

**Waterloo Multilevel Groundwater Monitoring System\***

The Waterloo System is used to obtain groundwater samples, hydraulic head measurements and permeability measurements from many discretely isolated zones in a single borehole.

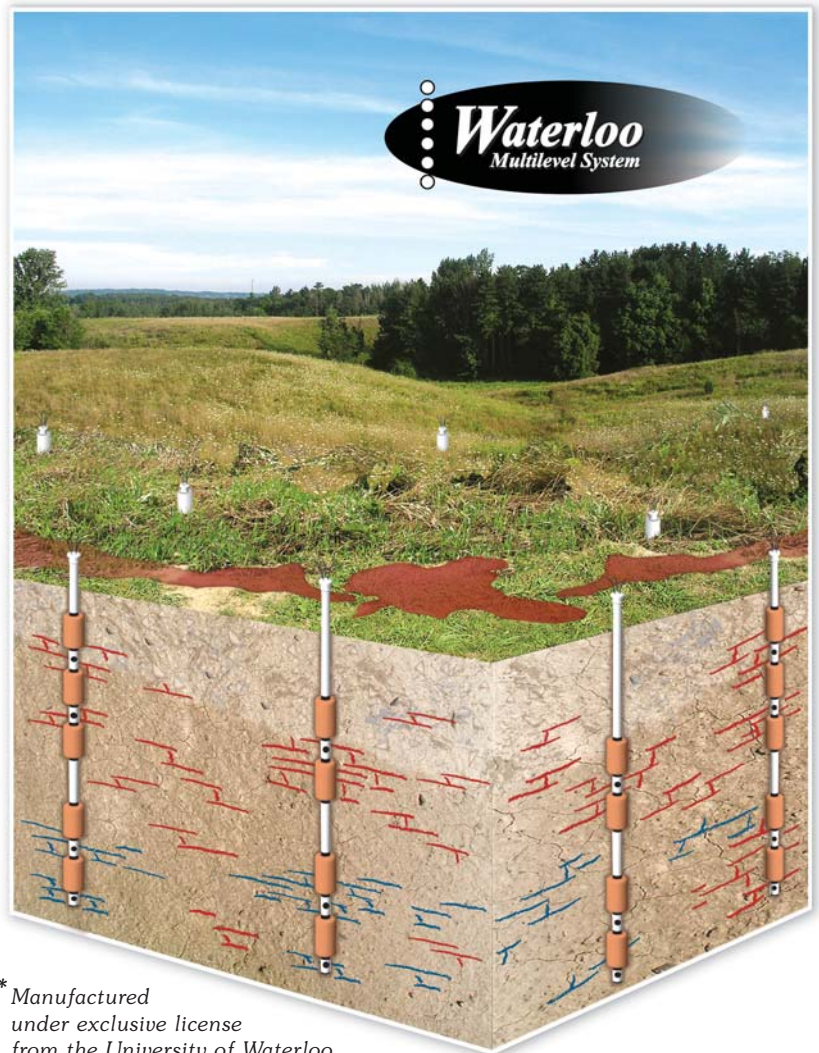
The Waterloo System originated with Dr. John Cherry at the Groundwater Institute of the University of Waterloo in 1984. Ongoing development of the System by Solinst has taken place on a continuous basis since then, with encouragement and suggestions from Dr. Cherry.

**Detailed 3-D Data**

When a number of Waterloo Systems are used at a site, they allow detailed three-dimensional groundwater information to be obtained at a reasonable cost. Fewer drilled holes are an advantage and monitoring times are reduced.

The simple modular system is customized for the needs of each project. This allows monitoring zones to be placed at desired depths using options suitable for either bedrock, overburden or combination applications and with either permanent or removable systems.

Discrete zone monitoring is the only means of obtaining accurate data for site interpretation and assessments. Transects of multilevels provide the detailed data necessary to calculate mass flux and conservatively assess risk to receptors.



\* Manufactured under exclusive license from the University of Waterloo. Canadian Patent #1232836 U.S. Patent #5048605 & International Patents.

