Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

INDIAN CREEK FLUVIAL GEOMORPHOLOGY STUDY, OLATHE, KANSAS

Final report to Olsson Associates for the City of Olathe, Kansas

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EXECUTIVE SUMMARY

Olsson Associates (OA) contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University to complete a geomorphic assessment of the channel network within Upper Indian Creek watershed in Olathe, Kansas. In this study, the field-based channel survey used is specifically focused on stream related problems involving public infrastructure and private property of a highly urbanized watershed. The assessment is designed to not only locate "problem" areas, but to also identify the causes of those problems. This study focused on the upper 11 mi^2 of Indian Creek that generally flows northeast from the City of Olathe from Avalon Street to Pflumm Road. The main channel of Indian Creek had the highest number of problems, but the tributaries have the highest density (problems per stream mile) of problems. In total, 5.2 miles of main channel and 9.6 miles of tributaries were evaluated for this project and 188 problems were identified and located. There were 55 problems located on the main channel, for a density of about 10 problems per stream mile. For the tributaries, there were 133 problems located for a density of nearly 14 problems per stream mile. This suggests the tributaries in this watershed appear to be changing more rapidly and offer more challenges in terms of infrastructure maintenance and protection than the main channel. The highest density of problems came from tributaries 7 and 8 (T-7 and T-8) west of Mur-Len Road and north of 135th street with >50 problems per stream mile. Impervious surfaces associated with urban land use have decreased infiltration capacity of the soil and increased the magnitude, duration and frequency of floods. Indian Creek and its tributaries have responded to the increase in flows by getting larger overall and locally unstable. Results of the main channel assessment suggest bank erosion is the major process creating infrastructure problems along the main channel as it appears bedrock is limiting incision along much of the channel. Channel incision along a series of head cuts moving upstream is the major process impacting public infrastructure and private property along the tributaries within the Indian Creek watershed. Additional study of geomorphic stability in Indian Creek should focus on the causes and rates of head cutting in the tributaries and the lateral rates of channel erosion in the lower segment with attention to the causes and bedrock control of bluff failure due to bank erosion.

SCOPE AND OBJECTIVES

Olsson Associates (OA) contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University to complete a geomorphic assessment of the channel network within Upper Indian Creek watershed in Olathe, Kansas. The City of Olathe is interested in protecting public infrastructure and private property adjacent to the actively eroding stream network. In this study, a field-based channel survey was used to assess stream related problems involving public infrastructure and private property of a highly urbanized watershed. The survey was combined with a geomorphic assessment to provide not only the causes of the current infrastructure problems, but can also indicate future potential problems based on indicators of erosion and visual field evidence. A geomorphic assessment involves the collection and interpretation of channel dimensions, boundary conditions, and disturbance indicators (e.g. bank erosion, bed scour, bar form) to support the planning and design phases for channel improvement and restoration projects. The purpose of this project was for MSU-OEWRI to provide OA with geomorphic information used to identify potential problems related to channel stability based on geomorphic activity, infrastructure protection, and level of concern. The objectives for the study were: (i) perform a field-based geomorphic assessment of stream related problems involving public infrastructure and private property, (ii) report the results of field surveys and in digital, GIS format, and (iii) provide general guidance to assess potential for future movement of the stream.

WATERSHED CHARACTERISTICS

Indian Creek (74.8 mi^2) is a 4th order tributary to the Blue River watershed of Kansas and Missouri (Figure 1). This study focused only on the upper 11 mi^2 of Indian Creek that generally flows northeast from the City of Olathe. Rapid encroachment by residential development has transformed an area previously in agriculture to urban residential and commercial land use today (Figure 2). This type of urban development typically increases the impervious surface area of the watershed and causes increased runoff into local streams.

In general, the bedrock geology of the area is composed of inter-bedded limestones and shales that are frequently exposed along the stream bed, especially along strath terraces in the main channel and lower tributaries (O'Conner, 2000). Upland and summit soils are derived from loess, while hillslope soils are formed in parent materials formed in the residuum and colluvium of weathered limestone and shale (Evans, 2005). Floodplains consist of relatively deep accumulations of silt-loam alluvium.

Streams in this urban setting typically show indications of relatively deep incision and channel widening in response to increased flows from urban development and possibly channelization during the construction phase. Small first and second order streams draining the uplands have downcut through easily erodible loess material and headcuts between 2-4 feet or more are common. As the streams enter the larger valley, alluvium thickness increases on the floodplains and sand and gravel start to appear along the bed of the stream. Larger gravel and cobble enter the stream near bedrock bluffs that occur along the valley margin and limit lateral channel migration. Bedrock also appears to limit channel incision at some locations since bedrock knickpoints were found along the bed in the main channel and lower reaches of the tributaries.

METHODS

Field-Based Assessment

OEWRI completed the field work for this report during the period March 19-21st, 2013 and May 7-9th, 2013. Two, two-person teams walked the length of main channel and tributaries to identify the location and severity of stream related infrastructure problems found in the watershed. These areas were classified as “Problems” and located on a map or with GPS points. A form was filled out for each problem that included the site number, stream ID, the station in feet, workers name, date, time, type of problem, the level of concern, and the geomorphic cause of the problem (Appendix A). A picture of each site was taken, cataloged, and put into the database for OA.

A total of 9 “problem” types were identified for this project and a description of each is provided below:

1. <u>Bank erosion and failure risk-commercial property</u> – Channel migration or channel widening poses a threat to commercial property that may include a building or parking lots (Photo 1). Level of concern is based on proximity to the property and the bank showing indicators of erosion such as bank angle, erosion scars, and newly uncovered tree roots.

2. <u>Bank erosion and failure risk-greenway trail</u> - Channel migration or channel widening poses a threat to a greenway trail (Photo 2). Much of the main channel has a greenway trail constructed adjacent to the stream. Level of concern is based on proximity to the trail and the bank showing indicators of erosion such as steepness of the bank angle, presence of recent erosion scars, and newly uncovered tree roots.

3. <u>Bank erosion and failure risk-public building</u> - Channel migration or channel widening poses a threat to a public owned building that may also include the parking lot (Photo 3). Level of concern is based on proximity to the property and the bank showing indicators of erosion such as steep bank angle, erosion scars, and newly uncovered tree roots.

