WATERtech 2010

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Economic Treatment of Frac Flow-Back Water to Recyclable Condition Using Physical Chemical Processes

By

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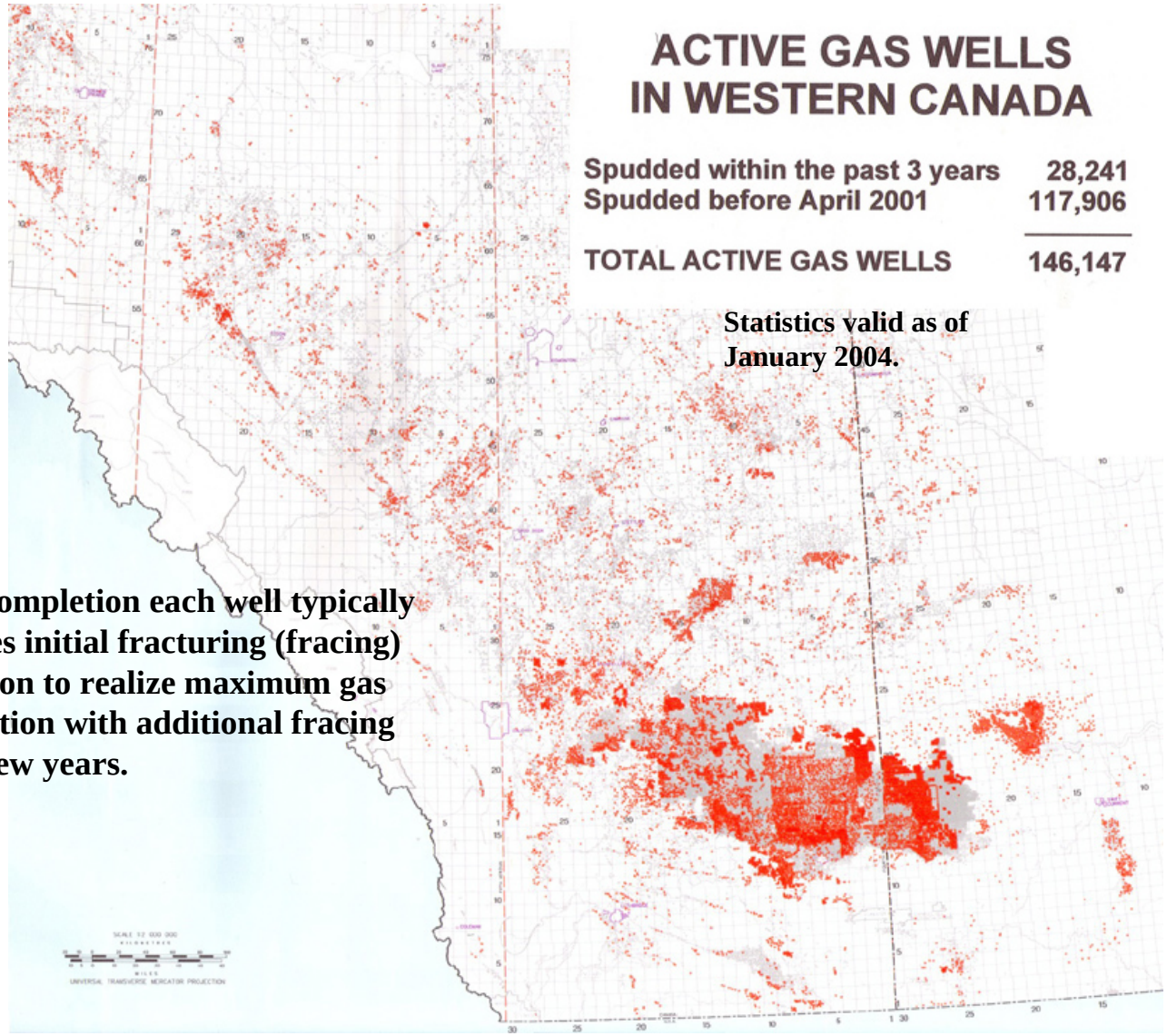


After completion each well typically requires initial fracturing (fracing) operation to realize maximum gas production with additional fracing every few years.

Basic Hydraulic Fracturing (Fracing) Process

- **Frac fluids are injected into producing formation under high pressure to fracture the reservoir matrix and in so doing increase porosity. Fractures are kept open by simultaneously injecting propant (frac sand) into fractures to prevent their closure when pressure is reduced.**
- **For shallow gas wells the volumes vary from hundreds to over 100,000 gallons (378 cubic meters) – typically much less in Alberta.**
- **Frac fluid additives that are used may vary widely depending on characteristics of formation, company and quality of water used for fracturing operation.**
- **Ideally water used for fracturing should be very high quality, free of chemicals that might interfere with those used during fracturing process or that might damage the formation being exploited and thoroughly disinfected.**

Substances added to water during fracturing process.

- Propant (frac sand).
- Foaming agents and antifoaming agents.
- Emulsifiers and de-emulsifiers.
- Gellants and gel breakers.
- Biocides.
- Surfactants.
- Viscosifiers.
- Cross linkers.
- Stabilizers.

Frac flow back

- Fluids recovered from water fracs when the fluid pressure is relieved (frac flow back) contain all of the chemicals used in the fracing process, formation water and some of the propant and other solids (including drilling muds) that have been flushed from the formation.
- Volume of flow back varies from approximately 20 to 80 per cent of volume of water injected into formation (40 to 60 per cent is common).
- Quality of the frac flow back varies widely with well condition and location and company performing the fracing operation (companies use different mixtures of chemicals).
- Flow back water is separated from the solid fraction and sent to disposal wells. Flow back water is very toxic. Solids (slurry) are stabilized (addition of lime) and sent to appropriate land fill.

