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WETLANDS AREA AND EMBANKMENT DESIGN FOR STIMULATING DUCK NESTING HABITAT AND SUCCESS IN SIOUX COUNTY, NORTH DAKOTA

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GeoE 485- Senior Design II

Geology & Geological Engineering Department
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Fall 2009

EXECUTIVE SUMMARY

For this project an embankment will be built in Sioux County, North Dakota, T129N, R85W, and Section 7. The purpose of this embankment is to develop wetlands areas for duck habitat and nesting in south-central North Dakota. The embankment will be constructed from compacted soils taken from two locations that are within a half mile from the proposed embankment location to create a lower transport cost. The embankment will contain a weir that will be approximately 115 feet in length with five feet on each side embedded into the embankment for stability. The weir will be constructed from steel sheet piles and be driven into the ground at a depth of twice the weir's height. The embankment will inhibit the flow of a small creek located about 1.6 miles west of ND Highway 31, and create up to a 22 acre wetlands area. The size of the wetlands area is dependent on the water level at any given time. This data was calculated in the stage capacity section of this project.

The purpose of this report is to construct a final design for the embankment. The environmental/biological, geological, and economical aspects of the site has been assessed. This project will document the hydrological characteristics of the area by discussing about soil and flow rates affected by each soil type. ArcGIS 9 was used for visualizing and creating the site data and area contours used in this report. An inflow hydrograph was calculated using data from the Hydrology Manual for North Dakota to calculate the maximum inflow.

The soil and hydrological characteristics of the proposed area where the embankment will be constructed will be collected from the Natural Resources Conservation Service county soil survey website. These data will help in deciding if the area can support a wetlands area successfully. The main concern for the project design is to increase the nesting and habitat areas for ducks. The wetlands area will be constructed to create a habitat for ducks to build nests and live successfully. The wetlands area will include three or four bays located mainly in the corners of the wetland that will create sufficient cover for the ducks. The number and size of the bays will be depended on by the water level. An economic analysis was also conducted to estimate a final cost of the embankment. The embankment is projected to cost approximately $522,000.

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INTRODUCTION

A final embankment design is being constructed to create a new wetland area in south-central North Dakota (Figure 1) for my geological engineering senior design project. This project is used to get a sense for how a project that could be offered out by Ducks Unlimited to an engineering firm would be in the engineering career field. The embankment will be built about 1.5 miles north of the North/South Dakota border and 1.6 mile west of ND Highway 31 (Figure 2). The watershed area is approximately 1503 acres. The wetlands area will extend southwest from the embankment and occupy an area up to 22 acres of pre-existing grassland. The size of the wetlands area will depend on the water height at any given time. The embankment design will be 287 feet long and 21 feet above the ground level. There will be a weir in the middle of the embankment made from steel sheet piles which will be 115 feet long. The construction of the embankment is meant to create a wetlands area to stimulate duck nesting and habitat formation.

Figure 1: Sioux County map with the area of interest highlighted in red (Photo 1).

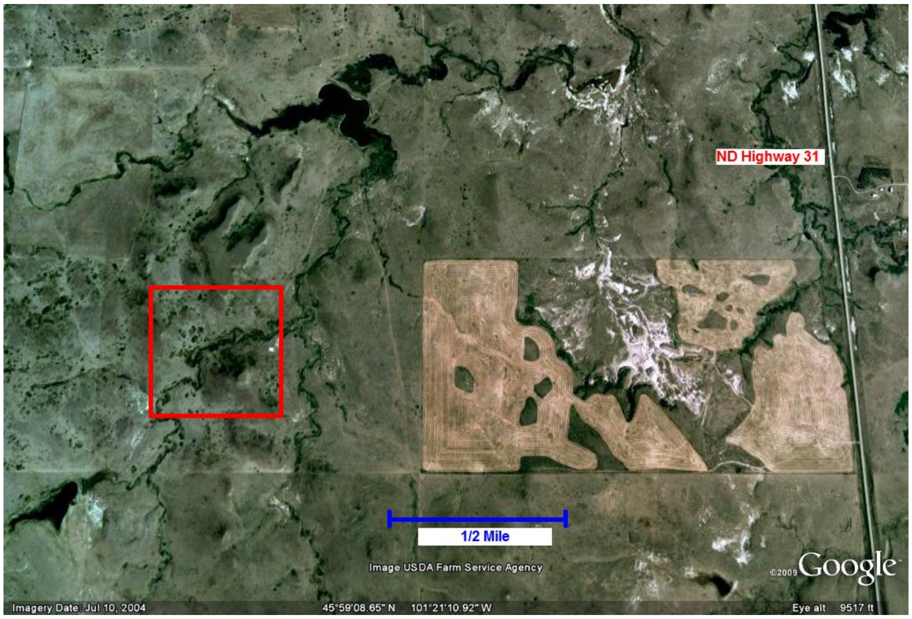

Figure 2: The area where the proposed embankment is located within the red box and is located west of ND Highway 31 (Google, 2009).

PROBLEM DEFINITION AND OBJECTIVE

The decline of several duck species populations, nesting, and nest success has been declining throughout the northern United States in the last 50 years. This problem is currently being investigated by Ducks Unlimited Inc (Ducks Unlimited, 2009). The purpose of this project is to build an embankment to impound a small creek and create a wetlands area upstream from the embankment. The proposal will deal with the geological, environmental/biological, economical and hydrological characteristics of the proposed site. Lastly, the cost of construction will be estimated by using current economic data and pricing. This is called an Engineer's estimate, keep in mind that this is not the exact amount it will cost to build the embankment.

BACKGROUND

Geological Constraints

The major element in focus is the soil types and their locations with respect to the wetlands area and the embankment. The soil classification is based on the National Resource Conservation Service (NRCS) soil classification. Hydrologic soil groups are based on estimates of runoff potential (NRCS, 2009). Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms (NRCS, 2009). “A” type soils have high infiltration rates when thoroughly wet. They consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission and are not viable for a wetlands area. “B” type soils have a moderate infiltration rate when thoroughly wet. They consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission and are also not acceptable for wetlands soils, when left by themselves. “C” type soils have a slow infiltration rate when thoroughly wet. They consist mainly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission. “D” type soils have a very slow infiltration rate that produces a high runoff potential when thoroughly wet. These soils consist of clays that have high shrink-swell potential, soils that have a high water Table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission (NRCS, 2009). “C” and “D” type soils are the best for creating a wetland area due to their low infiltration rates and slow water transmission rates. The percentages of soil types of the area are as follows: 0% type “A”, 46.5% type “B”, 33.2% type “C”, and 19.6% type “D”. There also was 0.7% surface water in the watershed area. The locations of the soils are acceptable. The “B” type soils seem to be in larger areas throughout the central and in the northern most regions of the watershed. The “C” type soils have large concentrations in the creek bed, west and southern most regions of the watershed. The “D” type soils are scattered throughout the watershed but do have a moderate concentration in the east region of the watershed. The areas where the different soil types are present are highlighted in Figure 3a and the names and descriptions are illustrated in Table 1. Figure 3b is a key that illustrates the soil types with their respective colors and other map markers and basic map information for an easier read map.

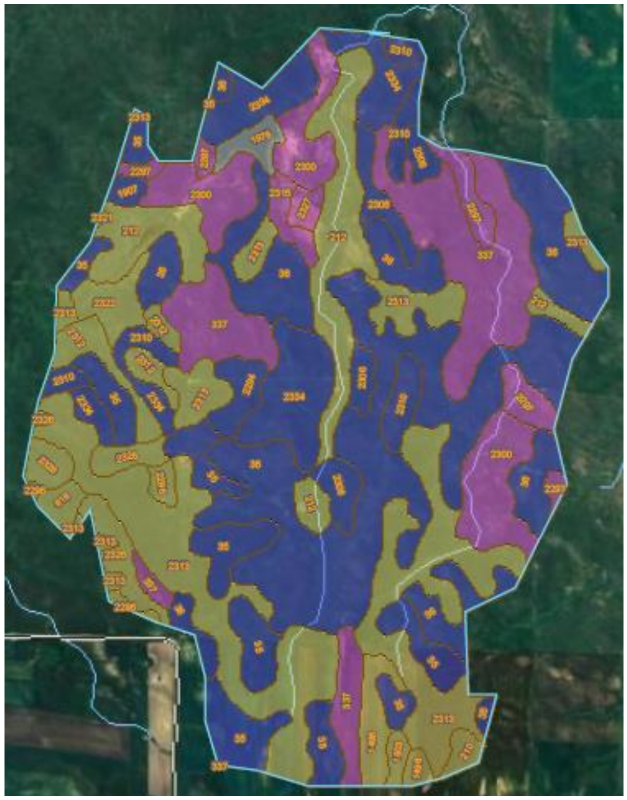

Figure 3a: The different NRCS classification soil types within the watershed which are divided by their respecting colors (NRCS, 2009).

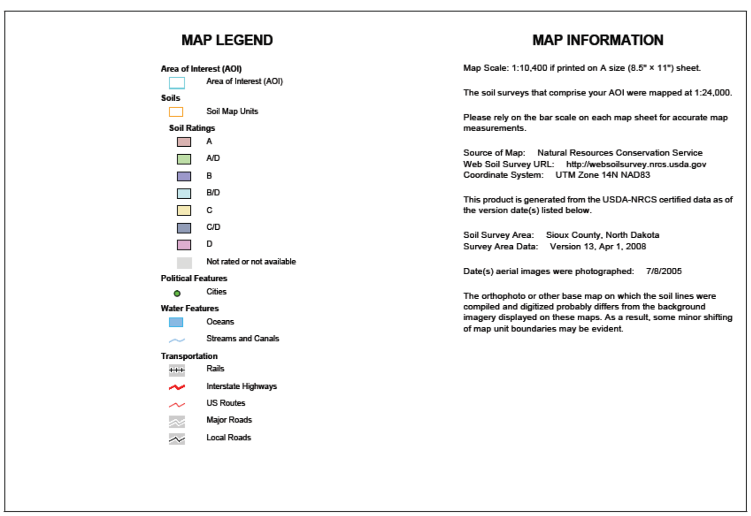

Figure 3b: Map legend that includes classification, map markers, and basic map information (NRCS, 2009).

Design Constraints

The topography of the watershed area where the embankment will be constructed varies from about 2200 to 2382 feet MSL. The area consists of rolling hills with some row crops but is mostly grassland. Limited commercial and agricultural activities in the area will help reduce land-acquisition costs. The climate of the area is a typical North Dakota climate. The winters are cold with moderate precipitation. In the spring the precipitation will increase and temperatures will rise as high as 65 degrees Fahrenheit. The summers are typically dry and hot. And in the fall, the temperatures are mild and the amount of precipitation is low to moderate. The design of the embankment must meet the criteria set forth from the Hydrology Manual for North Dakota (HMND). This design must be able to withstand water levels from a 25-year/24-hour storm with 1 foot of freeboard. The embankment will be compacted using soils taken from near the proposed wetlands area, and will have side slopes of a 3:1 height to length ratio. The soil compaction rate will be 95% of the maximum density with respect to the Standard Proctor Density. The embankment must be constructed with a 12 foot top width to allow maintenance vehicles to reach the weir safely. The soil classification used in the analysis is from the NRCS hydrological soil classification criteria. There are no major hydrological constraints in the watershed based on the lack of "A" type soils present. The hydrological soil classification must be between "B" and "D" type soils. The reason "A" type soils are not acceptable is because they allow too much seepage loss to maintain a proper wetlands area.

