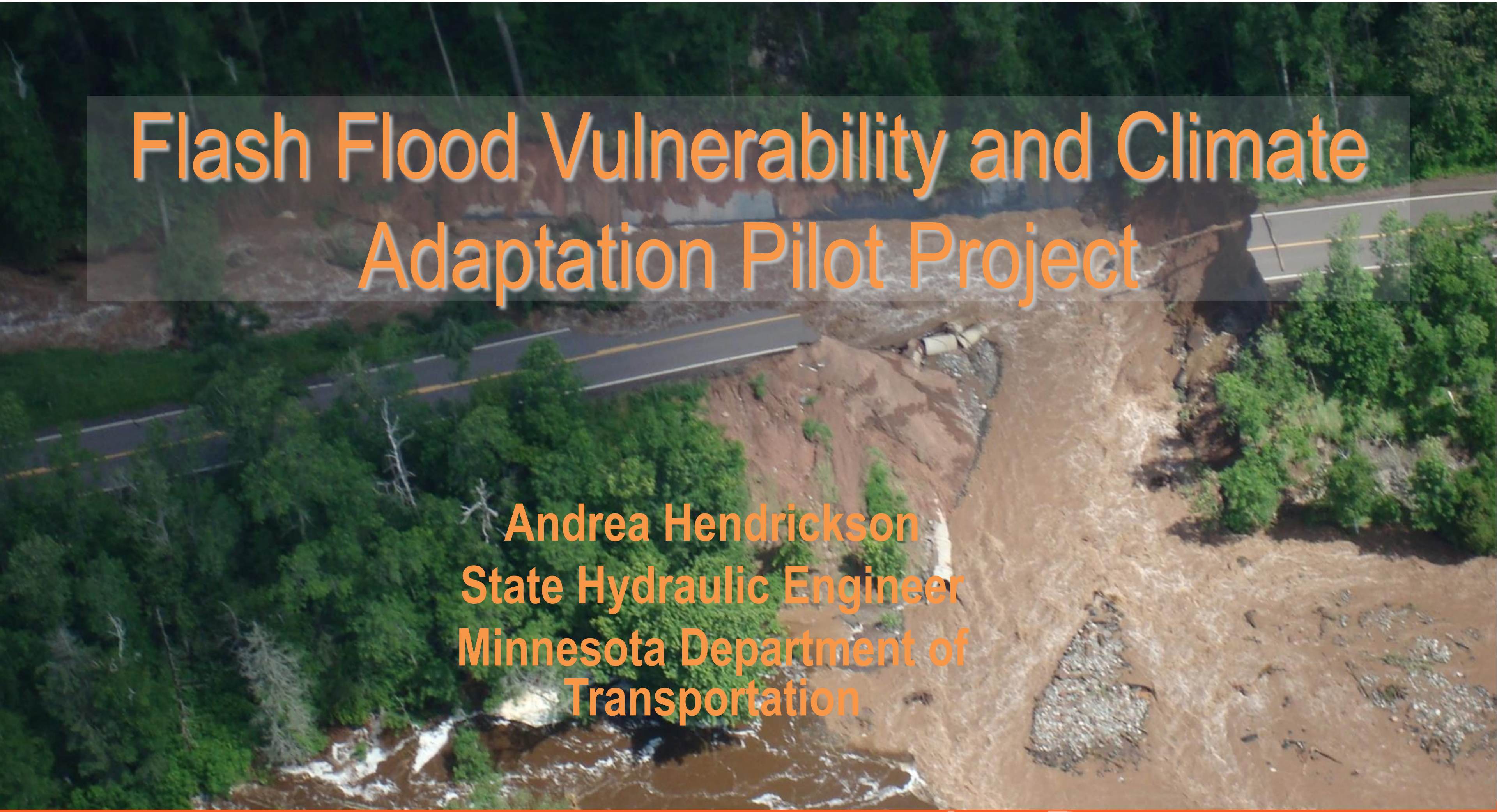
Flash Flood Vulnerability and Climate Adaptation Pilot Project

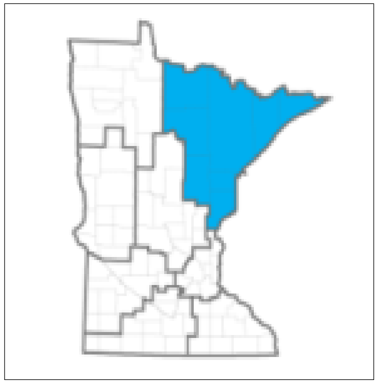


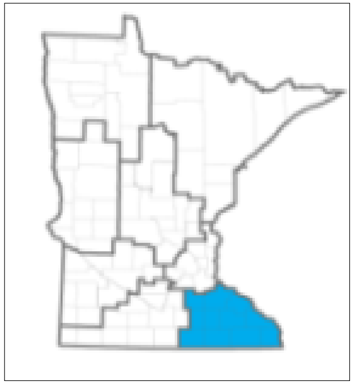
Andrea Hendrickson
State Hydraulic Engineer
Minnesota Department of Transportation

We all have a stake in A TO B

Pilot Project Overview

- Phase 1: System-wide vulnerability assessment
  - – High-level screen of state highway network in Districts 1 & 6



