Sustainable Remediation Forum (SURF)
SURF 20: July 24 through 26, 2012
Fort Collins, Colorado

SURF 20 was held at Colorado State University (CSU) in Fort Collins, Colorado from July 24 through 26, 2012. SURF members that participated in the three-day meeting are listed in Attachment 1. Participant contact information is available to members on the SURF website. After logging into the website, select “member resources,” “presentations,” and “SURF 20 presentations.”

The meeting marked the 20th time that various stakeholders in remediation—industry, government agencies, environmental groups, consultants, and academia—came together to develop the ability to use sustainability concepts throughout the remediation life cycle. Previous meeting minutes are available at http://www.sustainableremediation.org/library/meeting-minutes/.

Day 1

Day 1 of the meeting focused on the work of students from SURF student chapters at various universities.

The meeting began with Mike Rominger (meeting facilitator) welcoming participants. He discussed meeting logistics, ground rules, nonconfidentiality assumptions, export control laws, and antitrust issues. In addition, he thanked current SURF sponsors for supporting the organization. Members interested in sponsorship opportunities should contact Brandt Butler, SURF Treasurer (treasurer@sustainableremediation.org).

Tom Sale (CSU) welcomed everyone to the school and the area. He provided a brief overview of the Center for Contaminant Hydrology at CSU. The mission of the center is two-fold: (1) to develop and bring to the market cost-effective cleanup methods and (2) to educate future leaders in the field of environmental engineering. The evolution of the center has relied on a youthful group of empowered people, similar to the members of SURF’s student chapters. He encouraged students participating in the meeting to feel empowered and move SURF forward.

Karin Holland (SURF President) welcomed everyone to the meeting, especially students attending the meeting as part of the student day. Part of SURF’s mission statement is to advance the science of the practice of sustainable remediation, and Karin believes that students are the future leaders of sustainable remediation. She thanked Tom Sale (CSU) and the SURF student chapter members at CSU, as well as the Academic Outreach Initiative co-leaders for their help in making the student day a reality.

Day 1 presentations and subsequent discussions are summarized in the subsections below. Attachments 2 through 9 contain the presentation slides for Day 1 of the meeting.

Sustainable Remediation 101

Dave Ellis (DuPont) spent the afternoon before the meeting discussing with SURF student chapter members potential topics of interest for this presentation. Students expressed an interest in hearing more background about why remediation is performed. Consequently, Dave provided participants with an overview of the genesis of environmental regulations in the United States and reviewed the five phases of remediation: site assessment, remedy selection, remedy design, implementation, and closure. He described the implementation phase of remediation, explaining that this phase can be relatively short and effective or long and without reducing concentrations. This range in remedy effectiveness prompted discussions about how remediation could create a net benefit to the environment as a whole and led to an initial meeting of a group that would eventually become SURF. Dave provided an example to demonstrate the benefit of minimizing the impact of remedies. At one DuPont site, a remedy involving the excavation and disposal of over 10 million tons of soil was being promoted by regulators. An in situ treatment remedy was preferred by DuPont because of worker safety and greenhouse gas emission concerns. The in situ treatment remedy is currently being reviewed by the regulatory agency.

Dave reviewed the triple bottom line of sustainable remediation (i.e., environment, society, and economy) and noted that considering these elements often changes the remedy selected. Although sustainable remediation addresses these three elements in some form, the application of these elements is not uniform. For instance, SURF Brazil weighs the societal element more heavily than environmental and economic elements when implementing sustainable remediation. Dave emphasized the different thought process involved in sustainable remediation, specifically one that involves discussion and questioning. He believes this process results in improved thinking. He provided a quantitative example on how this improved thinking can affect the bottom line. DuPont performs $100 million in remediation each year and saves 2% to 5% of its budget by performing rigorous sustainability assessments.

Discussions focused on the following topics:

- Emission Calculations vs. Life-Cycle Assessments (LCAs)
  Dave acknowledged that many professionals calculate carbon dioxide (CO_2) emissions for different remedies and make remedy selection decisions based on these calculations. He said that LCA is commonly used and accepted in Europe where sea level rise is a concern and a more visible issues than in the U.S. He believes that the practice of LCA will become a skill-set differentiator in the remediation field. Dave said that experience with LCA is a basis for hiring remediation consulting firms at DuPont.

- Student Involvement at Battelle
  Mike Miller (Co-Chair, Academic Outreach) provided details to participants about the SURF student paper competition that will be held at Battelle in 2013. He encouraged students to write a paper and participate in the competition, emphasizing the opportunity for networking.

- Technologies
  Dave told participants that no *one* particular technology is more sustainable than another. The sustainability of a technology depends on how the technology will be applied to address site-specific considerations. One participant asked for a comparison of landfills and landfarms. Dave said that landfarms involve the biological treatment of hydrocarbons and tend to be relatively inexpensive compared to landfills. Landfarming requires sufficient area, drainage infrastructure for leachate, a means of maintaining the oxygen supply in soil, and time. Soil can be recycled after treatment.

- Experiences with Regulatory Community
  Dave described his experiences with the regulatory community when implementing sustainable remediation as “variable, but positive.” He stated that the U.S.

Environmental Protection Agency (USEPA) focuses on green remediation (vs. sustainable remediation). Since the Interstate Technology & Regulatory Council (ITRC) has begun developing sustainable remediation documents, he believes that the USEPA is more likely to accept a sustainability argument.

SURF Student Chapters and Student Presentations

Kevin McCoy (CSU Student Chapter) listed the following student chapters as participating in the meeting: CSU, Syracuse University, Clarkson University, University of Illinois at Chicago, and Colorado School of Mines. He reviewed the activities of the CSU Student Chapter and encouraged other student chapters to request SURF members located near their university to serve as guest speakers or help arrange field trips to remediation sites. The following representatives from each student chapter provided a brief update of their chapter's activities:

- Syracuse University
  Zeno Levy said that his chapter has experienced an influx of new members. They are following up with SURF members about speaking at upcoming chapter meetings.
- Clarkson University
  Gerlinde Wolf said that because her chapter was recently formed, they are working on increasing membership and holding elections. A guest speaker is scheduled to present at the next chapter meeting.
- University of Illinois at Chicago
  Erin Yargicoglu said that her chapter was also recently formed and is hoping to grow its membership.
- Colorado School of Mines
  Martin Dangelmayr said his chapter is active and welcomes SURF members to make presentations at meetings.

Students from various universities gave presentations, which are summarized in the paragraphs below. Student presentation slides are provided in Attachments 2 through 9.

- CO_2 Traps
  Kevin McCoy (CSU) presented CO_2 traps as a new tool for measuring light, nonaqueous phase liquid (LNAPL) loss rates at petroleum-impacted sites. As a result of recent studies suggesting that natural LNAPL losses are significant and may rival hydraulic recovery technologies, CSU developed an integral CO_2 trap that directly measures fluxes of CO_2 at grade. The fluxes are used to calculate natural LNAPL loss rates. Kevin described the traps as conceptually similar to flux chambers without the disadvantage of pressure buildup, allowing continuous integral measurements over a period of two to four weeks. In addition, the traps provide a low-cost, minimally invasive way to calculate natural LNAPL loss rates without exposing workers to contamination. Field surveys using these traps were performed at seven sites to estimate natural LNAPL losses under a range of site conditions. Calculated LNAPL losses ranged from 921 to 13,300 gallons per acre per year. These loss rates and the measured CO_2 fluxes showed distinct spatial and seasonal variability. Presentation slides are provided in Attachment 2.
- Combined Sewer Overflow Treatment
  Zeno Levy (State University of New York) presented his work on developing monitoring

protocols and baseline data for a wetland pilot project treating combined sewer overflow in Syracuse, New York. Combined sewer overflow is a mixture of sewage and stormwater runoff that discharges into urban waterways when flow through “grey” municipal sewers exceeds capacity. By pairing different constructed treatment wetland designs in tandem, a suite of green infrastructure alternatives were engineered and can be adapted to fit a variety of urban ecological niches. The design involves three wetland modules in three interchangeable flow configurations. Zeno presented the challenges associated with developing an adaptive monitoring plan addressing the experimental design, sampling methods, and sampling targets. In addition, he discussed how the pilot project and monitoring program could be used to help institutionalize monitoring protocols and standards for green combined sewer overflow treatment. The experimental design and monitoring data will be used to recommend future wetland treatment expansion projects in the area. Presentation slides are provided in Attachment 3.

- Biologically Enhanced DNAPL Dissolution in Fracture Zones
  Peggy Altman (Colorado School of Mines) presented research associated with biologically enhanced dense, nonaqueous phase liquid (DNAPL) dissolution in fractures. Eighty percent of Superfund sites and 3,000 Department of Defense sites contain DNAPL contamination. When located in fractured geologic media, this contamination presents unique and complex challenges. Peggy reviewed how fracture aperture and aperture variability affect flow and transport and how fracture aperture heterogeneity affects DNAPL distribution and dissolution. She cited studies that showed biodegradation near DNAPL source zones and at high aqueous concentrations as well as increased dissolution enhancement where DNAPL and organisms were segregated. Her research involved using an experimental apparatus to flood fractures with tetrachloroethylene (PCE) DNAPL. Then, the system was flushed until residual concentrations were reached. DNAPL dissolution and PCE concentrations were evaluated, and a bacteria culture was introduced. Effluent concentrations of PCE and daughter products of the system were monitored over time. Preliminary results and conclusions indicate the following: (1) DNAPL dissolution in fractures is slower than in single fractures or porous media, (2) DNAPL dissolution in the presence of biological activity was enhanced by a factor of 3.5, and (3) biomass growth has the potential to change flow paths as evidenced by blocked effluent tubing. Presentation slides are provided in Attachment 4.

- Slow-Release Permanganate Candles
  Gerlinde Wolf (Clarkson University) suggested the possibility of addressing large, dilute plumes by using a combination of passive in situ chemical oxidation and slow-release permanganate candles. The candles are made of a mixture of solid potassium permanganate ($KMnO_4$) particles and paraffin wax that allow for the sustained delivery of oxidant into the contaminated zone. In this technique, permanganate is distributed throughout the media via diffusion and dispersion, and a reactive zone is created that can destroy contaminants. With this idea in mind, a user-friendly, open-source design tool is being developed to help achieve full-scale field implementation of this technique. The design tool will simulate the release kinetics and permanganate reaction, including the effects of potential inner candle tortuosity on the release of permanganate over time. Gerlinde reviewed the input parameters of the tool and provided preliminary modeling work of solute transport and permanganate release. This Microsoft Excel® based tool will require users to input known site parameters and will model permanganate release

vs. time, determine the zone of influence of permanganate candles, lifespan of oxidation potential, required candle spacing and number of candles, and estimate the cost of the project. Future work involves scaling the tool from bench-scale testing to field-scale, addressing how permanganate candles will behave in low permeability media, optimizing the initial zone of influence, and incorporating permanganate natural oxidant demand into the model to estimate the time required to create a reaction zone for contaminant destruction. Presentation slides are provided in Attachment 5.

- Green and Sustainable Remedy Selection and Design
  Erin Yargicoglu (University of Illinois at Chicago) described the remedy selection process and recommended design at the Indian Ridge Marsh site in southeast Chicago, Illinois. The site is slated for remediation and re-development as part of the Calumet Open Space Reserve Initiative. Erin described the contaminants present at the site: heavy metals, pesticides, volatile organic compounds, and polycyclic aromatic hydrocarbons (PAHs). Remedial options for soil and groundwater treatment were evaluated for applicability, cleanup efficiency, and sustainability. The technologies considered included excavation, solidification and stabilization, in situ chemical oxidation, in situ bioremediation, and enhanced biostimulation with phytoremediation. Appropriate remedial options were subjected to a detailed evaluation using SiteWise™ and the Sustainable Remediation Tool™. These analyses, combined with a qualitative evaluation of sustainability based on California's Green Remediation Evaluation Matrix (GREM), resulted in the final remedy selection of phytoremediation with enhanced biostimulation in areas containing severely degraded soil. The recommended remedial strategy also incorporates plant species present on-site and restoration of the site's native vegetation. Presentation slides are provided in Attachment 6.

- Engineered Attenuation Zone for Petroleum Hydrocarbons
  Mitch Olson (CSU) discussed his work on a field demonstration of an engineered attenuation zone at a former refinery site in the western U.S. The project goal was to replace the pump-and-treat system with a remedy that uses less energy and resources. The engineered attenuation zone involves removing the impacted soil and replacing it with backfill soil that is engineered to enhance natural attenuation processes. Mitch described the pilot-scale study that evaluated (1) the feasibility of the engineered attenuation zone as a remedy, (2) the characteristics of the potential backfill, and (3) the long-term effectiveness. The pilot-scale system was designed with three flumes and uncontaminated material collected from the site as backfill. The influent water contained about 500 micrograms per liter (µg/L) of benzene and 10 to 50 µg/L toluene, ethylbenzene, and xylene. Source water originated from an on-site monitoring well and contained about 900 milligrams per liter (mg/L) of sulfate. A peristaltic pump transmitted groundwater directly from the well to the flumes. Performance data graphs of the aerobic flume showed that the system became biologically active quickly, although potential distribution issues may exist. Anaerobic flume performance graphs indicated that the system became active after six months, with near-complete removal of benzene, toluene, ethylbenezene, and xylene in the 2- to 4-foot soil interval. Mitch discussed the system upsets that occurred in both flumes during the winter months. Based on the field demonstration results, the engineered attenuation zone may provide a viable alternative to the current pump-and-treat system. Ongoing activities focus on economics, feasibility,

and the sustainability of full-scale implementation. Presentation slides are provided in Attachment 7.

- ❒ Anaerobic Membrane Bioreactor Optimization
  Dustin Whynman (Clarkson University) presented his work evaluating the potential of an anaerobic membrane bioreactor system to treat municipal and food wastes in decentralized communities such as operating bases (e.g., Afghanistan) and remote industrial locations (e.g., mining operations). Dustin provided an overview of the experimental design, which included a ceramic membrane, full automation, and backpulsing at high pressure for membrane cleaning. Fouling indices were calculated to compare fouling under different operating parameters, and experiments were performed with different waste streams to determine the best operating parameters. Biogas production was measured, and biogas was analyzed for composition to determine the efficiency of methane production. The reactor digestate and the membrane permeate water quality were evaluated to determine treatment efficiency (i.e., chemical oxygen demand, total organic carbon, total nitrogen, and turbidity). Preliminary results showed chemical oxygen demand removal greater than 90%, and low irreversible fouling indices proved that backpulsing is an effective way to mitigate fouling while working with high-strength waste streams. Dustin emphasized the importance of monitoring and adjusting the pH and alkalinity to maintain efficient digester operation. Presentation slides are provided in Attachment 8.

- ❒ Hydrocarbon Sheens: Governing Processes and Innovative Solutions
  Alison Hawkins (CSU) described four experiments designed to better understand the processes associated with hydrocarbon sheens and, through this understanding, advance innovative solutions for preventing hydrocarbon migration. These experiments focused on testing the following two hypotheses: (1) fully saturated capillary barriers preclude LNAPL migration as an intermediate wetting phase and (2) organoclay barriers are oleophilic systems that preclude LNAPL migration by sorption. (Capillary barriers in these experiments were defined as materials with a capillary rise that was higher than the adjacent formation.) A laboratory-scale tank was filled with medium silica sand, diesel was added to the tank at a flow rate of 6 mL/hour, and water levels were cycled through two high and two low levels each day. Alison showed participants videos of the experiments being conducted.

  - Experiments Testing Hypothesis 1
    The first experiment included a 4 centimeter thick vertical fine sand wall at the distal end of the tank. As seen in the video, the capillary barrier prevented migration of the diesel. In the second experiment, the above steps were repeated with the addition of two wells for hydraulic LNAPL recovery. As shown in the video, a large amount of diesel was recovered, prolonging the longevity of the barrier.

  - Experiments Testing Hypothesis 2
    The third experiment was identical to the first except that the barrier consisted of an organoclay and sand mix in a one to three ratio. Slow drainage, preferential flow paths, and low bulk sorption were observed. The fourth experiment improved upon the third experiment and included two organoclay barriers. Three impermeable baffles were added to the first barrier to prevent overtopping, and

drainage lines were added to the second barrier to prevent preferential flow. As seen in the video, the average saturation of the organoclay barrier increased with the improvements.

Further research is being conducted to improve both types of remedies, and supporting field work is scheduled in New York and British Columbia, Canada. Presentation slides are provided in Attachment 9.

Student Chapter Panel Discussion

Mike Miller (CDM Smith) moderated a panel discussion with the following students from SURF student chapters:

- Martin Dangelmayr (Colorado School of Mines)
- Zeno Levy (Syracuse University)
- Kevin McCoy (Colorado State University)
- Gerlinde Wolf (Clarkson University)
- Erin Yargicoglu (University of Illinois at Chicago)

Mike stated the ground rules and asked the panelists to comment on the two topics listed below. A summary of panelists' responses is also provided below.

- Reflect on Sustainability in Your Career
  Zeno said that his career as a wetlands scientist and environmental chemist reflects the interdisciplinary aspect of sustainability and promotes interdisciplinary solutions, similar to sustainable remediation. Kevin emphasized the importance of the social element of sustainability, such as job creation. Erin believes the concept of sustainability has shifted. In the 1990s, pump-and-treat systems were commonplace. Now, the idea of designing and implementing a pump-and-treat system seems inconsistent with long-term goals. Remediation practitioners are looking at problems differently (i.e., longer term) and considering future consequences. Gerlinde said sustainable solutions often "just make more sense." She acknowledged that sustainable remediation involves more work at the beginning of a project, but believes it pays off. She cited Dave Ellis' presentation in which he said DuPont saves 2% to 5% of its remediation budget by performing rigorous sustainability assessments. Martin agreed with the comments expressed by Erin and Gerlinde.

- Speculate about the Future of Sustainable Remediation
  Zeno believes that the definition of "sustainability" is broad and general and that it has become a buzzword. SURF examples of sustainable remediation are specific, which is what is needed. Zeno recommended reclaiming the word "sustainability" by providing concrete case studies, metrics, and philosophies. Kevin said that sustainable remediation is a combination of not only cutting-edge technology and forward thinking, but also common sense. He would like to see the thought process of sustainable remediation applied to areas outside of the environmental arena. Gerlinde said that technology advances have been growing exponentially. With this growth, she believes that sustainable remediation will become the norm. Erin said that the success of sustainable

remediation hinges on society. Although tools exist to assess sustainability, a broader discussion or a global effort needs to occur.

One participant asked panelists for their thoughts about whether university curricula is changing based on the interest in sustainability in general. Gerlinde said Clarkson University offers a class focused on LCA and engineering for sustainable design. Erin said that similar changes are happening at University of Illinois at Chicago; the remediation engineering class now incorporates sustainability metrics. Because of these changes, Erin believes that more people will be introduced to the concepts of sustainable remediation and progress will result. Zeno believes that the fundamental divide between physical and social sciences is a significant barrier to integrating sustainable remediation into university curricula. He said that multidisciplinary remediation projects (like those highlighted at SURF meetings) outnumber the projects and collaboration between these departments in academia.

Another participant asked the panelists for their ideas on how to bring research into current sustainable remediation projects. Following up on his last comment, Zeno said that research funding could catalyze collaboration between academic departments that do not usually work together. Erin said that her poster on biochar material (i.e., recycled activated carbon) is a good example of research efforts being integrated into sustainable remediation solutions. Kevin said that the CO_2 trap technology he presented resulted in long-term data that could support more sustainable ways to address sites contaminated with NAPL. Gerlinde said that a few professors at Clarkson University have shifted away from laboratory-oriented work to computer modeling work when possible to conserve resources and materials.

Day 2: The Resurgence of Oil and Gas Development

Hank Gardner (CSU) welcomed participants to the second day of the meeting and CSU. He said that 2012 marks the 150th anniversary of the passage of the Morrill Act, otherwise known as the Land-Grant Act. CSU is a Land-Grant university that provides skill sets of service, education, and research. Hank said that CSU is trying to broaden and deepen its interdisciplinary approach to problems and mentioned water research as an example. Water is a critical resource and, as such, water research needs to consider other spheres that it touches (e.g., economic, sociology, agriculture). Similar to other Land-Grant universities, CSU has a presence throughout the state through its extension network. Using this network, the university is able to reach out and provide a bridge between research and real-world applications.

A portion of Day 2 of the meeting was divided into three sessions. The first two sessions addressed two settings (i.e., subsurface air and air/water) and the associated implications for sustainable remediation. The third session addressed the policy implications of sustainable remediation. The presentations and subsequent discussions for each session are briefly summarized below. Attachments 10 through 14 contain the presentation slides for this portion of Day 2.

Implications for Sustainable Remediation: Subsurface Setting

The following topics were addressed during Session 1:

- Comments on Relevance to SURF
  Tom Sale (CSU) discussed his evolving perspective of SURF and the relevance of oil and gas development (including hydraulic fracturing) to SURF. Energy, water, and the

environment are all linked; they are inseparable, with huge impacts on one another. Similarly, hydraulic fracturing affects groundwater, surface water, air, and land. Because prevention is part of sustainability, it is necessary to be proactive and eliminate impacts *before* they exist. Tom explained that the goal of these three sessions is to inform participants about the hydraulic fracturing process and collectively brainstorm about how hydraulic fracturing can be conducted more sustainably. He emphasized the following rewards for being proactive in solving the challenges associated with hydraulic fracturing: high paying jobs, affordable fuels, improved trade balances, tax revenue for communities, energy security, natural gas as a bridge enabling renewable energy, and new technology that can be exported. Presentation slides are provided in Attachment 10.

❒ Brief Introduction to the Geology of Natural Gas and Oil
Sally Sutton (CSU) presented a brief introduction to the geology associated with natural gas and oil. As background, she explained that natural gas and oil form in rocks when heat changes buried organic matter. Specifically, dead organisms trapped in seafloor mud partially transform to kerogen, which has a complex and poorly organized molecular structure. As the sediment is more deeply buried, the kerogen "matures" to generate gas and oil.

Sally explained conventional gas and oil production where shales serve as flow barriers to keep natural gas and oil accumulations in place. To form conventional deposits, natural gas and oil migrate through connected pores and fractures and then accumulate in coarse-grained rocks with large pores. Some natural gas and oil is left behind as unconventional deposits in the low-permeability source rocks. Microscopic views of fine-grained rocks hosting unconventional deposits reveal heterogeneous rocks that vary in composition, organic matter content, and susceptibility to natural fracture and show that the organic matter maturation process that generates the gas can also create some porosity to hold the gas. Hydraulic fracturing causes additional fracturing in these areas and props the fractures open to achieve economic production. Presentation slides are provided in Attachment 11.

Discussions focused on the potential geological effects from the "violence" of the fracturing, gas recovery rates in the formation, and gas hydrates.

- Sally mentioned that the fracturing releases the gas and makes the shale more permeable. Other results depend on the composition of the shale. For example, shales with horizontal laminations can be opened during hydraulic fracturing but the process requires lifting the column of overlying rock, which can cause unwanted vertical rock propagation.
- Sally said that knowledge continues to evolve about the production rates of hydraulic fracturing wells. Although decline curves are used to predict production for conventional oil and gas wells, the curves are not well understood for unconventional wells. Therefore, they are not as effective in predicting the long-term production of hydraulically fractured horizontal wells.
- Sally explained gas hydrates as methane hydrates (i.e., a marriage between water and methane molecules) found in marine sediment settings at shallow to moderate depth. Gas hydrates contain a significant amount of methane on the sea floor and

are common in the Gulf of Mexico where they can complicate drilling. Although gas hydrates can be a potential significant future resource, they are also a potential significant environmental problem because they likely cannot be extracted without the liberation of methane.

- Environmental Implications of Drilling and Completion
  Tom Sale (CSU) presented the step-by-step process of drilling and completing oil and gas wells as well as an overview of hydraulic fracturing and its environmental implications. Tom provided an overview of the historical process of drilling to emphasize advances that have led to safer and more efficient practices. He reviewed the steps in completing a well: drill hole and set conductor casing; set plugs, cement, and displacing fluid; displace into annular space; and set surface, intermediate, and production casing and cement. Tom cited American Petroleum Institute guidelines and specifications used by California for horizontal drilling to demonstrate the methods used to protect groundwater. He showed how little pressure is needed to create a fracture and how hydrostatic pressures and the slurry flow rate are tracked via computer. Tom described Wells Ranch in Eastern Colorado, which has one production well, eight horizontal wells undergoing hydraulic fracturing, and eight wells producing flow back. At this site, UV oxidation is being used to heat the water and kill bacteria. During his closing thoughts, Tom listed the concerns associated with horizontal drilling, including long-term impacts to groundwater such as surface releases of hydraulic fracturing fluids, flow along historical and new penetrations, losses of fracturing fluids during handling and disposal, and water needs. Presentation slides are provided in Attachment 12.

  Participants' questions and Tom's comments are summarized below.

  - Tom commented on speculation that the reinjection of water may cause seismic activity. He cited a National Research Council report (*Induced Seismicity Potential in Energy Technologies*) that stated hydraulic fracturing would not cause earthquakes. The report is available at http://www.nap.edu/catalog.php?record_id=13355.
  - Participants asked about the carbon footprint of the hydraulic fracturing process. Tom said that all forms of energy production would need to be contemplated and the relative merits compared. One participant reminded the group that LCAs do not focus solely on carbon footprint; impacts such as water scarcity are also considered.
  - During his presentation, Tom mentioned that, according to the Colorado Oil and Gas Producers, 1% of all Colorado water was associated with hydraulic fracturing.
  - Because of the competition for water, one participant asked if other substances are being used for hydraulic fracturing. A participant from the oil and gas industry responded that other substances (e.g., propane) are being assessed, but safety remains a concern.
  - One participant asked about the triple bottom line implications of hydraulic fracturing, specifically social issues, and the associated metrics being used. A participant from the oil and gas industry responded that his company is evaluating

the energy, water, and food nexus. He said that trucking water to the site results in one of the largest carbon footprints associated with hydraulic fracturing, so his company is developing a 20-mile pipeline route to feed the water to sites. In addition, his company is assessing methods to monitor potential effects in deep groundwater to prevent issues such as methane gas release and brine contamination.

Implications for Sustainable Remediation: Air and Water Setting

The following topics were addressed during Session 2:

- Air Pollutant Emissions from Shale Gas Development and Production
  Allen Robinson (CSU) presented an overview of the air pollution associated with producing shale gas. Allen categorized well development (e.g., drill rigs, truck traffic) and gas production (e.g., fugitives, condensate tanks) parameters as major and minor sources of criteria pollutants, hazardous pollutants, and air toxics. He identified two data gaps that need to be addressed from an air quality perspective. The first deals with the variety of spatial scales associated with shale gas development. Because the spatial extent of development encompasses large geographic areas, the impacts of aggregate emissions on regional pollutant levels are needed. In addition, limited ambient data exist and there is poor spatial correlation between air monitoring networks and oil and gas development and production. Allen described a site in Garfield County, Colorado, in which air toxic emissions created local impacts. He ended his presentation by presenting his work mapping methane in the Marcellus region. Although climate implications are uncertain, methane levels in gas fields are elevated. Presentation slides are provided in Attachment 13.

  Discussions focused on potential tracer compounds. Allen said that fugitive gas emissions can serve as tracers.

- Managing Air Emissions from the Natural Gas Industry
  In an effort to help expand the discussion, Morgan DeFoort (CSU) focused on the mathematical and chemical advantages of using methane vs. coal from a pure energy conversion standpoint. Although methane has CO_2 impacts, he commented on the variability of coal and the ability of natural gas to fill this gap. Morgan presented the top 10 advantages and disadvantages of natural gas, stressing the need for using natural gas thoughtfully to avoid the disadvantages. He emphasized the complexity of the natural gas industry and presented a few of CSU's technologies designed to help meet National Emission Standards for Hazardous Air Pollutant (NESHAP): catalyst testing, syngas development, laser ignition, natural gas kinetics, and infrastructure monitoring. Presentation slides are provided in Attachment 14.

  No discussions occurred after the presentation.

Implications for Sustainable Remediation: Policy

Bill Ritter (Leader of CSU's Center for New Energy Economy) spoke during Session 3. He described his experiences with hydraulic fracturing as a former Colorado governor collaborating with industry, finding common ground among stakeholders, and developing rules and regulations that have become the national standard. Spurred by a factor of six increase in permitting requests for hydraulic fracturing in Colorado and believing that natural gas could be part of a clean energy economy, he focused on regulations to ensure the protection of human health and the environment. At the time, companies were not required to disclose information regarding hydraulic fracturing fluid. First, the makeup of the Oil and Gas Conservation Commission was reformed by reducing the amount of industry members and adding individuals from local government. The new commission identified the issues that needed to be addressed and began developing rules for hydraulic fracturing. The former governor said that, in some ways, the rules were written based on industry practice at the time. Companies are now required to fully disclose information about hydraulic fracturing fluid (with the exception of trade secrets). The former governor said the rules developed for Colorado are precedent setting; some of Pennsylvania's hydraulic fracturing rules and much of Ohio's drilling laws are modeled after those in Colorado. The former governor continues to educate state representatives (most recently in California) about the science associated with drilling and hydraulic fracturing. He acknowledged the work left to do and said that understanding the consequences of hydraulic fracturing can reveal tradeoffs. For example, in the western U.S., the tradeoff between energy production and food production exists. To achieve less of a tradeoff as far as food production, he recommended evaluating recycling and recovery options. He also mentioned social licenses to operate in which industry must make a case that the quality of life of the surrounding communities is not impacted. The goal of the license is to recognize that a community is impacted when hydraulic fracturing is conducted in its proximity and to include community concerns in the comprehensive drilling plan.

One participant asked about how to communicate the technical information associated with hydraulic fracturing effectively so that misperceptions can be eliminated. The participant suggested that communities were suffering from a "not in my backyard" (NIMBY) reaction to hydraulic fracturing. The former governor disagreed, citing newspaper reports all over the U.S. about real issues (e.g., methane) associated with the practice. He challenged industry to acknowledge the problems associated with the practice and develop engineering solutions. Then, the virtues of natural gas can be communicated because issues such as methane have been addressed. In response to another participants' skepticism that education would solve these issues, the former governor said that it is necessary for state representatives to maintain pressure on the environmental community and industry to rely on science.

The former governor was asked to comment on how to keep up with new developments in terms of hydraulic fracturing regulations and to share his litigation experiences. He said that the Joint Institute of Strategic Energy Analysis in Golden, Colorado, is identifying and evaluating industry best practices. He said there is very little litigation on this issue at the current time, but the history of environmental protection has shown that litigation plays a big role.

One participant asked about the current state of remediation surrounding gas extraction sites. A participant from an oil and gas company answered the question, saying that historical oil operations involved unlined pits. These unlined pits became a significant source of brine contamination. Now the pits are lined to prevent contamination. Surface operation impacts are being minimized as well; water treatment technologies are being evaluated and brine water and injection fluids are handled in an environmentally responsible manner.

The final question came from a participant who asked whether any state has a requirement for groundwater or gas formation. The former governor said that Ohio rules address these issues and commented that baseline testing and ongoing monitoring have improved.

Day 2: Hydraulic Fracturing and Remediation Discussion

After Sessions 1 through 3, participants had an impromptu discussion about hydraulic fracturing and remediation. Participants mentioned their opinions on a variety of topics; their recommendations are listed below.

- Involve stakeholders first, lay out the issues, and support with facts.
- Recall the presentations made at previous SURF meetings that address the social aspects of sustainable remediation and the education of stakeholders.
- Have public policy makers, economists, and social scientists “crunch the numbers” to determine the tradeoff of methane in wells for U.S. energy independence.
- Work on prevention as much as we do remediation.
- Consider using brine as a tracer.

Day 2: Updates of Natural Gas Application and ITRC Activities

At the end of Day 2, participants heard two presentations from SURF members. The presentations and subsequent discussions for each presentation are briefly summarized below. Attachments 15 and 16 contain the presentation slides.

Use of Natural Gas in Thermal Remediation

Grant Geckeler (TPS TECH) presented the evolution of the use of natural gas in thermal treatment. He began by reminding participants of the mechanics of off-site thermal desorption, which involves significant infrastructure to create heat gradients to desorb contaminants from soil. This initial concept was adapted and now three different thermal remediation techniques using natural gas are available. Two of these techniques can be used for in situ treatment; all can be used ex situ. The first technique is designed for ex situ use only and involves treatment via natural gas burners and a thermal oxidizer. The other techniques have an in situ mechanism that allows remediation practitioners to forego excavation. The heat from natural gas or propane is transversed through a closed-loop coaxial heater well. Heat is transferred to the impacted soil and groundwater through conduction. Grant told participants that issues related to sustainable remediation have driven these technological advances. He showed a graph comparing coal and natural power and emphasized the need to perform a comprehensive LCA to explore sustainability issues further. Grant discussed international projects with accelerated timeframes that do not allow for a comprehensive LCA. Instead, internal models are relied upon for baseline sustainability numbers. He ended his presentation with an international case study involving an abbreviated sustainability assessment for remediation of PAH-impacted soil. The assessment focused on societal implications of land reuse and demonstrated that sustainability elements can be integrated at any point in the project. In one project, the heater wells were reused for geothermal heating of an apartment building. Presentation slides are provided in Attachment 15.

No discussions occurred after the presentation.

ITRC Green and Sustainable Remediation

Stephanie Fiorenza (BP) provided an update of the green and sustainable remediation (GSR) efforts of the ITRC. Stephanie presented the background of the ITRC GSR team, which was formed in 2008 and is led by state regulators Tom O'Neill (New Jersey) and Rebecca Bourdon (Minnesota). Since its inception, the team has published an overview document and a technical and regulatory guidance document. Currently the team is providing internet-based training for these documents. Stephanie reviewed the training sections, including ITRC's definition of green and sustainable remediation and the flexible and scalable framework developed. The training also addresses the implementation of GSR and provides a methodology for identifying options, evaluating them, implementing the most appropriate, and tracking and documenting along the way. The training also emphasizes the need to set GSR goals, select metrics, include stakeholders, and set the boundaries of the evaluation *before* selecting a GSR tool. Case studies are also included in the training. Additional information about the ITRC GSR team is available at http://www.itrcweb.org/teampublic_GSR.asp. Presentation slides are provided in Attachment 16.

No discussions occurred after the presentation.

Day 3

Day 3 presentations and subsequent discussions are summarized in the subsections below. Attachments 17 through 21 contain the presentation slides for Day 3 of the meeting.

Committee and Initiative Breakout Sessions

SURF members continue to work on efforts that will further the mission of the organization. At this meeting, breakout sessions were held for the following technical initiatives: Sustainable Remediation Resource Index, Sustainable Remediation Rating and Certifications, Groundwater Reuse and Conservation, and Government Outreach. Presentation slides are provided in Attachment 17. SURF members can access the latest work and activities of these groups by visiting the "collaboration area" under the "member resources" menu on the SURF website. Members interested in joining an initiative or committee should contact the group's leader. Leaders are listed on the "2012 Committee and Initiative Chart" in the "collaboration area" of the website.

- Sustainable Remediation Resource Index (SRRI)
  Diana Hasegan (Langan Engineering) provided information about this technical initiative, which replaces the previously proposed initiatives "Sustainable Remediation Site Database" or formerly the "Site of Sites" initiative. The purpose of this initiative is to create a one-stop shop of publicly available sustainable remediation tools and resources on the SURF web site. The SRRI will have four primary components: (1) one to two Microsoft Excel® spreadsheets summarizing sustainable remediation online tools and resources with hyperlinks included, (2) a SRRI index card template containing standard criteria and metrics for evaluating the tools and resources, (3) a detailed summary of each sustainable remediation resource in the template format (one to two pages), and (4) a white paper. Help is needed from SURF members and students to obtain links to sustainable remediation tools and resources as well as completing the one- to two-page template for each resource. Prior to SURF 21 in December 2012, five to 20 sustainable remediation resources will be reviewed and SRRI index cards will be completed and uploaded to the SURF website. Presentation slides are provided in Attachment 17.

- ❒ Sustainable Remediation Rating and Certifications
  Diana Hasegan (Langan Engineering) presented an update on this technical initiative, which is aimed at determining if an adequate business case exists for developing and applying a site rating and professional certification system for sustainable remediation. Ongoing activities include the following: (1) a survey distributed to SURF members, with results summarized and reported; (2) a summary of sustainable rating tools; (3) a summary of sustainable rating organizations; (4) a report compiling survey results, tools, and organizations, and (5) a comparison of tools through "test drives." Presentation slides are provided in Attachment 17.

- ❒ Groundwater Reuse and Conservation
  Patrick Keddington (Haley & Aldrich) provided an update of this new technical initiative. The team held a kickoff meeting in May 2012 and met for the first time face-to-face at this meeting. A draft outline of a perspective paper about groundwater reuse and conservation has been developed, and case studies are being compiled. The team organized into several committees to complete action items to achieve their goal of submitting a paper to the SURF Board of Trustees for review by the first quarter 2013.

- ❒ Government Outreach
  Buddy Bealer (Shell Oil Products) said that the members of this initiative are attempting to build a coalition of organizations with the common goal of sustainable remediation. By coordinating efforts and leveraging synergies, he believes that SURF and other organizations can use each other's strengths to achieve the goal. A by-product of the initiative will be the engagement of state regulators. Immediate action items are as follows: (1) identify and contact organizations that may be interested in joining the coalition, (2) develop materials for standard coalition presentations, and (3) develop a strategy to promote sustainable remediation with states by prioritizing states based on the number of applicable projects or interest to adopting sustainable remediation principles.

SURF members also updated participants about the following activities:

- ❒ Academic Outreach
  This committee did not meet during the breakout session, but Mike Miller (CDM Smith) provided an update of their efforts. He encouraged students to get involved in the committee and in the various SURF technical initiatives. Mike highlighted the SURF Student Paper Competition that will be held at Battelle in 2012. A flyer is available on the SURF website at http://www.sustainableremediation.org/student-paper-competition. SURF members should feel free to add academic contacts to this listing so that SURF can leverage these contacts for various activities (e.g., meeting planning and presentations, student chapter interest). The group continues to work on a list of hot research topics and a value proposition for academics. Presentation slides are provided in Attachment 17.

- ❒ Potential Research Initiative
  Stewart Abrams (Langan Engineering) discussed a potential initiative that would identify, prioritize, support, and fund potential research in the field of sustainable remediation. Participants seemed to agree that this effort would dovetail nicely into the efforts already underway by the Academic Outreach team. Presentation slides are provided in Attachment 17.

Soil and Groundwater Environmental Protection in Taiwan

Shih-Cheng Pan (Sinotech Environmental Technology) provided an overview of Taiwan's introduction to environmental contamination, associated regulations to ensure environmental compliance, listed contaminated sites and applied remediation technologies, and an ongoing case study demonstrating the current approach to green and sustainable remediation. In 1994, the RCA factory in Taoyuan County became the first publicly known groundwater contamination site in Taiwan. The Soil and Groundwater Pollution Remediation Act was promulgated in 2000 to detail measures for prevention, investigation and assessment, and remediation and restoration as well as outline financing and responsibility and penal provisions. Shih-Cheng reviewed the categories of listed contaminated sites (815 total) and the remediation technologies used for cleanup. He said that green and/or sustainable remediation is needed in Taiwan for economic, social, and environmental reasons (see below).

- ❒ Economic: The Remediation Fund is far from sufficient to clean up contaminated sites where the responsible parties cannot be identified or have vanished.
- ❒ Social: Land revitalization is needed for the contaminated rice paddies and abandoned former factories.
- ❒ Environmental: More efficient and smarter use of resources is needed for remediation to achieve a reduced environmental or ecological impact and smaller footprint.

The first project dedicated to green and/or sustainable remediation was initiated by the Taiwan EPA in March 2012. The scope involves collecting green and sustainable remediation information from the United States and European countries, setting up a preliminary toolbox for green and sustainable remediation, holding conferences dedicated to the topic (including one international conference), and developing case studies. Shih-Cheng presented an ongoing case study of a 42-acre site contaminated with mercury, dioxin, and pentachlorophenol. Although many technologies (e.g., thermal destruction, soil washing, bioremediation) have been tested in the last five years, a phytoremediation laboratory study proved effective in partially degrading dioxin. A pilot-scale study is being planned. Presentation slides are provided in Attachment 18.

Discussions focused on the willingness of the Taiwan EPA to accept the approach of green and sustainable remediation. Shih-Cheng said that the U.S. EPA provided documents to the Taiwan EPA about green remediation. There is confusion (vs. opposition) about the approach. Shih-Cheng said that he will bring the information he has heard during this SURF meeting back to the Taiwan EPA to help clarify issues.

Reflections of Student Day

Near the end of Day 3, students and professionals were asked for their reflections about the first day of the meeting. Day 1 of the meeting focused on the work of students from SURF student chapters. A list of reflections and feedback provided by participants is provided in Attachment 19.

Business Items

Karin Holland (SURF President) discussed the following business items with participants:

- ❒ Potential Partnering Organizations
  Based on a recent SURF survey, participants listed organizations that would be good

potential partners with SURF to advance the field of sustainable remediation. Karin asked SURF members with connections at the organizations (see Attachment 20) to volunteer as liaisons to help SURF work more seamlessly with other organizations. Other SURF members wishing to volunteer as a liaison with a potential partnering organization should contact Karin (see Attachment 1 for contact information).

- 2012 Technical Initiative Themes
  Karin asked participants to provide additional themes than the three listed in Attachment 20 that they believe are important for SURF to work on in the short or long term. One participant suggested the topic of sediments.
- Communication Between Meetings
  Participants were asked for their ideas on how to keep members informed of the activities of the Board and various technical initiatives in between SURF meetings. After much discussion, most participants seemed to agree that quarterly status conference calls would be appropriate. Others seemed to like the idea of having regional meetings combined with a social element as a way to address potential budgetary issues associated with travel.

Presentation slides are provided in Attachment 20.

Future Meetings

The next SURF meeting (SURF 21) will be held December 12-13, 2012, at the National Academy of Science in Washington, DC. Information regarding the details of the meetings is posted on the SURF website. If you are a SURF member and would like to help plan or host an upcoming meeting, e-mail Mike Rominger (meeting facilitator) at mike.rominger@sustainableremediation.org.

ATTACHMENTS

Attachment 1
SURF 20 Participant Contact Information

SURF 20
Participant Contact Information

Participant	Affiliation
Abrams, Stewart	Langan Engineering and Environmental Services
Adams, Kathy	Writing Unlimited
Akhbari, Daria	Colorado State University
Altman, Peggy	Colorado School of Mines
Ampil, Rosemarie	Parsons Corporation
Aragona, Keith	Haley & Aldrich
Bealer, Buddy	Shell
Britt, Randy	Parsons Corporation
Byrne, Adam	Colorado State University
Chen, Su-Chen	Sinotech Environmental Technology
Dangelmayr, Martin	Colorado School of Mines
Daugherty, Ellen	Colorado State University
Davis, Jennifer	Colorado State University
DeFoort, Morgan	Colorado State University
Dugan, Pamela	Carus Corporation
Ellis, Dave	DuPont
Favara, Paul	CH2M HILL
Fiorenza, Stephanie	BP
Fisher, Angela*	GE Global Research
Frasco, Kelly	Carus Corporation
Gardner, Hank	Colorado State University
Geckeler, Grant	TPS TECH
Goodwin, Stephen	Colorado State University
Hadley, Paul	California Dept. of Toxic Substances Control
Hasegan, Diana	Langan Engineering and Environmental Services
Hawkins, Alison	Colorado State University
Hawley, Elisabeth	ARCADIS
Holland, Karin	Haley & Aldrich
Irianni Renno, Maria	Colorado State University
Jasmann, Jeramy	Colorado State University
Jones, Michael	High Prairie Environmental
Kean, Mary*	Sustainable Silicon Valley
Keddington, Patrick	Haley & Aldrich
Kluger, Mark	Dajak
Koberle, Melissa	CDM Smith
Krajewski, Dustin	AECOM
Levy, Zeno	State University of New York
Lowe, Kathryn	Colorado School of Mines
Mancini, Kristin	ARCADIS
McClenney, William	ENVIRON
McCoy, Kevin	Colorado State University
Miller, Mike	CDM Smith
Moubarak, Jasmeen	Colorado State University
Moxley, Katie	The Boeing Company
Olson, Mitchell	Colorado State University

* Participated remotely

SURF 20
Participant Contact Information

Participant	Affiliation
Pan, Shih-Cheng	Sinotech Environmental Technology
Petri, Benjamin	Colorado School of MInes
Philip, Heather	Parsons Corporation
Plampin, Mike	Colorado School of Mines
Raymond, Dick	Terra Systems
Rehder, Tim	EPA Region 8
Ritter, Bill	Colorado State University
Robinson, Allen	Colorado State University
Rominger, Mike	MCR Facilitation Services
Sadowski, Paul	Shaw Environmental
Sale, Tom	Colorado State University
Shannon, Todd	Colorado School of Mines
Shea, David	Sanborn, Head & Associates
Shogbon, Alicia	Colorado State University
Skinner, Anna	Colorado State University
Stanley, Curt	Shell Global Solutions
Stewart, Vincent	Sentinel Consulting Services
Sutton, Sally	Colorado State University
Taylor, Elysia	Clarkson University
Tunks, John	CH2M HILL
Wahlberg, Jennifer	Colorado State University
Wandor, David	Dow Chemical
Watts, Dan	Arasoc Group
Whynman, Dustin	Clarkson University
Williams, Theodore	Syracuse University
Wolf, Gerlinde	Clarkson University
Woodward, Dave	AECOM
Wunsch, Assaf	Colorado School of Mines
Yamini Sadasivam, Bala	University of Illinois at Chicago
Yargicoglu, Erin	University of Illinois at Chicago

* Participated remotely

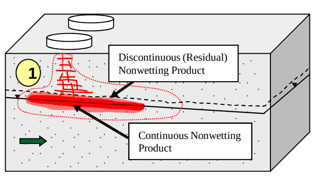
Attachment 2
CO_2 Traps

CO_2 Traps: A New Tool to Monitor Natural LNAPL Loss Rates

Kevin McCoy / M.S. Candidate / Colorado State University
Julio Zimbron / Research Associate / Colorado State University
Tom Sale / Associate Professor / Colorado State University

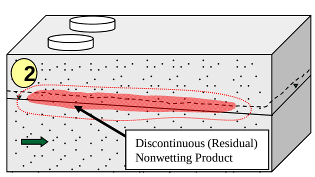
Presented at:
Sustainable Remediation Forum Student Day
SURF 20
Colorado State University
July 24, 2012

Motivation For Research



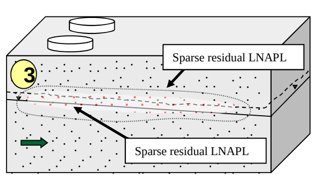
Early Stage

- During or shortly after a release.
- LNAPL body expands and/or migrates.



Middle Stage

- The release has been stopped.
- Natural losses lead to dynamic equilibrium.
- Overall LNAPL movement is primarily internal redistribution resulting in a stable LNAPL body.



Late Stage ?

- Sparse residual LNAPL is immobile.
- Natural losses reduce extent of (i.e. shrink) LNAPL body.

