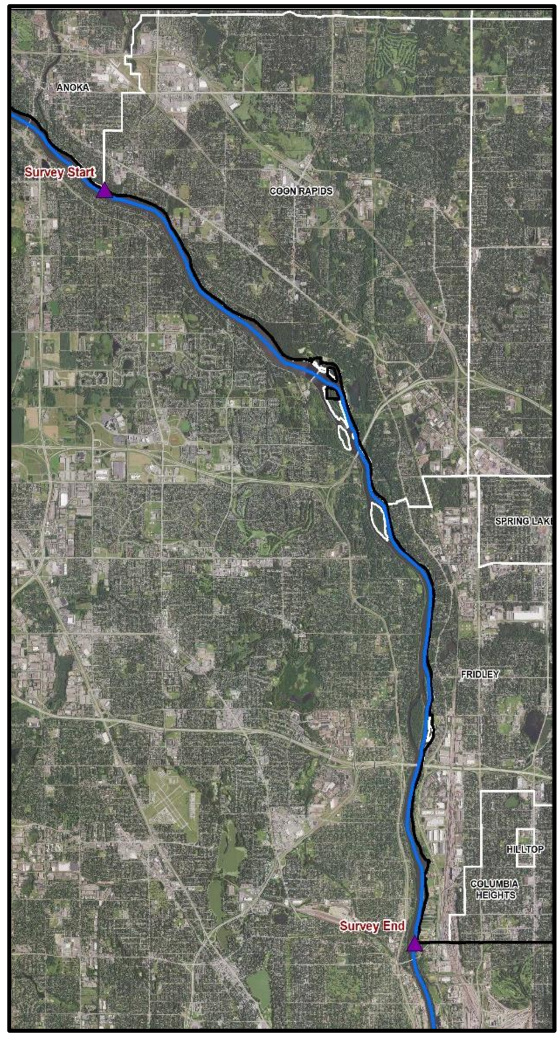
Mississippi Riverbank Erosion Inventory: Coon Rapids to Fridley



Prepared By

ANOKA CONSERVATION DISTRICT

November 2021

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Contents

Introduction

The Mississippi River fulfills the water resource needs of millions of people and provides hydrological and habitat benefits of national significance. In 1976, a coalition of state, regional, and local agencies developed the MRCCA (Mississippi River Corridor Critical Area) program to preserve the river's natural, cultural, and scenic resources along its course through the rapidly developing MSP (Minneapolis- St. Paul) metropolitan area in Minnesota. Unfortunately, this segment of the river continues to exhibit impairments for nutrients, total suspended solids, and other environmental pollutants identified through state guidelines. Failing riverbanks are one direct source of sediment and nutrient loading into the Mississippi River, contributing to reduced water quality, impaired aquatic habitats, diminished property values, and jeopardized infrastructure. Fortunately, a range of effective bank stabilization approaches exist, serving as mechanisms to meet water quality and ecosystem enhancement goals throughout this critical area while protecting critical infrastructure and property values.

Executive Summary

Process

The Anoka Conservation District (ACD) compiled an erosion inventory for the eastern bank of the Mississippi River extending from the westernmost boundary of Coon Rapids to the southernmost boundary of Anoka County in Fridley. Eroded riverbanks along this stretch were identified using 360° photos captured from watercraft in near-shore zones. These photos were used in conjunction with GIS resources and the Wisconsin NRCS Field Office technical guide for streambank erosion to estimate the size and severity of eroded banks. Approximately 33% (22,000 feet) of surveyed riverbanks showed evidence of moderate, moderate severe, or severe erosion. Annual soil loss metrics were calculated using measurements of riverbank length, height, and erosion severity. Cost estimates for each stretch of erosion were calculated using equations informed by previous ACD-led stabilization projects. Cost: benefit values derived from project cost estimates and bank sediment losses were then determined, providing a metric for gauging the cost effectiveness of each potential project. Profile pages with site-specific information for each eroded bank are included in this report. Collectively, the erosion inventory provided herein facilitates the strategic pursuit of riverbank stabilization projects that protect water quality and enhance riverine habitats within and alongside the Mississippi River.

Findings

In total, 48 projects encompassing 22,000 linear feet of bank stabilization opportunities spanning 76 separate properties (68 private, 8 public) were identified. If all 48 projects were completed, 8,517 tons of sediment would be prevented from entering the river each year at a total cost of approximately $14,600,000. The 15 highest priority projects in terms of total suspended solids (TSS) removal cost-effectiveness are listed in Table 1. A full listing of all candidate projects is included in Appendix A.

Table 1: Stabilization Project Cost: Benefit Estimations

Site ID	Cost: Benefit ($/ ton TSS removed)	Total Estimated Project Cost	Total Length (ft)	Ownership
16	$30.27	$297,377	488	Anoka County – Parks
18	$35.88	$622,574	935	Anoka County – Parks
47	$42.16	$546,274	653	Minneapolis; Municipal
12	$43.00	$204,814	183	Private
45	$43.42	$78,356	57	Minneapolis —Municipal
5	$43.76	$171,627	154	Private
9	$47.00	$118,400	91	Private
36	$48.60	$693,789	698	Private
44	$48.79	$1,295,904	1320	Anoka County – Parks; Minneapolis – Municipal
48	$52.35	$2,413,328	2489	Minneapolis – Municipal
28	$52.85	$73,099	102	Private
29	$56.63	$64,331	84	Private
24	$65.37	$40,431	88	Private
14	$65.45	$197,514	271	Anoka County – Parks
20	$67.76	$759,996	2229	Anoka County – Parks
		$7,577,814	9,842	

Limitations

This report is best used to compare relative cost-effectiveness of candidate projects. Individual site designs and cost estimates are needed to move forward confidently with project planning. Factors that can significantly impact costs that were not considered in this report include:

- site access constraints,
- site restoration costs,
- staging area constraints,
- bluff height preventing access to toe of slope from above,
- extremely steep slopes,
- building setback from bluff prohibiting slope grading,
- batching of adjacent properties into a single designed and bid project,
- depth below the water line to the toe of the slope,
- utility locations, and
- removing/repairing/relocating infrastructure.

Methods

Geographic Scope

This report includes riverbank erosion information for the eastern shore of the Mississippi River in the northern MSP metropolitan area of Minnesota, extending approximately 12.5 miles from the western Coon Rapids boundary to the southernmost boundary of Anoka County in Fridley. Uplands surrounding this stretch of the river are characterized by abundant urban development, intermittent developed open spaces, and publically owned parks. Additional erosion data are available extending upstream to the western boundary of Anoka County in Ramsey; this report may be expanded to incorporate those data later.

Field Surveying

360° geo-located photos were taken along the riverbank in zones near the eastern shore of the Mississippi River downstream of the Coon Rapids Dam using a Samsung Gear 360 camera mounted to a tripod in a small watercraft. Photos were captured at spatial intervals defined through the Google Street View app that equated to approximately one photo per 100 feet of shoreline. These photos were collected in November 2018 and are publically accessible through Google Maps. Late fall is the ideal time to capture bank erosion photos as the riverbank is minimally obstructed by dense summer foliage.

Photos upstream of the Coon Rapids dam on the eastern shore of the Mississippi River are derived from a shoreline inventory compiled by ACD in October 2012. These photos captured shoreline condition at intervals similar to those downstream of the dam, but were supplemented with additional 360° geo-located photos uploaded to Google Maps in 2016.

GIS Surveying and Erosion Classification

GIS tools and data resources were used in conjunction with the field-derived photo inventory to measure the extent and severity of eroded riverbank segments. The field-derived photos described previously were used alongside 2-foot LiDAR-derived elevation contours and high-resolution (1m) aerial imagery to digitize measureable polylines in ArcMap along the eroded stretches. Aerial imagery and LiDAR contours were also used to measure the height and depth of eroded sections, which allowed for the calculation of annual soil loss estimates.

Each polyline segment was classified according to a lateral recession severity metric originally derived from the WI NRCS Field Office Technical Guide (FOTG) for streambank erosion. These values ranged from a recession rate of <0.1 ft/year ("slight" erosion), to a rate of >0.5 ft/year ("severe" erosion). Because slight erosion is very common, this report only contains descriptions for eroded segments at the moderate, moderate severe, and severe thresholds to identify areas of greatest concern and prioritize projects that produce the greatest cost effectiveness. All definitions for the erosion categories are shown in Table 2 below; for consistency and due to effectiveness, these are the same categories used by ACD in similar erosion inventories. Note that each polyline represents a stretch of eroded riverbank exhibiting a similar level of severity throughout. A single eroded stretch may span across multiple privately and/or publically owned parcels, and one parcel may contain multiple separate eroded stretches.

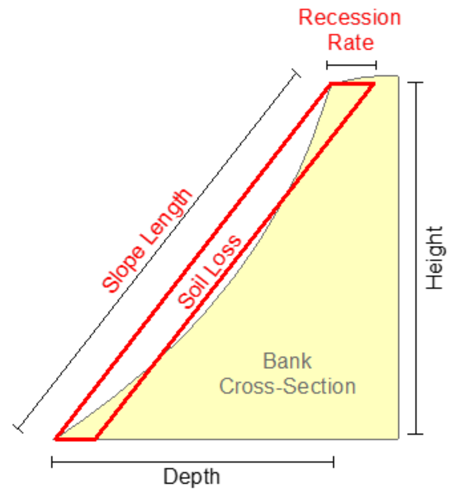
Table 2: Erosion Severity Categories

<table>
<tr><th>Symbol</th><th>Category</th><th>Lateral Recession Rate(ft/yr)</th><th>Description</th></tr>
<tr><td></td><td>Slight</td><td>< 0.1</td><td>Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang.</td></tr>
<tr><td></td><td>Moderate</td><td>0.1</td><td>Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips.</td></tr>
<tr><td></td><td>Moderate Severe*</td><td>0.3</td><td rowspan="2">Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped.</td></tr>
<tr><td></td><td>Severe*</td><td>0.5</td></tr>
</table>

*For this report, the original WI NRCS severe category was split into two thresholds ("moderate severe" and "severe") due to the prevalence of stretches that existed on both ends of this spectrum. Both exhibit similar characteristics, but the "severe" erosion is more pronounced.

Soil Loss Estimation

Riverbank sections classified as moderate, moderate severe, or severe were analyzed for annual soil loss estimates based on the following measurements and equation:



- **Depth (*D*):** Horizontal distance from the riverbank toe to the top of the bank.
- **Height (*H*):** Vertical distance from the riverbank toe to the top of the bank
- **Length (*L*):** Length of the eroded stretch along the riverbank
- **Slope Length (*SL*):** Length of diagonal riverbank slope, calculated using depth and height measurements
- **Recession Rate (*RR*):** Annual lateral recession of bank approximated using field-based photos and classifications defined in Table 1 ft^3
- **100 lb/ft^3 :** Approximate weight of sandy soils – the predominant soil type in the survey area

$$\frac{SL(ft) * RR(ft/yr) * L(ft) * 100(lb/ft^3)}{2000(lb/ton)} = \textit{Annual Soil Loss}$$

Project Cost Calculations

A total project cost estimate was calculated for each stretch of eroded riverbank based on ACD's previous experience with similar stabilization projects. This calculation incorporated cost estimates associated with the following metrics: stabilization approach (such as bioengineering vs hard armoring), total project area (reported in ft^2), total number of landowners present along the eroded stretch, and project mobilization considerations (Table 3). Cost estimates assume that the entire eroded stretch will be stabilized. True project costs will vary from these estimates based on additional site-specific factors not captured in these calculations as noted in the Executive Summary.

The equation used to calculate a cost estimate for each stretch of eroded riverbank is as follows:

For each SA: [(DPM * ft^2) + D + M + L(*n*-1) + (C*ft^2)] = Estimated Project Cost

Table 3: Stabilization Practice-Specific Cost Estimates

SA Stabilization Approach	**DPM** Design and Project Management ($/$ft^2$)	**D** Design Minimum ($)	**C** Construction ($/$ft^2$)	**L** Additional Landowner Upcharge ($/ *n*-1)	**M** Standard Mobilization Cost ($)
Hard Armoring	$5	$14,000	$35	$5,000	$10,000
Bioengineering	$3	$6,000	$25	$2,500	$5,000
Revetment	$1	$2,000	$5	$750	n/a

Findings

Erosion abundance

In total, ACD surveyed over 12 miles of Mississippi riverbank bordering Anoka County. Of this, 47 stretches totaling approximately 4.2 miles (22,006 feet) of riverbank exhibited moderate to severe erosion, with total soil loss estimates of 8,517 tons per year. Stretches classified as containing moderate severe erosion (bank recession rate = 0.3 ft/yr) are most abundant in total length and collectively produce the greatest soil losses relative to banks in the other erosion categories. See Table 4 and figures 1 and 2 below for a further breakdown of survey findings. See Appendix A for a table of all segment-specific erosion information.

Table 4: Total Eroded Riverbank Summary

Erosion Severity	Length (miles)	% of Total Surveyed Length	Soil Loss (tons/ year)	% of Total Soil Loss
None or Slight	7.84	65	n/a	n/a
Moderate	1.5	12	698	8
Moderate Severe	2.27	19	6110	72
Severe	0.39	4	1708	20

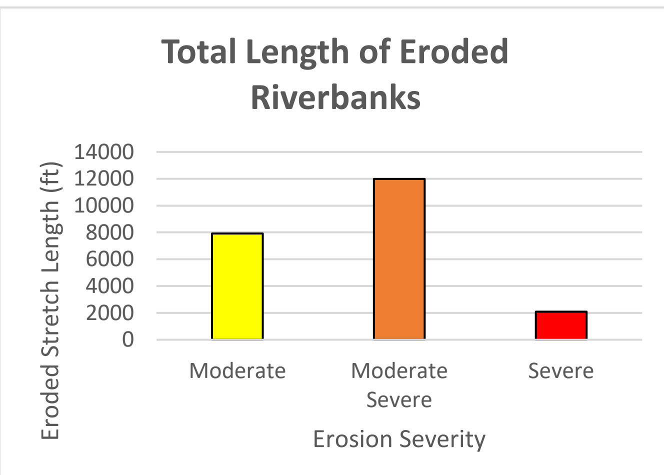


Figure 2. Eroded riverbank abundance categorized by erosion severity

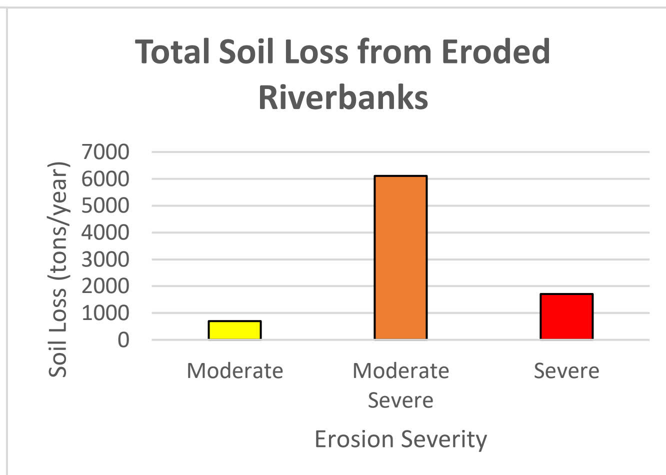


Figure 1. Total annual soil loss estimates for eroded riverbanks, categorized by erosion severity

Land Ownership Summary

Riverbank condition along this survey route varied widely along with landownership and, correspondingly, existing riverbank stabilization techniques (see *Figure 3* for an example). Because of this, several stretches identified in this report are relatively short in length (<100 ft). The longest continuous sections of eroded riverbank identified herein are commonly located on government-owned property in the form of county or city-owned parks or municipal facilities. Because of this, the majority of soil losses originate from public lands such as the Coon Rapids Dam Regional Park and the City of

Minneapolis' water treatment and distribution property in Fridley. See Table 5 for summary information on privately and publically owned eroded stretches.

Figure 3. Riverbank stabilized with riprap bordered on both sides by severely failing vertical slopes.

Table 5: Eroding Riverbank Summaries by Land Ownership

Eroding Bank Ownership	Number and Length of Eroding Stretches				Estimated Soil Loss	
	# Stretches	%	Total Miles	%	Tons/Year	%
Private (wholly or partially)	32	67	1.79	43	2,620	31
Public	16	33	2.32	57	5,892	69
Total	48	--	4.11	--	8,512	--

Riverbank Stabilization Approaches

Riverbank stabilization projects are designed to correct or prevent excessive erosion and undercutting, and thus are highly site-specific and dependent upon factors such as hydrology (e.g. river volume and flow rates), bank height, bank position (e.g. on an outer or inner river bend), riverine habitat objectives, and site accessibility. While a diverse range of stabilization options exist, ACD typically designs riverbank projects under the framework of hard armoring or bioengineering; these approaches may be applied individually, together, and/or in conjunction with other stabilization elements such as bank reshaping, cedar tree revetment, or live staking.

Hard Armoring

Hard armoring is a common approach that uses robust physical structures to minimize erosion along riverbank segments most vulnerable to repetitive erosive forces, such as the toe (i.e. the bottom) of the bank. Riprap (a layer of large stones or boulders) is commonly used for hard armoring. While highly effective at combatting erosion, hard armoring an entire slope often reduces the capacity to create banks that simultaneously maximize ecological benefits. Combining moderate hard armoring with additional stabilization techniques such as live staking and well-vegetated slopes can provide enhanced ecological benefits.

Bioengineering

Healthy riparian ecosystems are biodiversity hotspots and provide ecosystem services such as flood protection, carbon sequestration, and water quality protection. Bioengineering is an approach that combines engineering practices with naturally-occurring elements of riverbank structure to create a stabilized bank with an improved ecological status. Bioengineered design prioritizes the use of deep-rooted native vegetation to stabilize slopes, occasionally in conjunction with other techniques such as cedar tree revetments and bank reshaping. In addition to eliminating severe erosion, the benefits of restoring well-vegetated banks include the following:

- **Improved terrestrial, riparian, and aquatic habitat**.

  Well-established riparian zones often contain a wide range of vegetation adapted to varying soil moisture levels, thereby meeting the diverse habitat needs of both upland and aquatic biota. Abundant and overhanging riverbank vegetation also creates shade, lowering water temperatures and supporting higher oxygen levels needed for many aquatic species to thrive. The consideration of habitat-related benefits is especially important for bank stabilization projects along the Mississippi River corridor due to its role as a major migration route and refuge for populations already experiencing declines due to locally intensified landscape modifications.

- **Improved infiltration and environmental contaminant retention.**

  Besides contributing directly to nutrient and sediment loading, failing riverbanks also lack the capacity to filter aquatic contaminants stemming from adjacent land use practices- an ecosystem service frequently credited to riparian zones. By restoring banks to a well-vegetated and non-vertical slope, both soluble and particulate-bound contaminants are retained through enhanced ground cover and increased infiltration capacity throughout the bank. Riverbanks containing high amounts of biomass also serve as important carbon sinks.

- **Enhanced interface between flowing water and uplands.**

  Contact between flowing water and the riverbank helps reduce flow velocity, which minimizes erosion further downstream and allows for natural sedimentation that helps rebuild riverbanks. The flux of water levels at this interface also promotes the growth of specialized vegetation communities and facilitates important biogeochemical reactions occurring in the water and soils.

Practices for Promoting Resilient Riverbanks

While erosion is a natural process in all flowing water systems, erosive forces in large rivers like the Mississippi have been exacerbated by channel modifications and increased inputs from altered hydrological networks (such as manmade stormwater and agricultural drainage systems) in its upland watersheds. Furthermore, persistent soil losses from eroded riverbanks can decrease property values and threaten physical structures located near the bank. Instances of severe erosion typically require assistance from shoreline experts and engineers, but landowners experiencing early stages of erosion on their property can take steps to prevent larger issues from developing.

- **Encourage the growth of native, deep-rooted vegetation throughout the bank**

  Well-vegetated riverbanks improve soil health and structure. Promoting the growth of native vegetation with deep and fibrous root systems will enhance these benefits and provide improved riparian habitat. Allowing this vegetation to persist past the top edge of the bank/bluff by not mowing directly to the top of the slope will provide an additional layer of protection from overland flow that also contributes to bank erosion. Be sure to plant species that are well-suited to the site's soil and sun exposure characteristics.

- **Remove obstructions shading out the understory**

  Low-hanging branches, overabundant saplings, grapevines, and non-native species such as buckthorn can shade out and smother other understory species supporting stabilized banks. To enhance diverse understory growth, remove all nonnative vegetation, prune low-hanging branches on well-established tress, and thin out saplings.

- **Prevent excess surface flow from reaching the riverbank**

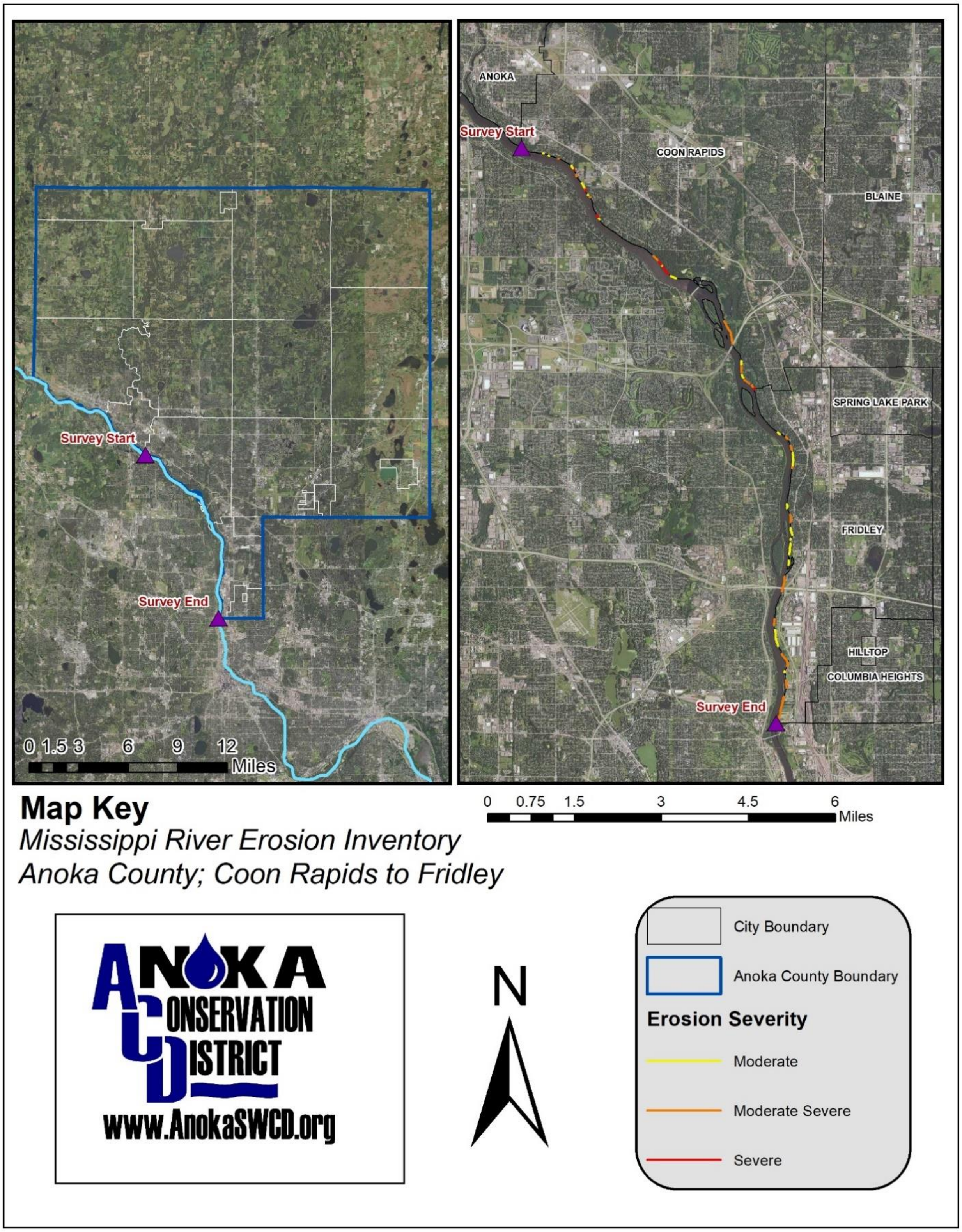
  Downspouts, pipes, and other impervious surfaces directed to the top of the riverbank increases erosion along a concentrated path that can eventually lead to gulleys or slumps. To prevent this, promote the infiltration of rainwater into soils throughout the property. If water must be redirected from the upland area, consider constructing a pipe conduit that reaches the water's edge.

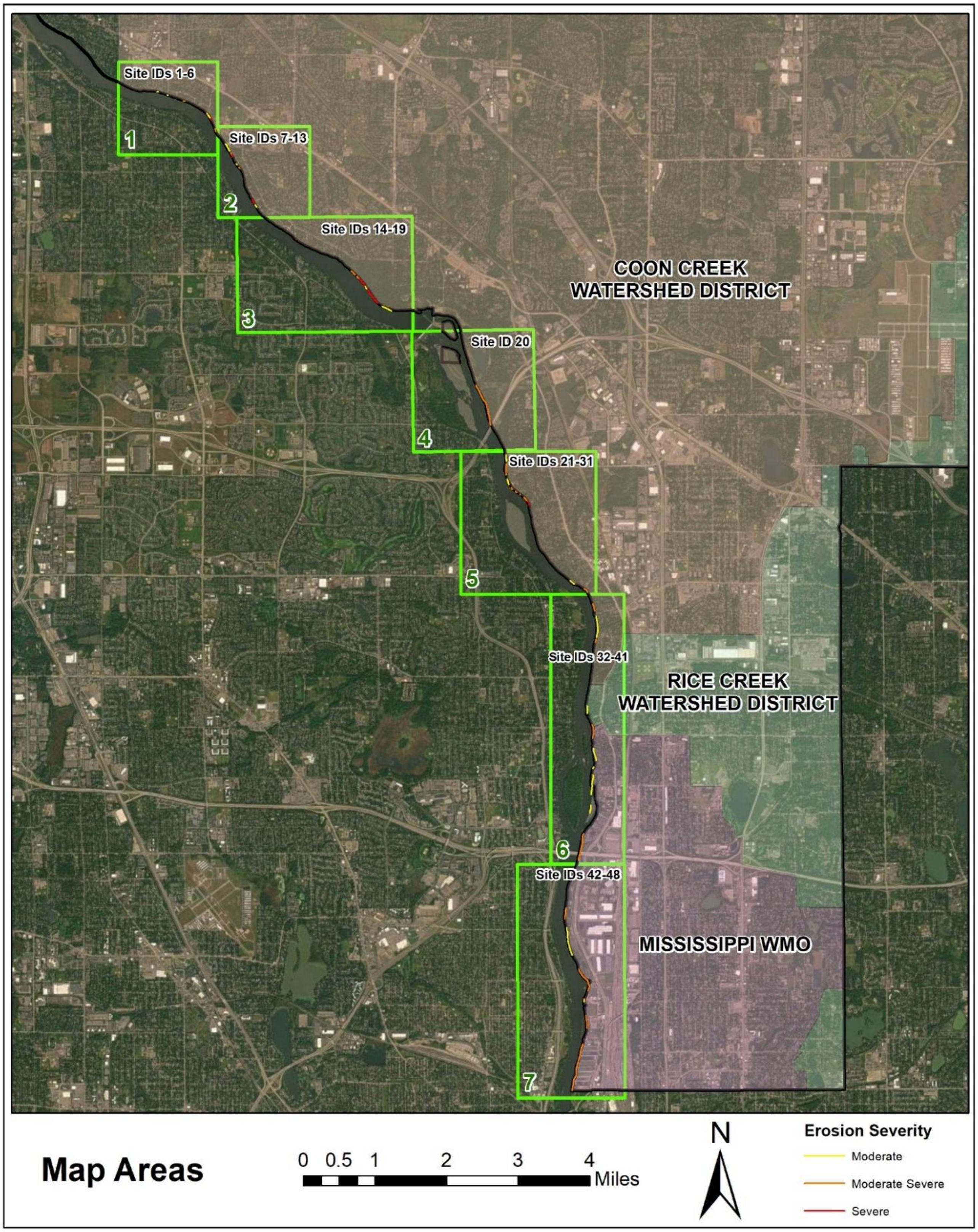
- **Manage large pieces of fallen woody debris**

  Depending on its orientation, large woody debris such as tree trunks can prevent or exacerbate erosion along a slope. If this debris is positioned horizontally along the bank or near the bank toe, it can help prevent undercutting or soil losses from overland flow. However, if it's positioned vertically down the slope, it may facilitate concentrated flow paths producing areas of more severe erosion.

- **Dispose of yard waste properly**
  Dumping leaves, grass clippings, weeds, and other types of yard waste down the riverbank contributes to additional nutrient loading in the river and can quickly smother rooted vegetation stabilizing the slope.

