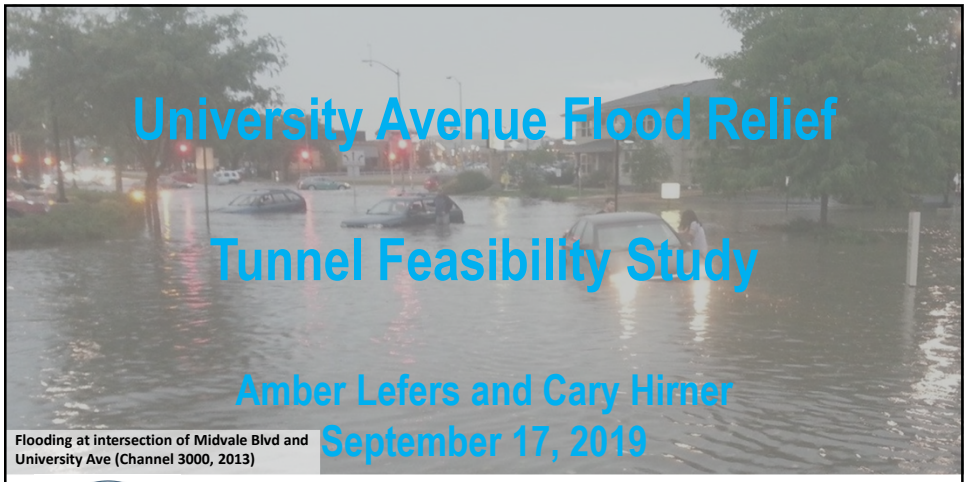


University Avenue Flood Relief

Tunnel Feasibility Study

Amber Lefers and Cary Hirner

September 17, 2019

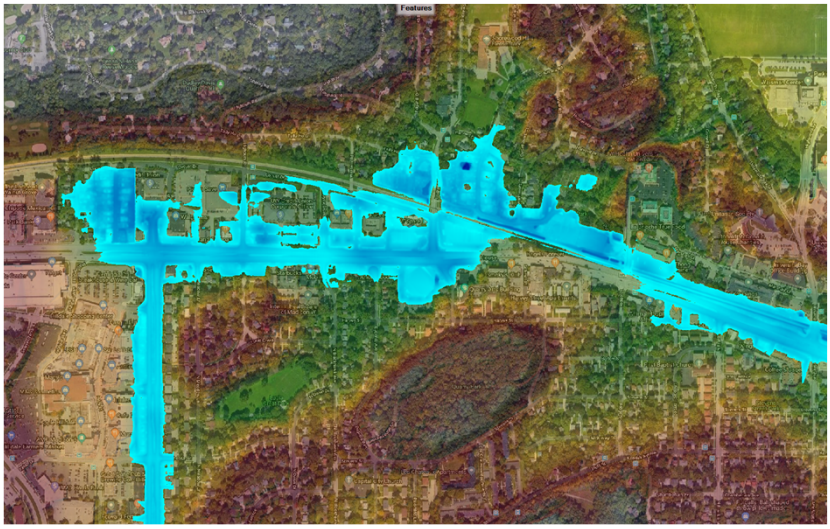
Flooding at intersection of Midvale Blvd and University Ave (Channel 3000, 2013)

DISCUSSION POINTS

- Recap Project Need
- Recap Study Purpose
- Recap Performance Objective
- Review Data Used and Collected
- Discuss Options Evaluated
- Discuss Tunneling Approaches
- Summarize Project Costs and Key Factors
- Highlight Key Unknowns
- Recap Conclusions
- Open Discussion / Q&A

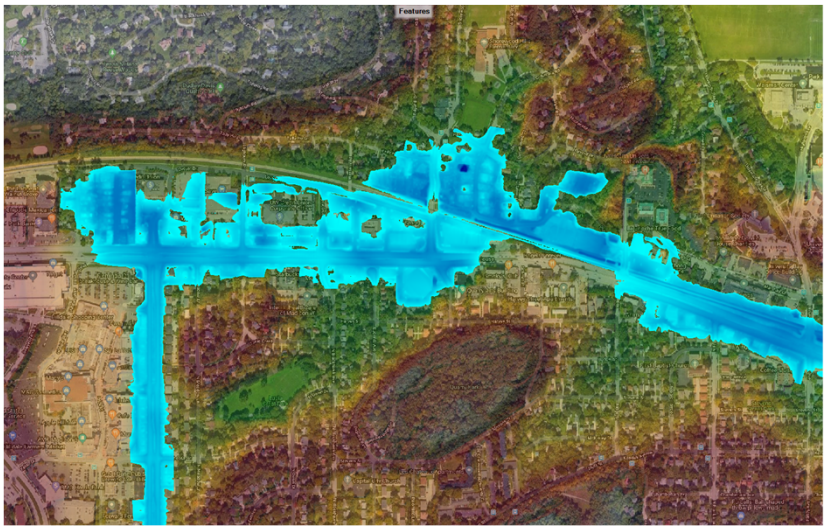
PROJECT NEED

Existing 25-Year Flooding



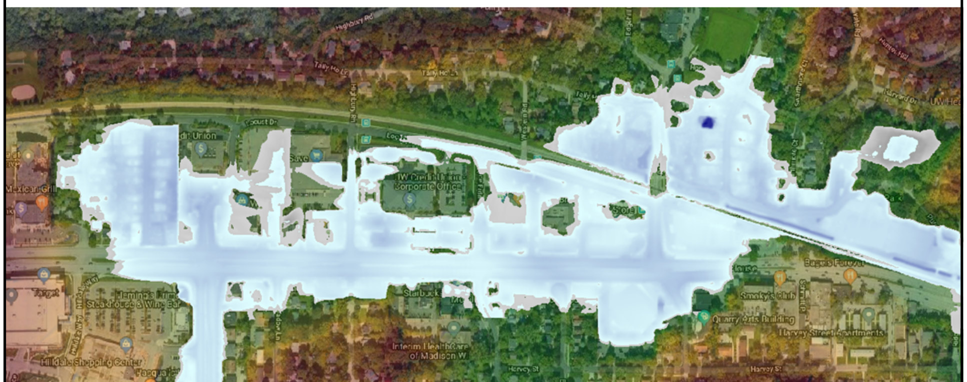
PROJECT NEED

Existing 100-Year Flooding



PROJECT NEED

Existing Flooding Comparison



PROJECT PURPOSE

- Numerous Other Alternatives Evaluated
- Tunnel to Lake – Most Benefit for Larger Storms

