Section 5
Geomorphic Evaluation

5.1 Introduction

Fluvial geomorphology is the science of how moving water shapes the land. It is the fundamental discipline of river science and provides a quantitative description of stream behavior now and reasonable predictions of future behavior under specified conditions. Fluvial geomorphology and the related disciplines of hydrology and hydraulic engineering, geology and soil science together provide the technical underpinnings for sound watershed management. A more thorough discussion of the basic principles of Fluvial Geomorphology is presented in Appendix E.

The purpose of the Haines Branch geomorphic investigation is to determine the basic geomorphic conditions of the main stem and selected tributaries. Understanding the geomorphic conditions of theses streams will help determine the locations and prioritizations of interventions for managing the main stem and tributaries. Following is a brief overview of geomorphic principles with an emphasis on their application to stream and watershed management.

Streams exist in a state of dynamic equilibrium in which the forces driving channel form are balanced by the resisting forces. The driving force is gravity, acting on a stream by determining the rate at which water and sediment move through the channel while the resisting forces are the strength of the channel boundary materials and friction expressed as the channel shape. When the driving forces exceed the resisting forces, the stress applied by water or sediment exceeds the channel strength. The stream channel responds by altering its shape in plan, profile and cross-section to accommodate the change in flow volume and applied shear. Once disturbed, the processes by which streams respond are (in order):

1) Incision or degradation
2) Widening
3) Aggradation or deposition and
4) Plan form adjustments

Through these processes, disturbed streams eventually re-establish equilibrium. Determining which process is dominant and the likely progression of stream processes is one of the principle challenges of stream management. Schumm (1984) and Simon (2001) have described the process by which streams reacquire equilibrium after a disturbance in the watershed. Simon separates changes in channel morphology into six stages:

Stage I Pre-disturbance

- Bed and bank materials balanced with erosive forces
- Permanent woody vegetation near the water line
- Two-stage channel shape evident at about 1.8 year return interval

Stage II Disturbance

- Channel altered, hydrology or sediment inputs modified
- Removal of permanent woody vegetation near the water line
- Two-stage channel shape eliminated or no longer supported by flow conditions

Stage III Incision

- Downcutting liberates sediment
- Lost or perched bankfull floodplains
- "U" shaped channel
- Woody vegetation high on bank with many "surfer" trees

Stage IV Channel Widening

- Widespread bank failures as banks exceed critical height or were undercut by toe scour
- Channel adjusts to new flow regime
- Significant sediment loads generated; most significant erosion hazard in this phase

Stage V Deposition

- Deposition begins from liberated sediment
- Vegetation establishes near water line

Stage VI Recovery and Reconstruction

- Bankfull floodplains may be reconstructed from liberated sediment
- Woody vegetation establishes near water line
- Stability re-established

Each of these phases is depicted on Figure 5-1.

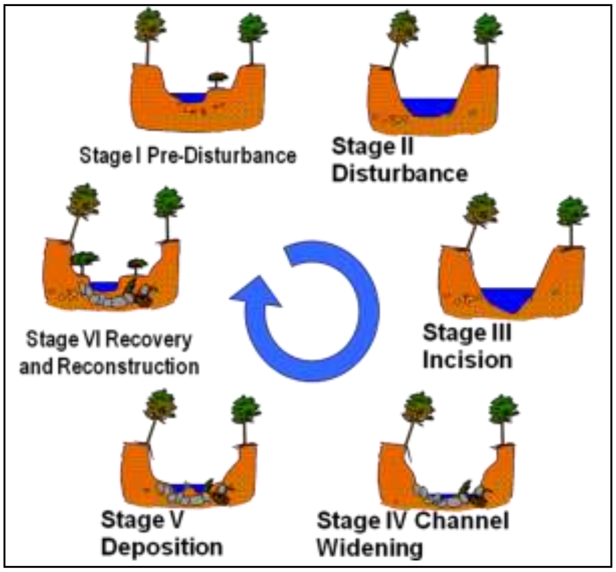

Figure 5-1 Channel Evolution Stages

5.2 Methodology

During April 2013, a geomorphic field reconnaissance was conducted on 28 miles of main stem and tributaries in the Haines Branch Watershed Study Area. A Rapid Reconnaissance Geomorphic Data Collection Method was used to determine the basic geomorphic conditions of the Haines Branch channels. This method was adapted from the Johnson, Gleason and Hey white paper "Rapid Assessment of Channel Stability in Vicinity of Road Crossing" published in the Journal of Hydraulic Engineering, June 1999 and evaluates the primary geomorphic parameters to determine the base health of the channel.