4. <u>Bank erosion and failure risk-residential private</u> - Channel migration or channel widening poses a threat to residential private property (Photo 4). This may include channel encroachment on the property line that may threaten fences or outbuildings. Level of

concern is based on proximity to the property and bank erosion indicators such as bank angle, fresh erosion scars, and newly uncovered tree roots.

5. Bed erosion/undermining at bridge - Channel incision, or down-cutting has compromised the integrity of a bridge (Photo 5). Typically this will occur on the downstream footing when a headcut moves upstream lowering the stream bed or when a deep scour pool is formed downstream that undermines the bridge footing or wingwalls. Level of concern is based on the depth of the stream bed below the footing and any signs of failure to the bridge structure.

6. Exposed pipes or cables due to erosion - Occurs when channel migration or channel widening expose utility lines in the channel bank, or when channel incision exposes utilities in the bed of the stream (Photo 6). Level of concern is based on the type and degree of exposure, as well as presence of bank erosion indicators such as bank angle, fresh erosion scars, and newly uncovered tree roots

7. Failed culvert/inlet due to undermining - This occurs when flow carried through a pipe to the stream outlet undermines, or scours, below the apron causing bank erosion to occur (Photo 7). In some cases an attempt to stop the bank scour has occurred with rip-rap or large flat bedrock slabs. Level of concern is based on the severity of erosion around the pipe and any structural failure of the pipe or apron.

8. Hanging culvert or inlet due to incision - Bed incision has left a culvert outlet above, or "hanging" out over the bed of the stream (Photo 8). In many cases the apron and last section of pipe may have fallen into the stream creating a flow obstacle inducing local bank erosion and bed scour. Level of concern is based on the severity of erosion, the distance from the pipe to the bed, and presence of structural failure of the pipe or apron.

9. Sedimentation inside culvert decreasing flow capacity – Over-widened culvert cells or bridges can accumulate sediment that will decrease the ability of the structure to pass flood flows. Clogged culverts can cause upstream flooding and sedimentation problems. Level of concern is based on the degree of which the cell is blocked.

GIS Database

Following the field-based evaluation, each problem location was mapped in ArcGIS and given a X,Y coordinate and a site number was added to the GIS database field. The paper forms filled out during the site visit were entered into an excel spreadsheet. The excel spreadsheet was then brought into ArcGIS and joined with the point file of the mapped problem locations.

These data were then combined into a Personal Geodatabase and the pictures were tagged to each point in the map.

RESULTS

This assessment found that the main channel of Indian Creek had the highest number of problems, but the tributaries have the highest density of problems. In total, 5.2 miles of main channel and 9.6 miles of tributaries were evaluated for this project and 188 problems were identified and located. There were 55 problems located on the main channel, for a problem density of about 10 per mile (Table 1). For the tributaries, there were 133 problems located for a problem density of nearly 14 per mile. This suggests the tributaries in this watershed appear to be changing more rapidly and offer more challenges in terms of infrastructure maintenance and protection than the main channel. This is expected since tributaries are still responding to recent development by head cutting, incision, and bank failure. A description of each stream and the number and types of problems that were found are outlined below.

Stream Descriptions and Problems

Main Channel – The main channel of Indian Creek begins at the confluence of the Upper Main channel and T-3 downstream of 151st street. The channel flows generally northeast to where the assessment ended at Pflumm Road. There were about 10 problems per mile of stream in the main channel with bank erosion being the most frequent. The riparian corridor is preserved along much of the main channel and therefore limits the number of places bank erosion threatens residential property. However, along the lower section of the main channel, bank erosion and bluff undermining are threatening to erode property and possibly compromise some of the structures along the north bank. A greenway trail is adjacent to the stream over much of the main channel and bank erosion threatened to undermine the trail at several locations. Bed and bank erosion has uncovered utilities along the main channel and several storm pipe outlets have been undermined or are hanging above the channel bed.

Upper Main (T-1) – The upper main channel starts at Avalon Street and flows south to the confluence of T-3 downstream of 151st street. Many places along this section of stream show signs of small head cuts, channel incision and widening, particularly above 153rd street. The head cuts do appear to be checked by several bridges that cross the stream due to the placement of large rock aprons on the downstream side. However, lateral migration has started to erode into utilities and property lines. Downstream of 153rd street to 151st street a concrete trickle channel limits incision, however, erosion of the backfill and erosion mat has started to occur. Downstream of 151st street a meander has formed just above a bedrock knick point creating lateral bank erosion. Below the channel is incised to where it meets T-3.

<u>T-2</u> – This is a short length of channel that flows parallel to 153rd street on the east side of the upper main tributary. Bank erosion has uncovered utilities and scour below the culverts have compromised the headwall/collars on the downstream side.

<u>T-3</u> – This tributary flows east from Ridgeview Road to the confluence of the upper main tributary. A series of progressive head cuts beginning at the confluence are moving upstream and end at the double barrel culvert at station 2,000 ft. Upstream of the culvert the channel is stable.   Bank erosion and incision are threatening pipe outlets, pedestrian bridges, and private property downstream.

<u>T-4</u> – Flows north from 148th street to the confluence with T-5 downstream of 147th street. Bank erosion and channel incision are threatening private property, utilities, and pipe outlets.

<u>T-5</u> – Begins at a park west of Blackfoot Road between 147th and 148th terrace. Bank erosion and channel incision are threatening private property, utilities, and pipe outlets.

<u>T-6</u> – This tributary begins just west of Brougham Drive and flows west toward the confluence with T-5. The stream flows from a large culvert and rectangular concrete channel into a natural bed stream. In this “natural” section, channel incision and bank erosion are threatening private property and utilities. A large grouted rip-rap channel connects this section to a section with a concrete tickle channel that is beginning to be undermined in places.

<u>T-7</u> – This tributary flows from a culvert west of Mur-Len to where it meets T-8. This tributary appears to have down cut substantially exposing several pipes and cables and undermining a possible sewer main crossing.

<u>T-8</u> – The tributary flows east from Lindenwood Drive, under Mur-Len Road and meets the main channel just north of 135th street. An extremely high number of problems were found along this stream and T-7, likely due to the proximity of commercial and residential property and the supporting utilities. Bank erosion and channel incision are threatening property and utilities, particular sanitary sewer, along most of the stream.