Scenario Descriptions

Feature	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Midvale/Univ Connect		✓		✓		✓		✓		✓		✓			✓	✓
Shorewood Cross Connect	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
96" to Farley	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
96" from Farley to Shorewood			✓	✓			✓	✓			✓	✓				
0.4-ac in SE plus lake tunnel					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
0.4-ac in both SE and NW plus lake tunnel									✓	✓	✓	✓		✓		✓

Scenario:	Existing			ALT A			ALT B			ALT C			ALT D			ALT E 120" TUNNEL			ALT F 120" TUNNEL		
	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR
Midvale JUNCTION: INLET_MIDVALE_NORTH																					
Max WSE	888.2	888.7	889.1	888.3	888.7	889.1	887.9	888.5	888.9	888.2	888.7	889.1	887.9	888.4	888.9	886.7	887.6	888.1	886.4	887.2	887.9
Shorewood JUNCTION: JCT-238																					
Max WSE	883.1	883.7	884.3	883.1	883.6	884.2	883.1	883.7	884.2	882.7	883.4	884.0	882.7	883.4	884.0	881.2	882.3	883.0	881.4	882.3	883.1
Farley JUNCTION: JCT-289																					
Max WSE	880.3	881.1	881.8	879.8	880.7	881.6	879.9	880.7	881.7	879.6	880.6	881.4	879.7	880.6	881.5	877.4	878.7	880.0	877.5	879.1	880.1
Grand JUNCTION: INLET_TP_4150-009																					
Max WSE	878.0	878.4	878.8	877.7	878.2	878.7	877.8	878.2	878.7	877.6	878.1	878.6	877.7	878.1	878.6	877.2	877.2	877.8	877.2	877.4	877.9

Scenario:	Existing			ALT G 120" TUNNEL			ALT H 120" TUNNEL			ALT I 144" TUNNEL			ALT J 144" TUNNEL			ALT K 144" TUNNEL			ALT L 144" TUNNEL		
	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR
Midvale JUNCTION: INLET_MIDVALE_NORTH																					
Max WSE	888.2	888.7	889.1	886.5	887.5	888.1	886.4	887.2	887.9	885.3	886.1	887.4	885.3	885.8	886.9	885.3	886.0	887.4	885.3	885.8	886.8
Shorewood JUNCTION: JCT-238																					
Max WSE	883.1	883.7	884.3	879.9	881.8	882.8	879.9	881.9	882.8	880.1	881.5	882.3	881.1	881.8	882.4	879.9	880.3	881.9	879.9	881.3	882.0
Farley JUNCTION: JCT-289																					
Max WSE	880.3	881.1	881.8	877.3	878.6	879.9	877.6	878.8	880.0	877.3	878.1	879.4	877.4	878.4	879.6	877.3	878.1	879.1	877.5	878.5	879.4
Grand JUNCTION: INLET_TP_4150-009																					
Max WSE	878.0	878.4	878.8	877.2	877.2	877.8	877.2	877.2	877.8	877.2	877.2	877.5	877.2	877.2	877.6	877.2	877.2	877.4	877.2	877.2	877.6

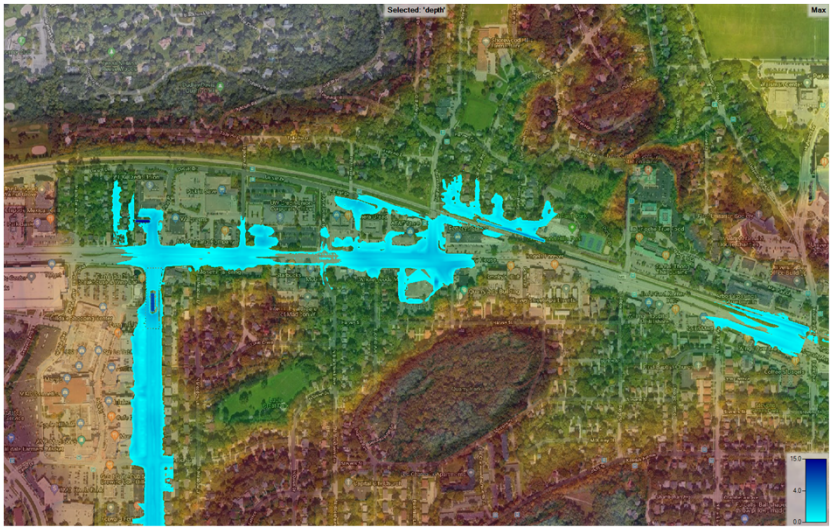
Scenario:	Existing			ALT M 132" TUNNEL			ALT N 144" TUNNEL			ALT O 132" TUNNEL			ALT P 144" TUNNEL		
	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR
Max WSE											887.0	887.7	885.3	885.9	886.8
Max WSE											882.2	883.0	881.2	881.9	882.4
Max WSE											879.3	880.3	878.3	879.0	879.8
Max WSE											877.5	878.0	877.2	877.3	877.7

Midvale (FFE ~887)	Green	<887
	Yellow	887-887.5
	Red	>887.5
Shorewood (FFE ~882)	Green	<882
	Yellow	882-882.5
	Red	>882.5
Farley	Green	<Existing
	Red	>Existing
Grand Ave	Green	<Existing
	Red	>Existing

