

From Pilot Study to Daily Processing Warren, Ohio's Documentary to **Hydraulic Fracturing Water Treatment**

By Tom Angelo
Director
City of Warren, Ohio
Water Pollution Control Department

Brine Water Treatment

In May of 2009, Warren and Patriot Water Treatment LLC began discussions with the OEPA to initiate the treatment of brine water from the Marcellus Shale.

Warren was asked to perform an eight (8) week **pilot study** to “clearly identify the amount of brine that Warren can receive without causing WWTP or water quality issues.”



Charged with this task, Warren first had a whole effluent toxicity (WET) test accomplished on September 4, 2009 to determine the ceiling of brine water acceptance.



This demonstrated that the facility could accept up to 664,000 gallons of brine water at 50,000 mg/l TDS before toxic conditions occurred.

Brine Water Treatment

An organizational meeting was held January 8, 2010 to set guidelines for the pilot study. The guidelines were set as follows:

1. Patriot Water Systems would supply ten 20,000 gallon frac tanks.
2. The tanks would be connected together to create one 100,000 gallon mixing system.
3. Brine water would be re-circulated in the combined tanks to create a homogeneous mix.
4. The initial mix will be tested for the parameters as defined by OEPA.
5. The City will sample influent, effluent, upstream and downstream prior to the discharge of brine water to develop a baseline concentration of TDS.
6. The City would conduct a live, 8 week, phased in trial to monitor and record effects on treatment processes, accumulation loading and receiving stream TDS.
7. The maximum amount of TDS in the brine water will not exceed 50,000 mg/l.



Brine Water Treatment

An organizational meeting was held January 8, 2010 to set guidelines for the pilot study. The guidelines were set as follows:

8. Brine water will be phased in as follows (all flows will be over an 8 hour period):
 - Week 1 – 5 days at 20,000 gallons
 - Week 2 – 5 days at 40,000 gallons
 - Week 3 – 5 days at 60,000 gallons
 - Week 4 – 5 days at 80,000 gallons
 - Week 5 – 5 days at 100,000 gallons
 - Week 6 – 5 days at 100,000 gallons
 - Week 7 – 5 days at 100,000 gallons
 - Week 8 – 5 days at 100,000 gallons
9. Testing will be accomplished as defined in Addenda 3

Testing Schedule

Acute & Chronic Toxicity

Base Neutral Organic Compounds

Pesticides & Total Phenols

Aluminum

Silver

Beryllium

Cadmium

Copper

Nickel

Selenium

Zinc

Low Level Mercury

HEM Oil & Grease

Total Suspended Solids

BOD5

TOC

Ammonia Nitrogen

Total Uranium

Total Alpha

Barium

Volatile Organic Compounds

Acid Organic Compounds

MBAS

Antimony

Barium

Boron

Chromium

Iron

Lead

Strontium

Hexavalent Chromium

pH

Total Dissolved Solids

Total Phosphorus

COD

Total Nitrogen

Nitrate/Nitrite Nitrogen

Total Thorium

Total Beta

Strontium

Brine Water Treatment

BASELINE SAMPLING

Initial baseline testing was accomplished on the river and plant flow to determine TDS levels prior to start-up of the pilot study. The baseline levels are as follows:

Baseline Level	TDS	Chloride
Raw	584	143
Final	599	157
Up	336	70
Down	332	60
Liquid Sludge		296

