



Exploration & Production **Technology**

delivering breakthrough solutions



Produced Water Technology Development

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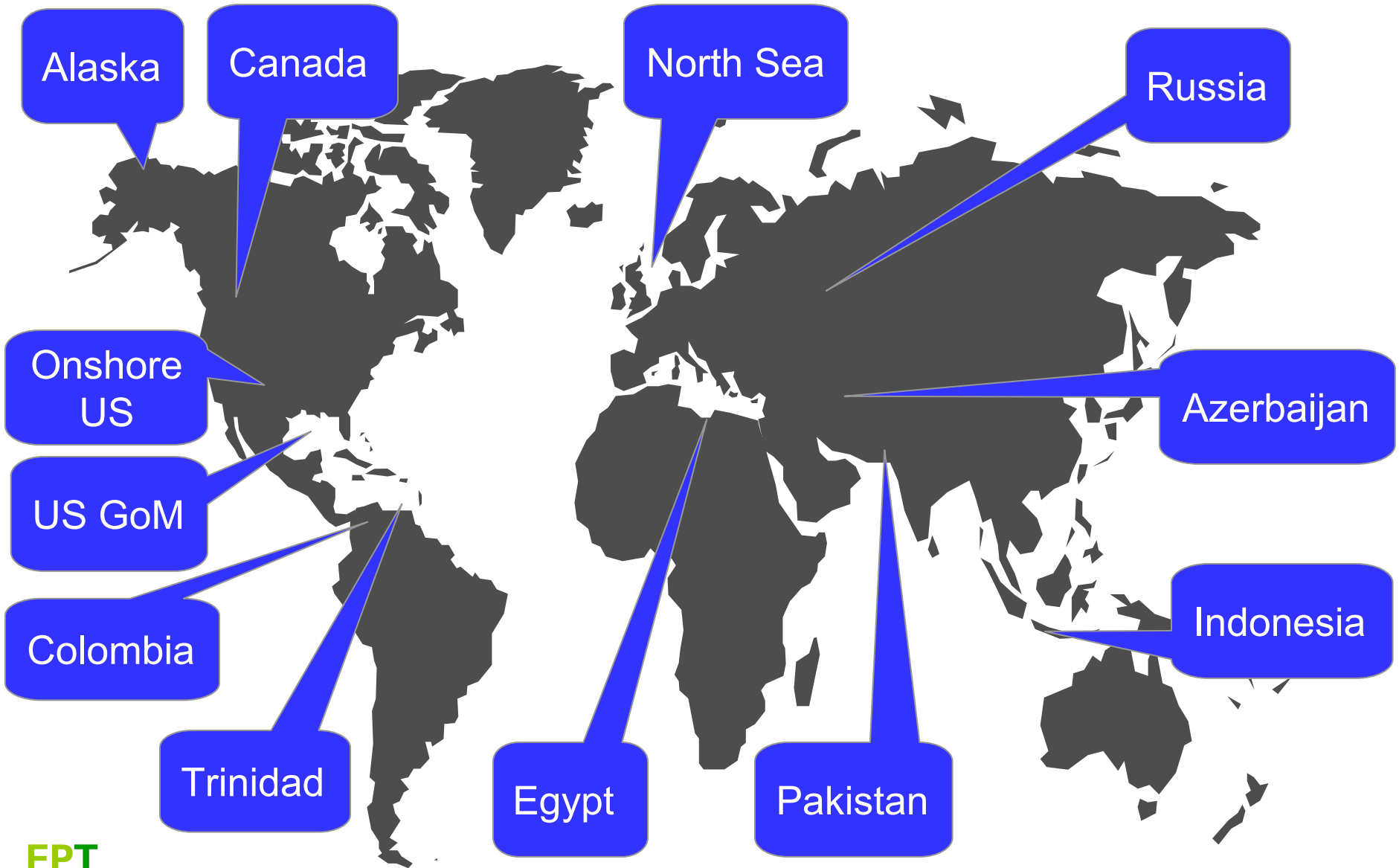
PW Update



