2014

WISCO special waste landfill: site location northwest 1/4 of section 26, township 154 north, range 104 west, Williams County, North Dakota

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WISCO SPECIAL WASTE LANDFILL

Senior Design
May, 2014

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Grand Forks, ND 58202
WISCO Special Waste Landfill

Site Location
Northwest ¼ of Section 26, Township 154 North, Range 104 West, Williams County, North Dakota

Prepared By:
Cutting Edge, in association with the UND Harold Hamm School of Geology and Geological Engineering
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Exclusively For:
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Grand Forks, ND 58202-8358

Date:
May 9, 2014
WISCO Special Waste Landfill

The WISCO Special Waste Landfill was developed to meet the need for a waste disposal site for the growing oilfield industry in western North Dakota. The landfill was designed to accept special and small volume industrial waste for at least 25 years while remaining economically feasible, socially acceptable, and environmentally safe for the surrounding area.
The special waste landfill will have the capacity to hold approximately 7.6 million cubic yards of waste with an annual projected disposal volume of 300,000 cubic yards, including waste, daily cover, and clay layers.

Types of waste accepted at the WISCO landfill include special waste such as well cuttings, inert waste, and other oil field related wastes.

Utilizing improved technology such as geonets, geotextiles, and geomembranes increases landfill life and conserves volume, creating a greater space for special waste.

The landfill site is located in the Northwest ¼ of Section 26, Township 154 North, Range 104 West, Williams County, North Dakota. The site is 16 miles west of Williston, North Dakota and is a mile away from the North Dakota and Montana border.

The cost to design and regulate the technologically advanced landfill is approximately $16 million. The quality, along with the safety and assurance, go above and beyond the regulations set forth by the North Dakota Century Code (NDCC).
Executive Summary

The WISCO Special Waste Landfill was developed to meet the need for a waste disposal site for the growing oilfield industry in western North Dakota. The design report was prepared on behalf of the North Dakota Department of Health – Division of Waste Management to demonstrate that the site meets the geological and hydrogeological requirements set forth in the North Dakota Century Code. The report details the site analysis utilized in design, the assumptions made in regards to contamination prevention, and the execution of the landfill design. The WISCO Special Waste Landfill was designed to accept special and small volume industrial waste for at least 25 years while remaining economically feasible, socially acceptable, and environmentally safe for the surrounding area. The design report focuses on environmental concerns of waste leakage and groundwater contamination that are a major concern at landfill sites. The landfill design provides adequate assurance that the overall liner and containment system will prevent contamination of groundwater in the vicinity. Measures taken to protect local plants and wildlife include daily cover and fencing, and monitoring programs are put into place to ensure these safety standards are achieved. The design report details these systems and programs, as well as the execution of the WISCO Special Waste Landfill.
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List of Abbreviations, Acronyms, and Terms

North Dakota Century Code (NDCC)
North Dakota Department of Health (NDDH)
North Dakota State Water Commission (NDSWC)
North Dakota Geological Survey (NDGS)
National Resources Conservation Service (NRSC)
Department of Mineral Resources (DMR)
North Dakota Aviation Council (NDAC)
North Dakota Game and Fish (NDGF)
North Dakota Fish and Wildlife Service (NDFWS)
National Park Service (NPS)
Federal Emergency Management Agency (FEMA)
Environmental Protection Agency (EPA)
American Association of Petroleum Geologists (AAPG)
North Dakota Pollutant Discharge Elimination System (NDPDES)
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1.0 Introduction (PJ)

The design report for a Special Waste Landfill facility was prepared on behalf of the North Dakota Department of Health - Division of Waste Management (NDDH). The report demonstrates that the selected site is both geologically and hydrogeologically suitable for a small volume industrial and special waste landfill in accordance to the requirements set forth in the North Dakota Century Code (NDCC). The report details the design approach as well as the execution of the landfill design while following guidelines outlined by the NDDH.

2.0 Problem Definition (PJ)

Due to the increased oilfield activity in Western North Dakota, a special waste landfill is needed to dispose of oil field related waste. This includes special waste, well cuttings, inert waste, and other oil field related wastes. The NDDH provides a detailed description of the types of waste accepted at a special waste landfill. The design report addresses geological and hydrogeological characteristic of the selected site, the design analysis, the assumptions made, and finally, the execution of the design.

3.0 Project Goals and Objectives (PJ)

3.1 Overall Goals (PJ)

The overall goal of the design report is to successfully design a landfill capable of accepting special and small volume industrial waste for 25 years while remaining in accordance with the requirements set forth by the NDDH. The design will be appealing both economically and socially, as well as environmentally safe for the surrounding area.
3.2 Specific Objectives (PJ)

The design report specifically addresses environmental concerns of waste leakage and contamination of the environment surrounding the site area. The landfill design provides adequate assurance that the overall liner and containment system will prevent contamination of groundwater in the vicinity, as well as protect local plants and wildlife. The site will be continually monitored to ensure these safety standards are achieved.

4.0 Background

4.1 Site Description (PJ)

The selected landfill site is located in the Northwest quarter of Section 26, Township 154, Range 104 West, in Williams County, North Dakota and can be observed in the figures below. The property is located approximately 16 miles from Williston, North Dakota and less than a mile from the Montana border. Highway 2 runs across the upper-middle part of the site area, dividing it into two sections. The northern half of the property is to be used for the development of an oil treatment plant and saltwater injection well. The proposed landfill is to be located in the southern half of the property.

4.2 History of the Site (PJ)

The natural vegetation located at the landfill site was historically considered a mixed grass prairie, but was used as an agricultural field for cultivating crops in recent years. In 1919, the Theodore Roosevelt International Highway was constructed, running directly through the landfill site. The highway was renamed in 1926 to what we now know as Highway 2.
5.0 Site Characterization

5.1 Geology (AS)

Information relating to the geology of the selected site was found mainly from publications from the North Dakota State Water Commission (NDSWC) and the North Dakota Geological Survey (NDGS), as well as from data collected from boreholes drilled throughout the area.

5.1.1 Surficial Geology (RR)

The surficial geology for most of Williams County and the entire proposed site area is glacial till, which consists mostly of silt and sandy-clay. The deposits are of Quaternary age from the Coleharbor Group. There is also river surface geology near the site area to the North and South. The surficial geology map is shown in Figure 1 (nd.gov, 2013).
Figure 1: Surficial Geology
The surface geology of the selected landfill site consists of Quaternary age glacial deposits (ND Hub Explorer).

5.1.2 Subsurface Geology (AS)

Subsurface geology of the region is presented in the cross sections in Figures 3 through 7. Data used to create cross sections comes from the borehole information provided by Barr Engineering Company. All units presented in the cross sections are in feet. A map of the boreholes and cross section locations can be observed in Figure 2. According to the cross sections, the subsurface geology of the Sentinel Butte Formation and Tongue River Formation consist mainly of glacial till, clay, volcanic tuff, and claystone. Layers of interbedded lignite are also present throughout the property (BARR, 2013).

- Glacial Till
The glacial till unit is approximately 1 to 2 feet thick and consists mainly of sandy clay (CL) and silty sand (SM). These layers are characterized by fine to coarse-grained sand with small amounts of gravel and lignite.

- Clay

Clay units consist of sandy clay (CL) and lean clay (CL) characterized by thinly laminated fine-grained sand beds with trace amounts of lignite. The unit also consists of fat clay (CH) layers characterized by fine to medium grained sand. These layers range from 3 to 25 feet below the ground surface.

- Volcanic Tuff/Gray Volcanic Tuff

The volcanic tuff unit ranges anywhere from 10 to 70 feet below the surface across the property. This unit consists of sandy clay (CL), sand with clay (SP-SC), sandstone, and poorly graded sand with silt (SP-SM). These units are made up of fine to medium grained sand. Layers within the volcanic tuff unit are mainly unconsolidated though very dense, slightly cemented layers exist throughout. Small amounts of gray volcanic tuff ranging from 60 to 115 feet below the surface are also present throughout the property consisting of silty sand (SM/SC-SM) and characterized by very hard and dense fine-grained sand.