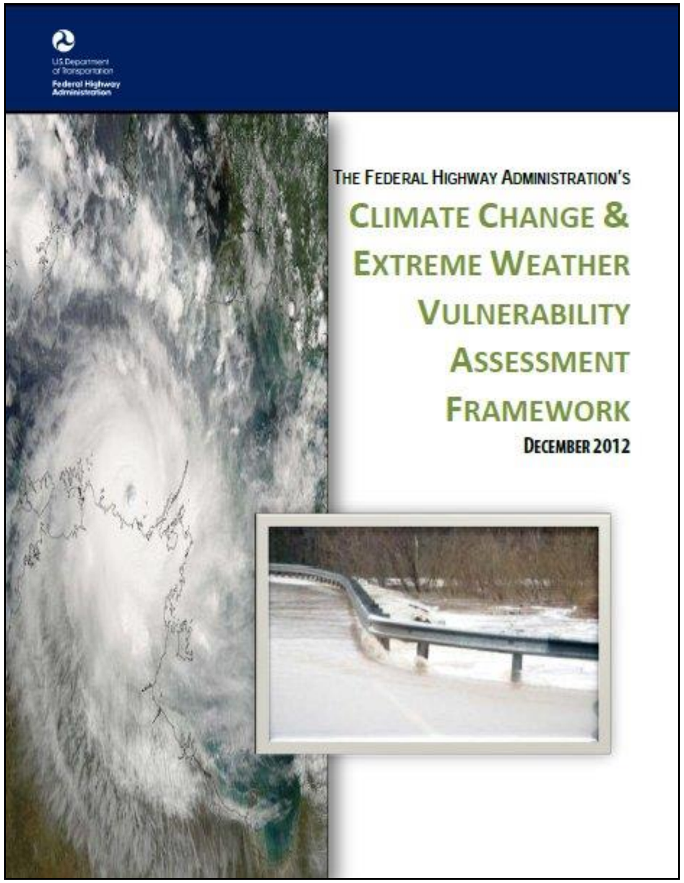


- Phase 2: Facility-level adaptation analysis
  - – Two high risk facilities (one in each district)

Consultant: PARSONS BRINCKERHOFF Catalysis Adaptation Partners LLC

MnDOT's Pilot Project Objectives

- Better understand the trunk highway network's risk from flash flooding
- Identify cost-effective options to improve the network's resiliency
- Provide feedback on the FHWA Draft Framework



Identify Assets of Interest

Bridges	Large Culverts	Pipes	Roads paralleling floodplains

Calculate the Vulnerability Scores for Each Asset

Sensitivity	Exposure	Adaptive Capacity

Rank Flood Vulnerability by District

Calculate the Vulnerability Scores for Each Asset

Sensitivity

- Capacity to han
  - % change
    required
    StreamSt
- Asset conditio
  - Pavemen
  - Scour rat
  - Substruct
  - Channel
    large culv
  - Culvert c
  - Pipe con

Exposure

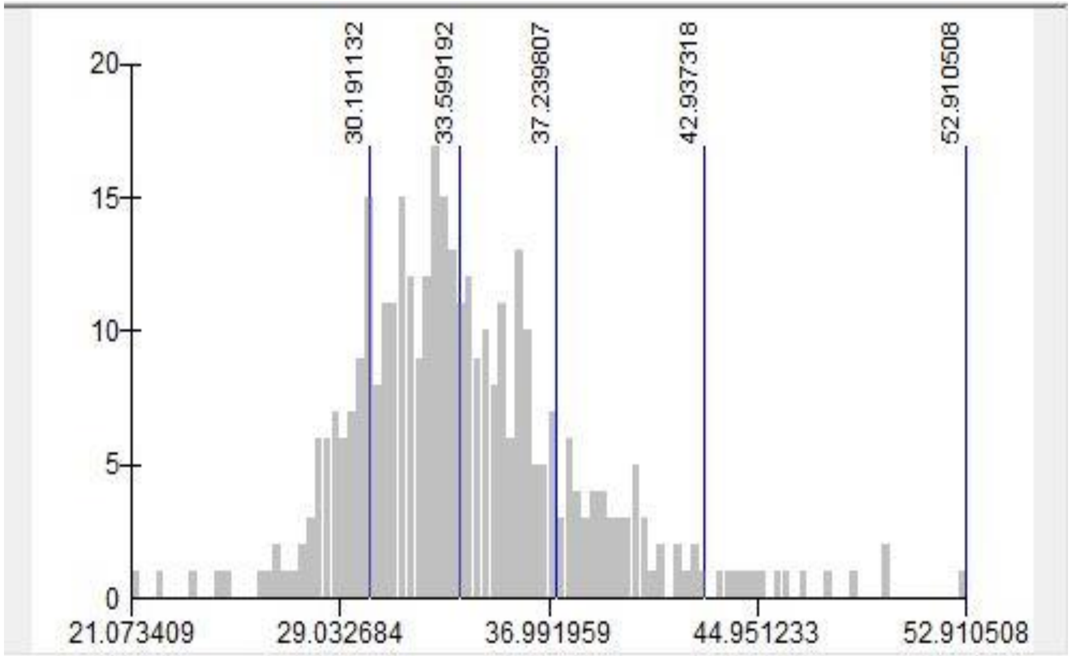
- Stream velocity
- Previous flooding
- Belt width to spa
  (bridges, large cu
- Belt width to floo
  (roads)
- % of total roadwa
  the floodplain at
  the stream chann
- % forest land cov
  (bridges, large cu
- % of drainage are
  lakes & wetlands
- % urban land cove

Adaptive Capacity

- Average annual daily traffic (AADT)
- Heavy commercial average daily traffic (HCADT)
- Detour length
- Flow control regime (bridges, large culverts, and pipes)

