UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8

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| In the matter of : | ) | |
| Murphy Exploration & Production Co., | ) | **Emergency Administrative Order** |
| Pioneer Natural Resources USA, Inc., and | ) | |
| Samson Hydrocarbons Co. | ) | Docket No. SDWA-08-2011-_____ |
| Respondents. | ) | |
| East Poplar Oil Field | ) | |
| Fort Peck Indian Reservation | ) | |
| Montana | ) | |
| Proceedings under Section 1431(a) of the Safe Drinking Water Act, 42 U.S.C. §300i(a) | ) | |

## STATUTORY AUTHORITY

1. The following findings are made and order issued under the authority vested in the Administrator of the U.S. Environmental Protection Agency (EPA) by Section 1431(a) of the Safe Drinking Water Act (the Act), 42 U.S.C. §300i(a). The authority to take this action has been properly delegated to the undersigned EPA officials.
2. Violation of any term of this order may subject Respondents to a civil penalty of up to $16,500 for each day in which such violation occurs or failure to comply continues, pursuant to §1431(b) of the Act, 42 U.S.C. §300i(b). In addition, actions or omissions which violate any requirements of the SDWA or its implementing regulations may subject Respondents to a civil penalty of not more

than $32,500 per day per violation pursuant to §1423 of the Act, 42 U.S.C. §300h-2.

3. Within 72 hours after receiving this order, each Respondent shall notify EPA in writing whether it intends to comply with this order. Such notification shall be made to Nathan Wiser at the address identified in paragraph 100 of this order and to Mr. Wiser's email address: wiser.nathan@epa.gov.

**LOCATION**

4. This matter relates to lands within the exterior boundary of the Fort Peck Indian Reservation in Roosevelt County, Montana, and addresses groundwater contamination in and around the East Poplar oilfield, which field is approximately five miles northeast of the City of Poplar, Montana.

**DESCRIPTION OF RESPONDENTS**

5. Murphy Exploration & Production Company (Murphy) is a Delaware corporation doing business in the State of Montana and therefore is a "person" within the meaning of 40 C.F.R. §141.2 and §144.2 and Section 1401(12) of the Act, 42 U.S.C. §300f(12).

6. Pioneer Natural Resources USA, Inc. (Pioneer) is a Delaware corporation and therefore is a "person" within the meaning of 40 C.F.R. §141.2 and §144.2 and Section 1401(12) of the Act, 42 U.S.C. §300f(12). Pioneer acquired the assets of Mesa Petroleum Co. Mesa Petroleum Co. did business in the State of Montana.

7. Samson Investment Company is a Nevada corporation and therefore a "person" within the meaning of 40 C.F.R. §141.2 and §144.2 and Section 1401(12) of the Act, 42 U.S.C. §300f(12). Samson Hydrocarbons Company (Samson), a

subsidiary of Samson Investment Company, is a Delaware corporation and therefore is a "person" within the meaning of 40 CFR §141.2 and §144.2 and Section 1401(12) of the Safe Drinking Water Act, 42 U.S.C. §300f(12). By 1961, C.C. Thomas, an original oil operator on the East Poplar Oil Field, transferred the lease to produce oil from the "Huber" property to Emile A. Polumbus. Emile A. Polumbus later formed the Polumbus Petroleum Corporation ("Polumbus"). Polumbus did business in the State of Montana. Polumbus later merged with W.R. Grace & Co. (a Connecticut corporation) to become Grace Petroleum Corporation in 1976. Grace Petroleum Corporation did business in the state of Montana. On or about January 21, 1993, Samson Investment Company acquired all issued and outstanding stock of Grace Petroleum Corporation and became that company's successor in interest. On or about that same day, Samson Investment Company changed the name of Grace Petroleum Corporation to Samson Natural Gas Company. Samson Natural Gas Company changed its name to SNG Production Company on or about April 19, 1993. On or about December 28, 1994, SNG Production Company changed its name to Samson.

8. Respondents did own and/or operate oil and gas production facilities, including but not limited to oil or gas production wells, produced brine disposal wells, secondary recovery injection wells, drilled and abandoned dry holes, production and waste pits, storage tanks, oil/water separators, and distribution pipelines and pumping facilities, in the East Poplar Oil Field located within the following locations: Township 28 North, Range 51 East; Township 29 North, Range 50 East; Township 29 North, Range 51 East, on the Fort Peck Indian Reservation in

Roosevelt County in the State of Montana.

**USGS STUDY BACKGROUND**

9. This area in and around the East Poplar oil field has been studied by the United States Geological Survey (USGS), and its findings have been documented in peer-reviewed studies published by the USGS.[1] Groundwater in the area has been determined by the USGS to be contaminated with produced brine. In its 1997 publication, the USGS mapped approximately 12.4 square miles of groundwater contamination within its 21.6 square mile study area. Since then, recognizing the need to extend the study area, the USGS has been mapping this groundwater contamination over an area greater than 100 square miles. The final report of this larger area study is not yet available, but some provisional aspects of the report have been made available.

10. The USGS in 2009 and 2010 analyzed strontium isotopes and trace elements at its laboratory.

11. Generally, provisional information is considered by the USGS to be subject to revision because the data or data interpretation has not been subjected to the USGS's normal and customary peer-review process. The USGS does not consider the 2009 or 2010 strontium isotope and trace element laboratory data to be provisional, but it has not yet published its conclusions regarding the interpretation of the data.

12. Of the approximately 150 groundwater monitoring well sites located among 38

[1] Thamke, J., and Craigg, S., 1997, Saline-Water Contamination in Quaternary Deposits and the Poplar River, East Poplar Oil Field, Northeastern Montana, U.S.G.S. Water-Resources Investigation Report 97-4000.
Thamke, J.N., and Midtlyng, K.S., 2003, Ground-Water Quality for Two Areas in the Fort Peck Indian Reservation, Northeastern Montana, 1993-2000, U.S.G.S. Water-Resources Investigation Report 03-4214.

square-mile sections in the area, the USGS provisionally considers 44 of them to be considerably contaminated (total dissolved solids above 9,640 mg/l and chloride above 5,200 mg/l) and an additional 45 of them to be moderately contaminated (total dissolved solids above 1,170 mg/l and chloride above 330 mg/l).

13. This order is issued with EPA's understanding that the USGS plans to publish two additional reports: one on its area-wide groundwater contamination mapping effort covering more than 100 square miles, and one with its conclusions from its 2009 and 2010 strontium isotope and trace element analysis

14. Because EPA concludes the data shows an imminent and substantial endangerment to the City of Poplar's public water supply and to area residents drawing water from the aquifer it is issuing this order without waiting for the USGS to complete its publication process. If the published USGS reports lead to different conclusions, EPA will consider them at that time.

15. EPA also issues this order at this time to allow Respondents more time to plan how to comply with the drinking water treatment and/or alternative water supply requirements of paragraphs 79 through 83, which may be more cost effective for said Respondents compared to issuing an order later requiring drinking water treatment and/or alternative water to be immediately supplied.

**EPA ADMINSTRATIVE ORDER BACKGROUND**

16. EPA has issued four previous Emergency Administrative Orders under §1431 of the Act for matters in and around the East Poplar oilfield, as described below.

17. On September 30, 1999, EPA issued an order to several Respondents, including

Respondents Murphy and Pioneer. This order was amended on November 5, 1999, and November 30, 1999. As amended, the order required the provision of bottled drinking water to area residences and the production of records. This order bears docket number SDWA-8-99-68 (the current numbering convention for this docket would be SDWA-08-1999-0068) and was appealed to the U.S. Tenth Circuit Court of Appeals.

18. On August 16, 2001, EPA issued an order to Respondent Pioneer. This order required Pioneer to properly plug and abandon a leaking oil well for which it had acquired liability, known as the Biere #1-22 well, which was known to be a source of on-going groundwater contamination. The order also required Pioneer to monitor near the Biere #1-22 well to determine whether the plugging and abandonment was successful. This order bears docket number SDWA-08-2001-0027 and was not appealed.

19. On September 20, 2001, EPA issued an order to several Respondents including Murphy, Pioneer and Samson. This order was amended on October 3, 2001. This order cited documentation of spills and past practices in the East Poplar oil field, particularly the management of produced brine, which caused groundwater contamination. As amended, this order required Respondents to provide an alternate, whole-house supply of water to area residences and to monitor near the City of Poplar to detect the leading edge of the groundwater plume to determine the risk to the City of Poplar Montana's public drinking water supply wells. This order bears docket number SDWA-08-2001-0033 and was appealed to the U.S. Tenth Circuit Court of Appeals.

20. On July 20, 2004, EPA issued a consensual order bearing docket number SDWA-08-2004-0035, still in effect, to Respondents Murphy, Pioneer and Samson. This consensual order terminated those orders on appeal to the Tenth Circuit Court of Appeals and required those Respondents to (a) construct a drinking water pipeline to several residences in the area, (b) monitor certain private water wells, (c) hold and participate in a public meeting, (d) continue to provide bottled drinking water to identified homesites until the newly-required drinking water pipeline delivers drinking water to those homesites, (e) report monitoring information to EPA as it is collected, and (f) submit documents to EPA. The consensual order also requires Respondents to monitor 11 groundwater monitoring wells for the purpose of detecting contaminated groundwater getting close to the City of Poplar's public water supply wells. This groundwater monitoring program is referred to as the "Poplar Well Threat Study."
21. EPA's previous emergency orders expressed EPA's concern that this contaminated groundwater may move in the direction of the City of Poplar's drinking water wells.
22. Respondents have been conducting the required sampling at the 11 groundwater monitoring wells in the Poplar Well Threat Study. The annual reports of Poplar Well Threat Study have identified that contamination in the groundwater is moving in the general direction of the City of Poplar, but the conclusions reached in each Poplar Well Threat Study report do not indicate that the City is affected.
23. There is now mixing of contamination into the City of Poplar's public water supply wells, which suggest the Poplar Well Threat Study failed to fulfill its

objective of intercepting groundwater contamination before it reached the City's wells. EPA suggests this failure is caused by an inadequate monitoring well network and the type of monitoring being conducted to detect contamination. EPA also suggests that the groundwater movement between the contaminated groundwater plumes and the City of Poplar's public water supply wells is complex.

24. The Poplar Well Threat Study monitoring program did not use strontium isotopes, a method EPA now understands to be more sensitive for detecting this type of groundwater contamination.

**FINDINGS OF FACT**

25. There exists groundwater contamination in the area alluvium and glacial till from historic management of produced brine in and around the East Poplar oilfield. EPA's previous emergency administrative orders describe how this contamination occurred. In summary, the groundwater contamination resulted from Respondents managing produced brine in unlined pits, Respondents' various spills of produced brine and crude oil, and produced brine and crude oil leaking at Respondent Pioneer's improperly plugged oil well.