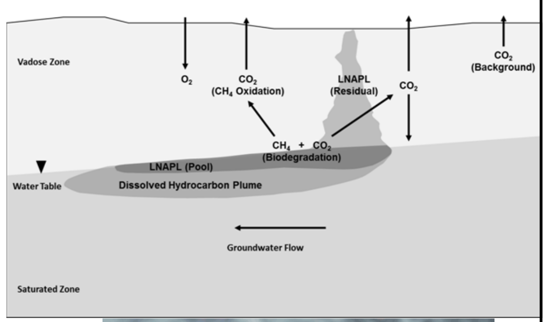
Natural losses rival losses via active remedies (100s to 1,000s of gallons/acre/yr)

Overview

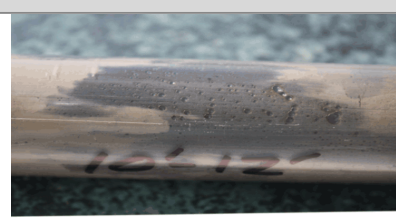
- Natural LNAPL losses
  - Processes and monitoring
- CO_2 Traps
  - Design
  - Laboratory analytical methods
  - Field studies
    - Site example
    - Carbon sources by isotopic analysis
- Ongoing work

Natural LNAPL Losses

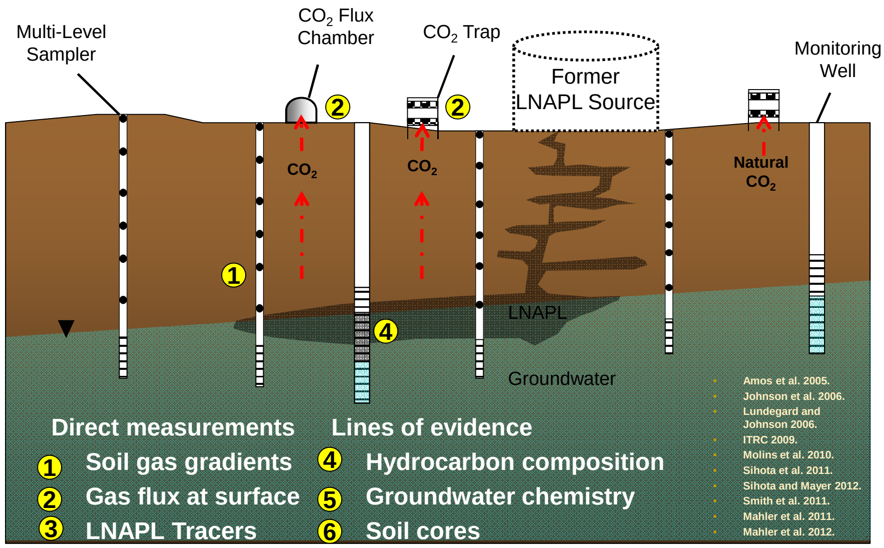
- Mechanisms
  - Volatilization
  - Dissolution
  - ***Biodegradation***



98% of carbon from contaminant degradation emitted as CO_2
Mollins et al. 2010 – modeling study



Monitoring LNAPL Losses



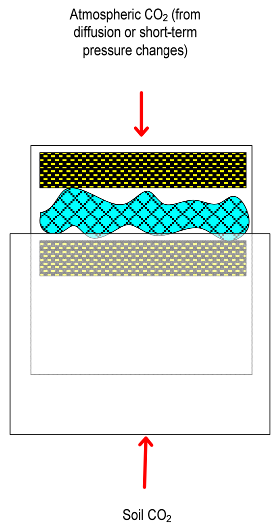
Idea…

Measure natural losses with CO_2 traps…

- Low Cost
- Minimally Invasive
- Low Site Impact.
- Minimal I.D.W.

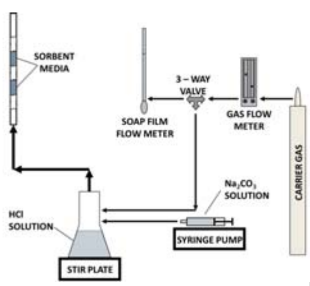
CO_2 trap design

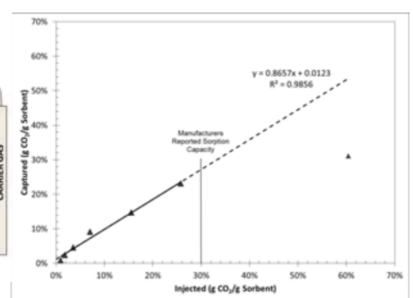
- Two sorbent elements.
  - Bottom captures CO_2 from soil.
  - Top intercepts atmospheric CO_2.
- Sorbent contains $Ca(OH)_2$.
  - CO_2 passing through trap reacts to form $CaCO_3$.
- Trap elements lab-analyzed for total carbonate content.



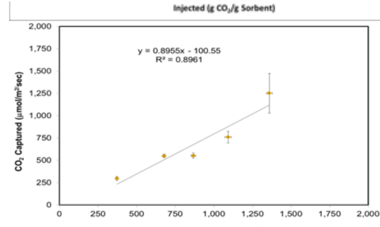
Laboratory Testing of CO_2 Traps

- Small scale, closed system





- Large scale, open system

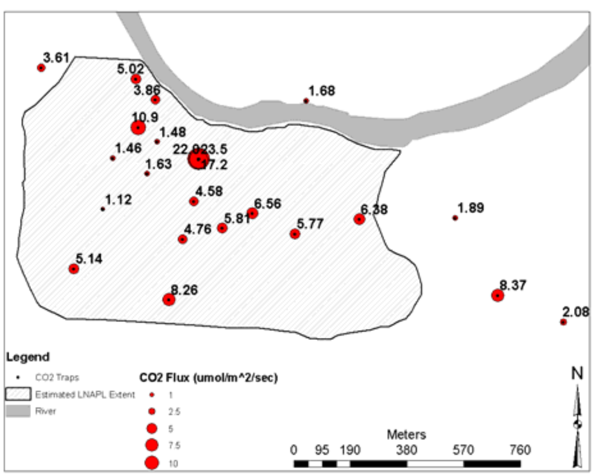


Field Studies

- 9 active studies.
- Deploy traps at grade for 2 - 4 weeks.
- Measure CO_2 flux above LNAPL bodies and at background locations.

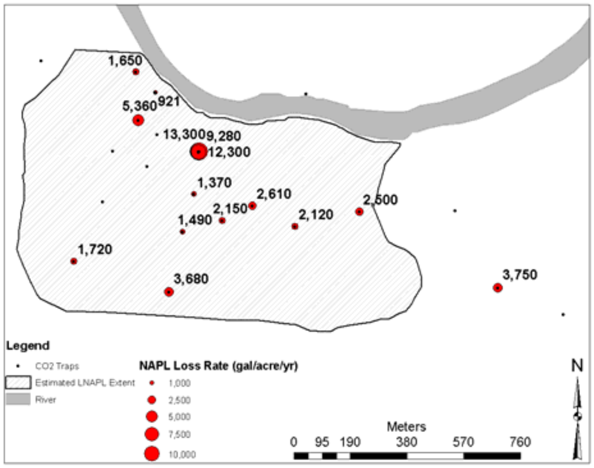
Current field studies
Planned field studies

Measured CO_2 Fluxes



- Symbol size proportional to measured CO_2 flux (µmol/m²/sec).
- Measured CO_2 fluxes significantly larger over LNAPL body than background locations.
- Some LNAPL locations not significantly different from background.

Calculated LNAPL Losses

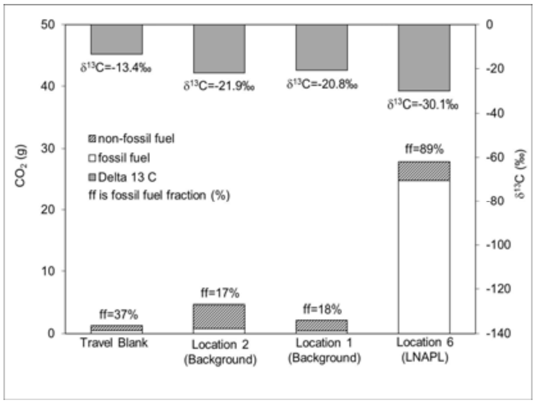


- Symbol size proportional to background corrected LNAPL loss rate (gallons/acre/yr).
- Calculated LNAPL loss rates (as C_6H_6) range from 921 – 13,300 gal/acre/yr.
- Uncolored symbols are not significantly different from background.

Carbon Sources by Isotopic Analysis

- Carbon isotope analysis (^{14}C) to evaluate fossil fuel fraction (*ff*) (Avery, et al. 2006) of captured CO_2.
- Results indicate significant CO_2 contribution from degrading LNAPL at impacted locations.
- Loss rate calculated from fossil fuel fraction matches loss rate calculated by background correction.
- δ13C data also support LNAPL natural attenuation as carbon source.

Isotopic Analysis Results



- Lower axis shows ^{14}C
  - Hatched areas - recent carbon
  - White areas - fossil fuel carbon
- Upper axis shows $\delta^{13}C$ (‰)
  - $\delta^{13}C$ values from nearby LNAPL samples (-26.5 to -27.3 ‰)

Comparison of Isotopic Correction to Background Correction

Sample	^{14}C Corrected equivalent LNAPL loss rate (gal/acre/yr)	Background Corrected LNAPL Loss Rate (gal/acre/yr)
Travel Blank	228	NA
BG01	377	NA
BG02	190	NA
LNAPL	12,300	12,300

Ongoing work

- Field scale laboratory studies

- Continuing field studies
  - Collaborative method comparison.
  - Additional field sites.
  - Resolving background correction.

- Ongoing studies of controlling factors.
  - LNAPL chemistry.
  - Smear zone thickness.
  - In-well LNAPL thickness.
  - Soil/water temperature.

Acknowledgements

- Co authors: Tom Sale and Julio Zimbron
- Funds provided through the University Consortium for Field Focused Groundwater Contamination Research
- Collaborators
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  - Paul Johnson / ASU
- Site owners (access to field sites)
  - Chevron
  - DuPont
  - ExxonMobil
  - Suncor Energy
- Site contractors (field support)
  - Arcadis
  - CH2MHILL
  - Stantec
  - Trihydro
- CSU laboratory staff
  - Gary Dick, Sonja Koldewyn, Sarah Breidt, Becca Bradley, Cali Campbell,

Questions?

Attachment 3
Combined Sewer Overflow Treatment

Developing Monitoring Protocols and Baseline Data for Assessment of a Novel, Full-scale CSO Treatment Wetland Pilot Project in Syracuse, NY

Zeno Levy[1] and Richard Smardon[1]

[1]State University of New York College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210

SURF 20
July 24th 2012
Fort Collins, CO

ESF State University of New York College of Environmental Science and Forestry

SURF Syracuse University Student Chapter

Acknowledgements

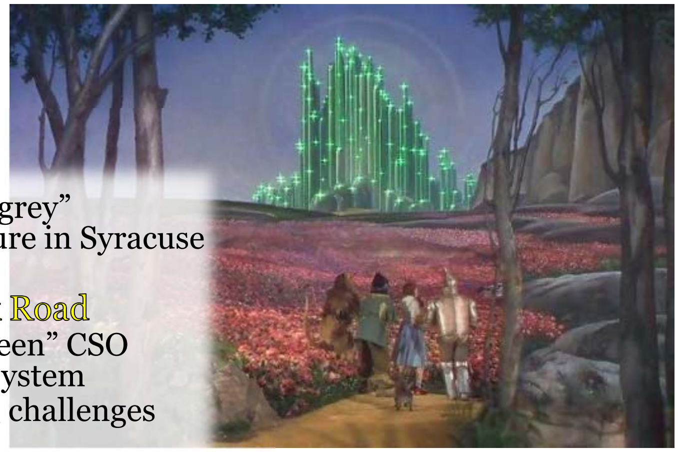
- *Special thanks* to County Executive Joanne Mahoney and Deputy County Executive Matthew Millea – **without whom this project would not be possible**

- CH2M HILL: Matthew Marko, Rita Fordiani, Erin Mosley, John Pries, Jim Bays

- CHA: Mike Hollowood, Rich Deguida, Chris Einstein

Save the Rain

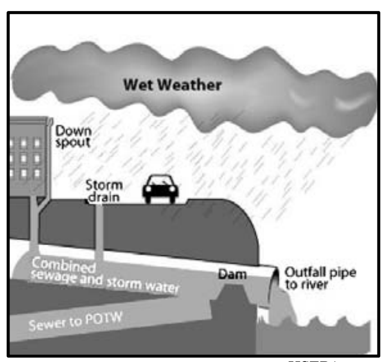
Outline



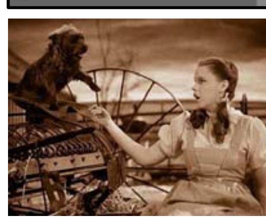
- **Kansas**
  - CSOs and "grey" infrastructure in Syracuse
- Yellow Brick Road
  - A novel "green" CSO treatment system
  - Monitoring challenges
- The Emerald City
  - Institutionalizing monitoring protocols for "green" CSO treatment

Combined Sewer Overflow (CSO) and "grey" mitigation

- **Nationwide:** 1,260 BILLION gallons/year (USEPA 2001)
- Point discharges regulated
  - NPDES - national
  - SPDES - state
- Increasing in-pipe storage and "grey" sewage treatment **traditional approach** (Stoner 2007)



USEPA 1994



CSO Abatement in Syracuse

- Amended Consent Judgment, 1998:
  - Enhance municipal sewage treatment plant
  - Reduce volume of CSO
- Fourth Stipulation of the ACJ, 2009:
  - **Target: 247 MILLION** gallons/year of CSO reduction through green infrastructure (GI) projects
- The County's "Save the Rain" program implementing GI improvements

Welcome to the Land of GI!

- GI focuses on reducing stormwater loads to municipal sewers:
  - Green roofs
  - Rain gardens
  - Rain barrels
  - Porous pavement
- Treatment wetlands
  - Also GI but…
  - Other end of pipe

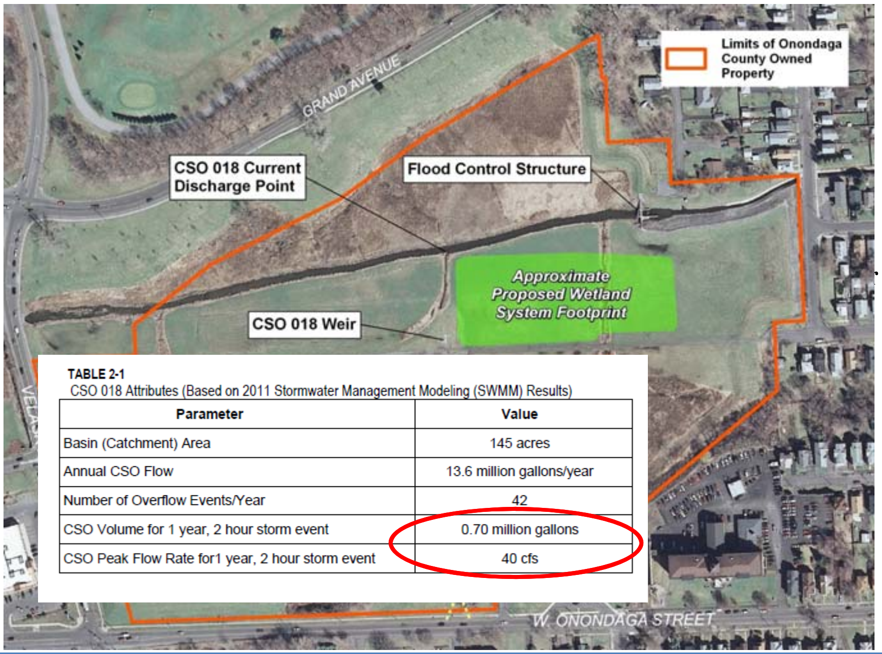


TABLE 2-1
CSO 018 Attributes (Based on 2011 Stormwater Management Modeling (SWMM) Results)

Parameter	Value
Basin (Catchment) Area	145 acres
Annual CSO Flow	13.6 million gallons/year
Number of Overflow Events/Year	42
CSO Volume for 1 year, 2 hour storm event	0.70 million gallons
CSO Peak Flow Rate for1 year, 2 hour storm event	40 cfs

The Concept

- 3 Wetland Cells
  1. Floating Wetland Islands
  2. Vertical Downflow
  3. Surface Flow

- 3 Flow Configurations
  1. Series
  2. Parallel
  3. Series-Parallel

Monitoring Goals:
"Follow the yellow brick road"

- **Experimental:** Compare treatment wetland design parameters
  - Wetland technologies
  - Flow configurations
    - Monitor at all wetland cell inflow/outflow points
- **Regulatory:** Required monitoring under SPDES
  - Discharge permit modification
    - Monitor at CSO bypass and treatment system "outfall"

Monitoring Challenges:
(1) Experimental Design

- Sample:
  - Target CSO pollutants
    - TSS, BOD_5, TP, nitrogen (TKN, NH_4-N, $NO_{2/3}$), Fecal Coliform
  - Flow
- ANCOVA Approach:
  - Two-way ANCOVA
    - 3 x 3 factorial design
  - Covariates
    - Influent volume
    - Influent pollutant mass loads

	Series	Parallel	S-P
FWI	% Removal	% Removal	% Removal
VDF	% Removal	% Removal	% Removal
SF	% Removal	% Removal	% Removal

11

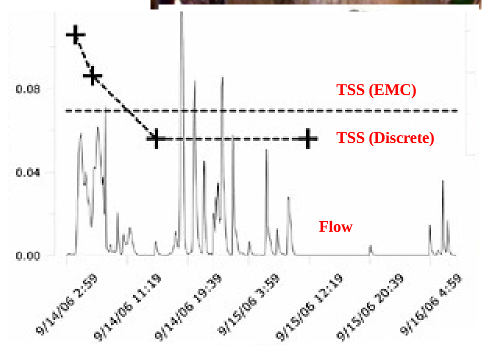
Monitoring Challenges:
(2) Sampling Methods

FLEXIBILITY is NEEDED → →

- Automated flow-weighted composite samples
  - Use model data to determine flow increments and limits
  - Must adapt to field conditions
  - Sample reduction

- Event mean concentrations (EMCs)

- Goal: estimate target pollutant **mass removal**



Batroney 2008

12

Monitoring Challenges:
(3) Sampling Targets

- **CSO 018:** 4 event/month average between March and Nov

- **Triage-based system**: Balance sampling of 3 flow configurations

- **Target:** 18 – 27 CSO event/year

TABLE 4-4
Target 1st Year Storm Event Sampling Schedule

Sampling Season	Spring								
Month	March			April			May		
Storm Event Sampling Configuration[1]	S	S	S	SP	SP	SP	P	P	P

The Emerald City:

Institutionalizing Monitoring Protocols and Standards for Green CSO Treatment

- Federal CSO Control Policy (1994)
  - Maximize CSO flow to "publicly owned treatment works" (POTWs)
- New York State
  - POTWs subject to SPDES
  - Technical and Operational Guidance documents (TOGs)
    - "CSOs" (1993)
    - "SPDES Permit Development for POTWs" (1998)

"A horse of a different color!"

- TOGSs for CSO POTWs focused on traditional **grey** facilities
- **Regulatory gap** for monitoring and performance standards of GI under SPDES
- CSO Treatment Wetlands are **green infrastructure**
  - Treatment standards
  - Hydraulic residence times
  - Largely unstaffed facilities

The Great and Powerful Wizard of GI

"BRING ME A PILOT MONITORING PROGRAM FOR GREEN CSO TREATMENT!"

Monitoring results can be used to develop TOGs for future GREEN CSO treatment in NYS

Cogent

Adaptive

Robust

Conclusions:

"There's no place like POTWs?"

- Treatment wetlands are GI focused on discharge side of CSO
- Pilot monitoring: link standards and monitoring protocols to treatment wetland design components
- Results could help to provide technical guidance for future efforts

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Attachment 4
Biologically Enhanced DNAPL Dissolution in Fracture Zones

Biologically Enhanced DNAPL Dissolution in Three-Dimensional Fracture Network

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SERDP

Motivation

- 80 % of Superfund sites and 3,000 Department of Defense sites consist of DNAPL contamination. (SERDP.org)
- DNAPL contamination in fractured geologic media present many unique and highly complex challenges.
- Bioremediation is incredibly cost effective for treating DNAPLs in unconsolidated media and holds high potential for fractured media.

Fracture Aperture Variability

- Fracture aperture and aperture variability affect flow and transport through a fracture system. (Becker and Shapiro, 2003)
- Fracture aperture heterogeneity affects DNAPL distribution and dissolution. (Pankow and Cherry, 1996)

Parameter	Relevance	Equation
e_{MB}	Describes large aperture regions along primary flow path	$e_{mb} = \frac{Qt_m}{LW}$
e_f	Describes small aperture regions along primary flow path	$e_f = L\sqrt{\frac{12\mu}{\rho g \lvert \Delta H \rvert t_m}}$
δ	Describes aperture heterogeneity along flow path	$\delta = \frac{e_f}{e_{MB}}$

DNAPL Dissolution

$$N = ka_iV(C_{sat} - C)$$

N = Rate of Dissolution (mg/sec)

k = Mass Transfer Coefficient (cm/s)

a_i = DNAPL-water interfacial area (cm^2/cm^3)

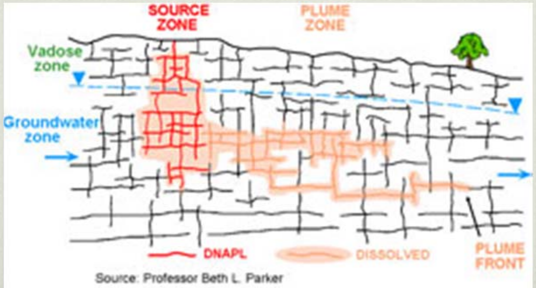
V = volume of surrounding groundwater (cm^3)

C_{sat} = PCE DNAPL solubility (mg/cm^3)

C = Aqueous-Phase PCE Concentration (mg/cm^3)

DNAPL in Fractures

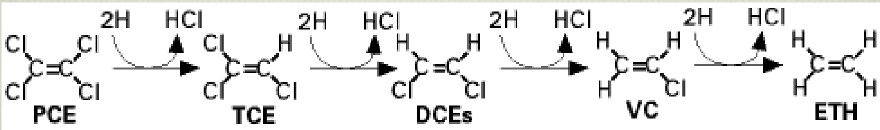
- DNAPL dissolution in single fracture experiments is significantly slower than in porous media. (Schaefer, 2009)
- Decreased dissolution in fractures is contributed to decreased mixing efficiency and preferential flow. (Berkowitz, 2002)



Bio-enhanced Dissolution

$$N = k a_i V (C_{sat} - C)$$

- $(C_{sat} - C)$ is the driving force for DNAPL dissolution
- Driving force increases → Dissolution rate increases
- *Dehalococcoides sp.* (SDC-9 from Shaw Environmental)



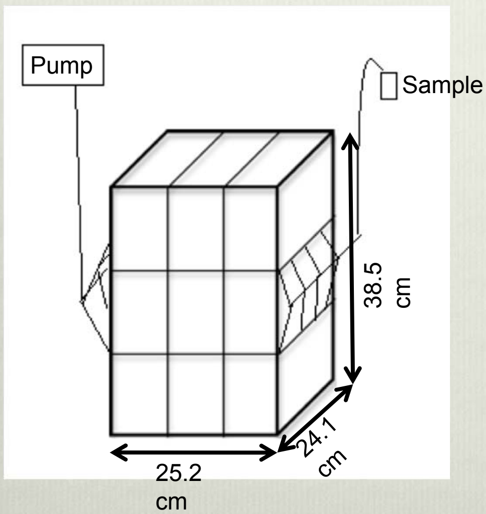
source: Holliger et al 1999

Potential for Successful Bio-Enhancement in Fracture Networks

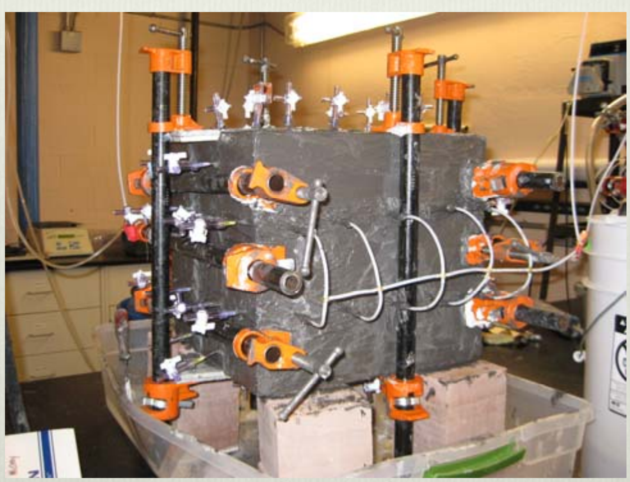
- Many studies have shown biodegradation can occur near DNAPL source zones and at high aqueous concentrations. (Yang and McCarty, 2000; Cope and Hughes, 2001; Kaplan et al., 2008)
- Dissolution enhancement is more in situations where there is segregation between DNAPL and organisms. (Yang and McCarty, 2000)
- Variable aperture fractures trap DNAPL in big aperture regions with water (with bacteria) filling small aperture regions → segregation
- Fracture intersections limit impact of flow channeling caused by variable apertures → better distribution of microbes

Current Research

Experimental Apparatus



Experimental Apparatus



Fracture Network Properties

- Negligent matrix diffusion – $D_{eff} = 10^{-8}$ cm^2/sec
  - Low porosity (<3.2%)
  - Quartz overgrowth filled
  - Limited pore-space connectivity
- Highly variable apertures:

Parameter	Equation	Hand Induced	Snap Cut	Saw Cut
e_{MB}	$e_{mb} = \frac{Qt_m}{LW}$	0.368 cm	0.268 cm	0.170 cm
e_f	$e_f = L\sqrt{\frac{12\mu}{\rho g \lvert \Delta H \rvert t_m}}$	0.004 cm	0.005 cm	0.003 cm
δ	$\delta = \frac{e_f}{e_{MB}}$	0.01	0.02	0.02

Experimental Method

Flood Fractures with PCE DNAPL

↓

Flush to Residual

↓

Evaluate DNAPL dissolution and PCE concentrations

↓

Introduce bacteria culture to network

↓

Monitor effluent concentrations of PCE and daughter products

Results

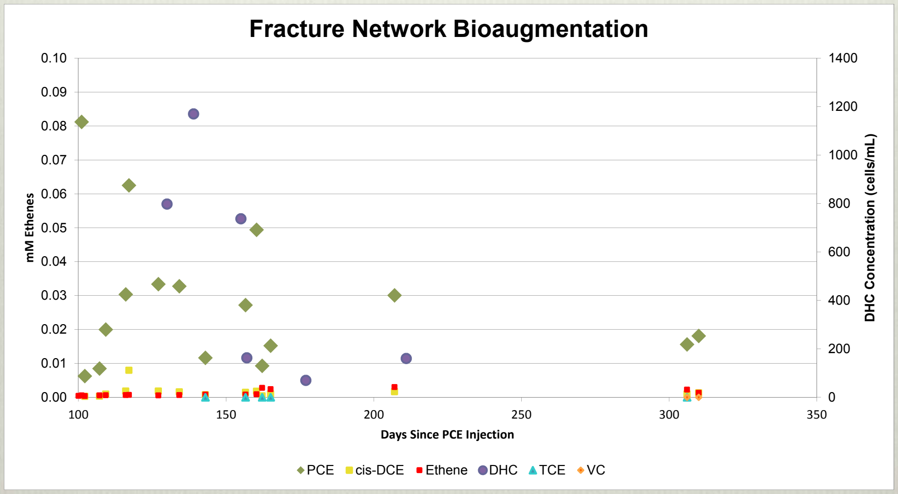
Abiotic PCE Dissolution

	K_L (min^{-1})	K_i (cm/min)	δ
Fracture Network – Hand	0.003	1.0 E-4	0.01
Fracture Network – Snap	0.021	2.9 E-4	0.02
Fracture Network – Saw	0.007	3.3 E-5	0.02
Fracture Network – ChemOx	0.02	3.0 E-5	0.08
Single Fracture (Schaefer et al, 2009)	0.02	1.0 E-3	0.14
Porous Media (Cho et al, 2005)	0.84	1.9 E-2	0.33

Schaefer, C. E.; Callaghan, A.; King, J.; and McCray, J.E. Dense Nonaqueous Phase Liquid Architecture and Dissolution in Discretely Fractured Sandstone Blocks. *Environ. Sci. Technol.*, **2009**, *43* (6), 1877-1883.

Cho, J.; Annable, M. D.; Rao, P. S. C. Measured mass transfer coefficients in porous media using specific interfacial area. *Environ. Sci. Technol.* **2005**, *39*, 7883–7888.

PCE and Daughter Products



Preliminary Results and Conclusions

- DNAPL dissolution in fractures is slower than in single fractures or porous media likely due to more variable fracture apertures within a fracture network
- DNAPL dissolution in presence of biological activity was enhanced by a factor of 3.5

$$E = \frac{[PCE] + ([TCE] + [DCE] + [VC] + [ethene])\left(\frac{[Cl^-]_{measured}}{[Cl^-]_{theoretical}}\right)}{[PCE]}$$

- Biomass growth has potential to change flow paths as evidenced by blocked effluent tubing

Future Work

- Evaluate effect of aperture variability on the extent of bio-enhancement of DNAPL dissolution using fracture networks with different aperture ratios, δ.

- Explore the effect of fracture intersections on bioaugmentation by comparing enhancement factors from single fracture and fracture network setups with similar δ.

Questions?

References

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Schaefer, C.E., Towne, R.M., Vainberg, S., McCray, J.E., and Steffan, R.J. (2010) Bioaugmentation for Treatment of Dense Non-Aqueous Phase Liquid in Fractured Sandstone Blocks. *Environmental Science & Technology*, 44(13), 4958-4964.

Attachment 5
Slow-Release Permanganate Candles

SLOW RELEASE PERMANGANATE CANDLES FOR SUSTAINABLE *IN SITU* CHEMICAL OXIDATION

1

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Environmental Science and Engineering[1]
Institute for a Sustainable Environment[2]

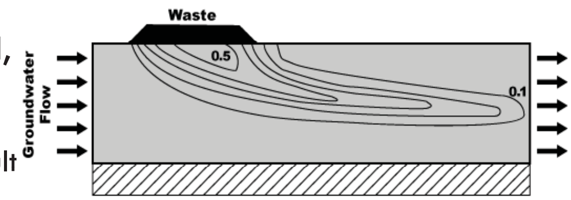
Introduction

2

- Worldwide contaminated areas pose a threat to human and environmental health and must be addressed through remediation techniques.
- However, all remediation technologies have some environmental social and economic impact.
- Sustainable remediation techniques strive to maximize environmental cleanup while also providing social and economical benefit.

The Problem

- **Common Contamination Challenge:** widely dispersed, low level contamination plumes.
  - Often very costly and difficult to treat. (WHY??)



Plume B

- **Possible Solution:** in-situ chemical oxidation using a controlled or slow release oxidation mechanism.
  - Passive, long term, low impact.

SRPC image??

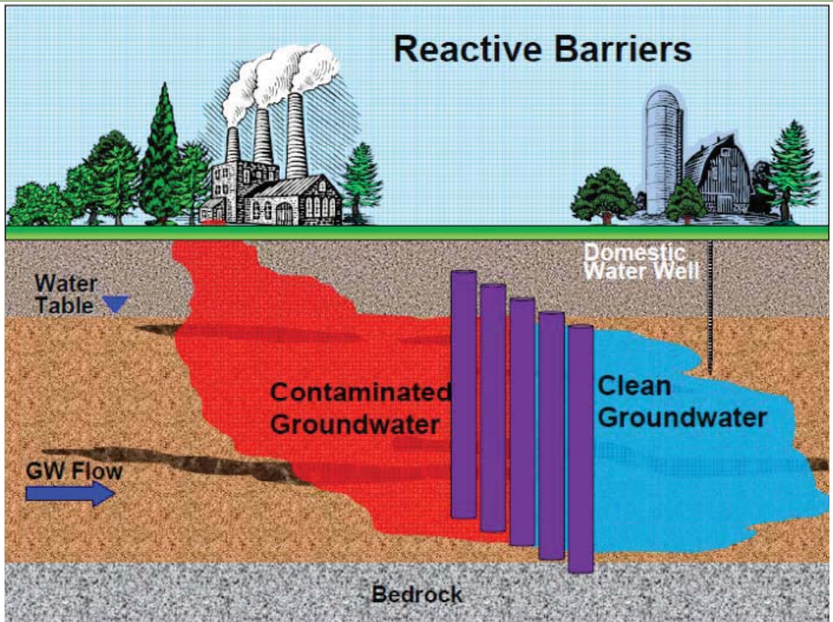
Permanganate Candles

- Slow Released Permanganate Candles (SRPCs), made of a mixture of solid $KMnO_4$ particles and paraffin wax, allow for the sustained delivery of oxidant into the contaminated zone.

- As groundwater flows by the SRPC barrier $KMnO_4$ is dissolved and available for contaminant destruction.

Permanganate Candle Reactive Barrier

5



http://www.esaa-events.com/remtech/2011/pdf/11-Dugan1.pdf

Objectives

6

- Develop a user friendly open source design tool to aid in full-scale field implementation of SRPCs.
- **Goals of Design Tool:**
  - Simulate/Model SRPC release kinetics and permanganate reaction
  - Include the affects of potential inner candle tortuosity on the release of permanganate over time

Design Tool Considerations

7

- Existing Models do not incorporate changes in candle morphology into oxidant release rates.
- SRPC release rates must be able to keep up with permanganate oxidation reaction rates.
- SRPCs will have initial 'spike' in $KMnO_4$ release from candle surface, then release will slow down with time.

Important Design Tool Input Parameters

8

Aquifer/Site Related

- Hydraulic Conductivity
- Cross sectional area to GW flow
- Soil Porosity
- Initial Contaminant Concentration in Groundwater
- Aquifer Volume
- Groundwater Velocity
- 3-D Dispersivity

SRPC Related

- Initial Oxidant Mass
- Effective Diffusion Coefficient
- Permanganate Flux out of SRPC
- Contaminant Concentration
- Initial SRPC Radius
- Ratio of Available mass of MnO_4 : Volume of candle
- Reaction Time

Preliminary Modeling Work: Solute Transport

$$\frac{\partial C}{\partial t} = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} + D_z \frac{\partial^2 C}{\partial z^2} - v\frac{\partial C}{\partial x} + q_s C_s^k + \sum R_n$$

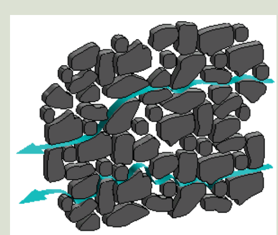
$$\frac{C_x}{C_o} = exp\left\{\frac{x}{2a_x}\left[1-\left(1+\frac{4\lambda\alpha_x}{v}\right)^{1/2}\right]\right\} erf\left[\frac{y}{4(\alpha_y x)^{1/2}}\right] erf\left[\frac{yz}{4(\alpha_z x)^{1/2}}\right]$$

Preliminary Modeling Work: Permanganate Release

$$\frac{r^2}{2}\ln\frac{r}{r_0} + \frac{1}{4}(r_0^2 - r^2) = \frac{C_s D_e t}{A}$$

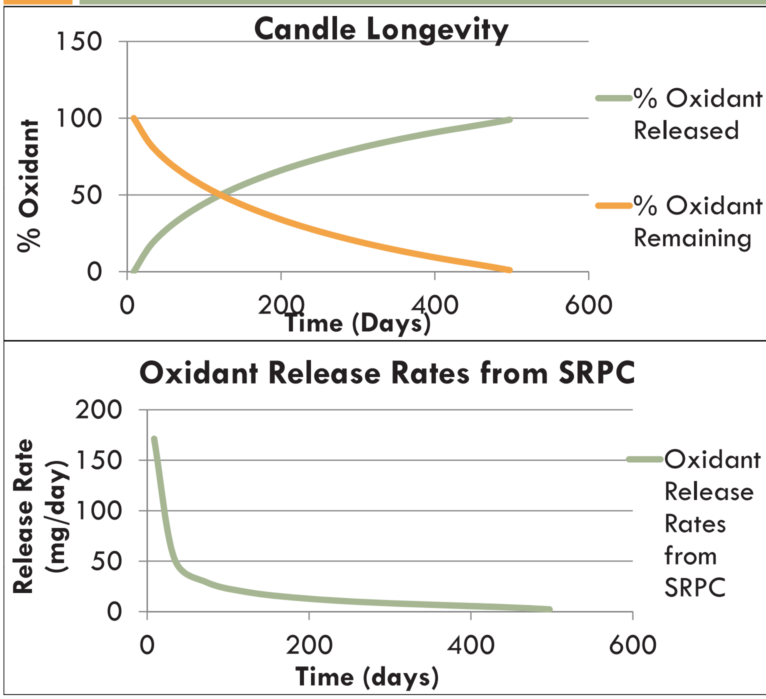
$$Q' = \pi h A(r_0^2 - r^2)$$

$$D_{et} = \frac{D_{e\,(t-1)}}{T}$$



Design Tool Output Examples

11



Expected Outcomes

12

- Model Permanganate Release vs. time
- Determine zone of influence of SRPCs
- Determine candle spacing and number of candles based on inputs
- Calculate lifespan of oxidation potential
- Allow for sustainable remediation options to be more accessible

Relevance of Design Tool

13

- Tool is not site specific
- Provides a project timeline, budget and treatment effectiveness estimation
- Allow for sustainable remediation options to be more accessible

Future Work

14

- Scale the design tool from mini SRPC bench tests to field scale
- Address how SRPCs will behave in LPM
- Run an optimization program to optimize the initial SRPC radius
- Incorporate Permanganate natural oxidant demand (PNOD) into the model and determine how long it will take to create a reaction zone for contaminant destruction.

Questions

Attachment 6
Green and Sustainable Remedy Selection and Design

Green & Sustainable Remedy Selection and Design for Indian Ridge Marsh, Chicago, IL

UIC Department of Civil and Materials Engineering
UNIVERSITY OF ILLINOIS AT CHICAGO
COLLEGE OF ENGINEERING

Erin Yargicoglu*, Jennifer Welch*, Gregory Bourgon* and Krishna Reddy**

*Graduate Student, **Professor

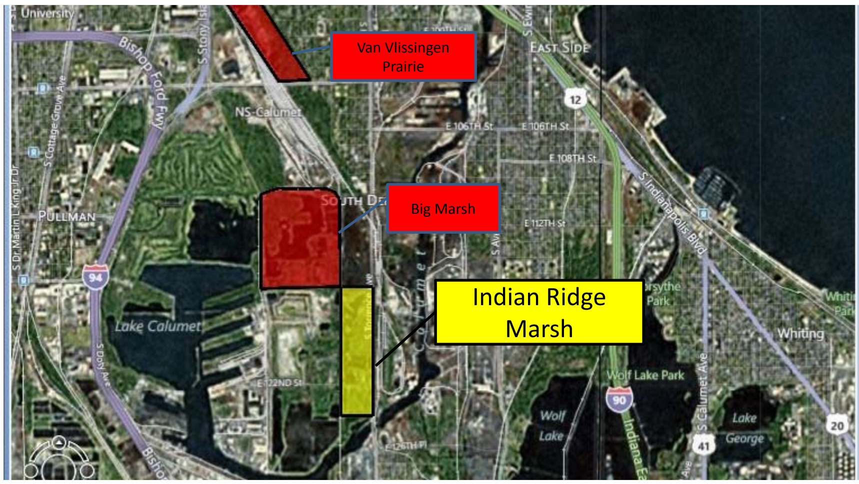
University of Illinois at Chicago

SURF 20 Meeting, Fort Collins, CO
July 24-26, 2012

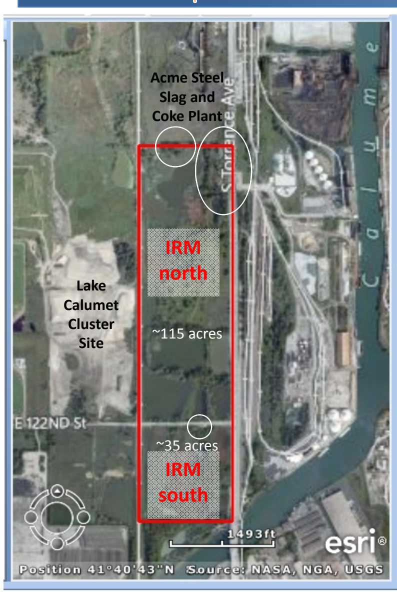
Presentation Outline

- Site Background
  - Location & Restoration Initiatives
  - Site Characterization
  - Identified Site Contamination
- Human and Ecological Risk Assessment
- Remedy Selection
  - Site-specific Considerations & Remedial Options
  - Sustainability Metrics & Remedy Selection
- Remedial Design
- Final Recommendations

Site Location: Southeast Chicago



Site Description & Sources of Contamination



- Indian Ridge Marsh (IRM) (~150 acres) is bounded by:
  - *North*: E. 116th Street
  - *East*: S. Torrence Avenue
  - *South*: Calumet River
  - *West*: Norfolk & Southern Railroad
- Mixed wetland/marsh, prairie, and woodland
  - IRM has existed primarily as wooded marsh and swamp land since about 1930
- **Residential parcels** along 116th St. and at northeast corner of site; industrial structure on 122nd St.
- Contamination sources:
  - Onsite: Dumping /infilling (illegal and historic legal)
  - Offsite: Fomer/current heavy manufacturing, use/presence of USTs, landfills, illegal dumping
    - **Lake Calumet Cluster Site** (Superfund) – west of IRM
    - **Acme Steel Slag and Coke Plant** (listed in CERCLIS, but not on NPL) – north of IRM

Current Site Uses & Future Redevelopment

Currently not open for public use

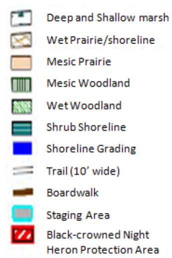
- Human
  - Historic Illegal dumping throughout site
  - Adjacent landfills; Cluster Sites
- Ecological
  - Nesting site for endangered wetland bird species (e.g. black-crowned night heron)

Future Use

- Human
  - Recreation
    - Calumet Open Space Reserve (COSR)
- Ecological
  - Calumet Wetland Unit

Previously proposed restoration design plan
(Ecotoxicology Report, 1999)

- Prairie rehabilitation
- Naturalization of marsh & pond shorelines
- Enhancement of pond habitat



Applicable Regulations

- Not federally mandated
- Voluntary State Remediation Program (SRP)
- Illinois Administrative Code (IAC)
  - —Title 35, Part 742
    - o *Tiered Approach to Corrective Action Objectives (TACO)*
  - —Title 35, Part 302, Section 407
    - o *Water Quality Standards, Secondary Contact and Indigenous Aquatic Life Standards*

Site Characterization - Prior Site Investigations

Year	Type	Performed By
1998	Phase I ESA	DOE
1999	Phase I ESA	Mostardi-Platt Associates, Inc.
1999	Phase II ESA	Earth Tech, Inc.
2001	Phase II ESA	Harza Engineering Co.
2002	Additional sediment data	MWH Americas, Inc.
2007	Additional groundwater data from cluster site	Ecology & Environment (E&E)
2009	Ecotoxicology Evaluation	Tetra Tech Inc.
2011	Phase I ESA	Terracon, Inc.

Phase I Results:

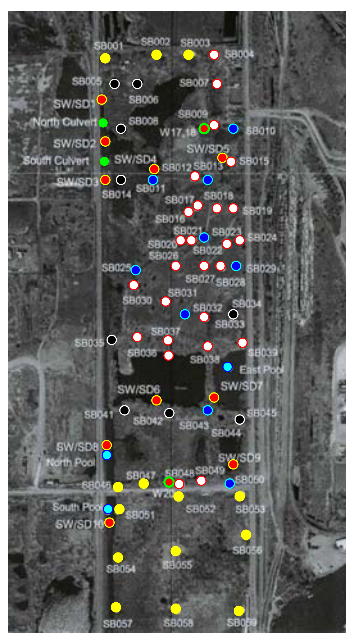
- Formerly SWDS
- Illegal fly/open dumping of slag and other materials
- Adjacent properties: solid waste disposal sites
- Northern property (offsite): Acme Steel Slag & Coke Plant (no longer in operation; listed in CERCLIS database)

Phase II Results:

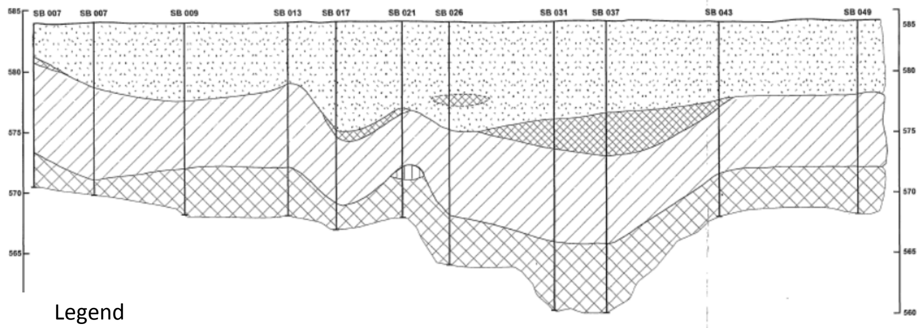
- Samples taken & analyzed (140+ soil; 20+ GW, 25+ sediment, 25+ SW)
- Documented contamination with **SVOCs, VOCs** (TCE, PCE, Vinyl Chloride)**, heavy metals**
- LNAPL found in one borehole (Well#20) with Total Petroleum Hydrocarbons (TPH), e.g. gasoline, diesel, oil

Sampling Locations

- Site contains sediments & surface water samples that exceeded allowable criteria for SVOCs, VOCs, RCRA metals, and TPH.
- Chlorinated solvent impact to the groundwater in the vicinity of Well #20.