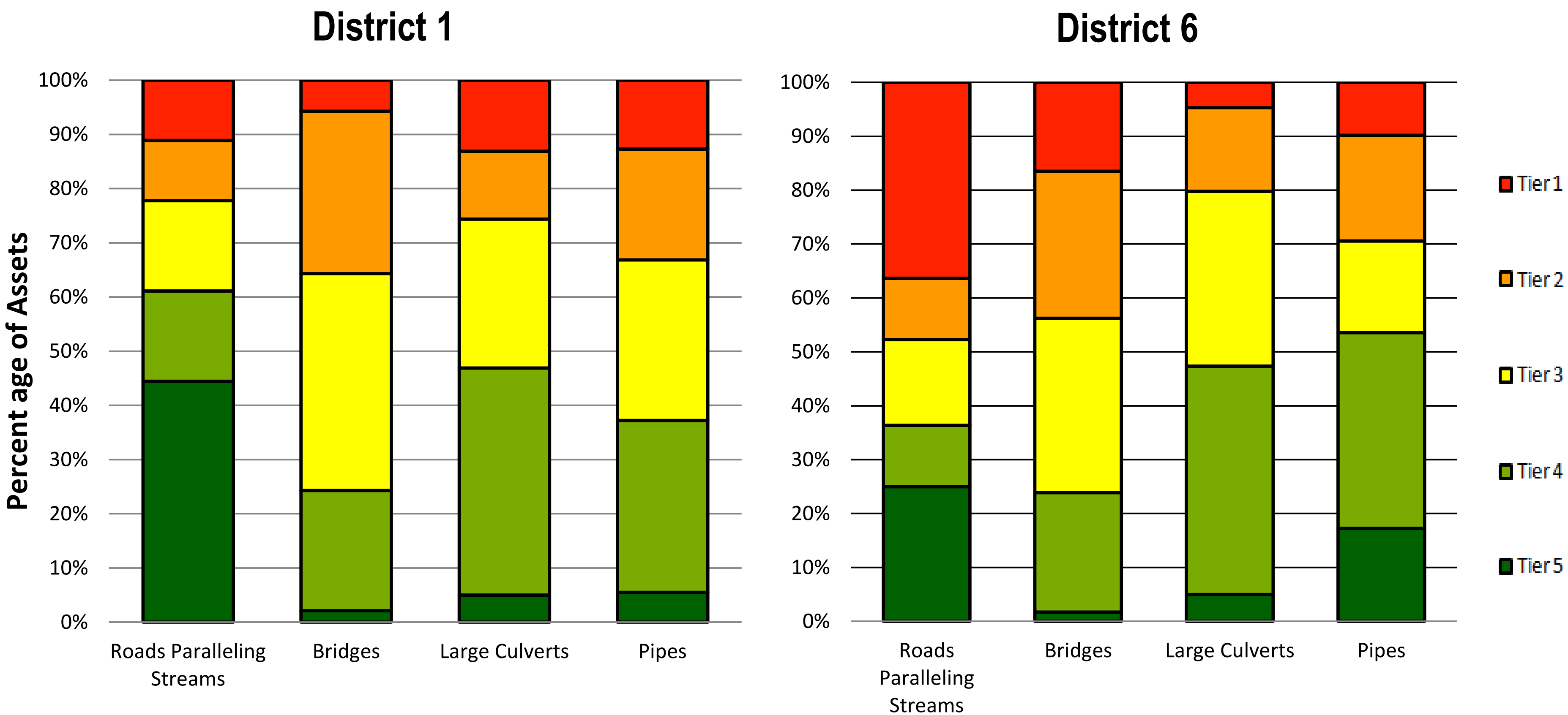
Vulnerability Tiers

- Five tiers of vulnerability scores by district
  - Tiers set at natural breaks
  - Tier 1 – Highest vulnerability
  - Tier 5 – Lowest vulnerability

