Developing a Tool for Standardized Hydraulic Risk Calculations

PRESENTED AT THE OHIO STORMWATER CONFERENCE
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Northeast Ohio Regional Sewer District

WADE TRIM

Agenda

- Background
- Flood Risk Challenges
- Developing the Probable Annual Risk (PAR) Tool
- PAR Tool Results
- Lessons Learned
- Next Steps

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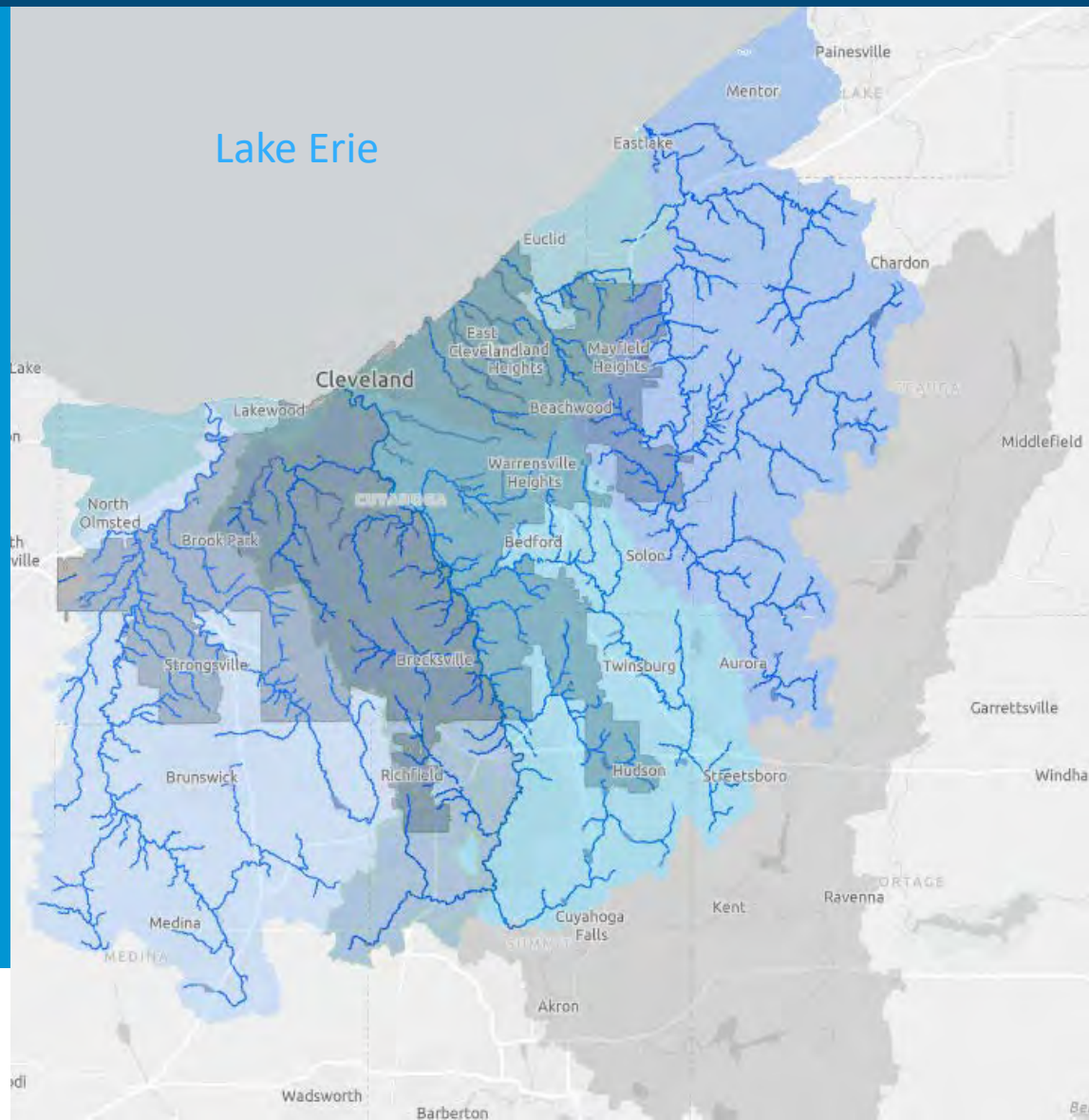
At a glance

- Wastewater and Stormwater Utility
- Serving Cleveland and surrounding communities
- 375 sq. mile service area
- 90+ billion gallons sewage treated annually
- 500 miles of regional stormwater system
- Water quality monitoring
- Lake Erie beach monitoring, maintenance
- Industrial pretreatment program



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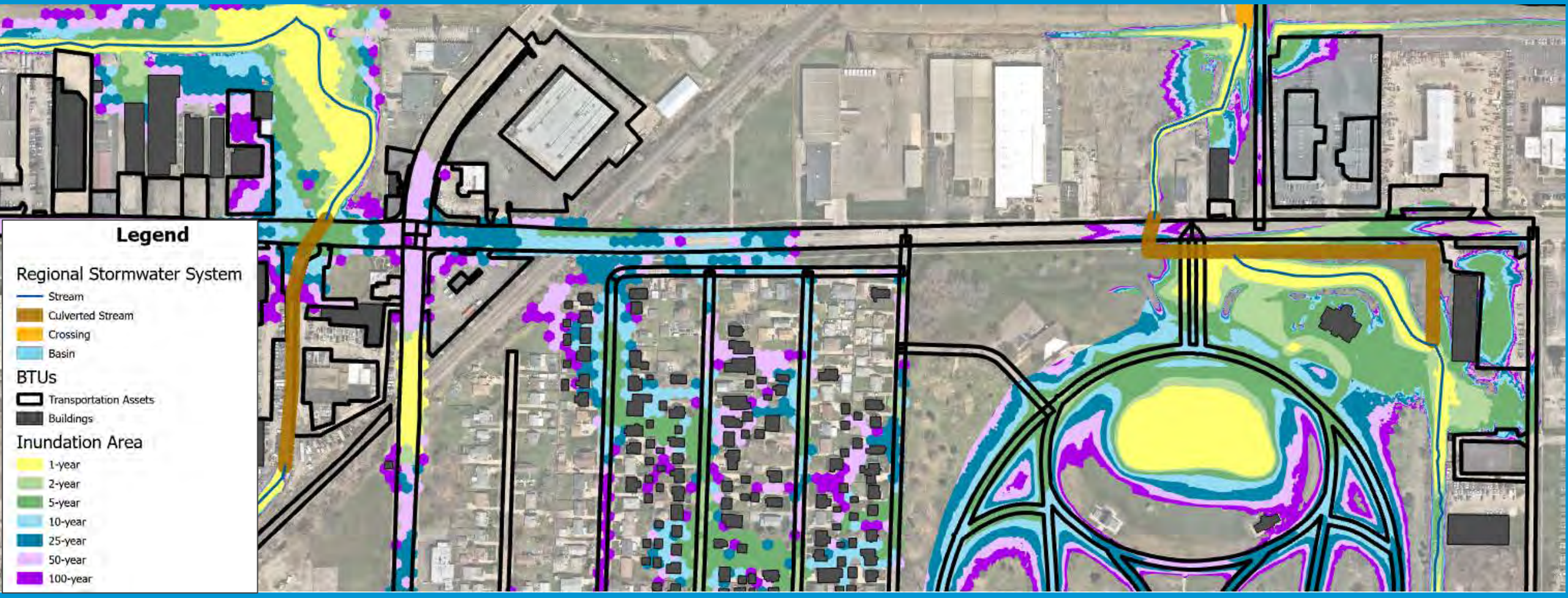
Flood Risk Challenges

- Identifying problems
- Evaluating & phasing alternatives
- Prioritizing projects for the stormwater construction plan
- Communicating findings and recommendations
- Tracking program success
- Supporting urgent storm event planning & field response
- Assessing potential impacts due to climate change

What Floods?



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Challenge: Identifying Building and Transportation Assets with a Flood Risk

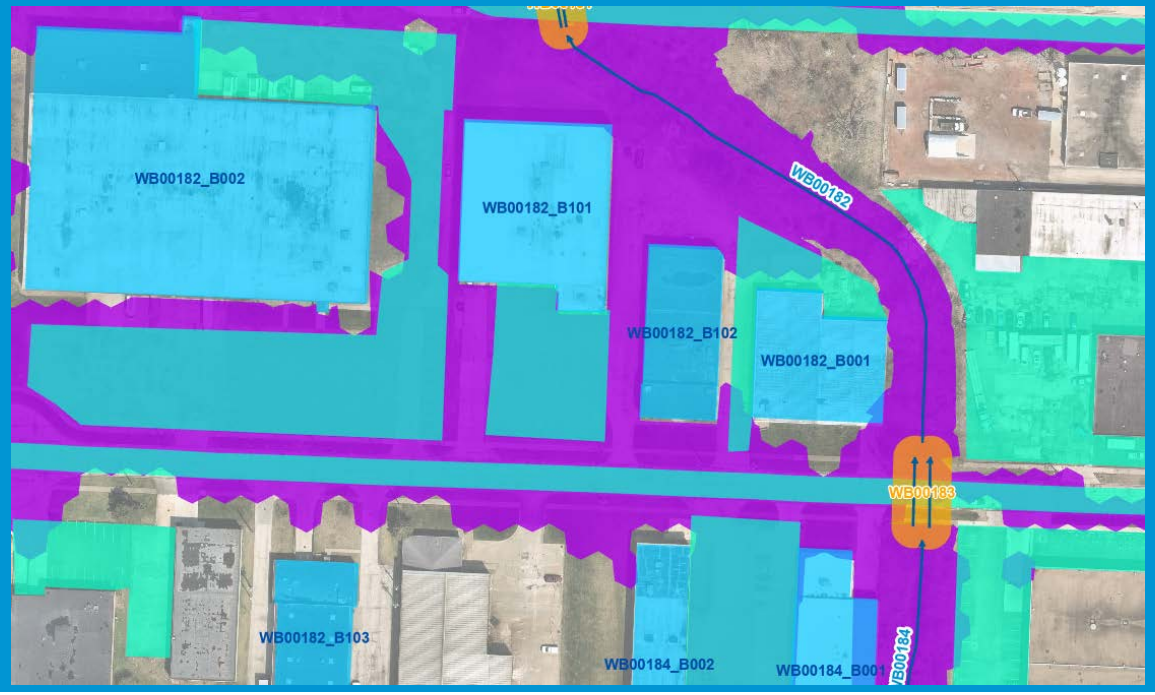
Condition Rating (CR)	Criticality						
	3	4	5	6	7	8	9
1	3	4	5	6	7	8	9
2	6	8	10	12	14	16	18
3	9	12	15	18	21	24	27
4	12	16	20	24	28	32	36
5	15	20	25	30	35	40	45