- **The development of the frac flow-back water treatment process described in this presentation was started in 2002 at a time when the Alberta 'Water for Life Program' was just being formulated.**

- **At this time water was just beginning to be considered in short supply in the South Saskatchewan River Basin.**

- **Development of a process to economically treat frac water to recyclable condition appeared to be an important commercial endeavour.**

Process Description

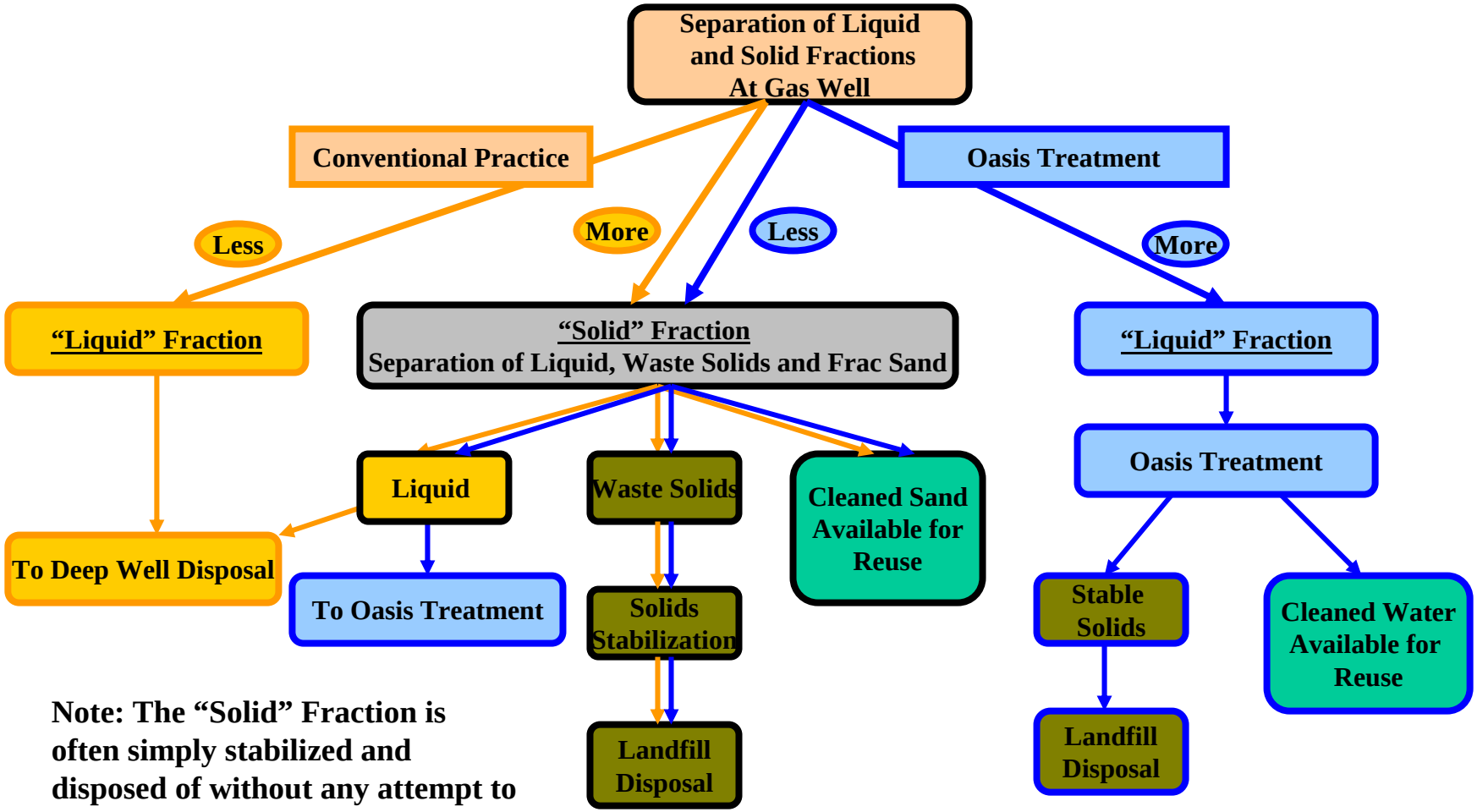
Three Stage Process:

- Stage One
  - Breaking complex polymeric suspensions
  - Sedimentation and clarification
- Stage Two
  - Breaking mineral complex.
  - Sedimentation and clarification
- Stage Three
  - Stabilization and polishing for end use.

Product Water

- 1st stage water is suitable for flushing and cleaning of the frac process equipment.
- 3rd stage water is suitable for recycling in frac process though it may be practical to treat all flow back water to this degree.
- Bacteria cannot survive in the treatment environment.
- Treated water cannot be returned to the environment.

Gas Well Frac Flow-Back Water Treatment



Note: The "Solid" Fraction is often simply stabilized and disposed of without any attempt to recycle sand.

