Appendix D

Sealable Joint Sheet Piling Information

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

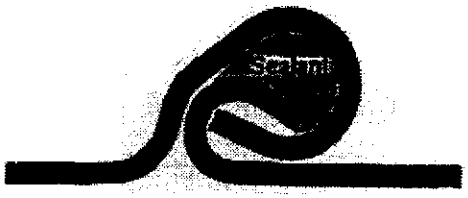
WATERLOO BARRIER®

A LOW PERMEABILITY CONTAINMENT WALL FOR GROUNDWATER POLLUTION CONTROL

Low permeability containment walls are used in groundwater pollution control and remediation. Containment enclosures (source zone isolation) can minimize or avoid the need for plume control by groundwater pumping with water treatment. Contaminants are prevented from moving off-site while control activities, such as source removal and plume remediation, are carried out in the isolated subsurface environment inside the walled enclosure. The Waterloo Barrier®, constructed of steel sheet piling with sealable joints, offers significant performance and safety advantages over conventional containment walls. The Waterloo Barrier® system is described in a British Patent No. 2228760, United States Patents 5782583, 5711546, 5957625, and 547520. Patent submissions in Canada are pending, Application No. 2011386-3.

THE WATERLOO SYSTEM

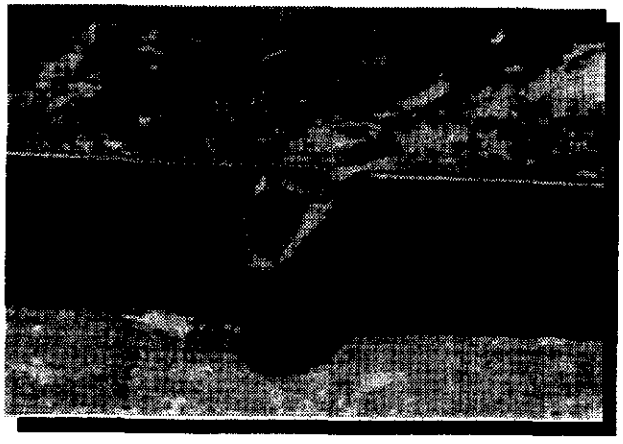
A new type of containment wall composed of sealable steel sheet piling has been developed at the University of Waterloo's Institute for Groundwater Research under the direction of Dr. John Cherry. The interlocking joints between individual sheet piles incorporate a cavity that is filled with sealant after driving to prevent leakage through the joints. Cold roll forming forms an internal cavity as the sheet pile itself is manufactured.



Internal Cavity

Standard pile driving equipment and techniques are used to construct a vertical sheet pile wall. Sheet piling can be driven to depths of 100 ft. (30 m) or more in unconsolidated deposits lacking boulders.

A footplate at the bottom of each cavity displaces soil laterally as the sheets are driven into the ground and the joints remain largely soil-free. Soil that does enter the joints is relatively loose and easily removed by jetting with water. A watertight sealant is then injected into the sealable cavities between sheet piles to create a low permeability barrier.



Foot Plate

DESIGN FEATURES

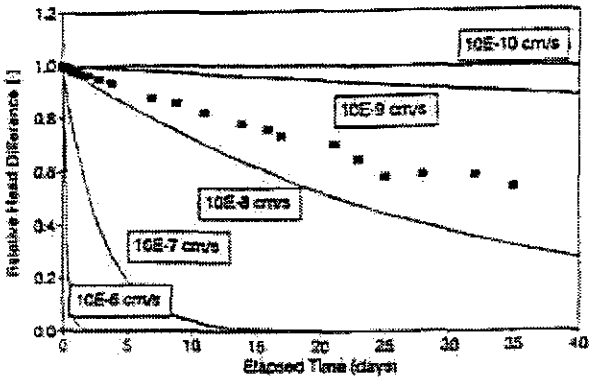
The internal cavity of Waterloo Barrier® is manufactured by cold roll forming under license by Canadian Metal Rolling Mills (CMRM) of Cambridge, Ontario. It is available in two sizes, WZ75, .295 (7.5 mm) in thickness and WEZ95, .375 (9.5 mm) in thickness.