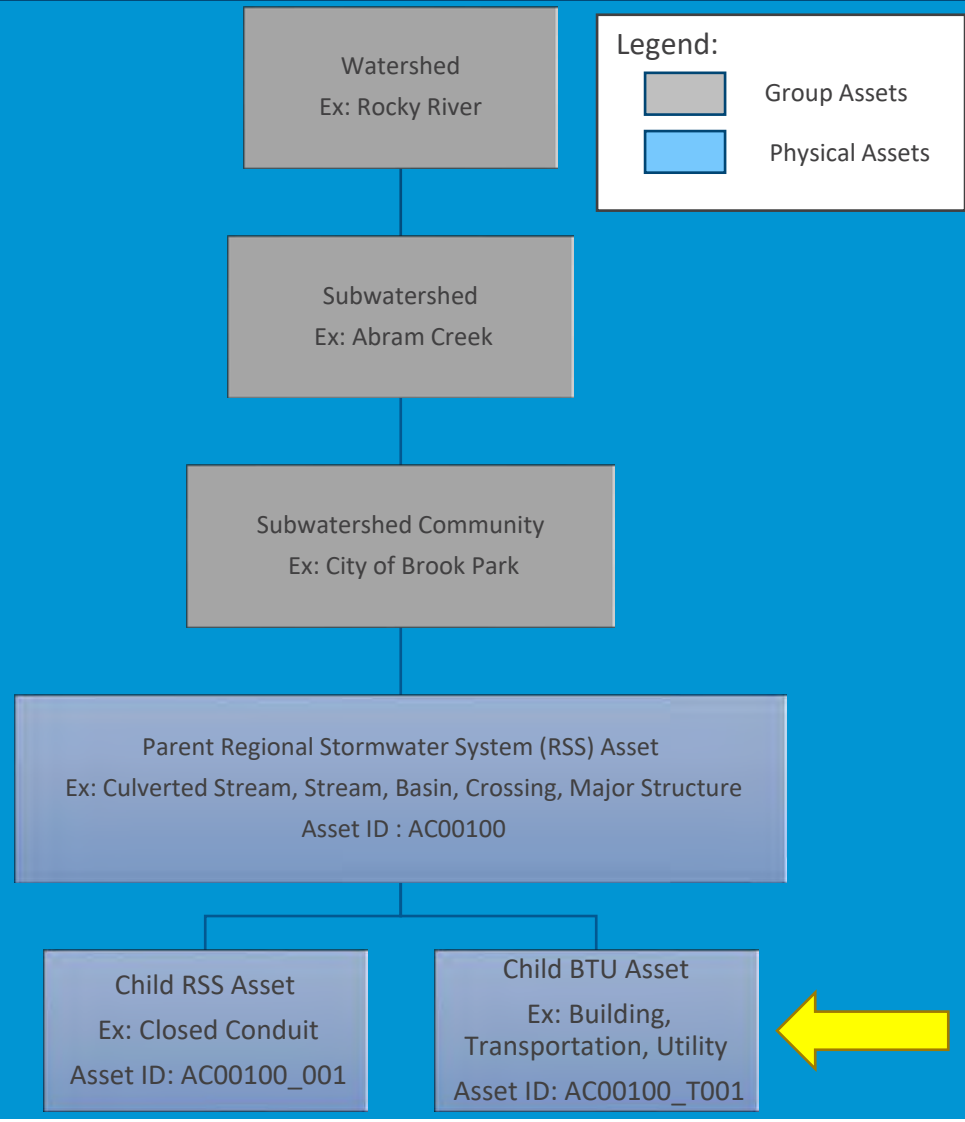
BRE = Condition x Criticality. BRE scores are generally organized into four tiers:

- BRE <12 = Low Risk ← Action As-needed
- BRE = 12 and < 20 = Moderately Low Risk ← Action As-needed
- BRE = 20 and < 34 = Moderately High Risk ← Action Required
- BRE = 34 – 45 = High Risk ← Action Required

Hydraulic Risk – Building and Transportation Inundation

- The District assesses hydraulic risk to individual building and transportation assets (polygon)
- Each asset has an inundation depth assigned by model results to assign a condition rating (CR)
- The BRE is calculated by design storm to assess its individual risk





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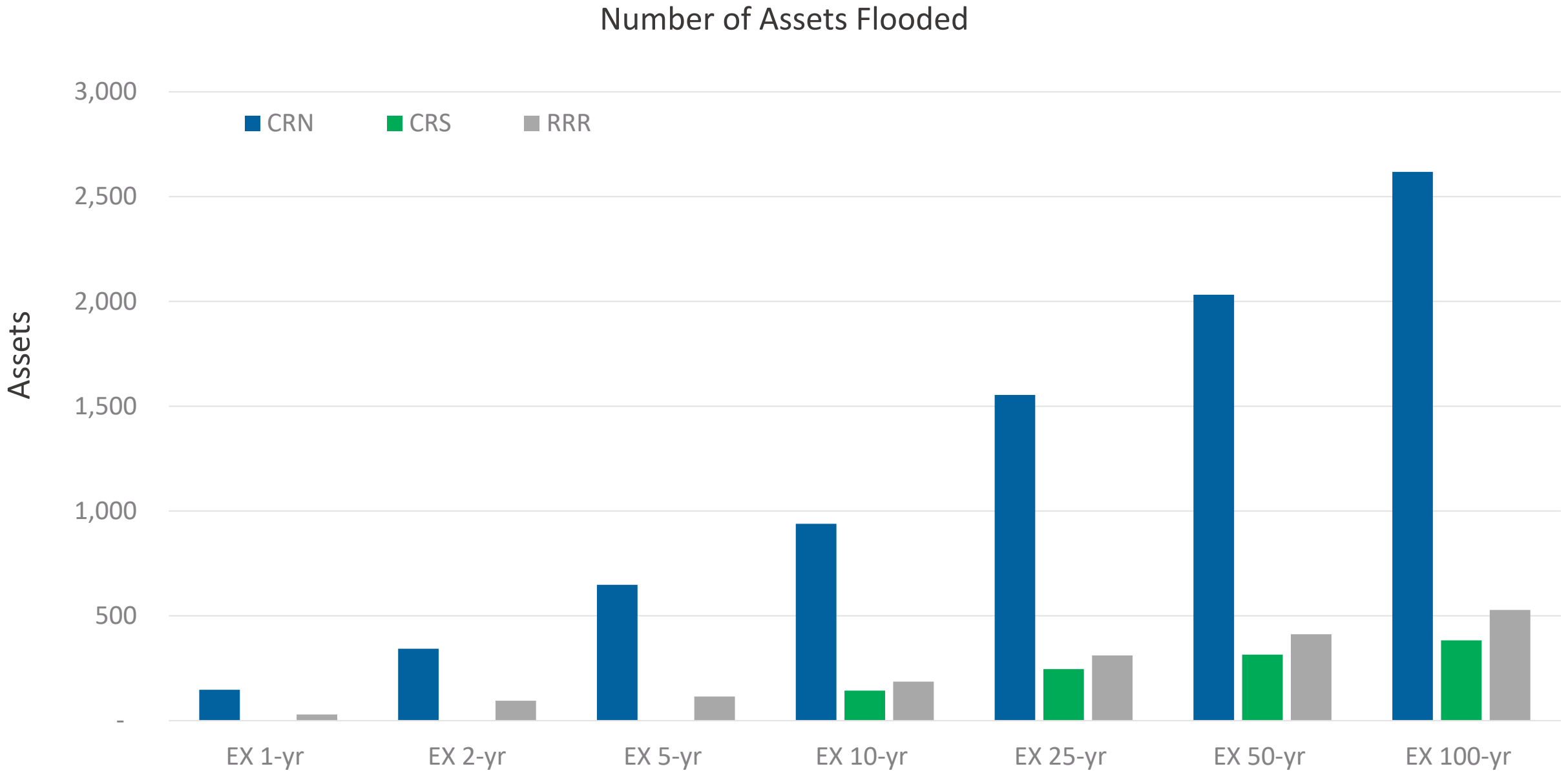

