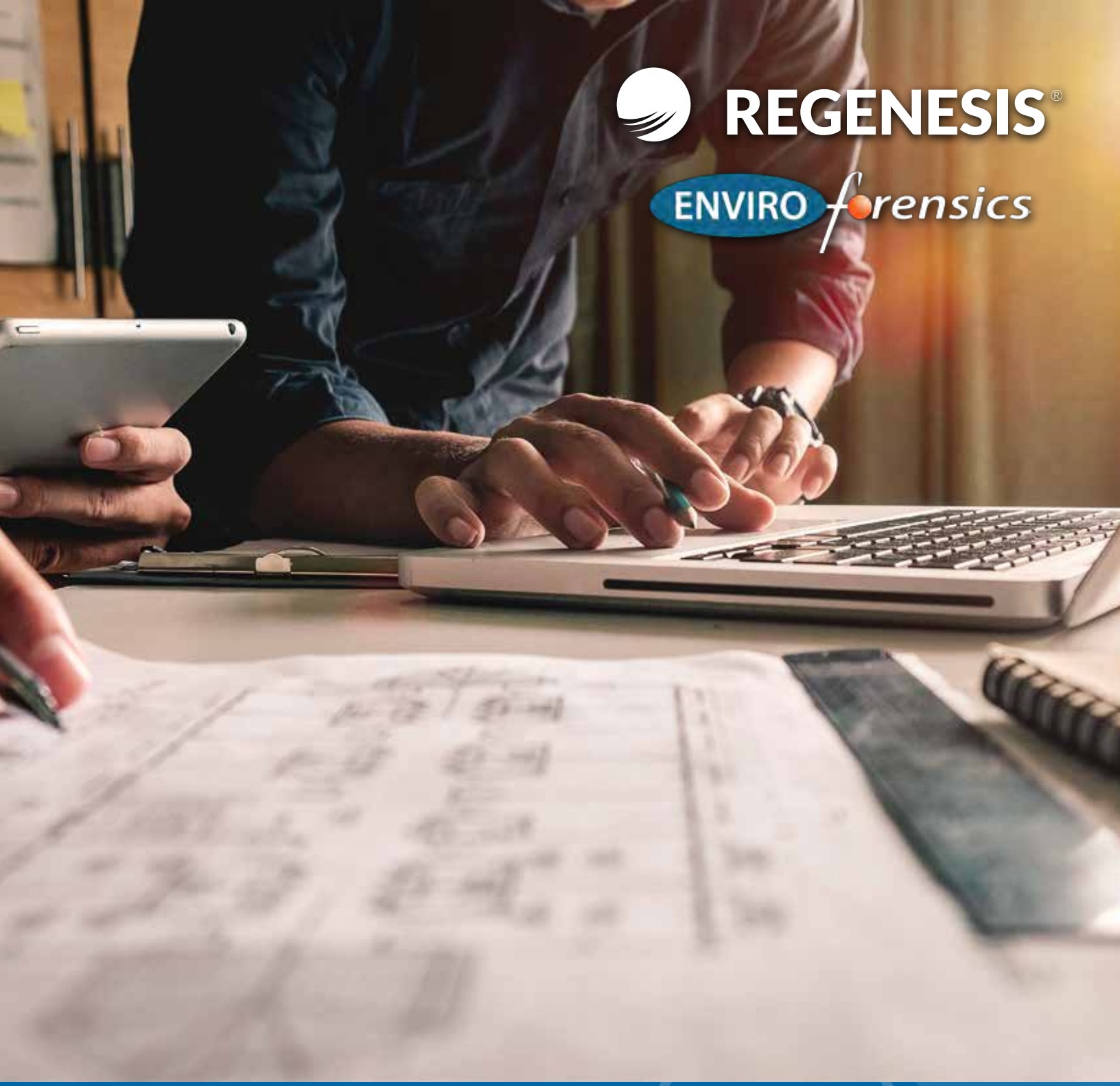


A BUSINESS CASE APPROACH TO SITE CLEAN UP

IN SITU REMEDIAL STRATEGY VS. LONG TERM STEWARDSHIP

When Remediation Makes Cents: Cost-Effective Approaches to Consider

When dealing with environmental issues, regulatory closure is often seen as the end goal. While regulatory closure can be attained via various strategies, most revolve around the elimination of exposure pathways.

When assessing risk, it has become increasingly clear that regulatory closure should be viewed as only an interim milestone. The various strategy options for eliminating exposure pathways and attaining regulatory closure can have vastly different costs when it comes to future liabilities and long-term stewardship (LTS).

For example, source removal can be a relatively large short-term expense compared to a vapor mitigation system. However, that same vapor mitigation system might end up costing far more than source removal if the system is not properly maintained or the building remains in use for a long time without any meaningful remedy to the source.

Present-Day Planning

Maintaining a shortsighted view during remedial planning can make it tempting to favor provisional savings over long-term costs. However, when looking at cleanup through the lens of a timeline extending into perpetuity, the need to balance present-day remedial efforts with anticipated future costs becomes far more important.

About the Author

Throughout his 20-year career in environmental consulting, Jeff Carnahan has remained true to his goal to understand and focus on the needs of his clients. While his current position as Executive Vice President of EnviroForensics,® a leading environmental engineering firm, garners much of his time, Jeff still puts a priority on providing personalized client service. It's a combination of successfully solving client challenges and honing his scientific, regulatory and management skill-set that continues to separate Jeff from his peers. It also is one reason why EnviroForensics, a REGENESIS® client, continues to excel in all phases of environmental engineering.

