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Technical Memorandum

Subject: Ground water issues related to the proposed MHA Nation Clean Fuels Refinery, Makoti, ND

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Introduction

The purpose of this technical memorandum is:

1. To provide information about ground water resources that occur in aquifers that lie beneath the Fort Berthold Indian Reservation in west central North Dakota.
2. To provide information about ground water classification and standards that might be considered by the Three Affiliated Tribes (TAT) for purposes of developing and implementing ground water management strategies.
3. To provide information about the types of ground water monitoring that the TAT should consider for purposes of long-term monitoring of ground water resources and facility specific monitoring related to the proposed refinery.

Hydrogeology - Fort Berthold Indian Reservation (FBIR)

Geology of FBIR

East and north of the Missouri River (and Lake Sakakawea) the Reservation is underlain by significant glacial deposits comprised primarily of till with lesser amounts of sand and gravel deposits (buried valley deposits). These deposits are collectively referred to as the Coleharbor Group. In places the glacial deposits exceed 400 feet in thickness, but are generally less than 150 feet thick. Five significant buried valley deposits have been mapped (Cates and Macek-Rowland, 1998). These are: (1) East Fork Shell Creek; (2) Shell Creek; (3) White Shield; (4) Sanish; and (5) New Town. The location of these buried valley deposits, which function as aquifers, are shown in the attached figure from Cates and Macek-Rowland, 1998. The buried valley deposits are comprised of Pleistocene age sands and gravels deposited by large, glacial-fed rivers. The deposits occur in eroded valleys eroded into the underlying Tongue River and Sentinel Butte members of the Ft. Union Formation. The five major buried valley deposits within the Reservation are linear, range in width from less than a mile to 10 miles and underlie from 8.5 to

48 square miles (Table 1). West and south of the Missouri River glacial deposits are scattered, isolated and thin.

Table 1 – Major buried valley aquifers – Fort Berthold Indian Reservation

Buried valley aquifer	*Areal extent (mi^2)*	*Width (mi)*	*Depth (ft)* *Thickness (ft.)*	*Estimated volume of GW storage (af)*
East Fork Shell Creek (Parshall)	12	1	Down to 100 Approx. 20	48,000
Shell Creek	10	0.75 -2	Down to 100 Up to 100, generally less	38,000
White Shield	48	2-10	Down to 350 ft. 18-226 (ave. – 100)	920,000
New Town	18	1.7 - 4.7	Up to 300 10-100	170,000
Sanish	8.5	1	Up to 300 25 -270	240,000

The Ft. Union Formation underlies the glacial deposit. Within the Reservation the Ft. Union is represented primarily by the Tongue River and Sentinel Butte members. Both of these members are comprised primarily of inter-bedded claystones, siltstones, shale and lignite. The Tongue River underlies the entire Reservation and crops out southwest of Newtown. The Sentinel Butte Member overlies the Tongue River Member and is the subcrop except in the valleys of Shell Creek and Deepwater Creek. The Ft. Union Formation generally exceeds 1000 feet in thickness and the top of the formation is typically identified by the first significant lignite deposit encountered. The lignite deposits, where thick enough, function as aquifers and can yield water to domestic wells.

The Fox Hills Formation underlies the Ft. Union Formation beneath the entire Reservation. The Fox Hills formation is comprised primarily of sandstone with lesser amounts of shale and siltstone. The Formation ranges from 100 to 350 feet in thickness. Within the Reservation, depths to the top of the Fox Hills range from about 1100 to 2000 feet.

