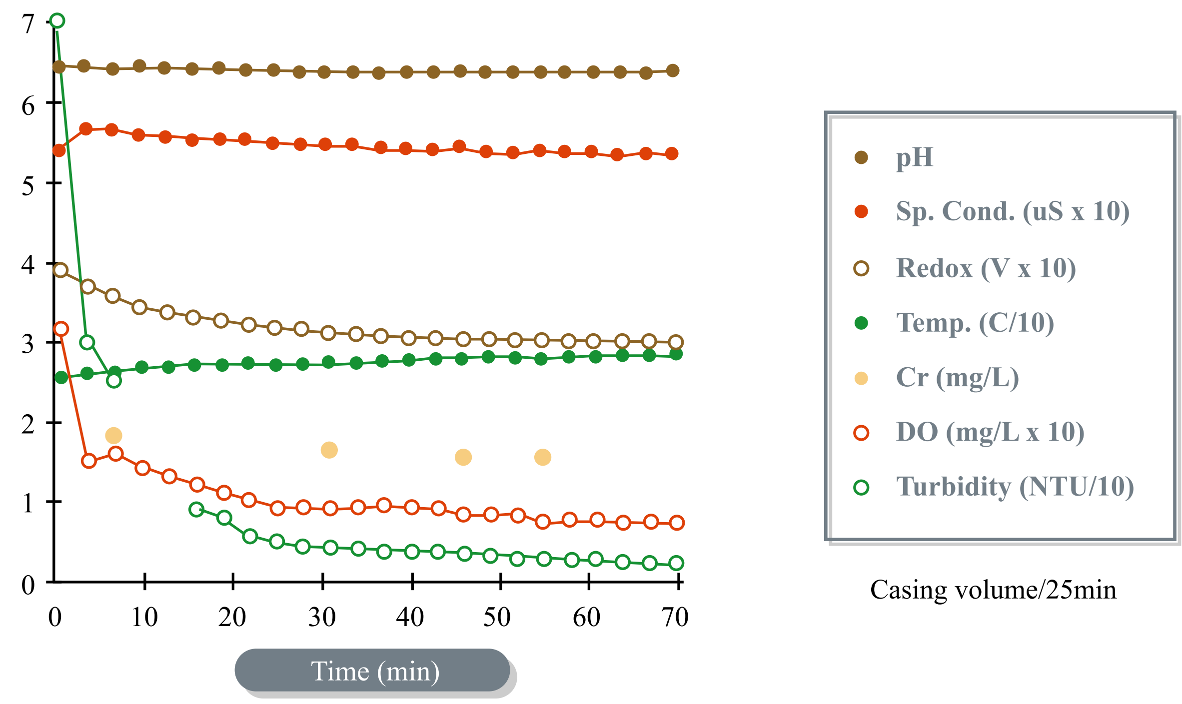
Bladder Pump

See images at the Web site of Solinst Canada Ltd. http://www.solinst.com/Prod/407/407d5.html. Accessed May 11, 2004.

Soil Water Lysimeter

See images at the Web sites of Earth Systems Solutions (http://www.earthsystemssolutions.com/assets/watersampler.htm) and the Wisconsin Department of Natural Resources, Vadose Zone Soil-Water Monitoring (http://www.dnr.state.wi.us/org/water/dwg/gw/dsk-7a.htm). Accessed May 11, 2004.

Well purging before sampling



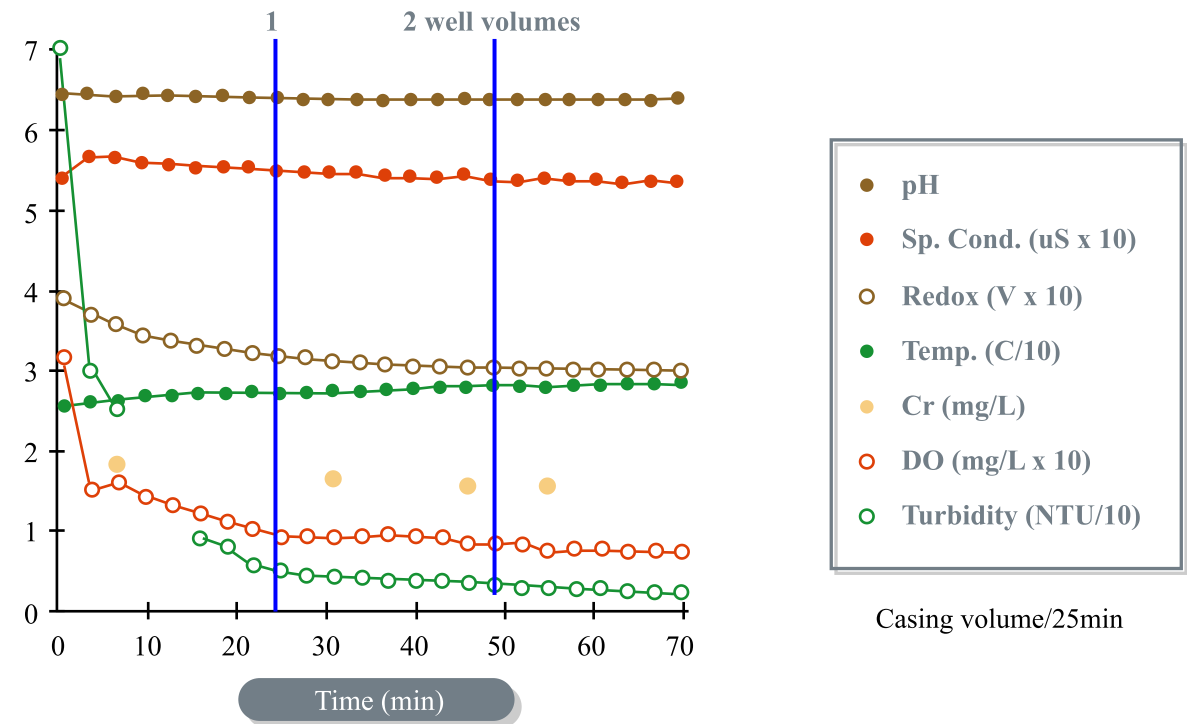
Equilibration of ground water quality indicators during purging and sampling (well 17, Elizabeth City, North Carolina; Grundfos Redi-Flo2 submersible pump, 0.2 L/min).