- Claystone

The claystone consists of lean clay (CL), fat clay (CH) characterized by hard, cohesive fine-grained sand with trace amount of shale. Claystone layers can be found anywhere from 60 to 120 feet below the surface.
Figure 2: Borehole Locations and Cross Section Data
The locations of the boreholes drilled by Barr Engineering are presented here as well as locations for the five different cross sections throughout the area (Map created in ArcGIS and Surfer).
Table 1: Surficial Geology Unit Descriptions

<table>
<thead>
<tr>
<th>Layer</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil</td>
<td>Brown</td>
</tr>
<tr>
<td>Till</td>
<td>Brown</td>
</tr>
<tr>
<td>Clay</td>
<td>Tan</td>
</tr>
<tr>
<td>Claystone</td>
<td>Black</td>
</tr>
<tr>
<td>Lignite</td>
<td>Black</td>
</tr>
<tr>
<td>Water Table</td>
<td>Blue</td>
</tr>
<tr>
<td>Gray Volcanic Tuff</td>
<td>Gray</td>
</tr>
</tbody>
</table>

Cross Section from A to A'

Figure 3: Cross Section for A to A'
Created in Surfer
Figure 4: Cross Section for B to B'
Created in Surfer

Figure 5: Cross Section for C to C'
Created in Surfer
Figure 6: Cross Section for D to D'
Created in Surfer

Figure 7: Cross Section for E to E'
Created in Surfer
5.1.3 Bedrock Geology (RR)

The bedrock geology for Williams County is composed of the Sentinel Butte and Bullion Creek Formations of the Tertiary period. These bedrock formations came from the erosion of the Rocky Mountains in the Paleocene Epoch. Most of Williams County, along with the proposed site area, is part of the Sentinel Butte Formation. The primary rock types of the Sentinel Butte Formation are clay, siltstone, and sandstone, while the Bullion Creek Formation is mainly composed of clay and mudstone. Other rocks that appear in the formations are claystone, shale, and coal. These bedrocks can be classified as soils due to the lack of compaction between the rock particles. The bedrock geology map is shown in Figure 8 (nd.gov, 2013).

![Bedrock Geology Map](image)

**Figure 8: Bedrock Geology**

Bedrock geology of the selected landfill site is Tertiary age Sentinel Butte formation of the Fort Union Groups. It consists of alternating beds of clays, silts, sand, and lignite (ND Hub Explorer).
5.1.4 Montana (RR)

The site location is less than a mile from the Montana border. Montana’s geology should be taken into consideration for the construction of a landfill; however, similar to North Dakota, Montana is mostly a plain state with open fields and farmland. There is no abnormal geology near the North Dakota and Montana border that would affect the development of a landfill at the proposed site. The hydrogeology, subsurface geology, bedrock geology, soils, and topography on the Montana side of the border is the same as that of the site location less than a mile east of the state border.

5.2 Soil Conditions (RR)

A soil investigation of the soil material that will be used for the construction or installation of any subliner, clay liner, drainage layer, subbase, or landfill cap needs to be identified and submitted to the North Dakota Department of Health - Division of Waste Management as deemed necessary (NDCC 33-20-03.1-02, subsection 6). The soil investigation for the site area will include a map and a description of the borings, as well as the soil parameters for any soil types that are to be used throughout the construction process (NDDH, 2014). These soil parameters for the soil investigation include, but are not limited to:

1. Atterberg limits
2. Laboratory moisture-density relationship (ASTM D698 or D1557)
3. Coefficient of permeability
4. Grain-size distribution
5. Water content

Table 2 below summarizes these properties for the various soil units found at the landfill site.
The topsoil, the volcanic tuff, the till, and the clay will be removed during excavation and will be stockpiled for later use as a cap cover and a composite liner respectively. The soils that won’t be used are not described with the five parameters given above. Examples of soils that will not be used are fat clays, which undergo large volume increases when they come into contact with water. Clay volume expansion can add additional stress onto the liner system and would be detrimental to the landfill design. However, the clays with the characteristics of a good liner material will be used and stockpiled for later use as a composite liner under the secondary geomembrane liner and above the methane capture system as part of the cap.

A soil survey of the proposed site area was obtained from the Natural Resources Conservation Service (NRCS), and a map of the soils in the area is shown in Figure 9. The three main soil types in the site area are the Williams, Bowbells, and Zahl soils. The area mostly contains the Williams soil, followed by the Bowbells soil, and lastly the Zahl soil. The Williams, Bowbells, and Zahl soils consist of fine-loamy till and clay loam. The depth to the bedrock and water table is more than 80 inches below the surface for each soil type, and the soils have a permeability ranging from 0.14 to 1.42 in/hr (NRCS, 2013). The slopes of the soils are low and gentle and will

<table>
<thead>
<tr>
<th>Table 2: Soil Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Average Till</td>
</tr>
<tr>
<td>Average Clay</td>
</tr>
<tr>
<td>Average Volcanic Tuff</td>
</tr>
<tr>
<td>Average Claystone</td>
</tr>
</tbody>
</table>
not affect pre- or post-construction of a landfill. During the installation of the cap, the topsoil composed of these soil types should be at a two degree angle to increase the amount of runoff of water after rain events occur and to reduce the amount of water infiltrating the ground.

According to the provided high intensity soil survey, the soil is considered as prime farmland and no hydric soils or wetlands were found in the site area. This prime farmland has many beneficial attributes including increasing soil stability, absorbing water that could cause leachate production, and enhancing the sites appearance to society after landfill closure (BARR, 2012). Little Muddy Creek in the southern area of the site was specifically evaluated for wetlands and hydric soils; however, after a field evaluation, this area was deemed acceptable and there would be no potential hazard.
Figure 9: Surficial Soil Conditions
Surficial soil of the surrounding area consists mainly of Williams-Bowbells loams and Williams-Zahls loams (NRCS Soil Survey).
5.3 Groundwater (AS)

Information pertaining to groundwater characterization of the selected landfill site comes mainly from the twenty-four boreholes drilled throughout the property and data acquired from the various tests performed at these boreholes by Barr Engineering Company (BARR, 2013).

5.3.1 Hydrogeology of Site (AS)

The selected landfill site is located in the Charlie-Little Muddy Creek Sub-basin of the Missouri Poplar River Basin. Infiltration is mainly the result of precipitation, which averages 14.47 inches per year (NDSWC, 1961). Infiltration may cause fluctuations in groundwater during periods of heavy rain. The landfill design takes this into account and will be constructed at least five feet above the water table throughout the site. Both surface water and groundwater drain into Little Muddy Creek to the south and southeast (Figure 10). This is consistent with groundwater flow in the area. The groundwater in the southeastern section of the site will be heavily monitored to ensure that it is not being contaminated with landfill waste.
5.3.2 Water Table Elevations (AS)

According to the wells, the average depth to groundwater at the site is approximately 68.55 feet, with the shallowest depth being 30.2 feet below ground surface. The depth to groundwater limits the depth to which we can construct our landfill (BARR, 2013). For this reason, the landfill will be constructed within areas of greatest depth to increase the depth to which we can excavate without hitting the water table. The water table depths can also vary with seasonal and yearly fluctuations. The landfill will be constructed at least five feet above the water table to prevent any contamination with rising water table levels.
5.3.3 Hydraulic Conductivity and Groundwater Flow (AS)

The water table lies within the volcanic tuff unit, which is characterized mainly by sand, sandy clay, and silt. According to the groundwater topography map below (Figure 11), groundwater flows to the south and southeast. In accordance with the North Dakota Century Code (NDCC) Chapter 33-20-13 Water Protection Provisions, three wells (SB-1, SB-3, and SB-4) were installed to monitor flow upgradient and four wells (SB-20, SB-16, SB-24, and SB-21) were installed to monitor groundwater flow downgradient or sidegradient (BARR, 2013). The locations of these piezometers are shown in Figure 12.

![Figure 11: Groundwater Elevations](image)

Groundwater elevations of the selected landfill site. The contour interval is 0.2 feet. According to the contour lines, groundwater flows to the south and southeast (Created in ArcGIS and Surfer).
Table 4 below lists information for each of the seven piezometers used to monitor groundwater flow. The groundwater elevations are listed, as well as its position relative to monitoring. The wells monitor total head and hydraulic gradient, as well as allow for future testing. Samples were also taken at each well to be tested for moisture content, dry density, hydraulic conductivity, Atterberg limits, and grain size distribution. These parameters were established using the Unified Soil Classification System (USCS). Slug tests were performed at each piezometer to determine aquifer properties and hydraulic characteristics of the volcanic tuff unit. The results concluded that the horizontal hydraulic conductivity of the unit was 24.80 feet per year. The unit had an
average porosity value of 0.4 and an average hydraulic gradient of 0.002 feet per foot. From here, groundwater velocity could be established. According to the acquired data, groundwater in the area is moving at a velocity of 0.124 feet per year. This means that it would take approximately 4000 to 5000 years to travel 500 feet. The analysis proves that the unit has low permeability that highly protects groundwater in the aquifers (BARR, 2013). Detailed calculations for groundwater velocity can be observed in Appendix A.