Geology at proposed refinery site

The area beneath the 469 acre site for the proposed refinery is underlain by glacial till deposits of the Coleharbor group, which in turn overlies the Ft. Union Formation. Based on geologic logs from 10 ground water monitoring wells installed by GeoTrans in February 2005 [five shallow wells (40 ft deep) and 5 deep wells (110-125 ft deep)], the till deposits range from 107 to more than 125 feet in thickness across the proposed refinery site. The thickest till occurs along the western boundary of the site. The till is comprised almost entirely of clay except for a 5-10 foot thick sandy to sandy silt layer that occurs in each of the 5 deep wells at a depth of about 95 – 105 feet. In four of the five deep wells the first lignite deposit in the Ft. Union Formation was encountered at about 105-110 feet. The proposed refinery site is located about 6-8 miles east of the eastern end of the East Fork Shell valley buried valley aquifer (as mapped by Cates and Macek-Rowland, 1998).

Ground water occurrence, FBIR

Within the FBIR ground water occurs in the till deposits, the buried valley deposits, the Ft. Union Formation and the Fox Hills Formation. All of these geologic units will yield enough ground water to a well to be considered an aquifer. The Ft. Union aquifers (Tongue River and Sentinel Butte Members) and the till typically yield only enough water for domestic uses. The buried-valley deposits and the Fox Hills Formation are capable of yielding enough water for public water supply, irrigation and/or industrial use. However, the chemistry of the ground water in all of these aquifers constrains the use to some extent.

Cates and Macek-Rowland (1998) report that an estimated 51 million acre feet of water is stored in that part of the Fox Hills- Hell Creek aquifer that underlies the FBIR. Well yields from the Fox Hills varies significantly. In the northeast part of the Reservation (Mountrail and Ward Counties) well yields from the Fox Hills are reported to be less than 10 gpm (Armstrong, 1971). Within the FBIR well yields in the Fox Hills increase towards the southwest. Yields of more than 300 gpm have been reported in Dunn County (Klausing, 1979). Also the potentiometric surface for ground water in the Fox Hills is reportedly above the land surface at places in Dunn County. Wells completed in the aquifer within these areas will flow.

Cates and Macek-Rowland (1998) estimate that 24 million acre feet of water is stored in the Tongue River member of the Ft. Union Formation beneath the FBIR. Well yields are generally low and highly dependent on local hydraulic properties. The lignite beds typically are the best aquifers within the Tongue River. Well yields of 200 gpm have been reported (Croft, 1985), however yields are generally less than 10 gpm. Well yields from the overlying Sentinel Butte member of the Ft. Union Formation are generally lower than well yields from the Tongue River. As with the Tongue River, the lignite beds, where sufficiently permeable are the best aquifers within the Sentinel Butte, with well yields as high as 100 gpm. However the lignite beds are not as common in the Sentinel Butte.

As indicated in Table 1, the estimated volume of ground water stored in the five major buried – valley aquifers within the FBIR is 1,414,000 af. Well yields from these aquifers are quite variable and are dependent on saturated thickness. These aquifers are capable of yielding more than 300 gpm where there is sufficient saturated thickness. Yields of less than 100 gpm are far more common. The East Fork Shell Creek aquifer has been used by the Town of Parshall to obtain municipal supplies.

Throughout the FBIR, hundreds of domestic wells have been constructed in the till deposits of the Coleharbor group (Jaret Wirz & Harlan Deane, personal communication). The TAT

Environmental Protection office has estimated that more than 700 wells have been installed on the FBIR. Of these, approximately 300 are less than 100 feet deep and currently in use.

Ground water flow - Ground water in the Fox Hills Formation flows from northwest to southeast across the Reservation. As discussed above, the potentiometric surface is above the ground surface in the Little Missouri River valley and near Lake Sakakawea. This indicates that ground water discharges from the Fox Hills to the Little Missouri River and to Lake Sakakawea. Ground water flow in the Tongue River member of the Ft. Union Formation is generally towards the Missouri River and Lake Sakakawea (Cates and Macek-Rowland, 1998).

In the upland areas of the FBIR, the hydraulic head in the Tongue River member is lower than the hydraulic head in the overlying Sentinel Butte member and lower than the hydraulic head in the underlying Fox Hills aquifer. This indicates that recharge to the Tongue River occurs via discharge from the Sentinel Butte member and the Fox Hills aquifer.

