FINDING THE PROPER MIX: METHODS SELECTION APPROACH for BROWNFIELDS SITE REMEDIATION

BUSINESS OF BROWNFIELDS CONFERENCE

APRIL 25, 2006

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Presentation Topic Points

- Focus for the Non-technical decision-maker
- Overview of property redevelopment process
- Overview of remediation approaches
- Technology options
- Methods selection approach
- Reference resources

Typical Explanation for Technology Selection & Deployment

Calculating Contaminant Mass Loading and Removal Rates

Contaminant mass loading and removal rates can be calculated with the same basic equation. However, the units and conversion factors are different for air than they are for water.

For Water:

$$M_{H_2O} = Q_{H_2O} \times C_{H_2O} \times \frac{3.785\ \text{L}}{\text{gallon}} \times \frac{1440\ \text{min.}}{\text{day}} \times \frac{2.2\ \text{lbs.}}{10^9\ \text{ug}}$$

M_{H_2O} = mass loading, removal rate in water (lbs / day)
Q_{H_2O} = flow rate in water (gpm)
C_{H_2O} = contaminant concentration (ug / L, ppb)

For Air:

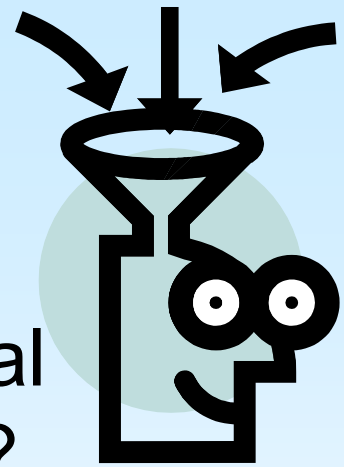
$$M_{air} = Q_{air} \times C_{air} \times \frac{0.0283\ \text{m}^3}{\text{ft}^3} \times \frac{1440\ \text{min.}}{\text{day}} \times \frac{2.2\ \text{lbs.}}{10^6\ \text{mg}}$$

M_{air} = mass loading, removal rate in air (lbs / day)
Q_{air} = flow rate in air (cfm)
C_{air} = contaminant concentration (mg / m^3)

For air calculations, C_{air} in mg/m^3 (with molecular weight, MW_X, in grams per mole) can be obtained at 70°F and pressure of 1 atmosphere from parts per million by volume (ppmv) by the following steps:

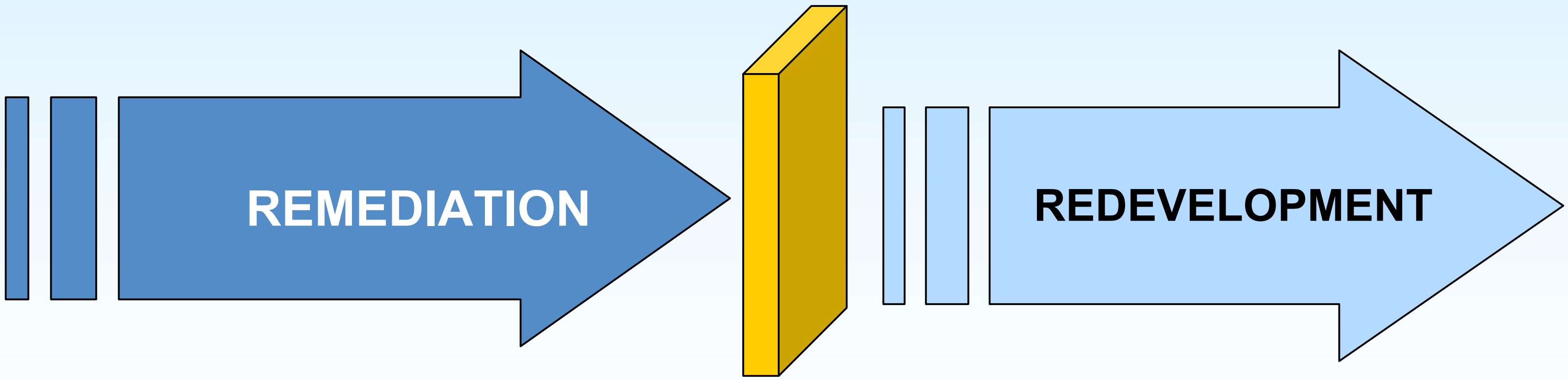
$$C_{air}(mg/m^3) = \frac{Conc(ppmv)}{10^6} \times \frac{1\ \text{mole air}}{24.1\ \text{L}} \times \frac{1000\ \text{L}}{\text{m}^3} \times \frac{1000\ \text{mg}}{\text{g}} \times MW_X$$

Elements of the Process – Does the Project Team:

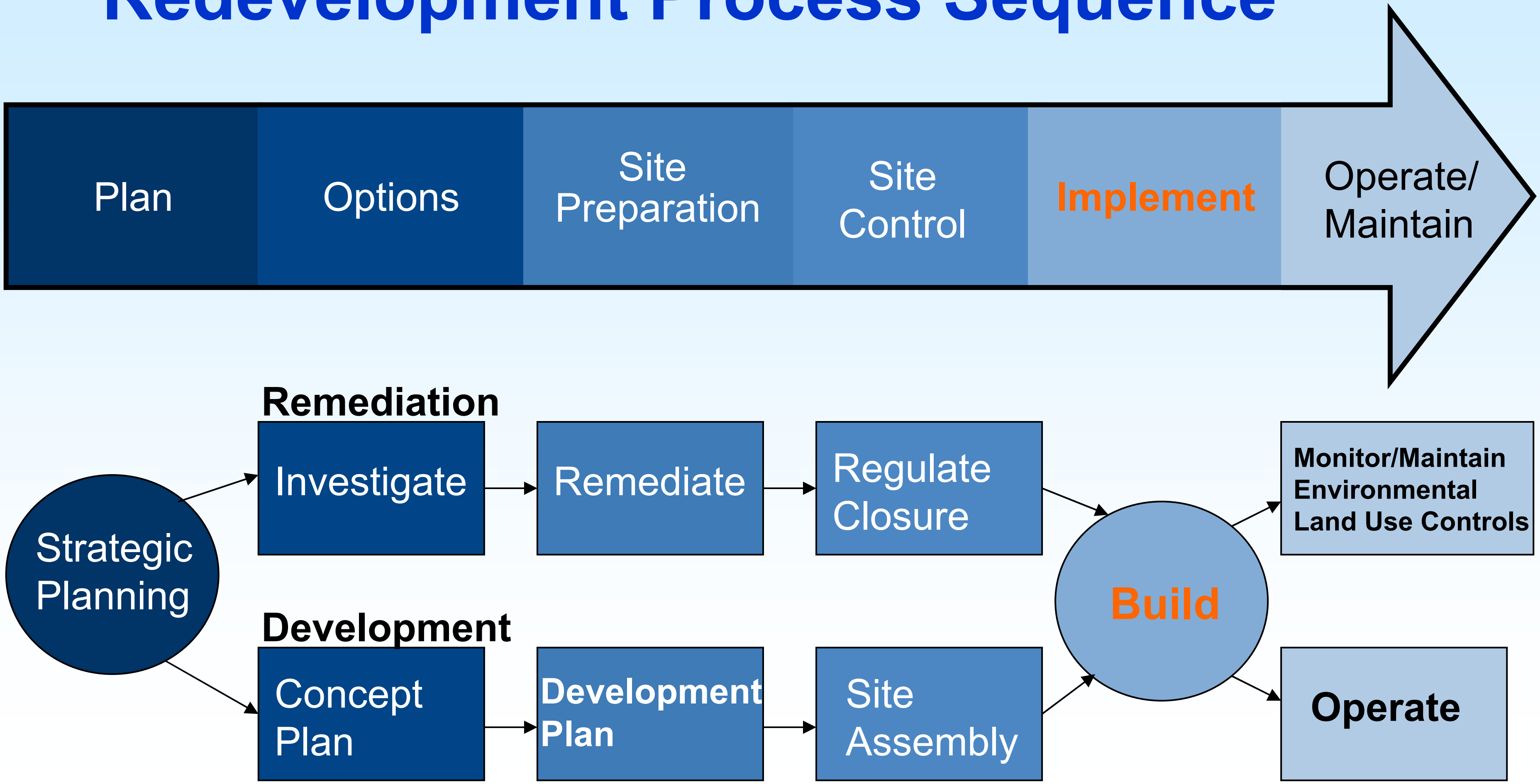


- Understand the Site its environmental characterization and projected uses?
- Understand regulatory parameters?
- Understand remedial technology limits?
- Understand financial constraints?
- Understand Project Management pitfalls and potential workarounds?