Sealant is selected according to site conditions and project requirements. A variety of sealant materials may be used including bentonitic clay grouts, attapulgite clay grouts, vermiculitic grouts, cementitious grouts, epoxies, and organic polymers. The preferred grout for permanent installations is WBS301, a silica fume modified cementitious grout.

PERFORMANCE

The joints of conventional sheet piling are designed for mechanical strength but not watertightness. Leakage of water through the unsealable joints is acceptable for most civil engineering applications but generally not for environmental applications. Conventional unsealed, cold roll formed sheet piling has a bulk hydraulic conductivity in the range of 10^{-4} to 10^{-5} cm/s.

In comparison, bulk hydraulic conductivities of 10^{-8} to 10^{-10} cm/s are typically achieved in test cells constructed of Waterloo Barrier®. An hydraulic conductivity at or below 10^{-7} cm/s is required by regulatory agencies for vertical barriers around waste sites.



Hydraulic Test Results of Waterloo Barrier® Test Cell Sealed With Bentonitic Grout

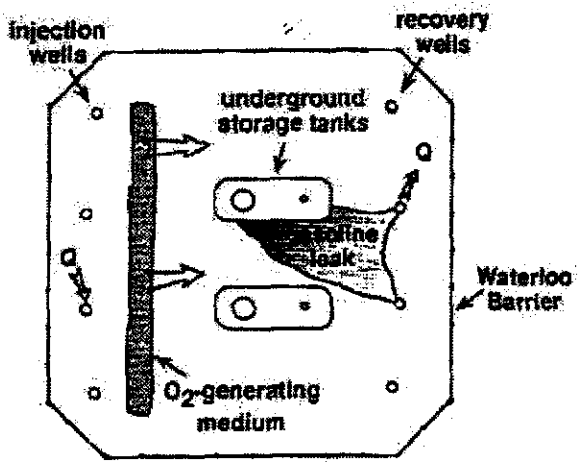
QUALITY ASSURANCE AND CONTROL

Potential leak paths through the Barrier are limited to the sealed joints and therefore the joints are the focus of quality control procedures. Joints are inspected between cleaning and sealing operations to confirm that the sheets have not separated and that the complete length of the joint is open and can be sealed. Each joint is sealed from bottom to top using sealant injection lines, facilitating the emplacement of sealant into the entire length of the joint. Repair procedures can be initiated if a joint separation or blockage is suspected.

Field Data Collection

APPLICATIONS

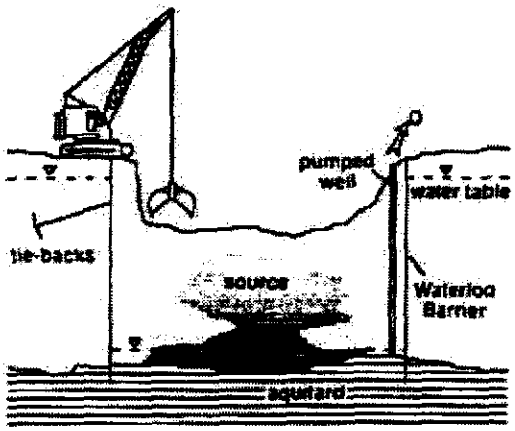
The Waterloo Barrier® offers considerable versatility. It can be installed to completely enclose a site (source zone isolation) to prevent off-site migration of contaminants until a remedial plan can be implemented, or to isolate a site while remedial actions are in progress.



Enclosure of a Gasoline Station During In Situ Bioremediation Using an Oxygen Flush

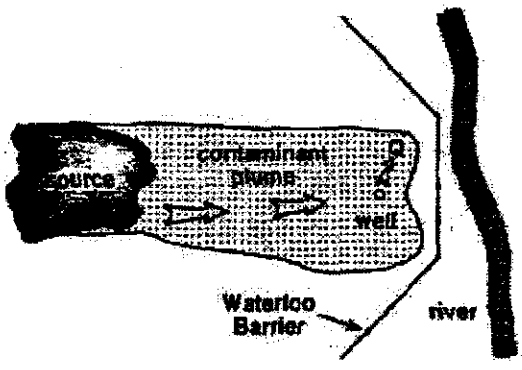
The hydraulic isolation afforded by complete enclosure can improve the effectiveness of in situ remedial processes by minimizing the dilution of treatment fluids and allowing flow directions to be easily controlled. Pump-and-treat costs can be reduced as a significantly smaller volume of contaminated ground water is processed.

