

SPECTRUM TRACER
SERVICES, LLC

Why Use Tracing?

- RA tracing allows a look at proppant distribution and fracture geometry.
- Chemical tracing helps describe frac fluid recovery post completion. Offset well communication can also be observed in the lab and reported.

Tracing Mediums

- Particulate radioactive tracing material
- Water soluble chemical tracers

RA Tracing

- ▣ We utilize radioactive tracing as a method to aid engineers in recognizing proppant placement and proppant distribution. Frac fluid distribution is also important in acid fracs. Fracture geometry at the wellbore can also be determined.

RADIOACTIVITY LEVELS OF SOME COMMON ITEMS

LANTERN SOCK - 5,000 pCi

SMOKE DETECTOR - 500,000 pCi

CHECK SOURCE - 10,000,000 pCi

DENSIOMETER - 50,000,000,000 pCi

NUCLEAR MEDICINE PROCEDURE - 20,000,000,000 pCi

RADIOACTIVE POTASSIUM IN HUMAN BODY - 130,000 pCi

BRAZIL NUTS - 1,400 pCi

SPECTRUM FLOW BACK - 1,000 pCi

TYPICAL RADIATION EXPOSURE (mREM/yr)

SMOKING CIGARETTES - 2,000
RADON IN DRINKING WATER - 4,000
COAL FIRED POWER PLANTS - 350
CHEST X-RAY - 30
FULL SPINE X-RAY - 2,000
RADIOACTIVE ELEMENTS IN BODY - 30
ARTIFICIAL TEETH - 10,000
HOUSES IN GRANITE ZONES - 6,000
HOSPITAL WORKER - 1,300
SPECTRUM TRACER ENGINEER - 1,300
STANDING NEXT TO FLOW BACK MATERIAL FOR ONE HOUR - 0.03
REGULATORY LIMIT FOR RADIATION WORKERS - 5,000
GENERAL PUBLIC - 100