<u>T-9</u> – This tributary flows north from 134th street to the main channel of Indian Creek. A head cut is progressing upstream and the culvert at 134th street is starting to become undermined. Also, a beaver dam is obstructing flow just upstream of 133rd street.

T-10 – This tributary begins just north of 124th Terrace and flows east toward to where it meets the main channel west of Blackbob road and north of 127th street. The channel in the upper sections of this tributary have a concrete trickle channel that is being undermined at some locations. The channel transitions into a large incised channel before it flows under Arapaho Drive. The channel flows adjacent to residential properties and has eroded around several grade control structures to where it becomes very sinuous with high banks just above Blackbob Road. Below Blackbob, a bedrock knick point limits further incision near the confluence with T-11.

T-11 – Flows south from a culvert and runs parallel to Blackbob Road to where it meets T-10 just north of 125th Street. This channel appears to have been channelized and grade control structures were installed to limit incision. While incision does appear to be minimized, the channel is beginning to migrate laterally which has caused the channel to erode around the grade control structures and is starting to compromise the block wall running along the east bank in some places.

T-12 – This short stream segment begins just south of 125th street and flows down to the main channel just upstream of the Hallet Street trailhead. A head cut has moved upstream from the main channel creating very high banks causing bank erosion and widening to occur.

T-13 – The tributary begins west of Greenwood street flowing north under 127th street to where it meets the main channel west of Pflumm Road. Incision and bank erosion, particularly lateral migration, in the upper portions of this tributary threatens residential property and has compromised the integrity of the pedestrian bridges that cross it several times in this reach. Below 127th street a series of head cuts is progressing upstream toward the bridge and utilities are exposed in several places.

T-14 – This stream begins west of Widmer street and flows northwest to the confluence of T-13. The majority of the channel is within a dense riparian corridor, but a high degree of meandering has the channel near residential property creating bank erosion.

GEOMORPHIC HISTORY AND ADJUSTMENTS TO LAND USE CHANGE

Results of the field-based assessment show incision and bank erosion are the main causes of problems in the study watershed. The processes of incision, widening, and lateral channel migration observed in this stream are similar to the classic Channel Evolution Model in fluvial geomorphology (Figure 3). Urban development has increased flow rates to Indian Creek causing the channel to respond. Incision, or down cutting, of the stream bed has created over-steepened reaches causing head cuts to move upstream through the channel network. In some cases, channelization during construction phase may have started the head cutting process. Downstream of the head cut the lowering of the bed leaves high banks with steep angles that are susceptible to erosion. This results in further widening of the channel. Sediment eroded from the bed and banks can be deposited downstream creating areas of low channel slope causing the stream to adjust by lateral migration.

Main Channel Processes

Results of the main channel assessment suggest bank erosion is the major process creating infrastructure problems along the main channel of Indian Creek as it appears bedrock is limiting incision along much of the channel. Increased impervious surface in the watershed due to urban development has caused the main channel to enlarge from increased storm water loads. Channel width increases rapidly downstream going from about five feet in the upper main channel to about 40 ft about five miles downstream at station 10,000 ft (Table 3, Figure 4). At the same time channel depth increases at a much lower rate from about 5-10 ft at station 15,000 ft. This suggests bedrock that was observed along the bed has limited the ability of the channel to incise, as a result the channel is increasing its capacity through bank erosion (Photo 10). However, below station 8,000 ft, where there is a large bedrock knick point in the stream, evidence suggests the channel bed has lowered through incision as the banks are getting higher as the channel width is getting lower (Photo 11). This pattern on incision and bedrock control is likely to continue downstream beyond the limits of this study. Also, in the lower 8,000 feet of steam the channel appears to be migrating into high loess bluffs with houses built near the edge. The stability of the slope and the level of stability due to bedrock needs to be determined.

Headcuts in the Tributaries

Channel incision is the major process impacting public infrastructure and private property along the tributaries within the Indian Creek watershed. Primary, secondary, and in some cases tertiary head cuts were observed in all tributaries investigated for this project (Photo 12). The lowering of the bed exposes utility crossings and undermines culverts as the head cuts progress upstream. Subsequent bank erosion has created a situation where liberated sediment is deposited downstream in areas of lower slope causing the lateral channel migration. Lateral migration creates problem areas in the tributaries when the channel meanders into private property and utilities (typically phone and cable lines) that are often placed adjacent to the back property lines (Photo 13). Furthermore, obstacles and other debris (homemade rip-rap, trees, trash etc.) along the tributaries add to local stream instability (Photo 14).

REFERENCES

Evans, B.C. (2005). Soil Survey of Johnson County, Kansas. United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Kansas Agricultural Experiment Station.

O'Conner, H.G. (2000). Geologic Map of Johnson County, Kansas. Kansas Geological Survey, The University of Kansas, MAP M-92. Geology Mapped in 1954-1961.

Schumm, S.A., M.D. Harvey, and C.C. Watson (1981). Yazoo Basin geomorphology. Final Report USDA, SCS, Project SCS 23-MS-80, 483 pp.

TABLES

Table 1. Problems by Stream Mile

Stream	Total Distance (mi)	# Problems	Problems/Mile
Main Channel	5.21	55	10.6
T-1 – Upper Main	1.91	17	8.9
T-2	0.08	3	37.5
T-3	0.59	4	6.8
T-4	0.38	4	10.5
T-5	1.67	12	7.2
T-6	0.51	11	21.6
T-7	0.11	6	54.5
T-8	0.57	30	52.6
T-9	0.27	2	7.4
T-10	1.46	15	10.3
T-11	0.49	9	18.4
T-12	0.17	1	5.9
T-13	1.14	12	10.5
T-14	0.25	7	28
Total	14.81	188	12.7