Site Profile Maps and Summaries

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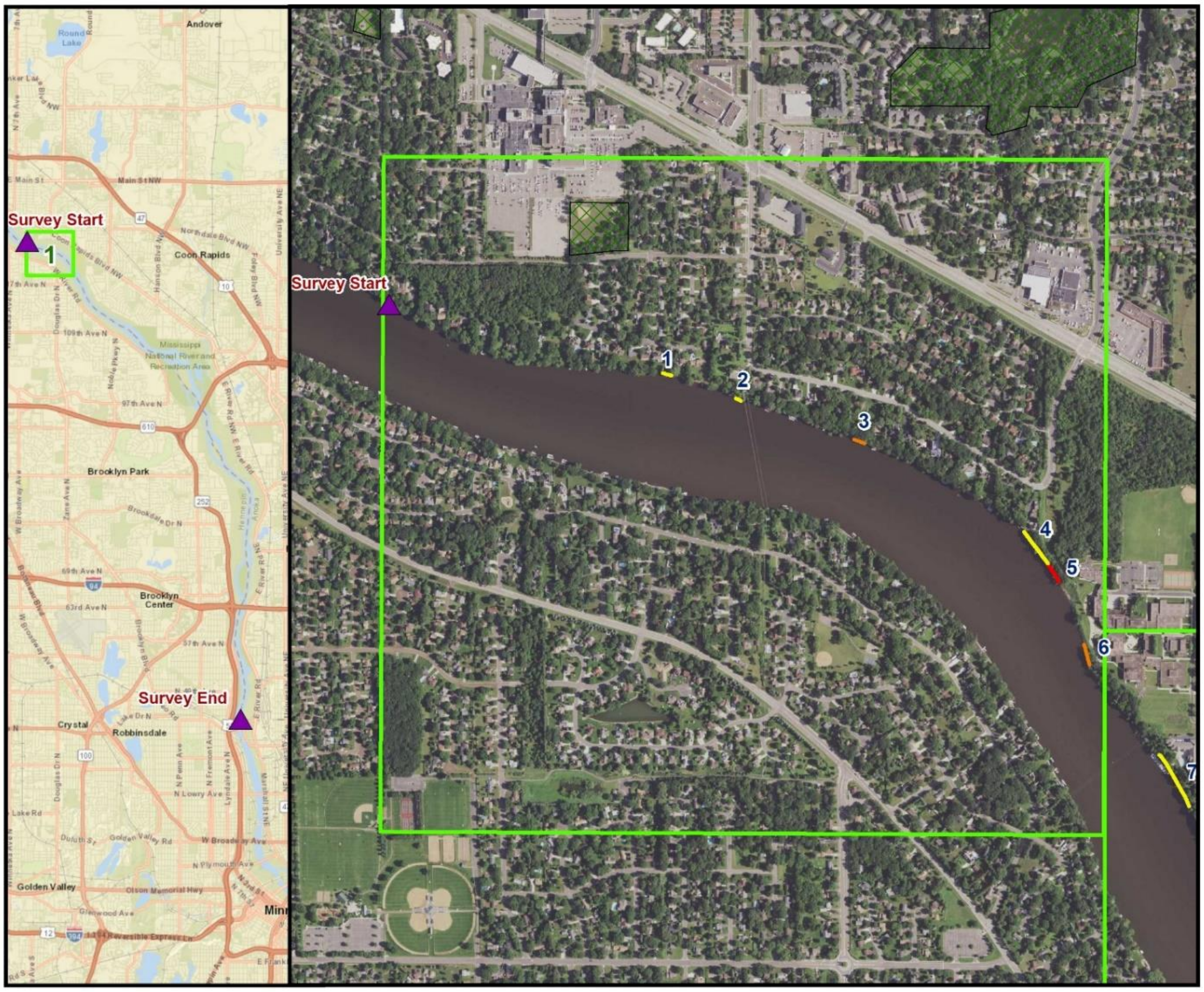
1
Site IDs 7-13
2
Site IDs 14-19
3
Site ID 20
4
Site IDs 21-31
5
Site IDs 32-41
6
Site IDs 42-48
7
COON CREEK
WATERSHED DISTRICT
RICE CREEK
WATERSHED DISTRICT
MISSISSIPPI WMO
Map Areas
0 0.5 1 2 3 4
Miles
N
Erosion Severity
Moderate
Moderate Severe
Severe



Map 1

Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley

0 0.075 0.15 0.3 0.45 0.6 Miles

Erosion Severity
Moderate
Moderate Severe
Severe
City Parks
County Parks
Map Area

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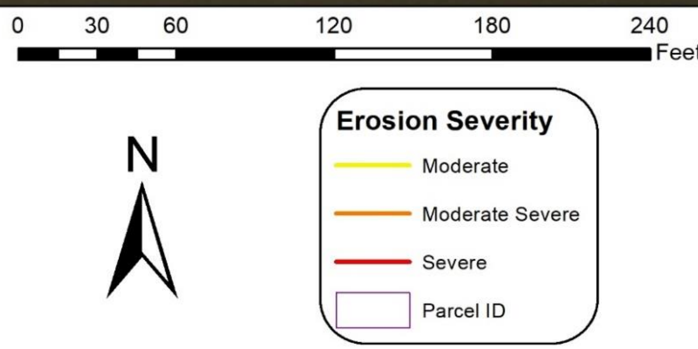
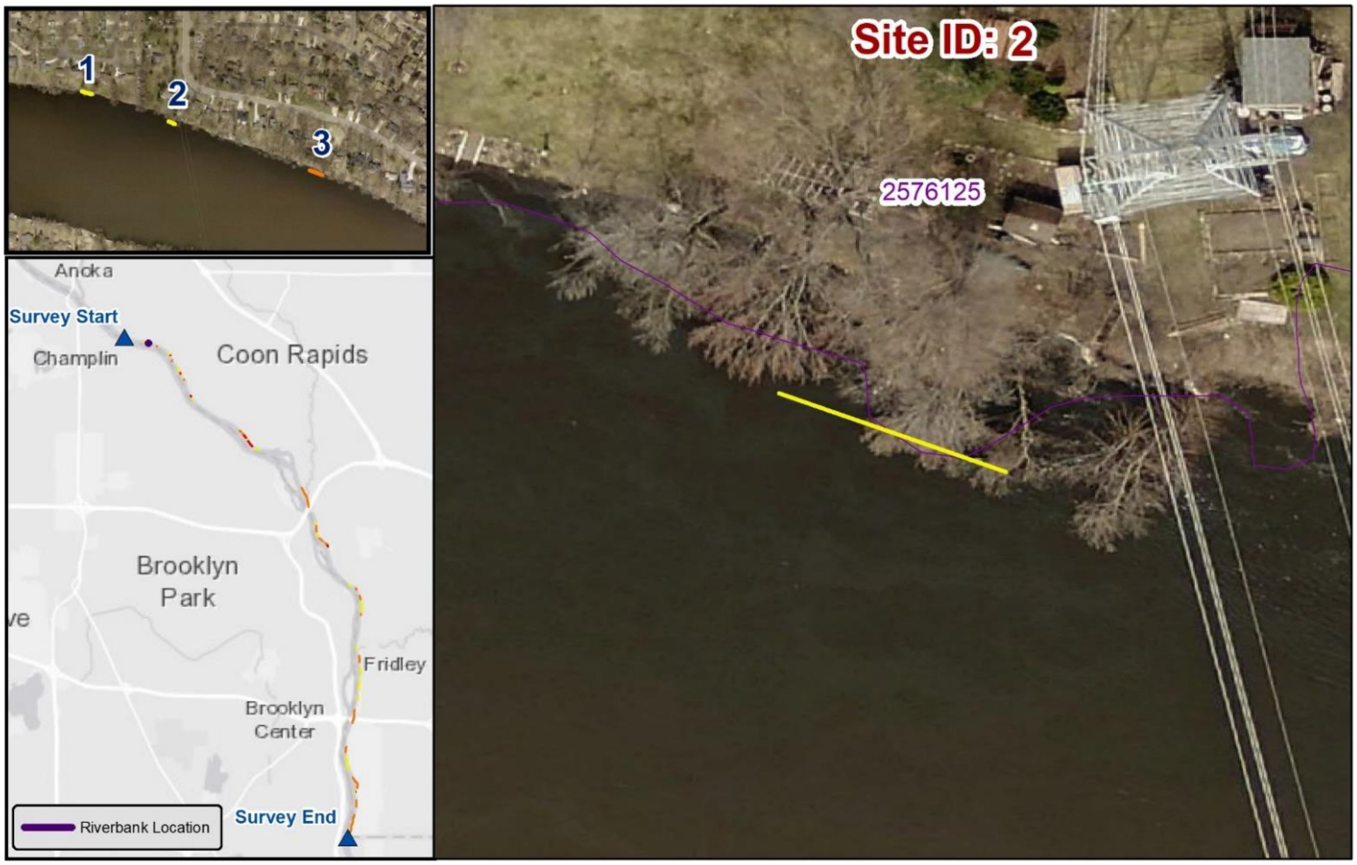
www.AnokaSWCD.org

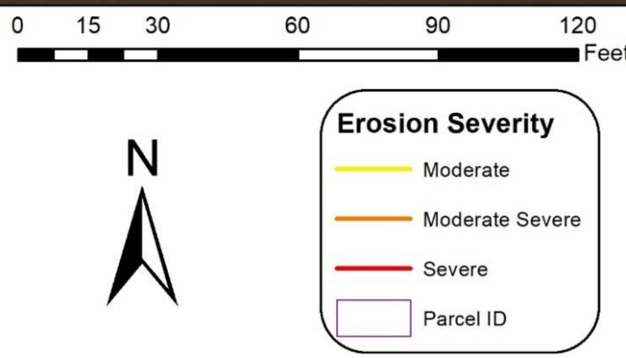
N



Length (ft)	63
Erosion Height (ft)	6
Bluff Height (ft)	6
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	5
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	21,632

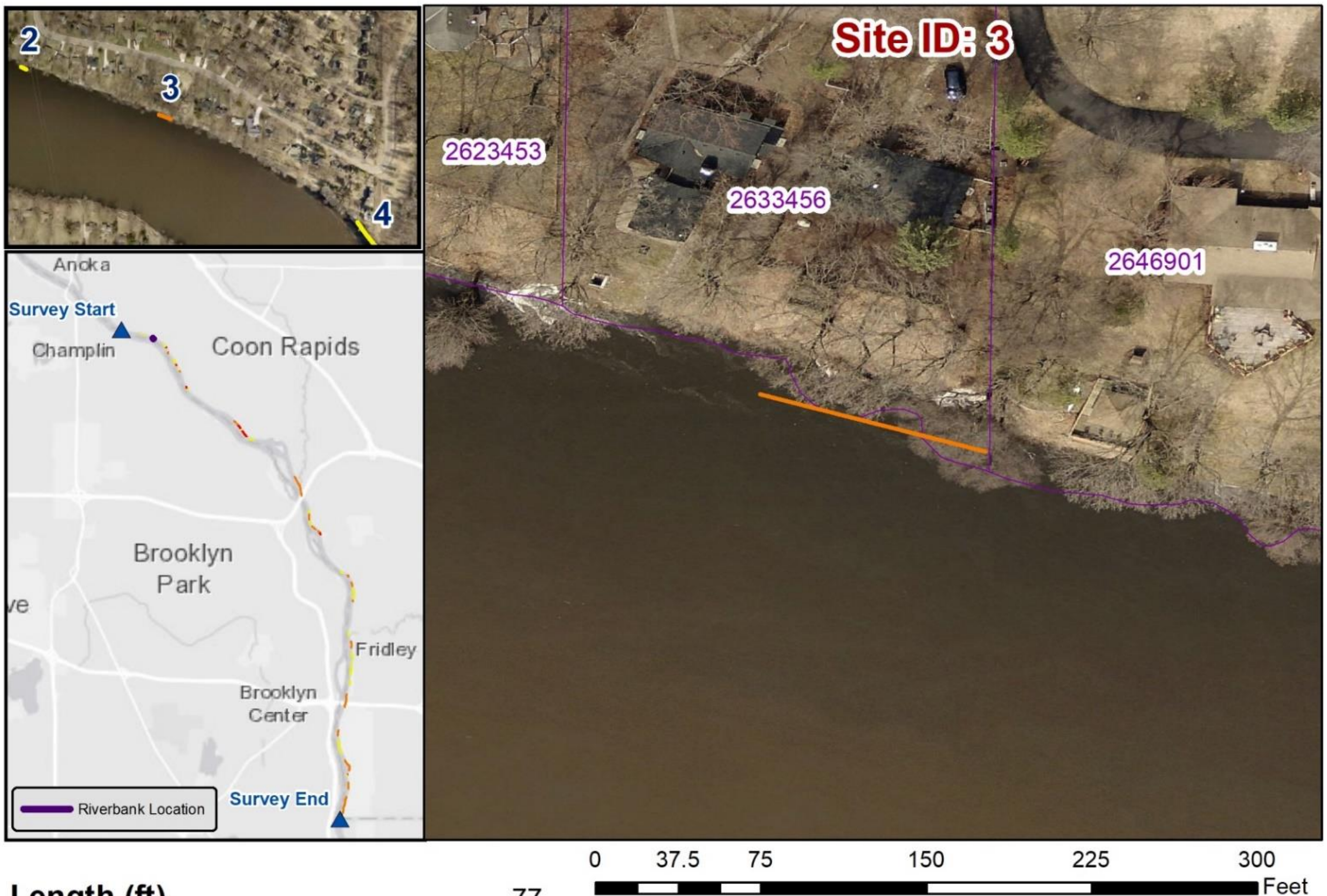
Description: Leaning trees and vegetation overhang an eroding toe. There is a thick vine growing that appears to be negatively impacting the bank.



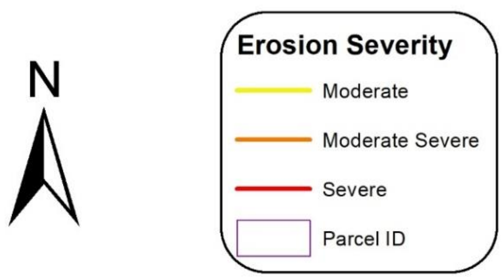


Length (ft)	38
Erosion Height (ft)	8
Bluff Height (ft)	8
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	4
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	19,579

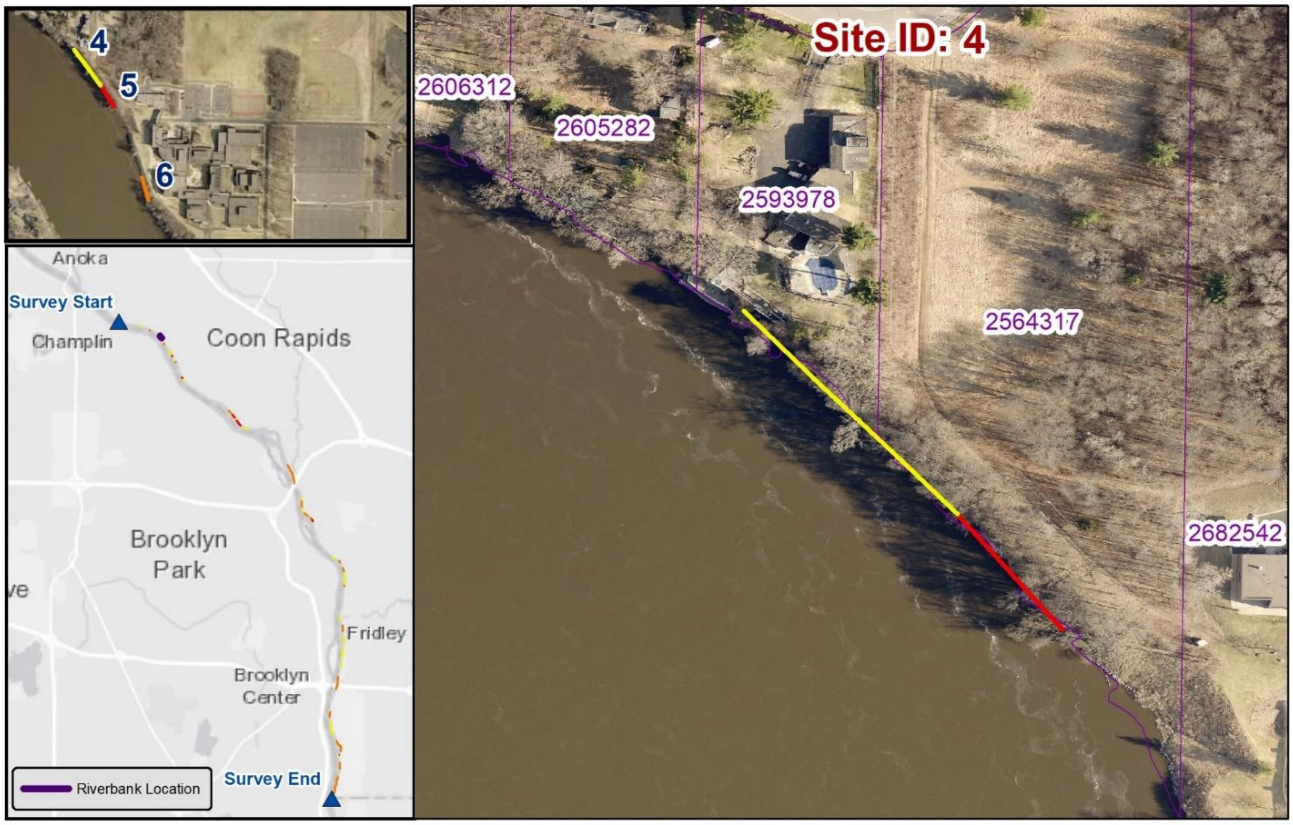
Description: Some slumping, exposed soils, and overhanging trees.

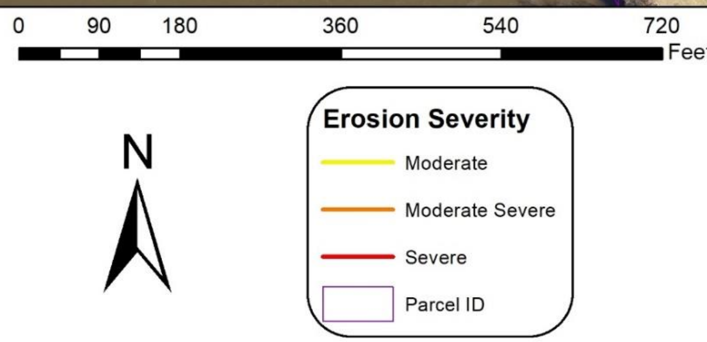


Length (ft)	77
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	29
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	36,757



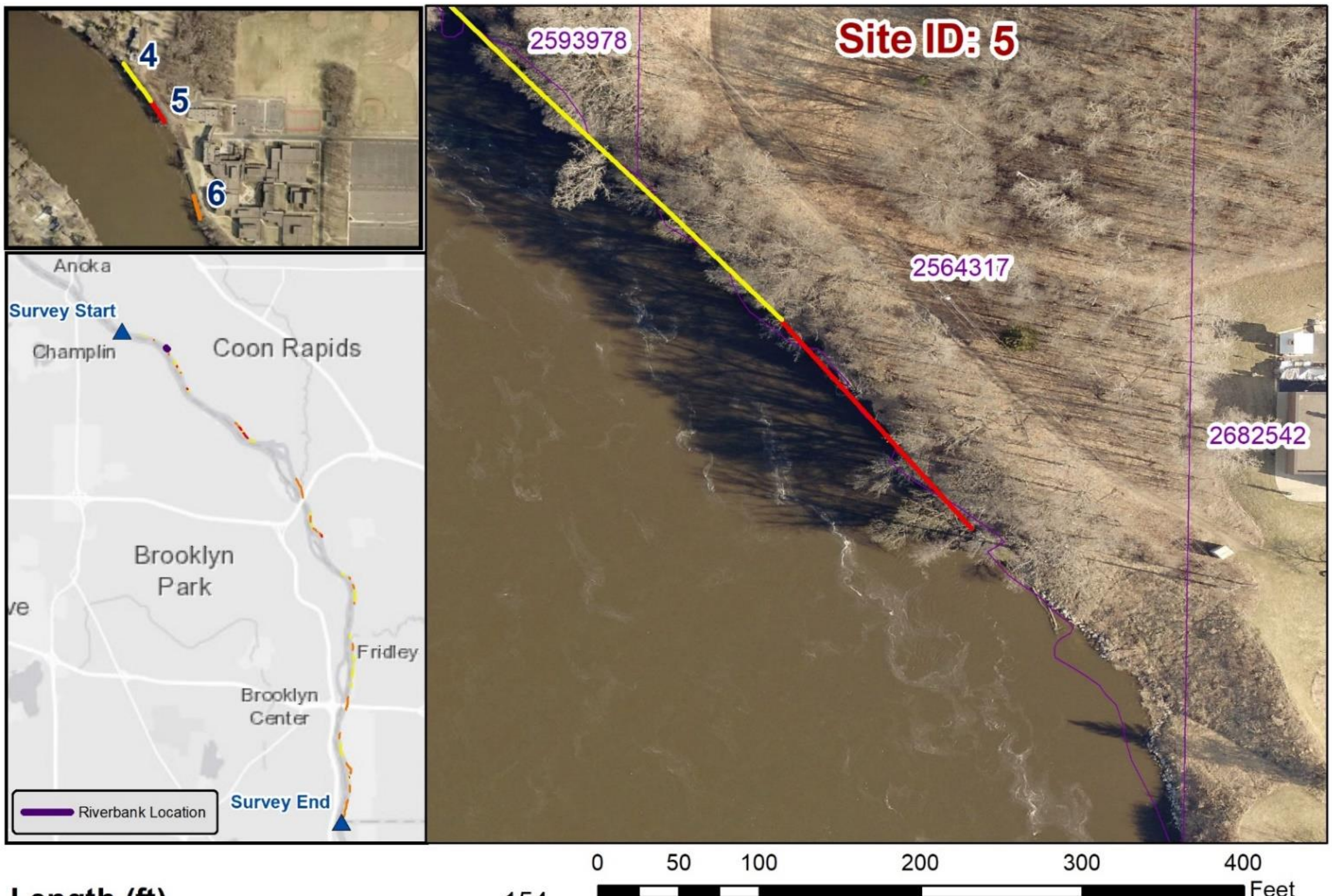
Description: Erosion has exposed root systems and resulted in two trees collapsing into the river; this progression can be seen in the 2012 and 2016 photos.



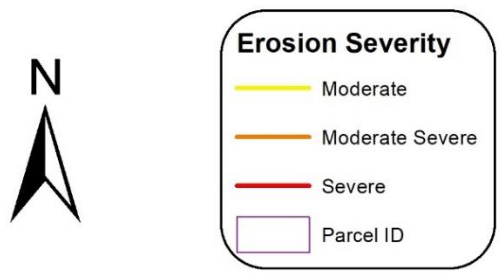


Length (ft)	283
Erosion Height (ft)	4
Bluff Height (ft)	20
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	15
Ownership	Private
Number of Owners	2
Stabilization Approach	Bio-eng.
Cost Estimate	172,218

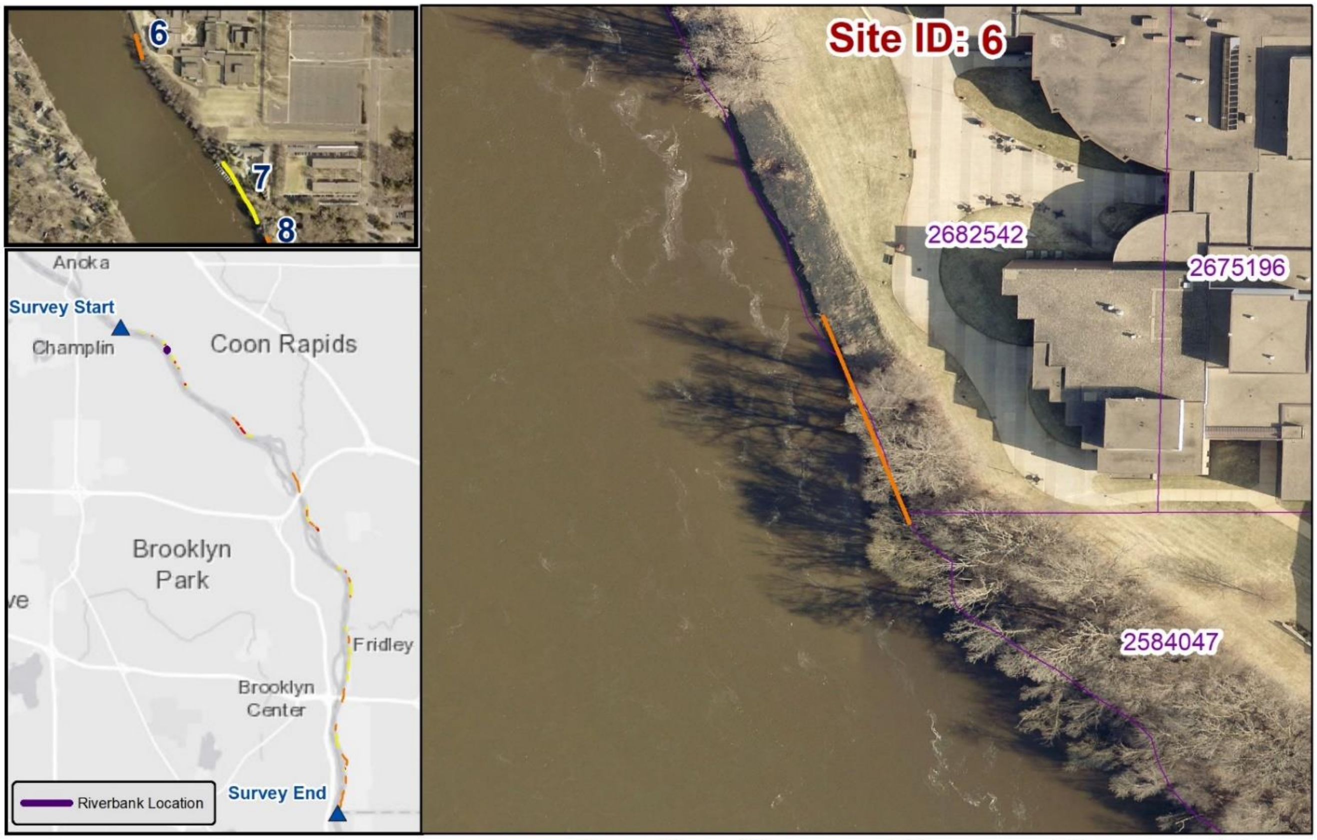
Description: Very steep bank upstream from more severe erosion; still vegetated but with intermittent exposed root systems and minor slumps.

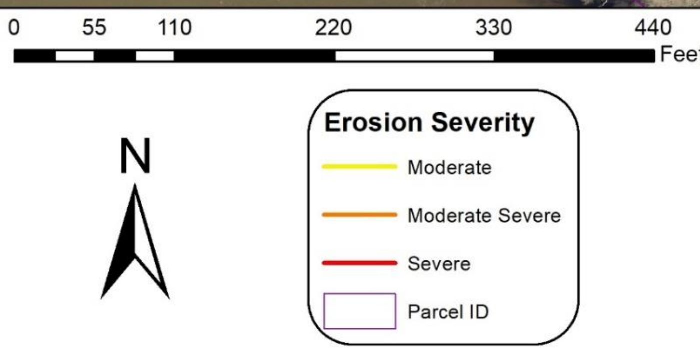


Length (ft)	154
Erosion Height (ft)	24
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	157
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	171,627



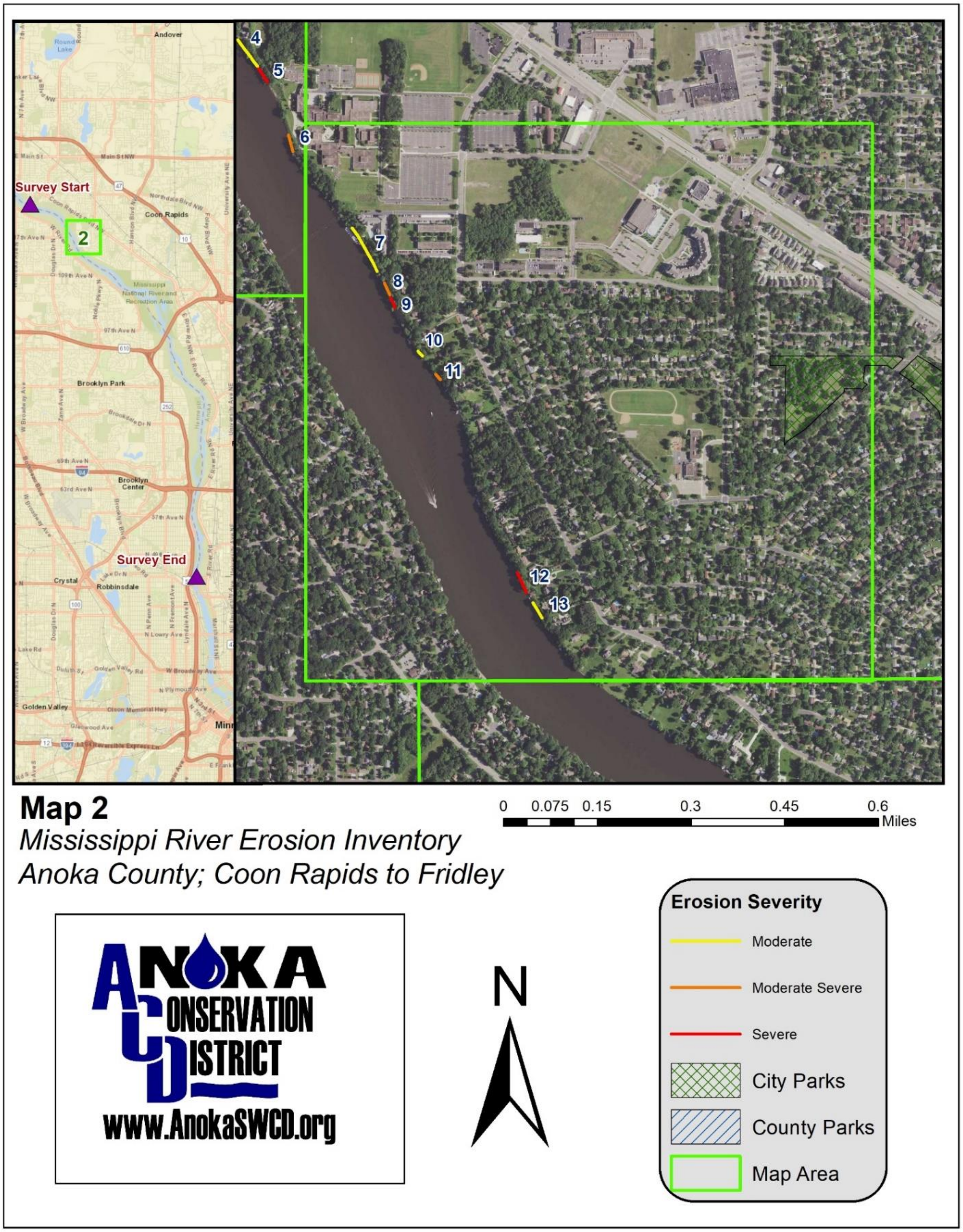
Description: Very large bare cliff on Anoka Ramsey Commmunity College Shoreline.





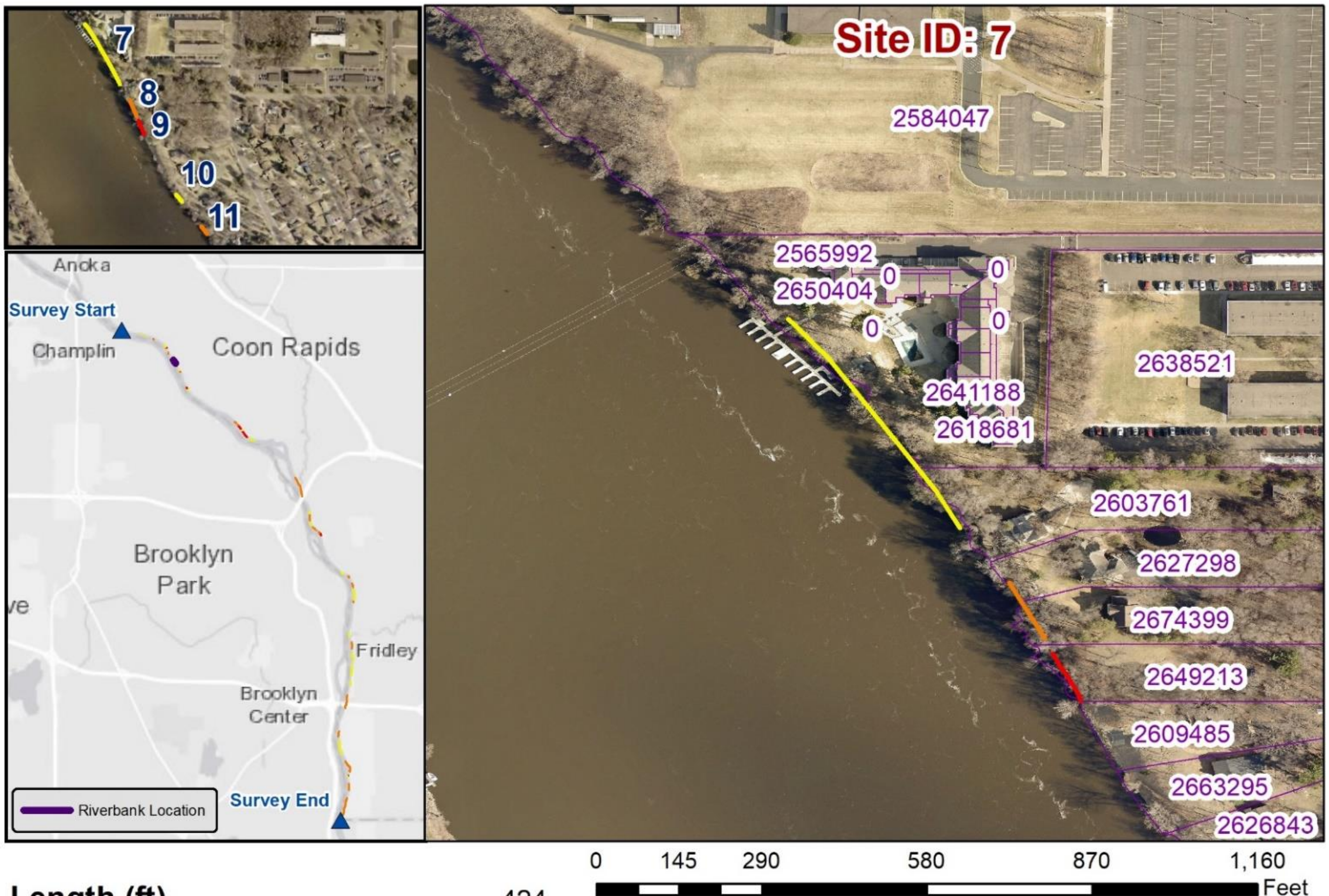
Length (ft)	148
Erosion Height (ft)	4
Bluff Height (ft)	18
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	24
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	85,435

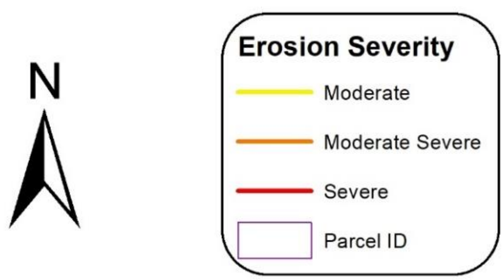
Description: Eroding toe and some exposed roots/ leaning trees throughout.