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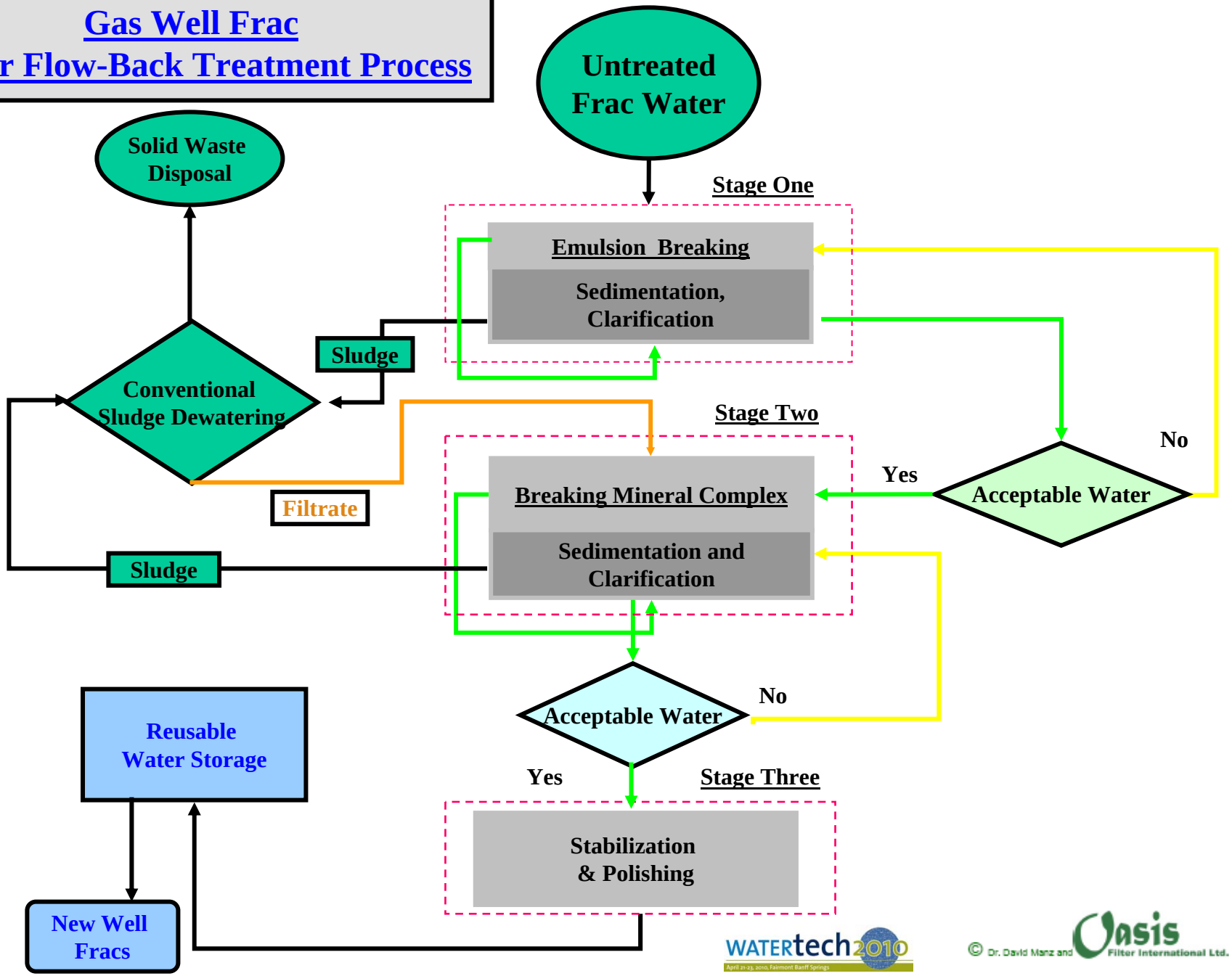
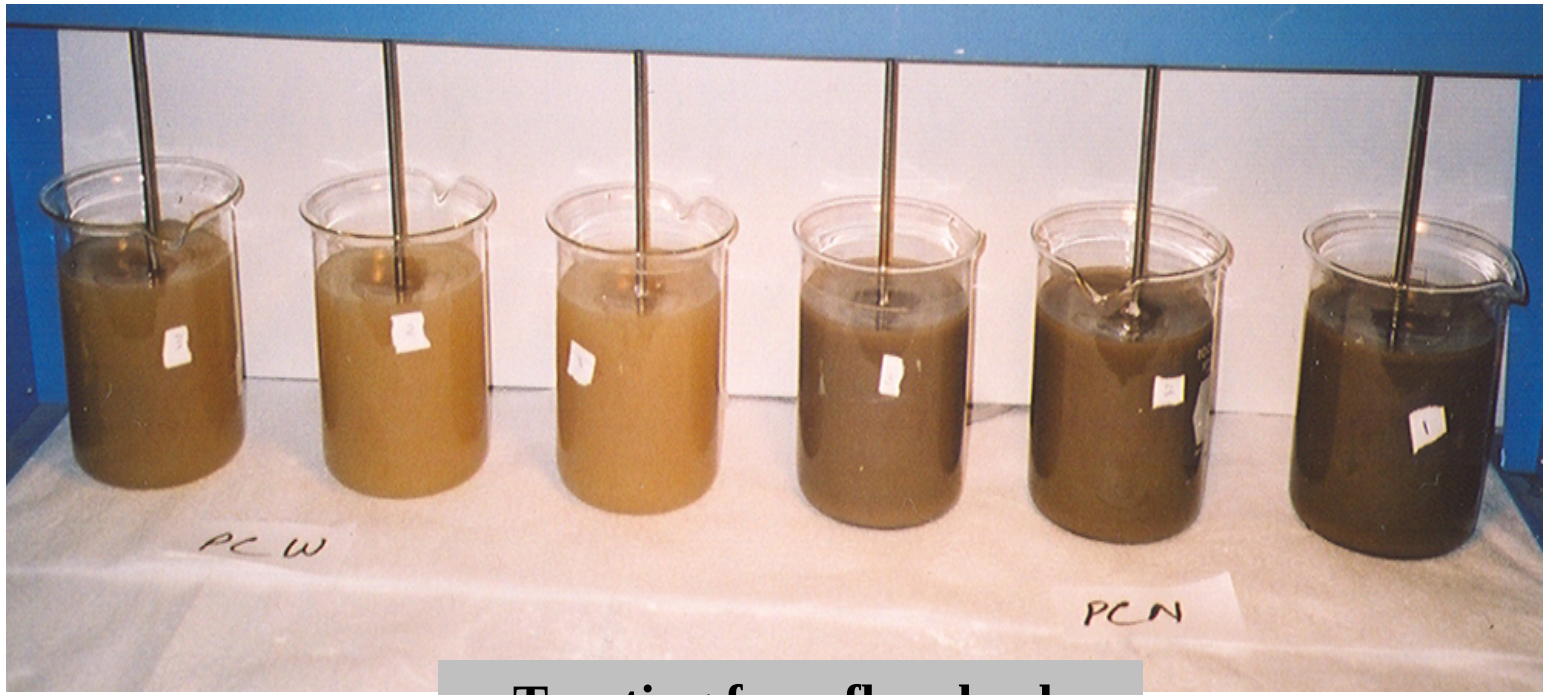
Gas Well Frac
Water Flow-Back Treatment Process