N-S Geologic Cross Section



Legend

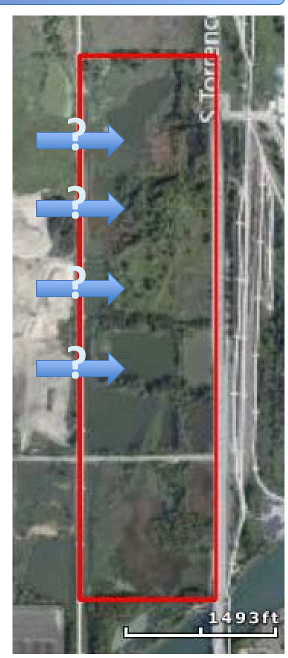
- Fill
- Sand with silt
- Organic clay with sand
- Gravel with sand
- Silty clay
- Contact uncertain

Harza Engineering Company June 2001

Sediment Type	Depth	Thickness	Hydraulic Conductivity
Fill	Surface to 4-12 ft depth (variable)	0-12 ft	Variable
Silty Sand	~5-15 ft	< 20 ft	10^{-5} to 10^{-3} cm/s
Clayey till/Clay	~15-40 ft	12-20 ft	10^{-9} to 10^{-7} cm/s

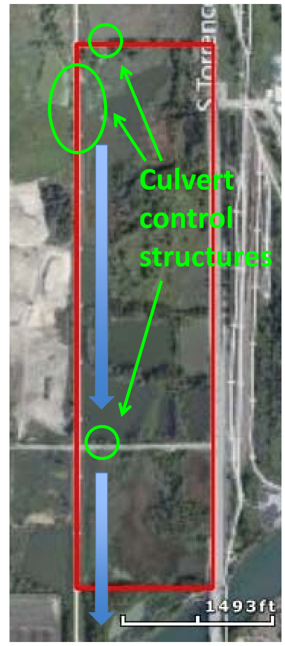
Hydrogeologic Considerations - Groundwater

- Hydrogeology strongly influenced by **heterogeneous distribution of fill materials** throughout pre-existing wetland complex
  - **GW flow & direction not easily quantified; highly variable**
- Higher permeability surface soils, fill, and till with a thickness of ~12-20 ft overly a clay-rich layer → acts as an **aquitard limiting vertical groundwater migration**
- Primary Bedrock Aquifer:
  - Silurian Dolomite (Top elevation ~ 500ft)
- **Seasonal groundwater fluctuation of ±3.5 ft** influenced by Calumet River and Lake Michigan when water levels are high, and mainly impact surface elevation of North Pool.
- Possible groundwater contribution from LCCS to the west following E-NE topographic gradient. **Actual seepage not observed.**
- **Low hydraulic gradient estimated at 0.002 – 0.025 cm/cm**



Hydrogeologic Considerations – Surface water

- Surface water impact mainly influenced by overland flow from adjoining LCCS to west, and ACME steel coke facility to north
  - **discharge from culverts beneath No & So R.R. and 166th St.**
- Surface water flow in IRM is **North to South**, passing through a culvert beneath 122nd St., then follows a channel along the western site boundary.
- Regular blockage of culvert control structures from debris accumulation can heavily influence surface water elevation and seasonal flooding.
- No flow control structure at discharge point to Calumet River
  - **Surface water impact expected during high-stage events**



Documented Contaminants & Impacted Media

	SOIL	GROUNDWATER	SEDIMENT	SURFACE WATER
PAHs	Benzo(a)pyrene (C; GI) Benzo(a)anthracene (C; GI) Benzo(b)fluoranthene (C; GI) Benzo(k)fluoranthene (C; GI) Dibenzo(a,h)anthracene (C; GI) Indeno(1,2,3-cd)pyrene (C; GI)	Benzo(a)pyrene (C; GI) Benzo(a)anthracene (C; GI) Benzo(b)fluoranthene (C; GI) Benzo(k)fluoranthene (C; GI) Bis(2-Ethylhexyl) Phthalate (C; L) Chrysene (C; GI) *1991-92 GW data: trans-1,2-trans-Dichloroethene, cis-1,2-Dichloroethene, 1,1-Dichloroethene, Benzene*	Benzo(a)anthracene (C; GI) Benzo(a)pyrene (C; GI) Dibenz(a,h)anthracene (C; GI) Naphthalene (C; R)	
VOCs	Tetrachloroethene (PCE) (C; L) Trichloroethene (TCE) (C; L) Vinyl chloride (C; L, RS)	Vinyl chloride (C; L, RS) LNAPL *(containing total petrolium hydrocarbons (TPH) gasoline, diesel, and oil)*		
METALS	Lead Mercury (NC; CNS, IS)	Iron Lead Manganese (NC; CNS)	Antimony (NC; CS) Arsenic (C; RS) Cadmium (NC; K) Chromium Copper Lead Nickel Thallium Zinc (NC; CS)	Iron Manganese (NC; CNS)

C	Carcinogen	**NC**	Non-Carcinogen

CS -	Circulatory System	**IM** -	Immune System	**L** -	Liver
GI -	Gastrointestinal System	**K** -	Kidney	**RS** -	Respiratory System

Human and Ecological Risk Assessment

Purpose:

- ***Identify remedial goals by assessing risk to human and ecological health***
  - Harza (2001) – human health COPCs
  - Tetra Tech (2009) - ecotoxicological COPCs

Approach:

- Compare human health and ecotoxicological RBSLs to chemical concentrations
  - Tiered Approach to Corrective Action Objectives (TACO) (IAC, Title 35, Part 742)
    - ***Tier 1 - Residential***
  - Calumet Area Ecotoxicological Protocol (CAEP)
    - ***Benchmark***
  - IAC, Title 35, Part 302, Section 401, Secondary Contact and Indigenous Life Standards

Assumptions:

- Soil
  - Ingestion and inhalation only (no dermal)
- Groundwater
  - Direct ingestion only (no soil component to groundwater)
  - Human Health – Class II
  - Ecotoxicological – surface water

Results:

- Table of media specific ROs
- 6 soil and groundwater remedial areas

Exposure Pathways & Sensitive Receptors

Primary Human Exposure Pathways

- Soil
  - Ingestion
  - Inhalation of particulates
  - Inhalation of volatiles
- Excluded pathways for RA
  - Dermal, sediment, surface water
  - Groundwater ingestion

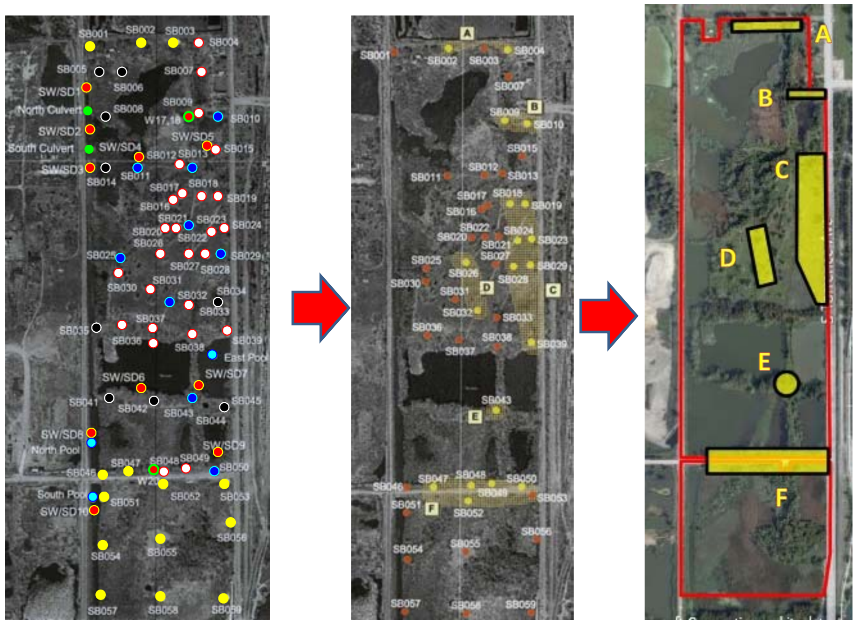
Ecological Pathways *(media exposure)*

- Soil
- Groundwater/surface water
- Sediment

Sensitive Receptors

- Ecological
  - Wetland birds - 6 T&E species
    1) **Black-crowned night heron**
    2) Least bittern
    3) Pied-billed grebe
    4) King rail
    5) Black tern
    6) Common moorhen
- Human
  - Visitors
  - Remediation workers (including construction)
  - Long-term monitors & researchers
  - Volunteers

Identified Areas of Concern (AOCs)



Contaminated AOCs Summary

	Surface area		Media for Remediation		Maximum Depth to Contaminant (ft)		Average Depth to Water Table (ft)
	ft²	acres	Soil	GW	Soil	GW	
A	60,000	1.4	x	--	2.0	--	1.3
B	27,000	0.6	x	x	3.0	14	2.8
C	320,000	7.3	x	x	6.5	13	6.6
D	85,000	2.0	x	--	7.0	---	4.1
E	50,000	1.1	x	x	2.0	13	2.5
F	186,000	4.3	x	x	2.0	19	2.3
Total	728,000	16.7					

pH	Dissolved $O_{2(g)}$	Hydraulic Conductivity (K)
7.8 - 9.0*	7.9 - 12.0 mg/L	10^{-5} – 10^{-3}

*In some areas, pH as high as 12

Soil RA-RO Table

Contaminants of Potential Concern (COPC)	Sample ID (Maximum Concentration)	Data Source	Sample Depth (ft bgs)	Concentration (mg/kg)	TACO Tier 1 Residential SROs		Calumet Area Ecotoxicology Protocol (CAEP) SROs		
					Ingestion (mg/kg)	Inhalation (mg/kg)	Background (mg/kg)	Threshold (mg/kg)	Benchmark (mg/kg)
Area A									
Benzo(a)pyrene	SB002	Harza (2001)	*2*	0.22	0.09	--	0.68	-- [1]	--
Area B									
Benzo(a)anthracene	SB009		*3*	3.62	0.9	--	1.1	--	--
Benzo(a)pyrene	SB009		*3*	3.13	0.09	--	0.0013	0.0113	0.113
Benzo(b)fluoranthene	SB009	Harza (2001)	*3*	3.41	0.9	--	1.5	1	10
Dibenzo(a,h)anthracene	SB009		*3*	0.47	0.09	--	0.2	--	--
Indeno(1,2,3-c,d)pyrene	SB009		*3*	1.49	0.9	--	0.86	1	10
Area C									
Benzo(a)anthracene	SB028		*6.5*	44.1	0.9	--	1.1	--	--
Benzo(a)pyrene	SB028		*6.5*	29.5	0.09	--	0.68	--	--
Benzo(b)fluoranthene	SB028		*6.5*	26.8	0.9	--	1.5	1	10
Benzo(k)fluoranthene	SB028		*6.5*	31.8	9				
Dibenzo(a,h)anthracene	SB029	Harza (2001)	*2.5*	8.43	0.09	--	0.2	--	--
Indeno(1,2,3-c,d)pyrene	SB028		*6.5*	12.9	0.9	--	0.86	1	10
Lead	SB023		*5.5*	1800	400	--	36	16	430
Mercury	SB023		*5.5*	81.3	23	10	0.06	0.07	1.3
Area D									
Benzo(a)pyrene	SB032	Harza (2001)	*7*	0.21	0.09	--	0.0013	0.0113	0.113
Area E									
Lead	SB043	Harza (2001)	*2*	499	400	--	36	16	430
Area F									
Benzo(a)pyrene	SB050		*2*	1.23	0.09	--	0.0013	0.0113	0.113
Tetrachloroethylene	SB050		*2*	21.1	12	11	--	--	--
Trichloroethylene	SB049		*1*	41.2	58	5	--	--	--
Benzo(a)anthracene	SB050		*2*	2.6	0.9	--	1.1	--	--
Benzo(b)fluoranthene	SB050	Harza (2001)	*2*	1.2	0.9	--	1.5	1	10
Dibenzo(a,h)anthracene	SB050		*2*	0.28	0.09	--	0.2	--	--
Vinyl Chloride	SB050		*2*	0.64	0.46	0.28	--	--	--
Lead	SB049		*1*	648	400	--	36	16	430

Groundwater RA-RO Table

Contaminants of Potential Concern (COPC)	Sample ID (Max. Concentration)	Data Source	Maximum Contaminant Depth (ft bgs)	Concentration (mg/L)	TACO Tier 1 Residential GROs	Calumet Area Ecotoxicology Protocol Surface Water ROs [1]		
					Direct Ingestion of Class II GW (mg/L)	Background (mg/L)	Threshold (mg/L)	Benchmark (mg/L)
Area B								
Manganese	SB010	Harza (2001)	*14*	1.11	10	0.042	1.0	1.0
Area C								
Manganese	SB029	Harza (2001)	*13*	1.19	10	0.042	1.0	1.0
Area E								
Manganese	SB043	Harza (2001)	*13*	1.48	10	0.042	1.0	1.0
Area F								
Benzo(a)anthracene	SB050		*10*	1.50E-03	6.50E-04	--	3.00E-05	2.00E-04
Vinyl Chloride	SB056		*16*	5.70E-02	1.00E-02	--	--	--
Iron	SB057	Harza (2001)	*17*	16	5	0.71	1	1
Lead	SB058		*18*	2.56	0.1	< 0.002	1.67E-02	3.18E-01
Manganese	SB059		*19*	1.8	10	0.042	1.0	1.0
Additional Samples Outside of Areas of Soil Contamination								
Manganese	SB025	Harza (2001)	*14*	1.82	10	0.042	1.0	1.0

Remedial Goals

Area	Media	COPC	Maximum Depth of Contamination (ft bgs)	Contaminant Concentration (mg/kg or mg/L)	RO (mg/kg or mg/L)	% Exceedence	Governing RO	
							HH	Ecotox
A	Soil	Benzo(a)pyrene	2	0.22	0.09	144	X	
B	Soil	Benzo(a)anthracene		3.62	0.9	302	X	
		Benzo(a)pyrene		3.13	0.09	3,378	X	
		Benzo(b)fluoranthene	3	3.41	0.9	279	X	
		Dibenzo(a,h)anthracene		0.47	0.09	422	X	
		Indeno(1,2,3-c,d)pyrene		1.49	0.9	66	X	
	GW	Manganese	14	1.11	1.0	11		X
C	Soil	Benzo(a)anthracene		44.1	0.9	4,800	X	
		Benzo(a)pyrene		29.5	0.09	32,678	X	
		Benzo(b)fluoranthene		26.8	0.9	2,878	X	
		Benzo(k)fluoranthene		31.8	9	253	X	
		Dibenzo(a,h)anthracene	6.5	8.43	0.09	9,267	X	
		Indeno(1,2,3-c,d)pyrene		12.9	0.9	1,333	X	
		Lead		1800	400	350	X	
		Mercury		81.3	1.3	6,154		X
	GW	Manganese	13	1.19	1.0	19		X
D	Soil	Benzo(a)pyrene	7	0.21	0.09	133	x	
E	Soil	Lead	2	499	400	25	x	
	GW	Manganese	13	1.48	1.0	48		
F	Soil	Benzo(a)pyrene		1.23	0.09	1,267	X	
		Tetrachloroethylene		21.1	11	92	x	
		Trichloroethylene		41.2	5	724	x	
		Benzo(a)anthracene		2.6	0.9	189	X	
		Benzo(b)fluoranthene	2	1.2	0.9	33	X	
		Dibenzo(a,h)anthracene		0.28	0.09	211	X	
		Vinyl Chloride		0.64	0.28	129	x	
		Lead		648	400	62	x	
	GW	Benzo(a)anthracene		1.50E-03	2.00E-04	650		X
		Vinyl Chloride		5.70E-02	1.00E-02	470	X	
		Iron	19	16	1	1,500		X
		Lead		2.56	0.1	2,460	X	
		Manganese		1.8	1.0	80		X

Remedial Technology Selection - Soil

Technology	Disqualifying Site Conditions
Soil Vapor Extraction	Less effective for removal of SVOCs than VOCs; N/A for saturated soils; ineffective for heavy metals
Soil Washing	Ineffective for low-permeability soils; high cost ($$$)
In-situ Chemical Oxidation	Not appropriate for mixed contaminant classes
Stabilization/ Solidification	Shallow depth & large distribution of soil COPCs; potential for desorption of heavy metals (lead) from cement matrix over time; detrimental to plant growth & wetland restoration
Monitored Natural Attenuation (MNA)	Ineffective with some radioactive metals, and has potential for contaminant migration
Electrokinetic Remediation	Potential for significant soil pH changes incompatible with long-term habitat/wetland restoration goals
Thermal Desorption	Ineffective for heavy metals, high water table requires dewatering, Ineffective with silty soils
Vitrification	Inefficient with organic-rich soils, energy intensive, large treatment area
Bioremediation	Heavy metals resistant to degradation, partial degradation of organics generates potentially more toxic intermediaries, difficult to maintain optimal environmental conditions

Remedial Technology Selection - Groundwater

Technology	Disqualifying Site Conditions
Pump & Treat	Residual contamination due to tailing, rebound; high cost ($$$), less effective in silty and heterogeneous soils
In-Situ Flushing	Ineffective for silty and heterogeneous soils, unintentional contaminant spread may occur; large treatment area
Permeable Reactive Barrier (PRB)	Low horizontal hydraulic gradient, potential for clogging due to iron precipitation, potential need for media replacement
Air Sparging	Ineffective for heavy metals, inefficient for silty and heterogeneous soils.
Bioremediation	Heavy metals resistant to degradation, partial degradation of organics generates potentially more toxic intermediaries, inefficient in low-permeability or heterogeneous soils, difficult to maintain optimal environmental conditions

Applicable Soil & GW Remedial Technologies

Soil Technology	Qualifying Site Conditions
Phytoremediation/ enhanced Biostimulation	Effective with a variety of mixed contaminants (heavy metals, PAHs, VOCs, SVOCs) in soil and groundwater
Excavate	Effective with non-hazardous and hazardous soils (PCBs, chlorinated solvents, lead)
Cap/Cover + vertical barrier	Prevents infiltration, which can lead to leaching

GW Technology	Qualifying Site Conditions
Phytoremediation/ enhanced Biostimulation	Effective with a variety of mixed contaminants (heavy metals, PAHs, VOCs, SVOCs) in soil and groundwater
In-situ Containment – Slurry Trench	Effective for containing a variety of organic & inorganic contaminants, it's cost-effective

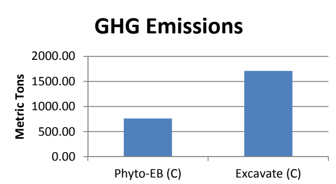
GREM Matrix

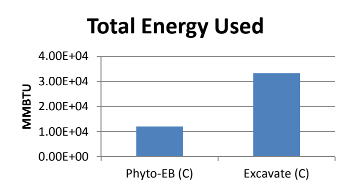
Stressors	Affected Media	Mechanism/Effect	Score			
			Excavate	Phytoremediation	Cap	Slurry Trench
Substance Release/Production						
Airborne NOx & SOx	Air	Acid rain & photochemical smog	Average	Below Avg	Average	Average
Chloro-fluorocarbon vapors	Air	Ozone depletion	Below Avg	Below Avg	Average	Average
Greenhouse gas emissions	Air	Atmospheric warming	Above Avg	Below Avg	Average	Average
Airborne particulates/toxic vapors/gases/water vapor	Air	General air pollution/toxic air/humidity increase	Average	Below Avg	Average	Average
Liquid waste production	Water	Water toxicity/sediment toxicity/sediment	Average	Average	Below Avg	Below Avg
Solid waste production	Land	Land use/toxicity	Above Avg	Average	Below Avg	Average
Thermal Releases						
Warm water	Water	Habitat warming	N/A	Average	N/A	N/A
Warm vapor	Air	Atmospheric humidity	N/A	Average	N/A	N/A
Physical Disturbances/Disruptions						
Soil structure disruption	Land	Habitat destruction/ soil Infertility	Above Avg	Average	Above Avg	Above Avg
Noise/Odor/Vibration/Aesthetics	General environment	Nuisance & safety	Above Avg	Below Avg	Above Avg	Average
Traffic	Land; general environment	Nuisance & safety	Above Avg	Below Avg	Above Avg	Average
Land Stagnation	Land; general environment	Remediation time; cleanup efficiency;re-development	Above Avg	Above Avg	Average	Average
Resource Depletion/Gain (Recycling)						
Petroleum (energy)	Subsurface	Consumption	Average	N/A	Average	Average
Mineral	Subsurface	Consumption	Average	N/A	Below Avg	Average
Construction materials (soil/concrete/plastic)	Land	Consumption/reuse	Above Avg	Below Avg	Above Avg	Average
Land & space	Land	Impoundment/reuse	Average	Above Avg	Above Avg	Average
Surface water & groundwater	Water, land (subsidence)	Impoundment/ sequester/reuse	Average	Average	Above Avg	Average
Biology resources (plants/trees/animals/microorganisms)	Air, water, land/forest, subsurface	Species disappearance/ diversity reduction regenerative ability reduction	Average	Average	Above Avg	Above Avg

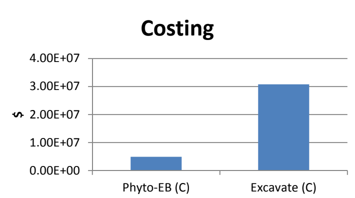
Quantitative Assessment: SiteWise^{TM} – Area C

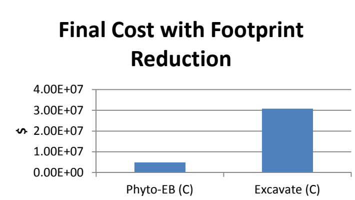
Relative Impact

Remedial Alternatives	GHG Emissions	Energy Usage	Water Usage	NOx emissions	SOx Emissions	PM10 Emissions	*Accident Risk Fatality	*Accident Risk Injury
Phyto-EB (C)	Medium	Medium	High	Medium	Low	Low	High	High
Excavate (C)	High	High	Low	High	High	High	High	Medium

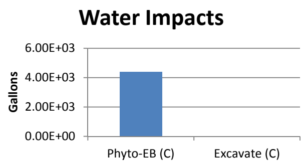


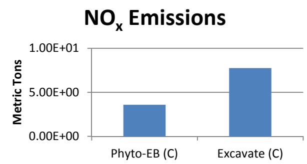


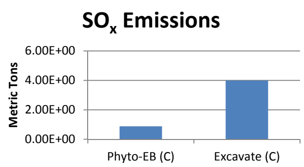


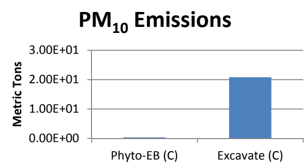


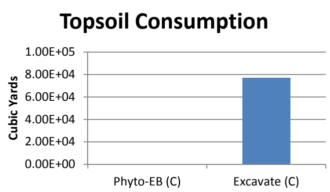
Quantitative Assessment – SiteWise™ – Area C (cont.)











Other Metrics Evaluated with SiteWise™:

- Accident Risk of Fatality & Injury
- Lost hours due to Injury
- Hazardous & Non-Hazardous Landfill Space (tons)

Final Remedial Selection

- **Preliminary evaluation of potential remedial technologies allowed disqualification of multiple methods based on site-specific conditions:**
  - Incompatibility with heterogeneous and silty soils
  - Saturated soils due to high water table
  - Chemical impacts on soil composition unsuitable for habitat rehabilitation
  - Uncertainty of long-term containment
  - Incompatibility with particular COC's and Mixtures
  - Low or uncertain groundwater flow

- **Qualitative (GREM) and Quantitative analysis (Sitewise™, Sustainable Remediation Tool™) allowed comparison of energy inputs and environmental sustainability of remaining technologies :**
  - Site disturbance
  - Material, energy, and total water inputs
  - Particulate (PM_{10}) and GHG emissions (i.e. CO_2, NO_x, SO_x)
  - Cost estimate comparison
  - Long-term waste disposal and treatment needs
  - Worker health & safety risks

- **Site-Specific engineering requirements: 122nd St. causeway located within remediation Area F poses technical challenges influencing final cost and input projections**

Final Remedial Selection:

Phytoremediation & Enhanced Biostimulation

Phytotechnology Mechanisms & Remedial Goals

Mechanism	Description	Remedial Goal
Phytosequestration	Sequestration of some contaminants in rhizosphere via exudation of phytochemicals & transport proteins & cellular processes on root	Containment
Rhizodegradation	Exudation of phytochemicals enhances microbial degradation of contaminants in the rhizosphere	*In-Situ* degradation of contaminants
Phytohydraulics	Ability of plants to evapotranspire sources of surface water and groundwater	Containment via hydrologic controls; will be applied at riparian buffer zones*
Phytoextraction	The ability of plant roots to extract, transport & accumulate contaminants aboveground in the shoots/leaves	Removal of COPC by disposal of plants*
Phytodegradation	Ability of plants to break down contaminants in the transpiration stream via internal enzymatic activity & photosynthetic oxidation/reduction	*In-Situ* degradation of contaminants
Phytovolatilization	Ability of plants to translocate & transpire volatile contaminants	Removal of COPCs (VOC, PAHs) through plants

ITRC - *Phytotechnology Technical and Regulatory Guidance and Decision Trees* (2009).

Phytoremediation - Design Specifications

Selected Tree & Plant Species:

- Chosen based on maximum uptake of organic and inorganic contaminants
- Demonstrated remedial efficacy at sites in the region
  - Argonne National Laboratory-East : nearby site; similar climate, local flora & fauna, and hydrogeology

- **Phreatophyte tree stands** (Willows, Cottonwoods, and Poplars)
  - High transpiration and growth rates; high water consumption
  - Long root systems that maximize contact with pollutants in groundwater
- Grasses and legumes used as **vegetative cover** within and around treated areas
  - Minimize erosion and stabilize soil; also serve to remediate shallow subsurface contamination
  - Enhance overall water consumption and reduce infiltration (minimizing leachate production)
  - Keep shallow soils dry to promote deeper rooting depths of the phreatophytic trees
- **Riparian buffer** of Reeds, Bulrush & Cattails around surface waters
  - Increase infiltration & minimize erosion of wetland shores; minimize runoff & migration of contaminated surface waters

Existing Vegetation:

- Native vegetation with known phytoremedial properties left in place
- Vegetation not applicable for phytoremediation AND not considered an invasive species will be cleared and chipped for compost
- Non-native invasive species will be removed completely (not composted to reduce possibility of reincorporation of invasive species into soil)

Existing Vegetation

- Only 51% of on-site vegetation identified as native species (marked by an *)
- Dominant existing vegetation – Common Reed (*Phragmites* spp.) - is more tolerant to high salinity (~20,000 mg/kg) than native vegetation
  - Common Reed also provides interim nesting habitat for black-crowned night heron

Plant Name/Species	Targeted Contaminants	Recommendation for Use?
Common water plantain (*Alisma subcordatum*)*	TBD or N/A	Determination based on analysis
Path rush (*Juncus tenuis)**	TBD or N/A	Determination based on analysis
Small duckweed (*Lemna minor*)*	Pb, Cr(VI), certain pesticides	**Yes**
Switchgrass (Panicum virgatum)	Anthracene, PAHs, Pyrene	**Yes**
Common reed (*Phragmities* spp.)	Benzene, Trichloroethane, Toulene, PCE, TCE, Cu, Fe, Mn	**Yes**
Eastern cottonwood (*Populus deltoides*)	TCE, PCE	**Yes**
Box elder (*Acer negundo*)	TBD or N/A	Determination based on analysis
Hackberry (*Celtis occidentalis*)	TBD or N/A	Determination based on analysis
Green ash (*Fraxinus penn.*)	TBD or N/A	Determination based on analysis

Enhanced Biostimulation

Purpose:

- Support plant growth & enhance phytoremedial processes
- Stimulate the natural microbial population in rhizosphere of trees
- Improve overall soil quality & stimulate soil microbial community

Strategy: Incorporation of O_2 and nutrients in tilled soil

- O_2 Amendment
  - Supplied via **ORC**s (Oxygen Release Compounds – MgO_2)
  - ➢Instead of direct injection (reducing energy and equipment costs)
  - ➢Soil pH must be monitored (MgO_2 can raise pH)
- NPK fertilizer (10-10-10)
  - ➢One initial application after tree installation
  - ➢Further applications as needed to prevent excessive losses
- Additional amendments as needed
  - ➢Granular Sulfur or $Al_2(SO_4)_3$ to reduce soil pH to levels for optimal tree growth (ex: Poplar grows optimally with pH of 5.5-8.0) at select locations
  - ➢Additional organic compost each spring to promote optimal plant growth & maintain pH

Phytoremediation – Implementation

Time of Year

— Trees and plants installed early in year (spring) to take advantage of entire growing season; remedial progress greatest during growth

Soil Preparation

— Areas to be tilled to aerate soil prior to planting (12-24 in); soil amendments added during tilling, eliminating need for injection wells

— Soil should be damp during installation to minimize dust production & potential exposure of contaminated soils/sediments to workers

Dimensions & Placement

— Each tree placed in 2 ft diameter trench dug to variable depths 10-15 ft bgs

— In areas with GW contamination, 50% of trees will be lined with tree wells to promote downward root growth into the aquifer

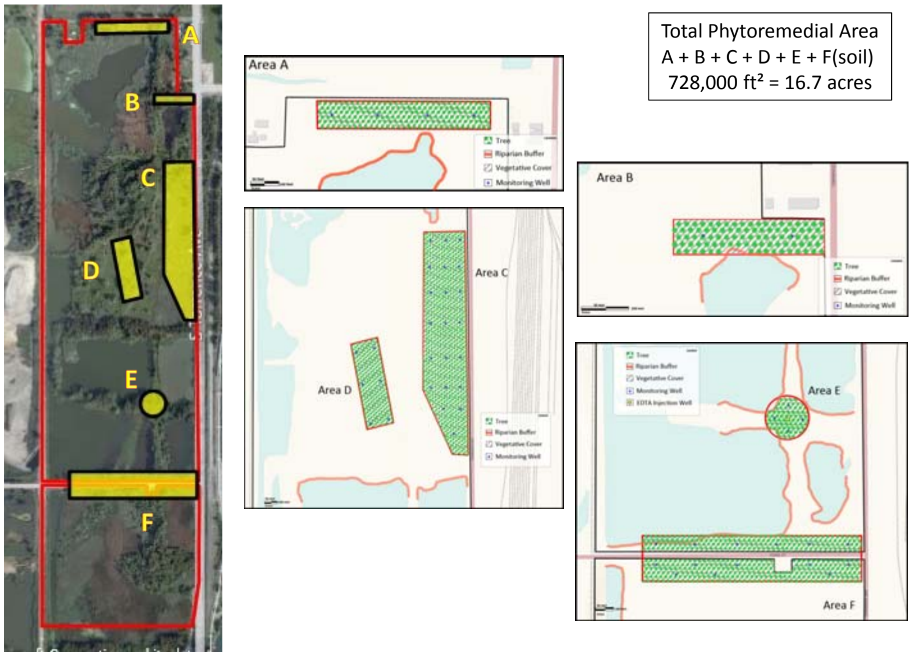
— Trees spaced ~10 feet apart to achieve high growth density → maximum remedial efficiency

***Area E Only:** Installation of 1 injection well for application of EDTA (chelating agent) to enhance Pb uptake

Planting Scheme

	Seed Mix (lbs)	Willows	Cottonwoods	Hybrid Poplars	Fencing (yards)	Fertilizer (lbs)	Rows	Columns
Area A	128	48	48	96	481	180	6	32
Area B	54	21	21	43	280	81	5	17
Area C	640	250	250	500	1040	960	69	13
Area D	170	67	67	135	270	255	27	10
Area E	100	40	40	80	225	150	10	10
Area F(North)	141	36	36	72	780	325	4	35
Area F(South)	202	82	82	165	805	250	6	55
Sum	1435	544	544	1091	3381	2201	127	299

Planting Scheme



Total Phytoremedial Area
A + B + C + D + E + F(soil)
728,000 ft² = 16.7 acres

Final Recommendations

- Initiate phytoremediation at all AOCs using mixed tree stands of Willows, Cottonwoods, and Poplars, supplemented by a vegetative cover of grasses and legumes to address shallow subsurface soils
  - Riparian buffer zones of cattails, bulrush, and reeds around surface water bodies to minimize runoff and interaction with contaminated groundwater
- Monitor remedial progress and ensure potential adverse effects on native vegetation and wildlife are not incurred during remediation; ensure non-native/invasive species are not introduced into seedbank
- Install additional monitoring wells at under-represented areas for LTM
- Ensure adequate habitat exists for seasonal migratory birds that depend on wetlands & is preserved during earthwork & agricultural activities
- Gain public support for project by increasing public awareness of phytoremediation & sustainable practices used at IRM
  - Involve community through educational activities & bulletins describing habitat restoration, native species and phytoremedial progress

Acknowledgements

SURF
(UIC Student Chapter and Travel Support)

Chicago Park District

Terracon Consultants, Naperville, IL

Thanks for listening!

Attachment 7
Engineered Attenuation Zone for Petroleum Hydrocarbons

Field Demonstration of an Engineered Attenuation Zone for Petroleum Hydrocarbons

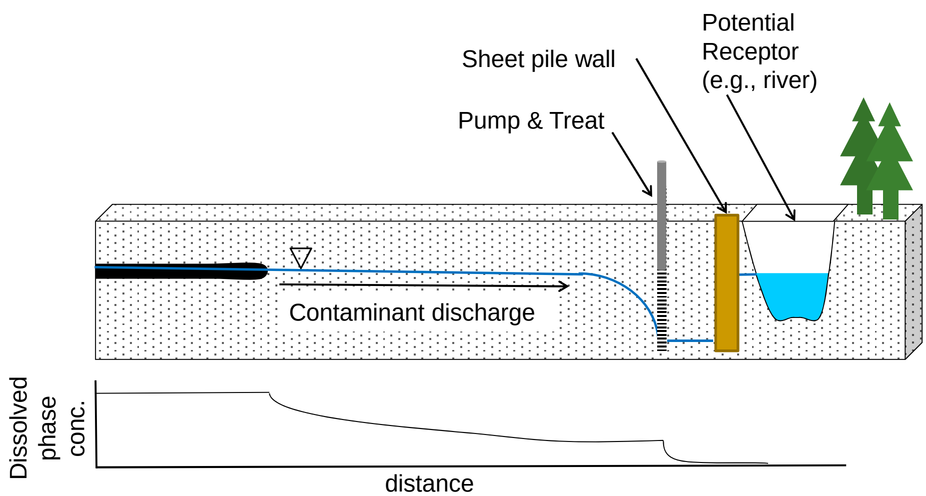
Mitch Olson and Tom Sale; Colorado State University

Sustainable Remediation Forum
SURF 20
Fort Collins, Colorado
July 24-26, 2011

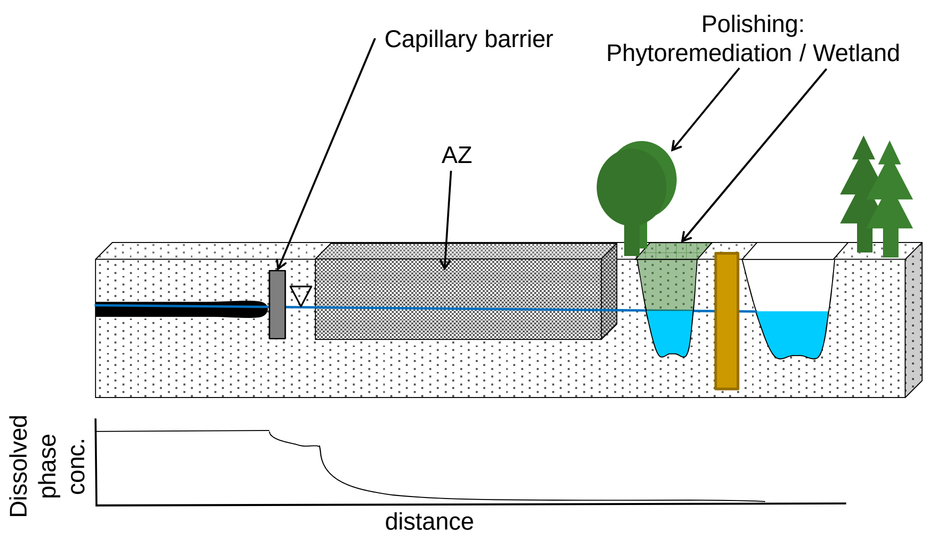
Engineered Attenuation Zone (AZ)

- Vision: replace pump-and-treat with a passive remedy
- Elements
  - Remove impacted soils
  - Replace with backfill
  - Engineer backfill to enhance natural attenuation
- Demonstration objectives
  - Evaluating feasibility, potential backfill, longevity

AZ implementation



AZ implementation



AZ Field Demonstration

- Flume 1
  - Clean backfill only
- Flume 2
  - Clean backfill plus O_2 emitter
- Flume 3
  - Clean backfill +
  - Gypsum (2%) and hematite (2%)

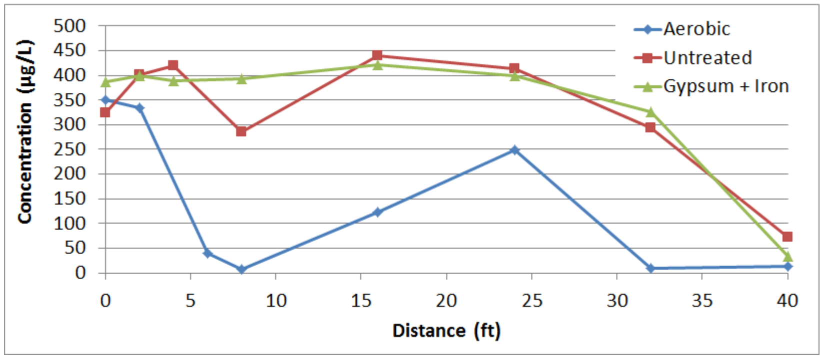
MacKay/ Einarson O_2 diffuser

Inspired by the Borden "Barker barn"

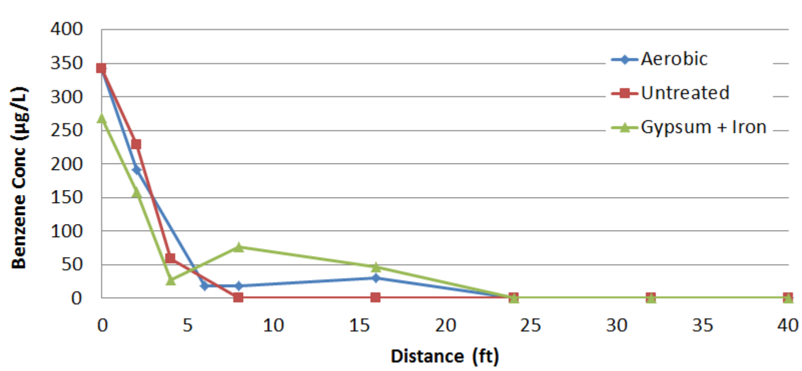
The beauty of indoor sampling

January 2010

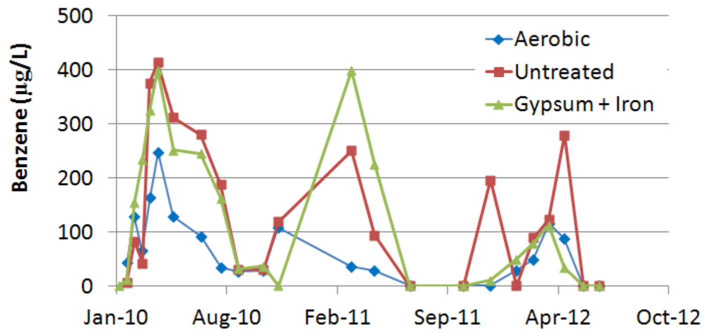
Benzene degradation
April 2010 (84 days)



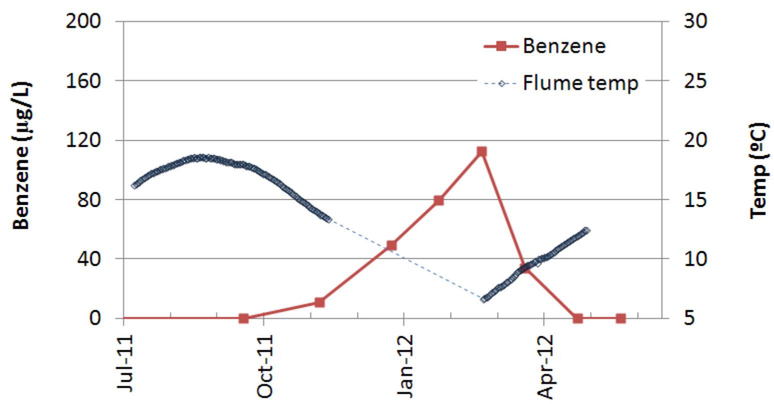
Benzene degradation
August 2010 (230 days)



Benzene concentration vs. time

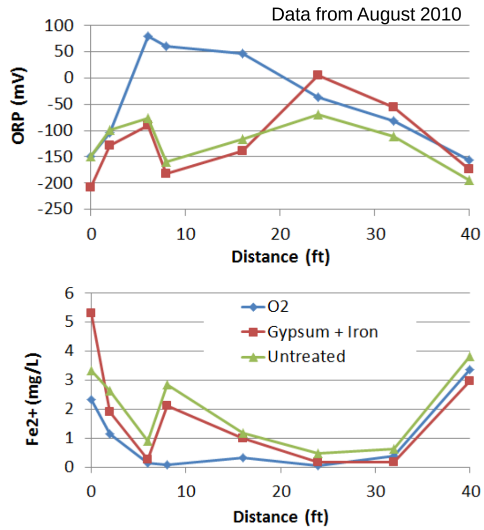


Effect of temperature



What processes are at work?

- Anaerobic flumes:
  - ORP: -100 to -200 mV
  - Fe^{2+}: ~5 mg/L near inlet
  - SO_4^{2-}: steady at ~900 mg/L
  - Iron reducing conditions?



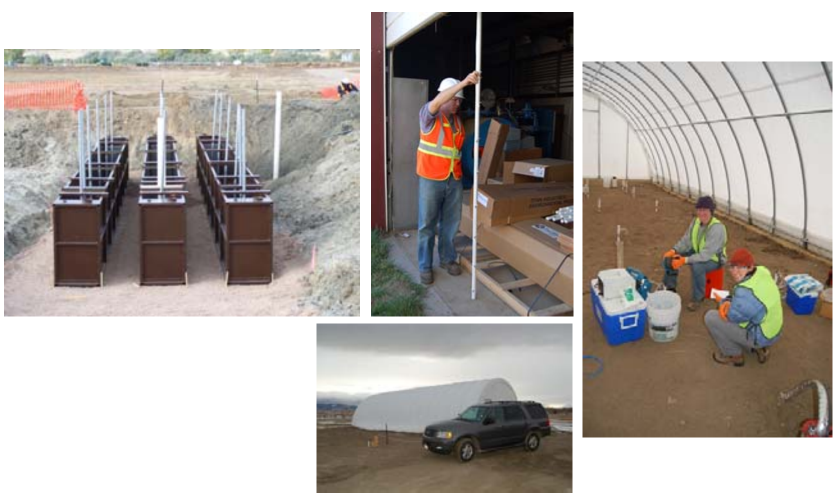
Conclusions

- AZ: promise of sustainable remediation
- Aerobic
  - Became biologically active quickly
  - Potential distribution issues
- Anaerobic
  - Long time (6 mos.) required for bio activity
  - Near-complete removal of BTEX in 2-4 ft
  - Appears to be iron-reducing conditions
- Upset by cold temperatures
  - Not relevant to full-scale treatment?

Acknowledgments

- Sponsor
- Trihydro
- Jr. Garza & Bart Rust, CSU

Questions?



Attachment 8
Anaerobic Membrane Bioreactor Optimization

SURF
SUSTAINABLE REMEDIATION FORUM

SURF 20
July 24, 2012

Optimization of an Anaerobic Membrane Bioreactor for Municipal Wastewater Treatment

Dustin Whynman and Christopher Bellona
Clarkson University Department of Civil and Environmental Engineering
Potsdam, NY

Outline

- Anaerobic Digestion
- Wastewater Treatment Options
- Research Objectives
- Experimental Design
- Results
- Future Work

Traditional Wastewater Treatment Options

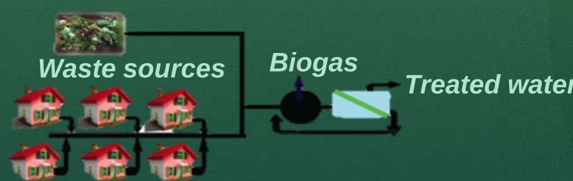
- Activated sludge
  - Most common form of wastewater treatment
  - Very energy intensive
  - All stored potential energy in wastewater is lost
  - Short treatment time of 1-5 hours
  - Higher quality effluent than anaerobic digestion
- Anaerobic digestion
  - Microbes convert organic material to methane
  - Produces a renewable energy source (biogas)
  - Much longer treatment time 30-50 days

Anaerobic Treatment of Primary Wastewater

- Anaerobic membrane bioreactors may offer advantages for primary wastewater treatment
  - Potential source of energy (biogas)
  - Reduced tank volume/footprint and HRT compared to conventional anaerobic digestion
  - Less energy intensive than aerobic digestion
- Disadvantages to anaerobic digestion and AnMBR
  - Low strength
    - Past results have shown that an additional carbon source may be necessary
  - Effluent water quality
  - Membrane fouling

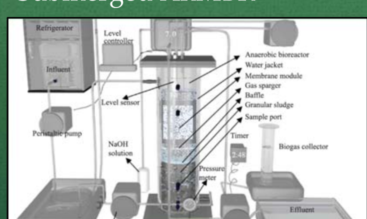
Purpose

- Evaluate the potential of AnMBR system for treating combined waste stream of wastewater and food waste in decentralized communities, such as:
  - Forward operating bases (e.g., Afghanistan)
  - Remote industrial applications (e.g., mining operations)
  - Residential installations



AnMBR Configuations

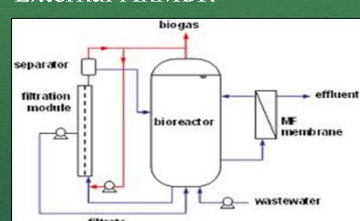
Submerged AnMBR



Xie, K et al. (2010): Performance and fouling characteristics of a submerged anaerobic membrane bioreactor for kraft evaporator condensate treatment, Environmental Technology, 31:5, 511-521

Past findings
- Low operating Flux <30 LMH
- More complicated system design
- Higher membrane failure rate

External AnMBR



Schematic representation of the anmbr with external filtration module for dynamic memrane filtration.,Retrieved from http://www.ejbiotechnology.cl/content/vol11/issue4/full/9/f3.html

Past findings
- High operating flux ≈ 100 LMH
- Need to consider sheer in system design
- Easier access to membrane module
- Higher recovery

Research Objective

- Evaluate the effect of cross flow velocity on AnMBR performance
  - Fouling
  - Biogas content and production
  - Effluent water quality
- Evaluate the effect of HRT on AnMBR performance
  - Biogas content and production
  - Effluent water quality

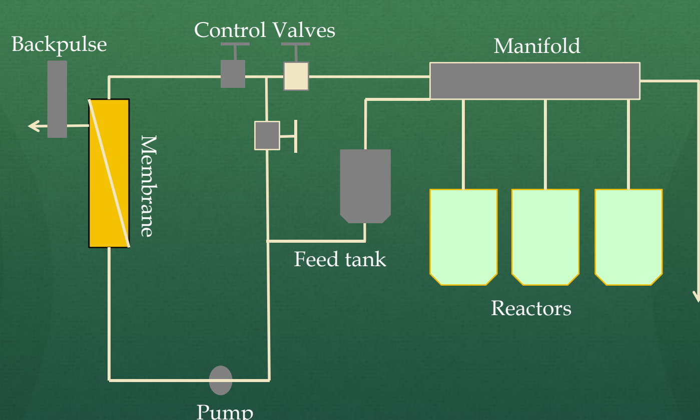
Experimental Design

- The reactor was started at a 10 day HRT
- Membrane was started with a CFV of 1.5 m/s. This will later be changed to 1.0 and then 0.5 m/s.
- After finding the optimum CFV for the system, the HRT will be lowered to find the lowest possible retention time that still provides adequate treatment.
- Membrane is cleaned by backpulsing at high pressure.

Membrane System

- Ceramic membrane
  - 25 mm long
  - 5 cm^2 surface area
  - 0.2 µm pore size
  - Al_2O_3 support
  - ZrO_2 active layer
- Backpulsing
  - 3 ml of permeate used for each back-pulse cycle

Design Schematic



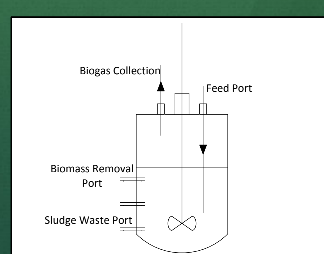
Substrate

- The digesters are fed a mixture of 2.3 grams of food waste per liter of municipal wastewater.