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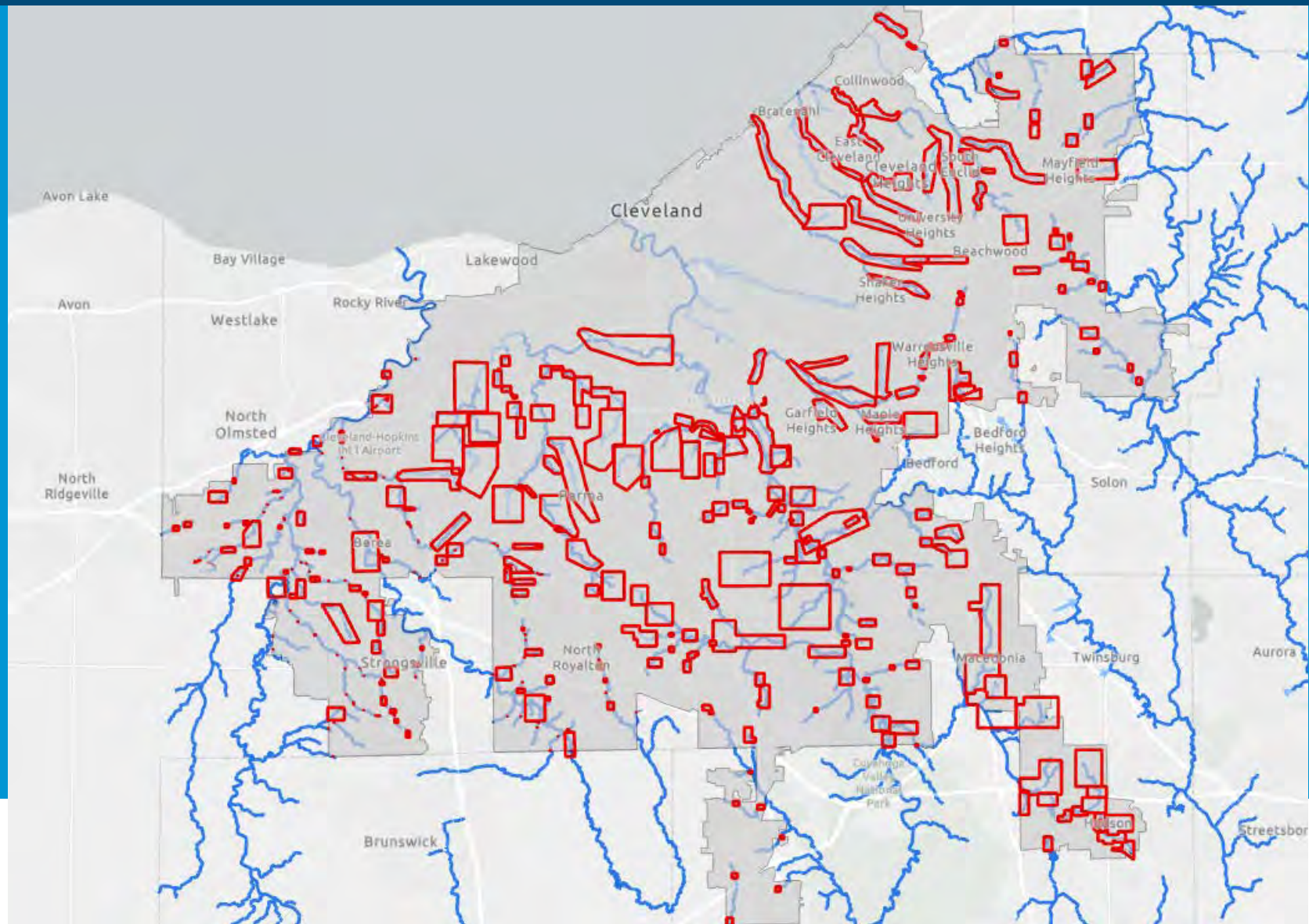
Challenge: How to Prioritize Projects for the Stormwater Construction Plan?

- 300 problem areas to nominate to the Stormwater Construction Plan
- $1.1 Billion in total SWMP problem area costs
- Approximately 50/50 split between structural and flooding project risks



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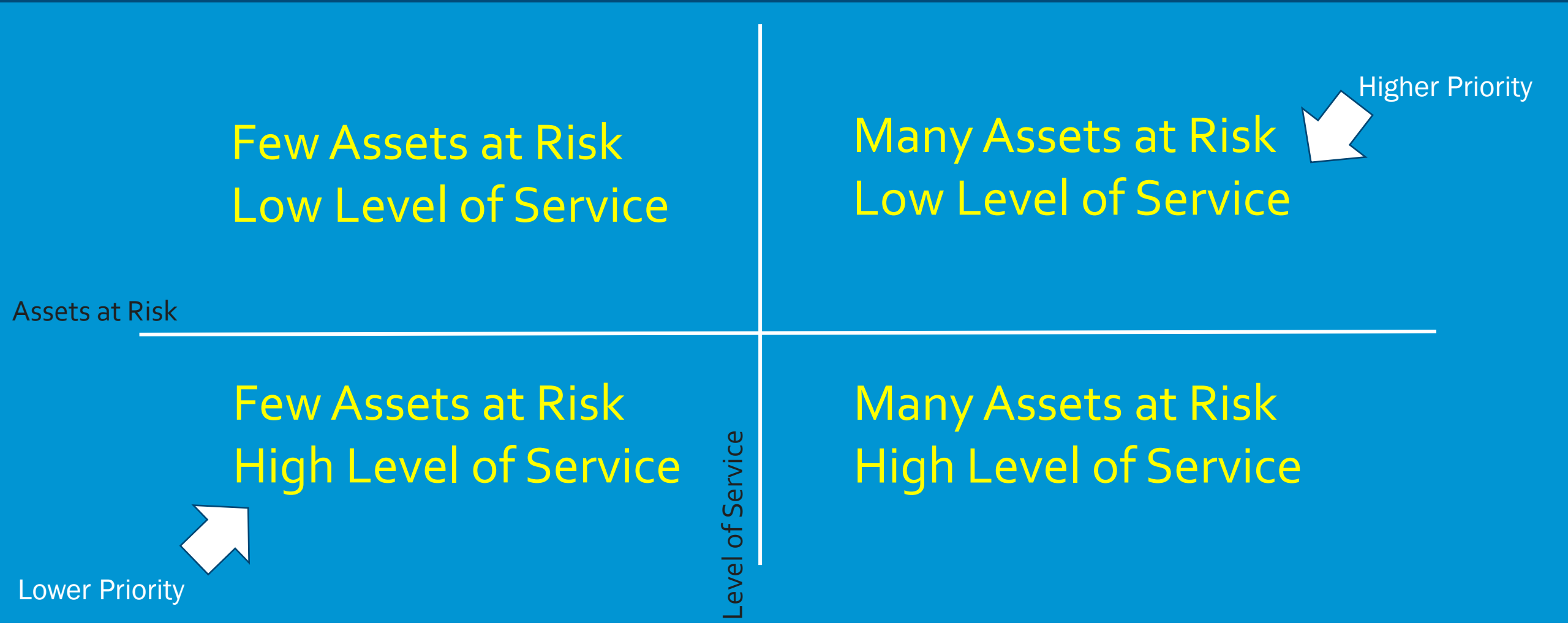
Project Prioritization

Prioritize Assets at Risk and Low Level of Service



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What is PAR?

PAR = The **Probable Annual Risk (PAR)** for an asset/problem area, where risk is defined as the BRE score above the acceptable level of risk (ALR), such that:

$$\text{Risk} = \text{BRE} - \text{ALR}, \text{ and}$$

$$\sum \text{PAR}_{\text{Design Storm}} = \sum [\text{Annual Probability}_{\text{Design Storm}}] * [\text{Risk}]$$

The goal is to have PAR = 0

PAR is calculated based upon the structural and hydraulic risks within a SWMP problem area and recommended alternative

The PAR reduced from implementing a project is calculated:

PAR(reduced) = PAR(existing) – PAR(post project)

Hydraulic Probable Annual Risk (PAR)

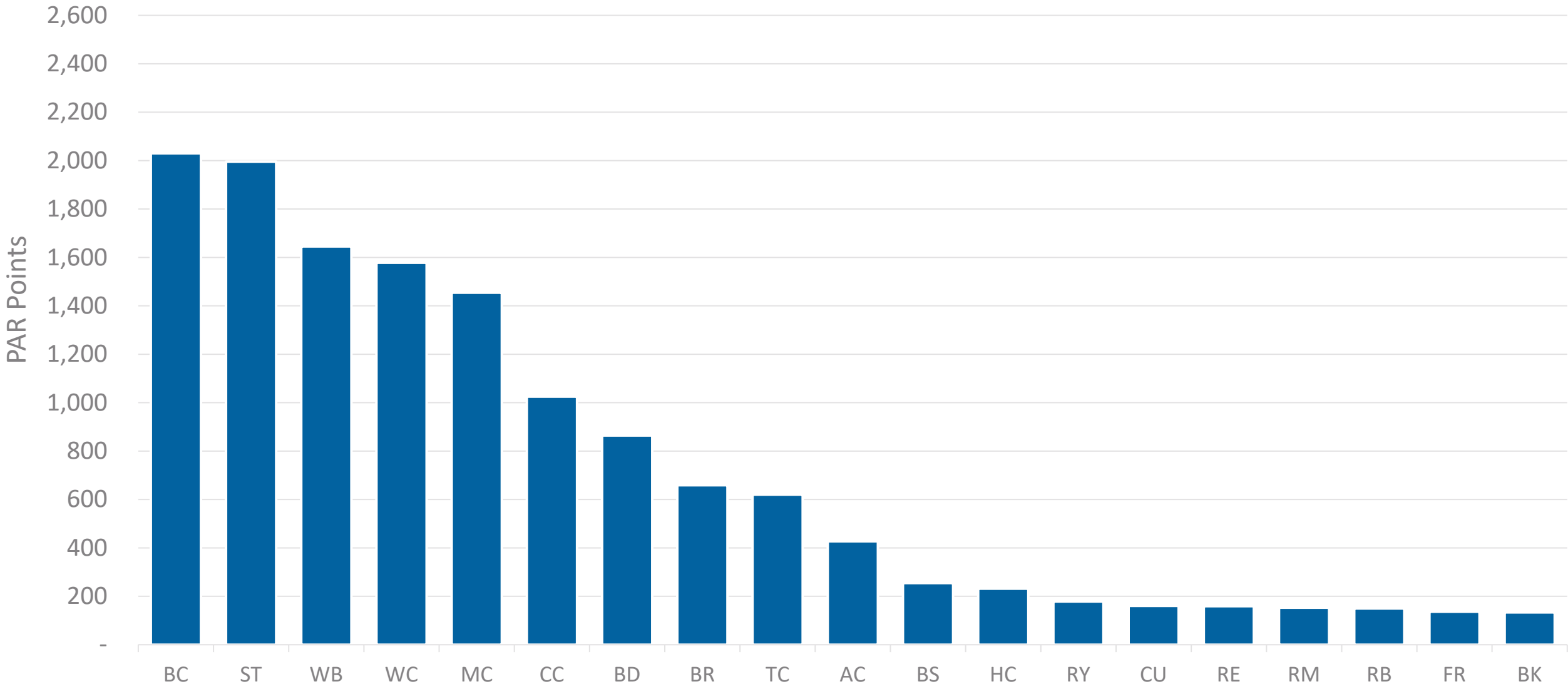
Example Nominated Project

	A	B	C	D	E	F
1	Hydraulic	Cond Rtg	Cond Rtg	BRE	BRE	BRE
2	Scenario	Assets	Violations	Assets	Violations	Points
3	Existing	179	369	183	383	82.63
4	Project	16	25	16	25	3.79
5	Risk Reduced	163	344	167	358	78.84
6						
7	Structural	Cond Rtg	Cond Rtg	BRE	BRE	BRE
8	Condition	Assets	Violations	Assets	Violations	Points
9	Existing	1	1	1	1	31.79
10	Project	0	0	0	0	0.00
11	Risk Reduced	1	1	1	1	31.79

- Challenges with calculating PAR
  - Data management
  - Consistency
  - Accuracy
  - Repeatability