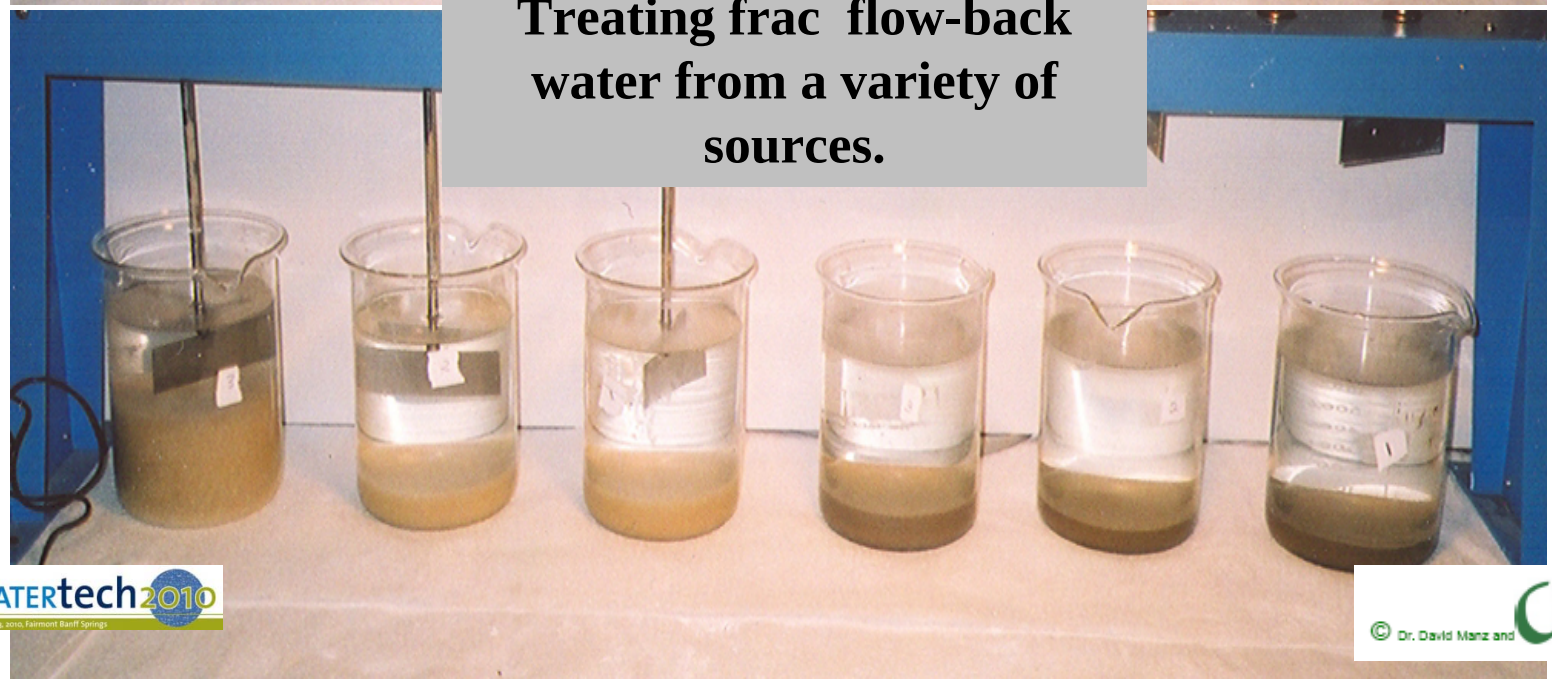


Bench Scale Testing of Frac Flow-Back Water Treatment Procedure

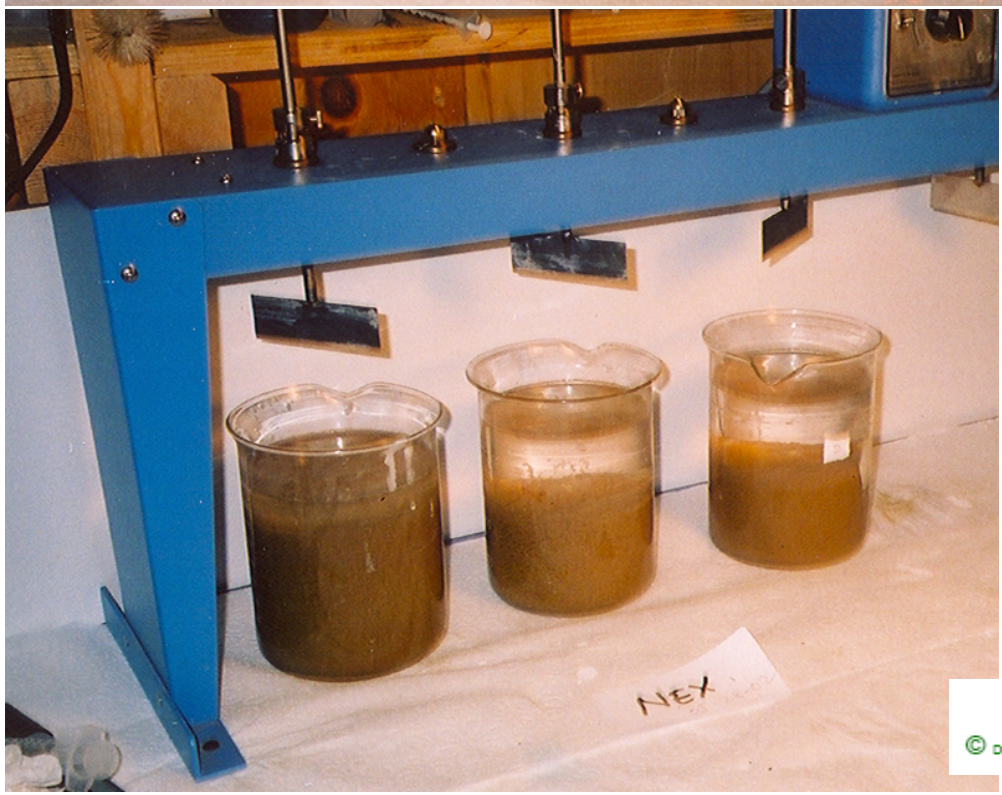
Before Treatment

After Treatment





Treating frac flow-back water from a variety of sources.



