Recycling Frac Fluid Pilot

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INVESTIGATION INTO WATER BASED FRAC FLUID USE IN DRILLING FLUIDS ASSOCIATED WITH SHALLOW GAS WELLS ON THE SUFFIELD BLOCK

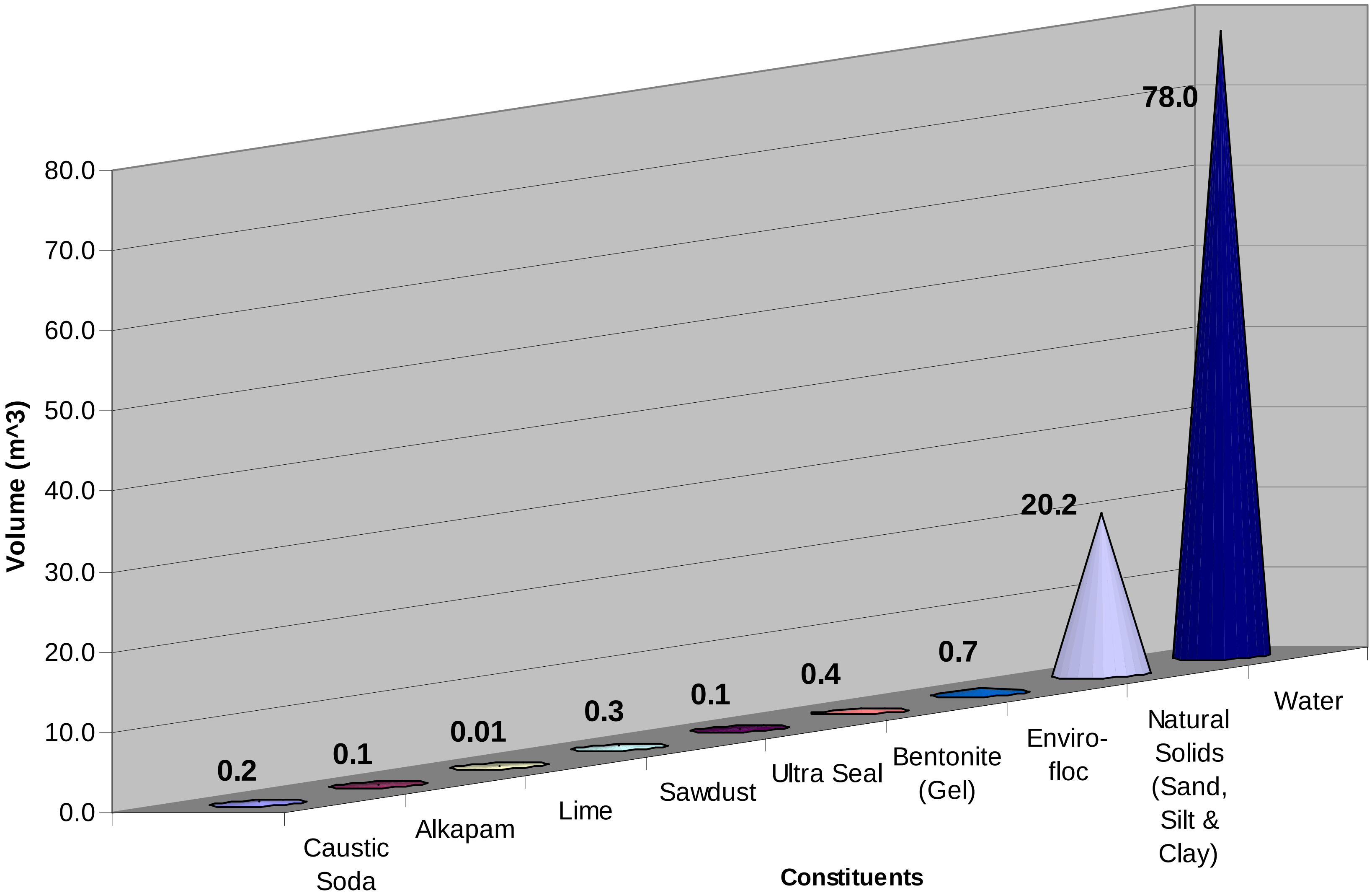
Background

- The intent of this project was to investigate the feasibility of replacing the approximately 100m3 of fresh water per shallow gas well added to drilling fluids as source water with used water based frac fluids
- Current disposal practice for the used WBFF is to transport the waste to an EUB or AENV approved facility, and then down-hole inject it
- This disposal practice completely removes the potentially reusable fluid out of the water cycle perpetually

Was it Possible?

- First step was to look at the products found in both the drilling fluids and frac fluids to determine if they were similar or interchangeable
- The mud system currently used in the drilling of a shallow gas well consists of fresh water (78% vol/vol) and about 20.2% (vol/vol) of the mud is natural solids (sand, silt, clay)
- Typical additives found in the WBFF on CFB Suffield by EnCana include:
  - Guar gum – This is a gel component used in frac fluids and also commonly found in drilling fluids as a viscosifier.
  - Enzyme breaker – These are denatured and broken up during fracing and as such would not impact the subsequent use of the frac fluids in the drilling fluid system
  - Clay control – Is used in frac fluids and drilling fluids to prevent the swelling of clays in the formations and is otherwise known as a shale control inhibitor
  - Buffers – Used in both frac fluids and drilling fluids to control the pH of the respective fluids

Illustration of Shallow Gas Well Products



Main Objectives

1. Wells must be drilled with no alterations to the drilling program and require no additional equipment onsite
2. The resulting drilling waste should be suitable for Landspray While Drilling (LWD) disposal
3. There should be no measurable impact on the receiving soils as a result of the LWD

Project Outline

- The project itself consisted of drilling 20 shallow gas wells in the southeast corner of CFB Suffield utilizing recycled WBFF
- The recycled WBFF was used as source water, replacing the fresh water normally used in the make up of the drilling fluids
- After drilling was completed the resulting drilling waste was managed using the LWD disposal option as outlined in the EUB’s *Guide 50: Drilling Waste Management*
- WasteCo Environmental provided all related drilling waste management services while EnviroTest Laboratories (ETL) conducted the analytical portion of the project

Project Timeline

- Nov 2003 - EUB and CFB Suffield were notified of the proposal
- Dec. 2003 - The Suffield Environmental Advisory Committee (SEAC) reviewed the project and provided comment to the parties involved
- Feb. 2004 - CFB Suffield gives approval for the project to proceed
- July 2004 - Drilling activities commence using the recycled WBFF
- Nov.2004 - Drilling of the 20 wells is completed
- Dec. 2004 – All required samples taken, field portion of project ended
- Jan. 2005 – ETL completes lab analytical

RECYCLED WBFF & DRILLING WASTE ANALYTICAL RESULTS

- Needed to evaluate whether or not there were any changes in the recycled WBFF after drilling
- The fluids were tested before (recycled WBFF) and after drilling (resulting drilling waste) for the following parameters:
  - Metals (full CCME metals analysis);
  - Microtox;
  - Hydrocarbons (CCME fractionization);
  - Detailed salinity; and
  - pH.