**Advantages**

- Detailed 3D data of flow and concentrations
- Data integrity
- Reduced project costs
- Purging and sampling times reduced
- Fewer drilled holes
- Reduced site disturbance
- Variety of monitoring options

**Detailed 3-D Data**

- **Overburden or Bedrock Installations**
  - Allow monitoring of multiple zones in any geologic setting
- **Permanent Waterloo Packers**
  - Excellent in bedrock or cased holes
  - Engineered for permanent seals
- **Removable Hydraulic Packers**
  - Reuse at new zones or locations
  - Easy decommissioning

## Why Multilevels

Superior quality of data is obtained when monitoring a series of discrete isolated intervals at various depths in a single borehole. The detailed information provided by Multilevels in the form of horizontal and vertical flow, in conjunction with discrete zone sampling for contaminants, is ideal for accurate site assessments.

- **Biases with Long Screened Wells**

- Contaminant mixing over long screens masks vertical variations resulting in underestimating the aerial extent of plumes and diluting the true concentration of contaminants.
- Ambient vertical flow within the well has potential to transmit contaminants to previously isolated zones.

- **Detailed Multilevel Data – Advantages**

- Transects of Multilevels across a groundwater flow path provide the best data to use for Mass Flux calculations. This has proven to be an important tool for site assessments that require realistic estimates of maximum contaminant concentration/risk to receptors.
- Optimize performance of in-situ remediation by using detailed 3-D data from a series of Multilevels. Subsequently, transects can be used to evaluate the success of the chosen remediation option and any improvements.

- **Economics**

- Proven cost reductions for drilling and sediment disposal
- Savings, both in field personnel time and disposal costs, when purge volumes are reduced. The discrete interval that a Multilevel port encompasses allows for smaller purge volumes, rapid responses to level changes and is ideal for low flow sampling techniques.

## The Waterloo System

The System uses modular components which form a sealed casing string of various casing lengths, packers, ports, a base plug and a surface manifold. This allows accurate placement of ports at precise monitoring zones.

Monitoring tubes attached to the stem of each port individually connect that monitoring zone to the surface. The standard system is built on 2" (50 mm) Sch. 80 PVC to fit 3" - 4" (75 - 100 mm) boreholes and uses 3 ft. (915 mm) long packers. Stainless steel components, custom packer materials and sizes, Teflon® tubing are available.



Manifold

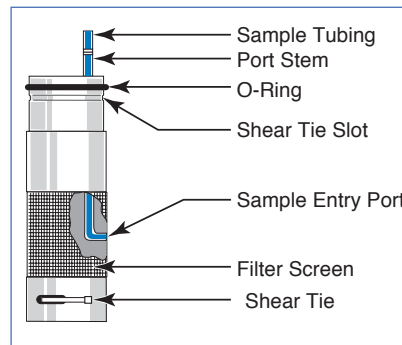


O-Ring Joints with Shear Wire

## Ports

Monitoring ports are constructed from 316 stainless steel. Ports are isolated by packers at each desired monitoring zone and are individually connected to the surface manifold with narrow diameter tubing. Thus formation water enters the port, passes into the stem, up into the monitoring tube attached to the stem, to its static level.

A sampling pump or pressure transducer may be dedicated to each monitoring zone by attachment to the port stem. Dual stem ports are available to allow both sampling and hydraulic head measurements from the same port. Alternatively, the monitoring tubes may be left open to allow sampling and hydraulic head measurements with portable equipment. For installations in silty deposits there are special sampling ports with extra screening to prevent silt entry into the port.



Stainless Steel Ports



## Joints\*

The patented method of joining components of the Waterloo System uses a nylon shear wire and an o-ring. This gives reliable, leakproof joints so that the core of the Waterloo casing string is isolated from external formation waters. Groundwater is only accessible via the port stems and attached monitoring equipment. This water-tight seal also prevents contact between packer inflation water inside the casing and the formation water outside the casing.

## Manifolds

The manifold completes the system at surface. It organizes, identifies, and coordinates the tubes and/or cables from each monitoring zone.