The hydraulic conductivity values are important because the native clay may be used as a liner to prevent waste from contaminating the groundwater if the values are less than $1 \times 10^{-7}$ cm/s (NDCC). The hydraulic conductivity of the clay within the selected site varies between $8.9 \times 10^{-8}$, $7.1 \times 10^{-8}$, and $1.8 \times 10^{-7}$ cm/s (BARR, 2013). This indicates that the most of the clay is suitable to be used in our design process.

Table 4: Piezometer locations and position relative to monitoring

<table>
<thead>
<tr>
<th>Boring ID</th>
<th>Piezometer ID</th>
<th>Northing</th>
<th>Easting</th>
<th>Monitoring Position</th>
<th>Ground Surface Elevation (ft MSL)</th>
<th>Total Depth (ft BGS)</th>
<th>Depth to Water (ft BGS)</th>
<th>Groundwater Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB-1</td>
<td>PZ-5</td>
<td>434321.99</td>
<td>1105676.82</td>
<td>Upgradient/Sidegradient</td>
<td>2223.5</td>
<td>80</td>
<td>68.6</td>
<td>2154.9</td>
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<tr>
<td>SB-2</td>
<td>PZ-6</td>
<td>434328.11</td>
<td>1106323.3</td>
<td>Upgradient</td>
<td>2219.2</td>
<td>120</td>
<td>64.3</td>
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<td>PZ-7</td>
<td>434363.79</td>
<td>1106937.52</td>
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<td>Upgradient</td>
<td>2266.6</td>
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<td>113</td>
<td>2153.6</td>
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<td>SB-6</td>
<td>PZ-10</td>
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<td>Downgradient/Sidegradient</td>
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<td>123</td>
<td>63.6</td>
<td>2154.7</td>
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<td>SB-7</td>
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<td>434354.71</td>
<td>1106671.43</td>
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<td>2215.9</td>
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<td>82</td>
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<tr>
<td>SB-8</td>
<td>PZ-12</td>
<td>434377.25</td>
<td>1107293.41</td>
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5.3.4 Perched Groundwater (AS)

Perched groundwater is present throughout the volcanic tuff unit, which is approximately 30 to 100 feet below the ground surface. This does not interfere with the landfill design due to the fact that excavation and construction will occur at least five feet above the water level. Areas on the surface of the property where perched water levels are very shallow (30 to 35 feet deep) will be used to hold daily cover stockpiles, weigh stations, or office buildings. This mainly occurs in the southern half of the property in Area 4 and 5 shown in Figure 16. As stated above, piezometers will be placed upgradient and downgradient to monitor groundwater conditions and ensure that contamination has not taken place.

5.4. Topography and Geomorphology

5.4.1 Topography (RR)

The topography of the proposed landfill site is shown in Figure 13 from the NDSWC Mapservice. As shown on the topographic map, the elevation decreases going from the N1/2 of Section 26 to the S1/2 of Section 26. A noticeable elevation change can be depicted by examining the surrounding area. Surface water will flow south to the intermittent river due to the decrease in elevation. The elevation difference is approximately 40 feet from the maximum to minimum elevation over the proposed site area (NDSWC, 2013). Most of the elevation change occurs along the southern border of the NW1/4 of Section 26. This elevation change over the site area should not affect landfill development or cause any future issues. The depths to the bottom of the landfill will follow the topography and cause any leachate from the waste to drain into the pipes installed above the geomembrane layers. The leachate will naturally flow to the south, thus, the piping system for the leachate is designed to flow to Area 4 into the leachate evaporation pond.
5.4.2 Geomorphology (RR)

In this section, a description of the geomorphology of the Williston Basin as a whole, including Williams County and the landfill site area, is presented. The bedrock for Williams County and the site area is composed of the Sentinel Butte and Bullion Creek Formations originating in the Tertiary period. These bedrock formations were formed from the erosion of the Ancestral Rocky Mountains in the Paleocene Epoch. In that same period, clastic sediments were transported during the Absaroka sequence deposition. Continental and shallow marine clastic sediments went
through a deposition process during the Zuni sedimentation, and then transitioned to deeper marine environments through a transgressive process in the Cretaceous. The Laramide orogenesis then occurred to the west resulting in detritus that was deposited in deltaic, fluvial, and marginal marine environments, which regressed to the east. Large lignite deposits in the area are part of this post-orogenic regressive rock body (Gerhard, 1982). There are also Quaternary age glacial deposits from the Coleharbor Group that were deposited across Williams County, including the site area.

5.5 Tectonic Framework (AS)

The tectonic framework of the landfill site and surrounding Williston basin comes from a large depression in the Canadian Shield, mostly likely caused by an offset in the Rocky Mountain chain. Structural trends throughout the area follow the north and northwest trend of the Rocky Mountains (Gerhard, 1982). The two main structural features in the Williston basin area are the Nesson Anticline and the Cedar Creek anticline (Figure 14). Neither of these structures is located within the selected site. The craton that runs through the region is considered very stable and remains unaffected by mountain–building tectonic collisions (Carlson, 1965).
Figure 14: Tectonic Framework of the Williston Basin
The tectonic framework and main structural features of the Williston Basin (USGS)

6.0 Design Analysis

6.1 Design Constraints and Considerations

6.1.1 Location Conditions (RR)

The location conditions in Chapter 33-20-04.1-01.2 of the NDCC are described below, as well as a discussion of how the selected site meets the standards.

(a) Aquifer – The nearest aquifer in the proximity of the site location is approximately eight miles away, ranging from eight to sixteen miles traversing in a quarter-circle arc from directly south of the site location, to directly east into Williston and continuing
north as shown in Figure 15 from the North Dakota State Water Commissions (NDSWC) Mapservice (NDSWC, 2013).

(b) **Wellhead Protection** – The site is not in the vicinity of public water system.

(c) **Hundred-Year floodplain** – According to FEMA, the site location is not located within a hundred-year floodplain (FEMA, 2013).

(d) **Geologic or Manmade Features Resulting in Differential Settlement** - According to the NDSWC Mapservice and USDA web mapper soil survey, the site is located on
farmland with an intermittent river, Little Muddy Creek, to the south and Highway 2 passing through center of the site area. Differential settlement may occur immediately along the river or the highway’s ditches (NDSWC, 2013).

(e) **Unstable slopes along channels, ravines, or steep topography** – Examining the topographic map in Figure 13, it is shown that the elevation stays rather level across the quarter-mile section. The elevation decreases at a faster rate along the southern edge of the quarter due to Little Muddy Creek cutting across the landscape, however, after a field evaluation it is deemed this will not affect the landfill design (NDSWC, 2013).

(f) **Woody Draws** – According to the NDSWC Mapservice there are no woody draws within the area of consideration (NDSWC, 2013).

(g) **Critical Habitats/Endangered Species** – According to the North Dakota Game and Fish Department, there are no critical habitats or other threatened or endangered species within or near the site area (NDGF, 2013).

(h) **Principal Glacial Drift Aquifers** – There are no principal glacial drift aquifers according to the NDSWC Mapservice (NDSWC, 2013).

(i) **Drinking Water Supply Wells** – Examining the information obtained from the NDSWC Mapservice it is found that there are no down gradient drinking water supply wells within a 1000 feet of the site location (NDSWC, 2013).

(j) **Surface Water and Wetlands** – The nearest surface water site is located approximately 2.5 miles east along Highway 2. The only region where the site area comes in contact with surface water is the intermittent stream along the southern edge of the quarter-section. According to the NDFWS, the site area is not within two hundred feet
horizontally from the ordinary high water elevation of any wetland or surface water (NDFWS, 2013).

(k) **Surface Mines** – There are no surface mines located on the selected site.

(l) **State and National Parks** – The site does not contain State or National Parks according to the National Park Service (NPS, 2013).

(m) **Airports** – The North Dakota Aeronautics Commission indicates that no airports are located within 10,000 feet of the selected site.

(n) **Solid Waste Management Units and Pipelines** – The selected site does not contain any known solid waste management units and any aboveground or underground pipelines other than a culvert under Highway 2, according to aerial photos from the NDSWC Mapservice.