One of the most important constraints is the minimization of the costs by preparing an economic analysis on the embankment that will be compared prices related to ratio of weir length to embankment length. There is a constraint with the curve number data as well. A curve number is an empirical parameter used in hydrology to predict direct runoff with respect to the land type and vegetation of the area. Because the data was collected using images from Google Earth, the land use may not be entirely accurate because of the lack of current imagery for the area of interest. Without visiting the site and investigating the area and its land uses, it is difficult to properly estimate the curve number. In this situation, you will find the curve number may vary slightly.

Preliminary Site Characteristics

When choosing a location to build an embankment, there are many factors that need to be considered. The very first item I considered was if there is a stream or creek in the area, which is needed to create a wetlands area. One of the most important characteristics, when locating an area of interest, is to find a place where the elevation change would be great enough that the watershed could be drawn accurately. An area with a very small change in elevation over a large area of land, such as eastern North Dakota, would be difficult to delineate the watershed due to the large area it would possess. After selecting an area based on elevation and location, the next characteristic is making sure the area has “C” and “D” type soils for the majority of site where the wetlands area will be. A description of “C” and “D” type soils is given in the next section. A preferred characteristic is that the land is not being farmed or any homesteads are located near the site. This criterion makes it easier and less costly to buy the land. The site is appropriate because of the environmental and economical features of the land. The land will be less costly to acquire because there are no homesteads within the projected wetlands area. The environmental impact is low because of the area consisting of rolling hills and grasslands. There are also no major roads that extend through the area. However, the land happens to be on the Standing Rock Indian Reservation, which could be a problem depending on current social relations.

With Ducks In Mind

The northern pintail is one of several duck species that have been declining in population throughout the northern United States for the last few decades. The reason for the construction of this embankment is to create a wetland area that will generate duck nesting and habitat. Ducks will usually nest near shore of the wetland, but are also known to nest in secluded grasslands and winter wheat fields. The wetlands area will give ducks not only a place to stay and nest, but it is vital that the hen gets enough food to eat while nesting. The food supply in the area will be sufficient for the ducks to live in and around the wetland area. A duck's diet primarily consists of aquatic plants and seeds, along with small aquatic insects and field seeds when possible. Predators are one of the leading causes of duck nesting failure. This is why the creation of several bays is a good way of providing the ducks the seclusion and cover they need to prosper.

Weighted Runoff Curve Number

The weighted runoff curve number is calculated by differentiating the area into several different areas based on vegetation, land use, and hydrologic features. The curve numbers of each area are calculated before averaging them together with respect to the percentage of each areas acreage versus the total acreage of the watershed. The following information was derived from the methodology and examples given throughout Chapter 3. The following information was tabulated onto Table 1 (Table 3-1 HMND). The watershed consists of three main sections which are straight row crops (poor), pasture (poor), and pasture (fair). The straight row crops section is located in the southern end of the watershed, it consists mostly of type “C” soils with small amounts of types “B” and “D” soils as well. The pasture (poor) area is located in the north-central region of the water shed and is the smallest area of the three. The pasture (poor) consists of all three soil types dispersed quite evenly throughout the area. The pasture (fair) is all of the rest of the watershed and consists of mainly of types “B” and “C” soils with a small percentage of type “D” soils. The final weighted runoff curve number was calculated to be 77 (Table 2). The area was analyzed by using the Google Earth land surface imaging program.

Since the curve number for the proposed area effects the other calculations, alternate curve numbers were calculated so that any possibility of an incorrect curve number calculation would not effect the following calculations. The alternate curve numbers that I chose to calculate were the lowest and highest possible curve numbers for the proposed area. Using the lowest and highest gives a look at the most extreme possibilities of the value of the weighted curve number. The lowest curve number was calculated by assuming that the entire region was type “B” soils which have lowest curve of the hydrologic soil types in the proposed area. The lowest curve number possible with the estimated land use was calculated to be 72. The highest possible weighted curve number was calculated to be 86. After analyzing the difference in curve numbers, the original calculated curve number was very close to the average between lowest and highest possible curve numbers.

Table 1: Data and calculations for the weighted runoff curve number. This data is useful for calculating the time of concentration. The table scan was from the U.S. Department of Agriculture Soil Conservation Service.

TABLE 3-1

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

HYDROLOGIC CURVE NUMBER COMPUTATION SHEET

PRESENT LAND USE FOR RURAL AREAS
Present or Future

Watershed ________ Site ________ D.A. ________ Acres ________

Computed by Corey Johnson Date Nov./09 Checked by ________ Date ________

Cover	Practice	Condition or Rotation	Acres per Practice	Curve Numbers Moisture Condition II A Soils	B Soils	C Soils	D Soils	Product
Fallow	Straight Row			77	86	91	94	
Row Crops	Straight Row	Poor	203	72	81	88	91	17,529
	Straight Row	Good		67	78	85	89	
	Straight Row	Mulch till		61	76	84	87	
	Contoured 2/	Poor		70	79	84	88	
	Contoured 2/	Good		65	75	82	86	
	Contoured 2/	Mulch till		62	73	80	85	
	C and T 1/	Poor		66	74	80	82	
	C and T 1/	Good		62	71	78	81	
	C and T 1/	Mulch till		61	70	77	80	
Sm. Grain	Straight Row	Poor		65	76	84	88	
	Straight Row	Good		63	75	83	87	
	Straight Row	Mulch till		58	74	82	86	
	Contoured 2/	Poor		63	74	82	85	
	Contoured 2/	Good		61	73	81	84	
	Contoured 2/	Mulch till		59	72	80	83	
	C and T 1/	Poor		61	72	79	82	
	C and T 1/	Good		59	70	78	81	
	C and T 1/	Mulch till		58	69	77	80	
Legumes or Rotation Meadow	Straight Row	Poor		66	77	85	89	
	Straight Row	Good		58	72	81	85	
	Contoured 2/	Poor		64	75	83	85	
	Contoured 2/	Good		55	69	78	83	
	C and T 1/	Poor		63	73	80	83	
	C and T 1/	Good		51	67	76	80	
Pasture		Poor	180	68	79	86	89	15,327
		Fair	1120	49	69	79	84	83,160
		Good		39	61	74	80	
Meadow (Permanent)		Good		30	58	71	78	
Wood or Forest Land		Poor		45	66	77	83	
		Fair		36	60	73	79	
		Good		25	55	70	77	
Farmstads		--		59	74	82	86	
Roads (Inc.R.O.W.)	Dirt Surface	--		72	82	87	89	
	Hard Surface	--		74	84	90	92	
Impervious Surfaces		--		100	100	100	100	
Water Surfaces (lakes, ponds)		--		100	100	100	100	
Swamp (open water) 3/		--		85	85	85	85	
Swamp (vegetated 4/		--		78	78	78	78	
Low Density Residential		--		47	65	76	82	
Medium Density Residential		--		54	70	79	84	
High Density Residential		--		70	81	87	90	
Commercial and Industrial		--		86	91	93	94	

Total Acres 1503 Product Total = 116,016

Weighted Runoff Curve No. $\frac{\text{Product Total}}{\text{Total Acres}} = \frac{116{,}016}{1503} = 77$

1/ Contoured and graded terraces or land with less than 2% slope.
2/ Includes level terraced areas. (runoff corrected by volume)
3/ 1/3 of swamp surface is open water.
4/ Swamp has no open water and the design is a 25-year frequency or less.

3-3

Calculations and Data

Time of Concentration

The time of concentration is a necessary calculation for this project. To calculate the time of concentration you first need the precipitation for a 25-year 24-hour storm event for the area. The precipitation value 3.85 inches for the area was measured using Figure 8 which was developed in Technical Paper No. 40 (Hershfield, 1961). When the precipitation and the curve number are known, the next step is to find the direct runoff value. This value is determined with the use of Figure 9 (Figure 3-2 HMND). I needed to compare how the difference in curve numbers effected the hydrologic factors of the proposed area so that proper a proper time of concentration and hydrograph could be calculated. I first looked at the amount of direct runoff using the different curve numbers and rainfall frequencies. It appeared that when you change the curve number and keep the same rainfall frequency, the direct runoff would change values, which is to be expected. If you use the same type of idea and change the rainfall frequency by the same factor as you changed the curve number before and left the curve number the same, the direct runoff changed approximately the same. This concludes that the curve number and rainfall frequency are directly related to the direct runoff value.

Time of concentration is the time that it takes for a “particle” of water to travel from the furthest point out from the embankment, within the watershed, to the embankment. This path the water takes includes sections that are broken up into different velocities. For instance, overland flow will have a much lower velocity than a low retardance channel waterway. The slope of the land for each section must be calculated as a percentage. The determination of the water velocity is determined by the use of both the slope percentage and the type of flow. Descriptions of each flow type are given in

Chapter 4 (HMND). The values for flow velocity are gathered through the interpretation of Figures 10 and 11 (Figures 4-1 and 4-3 HMND). The data given in Table 3 illustrates the type of flow, elevation drop, slope percentage, velocity and travel time for each section of the velocity path. The time of concentration is always rounded down to the nearest half-hour because it is better to be conservative and round down. Rounding down for the calculation of the time of concentration will make it so the amount of water that is produced by a flood event is better estimated. For example, the time of concentration that I calculated for the area was 1.16, I rounded down to a time of concentration of 1.00 hour because there would be more water coming faster towards the embankment at a 1.00 hour time of concentration than it would be at a 1.16 time of concentration. This data is needed for calculating the hydrograph.

A comparison between the lowest and highest time of concentrations was completed to see how an misrepresentation of a calculated time of concentration would effect the design. The highest time of concentration was calculated using an overland flow estimation that involved minimum tillage as the land use, which would cause water to flow very slowly. The channel phase for the lowest estimated value was described as very shallow (0.5 to 1 foot) depth and with high retardance. These factors would help estimate values that would produce a time of concentration of 2.61 hours, which was rounded up to 3.0 hours to simulate the longest possible time of concentration. The lowest time of concentration was calculated using nearly bare ground for overland flow and a deep (6 to 8 feet) channel phase with low retardance to simulate the shortest possible time of concentration. The calculated value for the shortest time was 0.42 hours, which was rounded down to 0.25 hours to minimize the time. This data is located in

Table 6. The reason for completing this comparison will be discussed in the hydrograph section of this report.

Table 2: Data and calculations for time of concentration. This data will be useful for tabulating the hydrograph.