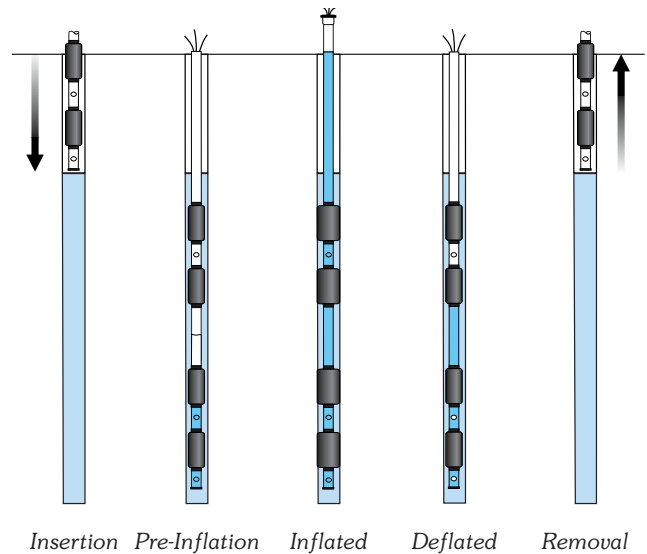
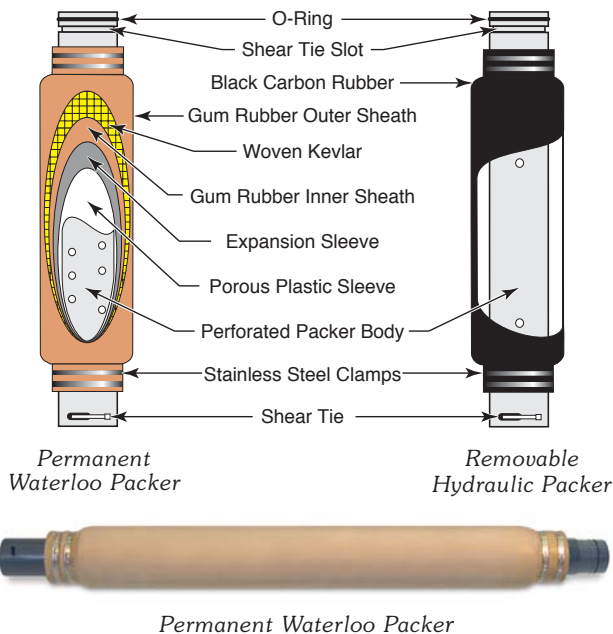
The manifold allows connection to each transducer in turn, and a simple, one-step connection for operation of pumps. When dedicated pumps are selected, it allows individual zones to be purged separately, or purging of many zones simultaneously to reduce field times.

\* US Patent 5,255,945 ® Teflon is a registered trade-mark of the Dupont Corporation.

## Permanent Waterloo Packers

Permanent packers ensure long term integrity of seals in cored bedrock holes and cased wells. They use a water activated expansion sleeve fitted over the perforated packer body. A layer of porous plastic distributes water evenly to the packer expansion material. A Rubber/Kevlar/Rubber sheath envelops the expansion material. The Kevlar layer provides strength to bridge across large fissures. The pliant gum rubber forms an effective seal against the borehole wall.

Water is added to the inside of the sealed casing string after installation. The water passes through the packer body into the expansion sleeve, causing the material to expand. Thus an engineered seal is permanently formed against the borehole wall.



## Removable Hydraulic Packers

These packers allow reuse of the system at other zones or new locations. They facilitate system maintenance and borehole decommissioning, simplify grouting of the hole and allow parts of the system to be reused.

Removable packers are made with black carbon rubber and are inflated hydraulically or pneumatically by pressurizing the interior of the Waterloo System casing string. Packers can be constructed to suit various diameters of holes.

## Installation within Wellscreen/Casing

A permanent 3" or 4" casing and screen string can be installed by a drilling contractor using typical sand and bentonite placement methods. Then a Waterloo System with either permanent or removable packers can be installed within the screen and casing string, as in a bedrock borehole.

