APPENDIX N:
Hydrology Report

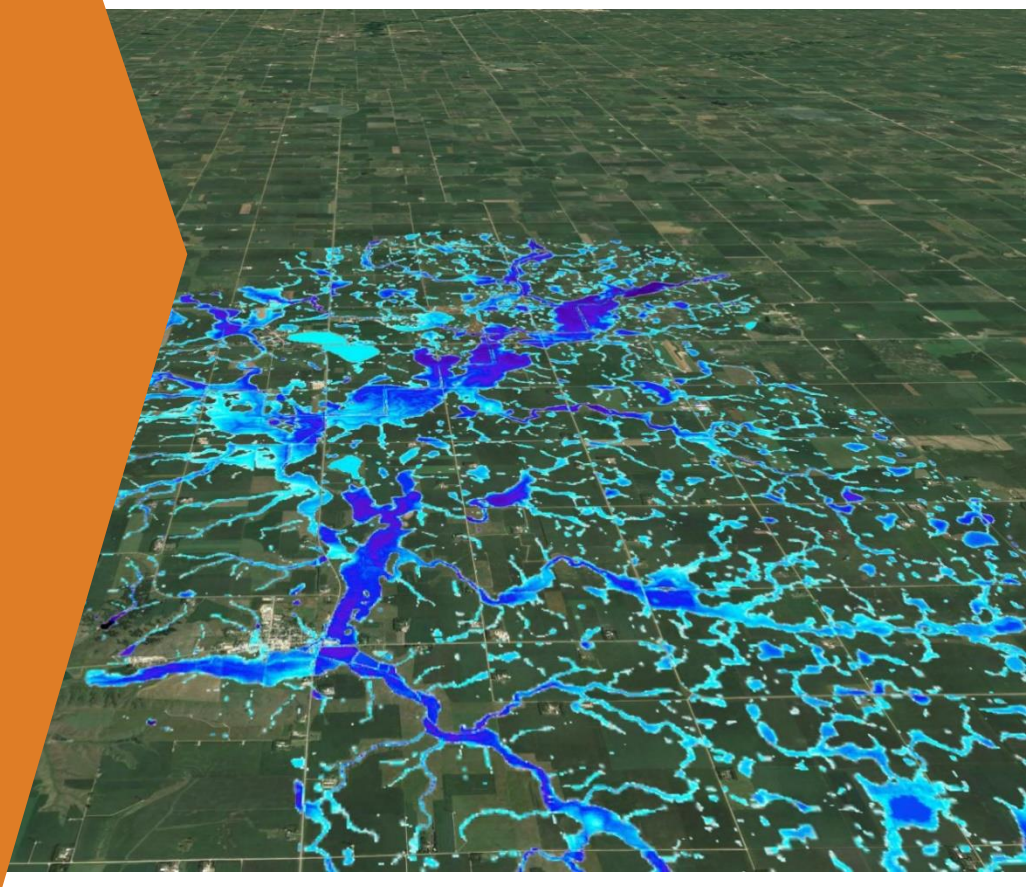
Westwood

PRELIMINARY HYDROLOGY REPORT

Lake Wilson Solar Project

Murray County, Minnesota

January 2020



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Preliminary Hydrology Report for

Lake Wilson Solar Project

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OVERVIEW

This study describes the hydrology of the proposed Lake Wilson Solar Project ("the project") and any impacts that the hydrology may play in the design of the solar array. This report was prepared to be used by the project team in the design of the project and not intended for submittal to reviewing agencies.

The project site is located on relatively flat terrain: most of the area has slopes less than 1% with steeper areas up to 5%. The site generally slopes from west to east and south to north. The modeled watershed area encompasses 78 square miles, which extends to the north and south. The existing landcover is row crops on soils of Hydrologic Soil Groups B, B/D, and C/D. Irrigation ditches running west-east and south-north through the project site are part of Judicial Ditch No. 14 according to the FEMA map.

FEMA has completed a study to determine flood hazard for the selected location; the project area is covered by FIRM panel 2706450350A (Exhibit 2). In the southeast corner of the proposed site, the FIRM shows a Zone A. A FEMA Zone A is a 100-year flood hazard with no base flood elevation determined.

The hydrologic modeling in this report was created using FLO-2D modeling software. FLO-2D was used to review the overall watershed drainage to and through the project to determine if any overland runoff causes flooding, velocity, or scour impacts to the site.

The analysis shows water depths (Exhibit 6 and 6A) that would be problematic for development. A large swath through the proposed site is inundated with 100-year flood depths up to 5 feet. The flooding source is Judicial Ditch No. 14 and some tributaries leading to it. These areas are not within the FEMA floodplain but would be very difficult to build in. Velocity and scour are not a major concern because the site is relatively flat.