Scenario:	EXISTING			ALT 1 FILL GARDEN HOMES SITE			ALT 2 FLOOD STORAGE AT SHOREWOOD BLVD.			ALT 3A VOLUME REDUCTION (RAINGARDENS)			ALT 3B PEAK REDUCTION (DETENTION BASINS)			ALT 4 168" RELIEF SEWER WITH 96" CONNECTION IMPR.		
	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR	025-YR	050-YR	100-YR
										~1.5" RUNOFF DECREASE	~2" RUNOFF DECREASE	~3" RUNOFF DECREASE	~40% PEAK DECREASE	~50% PEAK DECREASE	~60% PEAK DECREASE			
Midvale Blvd.																		
Max WSE	888.2	888.7	889.1	888.4	888.8	889.2	888.2	888.7	889.1	AREA OF RAINGARDENS			VOLUME OF DETENTION			888.2	888.7	889.1
Shorewood Blvd.										300-400 ACRES	400-500 ACRES	600-750 ACRES	120 ACRE-FT	160 ACRE-FT	210 ACRE-FT			
Max WSE	883.1	883.7	884.3	883.3	883.9	884.4	883.0	883.6	884.2							882.0	882.7	883.4
Ubay Drive / Farley																		
Max WSE	880.3	881.1	881.8	880.5	881.4	881.9	880.0	880.9	881.6							879.2	880.2	880.9
Grand Avenue																		
Max WSE	878.0	878.4	878.8	878.1	878.5	878.9	877.8	878.3	878.7							877.6	878.2	878.7

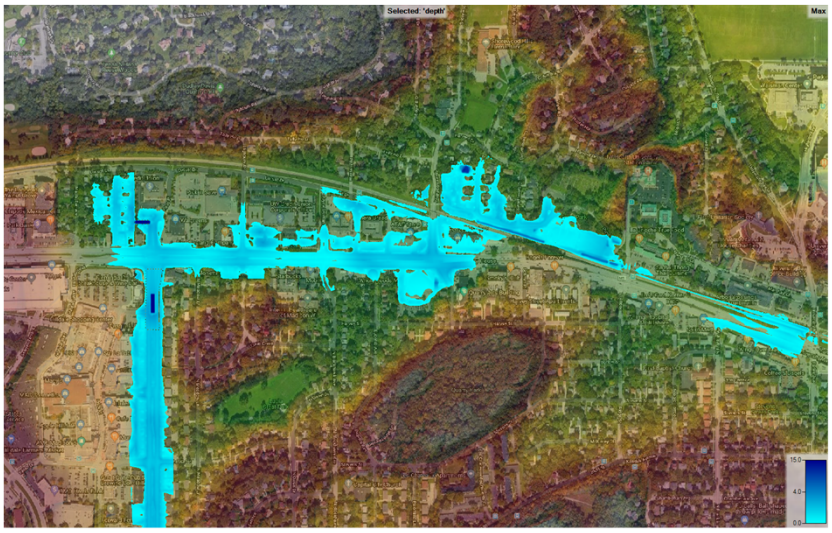
PROJECT PURPOSE

Proposed 25-Year Flooding



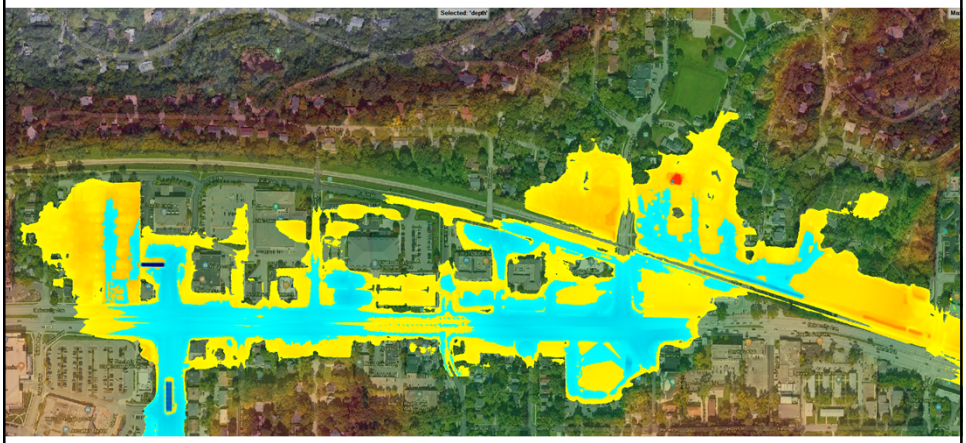
PROJECT PURPOSE

Proposed 100-Year Flooding



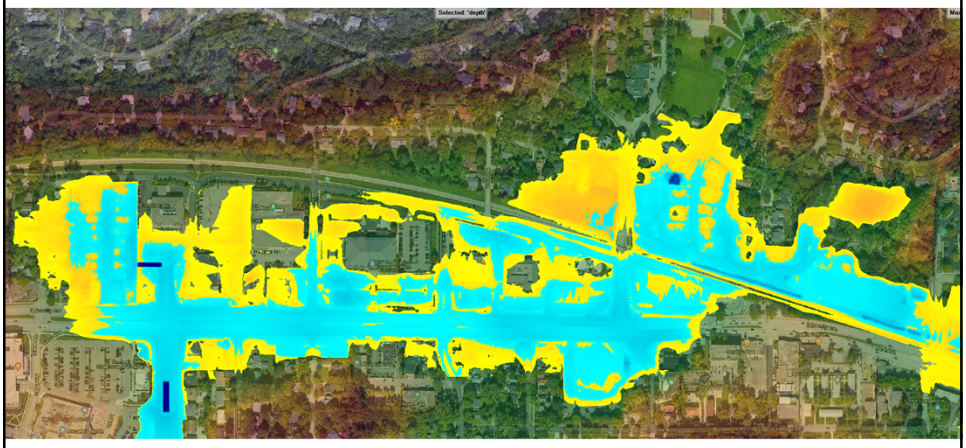
PROJECT PURPOSE

Existing to Proposed 25-Year Flooding Comparison



PROJECT PURPOSE

Existing to Proposed 100-Year Flooding Comparison



PROJECT PURPOSE

- Numerous Other Alternatives Evaluated
- Tunnel to Lake – Most Benefit for Larger Storms
- Feasibility and Cost – Unknown

- Purpose: Determine Feasibility and Costs for Tunnel

PERFORMANCE OBJECTIVES

- Provide Protection for Structures (not including remaining Garden Homes) along University Avenue for up to ~50- to ~100-Year Event