About EnviroForensics

EnviroForensics is a leading environmental engineering company addressing environmental liabilities and finding funding by locating and bringing to their client's defense old insurance policies. EnviroForensics has pioneered and perfected the utilization of Comprehensive General Liability insurance policies as a resource to pay for the high costs associated with soil and groundwater investigations, remediations, and legal defense.

With recalcitrant compounds such as perchloroethylene (PCE) and other chlorinated solvents, the threat of future exposure does not readily go away. If engineered or institutional controls fail, these lingering contaminants may present serious problems.

Proper cost-analysis that takes all these factors into account can help clients find a balance between short-term and long-term costs and make decisions that are right for them.

There is an inversely proportional relationship between money spent on immediate cleanup versus the costs of stewardship and the often overlooked component of potential legal damages resulting from contaminant mass left behind. Accidental polluters tend to be small businesses such as dry cleaners who must rely on personal assets to fund remedial efforts. Thus, these cost analyses are not merely academic exercises, but can result in significant real-world savings.

The Goal is to Eliminate Exposure

In the following case studies, point of exposure assessments were conducted to help identify where remedial and LTS programs would be most effective. Whether treating the contaminant mass reservoir (soil, groundwater, or vapor) directly or implementing a control system to cut off the pathway, the goal of any remedial strategy is to eliminate exposure to the receptor.

The following case studies provide a helpful guide for property owners, developers, and environmental professionals to consider when evaluating remedial efforts vs. long-term stewardship. The cases outlined are actual sites where EnviroForensics was involved in recommending and then implementing an effective remedial plan and ultimately saving their clients both time and money in addressing the contaminants of concern. A thorough analysis of each site is always recommended when determining the most cost-effective approach before moving forward with a remedial plan.

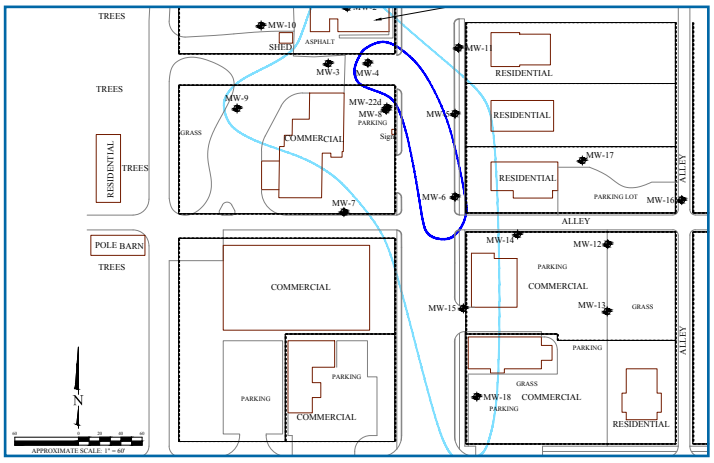
NOTE: The costs of future liability presented were determined by experienced attorneys who performed an analysis taking court cases nationwide and assigning a higher cost component for prevalent claims in similar cases. Alternatively, in a situation where claims were not made, they assigned estimated damages to parcels that may be potentially affected. The cost examples presented are case-specific and subject to margins of variability.

Case Study:
Dry Cleaning Site Uses ERD Approach to Achieve Site Goals and Lower Lifecycle Costs

#1

About the Site

This dry cleaning site had PCE contamination that extended beneath several buildings, including residential properties. Impacts were present in the vadose zone that exceeded direct contact (DC) thresholds and the migration-to-groundwater (MTG) standards. The groundwater plume was also expanding and contributed directly to vapor intrusion (VI) exposure issues. VI mitigation was necessary in both the source area and at downgradient residential structures.