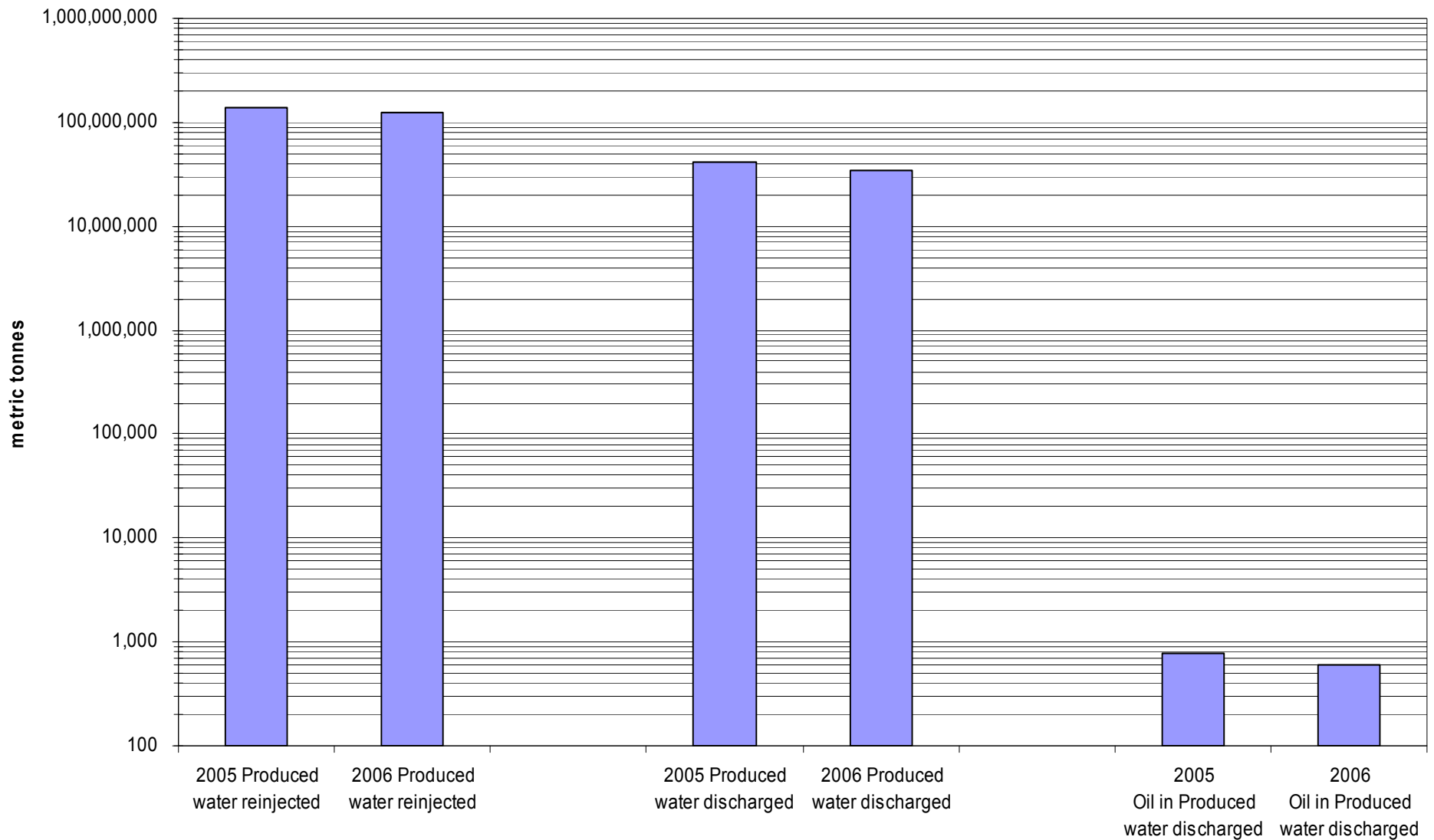
- **Issues**
- Technology Needs
- Technology Development Activities