26. The glacial till and river valley alluvium constitute the only available source of drinking water in the general area, and the three public water supply wells that service the City of Poplar's approximately 2,900 residents as well as area residents using private water wells derive their water from the same groundwater that is contaminated further up-gradient.

27. The peer-reviewed studies by the USGS described in paragraph 9 include its

findings of groundwater contamination from oil field activities.

28. There exists a 15 square mile area generally following the Poplar River which is located such that there are confirmed contaminated groundwater plumes present or up-gradient, while the City's wells are down-gradient, placing this area generally between the sources of contamination and the City's wells. This area is not presently fully characterized with regard to the presence of groundwater contamination. There are residents living in this same 15 square mile area drawing water from the same alluvium and glacial till aquifer via their private water wells. The 15 square mile area is described as follows, starting from north to south:

In Township 29 North, Range 51 East:
Section 31
Section 32
In Township 28 North, Range 51 East:
Section 4 (W/2 and NE/4)
Section 5 (E/2 and SW/4)
Section 8
Section 9 (W/2)
Section 17
Section 18 (E/2)
Section 19
Section 20 (W/2)
Section 29
Section 30
Section 31
Section 32
In Township 28 North, Range 50 East:
Section 25 (SE/4)
Section 36 (E/2)
In Township 27 North, Range 50 East:
Section 1 (S/2 and NE/4)
In Township 27 North, Range 51 East:
Section 6.

29. Groundwater in the East Poplar oilfield area was shown in 1999 and 2000 at

several locations to have benzene contamination. Replicate water well samples collected by the Fort Peck Office of Environmental Protection (OEP) at one home site during this time span had respective benzene concentrations of 0.058 and 0.078 mg/l (58 and 78 micrograms/liter), while samples taken by the USGS at five other locations in the field had benzene concentrations between 0.0016 and 0.0051 mg/l (1.6 to 5.1 micrograms/liter).

30. Groundwater in the East Poplar oilfield area was shown in 1999 and 2000 to have 1,4-dichlorobenzene contamination. Samples collected by the OEP and the consulting firm MSE-HKM, Inc. during this time at eight different locations in the field had 1,4-dichlorobenzene concentrations between 0.00056 and 0.00083 mg/l (0.56 to 0.83 micrograms/liter).
31. Groundwater in the East Poplar oilfield area was shown in 1999 and 2000 to have toluene contamination. Samples collected by the OEP and the consulting firm MSE-HKM, Inc. during this time at five locations in the field had toluene concentrations between 0.00008 and 0.0028 mg/l (0.08 to 2.8 micrograms/liter).
32. Groundwater in the East Poplar oilfield area was shown between 1982 and 2000 to have elevated total dissolved solids concentration. Samples collected by the USGS, OEP, and the consulting firm MSE-HKM, Inc. during this time at 65 locations in the field had total dissolved solids concentrations above the secondary maximum contaminant level (MCL)[2] (500 mg/l) including 22 above 10,000 mg/l and the highest at 67,000 mg/l.
33. Groundwater in the East Poplar oilfield area was shown between 1982 and 2000 to have elevated chloride concentration. Samples collected by the USGS, OEP,

[2] See Title 40 of the Code of Federal Regulations Part 143

and the consulting firm MSE-HKM, Inc. during this time at 41 locations in the field had chloride concentrations above the secondary MCL (250 mg/l) including 23 above 5,000 mg/l and the highest at 67,000 mg/l.

34. Groundwater in the East Poplar oilfield area was shown between 1982 and 2000 to have elevated sodium concentration. Samples collected by the USGS, OEP, and the consulting firm MSE-HKM, Inc. during this time at 56 locations in the field had sodium concentrations above 250 mg/l including 14 above 5,000 mg/l and the highest at 43,000 mg/l.

35. Groundwater in the East Poplar oilfield area was shown between 1982 and 2000 to have elevated sulfate concentration. Samples collected by the USGS, OEP, and the consulting firm MSE-HKM, Inc. during this time at 52 locations in the field had sulfate concentrations above the secondary MCL (250 mg/l) including 12 above 1,000 mg/l and the highest at 1,910 mg/l. Samples collected by the consulting firm PBS&J as recently as 2008 show sulfate concentration as high as 2,150 mg/l.

36. Manganese is found in the groundwater throughout the East Poplar oilfield area. Its concentration in the sampled produced brine is between 0.062 and 0.130 mg/l. Manganese in drinking water above 0.30 mg/l has adverse human health affects as described in paragraph 53. When the brine is in the presence of aquifer materials, such as shown in samples collected at monitoring wells showing high concentrations of dissolved solids, manganese values increase significantly. In 2010, the USGS collected a sample showing a manganese concentration of 5.12 mg/l at monitoring well USGS 09-06, located within a groundwater

contamination plume. In 1982, the USGS collected a sample showing manganese concentration of 14 mg/l at monitoring well W-16 (since renamed monitoring well USGS 92-11), also within a groundwater contamination plume. Manganese in the groundwater at concentrations above 0.30 mg/l has been found at 33 different locations in the field since 1982. This pattern is due to an increase in water-rock interaction occurring in the presence of the high ionic strength brine in which the produced brine contamination creates the secondary effect of dissolving manganese into the groundwater. In samples collected in 2010 and analyzed at the USGS Yucca Mountain Branch Laboratory, manganese concentrations entering the three public water supply wells for the City of Poplar ranged from 0.507 to 0.890 mg/l. Under current conditions, the City of Poplar's drinking water treatment system effectively removes manganese to below an endangering concentration, but it is unknown whether such treatment would remain effective if the manganese concentration entering the City's wells were to rise as high as 14 mg/l, a value observed in contaminated groundwater.

37. There have been three different efforts made to estimate the time lapse before the groundwater contamination plumes in the East Poplar oilfield reach the City of Poplar public supply wells. In March 2002, the Montana Department of Environmental Quality estimated a groundwater travel time of approximately 3 years (arriving in 2005) for a contamination plume to influence the source water for at least one of the Poplar public water supply wells. In March 2003, the consulting firm Land and Water Consulting, Inc., whose name later changed to PBS&J, under the direction of the Respondents Murphy, Samson and Pioneer,

estimated a travel time of 109 years (arriving in 2112) for contamination influence on the Poplar public water supply wells. In September 2008, the consulting firm S.S. Papadopulos & Associates, Inc., under the direction of the OEP, conducted a modeling effort yielding several contaminant travel time estimates based on different assumptions. The two flowpaths assumed included (1) contaminants flowing directly with groundwater movement to the City's wells, and (2) contaminants flowing first into the Poplar River and then re-entering the groundwater and arriving at the City's wells. Using various inputs into the model, these two flowpaths resulted in a range of 3.5 years to more than 200 years in the groundwater-only scenario, and a range of 1.63 years to 49.5 years in the scenario with contaminants moving into the Poplar River and then to the City's wells.

38. Water samples from the City of Poplar's Well #3 (COP-3) were collected by the OEP on March 3, 2009 and May 28, 2009. These sample results showed chloride concentration increased at the COP-3 from 439 mg/l on March 3, 2009 to 782 mg/l on May 28, 2009, an increase of 78%.

39. To determine if the chloride in COP-3 originated from a contaminated groundwater plume, OEP convened a technical workgroup comprised of representatives from OEP, Respondents, EPA, the Montana Department of Environmental Quality and the USGS, and the workgroup agreed to the use of isotopic ratios and trace elements. The results of the trace element and isotopic investigation show that produced brine is found in the City of Poplar's public water supply, which accounts for the increase in chloride, total dissolved solids and manganese concentration in COP-3.

40. Samples collected in May, June and August 2009, and in July 2010, by the OEP and the USGS were analyzed at the USGS Yucca Mountain Project Branch laboratory in Lakewood, Colorado. The samples were collected from all three of the City of Poplar's public water supply wells, as well as 14 groundwater monitoring wells from the glacial till and alluvium, one groundwater supply well from the Judith River Formation, two surface water samples from the Poplar River, and two salt water disposal wells in the East Poplar oilfield, disposing of produced brine. The analyses included tests for trace metals in the samples collected July 2010 and strontium isotopes in all the samples collected in 2009 and 2010. The results of these sample analyses are summarized in Tables 1 and 2.

41. Strontium (Sr) is an alkaline-earth element that behaves, in geochemical and biological cycles observed in nature, in a manner similar to calcium. Sr is composed of four stable (nonradioactive) isotopes--$^{84}Sr$, $^{86}Sr$, $^{87}Sr$, and $^{88}Sr$. For all practical purposes, the relative abundance of $^{84}Sr$, $^{86}Sr$, and $^{88}Sr$ are constant in nature, whereas some of the $^{87}Sr$ is created from the radioactive decay of rubidium-87 ($^{87}Rb$) with a half-life of 48.8 billion years.

42. In the past 20 years, strontium isotope ratios, expressed as $^{87}Sr/^{86}Sr$, have been successfully used as natural tracers[3] to study groundwater mixing. Because natural fractionation of Sr is nonexistent or exceedingly small in the hydrologic environment, $^{87}Sr/^{86}Sr$ values of dissolved Sr are not being affected by temperature, pressure, or changes of water into steam or ice. However,

[3] Shand, P., Darbyshire, D.P.F., Love, A.J., and Edmunds, W.M., 2009, Sr isotopes in natural waters: Applications to source characterization and water-rock interactions in contrasting landscapes: Applied Geochemistry, v. 24, p. 574-586.
Banner, Jay L., 2004, Radiogenic isotopes: systematic and applications to earth surface processes and chemical stratigraphy: Earth-Science Reviews, v. 65, p. 141-194.

groundwater $^{87}Sr/^{86}Sr$ values and Sr concentrations can be changed by mixing with other groundwater. The use of Sr isotopes in conjunction with dissolved major and minor ions and trace metals is a way to understand and quantify the effects of mixing where there are different groundwaters having chemically and isotopically distinct signatures, referred to as groundwater "end members."

43. In the East Poplar oilfield, oil is produced mainly from the Charles Formation of the Mississippian-aged Madison Group. The Mississippian geologic time period was between 318 and 359 million years ago. From oldest to youngest, the Madison Group is composed of the Lodgepole Formation, the Mission Canyon Formation, and the Charles Formation. The Mission Canyon and Charles Formations are thick limestone and dolomite rock formations. These rocks were formed at the bottom of an ancient ocean. There have been different ocean Sr isotope ratios dating back into geologic time.[4] Using a well-understood curve of the ocean Sr isotope ratio values through geologic time, the ocean water incorporated during the deposition and burial of the sediments that later became the Madison group, would likely have had Sr isotope ratios between 0.7080 and 0.7083.