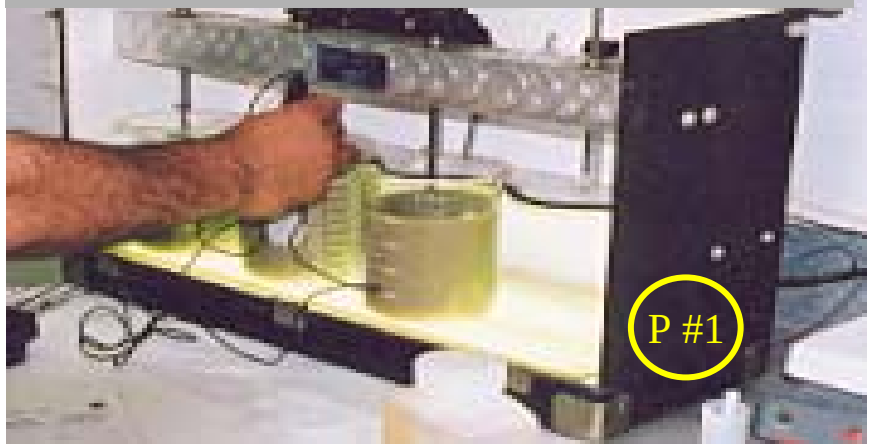
Field Trials

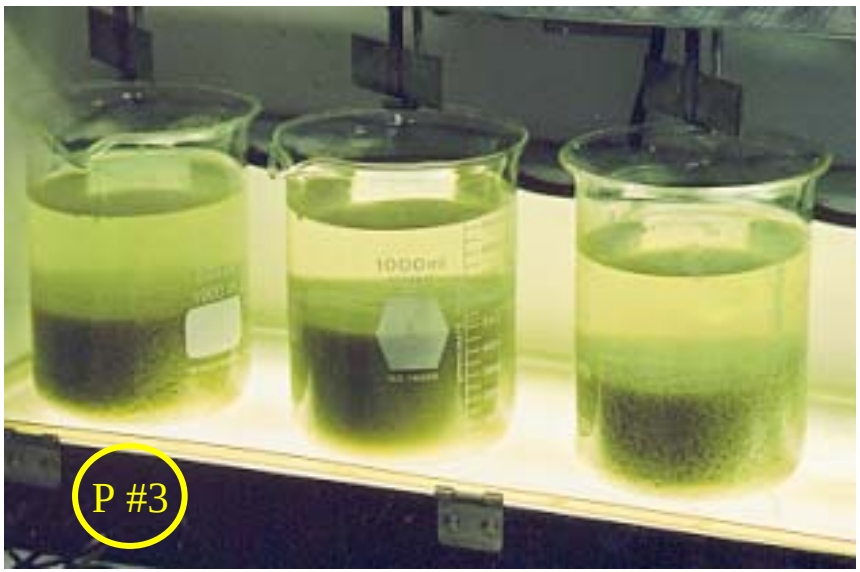
Jar Tests – to provide guidelines for treatment

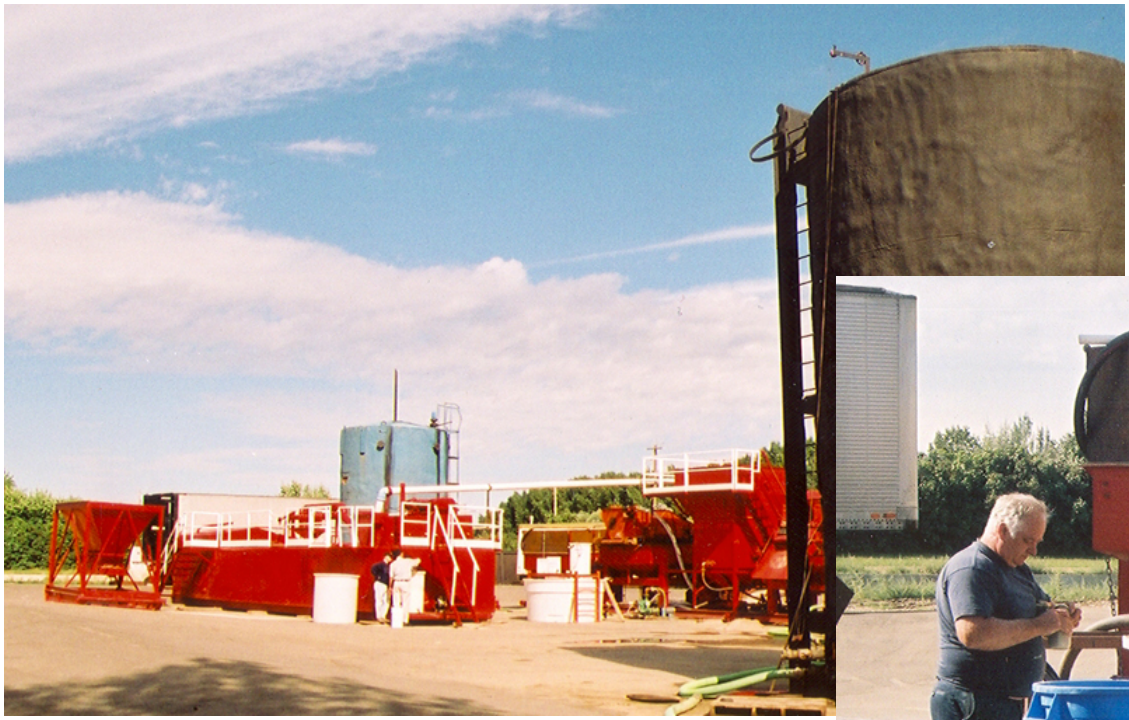
- **Establishing Chemical Demand** (P #1)
- **View of Floc Formation (P #2)**
- **Clarified Water (P #3)**

Four - 4 cubic meter samples from Haliburton fracs on Petro Canada Wells.

Demonstrations performed at Brooks, AB.