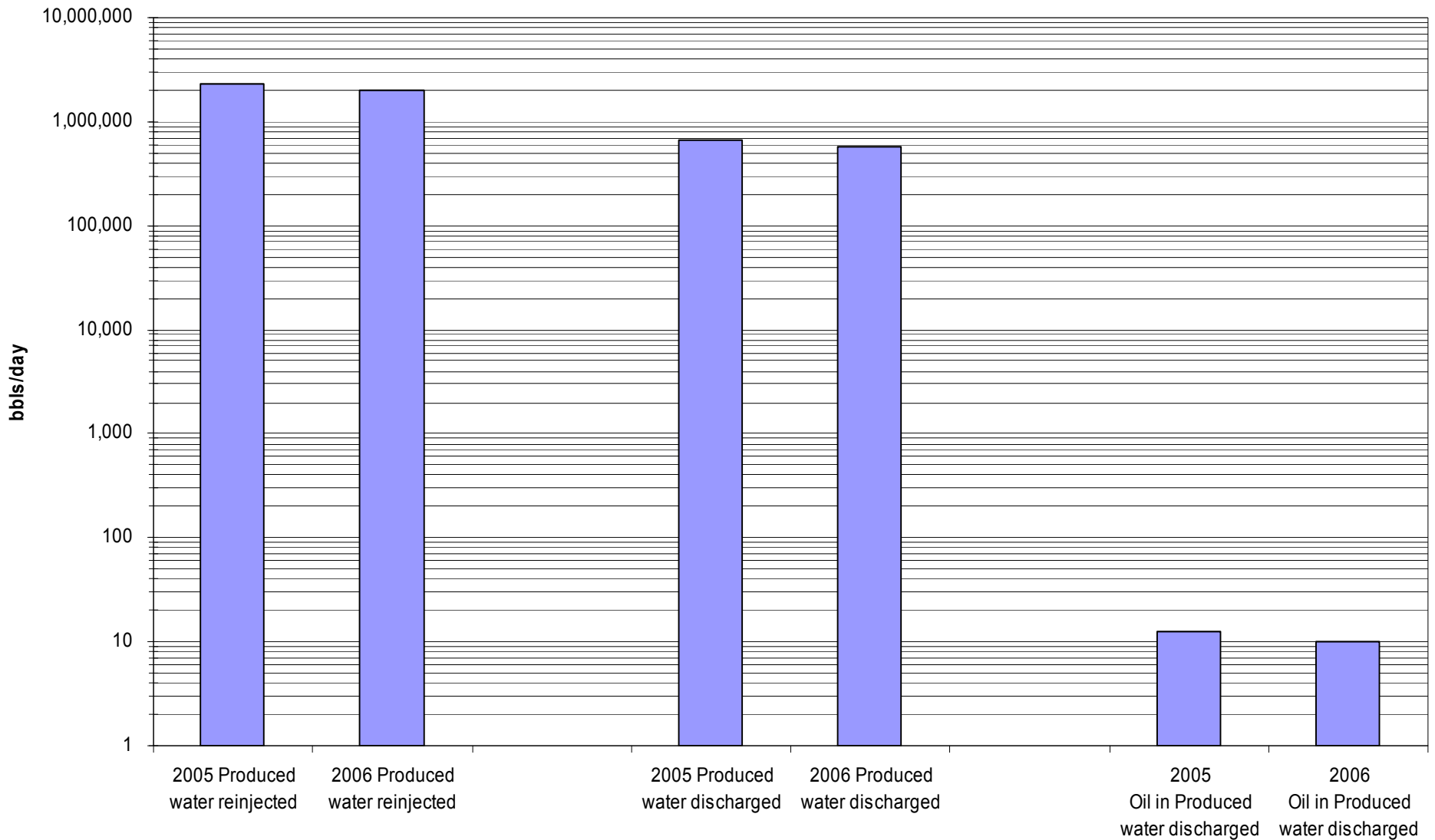
Most Significant PW Handling Projects



Volumes of Produced Water Handled



Volumes of Produced Water Handled



Hot-Topics



- Water management options in remote, onshore fields (conventional, CBM, shale, etc.)
- SRB activity – FeS formation
- Scale formation resulting from commingling of incompatible produced waters (from multiple zones, wells or fields)
- Recycling of reject streams (and buildup of surfactant-acting material, and stabilized emulsions)
- On-line monitoring of oil and solids, concentration and particle size distribution
- Impacts of production chemicals on water treatment processes (corrosion inhibitor, hydrate inhibitor)
- Sheens resulting from sources other than free-oil (free oil <10 ppm)