The field reconnaissance was completed by highly experienced Engineers/ Geomorphologists. The experience of the field team allowed the reconnaissance data to be further supplemented with the field engineer's opinion of dominant process based on the field observations at each channel condition data point. The field data was collected on a Trimble Yuma Rugged Tablet with integrated GPS and ESRI ArcMap 10.1 software containing the City's latest GIS data.

The main stem fieldwork limits were taken as the confluence with Salt Creek upstream to the approximate limit of the City's three-mile extraterritorial zoning jurisdiction. The tributary fieldwork limits were developed by focusing on the higher stream order reaches (the larger channels). The tributary upstream fieldwork limits began where there was one mile or more of identified drainage way contributing to the tributary. Typically, the upstream stopping point was set to the nearest roadway or confluence. It was anticipated that these headwater reaches, due to their location in the watershed, would be in dynamic equilibrium, managed by the landowner or in the early stages of incision. Some exceptions to the contributing stream length were made where the tributary was fed by a development or where known issues were present.

Fieldwork evaluation generally progressed from downstream to upstream. The rapid reconnaissance was stopped in the identified tributaries where the tributaries were found to be stable, a managed swale or in the early stages of incision, which was typically observed when the bank height approached four feet or less. This assessment was verified to not be a local anomaly by checking the tributary at the next upstream road crossing.

Field data was collected for three data categories:

1. Channel Condition Data
2. Reach Summary Data
3. Potential Capital Improvement Project Data

The following pages describe the methods and approach for each of the data categories.

<u>Channel Condition Data</u>

Channel Condition Data points were taken at regular intervals throughout the watershed. The following 13 rating categories were evaluated at each channel condition data point:

1) Bank soil texture and coherence
2) Average bank slope angle
3) Average bank height
4) Vegetative bank protection

5) Bank cutting
6) Mass wasting (wedge or slide slope failure)
7) Bar development
8) Debris jam potential
9) Obstructions, flow deflectors and sediment traps
10) Channel bed material consolidation and armoring
11) Percentage of channel cross section constriction
12) Sediment movement
13) Sinuosity (ratio of the channel length to valley length). This data was developed in the office, not in the field.

Each of the above 13 rating categories at each channel condition data point were assigned a score of 1 for good, 2 for fair or 3 for poor. The criteria used to determine a good, fair or poor rating for each of the rating is provided in Appendix F – Channel Condition Scoring Matrix and Channel Condition Data.

106 channel condition data points were taken during the rapid reconnaissance.

The Channel Condition Scores provide an indication of the lateral, vertical and overall stability of the channel at the channel condition point location as follows:

- GOOD – The channel is competently managing channel flows and sediment without significant erosion and the channel material, vegetation and shape in plan, profile and section are indicative of a state of dynamic equilibrium.

- FAIR – The channel is experiencing erosion and lateral/vertical migration but possesses channel material, vegetation and/or channel shape features that are indicative of active erosion that has not progressed to critical bank failures.

- POOR – The channel is actively eroding and moving laterally/vertically and many of the channel materials, vegetation and shape features indicate current and severe instability.

The field investigators also recorded the observer’s opinion of dominant process at each of the 106 channel condition points. Multiple dominant processes were recorded in the channel condition points if the observer noticed strong indications of multiple processes. The channel condition point locations are illustrated in Figure 5-3.

<u>Reach Summary Data</u>

The 28 miles of Haines Branch main stem and selected tributaries were sub-divided into 51 reaches based on road crossings, confluence locations and other natural and/or manmade features. The reach limits assigned in the office were verified in the field and several of the reach limits were adjusted in the field to correspond with observed physical features or changes in process. If a reach limit was changed in the field, a note was placed in the reach summary data explaining the revision.