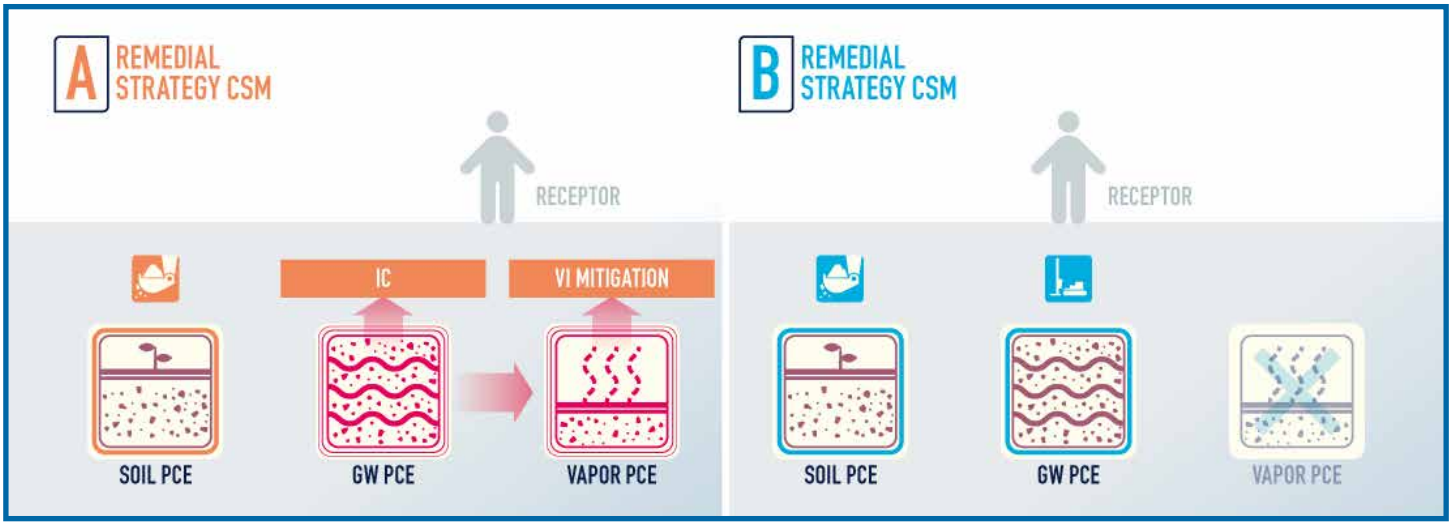
Two remedial strategies were considered

Remedial Strategy A:

- Impacted soil would be excavated to promote future plume stability
- Institutional Controls (IC) would be implemented to cut off exposure pathways from the groundwater to the receptor. ICs typically consist of groundwater usage restriction (i.e. no wells) but requirements vary from state to state
- VI mitigation would be installed and maintained

Remedial Strategy B:

- Impacted soil would be removed
- Groundwater plume would be treated *in situ* via amendment injections



Comparing the two strategies, the upfront cost of **Strategy A** is lower as there is no cost associated with groundwater treatment. However, as can be seen in the cost analysis of **Strategy B**, by removing the groundwater contaminant reservoir, the cost of groundwater monitoring and VI mitigation are eliminated.

The groundwater contaminant reservoir would be addressed by treating the plume with 3D-Microemulsion® (3DME), CRS®, and BDI Plus®; products designed to promote the anaerobic dechlorination of chlorinated solvents. This is a self-perpetuating treatment system, as opposed to a mechanical system that generates operation and maintenance costs.

Future liability is also significantly reduced because exposure pathways to outlying properties would be cut off.

A REMEDIAL STRATEGY COST ANALYSIS

SERVICE	COST
SOIL EXCAVATION	$45,000
GW TREATMENT	$0
VI MITIGATION	$100,000
LTS (GW MONITORING/VI)	$445,000
FUTURE LIABILITY	$95,000
TOTAL	$685,000

B REMEDIAL STRATEGY COST ANALYSIS

COST
$45,000
$200,000
$0
$0
$20,000
$265,000

Remediation Efforts

Based on projected cost savings, the client chose to implement **Strategy B**.

Impacted soils were excavated and 3DME, CRS and BDI Plus were injected in a grid across the plume using direct-push equipment.

Long term Vapor Intrusion (VI) issues were eliminated by virtue of removing the groundwater impacts, and short-term VI mitigation was implemented where there were known complete exposure pathways.

Results

Shortly after the injection of REGENESIS products, PCE concentrations across the site sharply decreased while, as expected, daughter products (trichloroethylene, dichloroethylene, vinyl chloride) all increased.

While remediation is ongoing, post-injection PCE concentrations have remained at non-detect. Because 3DME remains active for 2-4 years following injection, it is expected that the daughter product concentrations will also decrease towards non-detect provided there is no significant sorbed phase contamination.

Lifecycle Cost Savings Achieved

The total cleanup costs, including investigation and remediation efforts, was $1,450,000.

By spending $200,000 upfront to remediate the groundwater, the client avoided long-term expenditures and achieved a lifecycle cost savings of $420,000.

Total Savings Achieved $420,000

#2 Case Study: Multi-Residence Site's Remedial Approach Mitigates Vapor Intrusion and Saves $250,000

About the Site

This multi-residence site had a large soil gas plume located in a deeper sand vadose zone. The plume underlay a seven story multi-family residential unit onsite and several residential buildings offsite.

There was significant contamination onsite, with impacts in the source area reaching levels as high as 7,580,000 ug/m3.

There were soil contaminant reservoirs in both the shallow and deeper soils. The shallow impacts were in excess of DC thresholds while the deeper soils held very high vapor concentrations.

The groundwater plume was stable and dilute and did not represent significant VI concerns, however, concentrations still exceeded MCLs.

There were complete VI exposure pathways at numerous offsite properties with basements, so interim measures were installed to mitigate risk during the investigation process.

Soil Gas Plume - PCE Contours at 18 feet below ground surface

Two remedial strategies were considered:

