TENCATE
Geotube®

Environmental Dredging and Remediation TenCate Geotube® Case Studies

Protective & Outdoor Fabrics
Aerospace Composites
Armour Composites
Geosynthetics
Industrial Fabrics
Grass

TENCATE
materials that make a difference

TenCate Geotube® technology

TenCate Geosynthetics Group has been at the forefront of Geotube® technology for over 50 years. During that time our Company has built a formidable expertise with this technology.

Geotube® technology involves the permeable containment of fills and wastes using specially engineered textiles. These specially engineered textiles enable the passage of water while at the same time retain the solids component of the container fill and also any contaminants present. Geotube® containers are supplied in a range of shapes and sizes depending on the application. These can be tubular-shaped, bag-shaped, mattress-shaped, or more general container-shaped.

Today, our Geotube® technology is focused on two application areas – hydraulic engineering and environmental engineering.

Geotube® technology for hydraulic engineering
Here, the Geotube® technology is used to contain sandfill in order to provide erosion resistant structural units. These sandfill containment units are used for a wide variety of hydraulic and marine engineering applications.

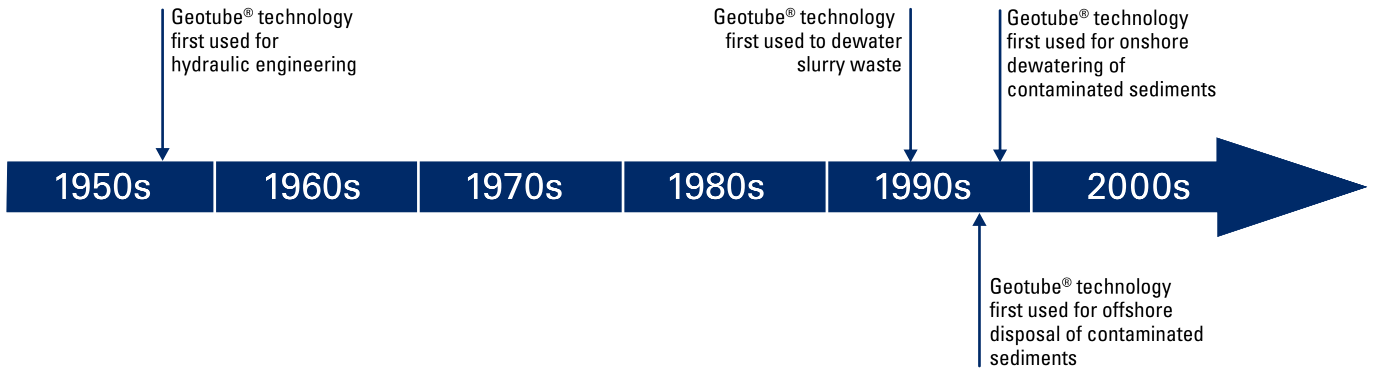
Geotube® technology for environmental engineering
Here, the Geotube® technology is used to contain and dewater slurry wastes. Where environmental dredging of contaminated sediments is performed the safe onshore containment and remediation of these sediments is crucial. In many instances dewatering is employed to significantly reduce the sediment storage volume and to render the sediments into a solid, stable form. Geotube® technology provides a simple and cost-effective means of dewatering large volumes of contaminated sediments.

Geotube® technology may also be used to contain contaminated sediments for safe offshore disposal where onshore disposal proves impossible.

Geotube® technology used for hydraulic engineering

Geotube® technology used for environmental engineering

TenCate Geotube® milestones



TenCate Geosynthetics Group is a pioneer in the field of Geotube® technology. The history of the Group's involvement with this technology stretches back over 50 years to the late 1950's. It was at this time that the earliest applications of what was to later become known as Geotube® technology began to be used for hydraulic engineering applications. This involved the use of specially engineered textiles to contain sandfill for use as structural erosion control units. Over the succeeding 50 years this technology has evolved, and been modified, so that today it is used in a wide range of hydraulic engineering applications ranging from surface erosion protection to structural units in offshore marine structures.

The earliest use of Geotube® technology for environmental engineering applications occurred in the mid-1990's for the dewatering of slurry wastes. The waste solids are retained within the Geotube® unit while the effluent water is discharged. By the late 1990's this technology began to be used for the onshore dewatering of dredged contaminated sediments. Since that time there have been many occasions where this technology has been applied successfully.

Also during the late 1990's Geotube® technology was first used for the contained offshore disposal of contaminated sediments. This technique has enabled the safe offshore disposal of contaminated sediments where onshore disposal is impossible due to land area restrictions.

TenCate Geosynthetics Group has been at the forefront of Geotube® applications technology for many years. During this time our expertise has enabled many innovative Geotube® technology procedures to be developed.

Environmental dredging and remediation

Environmental dredging involves the removal of contaminated sediments from waterways, lakes, estuaries and coastal areas, and depositing it in a safe, secure location. Once removed, the dredged contaminated sediments are remediated by treatment onshore and then reused, or disposed of, onshore, or may be specially disposed of offshore.

Uncontrolled industrial and domestic development have resulted in the generation of contaminants that when deposited in the sediments of waterways, lakes, rivers and harbours give rise to contaminated sediments. The presence of contaminated sediments involves a major environmental risk because many of the inorganic and organic pollutants remain in the sediments over long periods of time. Further, when absorbed by plants and ingested by aquatic life, these act as a major source of contamination within the animal and human food chain. Today, serious sediment contamination is found in the waterways of developed and developing countries throughout the world.

The focus of scientific and regulatory concern centres on five major types of contaminants within sediments:

- Nutrients and raw sewage: phosphorus and nitrogen compounds such as ammonia; and organic matter.
- Organic hydrocarbons: e.g. oil and grease.
- Halogenated hydrocarbons and pesticides: e.g. dichloro-diphenyl-trichloroethane (DDT), polychlorinated biphenyls (PCB's), and dioxins.
- Polycyclic aromatic hydrocarbons (PAH's): e.g. petroleum and petroleum by-products.
- Heavy metals: e.g. iron, manganese, lead, cadmium, zinc, and mercury, and metalloids such as arsenic and selenium.

Where contaminated sediments have to be removed from a particular location this is normally carried out by dredging. Dredging involves the disintegration of the insitu sediment layer, raising the dredged material to the surface and then horizontal transport of the contaminated sediment slurry. It is crucial that in performing the above three activities the dredging be done in a very controlled manner with minimal disturbance to, and contamination of, the surrounding environment.

The dredging equipment used can be either mechanical dredges or hydraulic dredges. Mechanical dredges operate by mechanically excavating the contaminated sediment layer. These are normally used where isolated pockets of contaminated sediments exist at relatively shallow depth. Hydraulic dredges operate by pumping the disturbed contaminated sediments to the surface, and then pumping it horizontally to its treatment location. Small scale hydraulic dredges generally have good dredging accuracy (in terms of dredging depth and dredging extent) while medium scale hydraulic dredges have less accuracy, but can dredge greater volumes. In some cases small scale hydraulic dredges have been specifically developed for environmental dredging applications where dredging accuracy and minimal sediment disturbance have been critical.

Once the contaminated sediments have been dredged they must be disposed of in an environmentally safe manner. Two different disposal methods have been used – onshore disposal or offshore disposal.

The onshore disposal of contaminated sediments involves their transport in slurry form to an onshore treatment site where the contaminated sediment volumes are reduced significantly by dewatering. The resulting contaminated sediment solids either are then disposed of in a containment facility, or are then recycled for beneficial reuse. Dewatering is an important treatment in the onshore disposal of contaminated sediments as it not only reduces the sediment slurry volume by 60% to 80% but also changes their consistency from a liquid to a solid, which facilitates subsequent disposal or beneficial reuse.

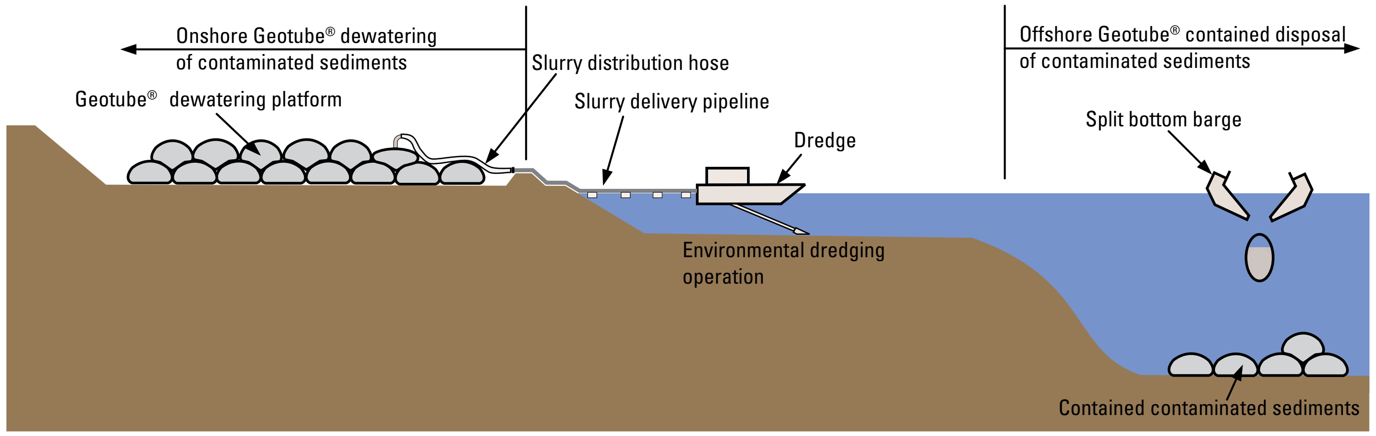
The offshore disposal of contaminated sediments involves the transport of the sediments to a specially designated offshore dumping site where they are deposited on the seabed. The most common form of offshore disposal is surface dumping from a split-bottom barge. Unfortunately, this dumping method results in dispersion of the contaminants into the surrounding water column and is made worse by local water and tidal currents. Consequently, such designated dumping sites are normally located well-offshore and well-away from human development and aquaculture sources.

Mechanical dredging using an excavator

Small scale hydraulic dredge

Medium scale hydraulic dredge

TenCate Geotube® dewatering and containment solutions



Onshore and offshore Geotube® contaminated sediment disposal solutions

TenCate Geotube® technology can be used to treat dredged contaminated sediments in two different ways. First, it can be used for the onshore dewatering of dredged contaminated sediment slurries. Second, it can be used for the offshore contained disposal of dredged contaminated sediments.

Onshore Geotube® dewatering of contaminated sediments

Geotube® containers provide a simple, low cost means of dewatering contaminated sediments. They enable the efficient dewatering of sediment slurries while at the same time ensure good effluent water quality. Further, the required Geotube® container numbers can be scaled easily depending on the size of the dewatering operation.

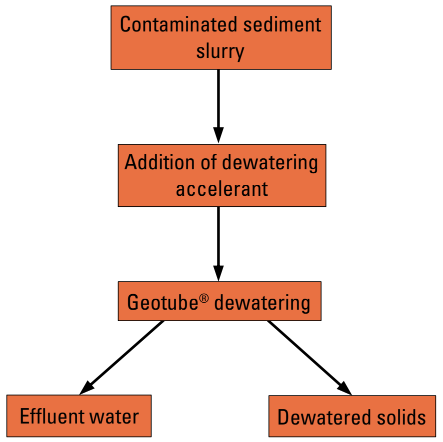
There are a number of steps involved in the Geotube® dewatering process. These are:

1. The dredged in-coming contaminated sediment slurry is dosed with a chemical dewatering accelerant to enhance the rate of dewatering and to trap contaminants within the structure of the contained dewatered solids. The use of the correct accelerant and its dosage rate is critical to dewatering efficiency.
2. The sediment slurry then enters the Geotube® dewatering containers. The slurry water passes out as effluent through the permeable skin of the Geotube® containers while the contaminated sediment solids remain inside the containers. It is normal practice for the containers to undergo several filling and drawdown cycles before the dewatering operation is complete.
3. The effluent water drains from the containers to a specific location in the dewatering facility and, if clean enough, may be returned directly to the natural environment, or alternatively, may undergo further treatment in order to meet specific water quality standards.
4. Once the dewatering process has been completed the dewatered solids may be transported to a designated offsite disposal facility, may be capped insitu, or put to beneficial reuse.

Geotube® dewatering is noramally carried out in a designed dewatering facility. When dealing with contaminated sediments the facility is normally lined with a geomembrane to prevent leakage into the surrounding environment. Also, a drainage layer is placed across the top of the geomembrane prior to installation of the Geotube® containers. The drainage layer enables the effluent water from the dewatering containers to be drained to a specific location in the dewatering facility.

Offshore Geotube® contained disposal of contaminated sediments

Where limited land area exists for the onshore treatment and disposal of contaminated sediments offshore contained disposal has been carried out. This has involved the use of Geotube® containers to prevent the dispersal of the contaminated sediments while they are being dropped through the water column from split-bottom barges at designated offshore dumping sites.



Geotube® dewatering process

Onshore Geotube® dewatering of contaminated sediments

Offshore Geotube® contained disposal of contaminated sediments

Selected TenCate Geotube® international case studies

TenCate Geosynthetics Group has been involved in many environmental dredging and remediation projects using Geotube® solutions, in many parts of the world, over the last 20 years. The selection of case studies contained in this booklet give an appreciation of the diverse Geotube® solutions that have been used in environmental dredging and remediation projects dealing with contaminated sediments. New and innovative Geotube® solutions in environmental dredging and remediation projects are continually evolving.

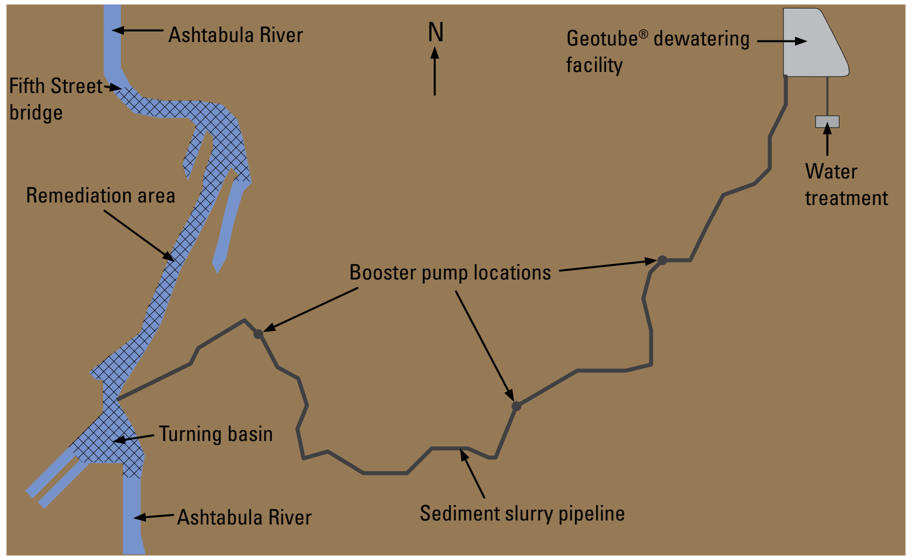
Canals and rivers: Remediation of contaminated sediments, Ashtabula River, Ohio, USA

The Ashtabula River lies in the Northeast of Ohio, flowing North into Lake Erie at the City of Ashtabula. Concentrated industrial development has occurred along the river and around the river mouth for many years. From the 1940's through to the late 1970's unregulated discharge and mismanagement of hazardous waste resulted in Ashtabula River sediments becoming highly contaminated. This has degraded biological communities in the lower reaches of the river, the entrance harbour and its environs.

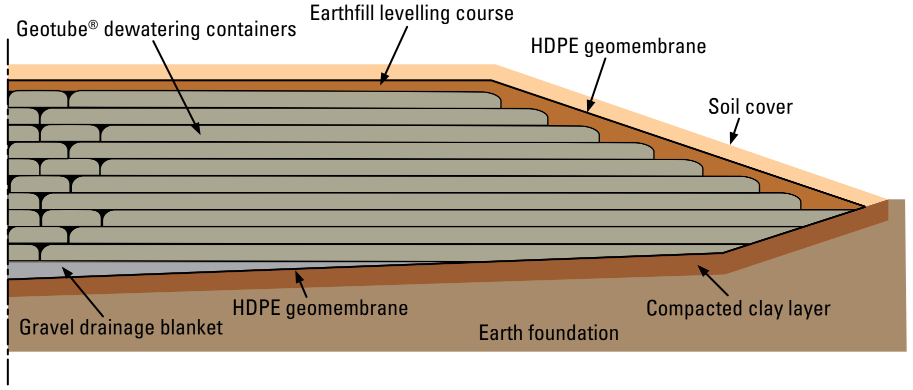
Major pollutants of concern were mercury, chromium, lead, zinc, and numerous chlorinated organic compounds, particularly PCB's and PAH's as well as low level radionuclides. An area covering the lower 3 km of the Ashtabula River, Ashtabula Harbour and the adjacent Lake Erie shore was designated an area of concern due to severe pollution problems. Compounding this problem, regular dredging has been prevented due to the presence of contaminated sediments and the inability to dispose of them properly. For years navigation in the Ashtabula River was restricted because of this buildup of contaminated sediments.