											Hydraulic EX_ASSETS_ 10YR	Hydraulic EX_ASSETS_ 25YR	Hydraulic EX_ASSETS_ 50YR	Hydraulic EX_ASSETS_ 100YR	
14															Assets in Violation
15															
16	SWMP	SWMP_DAT	ASSET_ID	PROBLEM ID	Asset Class Type	Asset Class	Asset Description	Asset Additional De	Criticality	Notes	18	69	113	183	183
17	CRN	PRELIM	MC00205_B111	MC-CL-08	BUILDING	RETAIL	4680 LEE RD, CLEVELAND, OH,	prime	8	0	0	0	0	0	0
18	CRN	PRELIM	MC00205_B102	MC-CL-08	BUILDING	RESIDENTIAL	16602 MYRTLE AVE, CLEVELAND, OH,	prime	6	0	0	0	0	0	0
19	CRN	PRELIM	MC00205_B165	MC-CL-08	BUILDING	RESIDENTIAL	16903 DEFOREST AVE, CLEVELAND,	prime	6	0	0	0	0	0	0
20	CRN	PRELIM	MC00205_B228	MC-CL-08	BUILDING	RESIDENTIAL	16301 JUDSON DR, CLEVELAND, OH,	prime	6	0	0	0	0	0	0
21	CRN	PRELIM	MC00205_B229	MC-CL-08	BUILDING	RESIDENTIAL	16309 JUDSON DR, CLEVELAND, OH,	prime	6	0	0	0	0	0	0
22	CRN	PRELIM	MC00205_B168	MC-CL-08	BUILDING	RESIDENTIAL	17005 DEFOREST AVE, CLEVELAND,	prime	6	0	0	0	0	0	0
23	CRN	PRELIM	MC00205_B129	MC-CL-08	BUILDING	RESIDENTIAL	4313 E 163 ST, CLEVELAND, OH,	prime	6	0	0	0	0	0	0
24	CRN	PRELIM	MC00205_B147	MC-CL-08	BUILDING	RESIDENTIAL	16671 CONCEPT RD, CLEVELAND, OH,	prime	6	0	0	0	0	0	0
25	CRN	PRELIM	MC00205_B268	MC-CL-08	BUILDING	RESIDENTIAL	16306 WESTVIEW AVE, CLEVELAND,	prime	6	0	0	0	0	1	1

Total PAR Reduced by Implementing Nominated Projects
Subwatershed



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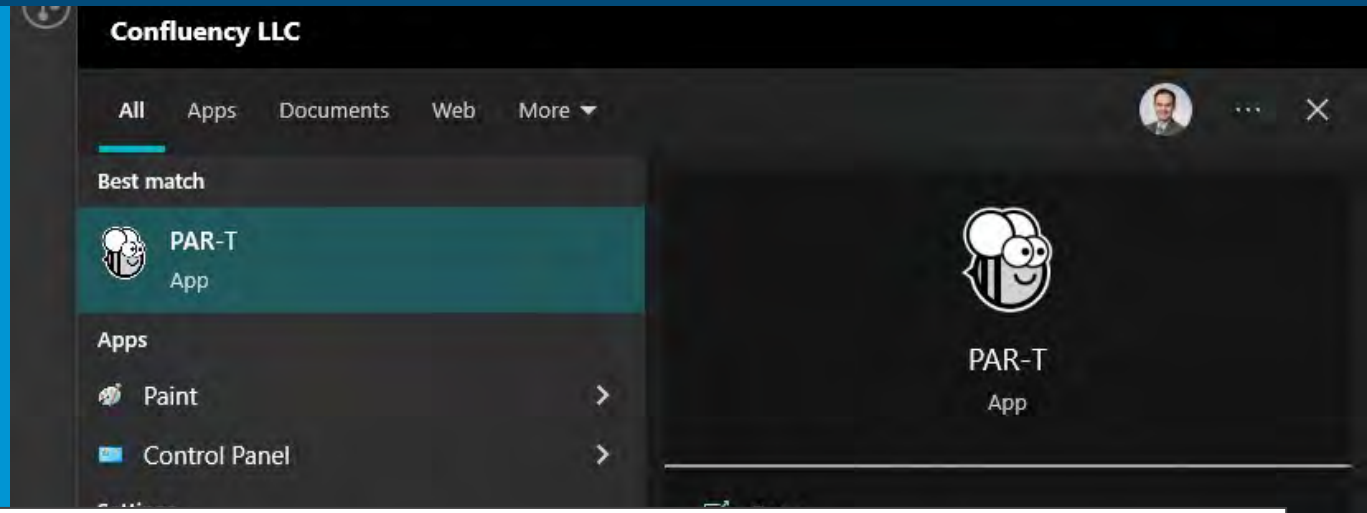
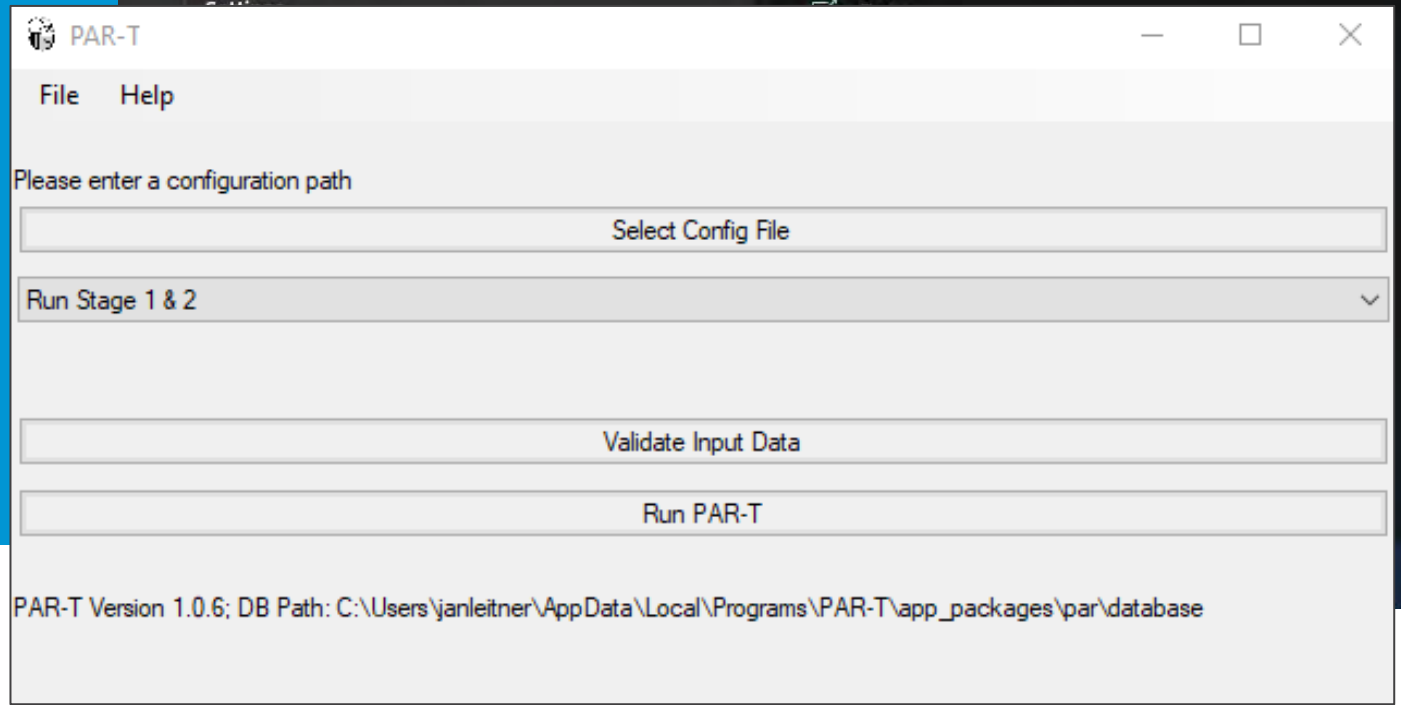
Hydraulic Probable Annual Risk (PAR)

PAR Tool (PAR-T)

- Executable application
- Template for input files
- Uses a config.yaml (text file) for user inputs





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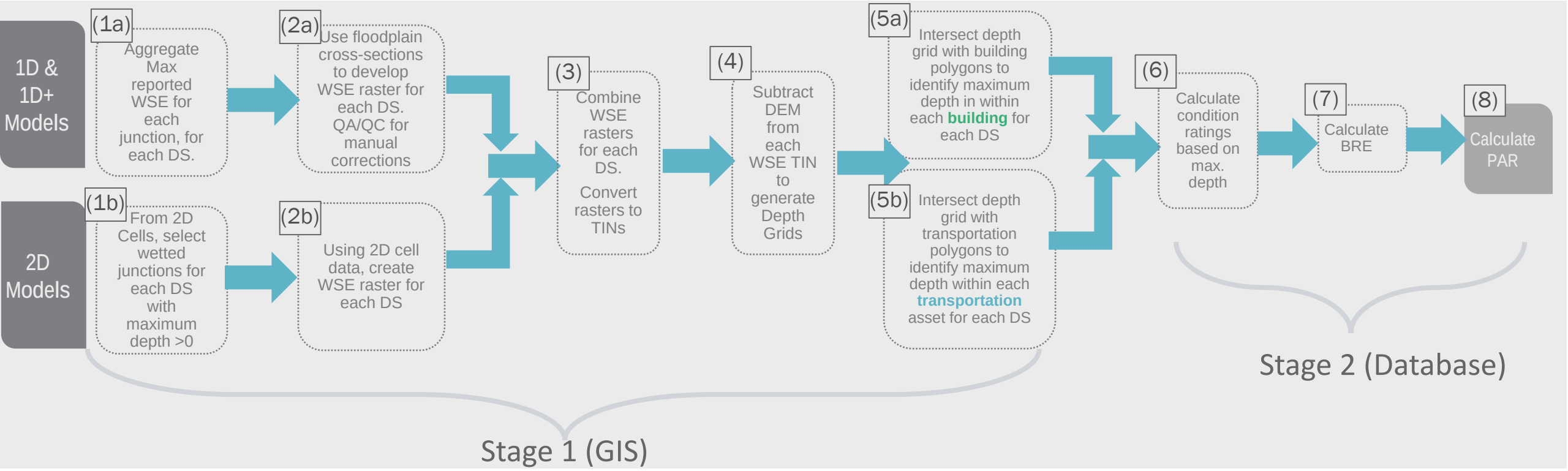
SWMDM PAR Calculator Tool Example

