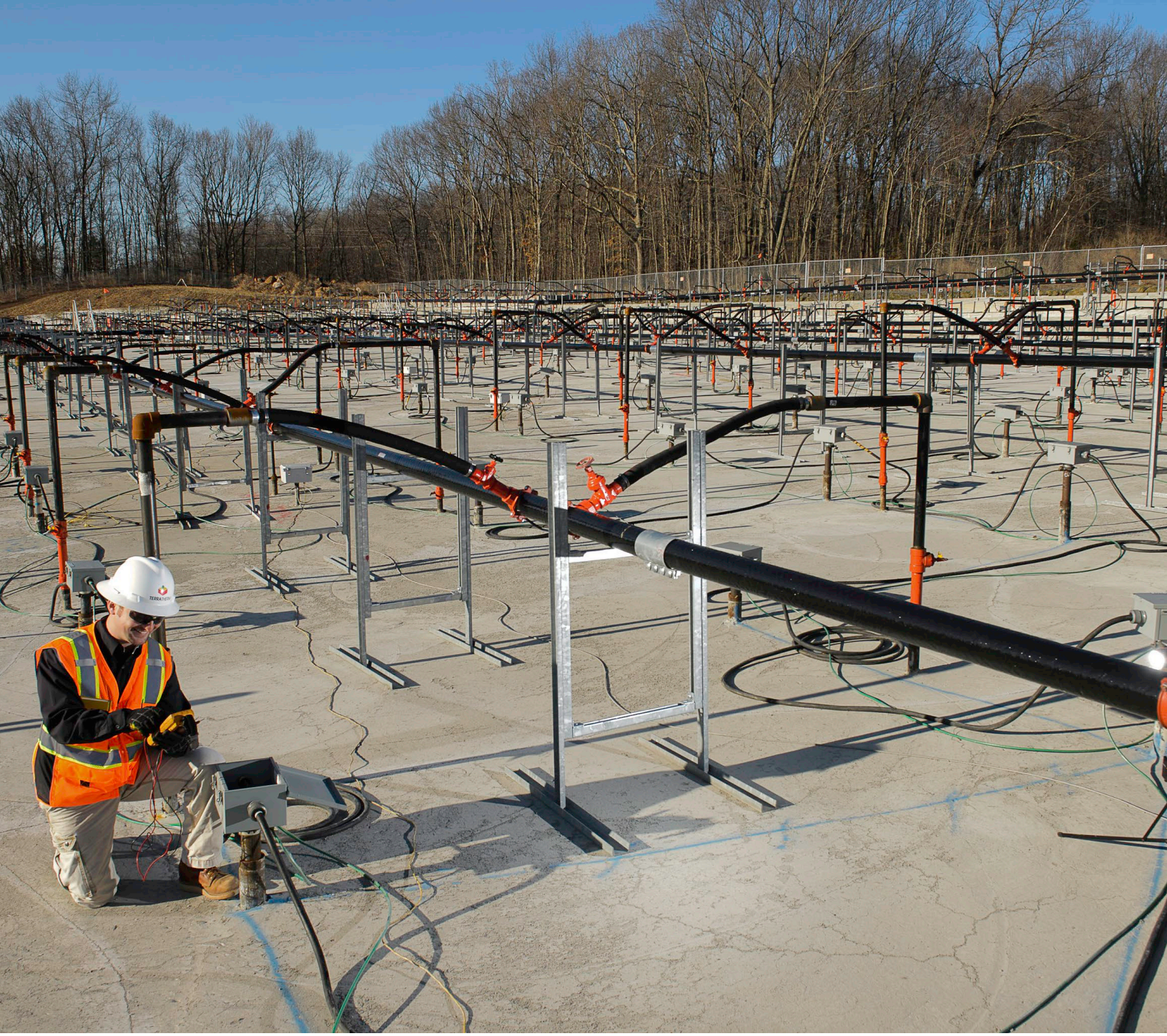

Source Zone Treatment
Contaminants in Bedrock

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Thermal Treatment in Bedrock

OVERVIEW

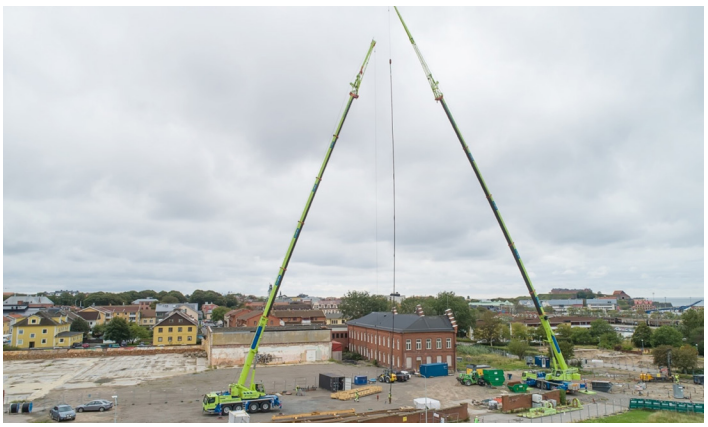
Treating fractured bedrock can be complex, and effective remedial options are limited. Due to the fractured nature of rock, it is difficult to reliably delivery amendments and reaction chemicals to where the mass is located. Fortunately, thermal remediation using Thermal Conduction Heating (TCH) overcomes these limitations and is a cost-effective, safe, and reliable means of treating fractured bedrock.