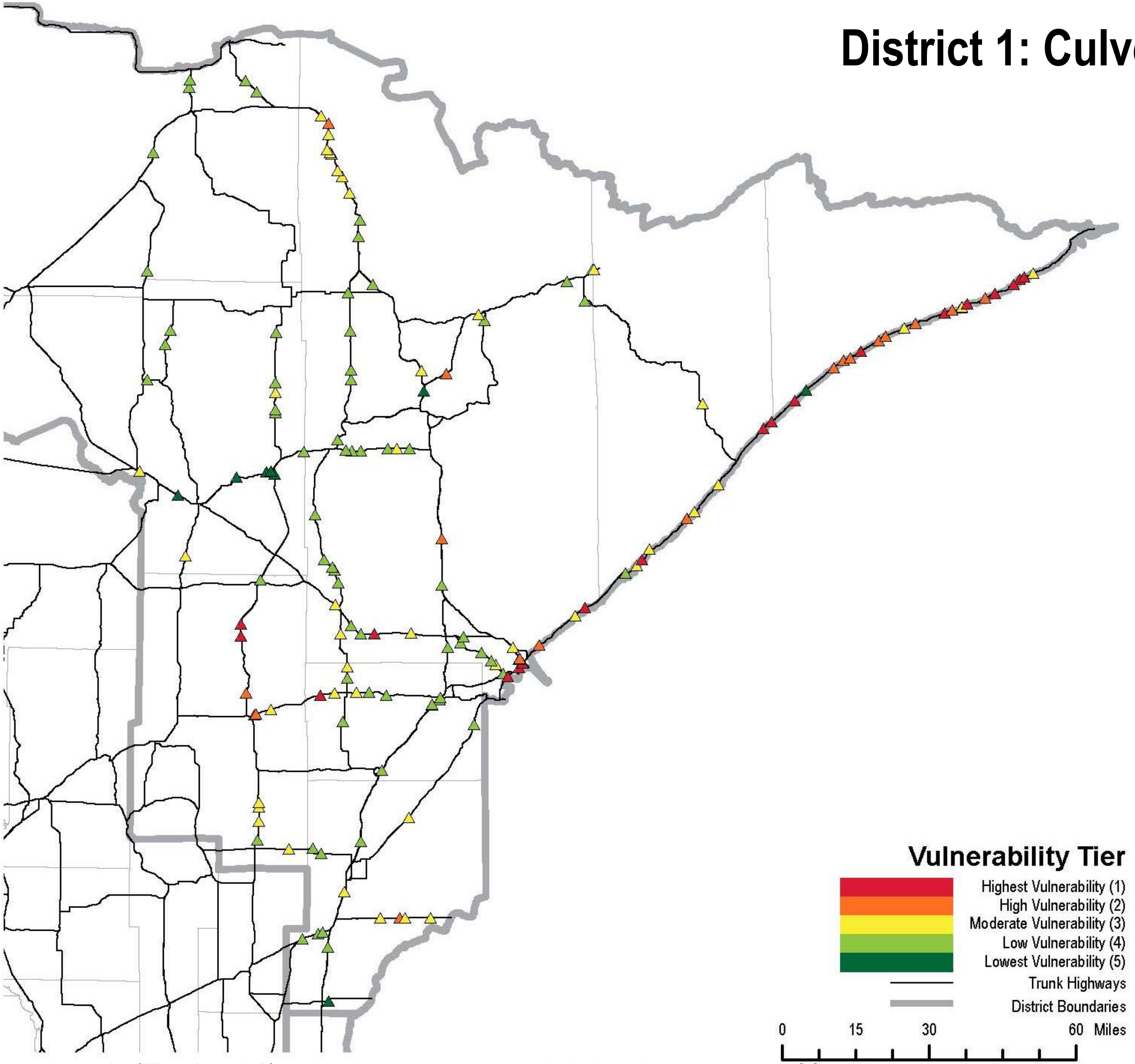


- Benefits
  - Aids in prioritization
  - Accounts for imprecision in scores

Vulnerability By Asset Type



District 1: Culverts



Highly vulnerable (Tier 1 and 2) assets are not necessarily in imminent danger of flooding, nor are lower vulnerability assets immune from flooding. Values are indicators of relative vulnerability compared with other assets in the same district.

Facility Level Adaption Assessment
Adaptation Assessment General Approach

1. Describe the site context
2. Describe the facility
3. Identify climate stressors
   - Heavy precipitation
4. Develop climate scenarios (Low*, Medium, High)
5. Assess performance of the facility

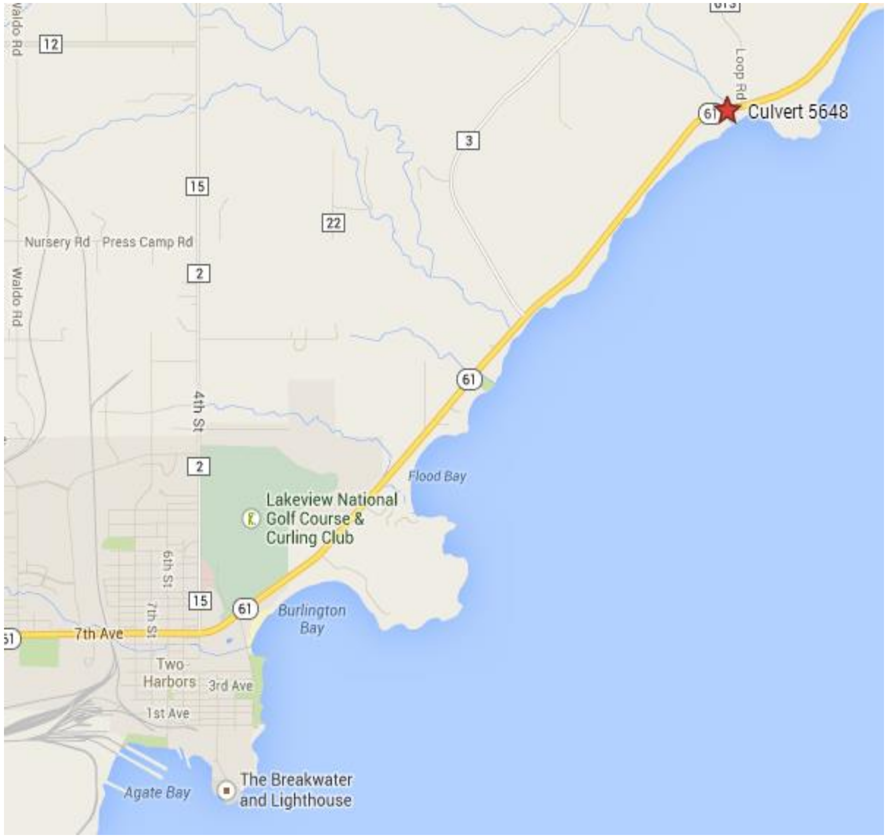
- *used IPCC RCP4.5 for the low,*

which used to be called a medium scenario

Adaptation Assessment General Approach

6. Identify adaptation options
   - Meet MnDOT 50-year clearance guidance
   - Meet FEMA 100-yr floodplain impact regulations
7. Assess performance of the adaptation options
8. Conduct an economic analysis
9. Evaluate additional considerations such as fish passage or replacement schedule