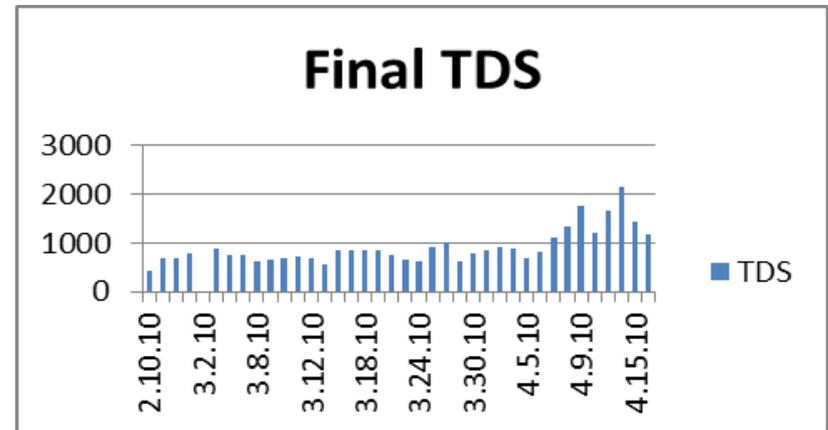
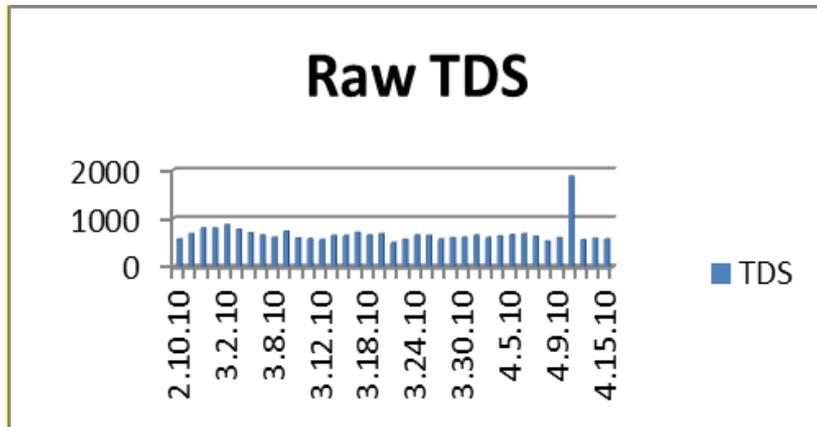
Initial radioactivity sampling:

Collect date 2/17/10

Parameter	Results	Units
Gamma Scan	All other nuclides <LLD	pCi/L
K-40	2.6E+02 +/- 2.6E+01	pCi/L

Brine Water Treatment

TDS is greatest pollutant of concern. Of that, Chlorides or salt, is the largest proponent.



Raw TDS average increased to 679 mg/l which is approximately 16% over the baseline of 584 mg/l. The average final effluent TDS increased by 47.8% above the baseline.

Brine Water Treatment

TDS OVERVIEW

Daily Chloride Loading to the River

This information provides a better model of loading in terms of pounds of chlorides to the river.

BASELINE DAILY CHLORIDE LOADINGS

	Upstream	Downstream	Plant
	Avg	Avg	Avg
	Daily	Daily	Daily
	Load	Load	Load
	lbs/day	lbs/day	lbs/day
Avg River Flow MGD	506,314.39	484,615.20	20,439.42