Metals

- Both the recycled WBFF and the resulting drilling waste were analyzed for a wide range of metals
- The concentration of metals was low as expected
  - No products used during fracing contained metals
  - The formations being drilled through were relatively shallow (500 – 700m in depth).
- This shallow depth does not allow for a large accumulation of metals from the formation whereas a deeper well (3000m plus) may see a slightly elevated level of metals introduced from the material being drilled through

Metal Concentrations

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Table #1 – Average Metals Concentrations in Recycled WBFF and Drilling Waste

Parameter	Recycled WBFF (mg/L)	Drilling Waste (mg/L)
Arsenic	**0.0617**	**0.507**
Barium	**1.44**	**13.01**
Beryllium	**0.0629**	**0.00263**
Cadmium	**0.00**	**0.00213**
Cobalt	**0.0328**	**0.315**
Chromium (total)	**0.091**	**0.857**
Copper	**0.133**	**1.174**
Mercury	**0.0078**	**0.0214**
Molybdenum	**0.0218**	**0.0294**
Nickel	**0.0121**	**1.13726**
Lead	**0.0894**	**0.137**
Antimony	**0.004**	**0.00121**
Selenium	**0.0171**	**0.055**
Tin	**0.00167**	**0.0105**
Thallium	**0.0004**	**0.00263**
Vanadium	**0.172**	**1.94**
Zinc	**0.544**	**3.29**

Microtox & Toxicity

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- Drilling fluid systems that can be disposed of via LWD must be non-toxic
- In order to evaluate the toxicity of the recycled WBFF and the resulting drilling waste the fluids were subjected to a microtox analysis using protocols outlined in the EUB's Guide 50
- All twenty sites passed microtox requirements and were deemed to be non-toxic

Microtox Breakdown

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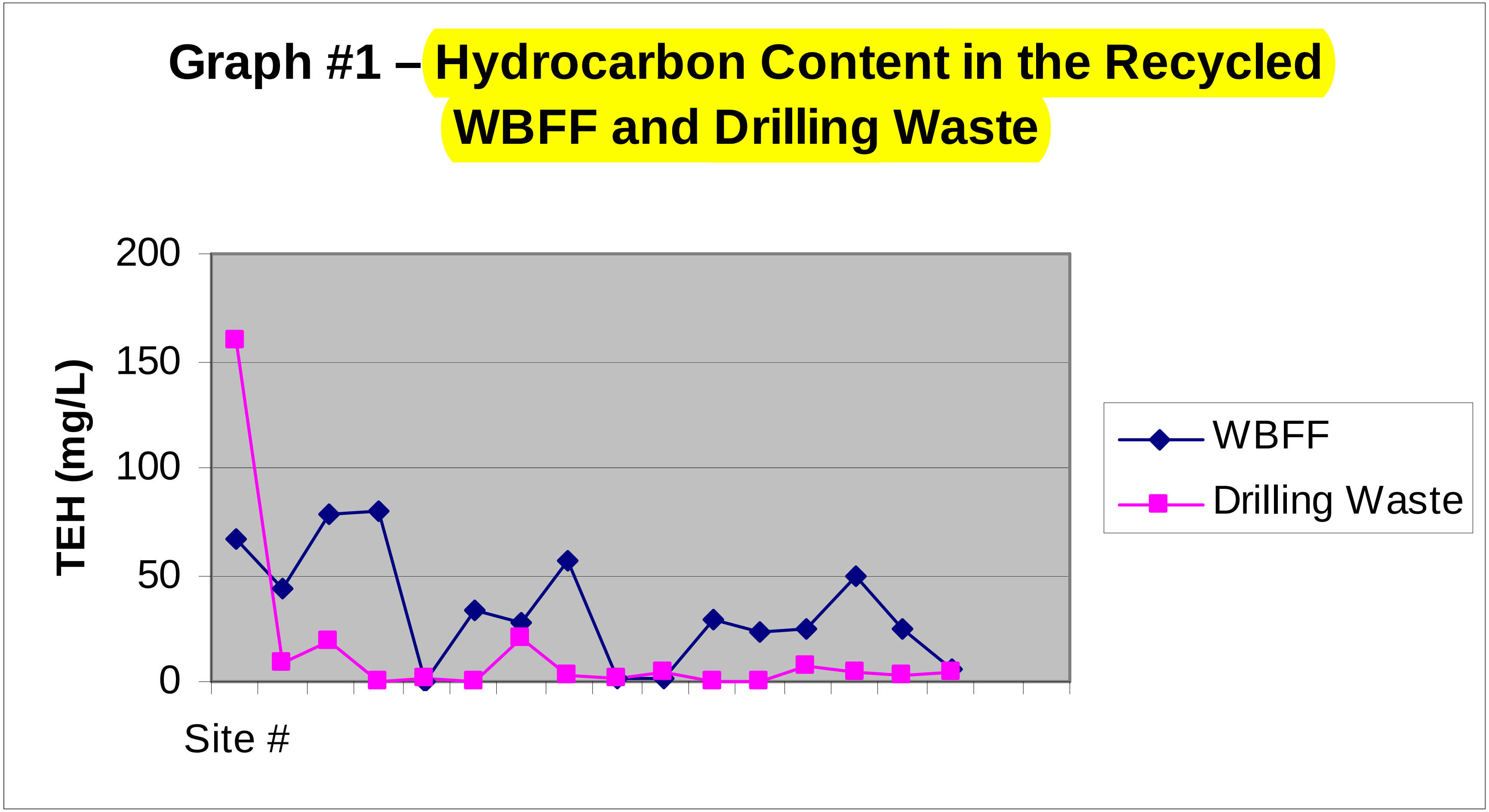
Table #2 – Microtox Assessment for the Recycled WBFF and Drilling Waste