Table 2. Problem Type Summary by Stream

Stream	# Prob.	Problem Types								
		Bank Erosion-Commercial	**Bank Erosion-Trail**	**Bank Erosion-Public**	**Bank Erosion-Private**	**Bed Erosion-Bridge**	**Bed/Bank Erosion-Utilities**	**Under-mined Outlet**	**Bed Erosion-Outlet**	**Culvert Sediment-ation**
Main	55	2	12	-	13	2	9	7	10	-
Upper Main	17	-	3	2	3	4	1	-	4	-
T-2	3	-	-	-	-	2	1	-	-	-
T-3	4	-	-	-	1	2	-	1	-	-
T-4	4	-	-	-	2	-	1	-	1	-
T-5	12	-	-	1	3	-	2	2	4	-
T-6	11	-	-	-	2	5	-	4	-	-
T-7	6	2	-	-	-	2	2	-	-	-
T-8	30	4	-	1	-	7	7	1	8	2
T-9	2	-	-	-	-	2	-	-	-	-
T-10	15	-	-	-	5	4	1	3	2	-
T-11	9	-	-	-	2	5	-	1	-	1
T-12	1	-	-	-	-	1	-	-	-	-
T-13	12	-	-	-	1	4	2	4	1	-
T-14	7	-	1	-	4	-	-	2	-	-
Total	188	8	16	4	36	40	26	25	30	3

Table 3. Channel Morphology

Stream	Station (ft)	Sinuosity	Channel Width (ft)	Bank Ht (ft)	% Exposed Bedrock
Main	700	Mod	23.0	14.8	0
Main	1,500	Mod	33.1	13.8	0
Main	2,250	Mod	14.8	6.6	5
Main	3,200	Mod	26.2	13.1	0
Main	3,600	Mod	31.5	9.5	0
Main	5,200	Low-Mod	32.1	8.5	5
Main	5,800	Hight	32.8	6.2	20
Main	8,600	Low	42.6	6.6	60
Main	10,100	Mod	36.1	6.9	0
Main	10,900	High	38.4	6.9	5
Main	11,700	Low-Mod	28.9	9.8	0
Main	14,400	Mod	29.2	9.8	5
Main	16,200	Mod	25.3	10.8	5
Main	17,200	High	36.1	8.2	50
Main	18,900	Mod	37.7	9.2	0
Main	20,800	Low	26.2	9.2	0
Main	22,000	Low	26.2	7.9	0
Main	23,200	Low	14.8	4.9	60
Main	23,700	Low	14.8	6.6	5
Main	24,600	Straight	14.8	4.6	0
Main	25,000	Low	11.5	3.3	0
Main	25,450	Low	16.4	3.6	0
Main	26,200	Low	18.0	3.3	30
Main	27,200	Mod	18.0	5.6	0
Main	27,700	Low-Mod	19.7	3.9	50
Upper Main	300	Low	13.1	8.2	0
Upper Main	1,200	Low	26.2	4.3	50
Upper Main	2,000	High	16.4	7.2	60
Upper Main	4,400	Straight	9.8	2.6	5
Upper Main	4,800	Straight-low	8.9	3.0	30
Upper Main	5,500	Mod	9.8	7.5	0
Upper Main	5,800	Mod	11.5	8.2	0
Upper Main	6,700	Mod	10.5	5.9	0
Upper Main	7,800	Mod	9.2	4.9	0
Upper Main	8,600	Low	3.9	3.9	0
Upper Main	9,200	Mod	5.6	4.6	0

FIGURES

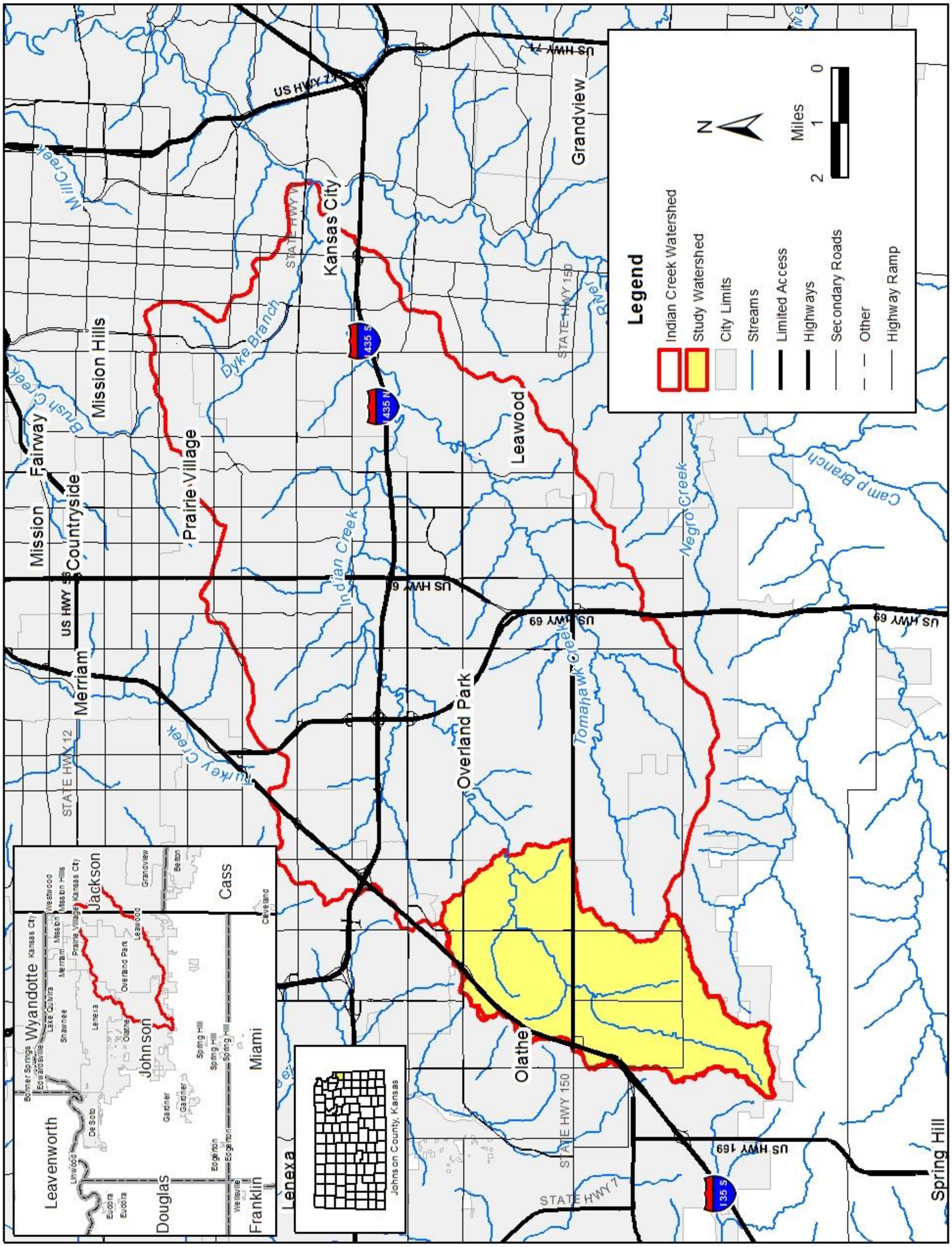


Figure 1. Indian Creek Watershed of Johnson County, Kansas and Jackson County, Missouri.