Brine Water Treatment

TDS OVERVIEW

STUDY RESULTS - DAILY CHLORIDE LOADINGS

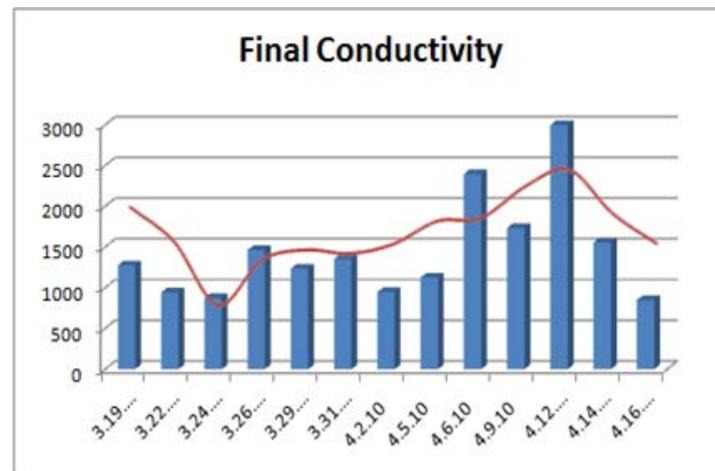
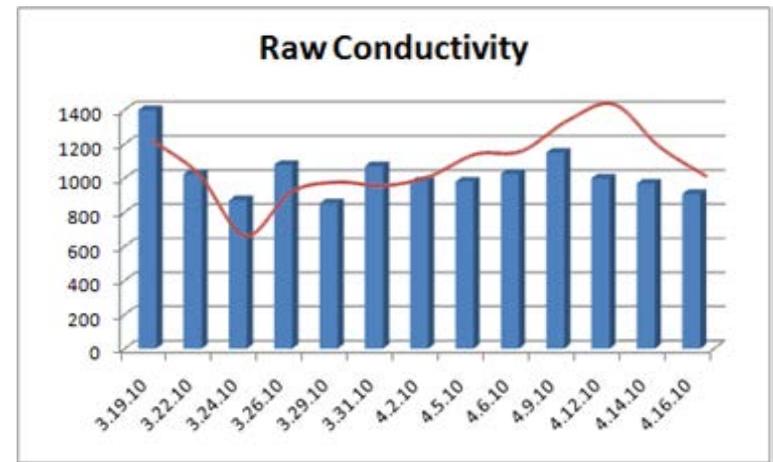
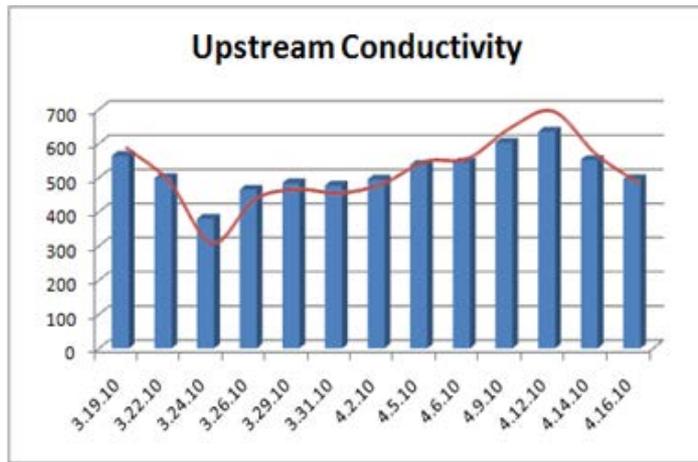
	Upstream		Downstream		Avg Plant Flow MGD	Plant Effluent	
	Avg Daily Load lbs/day	Peak Daily Load lbs/day	Avg Daily Load lbs/day	Peak Daily Load lbs/day		Avg Daily Load lbs/day	Peak Daily Load lbs/day
Avg River Flow MGD	867.27	1,612,972.97	873,134.10	1,446,612.53	15.61	46,867.46	118,995.12
% Over Baseline	168.37	318.57	180.17	298.51		229.30	582.18
Lbs. Over Baseline	346,174.38	1,106,658.59	388,518.90	961,997.33		26,428.04	98,555.70

This information demonstrates that the river was able to assimilate a peak daily load of chloride 318% greater than the baseline loading without any toxicology issues. In total pounds applied this means that an additional 1,106,658 pounds of chlorides over baseline was assimilated without adverse affects to the river biology. Warren's highest peak daily loading of chloride was only 118,995 pounds.

Brine Water Treatment

EPA Questions

What caused the high effluent results on 4/13, 4/14, and 4/15?



Brine Water Treatment

Toxicology

Date	Ceriodaphnia dubia		Pimephales promelas	
	TUa	TUc	TUa	TUc
February 20, 2010	AA	AA	-	-
March 6, 2010	AA	AA	-	-
March 13, 2010	AA	AA	-	-
March 20, 2010	AA	AA	-	-
March 27, 2010	AA	AA	-	-
April 3, 2010	AA	1.8	-	-
April 10, 2010	AA	AA	-	-
April 17, 2010	AA	AA	AA	AA

AA = below detectable limit

Overall the results of the study indicated that if Patriot Water Treatment discharges a consistent amount of brine water over an extended period of time then there will be no adverse changes in the water quality of Warren WWTP or in the Mahoning River downstream of outfall 001.