Waterloo Barrier® can function as a temporary enclosure during the excavation of soils. Internal bracing or tiebacks may be required dependent upon the soil conditions and the desired depth of excavation. Small temporary enclosures are also useful for conducting pilot scale field trials of remedial measures. In some situations, an open-ended Waterloo Barrier® can be effectively used in conjunction with extraction wells to provide hydraulic containment.



Enclosure During Excavation

At new industrial sites, Waterloo Barrier® can be installed to enclose the site as a preventive or security measure to control chemical releases that could occur in the future. Enclosures around new landfills can be coupled with caps or infiltration systems to manage the rate of waste degradation and leachate production.

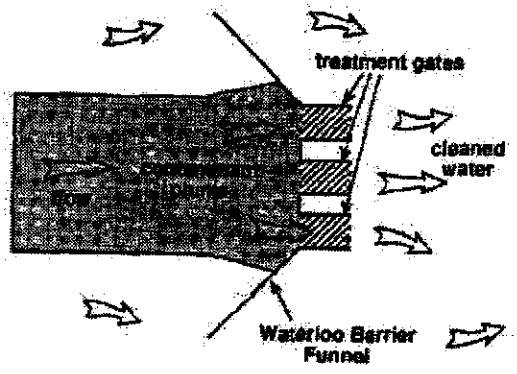


Waterloo Barrier® Along a Riverbank Prevents Seepage of Contaminated Groundwater

Waterloo Barrier® can be used to direct or funnel a contaminant plume into a subsurface treatment gate containing a reactive porous medium or other in situ treatment. The steel treatment gate is screened to allow the plume to flow through it and be remediated. Reactive porous media suitable for use in treatment gates include an abiotic, metal-catalysed dehalogenation medium for the remediation of DNAPLS and various biotic media. Air sparging can also be conducted in treatment gates.

The Funnel-and-Gate® treatment system can be designed to treat a variety of plume configurations and contaminants. An arrangement of multiple gates can be used to intercept exceptionally wide plumes.

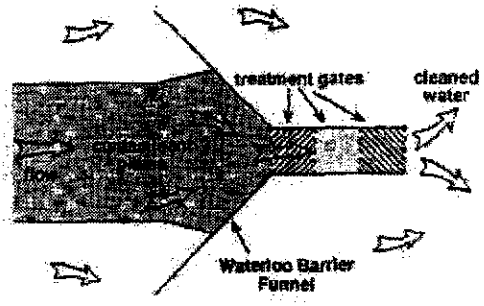
A complex plume containing a number of different contaminants can be treated by passing through a series of gates aligned in sequences, each containing a different reactive porous medium.



Sequential Gates

In civil engineering applications, Waterloo Barrier® can be used during excavation of compressible soils in urban areas to prevent settlement due to groundwater seepage.

The Barrier can also be used to limit the amount of dewatering required during construction below the water table. Its use in cofferdams can be cost effective on longer-term projects by virtually eliminating the necessity for continual pumping in order to dewater the enclosure.



Multiple Gates

ADVANTAGES

The Waterloo Barrier® serves the same general functions as other types of containment walls, such as the common soil bentonite wall. It has a number of unique advantages for containing polluted groundwater:

Minimal Site Disturbance

A major advantage of the Waterloo Barrier® is that excavation of subsurface materials is not required, thus there is less damage to the site and disruption of normal site activities. The high costs normally associated with the health and safety precautions necessary to excavate contaminated material and the high costs of its disposal are avoided.

Rapid and Easy Installation
Installation of the Waterloo Barrier® is relatively clean and rapid. Corners and irregular wall geometries can be easily constructed. Topography and depth to water table have little effect on installation techniques and the Barrier can even be installed through surface water bodies.