TIME OF CONCENTRATION TABLE						
Reach (ft)	Flow Condition	Reach Length (ft)	Elevation Drop (ft)	Slope (%)	Velocity (ft/s)	Travel Time (sec)
0 - 880	Overland Flow (Pasture or Cultivated Straight Row)	880	80	9.09	2.25	391.11
880 - 13218	Channel Phase (d=1-2ft, b=2-20ft, Medium Retardance)	12338	150	1.22	3.25	3796.31
	Total Travel Time (sec)	4187.42				
	Total Travel Time (hrs)	1.16				
	Time of Concentration (hrs)	**1.00**				

Hydrograph

A hydrograph is a graph that illustrates the maximum inflow and amount of discharge through some point in a river or stream. To calculate the hydrograph one will need various data including: time of concentration, precipitation, area of drainage area, direct runoff and the designated hydrograph family. The data for this hydrograph is illustrated in Table 3. The hydrograph family is determined by using the peak discharge and time of concentration in Figure 5-2 in Chapter 5 of the HMND. Hydrograph family 1 was chosen for this hydrograph. When determining the hydrograph family, it is important to remember to round down to the nearest family value. The time and discharge (CSM/in) values were taken from Table 6-6 from the HMND, which is illustrated in Table 7. The graph of the hydrograph data is depicted in Figure 4. The maximum inflow was about 355 feet^3/second at 10.5 hours.

To be sure that the maximum inflow and the chosen hydrograph family number are acceptable values, a comparison of time of concentration and hydrograph family numbers was conducted. The results of this comparison were that when looking at the peak discharge (CSM/in.), a change in time of concentration had a much greater effect on the value than a difference of hydrograph family number; and that as the time of concentration increases, the difference in peak discharge decreases when the time of concentration is compared to the hydrograph family number. Using a constant time of concentration and a varying hydrograph family number the peak discharge changed no more than 50 CSM/in (Figure 6). However, when the time of concentration changed and the hydrograph family stayed the same, the peak discharge change was between 50 and 170 CSM/in. This concludes that calculating the proper time of concentration value is more important than estimating a hydrograph family number.

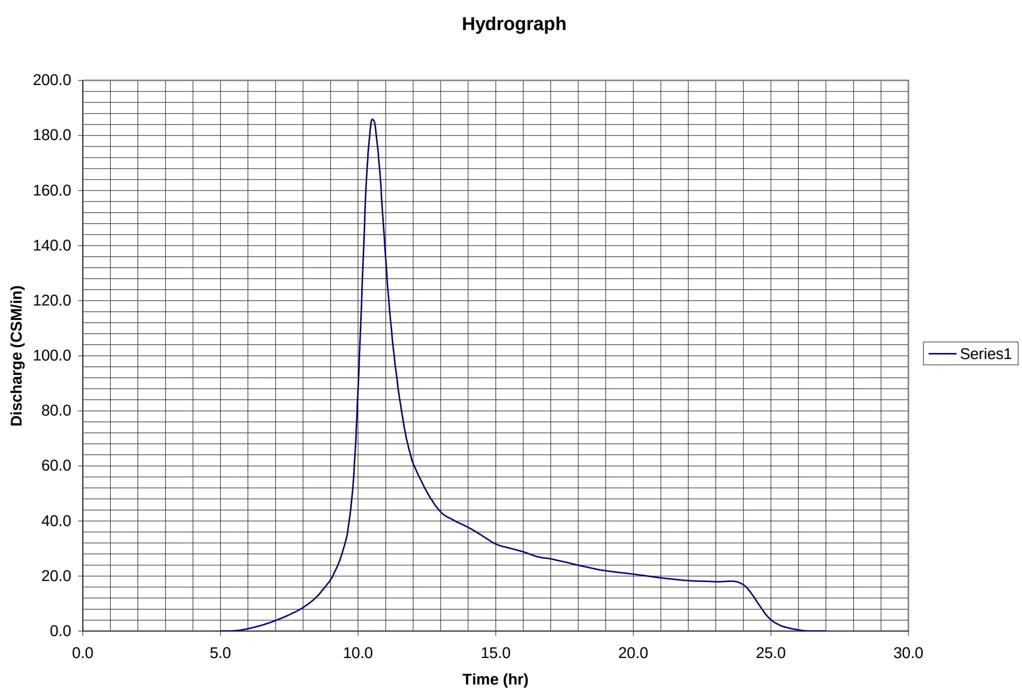

Figure 4: Hydrograph of basin for a 25yr/24hr storm event according to the data collected from the Hydrology Manual for North Dakota.

Stage Capacity

The reservoir capacity is the volume of water that is held in the reservoir at a specific water depth. The reservoir capacity data for elevations from 2200 to 2220 feet MSL are illustrated in Table 3. This data helps determine the volume of water that will be needing to be passed through the weir of the embankment. The storage capacity is represented by the calculation of the reservoir capacity divided by the reservoir area. The total amount of water that could be held within the wetlands area would be about 783 acre-feet. This data is most likely not variable due to the accuracy of the area contours collected using the ArcGIS 9.3.1 software. The software helped measure the area of the reservoir at each two-foot contour line going away from the proposed embankment construction location.

Table 3: Data collected by measuring the amount of water held within the wetlands area at a given elevation and the totals of the volumes.

STAGE CAPACITY DATA				
Elevation (ft)	Reservoir Area (acres)	Reservoir Capacity (ac-ft)	Reservoir Capacity (ft^3)	Storage Capacity (ft)
2200	0.19	0.10	4,138	0.50
2201	0.34	0.36	15,573	1.07
2202	0.48	0.77	33,323	1.59
2203	0.72	1.37	59,459	1.90
2204	0.96	2.21	96,050	2.30
2205	1.40	3.38	147,342	2.42
2206	1.83	5.00	217,582	2.73
2207	2.66	7.24	315,374	2.72
2208	3.49	10.32	449,321	2.96
2209	4.49	14.30	623,017	3.19
2210	5.48	19.29	840,055	3.52
2211	6.37	25.21	1,098,148	3.96
2212	7.26	32.03	1,395,009	4.41
2213	8.40	39.86	1,736,084	4.74
2214	9.54	48.83	2,126,817	5.12
2215	11.10	59.14	2,576,247	5.33
2216	12.65	71.02	3,093,413	5.61
2217	14.80	84.74	3,691,274	5.73
2218	16.95	100.62	4,382,789	5.94
2219	19.40	118.79	5,174,492	6.12

2220	21.85	139.42	6,072,917	6.38
TOTALS:	***150.34***	***783.94***	***34,148,426***	***78.23***

Routing the Flood

The last stage of calculations for the water passing through the weir will be routing the 25-year/24-hour flood event. The flood data depends greatly on the hydrograph data which is the main data source for calculating the flood data. When routing the flood through the weir, I made the assumption that for the calculation of the height of water over the weir is for a weir the length of the entire embankment. The length of the embankment was 287 feet. The maximum height of water over the weir was calculated to be about 1.86 feet, which gives a maximum area of water over the weir to be about 534 feet^2. The dimensions of the area had to be altered so that the area stayed the same, but the length was shortened and the height was increased. This helped determine an approximate weir length needed to pass the amount of water that would be seen during this type of flood event. The data from routing the flood also determined the exiting discharge, change in storage capacity, and the storage after outflow.

PRELIMINARY ANALYSIS

Design Criteria

This project focuses on the design of the principle spillway, even though there may be cause to build an emergency spillway but is out of the scope of this project. The design of the embankment must meet the criteria for a 25-year 24-hour storm with 1 foot of freeboard remaining. The embankment will be compacted using mainly “B” and “C” type soils taken from the area of the proposed wetland. The side slopes of the embankment will have a 3:1 length to height ratio. The weir will be embedded into the ground at a depth that is twice the height of the weir and will have a fully buried side embedment depth of 5 feet on each side. The side slopes at the weir will have a 2:1 length to height ratio. The embankment will be compacted with three passes with a sheep foot roller, along with using a water truck to properly wet the soil for optimal soil compaction. On the backside of the structure, there will be a set of gabion nets that will be used to decrease the erosion factors caused by the falling water from the weir. A hydrograph was constructed to calculate the peak discharge when using a specific time of concentration and hydrograph family. The stage capacity data was collected and analyzed to estimate the total amount of water in the reservoir at any given water depth. The embankment will be a Class II dam, according to the North Dakota Dam Design Handbook (1985). A low hazard/risk dam is described as: *a dam located in rural or agricultural area where there is little possibility of future development. Failure of low hazard dams may result in damage to agricultural land, township and county roads, and farm buildings other than residences. No loss of life is to be expected from the failure of a low hazard dam.*

FINAL DESIGN RESULTS

Design Assumptions

There are a few assumptions that need to be made when designing a project such as the embankment proposed in this report. The most important assumption is the acquisition of the land, if the land cannot be bought, then the project would not be considered or researched. The soil of the area seems to be sufficient for creating a wetlands area, but without further soil investigation and testing I will have to assume the soils will hold water and not infiltrate. The stream is also a possible problem, without visiting the area personally, the stream may not have the volume of water or flow that would be needed to create a wetland of sufficient size. I assume the stream is large enough to produce enough water to create a wetlands area within the proposed watershed. On a much larger note, the assumption that ducks will inhabit and nest in or around the wetland must be considered also. The number of ducks within the area throughout the past years and broods that have been hatched in Sioux County would be valuable to this project. But, the acquisition of this data would be difficult and above the scope of the project, so it is assumed ducks will live and nest at the wetlands area.

Design Characteristics

The top of the embankment will be at the elevation of 2221 MSL. The embankment will have a length of 287 feet and be 21 feet in height (Figure 5). The volume of compacted soil needed to build the embankment will be 4130 cubic yards. A swell factor of 0.85 will be utilized when doing the ex-situ soil volume calculations for the excavation costs in the economic analysis. The embankment will have a modular truss footbridge built across the weir for walking on to get better access to the weir for maintenance or data collection. The total weir length will be 115 feet which includes the 5 foot of embedment on each side of the weir. The total weir height will be about 45 feet which includes the embedment of twice the height of the exposed weir. The top of the embankment will be 12 feet wide so that maintenance trucks can drive on top of the embankment. The erosion defense for the embankment will be 18 inch thick gabion baskets that will be placed behind the embankment and will have an area of 1308 $feet^2$. This area will extend out 12 feet from the embankment and will be 109 feet long, two feet on each side longer than the exposed weir. These gabion baskets should provide sufficient erosion defense from the water flowing through the weir. The modular truss footbridge will be made of steel and pre-casted concrete structures for durability. The footbridge will be about 130 feet in length and 3 to 4 feet wide. The final embankment design is illustrated in Figure 8. This embankment would create up to a 22 acre wetlands area for ducks to have safe habitat to nest in (Figure 13).