Microtox Test	Percent of Sites For Recycled WBFF	Percent of Sites For Drilling Waste
Original (>75%)	70%	80%
Charcoal	30%	5%
Color Correction	0	15%
Percent Failed	0	0

Hydrocarbons

- Field reports for each location indicated no locations had any visible hydrocarbons (i.e. rainbow sheen) on the resulting drilling waste
- Trace amounts of lighter end hydrocarbons were detected via laboratory analysis
- The average hydrocarbon concentrations (TEH):
  - 34mg/L for the recycled WBFF prior to drilling; and
  - 15mg/L in the resulting drilling waste
- Both fluids were also analyzed for BTEX components and 13 out of the 20 locations had levels below detection limits
- Out of remaining 7 locations the highest BTEX conc. reported in drilling waste 0.35mg/L (xylene)

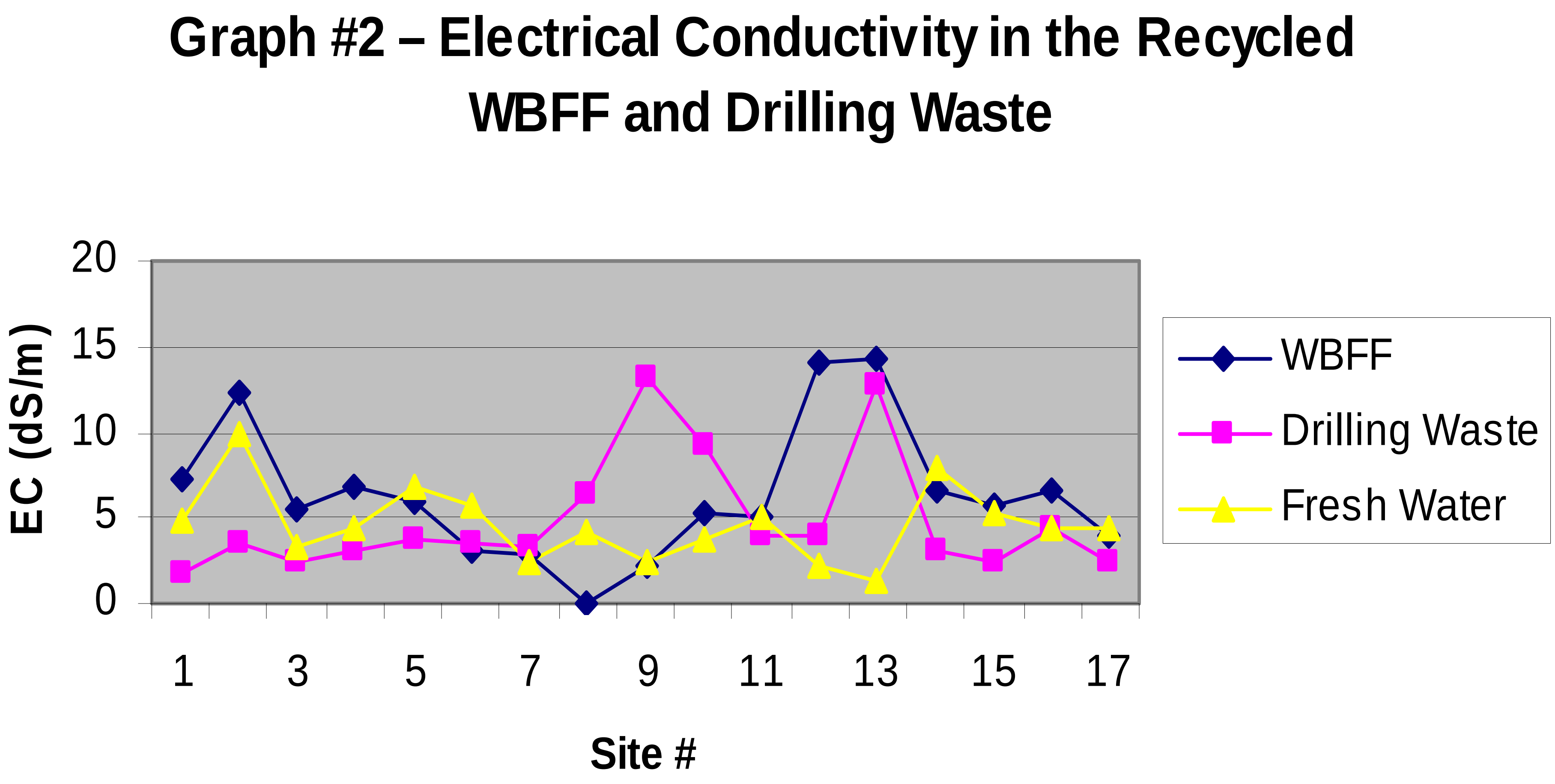
Hydrocarbons in Fluids



Detailed Salinity & pH

- pH in the recycled WBFF (average pH = 8.21) and the drilling waste (average pH = 8.63) was consistent
- Overall there was a noticeable reduction in the electrical conductivity (EC) at the majority of locations of the recycled WBFF after drilling operations
- The EC dropped from an average of 6.22 dS/m prior to drilling versus 4.67 dS/m in the resulting drilling waste
- In order to allow for a comparison the average EC was taken from 20 randomly chosen locations
- The average EC was found to be 4.59dS/m (data taken from resulting LWD Notification of Drilling Waste Disposal Form)

Salinity Cont..