Substrate	Parameter	
Food waste	COD	100 grams COD/kg
Wastewater	COD	0.5-0.7 grams COD/kg
Mixed waste	COD	~1000 mg COD/L
Mixed waste	Total Nitrogen	39 mg/L
Mixed waste	TOC	625 mg/L

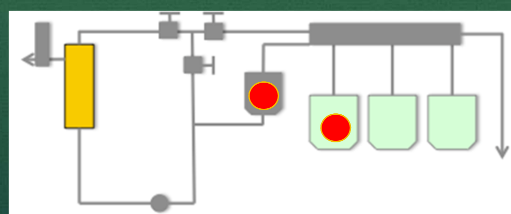
Reactors

- 10 L glass reactors
- Seeded with 5.5 liters of anaerobic effluent from WWTP and 1 liter of wastewater / food mixture
- Mixed continuously at 50 RPM
- Temperature kept at 37.5° C
- Target COD - 800 mg/l

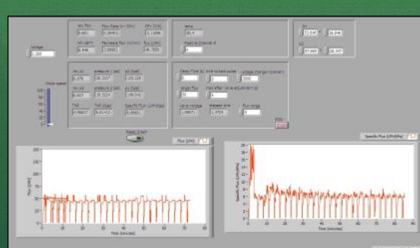


Membrane Operation

- The effluent is pumped into the tank connected to the membrane loop
- Effluent is cycled through the loop until the permeate removed equals the amount fed to the digester
- The remaining solids are then returned to the digester



Automation



Fully automated system developed through LabView allows for control of:

- Flux
- Cross-flow velocity
- Backpulse frequency

Data automatically logged:

- Permeate flow rate and flux
- Cross-flow velocity
- Trans-membrane pressure
- Specific flux
- Temperature

Measured Parameters

- Water quality analysis
  - COD
  - TOC
  - TN
  - Ammonia
  - Turbidity
- Biogas production
  - Monitored daily for content and volume
- Digester health
  - pH
  - Alkalinity
  - VFA

Fouling

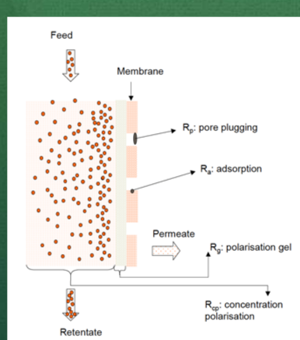
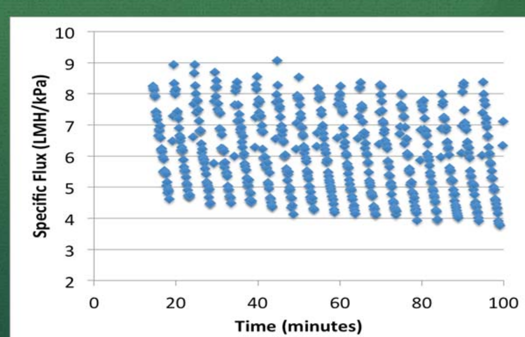


Image from: Membralox users manual



Raw data from SCADA system

Fouling

- Needed a way to compare fouling when working with different wastes, CFVs, membranes, etc…
  - Fouling indices can normalize data in order to compare fouling under different operating parameters.
    - Total Fouling Index (TFI) = HRFI+HIFI+CIFI
  - Performed experiments with different waste streams in order to determine the best operating parameters

Fouling Indices

$$J = \frac{\Delta P}{\mu K}$$

$$K = k_{Membrane} + k_{fouling} * V$$

$$\frac{J}{\Delta P} = \frac{1}{\mu(k_{Membrane} + k_{fouling} * V)}$$

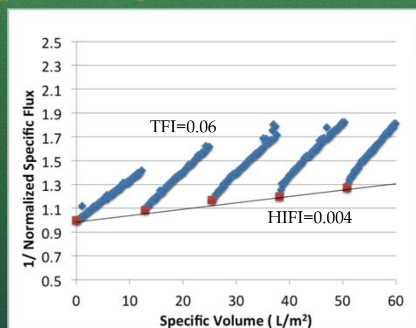
$$(\frac{J}{\Delta P})_0 = \frac{1}{\mu k_{Membrane}}$$

$$J_s^{'} = \frac{1}{1 + \frac{k_{fouling}}{k_{Membrane}} * V}$$

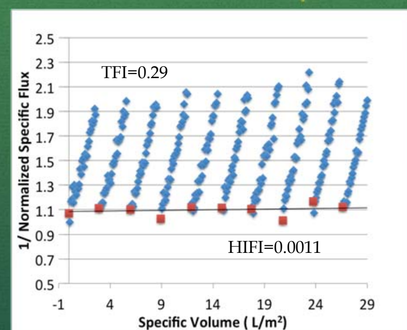
$$\frac{1}{J_s^{'}} = 1 + \frac{k_{fouling}}{k_{Membrane}} * V$$

$$\frac{1}{J_s^{'}} = 1 + (TFI) * V$$

Irreversible Fouling



Fouling Indices for Secondary Effluent



Fouling Indices for Digester Effluent

- Despite the high TFI of the digester effluent the HIFI is still comparable to secondary effluent due to the effectiveness of the backpulsing

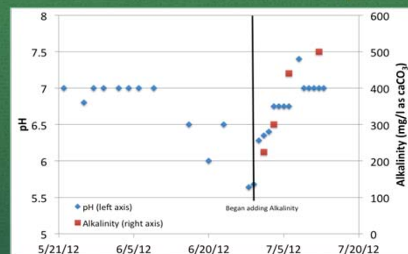
Water Quality Analysis

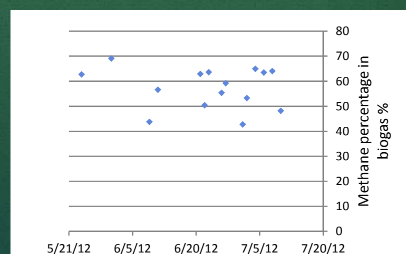
Average water quality values of the feed, digester effluent, and permeate

Parameter	Feed	Digester Effluent	Permeate
COD (mg/L)	1000	1900	70
TOC (mg/L)	625	140	27
TN (mg/L)	39	35	22
Ammonia (mg/L)	10	23	20
Turbidity (NTU)	205	1500	15

Reactor Health

- Reactor pH and alkalinity
- pH is an indicator of reactor health, If pH drops below 6.5, alkalinity is added
- Looking a methane concentration of >60% methane





Conclusions

- COD removal of greater than 90% demonstrates good wastewater treatment
- Low irreversible fouling indices prove backpulsing is an effective way to mitigate fouling while working with high strength waste streams
- Monitoring and adjusting of pH and alkalinity is very important to maintain the efficient digester operation

Future Work

- Finish experiment at 1.5 m/s CFV
- Perform other two CFV experiments
- Optimize HRT for treatment
- Investigate further polishing of permeate with NF and RO membranes.
- Acknowledgments
  - Christopher Bellona
  - Han Gao

Attachment 9
Hydrocarbon Sheens: Governing Processes and Innovative Solutions

Hydrocarbon Sheens – Governing Processes and Innovative Solutions

Alison Hawkins, Julio Zimbron, and Tom Sale

Sustainable Remediation Forum
Colorado State University
Fort Collins, CO
July 24, 2012

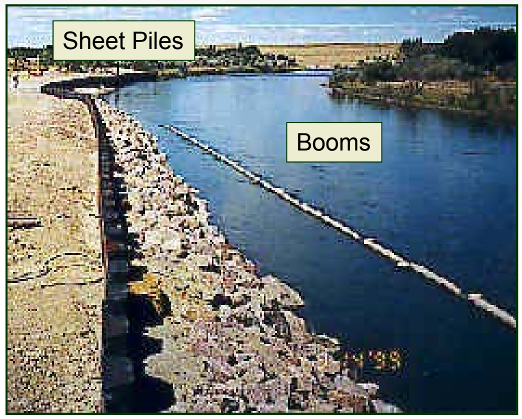
Colorado State University
Civil and Environmental Engineering
CCH
Center for Contaminant Hydrology

Research Motivation

- Sheens are
  - Common at many sites
  - Challenging to manage
- Scope
  - Understand processes
  - Advance innovative solutions
  - Sustainable

Best Management Practices
(Sustainable?)

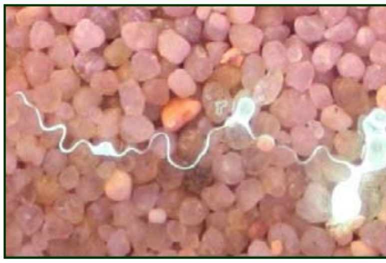
Hydraulic Control

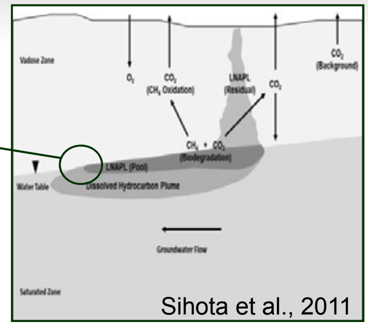


Outline

- Background
- Methods
- Innovative Solutions
  - Capillary Barriers
  - Organoclay Barriers
- Future Work
- Conclusions

Background



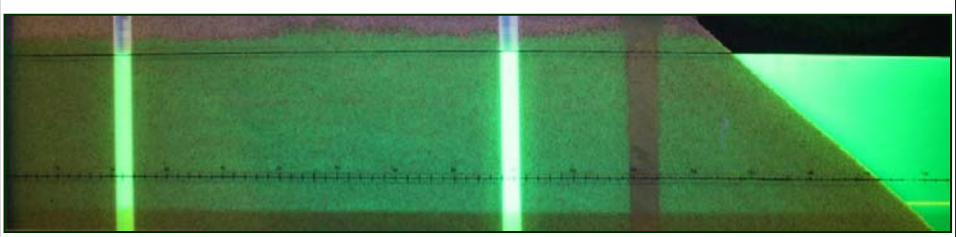


Sihota et al., 2011

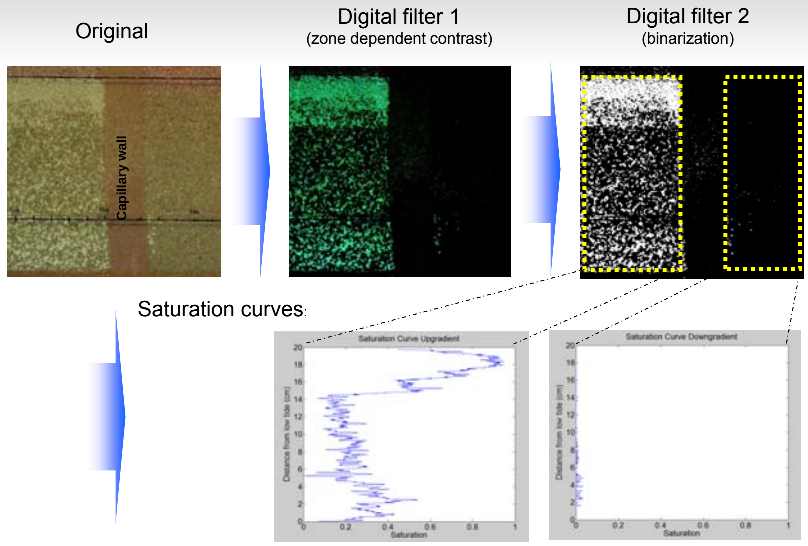
Conventional conceptual models of LNAPL distribution often overlook capillary forces at the LNAPL-water-air interphase

Methods

- 180 cm long sand tank
- Water dyed with Fluorescein
- Diesel dyed with Stay Brite
- Diesel inflow representative of a leak
- Tidal setting achieved with computer-controlled pumps

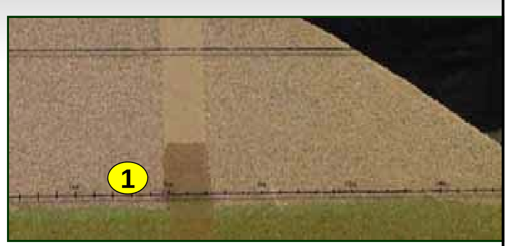


Saturation Curves



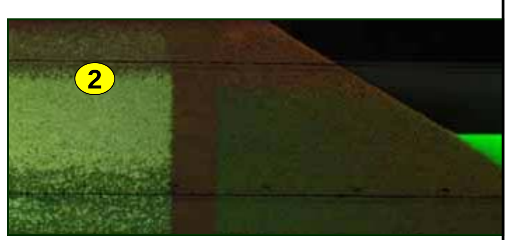
Capillary Barrier

1 Fine-grained media creates capillary rise that precludes intermediate wetting phase flow



2 Insufficient capillary pressure to displace water

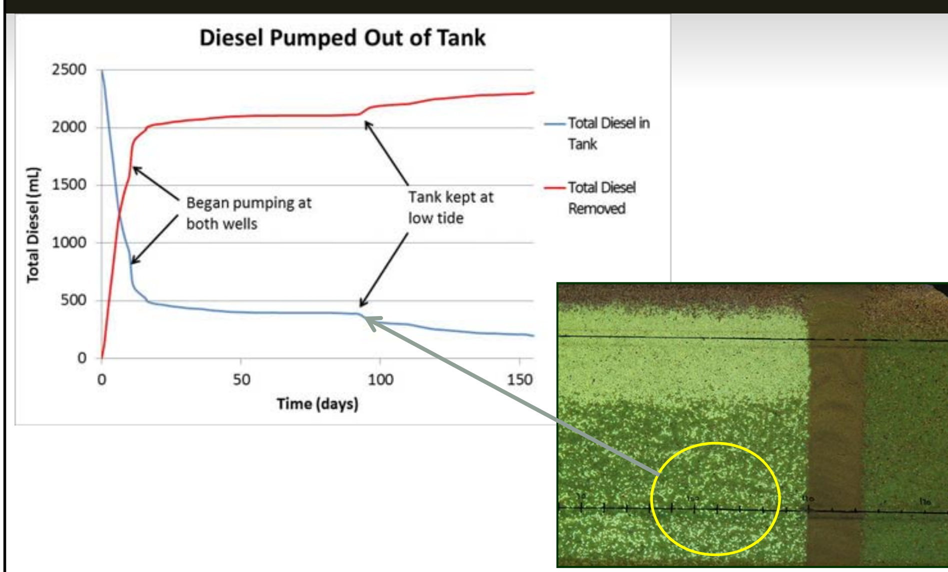
$$P_c < P_d$$



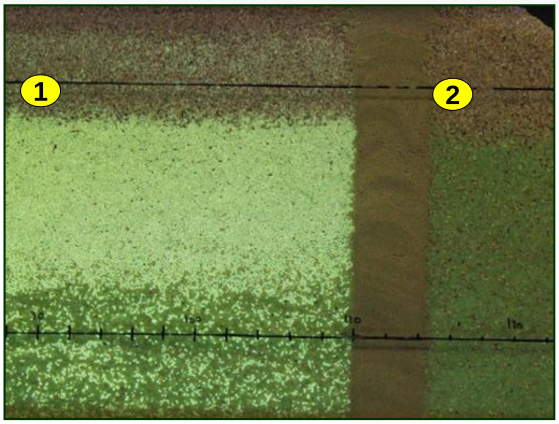
Capillary Barrier Video

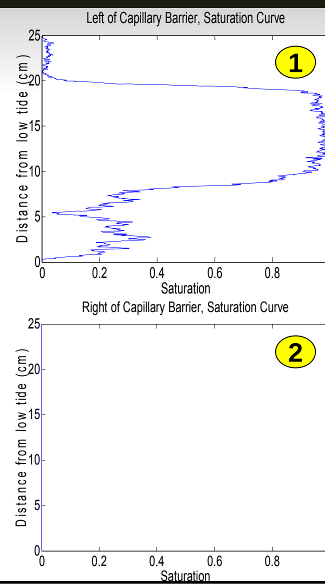
Cap Barrier - Short.mpg

Capillary Barrier with Pumping



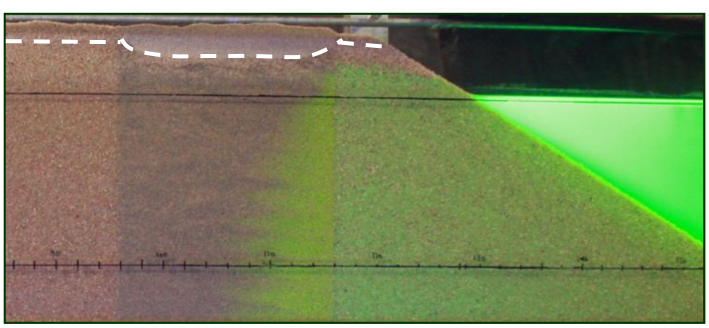
Capillary Barrier – Saturation





Organoclay Barrier

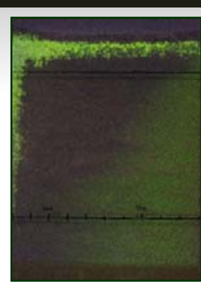
- Chemically altered bentonite
- Hydrophobic
- Mechanism - Adsorption

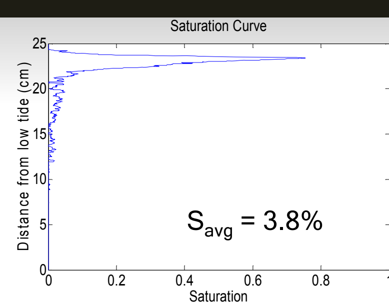


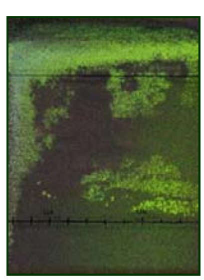
Organoclay Barrier Video

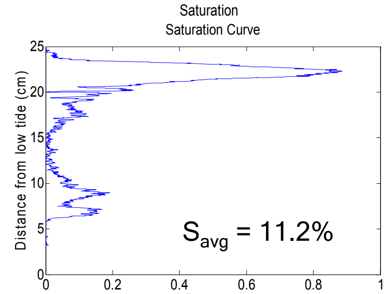
OC Barrier short.mpg

Organoclay Barrier – Saturation





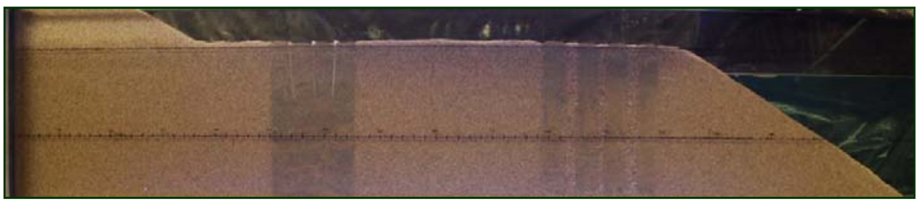




Jim Olsta – Organoclay barriers have been used for years on many creosote and coal tar DNAPL sites with no reports of breakthrough

Organoclay Limitations / Improvements

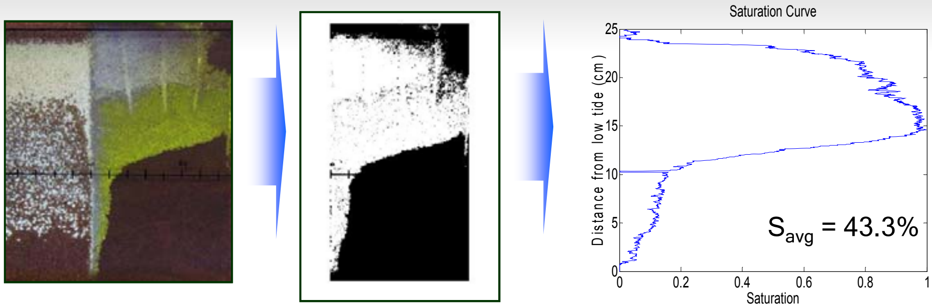
- Organoclay Limitations
  - Drainage
  - Preferential flow paths
  - Low bulk sorption
- Organoclay Improvements
  - -Impermeable barrier at top of OC
  - -Drainage Lines



Improved Organoclay Barrier Video

Organoclay Barrier Improved.mpg

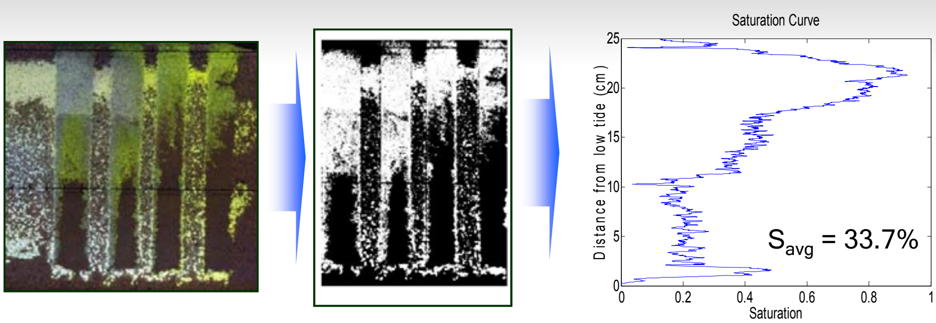
Organoclay Solutions



- HDPE barriers increase amount of organoclay / LNAPL contact

Organoclay barrier average saturation increases ~4x

Organoclay Solutions

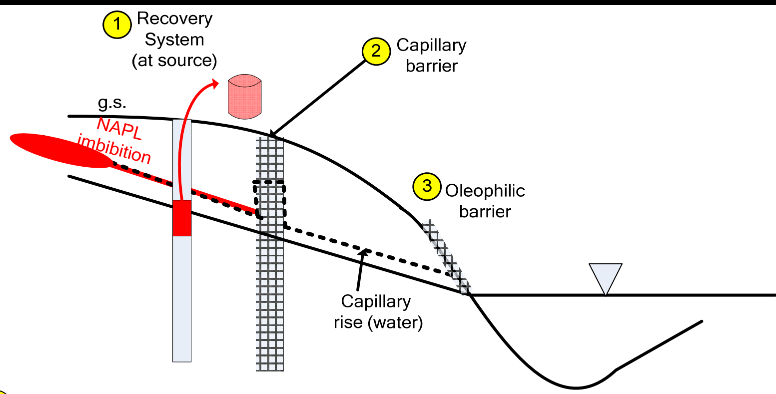


- Drain lines increase amount of organoclay / LNAPL contact

Organoclay barrier average saturation increases ~3x

Future Work

(Belt & Suspenders)

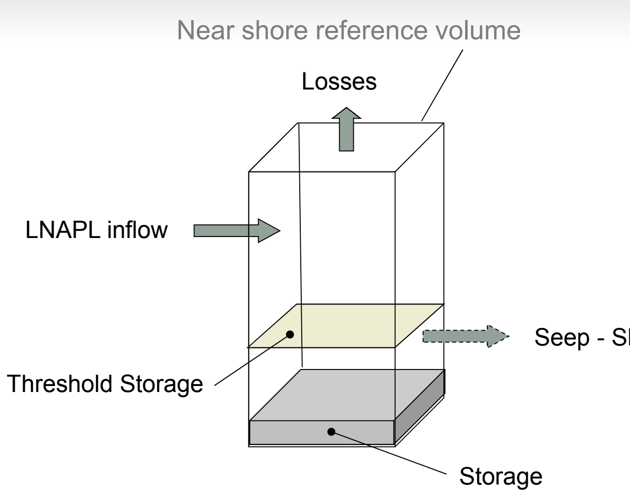


1 **Recovery system** deals with bulk mass at source

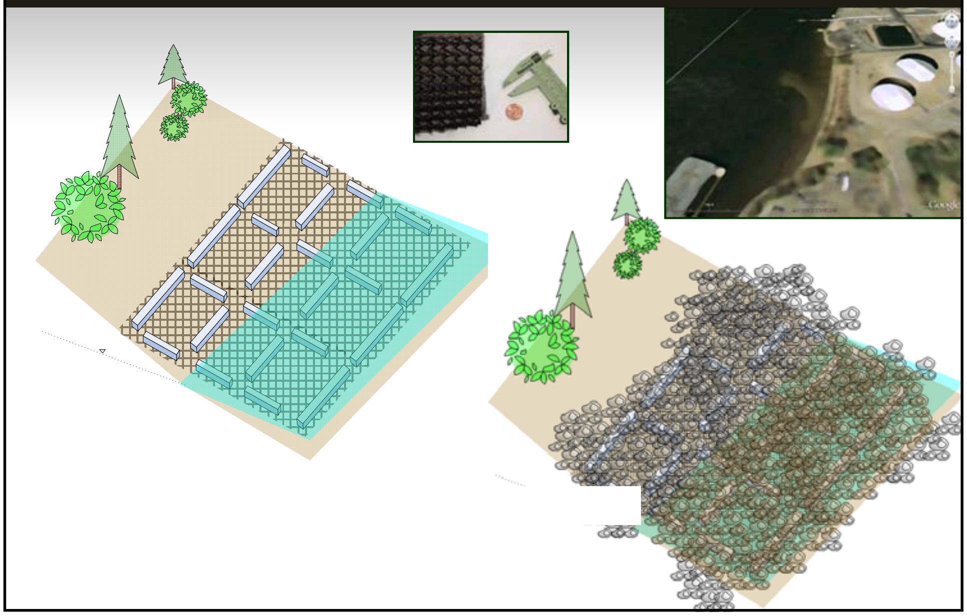
2 **Capillary barrier** stops or reduces flux into surface water and increases NAPL thickness at Recovery system 1

3 **Oleophilic barrier** offers a final layer of protection at surface water's edge and an additional depletion mechanism through biodegradation at the oxygen-rich interface

Mass Balance



Field Testing: Oleophilic Bio-Barrier



Conclusions

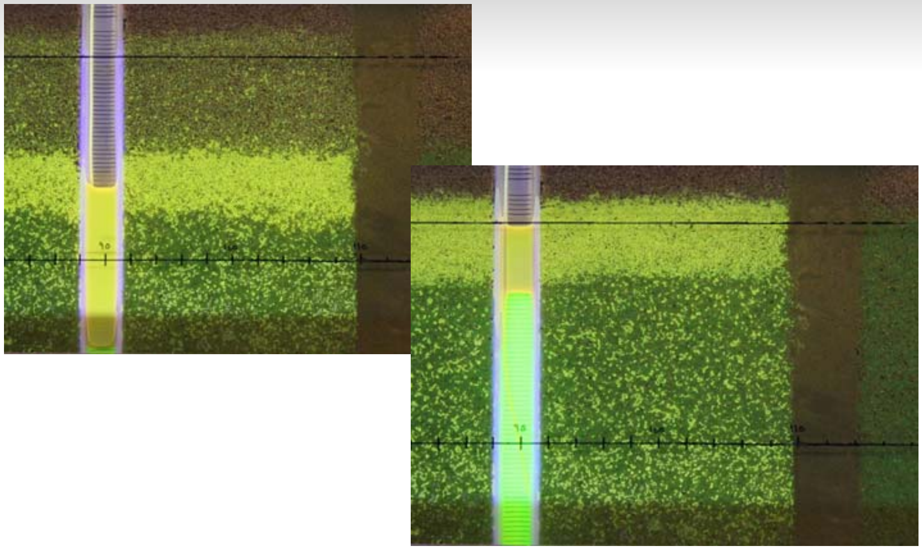
- Opportunity of more sustainable solutions
- LNAPL migration can be controlled by managing capillary forces
- Capillary and organoclay barriers are innovative solutions – fundamental research will drive improvements
- Preferential flow is a potential drawback of organoclay barriers
- Upcoming field demonstration of Oleophilic Bio-Barriers

Acknowledgements

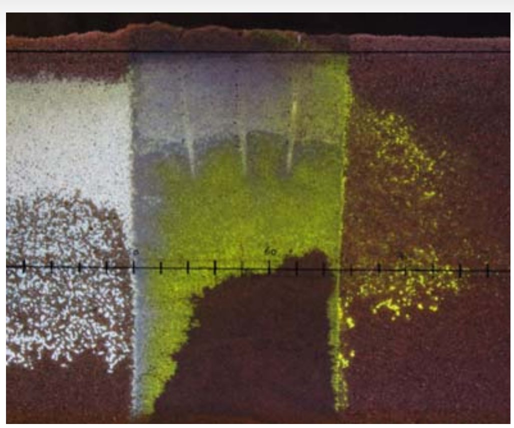
- Chevron
  - Mark Lyverse
  - Pat Hughes
- Fellow students and co-workers
  - Gary Dick
  - Anna Skinner
  - Adam Byrne
  - Tim Smith

Questions

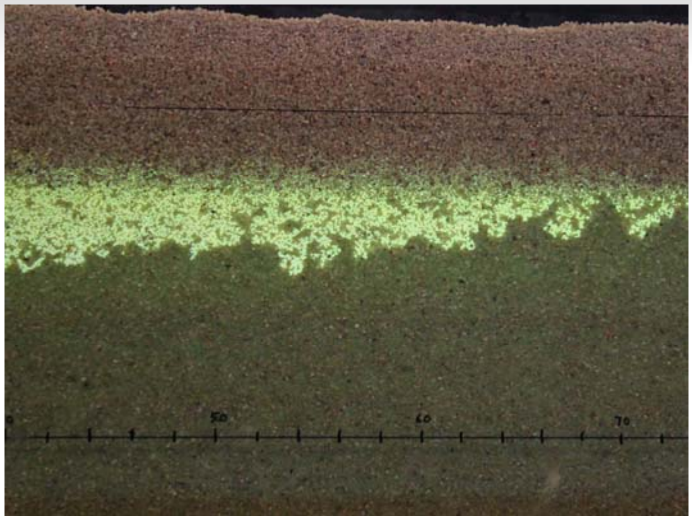
Well Thickness



OC Barrier with Baffles



Non Tidal



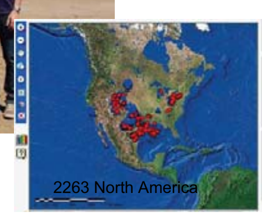
Attachment 10
Comments on Relevance to SURF

Resurgence of Oil and Gas Development Implications for Sustainable Remediation

SURF 20,

Wednesday July, 25, 2012

Resurgence

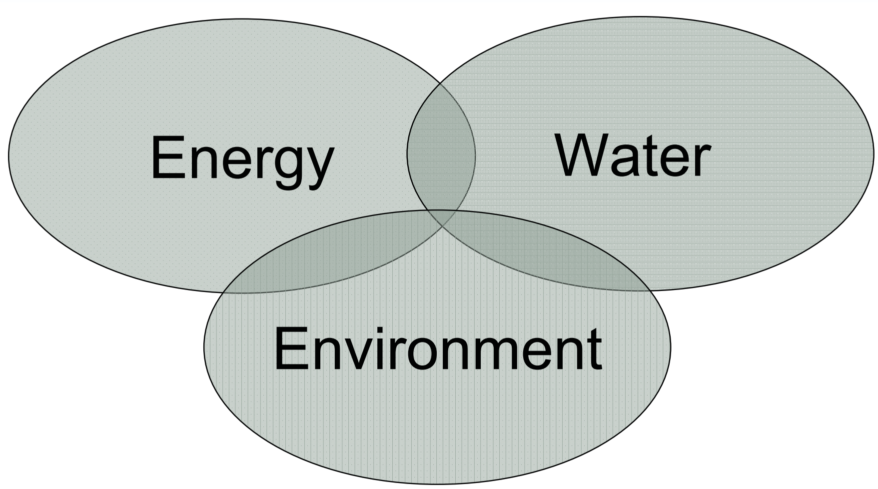


investor.shareholder.com/bhi/rig_counts/rc_index.cfm

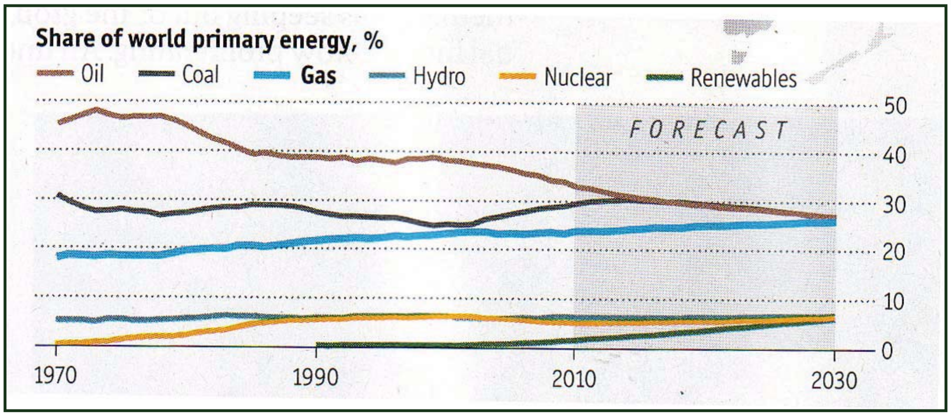
A revolution driven by

- Fast drilling methods
- New completion techniques
- Energy prices
- Recognition of a vast resource
- Licence to operate

Comments on Relevance to SURF



Energy future?



The Economist – July 14, 2012 - Special Report on the Gas Bonanza

Remediation

- Groundwater
- Surface water
- Air
- Land

Prevention

Rewards

- High paying jobs
- Afforable fuels
- Improved trade balances
- Tax revenue for communities
- Energy security
- Natural gas as a bridge enabling renewable energy
- New technology that can be exported to the world

2011 Field Trip Courtesy of ENSIGN Drilling and HydroResources

Doing Energy Right

Speakers

- **Dr. Sally Sutton** - Hydrocarbons in Shale
  Geosciences
- **Dr. Tom Sale** – Water: Drilling and well completions
  Civil and Environmental Engineering
- **Dr. Ken Carlson** - Water: Use and Treatment
  Civil and Environmental Engineering
- **Dr. Allen Robinson** - Air: Volatile Compounds and Greenhouse Gases
  Engines and Energy Conversion Laboratory
- **Dr. Morgan DeFoort** - Managing air emissions from well heads, processes units, tank batteries, and engines
  Engines and Energy Conversion Laboratory
- **Bill Ritter** - Policy
  Former Governor of Colorado

Attachment 11
Brief Introduction to the Geology of Natural Gas and Oil

A Brief Introduction to THE GEOLOGY OF NATURAL GAS AND OIL

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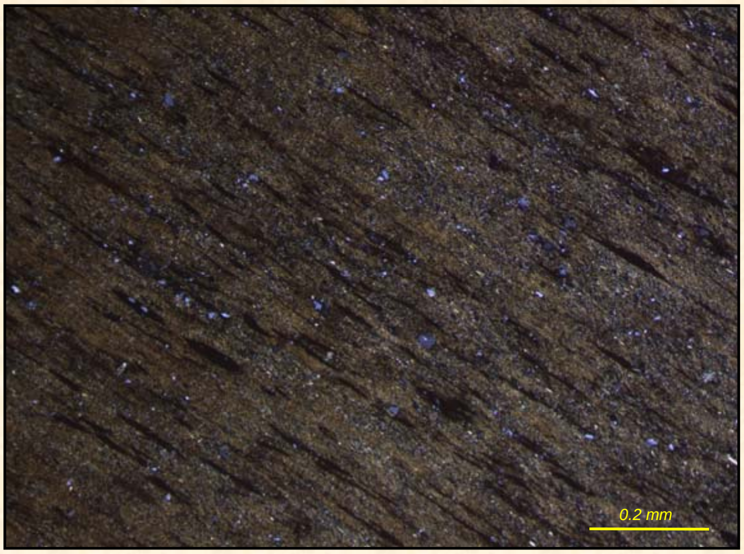
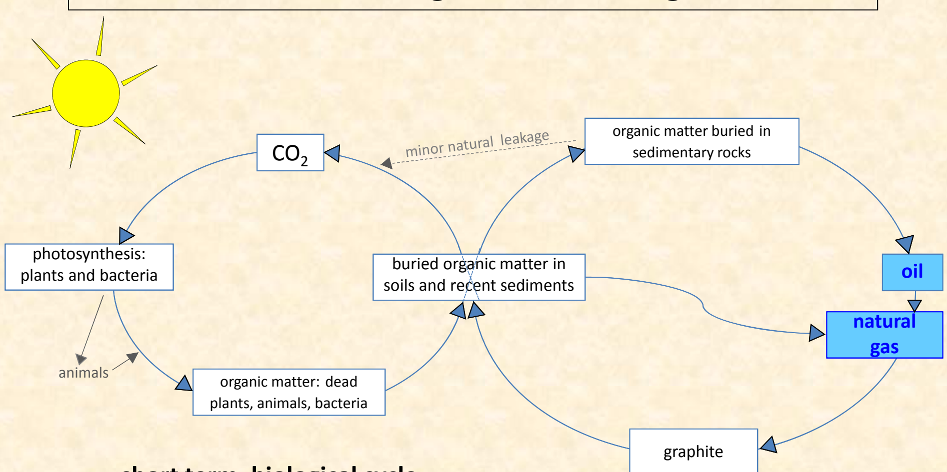
The recent surge in gas and oil development in the U.S. is in extraction from fine-grained rocks, “Shales” or “mudrocks”. These are fine-grained sedimentary rocks made from solidified mud. Here we use the term “shale” loosely to include most rocks solidified from fine-grained mud.



Most shales are very low in porosity and permeability.
Oil, natural gas, or water move through them at extremely low flow rates.
In conventional gas and oil production, shales are important as flow barriers that keep natural gas and oil accumulations in place.

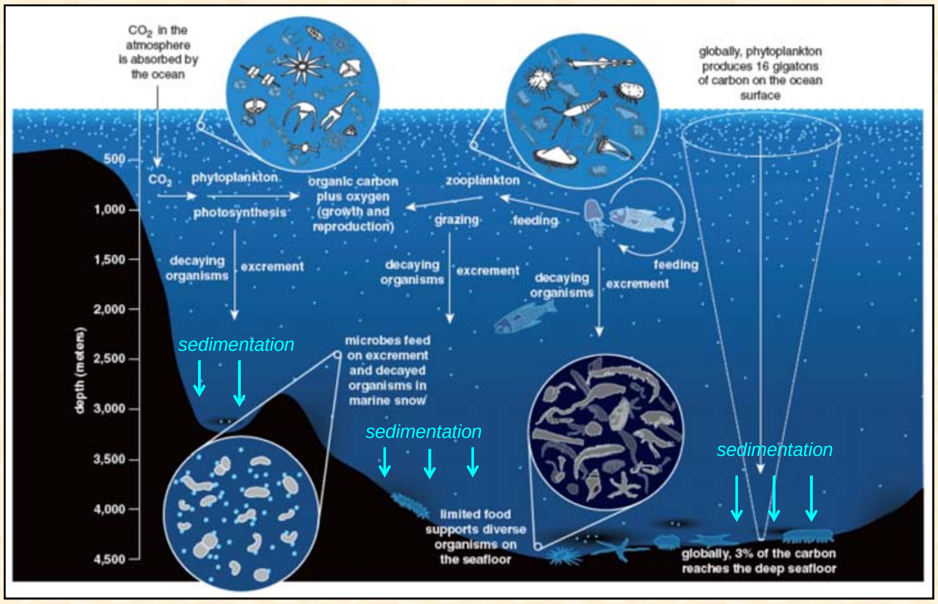
Where do natural gas and oil in rocks come from?
From chemical changes in buried organic matter.



short term, biological cycle
cycle length = days to years
3×10^{12} tons carbon

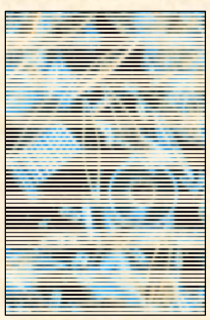
long term, geological cycle
cycle length = millions of years
6×10^{15} tons carbon

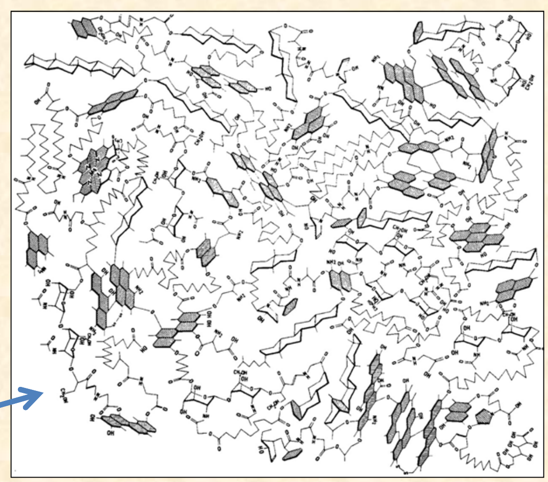
adapted from Tissot and Welte (1984)



Modified from mostlyopenocean.blogspot.com

Dead organisms trapped in seafloor mud are partially transformed to "kerogen".

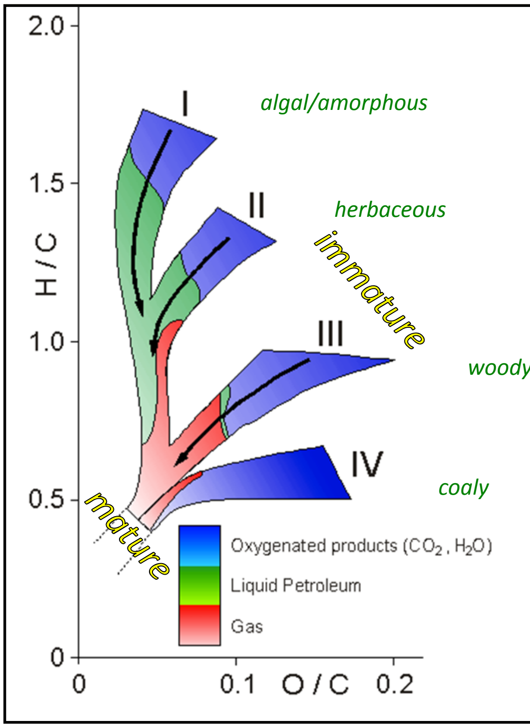




Kerogen has a complex, poorly organized molecular structure.

Immature "Type II" kerogen . From Behar and Vandenbroucke (1987)

As the sediment is more deeply buried, the kerogen "matures" to generate gas and oil.



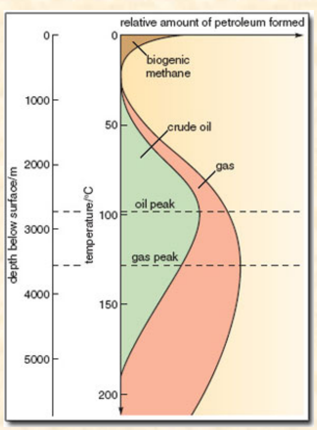
Kerogen Types

Kerogen occurs in different types that vary in content of hydrogen and oxygen, as compared to carbon, and that depend origin.

Different kinds of kerogen have differing potentials to produce gas or oil during thermal maturation.

Modified from <www.geosci.monash.ed.au/heatflow>

With increasing depth in sediments, the temperature increases and kerogen undergoes chemical reactions that yields hydrocarbons.



Organic matter can yield **natural gas** by two pathways:

1. **Biogenic gas**: At shallow depths, through metabolic processes of microbes.

1. **Thermogenic gas**: With deeper burial and heating that chemically alter organic molecules or oil, thermogenesis.

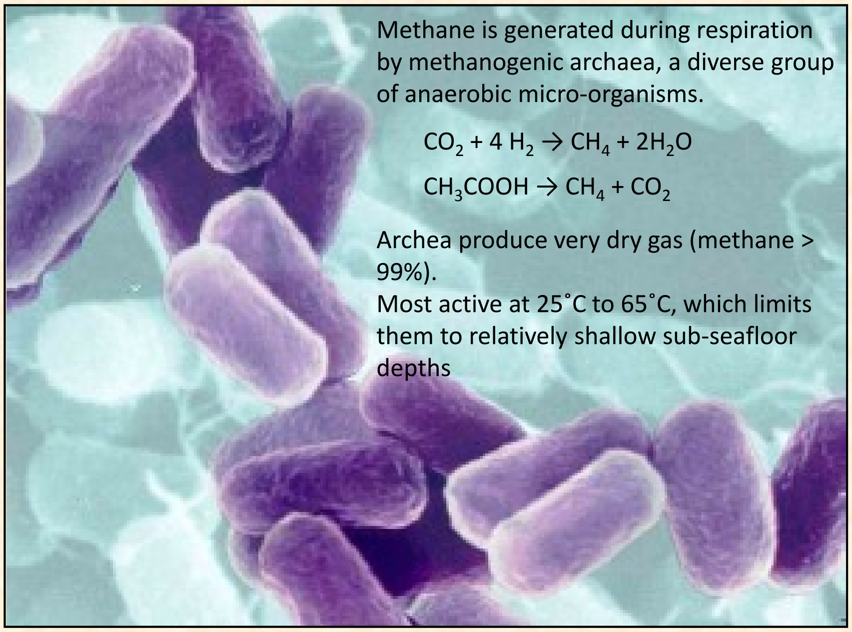
Oil is generated at burial depths between the two gas generating zones.

Most gas is generated deeper (hotter) than most oil.

Length of time at depth also affects gas and oil generation.

Plot from www.geo.wvu.edu

Biogenic Gas (a.k.a. "Microbial Gas" or "Bacterial Gas")



Methane is generated during respiration by methanogenic archaea, a diverse group of anaerobic micro-organisms.

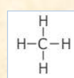
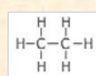
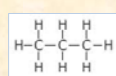
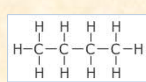
$CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O$

$CH_3COOH \rightarrow CH_4 + CO_2$

Archea produce very dry gas (methane > 99%).
Most active at 25˚C to 65˚C, which limits them to relatively shallow sub-seafloor depths

http://science-at-home.org/the-major-classifications-of-life/

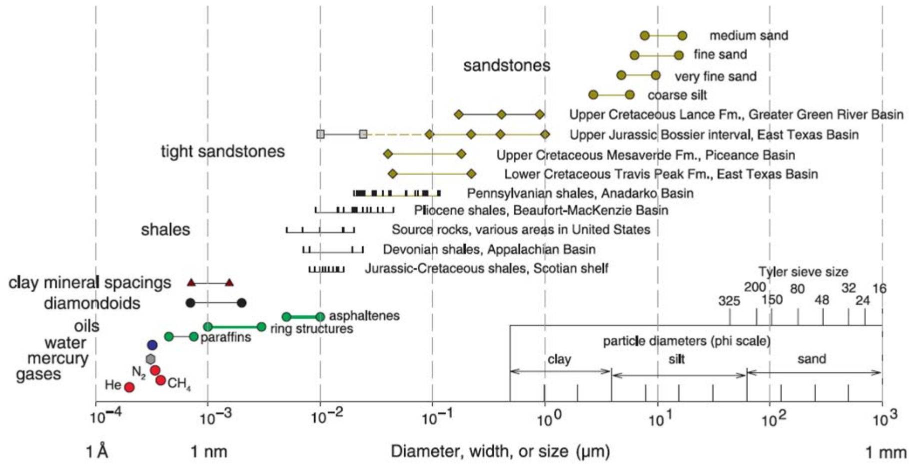
What is natural gas?

- Methane CH_4  > 85% = dry gas
- Ethane C_2H_6 
- Propane C_3H_8 
- Butane C_4H_{10} 

➢ 15% = wet gas (Some condensation of liquids at the Earth's surface)

- Non-hydrocarbons, including carbon dioxide, nitrogen, hydrogen sulfide, helium, others

To form conventional deposits, natural gas and oil migrate through connected pores and fractures and then accumulate in coarse grained rocks with large pores.



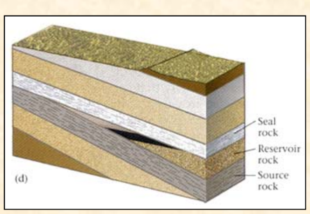
Pore throat and molecular sizes

Modified from Nelson, 2009

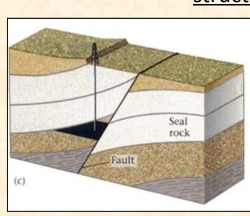
Conventional Natural Gas and Oil Deposits

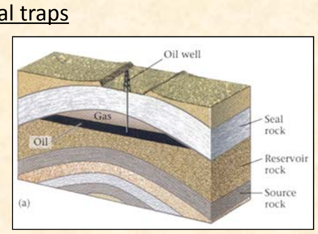
- Largest share of U.S. gas and oil wells and production historically, but share is declining.
- Gas can be found with oil (associated) or not (non-associated).
- Gas and oil matured in organic-rich **"source"** rocks, and migrated into reservoir rocks.
- Deposits are generally in porous sedimentary rocks or **"reservoirs"**, commonly sandstones.
- Gas and oil are trapped within reservoirs by **"traps"** or **"seals"** made of low permeability rocks that block upward migration out of reservoir rocks.
- These traps can originate from either stratigraphic (depositional layering) or structural (tectonic deformation) processes.

stratigraphic trap

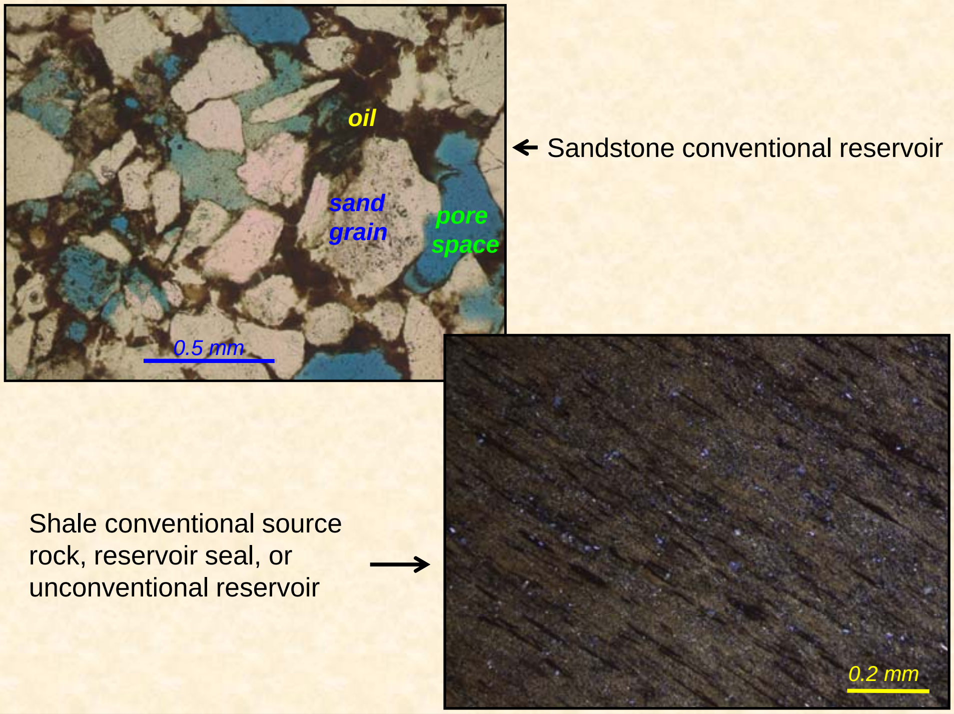


structural traps





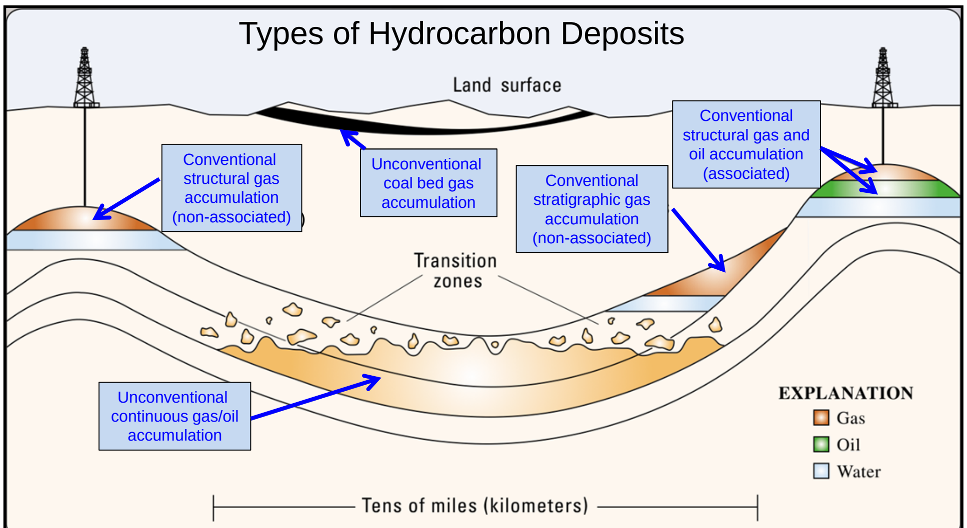
www.geol.umd.edu/jmerck



← Sandstone conventional reservoir

Shale conventional source rock, reservoir seal, or unconventional reservoir →

Types of Hydrocarbon Deposits



As hydrocarbons form from kerogen, some will migrate to form conventional deposits in high permeability rocks, but some will be left behind as unconventional deposits in the low-permeability source rocks

Modified from USGS fact sheet 0113-01

Unconventional Natural Gas

- Coalbed methane (CBM)
- Shale gas (recent explosion in exploration and production activity)

- Tight gas sands (important large fields)
- (Gas hydrates – not currently produced)

These deposit types are referred to as "continuous" gas accumulations because they are
- usually regionally extensive
- independent of structural or stratigraphic traps

These deposits are easy to find, but generally require "stimulation" to achieve economic production, so are expensive to produce.