Design Versatility
The Waterloo Barrier® offers a number of design options not available with other types of containment walls. Various options, such as single or double sealable joints, and single or double walls, can be combined on a single project where parts of the wall have one design and others parts another design.

The Barrier can be used for containment purposes only or used in combination with various in situ remediation techniques.

Economical Use of Sealants
The volume of sealant required is relatively small, so it is feasible to use special sealants particularly resistant to chemical degradation that are too expensive to use in large quantity.

Superior Quality Assurance and Control
The materials and construction techniques make the Waterloo Barrier® less prone to leaking than other types of containment walls, providing a greater degree of confidence in its performance.

The integrity of the Barrier can be confirmed by inspection during construction. Rigorous, post-construction hydraulic testing is possible with double-walled configurations.

Removability
The use of a removable sealant, such as a bentonitic grout, allows the sheet piles to be removed from the ground and used elsewhere once a site has been successfully remediated. Removability is also advantageous for the isolation of portions of a site for pilot scale tests and for progressive or temporary installations for construction purposes.

DESIGNING YOUR SYSTEM

The design specifications of each Waterloo Barrier® containment system must be customized to meet the site requirements.

The design is dependent on:

- Surficial Geology
- Nature and Depth of Contamination
- Plume Morphology and Flow Rate

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TECHNICAL DATA

Waterloo Barrier®

PILE DRIVING AND JOINT SEALING SPECIFICATION

TDS 1-98(Rev 3 March, 2000) Date: February, 1998

PART 1 - GENERAL

1.1 WORK INCLUDED

1.1.1 This section specifies requirements for furnishing all materials and equipment and for performing all operations to install the Waterloo Barrier® steel sheet pile walls, including joint sealing procedures, as shown on the contract drawings. Sheet piling shall also be installed where required by the Contractor's method of construction and the existing conditions. Waterloo Barrier® steel sheet pile wall technology is described in a British Patent No. 2228760, United States Patents 5782583, 5711546, 5957625, and 547520. Patent submissions in Canada are pending, Application No. 2011386-3.

1.2 REFERENCE STANDARDS

1.2.1 American Society for Testing and Materials (ASTM):

1. A 328 - Standard Specification for Steel Sheet Piling.
2. A 572 - High Strength Low Alloy Columbium-Vanadium Steels of Structural Quality.

1.2.2. American Welding Society (AWS). D1.1 - Structural Welding Code.

1.2.3. Figures showing sections of the Waterloo Barrier® are provided at the end of this section.

1.3 SUBMITTALS

1.3.1. Submit the following items for review by the Engineer:

a) Pile Installation Plan which outlines detailed pile placement, equipment to be used, splicing requirements, quality control measures and joint preparation prior to sealing.
b) Proposed welding procedures and certification of welders.
c) Certification of the License Agreement with Waterloo Barrier Inc. for the provision of quality control services for the sheet pile installation and joint seasling.
d) Mill test documentation for the piling to be used on the project.

1.4 COORDINATION

1.4.1. Notify the Engineer at least 5 working days prior to beginning pile driving operations at any location. This will not relieve the Contractor of his responsibilities for performing the work in accordance with these specifications and contract drawings.

1.4.2 The Contractor will be required to schedule work activities and work in conjunction with C3 Environmental Limited to complete the barrier wall installation in the scheduled time period and to the satisfaction of the Owner and Engineer.

1.5 QUALITY ASSURANCE/QUALITY CONTROL

1.5.1 The Quality Assurance/Quality Control (QA/QC) program and joint sealing operations shall be completed by C3 Environmental Limited.

1.5.2 Horizontal Alignment: The maximum permissible horizontal tolerance in pile driving shall be a deviation of not more than 150mm (6 inches) from the plan location indicated on the contract drawings.

1.5.3 All surveying and barrier wall layout is to be completed by the Contractor.

PART 2 PRODUCTS

2.1 SHEET PILES

2.1.1. WZ75 and WEZ95 sheet piles, as manufactured by CMRM (Canadian Metal Rolling Mills), will be supplied in custom rolled or custom cut, lengths as specified by the engineer.