INPUT DATA

- Model results for all 7 DS (reported peak HGLs at nodes and 2D cells)
- For 1D Models:
  - Floodplain cross-sections for open channels and surface routing
  - A table relating each floodplain cross-section to a model junction ("Near Junction").
- 2017 DEM
- Existing District BTU Assets
  - RSS Building Data
  - RSS Transportation Data

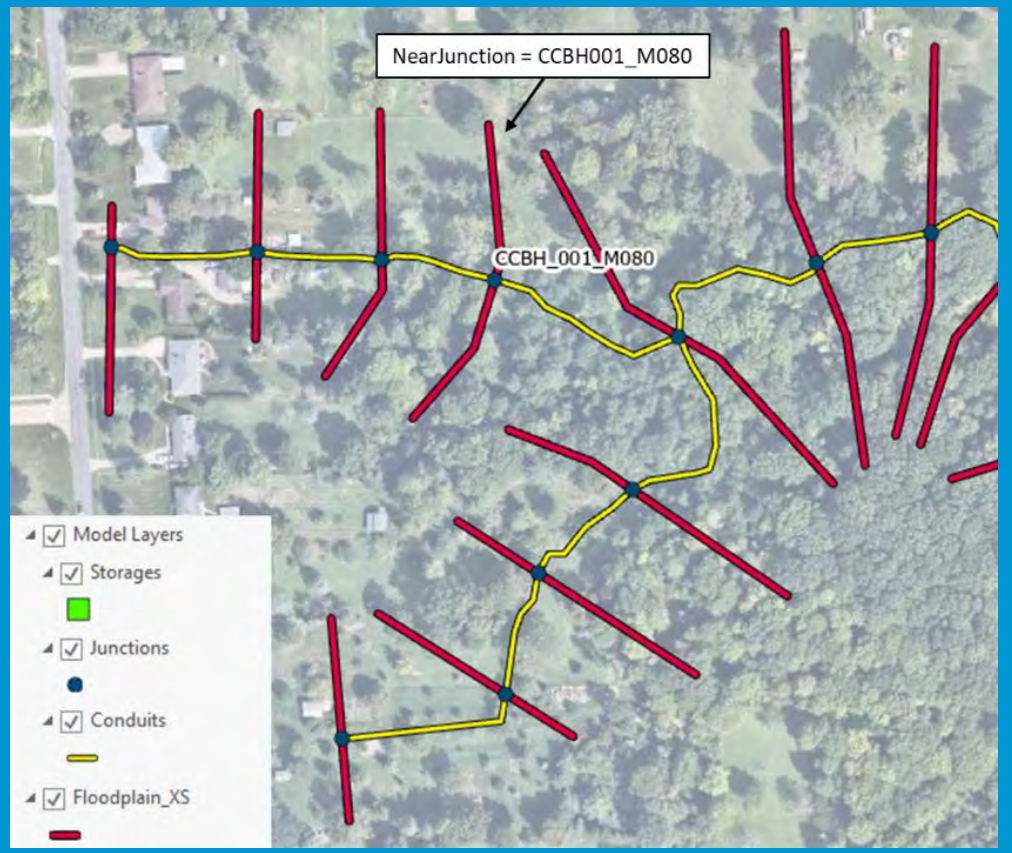


Hydraulic Probable Annual Risk (PAR)

PAR Tool – Stage 1

Develop Water Surface Elevation Raster in GIS (1D)

- Associate floodplain cross sections with model nodes in open channels or areas with surface flooding
- Tabulate Maximum WSE for each model node, for each DS
- PAR-T calls ArcGIS Pro functions to develop a water surface elevation raster for each design storm



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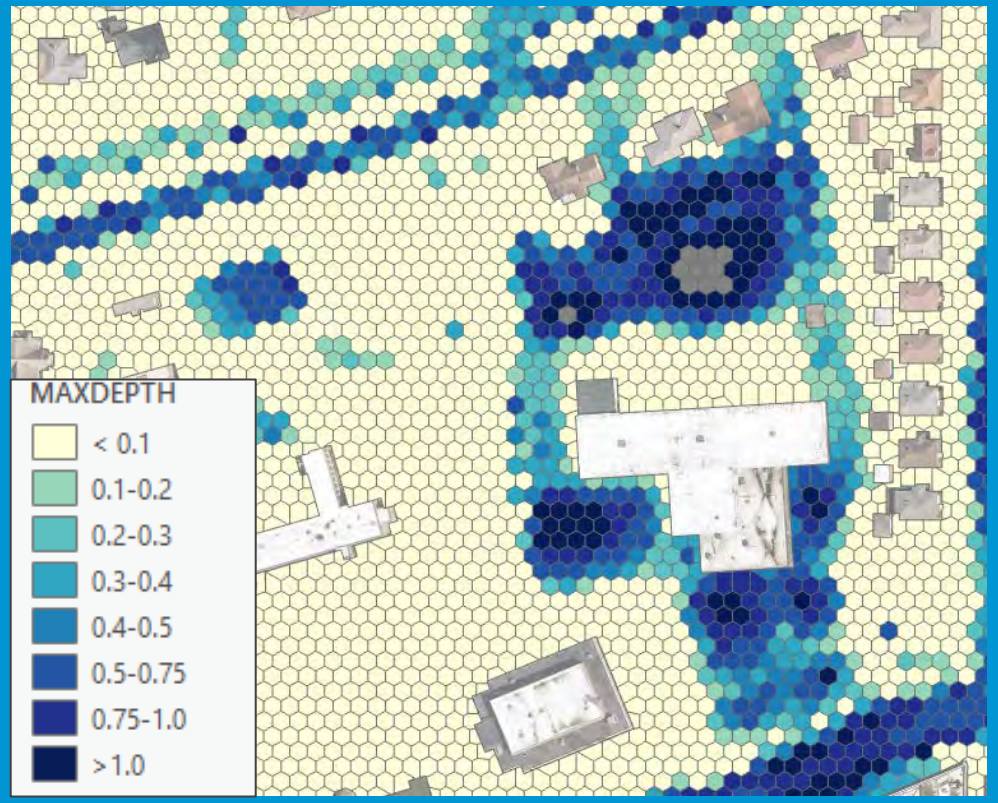
Hydraulic Probable Annual Risk (PAR)

PAR Tool – Stage 1

Develop Water Surface Elevation Raster in GIS (2D)

- PAR-T translates PCSWMM 2D cells into a WSE raster for each design storm



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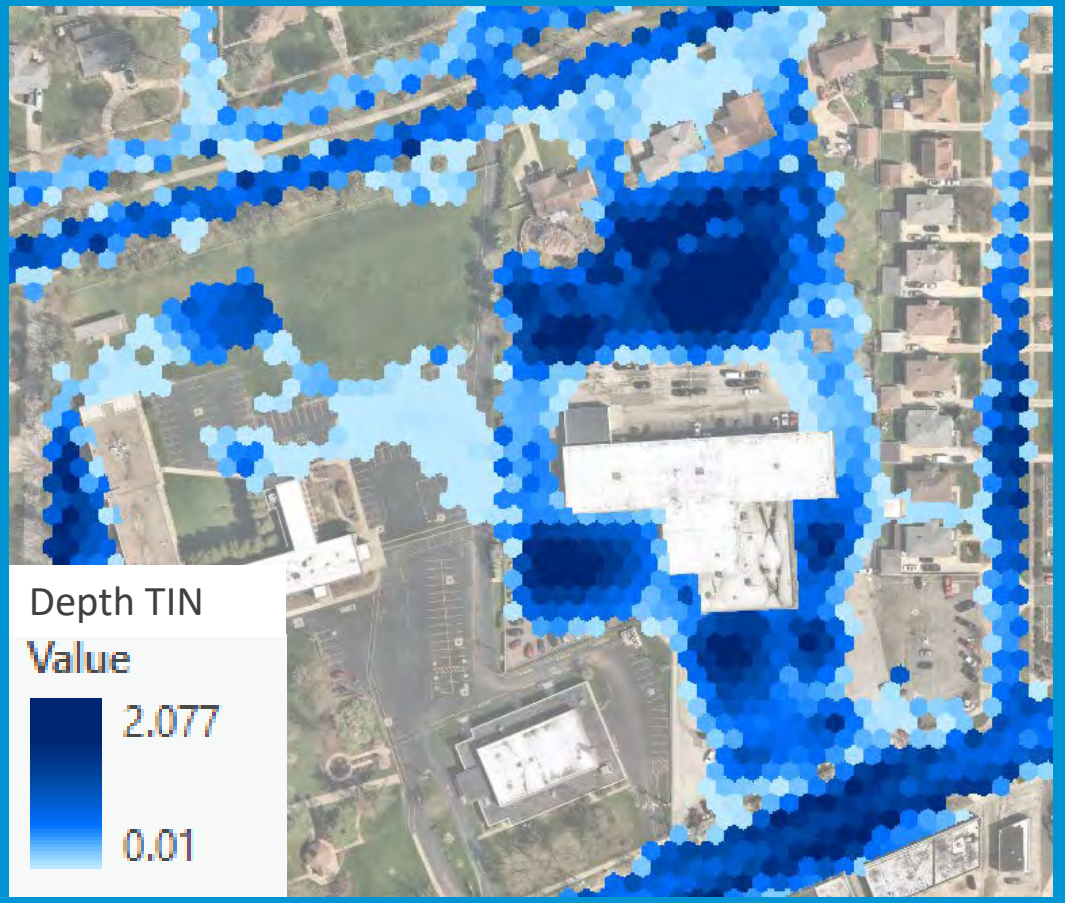
Hydraulic Probable Annual Risk (PAR)

PAR Tool – Stage 1

Develop Depth Raster & Convert to TIN

- Merge 1D and 2D rasters together
- Subtract DEM raster to develop depth raster
- Convert to a TIN