The reaches along the main stem were given a unique alphanumeric name with the format HBRXXX. “HB” is the two-letter code for the Haines Branch Watershed. “RXXX” is a three-digit reach number. Generally the reach numbers were assigned in increments of five to allow for future subdivision (e.g., HBR005, HBR010).

The tributary reaches were also given a unique alphanumeric name with the format HBYYYRXXX. “HB” is the two-letter code for the Haines Branch Watershed. “YYY” is a three-digit tributary number. Tributary numbers were assigned in increments of five. Generally, the hundredths placeholder was used to identify branches along the tributary. “RXXX” is a three-digit reach number. Generally the reach numbers were assigned in increments of five. An incremental assignment was used to allow for future subdivision or addition of tributaries. Figure 5-2 illustrates the Haines Branch Reaches.

Reach summary data was prepared in the field at the end of each reach walked. The reach summary data includes the observer’s opinion of dominant process for the reach based on key indicators of dominant process observed in the field. The field engineer recorded his observations by entering “TRUE” for each of the following 42 key indicators that were observed to be present in the reach:

Indicators of Dynamic Equilibrium –

- No persistent scour or erosion features
- Bankfull shelf along one or both banks
- Gradually sloping banks
- Herbaceous vegetation growing at or near the water surface
- Well established woody vegetation on healed failure surfaces
- Vegetated, consolidated bars
- Consolidated bed material
- Imbricated rock bed material
- De facto grade controls reinforcing knickpoints
- Healthy riparian corridor and canopy cover