Map 2

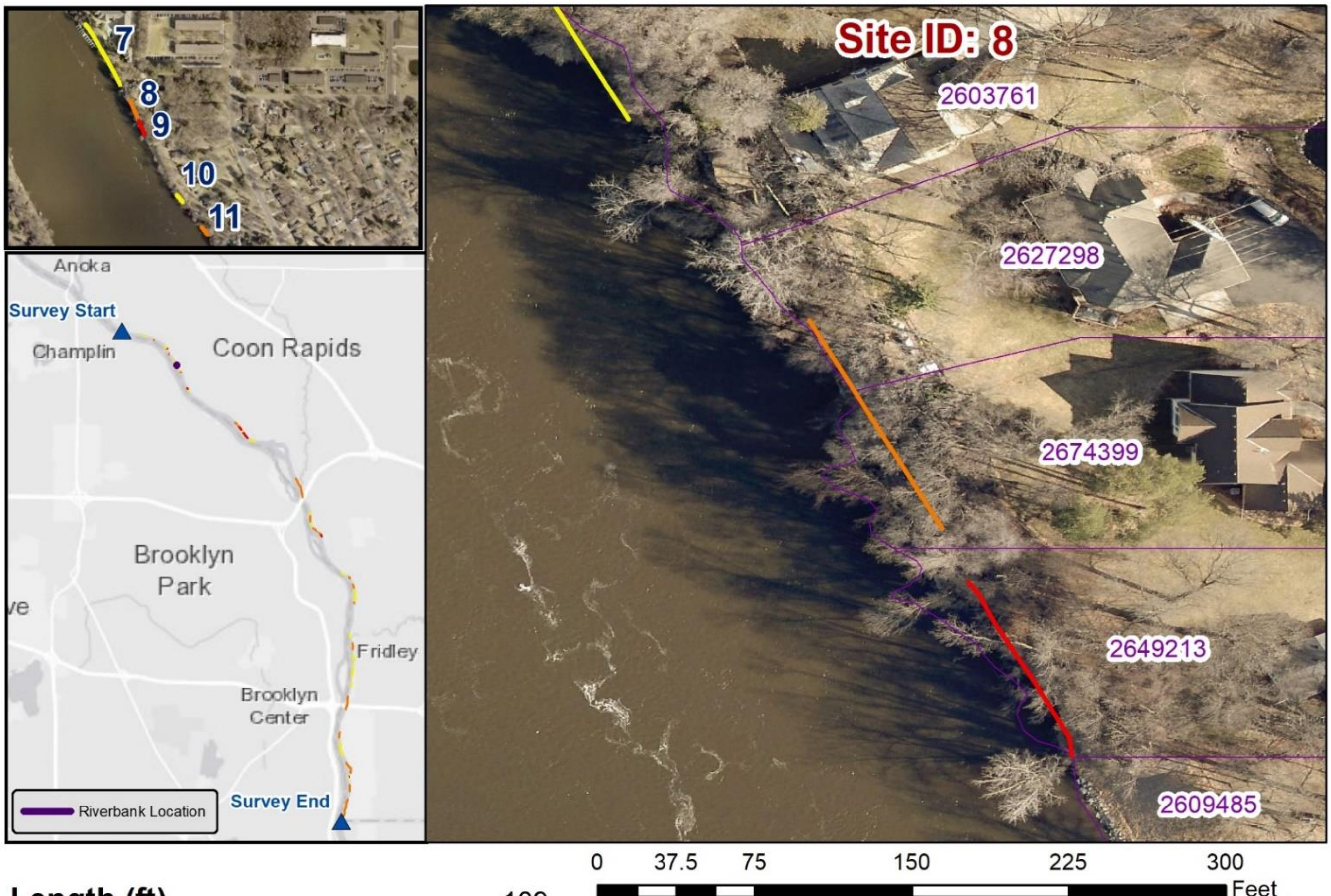
Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley



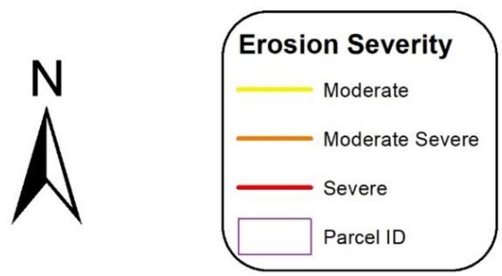


Length (ft)	424
Erosion Height (ft)	6
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	75
Ownership	Private
Number of Owners	2
Stabilization Approach	Bio-eng.
Cost Estimate	301,079

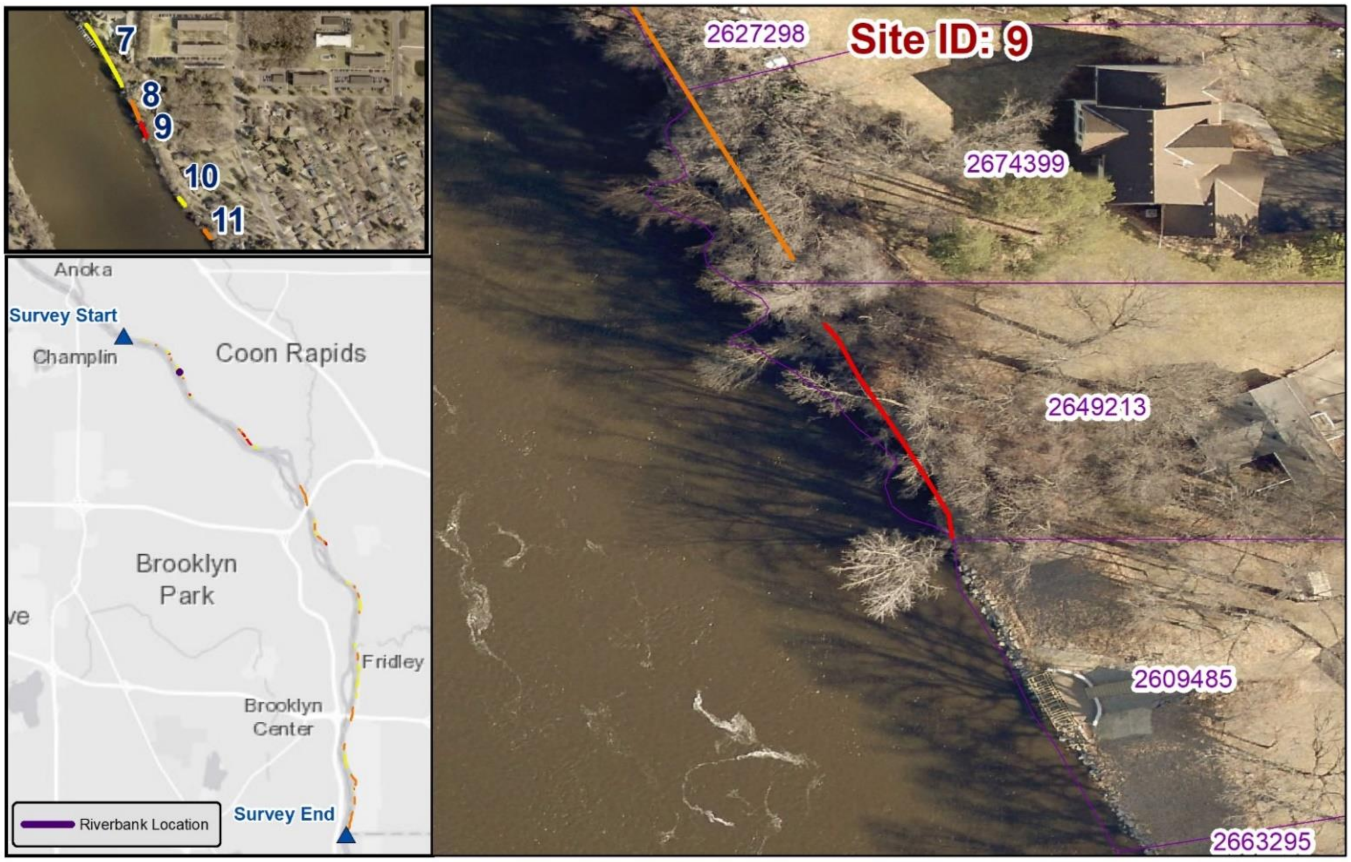
Description: Steep slope with some exposed root systems and soils on lowest 6 feet.

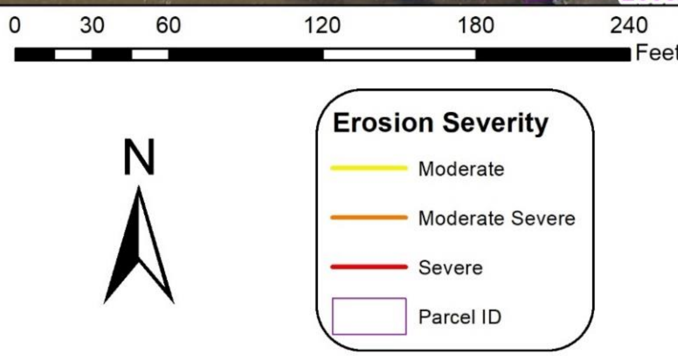


Length (ft)	109
Erosion Height (ft)	20
Bluff Height (ft)	20
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	66
Ownership	Private
Number of Owners	2
Stabilization Approach	Armor
Cost Estimate	116,123



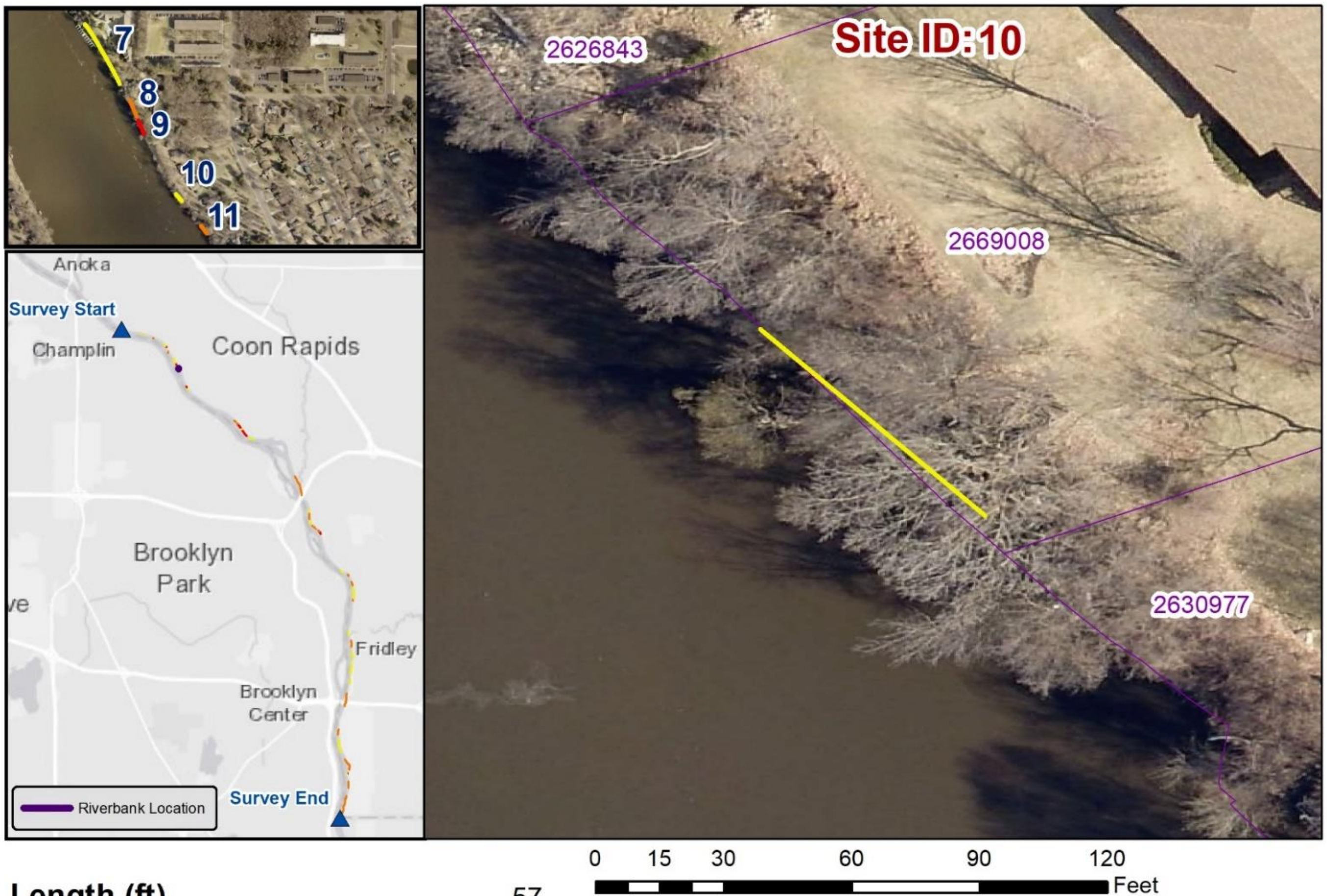
Description: Steep slope with erosion similar to upstream stretch but more severe.



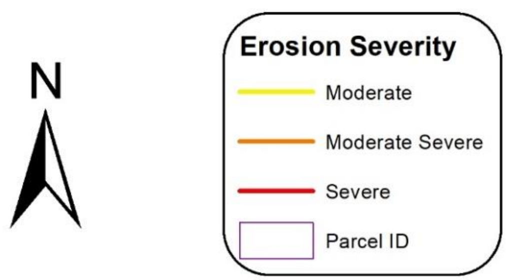


Length (ft)	91
Erosion Height (ft)	26
Bluff Height (ft)	26
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	101
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	118,400

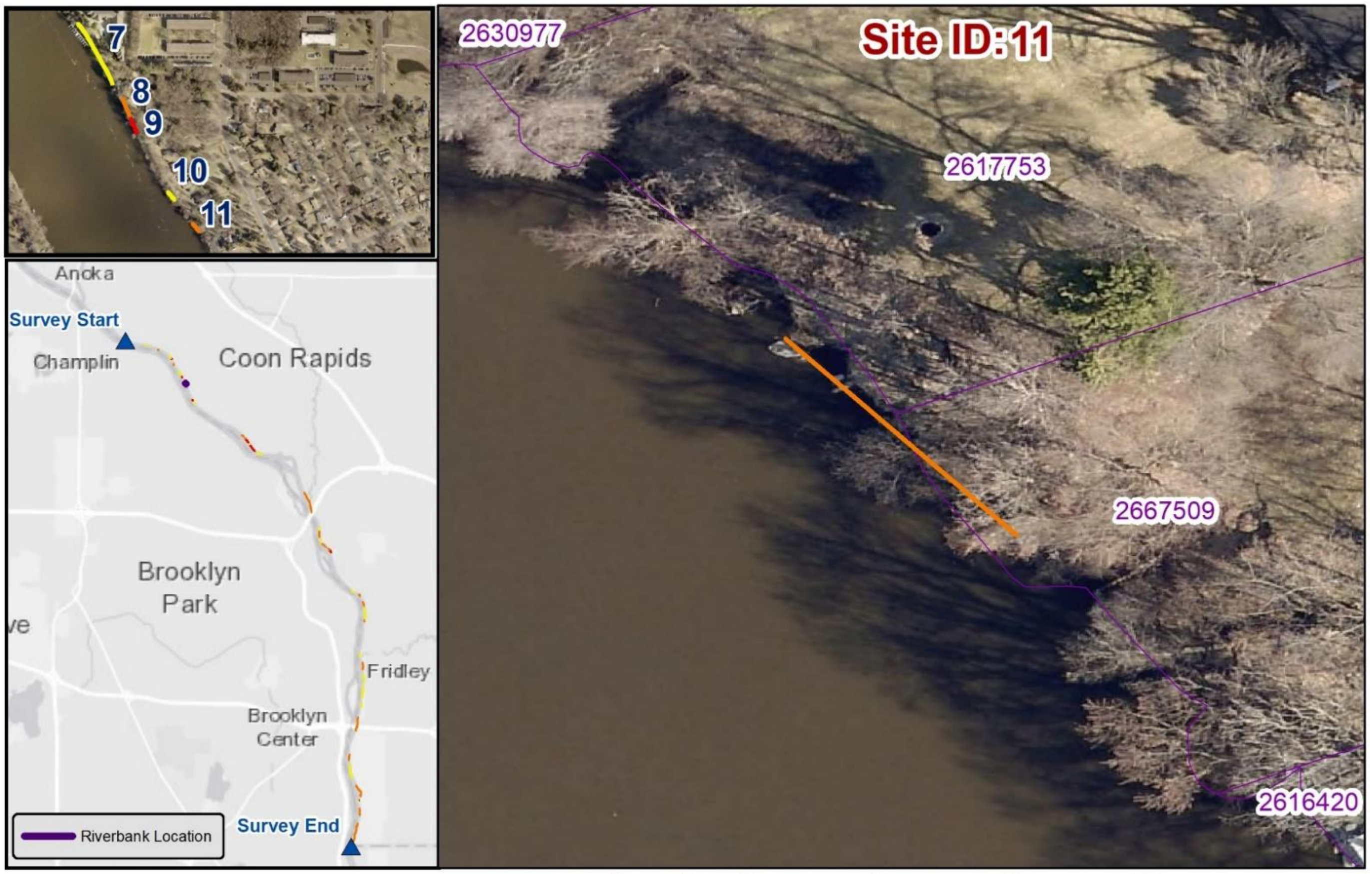
Description: Very steep eroding cliff north of recent "Stem" project.

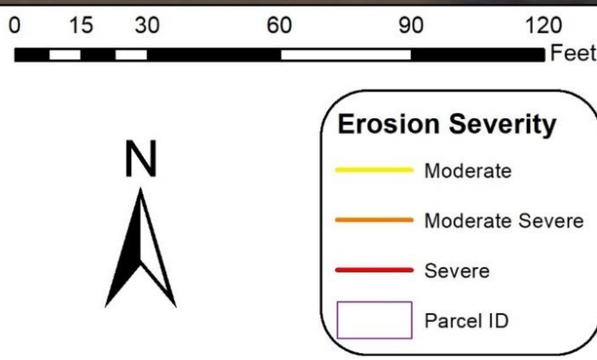


Length (ft)	57
Erosion Height (ft)	4
Bluff Height (ft)	22
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	10
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	46,404



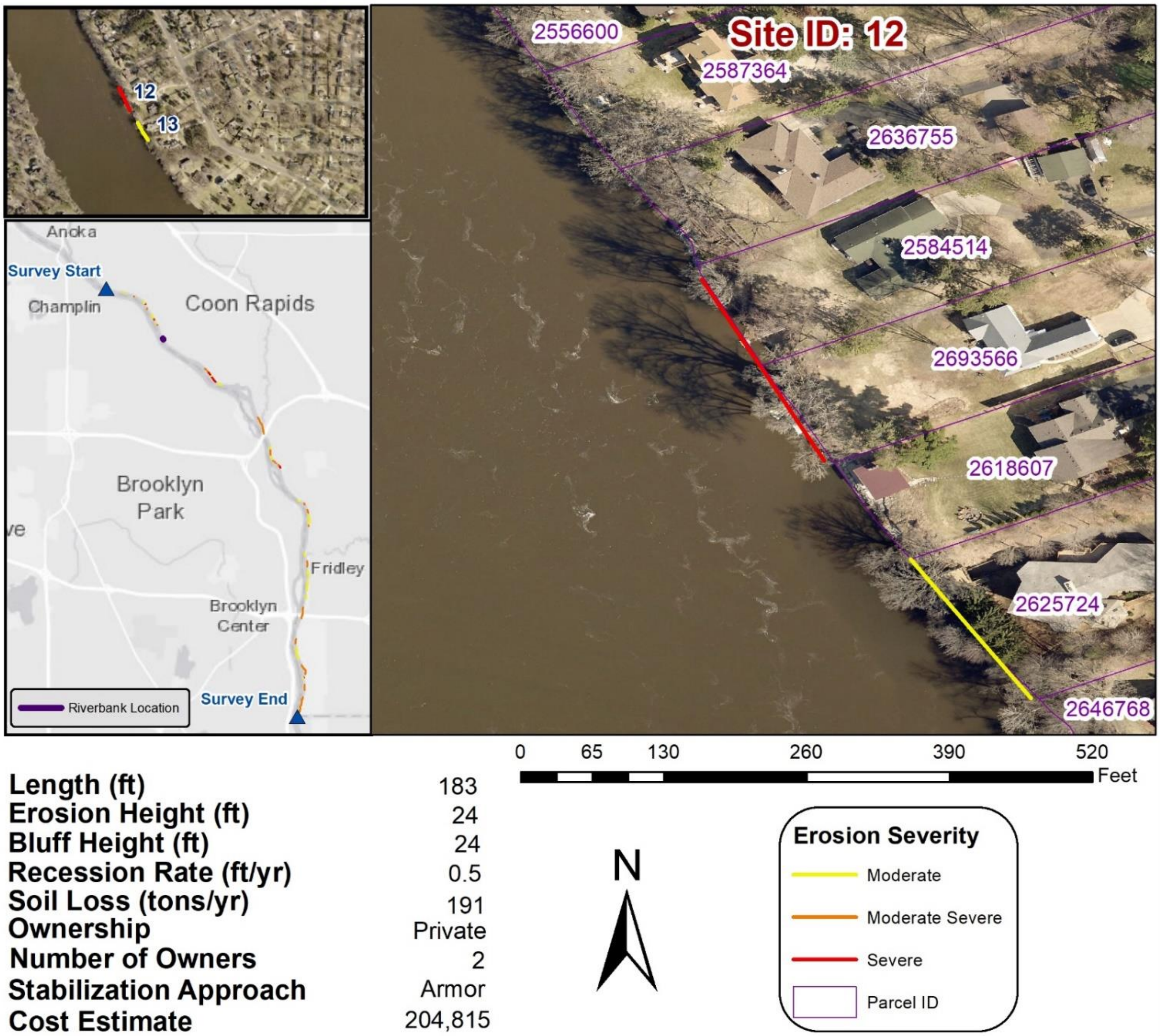
Description: Bank is difficult to see due to vegetation, but there are some leaning trees and an eroded toe.





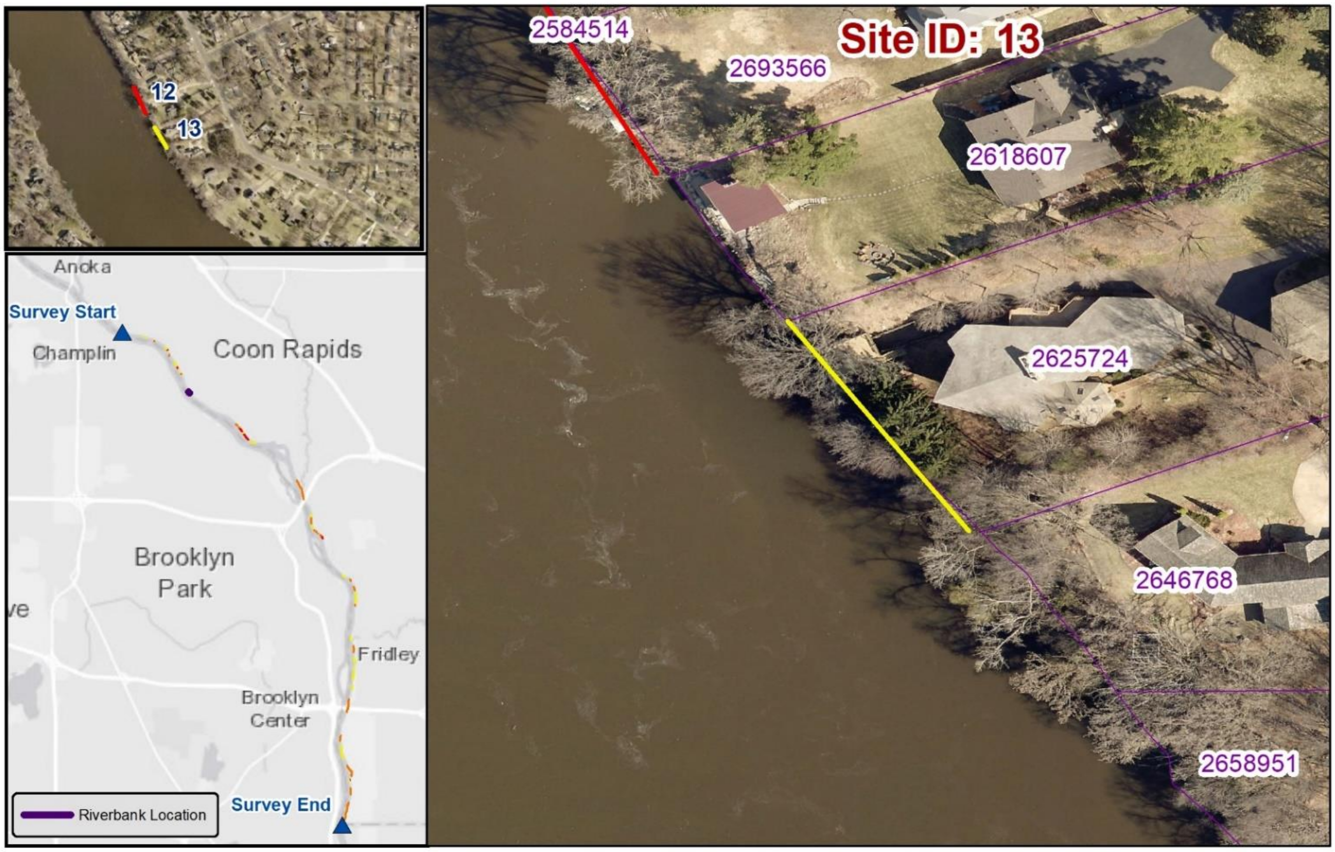
Length (ft)	58
Erosion Height (ft)	18
Bluff Height (ft)	18
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	30
Ownership	Private
Number of Owners	2
Stabilization Approach	Armor
Cost Estimate	70,780

Description: Short stretch containing a severe gully that leads to slumping and a cliff near the bottom. May be influenced by overland flow, or large boulder creating concentrated flow.

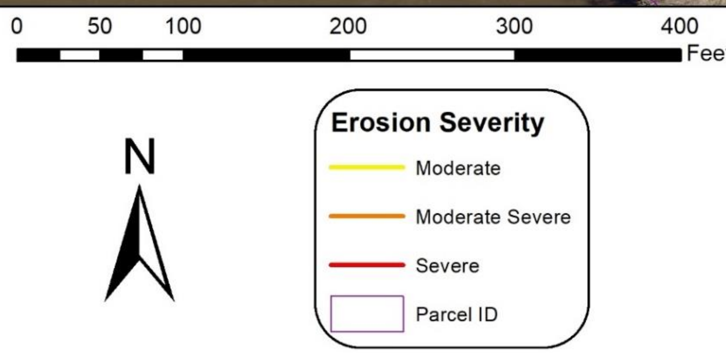


Length (ft)	183
Erosion Height (ft)	24
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	191
Ownership	Private
Number of Owners	2
Stabilization Approach	Armor
Cost Estimate	204,815

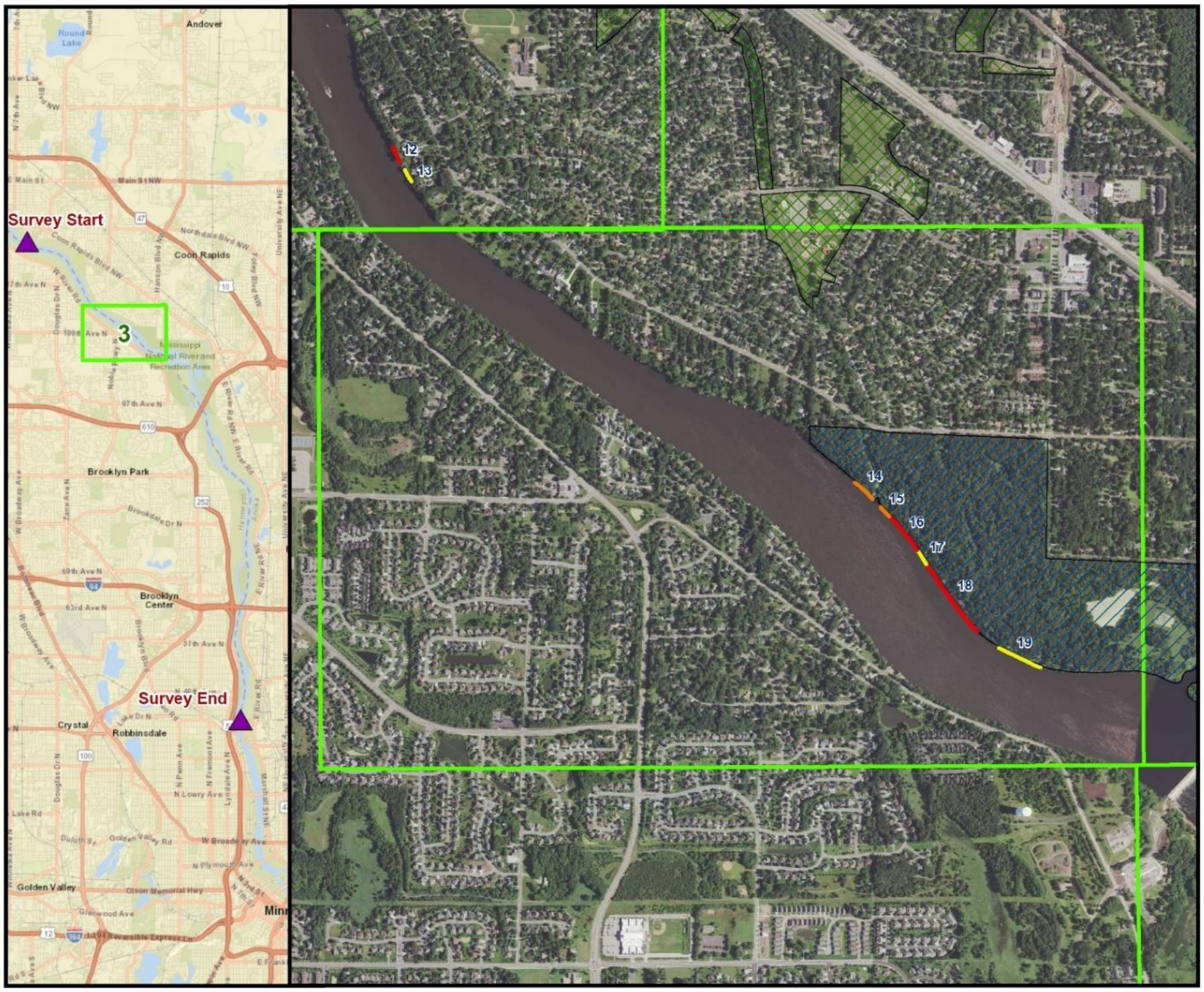
Description: Short but severe cliff that caused the collapse of a starcase leading to the river. Bank upstream of the cliff still contains vegetation but is equally steep and exhibits an eroded toe



Length (ft)	148
Erosion Height (ft)	10
Bluff Height (ft)	10
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	23
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	52,550



Description: Steep slope but well vegetated. Some moderate toe erosion has led to exposed roots.