Hot-Topics



Priority Produced Water Issues: General



- Produced Water Treatment Process Performance and Reliability
 - Efficiently troubleshooting and optimizing treatment systems
 - Assessment/mitigation of chemicals, sand, scale, asphaltenes & naphthanates
 - Managing Increased Produced Water Flows
 - Handling capacity expansion (de-bottlenecking, adding-to existing systems)
 - Increased water-cut / water production from mature fields
 - Tie-back to host facilities / hubs
 - New Developments - More oil production will be supported by waterflood
- Soluble Pollutants - Treatment designed to reduce Environmental Impact Factor (EIF)
- Increasingly stringent regulatory discharge limits - Uncertainty around future limits
- Produced Water Beneficial Reuse - Technology limits, regulatory hurdles & liability
- Development of treatment specifications on solids & oil-in-water concentration/particle-size for injection water and pipeline transport
- Scale & corrosion management of commingled PW & Seawater
- Knowledge Management & Organizational Capability

PW Update



- Issues
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Established / Recent / Emerging Technologies



- **De-Sanding / Solids Filtration**
 - Gravity separation
 - De-sanding (Solid/Liquid) Hydrocyclones
 - Media filtration (sand filter / dual media filter / deep bed filter)
 - Physical (barrier) filtration (cartridges / socks)
 - Membrane filtration (micro-filtration)
- **De-Oiling**
 - Gravity separation
 - Coalescence enhanced gravity separation
 - De-oiling (Liquid/Liquid) Hydrocyclones
 - Gas flotation (induced, dissolved, compact, etc.)
 - Absorption filtration
 - Media filtration (walnut shell)
 - Membrane filtration (ultra-filtration; ceramic, vibrating)

Opinion key:
Established
Recent
Emerging

Established / Recent / Emerging Technologies



- **Polishing - soluble pollutant removal**
 - **Absorption filtration**
 - **Chemical / pH adjustment**
 - **Membrane filtration (ultra- & nano-filtration)**
 - **Biological treatment (membrane bio-reactor, fixed film, etc.)**
 - **Solvent extraction**
 - **Oxidation**
 - **Constructed Wetlands**
- **Polishing - salinity reduction**
 - **Evaporation (Freeze/Thaw, ponds, etc.)**
 - **Membrane filtration (reverse osmosis)**
 - **Ion exchange**
 - **Electro-dialysis**
 - **Thermal distillation**

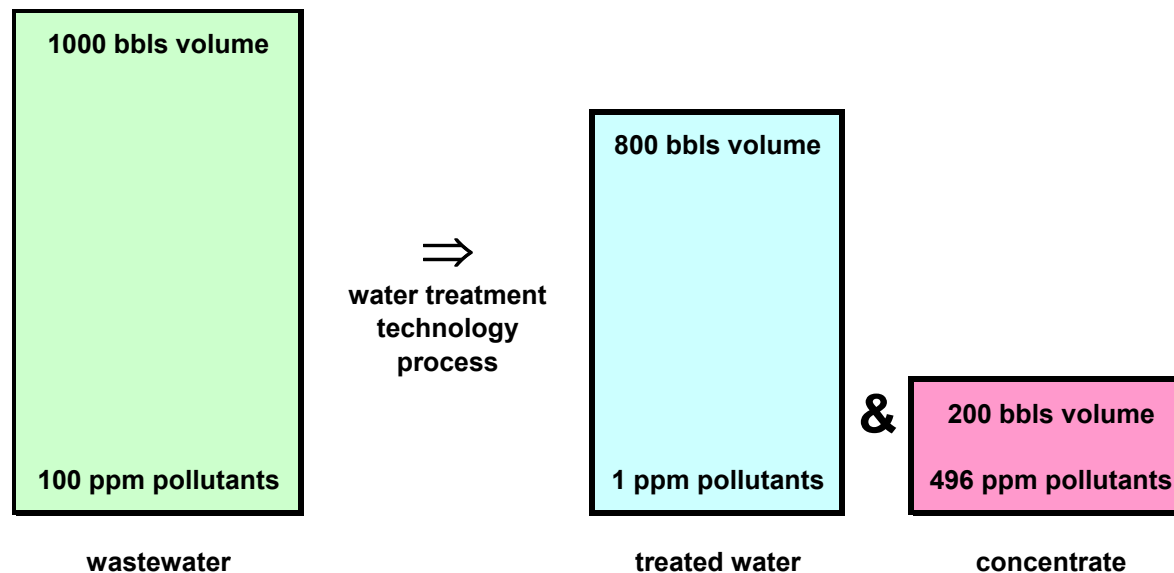
Opinion key:
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EPT