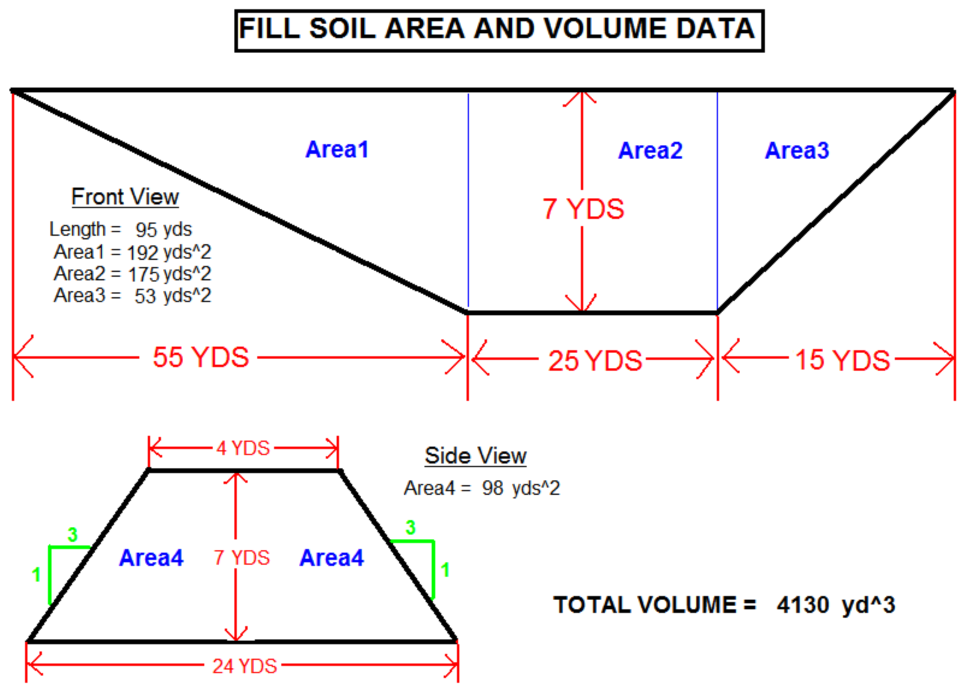

Figure 5: Geometric dimensions of the embankment design.

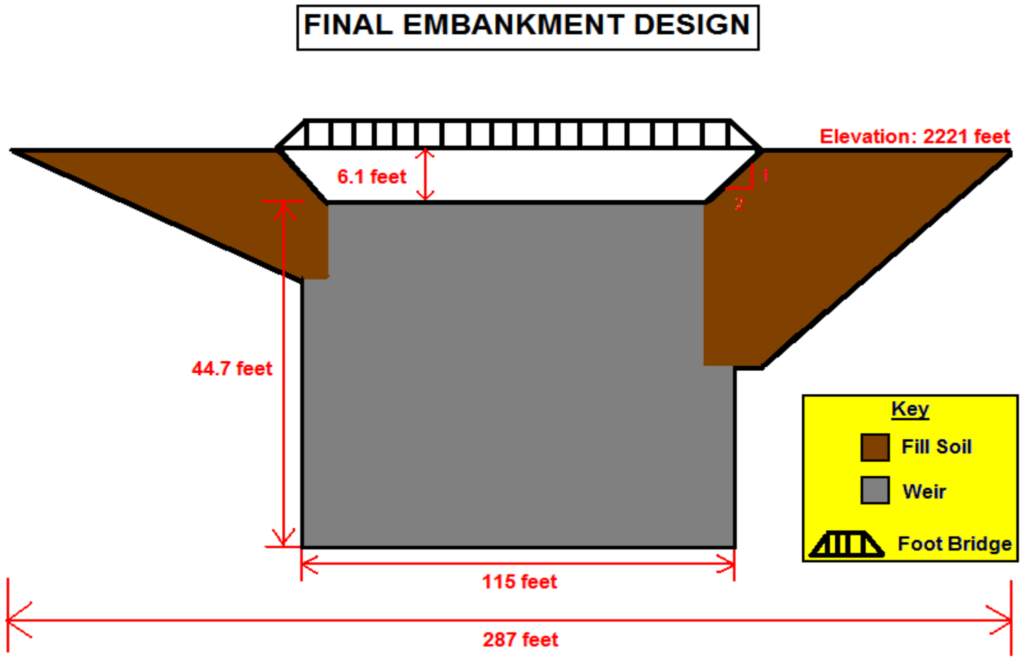

Figure 6: Final design illustration which includes the geometric dimensions.

Economic Analysis

The economic analyses were based on machinery, materials, erosion prevention and site preparation costs. The values for the cost estimations were established from the RS Means Engineering Cost Manual (1997) so the costs were adjusted using yearly inflation rates up to the current year. Site preparation is the excavating of the topsoil and any debris so that the soil used to construct the embankment will be on a level and clean surface. Because the surrounding area is mainly grassland, I estimated in the analysis that there would be one foot of topsoil removed from the area where the embankment will be created. The cost representative of the site preparation was about $7,900. The machinery costs included sheep foot rollers for compacting the soil of the embankment, a scraper for leveling the soil, a front-end loader for borrow soil excavation, a dump truck for soil hauling and the immobilization costs that go along with using the machinery. The machinery types and amount of each machine is needed to be taken into account because if you can get away with only one sheep foot roller compared to two, that will save on the overall machinery costs. The sheep foot rollers will make three passes for optimal soil compaction. The three passes from the sheep foot rollers will cost approximately $12,700. There will be one scraper required to move and level the soil for the embankment which will cost about $10,000. The front-end loader and dump truck will be used for about four days (8 hours/day). The cost for the front-end loader and dump truck was calculated to be about $26,300 and $7,700 respectively. The immobilization costs for all the machinery are included in their specified costs. To keep the dump truck cost and load efficiency low, soil will be taken from areas closest to the embankment as possible where the elevation exceeds 2,221 feet MSL. The material cost includes the sheet piles for the weir, random structural steel, and materials for the footbridge. Cost of the sheet piles for the weir are $40.00 per square foot. An additional $10,000 was added to the value for representation of the structural steel. The material costs greatly depend on the length of the weir. A balance point between weir length and weir cost must be determined to keep the cost in a sufficient range. The materials needed to construct the modular truss footbridge will consist of pre-formed concrete structures and random steel materials. The total cost of materials including the weir, structural steel, and footbridge was estimated to be about $241,000. Once the embankment is built, materials must be placed behind the weir so to prevent erosion of the embankment. 18 inch thick gabion baskets were selected to be the materials for erosion prevention. The cost of the 18 inch thick gabion baskets was $55.00/square foot. The total cost of the erosion prevention materials was estimated to be about $72,000. The total estimated cost to build the embankment is just over $520,000 (Table 4). A thought to remember when approaching this economic conclusion is to remember that estimated costs are Engineer's estimates and not the actual amount that it will take to build the embankment. When seeing the total estimated cost many people would think that it is very expensive, however the costs will most likely be much less because the construction is estimated in this report for a large construction company that is located 100 or more miles from the proposed area. A more accurate estimation could be developed by checking around the local area in Sioux County and getting a small construction company to complete the embankment. This makes the most sense because the cost to get the machinery out to the site will be minimal and the smaller companies usually will do a project for a lower cost than a large company, especially in the condition that the economy is in right now.

Table 4: Detailed economic analysis which includes the cost of each part of the embankment construction.

EMANKMENT COST ANALYSIS				
Equipment Description	**Cost ($)**	**Immobilization Costs/Yd^3 ($)**	**Amount**	**Total Cost (1997)**
3-Sheep-foot Rollers (3 passes)	0.61/yd^3	0.05	4859 yds^3	$9,621
1- Front-end Loader (5 C.Y. bucket, track mounted)	5.35/yd^4	0.06	4859 yds^3	$26,280
1-Scraper (common earth)	2.61/yd^3	0.04	3754 yds^3	$9,948
Site Preparation (excavation of 1 foot of soil)	5.00/yd^3	-----	1587 yds^3	$7,935
Sheet Piles and Structural Steel (weir materials, etc.)	40.00/ft^2	-----	5141 ft^2	$215,640
Modular Truss Footbridge Estimated Cost	200.00/ft	-----	130 ft	$26,000
Gabion Baskets (18 inches deep)	55.00/ft^2	-----	1308 ft^2	$71,940
60 C.Y. Dump Truck (1000ft Round trip, 3.6 loads/hour)	1.52/yd^3	0.07	4859 yds^3	$7,726
Total Cost for Embankment (2009)	***$522,647***			

Conclusions

A detailed engineering site assessment of a proposed embankment area was accomplished to determine whether the area could support a new wetland area that would be utilized by ducks for habitat during nesting. After investigating the geological, environmental, economical and hydrological characteristics of the proposed wetlands area; I have to conclude that due to a high estimated cost and the location of the proposed embankment, Ducks Unlimited would most likely chose a different site to construct an embankment. The estimated costs were quite high when compared to other embankments that could be smaller and easier to construct. Since the proposed wetlands area is located on the Standing Rock Indian Reservation, the land would most likely be difficult to acquire and would end up making the total cost be even higher than the estimated cost to build the embankment. However, if Ducks Unlimited still wanted to build the embankment design, despite the cost and location, the area's geological and hydrological characteristics should support a wetlands area sufficiently.