HALF-LIVES OF radioactive MATERIALS

IR-192 – 74 DAYS

SC-46 – 84 DAYS

SB-124 – 60 DAYS

CO-60 – 5.27 YRS

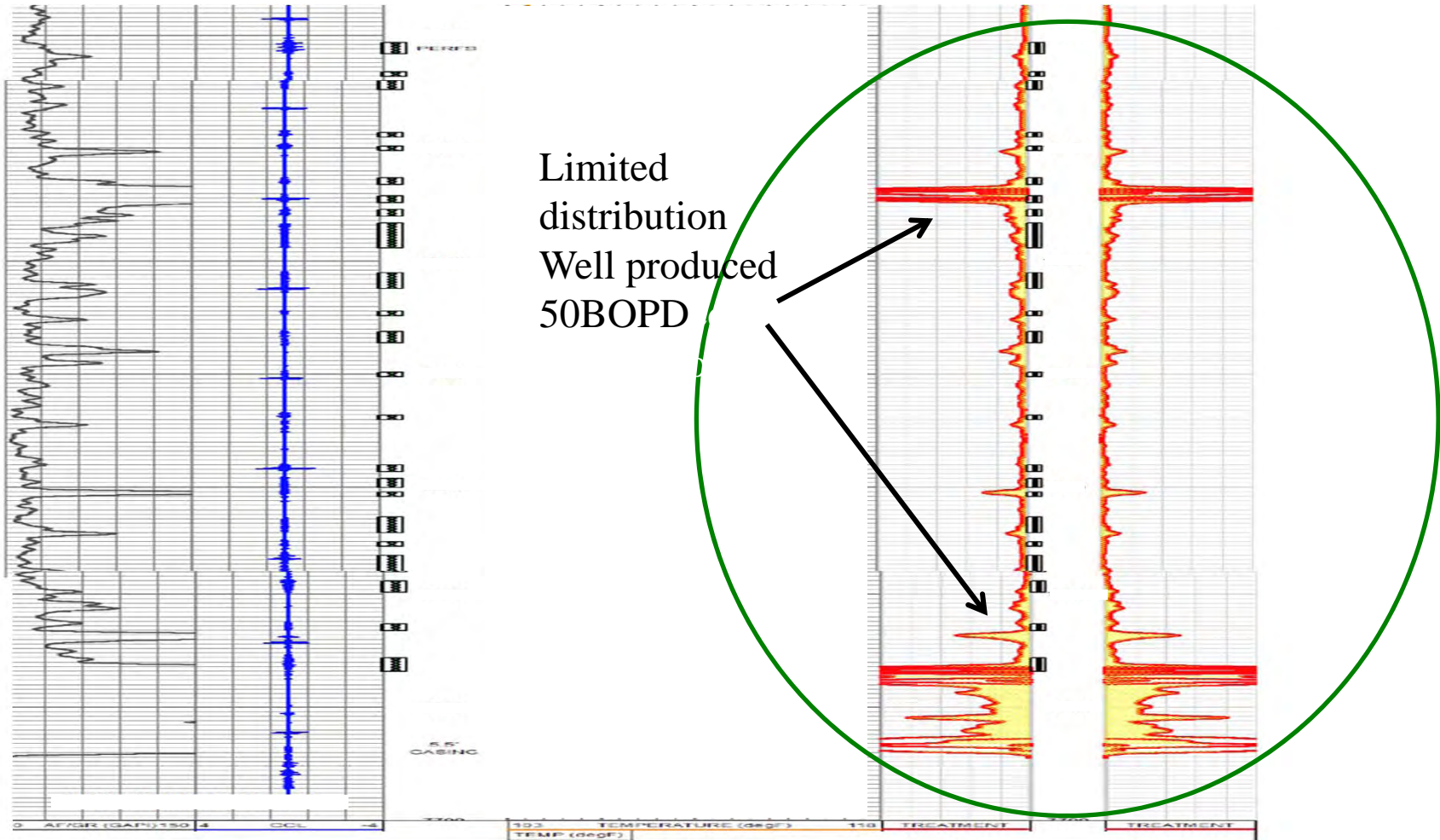
AM-241 – 458 DAYS

BA-133 – 10.38 YRS

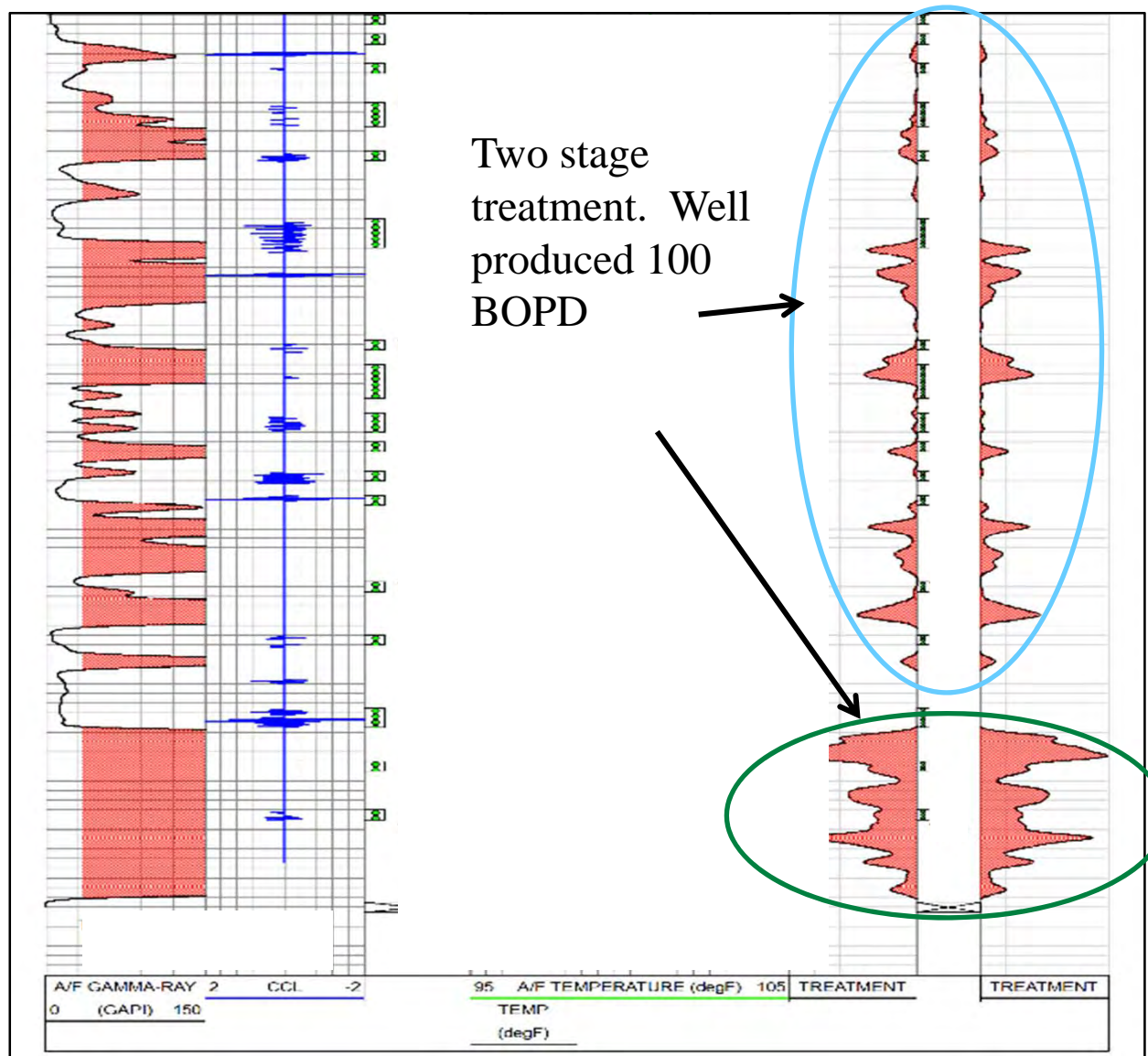
CS-137 – 30 YRS