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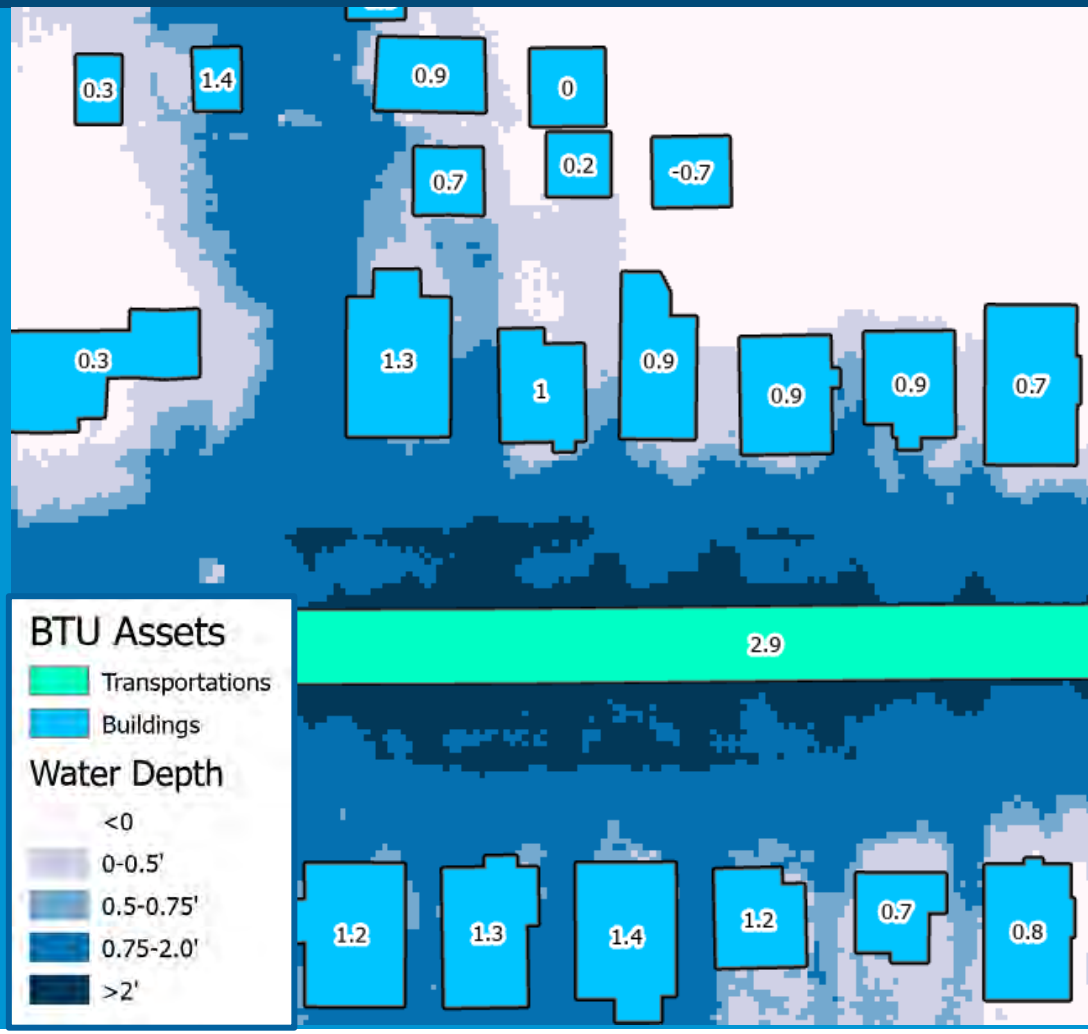
Hydraulic Probable Annual Risk (PAR)

PAR Tool – Stage 1

Calculating inundation depth

- Intersect the water depth TIN with building and transportation asset polygon layers
- The highest depth value within an asset polygon is assigned to the BTU



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Hydraulic Probable Annual Risk (PAR)

PAR Tool – Stage 2

Calculating PAR

- Inundation depth is used to calculate condition rating for each design storm, for each asset
- PAR-T performs subsequent calculations to get to PAR, by design storm:
  - Inundation depth → Condition Rating (CR)
  - BRE = CR * Criticality
  - Risk = BRE – ALR (19)
  - $PAR_{\text{design storm}} = Probability_{\text{design storm}} * Risk$

Hydraulic Probable Annual Risk (PAR)

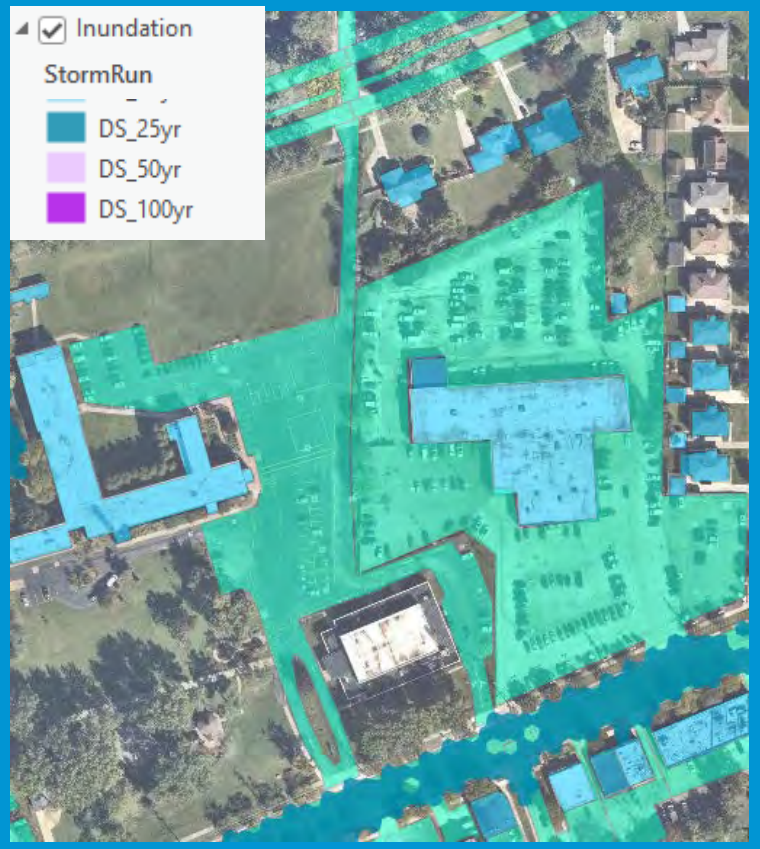
PAR Tool Results

- Tool produces GIS and tabular results
- Building and transportation polygons with assigned depth values
- Depth TINs and inundation polygons by design storm
- Risk metrics in tabular format by asset, by design storm
  - Inundation depth
  - Condition Rating
  - BRE
  - Risk
  - PAR (by design storm & overall)

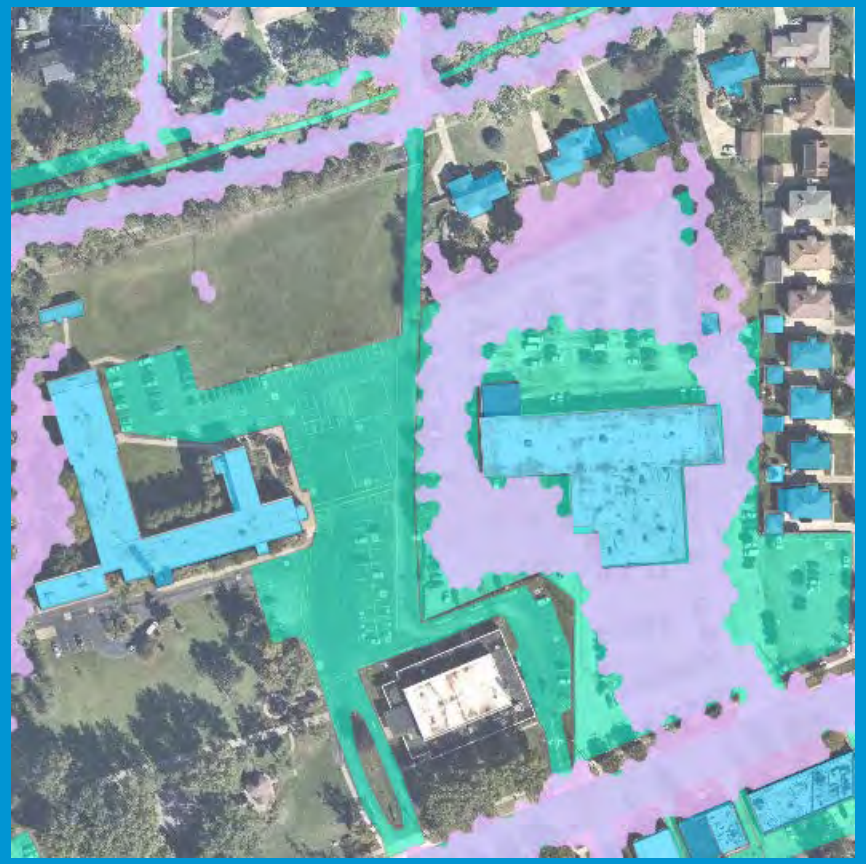
Hydraulic Probable Annual Risk (PAR)