Conclusion on Fluids & LWD

- The analytical data leads to the conclusion that the drilling waste is compatible with the LWD disposal option
- In order to verify this statement the next stage of the pilot project focused on any potential impacts on the receiving soils
- This was done by sampling before and after the LWD disposal was conducted so that a conclusion could be drawn via comparing the two sets of data

PRE AND POST DISPOSAL RECEIVING SOIL ANALYTICAL RESULTS

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- The receiving soils were sampled for the following intervals (both pre and post disposal):
  - 0-5cm
  - 5-10cm
  - 10-15cm
- Each of the 3 intervals (both pre and post disposal) were analyzed for the following parameters:
  - Metals (CCME metals analysis);
  - Hydrocarbons (CCME fractionization);
  - Detailed salinity; and
  - pH.

Metals & Receiving Soils

Table #3 – Comparison of Average Metals Concentration in Receiving Soils

Parameter	Regulatory Limits (mg/kg)	Pre Disposal Receiving Soil Concentration			Post Disposal Receiving Soil Concentration		
		0-5cm	5-10cm	10-15 cm	0-5cm	5-10cm	10-15cm
Arsenic	**12**	**5.36**	**5.65**	**6.78**	**5.31**	**5.36**	**6.32**
Barium	**750**	**166.95**	**166.1**	**180.1**	**171.5**	**164.4**	**175.9**
Beryllium	**5.0**	**0**	**0**	**0.05**	**0**	**0**	**0**
Cadmium	**1.4**	**0.079**	**0**	**0**	**0.17**	**0**	**0.025**
Cobalt	**20**	**6.05**	**6.80**	**7.60**	**6.15**	**6.55**	**11.45**
Chromium	**64**	**14.02**	**16.05**	**18.04**	**14.04**	**14.83**	**17.09**
Copper	**63**	**11.5**	**11.63**	**13.2**	**11.7**	**11.7**	**12.4**
Mercury	**6.6**	**0**	**0**	**0**	**0.004**	**0**	**0**
Molybdenum	**4.0**	**0**	**0**	**0.1**	**0**	**0**	**0**
Nickel	**50**	**11.63**	**13.68**	**18.3**	**12**	**12.8**	**15.65**
Lead	**70**	**10.45**	**9.0**	**9.50**	**9.9**	**8.6**	**9.0**
Antimony	**na**	**0**	**0**	**0**	**0**	**0**	**0**
Selenium	**2.0**	**0.395**	**0.360**	**0.330**	**0.389**	**0.490**	**0.405**
Tin	**na**	**0**	**0**	**0**	**0**	**0**	**0**
Thallium	**1.0**	**0**	**0**	**0**	**0**	**0**	**0**
Uranium	**na**	**0**	**0**	**0**	**0**	**0**	**0**
Vanadium	**130**	**24.85**	**28.6**	**33.3**	**24.5**	**26.6**	**31.5**
Zinc	**200**	**68.5**	**62.5**	**64.0**	**73.5**	**67.5**	**67.5**

Metals & Receiving Soils

- Out of the 120 samples at no time did any of the individual analytical results, either pre or post disposal, exceed the metals criteria
- This confirms given the trace concentration of metals in the fluids the ability to LWD the resulting drilling waste should not be inhibited
- It is evident that the metals concentration in the soils has not been increased or affected

Hydrocarbons & Receiving Soils

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- BTEX levels both pre & post disposal were <detection limits in all but two samples where the predisposal soil had very low conc. of 0.05mg/L & 0.04mg/L (Xylene)
- The hydrocarbon content in the soils were compared to the most restrictive applicable criteria; AENV's "*Alberta Tier I Hydrocarbon Guidelines for Coarse Surface Soils*"
- At no time did any of the hydrocarbon levels in the post disposal receiving soil samples exceed the applicable regulatory criteria

Hydrocarbon Concentration in Receiving Soils

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Table #4 – Comparison of Pre and Post Disposal Hydrocarbon Concentrations in Receiving Soils

Depth		**Criteria* (mg/kg)**	**Pre Disposal (mg/kg)**			**Post Disposal (mg/kg)**		
			Average	**Low**	**High**	**Average**	**Low**	**High**
0-5cm	F1	130	0	0	0	0	0	0
	F2	230	4.50	0	54	0	0	0
	F3	400	107	8	**670**	38.0	0	110
	F4	2800	79.1	6	510	25.9	0	77
5-10cm	F1	130	0	0	0	0	0	0
	F2	230	0	0	0	0	0	0
	F3	400	21.1	0	88	33.4	0	210
	F4	2800	16.3	0	57	20.1	0	65
10-15cm	F1	130	0	0	0	0	0	0
	F2	230	0.55	0	11	0	0	0
	F3	400	46.1	0	**430**	17.9	0	82
	F4	2800	50.2	0	480	12.55	0	54