THORIUM – MILLION YRS

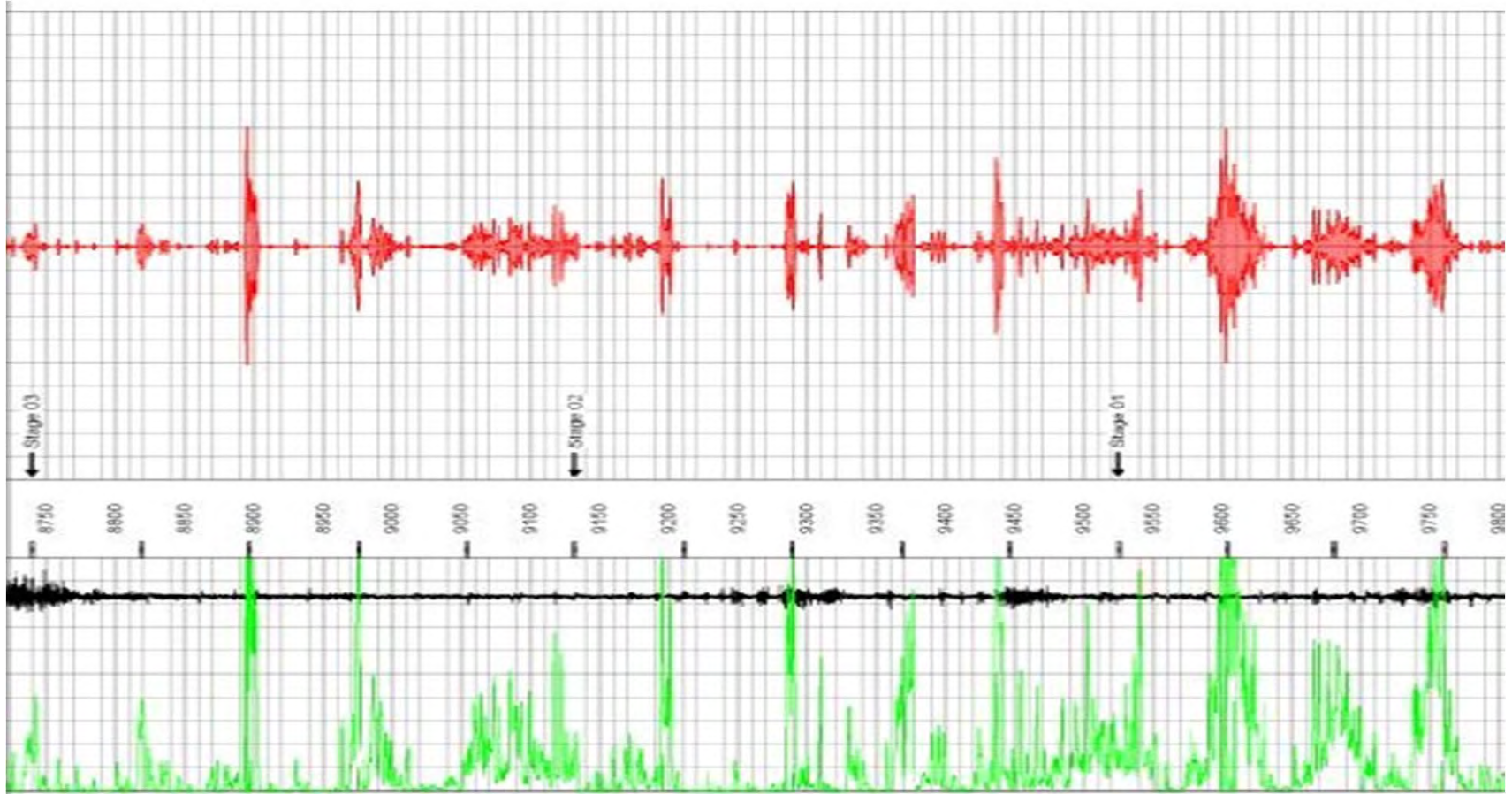
Single Stage Acid Treatment



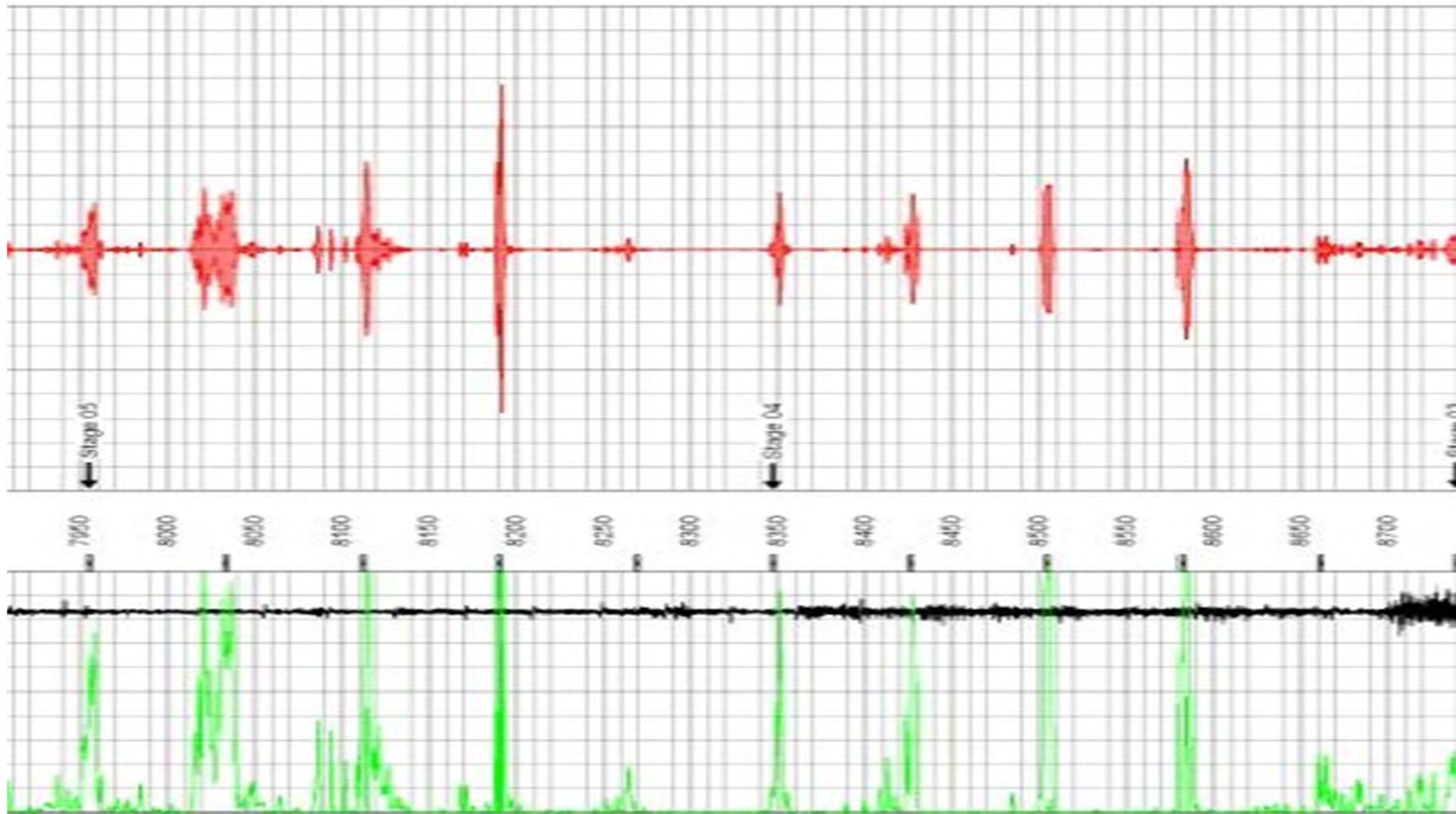
Two Stage Acid Treatment



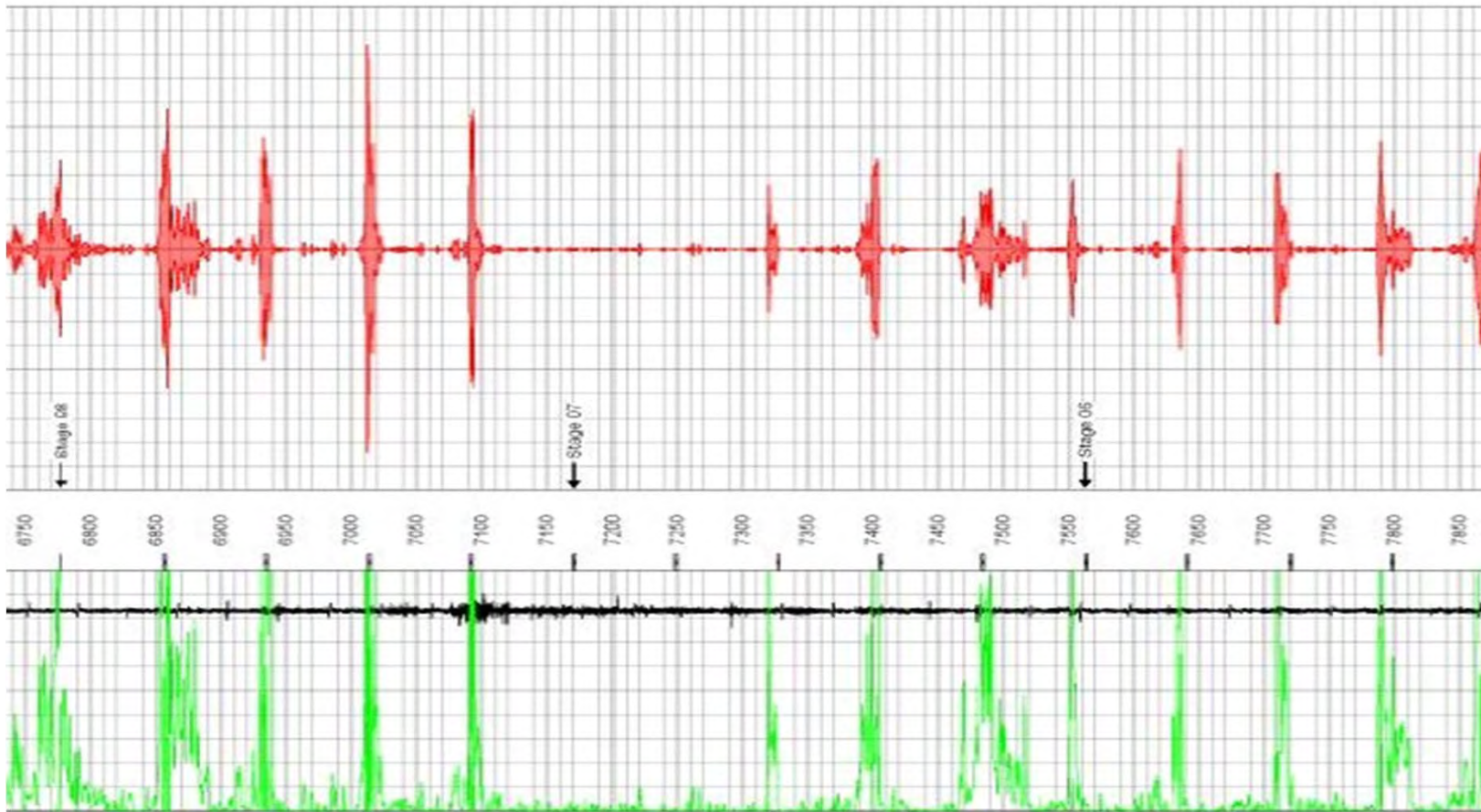
Stages 1-3, P&P