Historic Sequence for Property Remediation / Redevelopment



Integrated Property Remediation/ Redevelopment Process Sequence



Property Redevelopment Process Issues

- Intertwined processes of property remediation and redevelopment priorities
- Pathways are interdependent
- Developers need to understand both ends of process to achieve success
- Environmental goal:
  - Release of Liability (RoL)
  - ***Begin with the end in mind!***

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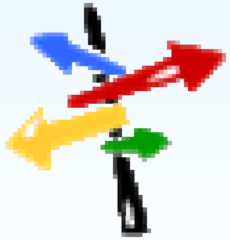
Brownfields Environmental Process Overview – (Understanding the Site)

- Site Characterization Process
- Obtain critical site characterization data
- Conduct conceptual site model process
- Identify & Understand regulatory cleanup criteria
- Evaluate remediation approach options

Brownfields Environmental Process Overview (contd.)

- Assess "*cheaper; better; faster*" trade-offs for selecting remedial methods
- Select remedial approach using both technical and financial criteria
- Deploy approach
- Monitor & assess approach – modify as necessary



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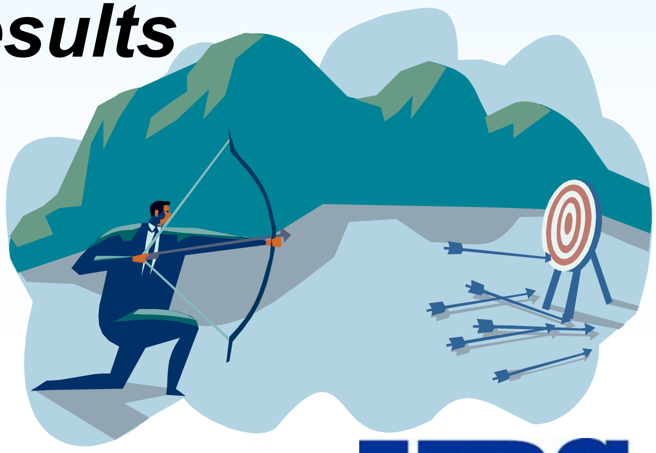
Site Characterization

- Probably most important remedial information gathered and need to understand
- Identifies CoC location and quantity
- ***Inaccurate site characterization is recipe for disappointing remedial results***



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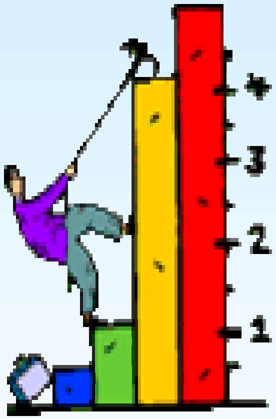
Site Characterization Elements

Goal:

- Provide representative data set to characterize nature & extent of impact
- Address risk assessment for future land use
  - Confirm accuracy of historical data
  - Design sampling plan –
    - Establish links between impacting material & release mechanism
  - Evaluate multiple pathways and potential receptors
  - Collect chemical & field data; perform required quality control checks
  - Verify & document all data collected



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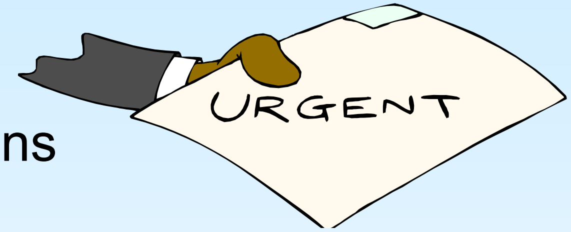
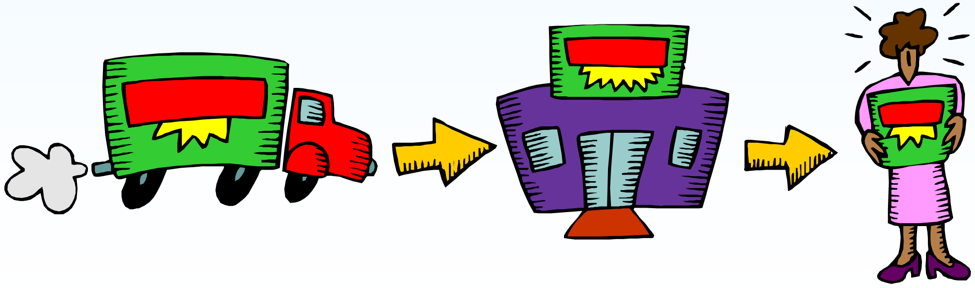
Critical Site Characterization Data



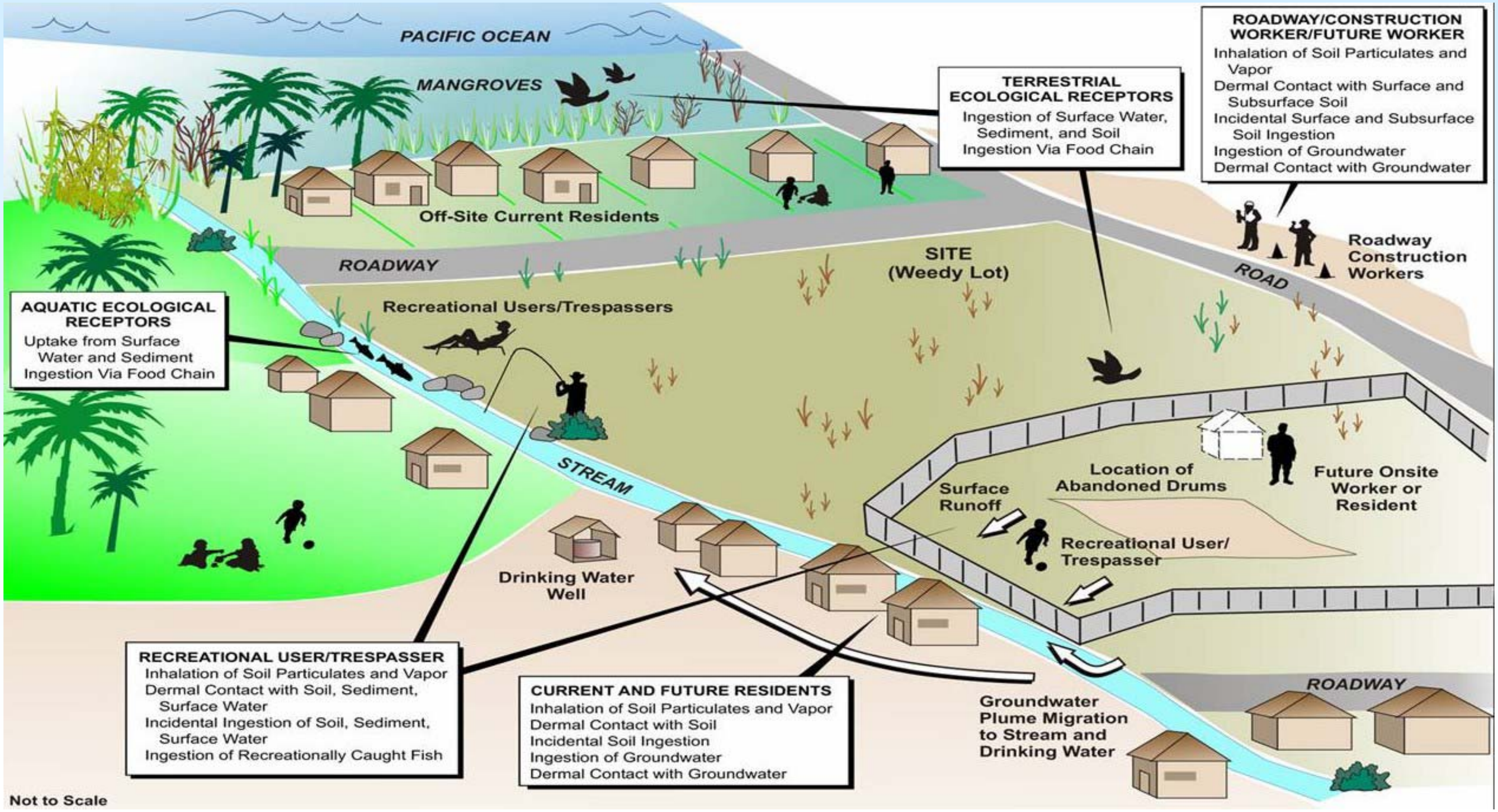
- Understand site issues:
  - Sources of impact; historical site operations
- Knowledge of environmental setting:
  - Soils, geology, hydrogeology, surface water bodies and overland drainage routes
- Identify all potential Contaminants of Concern (CoC)
- Site transport mechanisms/scenario
- Knowledge of targets/receptors and pathways
- Correlation to land usage:
  - Commercial, industrial, rural, recreational, residential