A group of Government Agencies and private companies raised $50 million to remove 400,000 m³ of contaminated sediments along a 2.5 km length of the Astabula River between the Fifth Street bridge in the North and the turning basin in the South. The remediation plan involved dredging the contaminated sediments from the river and pumping them through a slurry pipeline to a Geotube® dewatering facility located to the East of the Ashtabula River. After removal of the contaminated sediments habitat restoration took place along the East side of the river to provide a place for fish and other wildlife. It was also anticipated that the cleanup would improve the environment for recreational boating and stop contaminated sediments from flowing into Lake Erie, thereby improving the quality of the entire Great Lakes basin.

The 5 hectare Geotube® dewatering facility was designed to be a permanent contaminated sediment disposal facility to the same standards as current landfill structures. A double composite liner system was constructed across the base and up the sides of the facility. A gravel drainage blanket was then placed across the base of the facility. On top of this the first layer of Geotube® dewatering containers were placed before being connected to a pipe manifold system and the sediment slurry pipeline.



Site layout showing details of the Ashtabula River remediation



Section through the Geotube® dewatering facility following capping

The contaminated sediments were removed from the river using a 300 mm diameter hydraulic cutter head dredge. Initially, a considerable problem was experienced in dealing with trash and root debris which caused lost operations time. This problem was overcome, to a major degree, by installing special root cutters in the dredge pump and in all booster pumps.

The contaminated sediment slurry was pumped through a 300 mm diameter, 4.2 km long pipeline from Ashtabula River to the dewatering facility. Three booster pump locations along the length of the pipeline ensured even flows of sediment slurry. Geotube® dewatering containers of circumference 9.1 m and various lengths ranging up to 100 m were stacked up to 10 layers high to minimize the area footprint requirement for the dewatering facility. The effluent water was collected in a pit and treated by sand filtration and activated carbon filtration prior to release back to the local river.

Following completion of the dredging operation in Ashtabula River it was estimated that a total of 11,000 kg of hazardous PCB's and other contaminants were removed from the river bed along with the sediments.

After the dewatering operation had been completed the dewatering facility was capped. First, an earthfill levelling course was placed over the top of the dewatered Geotube® containers. Next, a geomembrane liner was placed over this levelling course before a surface soil layer was placed and the whole area vegetated.

The removal of the contaminated sediments has contributed significantly to the environmental quality of Ashtabula River and the local environs. The contaminant loading contribution from Ashtabula River into Lake Erie has been removed, which is a positive improvement for the lake itself, as well as for the entire Great Lakes basin. A secondary benefit is a much deeper Ashtabula River, enabling the return of normal commercial navigation and recreational boating in the river and harbour.

Client: US Environmental Protection Agency, Chicago, Illinois, USA.

Consultant: US Army Corps of Engineers, Buffalo, New York, USA.

Contractor: Infrastructure Alternatives, Inc., Rockford, Michigan, USA.

Ashtabula River looking North

First layer of Geotube® containers in dewatering facility

Geotube® dewatering containers stacked 10 high

Earthfill levelling course over dewatered Geotube® containers

Geomembrane liner installed in cap over Geotube® dewatering facility

Canals and rivers: Environmental dredging of Ypres-Yser Canal, Ypres, Belgium

The Yser River is a 77 km long, small river which flows through Northern France and Western Flanders in Belgium, and on into the North Sea. Numerous channels from the surrounding polders drain into the river. During World War I the Yser River formed the front line in Belgium for a number of years with many battles fought there. Decaying munitions and ordnance are still found in the river and on the surrounding land.

The Ypres-Yser Canal is a commercial waterway which links the town of Ypres to the Yser River. It was originally created in the 17th century by dredging and remains in use to this day. Following World War I the canal was dredged several times to maintain a suitable navigation depth and to remove unexploded munitions and ordnance. However, over recent years maintenance dredging has been lacking and this has resulted in silting up of the canal.

The Belgian Government decided to dredge and clean up a 15 km length of this canal to achieve a 10 m wide channel and a navigable depth of 1.5 m throughout to enable the passage of pleasure boats. Both ends of the canal contained sediment contaminated with PCB's and hydrocarbons over a length of 2 km due to industrial discharge into the canal. By Belgium Regulations this contaminated sediment required special disposal procedures.

The project called for the removal of 55,000 m³ of canal sediment, half by drying in a lagoon and half by using Geotube® dewatering technology. The advantage of the Geotube® method was that the sediment sludge could be transported by barge to the dewatering site, thus avoiding road transport congestion. Further, preliminary tests showed that it was possible to dewater the sediment slurry in a relatively short time, saving space and effort. Conversely, drying lagoons require relatively large areas and involve effort in periodically turning over the drying sediment.

Dredging of the contaminated sediment from the canal was carried out using a pontoon-mounted excavator. It was originally assumed that past dredging works would have removed any unexploded munitions and ordnance arising from World War I. However, this was found not to be the case and the dredging contractor had to find a way of dealing with unidentified explosive objects dredged up along with the sediment.

In total 2,512 unidentified explosive objects were found in the dredged sediment, including 627 grenades, 18 mortars and several projectiles with toxic contents or charged with phosphoric acid. Because of the likelihood of explosions, on two occasions solutions had to be found urgently to enable the dredging work to proceed in a safe manner. Barges were then armoured with thick steel plates in order to limit the damage in case of an explosion. Further, a steel grating was installed on the transport barge to sieve out the explosive objects. Water jets were installed to wash the objects of sediment, and they were then carefully removed and disposed of by explosive experts in a safe manner.

Once the transport barge had been filled with the dredged and sieved contaminated sediment, it was towed to the dewatering site where an excavator-fitted submersible pump was used to remove the sediment and pump it to the Geotube® dewatering platform.

Dredging of contaminated sediment into transport barge

An existing work yard that had a concrete surface and was located next to the canal was used as the dewatering site. A gravel drainage layer was placed across the top of the concrete surface prior to installing the Geotube® dewatering containers.

When dredged from the canal the sediment had a relatively high solids concentration of around 45%. Even after washing for unidentified explosive objects, the transported sediment still had to be diluted further to enable pumping from the transport barge. Consequently, water was added to dilute it to a slurry of about 10% solids concentration, which enabled hydraulic pumping using the submersible pump.

The sediment slurry was dosed with a chemical dewatering accelerant prior to entering the Geotube® containers. A control unit recording density, velocity and pressure automatically adjusted the accelerant dosage according to the solids concentration being pumped.

More than 80 Geotube® dewatering containers were used for the dewatering of 28,000 m³ of sediment dredged from the Ypres-Yser Canal. This technique had the additional advantage that contaminated and uncontaminated sediment could be contained and dewatered separately at no additional cost. The contaminated sediment was pumped into specially marked Geotube® dewatering containers, while the uncontaminated sediment was pumped into differently marked containers. The quality of the effluent water from both sets of containers was well within Belgium Government quality standards so that it could be discharged directly back into the canal without any environmental concerns. In fact, part of this effluent water was utilized as dilution water for the dredged sediment prior to its pumping to the Geotube® containers using the submersible pump. The target dewatered solids concentration was easily achieved within the short dewatering time of a few days.

When the containers were filled with solids, and had dewatered fully, they were cut open and the solids were loaded onto transport trucks. The contaminated solids from the specially marked Geotube® dewatering containers were sent to a landfill for disposal. The uncontaminated dewatered solids were beneficially re-used as general fill material in earthworks.

Client: Waterwegen en Zeekanaal N.V., Division Bovenschelde, Merelbeke, Belgium.

Contractor: Ghent Dredging N.V., Gent, Belgium.

Steel grating used to separate out unidentified explosive objects from contaminated sediment

Examples of unidentified explosive objects

Transport of contaminated sediment to dewatering site

Pumping slurry from docked transport barge to Geotube® dewatering platform

Geotube® dewatering of contaminated sediment

Canals and rivers: Conner Creek cleanup, Detroit, Michigan, USA

The Detroit River is a 20 km long international connecting river linking Lake St. Clair in the North (and the upper Great Lakes) to Lake Erie in the South. Heavy industrialization has occurred along the river over the last 100 years. This, combined with sewer overflows, has resulted in high levels of contamination at certain locations along the river and in streams and canals entering the river.

Conner Creek is a small tributary entering the Detroit River. Sediment deposits had been building up due to the ongoing combined sewer overflows at the upper end of the creek. A longstanding problem had also existed with noxious odours associated with anaerobic decomposition of sewage sludge in the sediments. Deeper sediment layers were contaminated with both inorganic and organic pollutants. The creek also had high levels of trash including machine parts, etc. The creek was last dredged in 1954.

In the late 1990's the City of Detroit began a program to clean up all of its combined sewer overflows by treating all future run-off before it enters the water course. The Conner Creek overflow system was prioritized for construction. It consisted of a combination of mechanical screening, sodium hypochlorite storage and feed system, flushing gates and odour control. However, before this could be implemented Conner Creek itself had to be dredged and remediated.

The Conner Creek cleanup project involved dredging 130,000 m³ of contaminated sediments along a 1.4 km long section of the creek. In addition to removing the contaminated sediments from the creek bottom the dredging lowered the natural depth of the waterway thereby increasing its hydraulic capacity to handle the effluent flow from the overflow system. Before dredging could commence an excavator placed on a barge was used to remove debris and trash from the creek bottom. Dredging was then carried out with a combination of a 200 mm hydraulic swinging ladder dredge and a 200 mm auger head dredge.

The dredged contaminated sediments were dewatered using Geotube® containers prior to disposal of the dewatered solids to a Class 2 landfill. Because of a lack of open land the Geotube® dewatering platform was established along the bank of Conner Creek adjacent to the dredging operation. The dewatering platform was geomembrane lined with a 300 mm thick gravel drainage layer placed on top.

A total of 70 Geotube® containers each measuring 18.3 m in circumference and 61 m in length were used to dewater the dredged slurry. Prior to entry into the containers the dredged slurry was dosed with a chemical dewatering accelerant to aid the dewatering process. Several Geotube® dewatering containers were laid out on the dewatering platform at any one time. One container was filled to a specific control height. Upon reaching this height, filling was stopped and the Geotube® container was allowed to drawdown while the slurry infill stream was diverted to an adjacent container that was prepared for filling. The effluent from the Geotube® dewatering containers was discharged directly back into Conner Creek.

Because of the limited area of the dewatering platform the Geotube® containers had to be stacked three layers high at three adjacent locations along Conner Creek.

High levels of debris and trash removed from Conner Creek*

Once the dewatered solids concentration had reached a value of around 50%, the dewatering process was deemed to be complete and more Geotube® containers were laid out on the dewatering platform for the process to be continued. Upon final completion of the dewatering of the dredged slurry the Geotube® containers were cut open and the dewatered solids were removed to a permitted landfill.

The effect of the dredging and the new sewage and run-off overflow system on the environment in Conner Creek and its surrounds has been major. As any flow discharge now has to meet permitted Government quality standards the Conner Creek water colour is blue, reflecting its cleanliness. Further, nearby residents do not complain of noxious odours.

Client: Detroit Water and Sewerage Department, Detroit, Michigan, USA.

Consultant: Hazen and Sawyer Environmental Engineers and Scientists, Detroit, Michigan, USA.

Contractor (dredging and dewatering): Infrastructure Alternatives Inc., Rockford, Michigan, USA.

Dredging of contaminated sediment*

First layer of Geotube® containers filling with dredged contaminated sediments

Geotube® dewatering of contaminated sediment slurry

Geotube® containers stacked three high on dewatering platform

Excavation of dewatered sediment for transport to offsite disposal facility

Canals and rivers: Melaka River remediation, Melaka, Malaysia

Melaka is a coastal city located on the Southwestern side of the Malaysian Peninsula on the strategic shipping lanes of the Melaka Strait. All through its history Melaka has been a major trading centre, and at various times has come under the influence of Malay, Arab, Indian, Chinese, Portuguese, Dutch and British traders. This has given Melaka and its environs a rich cultural heritage and in 2008 it was listed as a UNESCO World Heritage Site. Because of this rich heritage Melaka is a destination for many tourists.

The City of Melaka is located along the Melaka River which flows North to South through the middle of the city. The river has been the centre of activity throughout the long history of Melaka. However, industrialization and economic development over the last 20 years has led to the indiscriminate dumping of trash and the run-off of nutrients and raw sewage directly into the river. This, coupled with a buildup in sediment in the river bed, has resulted in it becoming non-flushing, foul smelling and murky and blackish in nature, along with algal plumes in certain locations.

To restore the Melaka River to its original clean condition the Government has undertaken a major remediation program. The first stage of this was to construct sewage treatment plants along the river to ensure all domestic and industrial wastewater entering the river was treated. The next stage involved the remediation of the river itself.

The decision was made to dredge the Melaka River along a 13.5 km length through the built-up area of the city in order to remove the contaminated sediments and to reshape the geometry of the river so that it would become naturally self-flushing. This entailed the removal of some 570,000 m^3 of sediments. The dredged contaminated sediments would be dewatered at two locations along the river using Geotube® dewatering containers. The dewatered solids would be transported to an offsite landfill for disposal.

To evaluate the feasibility of returning the Geotube® filtered effluent water directly to the Melaka River without the need for further treatment a test program was carried out. Samples of the raw contaminated sediments were obtained from a number of locations along the river and were tested for contaminant levels. The results obtained, shown in the table below, demonstrate the high amounts of nutrients and raw sewage deposited in the sediments of the river. Small scale Geotube® filtration tests were carried out on the raw contaminated sediment samples with the filtered effluent water tested for contaminant levels. The results, also shown in the table below, demonstrate that with the use of the correct chemical dewatering accelerant the filtered effluent water contained relatively small contaminant levels, and met the Government water quality requirements for direct return to the river.

Contaminant	Raw contaminated sediments	Geotube® filtered effluent water
Phosphorus	5 - 220 ppm	0.05 – 0.9 ppm
Nitrogen	2.5 - 65 ppm	0.3 - 0.6 ppm
TSS	43,000 - 160,000 ppm	2 - 50 ppm
BOD	140 - 360 ppm	2 - 5 ppm
COD	350 - 1,200 ppm	5 - 15 ppm

ppm – parts per million (by weight)
TSS – Total Suspended Solids
BOD – Biological Oxygen Demand
COD – Chemical Oxygen Demand

Melaka River by night

At two locations along the river Geotube® dewatering platforms were constructed to process the dredged contaminated sediments. The platforms consisted of a geomembrane liner covered with a geotextile protection layer. On top of this a granular drainage blanket was constructed before placement of the Geotube® dewatering containers. The plan was that these two dewatering sites would be returned to their natural condition following completion of the dredging and dewatering program.

Due to the high levels of trash encountered in the river sediments dredging had to be carried out in a careful manner. To prevent blockage of the pipeline to the Geotube® dewatering facilities a trash separation unit was installed to filter out out the trash from the contaminated sediment slurry following dredging.

The dredged contaminated sediment slurry was dosed with the optimum chemical dewatering accelerant prior to entry into the Geotube® dewatering containers. To efficiently fill the Geotube® containers approximately 10 filling and dewatering cycles were carried out. During dewatering, the effluent water was tested for quality and then returned directly to the Melaka River. The complete dewatering process occurred over a 2 to 3 month period.

Once the dewatering process had been completed the Geotube® containers were cut open. The dewatered contaminated sediments now resembled a solid material that could be easily excavated and loaded onto transport for removal to a local landfill facility.

Following removal of the dewatered contaminated sediments from the dewatering facility additional Geotube® containers were laid out on the dewatering platform and the whole dewatering process was repeated.

When the environmental dredging project had been completed each dewatering facility was returned to its natural condition.

Client: Jabatan Pengairan dan Saliran, Kuala Lumpur, Malaysia.

Consultant: Perunding Zaaba Sdn Bhd, Kuala Lumpur, Malaysia.

Contractor: Sinnaiyah and Sons Sdn Bhd, Johore Bahru, Malaysia.