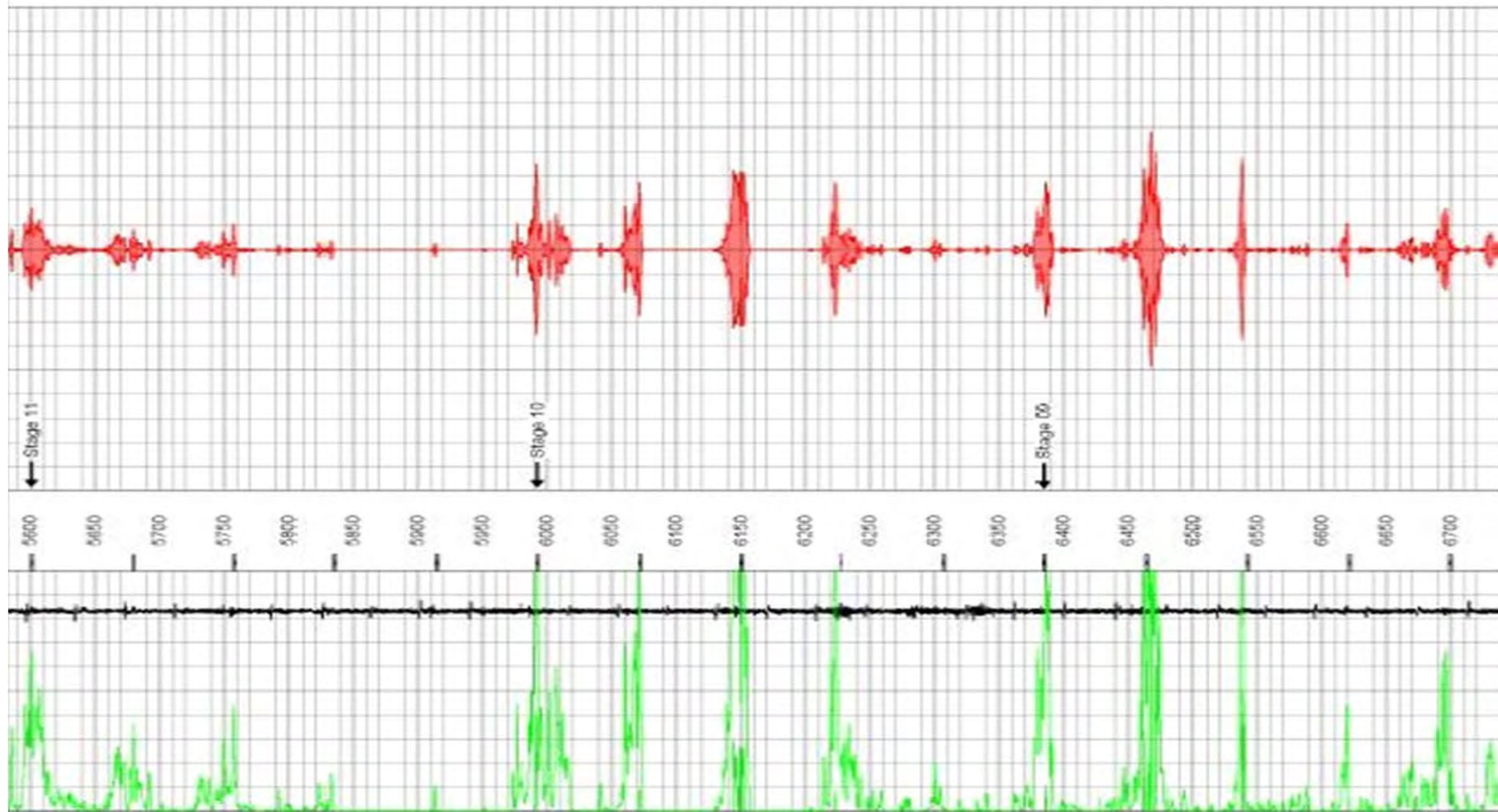
Stages 4&5, P&P



Stages 6,7,8, P&P



Stages 9,10,11, P&P



Frac Fluid Identification

- Proprietary family of chemicals we refer to as FFIs
- Commonly referred to as “salt-based aromatic acids”
 - Identify different frac stage load recoveries with detection limits as low as parts per trillion.
 - Inject during treatments and then upon fluid recovery, samples are sent to our lab for processing.
 - Present results as a qualitative and semi-quantitative report.