TCH uses simple electrical heaters suspended inside a bore-hole to deliver heat to the surrounding formation. In fractured rock systems, the heat migrates away from the heater borings primarily by thermal conduction driven by the temperature gradient. For lots of sites, heating the targeted bedrock zone and the overlying overburden to 100°C is an effective approach for treating CVOCS, DNAPL and VOCs, although lower temperatures can be effective too, if thermally enhanced hydrolysis or biodegradation is the targeted remediation mechanism.

When heating to boiling, the fractures are utilized as the pathways for the generated vapor (steam and contaminants) to escape and be captured by the vacuum extraction system. Every TCH heater, spaced approximately 15 ft apart, is typically supplied with a vapor recovery point. This ensures good connection with the fractures and that the entire treatment zone is kept under a vacuum, and that the mobilized contaminants are effectively captured.

In Situ Thermal Remediation (ISTR) using TCH has been successfully used to treat contaminants in a wide range of bedrock types and hydrogeologic settings, to depths as great as 170 ft below ground surface. Characteristics of the bedrock, such as porosity and saturation, play a key role in the heat-up rates and overall performance of treatment. Even with all the variables of a fractured bedrock site, TCH can achieve thorough heating of the matrix and fractures of the bedrock, prevent unwanted condensation of steam and vapors, and capture and remove the mass liberated from the bedrock and unconsolidated deposits.

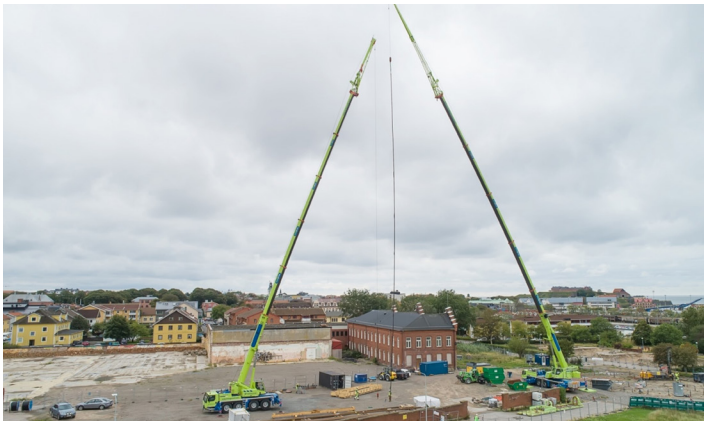
TerraTherm has successfully and safely completed more than 10 bedrock sites around the world including the deepest site to date at 170 ft. Contact us to learn more and discuss options for treating your contaminated bedrock site.

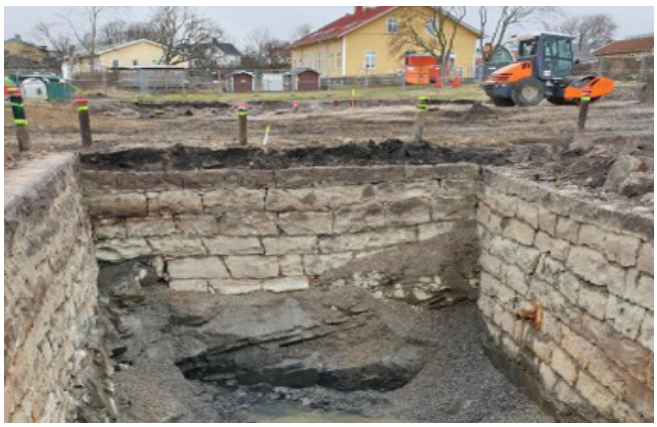


The World's Deepest TCH Treatment in Bedrock. The site is located in Varberg, Sweden, south of Gothenburg, in an industrial area that is slated to be redeveloped. A former textile and subsequent metalware factory had caused contamination of the deep bedrock at the site with chlorinated solvents. The contamination that occurred at least 45 years ago had spread to 164 feet (ft) below ground in a slightly fractured granite and was detected to a minimum of 148 ft below ground. Thermal Conductive Heating was chosen as the only real feasible and practicable remedial alternative to effectively remove the source zone.

The goal of the clean-up was to remove the contamination in the source area and thereby avoid potential vapor intrusion and indoor air issues. An 8,600 ft2 area to 164 ft below ground was defined as the source area to be remediated. The geology at the site consisted of 16 ft of overburden underlain by fractured granite with a maximum estimated total porosity of 0.5%. The water table was located approximately 6 ft bgs.