Adapted from: Puls, R. W. and R. M. Powell. "Acquisition of Representative Ground Water Quality Samples for Metals." *Ground Water Monitoring Review* 12, no. 3 (1992): 167.

Well purging before sampling

Rule of thumb is to purge 3 to 5 well volumes before sampling

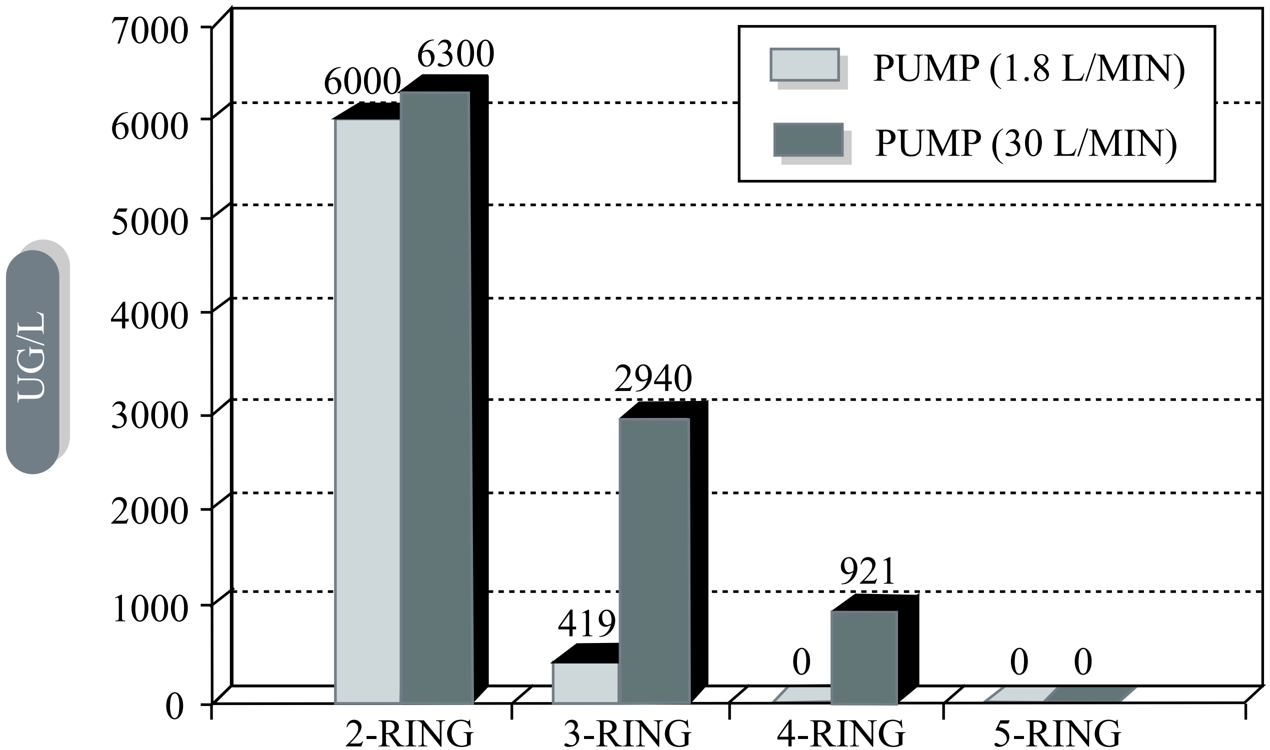
Results from previous slide show stabilization of parameters after around one well volume



Equilibration of ground water quality indicators during purging and sampling (well 17, Elizabeth City, North Carolina; Grundfos Redi-Flo2 submersible pump, 0.2 L/min).