Generalities



- A single Water Treatment Technology is usually not a complete solution
- Often, treatment in stages is necessary
 - Often, pre-treatment is necessary to protect and enable downstream processes
- Real systems have variations in flowrate, water quality (upsets)
- Real systems are subject to abuse, neglect and operating errors
- Often, treatment processes will concentrate pollutants into a smaller volume of water (often 5% - 35%), with highly concentrated pollutants, which still requires disposal or management. For example:



Technology Selection



Treatment Technologies:

**Reliability / Redundancy
Size / Weight**

Hydrocyclones

Gas Flotation

Coalescers

Absorption

Media Filtration

Membrane Filtration

Oxidation

Evaporation

Re-Injection

Etc.

Starting Point:

**Water Quality
Flow / Variability
Field Life
Chemicals**

End Point:

**Treatment Specifications
(Re-Use / Disposal)
Environmental Protection**

EPT

Wish List – a water treatment process...



- *Must work* - consistent effluent water quality; proven technology
- *Must fit* - small foot-print and low weight
- *Must integrate* with existing system (add-on)
- *Really should* be easy to operate (correctly)
- *Really should* be easy to maintain (correctly)
- *Really should* be able to handle momentary variability in flowrate and water quality due to flowline slugging and changing combinations of wells producing
- *Should* be easy to expand or reduce capacity to correlate with change in flowrate over facility life (modular design)
- *Should* have minimal waste by-products and minimal recycling of waste streams
- *Would be nice* to be replicated for service at many locations, thereby enabling equipment re-use and building of design and operating experience (standardization; design once; operate many)
- *Would be nice* to be reasonable cost – competitive with alternatives