## Installs Quickly

Installation of the Waterloo System is quick and easy. Starting with the base plug and lowermost sections, the components are joined together in the order required. As each new port is put into position a new monitoring tube, dedicated pump and/or transducer is connected to it. Successive components are threaded over these tubes, building the casing string, until the System is complete.

Typically, installations are completed in a day, using a 3-4 member team. Depending on the depth, a drill rig may be required. Solinst can provide a trained technician to assist with installation.

## Overburden Applications

Waterloo Multilevel Systems can be used to monitor multiple zones within unconsolidated formations, as well as in bedrock. There are three methods of System installation:

- Within hollow stem augers or temporary casing. Special screened ports are used and flowing sand formations are allowed to collapse around the System.
- Within hollow stem augers or temporary casing using standard tremie methods to place sand around the ports and bentonite seals in the annular space between the monitoring zones, as the augers or temporary casing is lifted.
- Within a cased and screened well, using packers to seal zones.



## System Flexibility

The Waterloo System is extremely flexible to your design criteria. Each System is customized to suit monitoring needs, site conditions and budget constraints:

- Removable or permanent system
- Bedrock or overburden applications for groundwater or vadose zone monitoring

Packers and ports can be accurately placed to monitor each zone of interest.

## Materials

For particular applications specific materials may be chosen. These may include stainless steel casing and packer bodies, and stainless steel, nylon or Teflon® tubing.

## Borehole Size

Waterloo or removable packers are designed for use in 3"- 4" boreholes (75 - 100 mm). Systems can be installed in larger boreholes using:

- Placement of sand and bentonite to isolate parts around a Waterloo casing string with no packers.
- 3-4" screen and casing, installed within a larger hole, completed by installing a Waterloo System with packers.

## Number of Monitoring Zones/Hole

The maximum number of monitoring zones for a System is determined by the number of tubes and/or cables that will fit inside the casing string. This number is dependent on the monitoring options chosen. Systems can be designed to monitor from 2 to as many as 24 zones.

Standard 2" (50mm) Waterloo System	
Site Dependent Monitoring Options	# Zones
Dedicated Pumps and Transducers	8
Open Tubes Only (varies with tube size)	15
Dedicated Pumps and Open Tubes	6
Dedicated Pumps Only	12
Dedicated Pressure Transducers Only	24



*Using core logs to identify placement of Ports and Packers*



*Multi-Purge Manifold with Transducers and Dedicated Pumps for four zone monitoring*

## Monitoring Options

### • Dedicated sampling pumps and/or pressure transducers

Each monitoring port may be fitted with a dedicated sampling pump and/or pressure transducer. This maximizes the speed with which each data set can be obtained, and avoids the need to decontaminate and repeatedly lower portable devices. The sampling pumps are suitable for sampling many types of contaminants, including VOCs.

Purge volumes are very small. With dedicated pumps all zones can be purged simultaneously. Ports with two stems allows a dedicated pump and a transducer to be placed at exactly the same level.

### • Open tubes

The most basic version uses open tubes attached to each port. This option allows monitoring with a portable sampler and a narrow diameter Water Level Meter. This provides a very economical and flexible multilevel monitoring device.

### • Mix of open tubes and dedicated equipment

A third option is to choose a mix of open tubes and dedicated equipment in different zones. This method combines the advantages of less expensive portable equipment for shallower zones (i.e. 100 ft., 30 m) and the more time efficient dedicated equipment for deeper zones.

### • Water level monitoring only

The System can comprise pressure transducers only, for pressure monitoring in up to 24 discrete zones.

## Dedicated Sampling Pumps

Dedicated equipment reduces the time and effort required to obtain data, as equipment is not lowered down the borehole and purge volumes are reduced. It gives significant cost savings and avoids cross contamination.

For long term or frequent sampling Waterloo Systems most commonly use the gas drive, Solinst Double Valve Pumps with stainless steel and Teflon® valves. A pump is connected directly to the stem of each port and dual line polyethylene or Teflon® tubing connects the pump to the wellhead manifold.