District 1 Culvert Adaption Analysis



- MN 61- Parallel to Lake Superior from Duluth up to Canadian Border
- Crosses Silver Creek
- AADT: 5,900
- Detour Length: 24 miles
- High quality stream with fish passage concerns

Existing Facility Performance

- Currently system is functioning well when compared to design storm
  - Does not overtop at the current 50-year storm
- Performance decreases under future climate projections

Projected Climate Conditions

24-Hr Storm Return Period	Atlas 14 Precip. Depth (in)	Low Scenario Precipitation Depth (in)			Medium Scenario Precipitation Depth (in)			High Scenario Precipitation Depth (in)		
		2040	2070	2100	2040	2070	2100	2040	2070	2100
2-yr storm	2.48	2.56	2.60	2.62	2.59	2.67	2.75	2.69	2.91	3.12
5-yr storm	3.26	3.36	3.42	3.44	3.41	3.51	3.62	3.54	3.83	4.12
10-yr storm	3.89	4.02	4.08	4.11	4.08	4.20	4.33	4.24	4.60	4.95
25-yr storm	4.8	4.96	5.05	5.09	5.04	5.21	5.38	5.26	5.73	6.19
50-yr storm	5.53	5.73	5.84	5.89	5.83	6.02	6.23	6.08	6.66	7.22
100-yr storm	6.31	6.55	6.68	6.74	6.67	6.91	7.16	6.98	7.68	8.36
500-yr storm	8.26	8.63	8.83	8.92	8.81	9.17	9.56	9.28	10.35	11.39

Data from SimCLIM

Projected Hydrologic Conditions

24-Hr Storm Return Period	Existing Discharges (cfs)	Low Scenario Discharges (cfs) 2100	Medium Scenario Discharges (cfs) 2100	High Scenario Discharges (cfs) 2100
2-yr storm	770	1,120	1,230	1,550
5-yr storm	1,350	1,830	2,000	2,460
10-yr storm	1,880	2,450	2,660	3,250
25-yr storm	2,690	3,390	3,670	4,460
50-yr storm	3,370	4,170	4,500	5,480
100-yr storm	4,140	5,000	5,420	6,610
500-yr storm	6,090	7,150	7,800	9,630

Adaptation Options

- Base: Replace in-kind
  - Construct cost: $710,000
- Option 1: Increase culvert to 16’ X 14’
  - Construction cost: $770,000
- Option 2: Replace Culvert with a 35’ span bridge
  - Construction cost: $1,130,000
- Option 3: Replace Culvert with a 40’ span bridge
  - Construction cost: $1,210,000

