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Memorandum

Project title	CHEERS
Job number	292054-00
File reference	
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Date	January 22, 2026
Subject	Stormwater Modeling Assumptions

This technical memo provides an overview of the stormwater analysis and modeling conducted for the Phase 1 Habitat Loop portion of the CHEERS project. The purpose of this model is to ensure conveyance methods are sized appropriately to accommodate the runoff in post-development conditions. Pre-development conditions were excluded in the analysis as there is no pre-existing site; dredge material will be placed in Lake Erie to create the park area for the post-developed condition. See the CHEERS Schematic Design: Basis of Civil Design Memorandum 50% Deliverable issued on September 29, 2023, for information on the basis of design and permit exemptions.

Meteorological Model

Frequency storms were used with rainfall data gathered from NOAA Atlas 14 Point Precipitation Frequency Estimates for the 5-yr, 10-yr, 25-yr, and 100-yr storms. A climate adjustment was estimated by the Environmental Law and Policy Center's Assessment of the Impacts of Climate Change on the Great Lakes[1]. A 4.5% increase was applied to reported depths; this adjustment was more conservative than utilizing the 99th percentile storm depth, calculated with Cleveland Airport daily historic rainfall data from 1995 to 2025. Climate adjusted storm depths were used to understand infrastructure performance under extreme future conditions. A summary table of values is shown in Table 1.

[1] https://elpc.org/resources/the-impacts-of-climate-change-on-the-great-lakes/

Table 1: Storm Intensities and Depths

Storm Event (24 hr)	NOAA Atlas 14 Intensity (in/hr)	NOAA Atlas 14 Depth (in)	Climate Adjusted Depth (in)
5-yr	0.121	2.93	3.05
10-yr	0.141	3.40	3.55
25-yr	0.170	4.09	4.27
100-yr	0.219	5.27	5.50

Conveyance Design Considerations

To align with project context and goals – limiting hard infrastructure, incorporating nature-based solutions, and increasing habitat area – vegetated swales were utilized as the primary conveyance method throughout the site. Three swales direct berm runoff away from public use spaces. Two culverts convey swale discharges underneath the crushed stone paths.

The chosen pipe material for the culverts is High Density Polyethene (HDPE). HDPE pipe is a durable, flexible plastic pipe. Its ductility allows it to withstand ground shifts and freezing, making it an ideal candidate for this site which has dredge settlement considerations and is located on Lake Erie.

The culvert layout was driven by efforts to minimize the effects of dredge settlement on physical infrastructure. Significant settlement is expected throughout the lifetime of the dredge material; therefore, culvert lengths were limited and steeper slope prioritized. See Table 2 for settling estimates. Refer to the Cleveland Harbor Eastern Embayment Resilience Strategy (CHEERS) Geotechnical Engineering Report – Park Design Advancement (January 22, 2026) for more information.

Table 2: Estimated Settlement

Total Settlement[1] [in]						
Section ID	Time = 0.16 years (2 months)[2]	Time = 1.16 years (14 months)	Time = 2.67 years (32 months)	Time = 5 years	Time = 10 years	Time – 20 years
BW STA 06+00.00 (H=28 ft)	3	5	7	8	10	13
BW STA 12+00.00 (H=30 ft)	21	35	43	48	54	60

Notes:
1. Settlements recorded at embankment midline.
2. Estimated breakwater end of construction time.
3. Time 0 marks beginning of breakwater construction, breakwater construction estimated to be completed at 18 months.

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Modeling Design

The site area was delineated into two catchments, with Catchment 1 (0.57 ac.) draining to the east side of the berm, and Catchment 2 (1.14 ac.) to the west side of the berm, depicted in Figure 1. A catchment represents the area of land from which surface runoff flows toward a common drainage point and is typically delineated by identifying topographic high points and flows paths that define the boundaries of contributing drainage areas.