Map 3

Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley

0 0.125 0.25 0.5 0.75 1 Miles

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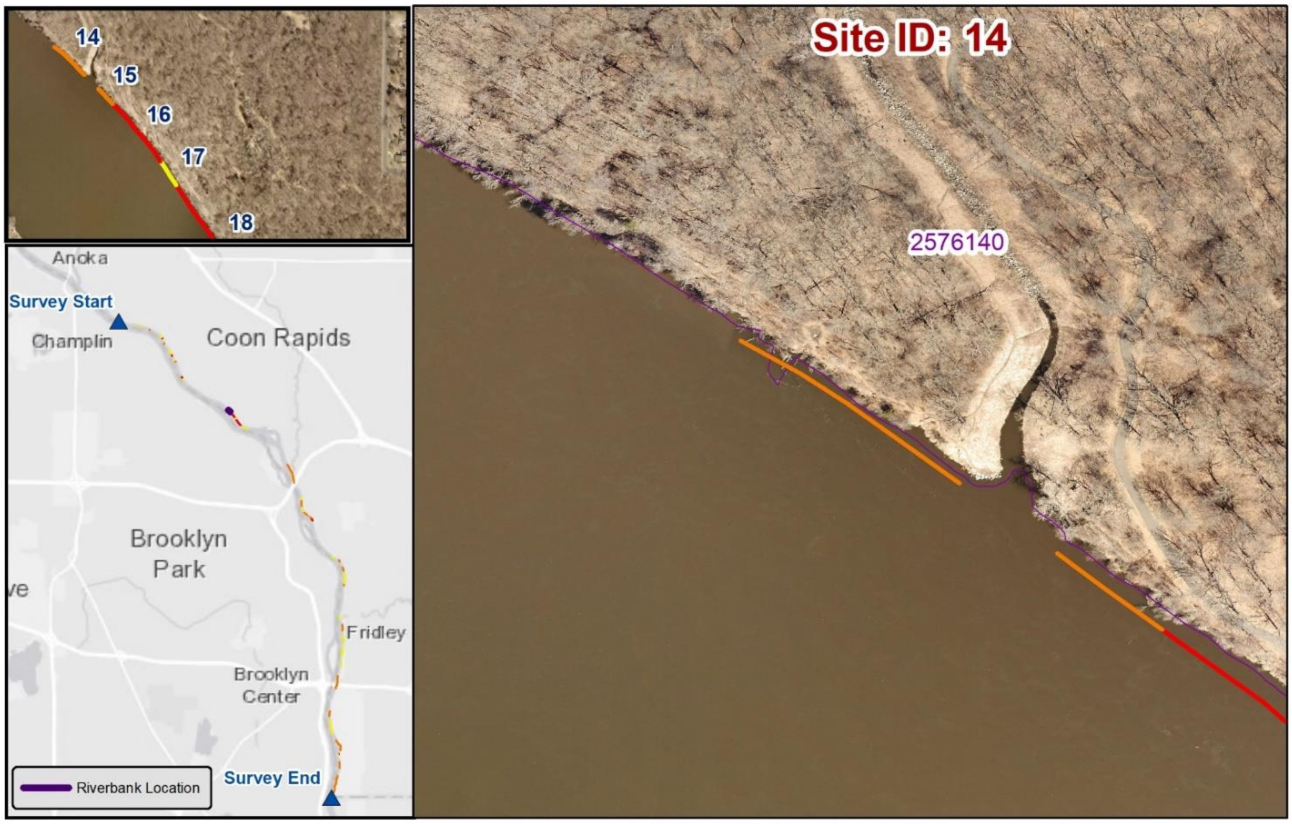
N

Erosion Severity

- Moderate
- Moderate Severe
- Severe
- City Parks
- County Parks
- Map Area



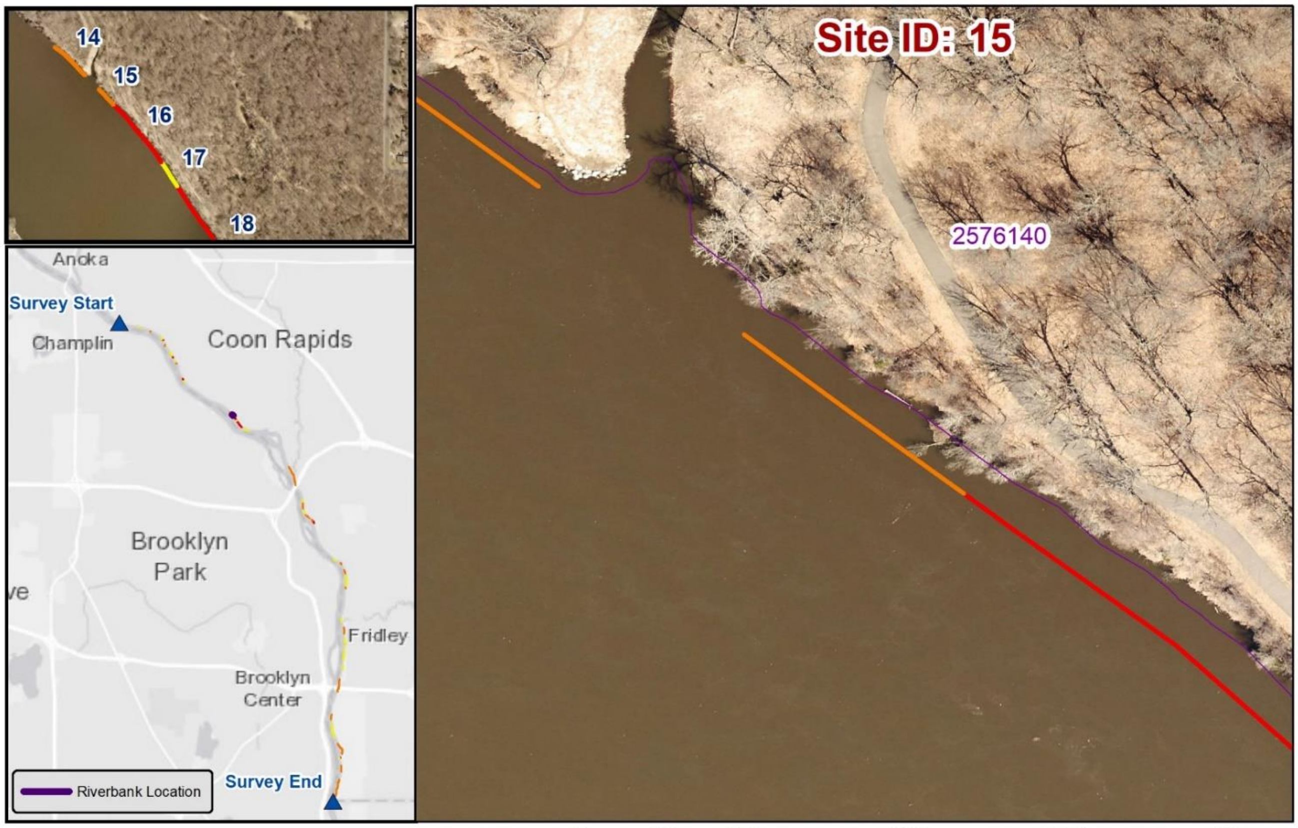
0 105 210 420 630 840 Feet

N

Erosion Severity
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Length (ft)	271
Erosion Height (ft)	16
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	121
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	197,514

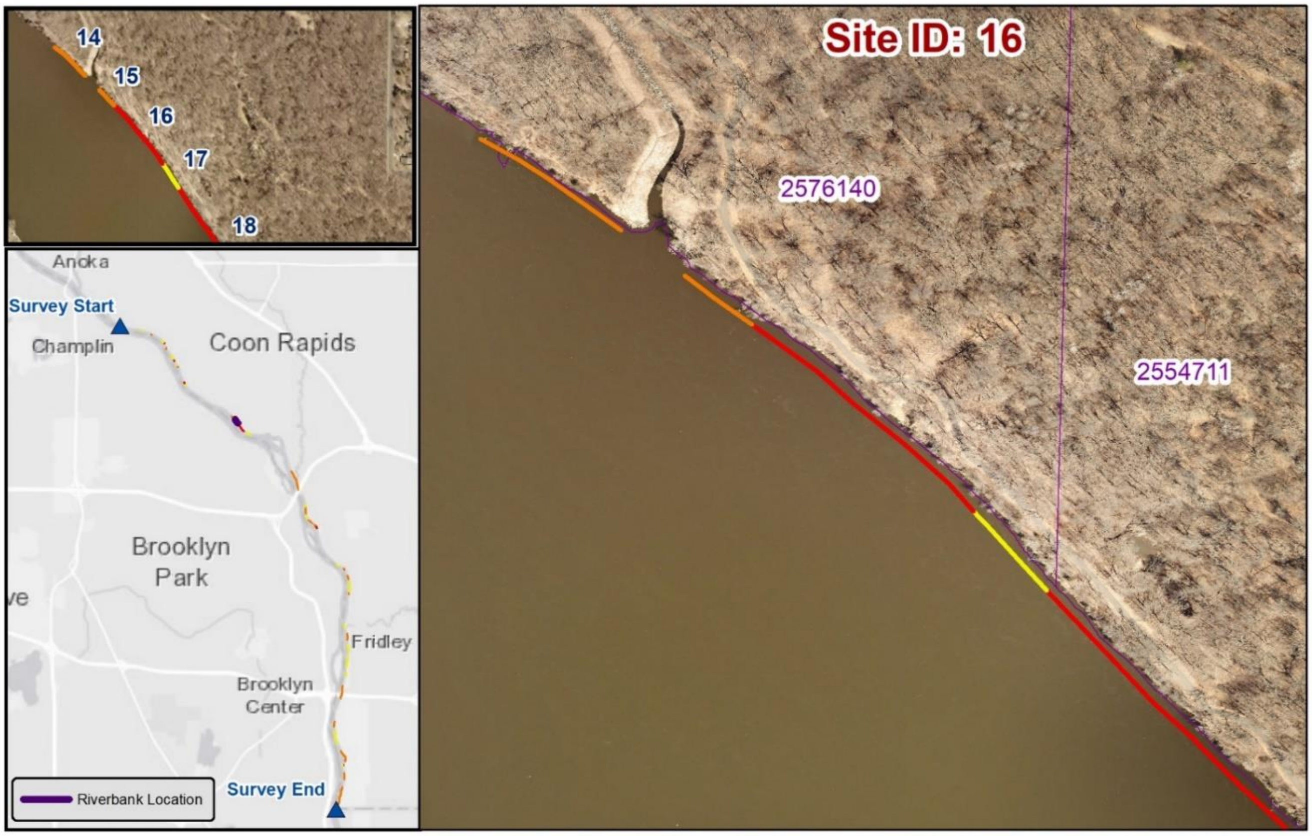
Description: Moderate severe erosion at the outlet of ditch system. Similar erosion is occuring on the other side of the ditch outlet. At Coon Rapdids Dam park.



Length (ft)	137
Erosion Height (ft)	16
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	63
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	111,631

Erosion Severity
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Description: Erosion has caused slumping, exposing soils and creating vegetative overhang. Located at Coon Rapids Dam park.



0 165 330 660 990 1,320 Feet

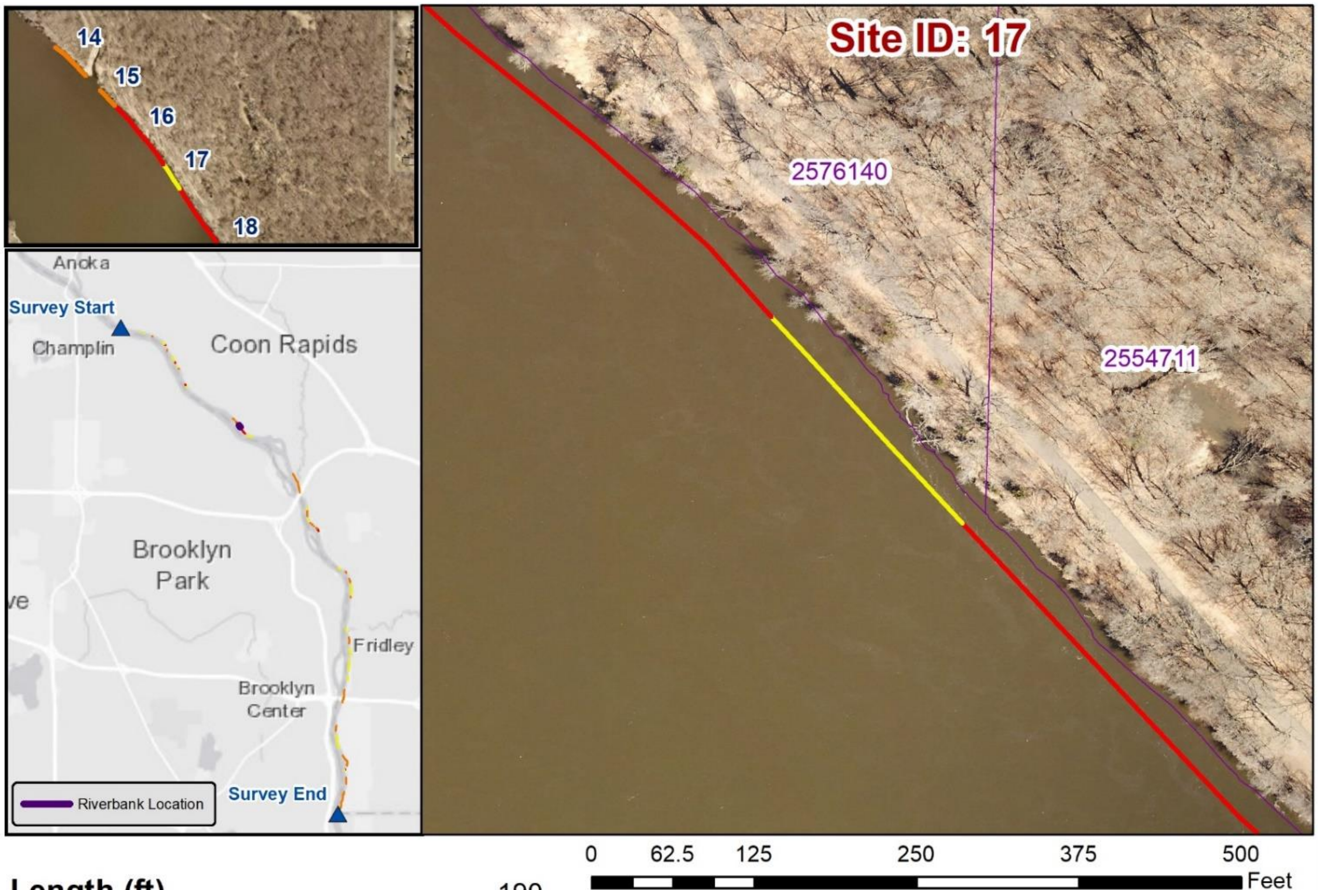
N

Erosion Severity

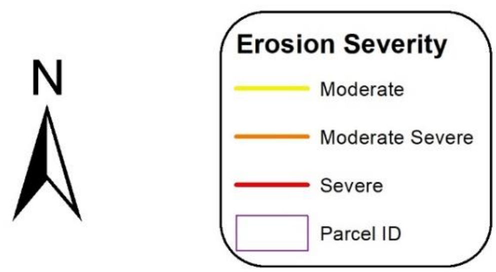
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Length (ft)	488
Erosion Height (ft)	14
Bluff Height (ft)	14
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	393
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	297,377

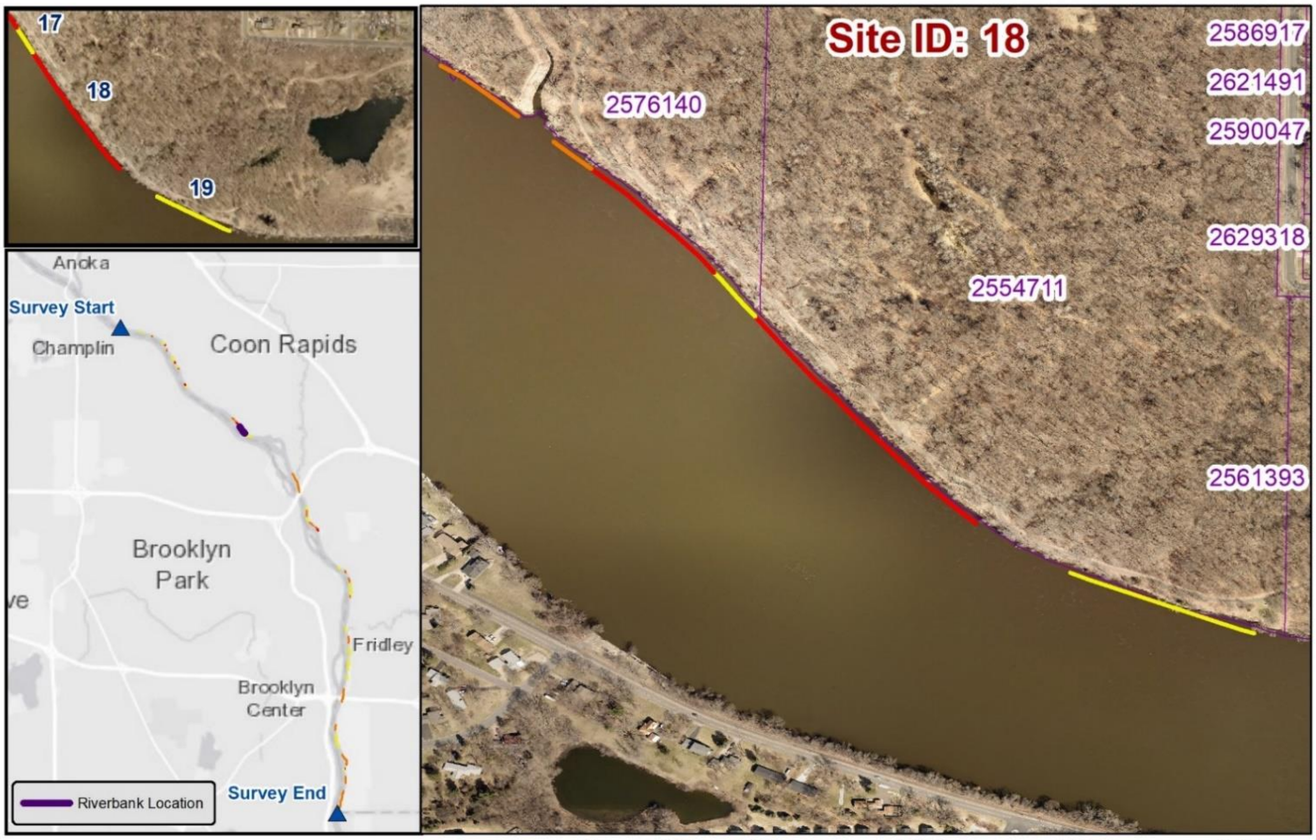
Description: Severe erosion has created cliffs along this stretch in Coon Rapids Dam regional park. Many fallen trees and exposed roots are present.

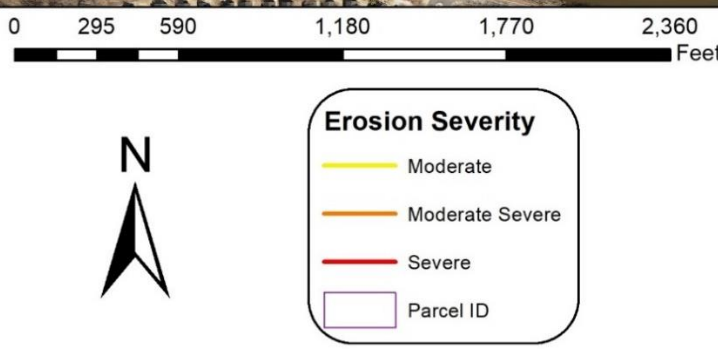


Length (ft)	190
Erosion Height (ft)	18
Bluff Height (ft)	18
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	33
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	160,609



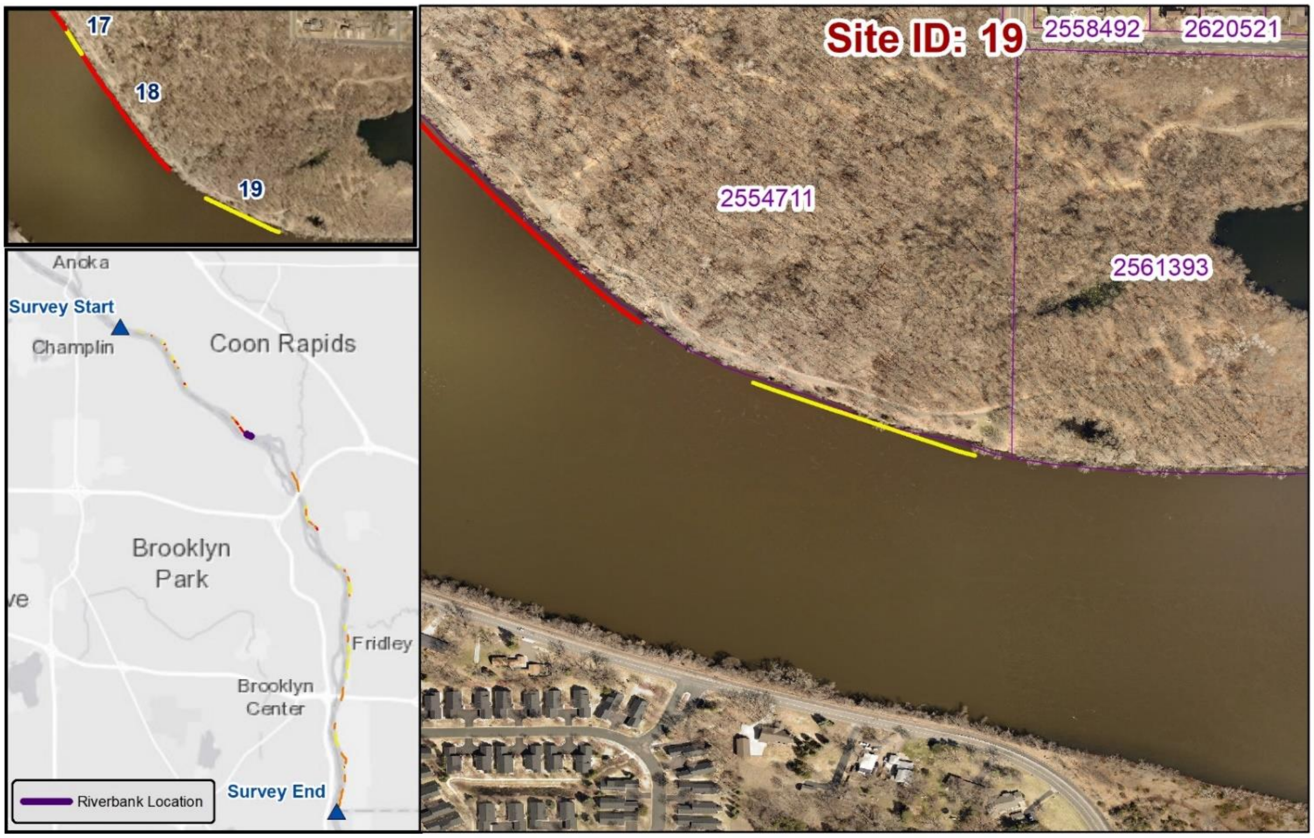
Description: Bank in early stages of erosion with some exposed soils; will likely erode to the severity of the banks up/ down stream of it over time. Located at Coon Rapids Dam Regional Park.

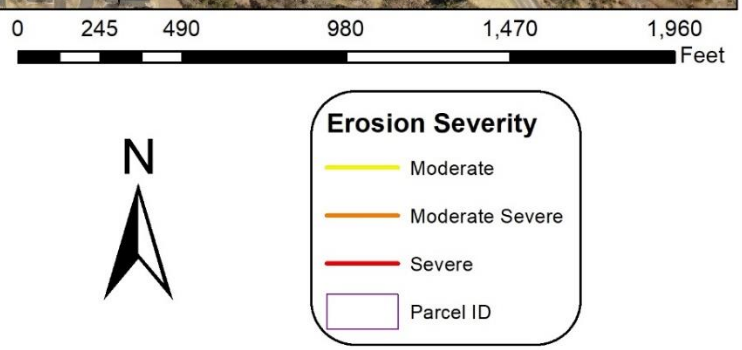




Length (ft)	935
Erosion Height (ft)	16
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	694
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	622,574

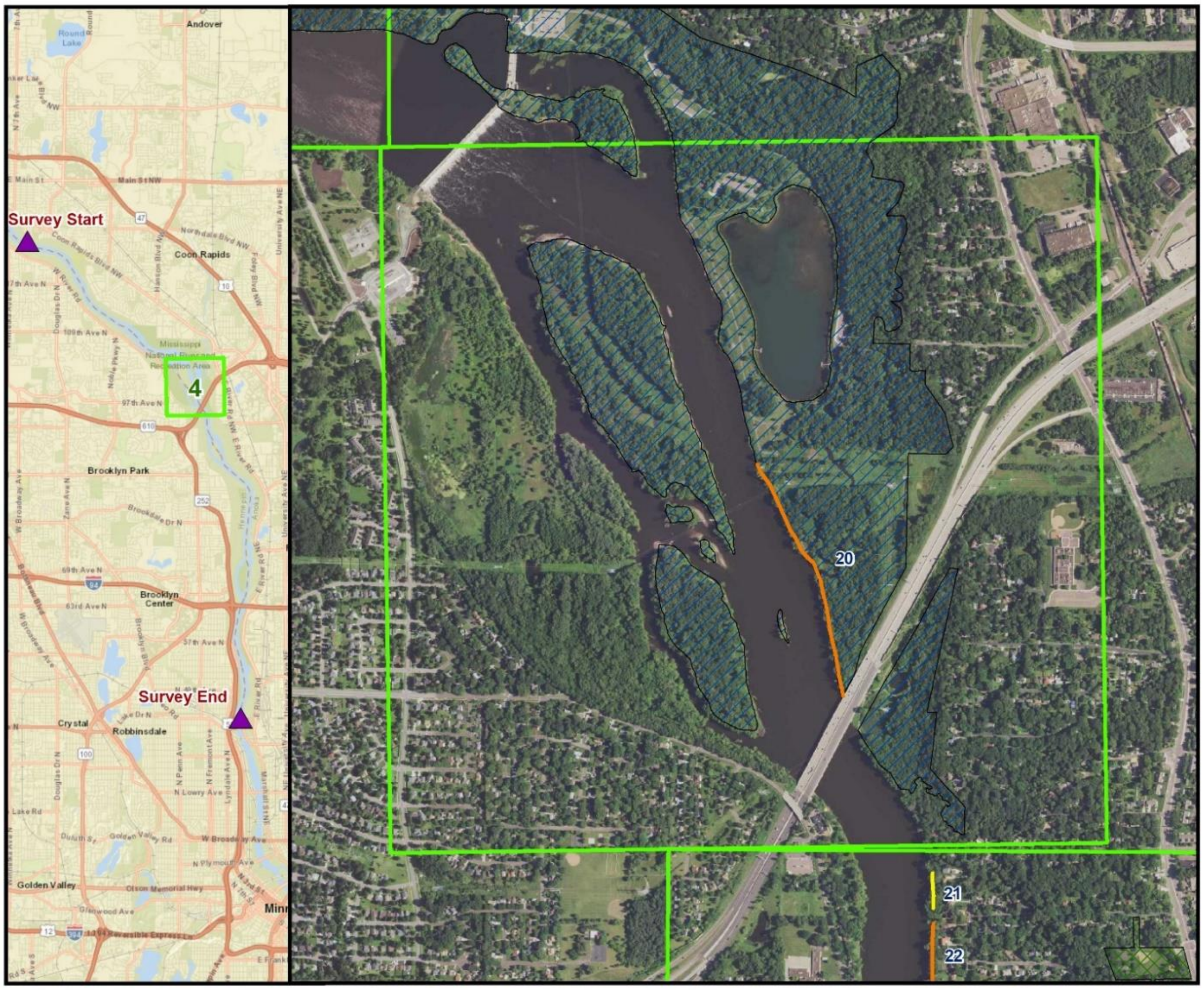
Description: Very severe erosion resulting in cliffs and fallen trees along the entire stretch. Encompasses nearly the entire upstream portion of the Coon Rapids Dam park.





Length (ft)	517
Erosion Height (ft)	4
Bluff Height (ft)	10
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	35
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	155,877

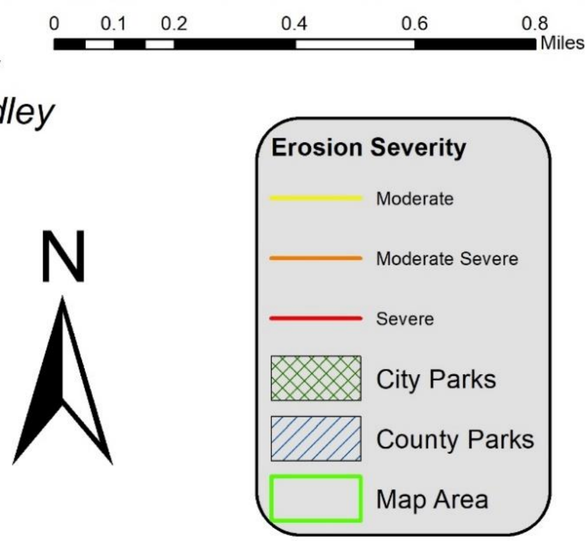
Description: Moderate toe erosion has exposed some roots and caused minor slumping/ leaning trees.