FFI Evolution


- ❑ Started with a handful of FFIs. Beta tested and went commercial in January 2011.
- ❑ Needed as many FFIs as possible and had to be able to turn data around in a 2 or 3 day period.
- ❑ We now have 26 known FFIs. Turn around time is still 2-3 days after samples reach the Tulsa lab.
- ❑ Always looking for additional testing candidates and wells.

What we know about chemicals

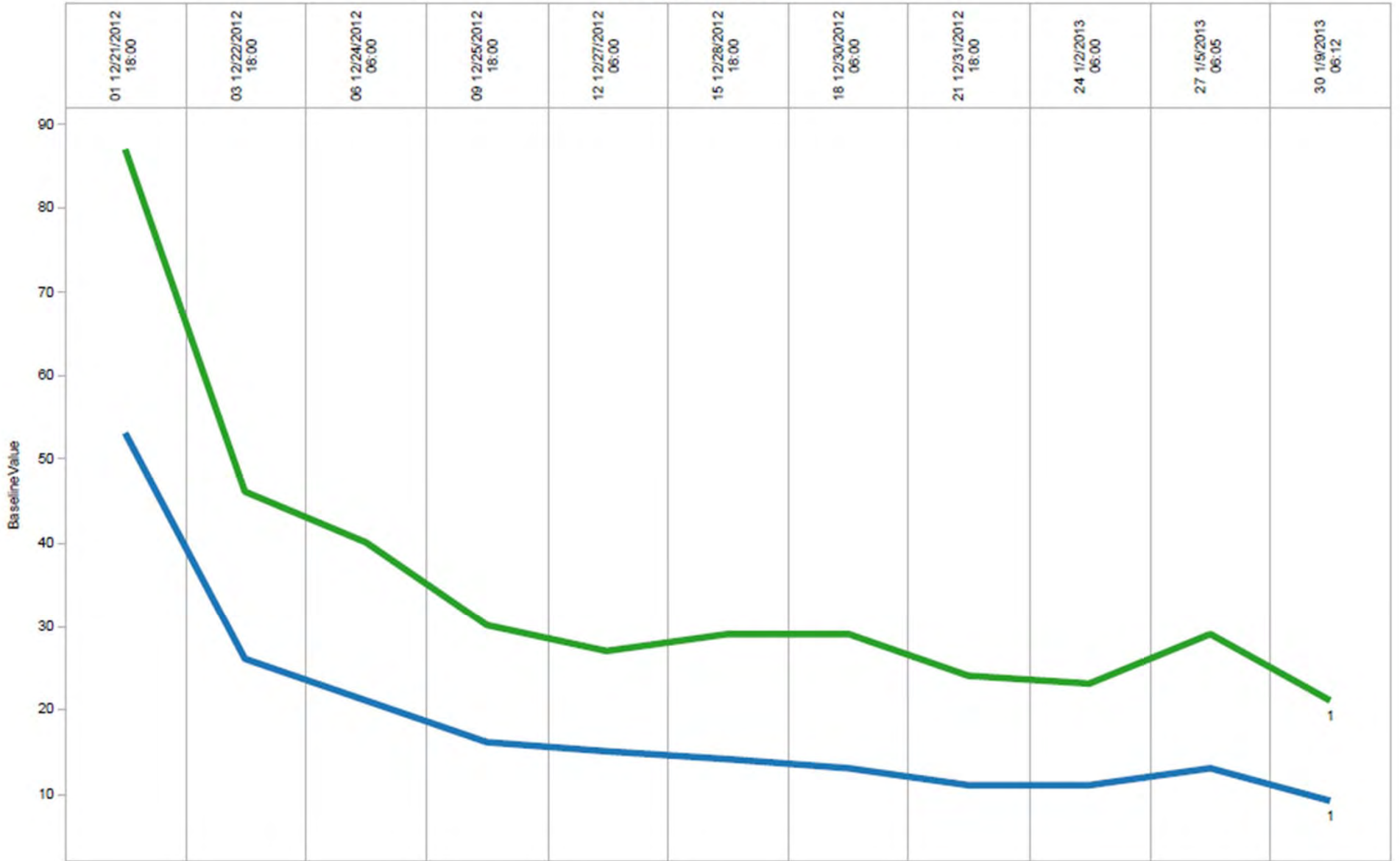
- ❑ Some chemical loss is expected and different in each formation.
- ❑ Therefore 10% of chemical recovery does not equal 10% load recovery.
- ❑ A qualitative review gives confidence in recovery from different stages
- ❑ A quantitative review can be mis-leading by itself but helpful and informative when coupled with other data, salinities for example.

FFI Flowback Results

Stage	Product	01	03	06	09	12	15	18	21	24	27	30
1	FFI 900	18:00	18:00	06:00	18:00	06:00	18:00	06:00	18:00	06:00	06:05	06:12
	FFI 1000	12/21/12	12/22/12	12/24/12	12/25/12	12/27/12	12/28/12	12/30/12	12/31/12	1/2/13	1/5/13	1/9/13

Results
 Present

FFI Flowback Results



Results (ppb)

BaseLine0

Stage	Product	12/21/12	12/22/12	12/24/12	12/25/12	12/27/12	12/28/12	12/30/12	12/31/12	1/2/13	1/5/13	1/9/13
		18:00 01	18:00 03	06:00 06	18:00 09	06:00 12	18:00 15	06:00 18	18:00 21	06:00 24	06:05 27	06:12 30
1	FFI 900	87	46	40	30	27	29	29	24	23	29	21
	FFI 1000	53	26	21	16	15	14	13	11	11	13	9

Things to Consider

- Minimum Detection Limit of FFI
- Sample interferences
- FFI recovery in sample
- Dilution with formation water
- Dilution with other frac. Stages
- Contamination

Instrument Detection Limit

- 0.5 Parts Per Billion (ppb)
- 0.5grams FFI/billion grams water
- 0.5grams FFI/264,200gal of Water
- FFI concentration must be at or above the minimum detection limit in the production fluid in order to be detected.