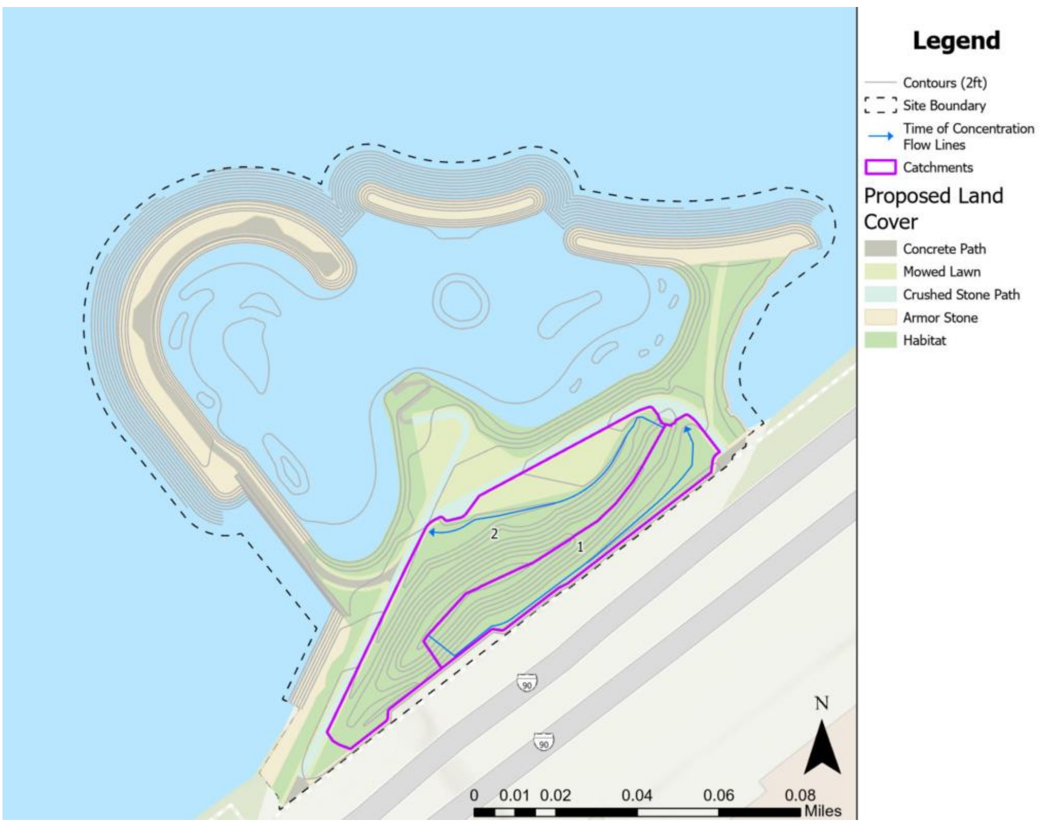

Figure 1: Proposed Catchments, Land Cover, and Time of Concentration Flow Lines

An InfoDrainage model was created to analyze hydraulic conveyance capacities under the 10-yr, 25-yr, and 100-yr 24-hr storm events. The model setup is shown in Figure 2.

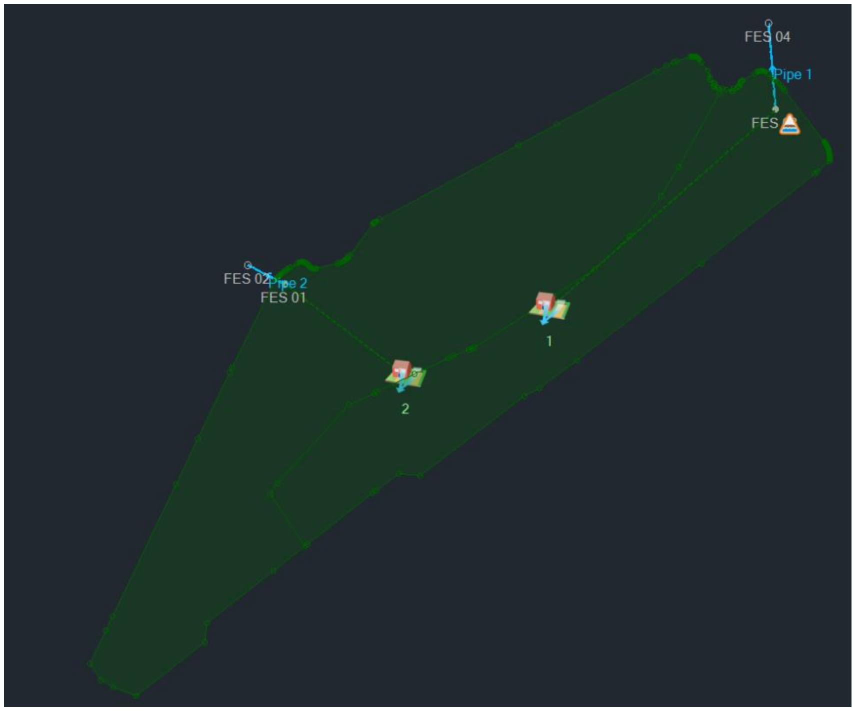

Figure 2: InfoDrainage Model

In InfoDrainage, curve numbers (CN) and time of concentration values were assigned to catchments using table Runoff Curve Numbers – SCS Method. It was assumed that the hydrological soil group is Type C based off the USACE's evaluation of dredge material in Cleveland Harbor, see Table 3, and the United States Department of Agriculture (USDA) National Engineering Handbook's classification of hydrological group C. USDA determines group C to be comprised of 20-40 percent clay and less than 50% sand[2]. The land type assigned was meadow land for the upland berm area and habitat areas, and good condition lawn for the mowed areas.