Scenario:	ALT P 144" TUNNEL		
	025-YR	050-YR	100-YR
Midvale Blvd. Intersection			
Max WSE	885.3	885.9	886.8
Shorewood Blvd. Intersection			
	881.2	881.9	882.4

Midvale (FFE ~887)	Green	<887
	Yellow	887-887.5
	Red	>887.5
Shorewood (FFE ~882)	Green	<882
	Yellow	882-882.5
	Red	>882.5

PERFORMANCE OBJECTIVES

- Provide Protection for Structures (not including remaining Garden Homes) along University Avenue for up to ~50- to ~100-Year Event

Tunnel Flows:

25-Year: ~1,500 cfs

50-Year: ~1,800 cfs

100-Year: ~2,000 cfs

Scenario:	ALT P 144" TUNNEL		
	025-YR	050-YR	100-YR
Midvale Blvd. Intersection			
Max WSE	885.3	885.9	886.8
Shorewood Blvd. Intersection			
	881.2	881.9	882.4

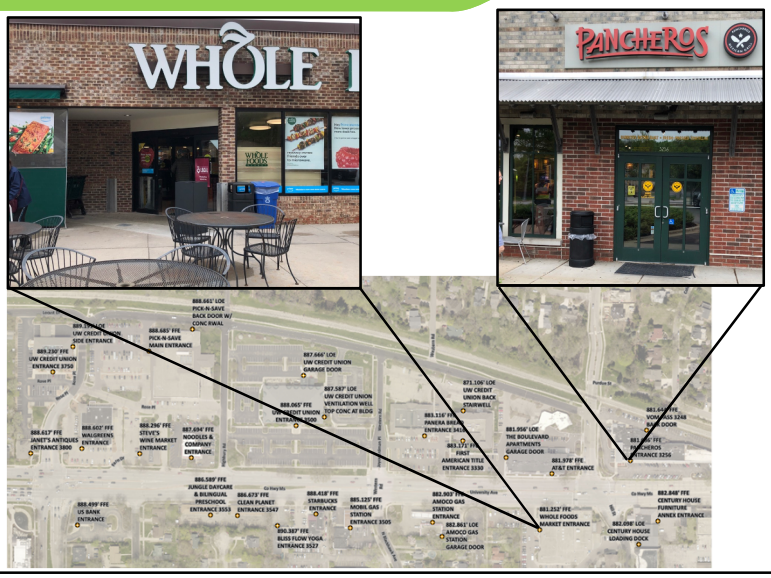
Midvale (FFE ~887)	Green	<887
	Yellow	887-887.5
	Red	>887.5
Shorewood (FFE ~882)	Green	<882
	Yellow	882-882.5
	Red	>882.5

DESIGN CONSTRAINTS

- Tunnel and outfall located to minimize community impacts
- Minimize impacts to railroad tracks, golf course, Lake Mendota Drive
- Minimize future development impacts
- Minimize property acquisition/easements along alignment

SUMMARY OF DATA USED AND COLLECTED

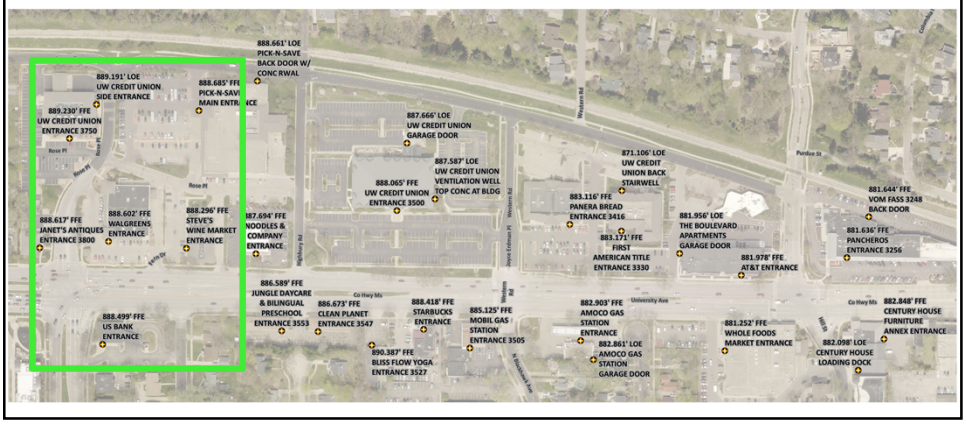
Lowest Opening Survey



SUMMARY OF DATA USED AND COLLECTED

Lowest Opening Survey

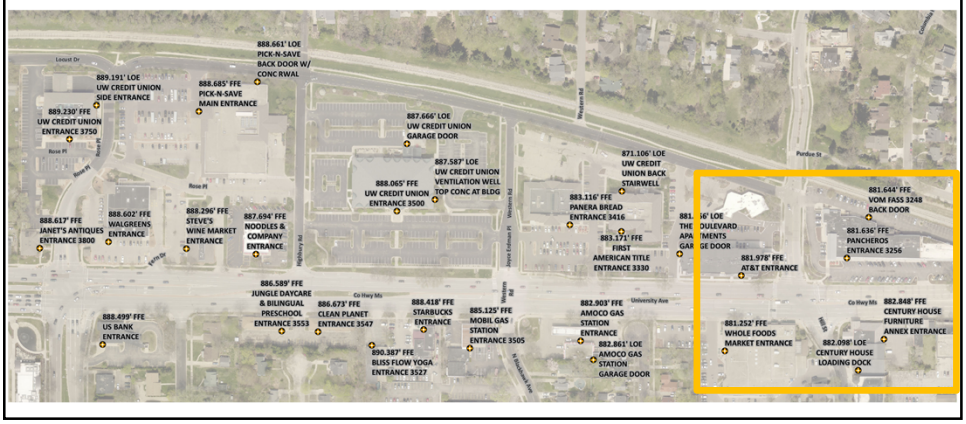
- Buildings around Midvale Blvd. Higher than Assumed Previously