Conceptual Site Model Process

- Planning tool that considers:
  - Sources of environmental contamination
  - Fate and transport mechanisms within media such as soil and ground or surface water
  - Potential risk pathways
  - Sensitive receptors
  - Perceived site uses



Site Conceptual Model



Remedial Methods Selection – Truths (Understanding the Technologies)

- No two sites are alike
- Remedial methods must reflect both the CoC and site conditions
- Remedial methods selected should trend toward permanent solution
- *Cheaper, Better, Faster*… Pick Any Two!
- **THERE ARE NO "MAGIC" BULLETS**!

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Spectrum of Remediation Options

- Presumptive = Removal (dig & haul) or Control (pump & treat)
- Exsitu treatment (on site or offsite & return)
  - Soil washing
  - Biopiles
- Insitu treatment (on site methods)
  - Physical methods: Soil vapor extraction/ Dual phase
  - Chemical oxidation
  - Fixation or barriers
  - Biodegradation (bioremediation)

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Presumptive Remedial Methods

- Presumptive remedial method - a technology that, reflecting past experience:
  - "…*generally will be the most appropriate remedy for a specified type of site*"
- Methods regulatory agencies expect to see
- Can expedite remedial process
- The "*usual suspects*" methods selection
  - (Although alternative methods can offer better solution for a site)

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Removal – Dig & Haul

- Pros
  - Surest means of reducing impact
  - Can be achieved quickly
- Cons
  - Cost
  - Physical limits on depth
  - On-going liability due to disposal
  - Cannot remove all impact

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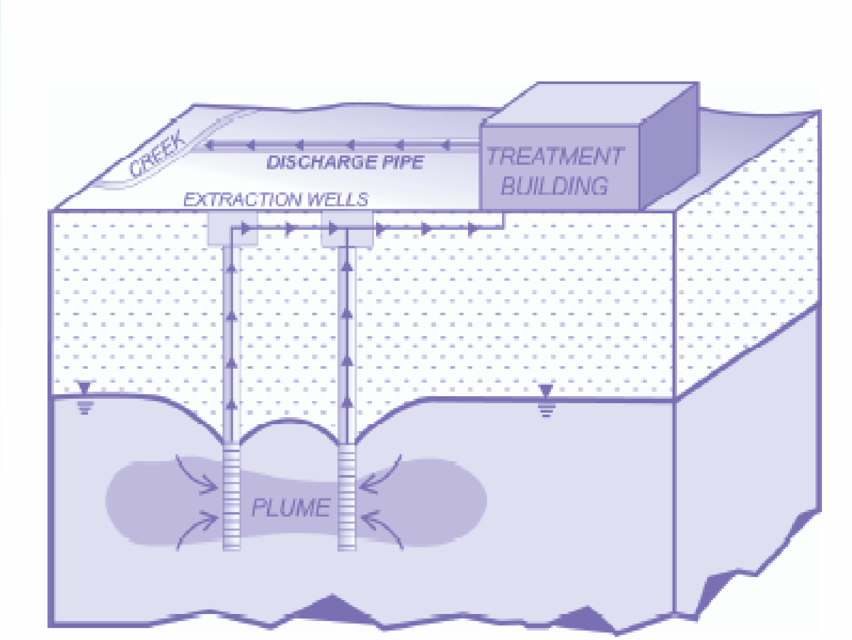
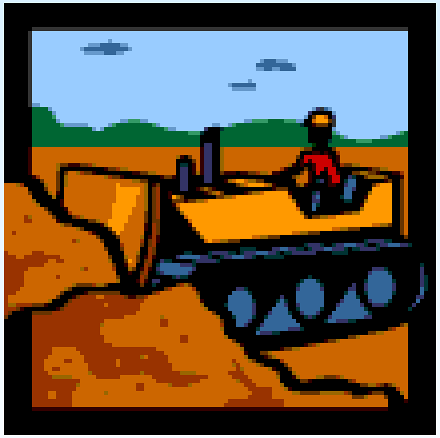
Control – Pump & Treat

- Removes CoC from groundwater only
- Limited by site hydraulics
- Can control plume expansion
- Short-term measure due to economics of O&M for system



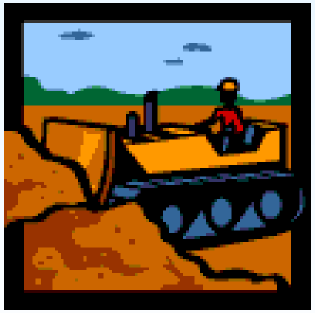
Exsitu Treatment Approach

- Pros
  - Can be as effective as removal
  - Can cost less to treat on-site
- Cons
  - Reduces site use for duration
  - May not be able to treat everything
  - Materials handling issues (batch process)



Exsitu Treatment - Methods

- Soil washing – use of solvent(s) to remove CoC from soil
  - Can remove metals as well as organics
- Biopiles – uses biological system to reduce organic CoC from soil
  - Very useful for large soil quantities
- Fixation and incineration
- Methods respond faster than insitu methods
- Require extensive materials handling

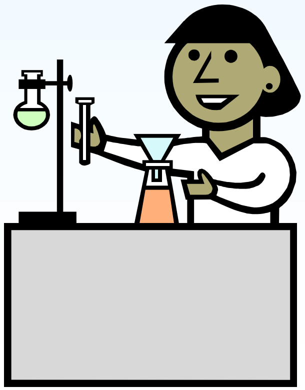


Insitu Treatment Approach

- **Pros**
  - Little or no soil handling
  - Can work around existing structures
- **Cons**
  - Treatment methods are relatively new – may require study
  - Success tied to site characteristics **AND** site characterization
  - Time to completion

Lab Feasibility Studies

- Purpose: estimate optimal results under ideal conditions
- Can identify unexpected counter indications/ analytical issues
- Verifies site characterization
- Helps scope materials needed