Coalbed Methane (CBM)

- coal is both source and reservoir for gas
- gas may be microbial or thermogenic
- gas is held in several ways:
  - -adsorbed on coal maceral surfaces
  - -absorbed in coal molecular structure
  - - in pore spaces
  - - in "cleats" (natural fractures)

Microbial CBM can form early or late in coal burial history
"Early stage" forms in low rank materials – peat or subbituminous coal
"Late stage" forms during groundwater movement through coal.
Methane forms by reduction of CO2 as groundwater encounters anoxic conditions. This is independent of coal rank.

Thermogenic CBM forms throughout the coalification process at and above bituminous rank.

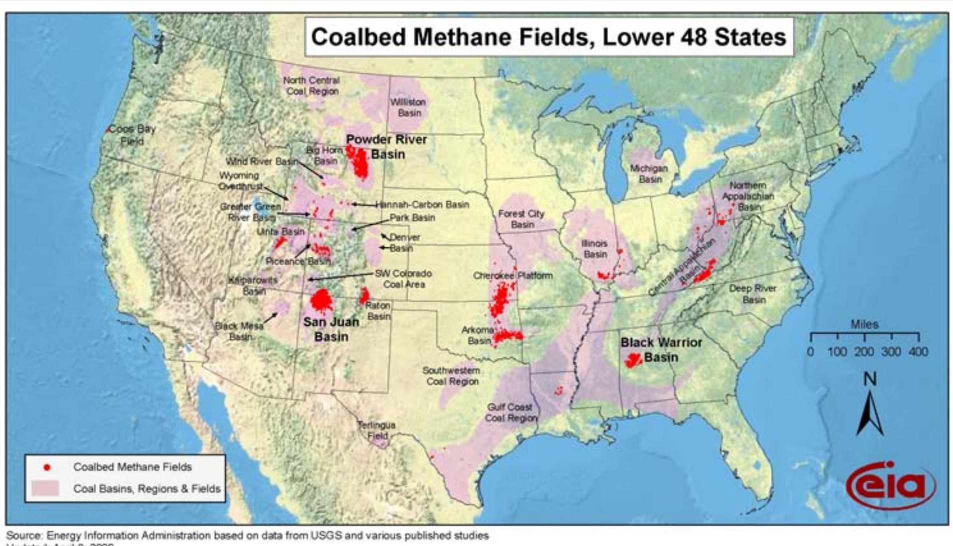
Production of Coal bed Methane

Gas is held in coal microstructure by reservoir pressure, so pressure reduction causes gas to desorb and can enhance migration and recovery.
Pumping of formation water is commonly used to decrease reservoir pressure and can generate disposal issues.

Productivity is commonly increased by hydraulic fracturing and horizontal drilling, but natural fractures are abundant and may allow significant productivity.

Alberta Geological Survey

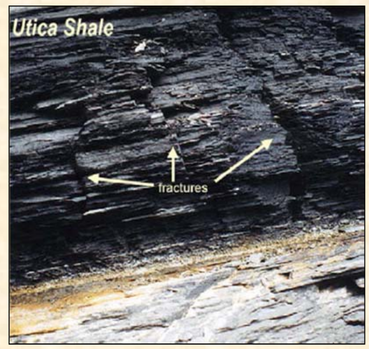
mt.water.usgs.gov



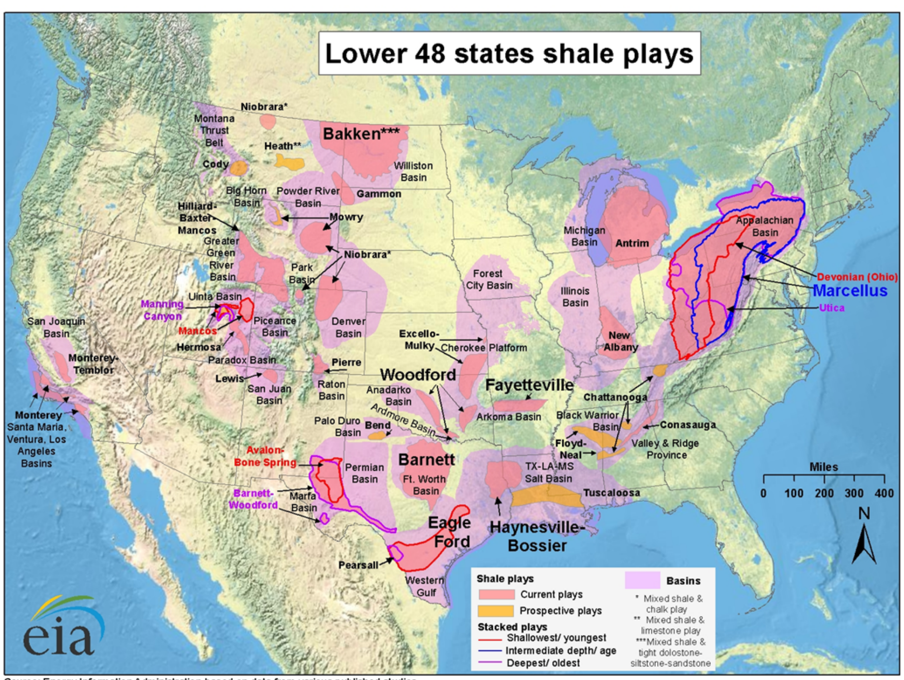
Shale Gas

Gas shales share several characteristics with Coal bed Methane:

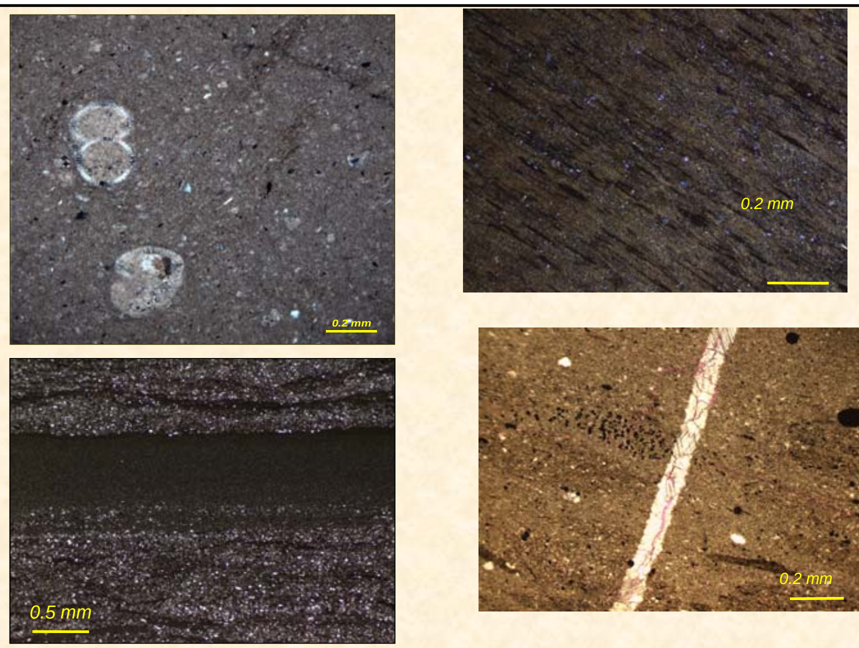
- both source and reservoir for gas
- gas may be microbial or thermogenic
- gas is held in several ways:
  - absorbed in kerogen molecular structure
  - in pore spaces
  - in natural fractures
- organic rich (>4% organic carbon)
- natural fractures may permit some production



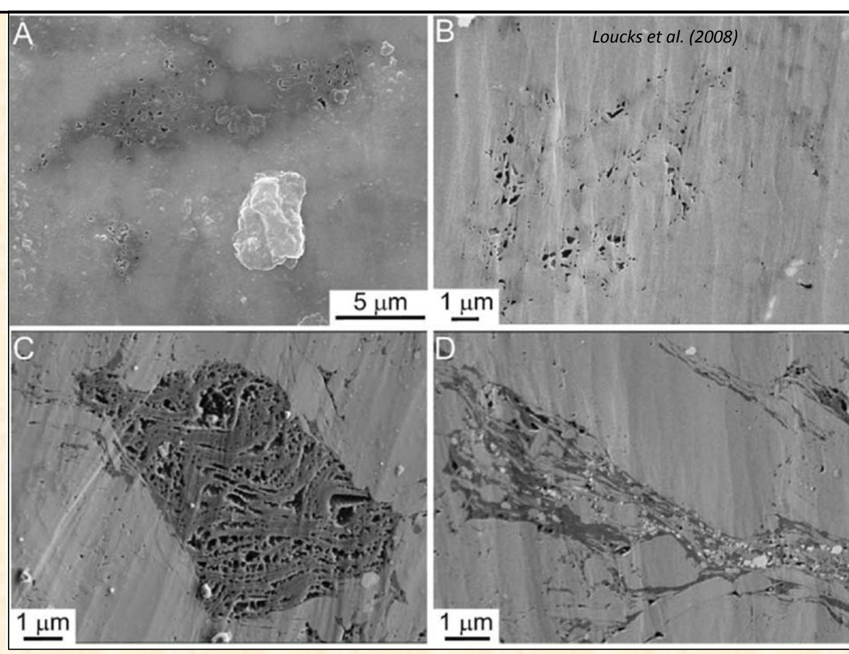
http://esogis.nysm.nysed.gov/



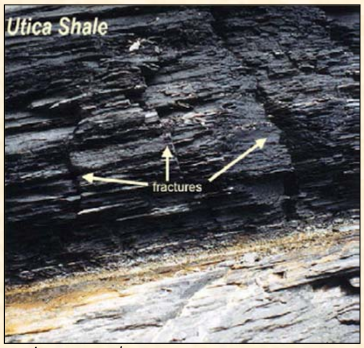
Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011



Microscopic views of shales reveal highly variable rocks that vary in composition, organic matter content, and susceptibility to natural fracture.



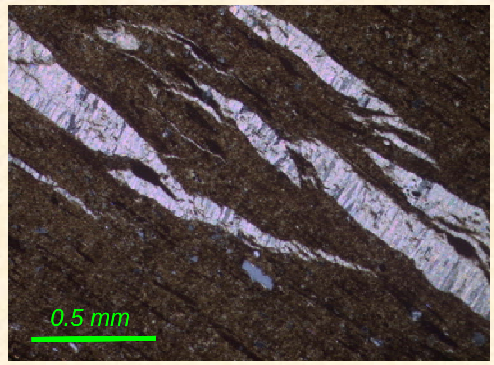
Shales have low porosity and permeability, but organic matter maturation can augment both. So maturation process that generates gas can also create porosity to hold gas.



esogis.nysm.nysed.gov

Shales can be naturally fractured

The degree of fracturing may depend on the burial and tectonic history, how brittle the shale is, and whether gas generation has caused high pressures.



AAPG Explorer, 2010

Natural fractures can be conduits for hydrocarbon migration.

But they may not be open to fluid flow and they commonly do not form a pervasive enough network to permit all the hydrocarbons to migrate readily.

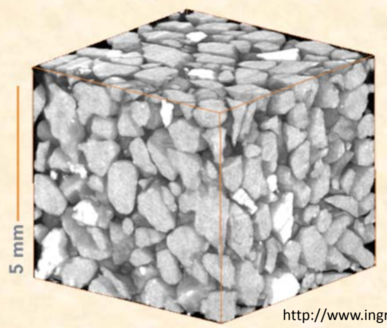
Hydraulic fracturing causes additional fracturing and props the fractures open.

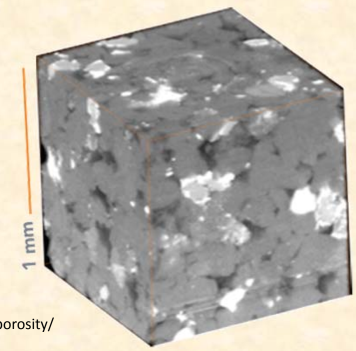
Tight Gas Sands

- low porosity
- very low permeability (<0.1 millidarcy)
- typically deep, commonly "overpressured"
- generally lacking gas-water contact

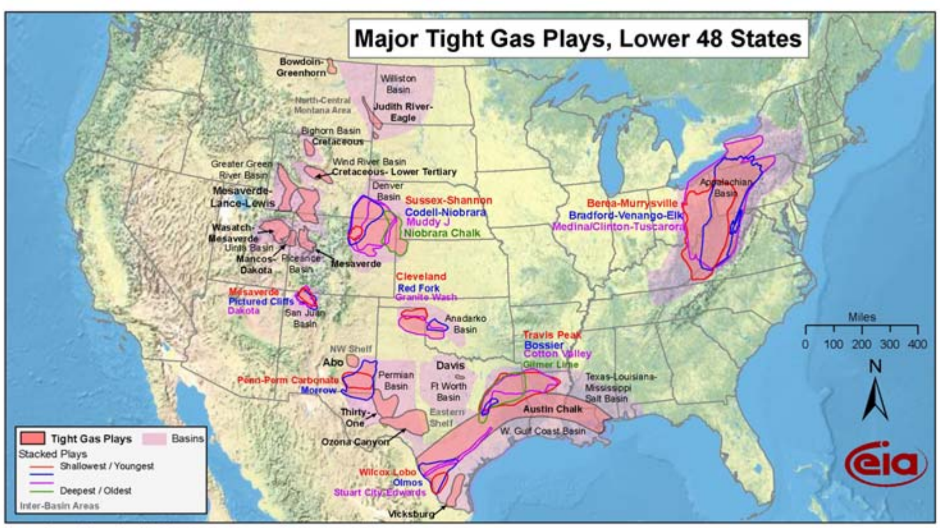
Many origins

- in situ generation from kerogen in the sands
- migration of gas into reservoir
- cracking of oil in reservoir





http://www.ingrainrocks.com/porosity/



Source: Energy Information Administration based on data from various published studies
Updated: June 6, 2010

Requirements for a conventional hydrocarbon deposit:

1. Production and accumulation of organic matter from plankton.
California.

2. Preservation of organic matter during and after burial to form an organic matter-rich source rock

3. Chemical transformation of organic matter to natural gas, oil, and other substances with burial, time, and heating

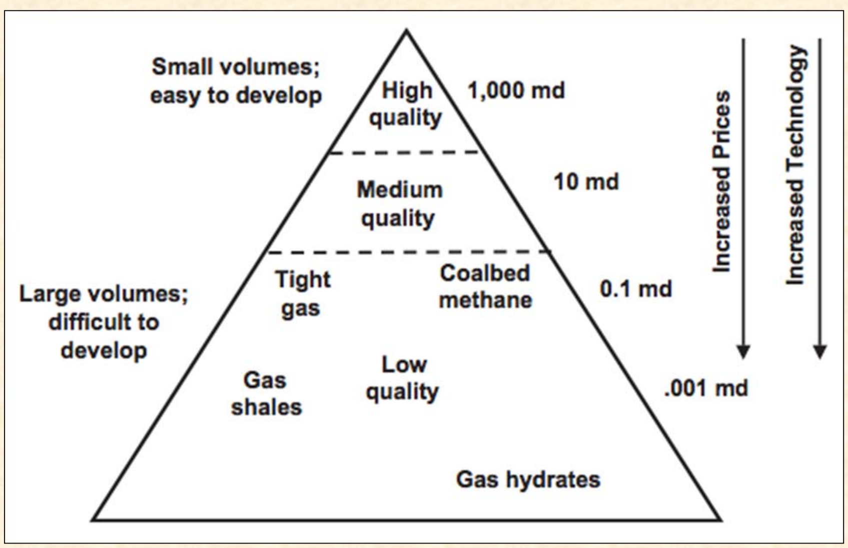
4. Migration of natural gas and oil to a reservoir rock (or storage of generated gas and oil within the source rock)

5. Low permeability barriers forming a "trap" for the gas and oil.

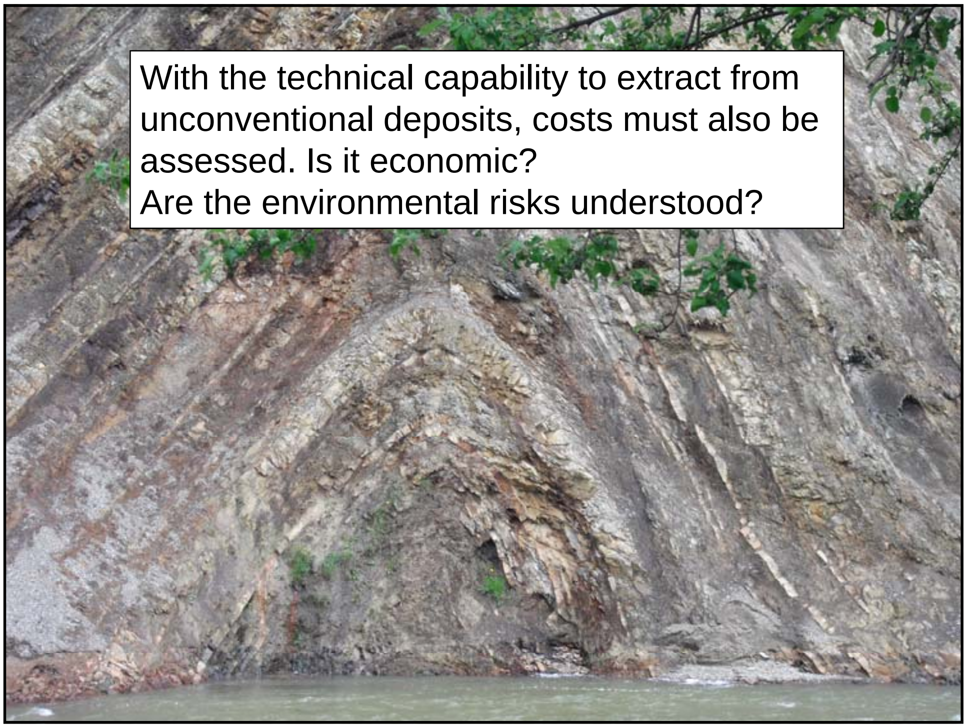
Requirements for an unconventional hydrocarbon deposit:

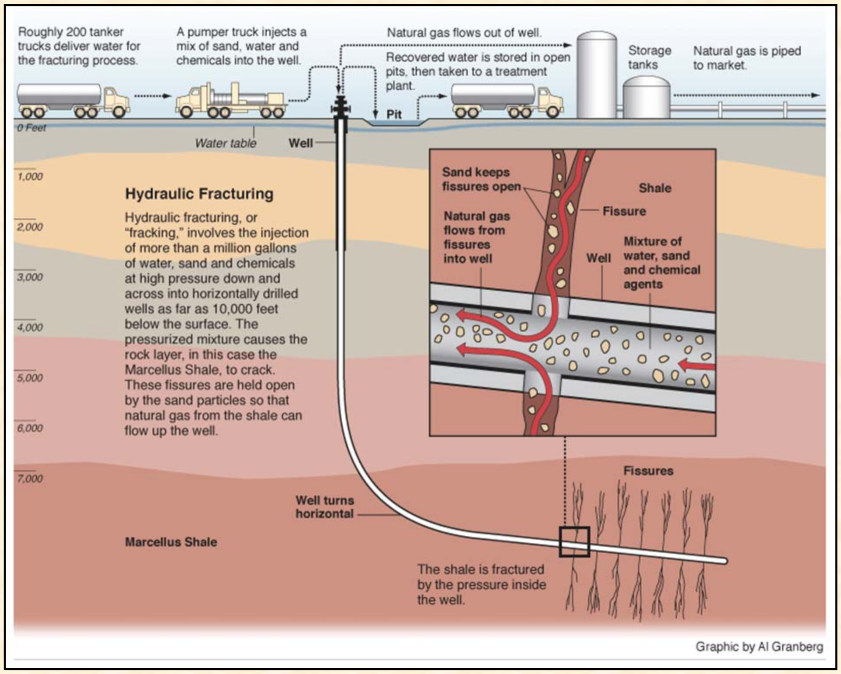
1., 2., and 3. plus the technical capability to get it out of the

Resource Triangle for Natural Gas

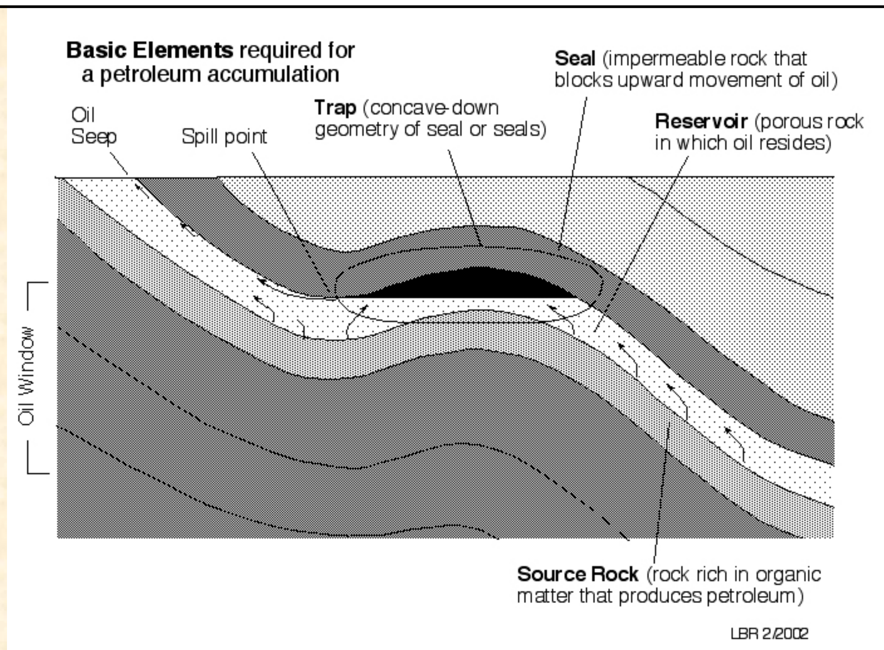


Holditch, 2006


With the technical capability to extract from unconventional deposits, costs must also be assessed. Is it economic?
Are the environmental risks understood?



www.propublica.org/special/hydraulic-fracturing-national

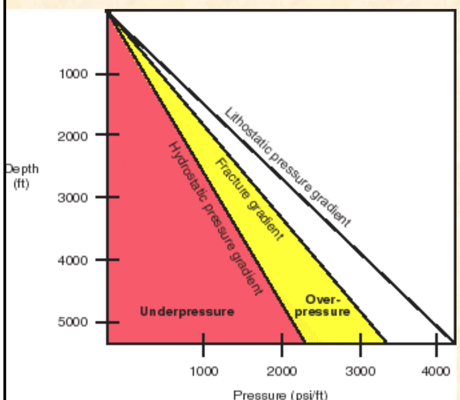


Bruce Railsback

Lithostatic Pressure – pressure exerted by weight of overlying rock column

Hydrostatic Pressure – pressure exerted by a water column equivalent to depth of burial

Pore Pressure – pressure exerted by pore fluids

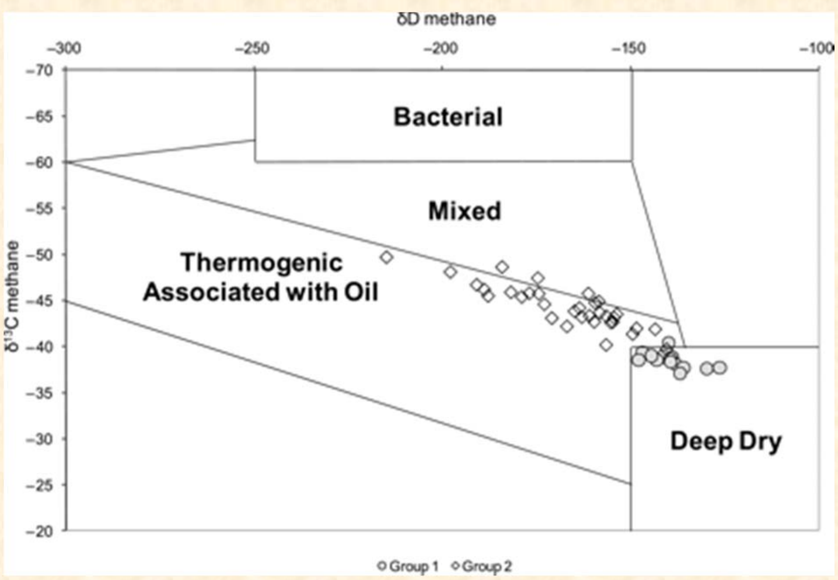


Abnormal pore pressures:

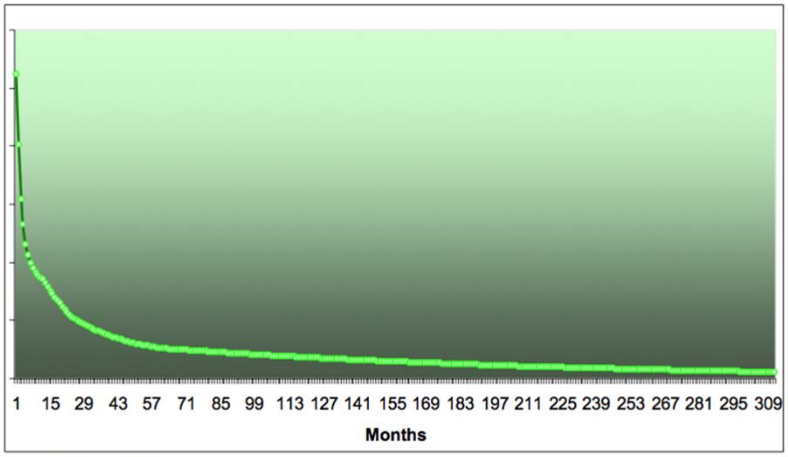
Overpressured = pore pressure exceeds hydrostatic pressure

Underpressured = pore pressure less than hydrostatic pressure

Schlumberger



A Typical Shale Gas Decline Curve



Source: Howard Weil

Attachment 12
Environmental Implications of Drilling and Completion

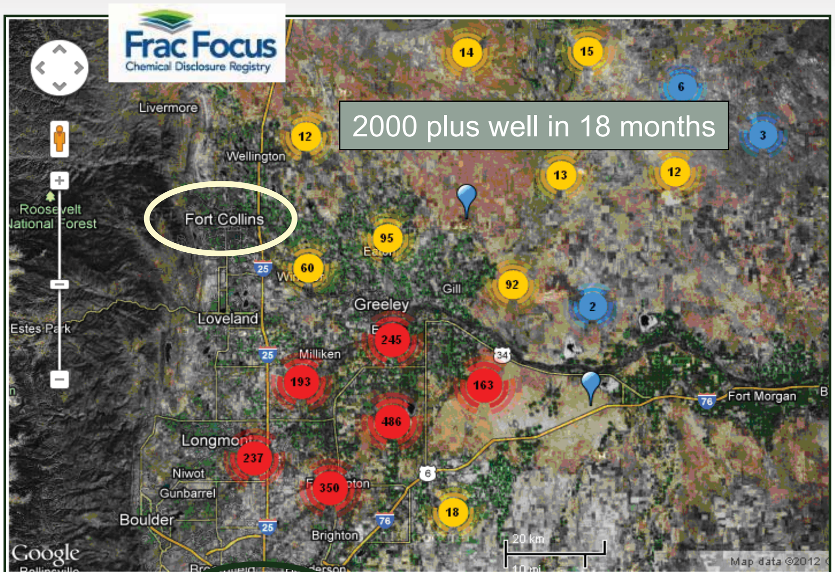
Drilling and Completion
(oil and gas)

Dr. Tom Sale
Colorado State University

SURF 20
Fort Collins, Colorado
July 25, 2012

Groundwater

Niobrara Formation

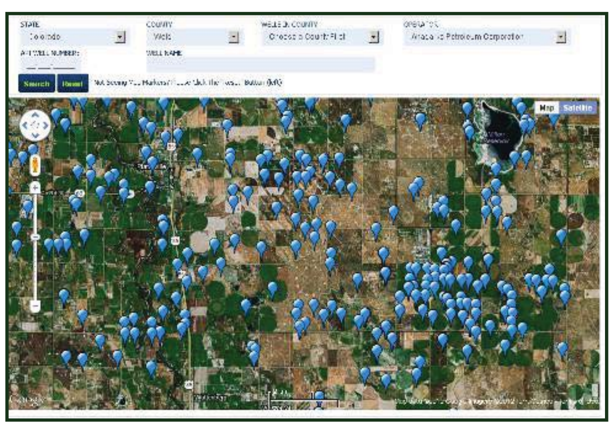


Denver

Fundamentals of the Natural Gas Industry

ENGR/GEOL 480A2

FracFocus.org

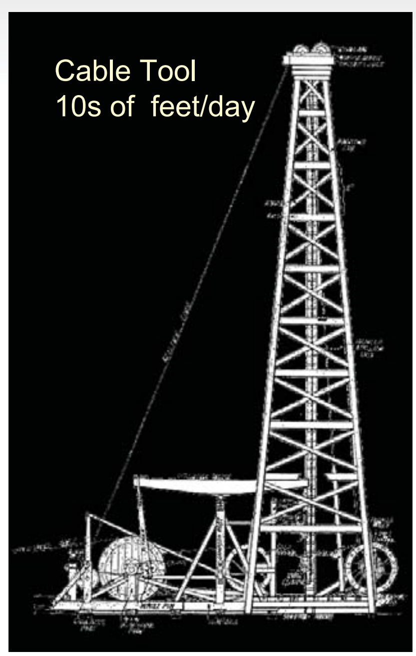


Topics

- Drilling
- Well Completions

Process

- Drilling
  - Break formation
  - Remove cuttings
  - Hold the hole open
  - Prevent blow out



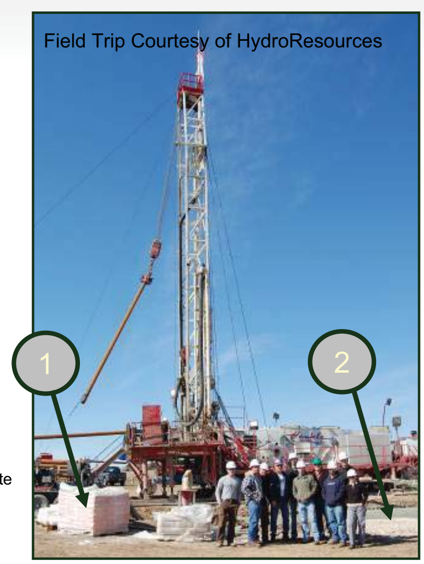
1850s

Balakhani oil field in Azerbaijan 1890s

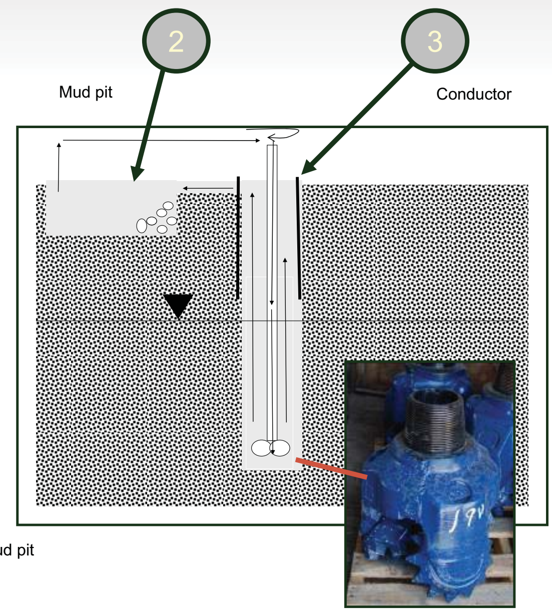
http://www.sjvgeology.org/history/baku.html

Mud Rotary

100s feet/day

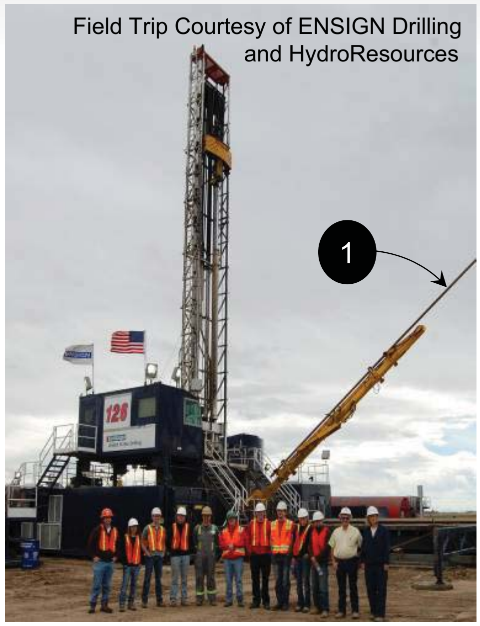


2010 Wells and Pumps Class



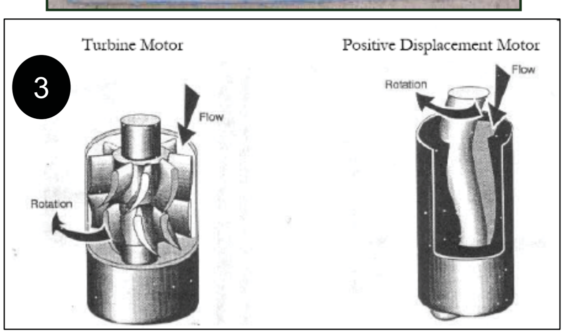
Mud rotary with down hole mud motor

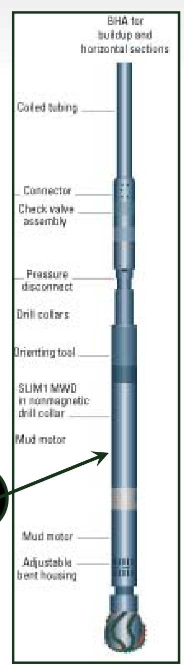
1000s feet/day



2011 Class Field Trip

Mud motor and directional drilling





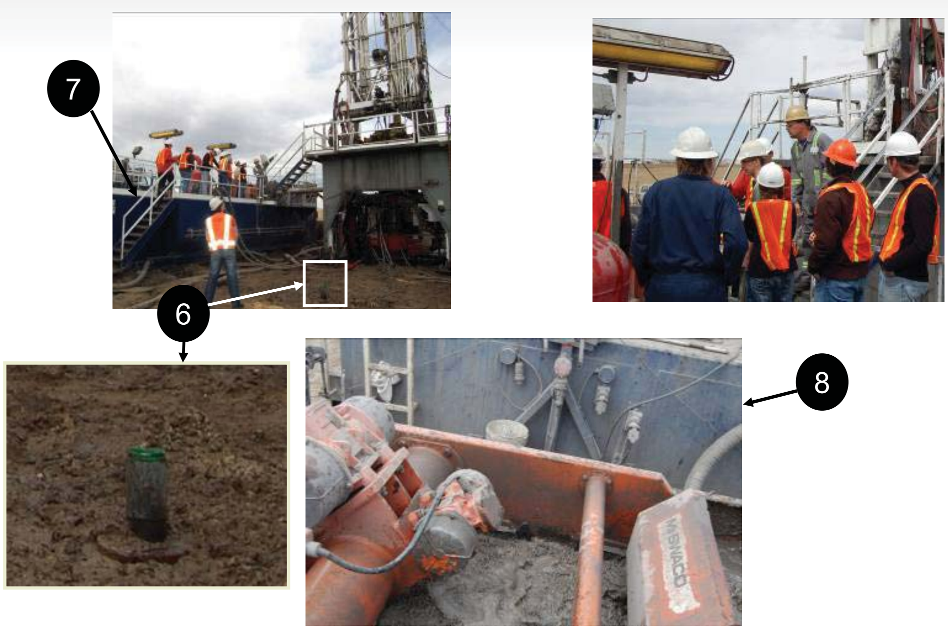
4

5

23 wells
completed
at one location

Multiple wells at a single location

Portable mud pit



Mud engineer

HydroResources, Fort Lupton, Colorado

- Viscosity to carry the cutting out of the hole
- Weight to hold the hole open
- Weight to prevent blow out
- Lubrication
- Solids to limit fluid losses

Blow out preventer

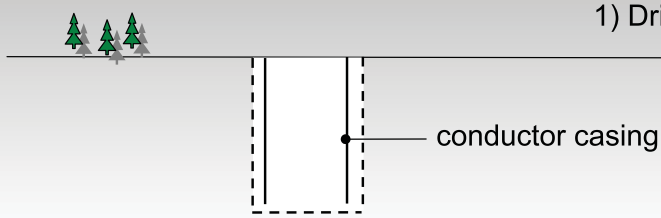
Then, now, and … tomorrow

…

Well Completions

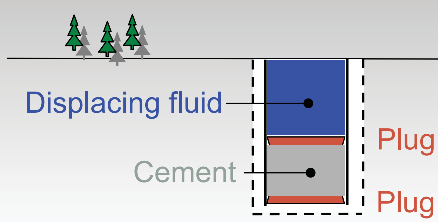
- Set casing and cement
- Perforate casing
- Stimulate Formation (Hydraulic Fracturing)

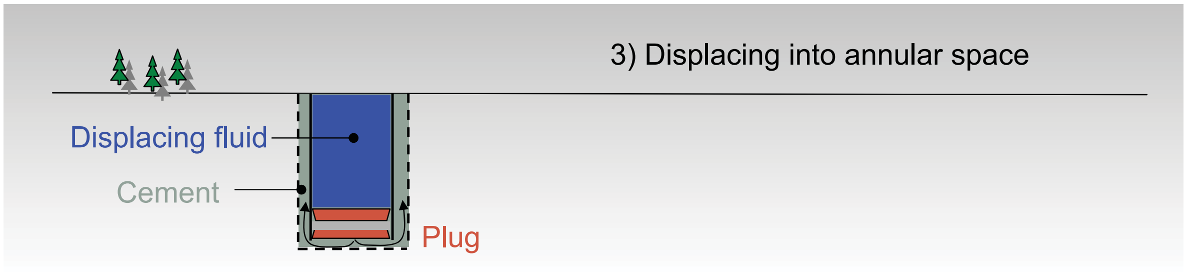
1) Drill hole and set conductor casing

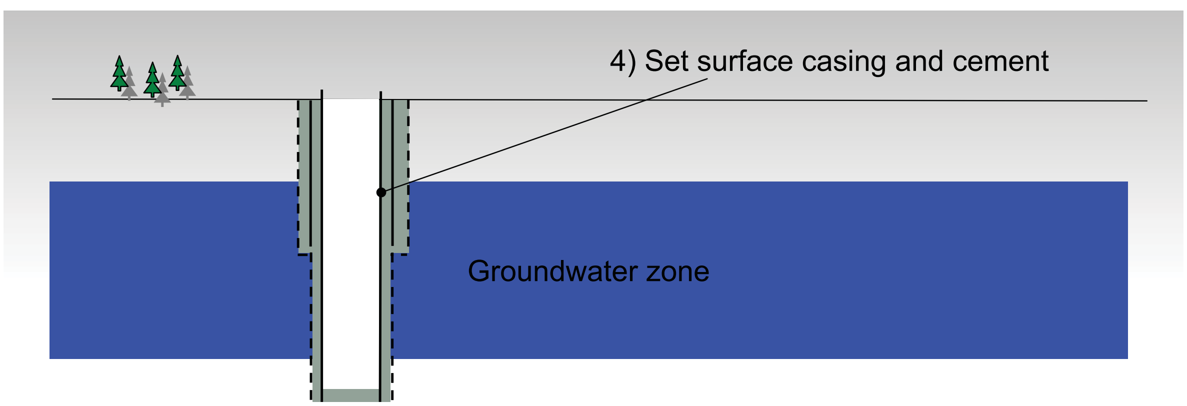


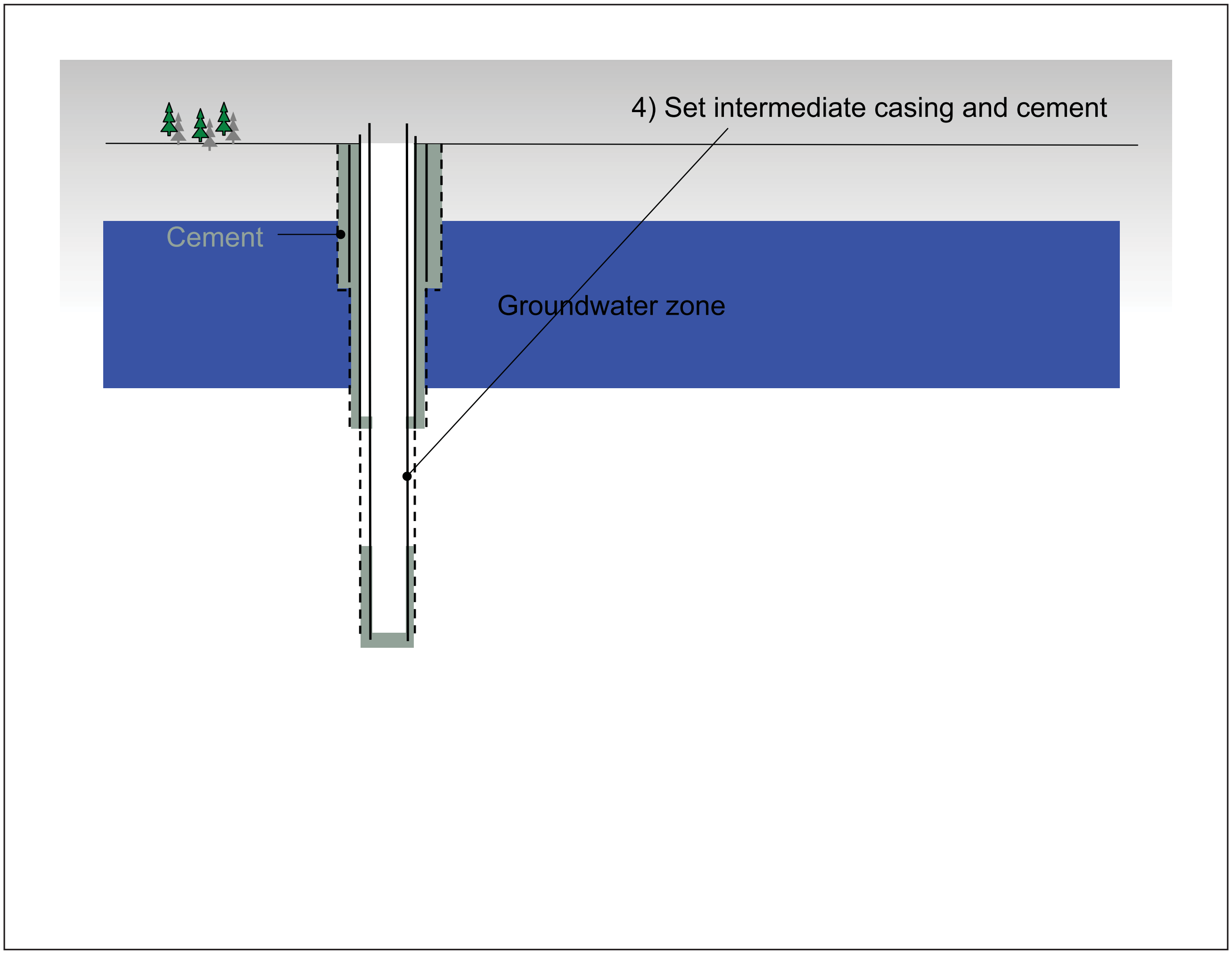
AN EXAMPLE

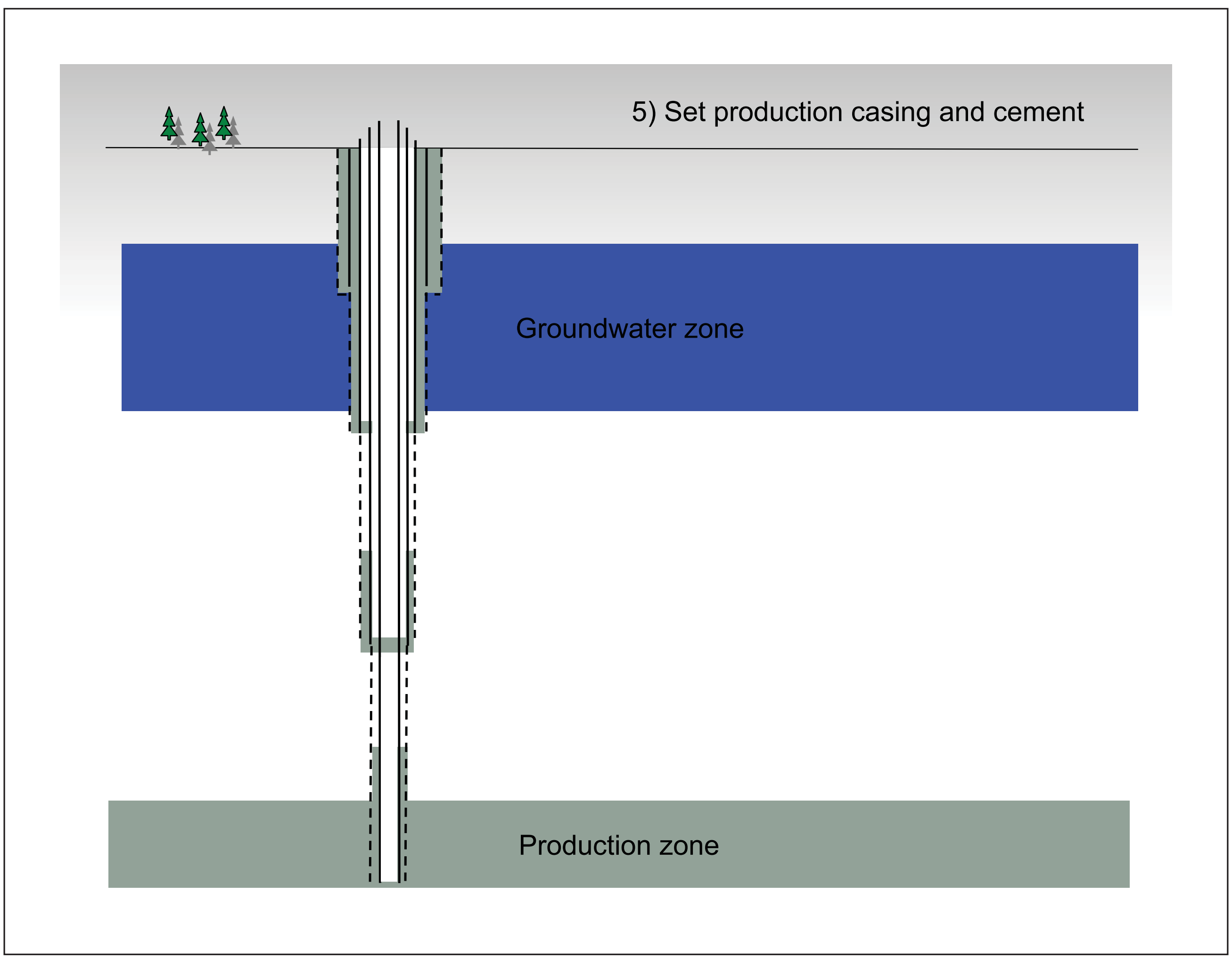
2) Set plugs, cement and displacing fluid

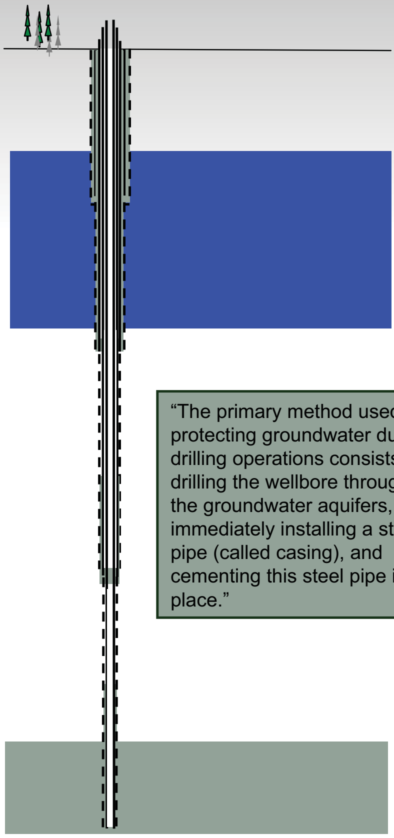



3) Displacing into annular space
Displacing fluid
Cement
Plug


4) Set surface casing and cement
Groundwater zone


4) Set intermediate casing and cement
Cement
Groundwater zone


5) Set production casing and cement
Groundwater zone
Production zone



"The primary method used for protecting groundwater during drilling operations consists of drilling the wellbore through the groundwater aquifers, immediately installing a steel pipe (called casing), and cementing this steel pipe into place."