SUMMARY OF DATA USED AND COLLECTED

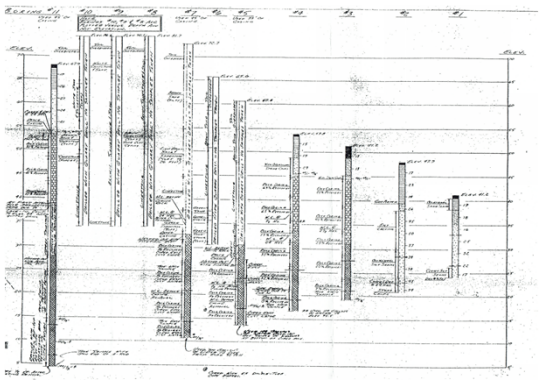
Lowest Opening Survey

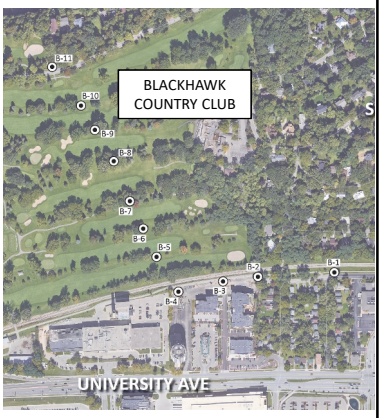
- Buildings around Shorewood Blvd. Lower than Assumed Previously



SUMMARY OF DATA USED AND COLLECTED

Geotechnical / Geologic Data





Soil Borings Performed by Warzyn Engineering in 1960s

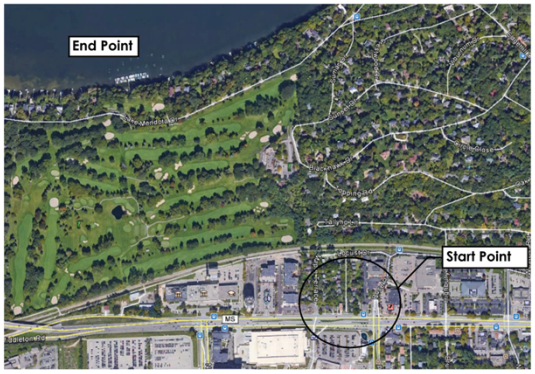
SUMMARY OF DATA USED AND COLLECTED

Additional Data

- Site Visit on July 22 with staff from:
  - City
  - Village
  - Blackhawk CC
  - KL Engineering
  - AE2S
  - Black and Veatch

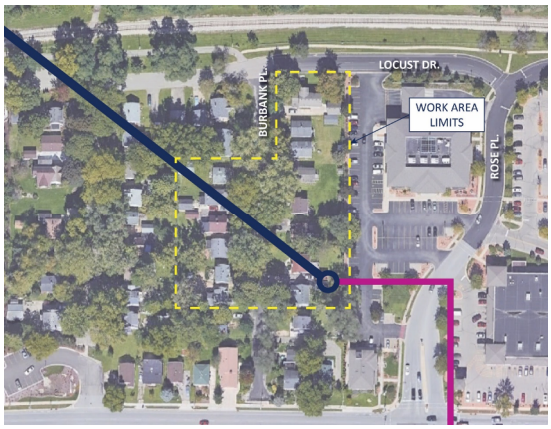
SUMMARY OF OPTIONS EVALUATED

- Option 1 – Minimize Open Cut
- Option 2 – Optimized Balance of Open Cut / Tunnel
- Option 3 – Maximize Open Cut (Minimize Tunnel)



SUMMARY OF OPTIONS EVALUATED

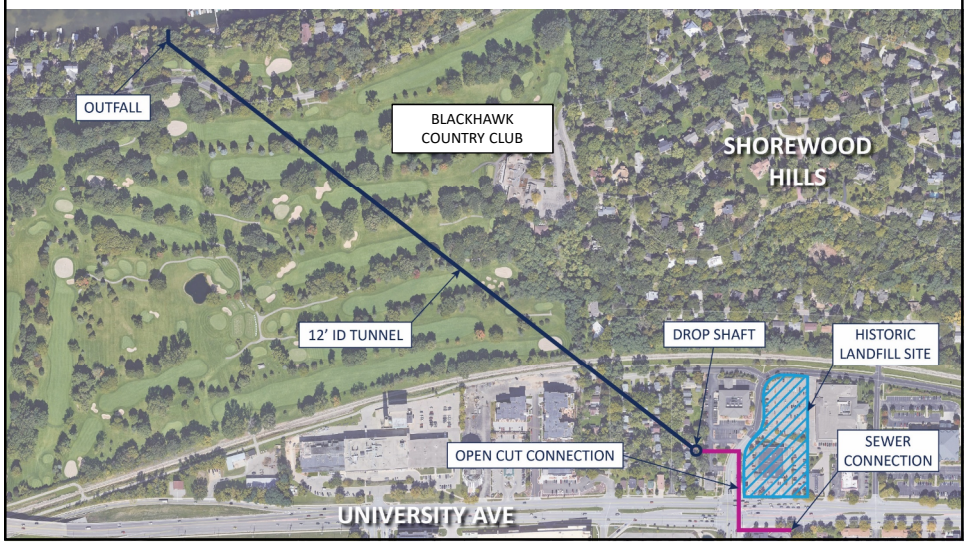
Option 1 Laydown & Staging Area



- Option 1 work area approx. 2 acres
- Supplemental laydown area required for storage of tunnel lining materials