Frac Fluid Identification

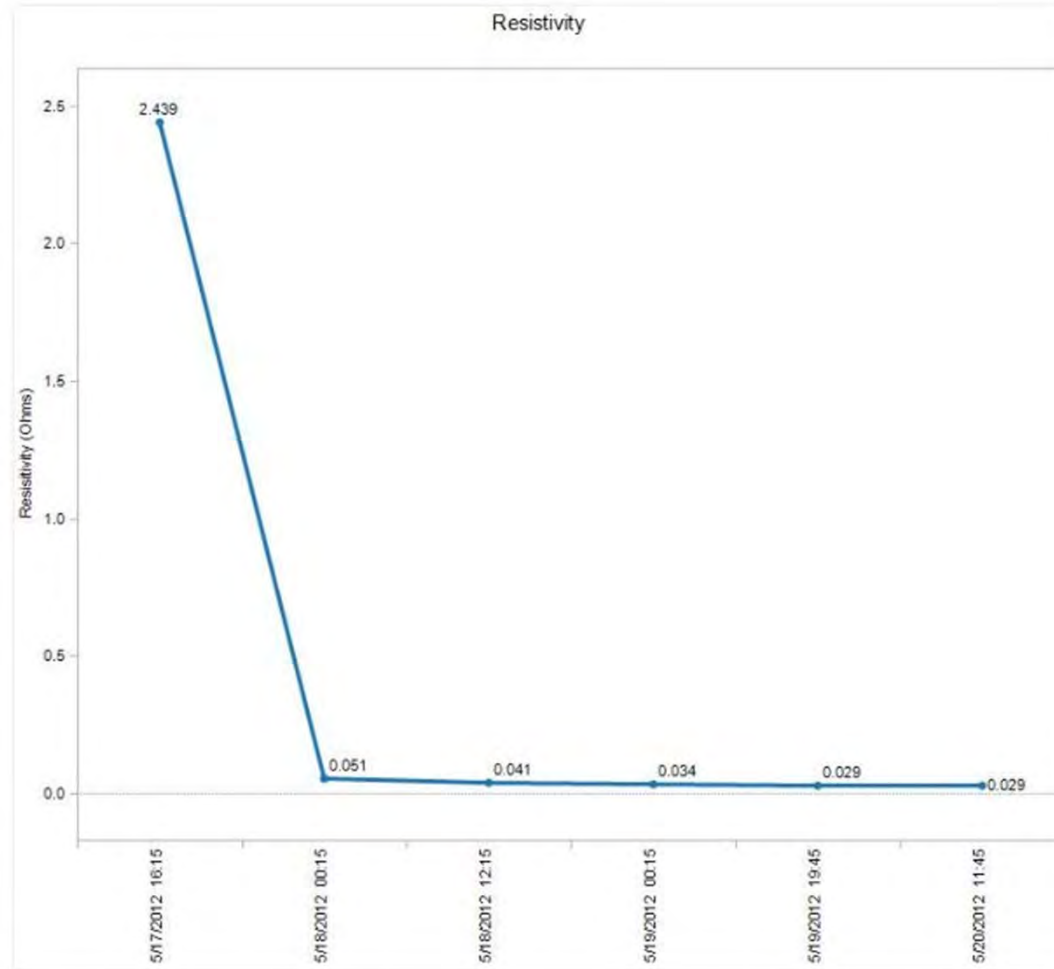
- Data is generated as a chromatograph .
- Data is converted to a simple qualitative report indicating the presence or lack of FFI.
- Data is also given in tabular form as ppb on an Excel spreadsheet
- Salinities graphed for correlation
- Data points allow the engineer to make determinations going forward .

Bakken Well 2

FFI Flowback Results

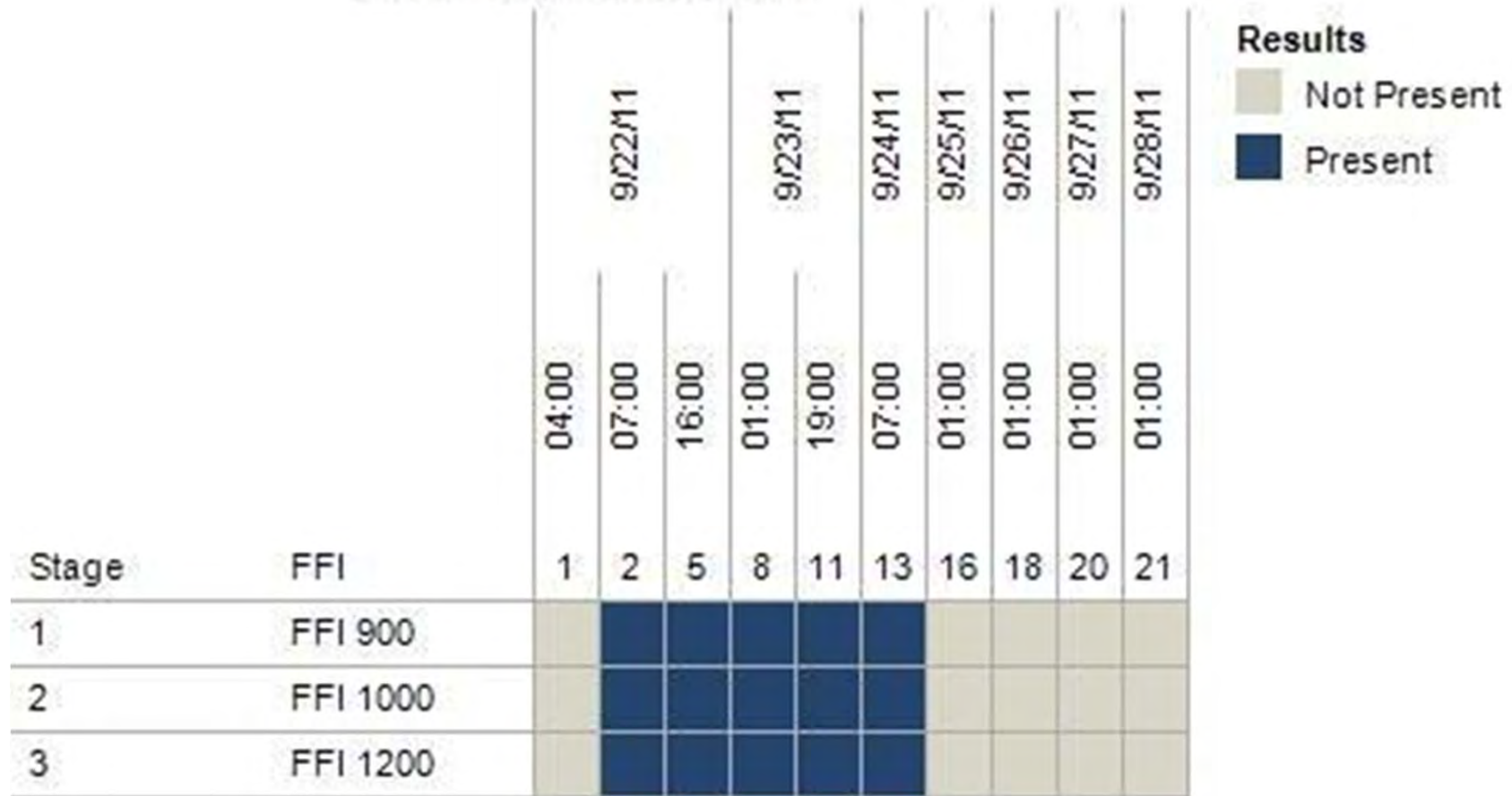
Stage	Product	Results					
		16:15 5/17/12	00:15 5/18/12	12:15 5/18/12	00:15 5/19/12	19:45 5/19/12	11:45 5/20/12
		1	3	6	9	12	14
1	FFI 2000	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
2	FFI 800	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
3	FFI 2100	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
4	FFI 1000	Not Present	Not Present	Not Present	Not Present	Not Present	Present
5	FFI 1100	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
6	FFI 2200	Not Present	Not Present	Not Present	Not Present	Not Present	Present
7	FFI 1300	Not Present	Not Present	Not Present	Not Present	Present	Present
8	FFI 2400	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
9	FFI 900	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
10	FFI 4200	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
11	FFI 2300	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
12	FFI 1400	Not Present	Not Present	Not Present	Not Present	Present	Present
13	FFI 2600	Not Present	Present	Present	Present	Present	Present
14	FFI 2600	Not Present	Present	Present	Present	Present	Present
15	FFI 1200	Not Present	Present	Present	Present	Present	Present
16	FFI 2700	Not Present	Present	Present	Present	Present	Present
17	FFI 2900	Not Present	Not Present	Not Present	Not Present	Not Present	Not Present
18	FFI 4100	Not Present	Not Present	Present	Present	Present	Present
19	FFI 200	Not Present	Present	Present	Present	Present	Present