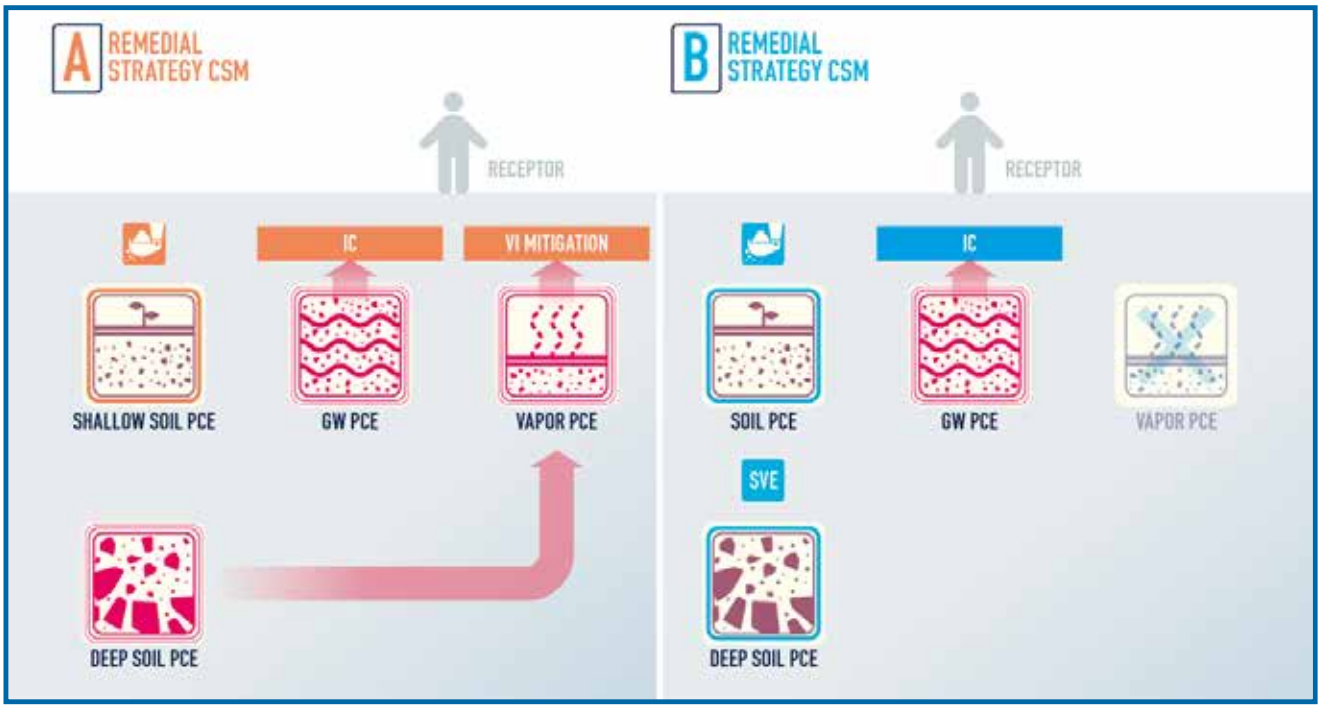
Remedial Strategy A:

- The onsite building would be demolished
- Shallow soils would be excavated
- IC would be implemented to restrict groundwater usage
- VI mitigation would remain in place

Remedial Strategy B:

- The onsite building would be demolished
- Shallow soils would be excavated and stabilized with chemical oxidant
- A soil vapor extraction (SVE) system would be installed

Neither remedial strategy included groundwater treatment since the primary concern was the vapor intrusion. With **Strategy A**, the costs are deferred, leaning towards keeping present-day dollars and instead opting to gamble on the costs of long term liabilities and stewardship costs. With **Strategy B**, the upfront costs are significant, due primarily to the capital expenditure required for the installation and operation of the SVE system. The payoff is that the cost of LTS, VI mitigation, and potential future liabilities would be greatly reduced or eliminated altogether because the contaminant mass, and therefore the risk, would be removed.



A REMEDIAL STRATEGY COST ANALYSIS

SERVICE	COST
DEMO SOIL EXCAVATION	$265,000
GW TREATMENT	$0
VI MITIGATION	$300,000
LTS (IC/VI)	$195,000
FUTURE LIABILITY	$250,000
TOTAL	$1,010,000

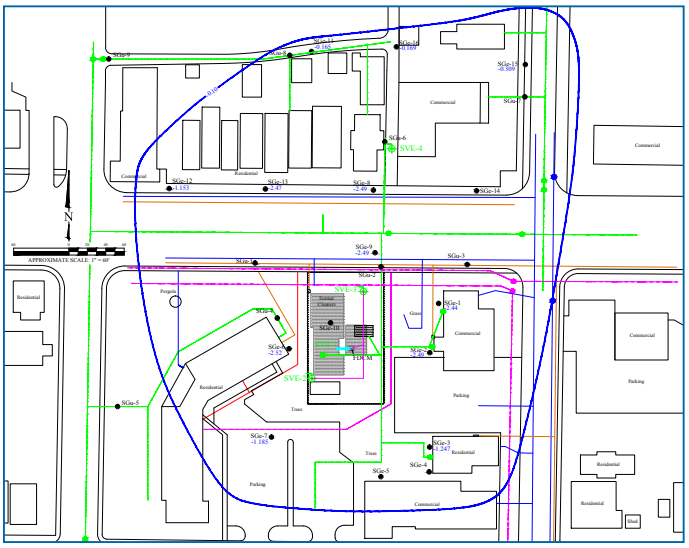
B REMEDIAL STRATEGY COST ANALYSIS

SERVICE	COST
DEMO SOIL EXCAVATION	$265,000
SVE	$450,000
GW TREATMENT	$0
VI MITIGATION	$0
LTS (IC)	$15,000
FUTURE LIABILITY	$30,000
TOTAL	$760,000

To further reduce costs, excavated soils would first be treated onsite with a chemical oxidant (PersulfOx®), which would allow them to be disposed of as a non-hazardous waste.

Remediation Efforts

Favoring a more aggressive remedial approach, the remediation plan that was implemented involved the demolition of the onsite building, the removal of shallow soils, and the installation of the SVE to treat the deeper soils. The shallow soils were stabilized using PersulfOx and subsequently disposed as of non-hazardous waste.