### 6.1.2 Potential Geohazards (AS)

Geohazards that could potentially affect landfill design relate mainly to the native soil found at the selected site. Fat clays are present throughout that have the tendency to expand when they come into contact with water. Expanding soils may cause failure in the liner system, which could lead to groundwater contamination. Fat clays will be excavated during the construction process, and a drainage system will be designed to keep as much water as possible from entering the landfill.

Geohazards that affect many locations in North Dakota include flooding and landslides. According to FEMA, the selected site is not located within a floodplain, so this is not of concern for our landfill site. The topography throughout the area is generally flat, and unstable slopes are not of concern at the site. Slopes created in the construction and excavation processes are designed at a degree that is safe for equipment to operate on and around. According to the
Department of Mineral Resources (DMR), landslides will not be a hazard at the selected landfill site.

6.1.3 Societal Aspects (PJ)

Many societal aspects need to be taken into account when designing a landfill. It is important to make the design appealing to the public, as well as protect the health and safety of the surrounding area.

State Highway 2 runs directly through the landfill site, which means there may be heavy amounts of traffic passing by the landfill each day. To prevent an unfavorable view to those passing by, fencing will be placed around the entire site. This is also required for safety reasons. A shelter belt may also be placed along the highway to create a more aesthetically appealing environment, as well as to prevent and minimize the odor from bothering drivers when the wind is in an unfavorable direction. The landfill is located in a rural area so odor will not be a problem for nearby residents.

The landfill also has the potential to affect local wildlife if proper precautions are not put into place. A daily cover of sand will be placed over the waste each day to prevent birds from coming into contact with the waste. The daily cover will also prevent wind from blowing waste out of the designated cell area. Landfill waste also produces leachate and methane gas that could potentially affect local plants and wildlife if it is not properly monitored. A liner and leachate collection system will be put into place, as well as a methane capture system to prevent these toxic wastes from harming the surrounding environment. These systems will also prevent leachate from leaking into the ground and contaminating groundwater. Multiple monitoring wells will be placed throughout the site to test groundwater levels and ensure that a leak has not occurred.
6.1.4 Economic Aspects (AS)

The goal of landfill design is to construct a system that runs efficiently and safely, while remaining economically appealing. The greater amount of waste the landfill is able to hold, as well as the number of years it is able to operate, increases the value of the design. To conserve space, geomembranes and geotextiles will be utilized in the liner system instead of clay and sand layers. This will allow the landfill to hold more waste. Native soils will be stockpiled and used in liner and cover design, as well as in daily cover. This will decrease the amount of soil we will need to import from outside sources and save money. The leachate and drainage systems will be constructed in accordance with the topography of the area. This means that the leachate and water will flow naturally into these systems, as opposed to being pumped against gravity. This will increase the efficiency of the design and decrease operation costs.

6.2 Design Approach

6.2.1 Projection of Capacity and Size (RR)

The size of the landfill is shown on the aerial photography map from the NDSWC Mapservice. North of Highway 2, the N1/2 of the NW1/4 of Section 26, is to be used for the development of an oil treatment plant and a saltwater injection well. This area spans approximately 46 acres with roughly 36 acres of useable land as shown by the purple box in Figure 16. South of Highway 2, the S1/2 of the NW1/4 of Section 26, is to be used for the landfill. This area spans approximately 107 acres with roughly 95 useable acres, 60 of which will be used for the landfill, due to the intermittent river to the south and the Highway 2 ditch to the north (NDSWC, 2013).

The area for the landfill is shown by the red, white, and blue boxes as shown in Figure 16. The total area of the landfill is approximately 60 acres where the bottom depth varies as shown by each of the boxes. Based on water table elevations, disposal of waste can occur at 45 feet below
the ground surface for Area 1 in blue, 55 feet for Area 2 in red, and 65 feet for Area 3 in white.

Three feet of clay will be used at the bottom of the liner beneath the depths given in the areas. Looking at Figures 3 and 4, cross-sections A-A’ and B-B’, the depth to the bottom of the clay is shown. Excavation will take place down to a depth of 68 feet with three feet of compacted clay already in the ground below in the Northeast part of Area 3. An additional three feet of space above the three foot clay layer will be used for the liner system, leaving 65 feet for waste. This will be addressed further in the Final Design section. From here the elevation decreases moving west, therefore, the depth of excavation will follow the depths shown in Figure 16 below for each of the areas. When moving to the west from the northeast corner of the landfill, the clay will have to be excavated and then replaced with a three foot layer for the bottom liner once the desired depth has been reached. The volume of clay in the excavated area for the landfill, found from the cross sections shown in Figures 3, 4, 6 and 7, is 81,300,000 ft³ (3,000,000 yd³). This will satisfy the requirements for the three feet at the bottom of the landfill for the clay liner, for the three foot clay layer that will be used as part of the landfill cap, and for the one-foot clay layers that will be used after every five feet of waste to prevent seepage. The volume of volcanic tuff, or till, in the excavated area for the landfill, found from the same cross-sections, is approximately 24,328,000 ft³ (900,000 yd³). This volume of till will meet the requirements for the use as daily cover for the waste. The volumes of clay and till were found by interpolating the thickness of each of the layers in the five different cross-sections. The thickness was averaged between the cross-sections and then multiplied by the area of the landfill. The excess soils will be placed in Area 4, shown in Figure 16 below. The landfill will have a twelve-degree slope from the ground surface to the bottom of the landfill along with the twelve-degree slope up to 55 feet above the ground surface with berm grades. Therefore, the landfill will have a capacity of
over 205,433,196 million cubic feet, approximately 7.6 million cubic yards, of volume to dispose of waste (NDSWC, 2013). The volume of the landfill was calculated with twelve-degree slopes for below and above ground berms. When calculating the volume, the slopes volume was calculated using the area of a triangle and multiplying it by the length of the side for all of the sides covering the perimeter of the landfill. This volume covers the perimeter of the landfill and goes up until the twelve-degree slopes reach the top or bottom of the landfill. The remaining volume of the landfill was calculated by measuring the area of the triangles and rectangles within the slopes of the landfill and then multiplying them by the height from the bottom of the landfill to the top berm, 55 feet above ground. Calculations for the volume are shown in Appendix B. It should also be noted that according to North Dakota state regulations waste cannot be exposed to air for more than 48 hours at one time, and daily cover will be used composed of the till from the initial excavation.
6.2.2 Years of Operation and Waste Types (RR)

The landfill will have a volume of approximately 7.6 million cubic yards for waste disposal. The projected annual disposal volume is 300,000 cubic yards including the waste, daily cover, and
the one-foot clay layers per every five feet of waste, thus allowing for a minimum landfill operation of 25 years.

The waste types included in disposal are special waste, well cuttings, inert waste, and other oil field related wastes. The North Dakota Department of Health Division of Waste Management provides a thorough description of special waste able to be disposed. (NDDH, 2013).

6.2.3 Description of Operation (RR)

The landfill area will be excavated to the desired depth of the clay layer, as shown in Figure 16 above, with heavy machinery, and the clay from the excavation will be stockpiled for lining the disposed waste layers. The area of disposal will be filled with waste starting from the bottom and up. Each successive layer of 5 feet will be topped with a foot of clay to prevent seepage from waste material.

Other facilities not mentioned, such as maintenance buildings, access roads, groundwater monitoring wells, lined disposal areas, etc., may be outside the site area or North of Highway 2. The area North of Highway 2 is outlined in purple in Figure 16 above. Three monitoring wells are developed upstream and four are developed downstream as is required by the state of North Dakota for a multiple liner landfill (NDDH, 2014). These monitoring wells will be used to distinguish if a leak has occurred by comparing the water qualities between the wells upstream and downstream. Waste to be disposed in the lined disposal area will be tested to meet requirements set forth by the permit.

6.2.4 Costs (AS)

Cost analysis performed at the selected site was split into four main categories: site investigation, landfill construction, overhead costs, and operating costs. Landfills typically have high upfront
construction costs, but day to day operating costs remain relatively low. A detailed cost analysis can be observed in Appendix C. Site investigation costs were estimated to be a total of $784,480. This includes the purchase price, physical site investigations performed, and written preliminary design reports. Landfill construction costs, including excavation, cell design, and leachate liner system, was estimated to be a total of $11,539,465.58. Overhead costs include construction management, QA/QC, and support facilities. This was estimated to cost approximately $2,177,230. Operating costs were estimated to be approximately $1,490,000. This is high due to the costs associated with purchasing heavy operating equipment. Day to day operating costs will consist mainly of fuel and equipment maintenance, which will be determined on a yearly basis. The total cost to design and construct the special waste landfill will be approximately $16,000,000. This does not include landfill closure and maintenance costs (Duffy, D.P., 2005). A tipping fee of $35.00 per ton will be charged at the WISCO Special Waste Landfill, with approximately 1300 tons of waste per day entering the site. A weigh scale will be used to monitor the amounts of waste coming into the landfill each day.