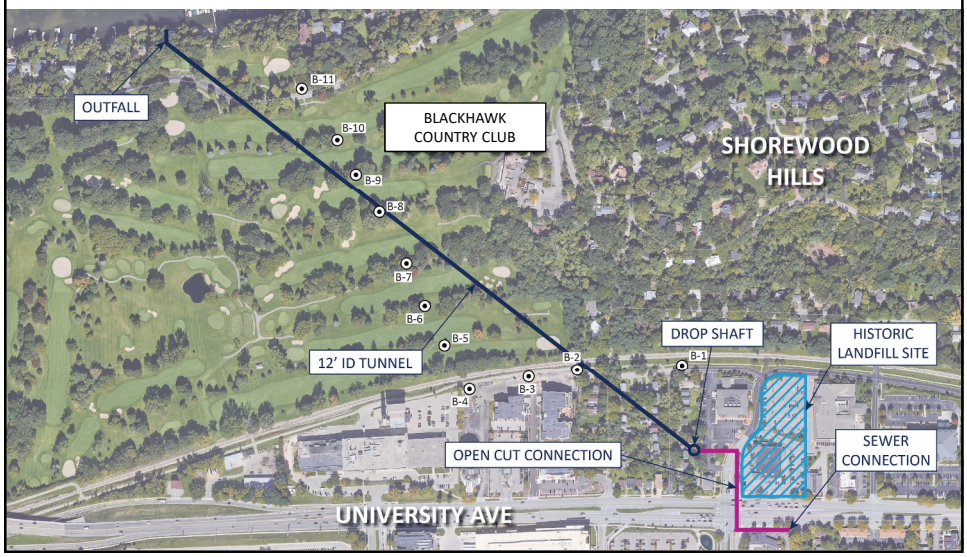
SUMMARY OF OPTIONS EVALUATED

Option 1 Tunnel Geometry



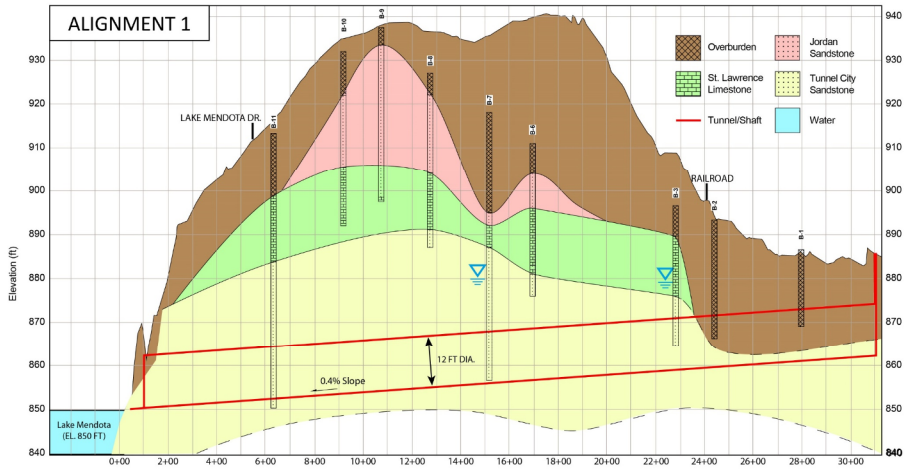
SUMMARY OF OPTIONS EVALUATED

Historical Boring Information



SUMMARY OF OPTIONS EVALUATED

Option 1 Tunnel Geologic Profile



Based on borings from Warzyn Engineering Study (1968)

SUMMARY OF OPTIONS EVALUATED

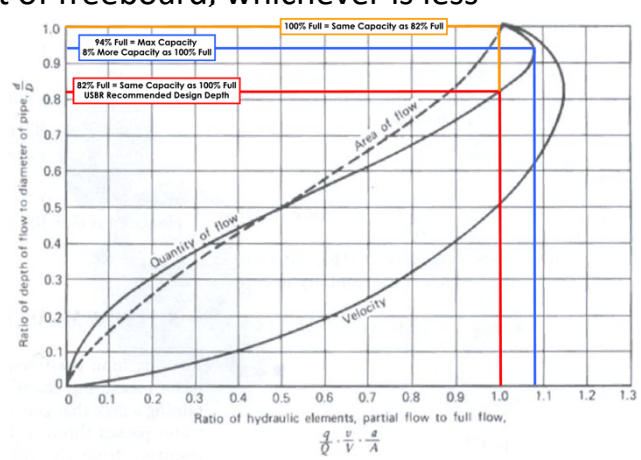
Tunnel Hydraulic Design Criteria

- USBR Design Guidance: 82% of tunnel depth or 1.5 feet of freeboard, whichever is less
  - 1.5 feet governs for a 12’ diameter tunnel

SUMMARY OF OPTIONS EVALUATED

Tunnel Hydraulic Design Criteria

- USBR Design Guidance: 82% of tunnel depth or 1.5 feet of freeboard, whichever is less



SUMMARY OF OPTIONS EVALUATED

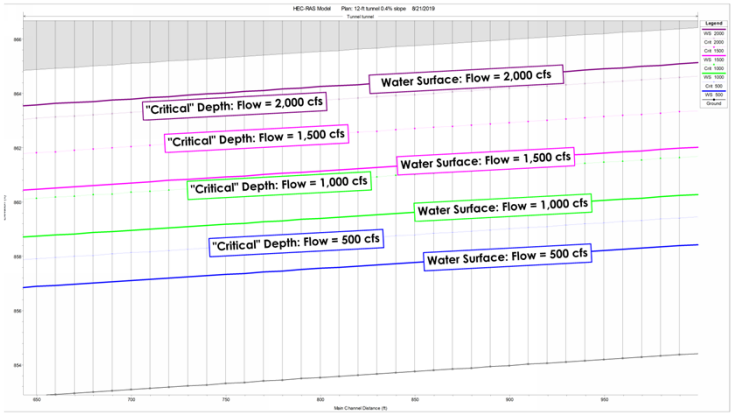
Option 1 Tunnel Hydraulics

- Lower flows are “supercritical” (really fast)