Because the treatment removed the vapor, any VI concerns were alleviated.

The costs of the anticipated LTS program were significantly reduced from an estimated $195,000 to $15,000, requiring only occasional IC monitoring for groundwater usage.

Results

While the initial costs of the SVE were high, the system was well-engineered and achieved a remarkable radius of influence, successfully eliminating the liability posed by the vapor in the deep soil reservoir.

Lifecycle Cost-Savings Achieved

The total cost of cleanup including investigation and remedial efforts came to $1,650,000.

The major difference between the two strategies was the implementation of the SVE system which cost $450,000 in the short-term, but garnered $250,000 in lifecycle cost savings by reducing the cost of LTS, VI mitigation, and potential legal damages.

Total Savings Achieved $250,000

Case Study: Residential Neighborhood Treated with PlumeStop Decreases Liability and Costs

#3

About the Site

A residential neighborhood had impacts in the sandy vadose zone above DC thresholds and MTG standards which contributed to both onsite and offsite VI concerns.

The groundwater plume was very large with shallow (<50 ft bgs) onsite impacts and a diving (150-200 ft bgs) downgradient plume which upwelled near the leading edge. At depth, the plume did not represent VI concerns, however, in the areas where it upwelled, the overlying residential neighborhood was at risk.

Because of the size of the plume, remedial strategy options were devised for two separate sections with different contaminant mass reservoirs: near source (soil, groundwater, and vapor reservoirs) and downgradient (groundwater and vapor only).

To evaluate the costs of any LTS program, plume behavior was modeled to determine the length of time it would require to achieve plume size reduction targets. With **Strategy B**, the additional treatment of the downgradient groundwater would cut the time frame in half from 16 to 8 years.

While these models may not be completely accurate, they can still serve as a useful tool in the decision-making process.

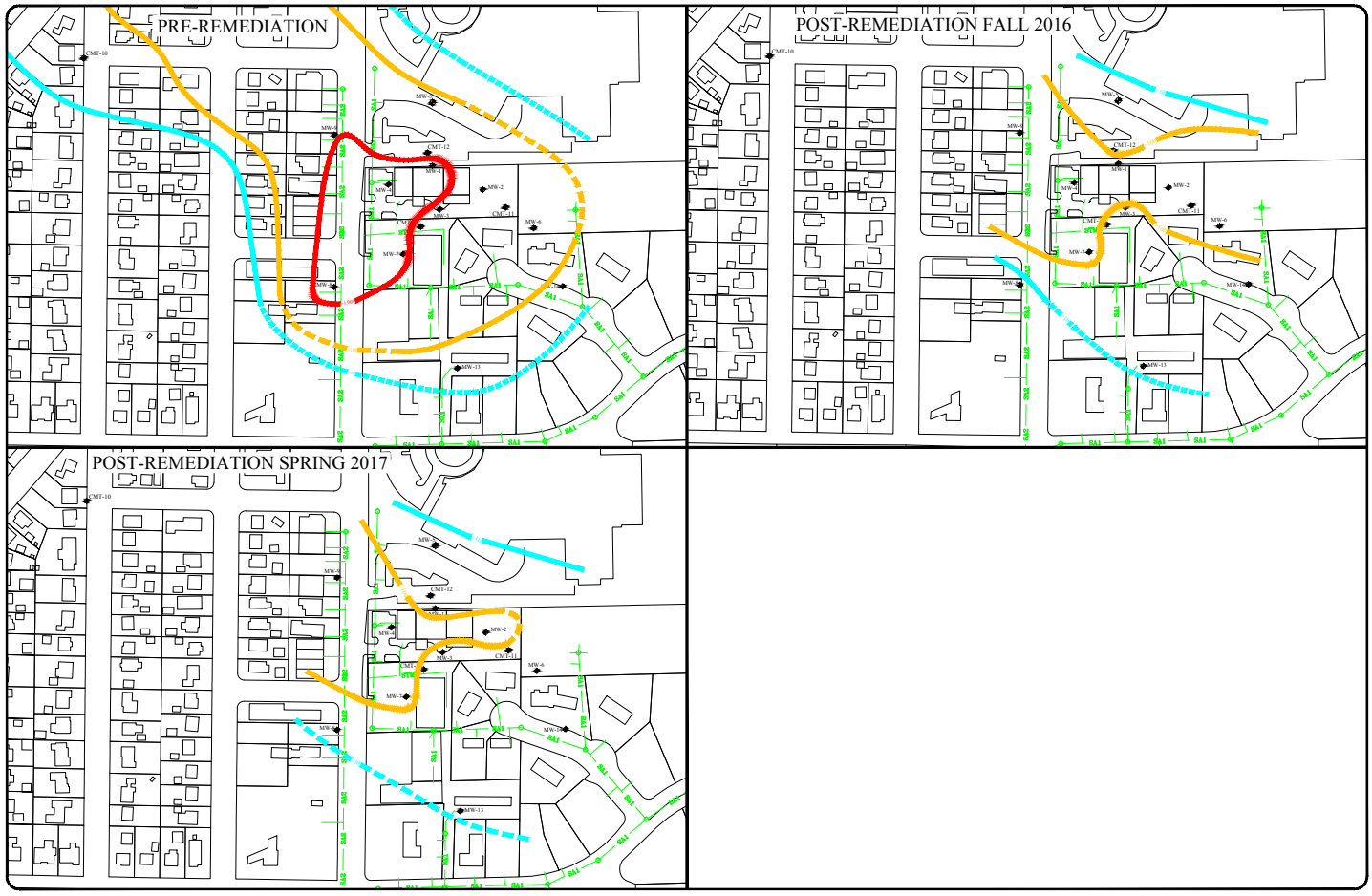
Comparing strategies, the cost of soil excavation and SVE implementation is the same for both but where they differ is the cost of groundwater treatment, with the additional downgradient treatment carrying an additional cost of $600,000.