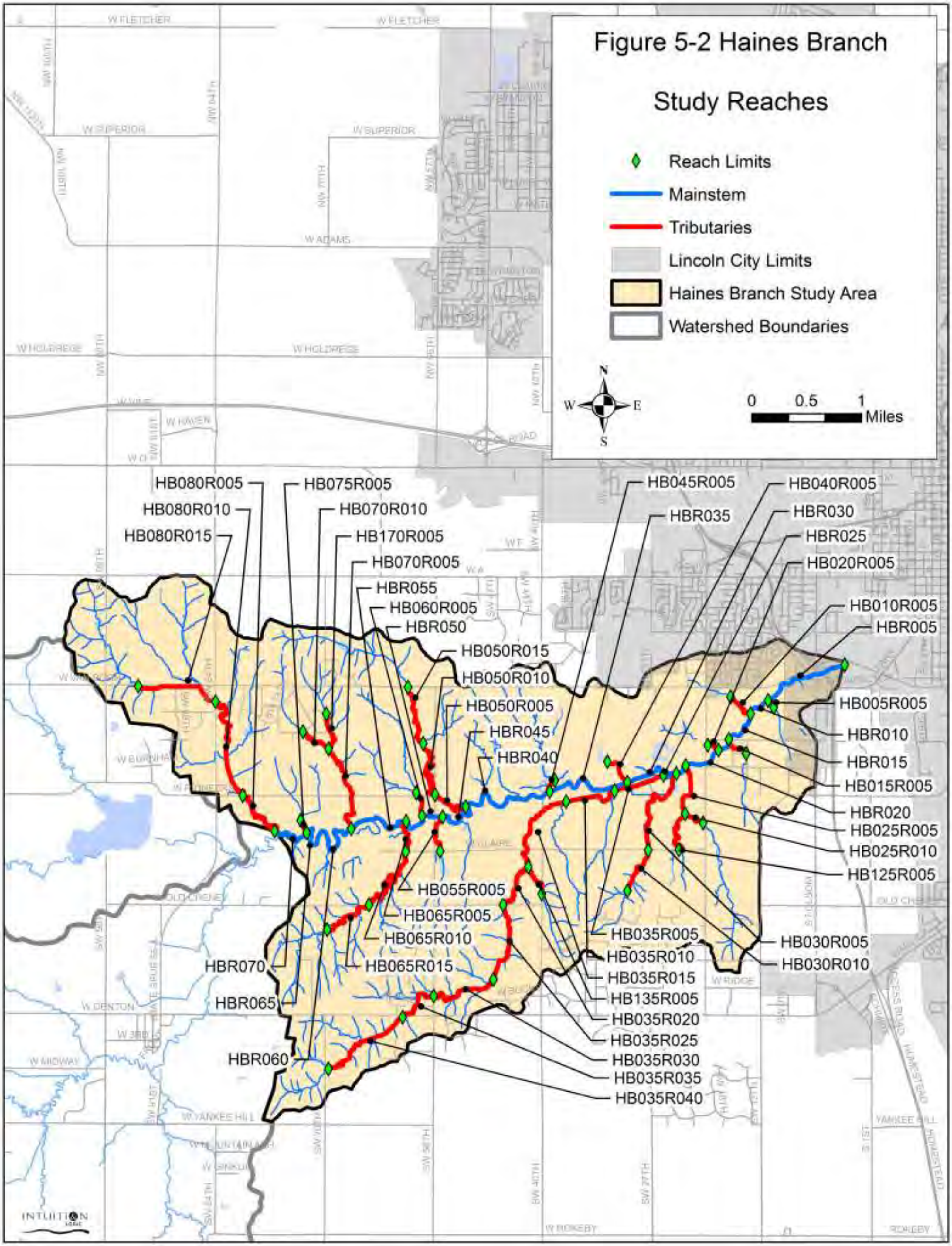

Figure 5-2 Haines Branch
Study Reaches
Reach Limits
Mainstem
Tributaries
Lincoln City Limits
Haines Branch Study Area
Watershed Boundaries
N
W
E
S
0
0.5
1
Miles
HB080R005
HB080R010
HB080R015
HB075R005
HB070R010
HB170R005
HB070R005
HBR055
HB060R005
HBR050
HB050R015
HB050R010
HB050R005
HBR045
HBR040
HB045R005
HBR035
HB040R005
HBR030
HBR025
HB020R005
HB010R005
HBR005
HB005R005
HBR010
HBR015
HB015R005
HBR020
HB025R005
HB025R010
HB125R005
HB030R005
HB030R010
HB055R005
HB065R005
HB065R010
HB065R015
HBR070
HBR065
HBR060
HB035R005
HB035R010
HB035R015
HB135R005
HB035R020
HB035R025
HB035R030
HB035R035
HB035R040
W FLETCHER
W SUPERIOR
W ADAMS
W HOLDREGE
W HAVEN
W BURNHAM
W DENTON
W MIDWAY
W YANKEE HILL
W ROKEBY
YANKEE HILL
ROKEBY
INTUITION

Indicators of Incision –

- “V” or “U”-shaped channel cross-section
- Persistent scouring on both banks toe to mid slope
- Wedge failures along both banks
- Steep, near vertical banks
- Perched bankfull floodplain or abandoned terraces
- Knickpoints and knickzones occurring in channel profile
- Steep bed slope
- Scoured bed material
- Consolidated bed material
- Frequent, large woody debris jams
- Lower limit of woody vegetation high with exposed roots
- Undercut or perched infrastructure

Indicators of Widening –

- Wide, “U”-shaped channel cross-section
- Increase in cross sectional area
- Increase in channel width and decrease in bank height from upstream to downstream
- Scouring or bank failures along both banks
- Persistent scouring on both banks mid to upper slope
- Residual failure material at bank toes
- Unconsolidated, depositional bed material
- Depositional center bars
- Unconsolidated, depositional sediment bars
- Reinforced knickpoints and knickzones
- Large woody debris jams
- Lower limit of woody vegetation high with exposed roots
- Numerous surfing or overhanging trees

Indicators of Planform Adjustment (meander advance and lateral migration)

- Cutbanks with active scour lines opposite of advancing bar formations
- Circular failures along alternating banks or at the outside of bends
- Alternating pattern of scour and deposition.
- Bar formations are consolidated, with an unconsolidated leading edge.
- Bar material unsorted with fines downstream.
- Bar is irregularly shaped and more than 1/3 across the channel.
- Poorly sorted bed material

The reach summary data is provided in Appendix G.