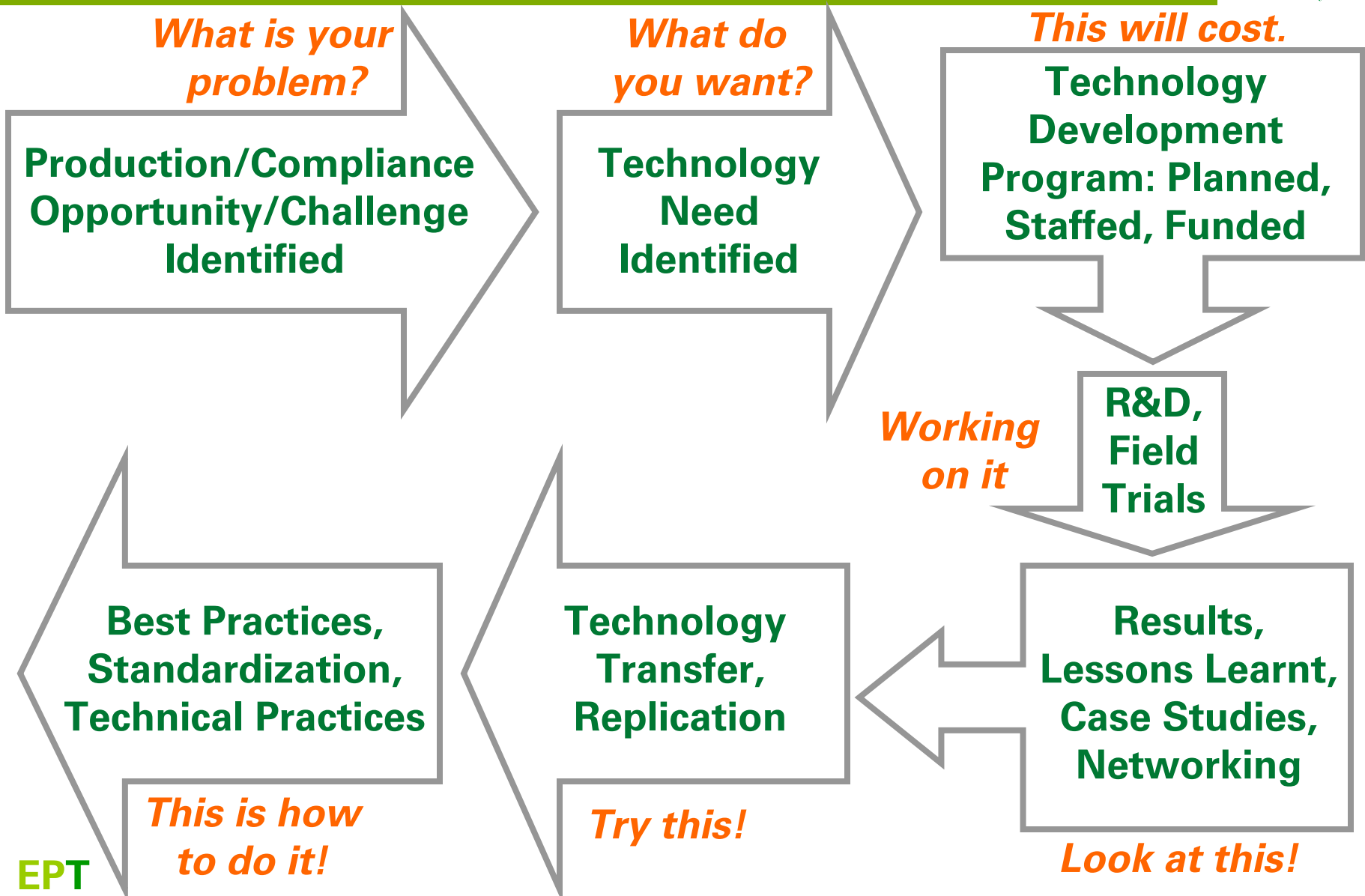
PW Update



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Water Technology Development: My Master Plan



Recent Activity



- 2007 Activity
 - Compact Flotation Unit Field Trial (Norway)
 - Absorption Media Bench Tests - evaluated dispersed & dissolved oil removal efficiencies: RM-25, CrudeSorp & Aqua Tech (Azerbaijan)
 - Ozone Oxidation Technology Evaluation
 - Ceramic Membrane Filtration Technology Evaluation
 - Produced Water Technical Training Course Offering (Internal BP)
- 2008 Underway/Ongoing
 - Evaluation of low dosage hydrate inhibitor (LDHI) on resin bead and polymer fiber coalescer technology performance (US GoM)
 - Mare's Tail long (in-line) polymer fibre based coalescence technology – installed 2007; commissioning 2008 (US GoM)
 - TORR Coalescer Field Trial (Pakistan)
 - PERF Membrane Bio-Reactor (MBR) JIP (refinery wastewater)
 - DREAM / ERMS (EIF) JIP

Being Considered



- Mycelx polymer imbedded filter technology evaluation (for oil-in-water reduction)
- Nanotechnology filtration technology evaluation (for oil-in-water reduction, solids removal & RO pretreatment)
- Media & Nutshell Filter Bench Test (possible JIP)
- Ozone Oxidation Bench Test
- Ceramic Membrane Filtration Bench Test or Field Trial
- Lakos Desander Field Trial
- Separatech COP Coalescer Field Trial
- Optical Imaging Technology Comparison Field Trial – for real-time analysis of oil and solid particles in produced water
- Mini Mass Spec Monitor technology evaluation (UK North Sea)
- Subsea on-line oil-in-water monitoring technology (JIP)

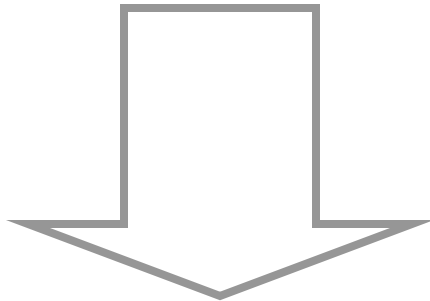
Rambling On



Tying it all Together

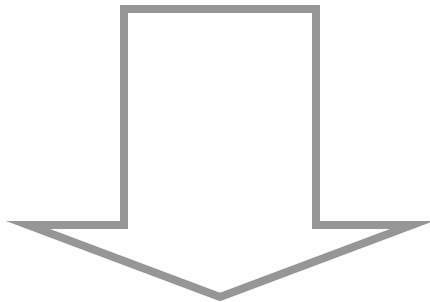


Environmental Science – Fate & Effects



Regulatory Process

(discharge limitations established to protect the environment)



Facility Design & Operation

(designed to comply with permits, thereby protecting the environment)

Environmental Management Systems (EMS)
Aspect/Impact – Continual Improvement



Environmental Monitoring
Feed-back to Science