Dredging of contaminated sediments from Melaka River

Separation of trash from contaminated sediment slurry

Geotube® dewatering of contaminated sediments showing slurry delivery pipes

State of contaminated sediments following Geotube® dewatering

Excavation of dewatered contaminated sediments for transport to offsite landfill

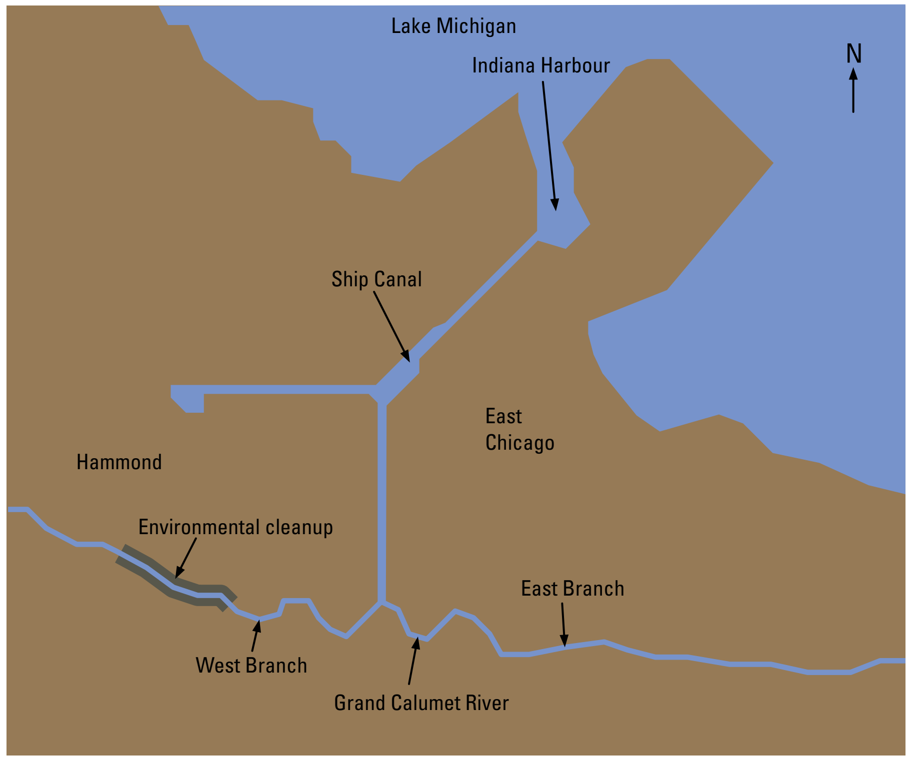
Canals and rivers: West Branch Grand Calumet River cleanup, Indiana, USA

The Grand Calumet River is a slow moving, meandering river that begins near the City of Gary, Indiana and flows 21 km in an Easterly direction through East Chicago and Hammond and onto the Southern shore of Lake Michigan at the Marquette Lagoons. In the early 1900's an artificial canal access was constructed, running North-South between the Grand Calumet River and the Southwestern Shore of Lake Michigan through East Chicago. This access is known as the Indiana Harbour and Ship Canal. This opened up the Grand Calumet River system to heavy industrialization which has occurred throughout much of the 20th century. The presence of the Ship Canal on the Grand Calumet River has been to split it into two parts – the West Branch and the East Branch.

The Grand Calumet River area has been the home of steel plants, metals processing, chemical production and petroleum refining for over 100 years. Consequently, the river has become polluted with heavy metals, PCB's, PAH's and pesticides. Today, it is estimated that 90% of the river's flow starts as municipal and industrial discharge, cooling and process water and storm water overflow.

Upland restoration activities near the Grand Calumet River have been underway for a number of years, including protection and restoration of rare habitats such as dune and swale and native prairies. Recently, a federal and State Government cooperative began a two-year undertaking to dredge contaminated sediments from a heavily polluted, 1.5 km length of the West Branch Grand Calumet River, Southwest of the Indiana Harbour and Ship Canal. This is a very unique area as not only is it one of the most industrialized areas in the country, but it is also home to some of the most diverse native plant and animal communities in the Great Lakes Basin.

Because pollutants had built up in the sediment layers over many years they were distributed throughout considerable sediment depth. Consequently, the river cleanup called for the removal of about 70,000 m³ of contaminated sediments by dredging, followed by the placement of an engineered capping layer over the dredged area to secure a further 75,000 m³ of contaminated sediments left in place. The sediments contain pollutants such as PCB's, PAH's, heavy metals and pesticides in relatively high concentrations. Approximately 60,000 m³ of clean sand was used as the capping layer (in various thicknesses) over the dredged area.



Location of the cleanup program in West Branch of Grand Calumet River

The plan was for the dredged contaminated sediments to be dewatered using Geotube® containers at a site close to the dredging operation, and once having attained the target dewatered solids concentration, would be removed to an offsite permitted landfill facility.

Samples of the contaminated sediments were tested for their dewatering characteristics. Also, dewatering polymers were evaluated based on water release rate, effluent water clarity, and flocculent appearance. Dosing rates were determined during small scale dewatering experiments and recommendations were provided during this phase of the evaluation program. During this evaluation program, it was determined that a dual chemical accelerant treatment would be most effective.

The dewatering platform had a footprint of 140 m by 85 m to allow for the deployment at any one time of up to 11 Geotube® dewatering containers, each measuring 23 m in circumference by 61 m in length. The base of the dewatering platform was constructed using a geomembrane liner with a geotextile protection layer, covered with a 300 mm thick gravel drainage blanket.

An automated chemical accelerant dosing system was set up at the dewatering site. The automated system monitored density and flow rates of sediment slurry, and continuously adjusted the chemical accelerant feed rate in response to both. A sample port provided visual samples of the slurry to determine if changes were needed to the accelerant feed rate settings. If required, adjustments were made either manually, or by remote control.

Based on the limited area available at this site, the Geotube® dewatering units were filled in sequence and allowed to dewater for approximately 12 to 15 days after which the Geotube® container was cut open and the dewatered solids loaded and hauled away to a permitted landfill for permanent disposal. Once the dewatered solids had been removed, new Geotube® dewatering containers were placed, and the sequential operation repeated. This procedure allowed for continuous dredging operations.

The effluent water from the Geotube® dewatering containers was drained through the gravel drainage blanket and entered a water treatment pond at the low corner of the dewatering site. Sand and activated carbon filtration was applied to the effluent water before it was discharged into the local authority sewer system.

In total, 5,600 linear metres of Geotube® dewatering containers were used and the project took 5 months to complete. Due to the success of this project, other sections of the Grand Calumet River are also planned to undergo the same remediation process.

Client: US Environmental Protection Agency, Chicago, Illinois, USA.

Consultant: US Army Corps of Engineers, Chicago, Illinois, USA.

Contractor: Infrastructure Alternatives, Inc., Rockford, Michigan, USA.

Polluted Grand Calumet River

Dredging contaminated sediment in West Branch Grand Calumet River

Geotube® dewatering platform

Final dewatering and transport of dewatered contaminated sediment to offsite disposal facility

Excavation of dewatered contaminated sediment for offsite disposal

Canals and rivers: Port entrance environmental dredging and riverbank restoration, IJssel River, Zutphen, The Netherlands

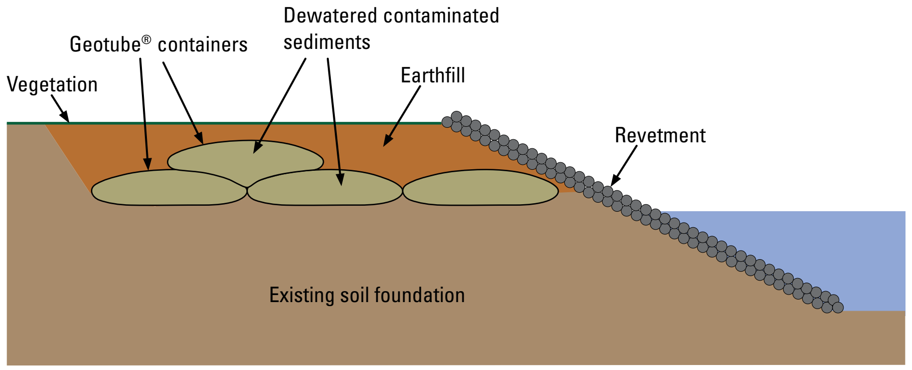
The City of Zutphen is located on the IJssel River which is a tributary of the Rhine River. The old industrial harbour of Zutphen was refurbished as part of a restoration plan for the entire industrial area. Part of this plan involved the accommodation of ships with a draught of 2.8 m; but because siltation of the harbour entrance had occurred over recent years, dredging of the entrance to the original depth was required. At the same time, the riverbank near the harbour entrance required restoration to prevent further erosion and subsequent re-siltation of the harbour entrance.

In The Netherlands there has been a change in strategy in recent times regarding the maintenance of waterways and harbours. This change has been from a disposal of dredged materials strategy to a beneficial reuse strategy. This new strategy is in line with recent European Union Regulations.

Studies at the harbour entrance showed that a total of 6,000 m³ of Class 2 sediment and 12,000 m³ of Class 3 contaminated sediment had to be dredged. The Class 3 contaminated sediment would have normally required placement in a confined disposal facility, which would have proved costly. The Geotube® container solution was able to solve the problem of disposal and beneficial reuse of both Class 2 and Class 3 sediments in an economical and environmental manner. Dredged sediment from the harbour entrance channel was pumped into the Geotube® dewatering containers, then dewatered, and reused as replacement for earthfill material, that otherwise would have been imported, to restore an adjacent eroded riverbank to the required level and shape. The final riverbank restoration had to fulfil geotechnical stability requirements as well as withstand the hydraulic forces of the IJssel River, the fastest flowing river in The Netherlands.

The riverbank restoration involved a 400 m length of eroded bank adjacent to the Zutphen harbour entrance. To isolate the dewatering platform area from the IJssel River four sheet-pile compartments, each 100 m long, were formed. Not only would the sheet-pile walls give protection in case of rising water levels, but each adjacent compartment could potentially serve as a temporary storage area where the effluent water from the Geotube® dewatering process could first be checked before being discharged back into the river. Work permits issued by the Rijkswaterstaat (Ministry of Transport, Public Works and Water Management) required testing of the effluent water before discharging into the river. During the whole dewatering operation the quality of the effluent water never exceeded the quality limits defined by the Rijkswaterstaat.

Each compartment held four Geotube® dewatering containers sized according to the required sludge dewatering mass balance and the total surface area. Dredging was carried out at a rate of 400 m³/hr with 10% solids concentration. Two Geotube® containers were filled with sediment slurry at a time. Due to the accurate in-line dosing system for the chemical dewatering accelerant, the solids concentration of the dewatering sediment reached 65% within four days. After all the dredging had been completed, and the contained sediment had dewatered, the Geotube® containers were covered with earthfill to raise the riverbank to the required level. Finally, a rock revetment was constructed to protect the slope of the restoration works from future erosion by the IJssel River and the earthfill surface was vegetated.



Typical section through riverbank restoration works

This project has proved highly successful. The beneficial reuse of the dredged sediments enabled a project cost saving of around 30% compared with conventional disposal procedures.

Client: City of Zutphen, The Netherlands.

Consultant: Ingenieursbureau Land B.V., Ede, The Netherlands.

Contractor: De Vries and van de Wiel B.V., Schagen, The Netherlands.

Riverbank erosion on IJssel River at Zutphen

Filling Geotube® containers with sediment slurry

Geotube® dewatering of sediments

Placing earthfill covering over dewatered sediments

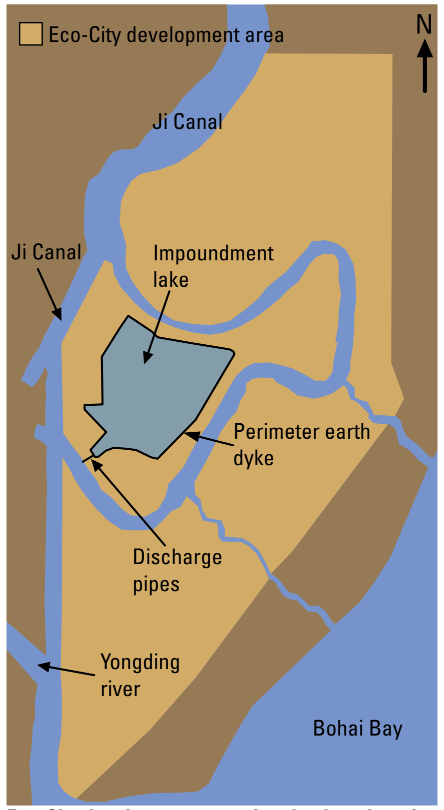
Completed riverbank restoration

Lakes and impoundments: Wastewater impoundment lake remediation, Tianjin Eco-City, China

Tianjin Eco-City is a 30 km² modern city project currently under joint development by the governments of Singapore and China. Located 40 km from Tianjin and 150 km Southeast of Beijing the project is scheduled to house a population of 350,000 when it is completed around 2020. Tianjin Eco-City will use sustainable technologies, such as solar and wind power, plus innovative wastewater treatment and seawater desalination to reduce its carbon footprint. The new city is designed to be ecologically friendly with existing wetlands and biodiversity preserved or improved.

Located within the Eco-City development area is an existing 3.0 km² wastewater impoundment lake that has been receiving domestic and industrial wastewater from the local Hangu District since the mid 1970's. The wastewater impoundment lake is surrounded by a 3 m high perimeter earth dyke and has an impoundment capacity of 5.6 million m³. At the Southern end of this lake are two pipe sluice gates which enable lake discharge via the 1,000 year old Ji Canal directly to the Bohai Sea. During the rainy season when the Ji Canal is prone to overflowing, the sluice gates are closed to prevent river water backflow into the wastewater impoundment lake.

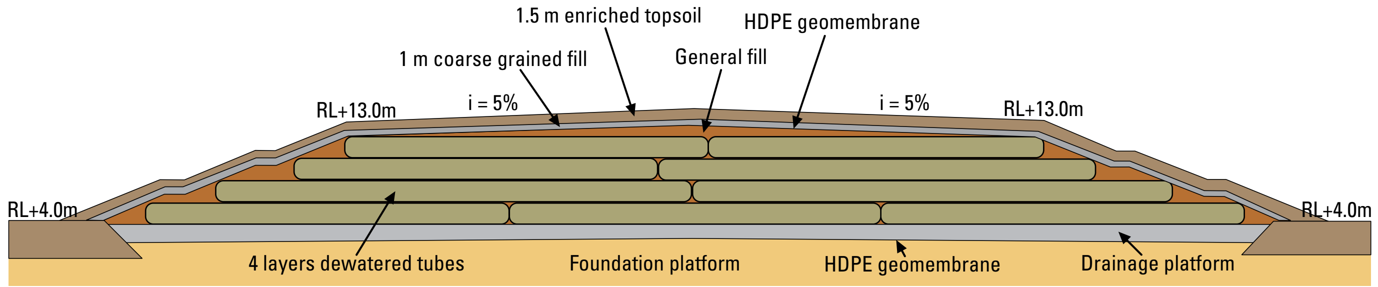
Central to the Eco-City development is the plan to remediate the wastewater impoundment lake that has become laden with contaminated sediments as a result of years of domestic and industrial waste runoff. The water and sediments within the impoundment are contaminated with high levels of heavy metals of mercury, arsenic, copper and cadmium, as well as hexachlorobenzene and DDT. According to the plan the wastewater impoundment was to be transformed into a wetland and recreational lake.



Eco-City development area showing location of impoundment lake

The remediation solution required the contaminated sediments to be dredged from the lake and dewatered to a consistency that allowed them to be used as the fill material for the construction of a landscaped mound along the Western shore of the transformed lake. Geotube® dewatering containers were used to contain the dredged contaminated sediments and dewater the material to a consistency similar to that of compacted borrow material. A total of 2,400,000 m³ of contaminated sediments were dredged and dewatered in order to construct the landscaped mound.

To begin with, a Geotube® dewatering platform was constructed on a reclaimed platform extending from the Western side of the lake. The close proximity of the dewatering platform to the dredging operation minimised the piping and pumping energy required to move the contaminated sediment slurry to the dewatering facility. The dewatering facility was designed along the same concept as an on-site waste containment facility. Thus, when dewatered, the contaminated sediment solids do not need to be removed to an external landfill, but are capped insitu.



Capped mound containing the dewatered contaminated sediments

The contaminated sediment solids remain within the Geotube® container units which are in turn secured within a geomembrane lined facility with both lower and upper barrier systems.

Because of the large scale nature of the dewatering project it was decided to carry out a full scale prototype dewatering test in order to determine accurate dewatering parameters that could be used in the final detailed design. By maintaining a constant sediment slurry inflow rate during filling the dewatering rates both during Geotube® filling and drawdown were recorded over specific time increments. Also, the quality of the effluent water was tested at different time increments. This enabled a determination to be made of project dewatering rates and the volumes and numbers of Geotube® dewatering containers required. It also confirmed the dosing levels of the chemical dewatering accelerant that had been determined in prior small scale testing.

Following the full scale prototype test, detailed design, tender and construction followed.

Three dredges with a combined dredging capacity of 3,000 m³/hr were used to deliver the contaminated sediment slurry to the dewatering platform. Prior to reaching the Geotube® containers the incoming slurry was dosed with the required concentration of chemical dewatering accelerant. Multiple valve controls were provided at regular intervals along the incoming slurry pipeline to allow convenient branching to fill the layout of the Geotube® containers with sediment slurry. Generally, at any time, 6 Geotube® containers were filled simultaneously.