44. Five samples were collected in 2009 at locations later repeated in 2010 and were analyzed for Sr concentrations and $^{87}Sr/^{86}Sr$ only: COP-1, COP-3, M-71, Huber 5D, and USGS06-11. Twenty-three samples collected in July 2010 from East Poplar oilfield included samples from 14 monitor wells, brine from two disposal wells and one water make-up well, two from the Poplar River, and four samples

[4] McArthur, J.M., Howarth, R.J., Bailey, T.R., 2001, "Strontium Isotope Stratigraphy: LOWESS Version 3: Best Fit to the Marine Sr-Isotope Curve for 0-509 Ma and Accompanying Look-up Table for Deriving Numerical Age", in Journal of Geology, vol. 109, p. 155-170.

from the COP public water supply wells. These samples were analyzed by the USGS for total dissolved solids, major and minor dissolved ions, trace metals, and Sr isotopes. The results of the 2010 analyses are shown in Table 1. Figure 1 is a map compiled by the USGS showing the sample locations. The map also shows other monitor well locations in the area. The colors on the map differentiate among highly contaminated groundwater (red), moderately contaminated groundwater (yellow), and uncontaminated groundwater (blue).

45. Figure 2 is a representation of the total dissolved solids and strontium values from the 2010 data, plotted at each sample location. The y-axis is logarithmic because of the large differences in measured values. There is a high correlation between these total dissolved solids and strontium (the correlation coefficient for the results is 0.9825). As a result, for plotting purposes, strontium can be used as a surrogate for total dissolved solids.

46. Figure 3 is a representation of 2010 data, plotting the reciprocal of the strontium concentration on the x-axis (in L/mg) against $^{87}Sr/^{86}Sr$ values on the y-axis. This type of plot demonstrates a linear mixing relationship between end members.[5] In Figure 3, high levels of groundwater contamination and the correlative increase in concentration of strontium plot to the left. Simple mixing between two groundwater end members appears on this plot as a straight line between each end member.

47. Spider diagrams[6] can be used for comparing major and trace element

[5] Gaure, Funter, and Mensing, Teresa M., 2005, Isotopes: Principles and Applications, 3rd edition, Chapter 16.
[6] Wilson, Marjorie,1989, Igneous Petrogenesis—A Global Tectonic Approach: Unwin Hyman, London, p. 19-21.

compositions of any material including ground water. Because of the large difference in concentrations of the different elements, ratios of the concentrations are usually displayed on a logarithmic plot. Figure 4 compares the ratios of key elements in COP-3 and COP-2 with those in COP-1. COP-1 and COP-2 are very similar in their concentrations of elements so the plot of their loci of ratios approximates a straight line at a y-value of 1. In contrast, COP-3 is depleted in sulfate but enriched in other major ions, especially chloride, bromide, and iodide. Such a pattern would develop by adding produced brine to water represented by COP-1 and COP-2, because most produced brine is enriched in chloride, bromide, and iodide, but relatively depleted in sulfate.[7] Figure 4 also compares in similar fashion the highly contaminated groundwater from monitoring well MOC-11 to COP-1, and a similar pattern is displayed, especially showing the relative depletion in sulfate in the MOC-11 water compared to the chloride, bromide and iodide.

48. On November 19, 2010, the OEP collected samples from the City of Poplar's public water supply, and the samples were analyzed at the EPA Region 8 laboratory for metals, anions, volatile organic compounds, total dissolved solids, alkalinity, pH, and electrical conductance using analytical methods prescribed for drinking water samples.[8] Samples collected at the same time and at each sample point were also sent to the USGS Yucca Mountain Project Branch laboratory in Lakewood, Colorado. The EPA Region 8 sample results are shown in Table 3. At the time the samples were collected, the pump at the COP-3 was broken, so

[7] Breit, George N., and Skinner, Chris, 2002, Produced waters database: U.S. Department of the Interior, U.S. Geological Survey Oct 2006 modified
[8] See Title 40 of the Code of Federal Regulations, Part 141

samples were collected solely from COP-1 and COP-2, both before and after drinking water treatment, and samples were also collected from the point at which the blended public water supply enters the water distribution system for the City of Poplar. Another sample was collected from within the distribution system (i.e. from a tap receiving its water from the City of Poplar's public water). At each location sampled, a replicate sample was also collected and analyzed.

49. Poplar's Verne E. Gibbs Health Center has a unit for administering dialysis to patients having renal problems. To function properly, this dialysis method requires water containing a limited amount of dissolved solids. Patients requiring dialysis treatment have compromised kidneys and need the treatment to prevent build-up of uric acid in their bloodstream. Unabated, uric acid build-up in human bloodstream can lead to death. The Health Center relies on the City of Poplar public water supply for operation and uses a reverse osmosis water treatment system to purify the water used for dialysis. On July 27, 2009, during a period when COP-1 was taken off-line and with the City supplying public water using an unusually high amount fraction from COP-3 containing its relatively higher concentration of dissolved solids, the purification capabilities of the reverse osmosis system were overwhelmed. This led to the shut down of the dialysis unit.

50. The Tribal Water Resources Office (WRO) issues groundwater use permits on the Fort Peck Indian Reservation. The presence of the groundwater contamination in and around the East Poplar oil field has effectively prevented the Tribal WRO from issuing at least two such permits in the last three years, including one permit that would have supported a new public water supply (PWS).

## HEALTH EFFECTS OF CONTAMINANTS

51. Benzene is a known human carcinogen. A causal relationship between benzene exposure and leukemia has been clearly established. EPA, in its consensus position on toxicological effects, the Integrated Risk Information System ("IRIS"), uses human occupational data to estimate the added risk of contracting cancer from exposure to benzene. Epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia and also suggest evidence for chronic nonlymphocytic leukemia and chronic lymphocytic leukemia. Other neoplastic conditions that are associated with an increased risk in humans are hematologic neoplasms, blood disorders such as preleukemia and aplastic anemia, Hodgkin's lymphoma, and myelodysplastic syndrome. These human data are supported by animal studies which indicate that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (hematopoietic, oral and nasal, liver, forestomach, preputial gland, lung, ovary, and mammary gland). According to IRIS, dated January 2000, the consumption of drinking water containing 0.078 mg/l benzene is associated with an added risk of cancer of between 1 in 10,000 people and 1 in 100,000 people.

52. In 1999, EPA toxicologist Dr. Robert Benson stated that water with a TDS concentration in excess of 1,000 to 2,000 mg/l is unpalatable and will not be voluntarily consumed by individuals. If an individual has no other source of water and is forced to consume water with TDS levels over 10,000 mg/l, the adverse health effects include severe osmotic diarrhea and severe dehydration.

Continued consumption after the onset of the above conditions may result in death.

53. There is a lifetime health advisory for manganese of 0.3 mg/l and is based on prevention of neurological damage which can lead to lethargy, increased muscle tonus, tremor and mental disturbances. Death has been attributed to humans consuming drinking water with manganese at levels as high as 28 mg/l.

54. The primary drinking water MCL for toluene is 1 mg/L. Toluene has adverse effects on the nervous system, the liver, and the kidney. The health effects of toluene are summarized at http://www.epa.gov/ncea/iris.

55. The primary drinking water MCL for ethylbenzene is 0.7 mg/L. Ethylbenzene has adverse effects on the liver and kidney. The health effects of ethylbenzene are summarized at http://www.epa.gov/ncea/iris.

56. The primary drinking water MCL for xylenes is 10 mg/L. Xylenes have adverse effects on the nervous system. The health effects of xylenes are summarized at http://www.epa.gov/ncea/iris.

**IMMINENT AND SUBSTANTIAL ENDANGERMENT FINDING**

57. Section 1431 of the Act allows EPA to take action, "upon receipt of information that a contaminant which is present in or likely to enter a public water system or an underground source of drinking water…may present an imminent and substantial endangerment to the health of persons." The action EPA may take "may include (but shall not be limited to)…issuing such orders as may be necessary to protect the health of persons who are or may be users of such system (including travelers), including orders requiring the provision of alternate water

supplies by persons who caused or contributed to the endangerment…"

58. Respondents contaminated groundwater in and around the East Poplar oilfield from their past practices managing produced brine in unlined pits, various spills of produced brine and crude oil, and from produced brine and crude oil leaking at Respondent Pioneer's improperly plugged oil well.

59. The groundwater contamination in and around the East Poplar oilfield is located up-gradient of the City of Poplar's public water supply wells and has been shown to contain total dissolved solids at levels up to 91,100 mg/l, chloride at levels up to 58,000 mg/l, sodium at levels up to 43,000 mg/l, sulfate at levels up to 2,150 mg/l, manganese at levels up to 14 mg/l, benzene at levels up to 0.078 mg/l, ethylbenzene at levels up to 0.0052 mg/l, toluene at levels up to 0.0028 mg/l, and xylenes at levels up to 0.0021 mg/l.

60. Every estimate of the movement of the East Poplar oilfield groundwater contamination plume(s) has concluded that such plume(s) will reach the City of Poplar's public water supply wells.

61. The 2009 and 2010 USGS Sr isotope and trace element data as plotted in Figure 3 illustrates the following conclusions:

    a. A nearly horizontal array of data points (the main trend) displays mixing between samples uninfluenced by contamination on the right (colored blue) and highly contaminated samples on the left (colored red), and

    b. The samples from the COP wells plot at intermediate positions on the main trend. Also, there is a distinct difference between the COP-3 and the

other two COP wells (COP-1 and COP-2). This means the COP well water is a mixture between the groundwater end members and is influenced by contamination, especially COP-3 which plots further to the left.

62. The spider diagram figure 4 showing relative concentrations of trace elements is further evidence that produced brine is mixing particularly into the COP-3 well.

63. The data expressed in Figures 1 - 4 indicates that the City of Poplar's water supply is now mixing with produced brine found in groundwater contamination areas in and around the East Poplar oilfield.

64. Because the up-gradient contamination is now mixing with the City's wells, the contamination may be flowing through a 15 square mile area located in an intermediate position where residents are drawing their drinking water from the same alluvium and glacial till aquifer, and the contamination may be entering these residents' private water wells.

65. Humans who drink water containing the constituents at the concentrations described in paragraph 59 will suffer adverse health effects that could lead to death.

66. The entry of produced brine into the City of Poplar's water supply represents an imminent and substantial endangerment to the people drinking the water.

67. The entry of produced brine into the City of Poplar's water supply during a period when COP-3 was contributing relatively higher amounts of supplied water caused the water purification system at the Vern E. Gibbs Health Center dialysis center to cease functioning and led to the shut down of dialysis treatment.

68. The Tribes' inability to issue groundwater use permits due to the presence of the groundwater contamination in and around the East Poplar oil field, including one permit that would have supported a new PWS, has effectively precluded the use of this aquifer as a drinking water resource.

69. No other appropriate governmental agency has taken the actions necessary to protect the health of persons whose source of drinking water is the contaminated aquifer.

70. EPA has determined that this action is necessary to protect the health of persons.

**ORDER**

71. Based on these findings and pursuant to the authority of Section 1431(a) of the Act, 42 U.S.C. § 300i(a), EPA orders that Respondents, in summary, take the following actions. Respondents shall (a) collect monthly samples at the City of Poplar's public water supply for analysis to detect impending contamination, (b) upon homeowner's request, collect monthly samples from homeowner's private water wells to detect impending contamination, (c) if triggered by an action level, provide treated or alternate drinking water to the City of Poplar, (d) if triggered by an action level, provide bottled water to affected homeowners, and (e) submit to EPA a plan for studying aquifer remediation options. The detailed actions are set forth below.