Map 4

Mississippi River Erosion Inventory

Anoka County; Coon Rapids to Fridley



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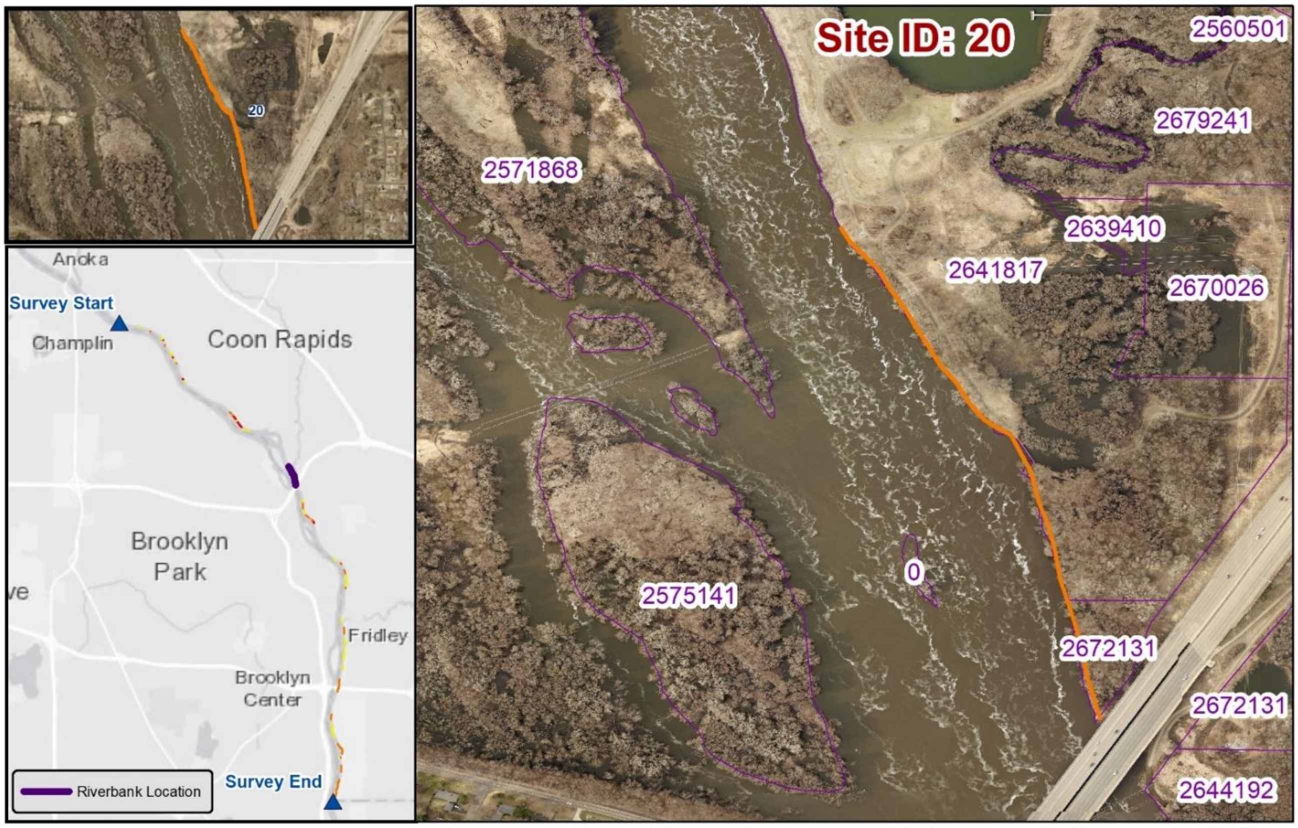
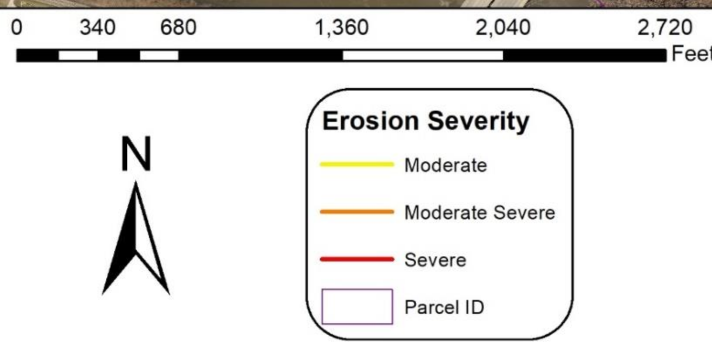
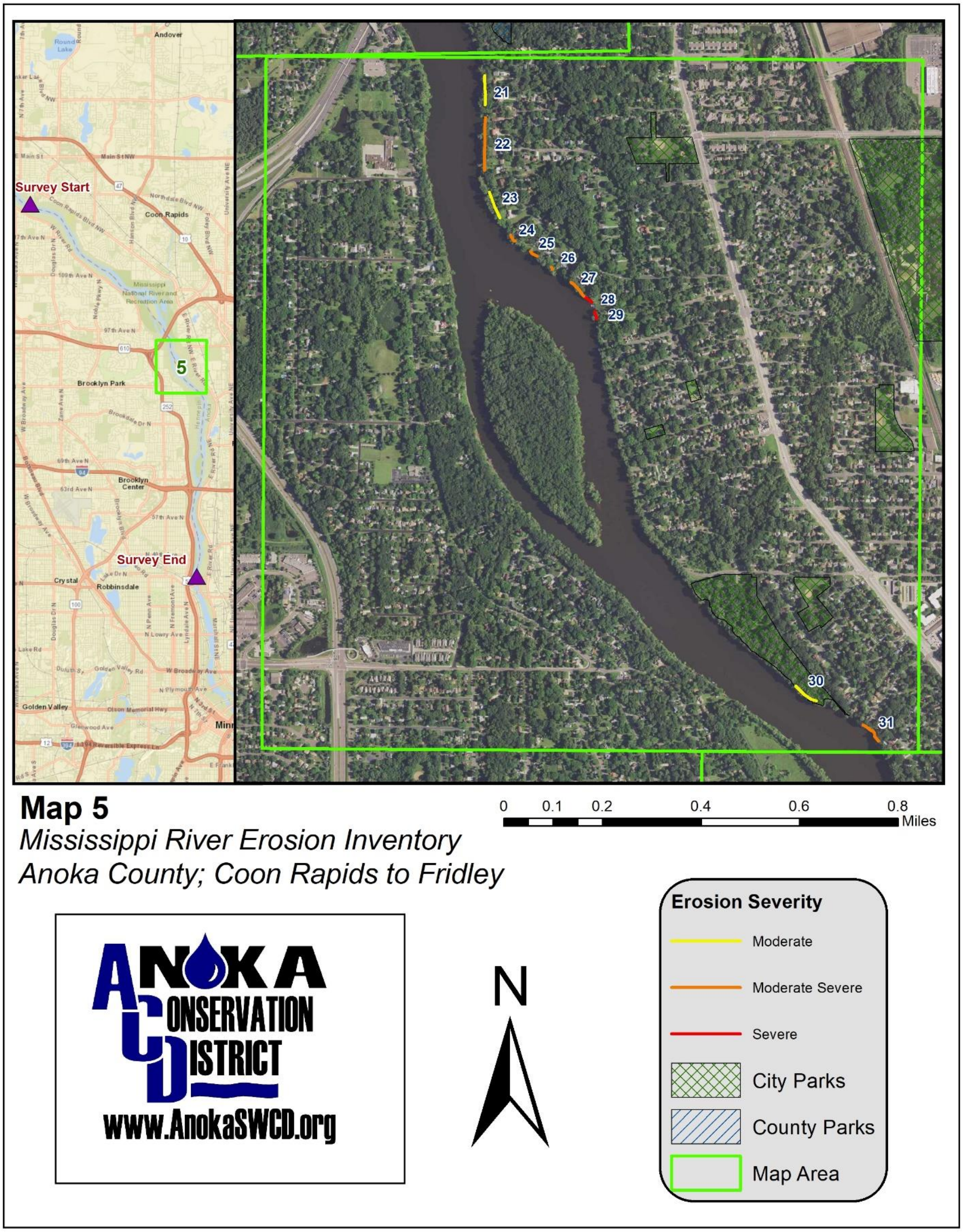


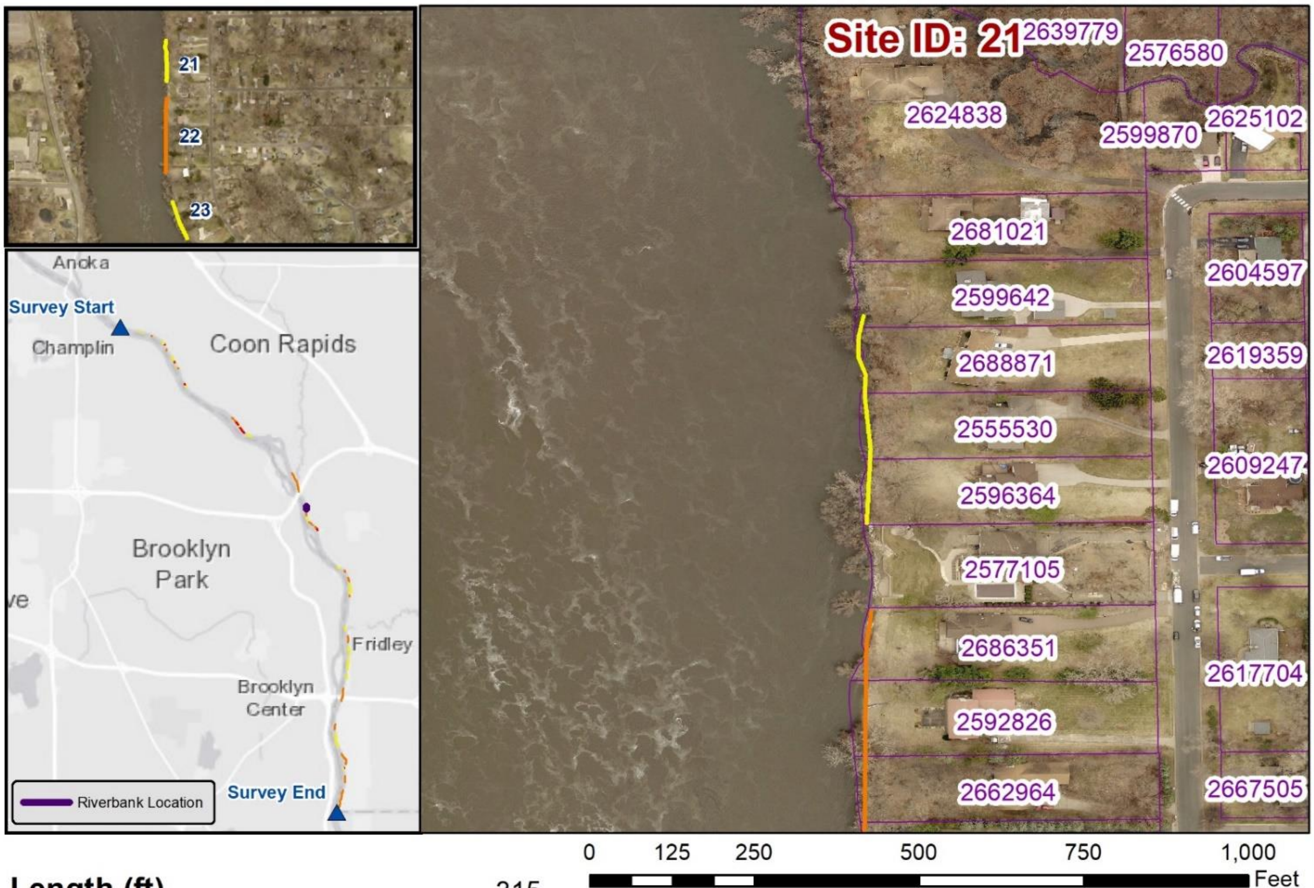


Length (ft)	2229
Erosion Height (ft)	10
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	748
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	759,996

Description: Located at the Coon Rapids Dam Regional Park. Bank is highly eroded with visible soil and a vertical bank on the upstream stretch; exposed roots/ fallen trees on the downstream stretch.



Map 5
Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley



Length (ft)	315
Erosion Height (ft)	12
Bluff Height (ft)	20
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	63
Ownership	Private
Number of Owners	4
Stabilization Approach	Bio-eng.
Cost Estimate	194,980

N

Erosion Severity
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Description: Slope is maintaining some vegetation but contains several fallen trees, exposed roots, and some minor slumps forming near the trunk bases.

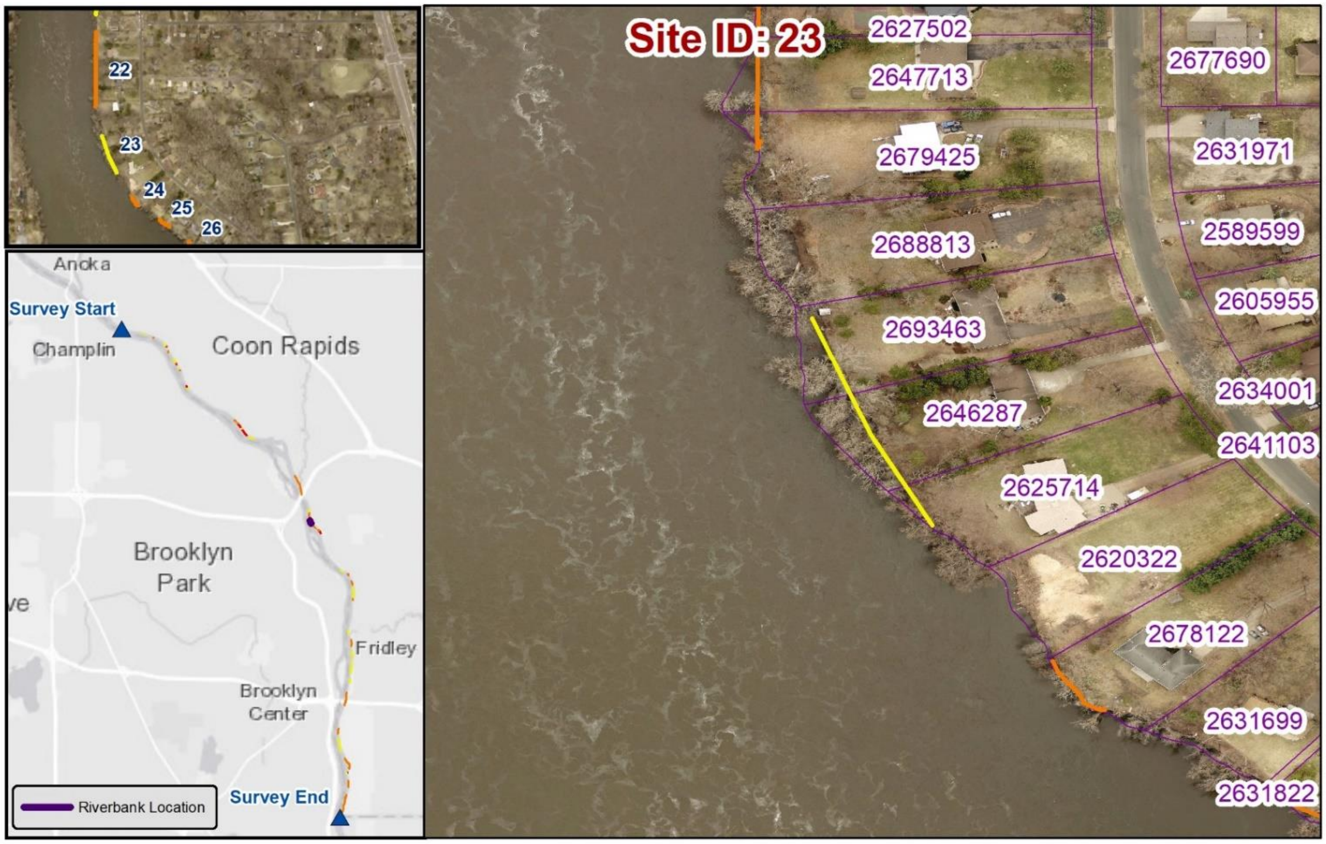
0 175 350 700 1,050 1,400 Feet

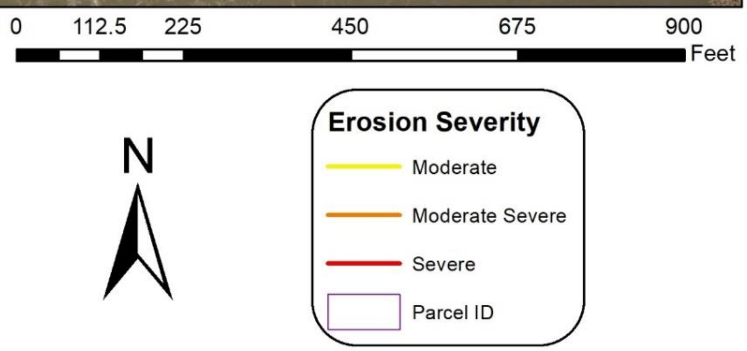
Length (ft)	581
Erosion Height (ft)	4
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	110
Ownership	Private
Number of Owners	6
Stabilization Approach	Bio-eng.
Cost Estimate	283,815

N

Erosion Severity
- Moderate
- Moderate Severe
- Severe
- Parcel ID

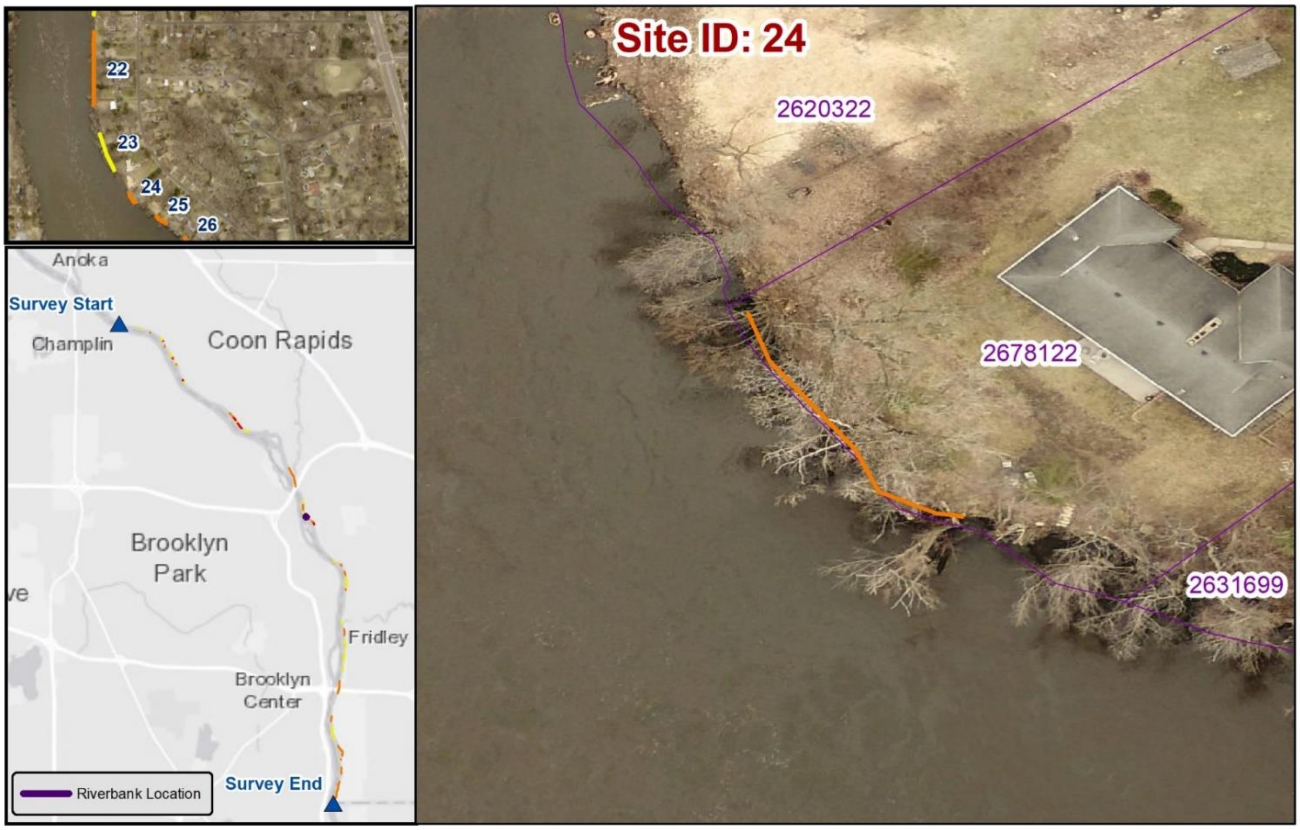
Description: Exposed edge with visible roots, vegetative overhang, and an undercut forming at the toe.

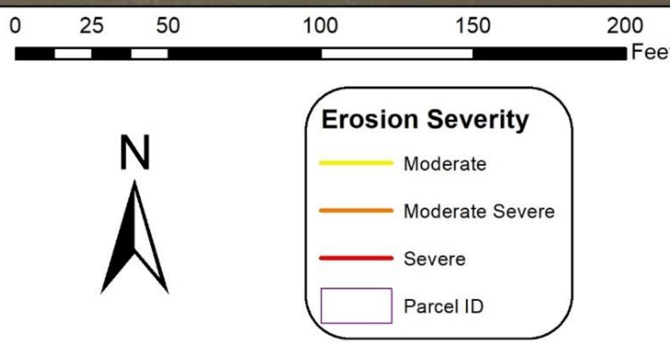




Length (ft)	303
Erosion Height (ft)	4
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	16
Ownership	Private
Number of Owners	3
Stabilization Approach	Bio-eng.
Cost Estimate	112,695

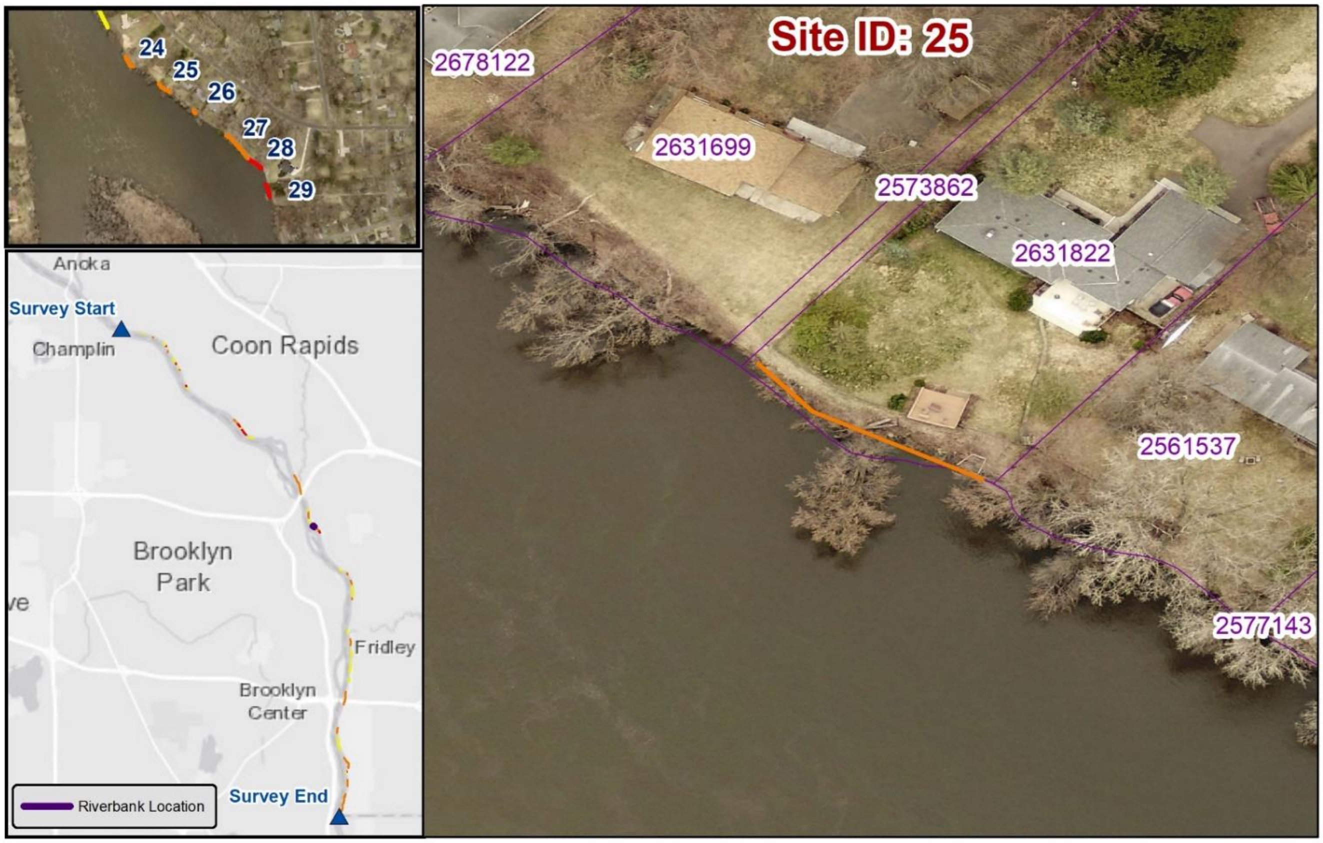
Description: Shoreline is relatively low-lying and the bank contains a slight undercut, exposed roots, and vegetative overhang. Erosion is most distinct on the lowest section of the bank.



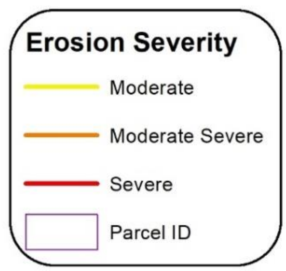


Length (ft)	88
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	41
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	40,431

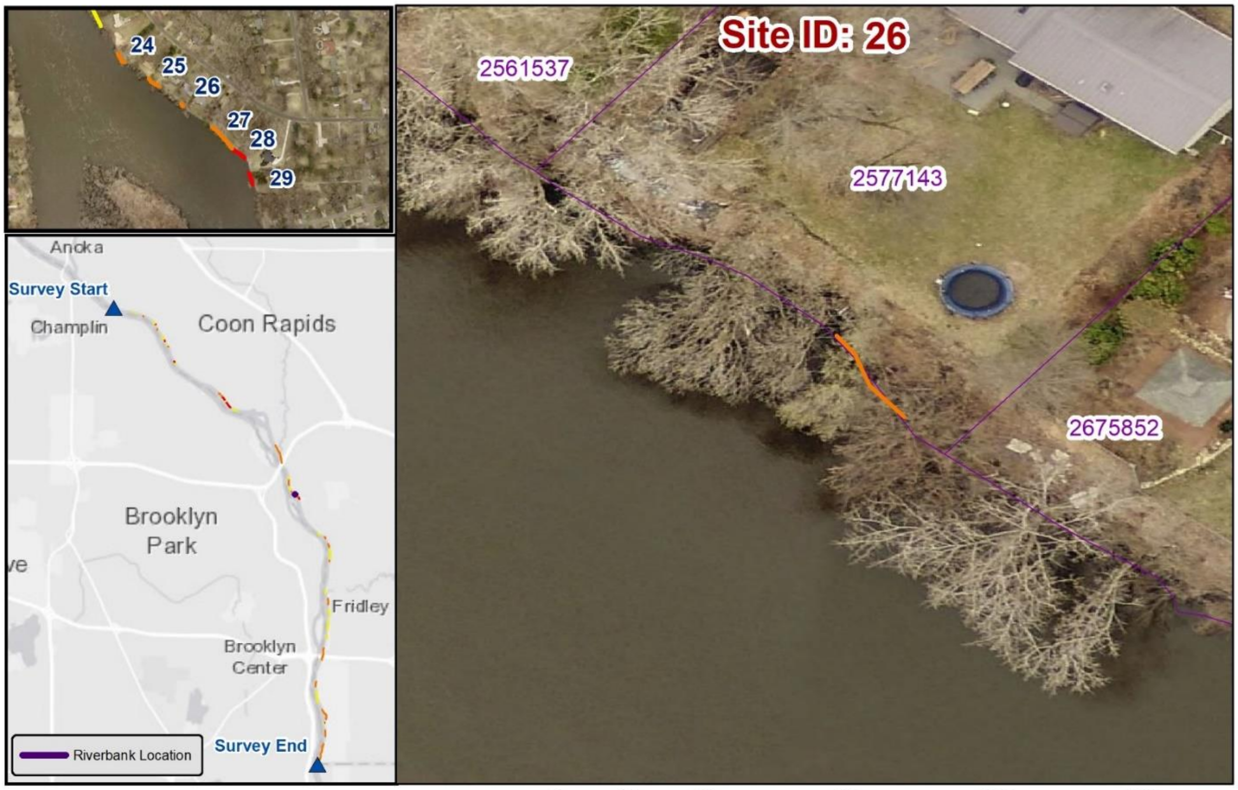
Description: Vegetation is present, but several fallen trees and exposed root systems are visible. Some undercuts and slumps have formed on the outer curve.

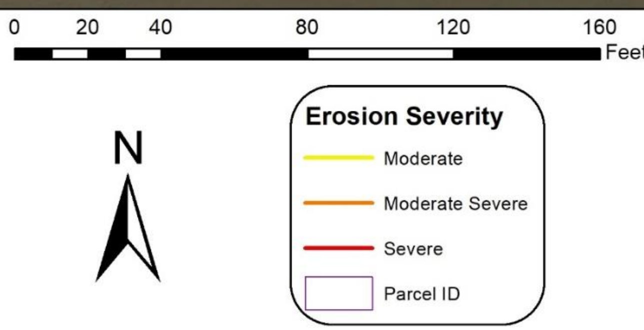


Length (ft)	94
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	33
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	42,522



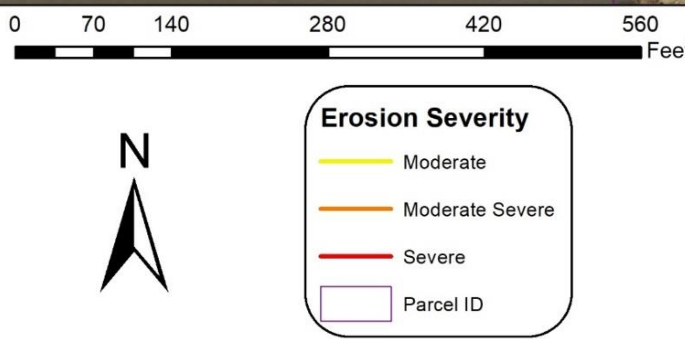
Description: There are no remaining trees on the steepest section, and those on the outer edges are leaning. Root systems are exposed and a large slump is present.





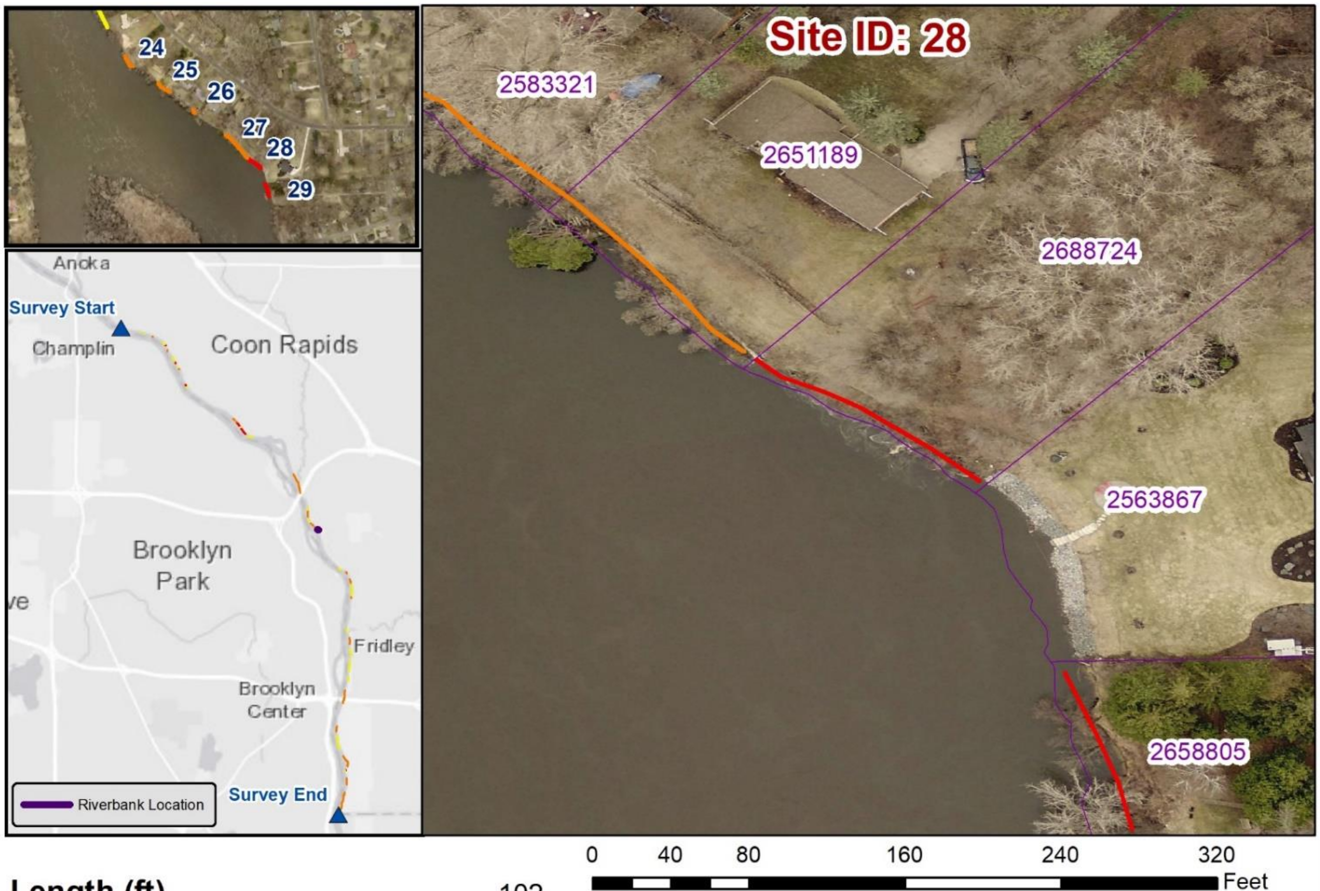
Length (ft)	26
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	8
Ownership	Private
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	19,768

Description: Short stretch of steep slope with exposed roots and leaninig trees. An undercut is forming at the toe. There is a pipe extending out of the bank.