6.3 Design Assumptions

6.3.1 Final Design (RR)

The creation of appropriate berms, embankments, and below ground analysis will occur before liner installation. A survey of the subgrade area is needed before constructing the liner and the subgrade surface should be smooth and absent of material before construction begins. Information relating to this survey is presented throughout this report (NDDH, 2014).

The preliminary design will include the construction of the landfill from the base up following the regulations given in the NDCC 33-20-10-03 and 33-20-10-04 for waste disposal and landfill cover and closure. The landfill will be excavated to certain depths according to Figure 16.
Excavation will take place so there are 3 feet of clay and 3 feet for the liner system below the depths specified. Excavation will take place with heavy machinery and will consist of building proper berms during the excavation process. The volcanic tuff or till, removed during excavation, should be stockpiled along the southern edge of Area 4 shown in Figure 16 for later use as daily cover. The first layer above the subsoil, the secondary composite liner, will consist of three feet of compacted clay from the excavation process with a permeability with an order of magnitude of $10^{-8}$ centimeters per second. The state of North Dakota requires clay to be at least $1 \times 10^{-7}$ centimeters per second (NDCC, 2014). A secondary geomembrane at least eighty mil thick (2.0 mm) will be above the secondary composite liner of clay and a geonet will be above the secondary geomembrane. The geonet will be used instead of a gravel or sand drainage layer to decrease the volume taken up by these gravels and sands and must have a permeability of at least $1 \times 10^{-3}$ centimeters per second. Continuing upwards, a geotextile will be used instead of a compacted clay layer to also save volume, and following the geotextile will be the primary composite liner. The primary composite liner will include a geosynthetic clay liner overlain by the primary geomembrane at least eighty mil (2.0 mm) thick. Above the primary composite liner there will be a geocomposite drain for the drainage layer to prevent buildup of leachate. According to North Dakota state regulations no more than twelve inches of leachate can be on top of the liner systems at once, whether it be the primary or secondary geomembrane liner. A geotextile is placed on top of the geocomposite drain to reduce the flow of leachate. The waste overlies the latter layers and must be completely covered within a forty-eight hour period after exposure to air with the till from the excavation process. Once the landfill is completely full of waste, and may no longer be used to store any additional special waste, a cap is used to seal off the landfill from environmental factors.
The final closure of the landfill must be at least eight feet thick and include many layers as will be discussed once again going from the bottom (above the waste) to the top (the surface). Directly above the special waste will be a methane capture system to capture the methane that is released by the special waste as it decomposes. Large amounts of methane buildup above the waste can cause the failure of the landfill cap, which in turn, can cause the leakage of leachate polluting the environment, or the addition of water from infiltration causing more leachate to form. Above the methane capture system there will be a three foot compacted clay layer from the stockpile with a hydraulic conductivity no greater than $1 \times 10^{-7}$ centimeters per second. Following the compacted clay layer will be a geomembrane liner at least eighty mil (2.0 mm) thick overlain by a drainage layer of sand at least six inches thick with a transmissivity of $3 \times 10^2$ centimeters squared per second or greater. The final layer to cap off the landfill will be a topsoil layer at least thirty-six inches thick to prevent the freezing of the synthetic liner and compacted clay layer. The top twelve inches of the topsoil are able to support plant growth and are mostly composed of the Williams, Bowbells, and Zahl soils consisting of fine-loamy till and clay loam considered to be prime farmland. According to the Environmental Protection Agency (EPA), the post closure period of a special waste landfill is thirty years (EPA, 2014). The site of the landfill, post closure, will be a park containing various types of small vegetation to provide stability to the soil and absorb water that may be infiltrating the soil. The landfill design options described in this section are based off of the book *Designing with Geosynthetics* by Robert Koerner (1994).

6.3.2 Leachate Collection System

A gravel road will be constructed and properly maintained on the west side of the site area for access to the landfill. Those accessing the landfill will enter through Area 4 shown in Figure 16 above. Area 4 has sufficient space for busy truck traffic and will contain a weigh station for all
those looking to deposit their special waste at the landfill. Area 5, shown in Figure 16 above, will contain the leachate evaporation pond. The leachate collected throughout the landfill via the leachate collection system (LCS) will be pumped into the leachate evaporation pond. The LCS will be comprised of the primary LCS, where the drainage pipes are located above the primary geomembrane, and the secondary LCS, where the drainage pipes are located above the secondary geomembrane. The pipes for the LCS will be schedule 80 polyvinyl chloride (PVC) and 8” in diameter as specified by the NDDH. The LCS will drain to a main location within each cell as shown in Figure 17, following the designed 2’ slopes within each cell as shown in Figures 18, 19, and 20. The leachate collected between all three cells will flow into the pumping system located along the center of cells 1 and 3. The leachate from cell 1 will follow the designed 2’ slopes to the center of the cell and enter the pumping system. The leachate from cell 2 will flow down a 2’ slope from south to north into cell 3 and then progress along the 2’ slopes in cell 3, which collect the leachate from cells 2 and 3 into the pumping system. This pumping system will then direct the flow of leachate to the eastern edge of Area 3 while passing through the center of cells 1 and 3. The leachate will then continue to be pumped along the perimeter of the site area south along Areas 3 and 2. From here the pumping system will direct the flow of leachate into the leachate evaporation pond outlined in yellow in Figure 17, in the middle of Area 5. The amount of leachate accumulated each year depends on many factors including the amount of precipitation, evaporation rates, decomposition rates, temperature, pressure, amount of water in the waste, waste volumes, etc. Leachate accumulation will be minimal during the beginning of the landfills life span. The leachate evaporation pond is designed to have a large surface area of 120,000 ft² to increase evaporation rates. Western North Dakota is a semi-arid environment with low average precipitation rates, and the evaporation rates generally exceed the precipitation rates and the
amount of leachate accumulated each year (NOAA, 2014). Years with irregular high precipitation rates, in which the evaporation rate is lower than the precipitation rate, may have to acquire the transport of leachate to a special waste treatment facility. The latter is not likely to occur due to the large volume of leachate that is able to be collected in the leachate evaporation pond. The volume of the leachate evaporation pond is discussed later in this report.

The previous explanation for the leachate flow and transport to the leachate evaporation pond can be summarized by Figure 17, showing the direction of leachate flow, and Figures 18, 19, and 20, showing the cross-sectional view of the slopes designed within each cell. The arrows in Figure 17 indicate the direction the leachate will flow based off of the designed \( Z \) slopes. The thicker arrows represent the pumping system, where the leachate collects, used to raise and transport the leachate into the leachate evaporation pond. The leachate collects into the pumping system at the end of the LCS pipes shown as yellow dots in Figure 17 below. The areas outlined in black in Figure 17 represent the bottom of each of the cells, therefore, excluding the lengths of the \( 1\) slopes. The initial \( 12\) slopes to reach the bottom of the landfill are excluded in the LCS analysis because leachate along these slopes will flow freely down onto the \( 2\) slopes at the bottom of the cells and will then act as the leachate previously discussed above. Figure 18, showing the cross section from A-A', consists of ten separate \( 2\) slopes from the western edge of cell 1 to the eastern edge of the cell. Ten different \( 2\) slopes are needed over the 1000 foot length of the bottom of cell 1, thus, only 3.5 feet of depth is needed for gravity drainage of the leachate in the cell. The pumping system is centered in cell 1 to reduce the depth required for gravity drainage of leachate flowing north and south. Figure 19, showing the cross section from B-B', consists of one \( 2\) slope dipping downwards from south to north. Only one \( 2\) slope is used, thus, only 3.5 feet of depth is needed for the gravity drainage of leachate along the 100 feet from the
southern edge of cell 2, to the slope down to cell 3. Figure 20, showing the cross section from C-C’, consists of eight separate \( Z \) slopes from the western edge of cell 3 to the eastern edge of the cell. Eight different \( Z \) slopes are needed over the 800 foot length of the bottom of cell 3, thus, only 3.5 feet of depth is needed for gravity drainage of the leachate in the cell. Leachate from cell 2 enters cell 3 from the southern edge following the \( Z \) slope into the pumping system. The pumping system is centered in cell 3 to reduce the depth required for gravity drainage for leachate flowing north and south. Calculations for depth required for gravity drainage is shown in Appendix B.
Figure 17: Leachate Flow and Collection System
Aerial view of the site showing the flow and collection of leachate in the LCS (NDSWC Mapservice).
Table 5: Leachate liner system key

<table>
<thead>
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<th>Key:</th>
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<tr>
<td>Primary/Secondary Geomembrane</td>
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<td>Geonet (Drainage Layer)</td>
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<tr>
<td>Geotextile</td>
</tr>
<tr>
<td>Geosynthetic Clay Liner</td>
</tr>
<tr>
<td>Special Waste</td>
</tr>
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</table>

Figure 18: Cross Section of Cell 1
Cross section of cell 1 showing the liner system and ten two-degree slopes.
Figure 19: Cross Section of Cell 2
Cross section of cell 2 showing the liner system and one two-degree slope.