Brine Water Treatment

*Pilot Study
Conclusion*

The 8 week Pilot Study demonstrated that a controlled discharge of brine water into Warren's WWTP did not have adverse water quality impacts to the treatment facility or receiving stream.

IT WORKED

Brine Water Treatment

Concerns

- Allow high levels of heavy metals to enter the receiving stream.
- Potential for radiation.
- Contaminate source drinking water and ground water.
- Increase TDS Levels in the receiving stream, specifically Chlorides or salt.

Brine Water Treatment

Daily Processing

Ohio's whole model for the treatment of low TDS flow back brine wastewater was based on the observance of issues that was witnessed during 2009 through 2010 by treatment plants that was processing brine wastewater in Pennsylvania.

Pennsylvania	Ohio
Direct discharge to the municipal wastewater treatment facility	Direct discharge to a municipal wastewater treatment plant will not be allowed
No limit set on volume of brine water being discharged	A limit will be set on the total volume of brine water that can be treated daily
No limit set on total suspended solids (TDS) in the brine water	A limit of no greater than 50,000 mg/l of TDS in the flow will be allowed
No testing of the brine water	All brine water will be regularly tested
No toxicity testing on combined flow discharge	Quarterly toxicity testing will be accomplished
No baseline testing initiated	Baseline levels will be established

Brine Water Treatment

Daily Processing

- Only Flow Back, muddy and brackish brine water will be allowed for treatment. No Produced water will be allowed.
- Direct discharge to a municipal wastewater treatment plant will not be allowed. Brine water must go to a centralized waste treatment facility (CWF) for pretreatment prior to discharging to a municipal wastewater treatment facility (POTW). The CWF will remove heavy metals, suspended solids and other pollutants to categorical and local limits and adjust pH prior to discharge.
- A limit will be set on the total volume of brine water that can be treated daily. This limit will be established based on the ability of the treatment facility to assimilate without toxic conditions or water quality conditions occurring.
- A limit of no greater than 50,000 mg/l of TDS in the flow will be allowed to be discharged from the CWF into the POTW.
- All brine water will be regularly tested for heavy metals, radiation and volatile compounds and will be summarized in a daily operational report.
- Quarterly toxicity testing will be accomplished by the POTW.

Brine Water Treatment

Daily Processing

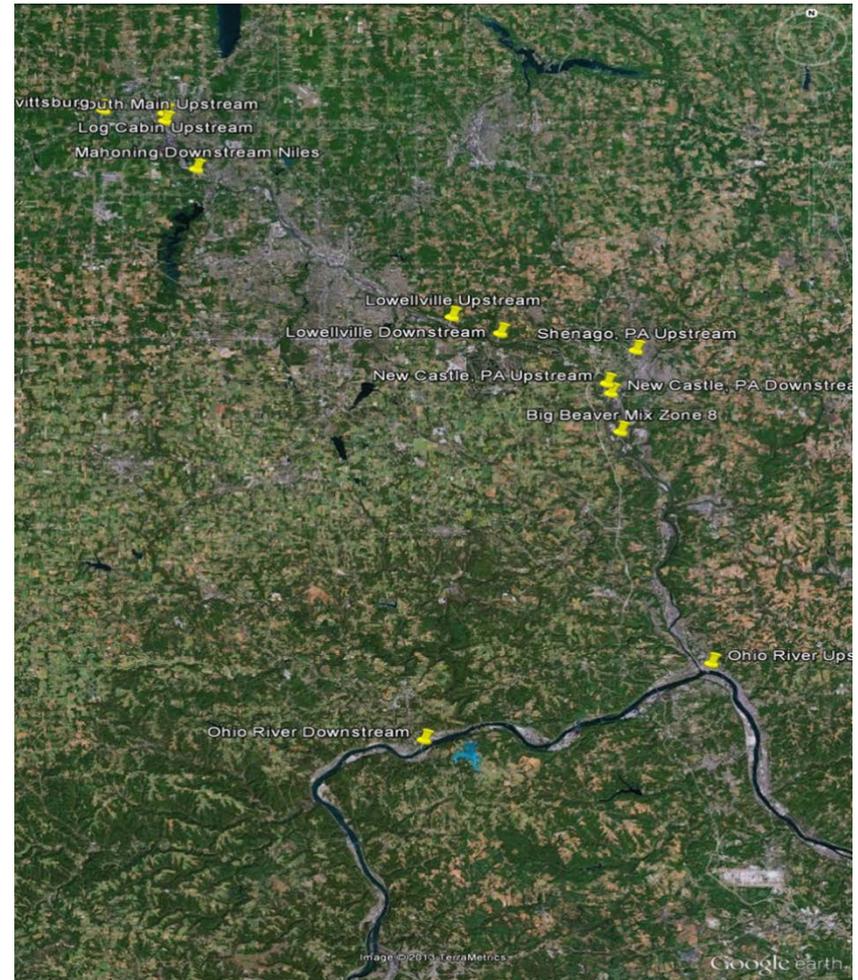
- October of 2010, OEPA issued a PTI to Patriot Water Treatment
- December 1, 2010, OEPA issued a NPDES modification to Warren that would allow for the acceptance and treatment of low TDS flow back brine wastewater from a CWF.
- Total acceptance of 100,000 gallons of flow back brine per day at a maximum concentration of 50,000 mg/l TDS.