Both automatic and manual pump control units are simple to use. They have quick-connect couplings with only a single connection to the manifold required. Samples from all levels are easily and rapidly obtained. Purging from some or all levels simultaneously is accommodated by the multi-purge feature of the manifold.



*Taking pressure measurements with Model 404 Geokon Vibrating Wire Readout*



*Collecting a Sample from a Dedicated DVP*

## Low Flow Purging and Sampling

Purge volumes are very small due to the small annular space and tubing diameters used in the system. Consequently sampling is rapid, even though flows are low, especially with dedicated pumps when all zones can be purged simultaneously.

Dedicated Bladder and Double Valve Pumps, (DVP), as well as a portable DVP are ideal for use when low flow sampling and purging techniques are desired.

## Portable Micro Double Valve Pump

The Micro Double Valve Pump (Micro DVP) provides high quality samples, uses coaxial Teflon® tubing, and is small enough to fit in 1/2" (13 mm) ID tubing. The unique combination of flexibility and size make the pump ideal for sampling at depth in small flexible tubes.



*Model 408M Double Valve Pump*

## Dedicated Transducers

Dedicated pressure transducers allow rapid and accurate measurement of temperature and total water pressure. Unless static water levels are shallow, transducers are the preferred method of water level measurement, both from an efficiency and an accuracy point of view.

The transducers chosen for use in the Waterloo System are vibrating wire transducers, which are very accurate and rugged. They have superior long term operation with minimal drift over time. They can be read with a manual readout, or with a datalogger which can provide remote, unattended monitoring and telemetry, if desired. Transducers are available with pressure ranges from 50 psi to 500 psi. (7.25 kPa to 72.5 kPa).



*Dedicated Sampling Pump & Transducer*



*Model 102, P1 Water Level Meter*

## Portable Monitoring Equipment

Water level measurements can be made in Waterloo ports fitted with an open tube using the narrow, Solinst Model 102, P1 Water Level Meter. It has a weighted, flexible probe, 1/4" OD by 1.5" long (6.35mm x 38 mm).

Sampling may be performed in open tubes using a Mini Inertial Pump, Micro Double Valve Pump, or a Peristaltic Pump.

® Teflon is a registered trade-mark of the Dupont Corporation.

## Designing Your System

The options chosen for each System will be site and application specific.

### Each design is dependent on:

- Zones of interest
- Geology of the site
- Monitoring methods preferred
- Cost considerations
- Borehole depth, diameter and type

Refer to the drawings below, then select the type of installation that suits your project. Consider the size and depth of each borehole, and whether casing is to be present. Decide if permanent or temporary Systems are preferred, the number of zones and depth of each zone per System, the monitoring options preferred, and any special materials required.

During development of your plans, the Solinst technical staff will be pleased to help evaluate the options and customize a System that best suits your needs.

## Projects

### Waterloo Systems have been used to monitor:

- Salt water intrusion
- Industrial cleanups
- Pipeline leaks
- Dam leakage/rehabilitation
- Contaminant identification/cleanup
- DNAPL & LNAPL spill sites
- Waste disposals/landfills
- Soil gas surveys

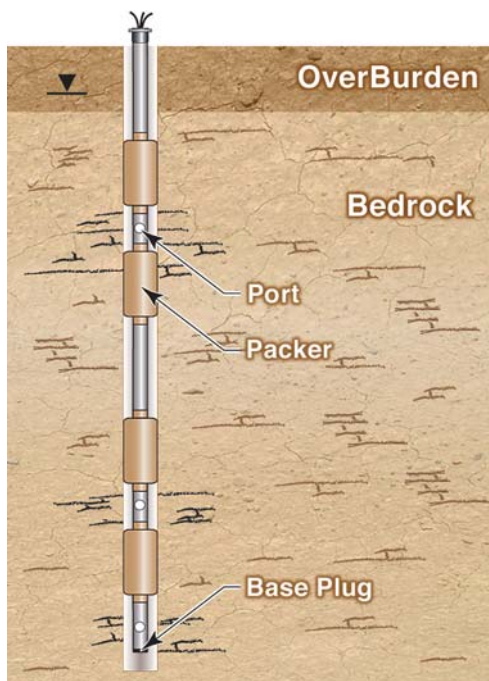
## Applications

The Waterloo System has been specified by various industries and consultants for numerous sites across the United States, Canada and overseas. Waterloo Systems have been specified and approved at several sites with Superfund or RCRA designations and in each of the U.S. E.P.A. regions.