When the Geotube® containers were filled to the control height of 3 m, the slurry control valves were shut with the sediment slurry being diverted to an adjacent battery of 6 tubes laid out ahead of time. The Geotube® containers were allowed to dewater for a few days before being filled again to the control height. This filling and dewatering was carried out over 6 or 7 cycles before a new layer of Geotube® containers was laid above.

The effluent discharged from the Geotube® dewatering containers was released back into the impoundment lake.

A new water treatment plant was constructed nearby to serve Tianjin Eco-City. Its first task was to treat the impoundment lake water. Following completion of the dredging of the impoundment lake it was pumped dry, re-profiled and impounded again with treated water from the nearby Ji Canal.

Almost 19 km of Geotube® containers of circumference ranging from 27.5 m to 30.5 m were used. These were stacked 4 layers high. The whole dewatering operation was carried out over a 6 month period. Finally, the dewatering platform was capped to form a 9 m high landscaped mound, with a plan footprint area of approximately 12 ha.

Client: Tianjin Eco-City Environmental Co., Ltd, Tianjin, China.

Consultant: Tianjin Municipal Engineering Design & Research Institute, Tianjin, China.

Contractor: CCCC Tianjin Dredging Co., Ltd, Tianjin, China.

Dredging contaminated sediments from the impoundment lake

Three layers of Geotube® containers on the dewatering platform

Geotube® dewatering platform

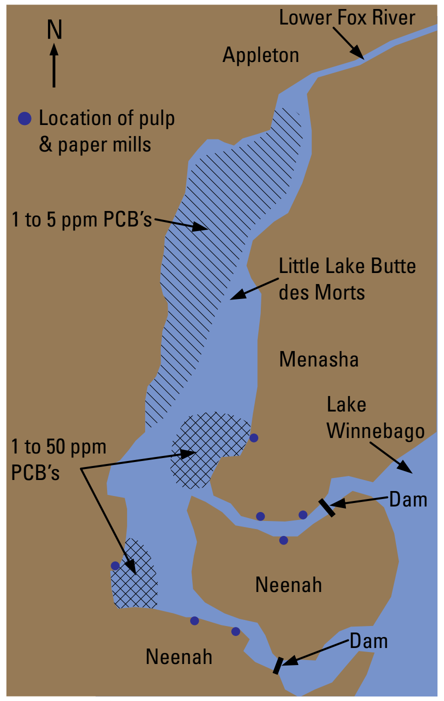
Part of the remediated lake following landscaping

Lakes and impoundments: Little Lake Butte des Morts environmental dredging, Fox River, Wisconsin, USA

The Lower Fox River flows Northeast approximately 65 km from Lake Winnebago (in the Southwest) to Green Bay (in the Northeast) and then into Lake Michigan. Since the late 19th century many pulp and paper companies were attracted to the area to establish plants along the Lower Fox River area because of its constant supply of fresh water and its close proximity to timber sources. By the mid 1950's this area had the highest concentration of pulp and paper operations in the world.

In 1954 the paper mills along the Lower Fox River began producing carbonless copy paper using PCB coated emulsions. Between 1954 and 1971, when the use of PCB's ceased, it is estimated that some 350 tonnes of PCB's had been discharged into the Lower Fox River. A portion of these PCB's settled into the river sediments and was ingested by fish and (then) birds. While the use of PCB's ceased in 1971, recycling of PCB coated paper after their continual migration into Green Bay it was decided to remediate the Lower Fox River. Little Lake Butte des Morts, which lies at the upper reaches of the river, was the first to undergo remediation.

Little Lake Butte des Morts is a shallow, slow flowing waterway approximately 5 km in length and 1 km in width located immediately downstream of Lake Winnebago. A number of pulp and paper mills are located at the upstream end of this lake. Pockets of PCB contamination ranging in concentrations of 1 to 50 parts per million by weight (ppm) are located in two Southern areas of the lake in the vicinity, or immediately downstream, of these existing pulp and paper mills. Another large area in the central North of the lake has PCB concentrations of 1 to 5 ppm due to movement of PCB's from the highest concentration areas before entering the Lower Fox River.



Locations of contaminated sediments in Little Lake Butte des Morts

It was decided to environmentally dredge the contaminated sediments in Little Lake Butte des Morts, treat them onshore by dewatering, and then dispose of the contaminated solids in an off-site permitted landfill. A target of 1 ppm was established as the required upper residual contaminant limit as this gave the optimum solution between long term safety to humans and wildlife and overall project cost. Ninety eight percent of the PCB contamination lies in the upper 1 m of the sediment layer. This required the dredging of approximately 600,000 m³ of contaminated sediments (approximately 1,700 kg of PCB's) in the lake, which was to be carried out over a 6 year seasonal period, beginning in 2004. Following this, a long term monitoring program will be put in place to track the concentration of PCB's in various media.

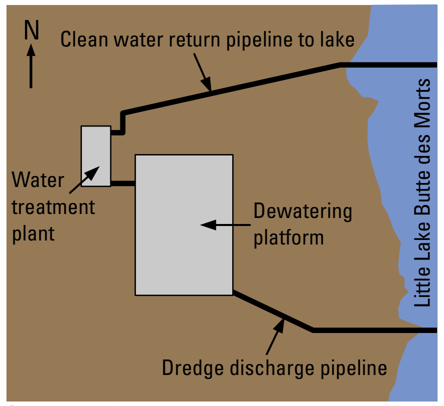
To reduce the local concentrations of PCB's to safe levels and to prevent further discharge of PCB's into the river.

An extensive evaluation programme was employed to determine the appropriate Geotube® dewatering parameters. A large number of semi-performance tests were performed to determine the appropriate chemical accelerant type and dosage rates, the consequent rates of dewatering and the resulting effluent quality. Calculations were then performed to determine the required quantities, sizes and safe filling heights of the Geotube® containers.

Dredging of the contaminated sediments began in 2004 in the area of highest PCB concentrations to the South and Southeast of the lake. The dredges used were special, small scale cutter-suction dredges that created minimal sediment disturbance during operation. The accurate positioning of the dredges was via GPS with an accuracy of 1 m. The depth of dredging varied according to the thickness of contaminant concentration ranging between 0.3 m and 1 m. The accuracy of the depth of dredging could be controlled to within 0.1 m.

The dredged contaminated sediment was pumped hydraulically through floating pipelines to the on-shore sediment processing area located on the Central Western shore of Little Lake Butte des Morts. The sediment processing area consisted of a sediment dewatering platform that supported the Geotube® dewatering containers and a water treatment plant that removed any contaminants from the effluent water. These two processing units were connected by pipeline from the dredges, and then from the dewatering platform to the water treatment plant. Once treated, the clean water was returned to the lake by pipeline.

The Geotube® containers were laid out on the gravel drainage platform and connected by a pipe and manifold system network to the incoming sediment slurry. The manifold system manages the filling and re-filling of the Geotube® containers 5 times before the final dewatering and consolidation stage is reached. The incoming sediment slurry was dosed and mixed with the appropriate amount of chemical dewatering accelerant prior to entering the Geotube® containers. The size of the containers, their filling heights, and the number employed at any point in time had to meet the volume of incoming sediment slurry, which ranged between 270 m³/hr and 330 m³/hr. Because of space limitations on the dewatering platform the Geotube® containers were stacked several high during the dewatering process.



Site layout of sediment processing area

The effluent water from the dewatering process was drained and then piped to the water treatment plant. The treatment plant utilized dissolved air flotation combined with sand and activated carbon filtration to clean the water. The clean water was then returned to the lake by means of an outlet pipeline.

After dewatering, the contained sediments ranged in solids concentration between 35% and 80%. This variation was due to the variation in the amount of granular particles in the Geotube® containers and the time over which the contained sediment was allowed to consolidate (the bottom tube layer was allowed more time to consolidate than the upper layer). This increase in solids concentration resulted in a major reduction in contained sediment slurry volume of 60% to 85% respectively.

At the end of each construction season the Geotube® containers were cut open and the dewatered contaminated sediment was loaded into specially lined trucks and transported to a permitted external landfill facility.

Client: P.H. Glatfelter Co. Ltd, and Wisconsin Tissue Mills, Co. Ltd, Wisconsin, USA.

Dredging contractor: J.F. Brennan Co. Inc., La Crosse, Wisconsin, USA.

Dewatering contractor: Infrastructure Alternatives Inc., Rockford, Michigan, USA.

Small scale cutter-suction dredge used to accurately dredge contaminated sediment layer

Geomembrane lined drainage platform for the dewatering platform

Geotube® dewatering of contaminated sediments

Sand filtration treatment of effluent water

Removal of dewatered contaminated sediment to external landfill

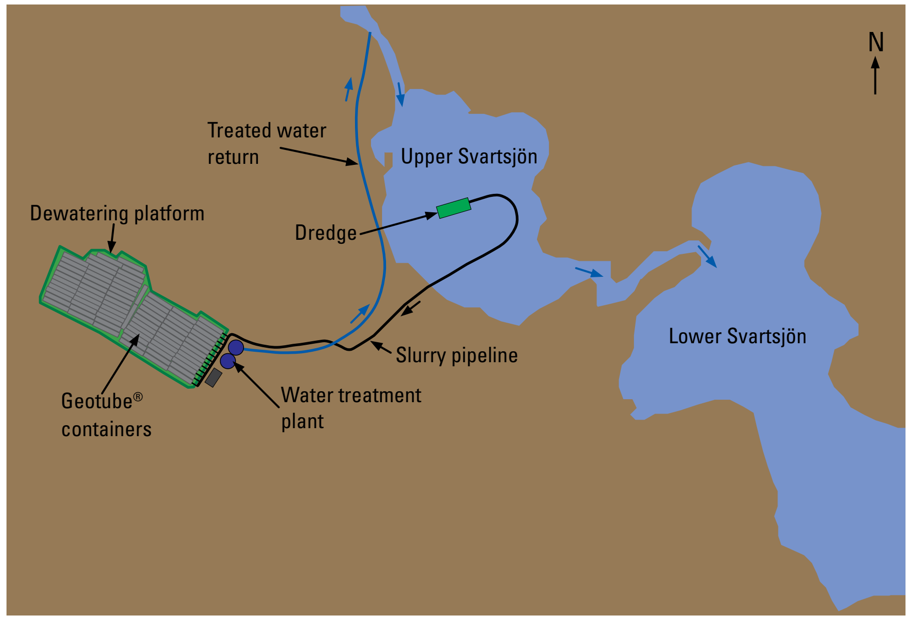
Lakes and impoundments: Environmental dredging of Svartsjön Lakes, Kalmar County, Sweden

The two Svartsjön lakes, Upper Svartsjön and Lower Svartsjön, in Kalmar County in Southeastern Sweden, have been contaminated by past pulp discharges originating from a paper mill upstream in the village of Paulström. Prior to 1968 a mercury compound was used to protect the pulp (which is highly organic) from bacterial attack, and this has led to mercury contamination in the two downstream lakes. The contaminated sediments in the Upper Svartsjön and the Northern basin of the Lower Svartsjön consist of high levels of cellulose fibres (from ground pulp) estimated to be 15,000 to 20,000 tonnes as well as mercury in the range 0.5 to 4 ppm (parts per million). This has caused a serious threat to the aquatic life and plants in the lakes.

It was decided to dredge the two lakes of the mercury-contaminated fibre sediment, which involved the removal of 300,000 m^3 of contaminated sediments, in order to return the lakes to their original natural condition. As the area is well known for its pristine beauty it was also decided to process the dredged contaminated sediment by dewatering at a specially constructed facility on the Western side of Upper Svartsjön. Once the dewatering had been completed the facility would be sealed and capped and the area returned to its original natural state.

The project was awarded as a design and construct contract. The design required the synchronized and rapid removal and dewatering of the contaminated sediments due to the relatively short, single construction season. Geotube® dewatering technology was adopted for the project and was a key factor in helping achieve these design objectives. The dewatering plan was to have the Geotube® dewatering containers encapsulated insitu within a landfill-based barrier system. Thus, the contaminated sediments would not have to be transported off site along the local narrow roads once they had been dewatered.

To ensure that the limited differential settlement of the finished landfill required by the Swedish EPA could be met, the contractor in cooperation with the Department of Geotechnics of Ghent University carried out an extensive study. The consolidation of the sediments, the drainage and release of effluent water and its quality were tested over months in large transparent columns. The overburden effect of the subsequent Geotube® layers was simulated by imposing a surcharge. The outcome of the tests were used for the design of the dredge, the chemical dewatering accelerant station, the landfill and the effluent water treatment plant.



Site layout of the Svartsjön Lakes Geotube® dewatering project

Due to the remote location of the lakes the dredge had to be completely dismountable and transportable over narrow roads as the nearest port was located 200 km away. The dredge that was specially designed for this project was based on seven connectable and transportable pontoons. In order to guarantee very accurate and low turbidity dredging, the positioning of the dredge was controlled by four anchoring points along the shoreline, and a set of four GPS controlled winches to enable a desired area to be dredged automatically.

The base barrier system for the dewatering facility consisted of a geomembrane liner system with a gravel drainage blanket on top. The drainage blanket channeled the effluent water to the lower end of the facility. The Geotube® dewatering containers were rolled out on the gravel drainage blanket with their inlet ports connected to the dredge slurry pipeline.

Adjacent to the dewatering platform a water treatment plant was constructed consisting of an aerobic bioreactor with a capacity of 150 m^3/hr. This plant processed the effluent water from the dewatering platform to ensure the water met the exacting quality standards for return to the upper lake. The treated water was then pumped to a location North of the upper lake where it was reintroduced back into the water course.

The contaminated sediment was dredged at a rate of about 300 m^3/hr and pumped via a 2 km long slurry pipeline system at about 5% solids concentration. Prior to entry into the Geotube® containers the slurry was dosed with an organic dewatering accelerant whose dosage rate was automatically adjusted according to the continuous measurement of solids concentration of the incoming slurry. The flocculated slurry stream was then directed to fill the Geotube® dewatering containers through a manifold system. Most of the Geotube® containers used had a length of 50 m and a circumference of 18.3 m. Dewatering all of the dredged contaminated sediments required the Geotube® containers to be stacked three high on the dewatering platform.

During the following summer when the dewatering process was complete the dewatering platform was capped before placing a topsoil cover and vegetating the area.

Client: Hultsfred Kommun, Hultsfred, Sweden.

Designer and Contractor: DEME Environmental Contractors–Dredging International JV, Zwijndrecht, Belgium.

Dredging the contaminated sediments from the lake

Geotube® dewatering of the contaminated sediments

Geotube® dewatering platform with the water treatment plant shown on the far side

Capping of the dewatering platform

Lakes and impoundments: Lake Dianchi remedial dredging, Kunming, China

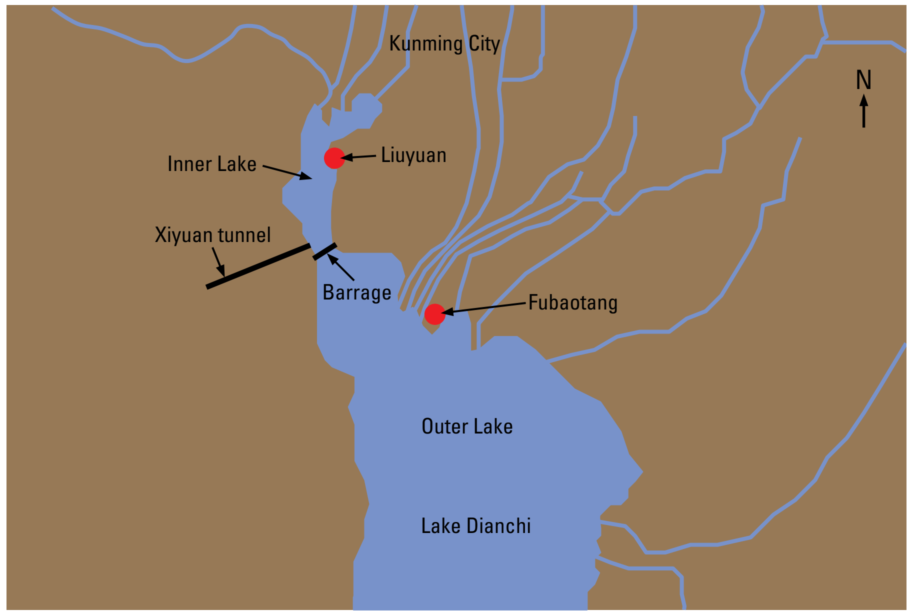
Lake Dianchi, located in Yunnan Province in the Southwest, is the sixth largest freshwater lake in China. It covers an area of approximately 300 km^2 (running 39 km North to South) with an average depth of 4.4 m. The provincial capital of Kunming is located on the Northern shore of the lake. There are more than twenty rivers that drain into Lake Dianchi from the surrounding region, with only one exit river which forms an upper tributary of the Yangtze River. Historically, Lake Dianchi was known as the "Pearl of the Plateau" because of its clear, bright water.