**Criteria is taken from AENV's Alberta Hydrocarbon Guidelines for Coarse Surface Soils*

Hydrocarbon Concentration in Receiving Soils

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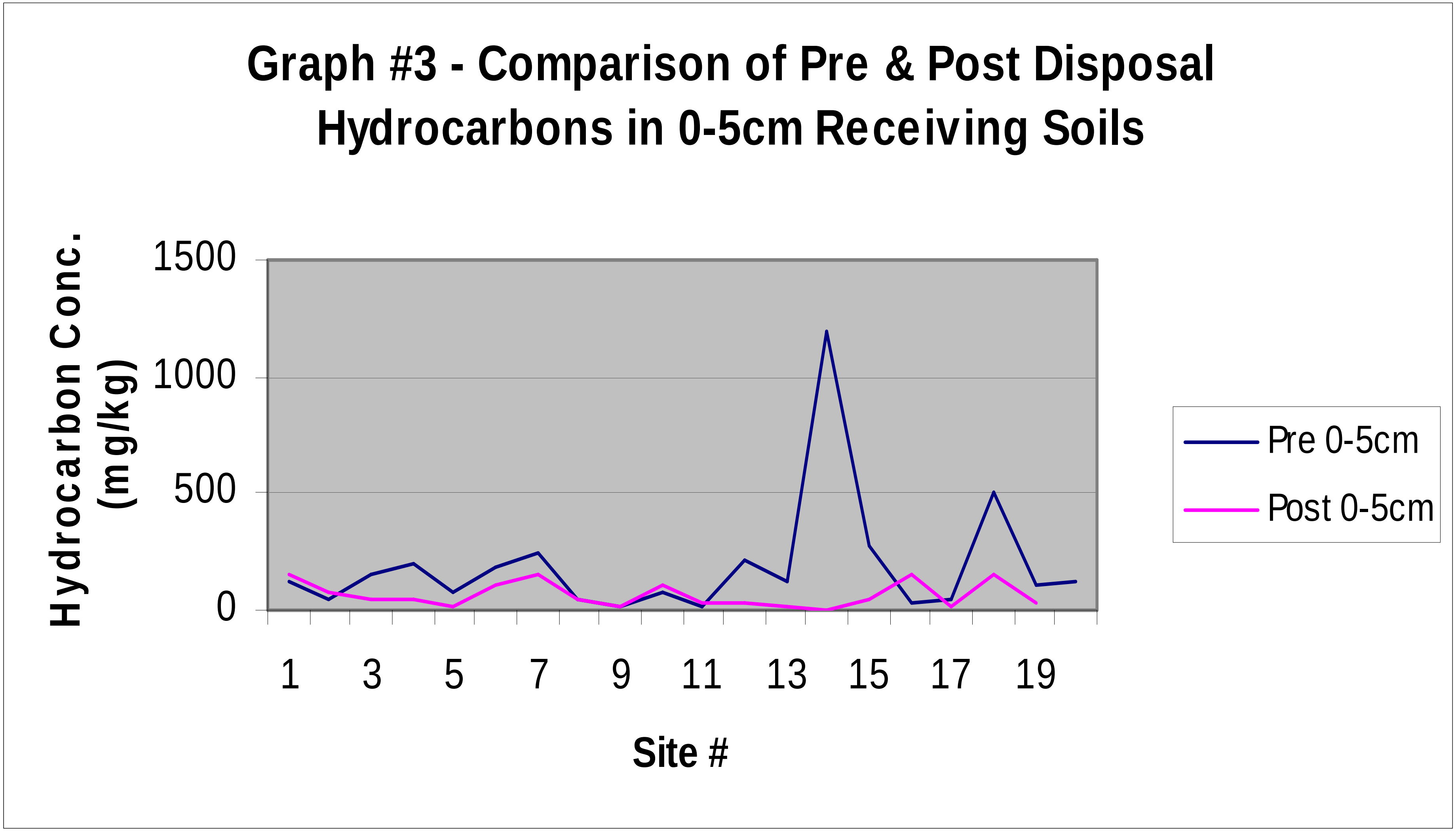
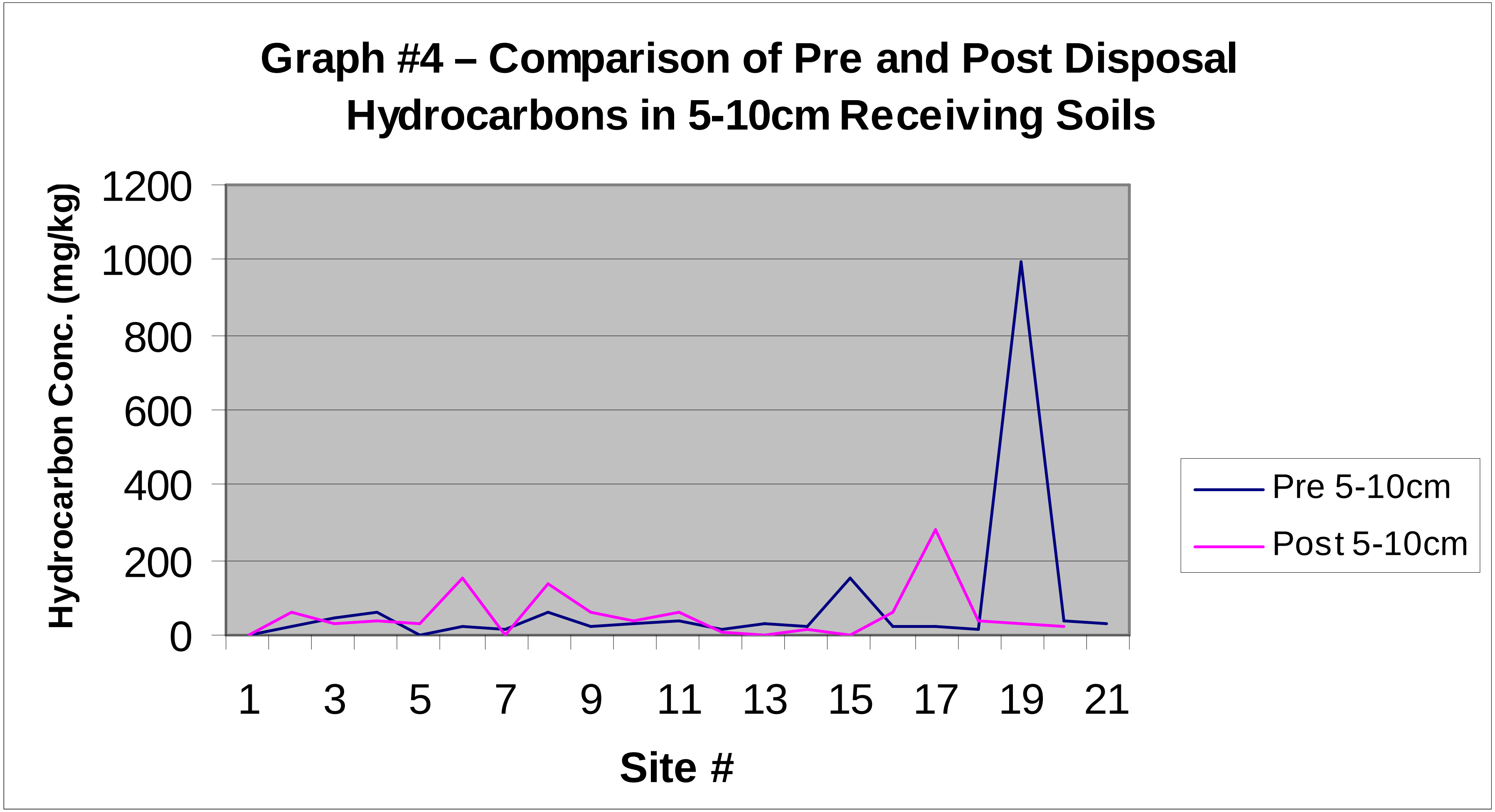
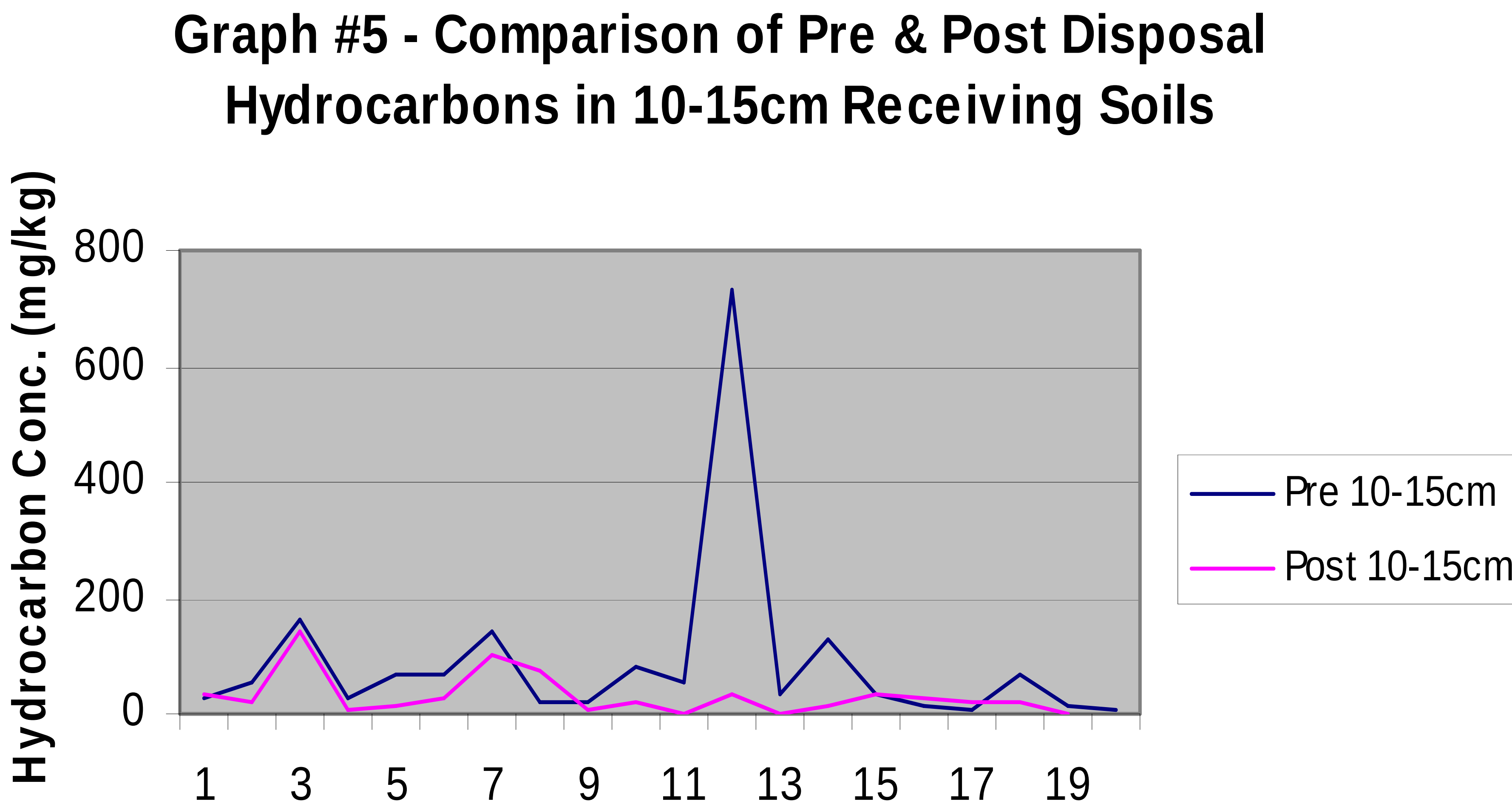