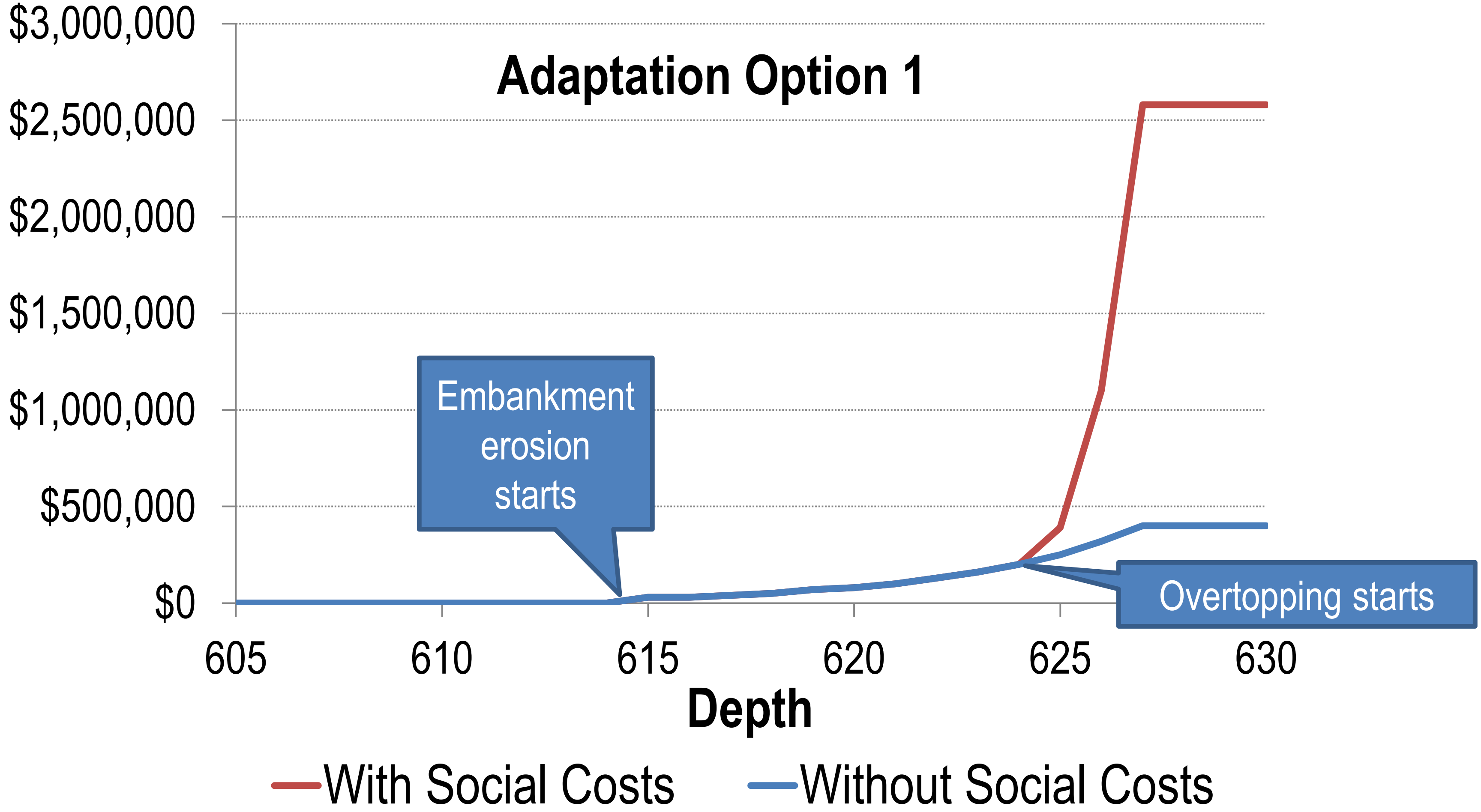
Benefit-Cost Assumptions

- Analysis period: 2020 – 2100 split in three time periods
- Standard discount rate: 2.0%
- Social costs
  - Safety cost: $80,000
  -

	Car	Truck	Total
Operating Costs	$40,176	$11,520	$51,696
Travel Time	$78,624	$9,555	$88,179
Total	$118,800	$21,075	$139,875