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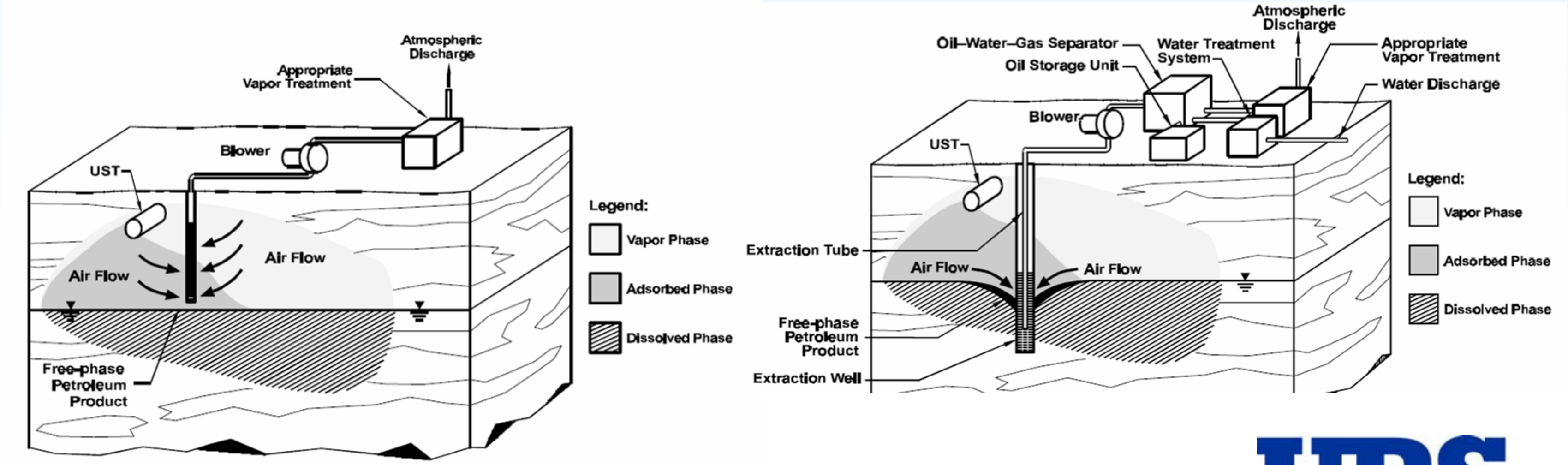
Types of Insitu Treatment Methods

- Vapor extraction/ Dual phase extraction
- Oxidation methods
- Insitu flushing
- Thermal extraction
- Fixation
- Biological
- Barriers

Insitu Treatment – Vapor Extraction

- Physical means to removal volatile chemicals by vaporization
- Both SVE & DPE can be presumptive methods
- Well-suited as an initial treatment approach

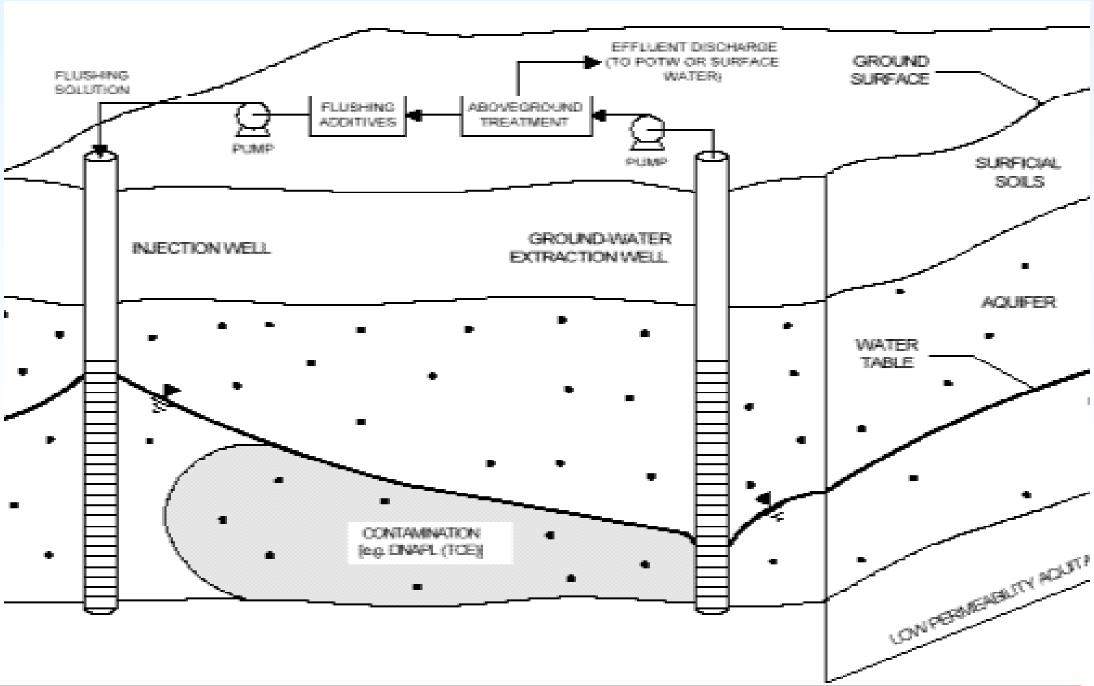


Insitu Treatment - Oxidation

- Compounds capable of chemically reacting with & oxidizing other materials
  - Peroxide/ Fenton’s Reagent
  - Ozone
  - Permagnate; Persulfate; Percarbonate
  - Single metal peroxygen compounds
- Selection dependent upon site conditions
- Good method to reduce impact quickly

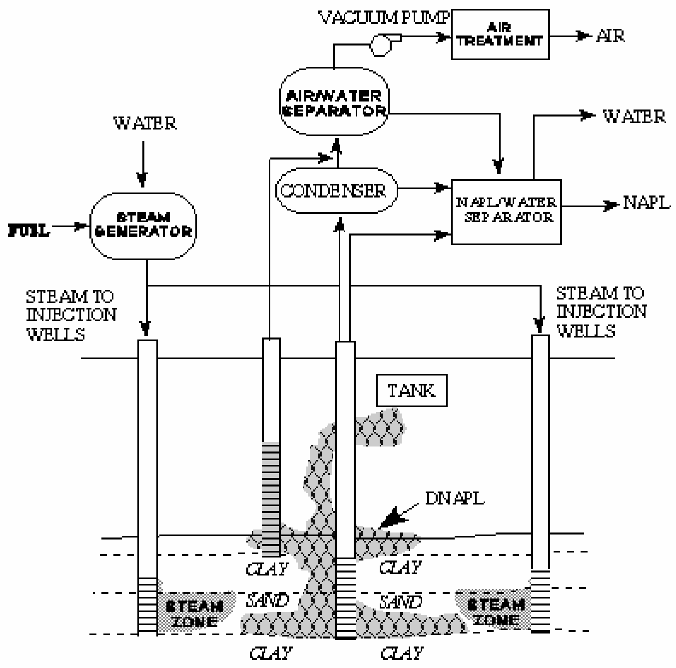
Insitu Treatment – Solvent Flushing

- Solvent used to reduce CoC concentrations
- Used in conjunction with extraction methods



Insitu Treatment – Thermal Extraction

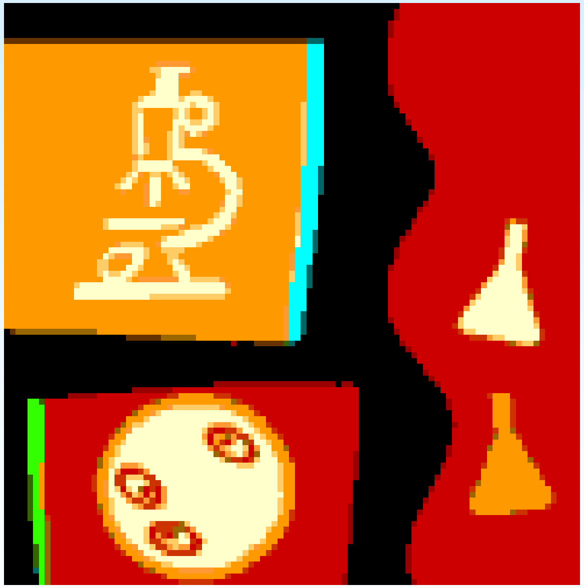
- Uses heat to enhance CoC extraction rates
- Rapid removal can occur, but more expensive