**Sample and Analyze the Poplar Public Water Supply**

72. On or after the effective date of this order, Respondents shall arrange to collect samples from the City of Poplar's public drinking water supply. Samples shall be collected, at a minimum, at the frequency shown in Table 4 and shall be

analyzed, at a minimum, for the parameters displayed in Table 4. For the purposes of this paragraph, samples shall consist of a raw water from each public water well and a sample taken at the point of entry into the public water distribution system. The first sample collection shall occur before the end of December, 2010.

73. Table 4 lists the required analytical methods applicable to the samples collected. For the required strontium isotope analysis, the laboratory must calibrate its reported data against the EN-1 standard, commonly used in laboratories analyzing samples for Sr isotopes.

74. EPA or its representative may obtain split samples during any sampling event. It shall be EPA's responsibility to have sample bottles ready and available, and to coordinate with the designated sampling team for timing and logistics purposes.

75. Respondents shall alert EPA at least seven (7) days prior to each sampling event, to allow EPA or its representative to collect split samples if desired.

76. Respondents shall pay for the sample collection efforts and sample analysis directed in this order. Respondents shall not charge the City of Poplar or its area citizens for any such sampling or analysis.

77. Respondents shall design the analysis work done by chosen laboratories in a manner to maximize repeatability and minimize any inter-laboratory variability in sample results. Samples shall be analyzed using drinking water methods, if one exists, at a laboratory certified to conduct drinking water methods.[9]

78. Respondents shall design the sample schedule to meet the frequency described in Table 4 with samples collected at approximately the same point within the sample

[9] See Title 40 of the Code of Federal Regulations, Section 141.28

collection interval.

**Provide Safe Public Drinking Water if Needed**

79. Respondents shall, if any of the monitored water quality parameters from water supply wells is confirmed to exceed a threshold value shown in Table 5, supply safe drinking water to the point of entry into the distribution network currently used by the City of Poplar to distribute its public water. Respondents shall bear the cost of providing such water. Paragraphs 80 through 83 describe the details for this process.

80. If results from the City of Poplar pubic water supply point-of-entry sample show an exceedance of the any of constituents listed in Table 5, Respondents shall, within 72 hours of any Respondent learning of the exceedance, sample again for each constituent exceeding the value shown in Table 5. Each re-sampled constituent found to be above the threshold value in Table 5 shall be deemed a confirmed exceedance.

81. Samples collected for confirming an exceedance shall be analyzed at the same laboratory that produced the original exceedance value. Only if the original laboratory is incapable of analyzing the re-sample shall an alternate laboratory be considered, and only after consultation with the alternate laboratory to ensure it employs the same analytical methods as those used at the original laboratory.

82. The threshold values shown in Table 5 for these constituents are based on the following rationale: the groundwater contamination plumes in the area have considerably higher concentrations of constituents named in Table 5 than are presently found in the City of Poplar's public water supply. At the concentrations

found in the more contaminated areas of the groundwater plume, the water would be rendered dangerous to drink and may not be useable for other domestic purposes. The contamination has moved and is now entering the City of Poplar's public water supply. The concentrations of the constituents listed in Table 5 are likely to increase and may do so abruptly with the arrival of the bulk of one or more of the groundwater contamination plumes. The threshold values represent an "early warning" of an impending condition whereby the public water wells are rendered unusable. The "early warning" is chosen to allow Respondents adequate time to react to new information to install the requisite treatment or alternate supply of public drinking water for the City of Poplar.

83. Upon a confirmed exceedance of one or more of the parameters in Table 5 in the City of Poplar's water, as described in paragraph 80, Respondents shall within seven days provide a safe supply of drinking water to the City of Poplar. The safe supply of drinking water shall meet all primary drinking water standards at the point of entry into the City's public water system, shall meet secondary drinking water standards such that the aesthetic characteristics of the water are equal to or better than those measured by EPA's November 19, 2010, sample results, and shall meet the current volumetric demand for consumptive uses in the homes of people served by the City's public water system. Respondents shall assure there are trained drinking water personnel operating the public water supply system, as the water supply is amended through Respondents' complying actions. This responsibility for ensuring there are trained operators at the public water supply shall include reasonable financial assistance to the City for its existing public

water supply system operator if one now exists, or, if trained personnel are not now present, Respondents shall provide the necessary means to obtain trained personnel.

**Sample and Analyze the Private Water Wells**

84. On or after the effective date of this order, and upon a request by any homeowner residing within the 15 square mile area described in paragraph 28, Respondents shall collect monthly samples for analysis of the constituents found in Table 4 from such homeowner's private water well used for human consumption. If the residence employs any water treatment, the minimum number of samples collected shall include both a raw and finished water sample. If there is no water treatment employed, the minimum number of samples collected shall be one raw water sample.

85. EPA or its representative may obtain split samples during any sampling event. It shall be EPA's responsibility to have sample bottles ready and available and to coordinate with the designated sampling team for timing and logistics purposes.

86. Respondents shall alert EPA at least seven (7) days prior to each sampling event, to allow EPA or its representative to collect split samples if desired.

87. Respondents shall pay for the sample collection efforts and sample analysis directed in this order. Respondents shall not charge the homeowner for any such sampling or analysis.

88. Homeowners within this 15 square mile area whose water supply is currently via one or more private wells may request to have their well water sampled and analyzed. Homeowners may contact either EPA or OEP, using the respective

contact information found in paragraph 100, EPA and OEP will communicate about homeowner well water sampling requests.

89. EPA will transmit to Respondents, via email, the information about homeowner well water sampling requests.

90. Upon receipt by Respondents of the homeowners wishing their water sampled, Respondents shall add these homes to a monthly sampling schedule. Unless there are fewer than 7 days prior to the next scheduled sampling event at the City of Poplar, newly added sample locations at private residences shall be collected during the City of Poplar sampling. For those timing situations where fewer than 7 days exist before the City of Poplar sampling is scheduled, the newly added sample locations at private residences shall be collected at the next monthly sampling event of the City of Poplar's public water.

91. Within seven days after Respondent receives the residential water sample results from the laboratory, the laboratory results shall be sent to each individual homeowner, and copies shall be submitted to the addresses in paragraph 100.

**Provide Bottled Drinking Water to Area Residents Using Private Wells if Needed**

92. If any of the monitored water quality parameters from a private homeowner's water well is confirmed to exceed a threshold value shown in Table 5, Respondents shall supply bottled drinking water to such private homeowner. Respondents shall bear the cost of providing such bottled water. Paragraphs 93 through 96 describe the details for this process.

93. If results from any private homeowner's well water show an exceedance of the any of constituents listed in Table 5, Respondents shall, within 72 hours of any

Respondent learning of the exceedance, sample again for each constituent exceeding the value shown in Table 5. Each re-sampled constituent found to be above the threshold value in Table 5 shall be deemed a confirmed exceedance.

94. Samples collected for confirming an exceedance shall be analyzed at the same laboratory that produced the original exceedance value. Only if the original laboratory is incapable of analyzing the re-sample shall an alternate laboratory be considered, and only after consultation with the alternate laboratory to ensure it employs the same analytical methods as those used at the original laboratory.

95. The threshold values shown in Table 5 for these constituents are based on the following rationale: the groundwater contamination plumes in the area have high concentrations of constituents named in Table 5, such that the contaminants upon arriving at a private homeowner's well, would render said water dangerous to drink and may not be useable for other domestic purposes. The contamination has moved and is now entering the City of Poplar's public water supply. The groundwater movement is complex and the contaminated groundwater may invade the area listed in paragraph 28. The concentrations of the constituents listed in Table 5 are likely to increase if the contaminated groundwater arrives abruptly with the bulk of one or more of the groundwater contamination plumes. The threshold values were chosen to represent an "early warning" of an impending condition whereby one or more homeowner's private water well is rendered unusable. The "early warning" is chosen to allow Respondents adequate time to react to new information to provide bottled water to such homeowners.

96. Upon a confirmed exceedence of one or more of the parameters in Table 5 in any

homeowner's private well water, as described in paragraph 93, Respondents shall within seven days provide bottled water such homeowner. The bottled drinking water shall meet all primary drinking water standards at the point of entry into the City's public water system, shall meet secondary drinking water standards such that the aesthetic characteristics of the water are equal to or better than those measured by EPA's November 19, 2010, sample results. The quantity of bottled water to be delivered upon a confirmed exceedance shall, at a minimum, be calculated as 2 liters per day per resident, unless this quantity is deemed by the homeowner to exceed their need.

**SUBMIT A PLAN TO EPA TO PROVIDE AQUIFER REMEDIATION OPTIONS**

97. Within 90 days of the effective date of this order, Respondents shall submit to EPA for approval, a plan describing how Respondents intend to identify options for cleaning, capturing or otherwise removing the groundwater contamination endangerment to the alluvium and glacial till. The plan shall include the following components.

    A. A review of available data relevant for characterizing the groundwater contamination and associated hydro-geologic setting,

    B. Identify gaps in the data necessary to characterize the groundwater contamination and associated hydro-geologic setting, and describe how such gaps would be filled,

    C. Identify options for cleaning, capturing or otherwise removing the groundwater contamination,

    D. Descriptions of efficacy testing and/or modeling to fully evaluate the

options in subparagraph C above, and a time estimate for conducting efficacy testing and/or modeling,

E. A time estimate to fully evaluate and recommend a preferred remedial option.

**OTHER REQUIREMENTS**

98. Respondents shall diligently seek any necessary approvals for complying with any requirements in this order.

99. Respondents shall continue to meet requirements in paragraphs 79 through 83 until the earlier of: (1) the City of Poplar's PWS is served by the Dry Prairie / Fort Peck Rural Water System, being built by the U.S. Bureau of Reclamation and said water system has been operating without exceeding any MCLs for a period of one month, or (2) EPA releases Respondents from these paragraphs.

100. Reporting:

Any reporting required under this Order shall be directed to recipients as follows:

For EPA,
Nathan Wiser
Mailing address: 1595 Wynkoop Street, Denver CO 80202 (8ENF-UFO)
Email address: wiser.nathan@epa.gov
Phone number (303) 312-6211;

For City of Poplar,
Linda Christiansen,
Mailing address: P.O. Box 630, Poplar MT 59255.
Street address: 406 2nd Ave West, Poplar MT 59255.
Email address: cityofpoplar@nemontel.net
Phone number (406) 768-3483;

For Montana DEQ,
Jon Dilliard
Mailing address: 1520 E. Sixth Ave., P.O. Box 200901, Helena, MT 59620-0901
Email address: jdilliard@mt.gov
Phone number: (406) 444-2409; and

For Fort Peck Tribes Office of Environmental Protection:
Deb Madison
Mailing address: P.O. Box 1027, Poplar MT 59255
Street address:
Email address: 2horses@nemontel.net
Phone number: (406) 768-2389.

