UNIVERSITY of HOUSTON

Mixing Oil, Gas and Nano:

Environmental Legal Implications of Using Nanotechnology in Oil and Gas Development

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Emerging Technologies & Environmental Law

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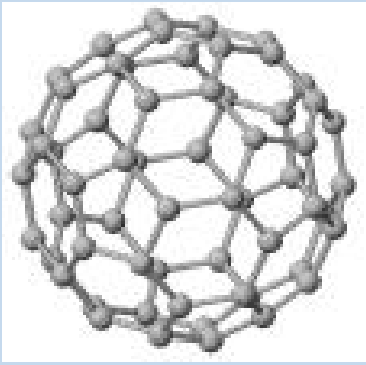
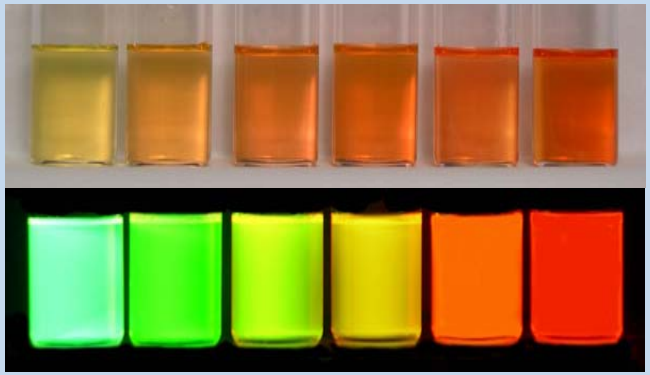




Four Themes

1. Nanoscale materials have unique and useful properties, and uses are already growing quickly
2. Operators are now exploring nanotech in E&P
3. Questions and concerns have grown over toxic aspects of nanomaterials
4. Companies will need to balance rapidly growing use of nanomaterials with unclear regulatory standards
   - Current nanotech disposal practices will be judged by future standards
   - Producers and users are anticipating future regulatory developments and tort liability

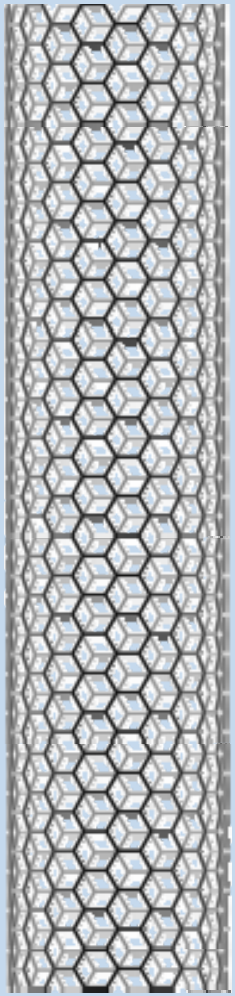
Exactly What is Nanotechnology?

- Definition remains unclear, but…
  - One functional dimension
  - Between 1 to 100 nanometers in size
  - Intentionally designed to exhibit properties due to that functional dimension

- Most notable:

nanoscale metals	hybrids
fullerenes (C60)	nanodevices
nanotubes	dendrimers

- NOT self-replicating nanobots



E&P Nano

HSE Concerns

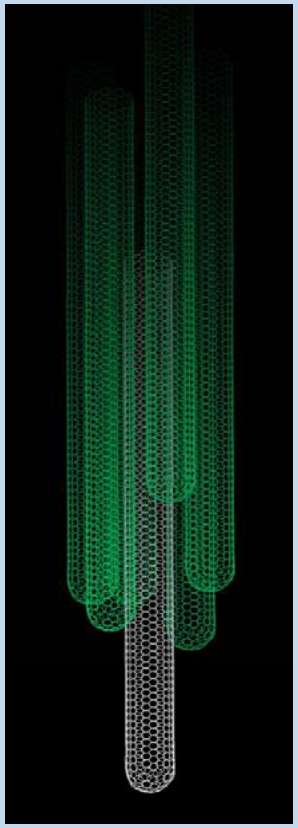
- Concerns emerging about unintended effects
  - Environmental fate and transport
  - Toxicological effects
  - Bioaccumulation