Resistivity



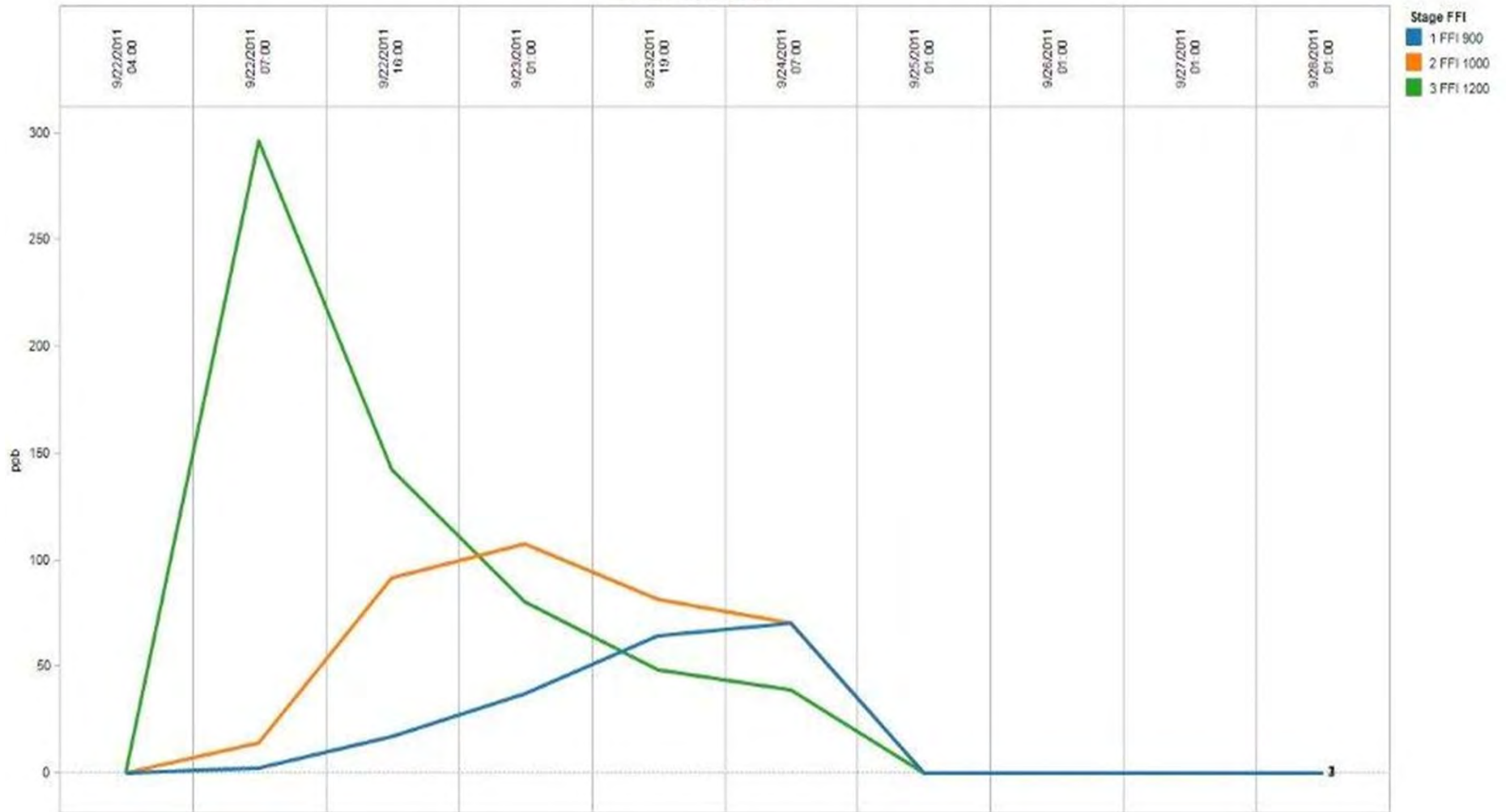
Bar Graph

FFI Flowback Results



Line Graph

FFI Flowback Results



FFI Flowback Results

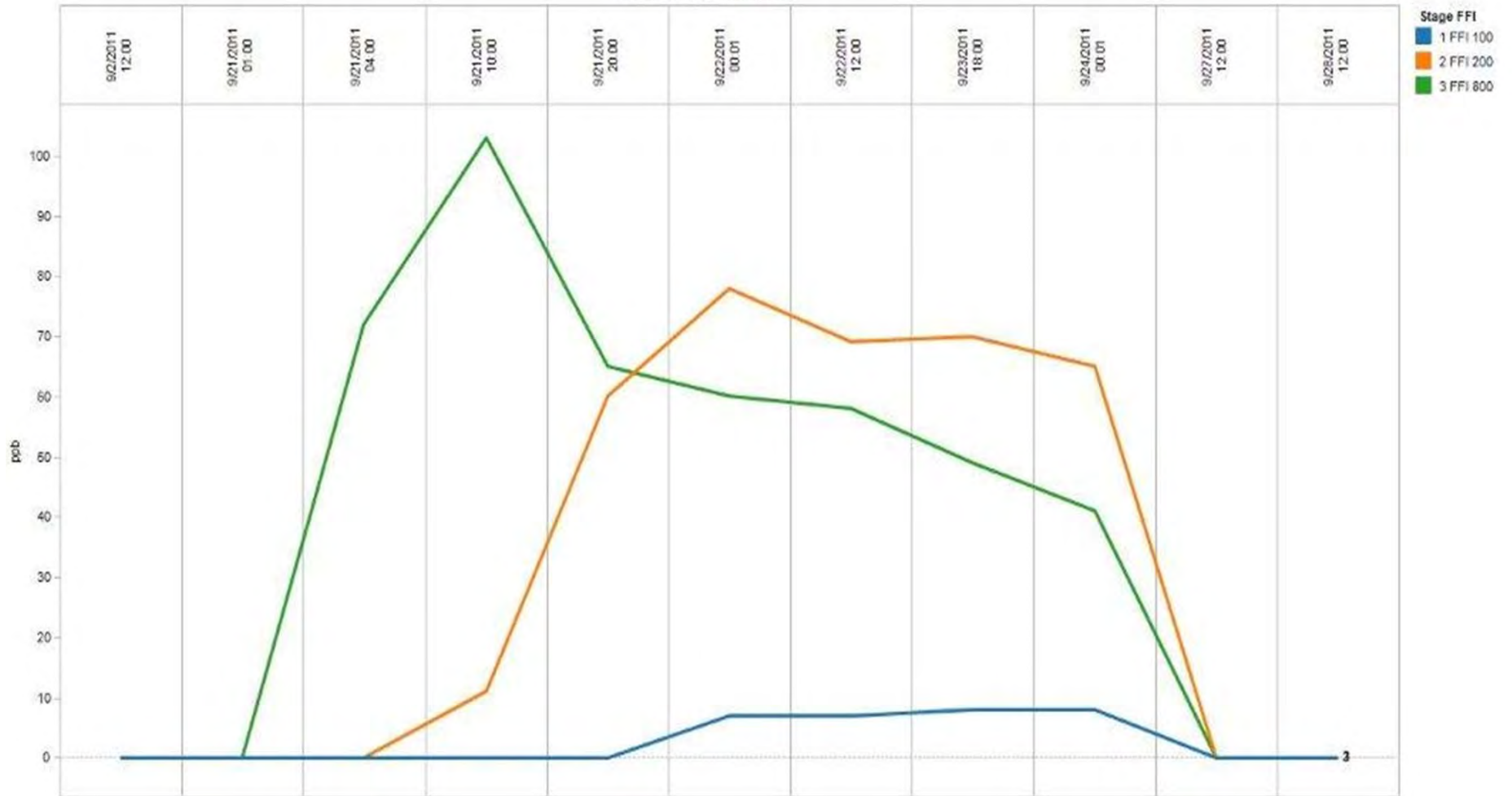
		9/21/11		9/22/11			9/23/11		9/24/11		9/27/11		9/28/11
		12:00	01:00	04:00	10:00	20:00	00:01	12:00	18:00	00:01	12:00	12:00	
Stage	FFI	20	1	2	4	7	10	12	15	17	22	23	
1	FFI 100	Not Present	Not Present	Not Present	Not Present	Not Present	Present	Present	Present	Present	Not Present	Not Present	
2	FFI 200	Not Present	Not Present	Not Present	Present	Present	Present	Present	Present	Present	Not Present	Not Present	
3	FFI 800	Not Present	Not Present	Present	Present	Present	Present	Present	Present	Present	Not Present	Not Present	

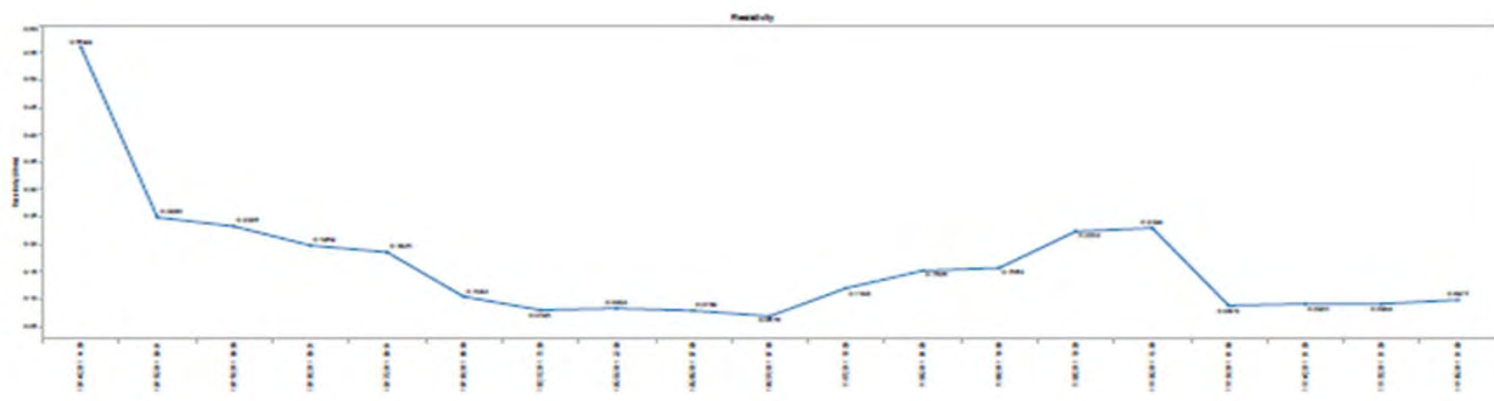
Results

Not Present

Present

FFI Flowback Results







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1/3/2012

Offset Well Communication Overview

8 Well Communication Project