2.1.2. A foot plate shall be welded to the base of each female joint of the sealable sheet piling to prevent soil from entering the joint as the pile is driven into the ground. The Contractor will be responsible for all cutting of the sheet piles and attachment of the foot plates. The Contractor shall make the necessary arrangements to assure that attachment of the foot plates does not delay the sheet pile installation.

2.1.3. Section Properties of Piling: **WZ75**

	Imperial	**Metric**
Thickness:	0.295 in	7.50 mm
Nominal Width:	24 in	610 mm
Section Area:	10.7 in^2	69 cm^2
Weight:	36.6 lbs/lineal ft.	54.3 kg/lineal m
Moment of Inertia	69.3 in^4/wall ft.	9460 cm^4/wall m
Radius of Gyration:	3.6 in	91.4 mm
Section Modulus:	15.9 in^3/wall ft.	860 cm^3/wall m

2.1.3. Section Properties of Piling: **WEZ95**

	Imperial	**Metric**
Thickness:	0.375 in	9.50 mm
Nominal Width:	25 in	635 mm
Section Area:	14.9 in^2	96.2 cm^2
Weight:	50.5 lbs/lineal ft.	75.2 kg/lineal m
Moment of Inertia	134 in^4/wall ft.	18300 cm^4/wall m
Radius of Gyration:	4.33 in	110 mm
Section Modulus:	24.9 in^3/wall ft.	1340 cm^3/wall m

2.1.4 Waterloo Barrier® Sealant Material:
The material used to seal the sheet pile wall shall be **WBS-301** supplied and installed by C3 Environmental Limited in accordance with existing site and design conditions and shall be compatible with the Waterloo Barrier® System.

PART 3 EXECUTION

3.1 SHEET PILE INSTALLATION

3.1.1. Handling Sheet Piles:

a) Lift in a manner which will not cause excessive bending stresses.
b) Do not damage sheet piles in either handling or installing operations.
c) The joint of each sheet pile shall be visually inspected by the Contractor prior to installation. Any foreign material shall be removed and damaged joints and/or sheet piles shall be rejected.
d) Replace or repair sheet piles which are damaged during installation.

3.1.2. Location and Tolerances:

a) Drive piles vertically and in correct alignment so that the top of the wall lies on a straight line and ensure a proper interlocking throughout the entire length of the piles.
b) Sheet pile locations on the contract drawings are approximate and will be field located when appropriate and when approved by the Engineer.
c) Deviation in horizontal alignment shall not exceed 10 degrees at each joint.
d) The maximum permissible vertical tolerance (plumbness) in the pile installation shall not be greater than a deviation of 1/5 inch per 1 foot vertical. The integrity of the interlock between adjacent piles shall be verified by flushing the joint. Joint inspection and flushing shall be performed by the Quality Assurance/Quality Control Technician (C3 Environmental Limited).

3.1.3 The Contractor shall use suitable templates to ensure alignment and plumbness during driving.

3.1.4 Sheet Pile Installation Equipment:

a). Install piles with vibratory pile driving equipment suitable for the conditions encountered. The method and equipment selected shall install the piling to the design depths as shown on the contract drawings and minimize damage to each end of piling and adjacent interlocks. Suitable procedures shall be employed to prevent damage to the pile tops and joints.

3.1.5. Pile Installation:

a) Prevent and correct any tendency of the sheet piles to bend, twist or rotate, and to pull out of interlock. The integrity of each pile and interlocked joint shall be maintained during and after driving.

b) Working from the start location the Contractor will install the sheet piling with the smaller (Male) joint leading and thread the larger (Female) joint with attached foot plate on to the installed Male joint to form the sealable cavity (as indicated on the foot plate drawing). The Contractor will ensure that the enlarged Female joint is not driven to an elevation lower than the previously installed Male joint in order to prevent obstructions from entering the sealable cavity. The only exceptions to this criteria will be when the pile length increases from one section of wall to another.

c) Top of pile at elevation of cut-off shall be within 1 inch of the specified elevation. Manipulation of piles to force them into position will not be permitted. Piles will be checked for heave. Piles found to have heaved shall be redriven to the required point elevation. Where required, to meet the top of wall elevation, the sheet piling shall be cut to remove excess material. Costs associated with sheet pile cutting are to be included in the sheet pile installation pricing.