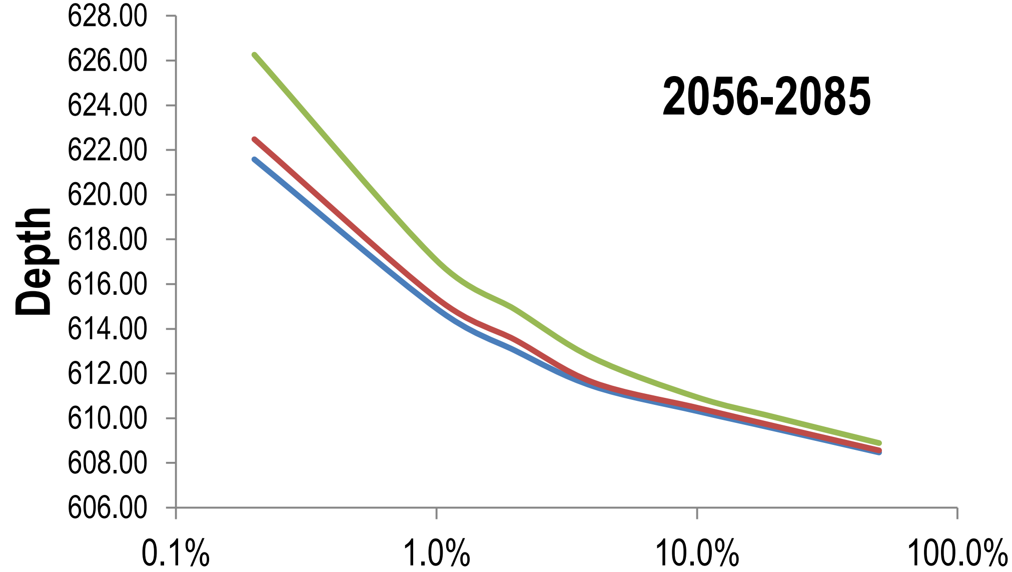
Depth Damage Function

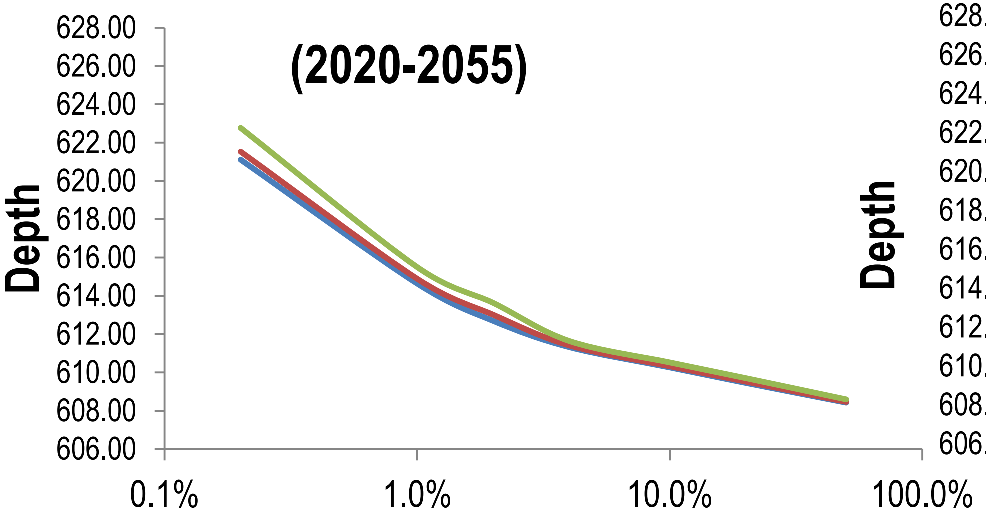
For Each Adaptation Option

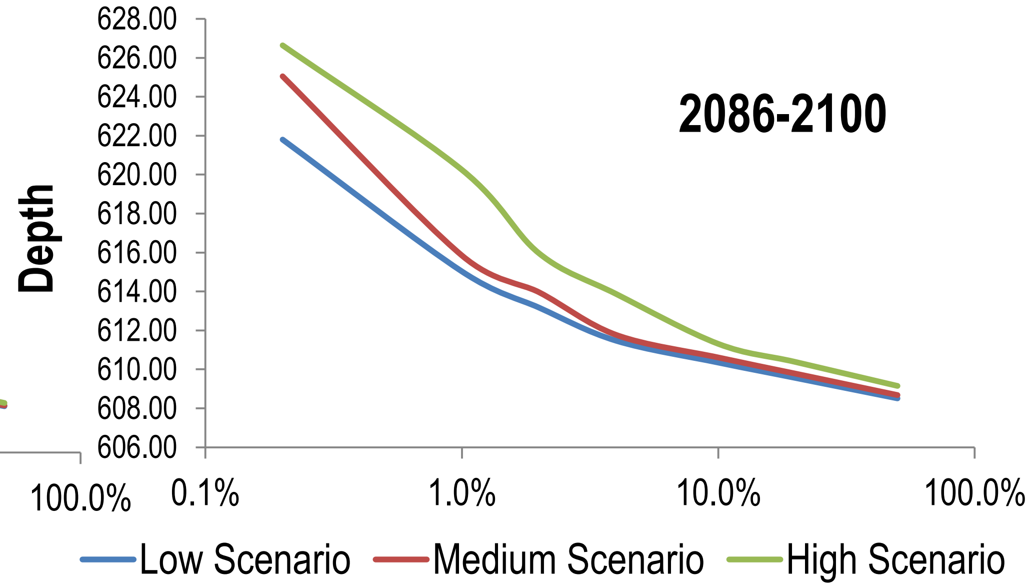


Depth Probabilities for Option 1

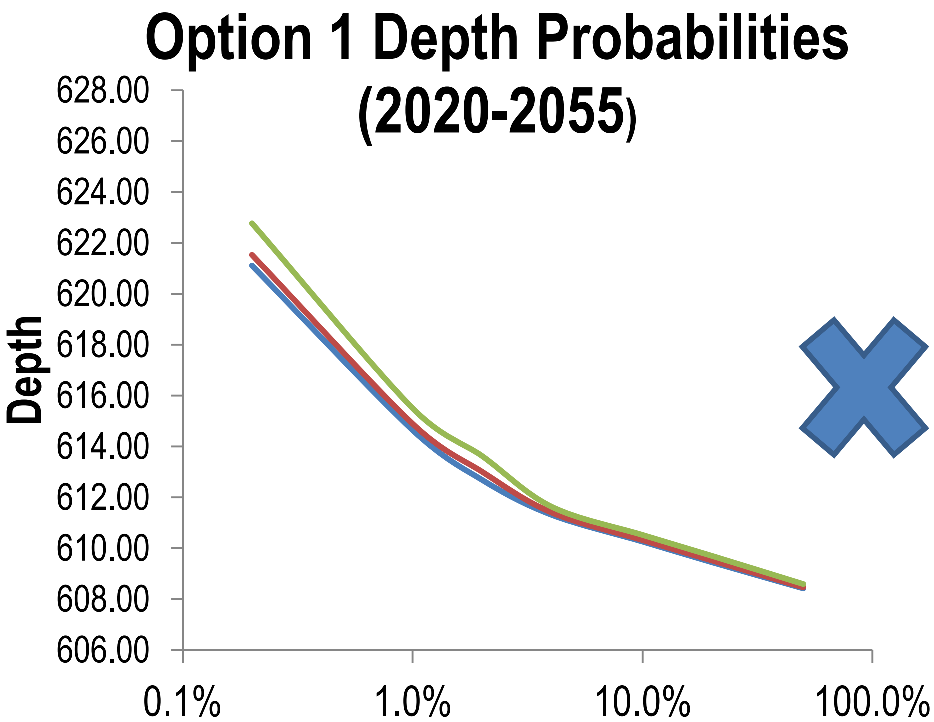
(each adaptation option for all 3 time periods)