Ground water occurrence, proposed refinery location

Depth to water in the till that underlies the proposed refinery site (based on the 5 Geotrans wells) ranges from 10 to15 feet. The ground water in the till appears to flow towards the southwest. The horizontal gradient that was calculated by Geotrans for May 2005 water levels is about 0.01 ft/ft. Based on this gradient and hydraulic conductivity values derived from slug tests, GeoTrans estimated horizontal ground water flow velocity in the till to be between 0.4 to 2.4 ft/year.

At least 4 of the 5 deep wells encountered the top of the Sentinel Butte Member of the Ft. Union Formation. Water levels in these wells were used to construct a potentiometric surface map for ground water in the Ft. Union Formation beneath the proposed refinery site. Based on potentiometric surface data from the GeoTrans wells, ground water flow direction in the Ft. Union is towards the southeast. The calculated horizontal gradient on the potentiometric surface is 0.0009 ft/ft. Based on this gradient and the hydraulic conductivity value obtained from a pump test using deep well PW-3, the horizontal ground water flow velocity in the Ft. Union Formation is as high as 100 ft/year. It is important to note that the potentiometric surface map included in Cates and Macek-Rowland (1998) indicates a northeast to southwest flow direction for the Tongue River east of the Missouri River.

Based on water level elevations in the 10 GeoTrans monitoring wells, there is a strong downward vertical gradient between the till and the Ft. Union Formation. Thus, to the extent that vertical ground water flow occurs, the direction of flow will be downward.

Ground water chemistry

There is a significant amount of chemistry data for ground water in the Fox Hills Formation, the Ft. Union Formation and the glacial deposits of the Coleharbor Group (Cates and Macek-Rowland, 1998, Pettyjohn, W.A., and Hutchinson, 1971, Gentians, 2005).

Fox Hills Formation - Since the Fox Hills Formation is quite deep in this part of North Dakota, ground water that occurs in the aquifer has had a long residence time. This results in relatively high concentrations of total dissolved solids (TDS). TDS concentrations typically exceed 1500 mg/l. With respect to the common cations in ground water - dissolved sodium concentrations commonly exceed 500 mg/l and dissolved boron concentrations commonly exceed 1000 ug/l. With respect to common anions – bicarbonate and alkalinity concentrations typically exceed 1200 mg/l (as $CaCO^3$), chloride concentrations commonly exceed 100 mg/l and locally sulfate concentrations exceed 500 mg/l. Ground water in the Fox Hills is a sodium-bicarbonate type of water.

The available water chemistry data for the Fox Hills formation in west-central North Dakota do not indicate any common exceedances of primary MCLs. Due to the high sodium concentrations, ground water in the Fox Hills Formation typically has a very high sodium adsorption ratio (SAR) with values typically exceeding 80. The combination of high salinity (TDS) and high SAR indicates that ground water from the Fox Hills Formation is unsuitable for irrigation.

Due to the significant depth to the top of the aquifer, not many wells are constructed in this aquifer within the Reservation. The U.S. Bureau of Indian Affairs draft report (2004) includes a table (Table 4) that lists 41 wells completed in the Fox Hills Formation within the Reservation. These wells range in depth from 1160 to 1980 feet.

Ft. Union Formation - The chemistry of the ground water in the two members of the Ft. Union is similar. Ground water in both members varies from a sodium - bicarbonate to a mixed calcium /magnesium/sodium – sulphate type. This reflects the dissolution of cations from the rocks that comprise the Ft. Union. Total dissolved solids concentrations presented in Cates and Macek-Rowland (1998) range from 133 to 4230 mg/l (135 wells) and commonly exceed the secondary MCL of 500 mg/l. Ground water from many wells in the Ft. Union exceeds the secondary MCL for iron, manganese and sulphate. The SAR for ground water in the Tongue River member is high. In combination with high salinity values, this indicates that the ground water in the Tongue River is unsuitable for irrigation. The SAR for ground water in the Sentinel butte member is low. In combination with high salinity values, this indicates that ground water from the Sentinel Butte member is suitable for irrigating soils with high permeability.