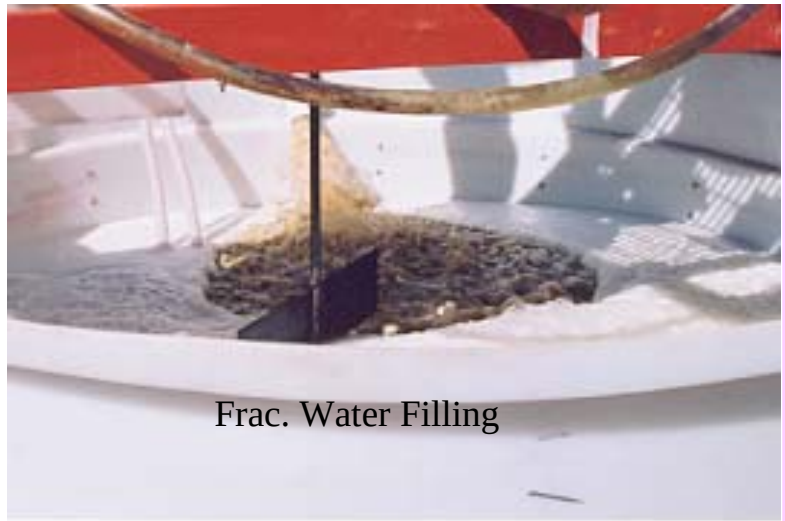


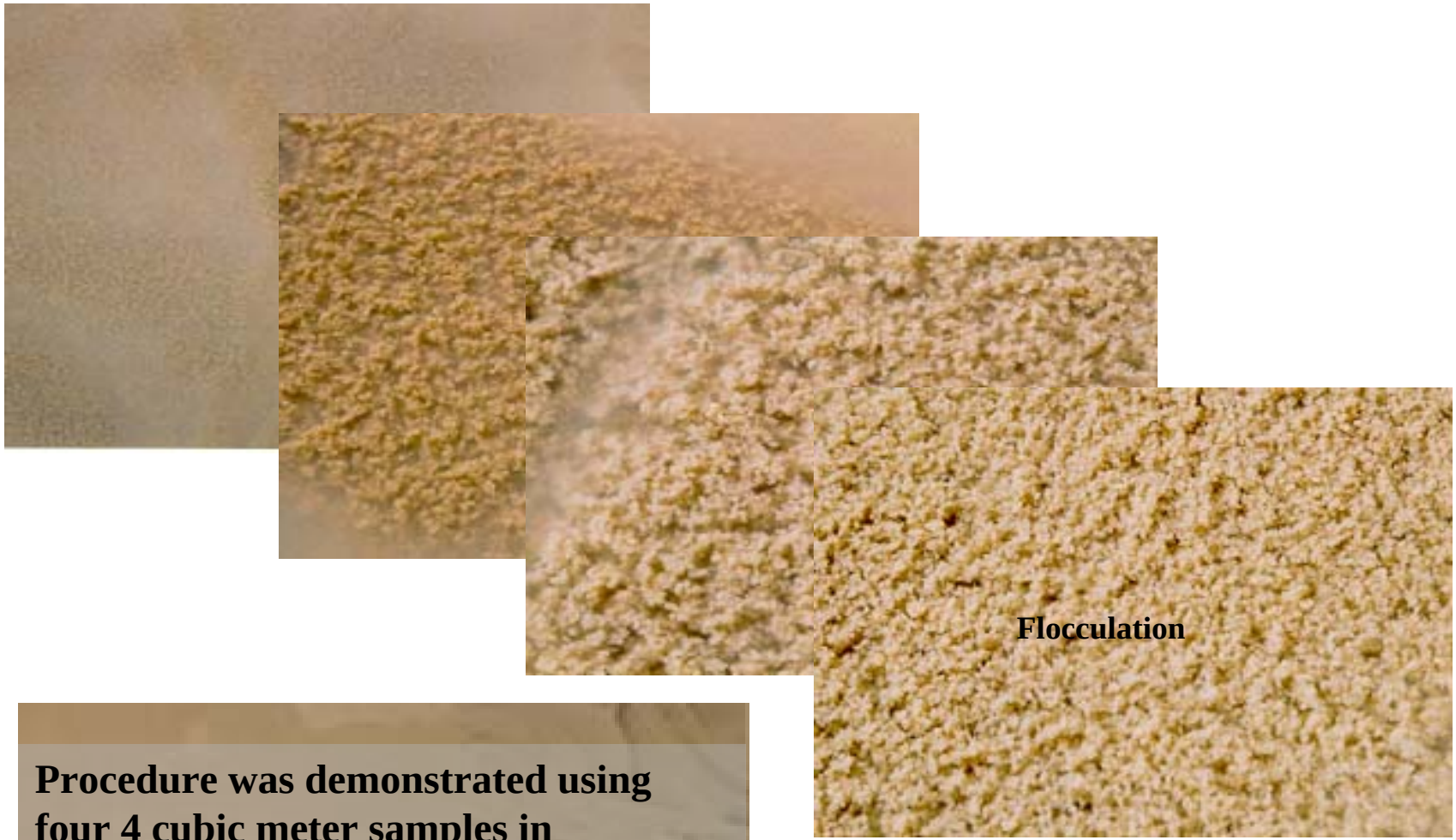
Setting Up the Batch Treatment Equipment for the Four Cubic Meter Samples at Smithbrook Operation Near Brooks, AB.

Field Trials (stage one)

4 cubic meter samples from Haliburton fracs on Petro Canada Wells.

Demonstrations performed at Brooks, AB.





Procedure was demonstrated using four 4 cubic meter samples in September 2002.

Analysis and testing indicated that the treated water was reusable for future fracturing operations – i.e. no waste.