PAR Tool Results: Compare Impacts Under Different Design Storms

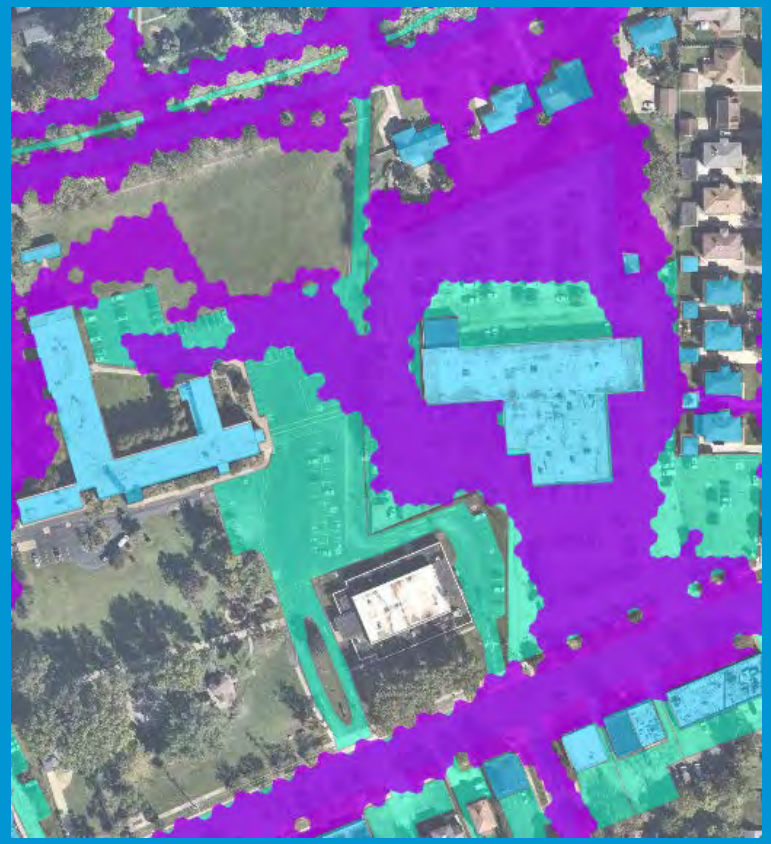
25-year



50-year



100-year



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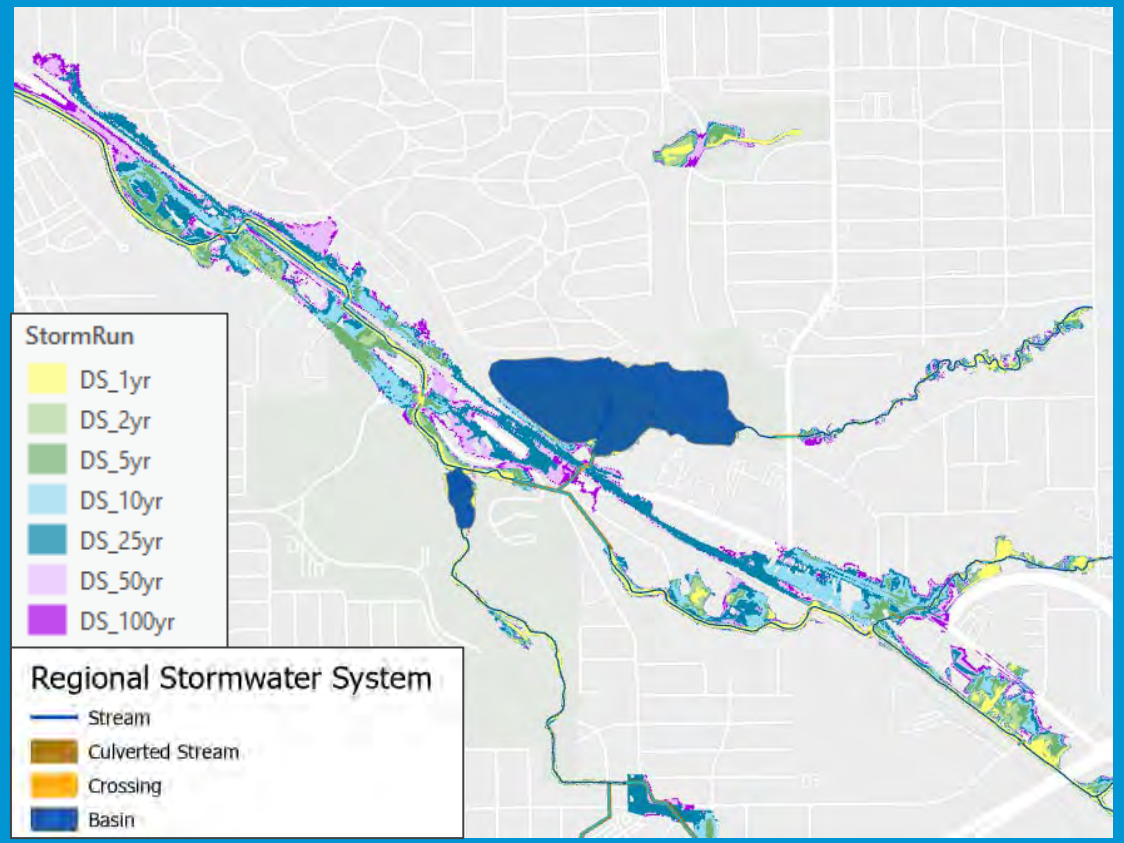
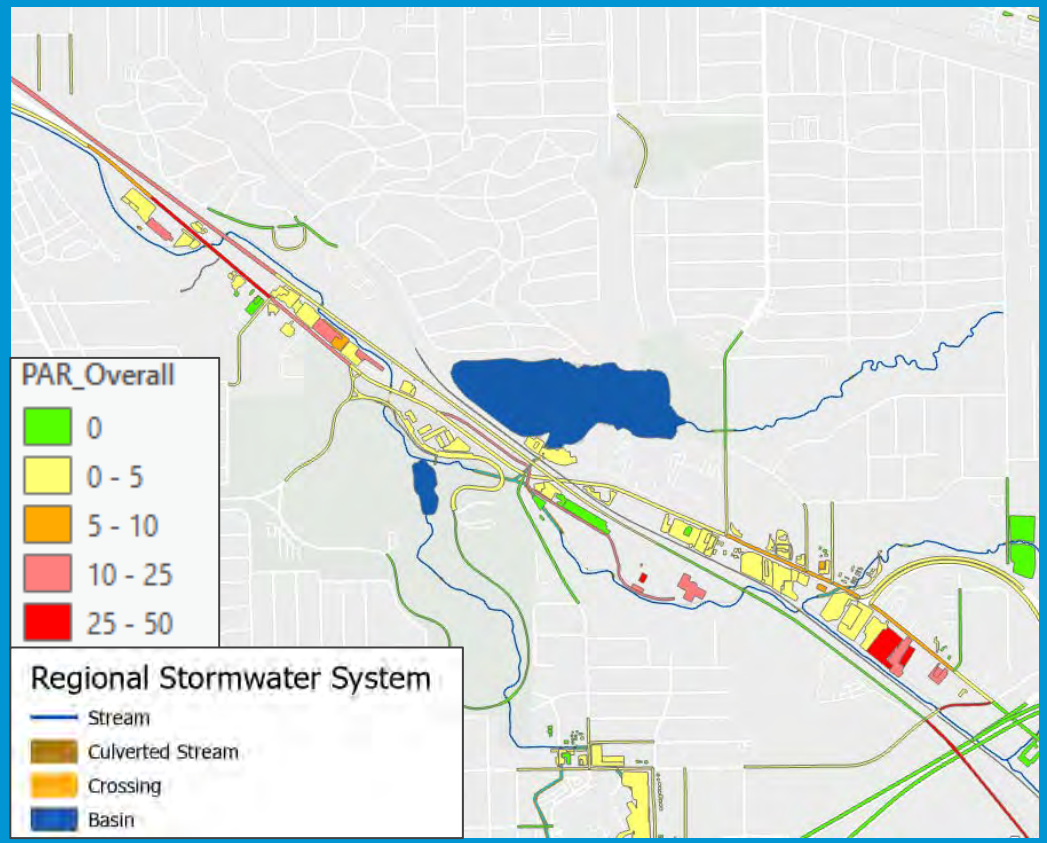
Hydraulic Probable Annual Risk (PAR)

PAR Tool Results: Problem Identification

Inundation Polygons



Building and Transportation PAR



Hydraulic Probable Annual Risk (PAR)

PAR Tool Results: Quantify Project Benefits

Existing Conditions

Alternative

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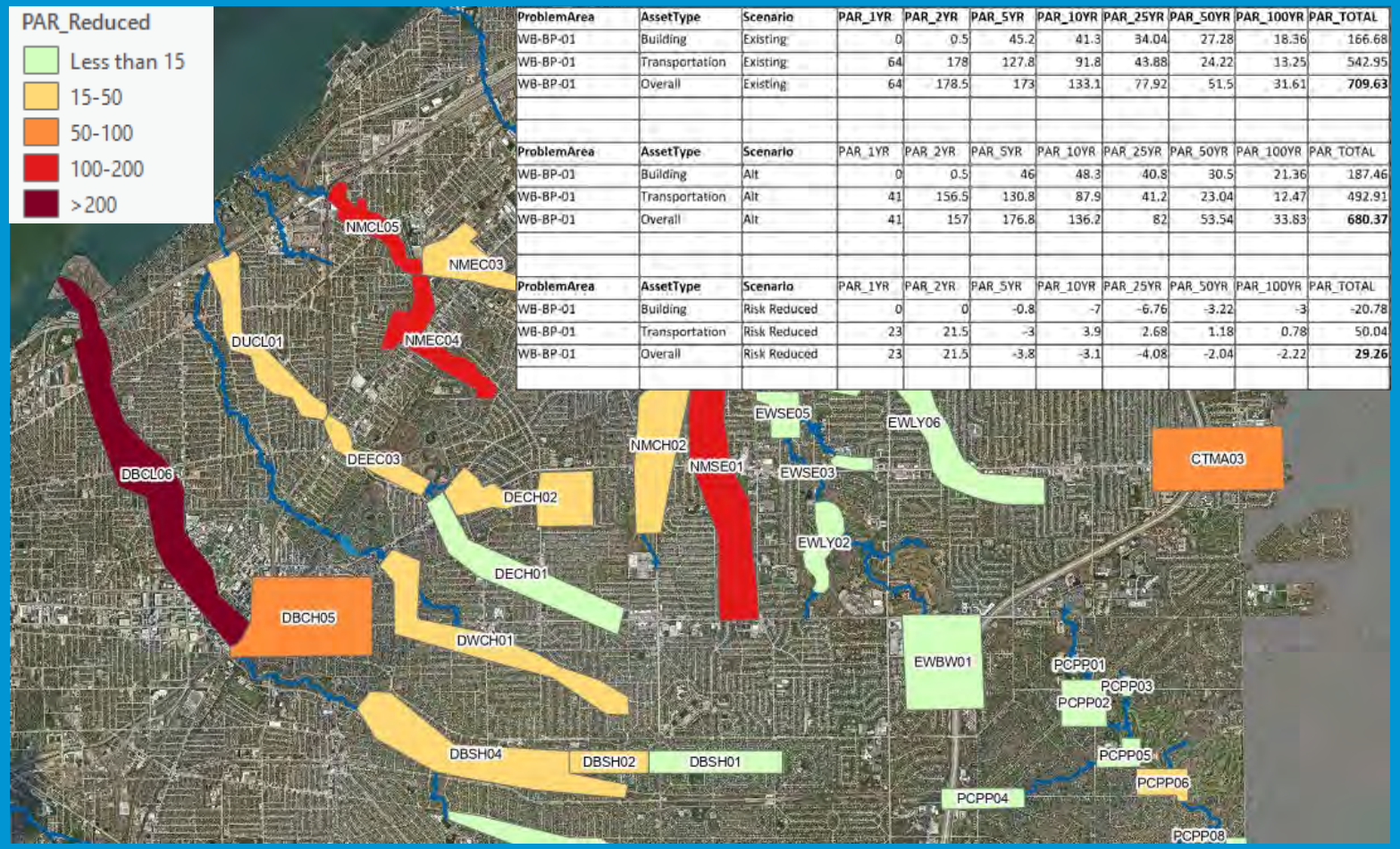
PAR Tool Results: Project Prioritization