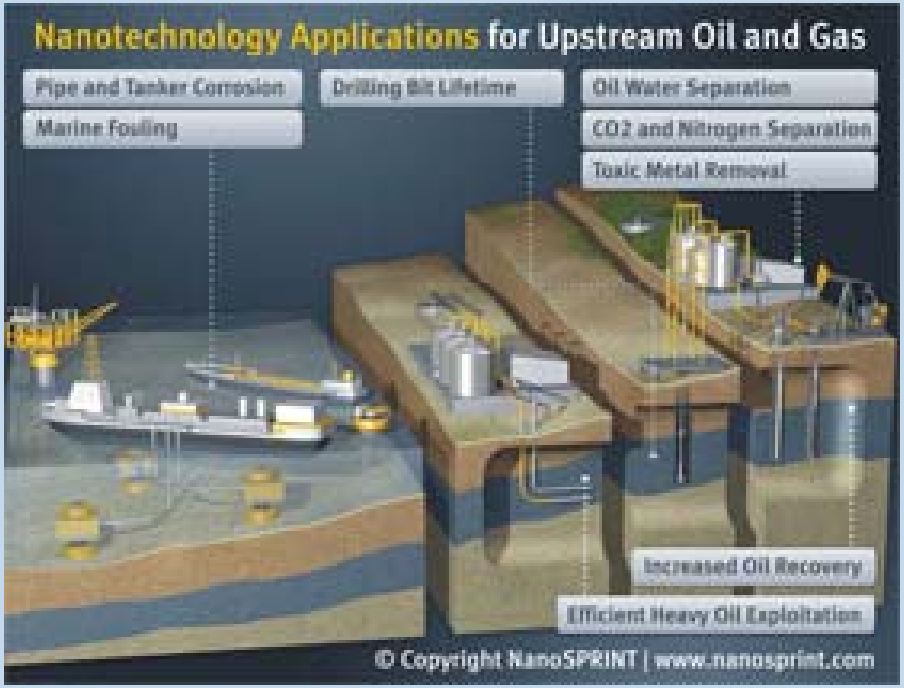
- Result: Growing opposition
  - Call for moratorium by Etc Group
  - Opposition to using nano to remediate Gulf Spill
  - Fears of repeating GMO experience

Nanotech and Oil/Gas E&P

- Relatively limited uses so far, but research growing rapidly and initial trials underway

- Uses currently fall in three categories:
  - Better sensing and detection
  - Improved operational tools and materials
  - Environmental remediation




Nanotechnology Applications for Upstream Oil and Gas
Pipe and Tanker Corrosion
Drilling Bit Lifetime
Oil Water Separation
Marine Fouling
CO2 and Nitrogen Separation
Toxic Metal Removal
Increased Oil Recovery
Efficient Heavy Oil Exploitation
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E&P Nano: Sensing

- Advanced Energy Consortium
  - Precompetitive research
  - Key players in energy field
  - $21 million
  - Broad array of projects underway

AEC
ADVANCED ENERGY CONSORTIUM

AEC Funded Projects 2008

project no.	Location	PI(s)	title	Short Desciption	Co-PI(s)
BEG08-013	Boston University	 Doerrer, Linda website	Integrated fundamental and applied studies of nanoparticles to probe reservoir rock	Develop paramagnetic iron- and vanadium-based metal oxide particles functionalized by organic ligands to act as contrast agents; approach is to enable quantification of the partition between water and oil-based phases using MRI for using enhanced sensitivity.	 Szleifer Northw Univers website
		 Wong, Joyce website			
BEG08-015 BEG08-028	Boston University University of Texas at Austin	 Goldberg, Bennett website	Graphene membranes as micro- and nano- pressure sensors	Joint project with Ruoff (Univ. TX) uses novel graphene membrane(s)-based micro- and nano-mechanical sensor to record pressure.	
		 Ruoff, Rod website			
BEG08-016	Boston University	 Grinstaff, Mark website	Downhole Li-ion Batteries Based on Network Ionic Liquids for Powering Micro and Nanosensors	New Lithium ion-based battery that is non-volatile, non-flammable, and thermally stable (>300°C) to power micro- and nanosensors. Most Li batteries are unstable above 75 °C and the electrolytes used are flammable and volatile.	
BEG08-012	Harvard University		High Resolution Fluidic Measurements with an Optical	Transport study (laboratory-on-a-chip) designed to better understand	