In Situ Thermal Extraction Process

Insitu Treatment – Biological Approach

- Can treat a wide range of organic chemical CoC
- Uses either/or both aerobic and anaerobic conditions effectively pending CoC
- Agent treatment generally less expensive than other methods
- Takes longer to achieve results
- Best results achieved in *treatment train* with other remedial method(s)



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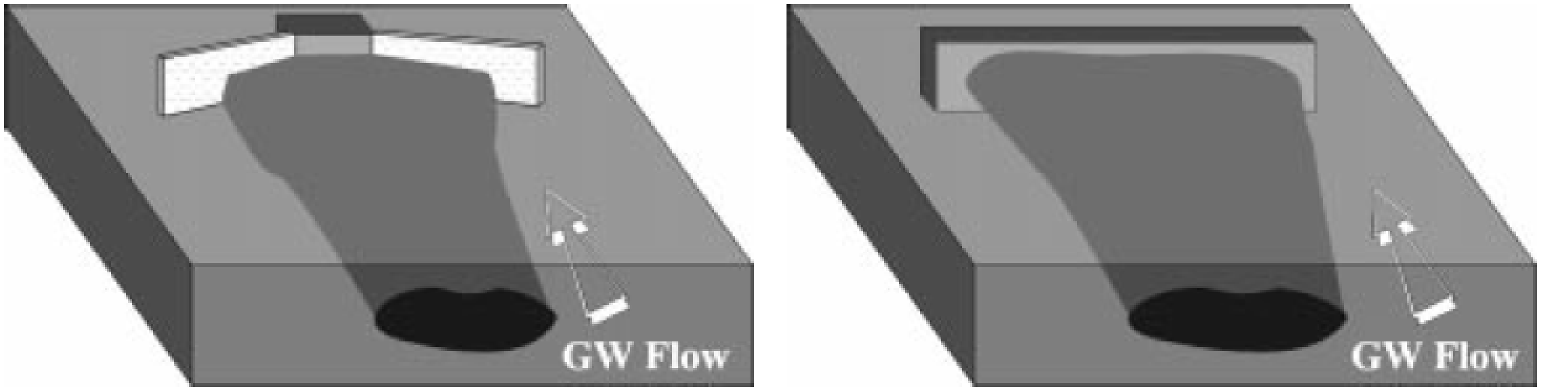
Insitu Treatment Walls and Permeable Reactive Barriers

- Treat and/or control groundwater flow
- Passive, long-term treatment method
- Higher capital costs due to structure, media, soil handling and O&M

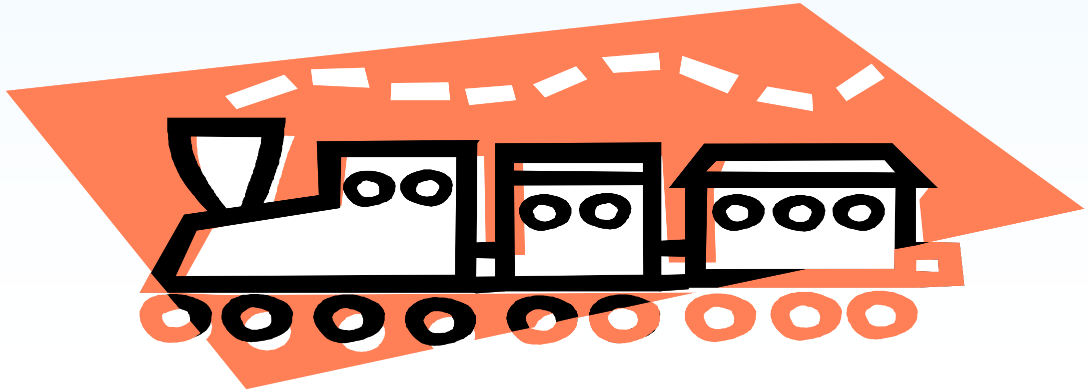


Insitu Treatment Agent Methods – Applicable Target Usage

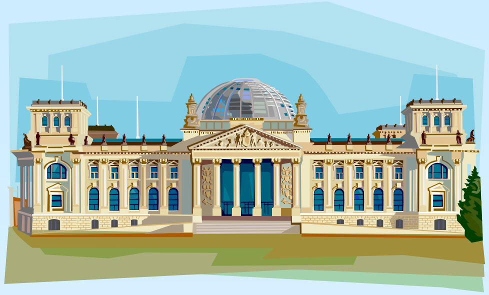
	Aerobic Bio	Anaerobic Bio	Fenton's Reagent	Perman-ganate	Persulfate	Ozone	Abiotic
Gasoline Compounds							
Benzene	X		X		X	X	
TEX	X		X	X	X	X	
MTBE	X		X	X	X	X	
Chlorinated Compounds							
• PCE • TCE, DCE, VC	X	X	X	X	X	X	X
TCA, DCA		X				X	X
CCl_4, Chloroform, Methylene Chloride		X			X		X
Other Organics							
PAHs	X		X	X		X	
PCBs		X				X	

Treatment Train – Mix & Match

- Use of multiple technology methods to achieve remedial standards at site
- Methods are used sequentially or in parallel
- Site needs dictate methods selection



Institutional Remedies



- Regulations allow several non-remedial methods to achieve RoL; e.g.,
  - Risk assessment/ Risk-based corrective action
  - Monitored natural attenuation (MNA)
  - Capping/ sealing impacted area & monitor
- Pros – lower short-term cost than active remediation approach
- Cons – not permanent solution; if RoL not achieved, requires long-term periodic monitoring & poses on-going potential liability

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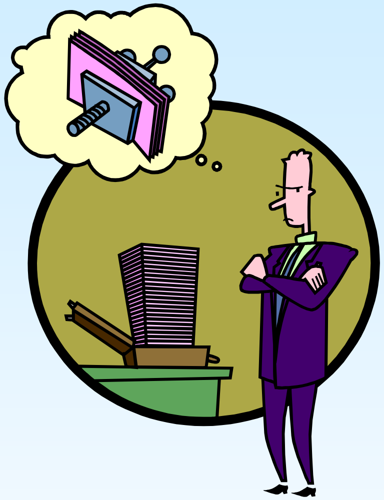
Role of Time Value of Money in Decision (Understanding the Financials)

- **$FV = PV(1 + i)^n$** where:
  - FV = Future Value of money
  - PV = Present Value of money
  - i = the interest rate per period
  - n = the number of compounding periods
- Money/ project funding is ultimate driver
- Financial professional's project role can dictate necessary technical remediation approach
- Timeline (how much time) to project completion can/ will dictate remedial approach

Decision-maker Questions to Ask (Understanding the Project Management)

- Ultimate site usage?
- Site history/ previous use? (AAI?)
- Well characterized?
- Defined impact vectors?
- Relative cleanup costs per treatment methods available?
- Time limits to meet site development goals?
- Impact of Time Value of Money on project timeline?