Rapid population growth over the last 50 years coupled with large scale industrial development has led to major pollution problems in Lake Dianchi. This development has also resulted in significant sediment accretion in Lake Dianchi due to extensive deforestation of the lake catchment area. Further, up until the 1990's all wastewater and other runoff from Kunming and surrounding areas was pumped directly into the lake untreated. There are also large volumes of contaminated sediments in the lake bed. Consequently, the lake water is now undrinkable and is also rated unfit for agricultural and industrial use.

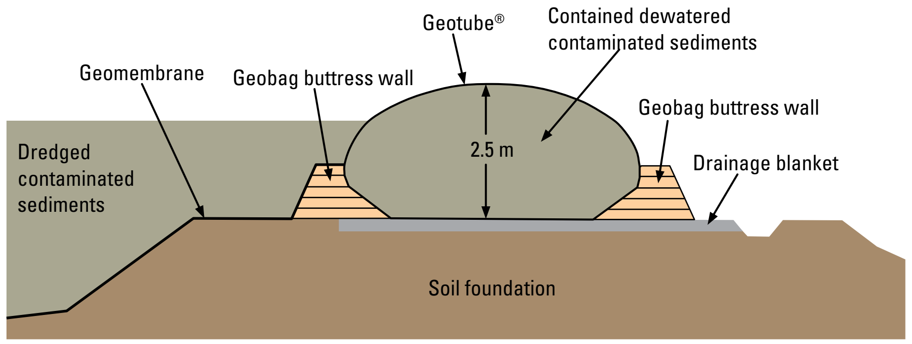
During the mid 1990's a barrage was constructed across the Northern part of Lake Dianchi to isolate the more-polluted Inner Lake area from the less-polluted Outer Lake area. While the Inner Lake accounts for less than 3% of the surface area of Lake Dianchi it is the source of much of the pollution. The table below shows a comparison of the typical concentrations of heavy metals in the contaminated sediments of the Inner and Outer Lakes. It is common for the water in the Inner Lake to resemble a green-pea soup colour with large algal plumes. To prevent the water of the Inner Lake from mixing with the water of the Outer Lake it is diverted via the Xiyuan bypass tunnel to a water treatment plant prior to discharge into a downstream river. This has resulted in an improvement of the water quality in Lake Dianchi.

Contaminant	Inner Lake	Outer Lake
Copper	360-714 ppm	34-446 ppm
Lead	661-1000 ppm	28-66 ppm
Cadmium	42-80 ppm	0.4-3.36 ppm
Mercury	1.0-1.4 ppm	0.1-0.35 ppm
Arsenic	267-332 ppm	13-43 ppm
ppm – parts per million (by weight)		

It was decided to implement a comprehensive environmental dredging program to remove the contaminated



Lake Dianchi layout showing contaminated sediment storage locations



Section through the Geotube® containment dyke

sediments from Lake Dianchi. This sustained program began with those areas most severely contaminated. In 2009 a contract was awarded to dredge 1.5 million m^3 of contaminated sediments from the Inner Lake and 1.9 million m^3 from the more-polluted area of the Outer Lake near the river mouths in the North. To contain the dredged sediments two containment lagoons were constructed – one at Liuyuan to contain the Inner Lake dredged sediments and one at Fubaotang to contain the Outer Lake dredged sediments.

To maximize the volume of dredged sediments in the containment lagoons it was decided to construct the containment dyke walls using Geotube® dewatering containers filled with dewatered contaminated sediments. First, the soil foundation was graded to the required level. Next, a granular drainage blanket was constructed across the base of the containment dyke wall in order to facilitate the efficient dewatering of the contaminated sediments that would be later pumped into the Geotube® dewatering units. Two geobag buttress walls were constructed along the alignment of the containment dyke. These walls fulfilled two roles. First, to provide additional lateral stability for the Geotube® containment units, and second, to confine the Geotube® units during filling to ensure the filled height could be maximized.

The Geotube® dewatering units were installed and were then filled with dredged contaminated sediments to form the structural containment dykes for both sludge lagoons. The Geotube® dewatering containers used had a circumference of 15.4 m and were filled to a control height of 2.5 m. The Geotube® containers were then allowed to dewater for a week before the next filling and dewatering cycle was repeated. This was repeated for about 10 cycles in order to achieve the final dyke design height of 2.5 m and the desired stability for the contained sediment. Finally, a geomembrane liner was installed across the base of the lagoons to prevent contaminant loss into the ground stratum.

Once the dyke walls were completed and the geomembrane liner installed the contaminated sediments were dredged from locations in the Inner and Outer Lakes and pumped into the two sludge containment lagoons. On completion of the dredging operation the sludge lagoons were allowed to consolidate and dry out sufficiently before the contaminated sediment was removed to a landfill site for permanent disposal. Once the sludge lagoons had been cleaned out the Geotube® dyke wall was demolished with the dewatered contaminated sediment fill also taken to the landfill for permanent disposal.

Client: Kunming City Lake Dianchi Authority, Kunming, China.

Consultant: CCCC Tianjin Port and Survey & Design Institute Co., Ltd, Tianjin, China.

Contractor: Beijing Hengchuan Helitong Science & Technology Development Co., Ltd, Beijing, China.


Algal plume in the Inner Lake


Installing Geotube® containers inside the geobag buttress walls


Filling Geotube® containers with contaminated sediments


Dredging of contaminated sediments in Lake Dianchi


Contaminated sediment containment lagoon

Lakes and impoundments: Environmental dredging of Sorte Sø, Skanderborg, Denmark

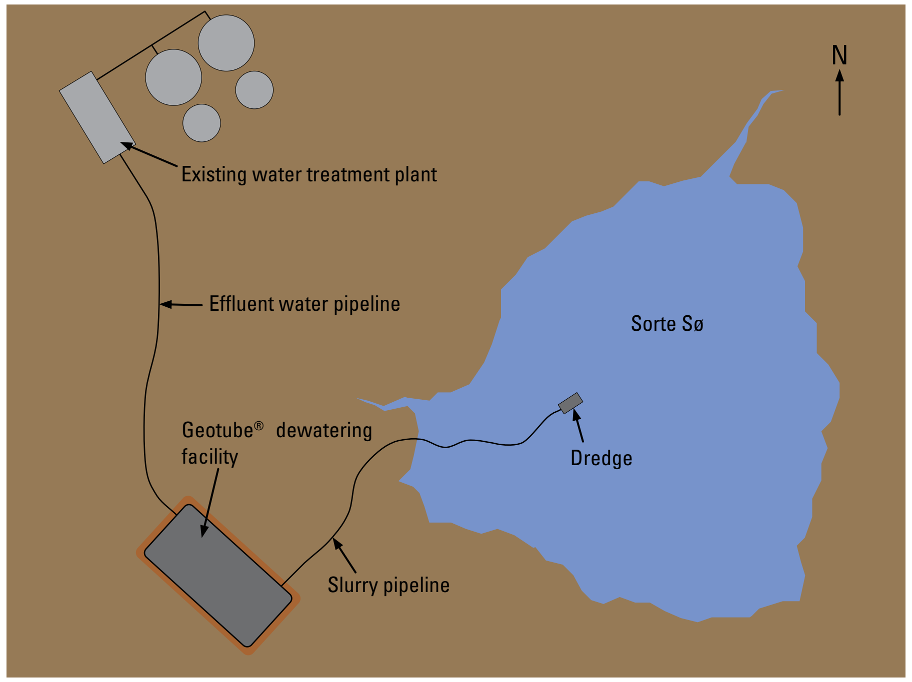
Historically, it was common practice in Denmark, as in other countries of Europe, to discharge the sewage that could not be used to fertilize farmland directly into the local watercourses. Over time, this has led to many problems with organic and nutrient contamination and noxious odours.

In the City of Skanderborg, for over 80 years raw sewage and local industrial effluent have been discharged directly into the 2 hectare sized lake Sorte Sø, which is located on the Western outskirts of the city. Although this discharge practice had stopped several decades ago, a study in 2005 showed that the bottom sediments of the lake were contaminated with high levels of phosphorus along with some heavy metals (cadmium and mercury) and hydrocarbons. The nutrient contamination was also affecting the quality of the downstream water courses from Sorte Sø.

The Skanderborg authorities therefore decided to prepare a remediation plan for the lake that is protected by the Danish Nature Protection Act. A large number of samplings and an analysis of the contaminants in the sediments were carried out, and this formed the basis for a strategy report on the removal of the sediments from Sorte Sø. The results of the testing program showed that the top 30 cm of the sediment layer contained high levels of nutrients as well as increased levels of heavy metals and hydrocarbons which classified the sediments as mildly contaminated under Danish Regulations. In total, around 16,000 m^3 of contaminated sediments at an average 10% solids concentration needed to be removed. The final plan estimated that some 80,000 m^3 of dredged sediment slurry would have to be pumped out of the lake (at around 2% solids concentration).

To minimize sediment disturbance and to ensure accurate dredging it was decided to use a MudCat auger dredger to remove the contaminated sediments.

To evaluate the effectiveness of different sediment dewatering technologies a series of full scale trials were carried out to compare the performance of four different dewatering methods – drainage containers, centrifuges, belt presses and the Geotube® dewatering system. Sediment slurry, dosed with the optimum chemical dewatering accelerant, was fed into each of the four different dewatering methods and the results were evaluated by the Consultant. The results showed clearly the superior performance of the Geotube® dewatering system compared to the other dewatering methods from the perspective of effectiveness, complexity, quality of effluent water, operational stability and cost. In fact, the belt press method was estimated to be 3 times the cost, and the centrifuge 1.7 times the cost of the Geotube® dewatering method. In the comparative cost calculation total project runtime also had a significant impact and also gave the Geotube® system a major advantage.



Site layout of the Sorte Sø dewatering project

Following the results of the full scale trials it was decided to carry out the dewatering of the dredged contaminated sediments using the Geotube® dewatering system. The flexibility of this system paid off handsomely when the insitu volume of sediments proved to be significantly greater than originally expected.

A dedicated Geotube® dewatering facility was constructed on the Southwestern side of Sorte Sø. It consisted of an earthworks containment facility internally lined with a geomembrane liner. On top of this a geocomposite drain layer was placed. The geocomposite drain layer performed two roles. First, it gave protection to the geomembrane liner, and second, it allowed drainage of the effluent water from the Geotube® dewatering containers to a sump where it was pumped out of the dewatering facility. Finally, the Geotube® dewatering containers were installed on top of the drainage layer and connected to the slurry pipeline from the dredge.

The contaminated sediments in the lake were dredged at a rate of around 200 m^3/hr. This meant that the 80,000 m^3 of sediments could be dredged within 2 months when using the Geotube® dewatering technology. However, the volume of sediments actually dredged from the lake turned out to be far greater at 146,000 m^3. The dredged sediments were pumped through a slurry pipeline to the dewatering facility.

On reaching the dewatering facility the slurry was dosed with a chemical dewatering accelerant prior to its entry into the Geotube® dewatering containers. The containers were filled and then allowed to dewater a number of times until a final solids concentration greater than 25% was obtained.

During the dewatering process the effluent water was monitored for quality and only on three occasions throughout the project life did the sediment composition rise above established limits. The effluent water was pumped to a nearby water treatment plant where it was processed and returned to the lake.

Following completion of the dewatering the Geotube® containers were cut open and the dewatered solids were used as earthfill material in the local area. The dewatering facility was then returned to its natural state.

Client: Skanderborg Kommune, Skanderborg, Denmark.

Consultant: COWI A/S, Århus, Denmark.

Contractor: Per Aarslef A/S and EnviDan A/S, Copenhagen, Denmark.

Dredging of contaminated sediments in Sorte Sø

Geocomposite drain placed over geomembrane liner prior to placement of Geotube® containers

First layer of Geotube® dewatering containers filled

Geotube® dewatering containers stacked three high

Excavation of dewatered solids for transport to offsite disposal facility

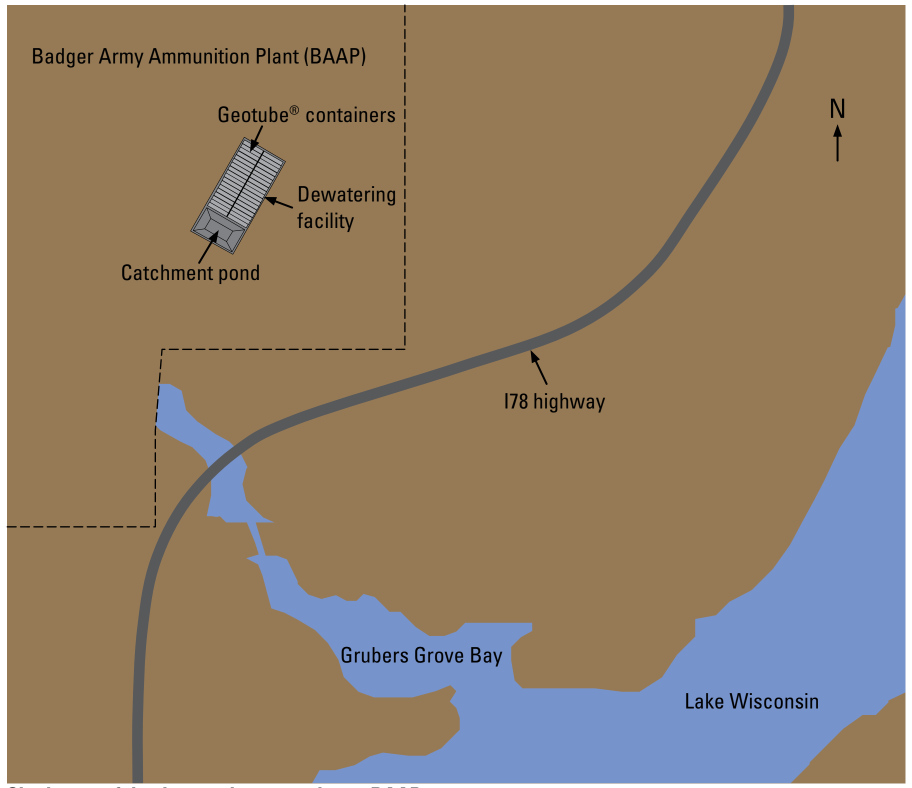
Lakes and impoundments: Grubers Grove Bay environmental dredging, Badger Army Ammunition Plant, Baraboo, Wisconsin, USA

Grubers Grove Bay (GGB) is about 10 hectares in size and is located on the Northwestern side of Lake Wisconsin. Within its local catchment area is the Badger Army Ammunition Plant (BAAP) that has been producing small arms and ordnance propellants from 1942 to 1975 when it was closed. Discharges and runoff from BAAP over the years have resulted in excessive levels of nutrients, mercury, copper and lead in the sediments of GGB.

The GGB sediments consist of black to brown clayey silts, organic silts, and silty sands. These sediments are thickest at the Western end of the bay being up to 4.6 m. The solids concentration of the sediments ranged from 8% to 73% with an average of 27%.

A large number of sediment samples were taken across GGB for contaminant analysis testing. The average concentrations of copper, lead and mercury in the sediment were 62 ppm (parts per million), 136 ppm and 2.2 ppm respectively. However, the maximum concentrations of copper, lead, mercury, methyl mercury, and ammonia in the sediments were 277 ppm, 1,220 ppm, 12 ppm, 0.15 ppm, and 740 ppm respectively. The levels of contaminants increased with depth and with distance from BAAP's discharge point into GGB. The sediments also contained low concentrations of polychlorinated biphenyls (PCB's), trichloroethene, and n-nitrosodiphenylamine.

The data collected also indicated that the contaminated sediments had adversely affected biological communities in GGB. The cleanup criterion for the affected sediments was established in consultation with the Wisconsin Department of Natural Resources and was based on obtaining a maximum target mercury level of 0.36 ppm. The volume of sediments impacted above this 0.36 ppm mercury cleanup criterion was assessed at 66,000 m^3.



Site layout of the dewatering operation at BAAP

Subaqueous capping and sediment removal were both evaluated for short-term and long-term effectiveness in meeting the cleanup objectives. Subaqueous capping was not considered a viable option due to issues regarding the long-term performance of the remedy. Further, because of the low shear strength of the sediments, it was considered that the capping operation would result in instability with significant displacement and re-suspension of the contaminated sediments. Contaminated sediment removal by dredging was determined to be capable of achieving the cleanup objectives both in the short-term and the long-term.

A number of options were considered for handling and dewatering the dredged contaminated sediments, and the subsequent management of the solids and the effluent water. A Geotube® dewatering solution was decided upon on the basis of performance, reliability and cost. The plan was to construct a lined disposal facility within the BAAP boundary to the North of GGB. Within this facility the Geotube® containers would be filled with the dredged contaminated sediments and allowed to dewater.