- Aggregate Existing and Alternative PAR by problem area
- Calculate PAR Reduced
- Rank problem areas by most significant reduction in risk



ProblemArea	AssetType	Scenario	PAR_1YR	PAR_2YR	PAR_5YR	PAR_10YR	PAR_25YR	PAR_50YR	PAR_100YR	PAR_TOTAL
WB-BP-01	Building	Existing	0	0.5	45.2	41.3	34.04	27.28	18.36	166.68
WB-BP-01	Transportation	Existing	64	178	127.8	91.8	43.88	24.22	13.25	542.95
WB-BP-01	Overall	Existing	64	178.5	173	133.1	77.92	51.5	31.61	**709.63**

ProblemArea	AssetType	Scenario	PAR_1YR	PAR_2YR	PAR_5YR	PAR_10YR	PAR_25YR	PAR_50YR	PAR_100YR	PAR_TOTAL
WB-BP-01	Building	Alt	0	0.5	46	48.3	40.8	30.5	21.36	187.46
WB-BP-01	Transportation	Alt	41	156.5	130.8	87.9	41.2	23.04	12.47	492.91
WB-BP-01	Overall	Alt	41	157	176.8	136.2	82	53.54	33.83	**680.37**

ProblemArea	AssetType	Scenario	PAR_1YR	PAR_2YR	PAR_5YR	PAR_10YR	PAR_25YR	PAR_50YR	PAR_100YR	PAR_TOTAL
WB-BP-01	Building	Risk Reduced	0	0	-0.8	-7	-6.76	-3.22	-3	-20.78
WB-BP-01	Transportation	Risk Reduced	23	21.5	-3	3.9	2.68	1.18	0.78	50.04
WB-BP-01	Overall	Risk Reduced	23	21.5	-3.8	-3.1	-4.08	-2.04	-2.22	**29.26**

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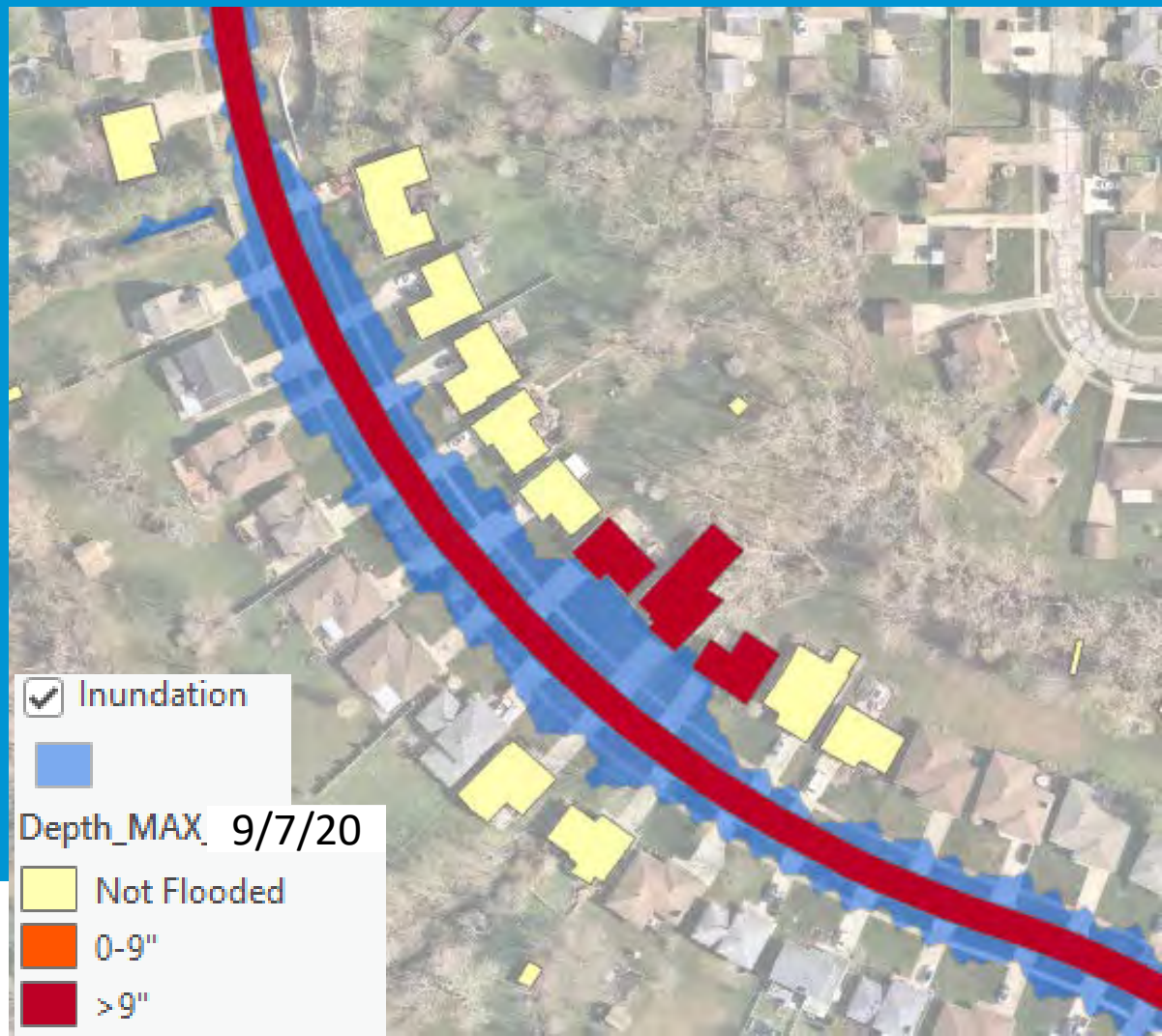
Hydraulic Probable Annual Risk (PAR)

PAR Tool Results: Run Observed Storm Events

- Compare modeled inundation areas to observations and reports
- Compare risk across observed storm events

Observed storm event results



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Hydraulic Probable Annual Risk (PAR)

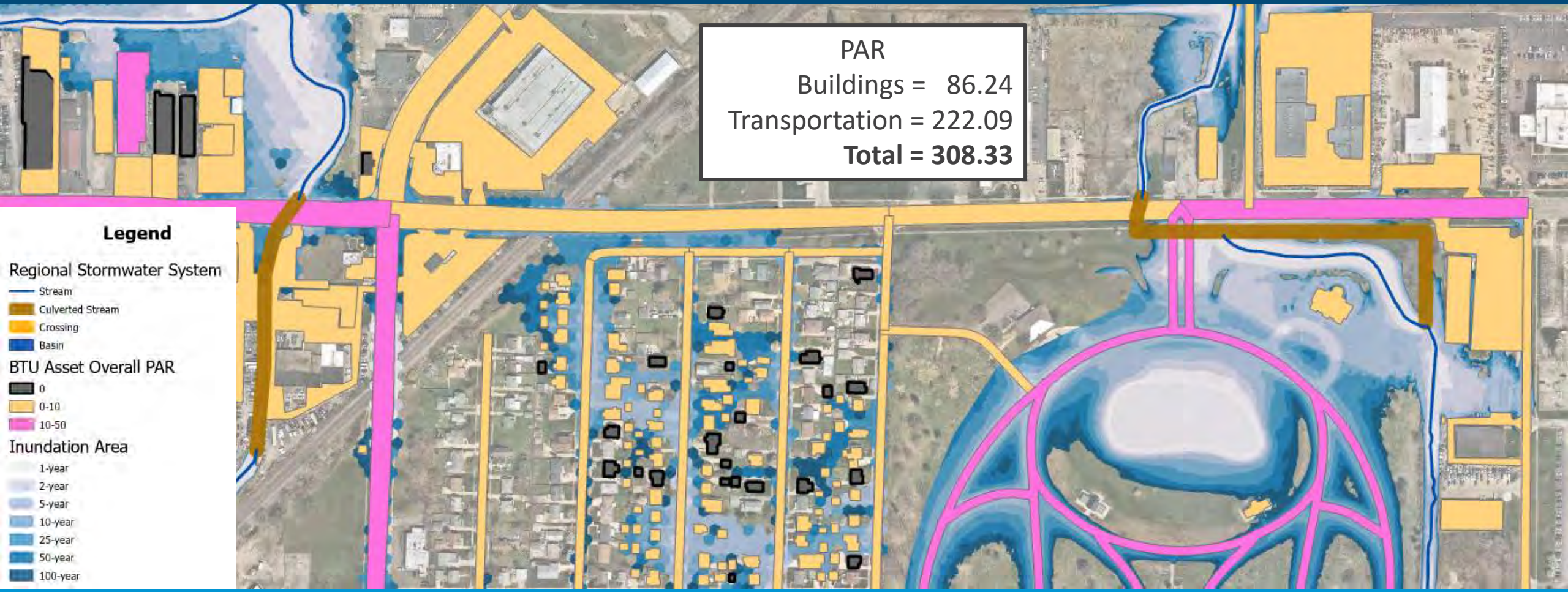
PAR Tool Results: Current Applications

- Applied to 7 subwatersheds (9 models)
- In process of applying to 30 additional models (existing & alts) to support annual project prioritization process
- Being tested by some District projects to quantify reduction in risk

Hydraulic Probable Annual Risk (PAR)
Lessons Learned

- Standardization of data sets and file structure is critical
- Basic knowledge of GIS and PCSWMM is helpful
- Clear documentation allows for repeatability and tracking changes over time
- Validation checks in tool save run time and user frustration
- Clear communication about expectations with re: run-time
- Familiarity with study area is necessary to identify questionable results

What Floods?



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Next Steps

- Continue with Beta testing of PAR-Tool
- Ensure all RSMP models are PAR-Tool compatible
- Utilize PAR-Tool on District contracts (Planning, Design)
- Use PAR-Tool to help with current RSMP flood risk challenges (e.g., prioritize projects for the stormwater construction plan)
- Explore predicting flood risks using forecasted rainfall and monitors
- Explore developing and maintaining flood risk maps

Questions?

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