Remedial Methods Selection – Element & Conclusions



- Project objectives (RoL)
- Site conceptual model
- Project timeline
- Time value of money driver
- Considerations for selection:
  - Faster & presumptive remedial methods not always best alternative for a given project
  - ***Select remedial methods that "fit" the site***
  - Treatment trains offer flexible approaches

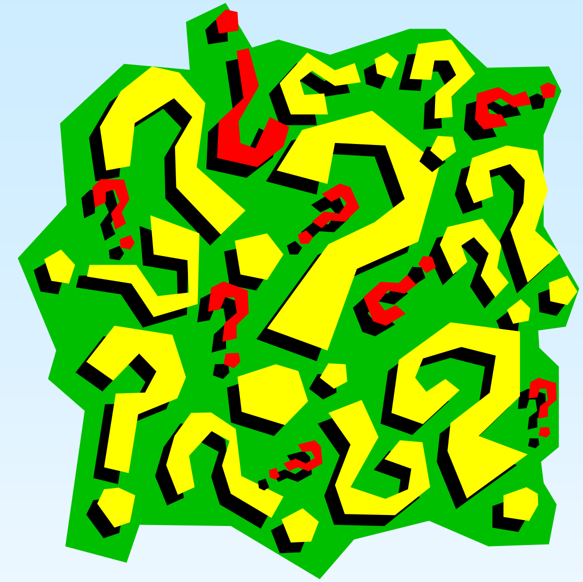
Technology Selection Approach

- "***Cheaper, Better, Faster***" approach can work!
- ***Cheaper*** (time dependent results)
  - Insitu methods (general); Biological methods are usually the least costly
- ***Better*** (thorough results)
  - Dig & haul; Exsitu; Multiple methods remove or treat soil impacts on-site
- ***Faster*** (thorough, quick, but higher cost)
  - Dig & haul; Exsitu; Oxidation; substitute project cost for time.

Remediation Technology Resources

- EPA Technology Innovation (http://cluin.org/)
- EPA Reachit (http://www.epareachit.org/)
- ITRC (http://www.itrcweb.org/homepage.asp)
- GWRTAC (http://www.gwrtac.org/)
- Federal Remediation Technologies Reference Guide (http://www.frtr.gov/matrix2/)
- SMARTe Brownfields Tool (http//:www.SMARTe.org)

Questions?



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BACKGROUND

Former industrial sites that have been impacted by previous industrial uses pose a variety of challenges for the site owner. Environmental constraints on the use of a property can and do impact the property's commercial and economic value. This situation poses the question, how should an owner identify the optimal mix of technical and institutional remedies that are available to meet the requirements of regulatory agencies and lending institutions that will maximize the value for successful re-use of the target property?

URS-Pittsburgh's Brownfields and remediation programs have had an excellent record in identifying a successful mix of institutional and technical site-specific remedies. This has been achieved by understanding the site and its present/ future potential uses, and then identifying a specific set of steps to meet a selected endpoint. This approach for the selection of methods goes beyond the simple "pump-and-treat" and "dig-and-haul" solutions commonly used to meet basic regulatory requirements. Although both philosophies of site response have value, their inherent costs and on-going liability offer an expensive solution to the property owner. Even then, these methods may not satisfy regulatory or liability concerns.

An ever-growing number of insitu treatment technologies offer the promise of a cost effective set of alternative methods to permanently treat impacted subsurface media; however, no single treatment method can provide the optimal approach to every situation. The selection of the optimal remedial approach in conjunction with potential application of institutional controls can achieve a cost effective endpoint. The question remains, how do we know which approach to select and when should various methods be used?

This presentation is intended for the non-technical site decision-maker. The focus is upon the technical pros and cons to Brownfields site remediation and technology selection as it applies to the most common types of soil and groundwater impacts. Although we will broadly introduce the most commonly deployed remedial methods (in general non-technical terms), we will also discuss how to select an appropriate method(s) and what can reasonably be expected from their implementation. The focus of this presentation is to provide a non-technical level of guidance through the maze of technology claims that can result in the identification of potential alternative strategies that can be implemented in meeting achievable and reasonable site development goals. In keeping with the theme of this session, our purpose is to pose the questions that need to be asked to achieve success with a given project effort.

Brownfields Process – The Basic Questions

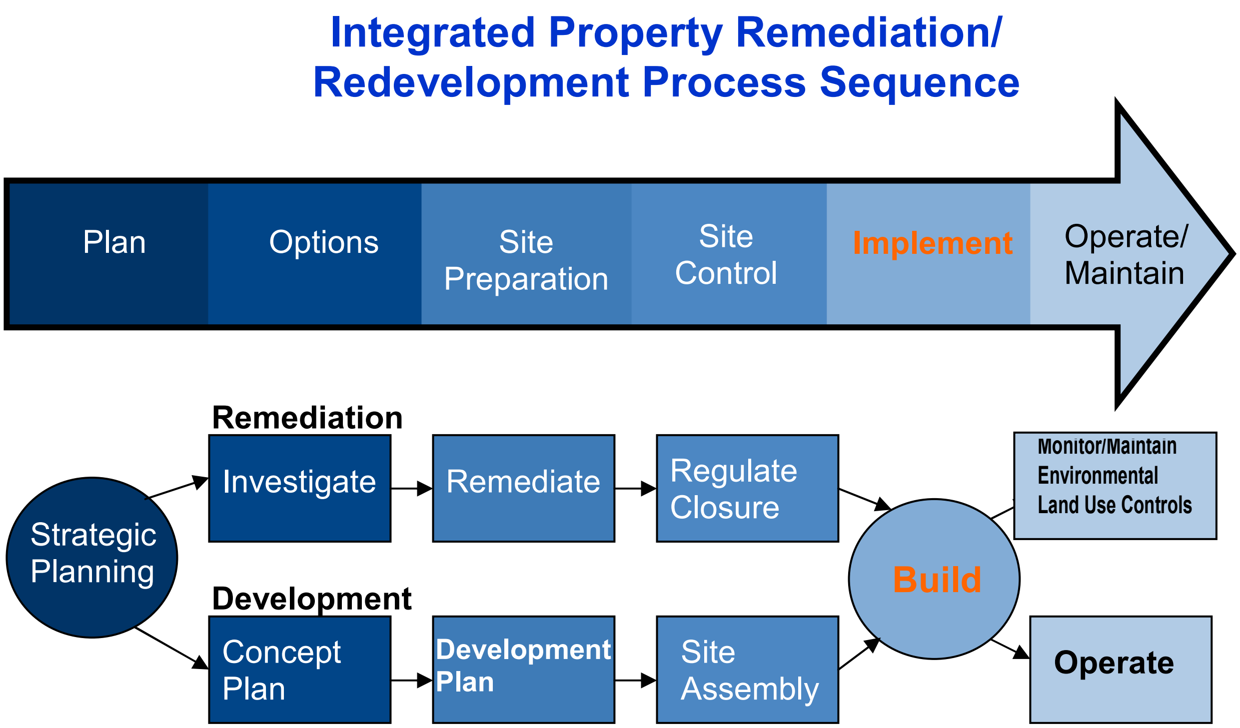
Technology selection for an impacted Brownfields site should actually begin with the end in mind. Among the basic Brownfields questions that need to be answered include:

- How was the site used historically?
- How is the site planned to be used eventually?
- What type of contact (exposure to the impacted soil, groundwater or vapors) could impact people possibly living and working in the area?
- How soon will the site be developed?
- What information exists about the current impacts to soil and groundwater?
- What are the regulatory targets for remediation?
- Will the remedial effort expose workers or the public to impacted soil, groundwater or vapors?
- Are there any funding constraints that may impact remedy selection from a timing or use perspective?

Once these questions are answered (at least philosophically), a site remediation approach can be developed for the site as a whole. The "Site Conceptual Model" will greatly assist in the remedial method selection since it answers the questions of impact to both human health and the environment. This planning process should be an integral part of technology selection.

Brownfields Process – The Big Picture

URS believes that the linear paradigm of Brownfields remediation and redevelopment (i.e., site remediation leading to property redevelopment) is not the best approach for achieving success for a given Brownfields project. Instead, URS subscribes to the concept that project success is actually a parallel process with remedial efforts and site project efforts tracking a parallel course. The following diagram illustrates this concept.