On-going Research on Nanomaterials for Oil and Gas Exploration and Production

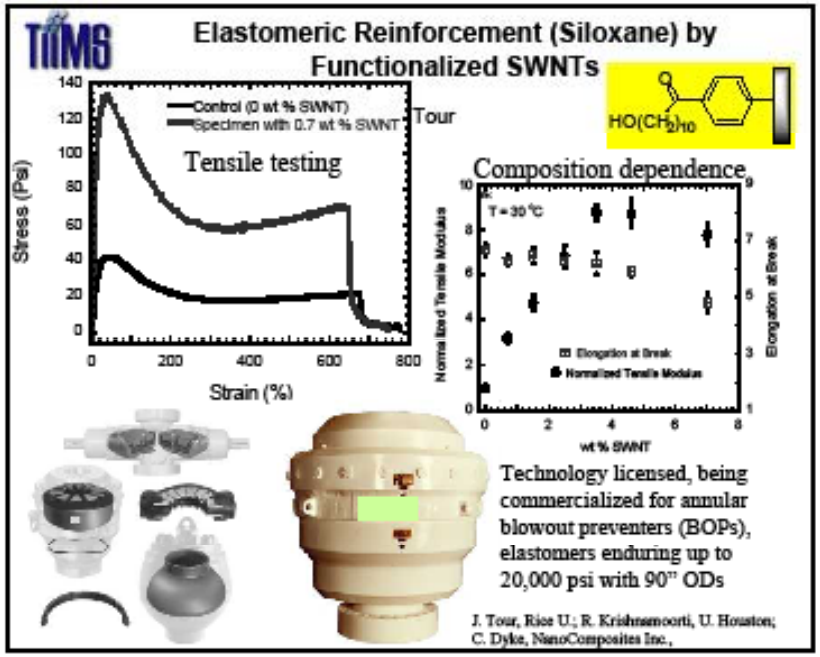
E&P Nano: New Production Tools

- Potential uses:
  - In-situ well-bore sensors and catalysts
  - Lighter and stronger drilling tools
  - Energetic materials for perforating
  - Improved elastomers
  - Enhanced coatings (pipelines)

E&P Nano: New Production Tools

- Examples:
  - Southwest Nanotechnologies (ConocoPhillips)
  - Hydril, Inc./Tenaris (Nanocomposites, Inc.)
  - ChevronTexaco's technology ventures group (Sub-One Technology, Inc.)
  - Shell Global Solutions nanotechnology lab (Westhollow), Nano Summit (10/09)
  - Oxane, Inc. (proppant)

Nanomaterials and New Production Tools



Nano – Loss of Exemptions?

- CERCLA –
  - Petroleum exclusion – limited scope for nano
  - Liability for past management of nano materials, even if standards only changed after use
- RCRA – Permitting requirements
  - E&P exclusion
  - Exclusion from RCRA does not insulate from liability under other statutes (CERCLA)
- State laws – application of TRRC rules