Hydrocarbon Concentration in Receiving Soils



Hydrocarbon Concentration in Receiving Soils



Detailed Salinity/pH & Receiving Soils

- Detailed salinity analysis was conducted on the 3 depth profiles of the receiving soils for the following parameters:
  - Electrical Conductivity (EC)
  - Sodium Adsorption Ratio (SAR)
  - Specific ions including; Sodium, Calcium, Potassium, Magnesium and Sulphate
- The parameters of EC and SAR were investigated in an attempt to detect any trends for salinity in the receiving soils

Detailed Salinity & Receiving Soils

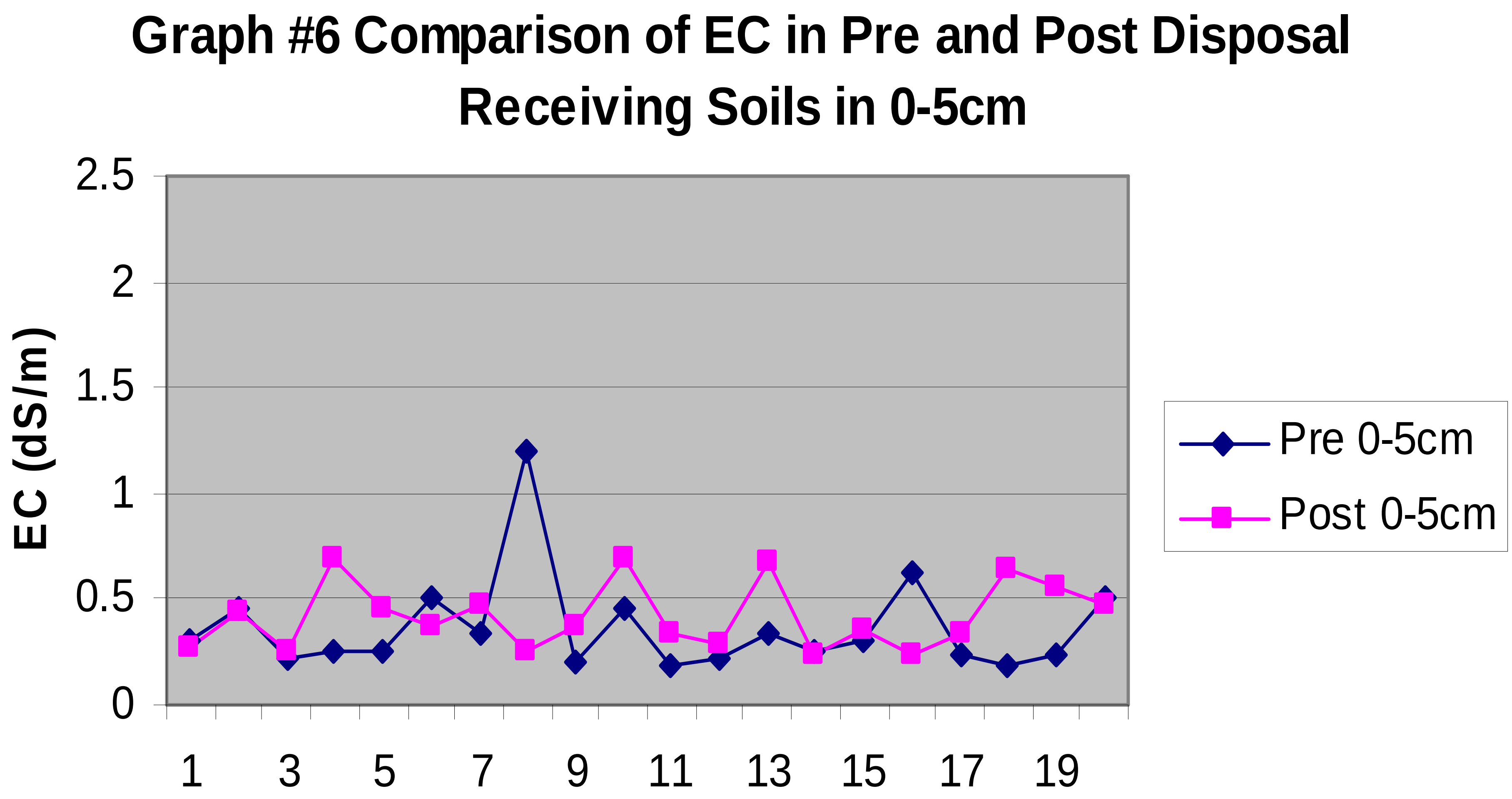
- One of the main goals of this project was to ensure that the EC in the receiving soils would not be increased above 1dS/m
- The highest recorded EC for a post disposal receiving soil sample was 0.69dS/m
- All of the post disposal receiving soil samples had an EC of <1dS/m
- This is expected because the EC of the drilling waste itself was similar to that found in fresh water based drilling wastes
- These systems are routinely sampled for EC and also do not usually result in an increase of 1dS/m

Detailed Salinity & Receiving Soils

Table #5 – Comparison of Average Salinity & pH Parameters in Receiving Soils

Parameter	Pre Disposal Receiving Soil Concentration			Post Disposal Receiving Soil Concentration		
	0-5cm	5-10cm	10-15 cm	0-5cm	5-10cm	10-15cm
Electrical Conductivity (dS/m)	**0.324**	**0.253**	**0.332**	**0.422**	**0.350**	**0.326**
Sodium Absorption Ratio (SAR units)	**0.523**	**1.32**	**1.55**	**0.56**	**0.49**	**0.374**
pH	**6.8**	**7.1**	**7.3**	**6.8**	**6.7**	**6.7**