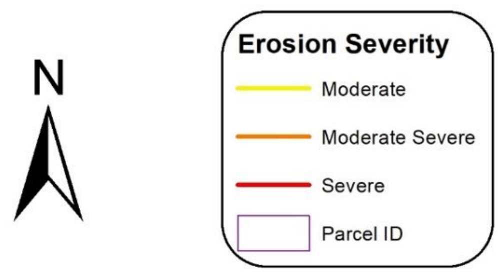


Length (ft)	206
Erosion Height (ft)	14
Bluff Height (ft)	14
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	66
Ownership	Private
Number of Owners	2
Stabilization Approach	Bio-eng.
Cost Estimate	94,070

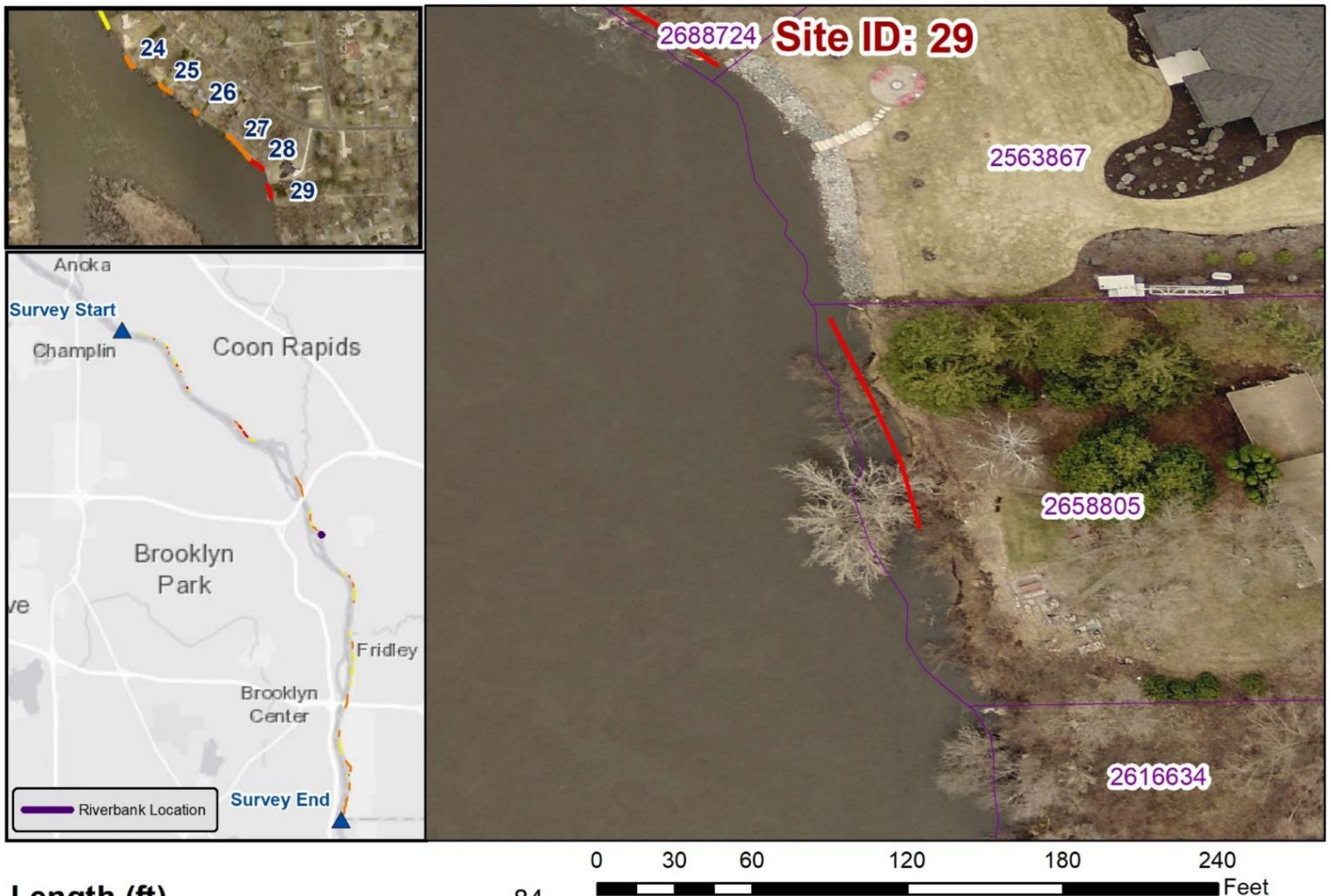
Description: Erosion has caused a slump on the upstream part of this shoreline and an undercut toe on the downstream portion. This transitions into severe erosion on the next stretch of shoreline.



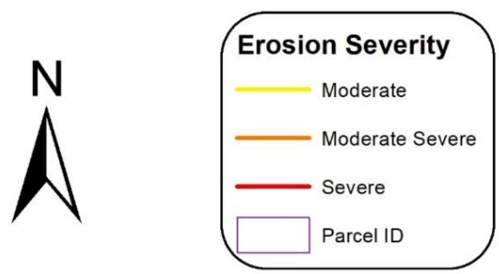
Length (ft)	102
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	55
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	73,099



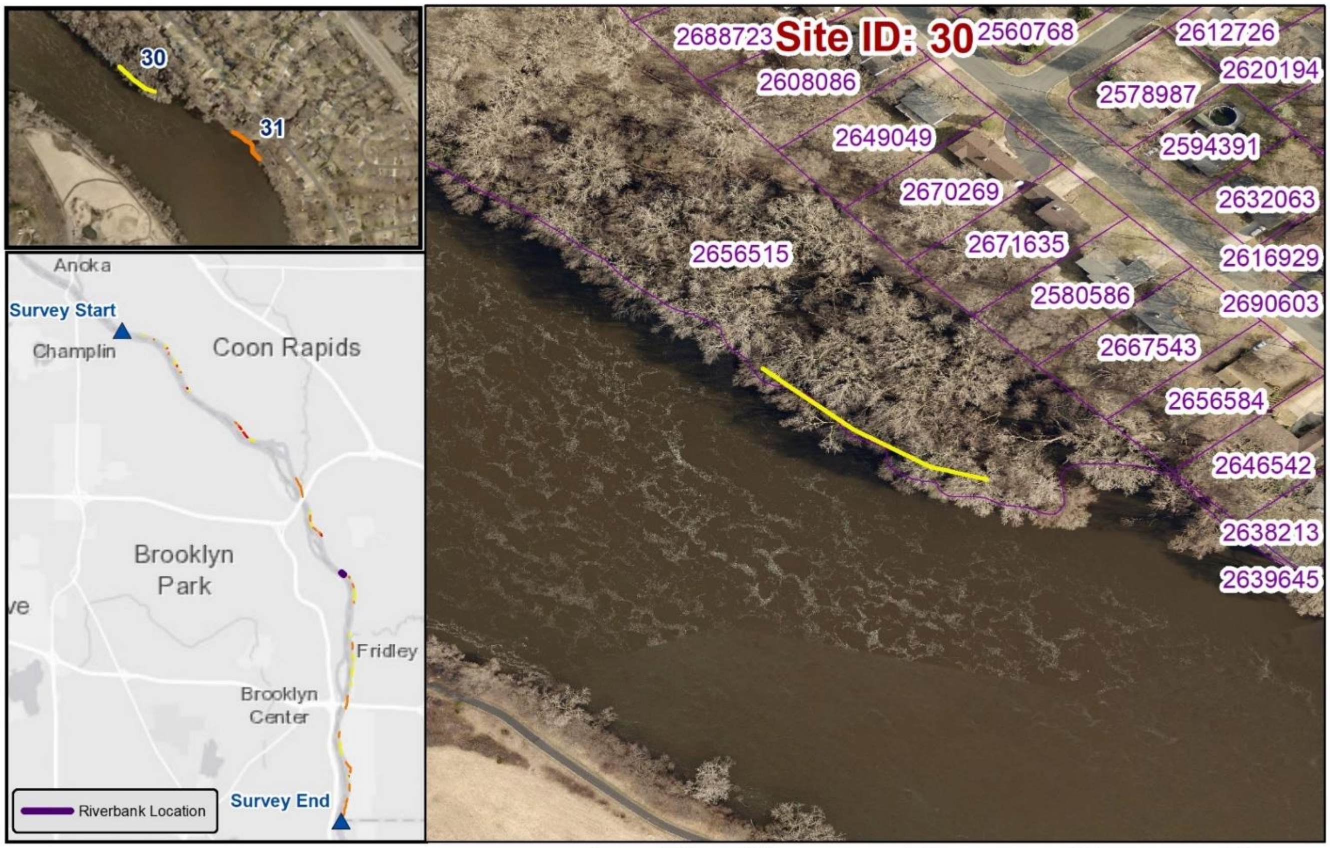
Description: Highly eroded steep slope with slumps, exposed roots, and fallen woody debris.

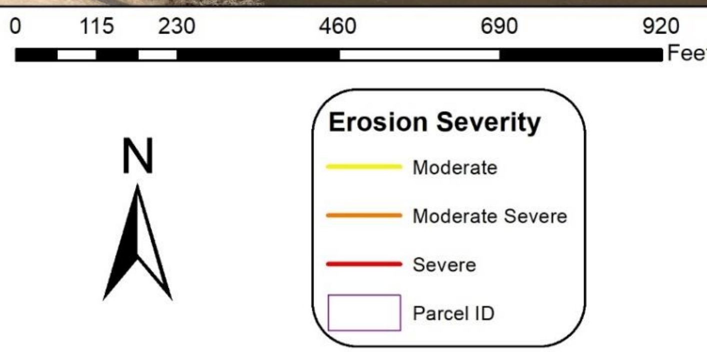


Length (ft)	84
Erosion Height (ft)	12
Bluff Height (ft)	12
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	45
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	64,331



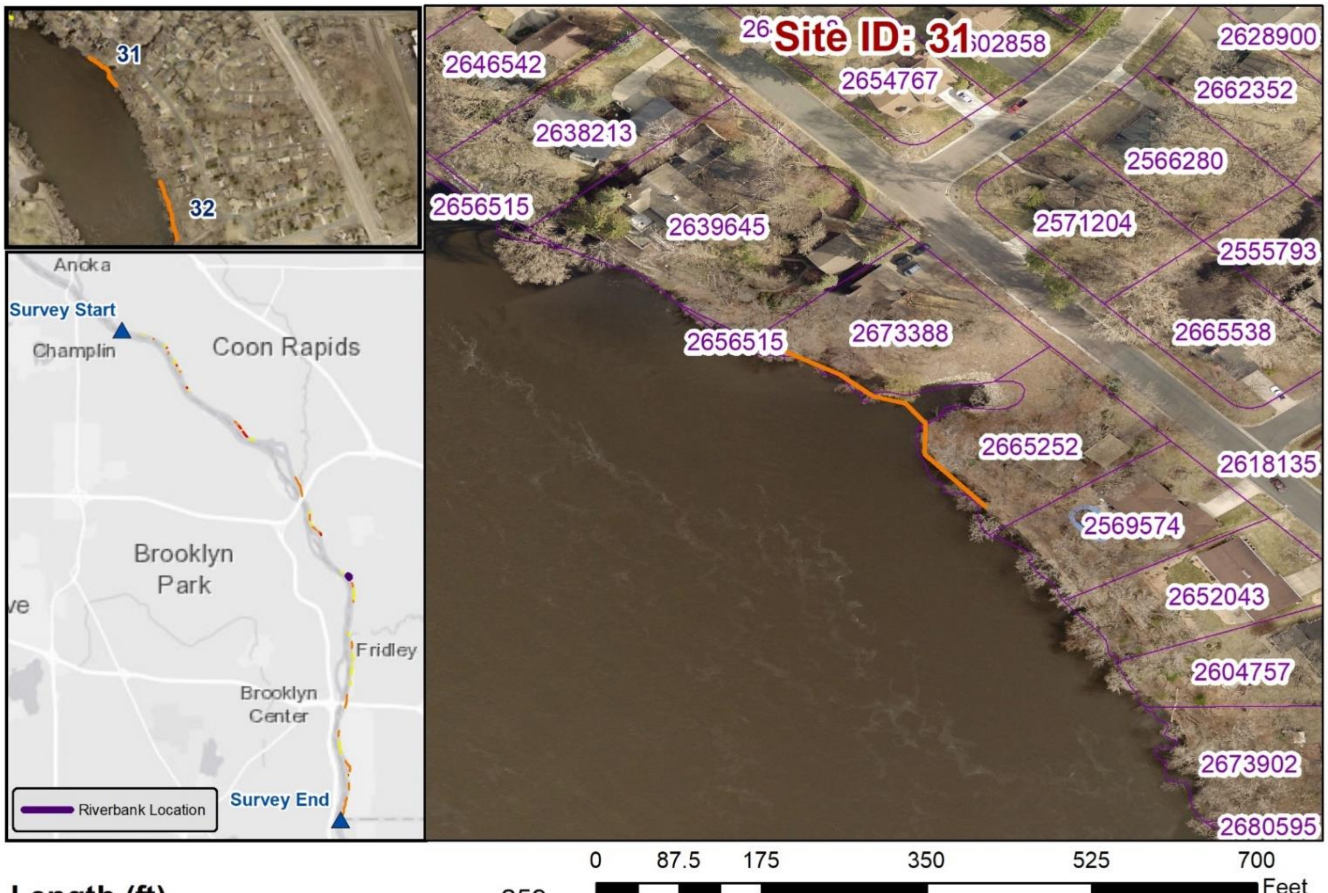
Description: Highly eroded steep slope with slumps, vegetative overhang, exposed roots, and leaning trees.



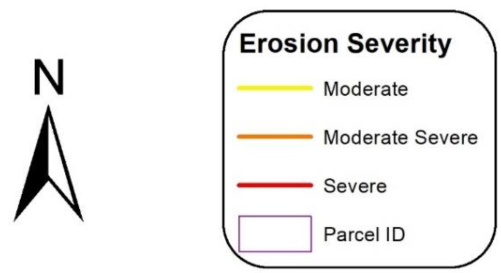


Length (ft)	280
Erosion Height (ft)	4
Bluff Height (ft)	4
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	22
Ownership	Fridley
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	42,404

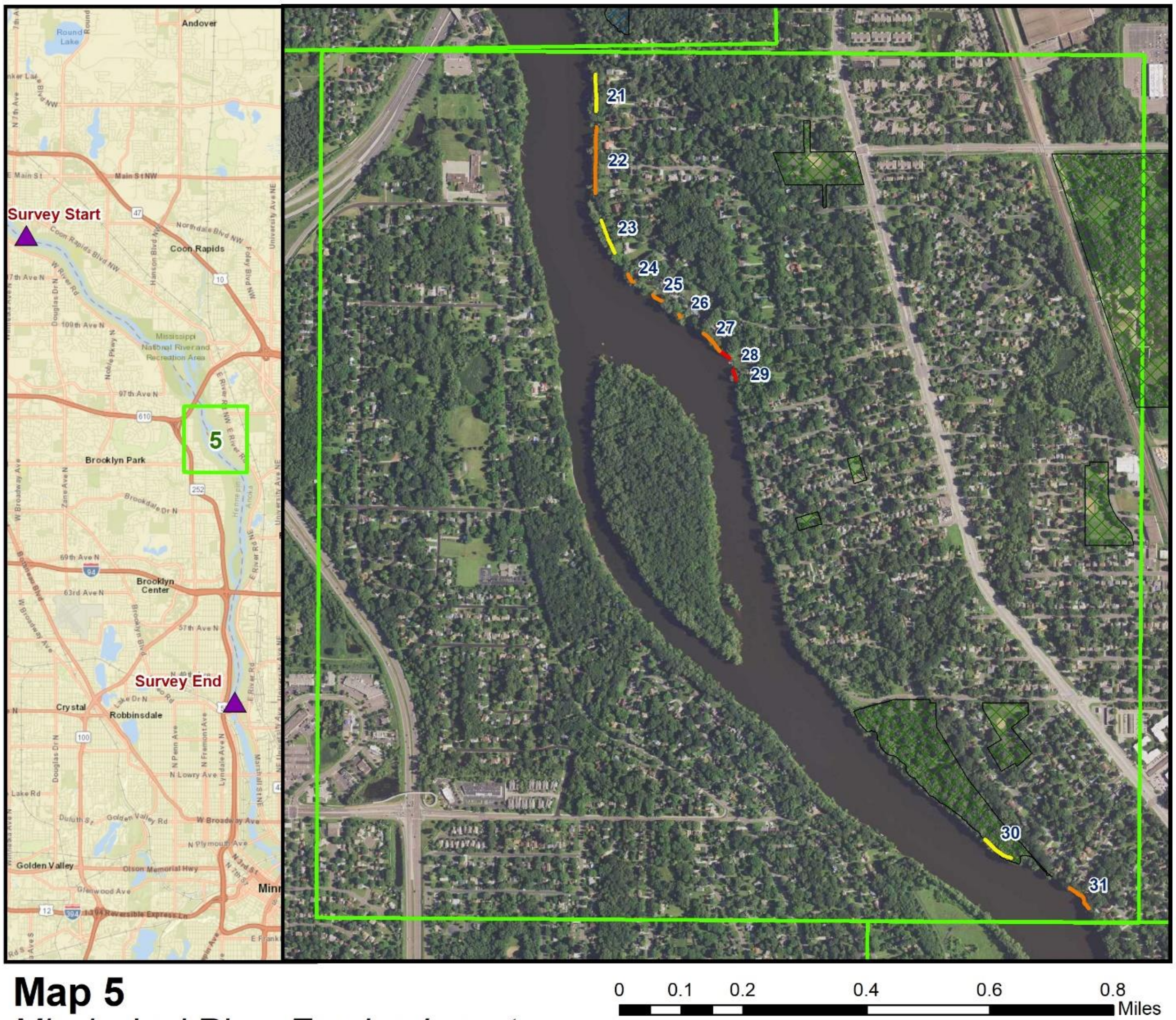
Description: Moderate erosion of the toe is causing an undercut and exposed roots. There is little to no slope on the visible shoreline because this is a floodplain area.



Length (ft)	259
Erosion Height (ft)	10
Bluff Height (ft)	28
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	94
Ownership	Private
Number of Owners	2
Stabilization Approach	Armor
Cost Estimate	319,314



Description: Slumps, exposed roots, and an undercut toe are present along this stretch. The slope above the slumps is still well-vegetated but compromised by the erosion below.



Map 5
Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley

ANOKA CONSERVATION DISTRICT
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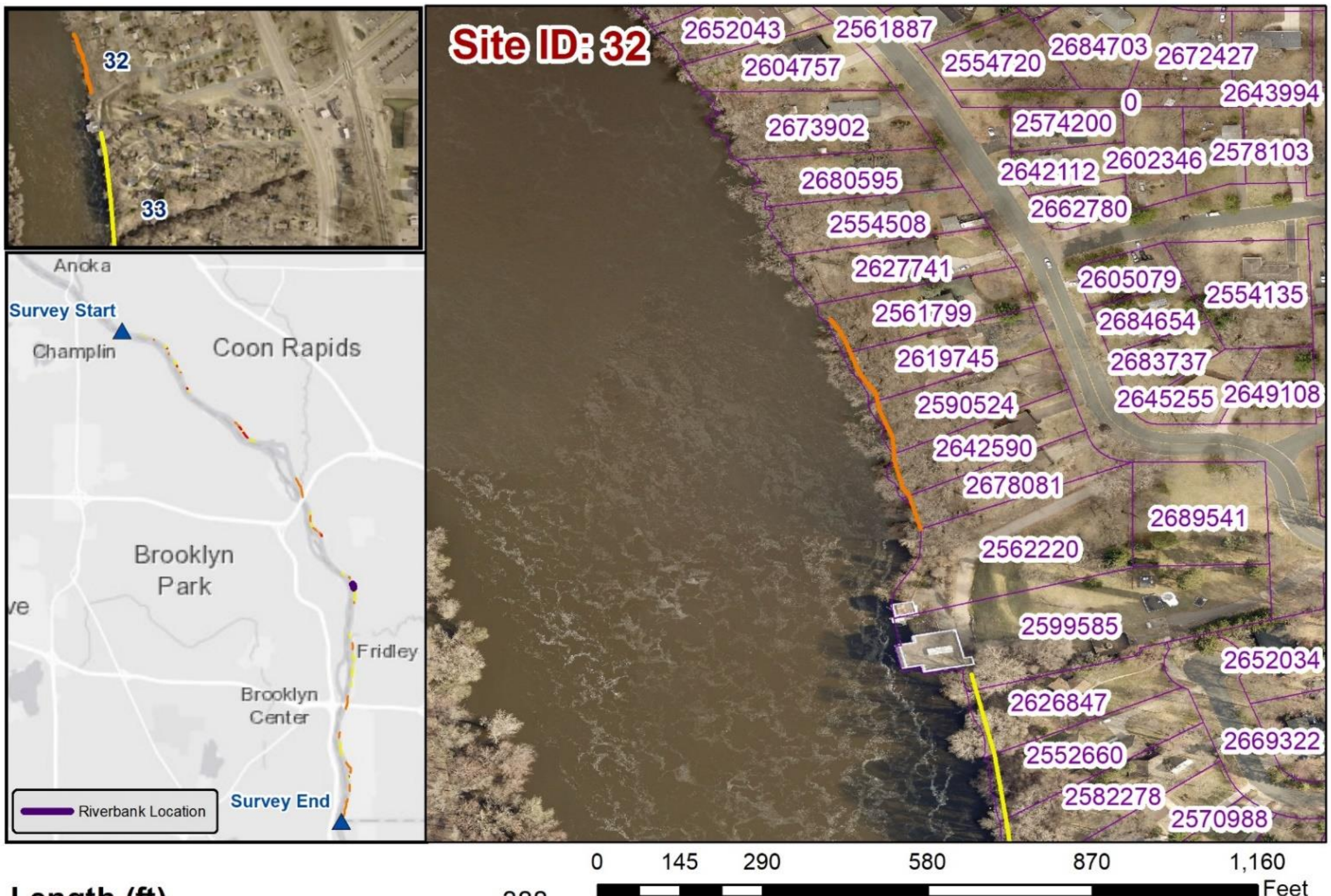
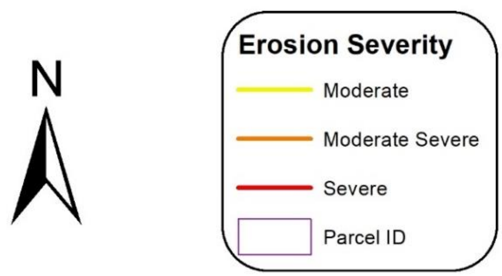
N

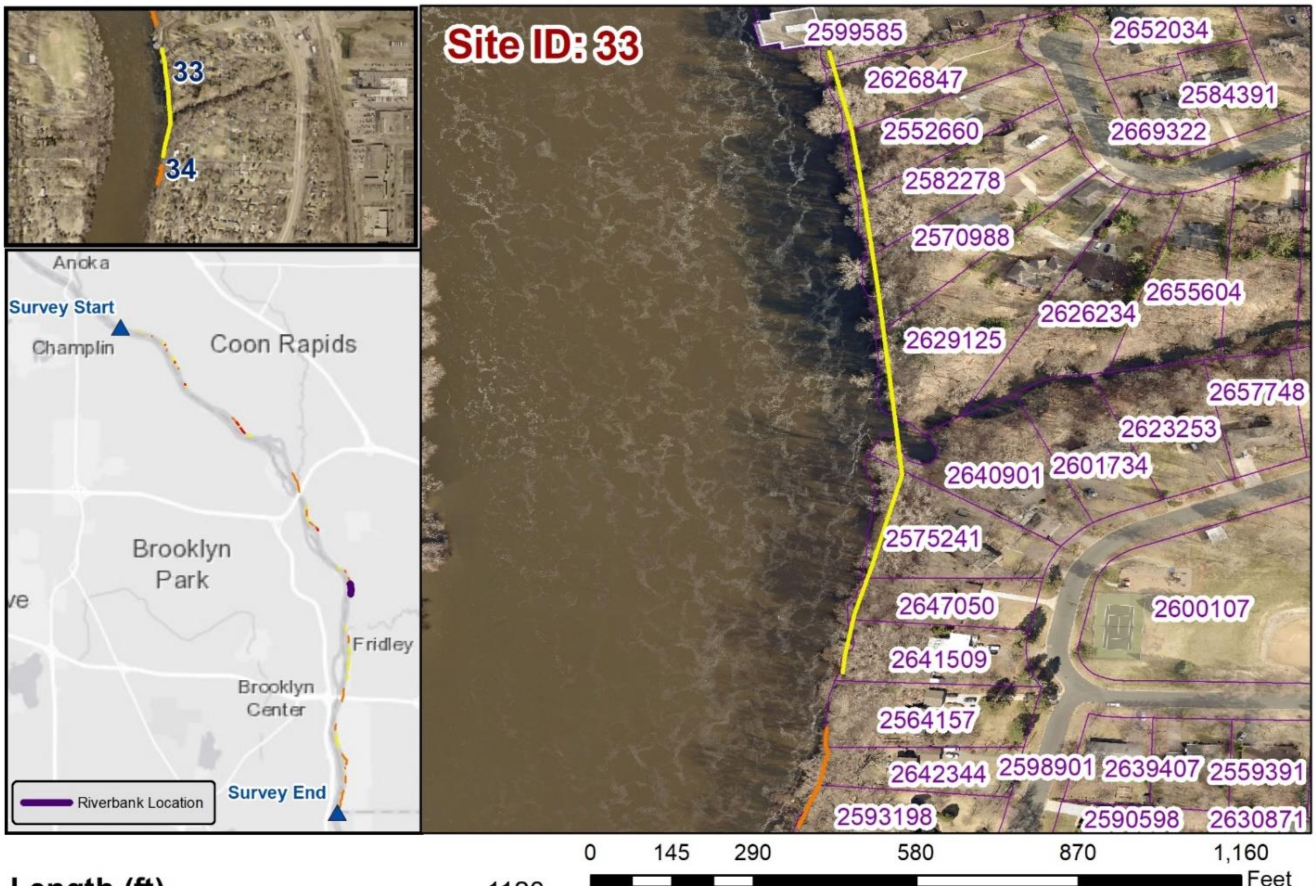
Erosion Severity
- Moderate
- Moderate Severe
- Severe
- City Parks
- County Parks
- Map Area



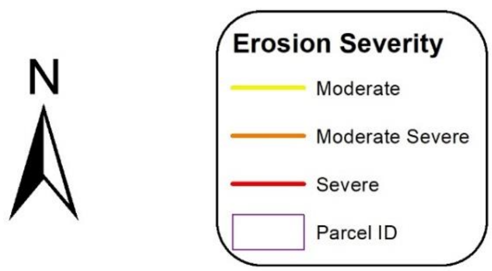
Length (ft)	388
Erosion Height (ft)	6
Bluff Height (ft)	46
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	94
Ownership	Private
Number of Owners	5
Stabilization Approach	Bio-eng.
Cost Estimate	521,112



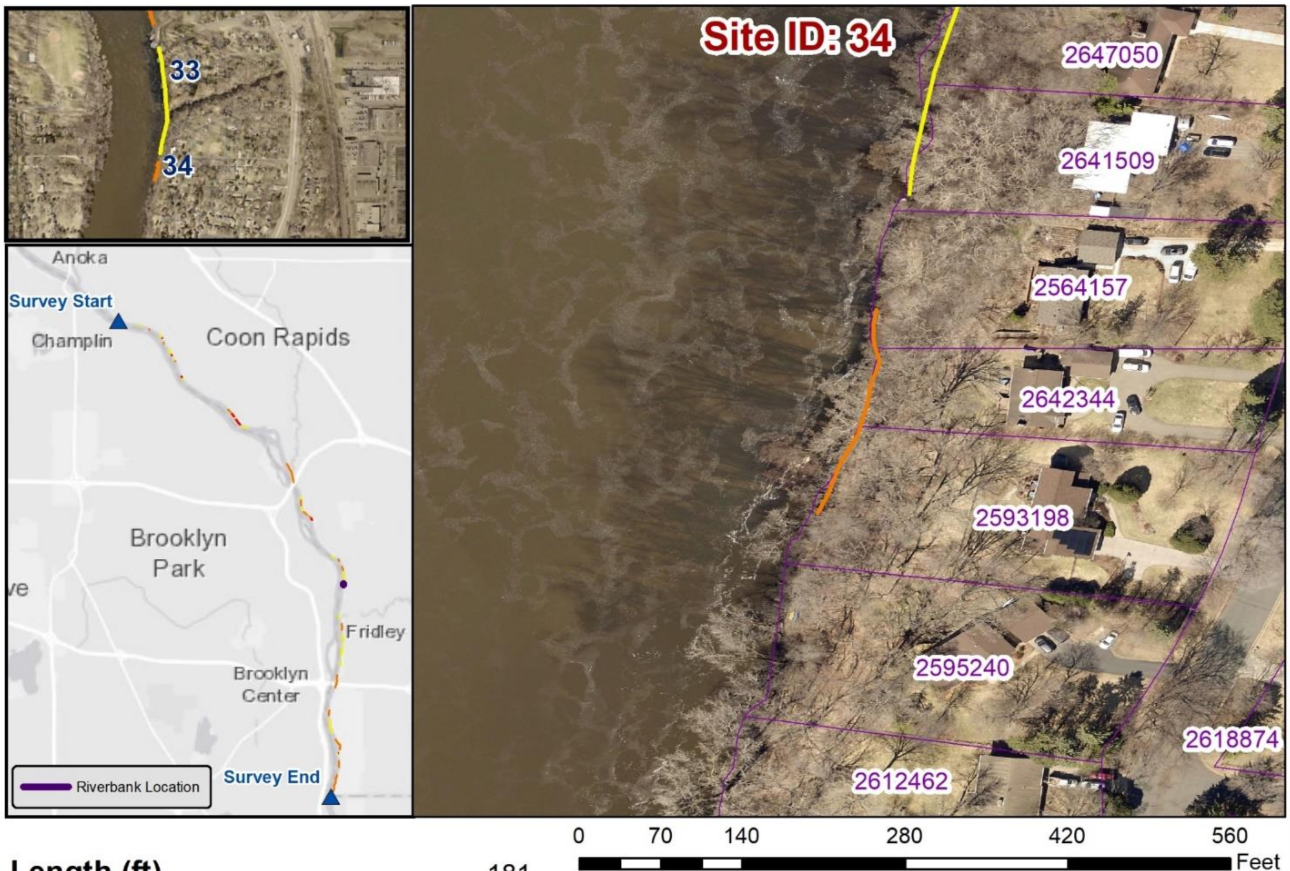
Description: An undercut toe is present along the entire stretch, resulting in exposed root systems, overhanging vegetation, and leaning trees near the edge. Some minor slumps have occurred near the bottom. Remainder of slope is steep but well vegetated.