E&P Nano: Current Nano Disposal Judged by Future Standards

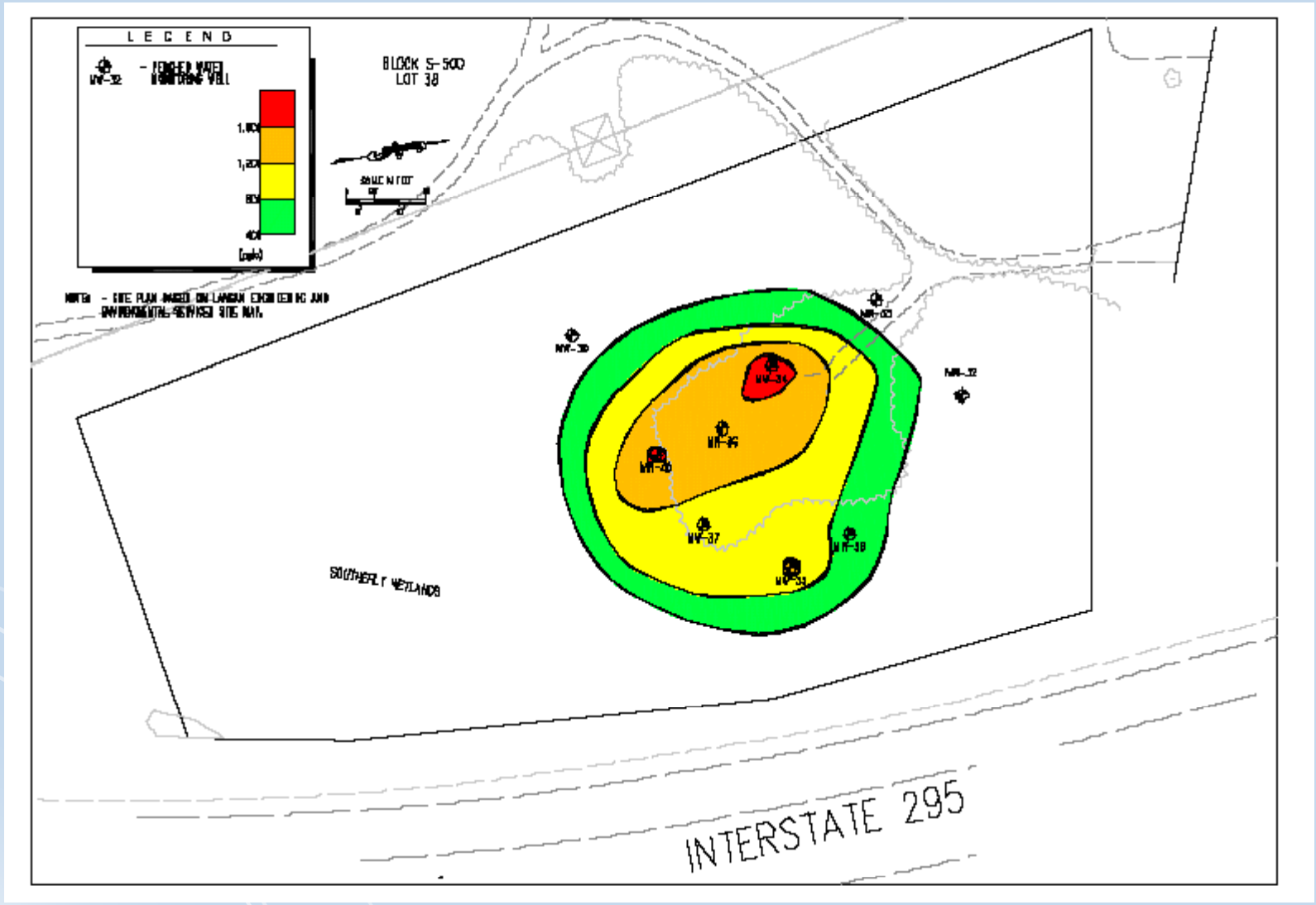
- If nanomaterials are hazardous substances, CERCLA liability will apply
- ABA SEER White Paper on CERCLA and Nano
- RCRA corrective action will raise similar issues

Effects on Nano Use?

- If you’re an oil and gas services company and can use nano to increase yield or safety, would you?
- If you represented an environmental gorup opposed use of nano in the oil patch, how would you go about fighting it?