[2] https://directives.nrcs.usda.gov/sites/default/files2/1712930597/11905.pdf

Table 3: USACE Evaluation of Cleveland Harbor Dredged Material: Grain Size Distribution in Cleveland Harbor Sediment Samples

ANALYTE	CARSN	UNIT	CH-1	CH-2	CH-3	CH-4	CH-5	CH-5 DUP	CH-6A	CH-6B	CH-7A	CH-7B	CH-8	DMMU-1
Clay	Clay	%	16.9	19	21.6	28.9	26.4	25.7	25.8	24.5	24	22	22	21.2
Silt	Silt	%	60.8	63.5	60.2	64.2	67.7	68.5	69	67	64.8	70.2	66.9	61.1
Fine Sand	Fine Sand	%	16.8	12.3	14.1	6.4	5.5	5.5	4.6	8.3	9.1	7.6	10	14.9
Medium Sand	Medium Sand	%	1.3	1.2	1.2	0.4	0.1	0.3	0.3	0.2	1.1	0.1	0.4	1.2
Coarse Sand	Coarse Sand	%	1	1.7	0.9	0.1	0.1	0	0.2	0	0.3	0.1	0.3	1.4
Sand	Sand	%	19.1	15.2	16.2	6.9	5.7	5.8	5.1	8.5	10.5	7.8	10.7	17.5
Gravel	Gravel	%	3.2	2.3	2	0	0.2	0	0.1	0	0.7	0	0.4	0.2

ANALYTE	CARSN	UNIT	DMMU-1S	DMMU-2	PB COMPOSITE	PB-1	PB-2	PB-3	PB-4	BS COMPOSITE	BS-1	BS-2	BS-3	BS-4
Clay	Clay	%	17.6	32.8	1.1	1.1	1.2	1	1.1	28.2	38.7	37	21.8	23.7
Silt	Silt	%	64.6	59.7	0.3	1.1	0.4	1.3	4.2	42.5	48.5	46.6	47.4	25.2
Fine Sand	Fine Sand	%	16.6	6.9	84.8	71.1	84.9	81	92.2	10.8	7.6	10.4	17.1	11.1
Medium Sand	Medium Sand	%	1.2	0.5	10.7	21.5	11.9	12.9	2.1	10.4	4.9	6	12	12.5
Coarse Sand	Coarse Sand	%	0	0.1	2.8	4.8	1	2.8	0.4	2.3	0.3	0	0.7	16.7
Sand	Sand	%	17.8	7.5	98.3	97.4	97.8	96.7	94.7	23.5	12.8	16.4	29.8	40.3
Gravel	Gravel	%	0	0	0.3	0.3	0.6	0.9	0	5.8	0	0	1	10.8

- Calculation Assumptions: SCS Curve Number
  - The weighted SCS curve number was determined per catchment through land use and soil type cover and thus inputted as a pre-calculated value.
  - As the weighted SCS value already factors in the impervious area, the impervious % was set to zero.

The time of concentration (TOC) for each catchment was calculated, with Catchment 1 having a TOC of 7.07 minutes and Catchment 2 having a TOC of 6 minutes. For Catchment 2, two flow paths were calculated: one along the swale behind the berm and one along the swale in front of the berm. Both indicated a TOC that was lower than 6 minutes, so 6 minutes was used as the minimum TOC. See Table 4 for a summary of each catchment. For further details on the calculation of CN and TOC see Table 5 and Table 6.