Brine Water Treatment

Daily Processing

Increase TDS levels in receiving stream

- The overall success of this program depended on how TDS would impact river quality.
- Warren initiated a self-imposed river sampling program that monitored TDS levels throughout the watershed.
- A total of 8 locations were finally part of the sampling regiment.
- Analyze for both Chlorides and Sulfides.
- Analyze for Bromide.



Brine Water Treatment

Daily Processing

State Showdown

- December 2010, Warren filed an appeal with the Environmental Review Appeals Commission (ERAC).
- May of 2011, OEPA issued a letter to the Ohio Department of Natural Resources (ODNR) indicating that the permits issued to Warren and Patriot were in violation of ORC 1509.22 and would not renew the modification when Warren's current permit expired on December 31, 2011.
- Legal Battle throughout 2011 & half of 2012.
- OEPA issues a new NPDES to Warren April 1, 2012.
 - Section BB; permittee shall stop accepting brine wastewater from oil or gas drilling, exploration or production

Brine Water Treatment

Daily Processing

State Showdown

- Warren ordered Patriot to cease discharging brine water to its Municipal Wastewater Plant effectively shutting down Patriot.
- ERAC hears Warren/Patriot's appeal (april/may 2012)
- July 3, 2012 ERAC determined that Section II, BB of the 2012 Warren NPDES was both unlawful and unreasonable.
- ERAC unilaterally modified Warren's NPDES to remove Section II, BB in its entirety.
- Patriot restarts operations in July of 2012 and Warren has continued to receive daily discharges since.

Brine Water Treatment

Daily Processing

USEPA Compliance Inspection

- September 2011, USEPA Region 5 conducted a compliance inspection to determine that the Warren WPCCC was only accepting brine waste water generated from the oil and gas industry from one CWT facility (Patriot), and that the POTW had not experienced any of the following conditions since accepting the brine waste water:
 1. Diminished or inhibited performance of the biological treatment processes,
 2. Adverse impacts to the downstream water quality,
 3. Adverse impacts to the quality of the facility's biosolids.