A silt curtain was installed across the mouth of GGB that temporarily prevented boat traffic into the bay during the dredging operation. Dredging was carried out using a hydraulic dredge which had a 2.5 m wide horizontal auger. The cutting head was equipped with a rigid metal shroud to reduce turbidity generated by the dredging operation. The sediment dredging rate was about 500 m^3/hr.

The rectangular shaped, lined dewatering facility was approximately 100 m wide by 400 m long and consisted of a Geotube® laydown area with a small catchment pond at the Southern (lower) end of the facility. The catchment pond was used to collect the effluent discharge from the Geotube® dewatering containers. The dewatering facility was leveled, banked all round and then lined with a geomembrane to prevent loss of the effluent water from the dewatering facility. The dewatering facility was designed with a slight fall to ensure the effluent water would drain into the catchment pond.

Dredging and Geotube® dewatering operations were carried out during the 6 month summer-autumn period. A total of 42 Geotube® dewatering containers, each of length 68 m and circumference 13.7 m, were laid side by side as the bottom layer in the dewatering facility. These Geotube® containers were connected with the incoming sediment slurry pipeline through a manifold system which allowed freedom of choice to fill any one, or more, specific Geotube® dewatering units at any point of time. A chemical dewatering accelerant was added to the incoming slurry stream ahead of the manifold system at a rate of 0.04 m^3/hr. Each Geotube® dewatering unit had a maximum holding capacity of 650 m^3 of sediment sludge for dewatering. The solids concentration of the incoming sediment slurry ranged from 7% to 10%. The solids concentration after dewatering and consolidation ranged from 30% to 40%.

The effluent water in the catchment pond was continually monitored to ensure it met the required quality standards. It was then pumped to a larger holding lagoon nearby where it was distributed for beneficial use to irrigate agricultural and grass land.

Following completion of the dewatering operation, the Geotube® dewatering facility was capped with a soil layer 0.9 m in thickness and then the area grassed. The catchment pond was left in place as a temporary wetland that would continue to receive any residual seepage out of the dewatering facility. Over time, this temporary wetland would dry out and be replaced with upland vegetation by natural colonization and succession.

Client: US Army Corps of Engineers, Omaha, Nebraska, USA.

Consultant: Shaw Environmental & Infrastructure Inc., Baton Rouge, Louisiana, USA.

Contractor: Bay West Inc., St Paul, Minnesota, USA.

Dredging of Grubers Grove Bay

Geotube® dewatering containers within the containment facility

Geotube® dewatering of the contaminated sediments

Overview of the Geotube® dewatering facility

Dewatering facility capped and grassed

Lakes and impoundments: Lake Komsomolsky sediment removal, Nizhnevartovsk, Siberia, Russia

The City of Nizhnevartovsk is located along the right bank of the Ob River and is the second largest city in Khanty-Mansi Autonomous Region, Siberia, Russia. With the discovery of oil in the area in 1961 the region has developed quickly. Today, the local Samotlor oil field is the largest oil field in Russia and the sixth largest in the world. Nizhnevartovsk is the centre of the West Siberian oil-producing region and one of the wealthiest cities in Russia with a population of 250,000.

Lake Komsomolsky is located in the centre of Nizhnevartovsk City and has a water surface area of around 30 hectares. The city literally grew around the lake over the last 40 years. Rainfall and runoff from the city area feeds into the lake constantly with no significant drainage out of the lake into the nearby Ob River. The rapid growth of Nizhnevartovsk City since the oil boom has resulted in the rapid sedimentation of Lake Komsomolsky. The sediments contain organic matter and other domestic and industrial contaminants. The contaminants arise from discharge from sewage treatment facilities and runoff from streets, construction sites and other land areas. The pollutants include petrol, lead, oil, rubber residues, fertilisers and insecticides.

As a result of the rapid growth of Nizhnevartovsk City, Lake Komsomolsky became a water body that consisted of extensive sediment deposits and which gave off noxious odours. The City Government decided to remove the sediment and to clean up the lake.

In Western Siberia there is only a short Spring-Summer construction window for the dredging and dewatering to be carried out. At other times, Lake Komsomolsky is frozen over. It was estimated that around 300,000 m^3 of organic sediments with a solids concentration of around 5% had to be dredged and dewatered within a 6 month operating period. Further, it was important for the adopted procedure to be able to operate with low noise and odour generation because the areas immediately around the lake are residential areas with parklands.

Geotube® dewatering technology was chosen for this project because the Geotube® dewatering solution was cost effective, could handle effectively large quantities of sediments, satisfied the short project duration constraint and could operate with low noise and odour generation.

Dredging of the contaminated sediments was carried out using a hydraulic dredge with a discharge rate of 400 m^3/hour. The dredged sediment slurry was passed along a floating and land pipeline connecting directly into the Geotube® dewatering containers. This closed dredging and sediment transport system effectively contained the smelly sediments within a closed system.

Dewatering of the contaminated sediments was carried out on an area of land on the Western shoreline of the lake. The dewatering platform consisted of a geomembrane liner covered with a 300 mm thick gravel drainage blanket. The incoming sediment slurry was dosed with a chemical dewatering accelerant prior to distribution through a manifold system into the Geotube® dewatering containers. The Geotube® containers were filled to maximum capacity through multiple filling and drawdown cycles. More than 100 Geotube® containers were used for the dewatering of the dredged sediments in the cleanup of Lake Komsomolsky. Because of the limited land area of the dewatering platform the Geotube® containers were stacked 2 layers high. Tube lengths and circumferences were adapted to fit the odd shaped dewatering platform and the stacking requirements. The effluent discharge from the Geotube® containers was passed directly back into Lake Komsomolsky.

The dredging and dewatering project was carried out during the Spring-Summer operation window. Upon completion of the dewatering operation, the Geotube® containers were left in place through the Autumn and Winter months as it was considered that the freeze-thaw process would help to further dewater and consolidate the contained sediments. During the following construction season the Geotube® containers were cut open and the dewatered sediments were then combined with stabilizing agents and/or local fill material for reuse in the construction of earthworks.

Client: City of Nizhnevartovsk, Siberia, Russia.

Consultant and Contractor: Admir Eurasia, Moscow, Russia.

Dredging of contaminated sediments in Lake Komsomolsky

Laying out Geotube® dewatering containers on dewatering platform

Filling first layer of Geotube® dewatering containers

Dewatering two layers of Geotube® containers

Geotube® dewatering containers left in place during Siberian Winter

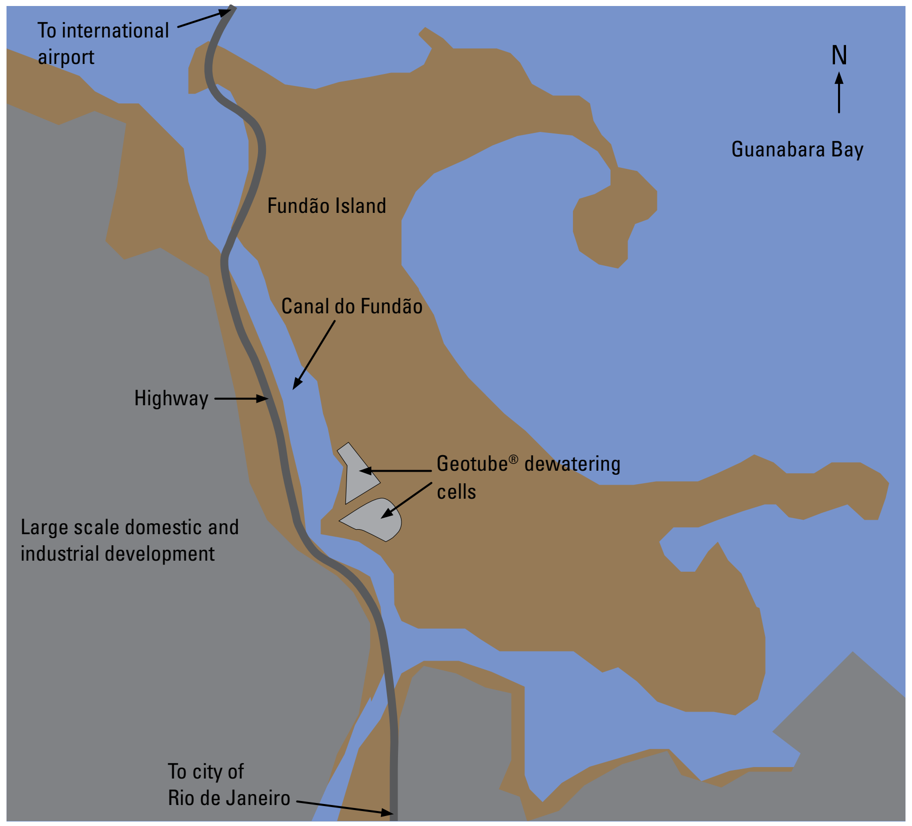
Estuarial and coastal: Canal do Fundão remediation, Rio de Janeiro, Brazil

Canal do Fundão is a 6 km long artificial estuary formed in the early 1950's when the Brazilian federal oil company (Petrobrás) conducted a large land reclamation project to connect 8 near-shore islands adjacent to the Western shore of Guanabara Bay in the state of Rio de Janeiro to form Fundão Island. Over time sediment has built up in the canal and it has not been able to self-flush for the last 20 years.

Since the formation of Canal do Fundão a number of favalas have evolved near the shoreline to the West and raw sewage began to collect in the canal. Also, local industrial development has discharged unprocessed waste into the canal with the result that the sediments in the canal were highly contaminated with domestic and industrial waste, trash and other garbage. Consequently, the canal had been identified as a major environmental concern impacting health and life. Compounding this problem, the canal lies alongside the major highway linking the city of Rio de Janeiro with its international airport. With the country hosting the FIFA World Cup in 2014 and the city hosting the Olympics in 2016 arriving tourists could not be subjected to the eyesore and the bad odour on arriving in Rio de Janeiro, hence the decision was made to remediate Canal do Fundão.

A plan was developed to deepen the canal by dredging the contaminated sediments and to narrow it by re-establishing shallow mangroves on the margins in efforts to remediate Canal do Fundão environmentally. To complete the solution, a sewage collection and treatment system would be constructed for all of the surrounding residential and industrial areas that had been contributing to the canal contamination.

A comprehensive testing program for contaminant types and concentrations was carried out along the length of the canal. At specific locations along the canal contaminants ranged from heavy metals (cadmium, copper, chromium, mercury, lead, zinc and arsenic) to aromatic organics (PAH's and PCB's) to raw sewage, phosphates and nitrates. High levels of trash were found along the whole length of the canal.



Layout of Canal do Fundão

To make the canal self-flushing required the dredging of 2 million m^3 of sediments. Of this, 600,000 m^3 was considered to be contaminated and would be dredged and then dewatered in special cells on Fundão Island. The remaining 1.4 million m^3 of sediments was considered to be uncontaminated and were dredged and transported to an offshore dumpsite for disposal.

It was decided to dewater the dredged contaminated sediments in specially designed cells using Geotube® dewatering containers. Once the dewatering was completed the cells would be capped and vegetated and become part of the natural landscape of Fundão Island including bike and jogging trails. The dewatering cells were designed in an identical manner to landfill containment units with geomembrane composite barrier systems in both the bases and the caps of the cells.

Numerous small scale Geotube® dewatering tests were carried out to determine the correct type of chemical dewatering accelerant to be used and its dosage rate. The results of this testing program demonstrated that a final minimum solids concentration of 55% could be attained within 30 days. Further, solids retention within the Geotube® containers was in excess of 99% and the effluent quality was such that it could be returned directly to the canal. Also, it was demonstrated that odour was effectively subdued once the sediment was fully contained within the Geotube® test unit.

The dewatering cells were constructed using a composite base liner over which was placed a 200 mm thick gravel drainage blanket. The dredged contaminated sediments were pumped to the designated dewatering cells where it was distributed to the Geotube® dewatering containers by means of a manifold system. The Geotube® containers installed had a circumference of 36.6 m with lengths varying to fit the geometry of the dewatering cells. The chemical dewatering accelerant was injected into the manifold system with the dosage rate managed by a computer controlled system.

The control filling height of the Geotube® dewatering containers was 2.4 m. When the control filling height was reached, filling would be discontinued and the Geotube® dewatering unit allowed to drawdown under gravity flow. The incoming slurry stream would then be diverted to fill other Geotube® dewatering units through management of the manifold valve system. This filling and drawdown cycle was repeated a number of times until a final dewatered filled height of 2.1 m was obtained. The operation was conducted 24 hours per day, 6 days per week. The effluent from the Geotube® units was collected in the under-drain system of each of the dewatering cells and discharged directly into Canal do Fundão. Effluent quality was continuously monitored to ensure that it met Brazilian Federal discharge standards. Each dewatering cell finally contained three Geotube® layers to handle the dewatering of the contaminated sediments volume.

Once the dewatering of the contaminated sediments was completed each dewatering cell was capped with an earth covering and then a barrier system was constructed over the top of each cell. Finally, the capped mounds were vegetated and they now form part of the natural landscape of Fundão Island.

Client: State of Rio de Janeiro Ministry of Environment, Brazil.

Consultant and dewatering contractor: Allonda Geossinteticos Ambientais Ltda, São Paulo, Brazil.

Dredging Contractor: Queiros Galvão SA, Rio de Janeiro, Brazil.

Dredging contaminated sediments in Canal do Fundão

Geotube® dewatering platform

One of the Geotube® dewatering cells

Capping a Geotube® dewatering cell

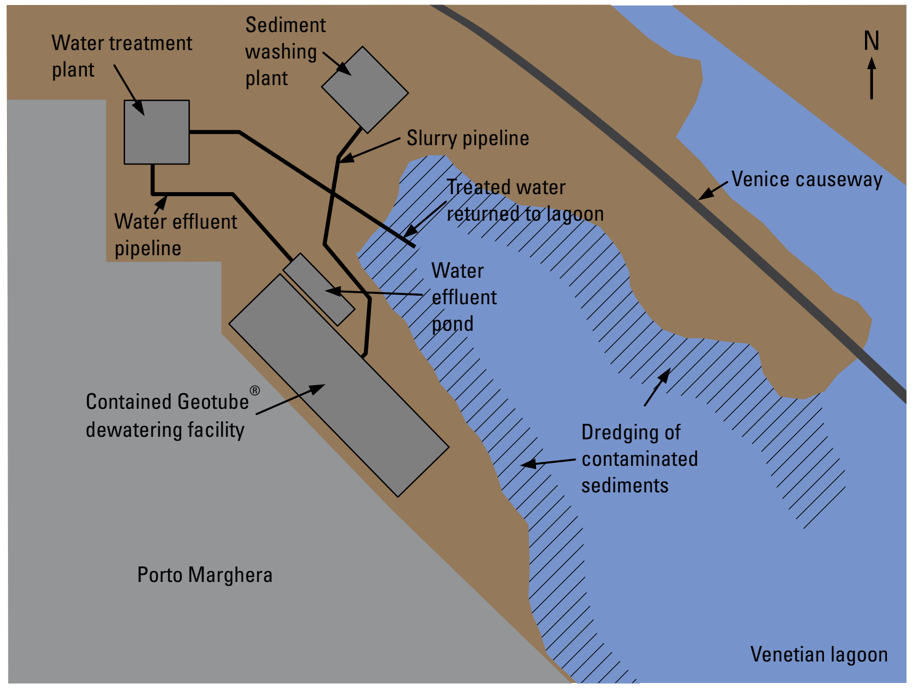
Capped and vegetated dewatering cell

Estuarial and coastal: Porto Marghera environmental dredging, Veneto Region, Italy

Porto Marghera is one of the most important industrial and commercial ports in Italy, and is located on the Western side of the Venetian lagoon, near the City of Venice, in North East Italy. The port began to be developed in the early twentieth century, and many chemical and petrochemical industries were established here between the 1950's and the 1980's. As a consequence of this heavy industrial development high levels of heavy metals, e.g. mercury, cadmium, lead, arsenic and caesium, and non-soluble organic compounds, e.g. PAH's, HCB's, PCB's, PCDD's and PCDF's, exist in the ground and sediments of the area. The highest concentrations of these contaminants occur in the sediments within the Porto Marghera area itself, and in its immediate vicinity. These levels of contamination had made Porto Marghera one of the most polluted sites in Europe.

As part of ongoing remediation works at Porto Marghera, the area immediately to the North of the port, and adjacent to the Venice causeway, has undergone remediation and development. This location, known as "Pili", consists in part of a low-lying, tidal inlet area, which had previously been a site for the dumping of industrial waste from Porto Marghera. Over time the inlet had become polluted due to rainfall run-off and seepage through these waste deposits. The whole site covers an area of around 52 ha with industrial waste deposits approximating 800,000 m^3. Contaminants present included heavy metals (cadmium, mercury), organic compounds (benzo-pirene, PCB's) and radio-active substances (radon 222). These contaminants were being leached from the industrial waste deposits into the sediments of the tidal inlet, and then on into the Venetian lagoon, contaminating benthic and bird life. Part of the Pili remediation involved the removal and treatment of 80,000 m^3 of contaminated sediments from a 50 m wide strip around the edge of the tidal inlet. Following removal, these sediments were dewatered, and then disposed of in a local landfill.