Figure 20: Cross Section of Cell 3
Cross Section of cell 3 showing the liner system and eight two-degree slopes.
6.3.3 Leachate Evaporation Pond (RR)

The leachate evaporation pond located in Area 5 from Figure 16 will be designed to store a maximum volume of approximately 33,000 yd$^3$ of leachate. The site of the leachate evaporation pond will be excavated with a slope of twelve degrees down to a depth of 14 ft., with 10 ft. for leachate accumulation, 1 ft. for a sand drainage layer underlain by the primary geomembrane, and 3 ft for a protective clay layer. The sand and clay used will be from the initial excavation stockpiled along the southern edge of Area 4 with a transmissivity of $3 \times 10^{-2}$ cm$^2$/s or greater for sand and a permeability on the order of $1 \times 10^{-8}$ cm/s for clay as is required by the NDDH. The leachate evaporation pond will be 600 feet long running east to west and 200 feet north to south giving a surface area of 120,000 ft$^2$ (13,333 yd$^2$). This large surface area is used to increase the evaporation rate from the leachate evaporation pond.

7.0 Execution of the Design (AS and RR)

After developing the final design, the site area will look as follows with dimensions shown in Figure 21 below. Trucks and other vehicles entering the site facility will turn off of Highway 2 onto the gravel road located on the western edge of the site area. The gate will be open during the hours of operation of the site facility, allowing vehicles access to the weigh scale to collect fees based the weight of the waste per ton. After these vehicles are weighed they will be directed to the cell being filled. Daily cover is provided from the stockpiles shown below.
7.1 Existing Systems and Integration (AS)

The landfill site was originally used as an agricultural field for cultivating crops. This indicates that no existing landfill systems were present at the start of construction. Privately owned domestic and stock wells were installed in previous years, which gave a general idea of groundwater levels and flow in the area, but further investigations were performed and more wells were drilled at the site to obtain more detailed information. All other systems utilized in landfill design were installed throughout the construction process.

7.2 System Instrumentation (AS and RR)
System instrumentation utilized in landfill operations includes, but is not limited to:

- Piezometers to monitor groundwater;
- Monitoring leachate accumulation to the leachate evaporation pond;
- Weigh scale to measure amount of waste coming in; and
- Monitoring of the methane capture system.

Specific details relating to these systems are detailed throughout the report.

7.3 Specified Equipment Needed (RR)

7.3.1 Maintenance Building and Equipment (RR)

A maintenance building used for the storage of equipment and heavy machinery will be constructed in Area 4, as seen in Figure 21. The equipment will consist of light everyday equipment to heavy machinery including a front end loader, landfill compactor, bulldozer, and dump truck. These will be used on a daily basis to move waste into certain cells and soil from the stockpile to be used as daily cover. The construction of the three cells will be completed by a third party contractor using their own equipment.

7.3.2 Signs and Fencing (RR)

Litter fences will be constructed around the perimeter of the facility to prevent blowing litter and debris from affecting the surrounding land and neighbors. The litter fences will be constructed by Metta Technologies and will be 15 feet in height and 8 feet wide. The total perimeter of the site area below Highway 2 is approximately 8240 feet. Each litter fence is 24 feet in length, therefore, 344 fences will be ordered to completely cover the site area South of Highway 2. Signs will be placed at the entrance of the landfill in Area 4 to give information and specifications about the landfill, which will include the following:
- Landfill name and permit number;
- The days and hours the landfill is open;
- Specific waste allowed;
- The names and telephone numbers of the owners and operators; and
- Restrictions to the landfill itself.

Any additional information can be acquired inside the administrative building or by calling the landfill facility owner. Access to the landfill will be through the main entrance located at the West side of Area 4 shown in Figure 21. During hours of closure the landfill facility entrance will be blocked off by a gate at the main entrance.

7.4 Permitting (AS)

Rules and regulations set forth by the North Dakota Department of Health – Division of Waste Management requires those wishing to construct a landfill to undergo a permitting application procedure. The first step in the process involves selecting a site that is both geologically and hydrogeologically suitable for landfill operations. According to the North Dakota Administrative Code (NDAC) subsection 1 of section 33-20-04.1-01:

“No solid waste management facility may be located in area which result impacts to human health or environmental resources or in an area which unsuitable because of reasons of topography, geology, hydrology, or soils.”

A pre-application must be submitted to the NDDH detailing the proposed landfill site, projected size of operation, as well as provide adequate approval from the local zoning authority. The pre-application should contain maps characterizing the geological and hydrogeological conditions of the selected site, as well as the general location standards listing the site’s proximity to features
such as wetlands, gravel pits, or woody draws that may prevent the site from becoming approved.

If the site meets the conditions listed above, a permit application may be filed, as well as a report detailing the following parameters:

1. Description of accepted waste types;
2. Description of site geology and soil conditions;
3. Site development and landfill layout;
4. Plan of operation;
5. Open burning and dust control methods (if applicable);
6. Plans for separating topsoil and subsoil;
7. Methods used for inspection and reporting;
8. Description of site access and facility signs; and
9. Written closure plan.

This information is further detailed by the North Dakota Department of Health – Division of Waste Management, and can be observed on their website.

7.5 Monitoring Plans

7.5.1 Groundwater Monitoring (AS)

According to the North Dakota Department of Health, a groundwater monitoring system must be put into place to ensure that the landfill is not contaminating the surrounding area. Seven monitoring wells were installed throughout the selected landfill site, as seen in Figure 12 above. The piezometers are constructed of two-inch PVC pipe and have 10-foot long screens with 0.01-inch slots and lockable steel protective casings. Baseline water parameters must be established to determine the groundwater elevation and quality that monitoring tests will be
compared to. To establish baseline groundwater elevation and water quality, four rounds of sampling will be performed within the first six months, taking seasonal fluctuations into account. Sampling tests groundwater parameters such as pH, temperature, specific conductivity, oxidation potential, and dissolved oxygen. These were established for the selected site and can be observed in Table 6 below (BARR, 2013).

<table>
<thead>
<tr>
<th>Piezometer</th>
<th>pH</th>
<th>Temperature (°C)</th>
<th>Specific Conductance at 25° (μS/cm)</th>
<th>Oxidation Reduction Potential (mV)</th>
<th>Dissolved Oxygen (mg/L)</th>
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</thead>
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<td>8.86</td>
<td>2805</td>
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<td>7</td>
<td>5.34</td>
<td>7.56</td>
<td>2078</td>
<td>110</td>
<td>4.79</td>
</tr>
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Once baseline groundwater criteria have been established, the wells will be subjected to two sampling rounds per year. This may be altered depending on the results of the baseline monitoring tests. The following information must be reported to the NDDH annually:

- Static water level for each monitoring well to the nearest 0.01 foot from a surveyed reference point;
- Stabilization test results for each well;
- Number of gallons of water and number of well volumes removed before sampling;
- Sampler’s field comments regarding anything unusual about the well;
- Deviations in sampling or analysis techniques;
- Laboratory results;
- Water table or potentiometric maps of each hydrogeological unit;
- QA/QC evaluation of data;
• Statistical analysis of results; and
• Recommendations and conclusions

If anything unusual is reported, additional monitoring tests will be performed and preventative action will be taken to ensure groundwater in the area is not contaminated with landfill waste (NDDH, 2013).