Brine Water Treatment

Daily Processing

USEPA Compliance Inspection

- Both Warren and Patriot were inspected and numerous tests were conducted. Overall, approximately 950 pages of documents were generated from the report. A summary of the key constituents of concern is shown below:

City of Warren, Ohio Patriot Water Treatment & Water Pollution Control USEPA Duplicate Data samples collected September 12-15, 2011 by Cher Salley & Mark Moloney of USEPA								
Conventionals		TSS	TDS	BOD	Bromide	Chloride	Fluoride	Sulfate
sample	date	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PWTS02 Influent	9/12/2011	360	51,600	544	263	29,400	0.58	43
PWTS14 Influent	9/13/2011	236	30,800	284	87	16,300	0.57	180
PWTS18 Influent	9/14/2011	150	31,400	436	96	15,900	0.46	133
PWTS01 Effluent	9/12/2011	518	36,800	496	153	19,500	0.45	128
PWTS10 Effluent	9/13/2011	664	33,500	404	138	16,900	0.4	103
PWTS17 Effluent	9/14/2011	976	35,000	404	107	17,200	0.35	190
WPCSO4 Influent	9/12 - 13/2011	112	748	39	5.32	365	3.36	256
WPCS13 Influent	9/13 -14/2011	106	744	33.3	5.43	374	4.13	251
WPCS22 Influent	9/14 - 15/2011	67	686	27.7	5.01	345	3.37	243
WPCS03 Effluent	9/12 - 13/2011	<4.00	648	<2.00	1.4	191	1.4	79.8
WPCS12 Effluent	9/13 -14/2011	<4.00	778	<2.00	1.89	252	1.95	83.7
WPCS20 Effluent	9/14 - 15/2011	<4.00	752	<2.00	1.41	195	2.14	67.8

Brine Water Treatment

Daily Processing

USEPA Compliance Inspection

- In addition to a complete metals analysis, radiological screening was accomplished.
- The report concluded that Warren's POTW was in compliance with the NPDES permit limitations.

City of Warren, Ohio Patriot Water Treatment & Water Pollution Control USEPA Duplicate Data samples collected September 12-15, 2011 by Cher Salley & Mark Moloney of USEPA								
Conventionals		TSS	TDS	BOD	Bromide	Chloride	Fluoride	Sulfate
sample	date	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PWTS02 Influent	9/12/2011	360	51,600	544	263	29,400	0.58	43
PWTS14 Influent	9/13/2011	236	30,800	284	87	16,300	0.57	180
PWTS18 Influent	9/14/2011	150	31,400	436	96	15,900	0.46	133
PWTS01 Effluent	9/12/2011	518	36,800	496	153	19,500	0.45	128
PWTS10 Effluent	9/13/2011	664	33,500	404	138	16,900	0.4	103
PWTS17 Effluent	9/14/2011	976	35,000	404	107	17,200	0.35	190
WPCSO4 Influent	9/12 - 13/2011	112	748	39	5.32	365	3.36	256
WPCS13 Influent	9/13 -14/2011	106	744	33.3	5.43	374	4.13	251
WPCS22 Influent	9/14 - 15/2011	67	686	27.7	5.01	345	3.37	243
WPCS03 Effluent	9/12 - 13/2011	<4.00	648	<2.00	1.4	191	1.4	79.8
WPCS12 Effluent	9/13 -14/2011	<4.00	778	<2.00	1.89	252	1.95	83.7
WPCS20 Effluent	9/14 - 15/2011	<4.00	752	<2.00	1.41	195	2.14	67.8

Brine Water Treatment

Summary

The waste treatment model used in Warren has almost 2 ½ years of operational data that demonstrates that it is a safe and viable alternative disposal that compliments other disposal options including deep well injection. The model requires both a CWT and a POTW. It requires extensive testing by both entities which are mandated and voluntary. It only allows for a small percentage of hydraulic fracturing wastewater to be accepted. The water that this model accepts; low TDS, pit, flowback, muddy and storm waters are also the waters that are most problematic for deep well injection.

Brine Water Treatment

Benefits

The waste treatment model used in Warren has almost 2 ½ years of operational data that demonstrates that it is a safe and viable alternative disposal that compliments other disposal options including deep well injection. The model requires both a CWT and a POTW. It requires extensive testing by both entities which are mandated at a county level. It only allows for a small percentage of hydraulic fracturing wastewater to be accepted. The water that this model accepts; low TDS, pit, flowback, muddy and storm waters are also the waters that are most problematic for deep well injection.

QUESTIONS?