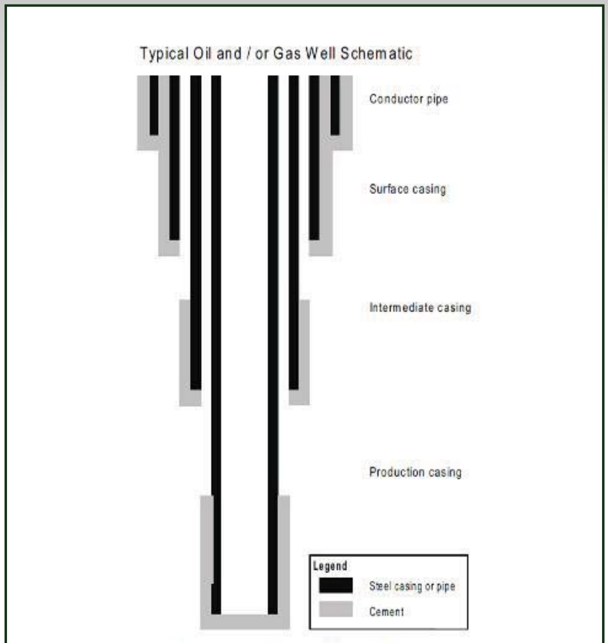
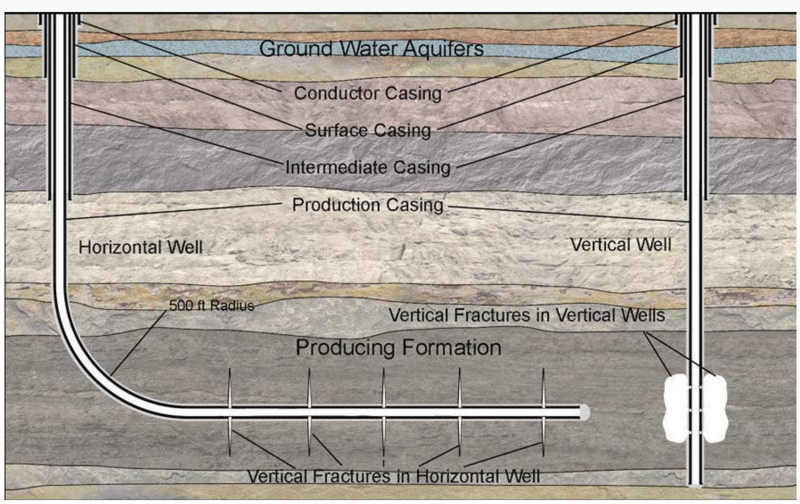


Figure 1—Typical Well Schematic

Hydraulic Fracturing Operations—Well Construction and Integrity Guidelines – API GUIDANCE DOCUMENT HF1 FIRST EDITION, OCTOBER 2009

Horizontal drilling



API GUIDANCE DOCUMENT HF1
FIRST EDITION, OCTOBER 2009

California

STATE OF CALIFORNIA
DEPARTMENT OF CONSERVATION
DIVISION OF OIL, GAS, & GEOTHERMAL RESOURCES

NO.: 607-079

RIVER BREAK GAS FIELD RULES

Date: May 30, 2007

Area(s)	Zone(s)/Pool(s)
Main, South	All productive zones

CASING PROGRAM

Casing String	Cementing Depth		Annular Cement Fill
	Marker or Zone	Remarks	
Surface	To at least 10% of the proposed TD and can be as deep as 1500'.	Cement into or through a competent bed.	To surface.
Production	Productive zone	Traditional or Barefoot completions	Across Zone to 500' above zone. Also across BFW and 100' above BFW, if BFW is below Surface Casing.
Intermediate	---	100'+ of lap w/lap test unless casing is run to surface. See CCR 1722.4	Across Zone to 500' above zone. Also across BFW and 100' above BFW, if BFW is below Surface Casing.

GEOLOGIC DATA

Reference: DOGGR Publication TR10 California Oil and Gas Fields, Northern California. Well data from 51 wells drilled.

BLOWOUT PREVENTION EQUIPMENT PROGRAM (Referenced from MO7)

Operation	Surface Pressure Category	DOGGR Class	Additional Requirements
Drilling below surface casing	Medium	III B 2-5M	None
Completions/Rework	Medium	II 2-5M	None

Additional Comments: If air or foam drilling below the production casing, please refer to Division publication M07, Section 4-3, for blowout prevention equipment requirements.

BASE OF FRESH WATERS

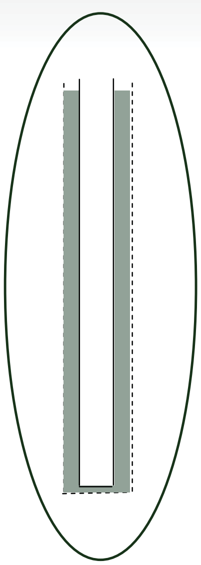
Depth: 250'+/-	Marker: None	Comments:

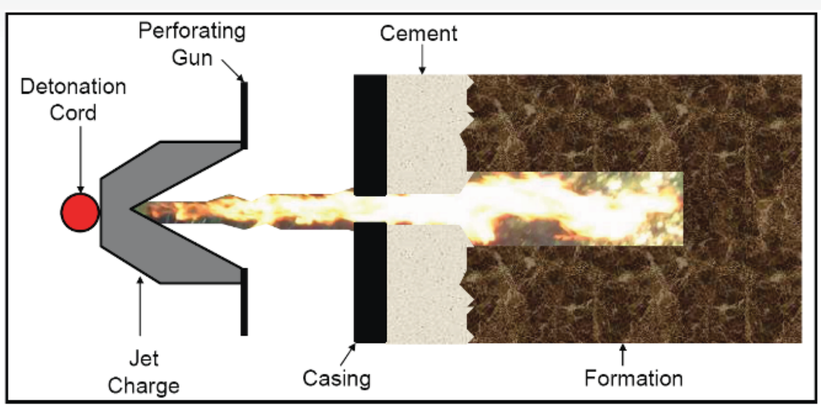
GENERAL COMMENTS

Due to the result of a long production history, and a history of successful water shutoffs, testing and approval of water shutoffs by either field-testing or by review of production data is not required. However, the Division of Oil, Gas, and Geothermal Resources routinely monitors production data, and if anomalous water production is indicated, remedial action may be ordered.

Field rules apply to development wells only. All operations are subject to California Code of Regulations (CCR)., Title 14, Division 2, Chapter 4.

Casing perforation



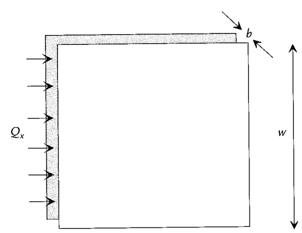


API GUIDANCE DOCUMENT HF1
FIRST EDITION, OCTOBER 2009

Formation stimulation via hydraulic fracturing

Cubic Law - Laminar flow in a smooth walled fracture (Romm 1966)

$$Q_w \propto b^3$$



Hydraulic fracturing

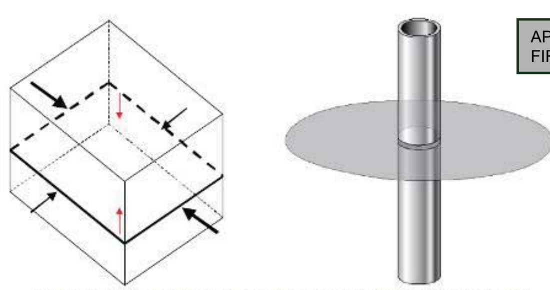


Figure 6—Least Principal Stress is in the Vertical Direction Resulting in a Horizontal Fracture

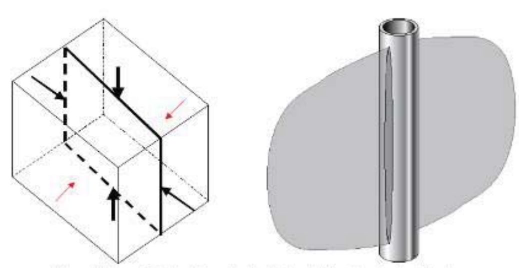


Figure 7—Least Principal Stress in the Horizontal Direction, Vertical Fracture

API GUIDANCE DOCUMENT HF1
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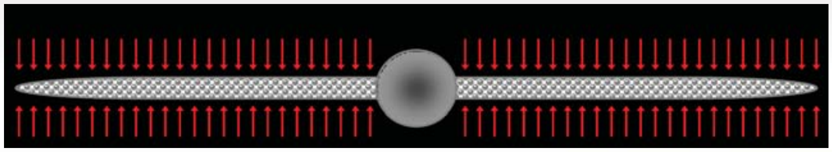
The maximum reported height of an upward propagating hydraulic fracture from several thousand facture operations in the Marcellus, Barnett, Woodfored, and Eagleton shale is 588m.

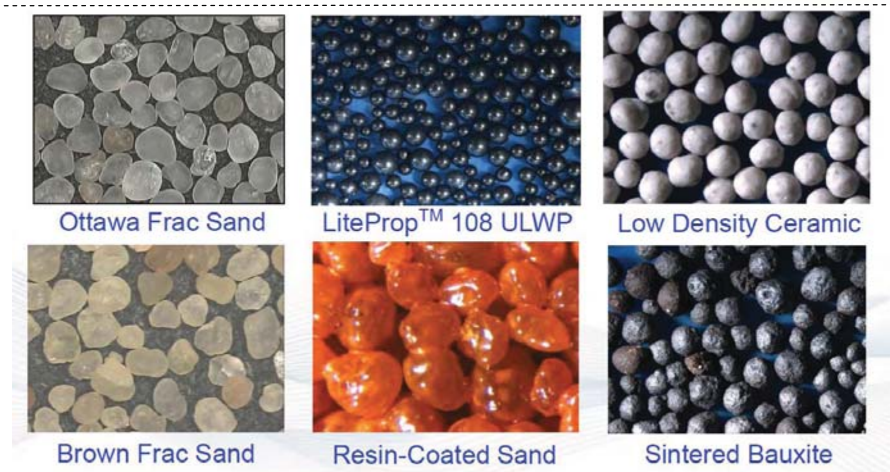
Davies et al. 2012, Journal of Marine and Petroleum Geology

Proppent

1



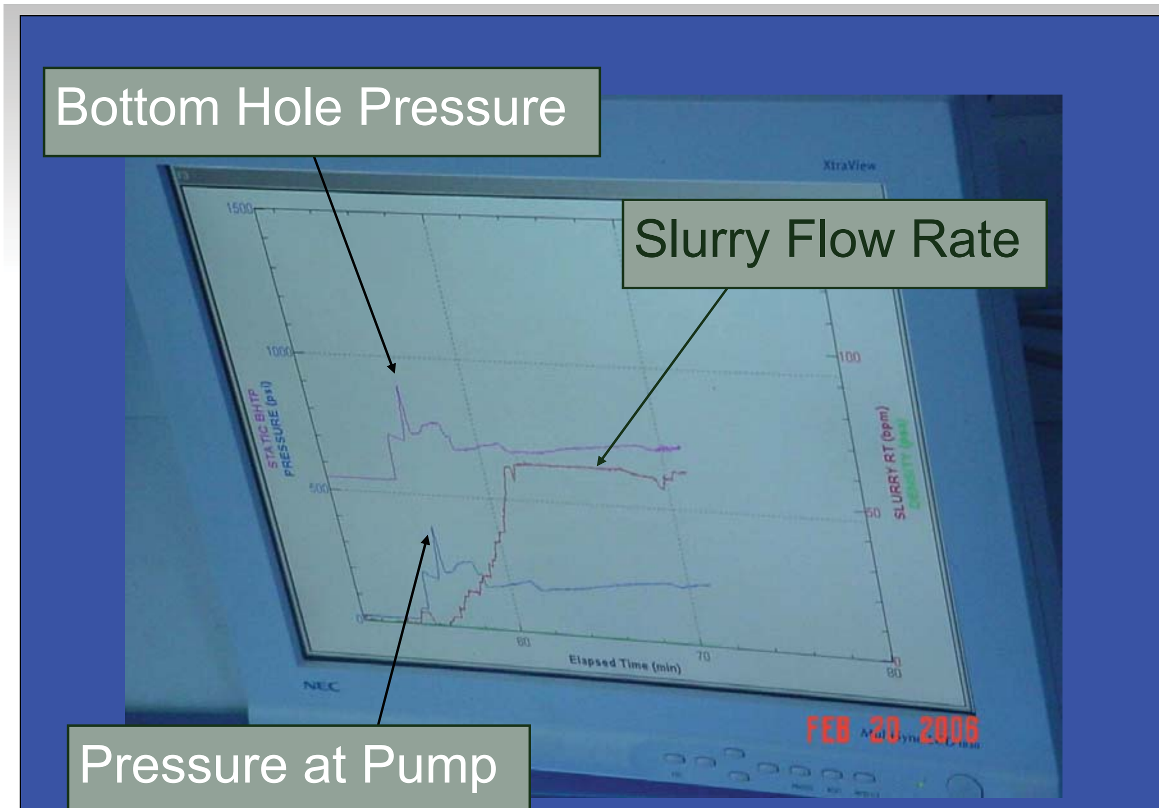
2



http://www.pttc.org/aapg/lafollette.pdf

Crosslinked Polymer

Field Trip Courtesy of Halliburton



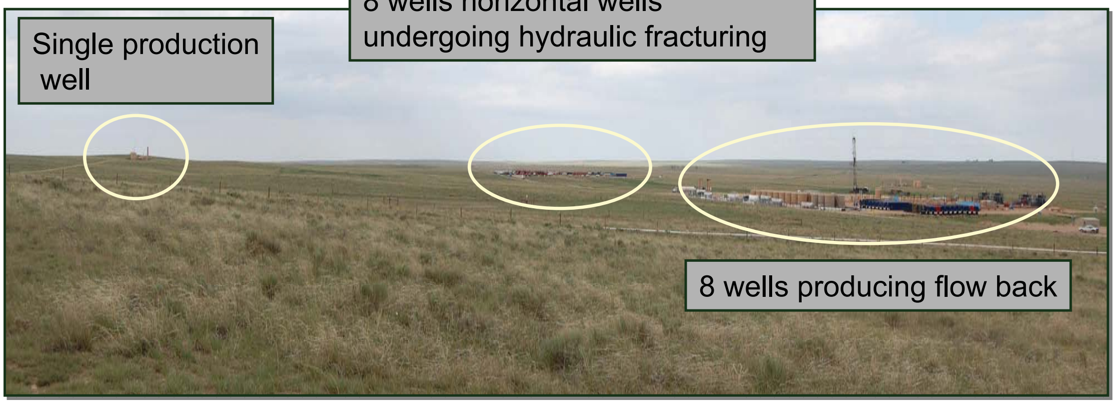
Water well hydraulic fracture – Colorado

Wells Ranch

Wells Ranch – Eastern Colorado – Field Trip Courtesy of Halliburton

Wells Ranch

Wells Ranch – Eastern Colorado – Field Trip Courtesy of Halliburton



Stimulation via Hydraulic Fracturing

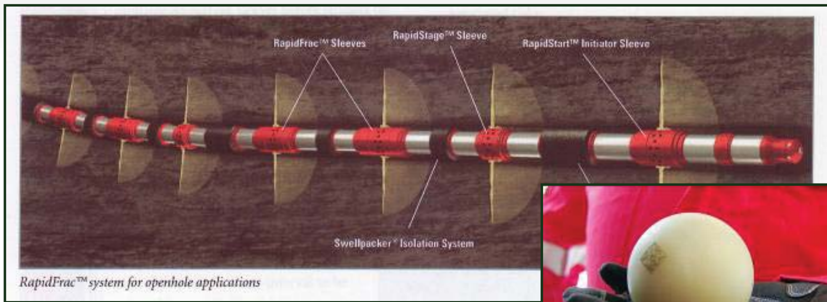
Injection of water, sand, and additives.

Numbers

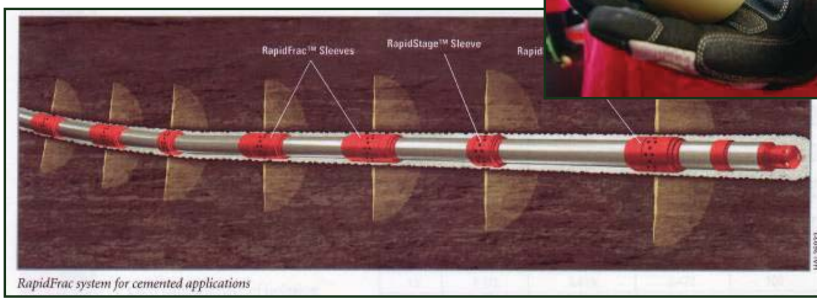
- 1900 gallons/min
- 18,000 horsepower

Evolving practice

Openhole application



Cemented application



Dropping the ball

Additives

- Water
- Sand
- Gel
- Biocide
- Corrosion inhibitor
- Acid
- Breakers
- Lubricant

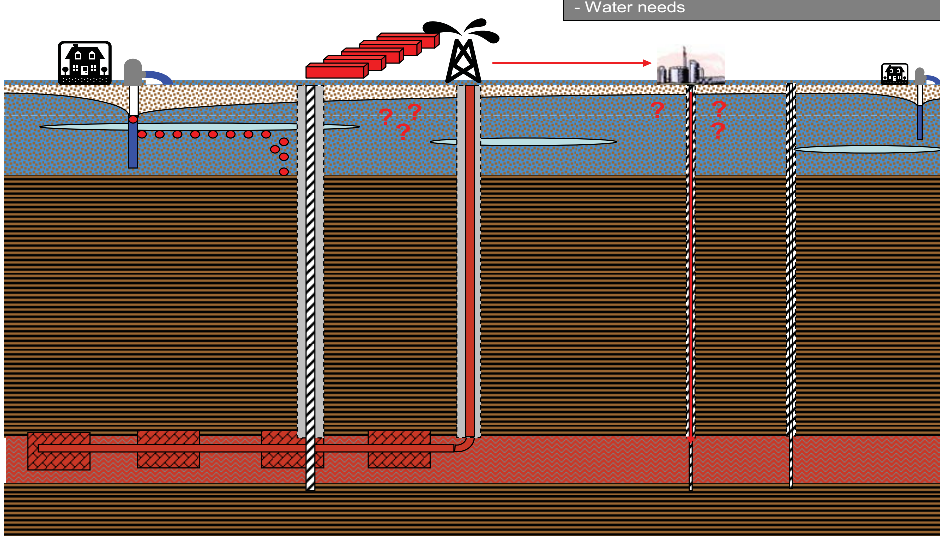
Closing thoughts

Concerns

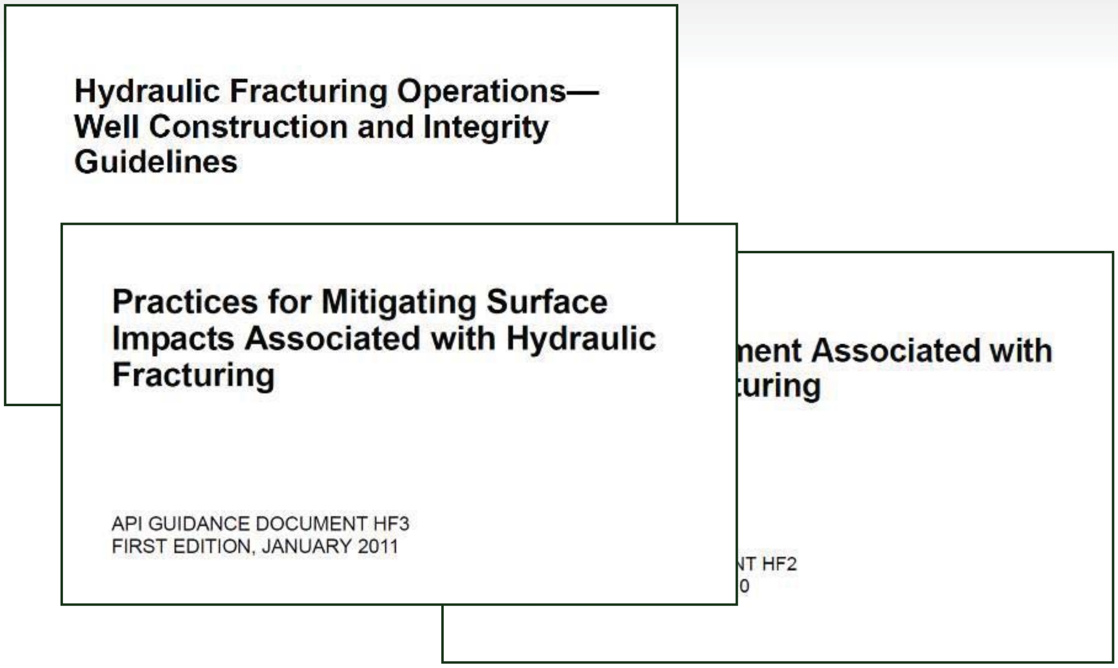
- Green house gases
- Local air quality
- **Long-term impacts to groundwater**
- Management of produced water,
- Competion for finite water resources,
- Disruption of communities.

Long-term impacts to groundwater

New GW Issues
- Surface releases of hydrofrac fluids
- Flow along historical and new penetrations
- Losses of frac fluids during handling –disposal
- Water needs



Guidance


Hydraulic Fracturing Operations—
Well Construction and Integrity
Guidelines
Practices for Mitigating Surface
Impacts Associated with Hydraulic
Fracturing
API GUIDANCE DOCUMENT HF3
FIRST EDITION, JANUARY 2011
ment Associated with
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NT HF2
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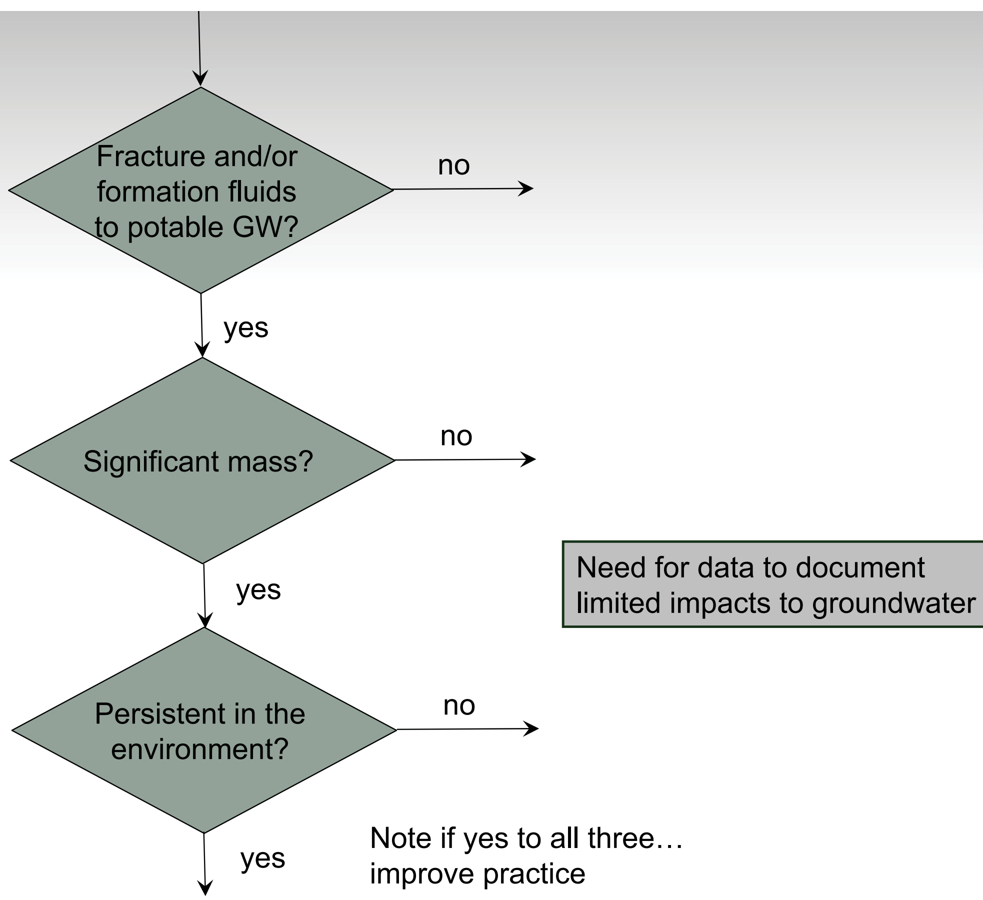

Fracture and/or
formation fluids
to potable GW?
no
yes
Significant mass?
no
yes
Need for data to document
limited impacts to groundwater
Persistent in the
environment?
no
yes
Note if yes to all three…
improve practice

Attachment 13
Air Pollutant Emissions from Shale Gas Development and Production

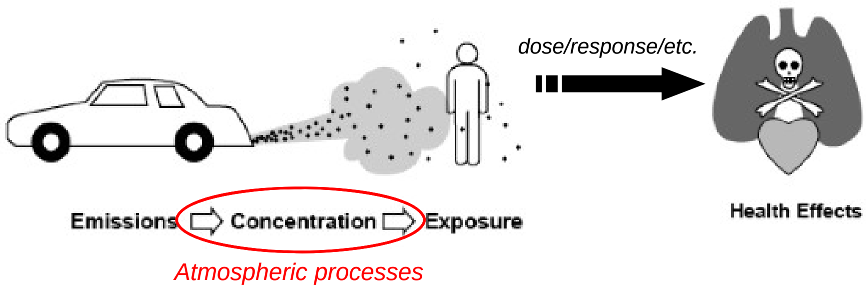
Air pollutant emissions from shale gas development and production

Allen L. Robinson
Department Atmospheric Science
Department of Mechanical Engineering
Colorado State University
Fort Collins, CO

Potential Air Quality Concerns

- Criteria Pollutants
  - O_3 (VOC + NOx + sunlight)
  - NO_2
  - $PM_{2.5}$
- Hazardous Air Pollutants / Air toxics
  - Diesel particulate matter
  - Formadehyde
  - Benzene, toluene, ethylbenzene, xylenes
- Climate
  - CH_4
  - Black carbon

Assessing air pollution impacts

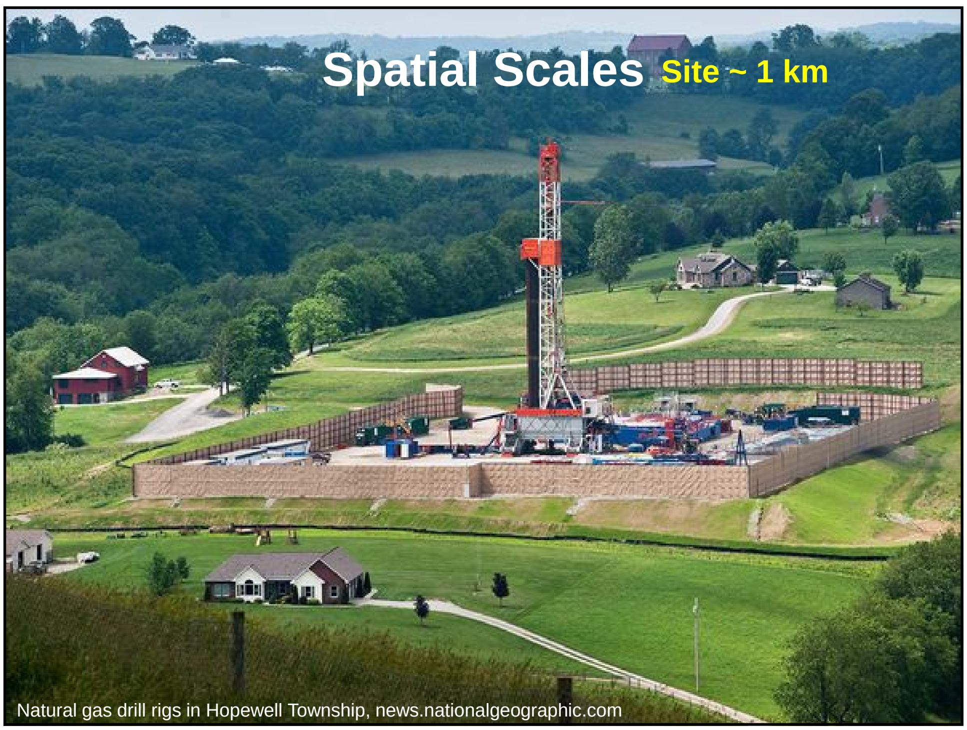


Graphic: J. Marshall

Source	NOx	VOC	PM	Air Toxics	Data Quality
Well development					
Drill Rigs	●	○	●	●	Medium
Frac Pumps	●	○	●	●	Medium
Truck Traffic	●	○	●	●	Medium
Completion Venting		●		●	Poor
Frac ponds		○		**?**	Poor
Gas Production					
Compressor Stations	●	●	○	●	Medium
Wellhead compressors	○	○	○	○	Medium
Heaters and dehydrators		○	○	○	Medium
Blowdown venting		○		○	Poor
Condensate Tanks		●		○	Poor
Fugitives		?		○	Poor
Pneumatics		○		○	Poor

● = major source ○ = minor source

Spatial Scales Site ~ 1 km



Natural gas drill rigs in Hopewell Township, news.nationalgeographic.com

Variety of scales -- widely distributed

Natural gas drill rigs in Hopewell Township,
news.nationalgeographic.com

wilderness.org

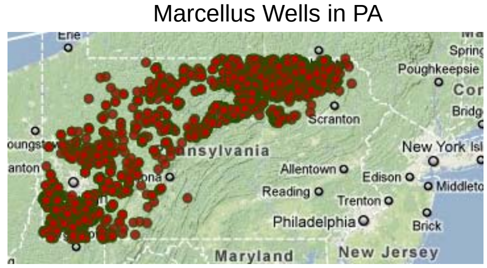
Regional ~ 100s to 1000s of km

Marcellus Wells in PA as of Mar 2012

Very large chemical plant or refinery distributed over 1000s of sq miles?!

Refinery

Marcellus Wells in PA

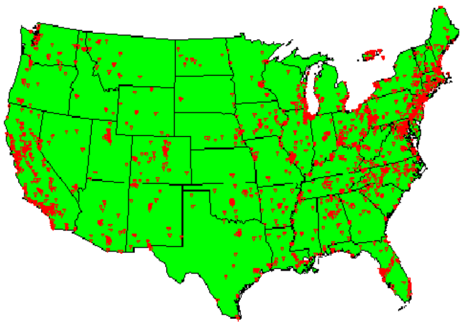


www.fractracker.org (data from PA DEP)

LIMITED AMBIENT DATA

Poor spatial correlation between air monitoring networks and oil and gas development and production

State and local air monitoring stations



http://epa.gov/airquality/qa/monprog.html#SLAMS

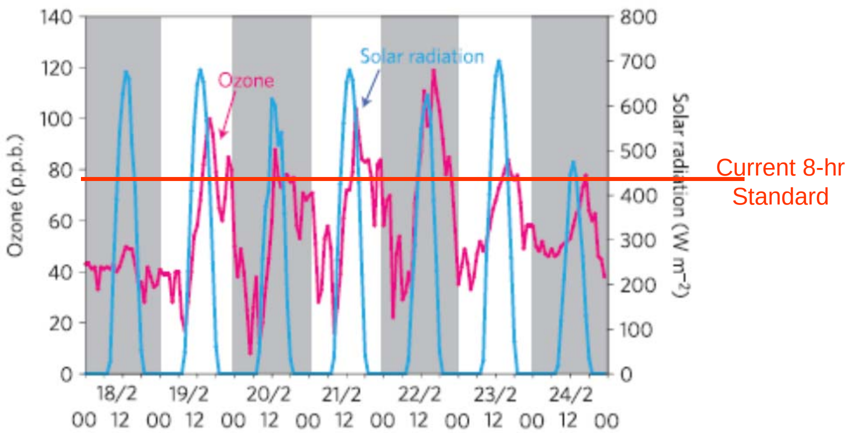
Ozone

$$VOC + NOx + Sun \rightarrow O_3$$

The Jonah–Pinedale Anticline natural gas field in Wyoming.

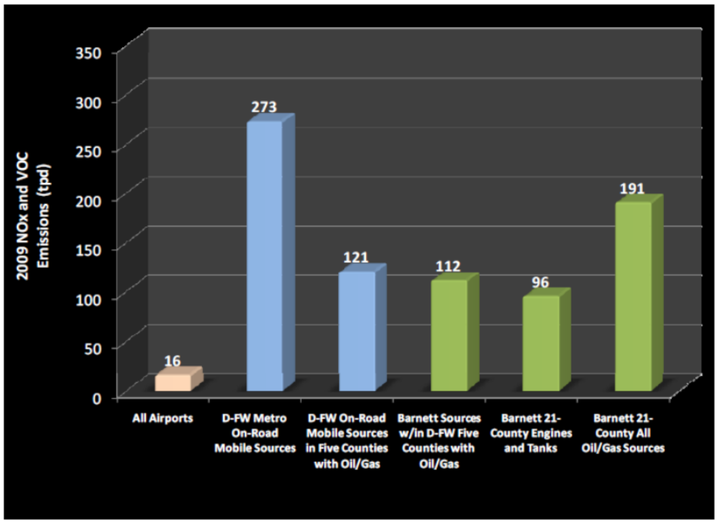
Joseph Pinto *Nature Geoscience* **2**, 88 – 89 (2009)

Ozone impacts, Wyoming



Schnell et al., *Nature Geoscience* **2**, 120 - 122 (2009) ***2009***

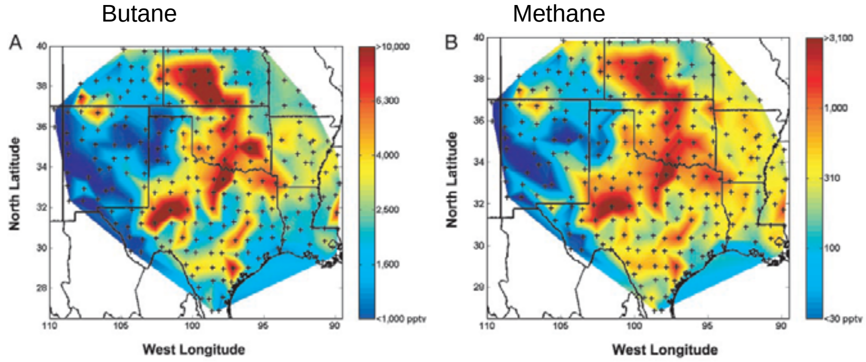
NOx and VOC Emissions in the Barnett Shale



Armendariz, 2009

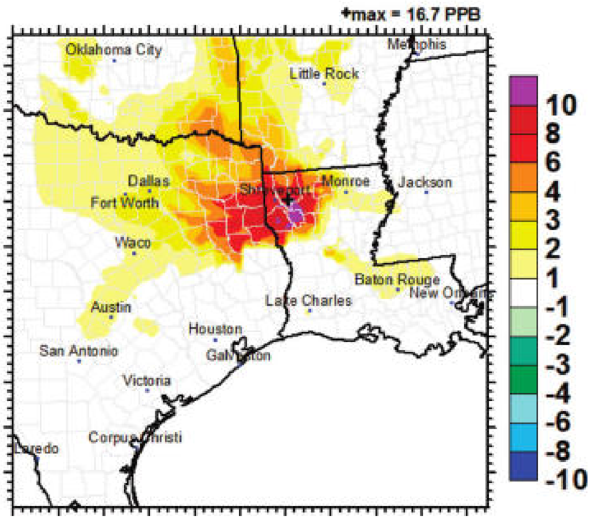
Enhanced Regional Light Alkanes

Butane   Methane



Katzenstein et al. PNAS 100(21) 2003

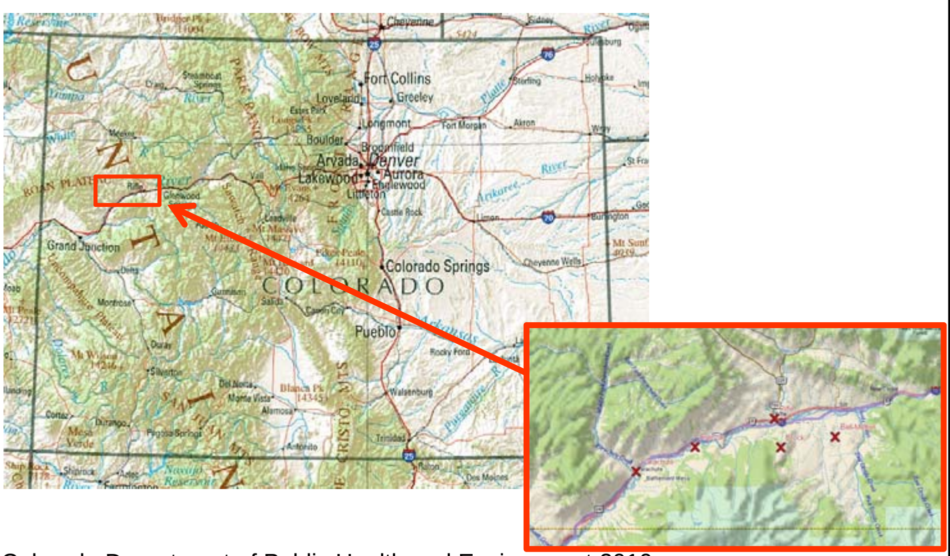
Regional Ozone and Haynesville Shale



ΔOzone (ppbv)
max daily 8-hr ave

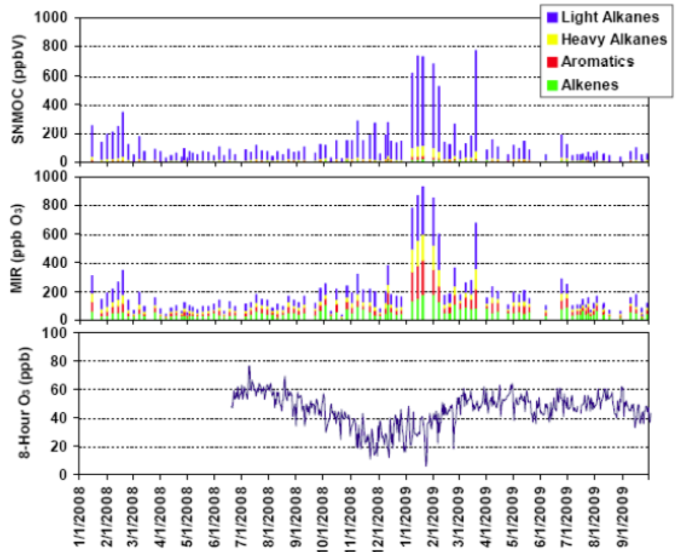
Kemabll-Cook *Environ. Sci. Technol.* **2010,** *44,* 9357–9363

Air Toxics in Garfield County CO



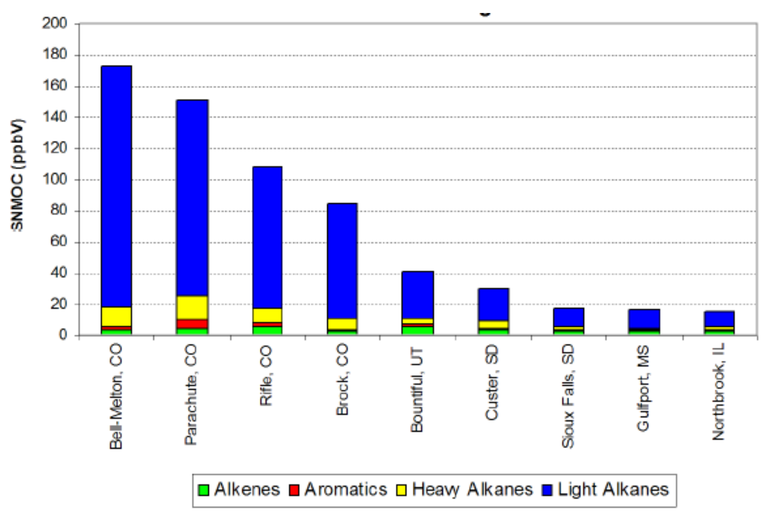
Colorado Department of Public Health and Environment 2010

Time Series of Data



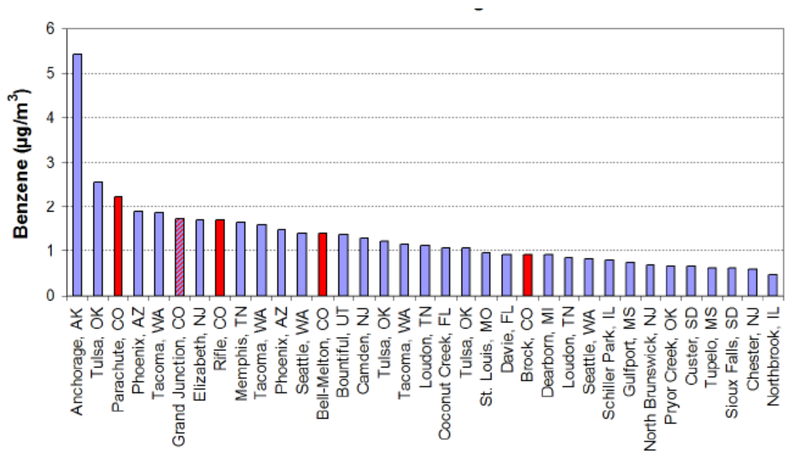
Cassie Archuleta Air Resource Specialists, Inc.

Speciated hydrocarbons are high



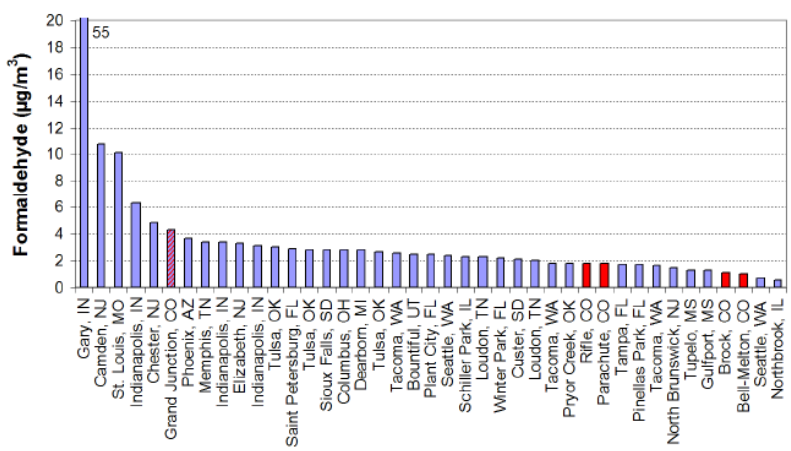
Cassie Archuleta Air Resource Specialists, Inc.

Benzene is elevated



Cassie Archuleta Air Resource Specialists, Inc.

Formaldehyde is not



Cassie Archuleta Air Resource Specialists, Inc.