In effect, the property redevelopment/Brownfields process consists of a parallel set of activities. There is an intertwined set of critical pathways that, even though they are separate, both paths need to be considered together to achieve ultimate success.

A necessary first step is understanding the site. This requires the following site characterization elements:

- Obtain Critical Site Characterization Data – (both historic data and current information);
- Conduct Conceptual Site Model Process – (scoping a vision for the site);

- Identify & Understand Regulatory Cleanup Criteria – (different States may have different requirements in meeting their vision of protective standards);

- Evaluate Remediation Approach Options – (there is more than one way to achieve remediation success using one or more method(s);

- Assess "*cheaper; better; faster*" trade-offs for remedial methods – (you can pick any two of the three trade-offs);

- Select remedial approach using both technical and financial criteria – (the options really do limit the ability to select the "best" method, but time is usually the critical issue);

- Deploy the approach – (once in the field, the decision-making will reflect the planning); and,
- Monitor & assess approach – modify as necessary – (results in the field will dictate how well any of these methods actually work; work around plans become apparent).

- Finally, (with apologies to Franklin Covey) a development project needs to begin with the end in mind!

Site Characterization –

Of any element in the remediation process determining what needs to be treated, where it needs to be treated, and finally in what quantity are among the most important criteria. Inaccurate site characterization information is a recipe for disappointment in the remedial results and inevitably leads to a higher cost project. Accurate chemical site characterization will facilitate the remedial technology selection process.

The goal of the site characterization is to provide a representative data set that definitively indicates where and to what extent the impacts to soil and groundwater exist. This information can be the basis for the inevitable risk assessment that will dictate the land use and potential site liability. It consists of the confirmation and accuracy of historical data collected to date and should reflect a sampling design plan that can establish links between impacting material & release mechanism as well as evaluating multiple pathways and potential receptors. The sampling plan will collect both chemical and field data, perform required quality control checks, and verify all data collected.

Site characterization data is used to understand the basic site issues. This information will identify the historic site operations and where they may have had impact on soil and groundwater. Since not all parts of a site always need to be treated to the same degree, this will facilitate a quicker remedial process. Among the most critical of the site characterization are the following:

- Knowledge of environmental setting including Soils, geology, hydrogeology, surface water bodies and overland drainage routes;
- Identification of all potential Contaminants of Concern (CoC);
- Site CoC transport mechanisms, in effect, what and who may be impacted;
- Knowledge of targets/receptors and pathways;
- Correlation to land usage; i.e., will the land be used for commercial, industrial, rural, recreational or, residential use.

Using these data, we can develop a Site Conceptual Model (SCM). The SCM is a planning tool that will be helpful in determining the site's risks and provides a set of priorities for what needs to be addressed, in which order, and to what level of risk is acceptable to the parcel's use.

Remedial Methods Selection –

To properly use a remedial technology, we need to understand the strengths and weaknesses of each method. First, we must understand some basic truths about remedial technologies. In general, no two sites are alike and must be considered separately. Even if two sites seem the same geologically, there are probably differences in the historic use of the sites. Selection of remedial methods must reflect both the CoC and site conditions. Next, when selecting a remedial method the selection process should trend toward a permanent solution. Moving soil to another location does limit future liability from a future remedial action. Finally, there are no "magic bullets" as far as remedial technologies behave. As noted previously, we can select from the "*Cheaper, Better, Faster*… pick any two" approach.

Remedial Methods Spectrum –

In the broadest sense, there are only a few general categories that cover most remedial technologies. These categories include presumptive methods (either removal by dig & haul methods or control methods such as pump & treat that limit the expansion of a plume); exsitu methods where impacted soil or groundwater is treated above ground, but usually on-site; and insitu methods that treats impacted media where it currently lies.

Presumptive remedial methods are those that have a great deal of basis in cleaning by removal. By definition they reflect methods which past experience has shown is "…*generally the most appropriate remedy for a specified type of site*". These methods (i.e., dig & haul and pump & treat) are those which regulatory agencies expect to see. Selection of these "*usual suspects*" methods can expedite remedial process due to their familiarity within the regulatory process. They can also be the surest means of reducing the impact and can be implemented quickly; however, their cost, physical limitations and on-going liability have spawned efforts to identify "alternative methods" that can offer a better solution for a site.

Exsitu remediation methods are a step above the presumptive methods. They allow for the rapid on-site and off-site treatment of soils that can either be returned to the site or changed out for other soils. They are generally more permanent solutions than presumptive methods, but require extensive materials handling and possible disposal of the concentrated impacting material (e.g., metals). The major methods of exsitu treatment include soil washing, fixation, incineration and biopiles. Soil washing and fixation methods can deal with impacts to soil from metals. Incineration and biopiles (a biochemical form of incineration) are most appropriate with high concentrations of organic material in the impacted soil.

Insitu methods represent the latest thinking in remedial technology deployment. Soil and groundwater impacting materials are treated in place and are usually reduced to levels that will allow an institutional release of liability. The success of insitu methods is highly susceptible to soil and groundwater conditions. Poor soil and/or aquifer transmissivity will require additional treatment to provide sufficient coverage. Insitu methods are very flexible and can used in many locations with existing structures that can be a part of a redevelopment plan. Prior to deploying an insitu method it is generally advisable to conduct a lab feasibility study to optimize how the agent(s)/method(s) are used. Expenditures for a lab feasibility study will usually pay dividends in identifying/ avoiding problems in the field and more closely estimating the amount of agent that may be needed to achieve an endpoint.

The major types of insitu treatment methods include the following:

- Vapor extraction/ Dual phase extraction
- Oxidation methods
- Insitu flushing
- Thermal extraction
- Biological
- Barriers.

Vapor extraction/ dual phase extraction provides a physical means to remove volatile chemicals via vaporization from a liquid to gas, then treatment of the gas (usually with granular activated carbon) to remove the impacting chemical. Soil Vapor extraction (SVE) and Dual-phase Extraction (DPE) can both treat the soil (vadose zone). DPE also treats the groundwater (saturated zone). Both technologies are generally used with petroleum releases and some chlorinated solvent releases. Both methods are well suited as an initial treatment method that can prepare an area for further treatment by reducing the initial impact of a release. Although some sites can be brought to compliance using these methods, usually physical subsurface limitations prevent these type of treatments from being a total remedial answer for a site.

Insitu oxidation uses the introduction of chemical agents that chemically react with an impacting product and reduce it to levels that can pass regulatory requirements. They can also be used in conjunction with biological methods to achieve long-term endpoints. Chemicals that are capable of chemically reacting with & oxidizing other materials include: Peroxide/ Fenton's Reagent; Ozone; Permagnate; Persulfate; Percarbonate; Single metal peroxygen compounds. The selection of insitu oxidation is highly dependent upon site conditions. That said, this approach is a good method to reduce impact quickly and prepare the site for treatment using other approaches such as insitu bioremediation.

Solvent flushing is an insitu method of soil washing. This approach takes advantage of the chemical characteristics of solvent solutions of various types to remove an impacting material. The selection of insitu solvent flushing is also highly dependent upon site conditions since the dissolved impacting material must be pumped out of the subsurface and hence is dependent on soil or aquifer transmissivity to remove them from the area. This is another method that can reduce higher levels of impact in preparation for biological methods of remediation.

Thermal desorption can be used as either an insitu or an exsitu process to remove impacting CoC from soil and other materials (like sludge and sediment) by using heat to change the chemicals into gases. The off-gasses are collected for treatment and disposal. Once a system is laid out in a site, it can facilitate the rapid removal of any impacting volatile chemical. This method's limitations are the costs of deployment and use (a high energy requirement).