Based on experience on other similar projects, portions of the site are suitable for the planned development if areas of high flood depths are avoided.

DATA SOURCES

The models and methods for this project utilize a combination of public and private data as shown in Table 1.

Table 1: Data Sources

Data Type	Format	Source	Use
Elevation	1-meter .bil	MnTOPO	FLO-2D Model Elevations
Crop Data	Shapefile	USDA 2013 Crop Data Layer	Curve Numbers
Soils	Shapefile	USGS SSURGO Dataset	Curve Numbers
Precipitation	PDF File	NOAA Atlas 14	Design storms
HUC-12 Drainage Boundary	Shapefile	USGS	Define Model Extents
Site Boundary	KMZ	Invenergy LLC	Define Model Extents
2014 Aerial Photography	ArcGIS Map Service	USDA FSA	Reference

EXISTING CODITIONS

Watershed Hydrology

The modeled watershed area encompasses approximately 78 square miles and extends north and south of the project site. Judicial Ditch No. 14 runs through the site from west to east and south to north. The site discharges to the northeast. Off-site drainage from the north and south could impact any solar array built here.

FEMA Flood Zone

FEMA has completed a study to determine flood hazard for the selected location; the project area is covered by FIRM panel 2706450350A (Exhibit 2). In the southeast corner of the proposed site, the FIRM shows a Zone A. A FEMA Zone A is a 100-year flood hazard with no base flood elevation. The FEMA Zone includes Moon Lake and the area south of it. There is extensive flooding outside the FEMA Zone A that also poses a risk.

Onsite Conditions

The project area is located between the towns of Lake Wilson and Chandler in Murray County, Minnesota. The project site is located in flat terrain slopes to the south. The project area is primarily used for agricultural row crops, and soils generally belong to Hydrologic Soil Groups B, B/D, and C/D (Exhibit 3). The potential hydrologic issue in this landscape is high water depths caused by flooding from Judicial Ditch No. 14 and its tributaries.

PROPOSED CONDITIONS

The proposed use of the site will be a solar facility. The solar facility will consist of solar modules mounted above grade on a racking system, gravel access roads, electrical equipment, and a perimeter security fence, although the layout is not yet finalized. The solar modules are located above the ground and the finished ground conditions will be completely pervious by converting to a vegetated filter. The project should be designed in a manner which will discharge drainage in a similar manner to that of existing conditions, and any existing drain tile onsite should be protected or replaced in order to provide proper drainage to the site.

Post-Construction Stormwater Management

County and State post-construction stormwater management regulations must be met by the project design. County Ordinance Section 14 Subdivision 10.13 prohibits discharge of stormwater that creates flooding or erosion on adjacent property. Due to the conversion of the site from crops to a solar array with grass, meeting this requirement will not be difficult.

The Murray County Renewable Energy Ordinance Section 10, Subdivision 1.2 states that solar energy facilities must follow the rules of the MPCA Construction Stormwater Permit. Those rules include post-construction requirements for stormwater quality facilities. Depending on soil type where the basin is located, an infiltration basin or a wet sedimentation basin must be designed. Sizing of any basin is determined by an MPCA spreadsheet.

The Murray County Subdivision Ordinance Section 5, Subdivision 5 lays out 4 general rules for storm drainage design. Any drainage ditch must have a minimum 1% grade and watercourses should be designed with adequate capacity and erosion control for safe passage of stormwater. These rules will not be difficult to satisfy.

Post-construction stormwater management might also be required to meet the rules in the Murray County Buffer Ordinance.

FLO-2D MODELING

FLO-2D is a physical process model that routes rainfall runoff and flood hydrographs over flow surfaces or in channels using the dynamic wave approximation to the momentum equation. FLO-2D offers advantages over 1-D models and unit hydrograph methods by allowing for breakout flows and visualization of flows across a potential site. This is particularly useful in areas where the detailed hydrological characteristics and potential at-risk areas have not been identified, such as the project site. The primary inputs are a DTM (elevation data), curve numbers and precipitation. Major culverts and hydraulic structures within the watershed were included in the model; roads and berms without modeled structures were allowed to overtop in the model.

Precipitation data was downloaded from the NOAA Atlas 14 (Appendix A) and used for the FLO-2D analysis for the 100-year, 24-hour storm (Appendix A). Using the 100-year rainfall event allows for the best initial analysis in order to determine the worst areas of flooding and erosion. The 100-year, 24-hour rainfall depth for the project area is 6.8 inches. Rainfall is distributed in a nested Atlas 14 distribution pattern.

The elevation data input into the FLO-2D model was 2-meter GeoTIFF data from the USGS Data Gateway (Exhibit 5), which was incorporated into the DTM using the export to xyz function in Global Mapper. These XYZ files are read directly into FLO-2D.