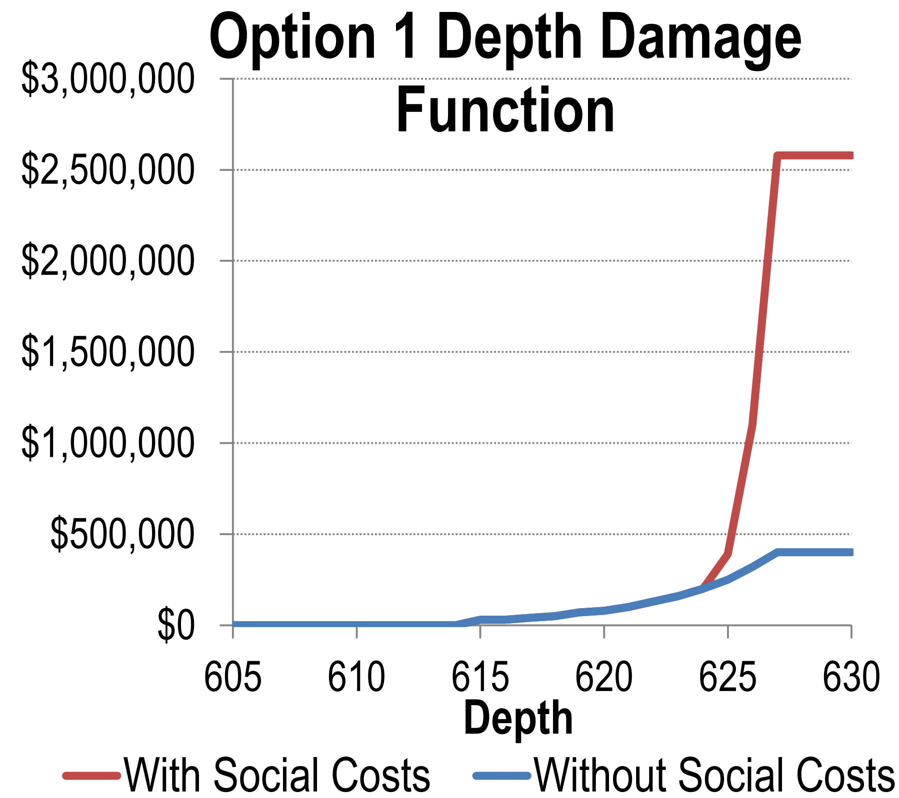






COAST Model

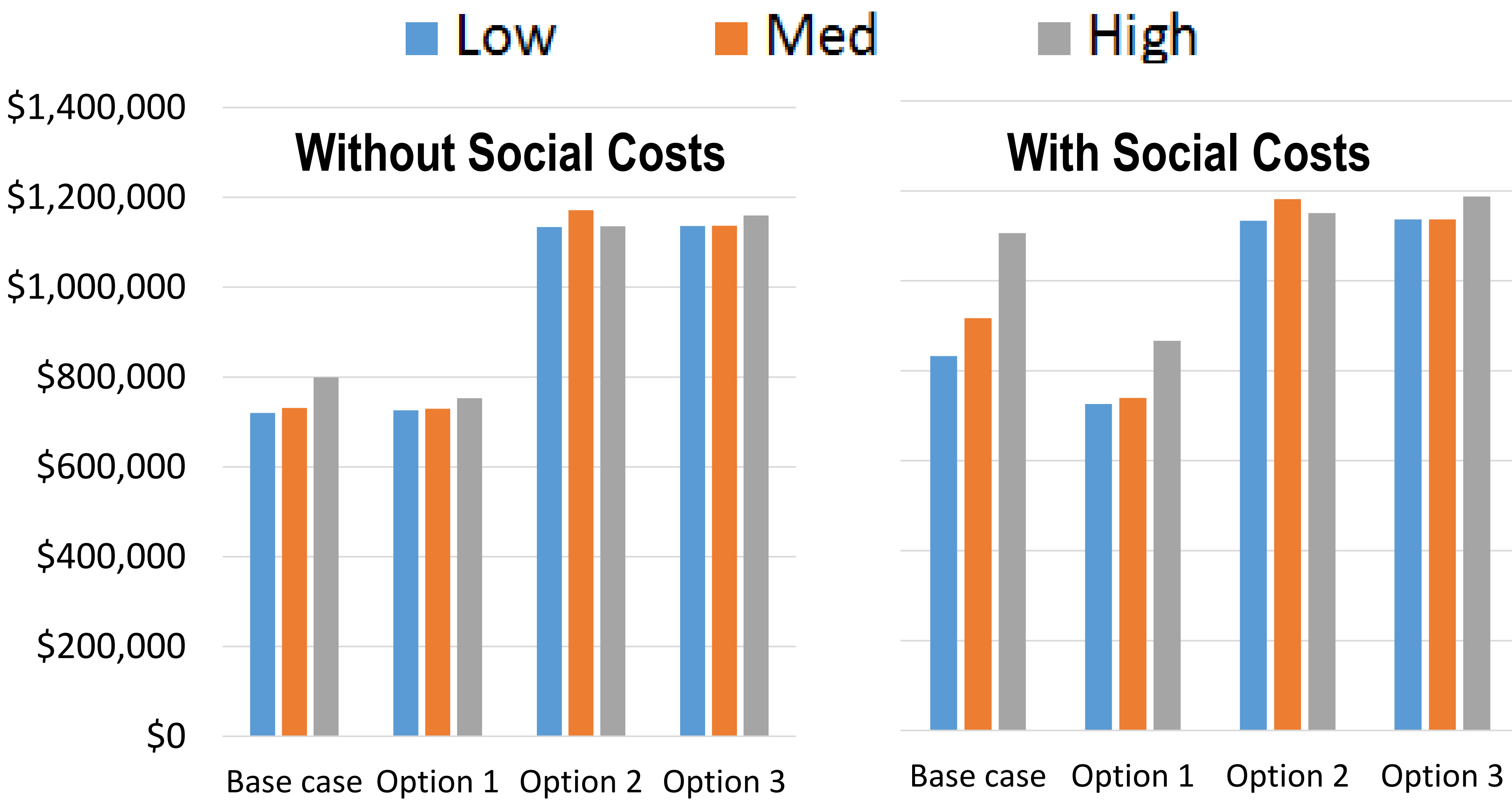




Construction Cost

Cost Effectiveness: Silver Creak

Cumulative Cost (Present Value)



Challenges Overcome

- Scope:
  - More assets: pipes and parallel roads
  - Districts interested in slope failures too
- Data not available, in wrong format or not in database
- LIDAR not hydrologically corrected

Challenges Remaining

- More time and money to apply adaption method
- Requires more expertise than most DOT's have
- Data availability
- Resilience of natural and built systems

Challenges Remaining

- Climate Models do not provide data in a format used in hydrologic modeling.
  - Single design event based on a probability of occurrence
  - Smaller spatial and temporal accuracy of GCM
  - Precipitation Depth over 24 hours
    - Rainfall Intensity needed for Rational Eqn.
    - Regression equations give flow not rainfall. Sometimes % increase in precipitation ≠ % increase in runoff

Challenges Remaining

- Is best available science good enough?
- Nationally accepted design procedures that consider climate change impacts
- Evaluated by experts across functional areas: climatologists, hydrologists, hydraulic engineers and costal engineers

Project Accomplishments

- Raise awareness

  More information on project at
  www.mndot.gov/climate/pilotproject.html