The Paradox of Nano: Nano-Remediation

- Great opportunities as well as challenges
  - More efficient use of materials and energy
  - Can displace more damaging old technologies
- One use: groundwater remediation
  - Nanoscale iron
  - Used in several field tests with generally positive results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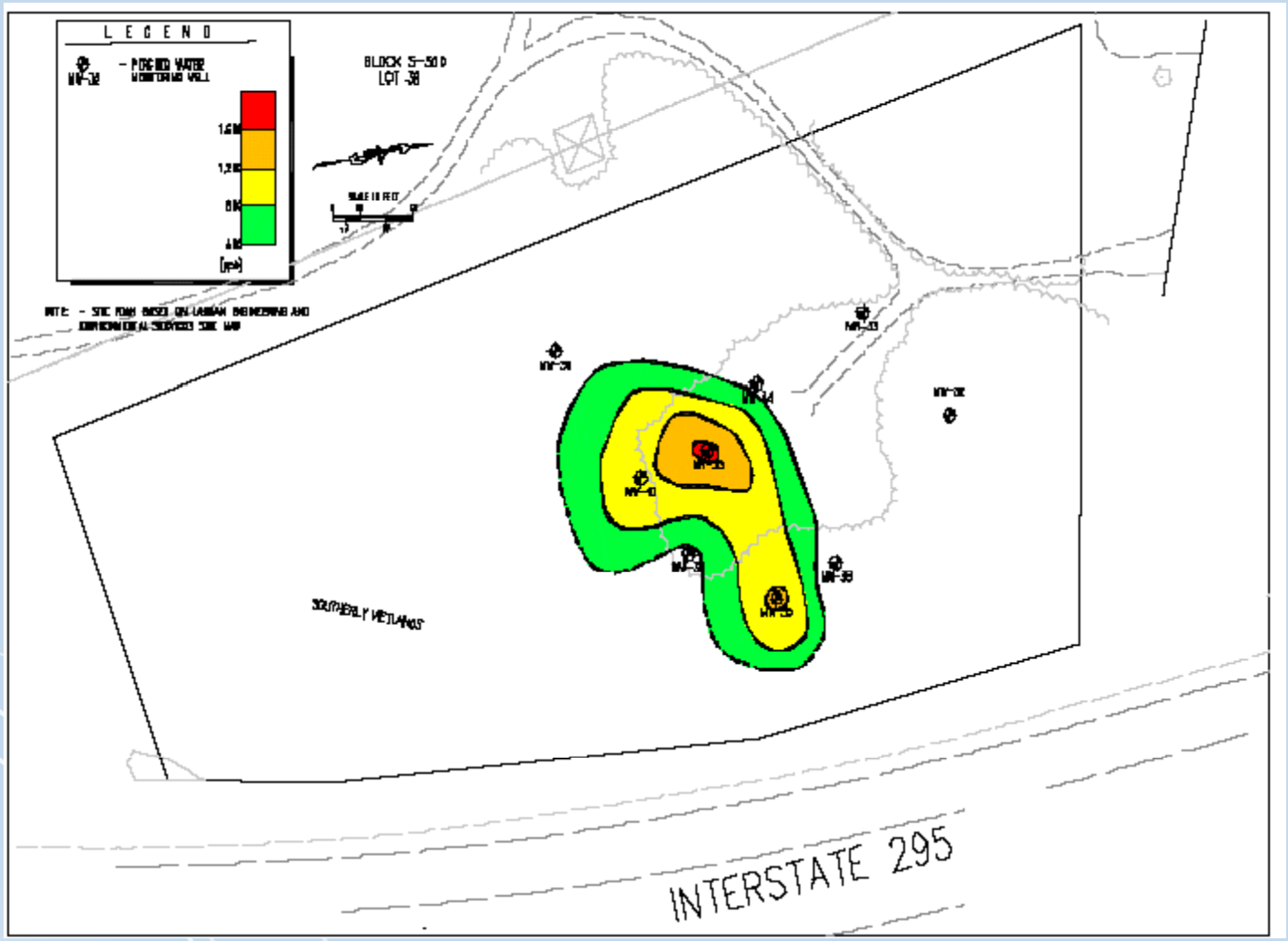
MW-35
MW-36
MW-37
MW-38
MW-33
MW-32
INTERSTATE 295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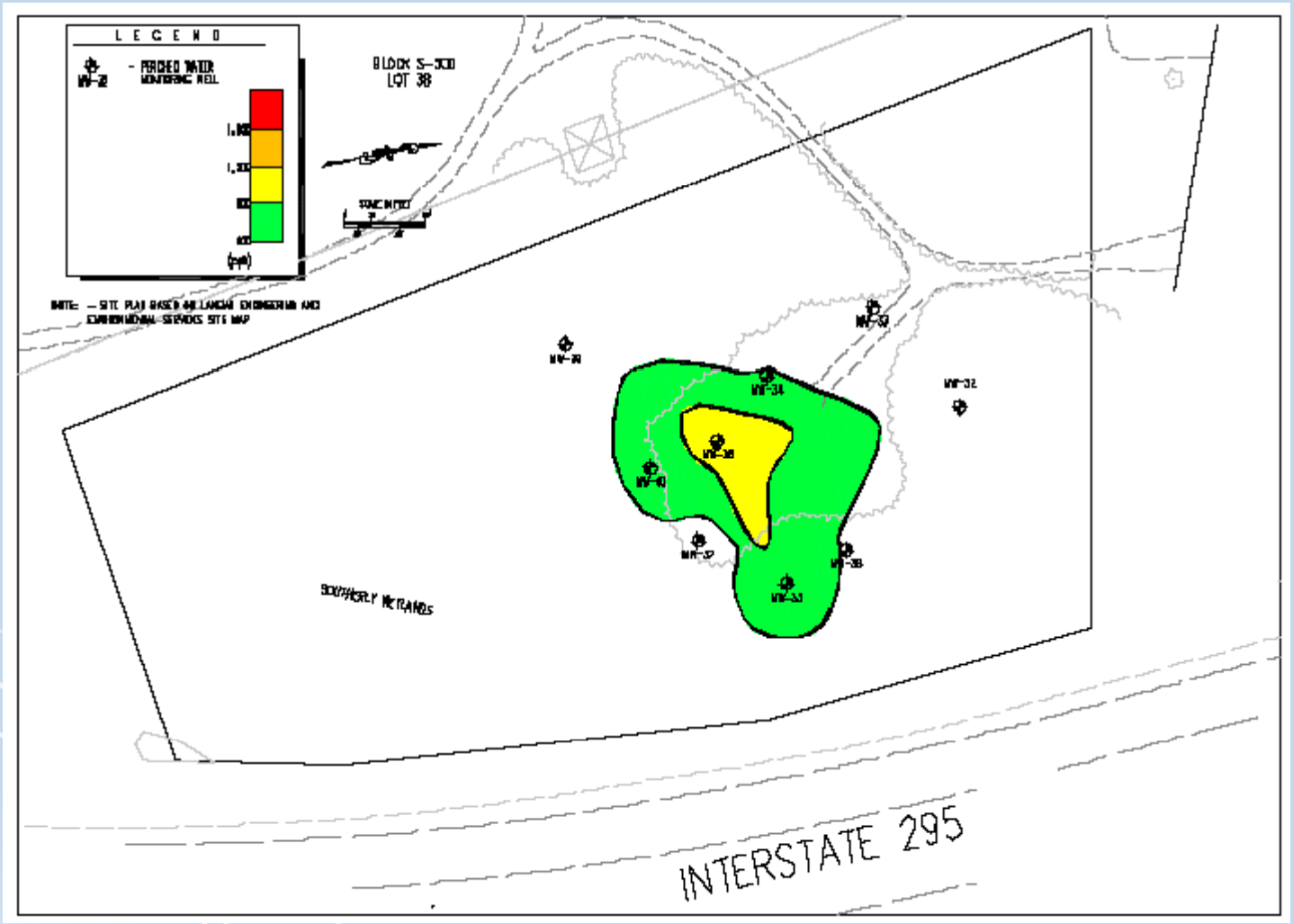
BLOCK 5-500
LOT 38
INTERSTATE 295