It is likely that there are at least a few hundred domestic wells within the Reservation that are withdrawing water from the Ft. Union Formation. Well yields that are sufficient for domestic /stock use are common.

Buried valley deposits - Though the buried valley aquifers are the most productive (and most accessible) aquifers within the Reservation their use is limited because, except for the White Shield aquifer, they are located along the northern border of the Reservation and close to Lake Sakawea. Most people in this part of the Reservation receive water from a PWS that obtains source water from Lake Sakawea.

The sediments that comprise the buried valley deposits are from the underlying formations. As a result, the chemistry of the ground water in these deposits is similar to that in the underlying Ft.

Union Formation. Cates and Macek-Rowland (1998) present chemistry data for 34 wells constructed in the five major buried valley aquifers within the Reservation. Ground water in the East Fork Shell Creek aquifer, the Shell Creek aquifer and the Whiteshield aquifer is a sodium – bicarbonate /sulphate type. Ground water in the Newtown and Sanish aquifers is a mixed calcium /sodium/magnesium – bicarbonate /sulphate type. Concentrations of TDS range from 459 to 4440 mg/l. Concentrations of iron, manganese and sulphate often exceed the secondary MCL. The use of ground water from the buried valley aquifers for irrigation is constrained by the high salinity. However, only ground water from the East Fork Shell Creek aquifer has a high SAR. Ground waters from the Whiteshield, Newtown and Sanish buried valley aquifers have low SAR values. Ground water from all but the East Fork of Shell Creek aquifer can be used to irrigate soils with moderate to high permeability.

Ground water chemistry, proposed refinery location

The 10 ground water monitoring wells installed by GeoTrans in February 2005 have each been sampled. In February 2005, all 10 wells were sampled and the samples analyzed for basic cations /anions, RCRA dissolved metals (Ar, Ba, Cd, Cr, Pb, Hg, Se, Ag), seven PCBs, 19 common pesticides, and 78 VOCs and PAHs (hydrocarbons, fuels, solvents, etc.). All ten wells were sampled again in May 2005 and the samples analyzed only for the suite of VOCs and PAHs.

Chemistry data from these two sampling rounds indicates the following:

a) ground water in the till deposits beneath the proposed refinery site is mainly a calcium-bicarbonate/calcium-sulphate type of water. Ground water in the underlying Ft. Union Formation is mainly a sodium-bicarbonate/sodium bicarbonate type of water;
b) all PCBs were at non-detectable levels in all samples;
c) RCRA metal concentrations were below MCLs in all samples;
d) very low concentrations of some VOCs were detected in some samples; however, the duplicate samples were non-detectable;
e) all samples were non-detectable for the 19 pesticides; and
f) total dissolved solids concentrations were high for all wells- concentrations from samples collected from the five till wells (MW1-MW5) ranged from 450 to 4200 mg/l with a mean value of 2280 mg/l, concentrations for the Ft. Union wells ranged from 2500 to 4500 mg/l with a mean value of 3860 ug/l. Sodium concentrations for the 10 wells ranged from 14 to 860 ug/l with a mean value of 355 mg/l. SAR values were not calculated from these data –but with the high sodium and TDS concentrations it is highly likely that SAR values are high and that most of the water beneath the proposed refinery site is not suitable for irrigation without treatment.

To supplement the chemistry data base EPA Region 8 sampled five of the ten wells for stable water isotopes in August 2005. Two samples were also collected from the pothole wetland immediately adjacent to the west side of the proposed refinery site and one sample from the perennial reach of the East Fork of Shell Creek about 15 miles northwest of the proposed refinery site. Preliminary results are shown in Table 2. As of September 13, 2005 final results have not been received from the lab. Data from the final lab report will be summarized in a separate memorandum.