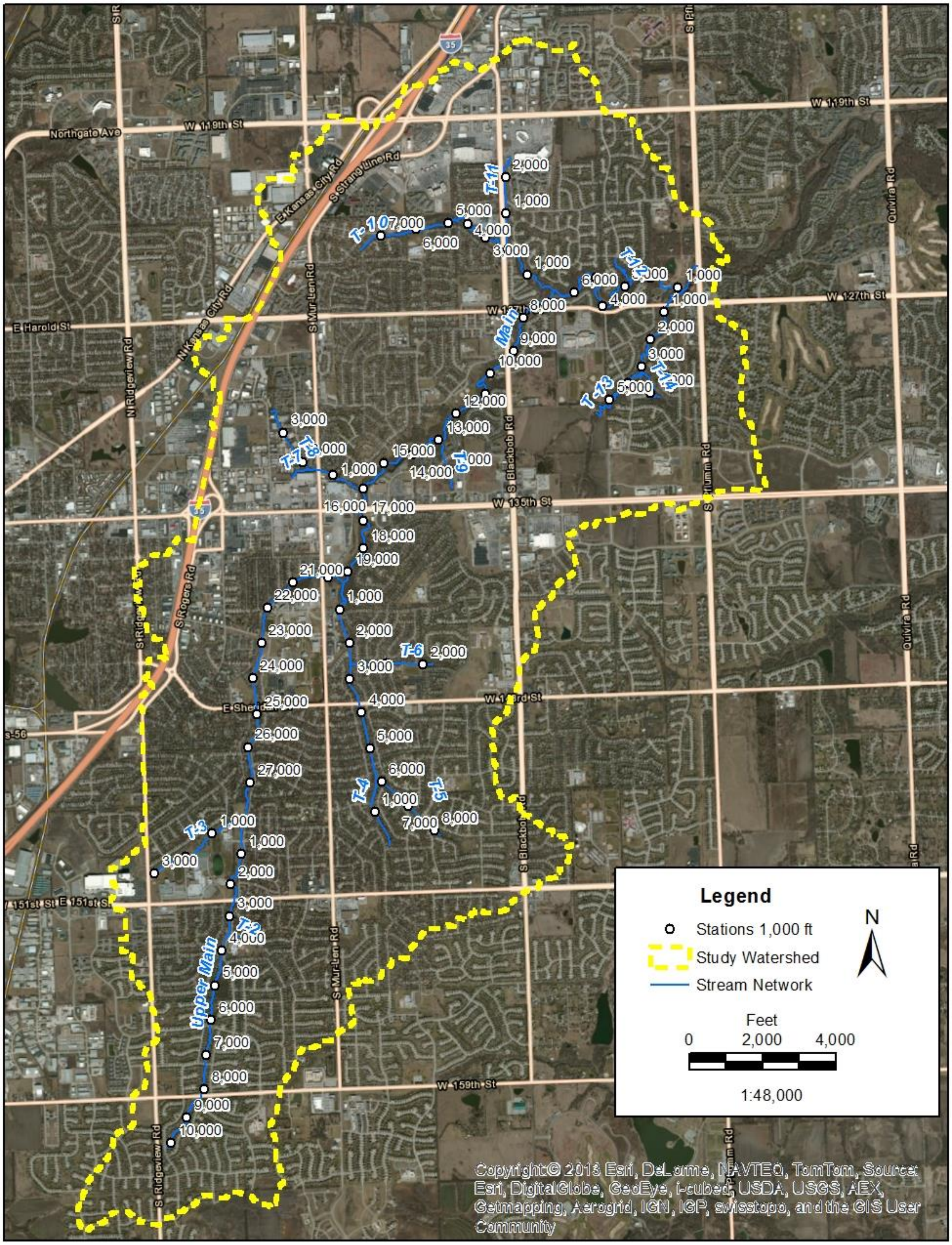


Figure 2. Study watershed with stations.

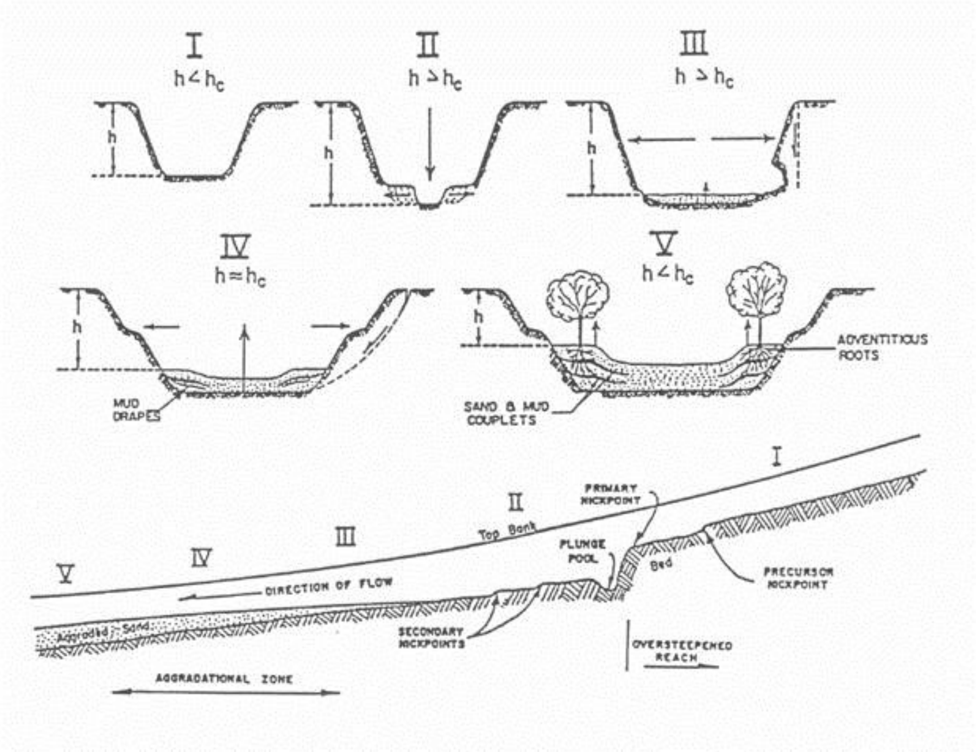


Figure 3. The Channel Evolution Model (Schumm et al. 1981)