Methane and Climate

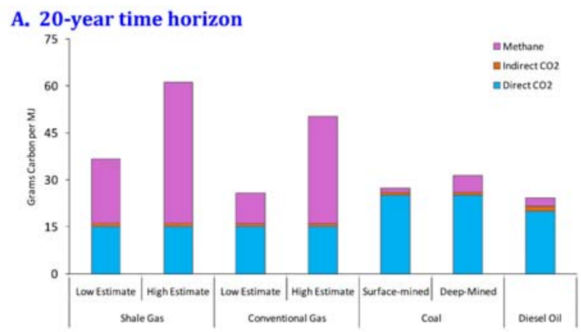
Climatic Change
DOI 10.1007/s10584-011-0061-5
LETTER

Methane and the greenhouse-gas footprint of natural gas from shale formations

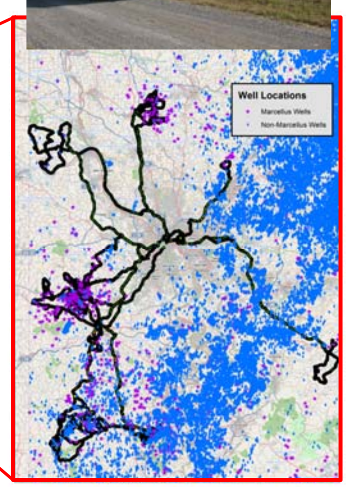
A letter

Robert W. Howarth · Renee Santoro · Anthony Ingraffea

Received: 12 November 2010 / Accepted: 13 March 2011

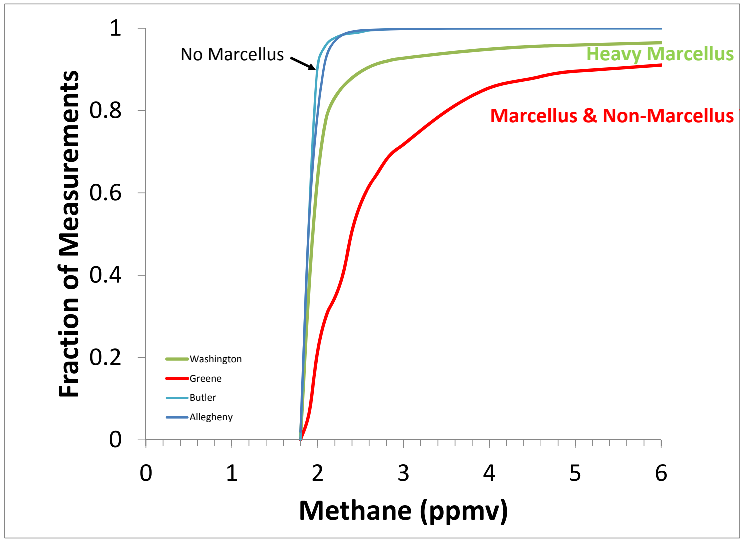


Marcellus Region



(USGS, 2009)

Methane Data



Air quality and oil and gas development

- More than just "fracing" -- Complex mix of "small" sources
- Widely distributed in space
- Poor coverage by routine monitoring networks
- Aggregate emissions are significant in regional context:
  - NOx and VOC (→ regional O_3)
- Air toxic emission may create local problems
  - Diesel PM and formaldehyde (local air toxics)
- Climate implications uncertain but methane levels in gas fields elevated
- Control measures exist

CSU activities in shale gas and air quality

- Garfield County Air Toxics Project (Collett)
- Marcellus Inventory Development and O3 Modeling (Robinson)
- Marcellus Pollutant Mapping (Robinson)

Acknowledgements

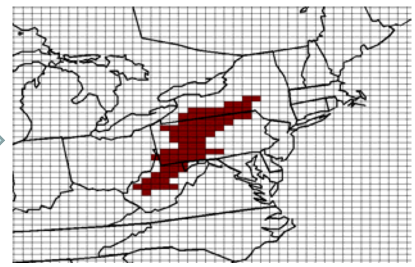
- Anirban Roy, Peter Adams
- Eric Lipsky, Rawad Saleh
- NETL, PA DEP, WV DEP, NY DEC, MARAMA, GASP, EQT
- Heinz Endowment and DOE-NETL (funding)

Estimating air emissions in Marcellus region

Actual region

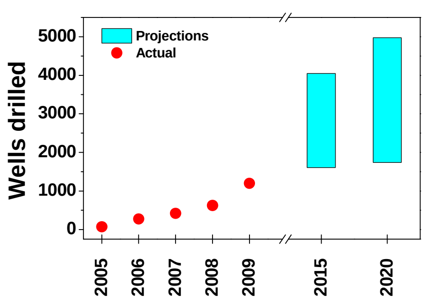
(USGS, 2009)

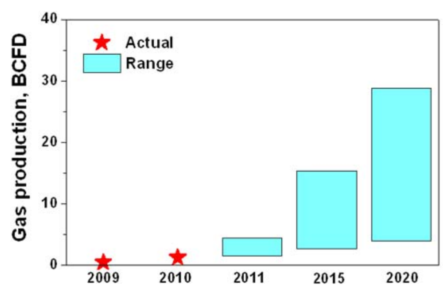
Inventory Domain



27

Past and future Marcellus well development and gas production

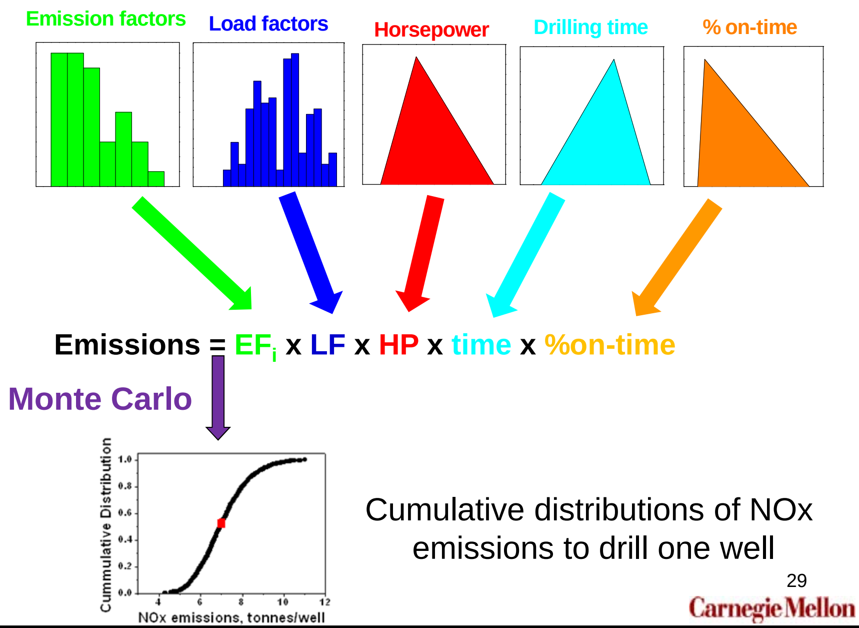




Considine, 2010; Considine et al. (2009, 2011); The Nature Conservancy, 2010; NETL, 2010; Annual Energy Outlook, EIA, 2011

28

Accounting for Uncertainty

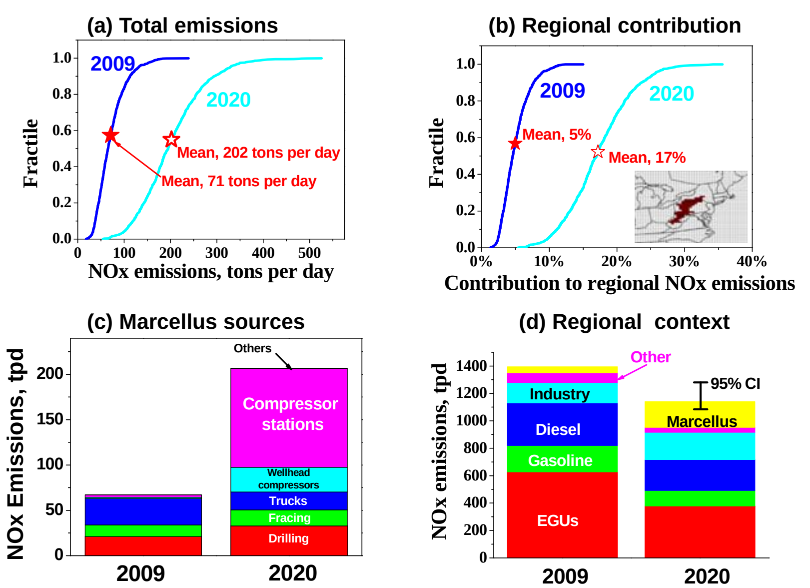


Cumulative distributions of NOx emissions to drill one well

29

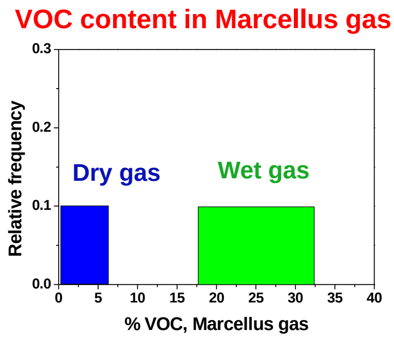
Carnegie Mellon

Aggregate emissions can be significant - - Marcellus NOx emissions

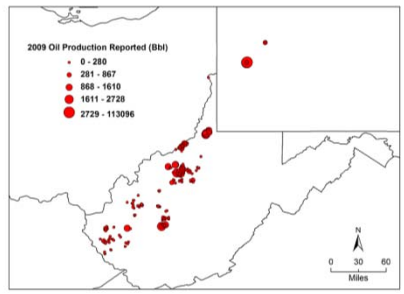


30

VOC emissions: Wet versus dry gas



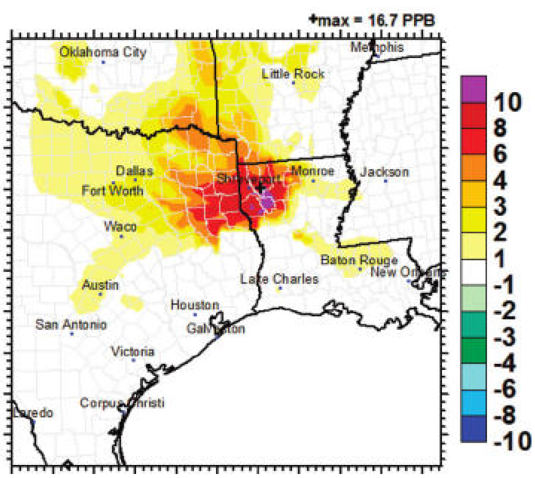
2009 Condensate production (bbl)



Bridgeport Analytical Services, 2009
Chesapeake, 2009; Jiang et al., 2011

NOx & VOC emissions likely impact regional ozone

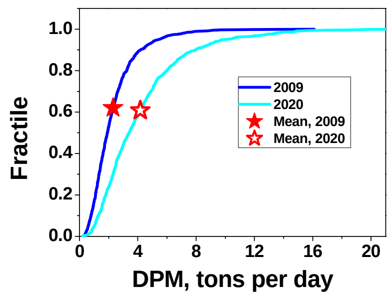
CAMx simulations of O_3 from Haynesville Shale

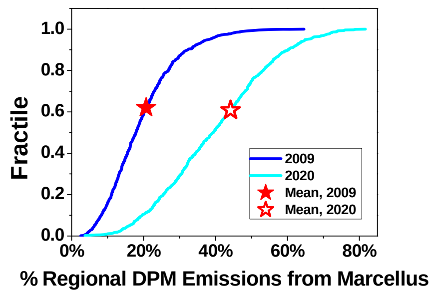


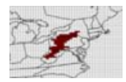
ΔOzone (ppbv)
max daily 8-hr ave

Kemabll-Cook et al. *Environ. Sci. Technol.* **2010,** *44,* 9357–9363

Air Toxics too -- diesel particulate matter

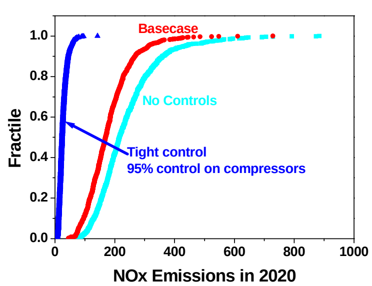






Diesel powered drill rigs, frac pumps and trucks

Effective control measures exist

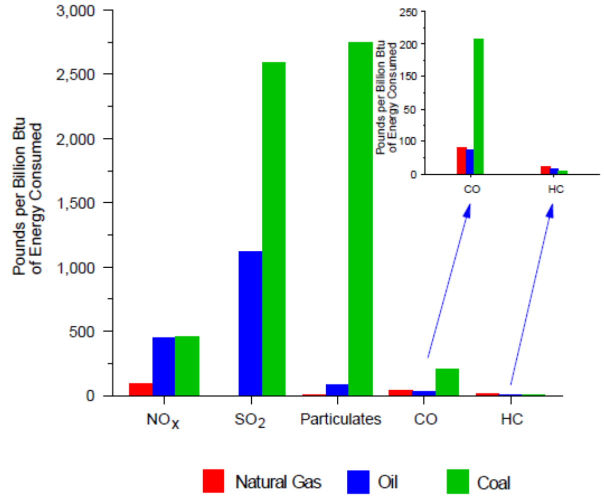


Compressor Stations
- Oxidation catalyst
- Stoichiometric combustion + 3-way catalyst
- Selective catalytic reduction (SCR)

Drill rigs and frac pumps
- Diesel particulate filters
- SCR
- Fuel switching to natural gas

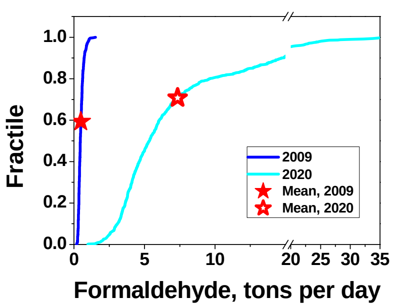
VOCs
- Green completion (~95%)
- Flaring (51-84%)
- Vapor recovery units for condensate tanks (~91-95%)

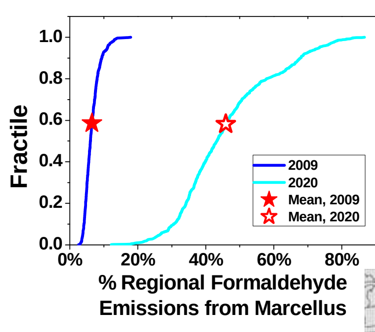
Air quality benefits from end of use: Comparison of EGU emission factors

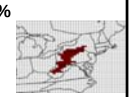


EIA, 1998, 2012 35

Air Toxics – Formaldehyde Emissions

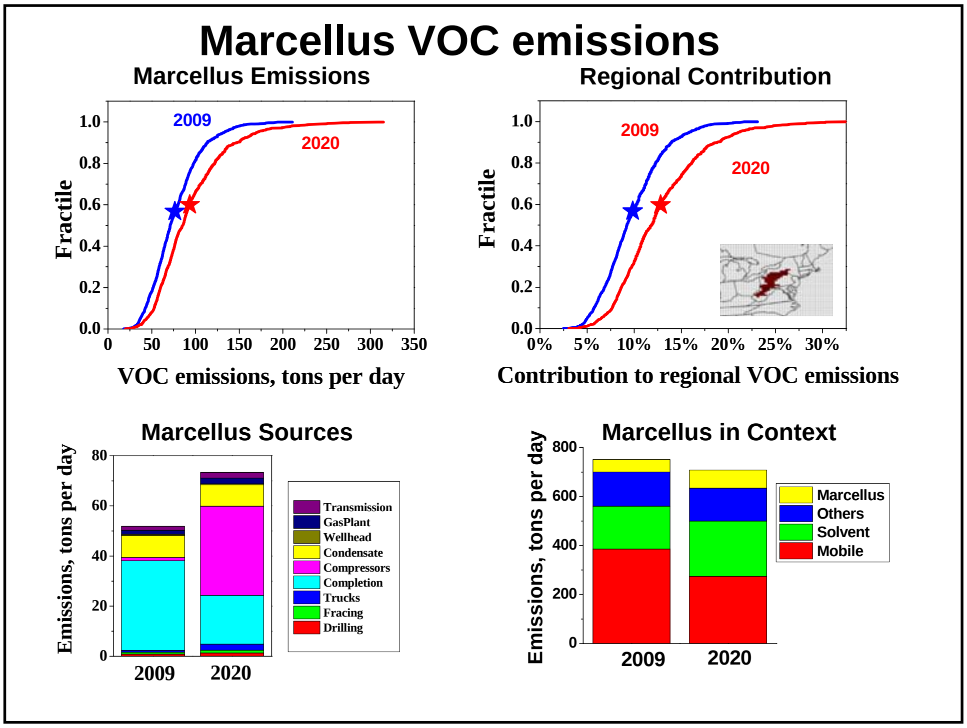




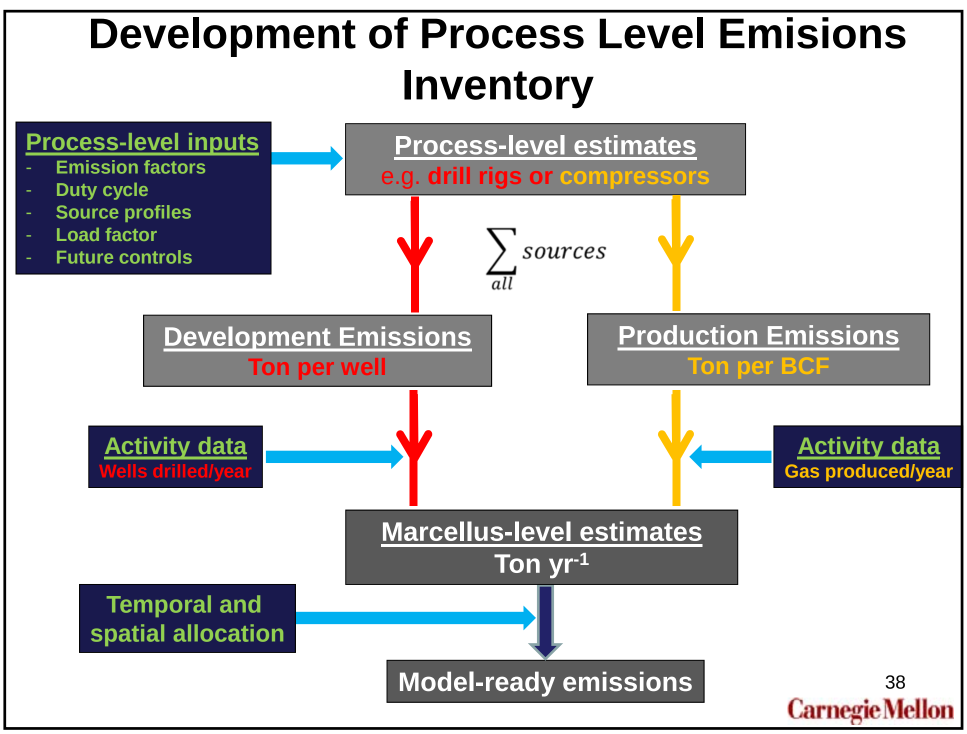


Natural gas powered compressor stations are major source.

This is for primary emissions – majority of formaldehyde in atmosphere is secondary.



Marcellus VOC emissions
Marcellus Emissions
Regional Contribution
2009
2020
Fractile
VOC emissions, tons per day
Contribution to regional VOC emissions
Marcellus Sources
Emissions, tons per day
Transmission
GasPlant
Wellhead
Condensate
Compressors
Completion
Trucks
Fracing
Drilling
Marcellus in Context
Marcellus
Others
Solvent
Mobile



Development of Process Level Emisions Inventory
Process-level inputs
- Emission factors
- Duty cycle
- Source profiles
- Load factor
- Future controls
Process-level estimates
e.g. drill rigs or compressors
$\sum_{all} sources$
Development Emissions
Ton per well
Production Emissions
Ton per BCF
Activity data
Wells drilled/year
Activity data
Gas produced/year
Marcellus-level estimates
Ton yr^{-1}
Temporal and spatial allocation
Model-ready emissions
38
Carnegie Mellon

Attachment 14
Managing Air Emissions from the Natural Gas Industry

Managing Air Emissions from the Natural Gas Industry

Dr. Morgan DeFoort, Department of Mechanical Engineering
Colorado State University

ENGINES & ENERGY CONVERSION LAB

Colorado State University

Carbon Impact of Coal vs. Natural Gas

$$Coal: \frac{205 \text{ lb } CO_2}{\text{mmbtu}} \times \frac{10.5 \text{ mmbtu}}{\text{MWh}} \times \frac{\text{ton } CO_2}{2000 \text{ lb } CO_2} = \frac{1.08 \text{ ton } CO_2}{\text{MWh}}$$

$$Gas: \frac{115 \text{ lb } CO_2}{\text{mmbtu}} \times \frac{7.0 \text{ mmbtu}}{\text{MWh}} \times \frac{\text{ton } CO_2}{2000 \text{ lb } CO_2} = \frac{0.40 \text{ ton } CO_2}{\text{MWh}}$$

Combustion

Cycle Efficiency

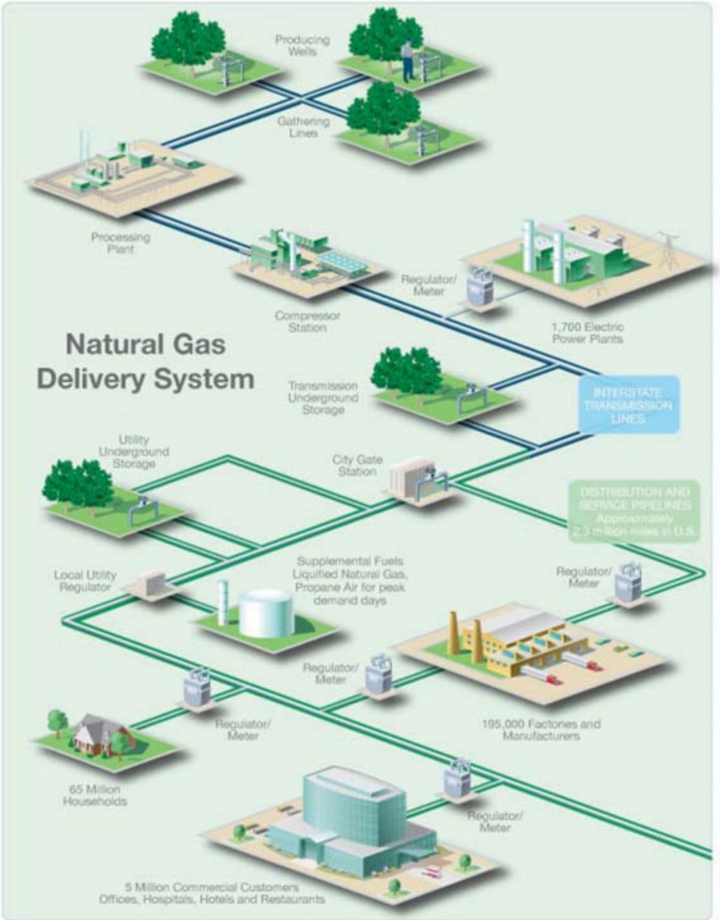
NOTE: This does NOT include the reduction of CO2 from CHP, combined heat and power

Top Ten Advantages…

1. Dispatchable power at scale - enabling for renewables
2. Can reduce combustion CO2 by 50%-80%
3. Combustion can have super-low emissions
4. Biggest capacity for scale – our fastest "wedge"
5. Cheap - best consumer economics of clean energy options
6. U.S. (& world) has a LOT of it
7. It's renewable - could be our largest-scale biofuel
8. Has centrist bipartisan support
9. CHP, NGVs & RNG
10. It's in your home (office, factory) NOW

Top Ten Disadvantages…

1. Low cost is threatening for renewables
2. Poor execution can increase life cycle CO2
3. Combustion / Leakage can have super-high emissions
4. Biggest capacity for scale – but unenlightened use could destroy "wedges"
5. Cheap – challenging producer economics & impact on renewables
6. U.S. (& world) has a lot of it – which could reduce our motivation for conservation & renewables
7. It's renewable – but at higher cost so we don't use this feature
8. Has centrist bipartisan support – but raging battles between the more "extreme" elements on both sides
9. CHP, NGVs & RNG – but we don't have any
10. It's in your home (office, factory) NOW – so our failure to enact an enlightened approach represents a huge opportunity cost!



The Natural Gas Industry: A complex system

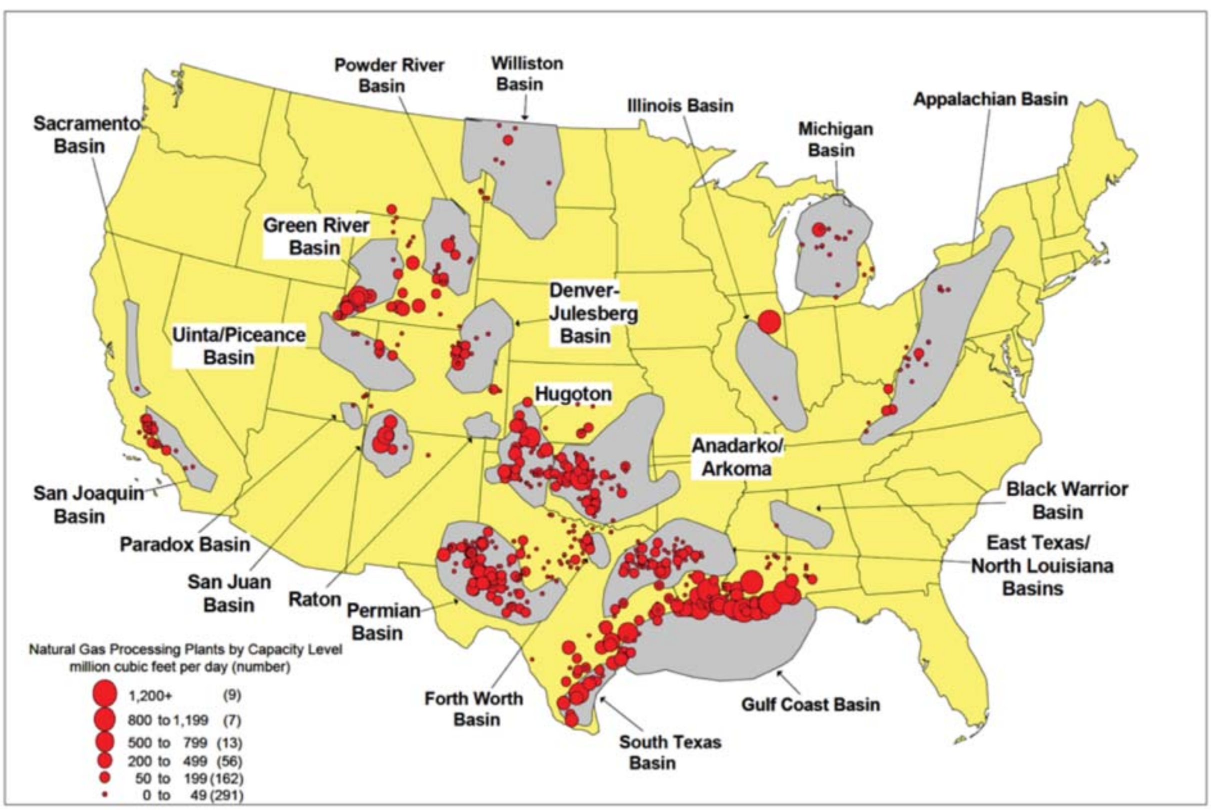
- Exploration & Production
- Midstream
- Transmission
- Delivery

Exploration and Production

Air Emissions Sources:

- **Vehicles**
- **Generators (Power and Compression)**
- **Flares**
- **Gas Processing**

Midstream Gas Plants

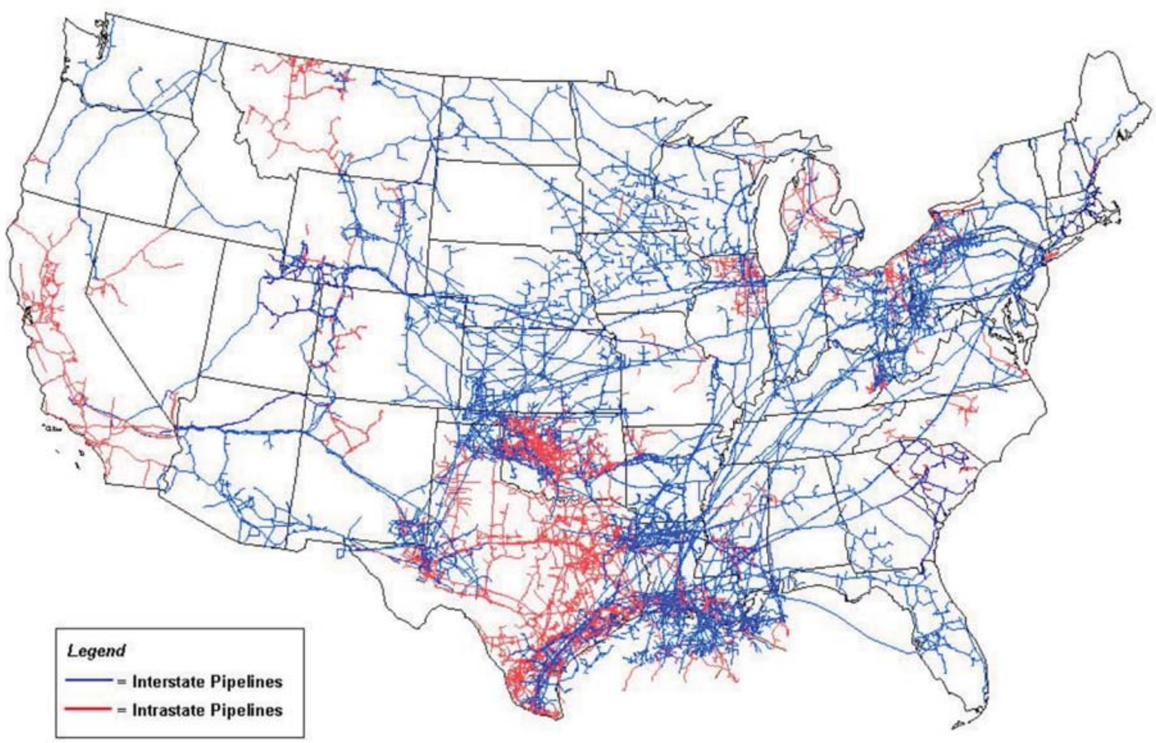


Transmission

Air Emissions Sources:

- Transmission Pipeline (Valves and Metering Equipment)
- Compressors
- Pigging Equipment (Insertion and Receiving)

Transmission



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

RICE NESHAP: 2004

	Area Sources		Major Sources	
> 500 HP	New	Existing	New 2004 rule	Existing 2004 rule
< 500 HP	New	Existing	New	Existing

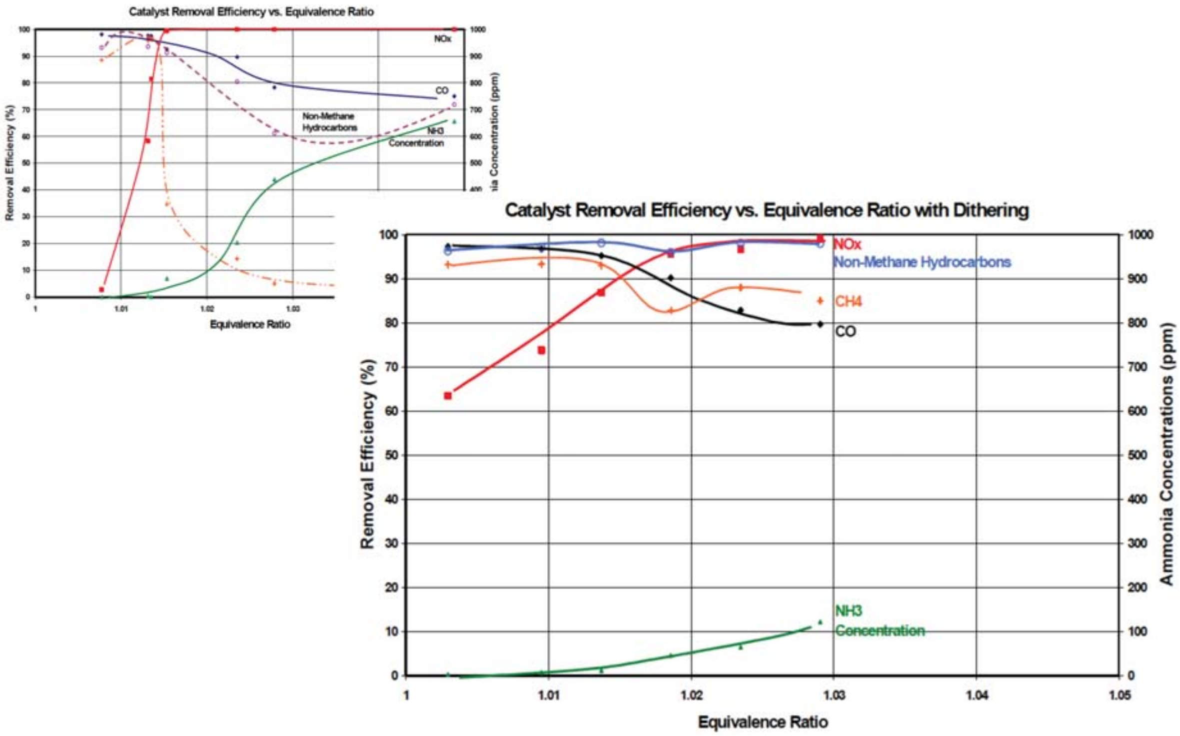
RICE NESHAP: 2008

	Area Sources		Major Sources	
> 500 HP	**New** **2008 rule**	**Existing**	**New** **2004 rule**	**Existing** **2004 rule**
< 500 HP	**New** **2008 rule**	**Existing**	**New** **2008 rule**	**Existing**

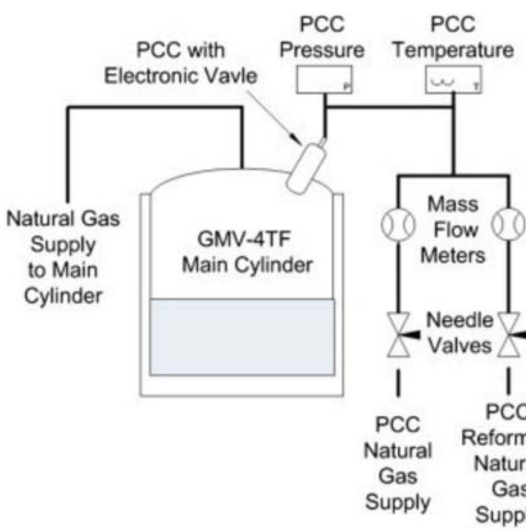
RICE NESHAP: 2010

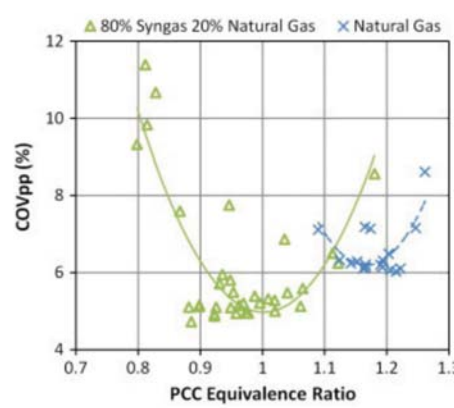
	Area Sources		Major Sources	
> 500 HP	**New** **2008 rule**	**Existing** **2010 rule**	**New** **2004 rule**	**Existing** **2004 rule**
< 500 HP	**New** **2008 rule**	**Existing** **2010 rule**	**New** **2008 rule**	**Existing** **2010 rule**

Technology Solutions at CSU
NSCR Catalyst Testing



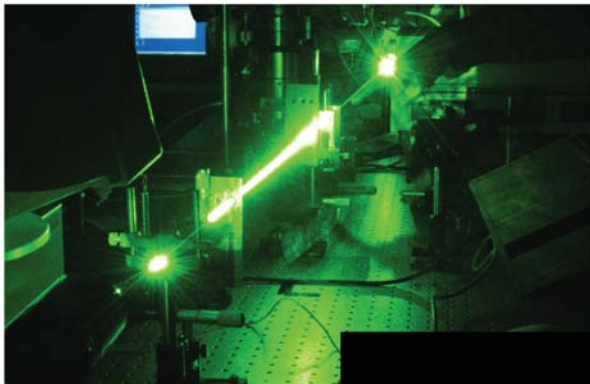
Technology Solutions at CSU
PCC Syngas Development

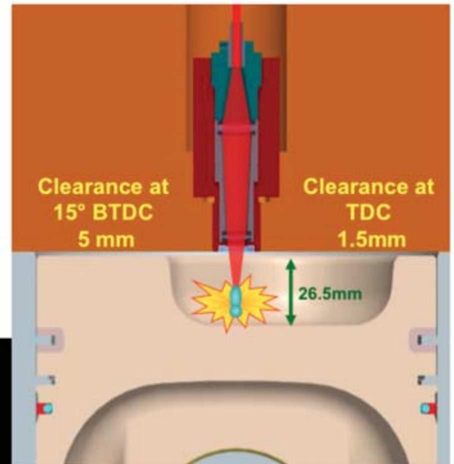




Technology Solutions at CSU

Laser Ignition

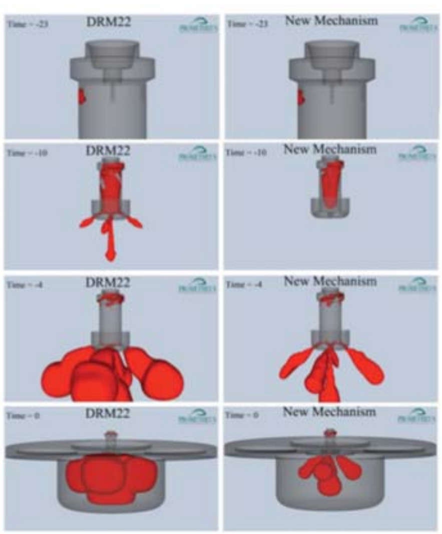


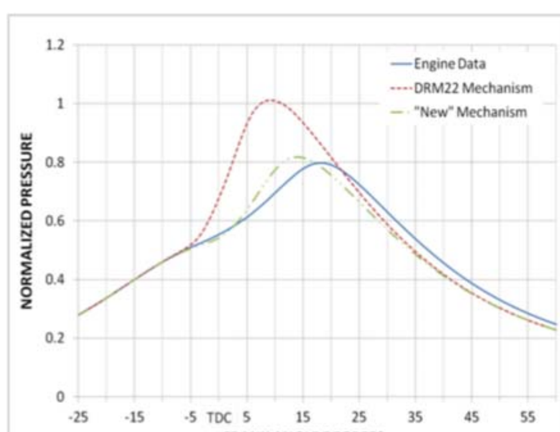


Technology Solutions at CSU

Natural Gas Kinetics: Prometheus

Converge modeling with new 20-species mechanism compares well with measured in-cylinder pressure data.





Martinez, D., Tozzi, L. and Marchese, A. J. (2012). A reduced chemical kinetic mechanism for CFD simulations of high BMEP lean-burn natural gas engines. *ASME 2012 Internal Combustion Engine Division Spring Technical Conference*, Torino, Italy, May 6-9, 2012

Technology Solutions at CSU

Infrastructure Monitoring: Logimesh

- Realtime data monitoring
- EECL is helping with industry connections, investor connections, and technology development

Contact:

Morgan DeFoort, Co-Director, EECL

Morgan.DeFoort@Colostate.edu

Attachment 15
Use of Natural Gas in Thermal Remediation

UPDATE: USE OF NATURAL GAS IN THERMAL REMEDIATION

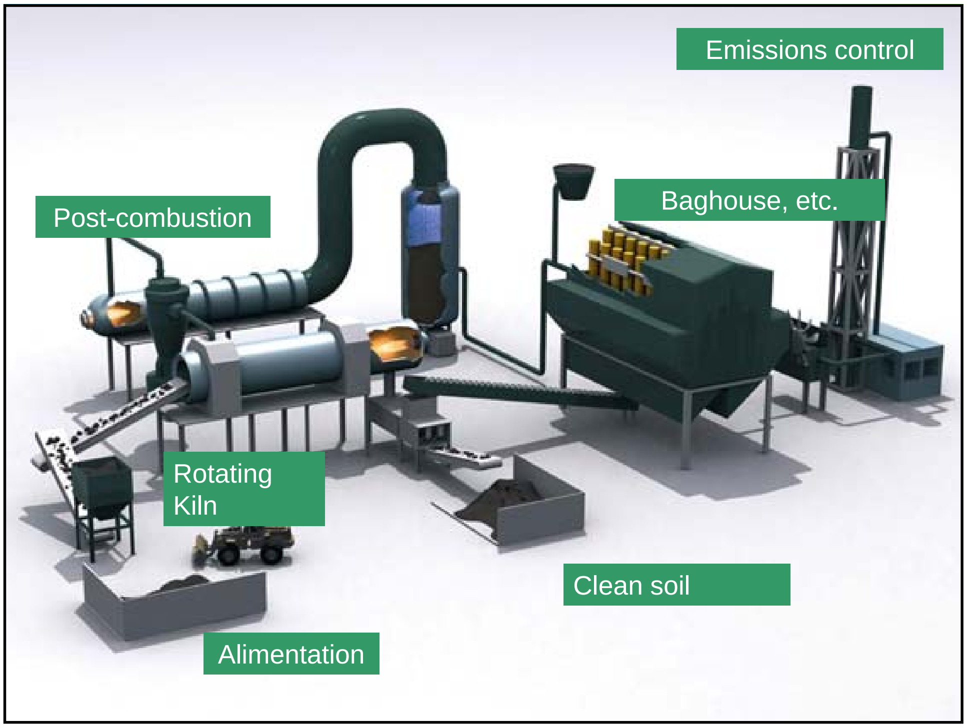
How industry is using natural gas

Measuring sustainability with natural gas

Peculiarities of thermal remediation sites

Grant Geckeler
TPS TECH

1

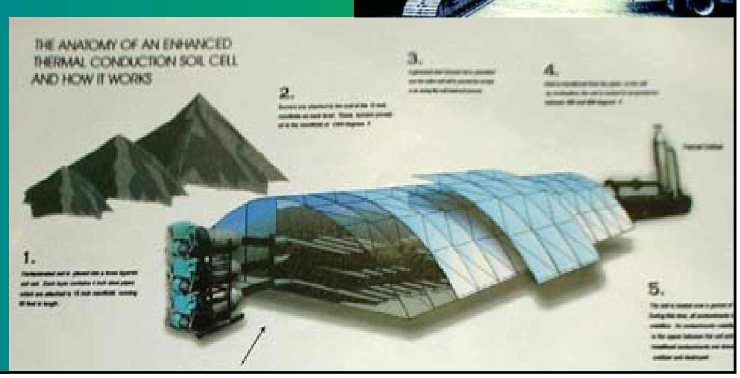


The Genesis of Natural Gas in Thermal Treatment

Bova, Richter (1997)

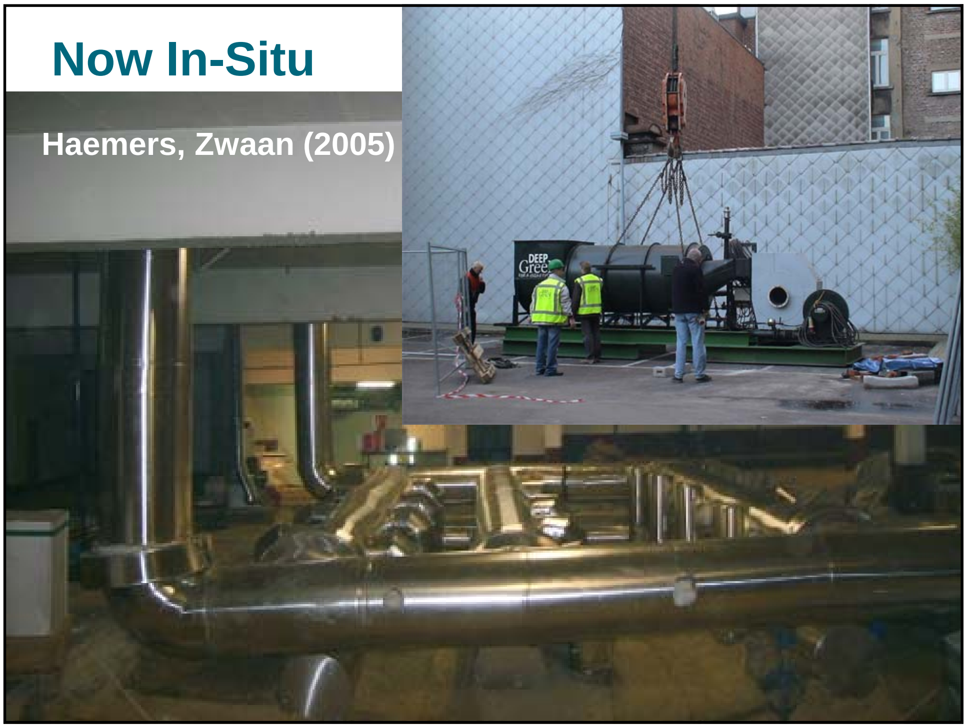
Thermal Conduction Soil Cell Arrangement

Natural Gas Burners and Thermal Oxidizer



Now In-Situ

Haemers, Zwaan (2005)

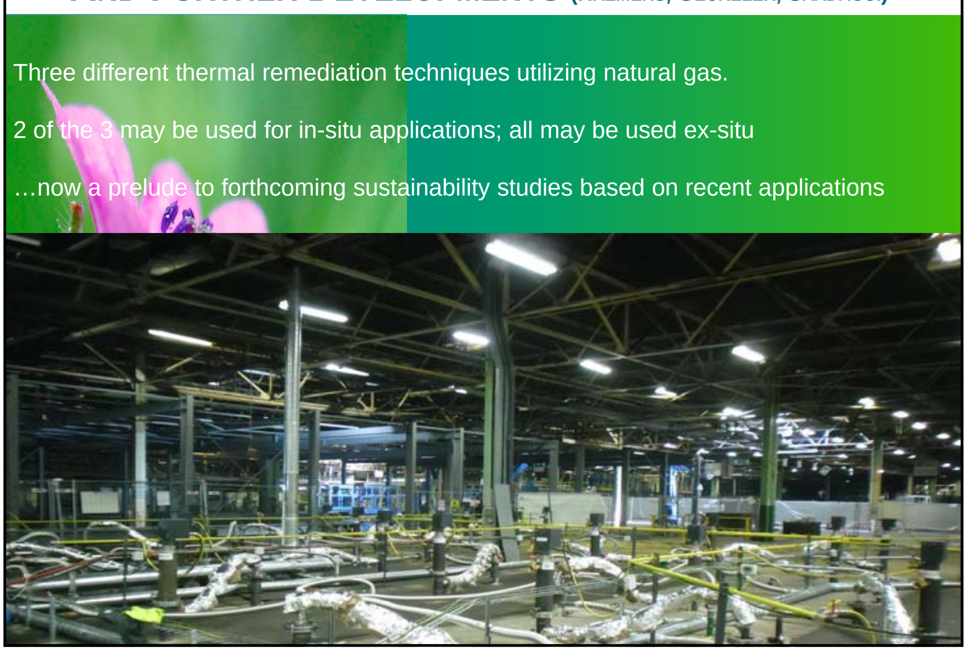


AND FURTHER DEVELOPMENTS (HAEMERS, GECKELER, SAADAOUI)

Three different thermal remediation techniques utilizing natural gas.

2 of the 3 may be used for in-situ applications; all may be used ex-situ

…now a prelude to forthcoming sustainability studies based on recent applications



WHY THE HISTORY LESSON?

Issues relating to sustainability in remediation (economical, environmental, and social) do affect innovation and resulting products in our sector.

People have been listening pre-SURF,
but now the volume is pumped up.

7

CO_2 Data

Coal Power vs. Natural Gas (CO_2 / MWh)

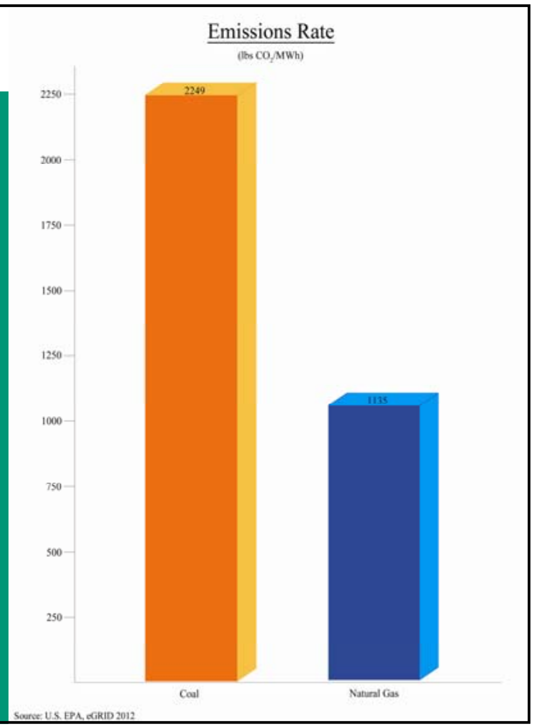
Compelling Graph…demonstrates many opportunities…

BUT

There there are many sustainability issues that must be explored further

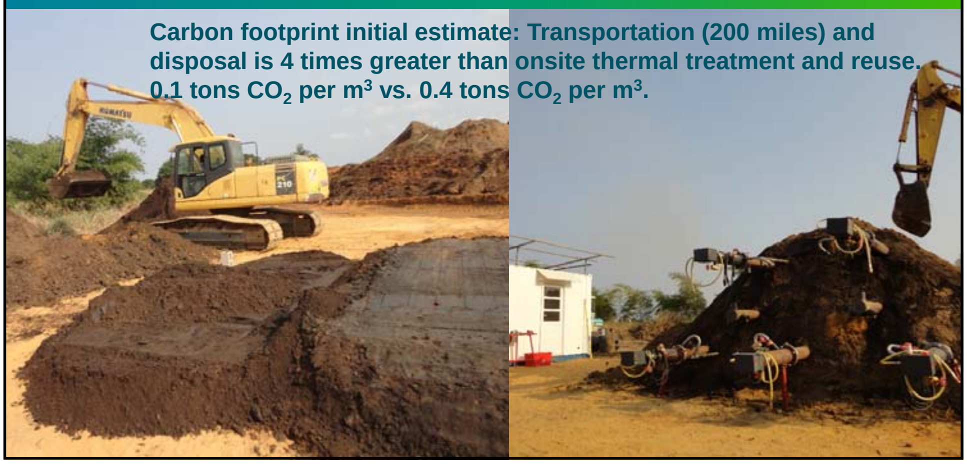
Do we have enough data to make a meaningful evaluation for our industry? Life Cycle Assessments? This data is very application specific.

Alas, remediations do not occur in a petri dish.



PAH Impacted Soils

80,000 cubic yards of soil in stored piles.
Nearest landfill / processing facility is 200 miles away.
"Back of the napkin" sustainability concerns → situational and time-based
•Transportation and off-site disposal vs. on-site treatment: CO_2, NO_X, SO_4
•Facility expansion must proceed in 6 months or less

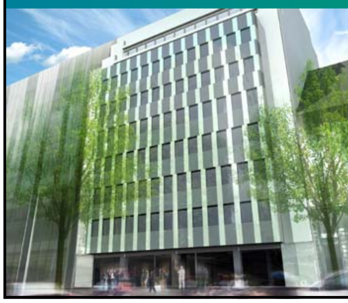


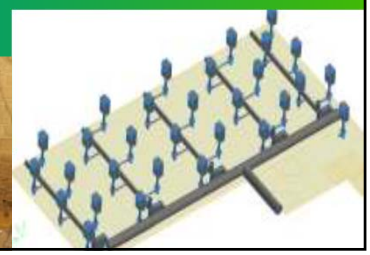
Carbon footprint initial estimate: Transportation (200 miles) and disposal is 4 times greater than onsite thermal treatment and reuse. 0.1 tons CO_2 per m^3 vs. 0.4 tons CO_2 per m^3.