d) Piles damaged or driven outside the above tolerances shall be replaced. Any sheet pile ruptured in the interlock or otherwise damaged during installation shall be immediately pulled and replaced.

e) All sheet piles shall be driven to the design depth or to refusal in underlying bedrock. Sheet pile driving will be considered complete when the sheet piling has been installed to the design depth or refusal to the assumed bedrock elevation shown on the contract drawings and progress on any one sheet pile is less then 2 inches per minute.

f) Once the sheet piling has been installed the Quality Control Technician shall confirm that the sealable cavity is open for the full length and free of obstructions. The Contractor shall cooperate with the Quality Control Technician and assist as required to remove obstructions and clear the sealable cavity to the base of the joint. This work will include providing the necessary labour, equipment and materials to vibrate the sheet piling while the Quality Control Technician flushes the sealable cavity of the problem joints and/or removing and replacing sheet piling damaged during driving at no additional cost to the Owner.

g) Pull any sheet piling that are known to have pulled out of the interlock or are suspected of having tip or interlock damage, as determined by the Quality Control Technician, for visual inspection before proceeding further.

h) Splicing is permitted if shown on the contract drawings or as approved by the Engineer.

i) Make splices using a full penetration weld or as otherwise directed by the Engineer for structural purposes.

j) An optional video inspection may be conducted on one sheet pile joint in every fifty installed. The inspection will be preformed by the C3 Environmental Limited's QA/QC Technician using fibre-optic video inspection equipment that can be lowered to the bottom of the sealable cavity.

3.2 JOINT SEALING

3.2.1 All sheet pile joints are to be sealed. Joint sealing shall be completed by C3 Environmental Limited.

3.2.2 Joint sealing shall not be performed within 100 feet of the sheet pile installation operation or until a satisfactory joint inspection is achieved.

3.2.3. After the sheet piling has been installed in the ground all sealable cavities shall be checked by probing and flushing of the joints with pressurized water to remove any loose material.

3.2.4 A tremie hose or tube for pressure injection of the sealant shall be inserted into the sealable cavity. When the tube has reached the bottom of the hole, sealant injection will begin. The hose shall be withdrawn progressively up the hole as the sealant fills the space below. Keep tremie nozzle at least 1 foot below the rising surface of sealant.

3.3 RECORDS

C3 Environmental's QA/QC Technicians will document the following information and provide it to the Owner and Engineer in report format upon completion of the barrier wall installation:

3.3.1. Provide accurate records of each sheet pile driven. Submitted records shall include the following information:

a) Pile identification number.
b) Date and time of driving.
c) Elevation of top of pile.
d) Length of sheet pile in the ground when driving is complete.
e) Driving logs showing the time to install each foot of each sheet pile.
f) Detailed remarks concerning alignment, obstructions, etc.
g) Plumbness records of each sheet pile installed.
h) Joint flushing records for each joint installed.

3.3.2 Mark a waterproof identification number that is clearly visible on each sheet pile, within 2 feet from the top of pile.

3.3.3 Spray paint all sheet piles rejected from the work for any reason, at the time of rejection, with the letter "X" within 3 feet of both ends.

3.3.4 Provide accurate sealant installation records. Submitted records shall include the following information:

a) Joint identification number.
b) Date and time of sealing operation.
c) A complete list of the equipment used during the installation.
d) Volume of sealant required to seal each joint.

3.4 REJECTION

3.4.1 If rejected from the work because of deviation from location, plumbness requirements, excessive bending, twisting, pulling out of interlock, or other reasons, take suitable corrective action at no additional cost to the Owner. Suitable action includes extracting, furnishing and driving of replacement sheet piles, so that all sheet piles installed meet the requirements of this Specification.

3.5 CERTIFICATION

C3 Environmental Limited shall certify the bulk hydraulic conductivity of the Waterloo Barrier wall will be equal or less than $1x10^{-7}$ cm/sec for up to one year after completion of the barrier wall installation.

END OF SECTION

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