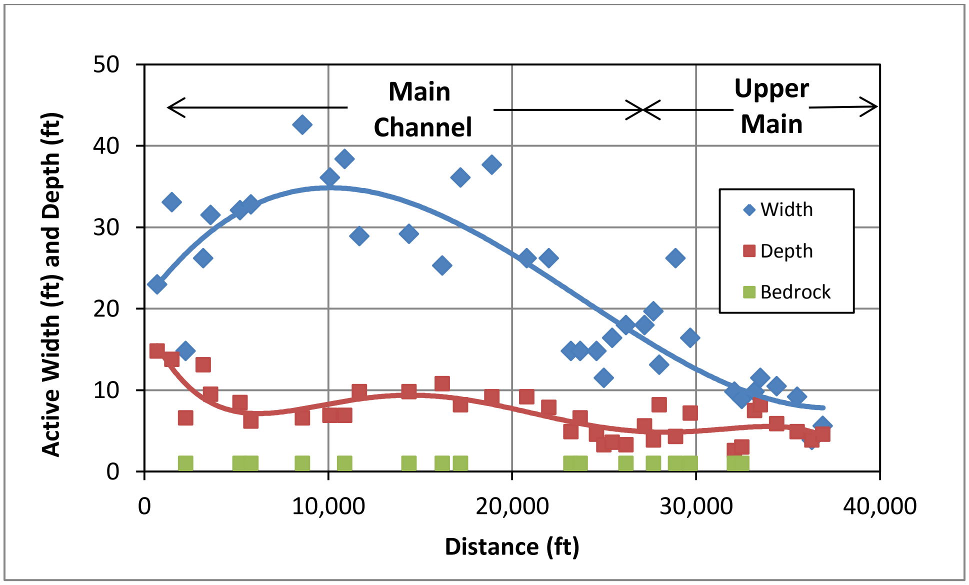


Figure 4. Channel Dimensions and Bedrock Influence

PHOTOS

Photo 1. Example of problem type 1. Bank erosion and failure risk-commercial property

Photo 2. Example of problem type 2. Bank erosion and failure risk-greenway trail

Photo 3. Example of problem type 3. Bank erosion and failure risk-public building

Photo 4. Example of problem type 4. Bank erosion and failure risk-residential private

Photo 5. Example of problem type 5. Bed erosion/undermining at bridge

Photo 6. Example of problem type 6. Exposed pipes or cables due to erosion

Photo 7. Example of problem type 7. Failed culvert/inlet due to undermining

Photo 8. Example of problem type 8. Hanging culvert or inlet due to incision.

Photo 9. Example of problem type 9. Sedimentation inside culvert decreasing flow capacity.

Photo 10. Example of main channel widening - high vertical banks, exposed tree roots, and slumping are indicators of erosion.

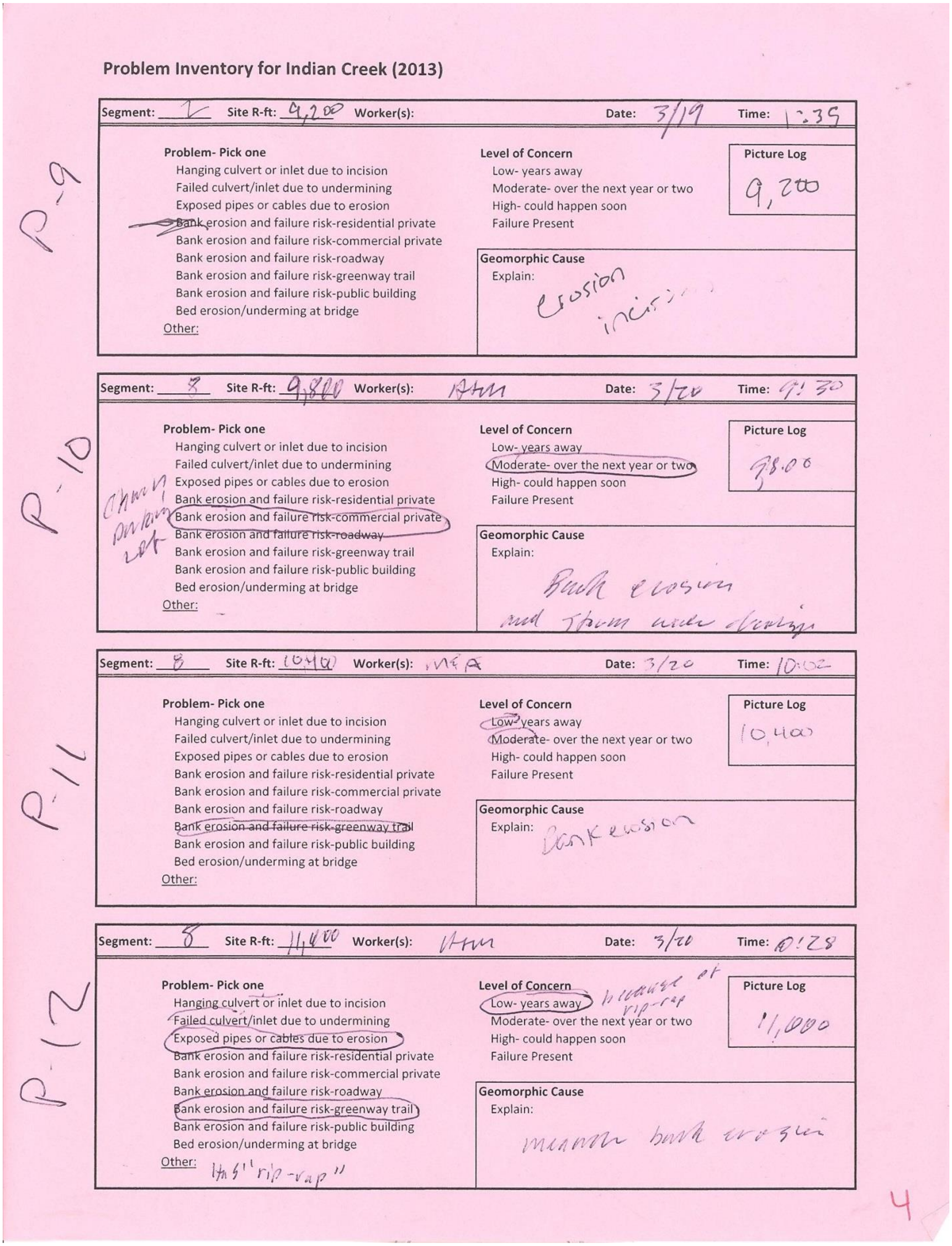
Photo 11. Bedrock knickpoints serve as natural grade controls in the main channel and in the lower reaches of many tributaries.