APPENDIX A – FIGURES

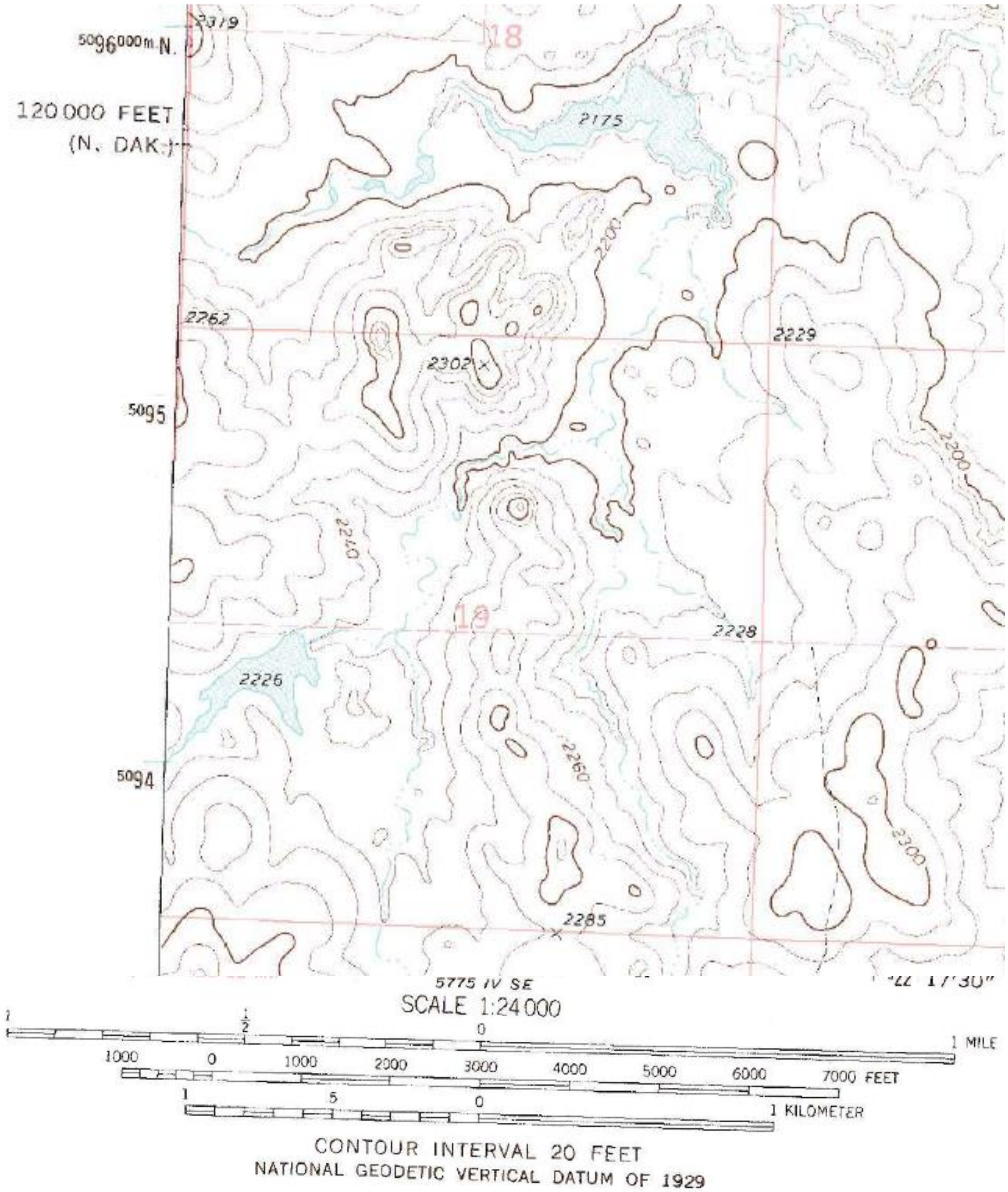

Figure 7: A contour map of the proposed area where the embankment would be constructed (USGS).

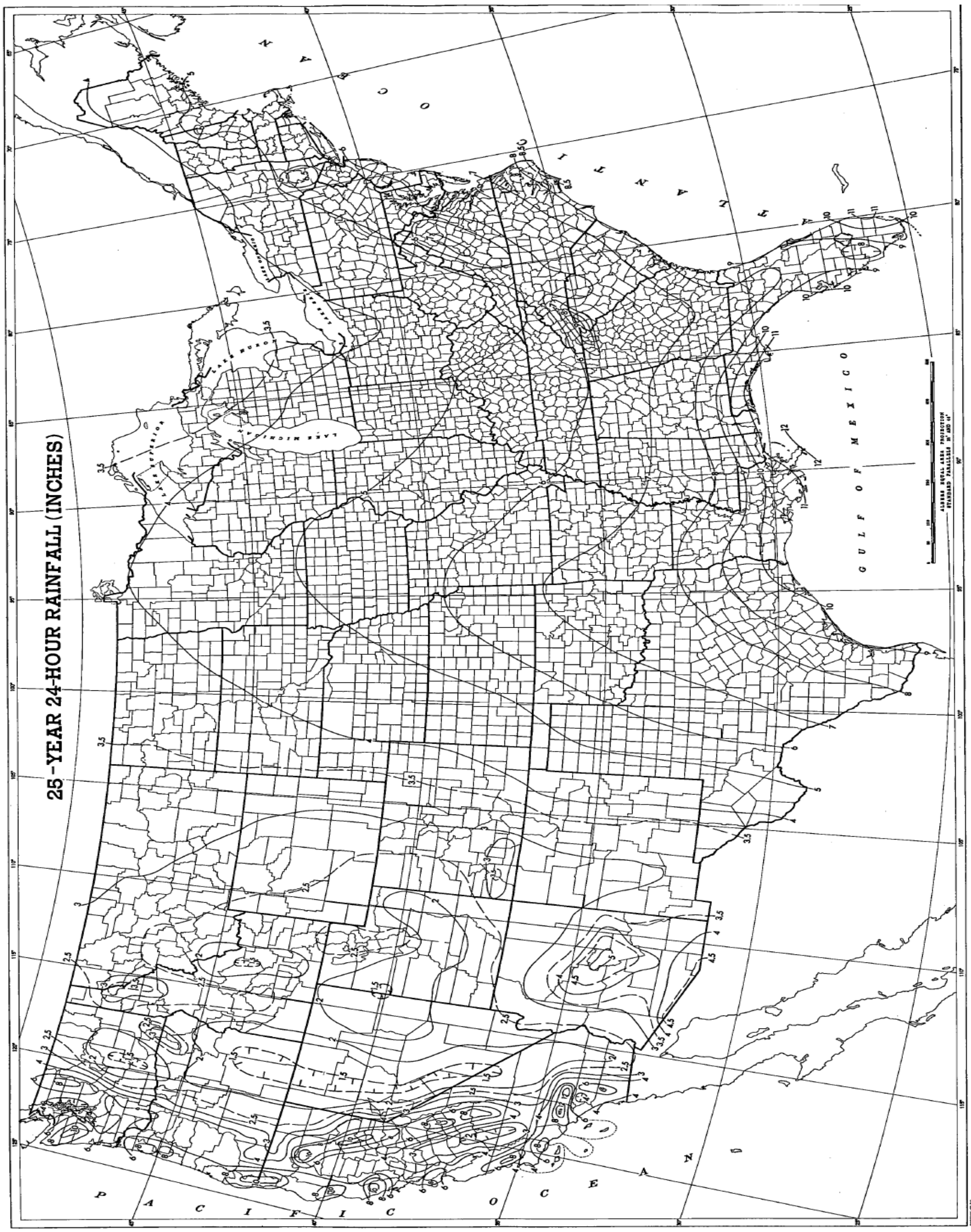

Figure 8 : 25 year/24 hour rainfall frequency atlas of the United States, collected from U.S. Department of Commerce Technical Paper No. 40.

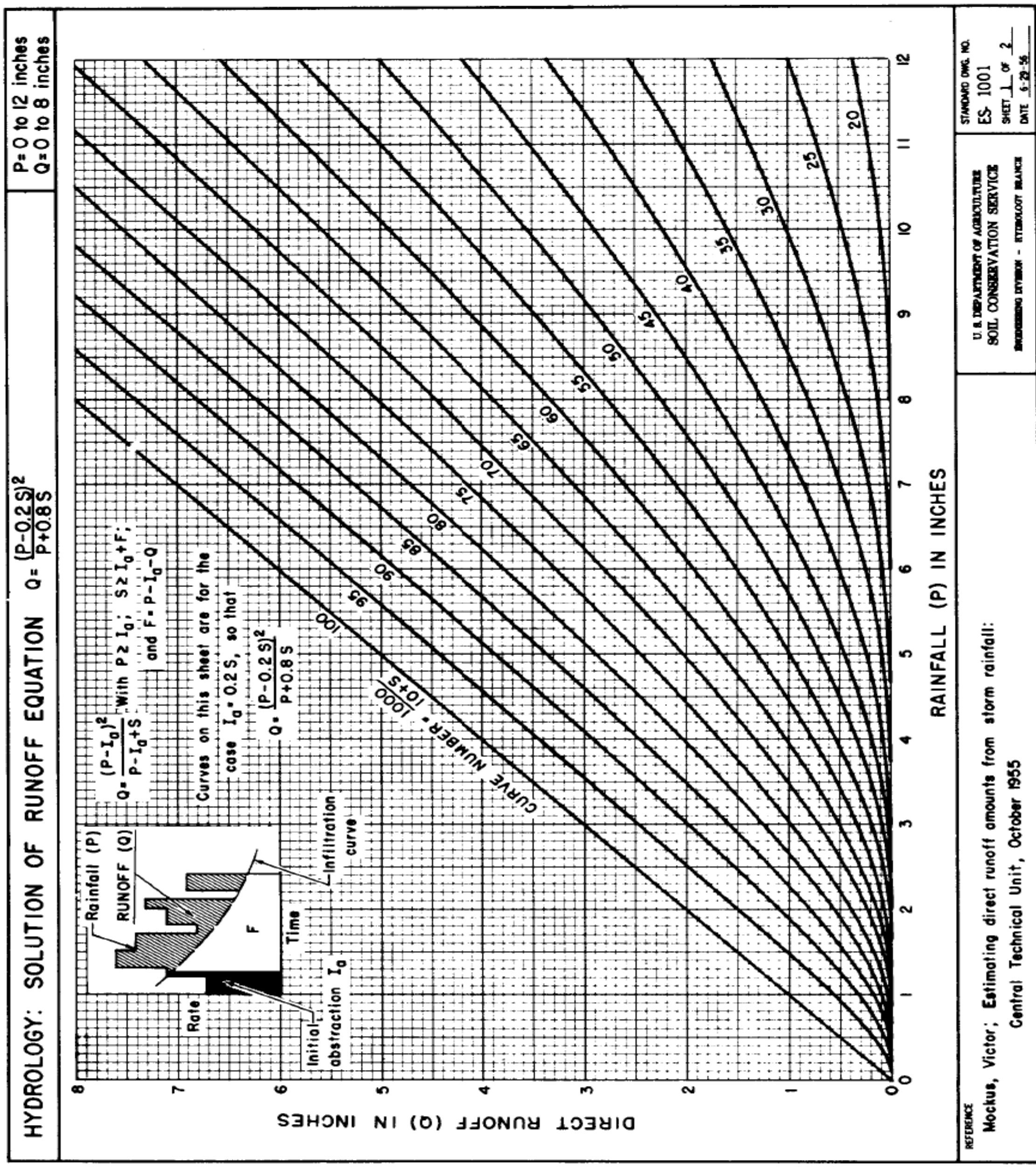

FIGURE 3–2

Figure 9 : Figure 3-2 from Chapter 3 of the Hydrology Manual of North Dakota which was used to estimate the direct runoff of the watershed.