101. The provisions of this Order shall apply to and be binding upon Respondents, their officers, directors, agents, successors and assigns. Notice of this Order shall be given to any successors in interest contemporaneous with succession. Action or inaction of any persons, firms, contractors, employees, agents, or corporations acting under, through or for Respondents, shall not excuse any failure of Respondents to fully perform their obligations under this Order.

102. This Order does not constitute a waiver, suspension, or modification of the requirements of any federal statute, regulation, or condition of any permit issued thereunder, including the requirements of the Safe Drinking Water Act, which remain in full force and effect. Issuance of this Order is not a waiver by EPA to forego any additional administrative, civil, or criminal action(s) otherwise authorized under the Act.

103. This Emergency Administrative Order is a final agency action by EPA.

104. This Emergency Administrative Order is binding on all Respondents.

105. Unless otherwise indicated, all days referred to in this Order are considered to be calendar days.

106. The effective date of this Order shall be three (3) days from the date of issuance, not including the day of issuance.

Issued this _____ day of _____, 2010.

_____
Sandra A. Stavnes, Director
UIC/FIFRA/OPA Technical Enforcement Program
Office of Enforcement, Compliance, and Environmental Justice
United States Environmental Protection Agency, Region 8

_____
Michael T. Risner, Director
Legal Enforcement Program
Office of Enforcement, Compliance, and Environmental Justice
United States Environmental Protection Agency, Region 8

| Table 1a. 2009 and 2010 Sample Locations and Descriptions | |
|---|---|
| **Sample Source** | **Description** |
| COP-1 | City of Poplar Public Water Supply Well #1 |
| COP-2 | City of Poplar Public Water Supply Well #2 |
| COP-3 | City of Poplar Public Water Supply Well #3 |
| DS-1 | City of Poplar distributed system water, collected at point of entry into distribution system |
| DS-2 | City of Poplar distributed system water, collected at point within the distribution system |
| EPU 1-D | Salt Water Disposal Well |
| EPU 4-G | Groundwater Well - Use unknown |
| Huber 5-D | Salt Water Disposal Well |
| LAW-M04 | Groundwater Monitoring Well |
| LAW-M07 | Groundwater Monitoring Well |
| M-3 | Groundwater Production Well |
| M-71 | Groundwater Production Well |
| MOC-11 | Groundwater Monitoring Well |
| MOC-4 | Groundwater Monitoring Well |
| PNR-27 | Groundwater Monitoring Well |
| PR-R-PR-009 | Surface Water - Poplar River |
| PR-R-PR-042 | Surface Water - Poplar River |
| USGS 06-11 | Groundwater Monitoring Well |
| USGS 06-8 | Groundwater Monitoring Well |
| USGS 09-2 | Groundwater Monitoring Well |
| USGS 09-6 | Groundwater Monitoring Well |
| USGS 09-7 | Groundwater Monitoring Well |
| USGS 92-11 | Groundwater Monitoring Well |
| USSG 09-3 | Groundwater Monitoring Well |

**Table 1b. USGS July 2010 Sample Results: Inorganic Constituents**

| Sample | Charge Balance | Lab pH | Lab SC | Na | Mg | K | Ca | F | Cl | $HCO_3$ | $SO_4$ | $NO_3$ | Br |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | percent | | µs/cm | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| LAW-M04 | -0.2 | 7.4 | 4640 | 556 | 153 | 12.6 | 221 | 0.18 | 1290 | 378 | 278 | 0.04 | 0.342 |
| COP-1 | -0.1 | 7.6 | 1926 | 337 | 32.6 | 5.87 | 66.0 | 0.38 | 189 | 600 | 271 | 0.11 | 1.81 |
| COP-2 | 0.3 | 7.7 | 1934 | 338 | 33.6 | 5.94 | 67.8 | 0.38 | 190 | 594 | 277 | 0.02 | 1.81 |
| COP-3 | 0.1 | 7.4 | 3230 | 518 | 56.0 | 8.20 | 109 | 0.28 | 783 | 516 | 105 | <0.02 | 7.80 |
| COP-3 | -0.2 | 7.4 | 3280 | 524 | 54.3 | 8.17 | 109 | 0.30 | 788 | 525 | 106 | <0.02 | 7.82 |
| EPU 1-D | -1.4 | 7.0 | 150000 | 42800 | 213 | 691 | 1460 | 5.05 | 70600 | 242 | 1350 | <0.80 | 23.0 |
| EPU 4-G | -0.3 | 6.5 | 18490 | 4190 | 19.5 | 9.56 | 100 | 0.57 | 6610 | 214 | 2.67 | 2.9 | 66.2 |
| Huber 5-D | -1.2 | 7.0 | 116400 | 32200 | 143 | 438 | 854 | 5.71 | 51800 | 274 | 1700 | 0.67 | 10.3 |
| LAW-M07 | -0.5 | 7.8 | 1211 | 223 | 22.4 | 4.57 | 38.1 | 0.39 | 28.1 | 540 | 194 | <0.02 | 0.082 |
| M-3 | -0.9 | 7.6 | 5130 | 773 | 139 | 12.7 | 172 | 0.21 | 1400 | 543 | 315 | <0.03 | 0.494 |
| M-71 | -0.5 | 7.4 | 2428 | 364 | 49.4 | 6.55 | 87.0 | 0.25 | 533 | 401 | 146 | <0.02 | 0.134 |
| MOC-11 | -0.9 | 7.0 | 24990 | 5180 | 274 | 26.0 | 512 | 0.21 | 8700 | 480 | 1250 | <0.12 | 17.9 |
| MOC-4 | -0.6 | 7.2 | 8690 | 1200 | 282 | 17.3 | 381 | 0.15 | 2460 | 443 | 928 | 0.05 | 1.33 |
| PNR-27 | -0.8 | 6.7 | 34900 | 5160 | 1320 | 61.9 | 1610 | 0.16 | 12900 | 722 | 2060 | 201 | 3.41 |
| PR-R-PR-009 | 0.7 | 8.8 | 1499 | 297 | 40.0 | 8.33 | 19.0 | 0.45 | 11.8 | 669 | 279 | <0.02 | 0.079 |
| PR-R-PR-042 | 0.8 | 8.7 | 1779 | 331 | 50.3 | 9.08 | 28.9 | 0.42 | 120 | 642 | 287 | <0.02 | 0.128 |
| USGS 06-11 | 0.0 | 7.6 | 1246 | 239 | 20.9 | 4.22 | 38.3 | 0.41 | 22.1 | 605 | 172 | 0.06 | 0.096 |
| USGS 06-8 | -0.1 | 7.7 | 1166 | 248 | 12.5 | 3.76 | 23.6 | 0.43 | 18.0 | 558 | 165 | <0.02 | 0.076 |
| USGS 09-2 | -0.7 | 7.6 | 2388 | 445 | 26.2 | 5.70 | 56.0 | 0.39 | 460 | 580 | 110 | <0.02 | 4.83 |
| USGS 09-6 | -1.3 | 6.5 | 19810 | 2310 | 778 | 33.2 | 967 | 0.10 | 7360 | 243 | 376 | <0.10 | 3.08 |
| USGS 09-7 | -1.0 | 7.4 | 5480 | 718 | 174 | 12.9 | 225 | 0.16 | 1580 | 421 | 327 | <0.03 | 0.367 |
| USGS 92-11 | -1.1 | 8.1 | 6330 | 1400 | 12.7 | 7.65 | 36.0 | 0.48 | 1730 | 614 | 309 | 0.08 | 0.643 |
| USSG 09-3 | -0.8 | 7.7 | 2147 | 374 | 34.1 | 6.02 | 60.7 | 0.26 | 315 | 487 | 272 | 3.7 | 0.150 |

**Table 1c. USGS July 2010 Sample Results: Inorganic Constituents**

| Sample | I mg/L | Li µg/L | Be µg/L | B µg/L | Al µg/L | Cr µg/L | Mn µg/L | Co µg/L | Ni µg/L | Cu µg/L | Zn µg/L | As µg/L | Sr µg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAW-M04 | 0.044 | 153 | <2.0 | 550 | <50 | <9.0 | 1180 | <2.5 | <30 | <5.0 | <30 | 8.3 | 2230 |
| COP-1 | 1.38 | 97 | <0.8 | 633 | <20 | 4.1 | 507 | <1.0 | <12 | <2.0 | <12 | 8.3 | 668 |
| COP-2 | 1.37 | 98 | <0.8 | 623 | <20 | 4.3 | 526 | <1.0 | <12 | <2.0 | <12 | 6.5 | 691 |
| COP-3 | 6.02 | 127 | <1.4 | 609 | <34 | <6.1 | 890 | <1.7 | <20 | <3.4 | <20 | 8.5 | 1110 |
| COP-3 | 6.10 | 122 | <1.4 | 587 | <34 | <6.1 | 867 | <1.7 | <20 | <3.4 | <20 | 8.5 | 1120 |
| EPU 1-D | 1.78 | 6000 | <5.8 | 32200 | <146 | <26 | 62 | <7.3 | <87 | <15 | <87 | 92 | 83000 |
| EPU 4-G | 50.3 | 411 | <2.0 | 4450 | <50 | <9.0 | 85 | <2.5 | <30 | <5.0 | 396 | 17 | 5960 |
| Huber 5-D | 0.605 | 4040 | <4.9 | 14300 | <123 | <22 | 130 | <6.1 | <74 | <12 | <74 | 73 | 47300 |
| LAW-M07 | 0.017 | 75 | <0.5 | 604 | <13 | 4.1 | 147 | <0.6 | <7.5 | <1.3 | <7.5 | 10 | 432 |
| M-3 | 0.079 | 159 | <2.0 | 741 | <50 | <9.0 | 400 | <2.5 | <30 | <5.0 | <30 | 10 | 1980 |
| M-71 | 0.018 | 115 | <1.0 | 533 | <25 | <4.6 | 725 | <1.3 | <15 | <2.5 | <15 | 8.2 | 831 |
| MOC-11 | 9.40 | 736 | <2.0 | 676 | <50 | <9.0 | 1240 | 3.0 | <30 | <5.0 | <30 | 29 | 6990 |
| MOC-4 | 0.272 | 225 | <1.0 | 632 | <25 | <4.5 | 2290 | <1.3 | <15 | <2.5 | <15 | 11 | 3890 |
| PNR-27 | 0.047 | 973 | <2.0 | 502 | <50 | <9.0 | 107 | <2.5 | <30 | 7.4 | <30 | 29 | 26000 |
| PR-R-PR-009 | 0.012 | 99 | <0.7 | 1070 | 23 | 4.9 | 2.7 | 1.3 | <10 | <1.7 | <10 | 4.6 | 406 |
| PR-R-PR-042 | 0.019 | 106 | <0.8 | 1100 | <20 | 4.7 | 3.7 | 1.1 | <12 | <2.0 | <12 | 4.6 | 569 |
| USGS 06-11 | 0.024 | 75 | <0.5 | 522 | <13 | 4.7 | 269 | <0.6 | <7.6 | <1.3 | <7.6 | 9.3 | 369 |
| USGS 06-8 | 0.020 | 76 | <0.5 | 552 | <13 | 4.3 | 112 | <0.6 | <7.5 | <1.3 | <7.5 | 8.2 | 241 |
| USGS 09-2 | 3.80 | 83 | <1.0 | 545 | <25 | <4.6 | 206 | <1.3 | <15 | <2.5 | <15 | 8.3 | 529 |
| USGS 09-6 | 0.451 | 369 | <2.0 | 598 | <50 | <9.0 | 5150 | <2.5 | <30 | <5.0 | <30 | 24 | 12500 |
| USGS 09-7 | 0.043 | 172 | <2.0 | 662 | <50 | <9.1 | 1030 | <2.5 | <30 | <5.0 | <30 | 9.4 | 2510 |
| USGS 92-11 | 0.057 | 183 | <1.0 | 756 | <25 | <4.5 | 143 | <1.3 | <15 | <2.5 | <15 | 3.5 | 833 |
| USSG 09-3 | 0.034 | 101 | <1.0 | 631 | <25 | <4.5 | 386 | <1.3 | <15 | <2.5 | <15 | 11 | 647 |