The contaminated sediments were mechanically dredged and then transported by truck to a sediment washing plant. Dredging proceeded at a rate of approximately 400 m^3/day. At the washing plant the contaminated sediments were washed, with the cleaned aggregate fraction separated out for alternative use. The remaining fines slurry was maintained in suspension by agitation in a holding tank until it could be pumped through a pipeline to the Geotube® dewatering facility at a rate of around 1,200 m^3/day. Before entering the dewatering facility the contaminated slurry was dosed with a chemical dewatering accelerant.



Site layout of the contaminated sediments treatment process

The Geotube® dewatering platform consisted of a lined facility having a compacted clay base layer coupled with a HDPE geomembrane liner on top. In the bottom of this lined facility a 300 mm thick gravel drainage blanket was placed to enable the effluent water from the tubes to travel to side-drains for collection where it was then piped to an external effluent water containment pond.

The Geotube® units were unrolled on the dewatering platform and connected to the inlet pipes containing the contaminated slurry. These units were filled with the slurry and allowed to dewater over a number of filling cycles. Around 7,200 linear m of 18 m circumference dewatering tubes were used for the dewatering project. Once the tubes had dewatered they were cut open and the contained solids were transported and disposed of in a nearby landfill site.

The effluent water from the dewatering process was drained to an adjacent effluent pond prior to being pumped to an on-site water treatment plant for further treatment before it was returned to the lagoon.

Client: Consorzio Venezia Nuova, Venice, Italy.

Consultant: Technital spa, Milan, Italy.

Contractor: Intercantieri Vittadello spa, Venice, Italy.


Loading contaminated sediments into a truck for transport to washing plant


Separation of aggregates from contaminated slurry fines


Agitation of slurry fines in a holding tank


Filled Geotube® units in the constructed dewatering platform


Water effluent pond adjacent to dewatering facility

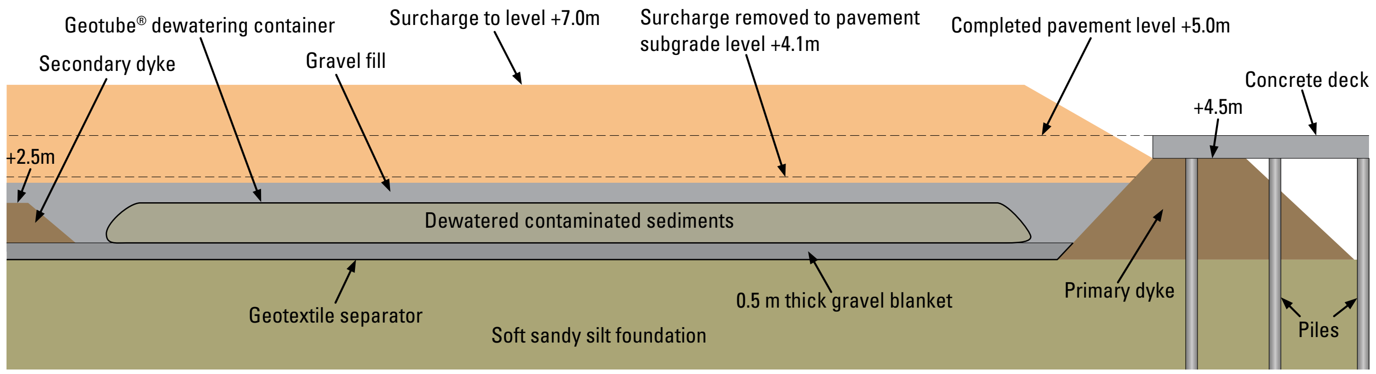
Estuarial and coastal: Dredging and reuse of contaminated sediments at Embraport, Santos, Brazil

Embraport is an 850,000 m² container and bulk goods terminal, being constructed in the Port of Santos, Brazil. When completed, Embraport will not only be the largest privately owned port facility in Brazil with over 600,000 m² dedicated to container storage alone, but it will be also the largest in South America. Further, the terminal will be able to turn over 2 million TEU (20 ft container equivalent units) and 2 billion litres of bulk liquids per year. The terminal is located on the North shore of the Estuario de Santos opposite the City of Santos in the State of São Paulo in an area that is primarily tidal flats.

In 2007 Embraport was granted a Government approval to develop the site for the terminal and port facility. The initial survey and soil borings indicated that more than 50% of the site was in the tidal flats with an elevation between -1.0 m and +1.0 m. All of the proposed terminal area was located over approximately 22 to 25 m of soft to medium sandy silt. To achieve the design platform elevation of +3.5 m and to account for anticipated settlements, it was determined that 1.5 million m³ of select fill would have to be imported to the site.

Further, as a condition of the Government approval the Embraport owners were also required to remove, dewater and dispose of 600,000 m³ of contaminated sediments that were located within the planned entrance channel and turning basin of the port. The source of the sediment contamination is due to heavy industrialization in the Santos region. Testing has shown a wide variety of contaminants in the sediments ranging from heavy metals (lead, copper, nickel, chromium and mercury) to PAH's and PCB's in varying concentrations.

The importation of 1.5 million m³ of select fill in conjunction with the removal of 600,000 m³ of contaminated sediments comprised a major cost implication for the Embraport owners and impacted the whole financial viability of the project. A highly innovative solution to this problem was found whereby Geotube® containers would be used to dewater and encapsulate the dredged contaminated sediments within the earthfill platform of the port. Once dewatered, the encapsulated sediments would then comprise the base for the container storage area. This solution proved highly attractive because not only did it significantly reduce the amount of imported fill required, but also saved on the cost of transporting the dredged contaminated sediments to an offsite disposal facility, or using part of the Embraport footprint for a disposal facility.



Section through the Embraport earthfill platform showing location of the insitu Geotube® dewatering of contaminated sediments

To evaluate the feasibility of using the dewatered contaminated sediments as part of the earthfill for the port platform a series of small scale dewatering tests were carried out on contaminated sediment samples to determine dewatering effectiveness, final solids concentration values and water effluent quality. The results of the tests demonstrated that with the correct dosage of chemical dewatering accelerant the contaminated sediments could be dewatered to a condition that would render them stable under the imposed surcharge loads and that the effluent water would remain consistent and require small additional treatment before release back into the environment.

A primary containment dyke was constructed around the port earthfill platform area to a level of +4.5 m. Within this, a woven geotextile separator was laid across the surface of the soft sandy silt foundation with a 0.5 m thick gravel drainage blanket placed over the top. This gravel layer performed two functions. First, it acted as a drainage layer to convey the effluent water from the dewatering contaminated sediments to an internal collection channel. Second, it acted as a drainage layer for the pore water drainage from the soft foundation during consolidation following placement of the surcharge. The dewatering area was then divided into two large cells by the construction of a secondary dyke to a level of +2.5 m.

The Geotube® dewatering containers were laid out in the first dewatering cell and connected the sediment slurry pipeline from the dredge. Dredging delivered the contaminated sediment slurry to the Geotube® containers at a rate of 1,400 m³/hr. Each Geotube® container was filled to a control height of 2.2 m before filling was stopped and the unit allowed to drawdown in height. This filling and drawdown process was repeated several times until the design objectives were achieved.

The effluent water flowing from the Geotube® units drained into a collection basin from where it was pumped to a water treatment basin. The pH of the effluent water was initially raised to precipitate out any dissolved solids. Next, the water was transferred to a second basin where the pH of the water was neutralized. The water was then passed through activated carbon filters and then released back into the environment.

The Geotube® units had a final dewatered height of about 1.8 m with each containing an average of 2,145 m³ of dewatered sediment. The Geotube® dewatering proved very effective with a 65% dewatered solids concentration achieved within 30 days after filling completion.

Once the dewatering operation was completed in the first cell the same dewatering procedure was repeated in the second cell. While dewatering was being performed in the second cell a gravel layer was placed around and over the filled Geotube® units in the first cell and then this was covered with surcharge to a level of +7.0 m. This surcharging consolidated the soft sandy silt foundation and the dewatered contaminated sediments to a level that met the settlement performance objectives of the earthfill platform. Once dewatering had been completed in the second cell the same surcharging procedure was repeated there.

Once foundation and sediment consolidation had reduced to an acceptable level the surcharge was removed down to a level of +4.1 m which coincided with the subgrade surface for the container terminal pavement. Following this, the container terminal pavement was constructed.

It was estimated that the 600,000 m³ of contaminated sediments, when dewatered and consolidated, provided a saving of 400,000 m³ of imported fill costs. This resulted in an overall saving of 20% to 30% of the earthfill platform cost for the terminal.

Client: Empresa Brasileira de Terminal Portuarios SA, Santos, Brazil.

Dredging Contractor: Jan de Nul do Brasil Dragagem Ltda, Rio de Janeiro, Brazil.

Environmental Engineering and Project Management: Allonda Geossinteticos Ambientais Ltda, São Paulo, Brazil.

Original site conditions at Embraport

Geotube® dewatering of contaminated sediments in the first cell while preparing the second cell

Geotube® dewatering of contaminated sediments within the earthfill platform

Surcharging the first Geotube® dewatering cell while operating the second Geotube® cell

Completed Embraport

Estuarial and coastal: Environmental dredging, Port of Arcachon marina, France

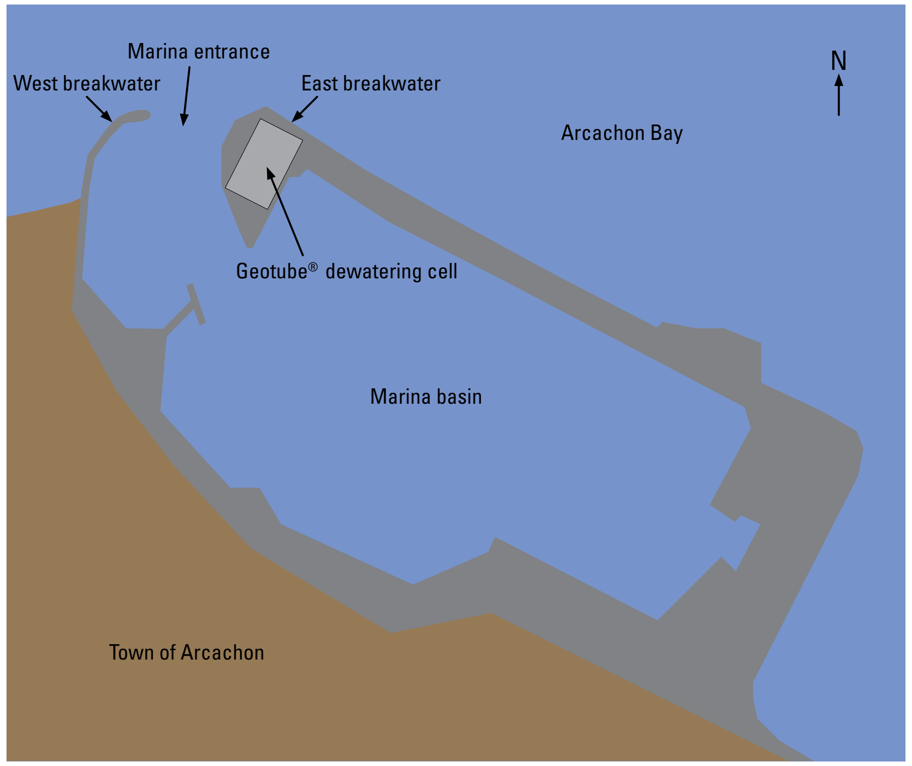
Arcachon Bay is situated along the Atlantic coastline in the region of Aquitaine, France. Arcachon Bay is ideal for swimming, sailing and pleasure-boating. It is also a protected natural habitat, well known for oyster farming and a sanctuary for migratory birds from all over Northern Europe.

Situated at the Northern part of the town of Arcachon is the Port of Arcachon marina with a capacity for 2,600 boats. It is the second most important fishing port on the Atlantic coast of France. The annual fishing catch is around 2,500 tonnes and valued at €14 million.

Since the late 1960's anti-fouling paints containing TBT biocide have been used to prevent the build-up of barnacles, muscles, etc. on the hulls of boats moored in the Port of Arcachon marina. The effect of TBT on the surrounding marine life was first observed in the early 1980's where oyster production had fallen by 75%. Consequently, the French Government banned the use of anti-fouling paints containing TBT, which helped to lower significantly TBT contamination in ports and marinas.

The sediments within the Port of Arcachon marina were contaminated with heavy metals, TBT and PAH's due to boat maintenance operations carried out over time. Even at concentrations as low as 1 ng/litre TBT is found to be toxic. Prior to the realization of the toxicity of TBT, dredged sediments from the Port of Arcachon marina were disposed of directly into the sea by unconfined dumping. In more recent times, sediment disposal directly into the sea is no longer allowed and on land disposal at specific permitted sites is required.

In the mid 2000's the Port Authority of Arcachon decided to dredge the contaminated sediments located within the marina basin. A test program was established where the Geotube® dewatering performance was evaluated along with different chemical dewatering accelerant additions. From this, the appropriate Geotube® container volumes, chemical dewatering accelerant dosage and effluent water quality was determined.



Plan view of Arcachon marina

As the area surrounding the marina has limited free space the Geotube® dewatering cell was created in a car park area at the tip of the East breakwater. The dewatering cell platform was lined with a geomembrane liner and its boundary bermed. Geotube® containers with a length of 200 m and a circumference of 18.3 m were used to dewater the dredged sediment slurry.

The dredging was carried out with a dredge owned by SIBA (Syndicat Intercommunal du Bassin d'Arcachon) because it was readily available on site. A 1 m thick layer of contaminated sediment, having an average solids concentration of 25%, was dredged from the marina basin. Prior to entry into the Geotube® containers the dredged slurry was dosed with the chemical dewatering accelerant.

Throughout the entire duration of the dredging operations the main pollutants (heavy metals, TBT and PAH's) were measured in the sea water inside and outside the port area as well as the water draining from the Geotube® containers. Also, the geochemical characteristics of the sediments were analyzed insitu and after dewatering. The scientific monitoring showed that there was no significant impact to the surrounding aquatic environment.

Originally, it was considered that the effluent water would have to be piped to a local water treatment plant to further treat it before returning it to the local environment. However, it was found that this was not required as the effluent water met all quality standards and thus was discharged directly back into the marina.

The final dewatered height for the filled Geotube® containers was about 1.8 m. While the target final solids concentration was 40%, after three weeks of dewatering the average solids concentration achieved was about 60%, which was well above the target value.

After dewatering, the Geotube® containers were cut open with the dewatered solids loaded onto trucks and transported to a landfill facility about 30 km away.

Following this, the dewatering cell was dismantled and the car park returned to its original form. The whole project was completed on time and demonstrated that Geotube® dewatering technology is a quick and effective method of dewatering TBT contaminated dredged sediments.

Client: Port D'Arcachon, Arcachon, France.

Engineering: IDRA Environnement S.A., Arcachon, France.

Contractor: Groupement Balineau S.A., Pessac, France.

Dredging contaminated sediment in the marina basin

Geotube® dewatering cell laid out on East breakwater

Dewatering contaminated sediment

Returning effluent water to marina basin

Dewatered contaminated sediment ready for offsite disposal

Estuarial and coastal: Intake tunnel dredging, Consolidated Edison, New York, USA

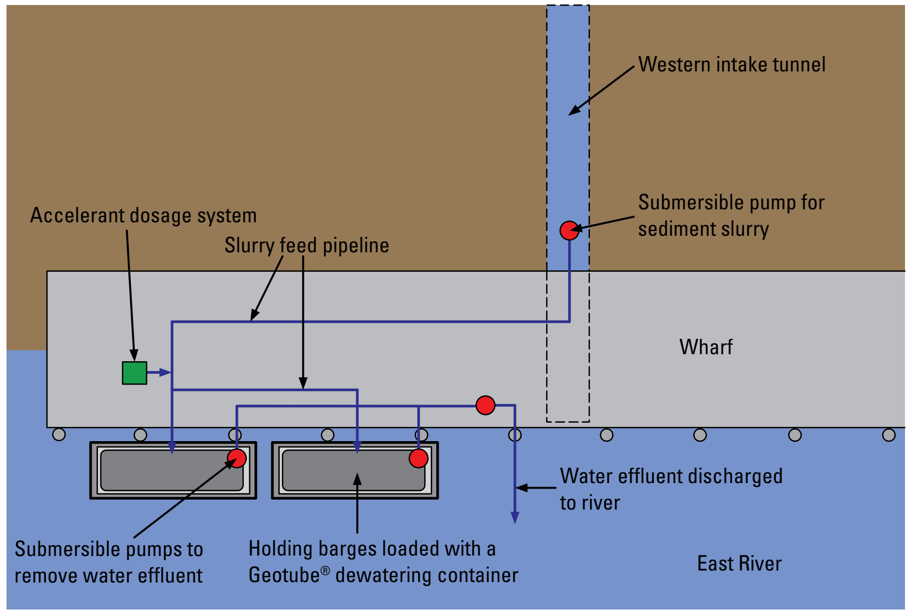
Consolidated Edison Inc. is one of the largest power utility companies in the United States. Its Hudson Avenue Generating Station is situated on the East River waterfront in New York City. The massive complex contains a range of facilities for steam heating and cooling that produce energy as a by-product. These facilities include an oil wharf specializing in the receipt of oil for consumption at the plant, a wash-water dock and a massive transformer area that makes the site easily recognizable. The large steam generating capabilities of the plant make it a source for heating, hot water and cooling in many of New York City's buildings.