Insitu bioremediation is a growing auxiliary remedial method. Bioremediation can treat a wide range of organic chemical CoC. Properly designed, bioremediation can use either/or both aerobic and anaerobic conditions effectively pending CoC to reduce the impact on the site's soil and groundwater. The cost for bioremediation agent treatment is generally less expensive than other alternative treatment methods; however, this approach generally takes longer to achieve results that meet release of liability regulated levels. The best results for insitu bioremediation are generally achieved in a *treatment train*; i.e., in conjunction with other insitu remedial method(s).

Treatment Walls and Permeable Reactive Barriers are passive, insitu treatment for chemical CoC impacting groundwater. In this approach groundwater is treated and/or channeled through a chemically reactive, permeable wall that is dug through an area where groundwater moves off-site. The CoC is transformed via oxidation, reduction or precipitation reactions to an immobilized or non-toxic form. This treatment approach affords a low-cost, low-maintenance, effective alternative for the treatment of contaminated groundwater as it leaves a site. This may not be an ideal treatment for most on-site remedial requirements. Once again, the application of this type of subsurface remediation approach places a premium on an adequate site characterization. It also requires a thorough understanding of the subsurface system targeted for remediation as well as the geochemical mechanisms controlling contaminant transformations. The capital costs and soil handling requirements for treatment barriers place the remedial cost investment upfront in the project. Once in place, operation and maintenance costs are low.

Remedial treatment trains are in effect the sequential use of more than one remediation technology deployed to treat the same volume of contaminated soil or groundwater. Treatment trains can manage both the uncertainty in relying upon a single remedial performance while reducing the overall costs for complex subsurface environmental treatment systems. The theory behind this multiple method approach is to leverage the individual characteristics of each treatment technology. By leveraging the use of more than one method through the use of a series of sequential treatment steps, the overall treatment process can occur more rapidly than with one method alone. Use of a treatment train system requires a dynamic remedial action plan along with associated monitoring to aid in decision-making. A proactive remedial action plan should provide the information necessary to support decisions about when to adjust existing treatment methods to improve performance, and/or when to switch from the initial treatment phase (e.g., SVE/DPE) to the secondary treatment phase (e.g., insitu oxidation), potentially to tertiary phase (e.g., insitu bioremediation and/or monitored natural attenuation). Treatment trains also afford the flexibility with site development plans so that more disruptive measures can occur prior to long-term site plan uses.

Institutional Remedies –

In addition to the proactive technical remedial approaches is the use of institutional methods to obtain a Release of Liability. Basically, this approach consists of using the data that are gathered in the site characterization to demonstrate that there are no pathways from the impacted area that may have a negative effect upon human health and the environment. This is an especially useful approach for sites with limited impact such as retail gasoline stations.

In effect, the institutional remedy allows for a scientific review of site conditions to provide an assurance that the likelihood of future releases or impacts to human health or the environment are minimal. The process is generally covered as "Risk-based Corrective Action" (RBCA). For example, petroleum releases from retail sites can vary considerably in their potential risk based on a number of variables. These variables can include issues related to the type of petroleum product, amount of released product, duration of the release, extent of the release, site geology/hydrogeology, number and type of exposure pathways, and location of human receptors relative to the source. Potential remedial actions may include approaches from long-term active cleanup to no action. Most regulatory agencies have a tiered approach to their petroleum release corrective action process to cost effectively manage impacted sites and focus the finite resources on the more critical sites.

Another example of an institutional remedy will also require a risk assessment and will use a demonstration of monitored natural attenuation (MNA) as an approach. MNA relies on natural processes to clean up or *attenuate* pollution in soil and groundwater. Natural attenuation will occur at most impacted sites via physical, chemical or biological means. To achieve desired endpoints for a site, the proper conditions must exist in the subsurface to allow a site to achieve an endpoint. Should these conditions not exist, an insitu treatment method can be used followed a period of monitoring until such time as target regulatory levels are achieved for the site. Another means of using MNA is by sealing a site with a cap and preventing further groundwater movement through the site; however, since the CoC is not removed, it will remain as a potential liability.

Time Value of Money –

In the broadest sense, the ultimate project driver is the funding for its implementation. Those institutions that provide the funding for a Brownfields project want to reduce their exposure to project failure. Among the criteria used to make this assessment is a calculus of when and if environmental issues can be resolved and how long it will take to meet regulatory requirements and obtain the environmental release of liability. The environmental contingent of a Brownfields project team needs to be aware of the role of the Time Value of Money as the force that will help make decisions.

How much a project will cost reflects the cost of funding. The formula for determining this is:

FV= PV (1 + i)n where:

- **FV** = Future Value of money
- **PV** = Present Value of money
- **i** = the interest rate per period
- **n** = the number of compounding periods.

How much time the remedial effort will take may or may not impact the project funding determination; however, it is a major concern. Selecting remedial methods that are “faster” but more costly may be viewed more favorably than remedial methods that are “cheaper” but will take longer to obtain the release of liability. In effect, the timeline to obtain the release of liability can and will determine the remedial approach that is selected. Being able to understand the demands of the project funding will play a key role in selecting a technology.

Assuming that any properly designed remedial approach can eventually obtain a release of liability for a given Brownfields site, decision-makers need to answer the following types of questions to begin the remedial technology methods selection approach:

- Ultimate site usage?
- Site history/ previous use? (including the All-Appropriate Inquiry information gathering)
- Well characterized?
- Defined impact vectors?
- Relative cleanup costs per treatment methods available?
- Time limits to meet site development goals?
- Impact of Time Value of Money on project timeline?

The typical elements for considering the remedial methods selection process should reflect the following:

- *Project objectives* – ultimately it is to obtain the release of liability from the site's environmental challenges.
- *Site conceptual model* – how will site actually work, how will human health and the environment be impacted and/or protected by the remedial approach?
- *Project timeline* – how long can remedial activities be performed on the site?
- *Time value of money driver* – which project element is more valuable to the success of the effort, time or cost?

General considerations that should play a role in the ultimate decision-making:

- Faster & presumptive remedial methods not always best alternative for a given project
- ***Select remedial methods that "fit" the site circumstances***
- Treatment trains can offer flexible approaches.

Given all of this information, how can the non-technical decision-maker understand and choose the type(s) of remedial technologies that may fit a given site? To answer the technology selection question, let's re-examine the "cheaper, better, faster" paradigm.

Technology Selection Approach –

As noted, the non-technical decision-maker needs some system to aid in the technology selection process. The technology consultant understands the technical challenges but may not be privy to the funding aspects of the project. The "cheaper, better, faster" paradigm provides a broad brush approach that can be very useful to this effort in balancing competing project elements.

A simplistic decision-tree would consist of the following:

- ***Cheaper*** (time dependent results)
  - Insitu methods (general); Biological methods are usually the least costly
- ***Better*** (thorough results)
  - Dig & haul; Exsitu; Multiple methods can remove or treat soil impacts on-site
- ***Faster*** (thorough, quick, but higher cost)
  - Dig & haul; Exsitu; Oxidation; we substitute project cost for time.

The non-technical decision-maker also needs to become familiar with the most common remedial methods. There are a number of government-run web sites that house this information including the following:

- EPA Technology Innovation (http://cluin.org/)
- EPA Reachit (http://www.epareachit.org/)
- ITRC (http://www.itrcweb.org/homepage.asp)
- GWRTAC (http://www.gwrtac.org/)
- Federal Remediation Technologies Reference Guide (http://www.frtr.gov/matrix2/)
- SMARTe Brownfields Tool (http//:www.SMARTe.org).

In conclusion, the non-technical decision-maker with a Brownfields project has a lot to consider. Asking the questions listed in this presentation and using the "cheaper, better, faster" decision-tree will afford a modest level of what it may take to select the most effective approach to this type of property redevelopment challenge.