USDA-NRCS SSURGO soil data provides soil types within the project boundary and full coverage of the contributing watershed. Soils in the area are primarily classified as Hydrologic Soil Groups B, B/D, and C/D in the project boundary (Exhibit 3). Land cover was obtained from the USDA 2013 Crop Data Layer. Exhibit 4 displays the Land Cover Classes for the entire watershed. Curve numbers were applied to each grid cell in the FLO-2D model based on intersecting the grid with the curve numbers (Exhibit 5).

FLO-2D Watershed Model

A FLO-2D model with 50-foot grid cells was utilized to determine flow depths and velocities throughout the site. The modeled watershed for the project area is approximately 78 square miles. The FLO-2D model area is sized to ensure all contributing flows are accounted for. Hydrologic modeling for the project was done with one watershed to accurately model the project's hydrology.

FLOOD ANALYSIS RESULTS

Existing Flood Analysis

The FLO-2D analysis shows water depths (Exhibit 6 and 6A) that would be problematic for development. A large swath through the proposed site is inundated with 100-year flood depths up to 5 feet. The flooding source is Judicial Ditch No. 14 and some tributaries leading to it. These areas are not within the FEMA floodplain but would be very difficult to build in. Velocity and scour are not major concerns because the site is relatively flat.

The FLO-2D results are mostly in agreement with the FEMA flood zone delineations in those areas where FEMA drew flood zones. There is flooding reported by FLO-2D that is not within a FEMA flood zone.

The large swath of high water runs from southwest to northeast through the project area. Access roads that cross the flood area will require extensive modeling, calculations, and permitting work. It is recommended that access roads avoid crossing the floodplain.

SUMMARY

Based on experience on similar project, portions of the site are suitable for the planned development and all hydrologic concerns can be addressed through detailed engineering design. Portions of the site are not suitable for this project because of high water in the 100-year storm.

According to the FLO-2D model, the maximum flooding depth during the 100-year 24-hour storm is approximately 5 feet and cover large areas within the proposed site. Due to the relatively flat land both velocities and scour depths are low throughout the project site.

There is FEMA Zone A floodplain within the site but widespread flooding also exists. The portions of the site not inundated are suitable for the planned development if the following recommendations are made as the design progresses.

NEXT STEPS

1. Final design should account for the proposed flood depths presented in Exhibits 6 and 6A. Proposed facilities should avoid FEMA Flood Zones.

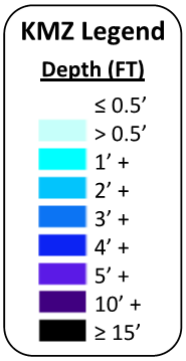
2. Facilities to be elevated 1-foot above the 100-year, 24-hour peak flood elevations.

3. Stormwater management should be revisited to ensure the final design meets the county and state requirements.

Included Output Files:

1. Shapefile of Existing Flow Depth
   2020-01-07_Lake_Wilson_Prelim_Flow_Depth_at_Cell.shp
   Attribute "ID" = Grid Cell Number
   Attribute "VAR" = Max Flow Depth (Feet)

2. KMZ of Existing Flow Depth
   2020-01-07_Lake_Wilson_Prelim_Flow_Depth_at_Cell.kmz
   Overlay in Google Earth for graphical representation.



3. Shapefile of Existing Velocity
   2020-01-07_Lake_Wilson_Prelim_Velocity_at_Cell.shp
   Attribute "ID" = Grid Cell Number
   Attribute "VAR" = Velocity (FPS)

4. KMZ of Existing Velocity
   2020-01-07_Lake_Wilson_Prelim_Velocity_at_Cell.kmz
   Overlay in Google Earth for graphical representation.

REFERENCES

National Engineering Handbook, Part 630 Hydrology. Chapter 9 Hydrologic Soil-Cover Complexes. USDA. NRCS. 210-VI-NEH, July 2004

USDA, USGS Data Gateway. 2-m LiDAR, Elevation data, Accessed May 2019, https://gdg.sc.egov.usda.gov/GDGOrder.aspx

Web soil survey. Retrieved May 2019, from https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

NOAA, & Service, N. W. AHPS Precipitation analysis. Retrieved May 2019, from http://water.weather.gov/precip/download.php

USGS. USGS water resources: About USGS water resources. Retrieved May 2019, from https://water.usgs.gov/GIS/huc.html

USDA 2013 Crop Data Layer, Landcover data, retrieved May 2019, from https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php

Frequency of Maximum Water Equivalent of March Snow Cover in North Central United States. US Department of Commerce Technical Paper No. 50, 1964

USGS. USGS stream stats. Retrieved May 2019, from

https://streamstats.usgs.gov/ss/