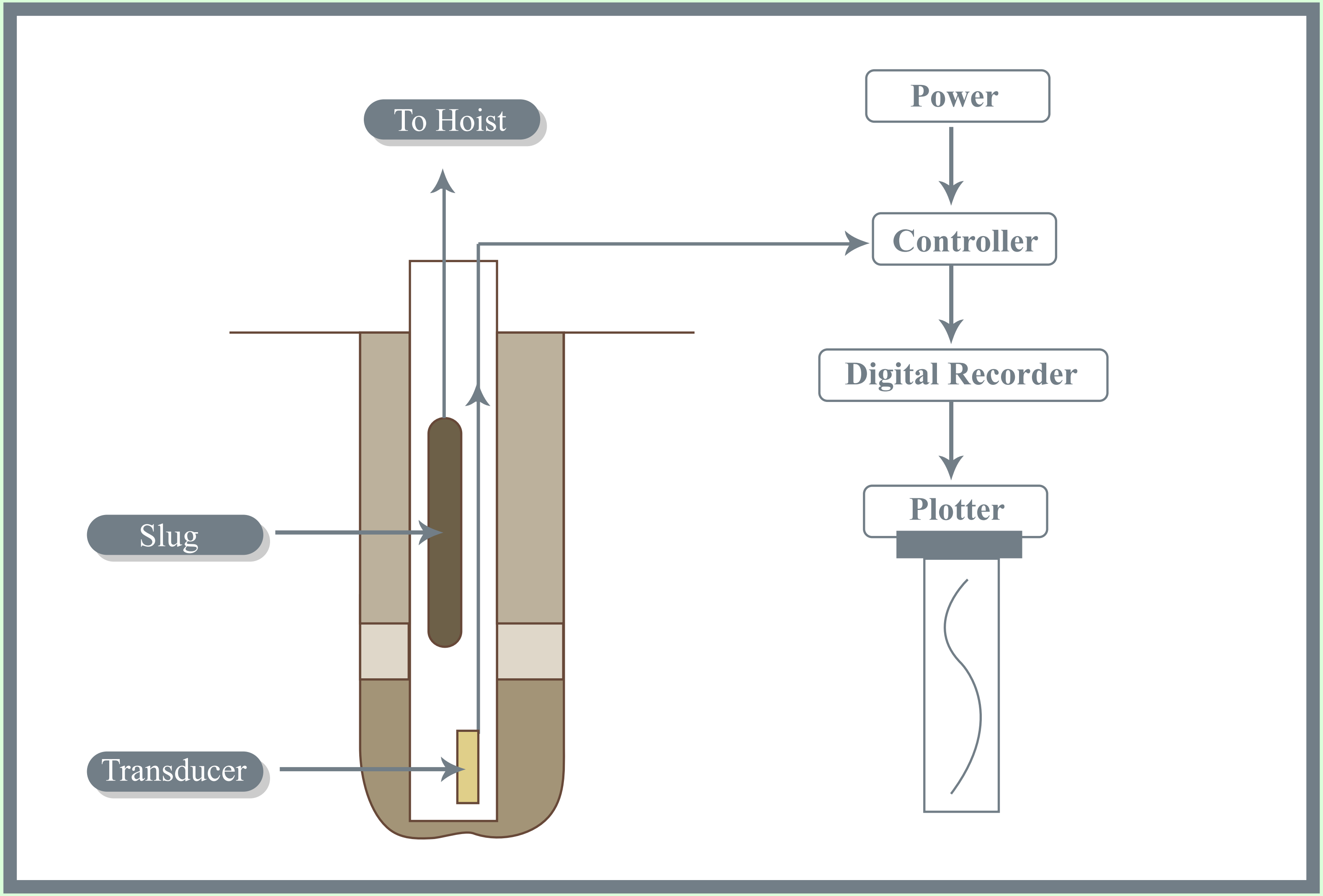
Adapted from: Puls, R. W. and R. M. Powell. "Acquisition of Representative Ground Water Quality Samples for Metals." *Ground Water Monitoring Review* 12, no. 3 (1992): 167.

“Low-flow” sampling



Adapted from: MacFarlane, I. D., J. L. Kocornik, F. T. Barranco, and A. R. Bonas. "The Application of Slow Pumping at a Manufactured Gas Plant." The Sixth National Outdoor Action Conference on Aquifer Restoration. Ground Water Monitoring and Geophysical Methods. Las Vegas, NV: Water Well Journal Publishing Company, 1992.

Slug test



To Hoist
Power
Controller
Digital Recorder
Plotter
Slug
Transducer

Slug test results