Photo 12. Headcuts are progressing upstream in most of the tributaries.

Photo 13. Lateral channel migration encroaches on to private property in areas downstream of headcuts.

Photo 14. Local residents are trying to protect their land in areas where bank erosion threatens their property.

APPENDIX A



Problem Inventory for Indian Creek (2013)

P-9

Segment: 7 **Site R-ft:** 9,200 **Worker(s):** **Date:** 3/19 **Time:** 1:35

Problem- Pick one
Hanging culvert or inlet due to incision
Failed culvert/inlet due to undermining
Exposed pipes or cables due to erosion
[✓ Bank erosion and failure risk-residential private]
Bank erosion and failure risk-commercial private
Bank erosion and failure risk-roadway
Bank erosion and failure risk-greenway trail
Bank erosion and failure risk-public building
Bed erosion/underming at bridge
Other:

Level of Concern
Low- years away
Moderate- over the next year or two
High- could happen soon
Failure Present

Picture Log
9,200

Geomorphic Cause
Explain: Erosion incision

P-10

Segment: 8 **Site R-ft:** 9,800 **Worker(s):** AHM **Date:** 3/20 **Time:** 9:30

Problem- Pick one
Hanging culvert or inlet due to incision
Failed culvert/inlet due to undermining
Exposed pipes or cables due to erosion
Bank erosion and failure risk-residential private
[✓ Bank erosion and failure risk-commercial private]
~~Bank erosion and failure risk-roadway~~
Bank erosion and failure risk-greenway trail
Bank erosion and failure risk-public building
Bed erosion/underming at bridge
Other: -

Chinese parking lot

Level of Concern
Low- years away
[✓ Moderate- over the next year or two]
High- could happen soon
Failure Present

Picture Log
98.00

Geomorphic Cause
Explain: Bank erosion and storm water drainage

P-11

Segment: 8 **Site R-ft:** 10400 **Worker(s):** MEA **Date:** 3/20 **Time:** 10:02

Problem- Pick one
Hanging culvert or inlet due to incision
Failed culvert/inlet due to undermining
Exposed pipes or cables due to erosion
Bank erosion and failure risk-residential private
Bank erosion and failure risk-commercial private
Bank erosion and failure risk-roadway
~~Bank erosion and failure risk-greenway trail~~
Bank erosion and failure risk-public building
Bed erosion/underming at bridge
Other:

Level of Concern
[✓ Low- years away]
[✓ Moderate- over the next year or two]
High- could happen soon
Failure Present

Picture Log
10,400

Geomorphic Cause
Explain: Bank erosion

P-12

Segment: 8 **Site R-ft:** 11,000 **Worker(s):** AHM **Date:** 3/20 **Time:** 10:28

Problem- Pick one
Hanging culvert or inlet due to incision
Failed culvert/inlet due to undermining
[✓ Exposed pipes or cables due to erosion]
Bank erosion and failure risk-residential private
Bank erosion and failure risk-commercial private
Bank erosion and failure risk-roadway
[✓ Bank erosion and failure risk-greenway trail]
Bank erosion and failure risk-public building
Bed erosion/underming at bridge
Other: has 5" rip-rap"