LEGEND
- PERCHED WATER MONITORING WELL
BLOCK 5-300
LOT 38
INTERSTATE 295

CERCLA and Nano-Remediation

- Nanoscale iron treatment can cost up to 90 percent less than pump-and-treat technology
- Much faster – weeks vs. decades
- Iron apparently degrades without long-term groundwater impacts
- Effective against difficult contaminants (PCE, TCE, PCBs, halogenated aromatics)

How to Safely Encourage Use of Nano at Remediation Sites?

Imagine a Superfund Site – south of Houston, received large amounts of oily chemical wastes and chlorinated solvents

- Should group of companies doing cleanup use nano-iron? Would consultant allow it?
- If you are at EPA or TCEQ, how would you respond to a request to use nano-iron?

CERCLA and Nano-Remediation

- **Here's the paradox:**
  - By definition, no data on long-term groundwater impacts (British Royal Society, DuPont)
  - Regulatory status of nanoscale iron used in treatment unclear
    - Naturally occurring element
    - TSCA status as "new chemical"
  - Response Action Contractor liability protection – loophole?

E&P Nano - Remediation

- BP Prudhoe Bay remediation site (Tuboscope facility)
- Cleaned pipes used in oil well construction, 1978-1982
- DCA, lead, diesel
- Nanoscale iron

E&P Nano – Remediation

- BP Prudhoe Bay results:
  - TCA – originally 58.4 ppm
  - Soil treatment with nZVI for 40.5 hours (in deep test)
  - TCA reductions:
    - 60% in shallow test
    - 90% in deep test

E&P Nano – Proactive Strategies

- ED/DuPont Risk Framework
- Insurance and risk spreading
- Auditing