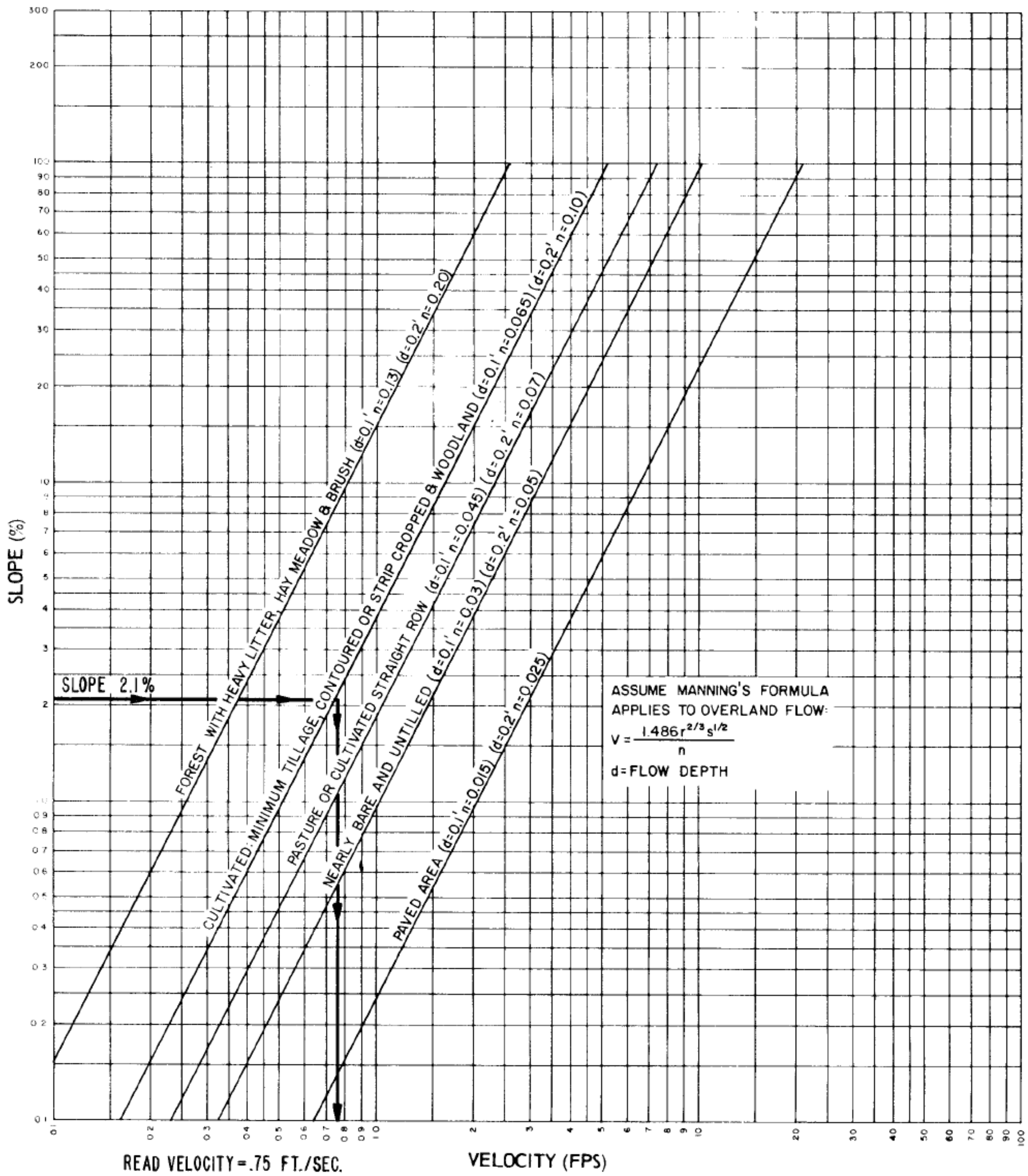

Figure 4-1
SLOPE VS. VELOCITY
OVERLAND FLOW

Figure 10: Figure 4-1 from Chapter 4 of the Hydrology Manual of North Dakota which was used to calculate the water velocity for overland flow for the time of concentration.

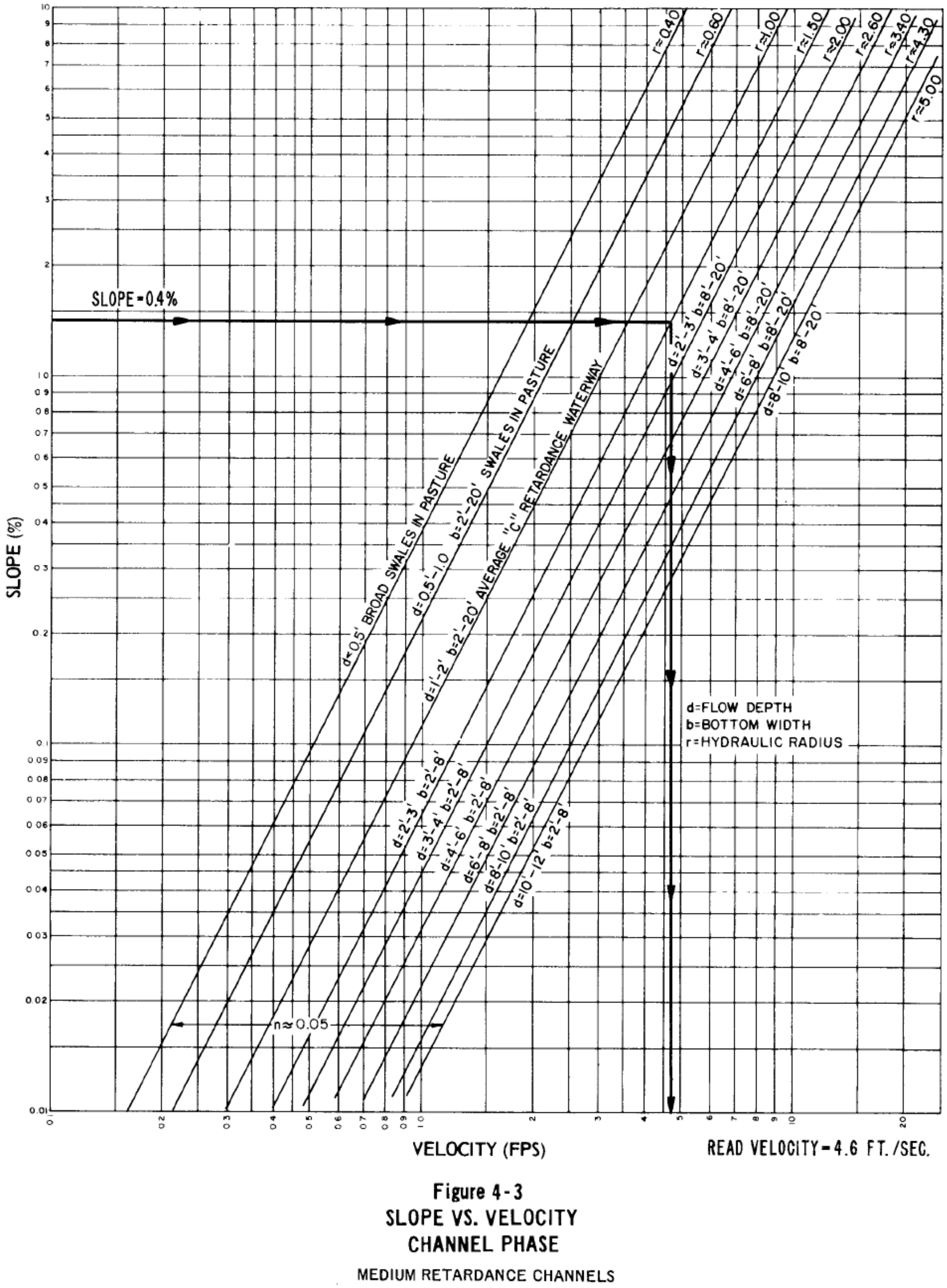

Figure 11: Figure 4-3 from Chapter 4 of the Hydrology Manual of North Dakota which was used to calculate the water velocity for the channel phase of the time of concentration.

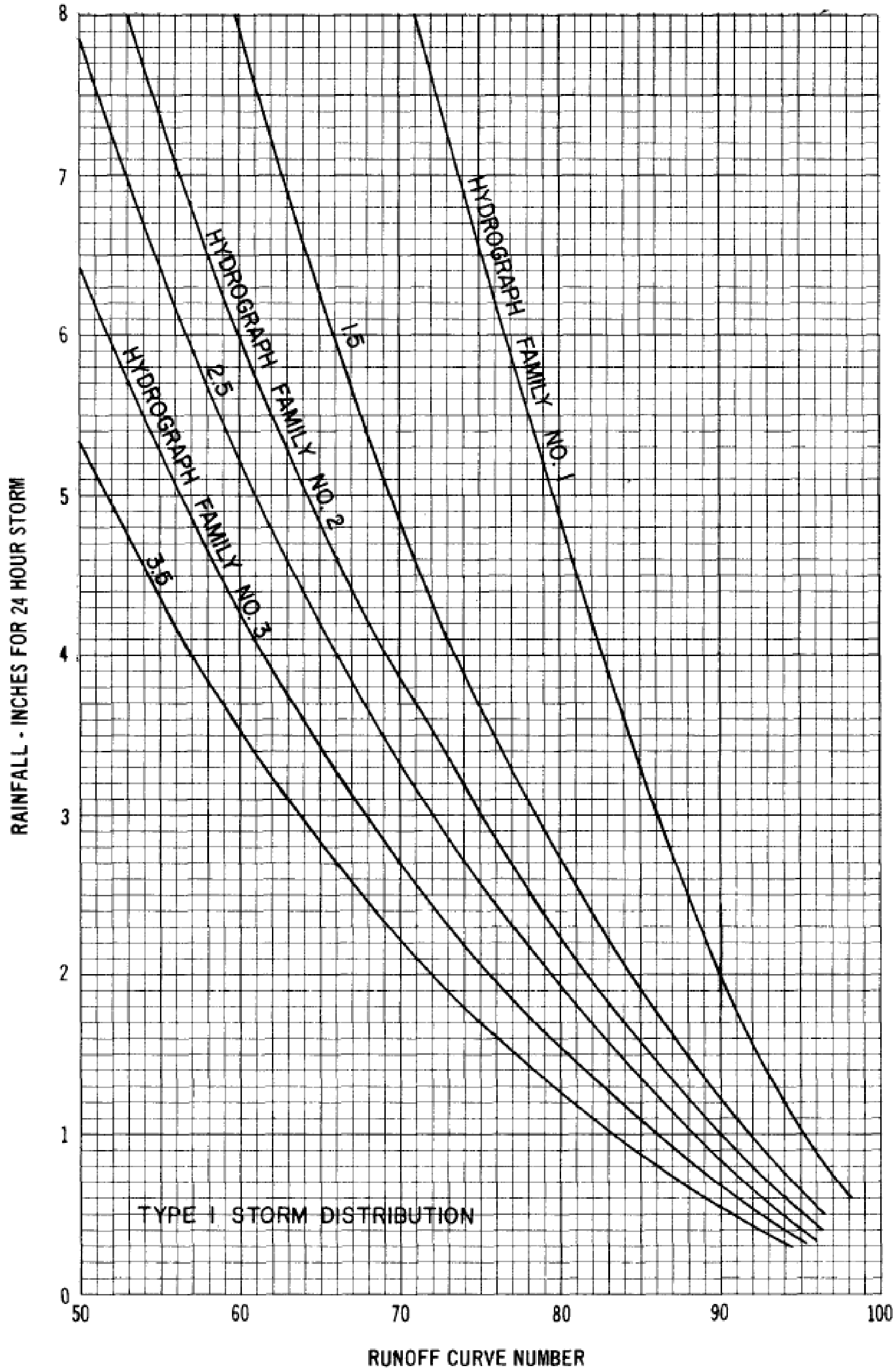

Figure 12: Figure 5-1 from Chapter 5 of the Hydrology Manual of North Dakota which was used to estimate a hydrograph family number.