**Table 1d. USGS July 2010 Sample Results: Inorganic Constituents**

| Sample | Rb µg/L | Mo µg/L | Ag µg/L | Cd µg/L | Sb µg/L | Cs µg/L | Ba µg/L | Pb µg/L | Th µg/L | U µg/L | Alkalinity as CaCO3 mg/L | Hardness as $CaCO_3$ mg/L | TDS mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAW-M04 | <1.0 | 2.1 | <7.0 | <2.0 | <2.0 | <2.0 | 142 | <1.8 | <0.30 | 0.90 | 310 | 1180 | 2700 |
| COP-1 | 2.0 | 11 | <2.8 | <0.8 | <0.8 | <0.8 | 45 | <0.73 | <0.12 | 1.17 | 492 | 299 | 1200 |
| COP-2 | 2.1 | 11 | <2.8 | <0.8 | <0.8 | <0.8 | 44 | <0.73 | <0.12 | 1.24 | 487 | 308 | 1210 |
| COP-3 | 2.7 | 8.0 | <4.7 | <1.4 | <1.4 | <1.4 | 89 | <1.2 | <0.20 | 1.35 | 423 | 502 | 1850 |
| COP-3 | 2.7 | 8.6 | <4.7 | <1.4 | <1.4 | <1.4 | 91 | <1.2 | <0.20 | 1.35 | 431 | 495 | 1870 |
| EPU 1-D | 1580 | <2.9 | <20 | <5.8 | <5.8 | 139 | 1120 | <5.2 | <0.87 | <0.87 | 198 | 4520 | 117000 |
| EPU 4-G | 8.4 | <1.0 | <7.0 | <2.0 | <2.0 | <2.0 | 6930 | 2.36 | <0.30 | <0.30 | 176 | 330 | 11200 |
| Huber 5-D | 974 | <2.5 | <17 | <4.9 | <4.9 | 82 | 564 | <4.4 | <0.74 | <0.74 | 225 | 2720 | 87400 |
| LAW-M07 | 0.6 | 5.7 | <1.8 | <0.5 | <0.5 | <0.5 | 36 | <0.45 | <0.08 | 0.71 | 443 | 187 | 778 |
| M-3 | 1.2 | 2.7 | <7.0 | <2.0 | <2.0 | <2.0 | 104 | <1.8 | <0.30 | 1.08 | 445 | 1000 | 3080 |
| M-71 | 0.7 | 3.8 | <3.6 | <1.0 | <1.0 | <1.0 | 73 | <0.92 | <0.15 | 0.79 | 329 | 420 | 1390 |
| MOC-11 | 2.6 | 2.9 | <7.0 | <2.0 | <2.0 | <2.0 | 49 | <1.8 | <0.30 | 2.64 | 394 | 2410 | 16200 |
| MOC-4 | 1.6 | 1.6 | <3.5 | <1.0 | <1.0 | <1.0 | 60 | <0.91 | <0.15 | 1.95 | 363 | 2110 | 5500 |
| PNR-27 | 6.8 | <1.0 | <7.0 | <2.0 | <2.0 | <2.0 | 52 | <1.8 | <0.30 | 76.5 | 592 | 9450 | 23700 |
| PR-R-PR-009 | 1.5 | 2.7 | <2.4 | <0.7 | <0.7 | <0.7 | 47 | <0.60 | <0.10 | 1.81 | 549 | 212 | 987 |
| PR-R-PR-042 | 1.6 | 2.8 | <2.8 | <0.8 | <0.8 | <0.8 | 65 | <0.73 | <0.12 | 2.07 | 527 | 279 | 1140 |
| USGS 06-11 | 1.0 | 11 | <1.8 | <0.5 | <0.5 | <0.5 | 31 | <0.45 | <0.08 | 1.90 | 496 | 182 | 796 |
| USGS 06-8 | 0.9 | 11 | <1.8 | <0.5 | <0.5 | <0.5 | 28 | <0.45 | <0.08 | 0.76 | 458 | 110 | 747 |
| USGS 09-2 | 1.3 | 10 | <3.6 | <1.0 | <1.0 | <1.0 | 49 | <0.91 | <0.15 | 1.66 | 476 | 248 | 1400 |
| USGS 09-6 | 3.4 | <1.0 | <7.0 | <2.0 | <2.0 | <2.0 | 321 | <1.8 | <0.30 | 1.07 | 199 | 5610 | 12000 |
| USGS 09-7 | 1.1 | 1.5 | <7.0 | <2.0 | <2.0 | <2.0 | 159 | <1.8 | <0.30 | 0.68 | 345 | 1280 | 3250 |
| USGS 92-11 | 0.8 | 5.5 | <3.5 | <1.0 | <1.0 | <1.0 | 42 | <0.90 | <0.15 | 1.95 | 504 | 142 | 3800 |
| USSG 09-3 | 0.8 | 3.9 | <3.5 | <1.0 | <1.0 | <1.0 | 112 | <0.91 | <0.15 | 1.10 | 399 | 292 | 1310 |

| Table 2. USGS 2009-2010 Sample Results: Strontium (Sr) Isotope | | | |
|---|---|---|---|
| **Sample** | **Sample Date** | **Sr (µg/l)** | **$^{87}Sr/^{86}Sr$** |
| COP-1 | 7/21/10 | 668 | 0.70821 |
| COP-1 | 6/24/09 | 594 | 0.70819 |
| COP-2 | 7/21/10 | 691 | 0.70823 |
| COP-3 | 7/21/10 | 1,110 | 0.70821 |
| COP-3 | 7/22/10 | 1,120 | 0.70821 |
| COP-3 | 5/28/09 | 1,020 | 0.70819 |
| EPU 1-D | 7/22/10 | 83,000 | 0.70916 |
| EPU 4-G | 7/22/10 | 5,960 | 0.70683 |
| Huber 5-D | 7/22/10 | 47,300 | 0.70991 |
| LAW-M04 | 7/20/10 | 2,230 | 0.70828 |
| LAW-M07 | 7/21/10 | 432 | 0.70814 |
| M-3 | 7/22/10 | 1,980 | 0.70813 |
| M-71 | 7/19/10 | 831 | 0.7082 |
| M-71 | 5/28/09 | 716 | 0.70817 |
| MOC-11 | 7/22/10 | 6,990 | 0.70812 |
| MOC-4 | 7/20/10 | 3,890 | 0.70828 |
| PNR-27 | 7/22/10 | 26,000 | 0.70793 |
| PNR-27 | 7/22/10 | 26,000 | --- |
| PR-R-PR-009 | 7/21/10 | 406 | 0.70818 |
| PR-R-PR-042 | 7/21/10 | 569 | 0.70814 |
| USGS 06-11 | 7/19/10 | 369 | 0.70814 |
| USGS 06-11 | 6/24/09 | 397 | 0.70811 |
| USGS 06-8 | 7/19/10 | 241 | 0.70811 |
| USGS 09-2 | 7/20/10 | 529 | 0.70825 |
| USGS 09-6 | 7/20/10 | 12,500 | 0.70819 |
| USGS 09-7 | 7/20/10 | 2,510 | 0.70822 |
| USGS 92-11 | 7/20/10 | 833 | 0.70741 |
| USSG 09-3 | 7/19/10 | 647 | 0.70812 |