### The System has been used for:

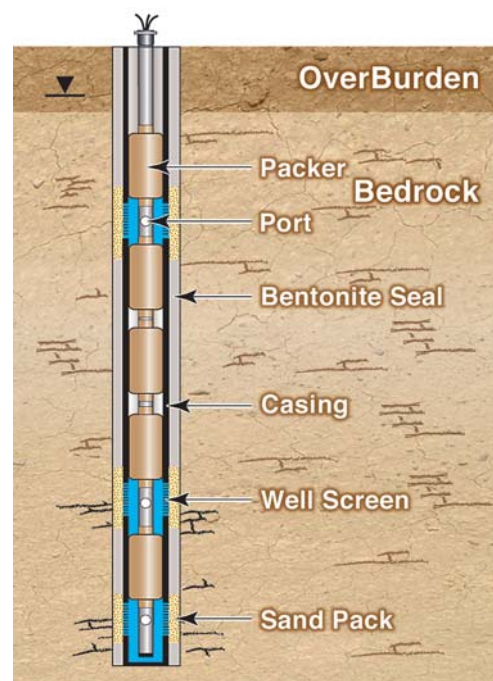
- defining groundwater flow patterns
- performance monitoring of pump and treat systems
- identification and determination of spatial distribution of contaminants
- early warning system/detection of migrating contaminants