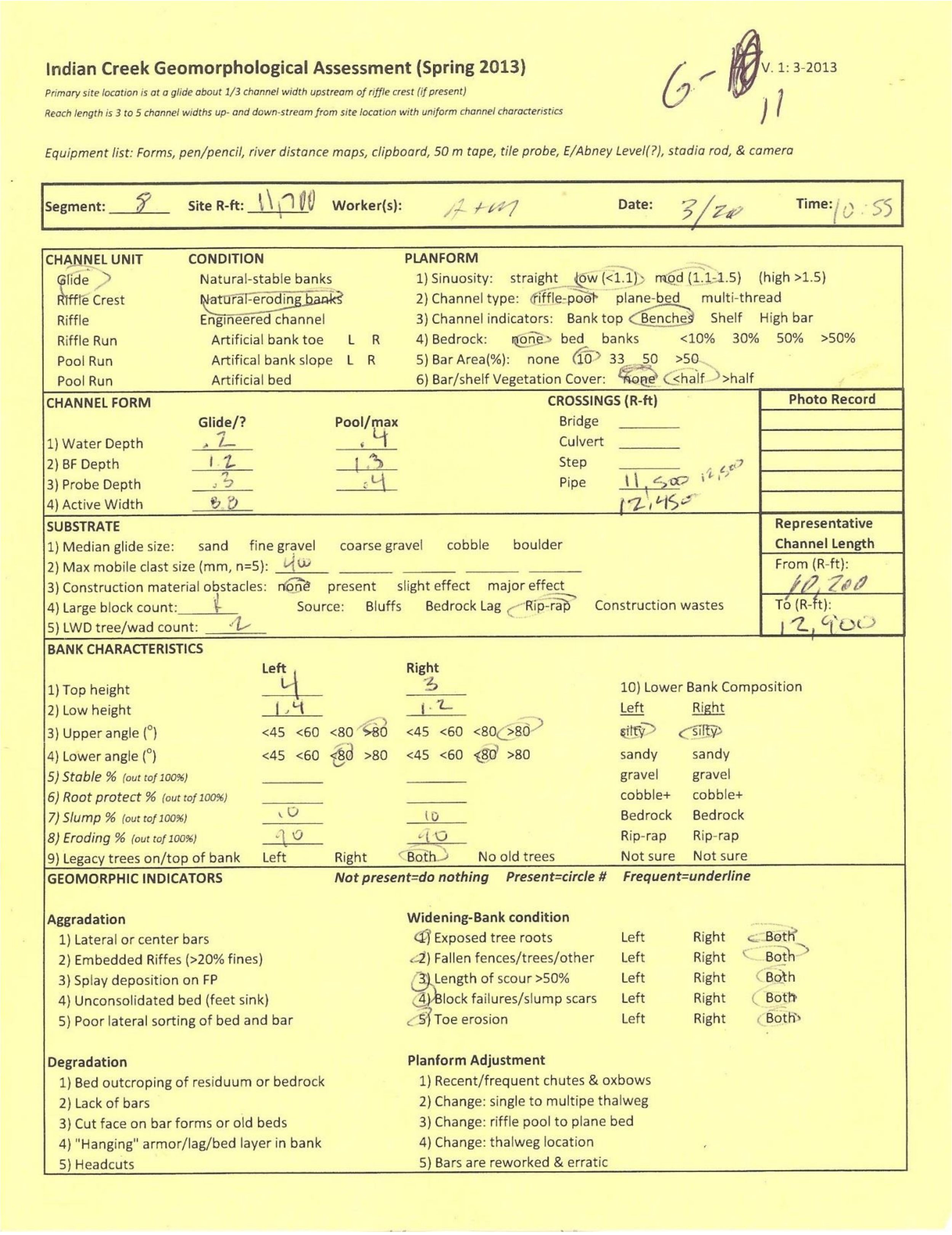
Level of Concern
[✓ Low- years away] because of rip-rap
Moderate- over the next year or two
High- could happen soon
Failure Present

Picture Log
11,000

Geomorphic Cause
Explain: meander bank erosion

4

APPENDIX B



Indian Creek Geomorphological Assessment (Spring 2013)

G-~~10~~ 11

V. 1: 3-2013

Primary site location is at a glide about 1/3 channel width upstream of riffle crest (if present)

Reach length is 3 to 5 channel widths up- and down-stream from site location with uniform channel characteristics

Equipment list: Forms, pen/pencil, river distance maps, clipboard, 50 m tape, tile probe, E/Abney Level(?), stadia rod, & camera

Segment: 8 **Site R-ft:** 11,700 **Worker(s):** A+M **Date:** 3/20 **Time:** 10:55

CHANNEL UNIT
- [✓ Glide]
- Riffle Crest
- Riffle
- Riffle Run
- Pool Run
- Pool Run

CONDITION
- Natural-stable banks
- [✓ Natural-eroding banks]
- Engineered channel
  - Artificial bank toe L R
  - Artifical bank slope L R
  - Artificial bed

PLANFORM
1) Sinuosity: straight [✓ low (<1.1)] mod (1.1-1.5) (high >1.5)
2) Channel type: [✓ riffle-pool] plane-bed multi-thread
3) Channel indicators: Bank top [✓ Benches] Shelf High bar
4) Bedrock: [✓ none] bed banks <10% 30% 50% >50%
5) Bar Area(%): none [✓ 10] 33 50 >50
6) Bar/shelf Vegetation Cover: [✓ none] [✓ <half] >half

CHANNEL FORM

	Glide/?	Pool/max
1) Water Depth	.2	.4
2) BF Depth	1.2	1.3
3) Probe Depth	.3	.4
4) Active Width	8.8	

CROSSINGS (R-ft)

Bridge ______
Culvert ______
Step ______
Pipe 11,500 12,500 12,450

Photo Record

SUBSTRATE
1) Median glide size: sand fine gravel coarse gravel cobble boulder
2) Max mobile clast size (mm, n=5): 40
3) Construction material obstacles: [✓ none] present slight effect major effect
4) Large block count: 1 Source: Bluffs Bedrock Lag [✓ Rip-rap] Construction wastes
5) LWD tree/wad count: 2

Representative Channel Length

From (R-ft): 10,200

To (R-ft): 12,900

BANK CHARACTERISTICS

	Left	Right
1) Top height	4	3
2) Low height	1.4	1.2
3) Upper angle (°)	<45 <60 <80 [✓ >80]	<45 <60 <80 [✓ >80]
4) Lower angle (°)	<45 <60 [✓ <80] >80	<45 <60 [✓ <80] >80
5) Stable % *(out tof 100%)*		
6) Root protect % *(out tof 100%)*		
7) Slump % *(out tof 100%)*	10	10
8) Eroding % *(out tof 100%)*	90	90

9) Legacy trees on/top of bank Left Right [✓ Both] No old trees

10) Lower Bank Composition

Left	Right
[✓ silty]	[✓ silty]
sandy	sandy
gravel	gravel
cobble+	cobble+
Bedrock	Bedrock
Rip-rap	Rip-rap
Not sure	Not sure

GEOMORPHIC INDICATORS ***Not present=do nothing Present=circle # Frequent=underline***

Aggradation
1) Lateral or center bars
2) Embedded Riffes (>20% fines)
3) Splay deposition on FP
4) Unconsolidated bed (feet sink)
5) Poor lateral sorting of bed and bar

Widening-Bank condition
[✓ 1)] Exposed tree roots Left Right [✓ Both]
[✓ 2)] Fallen fences/trees/other Left Right [✓ Both]
[✓ 3)] Length of scour >50% Left Right [✓ Both]
[✓ 4)] Block failures/slump scars Left Right [✓ Both]
[✓ 5)] Toe erosion Left Right [✓ Both]

Degradation
1) Bed outcroping of residuum or bedrock
2) Lack of bars
3) Cut face on bar forms or old beds
4) "Hanging" armor/lag/bed layer in bank
5) Headcuts

Planform Adjustment
1) Recent/frequent chutes & oxbows
2) Change: single to multipe thalweg
3) Change: riffle pool to plane bed
4) Change: thalweg location
5) Bars are reworked & erratic