7.5.2 Storm Water Protection Plan (AS)

A storm water monitoring plan must be put into place in accordance with the North Dakota Pollutant Discharge Elimination System (NDPDES). This type of system is needed to prevent surface water run-on from rainwater or areas surrounding the landfill site. It is also needed to control surface water discharges and to prevent erosion at the site. Plastic drainage pipes and storm liners will collect water from runoff areas around the landfill and channel it to drainage ditches that will surround the entire landfill perimeter. The ditches will be lined with gravel and transfer the water to a collection pond to be tested. The surface water samples must be tested for the following parameters and meet the requirements set forth by the NDPDES before it can be pumped off site:

• pH: 6.0 – 9.0 S.U.
• Total Suspended Solids – 100 mg/L
• Chemical Oxygen Demand (COD) – 120 mg/L
• Total Lead – 0.0186 mg/L
• Oil and Grease – No visible sheen (15 mg/L)

If the samples exceed these parameters, they will be treated as leachate and sent to the leachate collection pond for proper disposal (NDPDES, 2013).
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• Total Lead – 0.0186 mg/L
• Oil and Grease – No visible sheen (15 mg/L)

If the samples exceed these parameters, they will be treated as leachate and sent to the leachate collection pond for proper disposal (NDPDES, 2013).
7.5.3 Methane Capture (PJ)

Landfills are known for producing methane as a byproduct as the various types of refuse continue to decompose. This gas has been historically allowed to escape into the atmosphere, where it contributes to global warming. In recent years, however, capture systems have been implemented to help use the waste byproduct as a fuel source. To implement this in the design of a landfill horizontal perforated high density polyethylene (HDPE) pipes should be placed in each cell with a distance of four feet horizontally separating each pipe. The pipe size used is 4 inches in diameter. The pipes are buried just above the waste level. They are then connected to a series of collecting pipes. The methane then rises through the perforated pipes and is then transported through the transportation pipes to a processing plant. As each cell has an estimated volume of 6,944 cubic yards, 62 pipes will needed to be placed horizontally through each cell with a horizontal separation distance of 10 feet between each pipe.

The width of site containing cells will be 2500 feet across. Assuming each pipe section to be 20 feet in length, the total area will require 250 separate lengths of pipe running across. Total piping sections for cell one will be 4,092 sections, giving a total length of 81,840 feet of piping. Cell 2 will have 2,280 sections of piping, giving a total length of 45,600 feet of piping. Cell 3 will require 5,616 sections of piping, giving a total length of 112,320 feet of piping. Total piping for the entire site will be 242,280 feet. Using piping from Dultmeier, this will have a total cost of $39,733.92.
### 8.0 Project Schedule

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<th>Task Name</th>
<th>Duration</th>
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<td>Mon 12/22/14</td>
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9.0 References


Department of Mineral Resources. Areas of Landslides. https://www.dmr.nd.gov/ndgs/landslides/Williston/100k/wlst_100k_1.pdf


Appendix A

Groundwater Velocity Calculation (AS):

The following data was collected from slug tests performed at piezometers installed at the selected landfill site.

<table>
<thead>
<tr>
<th>Horizontal Hydraulic Conductivity (K_{h mean})</th>
<th>24.80 ft/year</th>
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<tr>
<td>Average Porosity (n_v)</td>
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<tr>
<td>Average Hydraulic Conductivity (i)</td>
<td>0.002 ft/ft</td>
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</table>

Groundwater velocity can then be calculated using Equation 1 below:

\[ v_a = \frac{K_{h mean} \times i}{n_v} \]  

\[ v_a = \frac{24.80 \text{ ft/yr} \times 0.002 \text{ ft/ft}}{0.40} = 0.124 \text{ feet/year} \]  

(Eq. 1)

The time it would take for any contamination to flow 500 feet can be calculated as follows:

\[ T = \frac{500 \text{ feet}}{0.124 \text{ feet/year}} = 4033 \text{ years} \]
Appendix B

Volume calculation for landfill (RR):

Volume of Slopes:
With a twelve degree slope for the berm grades it will take a certain length before reaching the top or bottom of the berm grades. The horizontal length to reach the bottom or top of the landfill for each depth or height above or below the ground surface is shown below. The areas corresponding to the depths or heights are from Figure 16.

For 45 feet (Area 1):
\[ \text{Length} = \frac{45 \text{ ft}}{\tan(12)} = 211.71 \text{ feet} \]

For 55 feet (Area 2):
\[ \text{Length} = \frac{55 \text{ ft}}{\tan(12)} = 258.75 \text{ feet} \]

For 65 feet (Area 3):
\[ \text{Length} = \frac{65 \text{ ft}}{\tan(12)} = 211.71 \text{ feet} \]

Evaluating the perimeter of the landfill from the North Dakota State Water Commission Map Services, the total perimeter of the landfill is multiplied by the area of the triangle for each slope to get the volume. Calculations are shown below for the volume of the slopes for each area where subscript, “B”, is for below the ground surface, subscript, “A”, is for above the ground surface, and subscript, “S”, is to denote slope for volume of the slope. The base, “b”, is the distance from the perimeter of the landfill to the bottom or top flat surface of the landfill as shown calculated above. The height, “h”, is the depth to the bottom of the landfill or the height to the top of the landfill from the ground surface. The length, “L”, is found from the North Dakota State Water Commission Map Services and is the distance the slopes range across each area.

\[ V_{\text{Triangular prism}} = \frac{1}{2} \times b \times h \times L \tag{Eq. 1} \]

Area 1:

\[ V(1)_B = \frac{1}{2} (211.7 ft)(45 ft)(1261.7 ft) + \frac{1}{2} (211.7 ft)(45 ft)(421.7 ft) + \frac{1}{2} (211.7 ft)(45 ft)(1105 ft) \]
\[ V(1)_B = 13,281,846.3 \text{ ft}^3 \]

\[ V(1)_A = \frac{1}{2} (258.75 ft)(55 ft)(1261.7 ft) + \frac{1}{2} (258.75 ft)(55 ft)(421.7 ft) + \frac{1}{2} (258.75 ft)(55 ft)(1105 ft) \]
\[ V(1)_A = 19,841,208.8 \text{ ft}^3 \]

\[ V(1)_S = V(1)_B + V(1)_A = 33,123,055.1 \text{ ft}^3 \]

Using the same procedure as above, the volume of the slopes of areas 2 and 3 are calculated giving the volumes shown below.

Area 2:

\[ V(2)_S = 20,009,137.5 \text{ ft}^3 \]
Area 3:

\[ V(3)_s = 36,287,767.2 \text{ ft}^3 \]

**Total Volume of Slopes:**

\[ V_{\text{slopes}} = 33,123,055.1 \text{ ft}^3 + 20,009,137.5 \text{ ft}^3 + 36,287,767.2 \text{ ft}^3 \]

\[ V_{\text{slopes}} = 89,419,959.7 \text{ ft}^3 \]

**Volume inside of the slopes:**
The remaining volume of the landfill is the volume inside that found in the section above. The volume inside of the slopes is calculated below using Equation 1 above and Equation 2 shown below where the length, “L”, and width, “w”, are found from using the North Dakota State Water Commission Map Services. The height is calculated by adding the depth below the ground surface to the height above the ground surface.

\[ V_{\text{Rectangular Prism}} = L \times w \times h \]  \hspace{1cm} (Eq. 2)

**Area 1:**

\[ V(1) = \frac{1}{2} (1050 \text{ ft})(206 \text{ ft})(100 \text{ ft}) + (1050 \text{ ft})(210 \text{ ft})(100 \text{ ft}) \]

\[ V(1)_l = 32,865,000.0 \text{ ft}^3 \]

Using the same procedure as above, the volume of areas 2 and 3 are calculated giving the volumes shown below.