A total of 76 heat wells were installed to 170 ft bgs. At the surface, a permeable layer of washed gravel was constructed to create a permeable zone for capture and extraction of steam, air, and COCs during thermal remediation. To avoid condensation of the CVOCs in shallow soils and vapor extraction plenum, and to ensure pneumatic control, an insulating lightweight concrete layer was constructed over the top of the treatment zone. The system was designed to meet a clean-up goal of 5 mg/L. After 6 months of heating, the remedy was complete after reaching the clean-up goals and removing approximately 6,614 lbs of chlorinated solvents.
In June 2021, one year after thermal operations were terminated, groundwater samples collected in the former source zone showed average concentrations of targeted CVOCs of 1.2 mg/L. No rebound was observed. This illustrates TCH's robustness and ability to effectively remove the contamination from not only the bedrock fractures, but also from the rock matrix. The bedrock source zone has now been removed and monitoring results shows that the groundwater plume is decreasing in size.





Confidential Southern California Site. TerraTherm was contracted to design and implement thermal remediation at this deep bedrock site. The CVOCs at the site, mainly TCE, had created a source zone to a depth of 100 ft. The geology at the site consisted of up to 30 ft of alluvium, underlain by a fractured granitic bedrock and a water table was encountered between 50-70 ft bgs. The exact source zone and volume were not fully delineated when the wellfield was installed, so our design adapted and our wellfield expanded based on data collected during well installation. Because the fracture network was not well understood at the site a robust vapor recovery system was essential, and all TCH heater borings were installed with a co-located extraction screen to maximize intersection of the fracture network and to draw contaminants towards the heated zone as the heat was moving away from the heaters. After the mass removal had peaked, three successive rounds of sampling of the extracted vapors were completed to document asymptotic TCE vapor concentrations. TCE vapor concentrations at heater locations were decreased 99.98% during operation, while the concentrations at nested soil vapor probes located at the midpoint between heater borings decreased 99.9%. Sampling was repeated 14 months after shutdown of the thermal system, and no rebound was documented, thereby successfully meeting the project remedial goals.

Confidential Southeastern Site. At an active manufacturing facility in the Southeastern United States, trichloroethene (TCE) was released via a sump/catch basin system associated with an aboveground TCE storage tank and a TCE reclamation unit. TerraTherm was contracted to design the remedial system and to treat the source zone to approximately 85 ft bgs. The geology consisted of 4 geologic units: an upper fill layer, saprolite, partially weathered bedrock, and a fractured gneiss. The treatment zone extended into the fractured gneiss. The system ran consistently with no downtime and the site reached target temperature within 100 days.
The pretreatment TCE concentrations were as high as 95,000 mg/kg at the site. 56 rock samples were collected to document the success of the remedy, and the 95% UCL mean TCE concentration were 0.017 mg/kg. well below the remedial goal of 0.060 mg/kg. All remediation goals were met.

Kvarnholmen, Sweden. TerraTherm supported the design for this project in Sweden, where TerraTherm's TCH technology, was implemented by our European partner Krüger. The client had ambitious plans to turn a former industrial harbor located on a small island into an attractive residential area in Stockholm. Former storage tanks on the island had been leaking PCE into fractures in the granite for years, and in the process contaminated a 13,300 ft2 area and a total volume of 38,700 cy. The contamination was located to a depth of more than 98 ft (33 ft below sea level) complicating the clean-up. During the remediation new road and bridge, going straight through the remediation area, was built, adding to the complexity of the project. Since the public had access to the road, added safety requirements had to be put in place.
TCH was chosen to uniformly heat the granite, and more than 1,000 lbs of CVOCs were removed utilizing a wellfield with 105 heaters. The island of Kvarnholmen is now starting its new life: It will still be a busy construction site for the next couple of years to become an attractive and vibrant neighborhood with its own identity.

SRSNE Superfund Site, CT. TerraTherm was contracted to address a large amount of CVOC DNAPL contaminant mass (estimated to range between 0.5 and 2M lbs.) located in the overburden and at the bedrock surface at the site. Our experienced design team develope a unique thermal approach to operate the wellfield in two phases to offset the contaminant loading from the wellfield and therefore minimize the size of the vapor treatment system. The contaminant removal rate peaked at10,000 lbs. per day during operation. During the installation of the thermal wellfield, it was discovered that the bedrock surface was undulating much more than anticipated in the design basis. To address the variances in the bedrock depth, an adaptive approach was utilized, such that all heater borings were installed a minimum of 6-7 feet into the undulating bedrock, to address contamination pooled on top of the bedrock. Subsequent the TCH heaters were custom designed and fabricated to the appropriate lengths required. The project was successfully completed with over 496,000 lbs. of VOC contamination removed. This resulted in >99% reduction in COC mass and achievement of all soil cleanup goals.

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