Table 4: Catchment Property Summary

Catchment	Time of Concentration (min.)	Curve Number (CN)
Catchment 1	7.07	71
Catchment 2	6	72

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Table 5: Curve Number (CN) Calculation

Catchment	Cover Type	Area (AC)	Assigned CN	Weighted CN
1	Meadow	0.56	71	71
	Mowed Lawn	0.01	74	
2	Meadow	0.91	71	72
	Mowed Lawn	0.23	74	

Table 6: Time of Concentration (TOC) Calculation

Catchment		1	2
Sheet Flow			
Surface description		Unpaved	Unpaved
Manning's roughness coefficient, **n**	TR-55 Manual, Table 3-1	0.05	0.05
Flow length, **L** (total =< 100ft) (ft)	Part 60 Hydrology, National Engineering Handbook, Chapter 15	100	100
2yr, 24-hour rainfall, $\mathbf{P_2}$ (in)		2.34	2.34
Land slope, **s** (ft/ft)	measured in Civil 3D	0.1008	0.0761
Sheet Flow time, $\mathbf{T_t}$ (hr)	TR-55 Manual, Equation 3-3	0.04	0.05
Sheet Flow time, $\mathbf{T_t}$ (min)		2.49	2.79
Shallow concentrated flow			
Surface description (paved or unpaved)		Unpaved	Unpaved
Flow length, **L** (ft)		360.2656	253.2655
Land slope, **s** (ft/ft)		0.0066	0.012505
Average velocity, V (ft/s)		1.31	1.80
Shallow Concentrated Flow time, $\mathbf{T_t}$ (hr)	TR-55 Manual, Equation 3-1	0.08	0.04
Shallow Concentrated Flow time, $\mathbf{T_t}$ (min)		4.58	2.34
Total			
Time of Concentration, $\mathbf{T_c}$ (min)	TR-55 Manual, Equation 3-2	7.07	5.13
Minimum $\mathbf{T_c}$ requirement (min)	as per TR-55 Manual	6.00	6.00
$\mathbf{T_c}$ to be used in analysis (min)		7.07	6.00
$\mathbf{T_c}$ to be used in analysis (hr)		**0.12**	**0.10**

Results

The 10-yr, 25-yr, and 100-yr design storms were computed. With the model results, the western culvert was set to be 12" in diameter, and the eastern culvert was set to be 12" in diameter. A summary of results for the eastern culvert in Catchment 1 and the western culvert in Catchment 2 are shown in Table 7 and Table 8, respectively. Results provided max flow, max velocity, which represents the maximum velocity through each culvert during the rainfall event, and the Flow/Capacity, which represents the ratio between the maximum inflow and the Mannings equation calculated pipe capacity. If the flow to capacity ratio is below 1, then the pipe has capacity to handle all flow. Given the culvert conditions and Mannings pipe flow equation, the potential maximum velocity the eastern culvert could convey is 6.22 ft/s and the western culvert around 8.94 ft/s (assumed Manning's n value of 0.012 for HDPE pipe). Given the Flow/capacity ratio is less than 1 and max velocities are below potential maximum velocity, the culverts are sufficiently sized to handle the 10-year, 25-year, and 100-year storms.

Table 7: Eastern Culvert Model Conveyance Values

	10-year	25-year	100-year
Max flow (cfs)	0.44	0.57	0.83
Flow/Capacity	0.09	0.12	0.17
Max Velocity (ft/s)	3.7	4.0	4.4

Table 8: Western Culvert Model Conveyance Values

	10-year	25-year	100-year
Max flow (cfs)	1.71	2.48	3.92
Flow/Capacity	0.24	0.35	0.56
Max Velocity (ft/s)	6.8	7.4	4.4

A HydroCAD model was created to assess the potential ponding in swale upstream of western culvert, Catchment 2, due to its proximity to public gathering area and larger catchment area. The ponding depth, the depth of any standing water in the low point of the swale, and the associated freeboard, the difference between the elevation of the adjacent public spaces and the ponding elevation, were assessed. The model indicated ponding would not reach levels to impact public spaces. A summary of values is shown in Table 9.

Table 9: Western Culvert Ponding Depths

Storm Event (24-hour duration)	Peak Ponding Elevation (ft)	Ponding Depth (ft)	Freeboard (ft)
10-year	576.23	0.73	1.77
25-year	576.43	0.93	1.57
100-year	576.87	1.37	1.13

Rip Rap Design

Outlet protection is designed for culvert discharge locations to prevent erosion. A Manning's n value of 0.012 and minimal tailwater conditions were assumed in sizing rip rap for this site. Utilizing full pipe flow for apron design, the aprons were sized to accommodate any current and future discharge through the culverts. Based on the Manning's equation, the velocity for Pipe 1 and Pipe 2 at full flow are calculated as 6.22 ft/s and 8.94 ft/s, respectively. Apron sizing can be found in the civil details in the January 22, 2026 Cleveland Harbor Eastern Embayment Resilience Strategy (CHEERS) Early Action Project, Habitat Loop 90% Design.