However, treating the downgradient groundwater plume eliminates the need for a LTS program and VI mitigation, both of which were high due to the extended time frames involved, and also greatly decrease costs associated with future liability.

The planned cutoff barriers would consist of PlumeStop® Liquid Activated Carbon,™ a colloidal suspension of activated carbon designed to adsorb contamination from groundwater. Once adsorbed, the contamination remains in place until it is removed by biological degradation, freeing up the adsorption site to trap additional contaminant.

The PlumeStop is expected to last for decades and will continue to adsorb incoming contamination provided the rate of adsorption does not exceed the rate of degradation. Therefore, if the contaminant flux remains as expected, there should be no need for additional injections. This provides a level of certainty as to the cost.

The PlumeStop is expected to last for decades and will continue to adsorb incoming contamination provided the rate of adsorption does not exceed the rate of degradation.



Two Remedial Strategies Considered

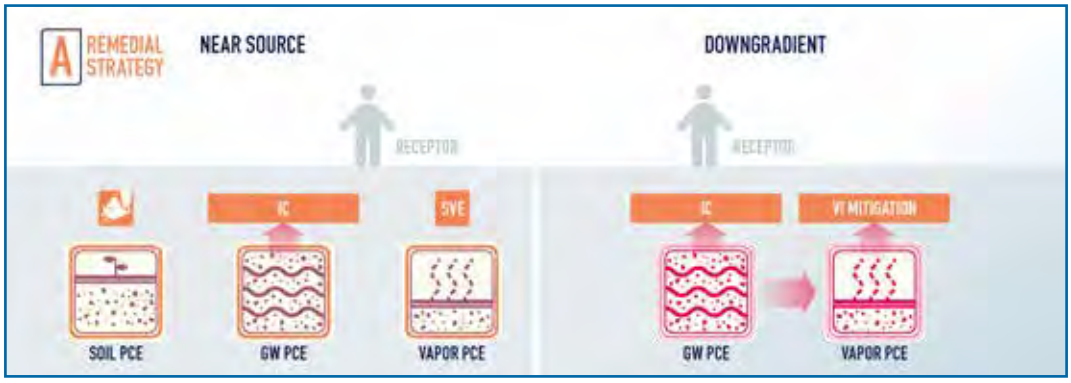
Remedial Strategy A:

Near Source

- All contaminant reservoirs (soil, groundwater, and vapor) would be removed/treated via a combination of SVE and amendment injections
- A cutoff barrier would be installed immediately downgradient of the source

Downgradient

- No treatment plans
- Groundwater usage would be restricted
- Vapor would be handled through VI mitigation strategies



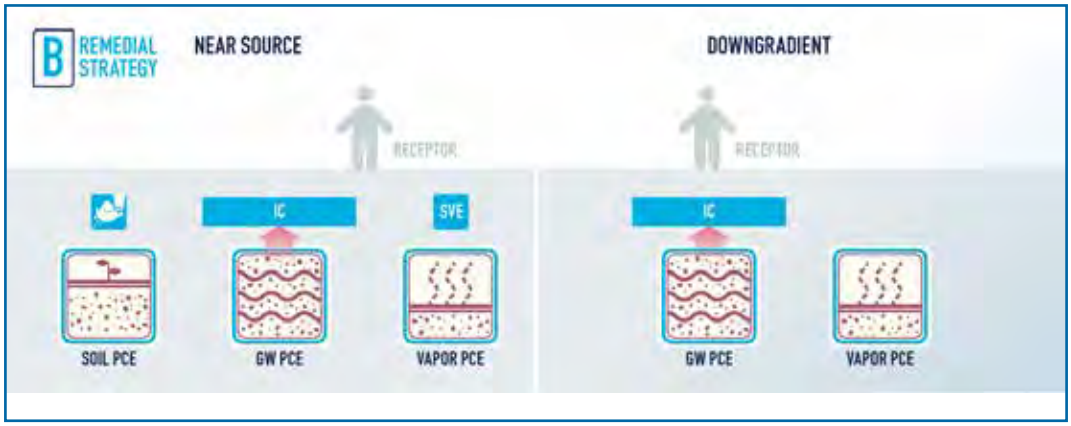
Remedial Strategy B:

Near Source

- All contaminant reservoirs (soil, groundwater, and vapor) would be removed/treated via a combination of SVE and amendment injections
- A cutoff barrier would be installed immediately downgradient of the source

Downgradient

- Additional cutoff barriers would be installed in the downgradient areas of the plume to promote contaminant mass reduction



A REMEDIAL STRATEGY COST ANALYSIS

SERVICE	COST
SOIL EXCAVATION	$50,000
SOIL VAPOR EXTRACTION	$380,000
SOURCE GW TREATMENT	$800,000
VI MITIGATION	$400,000
LTS (16 yrs VMS + GW MONITORING)	$825,000
FUTURE LIABILITY	$375,000
TOTAL	$2,830,000

B REMEDIAL STRATEGY COST ANALYSIS

SERVICE	COST
SOIL EXCAVATION	$50,000
SOIL VAPOR EXTRACTION	$380,000
SOURCE & DOWNGRADIENT GW TREATMENT	$1,400,000
VI MITIGATION	$0
LTS	$0
FUTURE LIABILITY	$75,000
TOTAL	$1,905,000

Remediation Efforts

The client chose to go with a more aggressive remediation approach in order to minimize long-term costs. Impacted soils were excavated, and the SVE system was installed, and source area groundwater was treated through injections of 3DME, CRS, and BDI Plus.