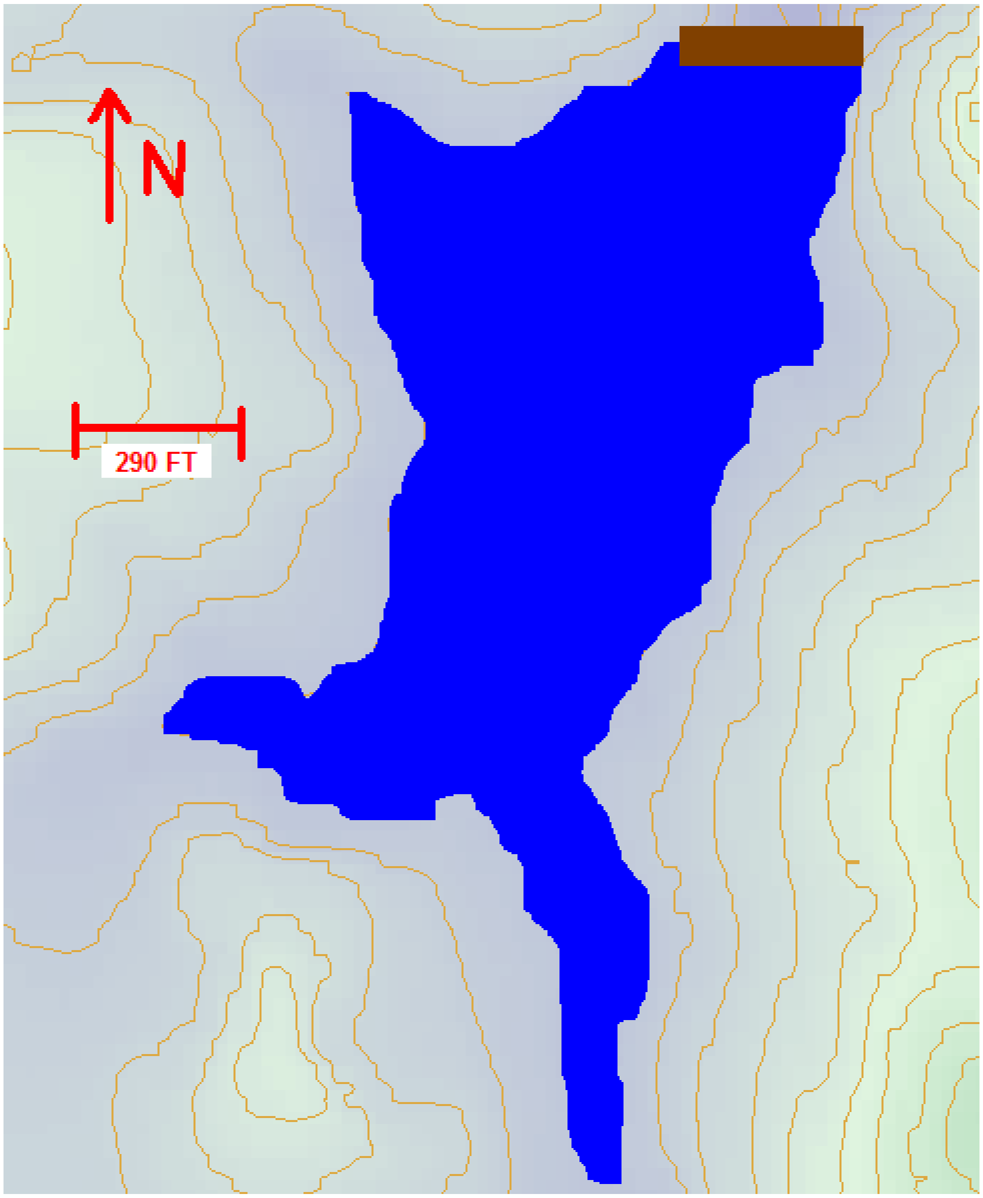

Figure 13: A picture of the maximum size of the wetlands area (ArcGIS 9). The maximum size of the wetlands area is 22 acres.

APPENDIX B - TABLES

Table 5: Soil names and brief descriptions, NRCS classification and percentage of each soil type found within the watershed are given (NRCS, 2009).

Hydrologic Soil Group— Summary by Map Unit — Sioux County, North Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
35	Amor-Cabba loams, 6 to 9 percent slopes	B	131.6	8.8%
36	Amor-Cabba loams, 9 to 15 percent slopes	B	367.0	24.4%
210	Belfield-Daglum silt loams, 0 to 2 percent slopes	C	6.6	0.4%
212	Belfield-Daglum silt loams, 2 to 6 percent slopes	C	109.0	7.3%
337	Cabba-Amor loams, 15 to 50 percent slopes	D	149.9	10.0%
818	Grail clay loam, 0 to 2 percent slopes	C	7.7	0.5%
1496	Regent-savage silty clay loams, 3 to 6 percent slopes	C	22.2	1.5%
1603	Savage silty clay loam, 0 to 2 percent slopes	C	5.2	0.3%
1907	Vebar-Cohagen fine sandy loams, 3 to 9 percent slopes	B	5.0	0.3%
1976	Water		10.5	0.7%
2294	Amor-Vebar complex, 0 to 6 percent slopes	B	14.7	1.0%
2296	Belfield-Grail silty clay loams, 0 to 2 percent slopes	C	8.3	0.5%
2297	Daglum-Rhoades complex, 0 to 6 percent slopes	D	33.3	2.2%
2300	Dogtooth-Janesburg-Regent complex, 6 to 15 percent slopes	D	92.8	6.2%
2306	Farnuf loam, 6 to 15 percent slopes	B	39.6	2.6%
2310	Flasher-Vebar-Parshall complex, 9 to 35 percent slopes	B	38.1	2.5%
2312	Grail-Belfield silty clay loams, 2 to 6 percent slopes	C	27.9	1.9%
2313	Grail-Savage clay loams, 2 to 6 percent slopes	C	259.8	17.3%
2315	Janesburg-Dogtooth silt loams, 0 to 6 percent slopes	D	9.8	0.7%
2321	Regent-Janesburg complex, 0 to 6 percent slopes	C	0.3	0.0%
2322	Regent-Janesburg complex, 6 to 9 percent slopes	C	17.2	1.1%
2326	Regent-Reeder complex, 3 to 6 percent slopes	C	36.2	2.4%
2327	Rhoades-Slickspots-Daglum complex, 0 to 9 percent slopes	D	6.3	0.4%

Table 5: Continued

Hydrologic Soil Group— Summary by Map Unit — Sioux County, North Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
2334	Vebar-Flasher-Tally complex, 9 to 15 percent slopes	B	104.3	6.9%
Totals for Area of Interest			**1,503.3**	**100.0%**

Table 6: Table of data reflecting the differences between curve numbers, time of concentrations, and how they effect the hydrograph data.

Difference in Curve Number Data			
Lowest Possible Curve Number	***72***	***Highest Possible Curve Number***	***78***
Row Crops (poor) CN = 81 (B soil)	203 acres	Row Crops (poor) CN = 91	203 acres
Pasture (poor) CN = 79 (B soil)	180 acres	Pasture (poor) CN = 89	180 acres
Pasture (fair) CN = 69 (B soil)	1120 acres	Pasture (fair) CN = 84	1120 acres
Total Product	107943	Total Product	116016
Total Acreage	1503 acres	Total Acreage	1503 acres
Difference in Time of Concentration			
Lowest Possible Time of Concentration	***3.0 hours***	***Highest Time of Concentration***	***1.0 hours***
Overland Flow Slope (%)	9.09	Overland Flow Slope (%)	9.09
Channel Phase (high ret.) Slope (%)	1.22	Channel Phase (low ret.) Slope (%)	1.22
Overland Reach Length (feet)	880	Overland Reach Length (feet)	880
Channel Phase Reach Length (feet)	12338	Channel Phase Reach Length (feet)	12338
Stream Depth Minimum	0.5-1 feet	Stream Depth Maximum	1-2 feet
Overland Flow (Min. Tillage) Velocity	1.50 feet/sec	Overland Flow (Nearly Bare) Velocity	2.25 feet/sec
Channel Phase (high ret.) Velocity	1.40 feet/sec	Channel Phase (low ret.) Velocity	3.25 feet/sec
Overland Flow Travel Time (seconds)	586.67	Overland Flow Travel Time (seconds)	391.11
Channel Phase Travel Time (seconds)	8812.86	Channel Phase Travel Time (seconds)	3796.31
Total Travel Time (seconds)	9399.52	Total Travel Time (seconds)	4187.42
Total Travel Time (hours)	2.61	Total Travel Time (hours)	1.16
Difference in Hydrograph Data			
Using Lowest TOC and Curve Number		***Using Highest TOC and Curve Number***	
Lowest Rainfall Frequency	3.5 inches	Highest Rainfall Frequency	3.85 inches
Lowest Curve Number	72	Highest Curve Number	78
Hydrograph Family Number	2.0	Hydrograph Family Number	1.0
Lowest Time of Concentration	3.0 hours	Highest Time of Concentration	1.0 hours
Lowest Direct Runoff (Q)	1.15 inches	Highest Direct Runoff (Q)	1.80 inches
Maximum Discharge (CSM/inch)	80.1	Maximum Discharge (CSM/inch)	185.7
Time When Max. Discharge is Reached (hours)	12.4	Time When Max. Discharge is Reached (hours)	10.5

Table 7: Table of the calculated data for producing a hydrograph for the watershed. The precipitation data was collected from Technical Paper No. 40 (Hershfield, 1961). The direct runoff and hydrograph family was collected from the HMND Chapter 4 and 6 respectively.

HYDROGRAPH DATA	
Drainage Area (mi^2) (A)	2.35
Precipitation (in) (P)	3.85
Time of Concentration (hr) (Tc)	1.00
Watershed Size (acre) (WS)	1503
Curve Number (CN)	77
Direct Runoff (in) (Q)	1.80
Hydrograph Family	No. 1
Peak Discharge (CSM/in) (PQ)	185.7
Discharge (cfs)	785.51

Time (hr)	CSM/in	Inflow (cfs)	ΔTime*Inflow
5.0	0.0	0.00	0.0
5.5	0.1	0.19	0.1
6.0	0.8	1.53	0.8
6.5	2.1	4.02	2.0
7.0	3.8	7.28	3.6
7.5	5.9	11.30	5.6
8.0	8.5	16.28	8.1
8.5	12.4	23.75	11.9
9.0	18.6	35.62	3.6
9.1	20.4	39.07	3.9
9.2	22.5	43.09	4.3
9.3	24.8	47.49	4.7
9.4	27.4	52.47	5.2
9.5	30.8	58.98	5.9
9.6	34.7	66.45	6.6
9.7	41.6	79.66	8.0
9.8	51.0	97.67	9.8
9.9	66.4	127.16	12.7
10.0	87.0	166.61	16.7
10.1	111.5	213.52	21.4
10.2	138.0	264.27	26.4
10.3	163.1	312.34	31.2
10.4	177.7	340.30	34.0
10.5	***185.7***	***355.62***	***35.6***
10.6	184.9	354.08	35.4
10.7	176.8	338.57	33.9
10.8	165.8	317.51	31.8
10.9	150.4	288.02	28.8
11.0	135.7	259.87	26.0
11.1	122.6	234.78	23.5

11.2	111.2	212.95	21.3
11.3	101.1	193.61	19.4
11.4	92.8	177.71	17.8
11.5	85.0	162.78	16.3
11.6	78.7	150.71	15.1
11.7	73.0	139.80	14.0
11.8	68.2	130.60	13.1
11.9	64.4	123.33	12.3
12.0	60.9	116.62	58.3
12.5	50.6	96.90	48.4
13.0	43.3	82.92	41.5
13.5	40.1	76.79	38.4
14.0	37.7	72.20	36.1
14.5	34.7	66.45	33.2
15.0	31.6	60.51	30.3
15.5	30.1	57.64	28.8
16.0	28.8	55.15	27.6
16.5	27.0	51.71	25.9
17.0	26.2	50.17	25.1
17.5	25.1	48.07	24.0
18.0	23.9	45.77	22.9
18.5	22.8	43.66	21.8
19.0	21.9	41.94	41.9
20.0	20.7	39.64	39.6
21.0	19.3	36.96	37.0
22.0	18.3	35.04	35.0
23.0	17.9	34.28	34.3
24.0	16.8	32.17	32.2
25.0	4.1	7.85	7.9
26.0	0.4	0.77	0.8
27.0	0.0	0.00	0.0

Table 8: Table includes the routing of the flood calculations which include; height of water over the weir, weir coefficient, discharge over and out of the weir, change in storage and storage after outflow.