SUMMARY OF OPTIONS EVALUATED

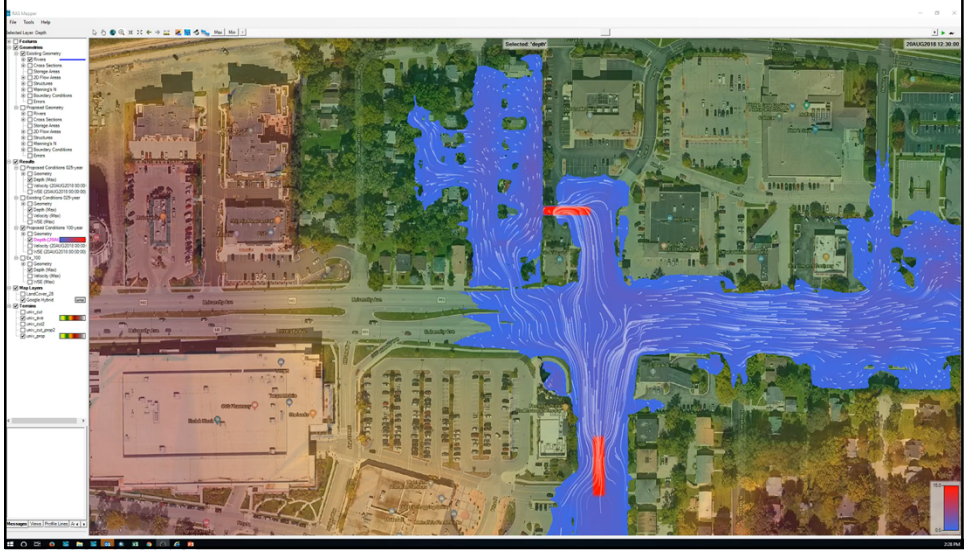
Option 1 Tunnel Hydraulics

- Design flow is approximately “critical depth”
- Velocities are about 20 feet per second



SUMMARY OF OPTIONS EVALUATED

Option 1 Inlet Portal Hydraulics



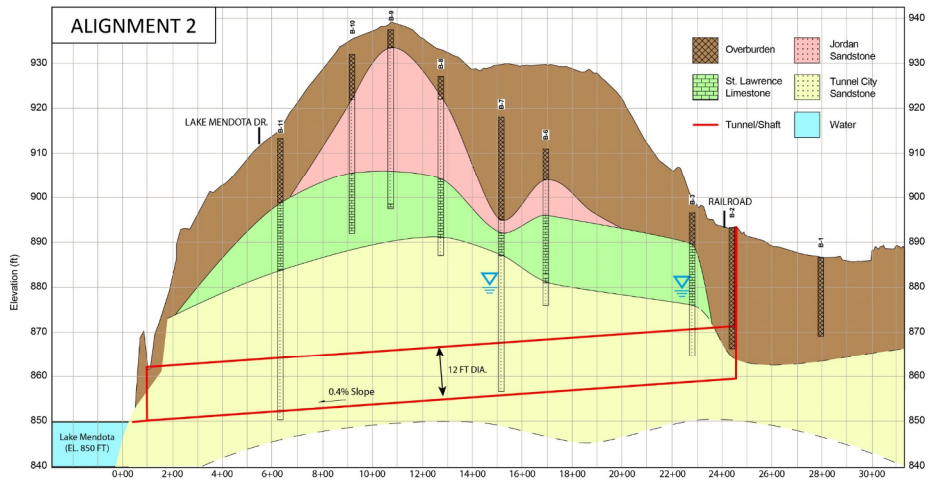
SUMMARY OF OPTIONS EVALUATED

Option 2 Laydown & Staging Area

- Option 1 work area approx. 1 acres
- Supplemental laydown area required for storage of tunnel lining materials

SUMMARY OF OPTIONS EVALUATED

Option 2 Tunnel Geologic Profile



Based on borings from Warzyn Engineering Study (1968)

SUMMARY OF OPTIONS EVALUATED

Option 2 Tunnel & Inlet Hydraulics

- Very similar to Option 1
  - Dealing with high velocities

SUMMARY OF OPTIONS EVALUATED

Feasibility Summary

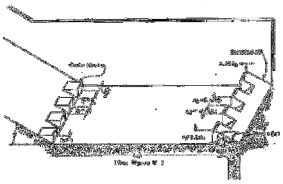
- Option 1 – Lack of Cover Creates Challenges for Garden Homes Redevelopment
- Option 2 – Feasible (Pending Cost Considerations)
- Option 3 – Topography Creates Excessive Cut and Impacts

OUTFALL STRUCTURE

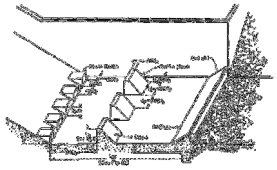
Design Assumed in Costing

- US Bureau of Reclamation (USBR) has standard energy dissipation structures
- Assumed outfall invert above Lake Mendota level most of the time

Example USBR Type II Stilling Basin (475 cfs Design Flow)



USBR Type II Stilling Basin



USBR Type III Stilling Basin

OUTFALL STRUCTURE

Likely Construction Approach

- Outfall site work area of approx 0.5 acre (min)
- Construction barge likely required to remove equipment after tunnel excavation is complete & support outfall construction

TUNNELING APPROACH

Pressurized Tunneling Compatible with Ground Conditions

- Overburden soils under groundwater prone to flowing if not supported
- Tunnel City Sandstone is poorly cemented and subject to flowing below groundwater unless supported

Settlement concerns exist if tunnel not controlled at excavation face

TUNNELING APPROACH

Microtunneling

- Tunnel Boring Machine (TBM) installed in shaft with jacking frame
- Installation of pipe as machine advances (pipe jacking)
- Drive length is long but possible by microtunneling
- Diameter is on upper end for pipe jacking – limited MTBM manufacturers

TUNNELING APPROACH

Microtunneling

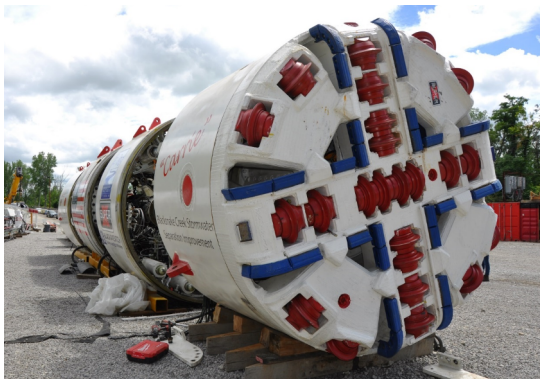
TUNNELING APPROACH

Earth Pressure Balance Machine

- Installation of precast concrete segments for tunnel lining as machine advances
- Drive length is on the shorter end for EPBM
- Diameter is acceptable for precast concrete segments

