Control of contaminated groundwater

Using sealable joint steel sheet piling, contaminants are prevented from moving off site.

Low permeability containment walls are increasingly used in groundwater pollution control and remediation. Containment enclosures minimize or eliminate the need for contaminant plume control by groundwater pumping and water treatment. Contaminants are prevented from moving off site while site control activities, such as source removal and plume remediation, are carried out in the isolated subsurface environment inside the walled enclosure.

New passive and semi-passive treatment technologies for the interception and *in situ* treatment of groundwater contaminants provide alternatives to conventional pump-and-treat approaches. In systems such as these, containment walls can be used to direct plumes into subsurface treatment zones containing reactive media. This article describes the development and recent applications of sealable joint steel sheet piling for groundwater containment wall construction.

Waterloo Barrier

The Waterloo Barrier® is a steel sheet piling system that incorporates a sealable cavity at each interlocking joint (**Figure 1**). It was developed in the late 1980s by researchers at the University of Waterloo for the purpose of constructing secure test cells for controlled releases of DNAPL chemicals to a shallow sand aquifer at Canadian Forces Base Borden near Alliston, Ontario.

Several available containment wall technologies were investigated and found to be cost-prohibitive for the construction of small scale, closed test cells, or they were found to be insufficiently watertight. Hydraulic testing of prototype sealable joint sheet piling in numerous closed cells at CFB Borden and an industrial site near Sarnia, Ontario, indicated that bulk wall hydraulic conductivities of 10^{-8} to 10^{-10} cm/sec could be achieved; this was well below the 10^{-7} cm/sec limit normally required by regulatory agencies for vertical barriers at contaminated sites. A roll-formed, manufactured version of the sealable sheet piling became commercially available in late 1993 and is now in use at more than 25 contaminated sites in North America.

The Barrier was driven to refusal through stiff to hard soils comprised of a mixture of sand, clay and gravel using a crane-mounted vibratory hammer.

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Standard pile driving equipment and techniques are used to install the Barrier. A foot-plate at the base of the sealable cavity displaces soil laterally as the steel sheets are driven into the ground, preventing the build-up of compacted soil within the cavity. After driving, any loose soil remaining in the cavity is jetted clean with pressurized water. A sealant injection line is then lowered to the base of the open cavity and a low permeability grout is emplaced from bottom to top.

Potential leak paths through the Barrier are limited to the sealed joints and, therefore, the joints are the focus of quality assurance and quality control procedures (QA/QC). The vertical alignment of piles is monitored during driving, and the flushing and probing of the sealable cavities provides documentation regarding the ability to inject sealant the full length of the cavity. Records of grout volume, pumping time and starting depth provide assurance that the entire cavity has been sealed.

Several types of sealants have been developed to meet specific project requirements. These include clay based grouts such as bentonite and attapulgite, cement based grouts modified with expanding agents, epoxy polymers, urethane polymers and inflatable mechanical packers. Grout selection is governed by the required service life of the installation, chemical compatibility with groundwater contaminants, and whether or not the piling has to be removed from the ground after site cleanup.

The Waterloo Barrier has proven its versatility in differing geological conditions and in a wide variety of applications. However, as with all steel sheet pile walls, the Barrier is not suitable for use in extremely dense or rocky soils, and in densely populated urban areas the noise and vibration from pile driving equipment may be a concern. Typical applications include containment to limit offsite migration or protect waterways, the construction of subsurface *in situ* treatment systems, and structural support and dewatering for the excavation of con-

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The Waterloo Barrier® system showing interlocking steel sheet piling and modified joint with the sealable cavity.

taminated soils. Two examples of Canadian projects are described in more detail.