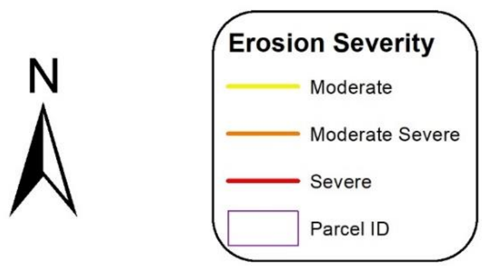
Length (ft)	1120
Erosion Height (ft)	6
Bluff Height (ft)	46
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	65
Ownership	Private
Number of Owners	9
Stabilization Approach	Bio-eng.
Cost Estimate	1,468,210



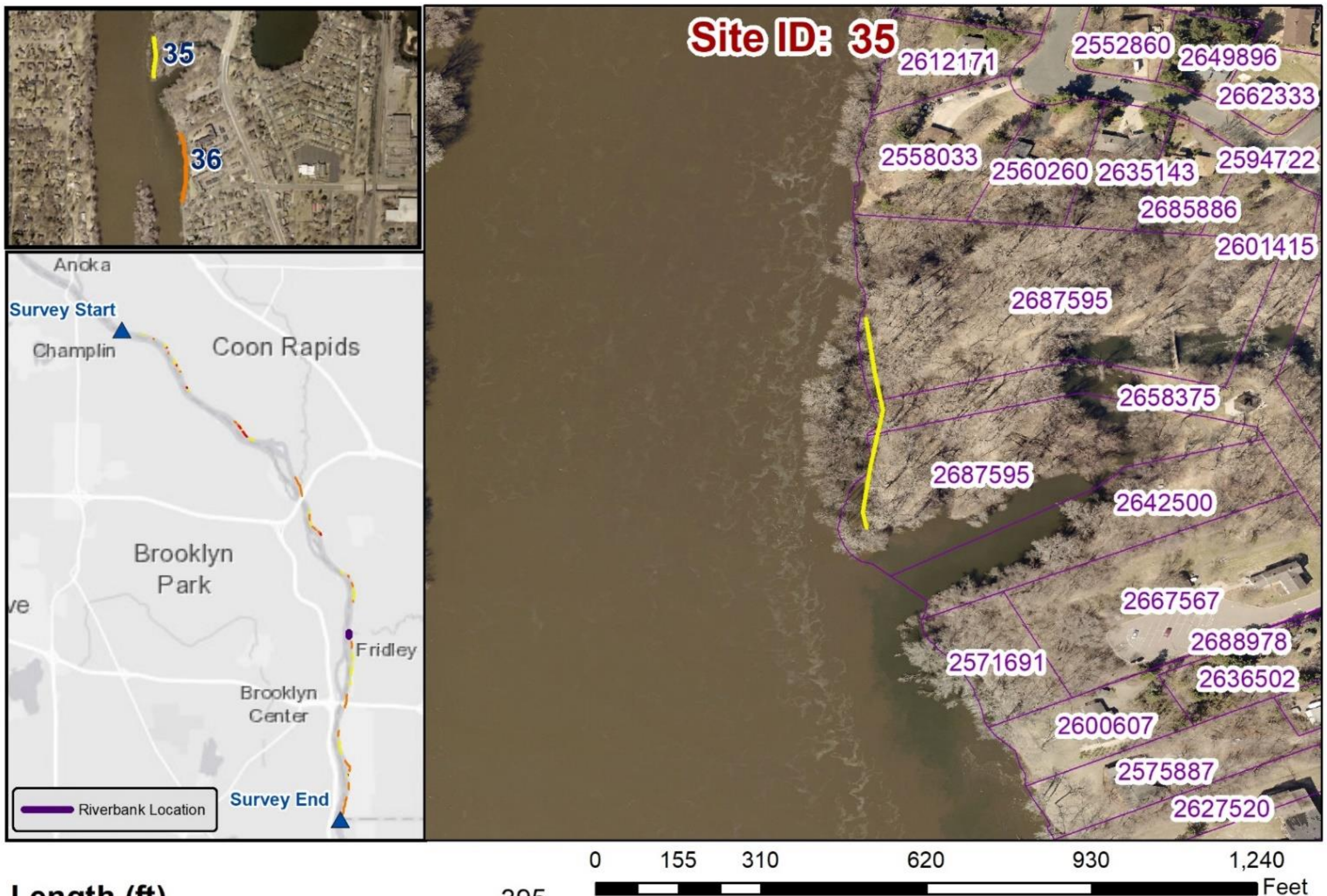
Description: An undercut has formed at the toe, exposing some root systems. The remainder of the slope is steep but currently well-vegetated.



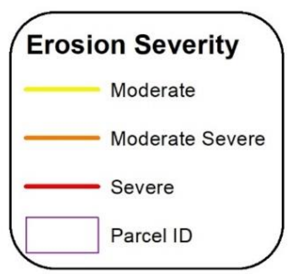
Length (ft)	181
Erosion Height (ft)	8
Bluff Height (ft)	42
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	58
Ownership	Private
Number of Owners	3
Stabilization Approach	Bio-eng.
Cost Estimate	228,379



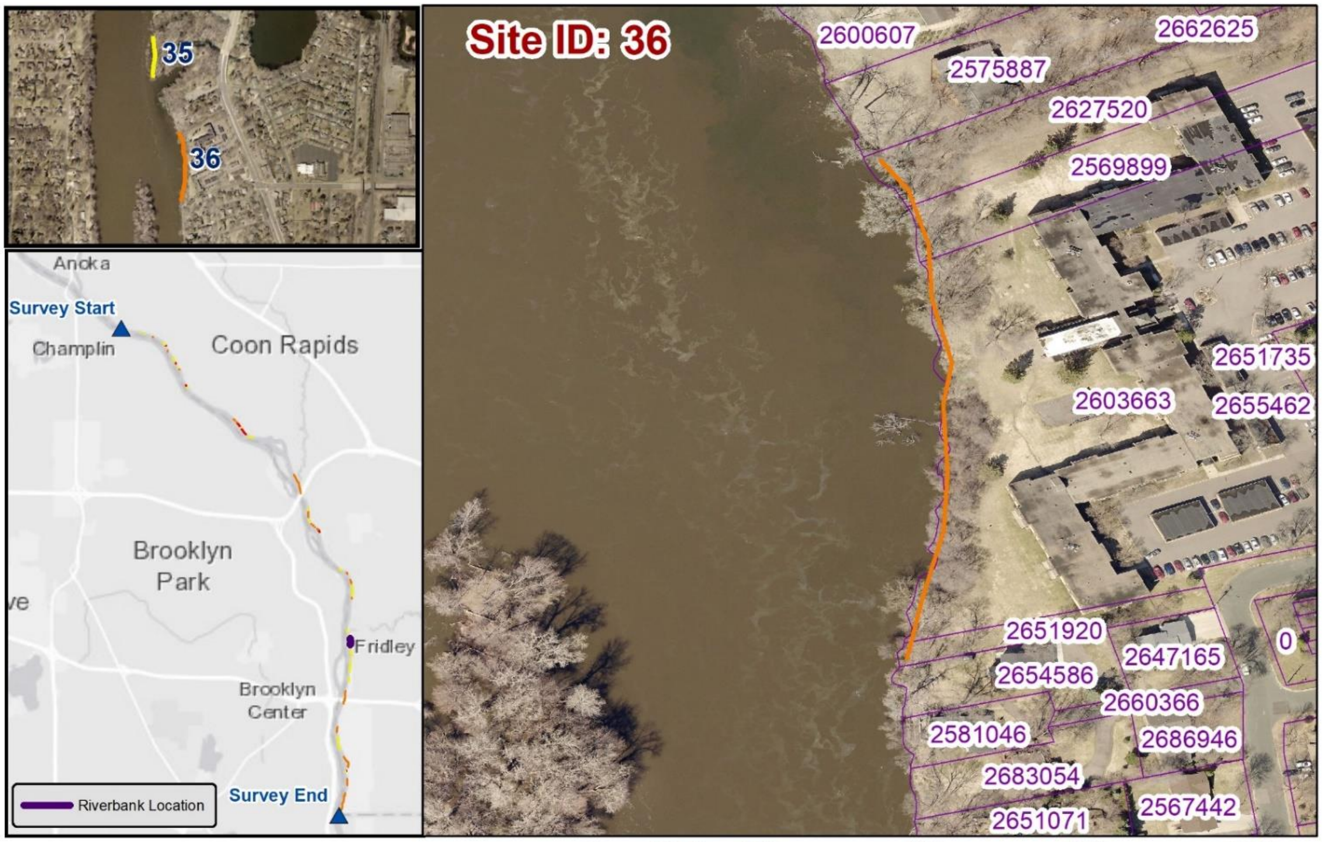
Description: On the northern and southern stretch, an undercut has formed. In the center, a slump is present, exposing tree roots and creating a vertical face.



Length (ft)	395
Erosion Height (ft)	4
Bluff Height (ft)	4
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	40
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	55,240



Description: This is a floodplain area with minimal slope, but the bank is vertical and several trees have fallen into the river. This is a Fridley park owned by Anoka County.



0 112.5 225 450 675 900 Feet

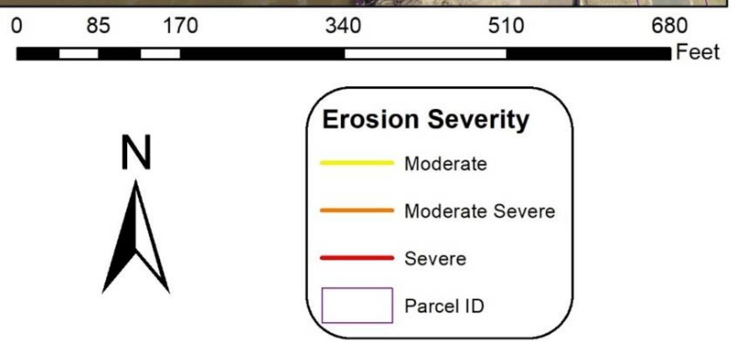
Length (ft)	698
Erosion Height (ft)	24
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	571
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	693,789

N

Erosion Severity

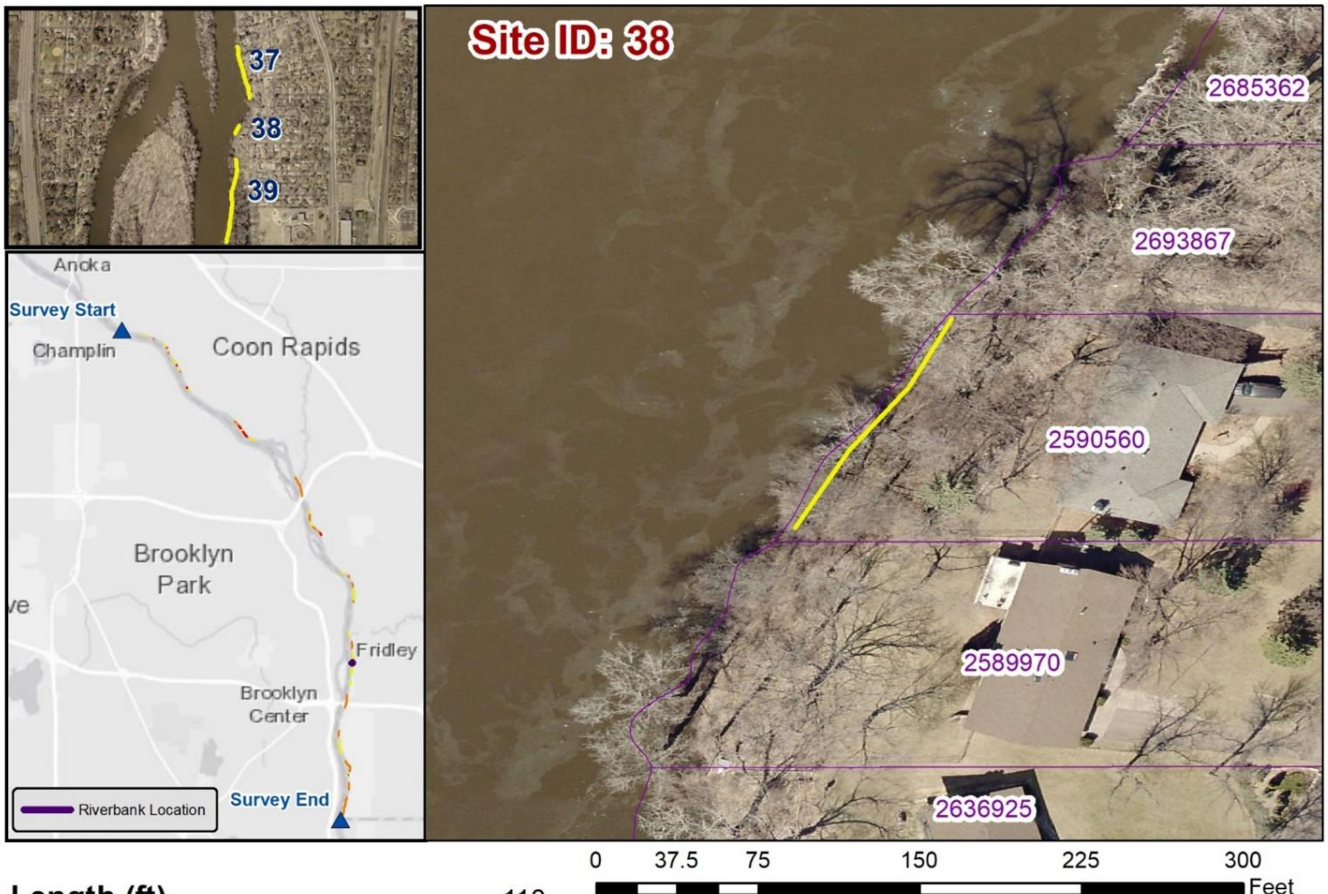
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Description: Slope is very eroded but maintaining some vegetation. Several trees have fallen into the river and many root systems are exposed. 18' slumps are present throughout the stretch.

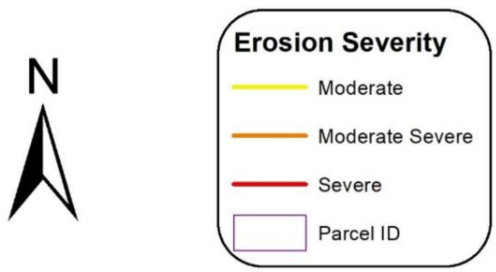


Length (ft)	649
Erosion Height (ft)	4
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	35
Ownership	Private
Number of Owners	7
Stabilization Approach	Bio-eng.
Cost Estimate	314,096

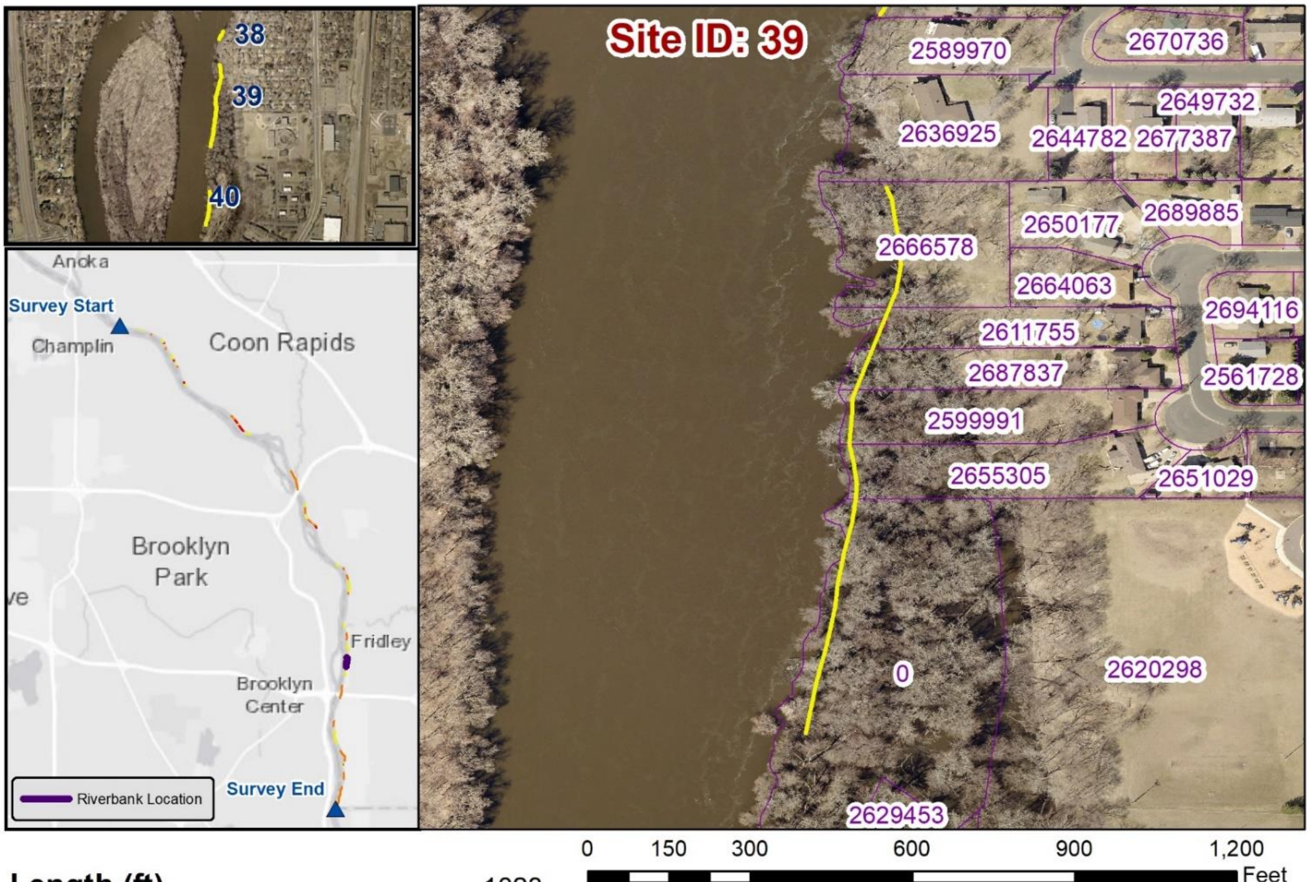
Description: Erosion has caused the toe to recede and the bank to become vertical with some exposed root systems. The most visible erosion is occurring only on the bottom section of the shoreline.



Length (ft)	110
Erosion Height (ft)	22
Bluff Height (ft)	22
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	21
Ownership	Private
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	120,598



Description: Moderately eroded toe and slight 4' slump which has exposed root systems.

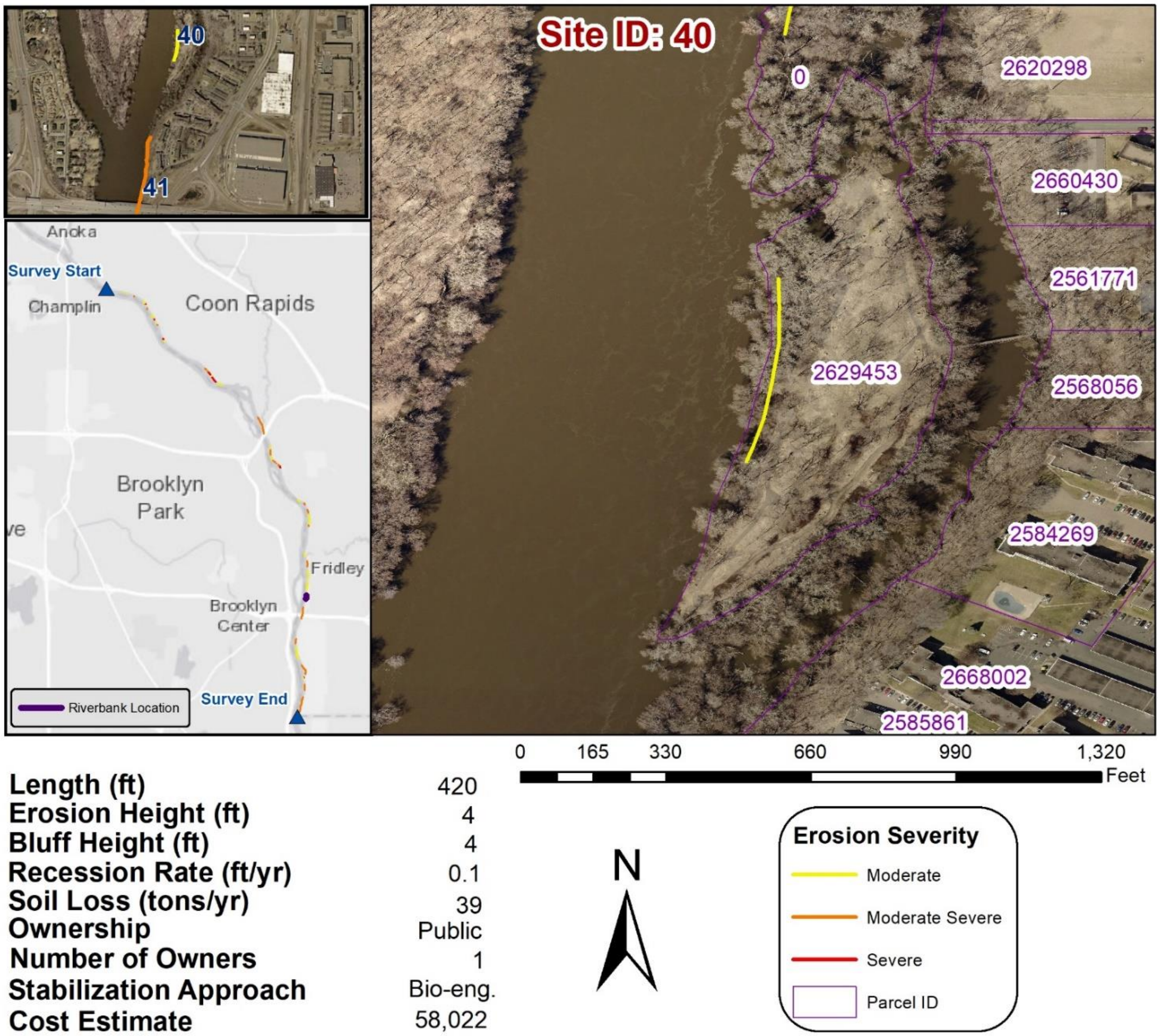


Length (ft)	1023
Erosion Height (ft)	4
Bluff Height (ft)	4
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	79
Ownership	Private; Public
Number of Owners	6
Stabilization Approach	Bio-eng.
Cost Estimate	130,569

N

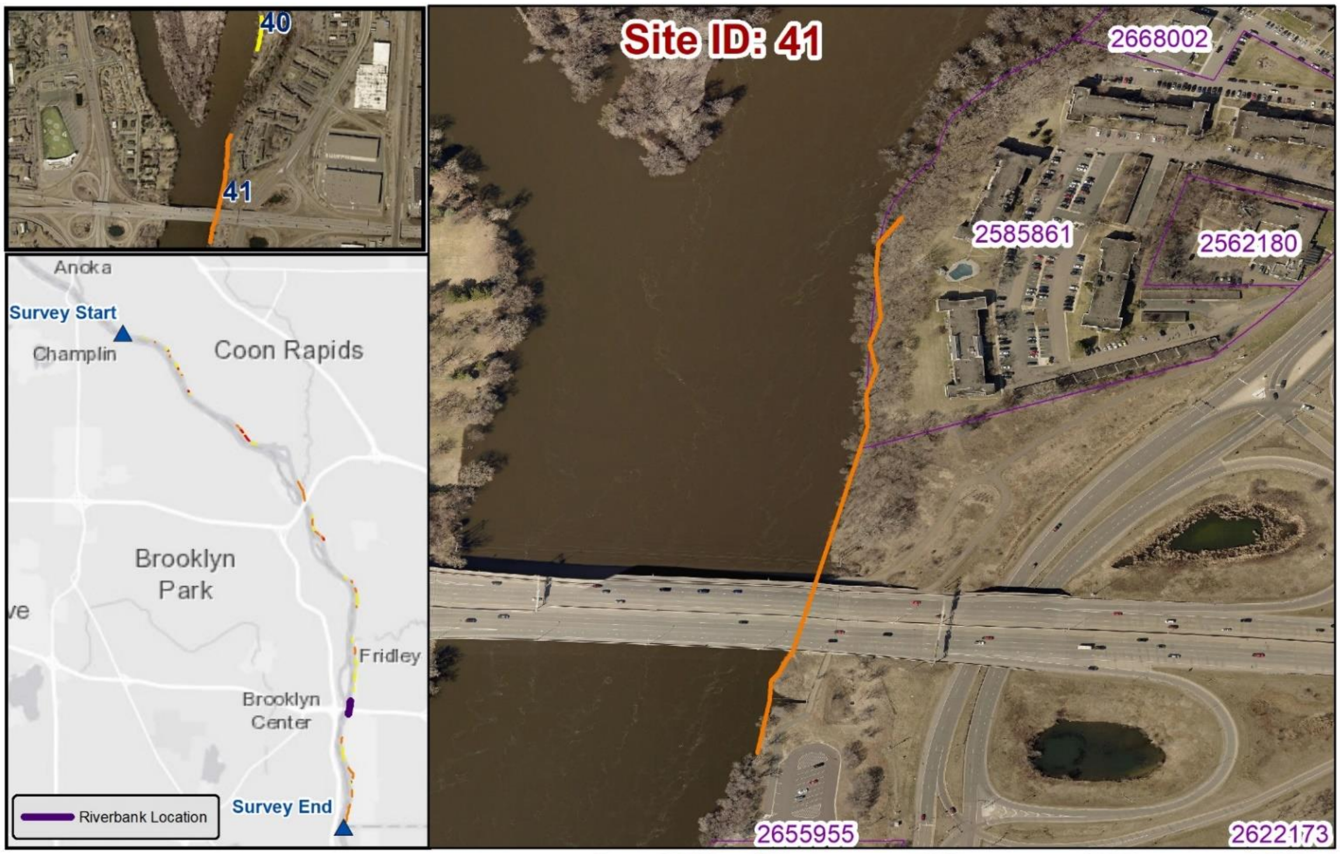
Erosion Severity
- Moderate
- Moderate Severe
- Severe
- Parcel ID

Description: Low-lying piece of land adjacent to more steeply sloped shoreline with moderate erosion creating a short vertical slope and exposed roots.

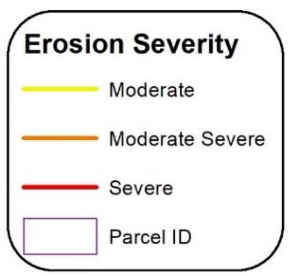


Length (ft)	420
Erosion Height (ft)	4
Bluff Height (ft)	4
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	39
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	58,022

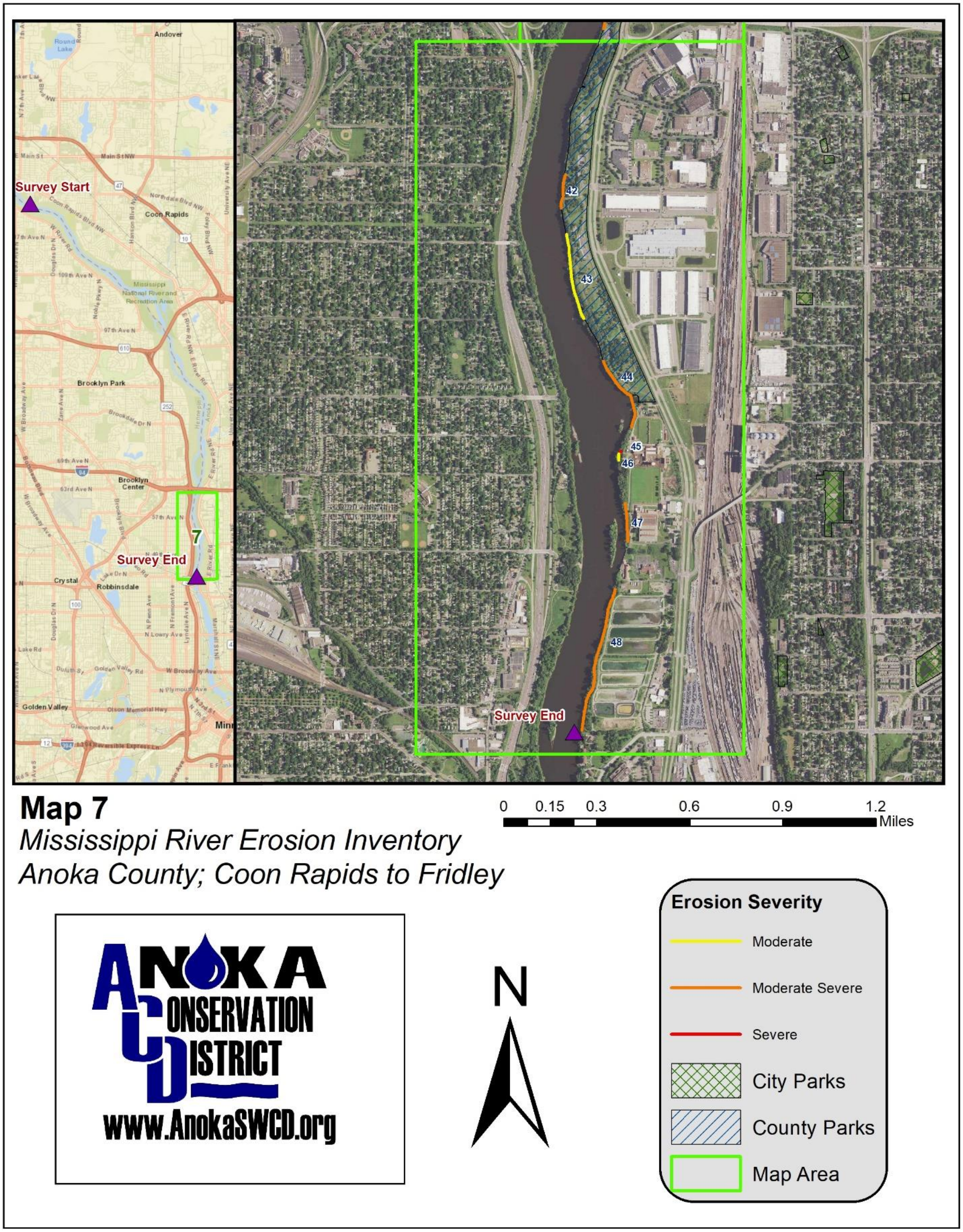
Description: Western shoreline of an island. There is little to no slope, but moderate erosion is causing a vertical edge and exposed roots/leaning trees.



Length (ft)	1395
Erosion Height (ft)	6
Bluff Height (ft)	14
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	437
Ownership	Private; Unknown
Number of Owners	2
Stabilization Approach	Bio-eng.
Cost Estimate	560,226

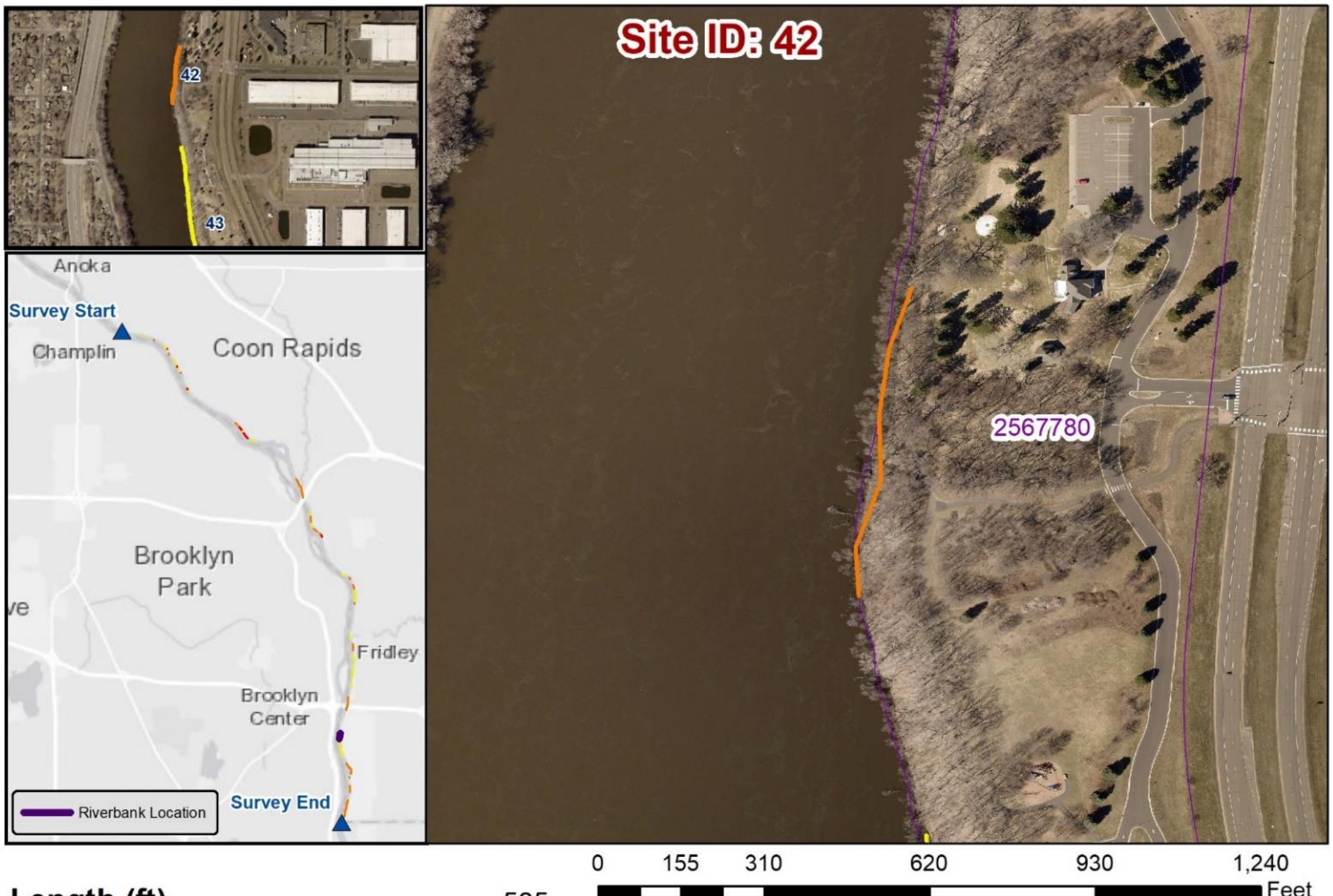


Description: The upstream portion conatins an undercut toe that leads to an eroded slope with a slump and slight undercut. The remainder of the bank above the eroded portion contains intact vegetation.