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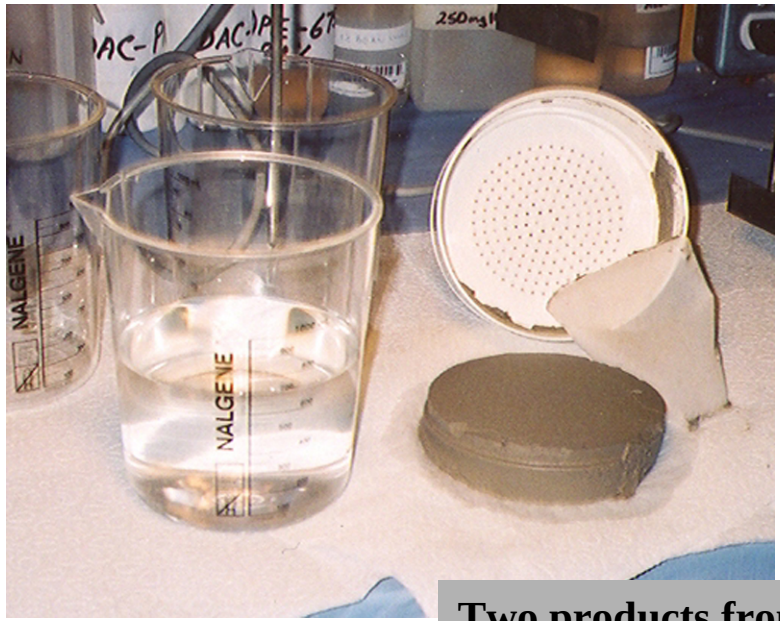


Two products from treatment:

- **Reusable water.**
- **Disposable filter cake.**

Note separation of sludge and water.

Amount of sludge will depend on sample.

Sample Description				Raw Frac Water	(2nd Stage) Treatment
Sampled Date				7/16/2004	7/14/2004
Parameter Name	**Parameter Description**	**Unit**	**Detection Limit**		
Organic Carbon	Total	mg/L	0.5	1650	770
Organic Carbon	Dissolved	mg/L	0.5	1220	Not Analyzed
Silicon	Dissolved	mg/L	0.05	5.09	<0.5
Sulphur	Dissolved	mg/L	0.05	30.2	84.6
Mercury	Dissolved	mg/L	0.0001	<0.001	<0.0001
Aluminum	Dissolved	mg/L	0.005	<0.05	0.11
Antimony	Dissolved	mg/L	0.0002	<0.002	<0.002
Arsenic	Dissolved	mg/L	0.0002	<0.002	<0.0020
Barium	Dissolved	mg/L	0.001	1.26	0.047
Beryllium	Dissolved	mg/L	0.0001	<0.001	<0.001
Bismuth	Dissolved	mg/L	0.0005	<0.005	<0.005
Boron	Dissolved	mg/L	0.002	2.82	1.47
Cadmium	Dissolved	mg/L	0.00001	0.0006	0.00027
Chromium	Dissolved	mg/L	0.0005	0.0089	<0.0050
Cobalt	Dissolved	mg/L	0.0001	0.0141	0.0123
Copper	Dissolved	mg/L	0.001	0.165	0.516
Lead	Dissolved	mg/L	0.0001	0.0228	<0.001
Lithium	Dissolved	mg/L	0.001	0.122	0.07
Molybdenum	Dissolved	mg/L	0.001	0.016	<0.01

Nickel	Dissolved	mg/L	0.0005	0.105	0.794
Selenium	Dissolved	mg/L	0.0002	<0.0020	<0.0020
Silver	Dissolved	mg/L	0.0001	0.0011	<0.001
Strontium	Dissolved	mg/L	0.001	1.84	1.4
Thallium	Dissolved	mg/L	0.00005	<0.0005	<0.0005
Titanium	Dissolved	mg/L	0.0005	0.047	<0.0050
Uranium	Dissolved	mg/L	0.0005	<0.005	<0.005
Vanadium	Dissolved	mg/L	0.0001	<0.0010	<0.0010
Zinc	Dissolved	mg/L	0.001	2.59	0.419
Temp. of observed pH and EC		°C		18.6	19.3
Suspended Solids	Total	mg/L	1	85	Not Analyzed
pH				6.95	7.84
Electrical Conductivity		µS/cm at 25°C	1	3320	6390
Calcium	Dissolved	mg/L	0.2	102	537
Magnesium	Dissolved	mg/L	0.1	21.2	2.6
Sodium	Dissolved	mg/L	0.4	735	917
Potassium	Dissolved	mg/L	0.4	9.3	20
Iron	Dissolved	mg/L	0.01	3.91	<0.10
Manganese	Dissolved	mg/L	0.005	0.887	1.38
Chloride	Dissolved	mg/L	0.5	460	1930
Phosphorus	Dissolved	mg/L	0.05	0.25	<0.05
Nitrate - N		mg/L	0.1	<0.5	<1
Nitrite - N		mg/L	0.05	<0.2	<0.5
Nitrate and Nitrite - N		mg/L	0.2	<0.8	<2
Sulphate (SO_4)	Dissolved	mg/L	0.2	90.7	254

Hydroxide		mg/L	5	<5	<5
Carbonate		mg/L	6	<6	<6
Bicarbonate		mg/L	5	1400	431
P-Alkalinity	as $CaCO_3$	mg/L	5	<5	<5
T-Alkalinity	as $CaCO_3$	mg/L	5	1150	353
Total dissolved solids	Calculated	mg/L	1	2110	3870
Hardness	as $CaCO_3$	mg/L		341	1350
Ionic Balance	Dissolved	%		104	101

Samples of treated water were determined to be recyclable for future fracturing operations – without dilution of fresh water.

Important to emphasize that though the treatment process demonstrated produced a satisfactory product the process could have been adjusted in several ways to produce treated water with different quality.

Advantages of Water Flow-back Treatment Process

1. Recycle 100% of frac water flow-back water – with appropriate dilution of fresh water.
2. Reduce consumption of fresh potable water by 30% to 50%.
3. Treatment and recycling competitively priced when compared to currently used disposal methods.
4. Solid waste is stable or can readily be stabilized (depending on variation of process) and be land filled.
5. Waste water from frac sand cleaning operations can be treated and reused/ recycled.
6. Treatment process is simple and robust.
7. Treatment process is readily piloted and may be tailored to suit chemistry of particular site.

Specific advantages or proposed treatment process:

1. **Minimize water demand for fracturing operations.**
2. **Eliminate need for frac flow-back disposal.**
3. **Process does not produce any fluid waste products.**
4. **Solids resulting from treatment are similar in nature to those normally produced when stabilizing solid fraction in flow-back and are readily land filled.**
5. **Treatment process may be tailored to specific conditions (bench scale and pilot plant testing).**

- **Processes may be batch or continuous flow.**
- **Sedimentation and clarification processes may use one of a variety of solid-liquid separation technologies.**
- **Process facilities may be permanent or mobile or combination of permanent and mobile.**
- **Tailored to specific situation.**

In 2004 – 2005 there was very little interest in Alberta for the treatment technology and attempts to commercialize were abandoned.