A cut off barrier consisting of PlumeStop was installed just outside of the source area with plans to install additional PlumeStop cutoff barriers in the downgradient plume area. It is anticipated that VI concerns should be eliminated via the treatment outlined.

Results

While the remediation work is still on going, the results are promising.

Within six months, remediation efforts achieved an order of magnitude reduction in contaminant concentrations and ongoing monitoring indicates continuing declines.

Lifecycle Cost-Savings Achieved

The total cost of cleanup, including investigation and remediation, came to $3,800,000.

By spending an additional $600,000 in the short-term to install downgradient cutoff barriers, the client stands to realize a lifecycle cost-savings of $925,000.

Total Savings Achieved $925,000

Remedial Approaches Used: Products & Solutions

PLUME STOP
Liquid Activated Carbon

PlumeStop Liquid Activated Carbon is a fast-acting groundwater remediation reagent which captures and biodegrades a range of contaminants, thus accelerating the successful treatment of impacted sites and leading to their permanent closure. As a science-based, *in situ* treatment technology, REGENESIS' PlumeStop rapidly removes contaminants from groundwater and stimulates their permanent degradation. This exciting, turn-key solution offers several key benefits for addressing site treatment, including:

- Rapid reduction of dissolved-phase plumes
- Distribution of widely under low injection pressures
- Achievement of stringent groundwater clean-up standards
- Providing a long-term means of addressing matrix back–diffusion, so contaminants do not return
- Elimination of excessive time and end-point uncertainty associated with groundwater remediation

PERSULF Ox
Catalyzed Persulfate

PersulfOx is an advanced *in situ* chemical oxidation (ISCO) reagent that destroys organic contaminants found in groundwater and soil through abiotic chemical oxidation reactions. It is an all-in-one product with a built-in catalyst which activates the sodium persulfate component and generates contaminant-destroying free radicals without the costly and potentially hazardous addition of a separate activator. The patented catalyst enhances the oxidative destruction of both petroleum hydrocarbons and chlorinated contaminants in the subsurface.

- Contains a built-in catalyst that remains active through the entire lifespan of the persulfate oxidation reaction
- The catalyst also eliminates the need for the co-application of alternate and potentially hazardous activation chemistries
- Contaminant oxidation performance equivalent to best alternative persulfate activation methods
- Fewer health and safety concerns than with use of traditional activation methods such as heat, chelated metals, hydrogen peroxide or base
- Single component product results in simplified logistics and application
- No additional containers or multi-step mixing ratios required prior to application

3-D MICROEMULSION

3-D Microemulsion is an injectable liquid material specifically designed for *in situ* remediation projects where the anaerobic biodegradation of chlorinated compounds through the enhanced reductive dechlorination (ERD) process is possible. ERD is the primary anaerobic biological process by which problematic chlorinated solvents such as tetrachloroethylene (PCE) and trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC) in groundwater are biologically transformed into less harmful end products such as ethene. Benefits of 3-D Microemulsion include:

- Engineered, wide-area subsurface distribution mechanisms significantly reduce the number of injection points and events required.
- Three stage; immediate, mid-range and long-term controlled-release of lactic, organic and fatty acids for the steady production of hydrogen for optimized enhanced anaerobic biodegradation.
- High volume application optimizes contact with contaminants and reduces number of injection points required for treatment
- A viable, long-term source of staged-release hydrogen, on the order of 2-4 years from a single application

CHEMICAL REDUCING SOLUTION

CRS (Chemical Reducing Solution) is an iron-based amendment for *in situ* chemical reduction (ISCR) of halogenated hydrocarbon contaminants such as chlorinated ethenes and ethanes. It is a pH neutral, liquid iron solution that provides a soluble, food-grade source of ferrous iron (Fe2+), designed to precipitate reduced iron sulfides, oxides, and/or hydroxides. These Fe2+ minerals are capable of destroying chlorinated solvents via chemical reduction pathways, thus improving the efficiency of the overall reductive dechlorination process by providing multiple pathways for contaminant degradation in groundwater.

- Facilitates biogeochemical *in situ* chemical reduction (ISCR) of chlorinated contaminants
- Provides multiple pathways, both abiotic and biotic, for contaminant degradation in groundwater
- Contains a form of liquid iron which provides better distribution than can be achieved by directly injecting a solid iron material
- Seamless integration with anaerobic bioremediation
- Easy to apply with the electron donor 3-D Microemulsion

BIO-DECHLOR INOCULUM

Bio-Dechlor INOCULUM Plus (BDI Plus) is designed for use at sites where chlorinated contaminants are present and unable to be completely biodegraded via the existing microbial communities. BDI Plus is an enriched, natural microbial consortium containing species of Dehalococcoides sp. (DHC) which are capable of completely dechlorinating contaminants during *in situ* anaerobic bioremediation processes. BDI Plus has been shown to stimulate the rapid dechlorination of chlorinated compounds such as tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC). It also contains microbes capable of dehalogenating halomethanes (e.g. carbon tetrachloride and chloroform) and haloethanes (e.g. 1,1,1 TCA and 1,1, DCA) as well as mixtures of these halogenated contaminants.