### Bedrock



Permanent or Removable Packers  
in Cored Hole

### Bedrock and/or Overburden

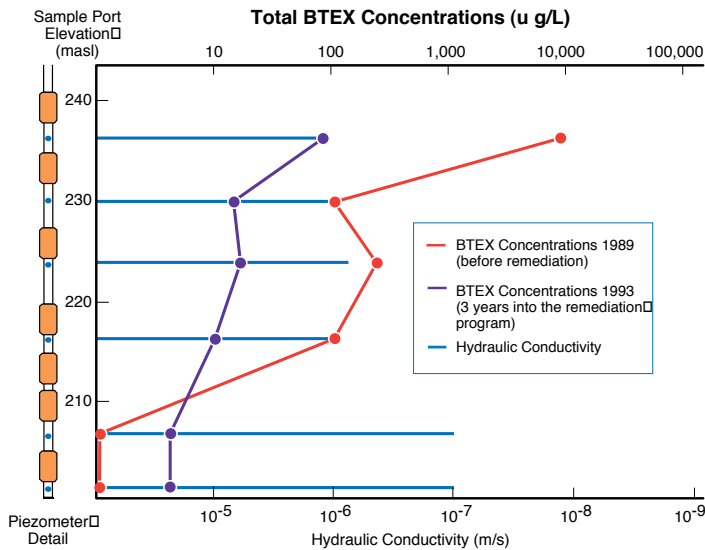


Permanent or Removable Packers  
in Casing or Well Screen



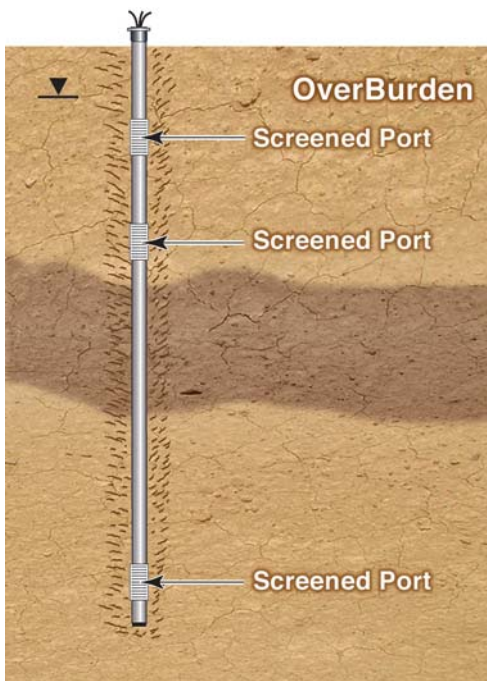
## Reliable Data

The effectiveness of the Waterloo System is proven by its ability to accurately and repeatedly obtain pressure and groundwater chemistry data from several distinct zones in a single borehole. The data set below shows a decrease in Total BTEX contamination due to ongoing pump and treat operations at an oil pipeline leak.



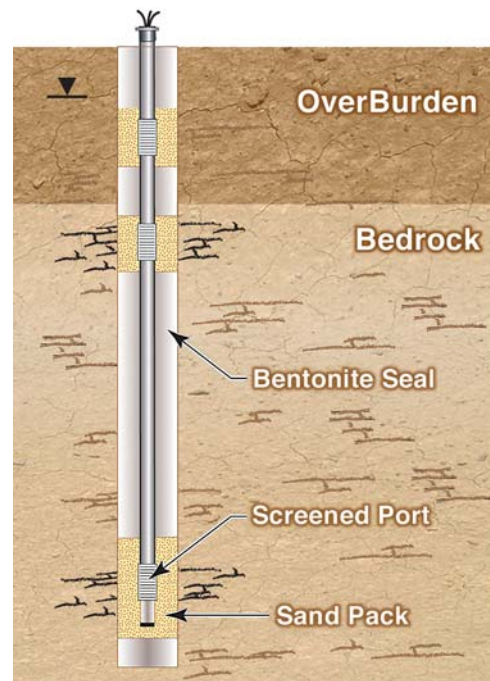
Underground oil pipeline leak assessment. Three 150 ft. (45m) installations. Two point rising head permeability tests were conducted in each interval of the Multilevel System. (See diagram showing contaminant distribution at left.)

## Overburden



Direct Burial: Formation Collapse with Screened Ports

## Bedrock and/or Overburden



Direct Placement: Sand and Bentonite with Screened Ports



Waterloo Systems comprised entirely of stainless steel casing, packers and ports with Teflon-lined tubing were used to monitor contaminant flow in this bedrock application.



Contaminant investigation at a U.S. Air Force Base. Waterloo Systems installed to 700 ft. in overburden using screened and cased wells. Up to 6 zones per hole with dedicated pumps and transducers.



Detailed investigation of PCE delineation in carbonate bedrock. A cost analysis of the 14 Waterloo Systems compared with nested piezometers indicated savings both on the capital costs and on the on-going monitoring.



Landfill site over fractured granite, monitored with five Waterloo Systems. Each System comprised of dedicated Double Valve Pumps and Pressure Transducers in 4-6 intervals to depths of 275 feet (84m). The Multi-Purge Manifold allowed the monitoring of 21 zones to be completed in less than 2 days.



An EPA regulated site in Northeast, USA. This multilevel array allowed a sampling team to purge and sample from 40 monitoring zones across 10 borehole locations in just 4 days. These Waterloo Systems were installed in overburden using preinstalled casing.



750ft. (230m) Waterloo System installation for a deep tunnel assessment study. Three zones monitored with dedicated Double-Valve Pumps and pressure transducers. Picture shows technician obtaining pressure measurements and groundwater samples with portable readout and pump control unit.



An investigation of hydraulic properties beneath a large waste site. Waterloo Multilevel Systems were chosen to allow water quality sampling and to help determine the zones of highest permeability within the aquifer.



A large Midwestern USA research project studying agricultural effects on water quality. 22 Waterloo System installations with 3-4 zones each were installed to depths of 24-60 ft. (7.3-18.3 m) in overburden. Dedicated Double Valve Pumps and Peristaltic Pumps were used.