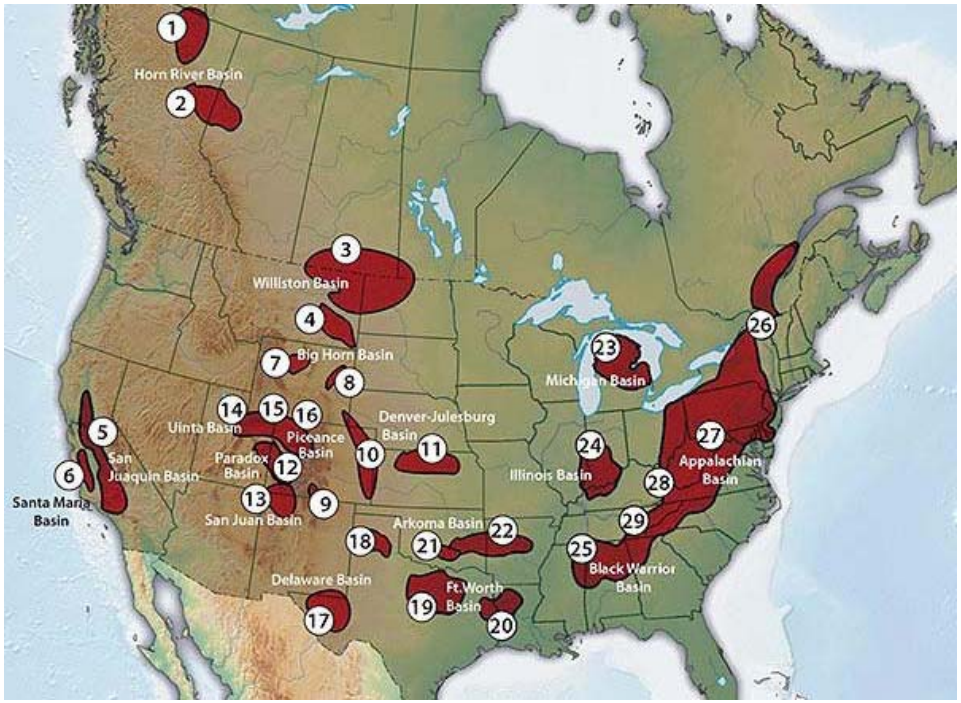
Probable reasons for lack of interest:

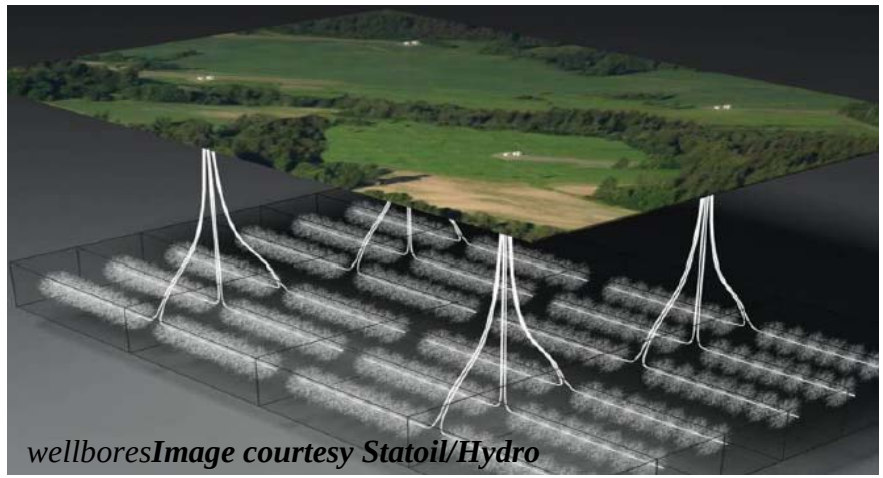
- **Water for use in frac operations was available at low cost.**
- **Volumes of water involved were not considered large.**
- **Disposal (deep well) was convenient and not very costly considering overall cost of performing fracing operations.**
- **No regulatory requirement or other incentives to reuse/ recycle frac flow-back water.**

Fast forward: 2010

Shale - Gas

Economic exploitation requiring extensive fracturing operations.





*wellbores**Image courtesy Statoil/Hydro***

Important differences between shallow gas well fracturing operations and shale gas well fracturing operations:

1.Volume of water used in single frac of a shale gas well may vary from 1,000,000 gallons to 10,000,000 gallons (100 times or more water than for shallow gas fracturing).

2.Disposal using deep wells may not be available or economical (location and cost).

3.Disposal in the environment is not an option.

4.Water for fracturing operations is or will soon become difficult / expensive to obtain.

5.Volumes of frac flow-back water are so large that large semi-permanent treatment facilities may be economical.

Previously developed technology for physical – chemical treatment of frac flow-back water that was unwanted or marginally economical in 2004 -2005

promises to provide significant support for shale gas exploitation and be very economical and commercially viable in 2010.

Physical – chemical processes may be used alone or in combination with other treatment technologies.

While the concept has been proven on a number of frac flow-back water samples from several shallow gas well fracturing operations in Southern Alberta and appears very promising for use in shale – gas basins, *the technology still requires further testing and process / proto-type development.*

Process and proto-type development should be undertaken carefully considering:

1. **Specific shale – gas basin,**
2. **Method of fracturing used (volume and quality of water),**
3. **Characteristics of flow-back,**
4. **Availability of fresh water for fracturing operations,**
5. **Opportunities for disposal and storage,**
6. **Probable frequency of fracturing and**
7. **Economics.**

Prospects for treating flow-back water to a recyclable condition from gas well fracing operations in shale – gas formations appears very good.

Oasis Filter International Ltd is seeking partner(s) to realize the potential of its proprietary frac flow-back treatment technology.

Thank You

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