**Area 2:**

\[ V(2)_l = 6,300,945.0 \text{ ft}^3 \]

**Area 3:**

\[ V(3)_l = 76,847,292.0 \text{ ft}^3 \]

**Total Volume Inside of Slopes:**

\[ V_{\text{inside}} = 32,865,000.0 \text{ ft}^3 + 6,300,945.0 \text{ ft}^3 + 76,847,292.0 \text{ ft}^3 \]

\[ V_{\text{inside}} = 116,013,237 \text{ ft}^3 \]

**Total Volume of WISCO landfill:**
Additional depth/number of slopes required for gravity drainage of leachate in the LCS (RR):

Depth/number of slopes required for the flow of leachate:
The maximum length the leachate will flow down a Z slope before entering the LCS is calculated by taking the length of the dimensions of a cell and subtracting the distance of the Z slopes along the edge of the cell. The Z slopes are subtracted because leachate will flow down these slopes without any additional depth required, unlike the Z slopes. The lengths found are represented by the black outlined areas in Figure ?? . This analysis is done to make sure the Z slopes don’t cause too much additional depth to prevent the landfill from being excavated too close to the water table. First the amount of depth required for a Z slope over 100 ft. will be found.

\[
\text{Depth} = (100 \text{ft})(\tan(\frac{\pi}{6}))
\]
\[
\text{Depth} = 3.5 \text{ ft.}
\]

Cell 1:

\[
\text{Hor. Length of } Z \text{ Slope} = 1260 \text{ ft} - 212 \text{ ft} - 47\text{ft}
\]
\[
\text{Hor. Length of } Z \text{ Slope} = 1001 \text{ ft}
\]
Cell 1 has ten Z slopes, therefore,

\[
\text{Length of each Slope} = \frac{(1001 \text{ ft})}{(10 \text{ slopes})}
\]
\[
\text{Length of each Slope} = \text{Approximately} 100 \text{ ft}
\]
Therefore, 3.5 ft. is required for the gravity drainage of leachate in cell 1.

Cell 2:

\[
\text{Hor. Length of } Z \text{ Slope} = 365 \text{ ft} - 259 \text{ ft}
\]
\[
\text{Hor. Length of } Z \text{ Slope} = 106 \text{ ft}
\]
Cell 2 has one Z slope, therefore,

\[
\text{Length of each Slope} = \frac{(106 \text{ ft})}{(10 \text{ slopes})}
\]
\[
\text{Length of each Slope} = \text{Approximately} 100 \text{ ft}
\]
Therefore, 3.5 ft. is required for the gravity drainage of leachate in cell 2.

Cell 3:

\[
\text{Hor. Length of } Z \text{ Slope} = 1160 \text{ ft} - 306 \text{ ft}
\]
\[
\text{Hor. Length of } Z \text{ Slope} = 854 \text{ ft}
\]
Cell 3 has eight Z slopes, therefore,

\[
\text{Length of each Slope} = \frac{(854 \text{ ft})}{(8 \text{ slopes})}
\]
\[
\text{Length of each Slope} = \text{Approximately} 100 \text{ ft}
\]
Therefore, 3.5 ft. is required for the gravity drainage of leachate in cell 3.
Appendix C

Cost Analysis (AS and RR):

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<th>Units Needed</th>
<th>Total Cost</th>
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<tr>
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*included in Physical Site Investigation

Subtotal $784,480.00

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Subtotal $11,539,465.58

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<td>Leachate Liner System:</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary/Secondary Geomembrane</td>
<td>$0.75</td>
<td>per square foot</td>
<td>5363962.2</td>
<td>$4,022,971.65</td>
</tr>
<tr>
<td>Geonet (Drainage Layer)</td>
<td>$0.34</td>
<td>per square foot</td>
<td>2681981.1</td>
<td>$911,873.57</td>
</tr>
<tr>
<td>Geotextile</td>
<td>$0.50</td>
<td>per square foot</td>
<td>2681981.1</td>
<td>$1,340,990.55</td>
</tr>
<tr>
<td>Geosynthetic Clay Liner</td>
<td>$0.46</td>
<td>per square foot</td>
<td>2681981.1</td>
<td>$1,233,711.31</td>
</tr>
<tr>
<td>Piping Network</td>
<td>$8.00</td>
<td>per foot</td>
<td>3200</td>
<td>$25,600.00</td>
</tr>
<tr>
<td>Aggregate Filler</td>
<td>$25.00</td>
<td>per linear foot of pipe</td>
<td>3200</td>
<td>$80,000.00</td>
</tr>
<tr>
<td>Sump Installation</td>
<td>$20,000.00</td>
<td>each</td>
<td>1</td>
<td>$20,000.00</td>
</tr>
<tr>
<td>Sump Piping Network</td>
<td>$10,000.00</td>
<td>each</td>
<td>1</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Leachate Collection Pond</td>
<td>$80,000.00</td>
<td>each</td>
<td>1</td>
<td>$80,000.00</td>
</tr>
</tbody>
</table>

Subtotal: $11,539,465.58
### Construction Management:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Price Per Unit</th>
<th>Unit</th>
<th>Units Needed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>$5,000.00</td>
<td>per acre</td>
<td>60</td>
<td>$300,000.00</td>
</tr>
<tr>
<td>Surveying and Drawing Costs</td>
<td>$8,000.00</td>
<td>each</td>
<td>1</td>
<td>$8,000.00</td>
</tr>
</tbody>
</table>

### QA/QC:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Price Per Unit</th>
<th>Unit</th>
<th>Units Needed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthwork</td>
<td>$18,000.00</td>
<td>each</td>
<td>1</td>
<td>$18,000.00</td>
</tr>
<tr>
<td>Liner Management System</td>
<td>$19,000.00</td>
<td>each</td>
<td>1</td>
<td>$19,000.00</td>
</tr>
<tr>
<td>Leachate Management System</td>
<td>$8,000.00</td>
<td>per acre</td>
<td>60</td>
<td>$480,000.00</td>
</tr>
</tbody>
</table>

### Support Facilities:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Price Per Unit</th>
<th>Unit</th>
<th>Units Needed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative Building</td>
<td>$80.00</td>
<td>per square foot</td>
<td>2500</td>
<td>$200,000.00</td>
</tr>
<tr>
<td>Maintenance Building</td>
<td>$60.00</td>
<td>per square foot</td>
<td>10000</td>
<td>$600,000.00</td>
</tr>
<tr>
<td>Fencing</td>
<td>$15.00</td>
<td>per linear foot</td>
<td>8850</td>
<td>$132,750.00</td>
</tr>
<tr>
<td>Gates</td>
<td>$1,500.00</td>
<td>per linear foot</td>
<td>25</td>
<td>$37,500.00</td>
</tr>
<tr>
<td>Signage</td>
<td>$15.00</td>
<td>each (per 200 ft)</td>
<td>44</td>
<td>$660.00</td>
</tr>
<tr>
<td>Weigh Scale</td>
<td>$125,000.00</td>
<td>each</td>
<td>1</td>
<td>$125,000.00</td>
</tr>
<tr>
<td>Wheel Wash Facility</td>
<td>$200,000.00</td>
<td>each</td>
<td>1</td>
<td>$200,000.00</td>
</tr>
<tr>
<td>Gravel Road</td>
<td>$2.00</td>
<td>per square foot</td>
<td>28160</td>
<td>$56,320.00</td>
</tr>
</tbody>
</table>

**Subtotal:** $2,177,230.00

### Operating Costs:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Price Per Unit</th>
<th>Unit</th>
<th>Units Needed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front End Loader (963)</td>
<td>$150,000.00</td>
<td>each</td>
<td>1</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>Dozer (D8T)</td>
<td>$650,000.00</td>
<td>each</td>
<td>1</td>
<td>$650,000.00</td>
</tr>
<tr>
<td>Landfill Compactor (836H)</td>
<td>$550,000.00</td>
<td>each</td>
<td>1</td>
<td>$550,000.00</td>
</tr>
<tr>
<td>Pick-up Truck</td>
<td>$20,000.00</td>
<td>each</td>
<td>2</td>
<td>$40,000.00</td>
</tr>
</tbody>
</table>

**Miscellaneous:**

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Price</th>
<th>Unit</th>
<th>Units Needed</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leachate Treatment</td>
<td>$10,000.00</td>
<td></td>
<td>1</td>
<td>$10,000.00</td>
</tr>
<tr>
<td>Sampling and Monitoring</td>
<td>$30,000.00</td>
<td></td>
<td>1</td>
<td>$30,000.00</td>
</tr>
<tr>
<td>Engineering Services</td>
<td>$60,000.00</td>
<td></td>
<td>1</td>
<td>$60,000.00</td>
</tr>
</tbody>
</table>

**Subtotal:** $1,490,000.00

Additional equipment operation costs such as loan payments, fuel, oil, and maintenance will be determined on a yearly basis.

<table>
<thead>
<tr>
<th>Daily Income</th>
<th>Price</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tipping Fee:</td>
<td>$35.00</td>
<td>per ton</td>
</tr>
<tr>
<td>Daily Waste:</td>
<td>1300</td>
<td>tons per day</td>
</tr>
<tr>
<td>Daily Income:</td>
<td>$45,500.00</td>
<td>per day</td>
</tr>
</tbody>
</table>

**TOTAL COST:** $15,991,175.58