- **Land consumption**
  - Worldwide: 20 million hectares a year, i.e. **6300 m²/sec**
  - United States: **800 m²/sec**
  - European Union: **500 m²/sec**

Societal Implications of Land Reuse

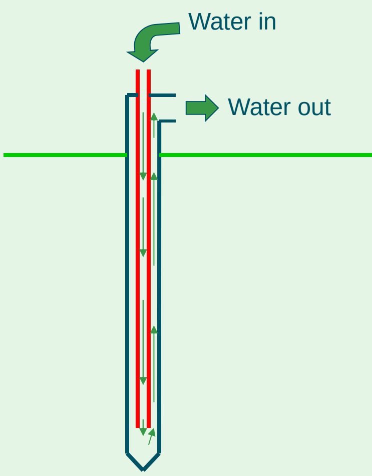
+ **Remediation still is often a conditional outcome of extra-regulatory conditions:**
  - Buyer to purchase and redevelop office building into apartment housing; must have remediation complete in less than three months to secure redevelopment financing. Either redevelop or building will essentially be non-utilized (Brownfields).
+ **Societal benefits in this case:**
  - 72 apartment homes created in urban environment
  - Local construction companies hired for redevelopment
  - Long-lasting boost to local retailers and businesses

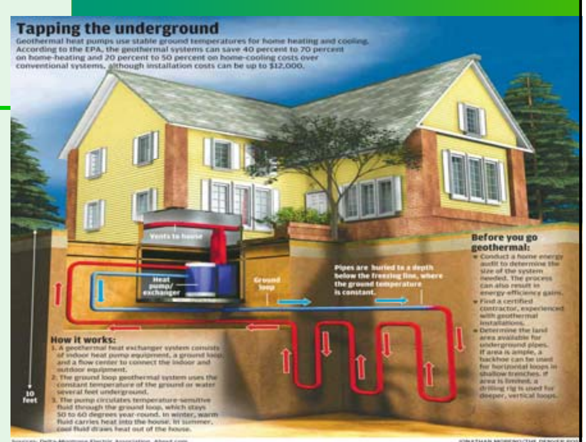




Sustainability Can Occur at Any Juncture

+ **Remediation infrastructure partially reused onsite for geothermal heat pump applications**
  - Reduces water heating/cooling electrical demands by ~ 20%.





Attachment 16
ITRC Green and Sustainable Remediation

1

ITRC GSR Update

Stephanie Fiorenza, BP
ITRC GSR Team Member and IBT Trainer

2

ITRC GSR Update

- Background
  - Started 2008
  - Largest ITRC team
  - State leads- Tom O'Neill NJ and Rebecca Bourdon MN
- Products
- Implementation / Internet-based Training
- Next Steps

3

ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners

    DOE DOD EPA

  - ITRC Industry Affiliates Program

    IAP

  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

4

ITRC GSR Products

- Overview Document

  Green and Sustainable Remediation: State of the Science and Practice
  - (GSR-1, 2011)
- Technical & Regulatory Guidance Document:

  Green and Sustainable Remediation: A Practical Framework
  - (GSR-2, 2011)

5

GSR Training Roadmap

GSR Framework

Introduction (Section 1 Tech Reg)
- Definitions
- GSR Intent and Benefits

GSR Planning (Section 2 Tech Reg)
- Common Considerations
- Relevant GSR Questions

GSR Implementation (Section 3 Tech Reg)
- Lifecycle Phase Approach
- Consistent Methodology

Q&A #1

GSR Tools (Section 4 Tech Reg)
- Choosing the right tool
- Examples of BMPs, Simple, and Advanced Tools

Case Studies (Appendix C Tech Reg)

Training Wrap-Up

Q&A #2

6

Meet the ITRC Instructors

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7

ITRC's GSR Definition

The site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects.

8

GSR Framework

Flexible and Scalable

- Flexibility similar to that found in conceptual remedial designs
- Scalable to the size and level-of-detail of the project

Example: UST site vs. Superfund site

9

Relationships with Existing Programs

ITRC GSR-2: Table 3.1 (excerpt)

- Can be applied to any federal or state program

Remedial Phase	RCRA	CERCLA	State Programs	LUST
Investigation	RCRA Facility Investigation	Remedial Investigation	Site Assessment	Remedial Investigation; Secondary Investigation
Remedy Evaluation and Selection	Corrective Measures Study and Statement of Basis	Feasibility Study, Proposed Plan, and Record of Decision	Remedial Alternative Evaluation	Conceptual Corrective Action Design; Corrective Action Plan
Remedy Design	Corrective Measures Design/Corrective Measures Implementation Work Plan; Interim Measure	Remedial Design	Remedial Action Plan; Interim Source Removal Plan	Focused Investigation, Detailed Corrective Action Design

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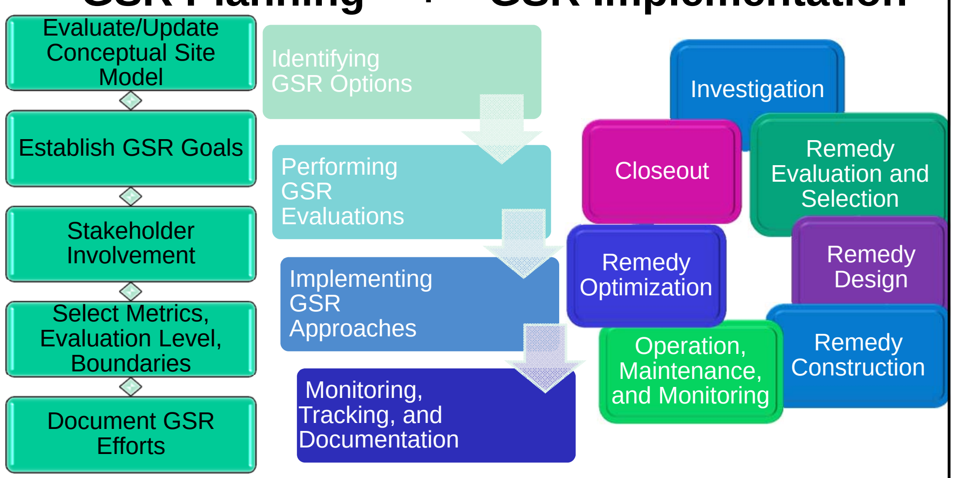
GSR Framework

GSR Planning + GSR Implementation



= GSR Framework

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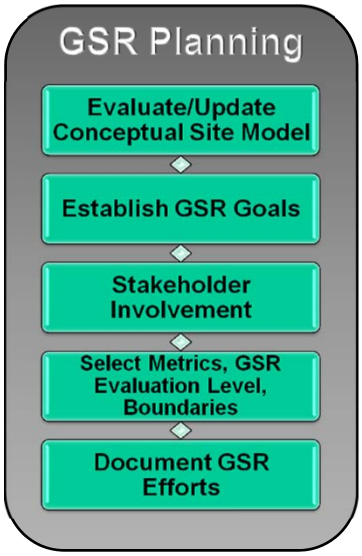
GSR Planning

Tech Reg Section 2



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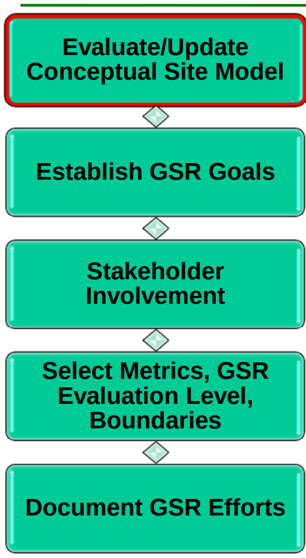
GSR Planning

Evaluate/Update Conceptual Site Model (CSM)



- Evaluate and update as necessary
- Integrate relevant GSR information to reflect potential opportunities were GSR can be considered and implemented
- CSM similar to that discussed in ITRC Performance Based Environmental Management Document (RPO-7)*

*http://www.itrcweb.org/Documents/RPO-7.pdf

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GSR Planning

Establish GSR Goals

- **Evaluate/Update Conceptual Site Model**
- **Establish GSR Goals**
- **Stakeholder Involvement**
- **Select Metrics, GSR Evaluation Level, Boundaries**
- **Document GSR Efforts**

- Site setting and circumstances
- GSR components
- EPA's green remediation core elements*
- Drivers: regulatory guidance/policy, corporate directives, incentives
- Goals can relate to remediation and non-remediation activities

*www.clu-in.org/greenremediation

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GSR Implementation

Tech/Reg Section 3

- Identifies how GSR approaches may be

- Covers each remediation phase
- Provides a flexible approach

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How Does GSR Fit In?

Investigation	• GSR application during planning
Remedy Evaluation and Selection	• Ideal point for incorporating GSR
Remedy Design	• Integration of GSR into selected remedy
Remedy Construction	• GSR integral part of remedy
Operation, Maintenance and Monitoring	• Cumulative benefits resulting from GSR
Remedy Optimization	• Sustainability performance improvement for existing remedies
Closeout	• Support for site reuse

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Approach

- Consistent for each phase
- Provides a methodology for

GSR Options

GSR Evaluation

GSR Implementation

Tracking and Documentation

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GSR Options

Remedy Construction Example

Environmental	Social	Economic
- Minimize idling - Control/mitigate dust and odors - Conduct air monitoring - Set up an on-site recycling program - Minimize fuel/energy use	- Implement community notifications - Conduct community meetings - Post information on project progress - Maximize use of local businesses - Sequence construction activities	- Consider economic benefits to community

ITRC GSR-2: Table 3.7

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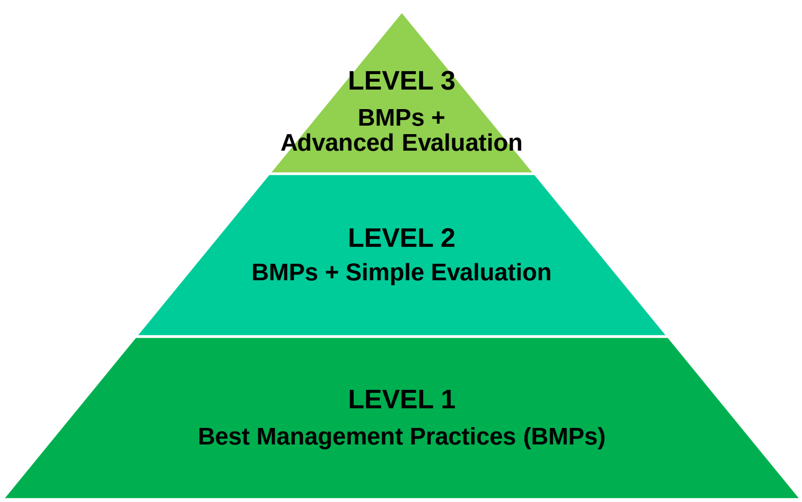
GSR Evaluation Levels



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Tracking and Documentation

- Ensures transparency
- Documents GSR practices
- Identifies sustainability benefits
- Tracks successes and lessons learned
- Incorporated in regulatory reports

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GSR Training Roadmap

GSR Framework

- Introduction (Section 1 Tech Reg)
  - Definitions
  - GSR Intent and Benefits
- GSR Planning (Section 2 Tech Reg)
  - Common Considerations
  - Relevant GSR Questions
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  - Consistent Methodology

Q&A #1

- GSR Tools (Section 4 Tech Reg)
  - Choosing the right tool
  - Examples of BMPs, Simple, and Advanced Tools
- Case Studies (Appendix C Tech Reg)
- Training Wrap-Up

Q&A #2

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Before Selecting GSR Tools

Set GSR Goals and Select Metrics

Goals → Metrics → Tools

Example Goals	Example Metrics
Reduce emissions	Greenhouse gases Air quality emissions
Conserve natural resources	Energy and water use Resource consumption
Create habitat	Ecological service value
Improve community	Traffic volume Jobs for local workers

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Before Selecting GSR Tools

Include stakeholders

Stakeholders	Values	GSR Metrics
Project leader	Project efficiency	Energy & cost savings
Property owner	Property value	Land use
Community group	Safety and quality of life	Traffic volume
Site regulator	Health and environment	Air pollutant emissions Ecological habitat

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Before Selecting GSR Tools

Set Boundaries for GSR Evaluation

On-Site Impacts

System construction materials

Land footprint

Electricity used

Extracted water

Treated water discharge

Construction materials

Treatment media (carbon)

Off-Site Impacts

Materials used

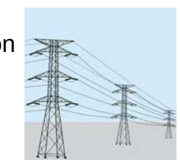
Air pollution

Transportation

Fuel consumption

Air pollution

Traffic volume



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Tool Selection

Select the Right Level of Evaluation

	Level 1 BMPs	Level 2 BMPs + Simple	Level 3 BMPs + Advanced
Description	• Best practices (e.g., no idling of truck engines at job site)	• Qualitative ranking process	• Quantitative analysis (e.g., footprint analysis, Net Environmental Benefits Analysis)
Pros	• Simple • Cost-effective • Easy to implement	• Evaluates multiple metrics • Simple calculations only (lb CO_2/lb contaminant treated)	• Quantifies multiple metrics • Track impacts from cradle to cradle
Cons	• Does not evaluate trade-offs	• Requires scoring method	• Requires scoring method • More costly, time-consuming • More data required

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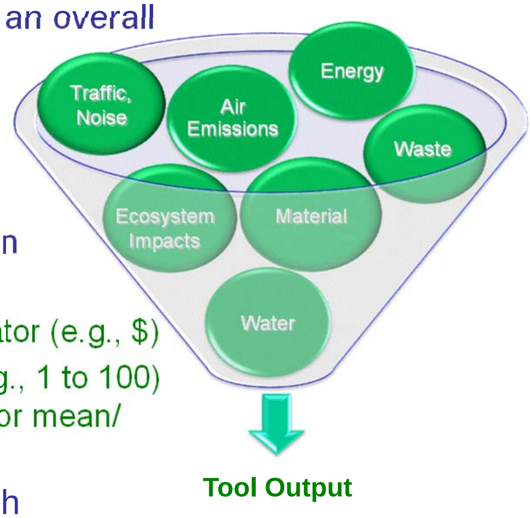
GSR Tools

Weighting and Scoring Methods

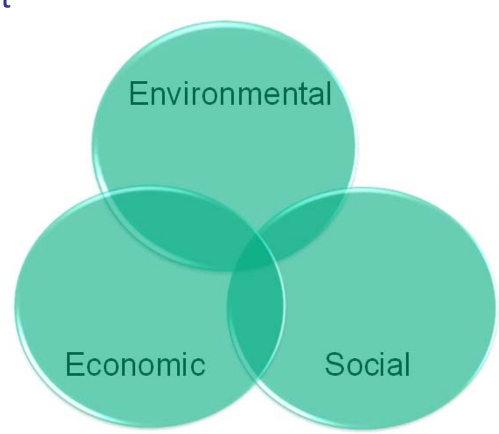
- Some tools give you an overall GSR score
- Decide relative importance of each GSR metric
- Normalize to common units and range
  - Common denominator (e.g., $)
  - Common range (e.g., 1 to 100) based on min/max or mean/ standard deviation
- No “perfect” approach



26

Case Studies

- Application of Green & Sustainable Remediation to sites
- Examples with different
  - GSR levels
  - Remediation phases
  - Metrics
  - Regulatory programs



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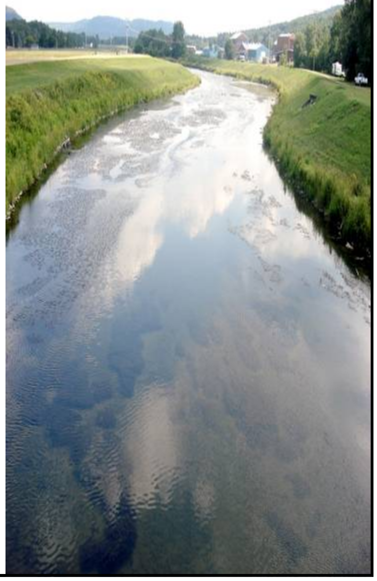
Former Refinery Site (Level 1)

Overview

- Pre-GSR: no formal evaluation for selection of optimization measures
- GSR scope: applied during Remedy Optimization
- GSR metrics
  - Energy consumption
  - Ecological diversity
  - Community benefits



ITRC GSR-2: Appendix C

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RCRA Site (Level 2)

Site Remediation

Setting

- State RCRA program, confidential location
- Permeable sand and glacial outwash with glacial till near surface
- 39 volatile and semivolatile organic compounds (VOCs) + (SVOCs) in subsurface soil and perched groundwater
- Remediation driver
  - Sole source aquifer
- Remedy selected
  - Source excavation of 70,000 tons
- Other remedies considered
  - Ex situ thermal
  - In situ electrical resistive heating (ERH) and hot spot excavation

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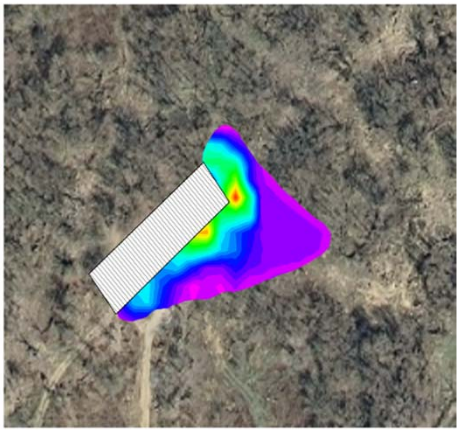
Brownfield Site (Level 3)

Significant GSR Elements

- Environmental
  - Triad - Membrane Interface Probe
  - Biofuels
  - Footprint/Tool Comparison
- Social
  - Revitalize blighted neighborhood
  - Reduce accident risk
- Economic
  - Leverage public/private investment for future redevelopment



30

Brownfield Site (Level 3)

Summary

- Benefits of GSR approach
  - Triad process expedited investigation and redevelopment, improved remediation
  - Community institutions were strengthened
  - Air emissions (including GHG) were reduced
  - Project catalyzed neighborhood revitalization and job creation will reduce poverty
- Challenge to implementing GSR
  - Weighting social, economic and environmental metrics was difficult
- Lessons learned
  - Tool selection depends on amount of information available and technologies being evaluated

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Key Lessons from Case Studies

- FLEXIBILITY: GSR process can be applied to a variety of sites, remediation phases and regulatory programs
- COMMUNICATION: Communication with stakeholders is critical to successful application of GSR
- ASSUMPTIONS: Because evaluation methods are new, users must understand the assumptions of the tools being used
- HOLISTIC: This holistic approach will minimize a project's life cycle impacts

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Concluding Statements

- Make the ITRC GSR Framework your own
- GSR potential is limitless
- Top-down or bottom-up, integration is possible
- Share your successes!

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Future Directions

- SURF Government Outreach
- Partnering with ITRC and API
- Taking GSR initiative and training to individual states

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Relationship to Other GSR Efforts

Information clearinghouse, Core Elements, fact sheets, best management practices, standard guide

Detailed information specific to metrics, framework, and life-cycle assessment

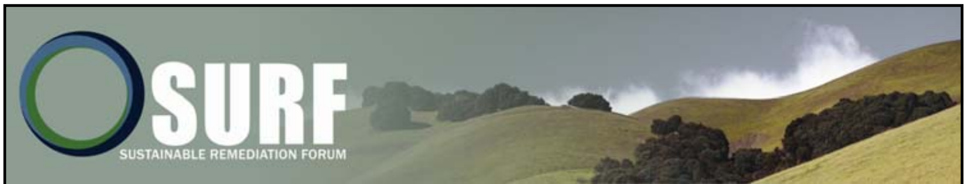
White papers, BMPs, and incentives

Sustainable Remediation Tool™, SiteWise™ Tool, Fact Sheets, Case Studies

Practical guidance with a framework, metrics and tools for remedial practitioners

Attachment 17
Committee and Initiative Breakout Sessions

Sustainable Remediation Resource Index



Sustainable Remediation Resource Index Technical Initiative

(SRRI TI)

Formerly “Site of Sites”
July 2012

Co-Chairs
Pamela Dugan, Ph.D, P.G., *Carus Corporation*
Mary Kean, PE, *Sustainable Silicon Valley*

Presented by SRRI Team Member
Diana Hasegan, E.I.T., *Langan Engineering*

BACKGROUND – “SITE OF SITES”

- Launched during SURF 17 (April 2011)
- Collaborative effort:
  - 2011 SURF and Illinois Institute of Technology faculty and students from the
  - 2012 SURF refined scope/guidelines
- End goal: Sustainable Resources database/clearinghouse
- White Paper: Evaluate current status sustainable remediation resources

SRRI…What and Why?

- "One–stop" searchable online resource
  - Comprehensive
  - Summarize federal, state, public, private, NGO, international
  - Reference for improving sustainability of remediation
- Develop white paper: existing sustainable remediation resources & tools available
  - Track industry progress
  - Research & education tool
  - Identify current gaps and future needs

SRRI…What and Why?

- To be used by remediation professionals and academia
- Collaborative effort:
  - SURF professionals as mentors and SURF student chapter members
- Purpose
  - Develop online SR resource
  - Highlight sustainable remediation resources and tools
  - Advertise SURF efforts

RESOURCE AND TOOL EXAMPLES

Tools:
- Excel Spreadsheet Tool: AFCEE-SRT
- Online Calculator: Leaking UST Footprint Calculator

Information portal websites:
- EPA CLU-IN green remediation and SURF

Guidance Documents/White Papers/BMPs:
- ASTSMO Matrix for Greener Cleanups

Regulatory Websites & Portals
- CA DTSC Green Remediation

SRRI COMPONENTS

- SRRI Index Cards – 1-2 pg Downloadable PDF with detailed information on resource/tool (50-75)
- Spreadsheets summarizing SR online tools and resources linked to “SRRI Index Cards”
- White Paper of currently available resources

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SRRI Draft Excel Table 1

Table 1: Overview of the key characteristics of Publically Available Sustainable Remediation Resources

Resource (Developer)	Sustainability defined?	Issues considered			Measures impact		Techni... referen...
		Environmental	Economic	Social	Qualitative	Quantitative	
Government – State							
DER-31/Green Remediation (NY DEC)		Y		Y		Y	Y
Greener Cleanups (IL EPA)		Y		Y	Y		
Green Practices for Business, Site Development, and Site Cleanups (MN PCA)	Y	Y	Y	Y	Y		
Green Remediation Initiative (CA DTSC)		Y	Y	Y	Y		
Non-governmental – Non-profit organizations							
Brownfields Assistance Project (Ctr Public Environ. Oversight)	Y		Y	Y	Y		
Creating Community-Based Brownfields Redevelopment (Am. Planning Assoc.)			Y	Y	Y		

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SRRI Draft Excel Table 2
Overview of Triple Bottom Factors

Resource	natural resources	Air impacts	Recycle or reuse	Remediation technology	Groundwater	Wetlands	Carbon footprint	Life cycle assessment	Health and safety	Social or environmental justice	Community engagement	Cost-benefit analysis
Government – Federal												
Best Management Practices for Soil Treatment Technologies (USEPA)		Y		Y					Y			
"Clean in Green" (USEPA Region 2)	Y	Y	Y				Y		Y			Y

- energy or natural resources harnessing or mimicking natural resources
- air impacts
- recycling or reuse of discarded materials or land
- remediation technologies
- water
- wetlands
- carbon footprint
- social or environmental justice
- community engagement
- economic cost benefit analysis
- life cycle assessment
- health and safety

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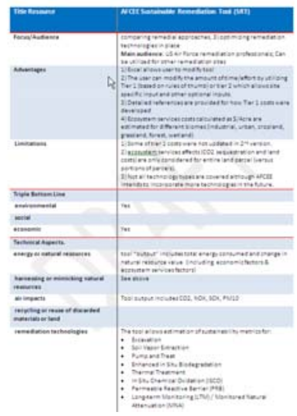
SRRI INDEX CARD DRAFT EXAMPLE – TOOL

Card Updated: June 12, 2012

Example - Tool

AFCEE Sustainable Remediation Tool (SRT)

Title Resource	AFCEE Sustainable Remediation Tool (SRT)
Resource Date	1st Version: May 2009; 2nd Version: available, expected to be expanded to include additional technologies
Organization/Source & Contact	Air Force Center for Engineering and the Environment (AFCEE) Technology Transfer Office (Headquarters San Antonio)
Website	[illegible]
Type of Organization	Government – Federal
Tool or Calculator	Includes Excel tool with macros
Cost of Resource	Free
Brief Description of Resource	The SRT is excel worksheets with macros & an FAQ/Backup Document. The "SRT allows users to estimate sustainability metrics for specific groundwater and soil remediation technologies." (see below for technologies). Sustainability metrics calculated include: Carbon Dioxide Emissions, Nitrogen Oxide Emissions, Sulfur Oxide Emissions, PM10, Total Energy Consumed, Change in Resource Service, Technology Cost, Safety / Accident Risk Tool is "structured using analytical "tiers" similar to the tiered structure of the Risk-Based Corrective Action (RBCA) Tool Kit". Optionally, user can vary future costs for CO2 offsets and energy and allows weighting of each metric.
Kind of resource	Tool – excel with macros
Sustainability Definitions	
general sustainability	See AFCEE General Sustainability Website
sustainable remediation	See AFCEE Green and sustainable remediation definition
green remediation	see above
other sustainable definitions	See AFCEE General Sustainability Website
Intended Use/Geographic	Purpose: 1) planning for remediation activities at a site; 2)



Title Resource	AFCEE Sustainable Remediation Tool (SRT)
Focus/Audience	comparing remedial approaches, 3) optimizing remediation technologies in place Main audience: US Air Force remediation professionals; Can be utilized for other remediation sites
Advantages	1) Excel allows user to modify tool 2) The user can modify the amount of time/effort by utilizing Tier 1 (based on rules of thumb) or tier 2 which allows site specific input and other optional inputs 3) Detailed references are provided for how Tier 1 costs were developed 4) Ecosystem services costs calculated as $/Acre are estimated for different biomes (industrial, urban, cropland, grassland, forest, wetland)
Limitations	1) Some of tier 1 costs were not updated in 2nd version. 2) ecosystem services effects (CO2 sequestration and land costs) are only considered for entire land parcel (versus portions of parcels). 3) Not all technology types are covered although AFCEE intends to incorporate more technologies in the future.
Triple Bottom Line	
environmental	Yes
social	
economic	Yes
Technical Aspects.	
energy or natural resources	tool "output" includes total energy consumed and change in natural resource value. (including economic factors & ecosystem services factors)
harnessing or mimicking natural resources	See above
air impacts	Tool output includes CO2, NOX, SOX, PM10
recycling or reuse of discarded materials or land	
remediation technologies	The tool allows estimation of sustainability metrics for: • Excavation • Soil Vapor Extraction • Pump and Treat • Enhanced In Situ Biodegradation • Thermal Treatment • In Situ Chemical Oxidation (ISCO) • Permeable Reactive Barrier (PRB) • Longterm Monitoring (LTM) / Monitored Natural Attenuation (MNA)

SURF SUSTAINABLE REMEDIATION FORUM

SRRI INDEX CARD DRAFT – TOOL

Title Resource	AFCEE Sustainable Remediation Tool (SRT)
water	
wetlands	Calculates change in CO2 sequestration value assuming total project land type is changed from one land type to another
carbon footprint	Calculates tons CO2; lbs CO2/lb contaminant
social	
community engagement	
economic cost benefit analysis	Calculates technology costs (dollars or $/lb contaminant)
lifecycle	

SURF SUSTAINABLE REMEDIATION FORUM

Next Steps

- Aug-Dec 2012– Develop SRRI
  - Refine Template
  - Develop Excel Tables & SRRI Index Cards
    - 50 -75 resources
- Dec-Feb 2013: Extend SRRI
  - White Paper

SRRI TI: Help Needed

- Students - Create SRRI Index Cards
- Senior Professionals - Technical Reviewers
- SR Tools/Websites/Documents

Contact:
Mary Kean, PE
mekean@uwalumni.com
Pamela Dugan, Ph.D, P.G.
Pamela.Dugan@caruscorporation.com

Sustainable Remediation Rating and Certifications

SR Rating Tool

Key Points

- Survey
  - Finalize and distribute by August 10
  - Summarize and report by Sept. 15
- Summary of sustainable rating tools
  - Review and comment on draft copy by August 31.
- Summary of sustainable rating organizations
  - Draft report available by Sept. 15
- Compile survey, tools, and organizations report by Oct. 15

- “Test drive” rating tools and compare

Volunteers

- Diana Hasegan – Langan
  - dhasegan@langan.com
- Dick Raymond – Terra Systems Inc.
  - draymond@terrasystems.net

Academic Outreach

SURF 20 Academic Outreach Initiative (AOI) Update

Mike Miller, CDM Smith
millerme@cdmsmith.com
Pamela Dugan, Carus Corporation
pamela.dugan@caruscorporation.com

PRESENTATION SUMMARY

- *New SURF student chapters*
- *New AOI Technical Initiative*
- *Battelle 2013 Biosymposium*
- Need student volunteers for:
  - Populate academic contact database
  - AOI newsletter (under development)
  - SURF website: student chapter space
  - Hot research topic development
  - Value proposition for academics – final round of reviews

NEW SURF STUDENT CHAPTERS

- Univ. of Illinois-Chicago (Prof. Krishna Reddy)
- Stanford University (YeoMyoung Cho, Ph.D.)
- Rutgers Univ. (TBD)
- University of Michigan (TBD)

Established chapters:

- Colorado State University (Prof. Tom Sale)
- Syracuse University (Prof Don Siegel)
- Clarkson University (Prof. Michelle Crimi)
- Colorado School of Mines (Ms. Kathryn Lowe)

NEW AOI INITIATIVE:
SURF STUDENT CHAPTER COMPETITION

- **Co-Leaders:**
  - Prof. Michelle Crimi (Clarkson)
  - Scott McDonough (AECOM)

- **DESCRIPTION:**
  - Annual competition between student chapters
  - Design a sustainable solution to a remediation problem
  - Panel of SURF judges
  - Award to winning chapter

- **WE NEED VOLUNTEERS:** *See Mike Miller today!*

STUDENT CHAPTER COMPETITION TIMELINE

Task	Timeline
Research current student design competitions	May 2012
Consolidate research and draft Basis of Competition Memorandum	June-July 2012
Basis of Competition Memorandum submitted to Technical Initiatives Committee	July 2012
Basis of Competition Memorandum finalized for publication	August 2012
Draft Competition rules and marketing materials	August-October 2012
Market Competition	November 2012 - January 2013
Hold Competition	January- April 2013
Assess competition results and conformance with mission	May 2013

BATTELLE BIOREMEDIATION SYMPOSIUM 2013 – NEW DEVELOPMENTS

- SURF award for sustainable remediation paper
- Link to SURF on the Battelle website
  - Info on SURF
  - Desired elements for student papers
  - Contacts for questions
- – SURF representative presents student award
- – SURF participation in student mentor lunch

- **STUDENTS:** *Plan your entries now!*

ACADEMIC OUTREACH NEWSLETTER

UNDER DEVELOPMENT: CONTACT PAMELA DUGAN

- Purpose –
  - Advertise SURF efforts
  - Recruit new members
  - Support student chapters
  - Highlight research with a sustainable remediation component
  - Encourage student participation in SURF-sponsored competitions
- Frequency –
  - Quarterly
- Target Audience
  - Academia (professors & students)
  - Research organizations
  - SURF members & student chapters

ACADEMIC OUTREACH DATABASE

(IN PROCESS)

Last Name	First Name	Institution	Email Address	Areas of Research	Link to Academic Program or Areas of Research
Abriola	Linda	Tufts	Linda.Abriola@tufts.edu	Characterization and	http://engineering.tufts.edu/about/deansoffice/dean.htm
Allen-King	Richelle	SUNY-Buffalo	richelle@geology.buffalo.edu		
Annable	Michael	University of Florida	annable@ufl.edu		
Ashton	Weslynne	Illinois Institute of Technolog	washton@iit.edu	Green business devel	http://www.stuart.iit.edu/graduateprograms/ms/environmental
Bedient	Phil	Rice University	bedient@rice.edu		
Borden	Bob	North Carolina	rcborden@eos.ncsu.edu		
Brusseau	Mark	University of Arizona	brusseau@cals.arizona.edu		
Capiro	Natalie	Tufts University	natalie.capiro@tufts.edu	Environmental biotech	http://engineering.tufts.edu/cee/impes/personnel_files/person
Comfort	Steve	University of Nebraska	scomfort@unlnotes.unl.edu	Passive in situ treatm	http://snr.unl.edu/aboutus/who/people/faculty-member.asp?pi
Crimi	Michelle	Clarkson University Insititute	mcrimi@clarkson.edu	In situ remediation of	http://www.clarkson.edu/ise/index.html
Cummings	Jim	EPA	Cummings.James@epamail.epa.gov		
DeMond	Avery	University of Michigan	averyd@umich.edu		
Falta	Ron	Clemson	faltar@exchange.clemson.edu		
Finneran	Kevin	Clemson	ktf@clemson.edu		
Gardner	Kevin	University of New Hampshir	kevin.gardner@unh.edu		
Hatfield	Kirk	University of Florida	khatf@ce.ufl.edu		
Illangasakare	Tissa	Colorado School of Mines	tillanga@mines.edu	Vapor intrusion, mode	http://cesep.mines.edu/
Johnson	Paul	Arizona State	paul.c.johnson@asu.edu		
Kueper	Bernie	Queens University	kueper@civil.queensu.ca		
LeBron	Carmen	NAVFAC	carmen.lebron@navy.mil		
Lee	Eung Seok	Ohio University	leee1@ohio.edu		
Looney	Brian	SRNL	brian02.looney@srnl.doe.gov		
McCray	John	Colorado School of Mines	jmccray@mines.edu	Potential release and	http://ese.mines.edu/people/faculty/mccray.html
Naugle	Alex	CA Waterboard	anaugle@waterboards.ca.gov		
Parker	Beth	Univeristy of Guelph	bparker@uoguelph.ca	Diffusion into and out	http://g360.uoguelph.ca/about-g360/our-people
Parker	Jack	University of Tennessee	jparker@utk.edu		
Reddy	Krishna	University of Illinois Chicago	kreddy@uic.edu	Green and sustainable	http://www.uic.edu/labs/geotech/
Sale	Tom	Colorado State University	tsale@engr.colostate.edu	Innovative solutions fo	http://www.engr.colostate.edu/ce/facultyintros/Sale.shtml
Schwartz	Frank	Ohio State University	frank@geology.ohio-state.edu	Slow-release oxidants	http://www.earthsciences.osu.edu/faculty_bios.php?id=45
Semprini	Lewis	Oregon State	lewis.semprini@oregonstate.edu		
Shapiro	Allen	USGS	ashapiro@usgs.gov		
Siegrist	Robert	Colorado School of Mines	siegrist@mines.edu	ISCO, coupling remed	http://ese.mines.edu/people/faculty/siegrist.html
Shouakar-Stash	Orfan	Waterloo	orfan@uwaterloo.ca		
Spengler	John	Harvard University	spengler@hsph.harvard.edu	Sustainability and Env	http://www.extension.harvard.edu/degrees-certificates/sustai
Sudicky	Ed	Waterloo	sudicky@sciborg.uwaterloo.ca		
Wood	Lynn	EPA	wood.lynn@epa.gov		

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Hot Research Topic Development
(In Process)

Topic: Who/what/where is doing interesting research around remediation?

Academics-Institutions doing interesting research	Hyperlink to information
Terry Collins TAML - Institute for Green Science Carnegie Mellon	http://www.chem.cmu.edu/groups/collins/about/about.html
Paul Stamets Fungal Remediation (i.e., Mycoremediation)	http://www.fungi.com/mycotech/index.html
Waterloo - in-situ work John Cherry, Beth Parker, Neil Thomson	http://www.environmental.uwaterloo.ca/
Golder - stabilization /solidification mixture	
Stanford and UMBC upal gosh, luthy	http://www-ce.stanford.edu/faculty/luthy/
Starnet	http://www.claire.co.uk/index.php?option=com_resource&controller=article&article=11
medical school community health programs	
inter-disciplinary programs - U of Wash Env Management program on climate change	
ILLEI (Via Robert Armstead)	http://www.wrscompass.com/content/?section=462&section2=483&section3=584&se
ASU - mass flux - P. Johnson	https://webapp4.asu.edu/directory/person/31728
Rice U - Pedro Alvarez	http://alvarez.rice.edu/
Tom Sales CSU - back diffusion	http://www.engr.colostate.edu/ce/facultyintros/Sale.shtml
Narom Gerhard - ???	
Queen's University Bernie Kueper	http://www.civil.queensu.ca/Research/Environmental/Bernard-H-Kueper/
MSU - soil organic carbon studies ; "Daycent" model used in farming studies	
Economics: Duke doing rural and urban evaluations of biomass	
Elizabeth Edwards - U of Toronto	http://chem-eng.utoronto.ca/~biodegraders/
Bob Borden - NC State	
Todd Halihan - Ok State	http://geology.okstate.edu/index.php?option=com_content&task=view&id=95&Itemid=1
Larry Murdoch - Clemson	http://www.clemson.edu/ces/departments/eees/people/facultydirectory/murdoch.html
Jerry Schnoor - U of Iowa, CEE ("Sustainability Tax")	http://www.cee.engineering.uiowa.edu/Faculty/schnoor.php
Derrick Lovley - U Mass microbiology	http://www.bio.umass.edu/micro/faculty/lovley.html
Georgia Tech - Spyros Pavlostathis - anaerobic degradation of qual	http://people.ce.gatech.edu/~spavlost/
David Freedman - Clemson ; bioremediation of CT, CF under high	http://www.clemson.edu/ces/departments/eees/people/facultydirectory/freedman.htm
Stanford - Luthy - sediment in-situ	http://www.stanford.edu/group/luthygroup/people.htm
Bruce Rittmann - ASU biodesign	http://www.biodesign.asu.edu/people/bruce-rittmann
U of New Hampshire - Kevin Gardner: sediment in-situ	http://www.unh.edu/civil-engineering/dr-kevin-gardner
Jackie Quinn - U of Central Florida	http://www.spacetechhalloffame.org/inductees_07_EmulsifiedZero-Valentiron.html
U of Florida - phyto reduction; mass flux meter development (Mike A	http://www.ees.ufl.edu/homepp/annable/
Missouri Science and Technology - Curt Elmore ; wind-powered res	http://campus.mst.edu/cee/faculty/pages/elmore.html
Groundwater Consortia: U of Waterloo, Queens, U of Colorado (Joh	http://www.gwconsortium.org/
Environmental/Resource Economics Depts: UCB, MIT, UNC (Jack	http://www.sph.unc.edu/?option=com_profiles&Itemid=1891&profileAction=ProfDetail
Tom Borch - CSU - soil/crop	http://soilcrop.colostate.edu/borch/home.html
Chuck Shackleford - CSU - Geotech/environmental	http://www.cwi.colostate.edu/CSUWaterFaculty/?WF_ID=109
Uli Mayer - UBC Canada -	http://www.eos.ubc.ca/public/people/faculty/U.Mayer.html
Tissa Illangasakare and John Spears - Colorado School of Mines	http://inside.mines.edu/~jspear/research.html http://hydrology.mines.edu/fac
Martin Tielbaard - Rock Tenn Solvay Process - research on activated bacterial sludge from paper industry	
Eric Lui - Syracuse U - Dept of CEE	http://www.ecs.syr.edu/faculty/lui/
Andrea Costello - RIT	http://www.rit.edu/fa/ritgreen/
Harvard - Online grad degree in sustainability and env mgmt Georg	http://www.extension.harvard.edu/environmental-sustainability/default.jsp
STAR David Major	http://star.siremlab.com/team.php
Steve Comfort University of Nebraska	http://snr.unl.edu/aboutus/who/people/faculty-member.asp?pid=21
ES Lee Ohio University	http://www.ohio.edu/geology/lee/
Michelle Crimi - Clarkson University	http://www.clarkson.edu/ehs/faculty-pages.html

Academic Value Proposition:
What's in it for me?

What can SURF do for students/professors?

1. Networking
2. Research facilitation/discussion
3. Participation in SURF meetings
4. Scholarships
5. Research funding
6. Paper competitions
7. Resume repository
8. Provide access to field sites

- Being finalized now
- Final round of reviews to follow

What can students/professors do for SURF?

1. Help define the future of the remediation field
2. Increase the presence of SURF at other conferences
3. Assistance with the creation of documents and provide alternate perspectives
4. Provide academic collaboration for proposals

Potential Research Initiative

Research Initiative Ideas

July 26, 2012 – SURF 20

Stew Abrams
Dan Watts
Dustin Krajewski
Zeno Levy
Dave Ellis
Tom Sale
Mark Kluger
Dan Watts
Curt Stanley

Background

- What would we research?
- Different needs?
- Budget constraints?
- Economics & social sciences?

Ideas to Research

- Payment for Ecosystems Services (PES)
  - Monetization of Sustainable Remediation
  - Social science focus
  - Fully quantifies values
- "Smart grid" for remediation
  - Optimization of electrical usage
- Nexus between Risk & Sustainable Remediation
  - "well worn" perhaps not new

Ideas for Research

- Brownfields
  - Economic impact of redevelopments
  - What do they predict and what do they really get
  - Overall benefit to society
- Society Component
  - What is it?
  - What are the social metrics? This is the question we keep asking?
  - How do we understand the social side?

Ideas of Research

- Science Communication
  - Permission to Operate
  - Science of Communication
  - Connect and communicate
  - Make the community part of the team
  - Goes to the social aspect

Ideas - Technical

- Enhanced Natural Attenuation
  - Heat enhanced natural attenuation, for instance
- Stagnation of Plumes
  - Slow them down and accelerate degradation
- Persistence of reagents

Funding

- Rundown:
  - $30 M SERDP/ESTCP
  - $30 M Industry
  - Others? Consulting Firms
- Funding
  - $100K per student
  - $1,000,000 for 10 students
- SURF could be clearing house
- Philanthropic organizations

Catalysts of Research $

- Encourage Owners to require their consultants to have a research programs
- NSF is looking at interdisciplinary studies
  - Industry/University Cooperative Research Center
- Invite SERDP/ESTCP to the December meeting
- Foundations – Dan/Tom

Funding

- Need a specific idea to fund
  - Interdisciplinary
  - “Making Better Decisions”
- Members of student chapters
- “Concise package”
  - Fellowship program
  - Something for the Board to approve?
  - Defined evaluation process
    - Both the successful and the unsuccessful
  - NSF, other organizations, look at them for templates

Next Steps

- December Commencement
- Board Interaction and Approval
- Something available to funders

Attachment 18
Soil and Groundwater Environmental Protection in Taiwan

Introduction to the Soil and Groundwater Environment Protection in Taiwan

Shih-Cheng Pan
Sinotech Environmental Technology, Ltd.

The First Breakout

- The TCE contamination in groundwater was found in the former RCA Factory at Taoyuan County in 1994, and then became the first publicly known groundwater contaminated site in Taiwan.

Law Enforcement

- Soil and Groundwater Pollution Remediation Act (SGWPRA)
  - First promulgated on February 2, 2000
  - Major chapters
    - Prevention measures
    - Investigation and assessment measures
    - Regulatory measures
    - Remediation and restoration measures
    - Financing and responsibility
    - Penal provisions

Listed Contaminated Sites

- Farmland, rice paddies: 598 sites, total area 240 ac.
- Gasoline stations: 65 sites
- Factory and USTs: 89 sites
- Illegal dumping sites: 13 sites
- Others: 50 sites
- Overall listed contaminated sites: 815 sites

Remediation Technologies Applied

- For vadose zone impacted by petroleum hydrocarbons
  - Soil vapor extraction
  - Bioventing
  - In-situ or ex-situ bioremediation
  - Ex-situ thermal desorption
  - Soil washing
- For topsoil impacted by heavy metals
  - Dig-and-haul
  - Soil washing with acidic solutions

Remediation Technologies Applied

- For aquifer impacted by organic chemicals
  - Pump & treat
  - Bioslurping
  - Air sparging
  - In-situ bioremediation with ORC/HRC
  - In-situ chemical oxidation
  - Surfactant/co-solvent flushing
  - Zero-valent iron
  - Monitored natural attenuation

Why GR/SR is needed in Taiwan?

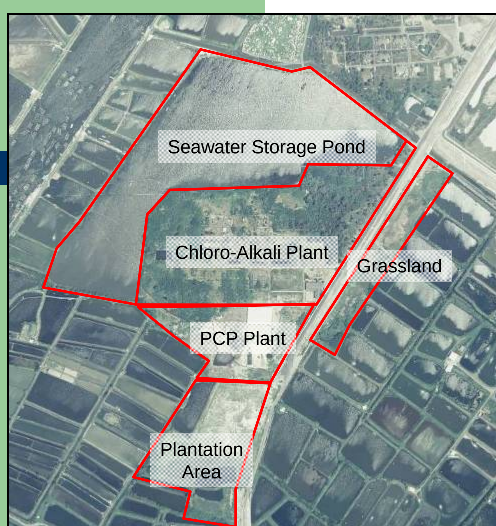
- Economic
  - The Remediation Funds is far from sufficient to clean up the contaminated sites which the responsible parties can not be identified or already vanished.
- Social
  - Land revitalization for the contaminated rice paddies and abandoned former factories
- Environmental
  - More efficient and smarter use of resources in remediation works
  - Reducing environmental/ecological impact, smaller footprints

Strategy Planning of Applying Green Remediation and Sustainable Remediation to the Contaminated Sites in Taiwan

- The first project dedicated to GR/SR initiated by Taiwan EPA
- Period: March 2012 – December 2012
- Contractor: Sinotech Environmental Technology Ltd. (SETL)
- Project amount: 140,000 USD
- Scope
  - Collect GR/SR information form US and EU countries
  - Setup a preliminary tool box for GR/SR
  - Hold conferences dedicated to GR/SR including one international conference
  - Case studies

Case Study-Tainan An-Hsiung Site

- Former chloro-alkali and pentachlorophenol (PCP) plant
- Contaminants: mercury, dioxin, PCP
- Site area: 42 ac.
- Responsible party: CPDC
- Status
  - Listed soil contaminated site since 2004
  - Many technologies have been tested in the last 5 years including thermal destruction, soil washing, bioremediation etc.
  - Phytoremediation lab study proved effective in dioxin degradation (partial), pilot study is under planning



Dig activity in the site

Sea water storage pond

Tainan An-Hsiung Site

For more information, please visit the website of Taiwan EPA
http://sgw.epa.gov.tw/public/En/Default.aspx
or
e-mail to Shih-Cheng Pan
scpan@setl.com.tw

Thank You!

Attachment 19
Day 1 Reflections and Feedback

DAY 1 REFLECTIONS AND FEEDBACK

Students

- Thanks to SURF for taking passionate direction in getting students involved. It would be interesting to invite students outside of the engineering department and get some social scientists and economists in the group. How do we interest them and then how do we get them? Think about it and send Mike Rominger an email.
- For professionals, consider getting input from students and getting them to volunteer to help on initiatives. (These activities will help get them feel more a part of the organization while helping SURF.) For students, go back to schools and keep the energy up. SURF student chapters have grown past what could have been imagined two years ago.
- Consider inviting someone from sustainability department at your university to participate in student chapter.
- Distill presentation information into a few slides so students who don't know about remediation can get background.
- It was a great experience to talk to people who have been working in various disciplines. Enjoyed the broad mix of experience of SURF members.
- Everyone was approachable and helped us learn more.…looking forward to more interactions.

Professionals

- Assign one SURF professional per student chapter to be liaison, help provide speaker suggestions, visit, etc. Ideally, SURF members would be a liaison for a student chapter within their geographical area.
- If SURF members are traveling, schedule time to make a presentation at a student chapter.
- A continuing challenge for student chapters is the need to reinvent themselves every few years as students leave.
- As students graduate, continue participating in SURF.
- Consider a different format for the student day. Students could give a brief 10-minute presentation about their work, possibly in combination with a poster session.
- Involve one or more student chapters in the planning process of the student day, which will allow students to have more of a voice in the process.
- Include a session on networking and transitioning into the workforce.

Attachment 20
Business Items

Potential Partnering Organizations*

- National Groundwater Association
- National Brownfields Association
- Environmental & Engineering Geophysical Society (EEGS)
- ASTM
- ITRC
- South Coast Geological Association
- American Society of Civil Engineers
- Remediation Journal
- Groundwater Resource Association
- International Phytotechnology Society
- PE and PG licensing programs
- American Institute of Professional Geologists
- Licensed Site Remediation Professional program (NJ)
- State Coalition for Remediation of Drycleaners (CA)
- Montclair State University
- Environmental Research and Education Foundation (EREF)
- Water Environment Federation
- Engineers without Borders
- American Water Works Association
- American Society of Civil Engineers

* Suggestions provided in recent SURF survey

SURF's 2012 Technical Initiative Themes

- Cleanup of water is a central focus of the remediation industry. How can SURF help practitioners better conserve water resources during remediation projects?
- How can SURF better collaborate with other groups both nationally and internationally to develop and implement technical initiatives?
- How can SURF assist practitioners to rate the sustainability of their remedial projects in a way that is aligned with other rating systems, such as Envision, LEED and SITEs?

How to Keep up to Date with SURF Between Meetings

Call for Ideas