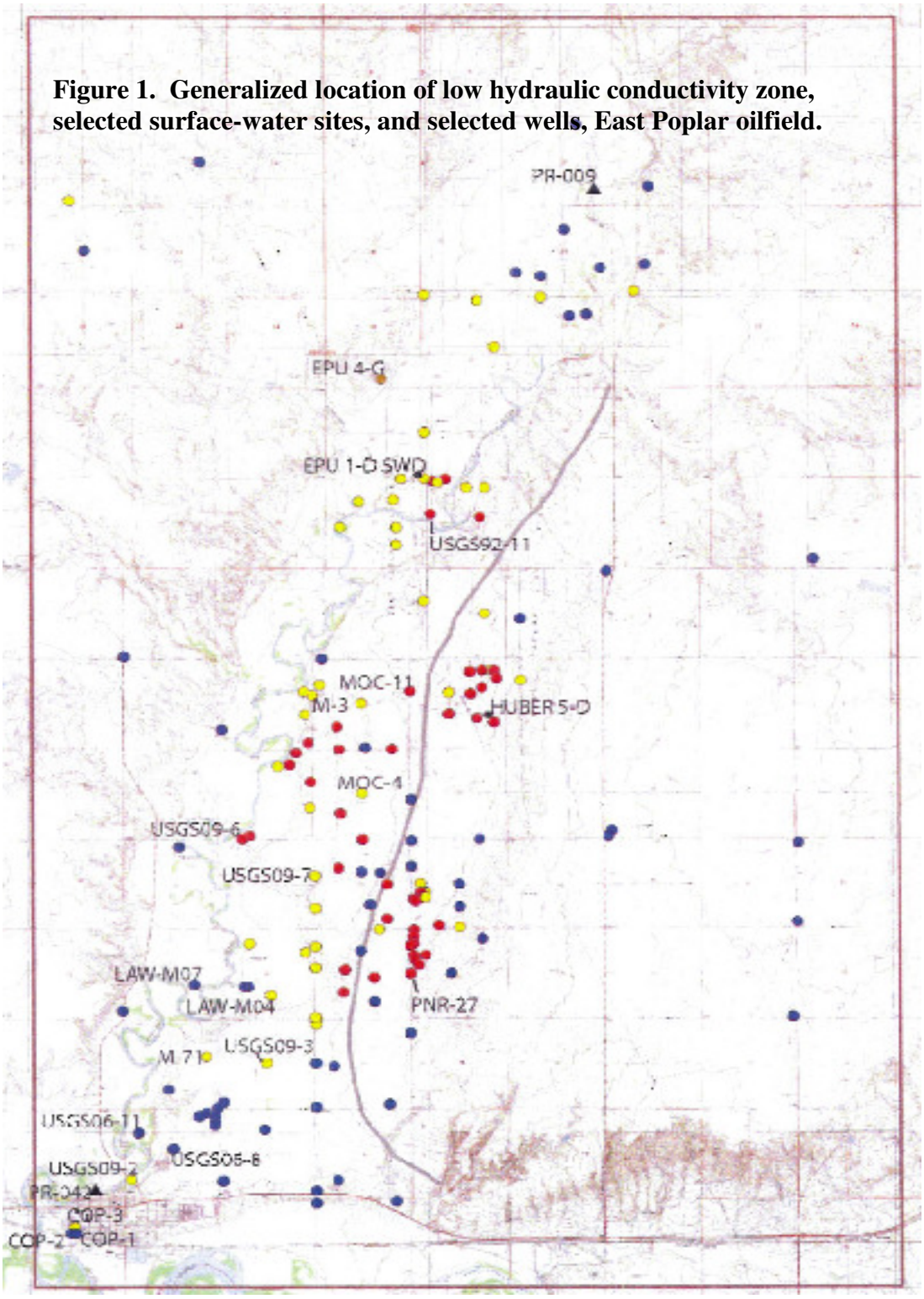
| Table 3. USGS November 2010 Sample Results: Organic and Inorganic Constituents | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Source | COP-1 | COP-1 | COP-1 | COP-1 | COP-2 | COP-2 | COP-2 | COP-2 | DS-1 | DS-1 | DS-2 | DS-2 |
| Sample Type | U | U R | T | T R | U | U R | T | TR | | R | | R |
| **Inorganic Constituents (mg/L)** | | | | | | | | | | | | |
| Sodium | 289 | 278 | 285 | 261 | 294 | 294 | 316 | 302 | 323 | 320 | 289 | 283 |
| Calcium | 43.7 | 41.5 | 44.7 | 43 | 56.8 | 59.3 | 62.2 | 58.5 | 65.9 | 65.9 | 45.9 | 44.3 |
| Potassium | 4.76 | 4.55 | 4.81 | 4.63 | 5.35 | 5.3 | 5.52 | 5.42 | 5.77 | 5.61 | 4.99 | 4.81 |
| Magnesium | 24.7 | 23.4 | 24.9 | 24 | 27.1 | 27.1 | 37.8 | 37.8 | 39.4 | 38.3 | 25 | 24.4 |
| Manganese | 0.366 | 0.339 | <0.002 | <0.002 | 0.0073 | 0.0072 | <0.002 | <0.002 | <0.002 | <0.002 | 0.003 | 0.002 |
| Iron | 1.89 | 1.81 | <0.10 | <0.10 | 0.111 | 0.1 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Strontium | 0.48 | 0.459 | 0.468 | 0.424 | 0.693 | 0.704 | 0.65 | 0.618 | 0.685 | 0.679 | 0.471 | 0.459 |
| Chloride | 120 | 120 | 138 | 142 | 121 | 121 | 121 | 122 | 136 | 134 | 229 | 228 |
| Bromide | 1.2 | 1.2 | <0.5 | <0.5 | 2.3 | 2.3 | 0.9 | 0.9 | 0.9 | 1 | <0.5 | <0.5 |
| Sulfate | 233 | 231 | 234 | 234 | 290 | 289 | 398 | 401 | 388 | 383 | 229 | 228 |
| Alkalinity | 477 | 477 | 449 | 449 | 487 | 488 | 502 | 502 | 502 | 503 | 450 | 449 |
| TDS | 1,040 | 1,030 | 1,020 | 1,030 | 1,110 | 1,110 | 1,270 | 1,280 | 1,270 | 1,270 | 1,030 | 1,020 |
| **Organic Constituents (µg/L)** | | | | | | | | | | | | |
| 1,1,1-trichloroethane | | | | | 0.92 | 0.92 | | | | | | |
| 1,1-dichloroethene | | | | | 0.24 J | 0.26 J | | | | | | |
| 2-butanone | | | 0.18 | 0.27 J | 0.94 | 1.04 | | | | | 0.10 J | 0.10 J |
| Acetone | | | 1.34 | 2.25 | 9.82 | 10.6 | | | | | 0.76 J | 1 |
| Bromochloromethane | | | | | 4.31 | 4.28 | | | | | | |
| Bromodichloromethane | 0.12 J | 0.31 J | 29.8 | 30.3 | 27.5 | 28.1 | 4.73 | 4.39 | 4.15 | 4.3 | 18.6 | 19.5 |
| Bromoform | 0.18 J | 0.44 J | 59.5 | 58.4 | 24.8 | 25 | 11.3 | 11.2 | 10.9 | 11.2 | 59.4 | 93.3 |
| Carbon tetrachloride | | | | | | 0.13 J | | | | | | |
| Cardon disulfide | | | | | 0.27 J | 0.25 J | | | | | | |
| Chloroform | 0.11 J | 0.30 J | 6.32 | 6.42 | 17.2 | 17.5 | 1.4 | 1.3 | 1.21 | 1.21 | 3.4 | 3.56 |
| Chloromethane | | | 0.27 J | 0.37 J | | | | | | | 0.17 J | 0.20 J |
| Dibromochloromethane | 0.22 J | 0.6 | 70.8 | 71.5 | 36.4 | 36.9 | 8.97 | 8.6 | 8.03 | 8.29 | 44.7 | 70 |
| Dibromomethane | | | | | 8.36 | 8.51 | | | | | 0.1 J | 0.15 J |
| Ethylbenzene | | | | | | | 0.24 J | 0.24 J | | | | |
| m, p-xylene | | | | | | | 0.60 J | 0.64 J | | | | |
| Methyl acetate | 0.24 J | 0.24 J | 0.31 J | 0.43 J | 0.21 J | 0.22 J | 0.18 J | 0.18 J | 0.20 J | 0.21 J | 0.26 J | 0.31 J |
| Methyl iodide | | | | | 0.55 | 0.54 | | | | | | |
| Methylene chloride | | | | | 0.84 | 0.86 | | | | | | |
| o-xylene | | | | | | | 0.24 J | 0.26 J | | | | |
| Tert-butyl alcohol | | | 1.11 | 2 | | | | | | | 0.72 | 0.86 |
| Tetrachydrofuran | | | | | 0.63 | 0.59 | | | | | | |
| Toluene | | | | | 0.48 J | 0.46 J | 0.84 J | 0.86 | 0.17 J | 0.17 J | | |

U =Untreated, sample collected as raw water
T =Treated, sample collected after Fe, Mn removal and chlorination treatment
R =Replicate sample, sample collected immediately following initial sample
J =Sample result is above method detection limit and below method reporting limit

| Table 4. Sampling Parameters, Schedule and Methods | | |
|---|---|---|
| **Analyte** | **Sample Collection Frequency** | **EPA Analytical Method (See 40 CFR Part 141)** |
| Benzene | Monthly | 524.3 |
| Toluene | Monthly | 524.3 |
| Ethylbenzene | Monthly | 524.3 |
| Xylenes (total) | Monthly | 524.3 |
| Total Dissolved Solids (TDS) | Monthly | 160.1 |
| Strontium (Sr) Isotope | Monthly | The $^{87}Sr/^{86}Sr$ ratio must be accurate to within ±0.00002. The data must be calibrated against the EN-1 standard. |
| Strontium (Sr) | Monthly | 300.0 |
| Manganese (Mn) | Monthly | 200.7 |
| Sodium (Na) | Monthly | 200.7 |
| Sulfate ($SO_4$) | Monthly | 300.0 |
| Chloride (Cl) | Monthly | 300.0 |
| Calcium (Ca) | Monthly | 200.7 |
| Bromide (Br) | Monthly | 300.0 |
| Iodide (I) | Monthly | Method reporting limit must be at least 5 micrograms per liter |
| Lithium (Li) | Monthly | Method reporting limit must be at least 0.5 micrograms per liter |
| Barium (Ba) | Monthly | 200.7 or 200.8 |

| Table 5. Action Levels Imposed on Samples Collected by Respondents | | |
|---|---|---|
| **Constituent** | **Action Level (mg/L)** | **Sample point** |
| Benzene | 0.001 | Entering distribution system |
| Toluene | 0.2 | Entering distribution system |
| Ethylbenzene | 0.14 | Entering distribution system |
| Xylenes | 2 | Entering distribution system |
| Total Dissolved Solids (TDS) | 2,000 | Entering distribution system |
| Manganese (Mn | 0.3 | Entering distribution system |
| Sodium (Na) | 400 | Entering distribution system |
| Sulfate ($SO_4$) | 500 | Entering distribution system |
| Chloride (Cl) | 250 | Entering distribution system |

**Figure 1. Generalized location of low hydraulic conductivity zone, selected surface-water sites, and selected wells, East Poplar oilfield.**




EXPLANATION

LOW HYDRAULIC CONDUCTIVITY ZONE (S.S. Papadopulos & Associates, Inc., 2008)

▲ STREAMFLOW MEASUREMENT SITE AND NUMBER

WELL AND NUMBER--Water type determined using concentration range in Thamke and Midtlyng (2003).