Delta ^{18}O values in shallow ground waters are typically close to values for the weighted average of annual precipitation (Clark and Fritz, 1997). Furthermore the delta ^{18}O values for precipitation are more depleted (more negative) with increasing latitude. The delta ^{18}O values shown for ground water samples in Table 2 (MW-4, MW-3, MW-1, MW-2 , P-5) are typical for precipitation in west central North Dakota. These data suggest that the till is recharged by direct infiltration of precipitation.

Table 2 – Preliminary data for stable water isotopes obtained from analysis of samples collected in August 2005

Location	**Delta ^{18}O**	**Deuterium**
South inlet to wetland	-4.85	-41.5
North outlet from wetland	-5.16	-42.8
MW-4	-16.56	- 129.4
MW-3	-13.63	Cond. too high
MW-1	-15.05	-117.7
MW-2	-13.70	Cond. too high
P-5	-16.34	Cond. too high
East Fork Shell Creek	-10.66	Cond. too high

In summary, ground water in the till deposits and underlying Ft. Union Formation beneath the proposed refinery site is suitable for drinking water and stock watering but is not suitable for irrigation.

<u>Wetland Hydrology</u>

A moderately sized, healthy (as of August 2005) pothole wetland occurs along the north end of the western boundary of the proposed refinery site. The wetland occupies a swale in the till. The swale appears to be part of the ephemeral channel of the upper part of the East Fork of Shell Creek drainage. This wetland has not been significantly impacted by surrounding agricultural land use. During mid-August, when the isotope samples were collected, there was no discharge from the wetland. Isotope samples were collected from the upgradient end (south) and the downgradient end (north) of the wetland. The delta ^{18}O values shown for the two wetland locations are much more enriched in ^{18}O (-4.85 and -5.16) than the ground water in the till and underlying Ft. Union Formation. This enrichment is due to extensive evaporation of water in the wetland. These values are also a strong indication that the wetland does not receive ground water discharge.

Ground Water and Wetland Vulnerability

Ground water in the till beneath the proposed refinery site is highly vulnerable to contamination. Depth to the top of the water table in the till is typically less than 15 feet. Infiltration of water contaminated by land use practices is a concern. Water management practices associated with any land use that will include the use and disposal of substances that are known ground water contaminants should accommodate the high vulnerability.

The existing wetland along the west boundary of the proposed refinery is also highly vulnerable. This wetland apparently receives most or all of its water from run-in of precipitation. If the topography of the surrounding land is altered, it is likely that the surface pathways that have historically routed precipitation into the wetland will be altered and recharge to the wetland will be reduced or possibly increased. In addition, surface run-in of water contaminated with refinery related contaminants is highly likely. Over time the cumulative effects of this increasing contamination will have a negative ecological effect on the wetland.

Ground Water Classification and Standards

Many states have promulgated rules that provide the authority to classify ground waters for purposes of applying applicable water quality standards that are aimed at preventing undue contamination and protecting beneficial uses. These rules are typically related to an "anti-degradation" or "non-degradation" policy. Classification schemes can be applied to all ground waters within a state (or Reservation) or to specific ground waters. For example, ground water that occurs within a specific aquifer could be classified or ground water that occurs in an aquifer or aquifers beneath a specific area could be classified. Classification can be based on existing water quality or based on primary beneficial uses. Classification systems must be adopted by the appropriate governing body and specific rules must then be promulgated to allow for enforcement of the provisions of the classification system. Once a classification system is adopted and applicable rules are promulgated, the process of classification must be an open process conducted by a governmental group that has been given the power to apply a classification to a specific ground water area.

EPA directly implements our federal environmental programs on the Fort Berthold Indian Reservation. While we have not approved the State of North Dakota to implement EPA programs on the Reservation, background on North Dakota's ground water program provides helpful information with regard to this technical memorandum.