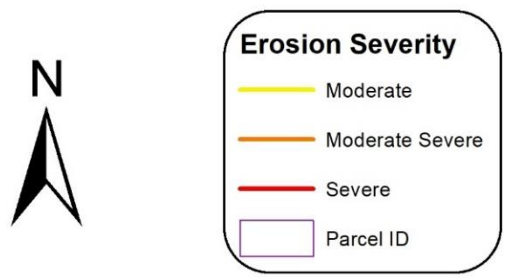


Map 7

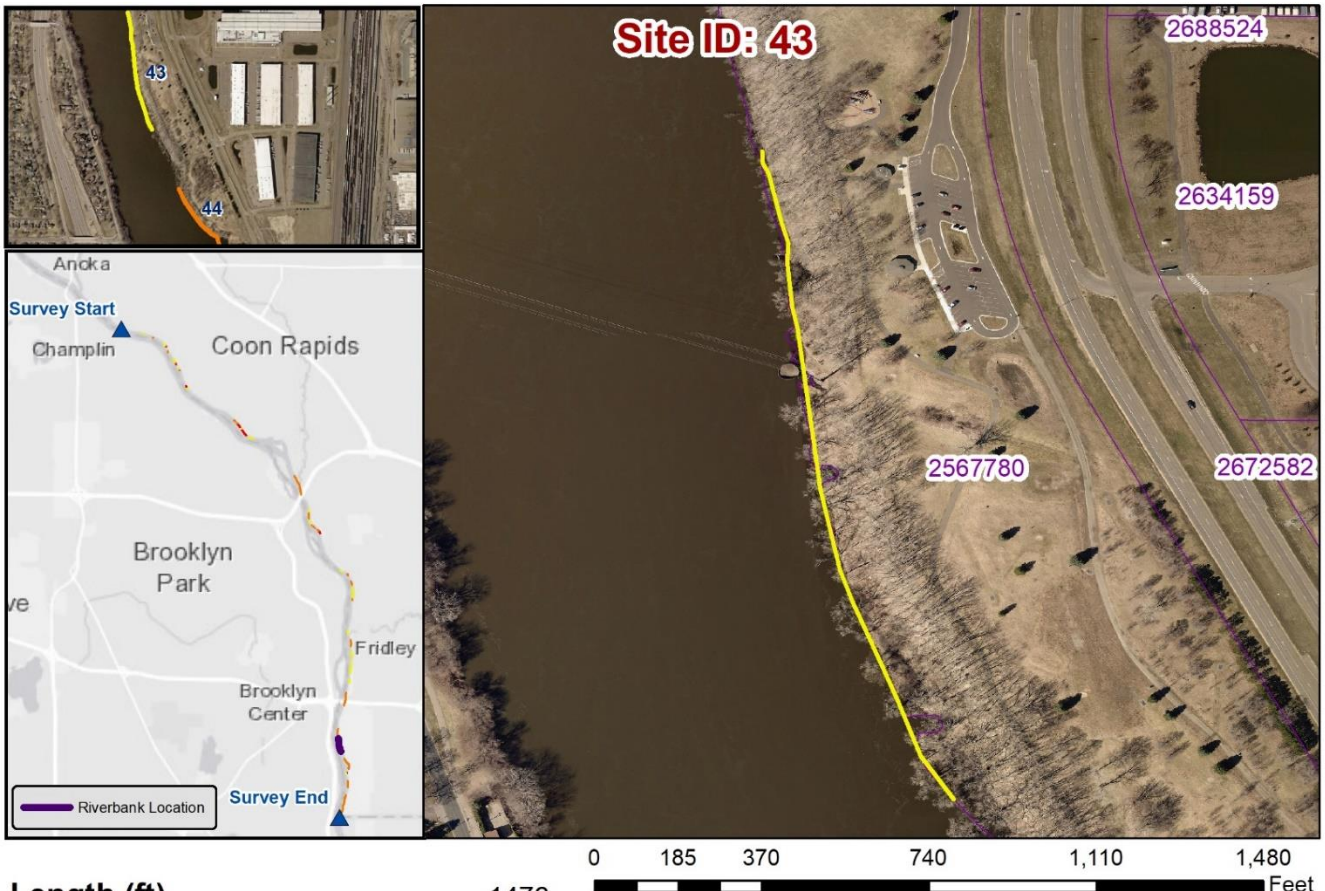
Mississippi River Erosion Inventory
Anoka County; Coon Rapids to Fridley



Length (ft)	585
Erosion Height (ft)	4
Bluff Height (ft)	22
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	94
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	371,136

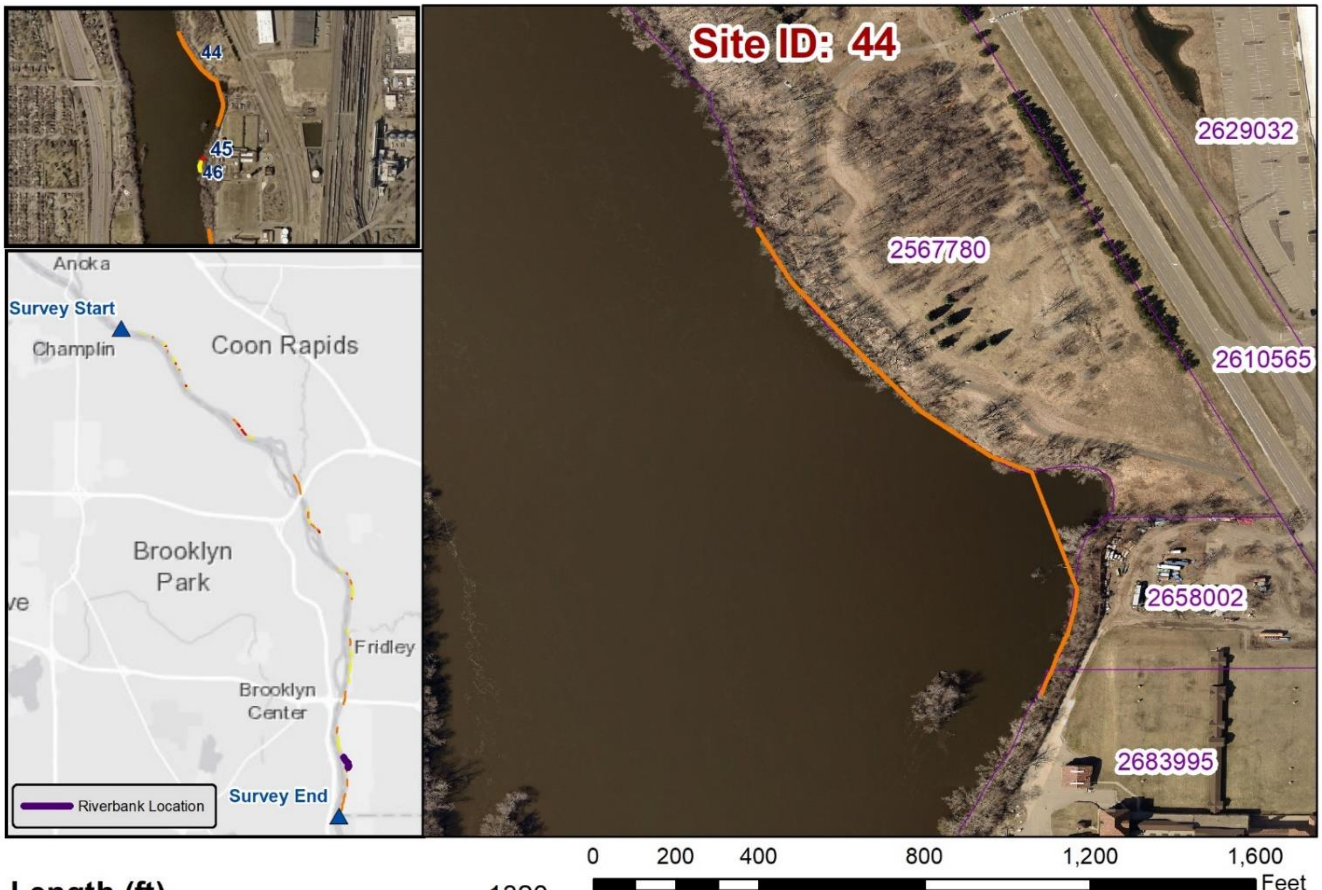


Description: Relatively short erosion height on a larger slope, but it has caused an undercut, exposed roots/leaning trees, and some moderate slumps.

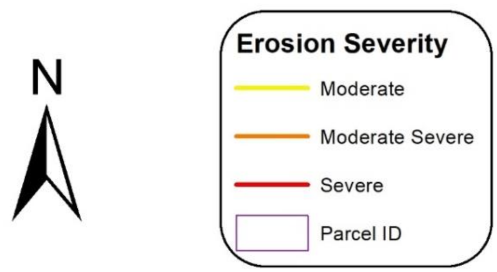


Length (ft)	1476
Erosion Height (ft)	5
Bluff Height (ft)	16
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	110
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	672,308

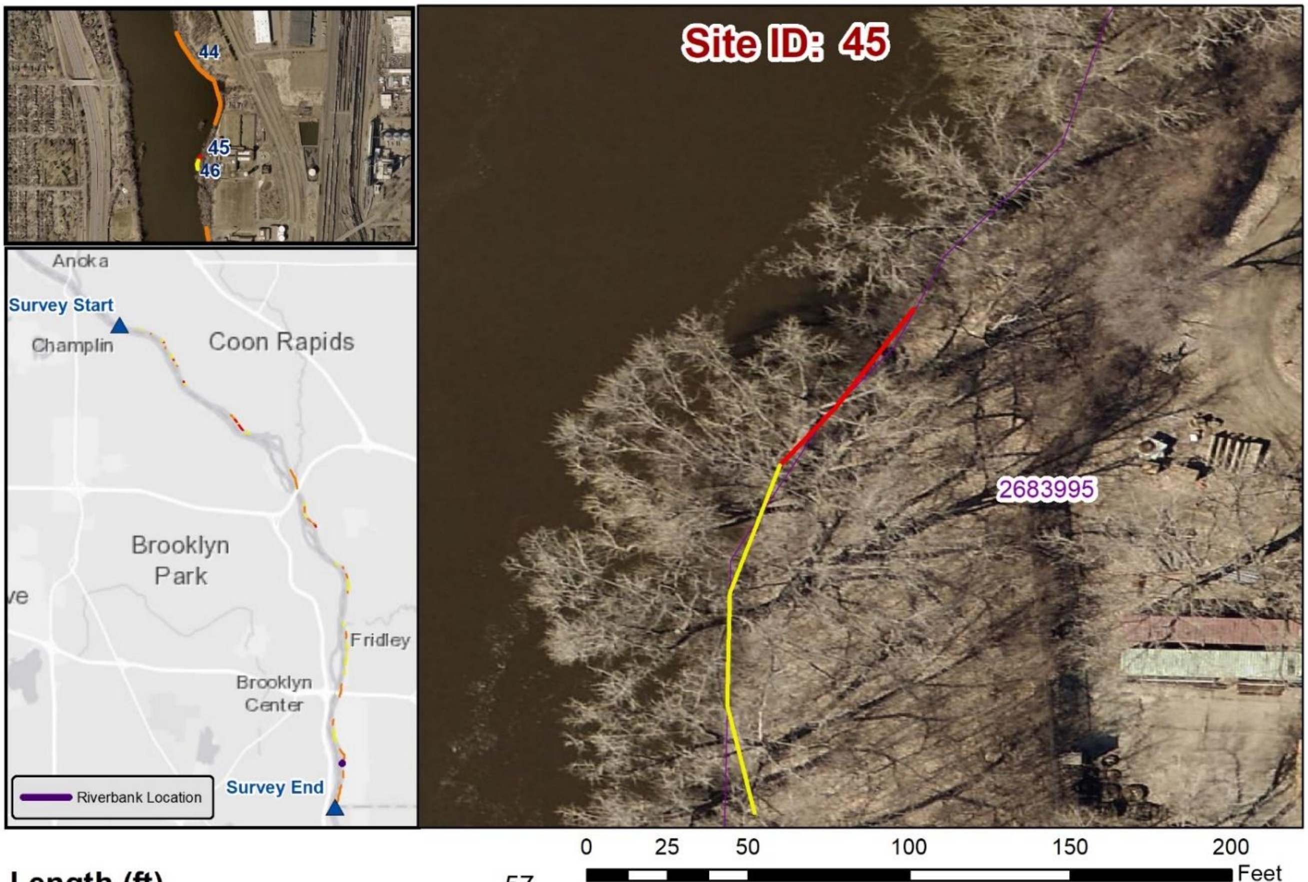
Description: Moderate erosion is causing some undercuts and minor slumps with overhanging trees and exposed roots.



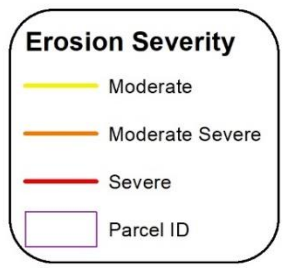
Length (ft)	1320
Erosion Height (ft)	24
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	1,062
Ownership	Public
Number of Owners	2
Stabilization Approach	Armor
Cost Estimate	1,295,900



Description: Steep slope with bare soils, several fallen trees and inermittent slumps. Occassional undercuts have also formed throughout the stretch, exposing root systems.

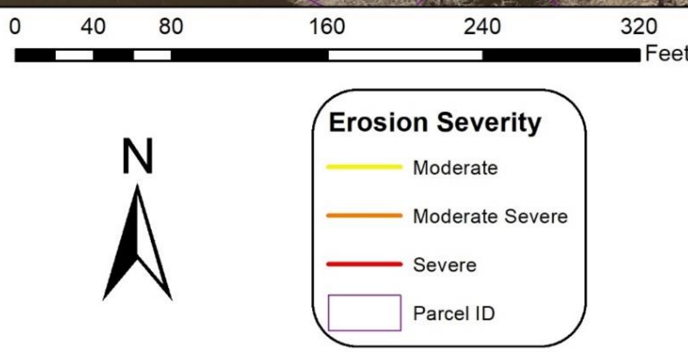


Length (ft)	57
Erosion Height (ft)	24
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.5
Soil Loss (tons/yr)	72
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	78,356

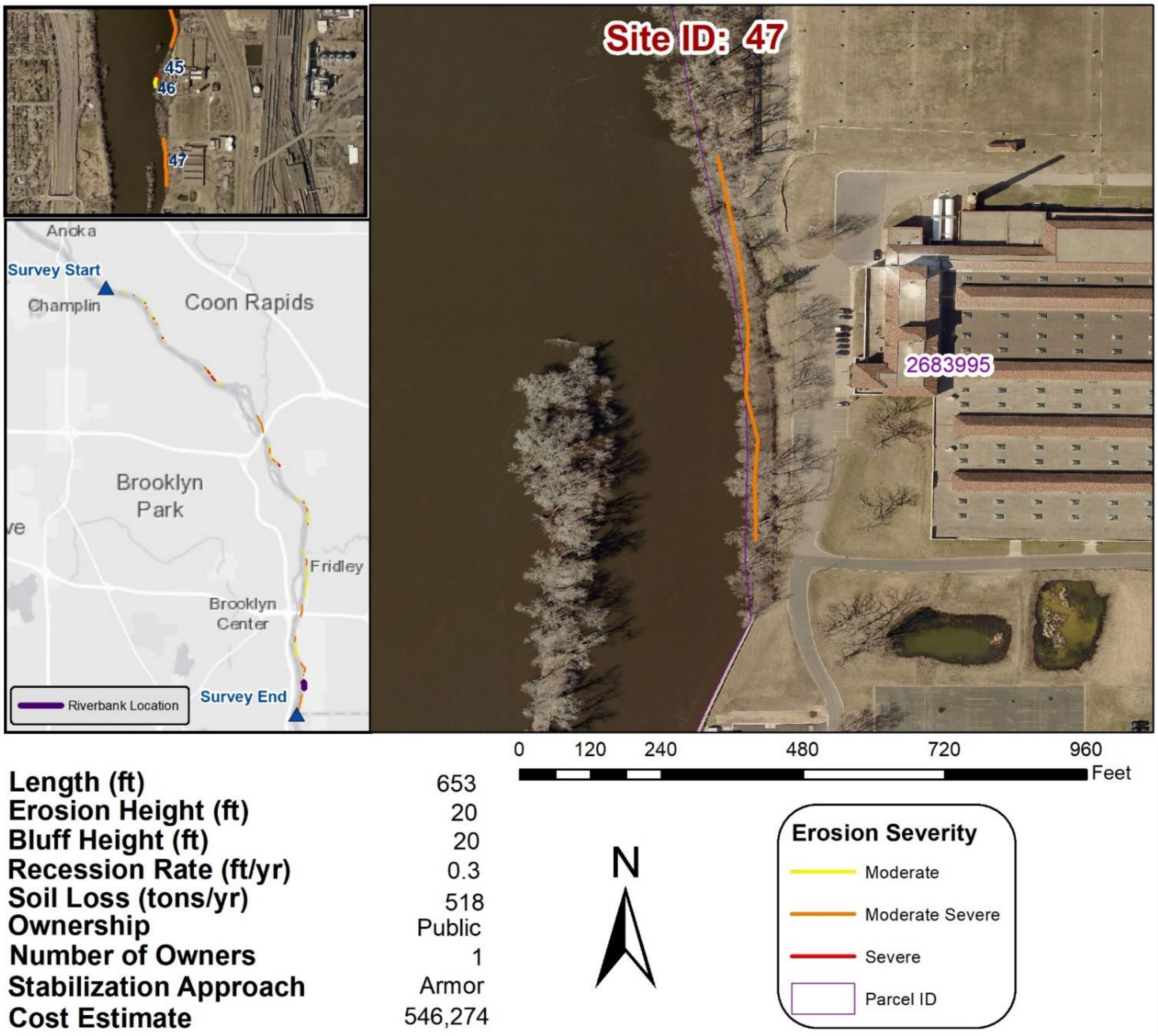


Description: Severe erosion is causing a vertical cliff. The adjacent stretch upstream is covered with concrete chunks stabilizing the bank.

Length (ft)	110
Erosion Height (ft)	4
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.1
Soil Loss (tons/yr)	6
Ownership	Public
Number of Owners	1
Stabilization Approach	Bio-eng.
Cost Estimate	84,821

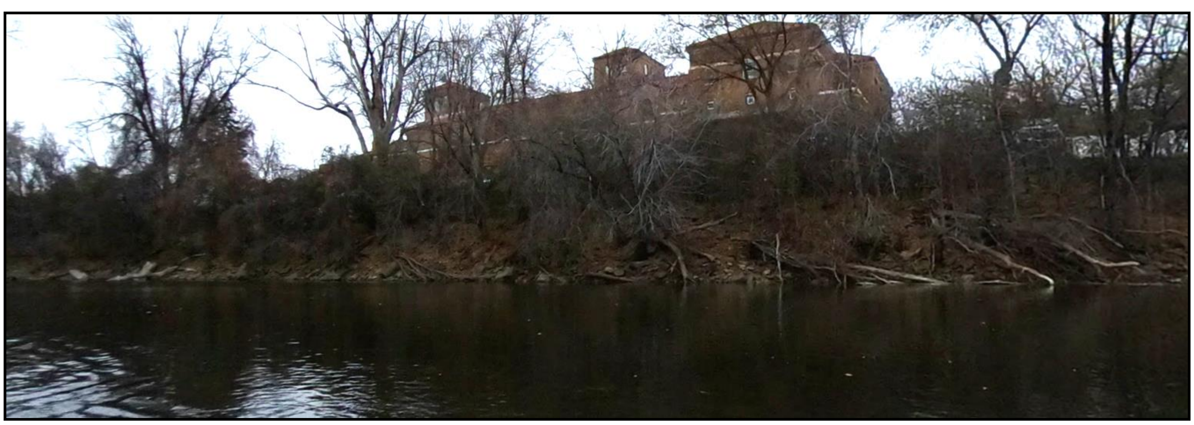


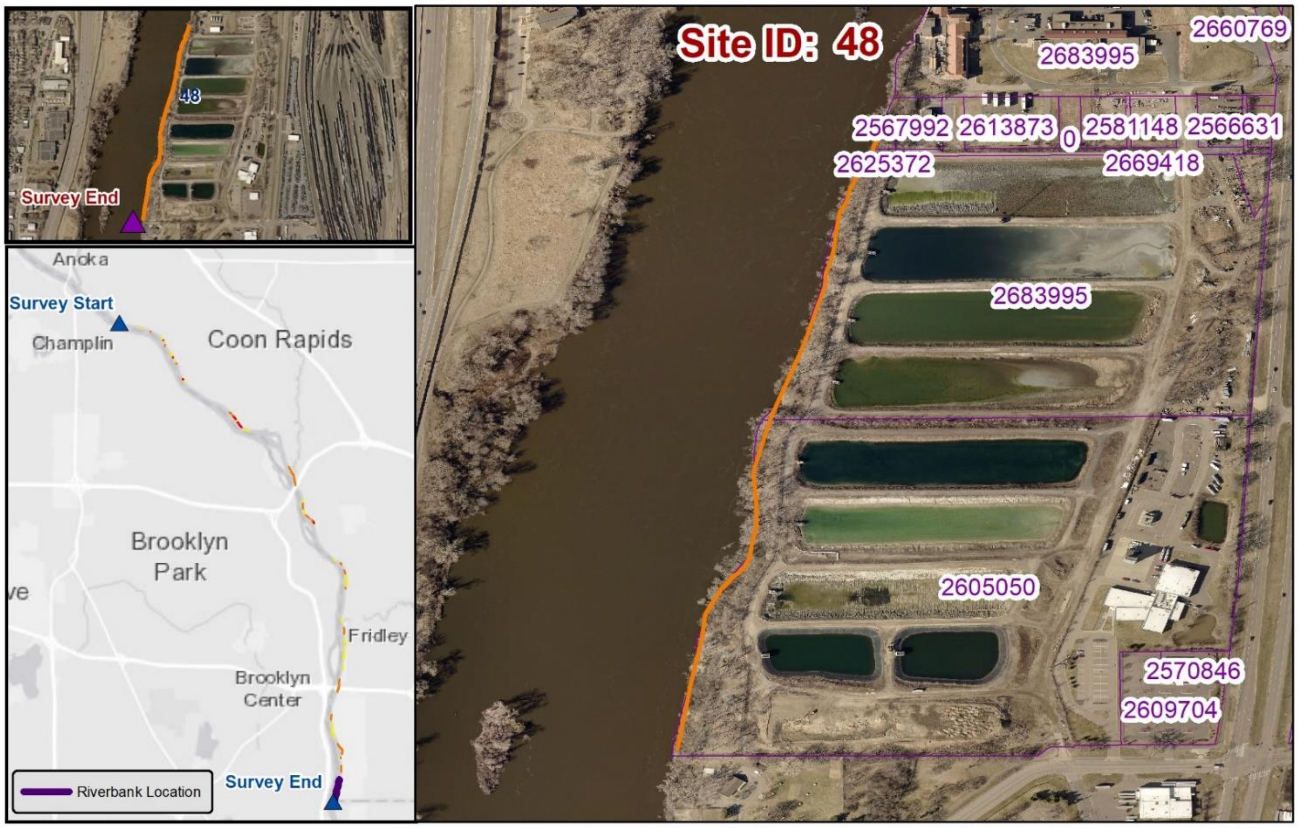
Description: An undercut at the toe is causing some vegetative overhang and exposed roots. Located along city of Minneapolis' water treatment facility.

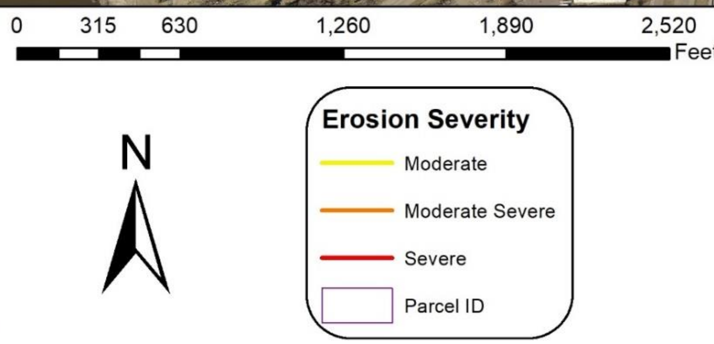


Length (ft)	653
Erosion Height (ft)	20
Bluff Height (ft)	20
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	518
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	546,274

Description: The slope is mostly bare with several trees that have fallen over along the slumped zone. Adjacent to City of Minneapolis' water treatment facility.







Length (ft)	2489
Erosion Height (ft)	18
Bluff Height (ft)	24
Recession Rate (ft/yr)	0.3
Soil Loss (tons/yr)	1,844
Ownership	Public
Number of Owners	1
Stabilization Approach	Armor
Cost Estimate	2,413,330

Description: Very steep slope ranging from 20' - 30' maintaining some vegetation but otherwise abundant in fallen trees and severely exposed roots from slumps/slips. An undercut toe is present in some portions. Adjacent to Minn. water treatment facility.

Appendix A: Eroded Riverbanks Data Table

Site ID	Length (ft)	Erosion Height (ft)	Bluff Height (ft)	Approach	Total Cost	Cost: Benefit ($/ton TSS)	Recession Rate (ft/yr)	Ownership	# Parcels	TSS (tons/yr)
1	63	6	6	Bio-eng.	$21,632	$299.22	0.10	Private	1	4.82
2	38	8	8	Bio-eng.	$19,578	$303.33	0.10	Private	1	4.30
3	77	12	12	Bio-eng.	$36,757	$85.04	0.30	Private	1	28.82
4	283	4	20	Bio-eng.	$172,218	$752.23	0.10	Private	2	15.26
5	154	24	24	Armor	$171,627	$43.76	0.50	Private	1	156.87
6	148	4	18	Bio-eng.	$85,435	$238.71	0.30	Private	1	23.86
7	424	6	24	Bio-eng.	$301,079	$266.48	0.10	Private	3	75.32
8	109	20	20	Armor	$116,123	$70.54	0.30	Private	2	65.85
9	91	26	26	Armor	$118,400	$47.00	0.50	Private	1	100.77
10	57	4	22	Bio-eng.	$46,404	$305.59	0.10	Private	1	10.12
11	58	18	18	Armor	$ 70,780	$95.30	0.30	Private	2	29.71
12	183	24	24	Armor	$204,814	$43.00	0.50	Private	2	190.54
13	148	10	10	Bio-eng.	$52,550	$149.31	0.10	Private	1	23.46
14	271	16	16	Armor	$197,514	$65.45	0.30	Public	1	120.71
15	137	16	16	Armor	$111,631	$71.21	0.30	Public	1	62.70
16	488	14	14	Armor	$ 297,377	$30.27	0.50	Public	1	393.01
17	190	18	18	Armor	$160,609	$193.56	0.10	Public	1	33.19
18	935	16	16	Armor	$622,574	$35.88	0.50	Public	1	694.01
19	517	4	10	Bio-eng.	$155,877	$295.32	0.10	Public	1	35.19
48	2489	18	24	Armor	$2,413,328	$52.35	0.30	Public	1	1844.13
20	2229	10	12	Bio-eng.	$759,996	$67.76	0.30	Public	1	747.68
21	315	12	20	Bio-eng.	$194,980	$207.01	0.10	Private	4	62.79
22	581	4	16	Bio-eng.	$283,815	$171.62	0.30	Private	6	110.25
23	303	4	12	Bio-eng.	$112,695	$460.95	0.10	Private	1	16.30
24	88	12	12	Bio-eng.	$40,431	$65.37	0.30	Private	1	41.24
25	94	12	12	Bio-eng.	$42,522	$86.37	0.30	Private	1	32.82
26	26	12	12	Bio-eng.	$19,768	$168.34	0.30	Private	1	7.83
27	206	14	14	Bio-eng.	$ 94,070	$95.68	0.30	Private	2	65.55
28	102	12	12	Armor	$73,099	$52.85	0.50	Private	1	55.32
29	84	12	12	Armor	$ 64,331	$56.63	0.50	Private	1	45.44
30	280	4	4	Bio-eng.	$42,404	$129.89	0.10	Fridley	1	21.76

Site ID	Length (ft)	Erosion Height (ft)	Bluff Height (ft)	Approach	Total Cost	Cost: Benefit ($/ton TSS)	Recession Rate (ft/yr)	Ownership	# Parcels	TSS (tons/yr)
31	259	10	28	Armor	$319,314	$135.93	0.30	Private	2	93.96
32	388	6	46	Bio-eng.	$521,112	$369.21	0.30	Private	5	94.09
33	1120	6	46	Bio-eng.	$1,468,211	$1,499.15	0.10	Private	7	65.29
34	181	8	42	Bio-eng.	$228,379	$260.92	0.30	Private	3	58.35
35	395	4	4	Bio-eng.	$55,240	$91.42	0.10	Public	1	40.28
36	698	24	24	Armor	$693,789	$48.60	0.30	Private	1	571.01
37	649	4	16	Bio-eng.	$314,096	$599.46	0.10	Private	6	34.93
38	110	22	22	Armor	$120,598	$226.33	0.10	Private	1	21.31
39	1023	4	4	Bio-eng.	$130,569	$109.63	0.10	Private; Public	3	79.40
40	420	4	4	Bio-eng.	$58,022	$99.93	0.10	Public	1	38.71
41	1395	6	14	Bio-eng.	$560,226	$85.50	0.30	Private; Unknown	2	436.84
42	585	4	22	Bio-eng.	$371,136	$261.96	0.30	Public	1	94.45
43	1476	5	16	Bio-eng.	$672,308	$408.49	0.10	Public	1	109.72
44	1320	24	24	Armor	$1,295,904	$48.79	0.30	Public	2	1062.33
45	57	24	24	Armor	$78,356	$43.42	0.50	Public	1	72.19
46	110	4	24	Bio-eng.	$84,821	$955.88	0.10	Public	1	5.92
47	653	20	20	Armor	$546,274	$42.16	0.30	Public	1	518.27
Total	22,006				$14,622,770				85	8,517

Stabilization Approach	Design/ Project Management ($/sq. ft.)	Design Minimum	Construction ($/sq.ft.)	Mobilization Cost	Landowner Upcharge	Description
Armor	$5.00	$14,000	$35.00	$10,000	$5,000	Heavy toe armament, significant grading, bank geotechnical stabilization
Bio-eng	$3.00	$6,000	$25.00	$5,000	$25,000	Light toe armament with minor grading and vegetative bank stabilization

Appendix B: Bank Measurement Methods

Height

Length