- Rapid and effective treatment of undesirable anaerobic dechlorination intermediates such as dichloroethene (DCE) and vinyl chloride (VC)
- A low-cost means of enhancing the anaerobic biodegradation process
- Application can occur at almost any stage of a project, beginning, middle or end
- Highly compatible with a range of electron donors such as 3D Microemulsion and HRC.
- Ease-of-application and handling

About EnviroForensics: The Best Science and the Best Strategy™.

EnviroForensics strives to provide the best science and the best strategy. Providing quality engineering and litigation support services to businesses, law firms and municipalities, EnviroForensics delivers accurate, defensible products on time and within budget. Trust, earned from clients, forms the basis of a strong partnering philosophy and is the foundation of EnviroForensics' success.

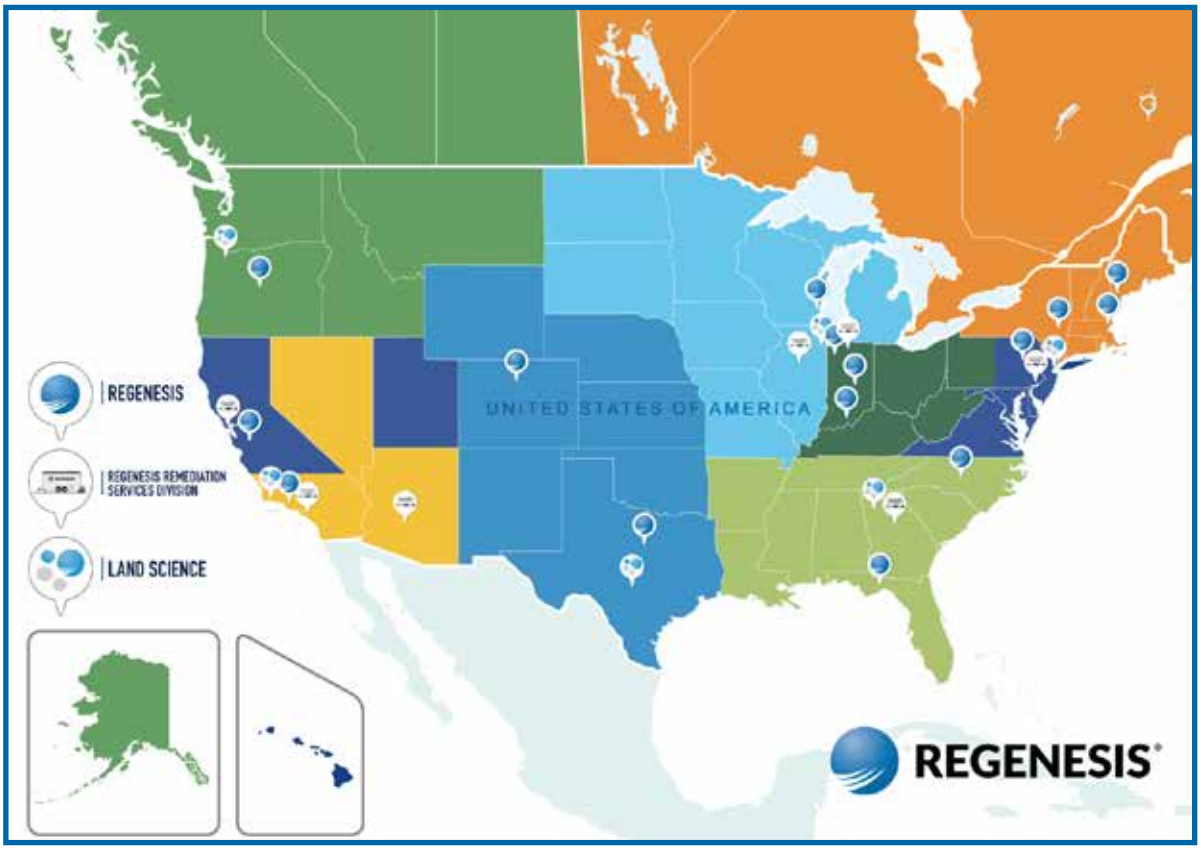
EnviroForensics is an environmental engineering firm comprised of the finest team of engineers and scientists who offer dynamic leadership and international experience in Site Investigation and Remediation, Legal Support and Resource Management. EnviroForensics is a pioneer in helping clients find funding sources to pay for site investigations, cleanup, and legal expenses.

Understand Your Total Cost to Remediate

All too often, remediation strategies focus on short term costs without factoring in requirements for proper LTS and the associated costs of implementation. Additionally, future liabilities and risks of legal damages to third parties should be included in the analysis.

Only by taking these real costs into account will it be possible to find a well-informed balance between short-term and long-term expenditures that can help clients maximize their potential savings.

When it comes to environmental liability, regulatory closure is seldom the end of the story. It is often just an interim step in the process of protecting clients from risk, communities from exposure, and the environment from harm.



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