The State of North Dakota has a simple two-tiered ground water classification system. Class 1 includes all ground waters with a TDS concentration less than 10,000 mg/l. Class 2 includes all ground waters with a TDS concentration greater than 10,000 mg/l. The State anti-degradation policy was established in1972 and applies to all Class 1 ground waters. This means that, for all Class 1 ground waters, there shall be no increase in concentrations of known contaminants (there are specific exemptions).

Some States also have adopted, by rule, a ground water discharge permit program apart from UIC. These discharge permit programs allow for a controlled, permitted discharge of waste water independent of UIC. This can apply to agricultural waste water ponds, mine waste water ponds, municipal waste water ponds, etc. The State of North Dakota does not have a ground water discharge permit program. Discharges to waters of the State, not regulated under UIC are regulated under NDCC 61-28-04, Section 33-16-02. 1-11 which deals with the discharge of wastes and specifies levels of treatment and identifies types of waste that are prohibited to be discharged to waters of the State.

EPA recommends that the TAT pursue the development and adoption of a ground water classification system that is based on existing water quality or expected beneficial uses. A ground water classification system may be enforced through rules promulgated by the Tribal Council, could provide a means to assure that the ground water resources beneath the FBIR would not be contaminated beyond allowable limits and could help assure a sustainable use of this important resource. The Tribal Council could establish the specific classification of any ground waters within the FBIR. Another option could be for the Tribes to appoint a “Water Resource Board” and delegate the process of evaluating the requests for and need for classification of specific ground waters.

Ground Water Monitoring

An appropriate ground water monitoring program is an important component of an overall water resource management plan. Ground water monitoring is important for a variety of reasons:

1. Water level and chemistry data can be used to continuously evaluate the condition of the resource – to monitor the water supply impacts from development of the ground water resource and to monitor the chemistry of the resource to help assure that ground waters do not become unduly contaminated.

2. Ground water monitoring programs can be utilized to provide data to verify that water and waste management practices are not resulting in ground water contamination. Early warning monitoring locations can be determined based on the need to provide an early indication of ground water contamination. Trigger levels can be established that would require specific actions to prevent further contamination.

3. Ground water monitoring can be used to evaluate compliance with discharge permits (NPDES, UIC, etc.). Compliance monitoring is a common requirement at facilities/land uses where known ground water contaminants are used and permit discharge conditions or formal classification specify concentration limits that cannot be exceeded.

EPA recommends that the TAT develop a two-tiered ground water monitoring program. The first tier could include the entire FBIR. The TAT Environmental Office has recently initiated a

Reservation wide monitoring program utilizing 25 domestic water wells. This program could be expanded to include more wells – perhaps up to 100 wells for water level monitoring. The wells included in the broad monitoring program should include wells developed in the Ft. Union Formation, the Fox Hills Formation, all five of the buried valley aquifers and the till deposits. These wells should be monitored four times a year for water levels and field parameters (temperature, specific conductivity, pH, and dissolved oxygen). A subset of the 100 wells should be sampled at least once per year for a list of parameters that includes basic cations (Na, Mg, Ca), basic anions (sulphate, chloride, bicarbonate /alkalinity), selected metals and selected organic compounds (VOCs, PAHS, pesticides, PCBs). EPA Region 8 is willing to work with the TAT Environmental Office to help determine which specific parameters should be included.

The second ground water monitoring program could focus on monitoring ground water that may be impacted by the operation of the proposed refinery. The 10 wells installed by GeoTrans in February 2005 should be included in this program. A few additional wells should be located or installed along the south and west boundaries of the facility site. These wells should be screened in the till deposits. They will provide early warning of any contaminated ground water resulting from refinery operation. At least one deeper Ft. union monitoring well should be installed along the SE boundary of the refinery site. This well will serve as an early warning monitoring well for contamination of the Ft. Union aquifer. Monitoring wells associated with the refinery should be sampled for a short list of indicator parameters twice a year. Water quality parameters should include key VOCs / PAHs that are associated with the refinery product.

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