Time (hr)	Inflow (cfs)	Inflow (ft^3)	Inflow (ac-ft)	S Before Outflow (ac-ft)	Height Over Weir (ft)	Weir Coeff.	Weir Q (cfs)	Qout (cfs)	ΔStorage (ac-ft)	S After Outflow (ac-ft)
5.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.5	0.19	172.4	0.00395661	0.0039566	0.0001313	3.1700	0.003	2.504	0.0000575	0.0038991
6.0	1.53	1551.2	0.0356095	0.0395086	0.0013107	3.1700	0.004	6.549	0.0001503	0.0393583
6.5	4.02	4998.2	0.11474174	0.1541000	0.0051109	3.1700	0.012	14.484	0.0003325	0.1537675
7.0	7.28	10168.7	0.23344008	0.3872076	0.0128350	3.1700	0.032	38.915	0.0008934	0.3863142
7.5	11.30	16718.0	0.38379132	0.7701056	0.0255042	3.1701	0.076	97.251	0.0022326	0.7678730
8.0	16.28	24818.4	0.56975207	1.3376250	0.0442400	3.1702	0.163	215.512	0.0049475	1.3326776
8.5	23.75	36021.2	0.82693182	2.1596094	0.0712880	3.1703	0.322	436.117	0.0100119	2.1495975
9.0	35.62	53428.5	1.22654959	3.3761471	0.1111271	3.1704	0.612	840.434	0.0192937	3.3568534
9.1	39.07	13443.3	0.3086157	3.6654691	0.1205682	3.1705	0.690	234.378	0.0053806	3.6600885
9.2	43.09	14787.6	0.33947727	3.9995658	0.1314544	3.1705	0.783	265.101	0.0060859	3.9934799
9.3	47.49	16304.3	0.37429545	4.3677754	0.1434323	3.1706	0.890	301.116	0.0069127	4.3608627
9.4	52.47	17993.3	0.41307025	4.7739330	0.1566205	3.1706	1.013	342.487	0.0078624	4.7660705
9.5	58.98	20061.5	0.46054959	5.2266201	0.1712899	3.1707	1.156	390.314	0.0089604	5.2176598
9.6	66.45	22577.8	0.51831612	5.7359759	0.1877582	3.1707	1.323	446.190	0.0102431	5.7257328
9.7	79.66	26300.6	0.60377893	6.3295117	0.2068983	3.1708	1.527	513.100	0.0117792	6.3177325
9.8	97.67	31919.2	0.73276446	7.0504970	0.2300765	3.1709	1.787	596.621	0.0136965	7.0368005
9.9	127.16	40467.8	0.9290124	7.9658129	0.2593886	3.1710	2.135	705.972	0.0162069	7.9496060
10.0	166.61	52877.0	1.21388843	9.1634944	0.2975527	3.1712	2.617	855.381	0.0196368	9.1438576
10.1	213.52	68422.9	1.57077479	10.7146323	0.3466602	3.1713	3.284	1062.313	0.0243873	10.6902450
10.2	264.27	86002.6	1.97434917	12.6645942	0.4078867	3.1716	4.184	1344.358	0.0308622	12.6337320
10.3	312.34	103789.2	2.38267149	15.0164035	0.4809854	3.1719	5.350	1716.072	0.0393956	14.9770079
10.4	340.30	117473.8	2.69682645	17.6738343	0.5626139	3.1722	6.759	2179.568	0.0500360	17.6237983
10.5	355.62	125264.0	2.87566529	20.4994636	0.6482946	3.1726	8.353	2720.137	0.0624458	20.4370178
10.6	354.08	127745.8	2.9326405	23.3696583	0.7341670	3.1729	10.059	3314.118	0.0760817	23.2935767
10.7	338.57	124678.0	2.86221281	26.1557895	0.8164220	3.1732	11.790	3932.843	0.0902857	26.0655038
10.8	317.51	118094.2	2.71107025	28.7765741	0.8928181	3.1736	13.478	4548.265	0.1044138	28.6721603
10.9	288.02	108994.1	2.50216116	31.1743214	0.9618937	3.1738	15.068	5138.297	0.1179591	31.0563624
11.0	259.87	98618.7	2.26397314	33.3203355	1.0230618	3.1741	16.525	5686.681	0.1305482	33.1897873
11.1	234.78	89036.0	2.04398554	35.2337728	1.0770845	3.1743	17.848	6187.075	0.1420357	35.0917371
11.2	212.95	80590.9	1.85011157	36.9418487	1.1249022	3.1745	19.047	6641.184	0.1524606	36.7893881
11.3	193.61	73179.8	1.67997727	38.4693653	1.1673430	3.1747	20.134	7052.617	0.1619058	38.3074595
11.4	177.71	66837.3	1.53437397	39.8418335	1.2052186	3.1749	21.120	7425.679	0.1704701	39.6713634
11.5	162.78	61287.7	1.40697107	41.0783344	1.2391351	3.1750	22.017	7764.585	0.1782503	40.9000841
11.6	150.71	56427.4	1.29539463	42.1954787	1.2696101	3.1751	22.833	8072.858	0.1853273	42.0101514
11.7	139.80	52291.0	1.20043595	43.2105873	1.2971646	3.1753	23.579	8354.115	0.1917841	43.0188032
11.8	130.60	48671.6	1.11734711	44.1361503	1.3221754	3.1754	24.264	8611.671	0.1976968	43.9384536
11.9	123.33	45707.2	1.04929339	44.9877470	1.3450926	3.1755	24.896	8848.790	0.2031403	44.7846067
12.0	116.62	43190.9	0.99152686	45.7761336	1.3662282	3.1755	25.485	9068.640	0.2081873	45.5679462
12.5	96.90	192170.3	4.4116219	49.9795681	1.4776231	3.1760	28.662	48731.904	1.1187306	48.8608376
13.0	82.92	161836.7	3.71525826	52.5760958	1.5453607	3.1763	30.654	53383.753	1.2255223	51.3505735
13.5	76.79	143739.9	3.29981405	54.6503875	1.5988957	3.1765	32.259	56621.752	1.2998566	53.3505310
14.0	72.20	134088.3	3.0782438	56.4287748	1.6443899	3.1767	33.645	59314.387	1.3616710	55.0671038

14.5	66.45	124781.4	2.86458678	57.9316906	1.6825494	3.1769	34.823	61621.627	1.4146379	56.5170527
15.0	60.51	114268.1	2.62323347	59.1402861	1.7130465	3.1770	35.774	63537.183	1.4586130	57.6816731
15.5	57.64	106340.0	2.44122934	60.1229025	1.7377179	3.1771	36.549	65090.847	1.4942802	58.6286222
16.0	55.15	101514.2	2.33044421	60.9590664	1.7586254	3.1772	37.211	66384.121	1.5239697	59.4350967
16.5	51.71	96171.3	2.20778926	61.6428860	1.7756648	3.1773	37.753	67467.333	1.5488369	60.0940491
17.0	50.17	91690.2	2.10491736	62.1989665	1.7894822	3.1774	38.194	68352.526	1.5691581	60.6298084
17.5	48.07	88415.6	2.02974174	62.6595501	1.8009004	3.1774	38.560	69079.381	1.5858444	61.0737058
18.0	45.77	84451.5	1.93873967	63.0124454	1.8096328	3.1774	38.841	69661.612	1.5992106	61.4132349
18.5	43.66	80487.5	1.8477376	63.2609725	1.8157742	3.1775	39.039	70092.431	1.6091008	61.6518717
19.0	41.94	77040.5	1.76860537	63.4204770	1.8197122	3.1775	39.166	70384.893	1.6158148	61.8046622
20.0	39.64	146842.2	3.37103306	65.1756953	**1.8628589**	3.1777	40.568	143520.797	3.2947841	61.8809112
21.0	36.96	137880.0	3.16528926	65.0462004	1.8596873	3.1777	40.464	145856.670	3.3484084	61.6977920
22.0	35.04	129607.2	2.9753719	64.6731639	1.8505406	3.1776	40.166	145133.530	3.3318074	61.3413565
23.0	34.28	124781.4	2.86458678	64.2059433	1.8390628	3.1776	39.793	143925.183	3.3040676	60.9018757
24.0	32.17	119610.9	2.74588843	63.6477642	1.8253187	3.1775	39.347	142452.094	3.2702501	60.3775141
25.0	7.85	72042.3	1.65386364	62.0313777	1.7853217	3.1773	38.061	139335.570	3.1987045	58.8326732
26.0	0.77	15511.5	0.35609504	59.1887682	1.7142664	3.1770	35.812	132971.968	3.0526163	56.1361519
27.0	0.00	1378.8	0.03165289	56.1678048	1.6377370	3.1767	33.442	124656.501	2.8617195	53.3060853

APPENDIX C – CALCULATION EQUATIONS

Volume of Embankment Fill – Section 1 + Section 2 + Section 3 = Total Volume

Section 1 = {H*[(B1 + B2)/2]}*(1/2*L*H)

Section 2 = {H*[(B1 + B2)/2]}*(L*H)

Section 3 = {H*[(B1 + B2)/2]}*(1/2*L*H)

H = Height of Embankment, L = Length of Section, B = Top/Bottom Width of Embankment

Weighted Curve Number – Total Product/Total Acres = Weighted Runoff CN

Σ(# of Acres Per Area)*(Curve Number Per Type of Soil) = Total Product

Time of Concentration – Travel Time = Reach Length/Water Velocity

Slope % = Elevation Drop/Reach Length

Direct Runoff Equation – $Q = (P - 0.2*S)^2/(P + 0.8*S)$

Q = Direct Runoff, P = Precipitation, S = Storage

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