Dow Chemical Canada Landfill Site
Sarnia, Ontario

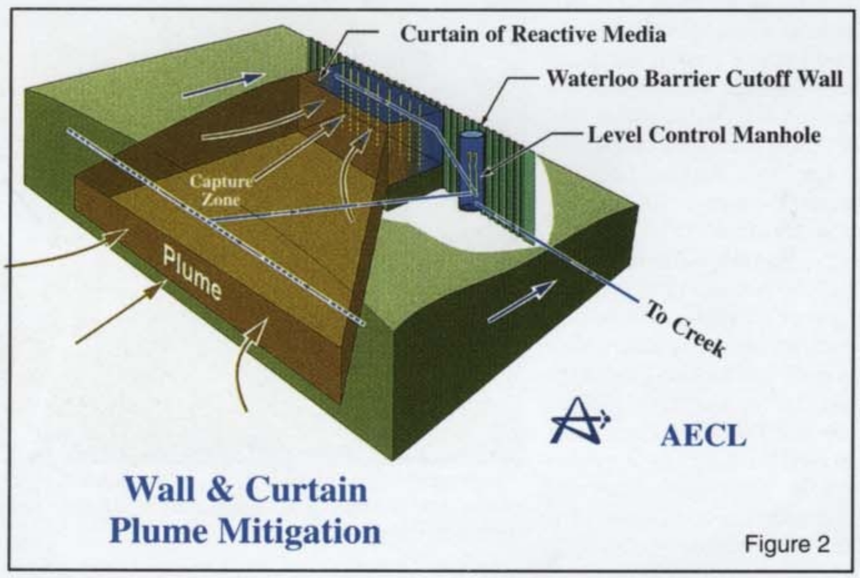
A Waterloo Barrier containment wall system totalling approximately 16,000 square metres was completed at this inactive disposal facility in the summer of 1997. Past disposal activities at the landfill resulted in lateral migration of contamination from the landfill through fissures in weathered clay, and pooling at the top of unweathered consolidated clay at various depths up to 6 metres.

The Waterloo Barrier was installed to prevent future migration of contaminants beyond the limits of the property. The Barrier was driven to refusal through stiff to hard soils comprised of a mixture of sand, clay and gravel using a crane-mounted vibratory hammer. A diesel hammer was then used to key the wall into the dense clay formation. Final depths of the wall range up to 7.3 metres.

A proprietary organic polymer manufactured by Dow was selected to seal the joints because of its low permeability, elasticity and resistance to chemical degradation. Subsequent phases of work at the site entailed excavation of contaminated soils on the down-gradient side of the Barrier and replacement of the contaminated soil with clean material.

AECL Facility
Chalk River, Ontario

A novel wall-and-curtain system has been designed to intercept and treat a strontium-90 (^{90}Sr) plume situated in the lower half of a 12 metre thick sandy aquifer. The system incorporates a subsurface reactive curtain of granular clinoptilolite oriented perpendicular to groundwater flow and backed by a Waterloo Barrier containment wall sealed to the underlying bedrock (**Figure 2**). A passive tile drain maintains a uniform hydraulic head across the reactive media. Monitoring and control is performed at two adjustable weirs allowing the capture zone to be manipulated. Shallow uncontaminated groundwater will be diverted around the treatment system.



Clinoptilolite is a hydrated aluminosilicate mineral (zeolite) that removes the ^{90}Sr from solution by sorption and retains it for an extended time. The reactive curtain is predicted to have an operating life of more than 20 years and could be rejuvenated for longer service with the addition of new reactive material. During construction, the Barrier functions as a structural wall as the clinoptilolite is installed in an excavated, temporary sheet pile enclosure. The upgradient side of the enclosure is then removed to open the reactive curtain to groundwater flow. The downgradient Barrier remains in place as an impermeable cut-off wall to prevent ingress of surface or groundwater into the reactive medium.

The curtain-and-wall *in situ* treatment system was designed with the aid of three dimensional numerical modelling and then tested in the laboratory. It offers a cost advantage and also a higher degree of hydraulic control and monitoring than alternative methods. Construction of this system was scheduled for mid-1998.

Conclusions

Waterloo Barrier sealable joint steel sheet piling has demonstrated its ability to limit the migration of groundwater from contaminated sites, thereby reducing the impact to adjoining property or waterways. Installation is clean and rapid with minimal site disturbance and no excavation of contaminated soils; however, its use may be subject to limitations in certain geotechnical environments.

The construction of irregular layouts with the Barrier, for example as in subsurface *in situ* treatment systems, can be easily achieved. Significant advantages of the Barrier are its predictable hydraulic performance and documentable QA/QC during the construction process.