Detailed Salinity & Receiving Soils



Detailed Salinity & Receiving Soils

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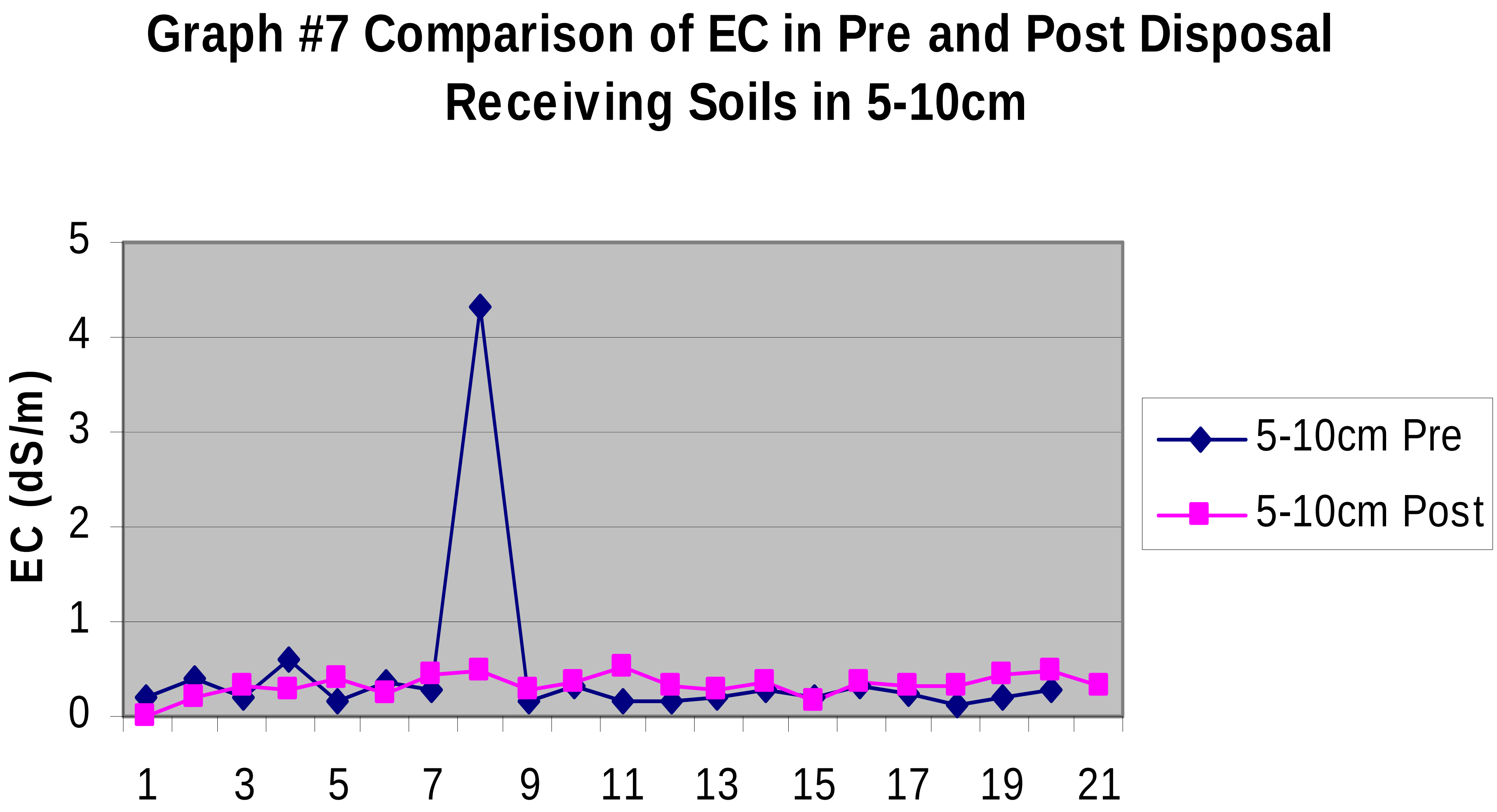
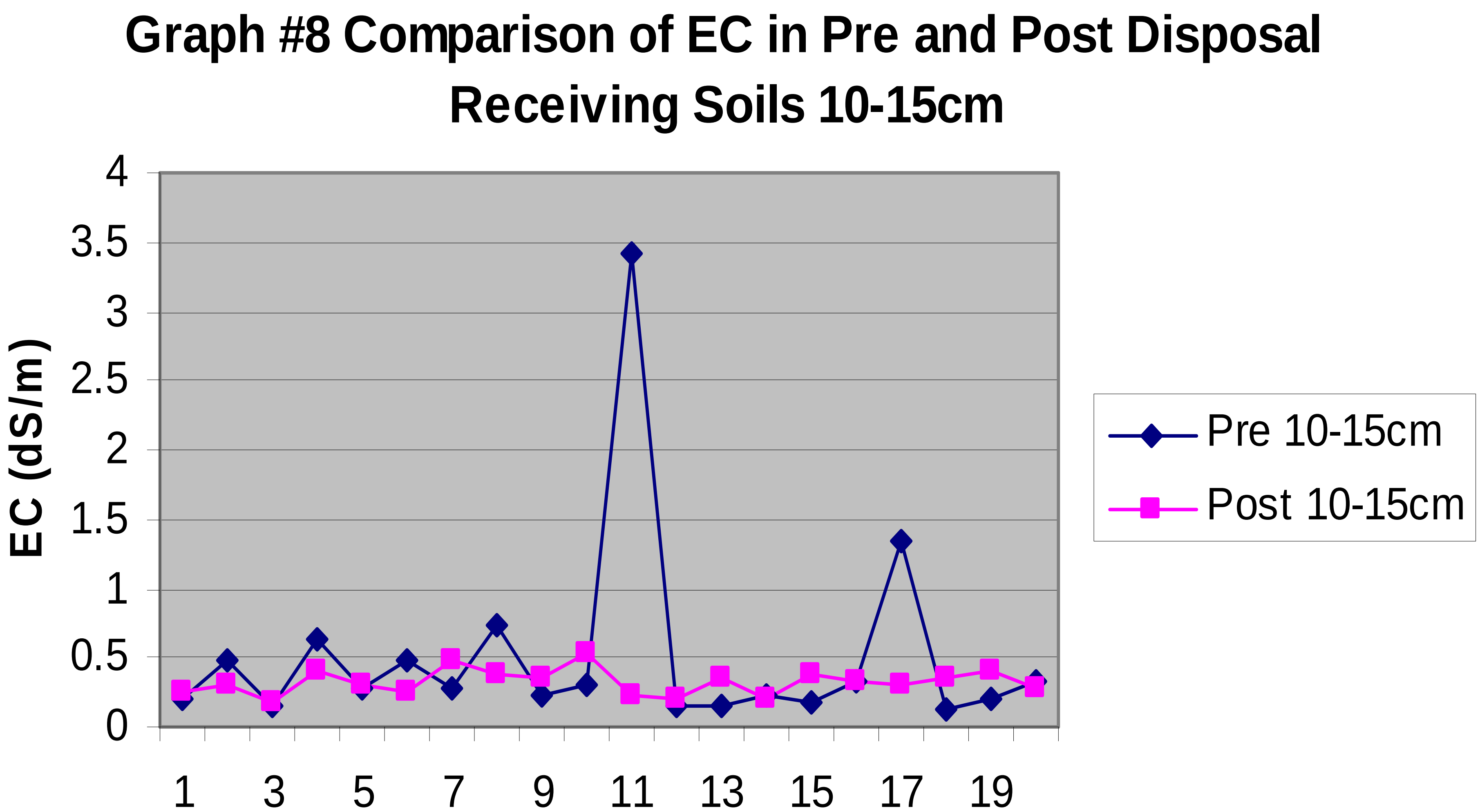


Detailed Salinity & Receiving Soils



Conclusion

1. Based on the results of this pilot project it appears there was no measurable impact on the receiving soils as a result of the LWD

2. The drilling fluid system containing the recycled WBFF behaved just like a fresh water based system with no impacts to the drilling process itself

3. The resulting drilling waste was compared against a random population of fresh water based drilling waste samples and appeared to have equivalent chemical and toxicity characteristics

Environmental Benefits

- The environmental benefits of this project are very simple in nature but also potentially extremely significant with regards to the overall reduction of water usage associated with drilling shallow gas wells
- In 2003 approximately 1000 gas wells were drilled within CFB Suffield boundaries which resulted in the extraction of approximately 100,000m3 of fresh water
- During the first year a more conservative estimate of replacing 50% of the water may be more realistic as ongoing issues are resolved and processes streamlined

Next Steps

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1. Frac fluid companies should investigate the use of alternative additives that may be even more environmentally friendly (i.e. lower toxicity)

2. A presentation & thorough explanation on the findings of this project should be conducted for stakeholders & regulators

3. Alternatives for short term storage of the WBFF would have to be investigated

4. A set of protocols (SOP) would have to be written up for the environmental field consultants to follow