The State of New York State has strict regulations that control pollutants in both wastewater and stormwater and specific quality standards are required for each point source of discharge into the groundwater and the surface water.

A severe buildup of sediment to unacceptable levels in the Western intake tunnel of the Hudson Avenue Generating Station resulted in the need for its removal in order to maintain Government regulatory conformance. The sediment consists generally of silt and clay (92% passing sieve no. 200) contaminated with PCB's and hydrocarbons. The PCB and hydrocarbon source is the result of past upstream East and Hudson River industrial activities. The sediment deposit was rather consolidated with a solids concentration of about 48%. Consequently, this sediment could only be removed through hydraulic pumping with the mechanical aid of divers in the intake tunnel. This combined method of removal resulted in loosening the sediment and diluting it during pumping to a solids concentration of about 4%.

There was a lack of a work area at the site to allow onshore dewatering and disposal of the contaminated sediments. Also, transportation of the pumped slurry using deep hopper barges to an offsite dewatering location was estimated to be costly as it would involve a total of 52 barge trips. An alternative innovative solution using Geotube® dewatering technology was developed where a flat holding barge was used as the dewatering cell with the effluent water being returned directly to the East River. Since this solution involved the dewatering in floating barges no land area would be required for the dewatering of the contaminated sediment.

This solution utilized two flat holding barges, each housing a lower and upper Geotube® dewatering container. At the end of the dewatering operation, both barges sailed to a location where the dewatered solids were transferred onto hauler trucks for removal to a permitted landfill for disposal. This floating Geotube® dewatering solution was a vastly simpler operation and was foreseeably much more economical.



Site layout showing the Geotube® dewatering on the wharf in the East River

To prove the effectiveness of the Geotube® dewatering system it was necessary to demonstrate that a high volume reduction ratio would be achieved within a reasonably short time period and that the effluent water from the dewatering operation met the New York State Government discharge quality requirements at all times. Small scale Geotube® testing was carried out on samples of the contaminated sediment slurry. The ideal chemical accelerant and its optimum dosage rate were determined. The test results showed that a final solids concentration of 54% could be reached within 30 days. The effluent water quality would remain within the quality limits stipulated by the New York State Government regulations provided the chemical accelerant dosage could be automatically adjusted in accordance with the changing solids concentration of the pumped sediment slurry.

To ensure the chemical accelerant dosage was automatically adjusted to maintain optimum treatment conditions the Smartfeed™ Chemical Conditioning System was incorporated into the project. The Smartfeed™ system was able to monitor changes in sediment solids and flow while adjusting chemical accelerant injection to an optimum level at five second intervals.

Two flat holding barges were deployed, each measuring 40 m length x 9.1 m width x 4.9 m depth. A Geotube® dewatering container of length 35 m and circumference 18.3 m was placed in each holding barge and used to contain and dewater the pumped slurry. The filling control height was set at 2.1 m. The reason for having two barges instead of one was because this arrangement meant there was always a Geotube® container ready for filling, and pumping of the sediment would not have to stop unnecessarily. The rate of pumping was such that between 15 and 75 m³ of insitu sediment could be removed per 8 hours working shift. Overall, there was on average a 10% pumping downtime as a result of the presence of debris and garbage. The solids concentration monitored through the Smartfeed™ system was between 4% and 11%.

The average filling time for each Geotube® container was around 2 days. When the container reached the filling control height, the slurry stream was diverted to the Geotube® container in the adjacent barge. This alternating filling process continued for several cycles before an upper Geotube® dewatering container was then deployed. The upper container was slightly smaller with length 31 m and circumference 13.7 m. The filling control height of the upper container was set at 2 m. At the end of the pumping and dewatering operation, the two barges were towed to an offsite location. Within 45 days the slurry that was pumped into the Geotube® containers had dewatered to 67% solids concentration. Once dewatered, the containers were cut open and the solids were removed onto hauler trucks and transported to a permitted landfill in New Jersey.

Client: Consolidated Edison Inc., New York, USA.

Consultant: Consolidated Edison Inc., New York, USA.

Contractor: Mineral Processing Services LLC, South Portland, Maine, USA.


Geotube® dewatering containers in barges in East River


Geotube® dewatering of contaminated sediment in barges


Dewatered contaminated sediment inside holding barge


Dewatered contaminated sediment being removed from barge

Estuarial and coastal: Contaminated sediment removal, Central-Wan Chai Bypass, Hong Kong

Offshore disposal has been the preferred disposal option for dredged sediments in Hong Kong as land is scarce and the onshore disposal option is often neither economical nor practical. Prior to 2002 dredged sediments with contaminants exceeding permissible levels were transported to the East Sha Chau confined contaminated mud pits for disposal by the conventional unconfined open water dumping method. In January 2002, the Hong Kong Government introduced a new management framework for dredged sediment disposal which complies with the 1996 Protocol to the London Convention of 1972. In Hong Kong, sediment quality is classified into 3 categories (Categories L, M or H) according to contaminant levels based on defined heavy metals, polycyclic aromatic hydrocarbons (PAH's), poly-chlorinated biphenyls (PCB's) and tributyltin. Besides the chemical testing of heavy metals to determine contamination levels, Categories M and H sediments may also need to undergo biological screening. In case category H sediment also fails the biological screening tests, it is classified as Type 3 material – the most extreme form of contamination in Hong Kong.

Conventional unconfined open water disposal results in dissipation of sediments as they fall through the water column. As a result, contaminants are released into the water environment and may be carried by water currents to impact areas away from the dumping site. With the introduction of the Hong Kong Government management framework, the unconfined open water disposal of Type 3 dredged contaminated sediments was banned.

In 2003, the special confined disposal method using Geotube® containers for open water disposal was successfully tested and approved. This involved filling Geotube® containers with contaminated sediments and then dropping them using a split-bottom barge at a designated offshore disposal site. The advantage of this technique is that the contaminated sediments remain encapsulated within the container and cannot dissipate into the surrounding water column during the dumping process.

The dropping of Geotube® containers filled with contaminated sediments at considerable water depth (over 30 m) places severe performance constraints on the containers and their manufacture. Not only do the containers have to avoid rupture and damage on exiting the split-bottom barge and impacting the seabed at the dump site, but they also have to ensure the water quality in the vicinity of dumping does not change. Furthermore, once dropped on the seabed the Geotube® containers prevent erosion of the encapsulated contaminated sediments, thus ensuring stable, secure storage of the sediment.

The districts of Central, Wan Chai and Causeway Bay lie along the Northern shore of Hong Kong Island and are densely developed. The Central-Wan Chai Bypass is a new trunk route providing an expressway standard system for East-West traffic flows in Central and Wan Chai. This new trunk route will consist of 3.7 km of tunnel underneath existing reclaimed land over the seabed. Most of the tunnel section was constructed using the cut-and-cover technique which involved excavation into the reclaimed land fill.

During the design stage site investigations revealed the existence of 3,500 m^3 of Type 3 contaminated sediment on the seabed of the Causeway Bay Typhoon Shelter along the proposed tunnel alignment and beside the Cross-Harbour Tunnel entrance portal. The removal of this Type 3 contaminated sediment had to be carried out ahead of tunnel construction. The Geotube® container offshore disposal of the Type 3 contaminated sediments was carried out at the East Sha Chau confined contaminated mud pits to the Northwest of Hong Kong Island.

The split-bottom barge used to hold, transport and dump the Geotube® containers had a hopper length of 34 m, width of 9.6 m and depth of 5 m. The hopper was partitioned into three equal portions of 11 m length each using transverse bulkheads of thickness 0.5 m in order to create three equal sub-compartments, each with a holding capacity of about 300 m^3. Each Geotube® container was designed to fit the sub-compartments of the split-bottom barge and was filled to about 70% of its holding capacity, or about 210 m^3 for each container.

The installation commenced by placing slip sheets clamped along the coaming of the barge hopper. The slip sheets were placed to protect the Geotube® containers during exit from the barge. Three Geotube® containers were deployed simultaneously in the split-bottom barge. Contaminated sediment was dredged from the seabed using a clam-shell excavator. Full depth silt curtains were used to confine the dredging works in order to minimize the impact of sediment resuspension. The dredged sediment was then placed into each of the Geotube® containers.

Red polystyrene balls were placed on top of the dredged sediments before container closure to act as an onsite leak detection method. If any rupture develops in the Geotube® containers during barge exit, fall and impact on the seabed, the polystyrene balls would escape and float to the surface. Closure of the Geotube® containers was done in two stages. First, the two inner flaps were laced together continuously for soil tightness using a 6 mm diameter rope. Next, the two outer edges of the Geotube® container were closed using rope knots at 150 mm centres to prevent rupture. After closure, the split-bottom barge was towed to the East Sha Chau contaminated mud pits for offshore disposal. No ruptures were detected for all 17 containers dropped. This was evidenced from the fact that no polystyrene balls were observed floating on the sea surface during and following the dropping of the Geotube® containers. Water quality measurements carried out in the vicinity as well as down-current of the drop area detected no change in levels of water pollutants and contaminants over the baseline levels.

Client: Highways Department, Hong Kong.

Consultant: AECOM Asia Co. Ltd, Hong Kong.

Contractor: China State Construction Engineering (HK) Ltd, Hong Kong.

Dredging contaminated sediments at Wan Chai

Contaminated sediment placed inside Geotube® container

Filled Geotube® container closed and transported to offshore dumpsite

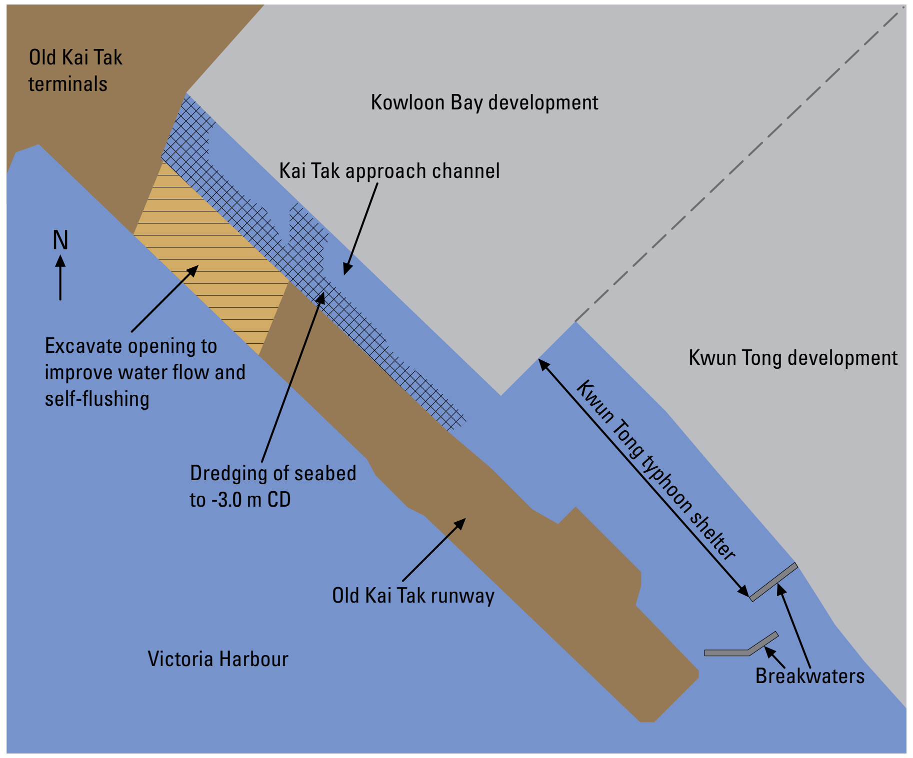
Filled Geotube® container dropped through split-bottom barge at offshore dumpsite

Estuarial and coastal: Kai Tak redevelopment project, Hong Kong

Kai Tak is the site of Hong Kong's original international airport prior to the opening of the new international airport at Chek Lap Kok in 1998. The Kai Tak runway was formed by reclaiming a 3.4 km length of land extending into the North of Victoria Harbour. The runway reclamation formed a narrow bay channel, the Kai Tak approach channel, around 200 m wide, adjacent to the runway on its Eastern side. This channel connects to the Kwun Tong typhoon shelter before opening into Victoria Harbour. The total length of this channel is around 2.6 km. Two breakwaters overlap to form a zig-zag entrance to allow marine movement into the Kwun Tong typhoon shelter which provides shelter for boats and barges operating in Victoria Harbour during typhoon events. However, the presence of the two breakwaters makes the water circulation within the approach channel very poor.

Over the last 40 years there has been much development adjacent to the Eastern side of Kai Tak airport. This has resulted in the establishment of two large areas, Kowloon Bay development and Kwun Tong development, being a mix of residential and industrial development. As a consequence, domestic and industrial sewage has been discharged into the Kai Tak approach channel. This, and the surface runoff from the Kai Tak runway, has resulted in a buildup of contaminated sediments in the Kai Tak approach channel. The contaminants are heavy metals, petroleum hydrocarbons and raw sewage.

With the closure of Kai Tak airport the Hong Kong Government decided to undertake the large scale redevelopment of the area over a 20 year period. Part of this redevelopment was the remediation of the Kai Tak approach channel and the Kwun Tong typhoon shelter. This environmental remediation package involved insitu bioremediation treatment of sediment over an area of about 90 hectares of seabed to abate the impact of odour emanating from the channel, and dredging of about 13 hectares of seabed in the approach channel to a depth of -3.0 m Control Datum to ensure sufficient water depth is available to effect odour suppression. Further, a



Site layout of Kai Tak redevelopment project showing location of dredging

600 m wide opening was excavated across the Northwestern end of the former runway to improve water circulation and self-flushing within the approach channel. A piled deck was then constructed on top of the opening for support of the construction of Metro Park.

From site investigations it was estimated that environmental dredging of about 1 million m³ of contaminated sediment would be required, of which 150,000 m³ was classified as Type 3 contaminated sediment. Type 3 is a Hong Kong Government classification of contaminated sediment that has high levels of chemical pollutants and has also failed the standard biological screening tests for toxicity. The Government only allows offshore dumping of this class of contaminated sediment if it is containerized. This ensures that the contaminated sediment cannot be dispersed into the surrounding water column during the dumping process. Geotube® containers were selected for this offshore disposal project.

The split-bottom barges used to dump the Geotube® containers had a hopper length of 34 m, width of 8.7 m and depth of 4.6 m. The installation commenced by placing slip sheets clamped along the inside of the barge hopper. The slip sheets were placed to protect the Geotube® containers during exit from the barges. Two Geotube® containers were placed end-to-end in the bottom of each hopper. Each Geotube® container measured 20 m in circumference and 16.5 m in length. Three fill ports spaced 5 m apart were provided along the top centre line of each Geotube® container. Contaminated sediment was dredged from the seabed using a long-arm mechanical excavator. Full depth silt curtains were used to confine the dredging works and to minimize any effects of sediment resuspension.

The Geotube® containers were filled with the dredged contaminated sediment while in the split-bottom barges. Polystyrene balls were also placed inside the containers during the filling process. These balls were used as a means of measuring the mechanical integrity of the containers during the dumping process, because if the container ruptured then the polystyrene balls would float to the surface. Each Geotube® container was filled with about 150 m³ of contaminated sediment. When the filling was completed, all fill ports were secured, and the barge was then towed to the East Sha Chau contaminated mud pits, to the Northwest of Hong Kong, for offshore disposal. During the dumping process water quality measurements were carried out in the vicinity of the dump site and no detected spikes in the levels of water pollutants over the baseline levels were detected.

Client: Civil Engineering and Development Department, Hong Kong.

Consultant: AECOM Asia Co. Ltd, Hong Kong.

Main Contractor: Penta-Ocean – Concentric – Alchmex JV, Hong Kong.

Sub Contractor (environmental dredging and disposal): Kwan Sing Contractors Ltd, Hong Kong.

Mechanical dredging of contaminated sediments at Kai Tak

Geotube® container placed in split-bottom barge

Filled Geotube® container being taken to offshore dump site

Geotube® container being dropped through split-bottom barge at offshore dump site

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