TUNNELING APPROACH

Earth Pressure Balance Machine



EPB Machine Assembly and Testing

Segmental Tunnel Lining Installed

Tunnel Lining Segments Staged

TUNNELING APPROACH

Earth Pressure Balance Machine

Source: Robbins (Tunneling Equipment Manufacturer)

GEOTECHNICAL INVESTIGATION PLAN

Preliminary Design (if Moving Forward)

Structure	Total Borings	Approx. Depth (ft)
Tunnel	7	50 – 100
Drop Shaft	2	50
Outfall	2	50
Inlets	2 (1 ea.)	30
Near Surface	1	15

Boring spacing of approximately 300 ft along microtunnel alignments recommended by ASCE Microtunneling Guidelines (2015)

GEOTECHNICAL INVESTIGATION PLAN

Preliminary Design (if Moving Forward)

GEOTECHNICAL INVESTIGATION PLAN

Preliminary Design (if Moving Forward)

- Soil Testing
  - Moisture content
  - Grain size analysis
  - Soil box resistivity
  - Chloride and Sulfate Corrosivity
- Rock Testing
  - Unconfined compressive strength
  - Density (unit weight)
  - Soil abrasion
  - Cherchar abrasion
  - Brazilian tensile strength

Typical Rubber Tire ATV Drill Rig

GEOTECHNICAL INVESTIGATION PLAN

Preliminary Design (if Moving Forward)

- Water Pressure (Packer) Testing)
- Environmental Testing
  - Diesel range organics
  - Gasoline range organics
  - RCRA metals
  - Volatile organic compounds
  - Semi-volatile organic compounds

Soil Sampling

OPINION OF PROBABLE COSTS

Level of Certainty

- Association for the Advancement of Cost Engineering (AACE International)

Estimate Class	Design Level	Design Phase	Expected Accuracy Range
Class 5	0% to 2%	Concept Screening	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Feasibility Study	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Preliminary Design (30%)	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Preliminary Design (60%)	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Final Design and Bidding	L: -3% to -10% H: +3% to +15%

OPINION OF PROBABLE COSTS

Base Costs

Cost Item	Dollar Amount
Bonding, Mobilization, Traffic, Erosion, Restoration	$925,000
NW Inlet	$400,000
SE Inlet	$1,500,000
Open Cut Box Storm	$1,500,000
Tunneling	$14,750,000
Energy Dissipator	$2,350,000
Subtotal Construction	$21,400,000

*Costs Rounded. Line Items May not Add to Exact Total.

OPINION OF PROBABLE COSTS

Base Costs

Cost Item	Dollar Amount
Subtotal Construction	$21,400,000
Legal, Admin, Engr	$3,210,000
Estimating Contingency (+)	$5,350,000
Estimating Contingency (-)	-$2,140,000
Total Project Costs	$22.5M - $30.0M
Land Acquisition Allowance	$665,000
Total Facility Costs	$23.2M – $30.7M

*Costs Rounded. Line Items May not Add to Exact Total.

OPINION OF PROBABLE COSTS

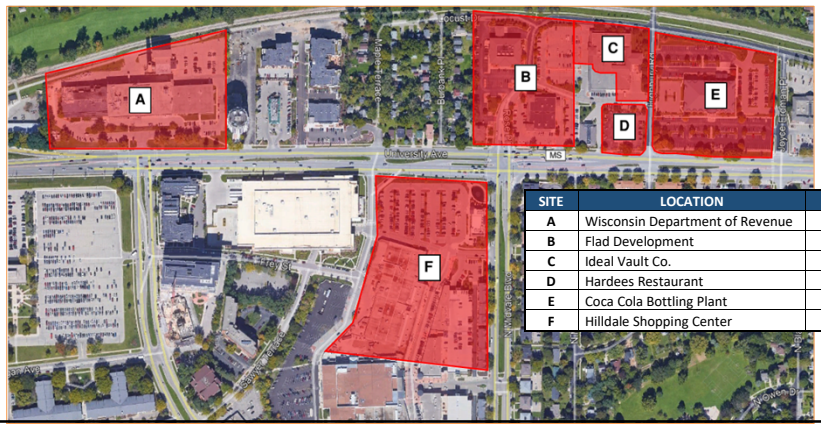
Potential Future Value Engineering

- Location, Size, and Geometry of Inlet Portals: Could Save ~$1M+
- Tunnel Size (10’ Diameter): Could Save ~$2M
- Energy Dissipation: Using Submerged Lake Outlet Could Save $1M
- Land Negotiations

KEY UNCERTAINTIES

Potential Cost Increases

- Geology and Unsuitable Soils
- Contaminated Soil



SITE	LOCATION	STATUS
A	Wisconsin Department of Revenue	Closed
B	Flad Development	Closed
C	Ideal Vault Co.	Closed
D	Hardees Restaurant	Closed
E	Coca Cola Bottling Plant	Closed
F	Hilldale Shopping Center	Open

KEY UNCERTAINTIES

Potential Cost Increases

- Geology and Unsuitable Soils
- Contaminated Soil
- Outlet Configuration
- Major Utility Crossings / Conflicts
- Future Design Details
- Bidding Environment

CONCLUSIONS

- Buildings around Shorewood Boulevard Lower than Previously Assumed
- Buildings around Midvale Boulevard Higher than Previously Assumed
- Beginning Tunnel in NW Corner of Garden Homes is Likely Best Option

CONCLUSIONS

- Tunneling is Possible with Ground Conditions
- Provide Contractors with Tunneling Methodology Options
- Costs Could Range from ~$23M to ~$30M
- Re-Development of Garden Homes Site Would Increase Future Costs Substantially

NEXT STEPS

(If Project Could Be Funded)

- Preliminary Design Phase
  - Hydraulic optimization
  - Alignment analysis and selection
  - Water quality evaluation
  - Supplemental geotechnical investigation
  - Land acquisition and easements
  - Permit requirements (railroad and outfall)
  - Stakeholder communication
  - Opinion of Probable Cost Updates
  - Funding Options

SCHEDULE

(If Project Could Be Funded)

- Design 12-16 Months
- Bidding and Award 3-4 Months
- Construction 24 Months

University Avenue Flood Relief Tunnel – Feasibility Study
September 17, 2019