- Disposal well
- Water well completed in Judith River Formation
- Uncontaminated
- Moderately contaminated
- Extremely contaminated

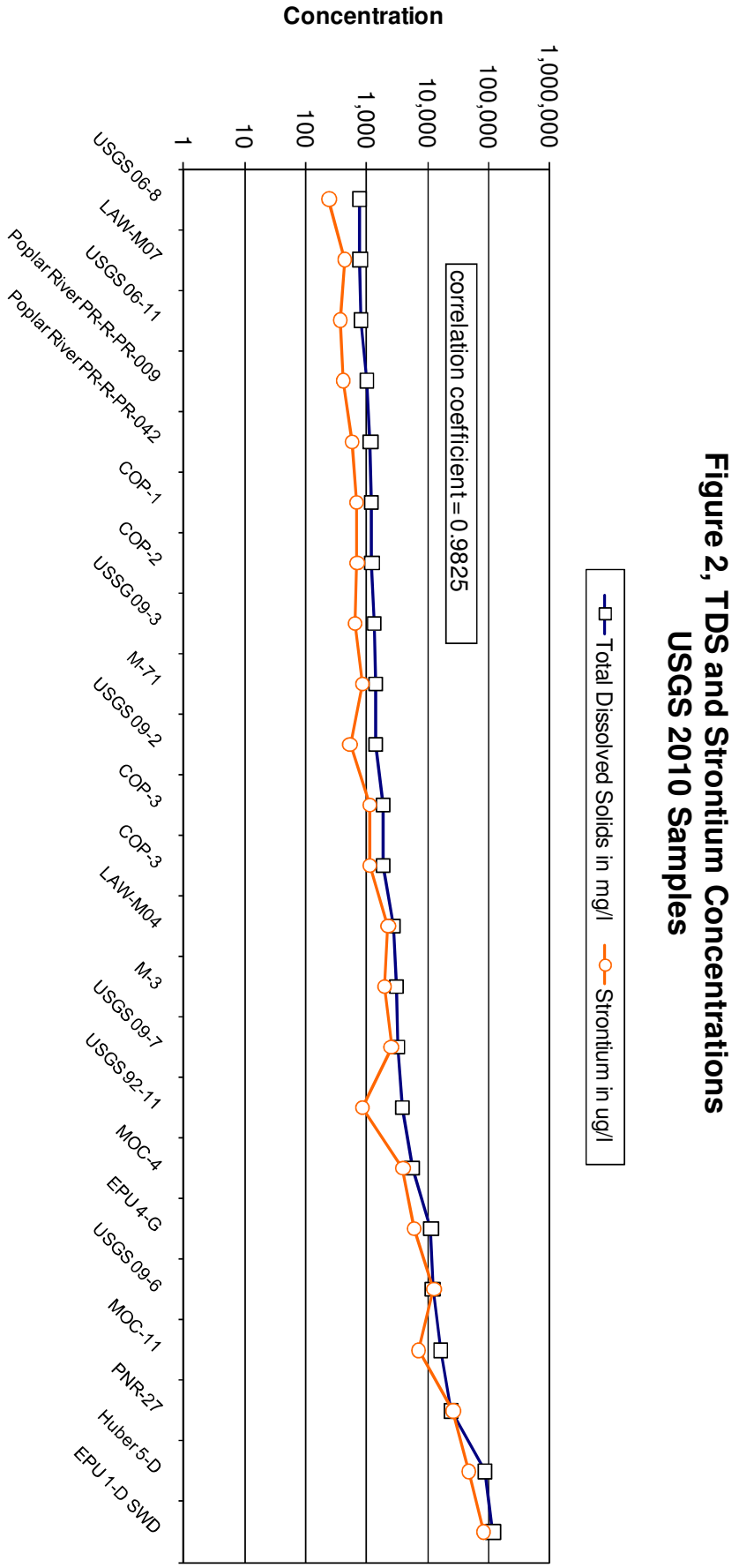
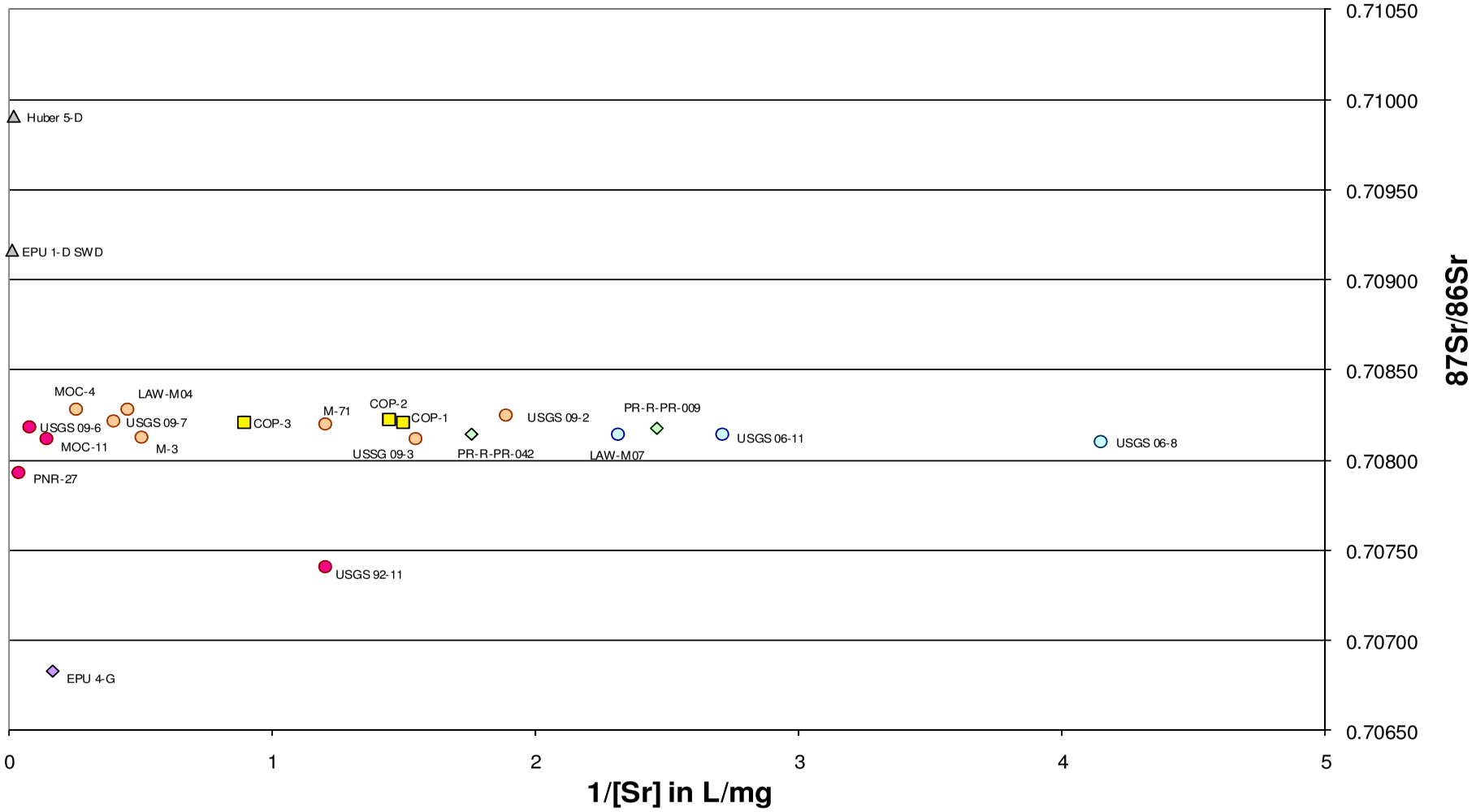



**Figure 2, TDS and Strontium Concentrations**
**USGS 2010 Samples**

# Figure 3, Reciprocal Strontium
# USGS 2010 Samples




= Monitoring Wells - Highly Contaminated
= Monitoring Wells - Moderately Contaminated
= Monitoring Wells - Uncontaminated
= Poplar River Surface Water
= Judith River Formation Well
= Poplar, MT Water Supply Wells
= Injection Wells

East Poplar oil field matter

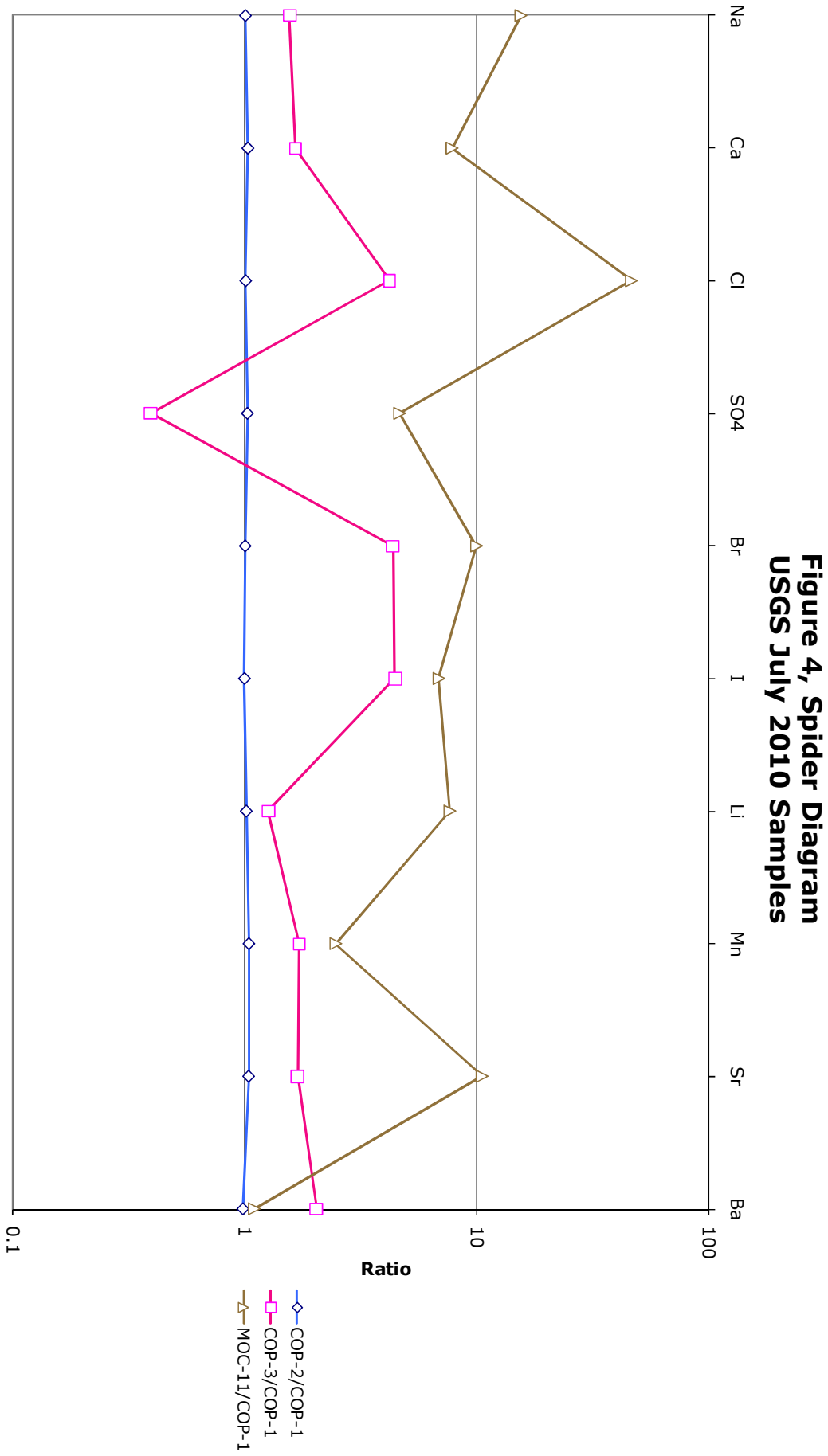


Figure 4, Spider Diagram
USGS July 2010 Samples
Na
Ca
Cl
SO4
Br
I
Li
Mn
Sr
Ba
0.1
1
10
100
Ratio
COP-2/COP-1
COP-3/COP-1
MOC-11/COP-1