<u>Potential Capital Improvement Project Data</u>

In addition to the Channel Condition Data and the Reach Summary Data, potential capital improvement projects were investigated and/or identified in the field. Utilities near or crossing the channel and structures near the top of bank were located in GIS prior to field work and each location was evaluated in the field as potential capital improvement projects. If a potential project was identified, potential solutions were identified and project data was recorded in the field. Project data included the potential project location point, project notes, grade control locations, bank stabilization limits and more as appropriate for each potential project. The project identification process, associated data and the identified projects are discussed in further detail in Section 7.

At the conclusion of the field work, the following data is available:

1. Channel Condition Point Data – erosions features identified and scored producing a channel condition score at each channel condition data point in addition to the observer's opinion of dominant processes for each channel condition point.
2. Reach Summary Data – the observer's opinion of dominant process for each reach and a list of indicators observed throughout the reach which resulted in the dominant process opinion.
3. Potential Capital Improvement Projects identified

5.3 Results

Channel Condition Data

Each of the 13 previously mentioned rating categories were evaluated at each of the 106 channel condition data point locations and assigned a score of 1 for good, 2 for fair or 3 for poor. The following table presents the average assigned values recorded for each of the 13 channel condition rating categories of the 106 field scores:

Table 5.1 Average Field Score Per Channel Condition Rating Category

Table 5.1 **Channel Condition Rating Category**	**Average Field Score**	**Average Rating**
Bank soil texture and coherence	1.0	Good
Average bank slope angle	2.5	Fair - Poor
Average bank height	2.2	Fair
Vegetative bank protection	2.5	Fair - Poor
Bank cutting	2.6	Poor - Fair
Mass wasting (wedge or slide slope failure)	2.6	Poor - Fair
Bar development	2.8	Poor
Debris jam potential	2.0	Fair
Obstructions, flow deflectors and sediment traps	1.5	Good - Fair
Channel bed material consolidation and armoring	2.9	Poor
Percentage of channel cross section constriction	1.3	Good - Fair
Sediment movement	2.5	Fair - Poor
Channel Sinuosity	1.7	Fair - Good

The scores for each of the above 13 categories were weighted according to Johnson et. al and the weighted scores summed to produce an overall channel condition score for each field channel condition data point. The weighting factors for each data category are presented in Appendix F - Channel Condition Scoring Matrix. The weighted Channel Condition Score for each data point ranges between 8 and 24. The resulting weighted channel condition score and rating for each data point are as follows:

Table 5.2 Number of GOOD, FAIR and POOR Field Scores

Table 5.2 Weighted Channel Condition Score Range	Number of Channel Condition Points in the Range	Percent of Channel Condition Points in the Range
GOOD – score of 8 – 10.9	1	1%
FAIR – score of 11 to 16.9	23	22%
POOR – score of 17 or greater	82	77%

Overall the Haines Branch channels walked are rated poor with an average channel condition score of 18.0. The overall score of 18 for the assessed Haines Branch channels should not be taken as a true average condition for the entirety of the study area. This score does not include the upper channels that were not walked and the upper channels were observed to be stable, managed swales or in the early stages of incision. The overall score of poor instead represents a general condition of the major channels located lower within the watershed study area.

The major drivers of the poor channel scores were bank cutting, mass wasting, bar development and bed material. Bank cutting was observed as significant and frequent cutting to almost continuous cut banks. Mass wasting was also observed to be frequent and extensive on the main stem and lower tributary reaches. The poor bar development and bed material scores indicate that channel instability is ongoing and normal bar patterns are not forming. The bed material is not suitable to resist erosion and self-armor in a stable riffle pool sequence. High banks (over 12 feet tall) with steep bank slopes, overhanging vegetation with extensive root exposure were common throughout the main stem and lower tributaries. These conditions were repeatedly observed throughout the channels walked as illustrated in Figure 5-3.

Photo - Haines Branch Main Stem Mass Wasting

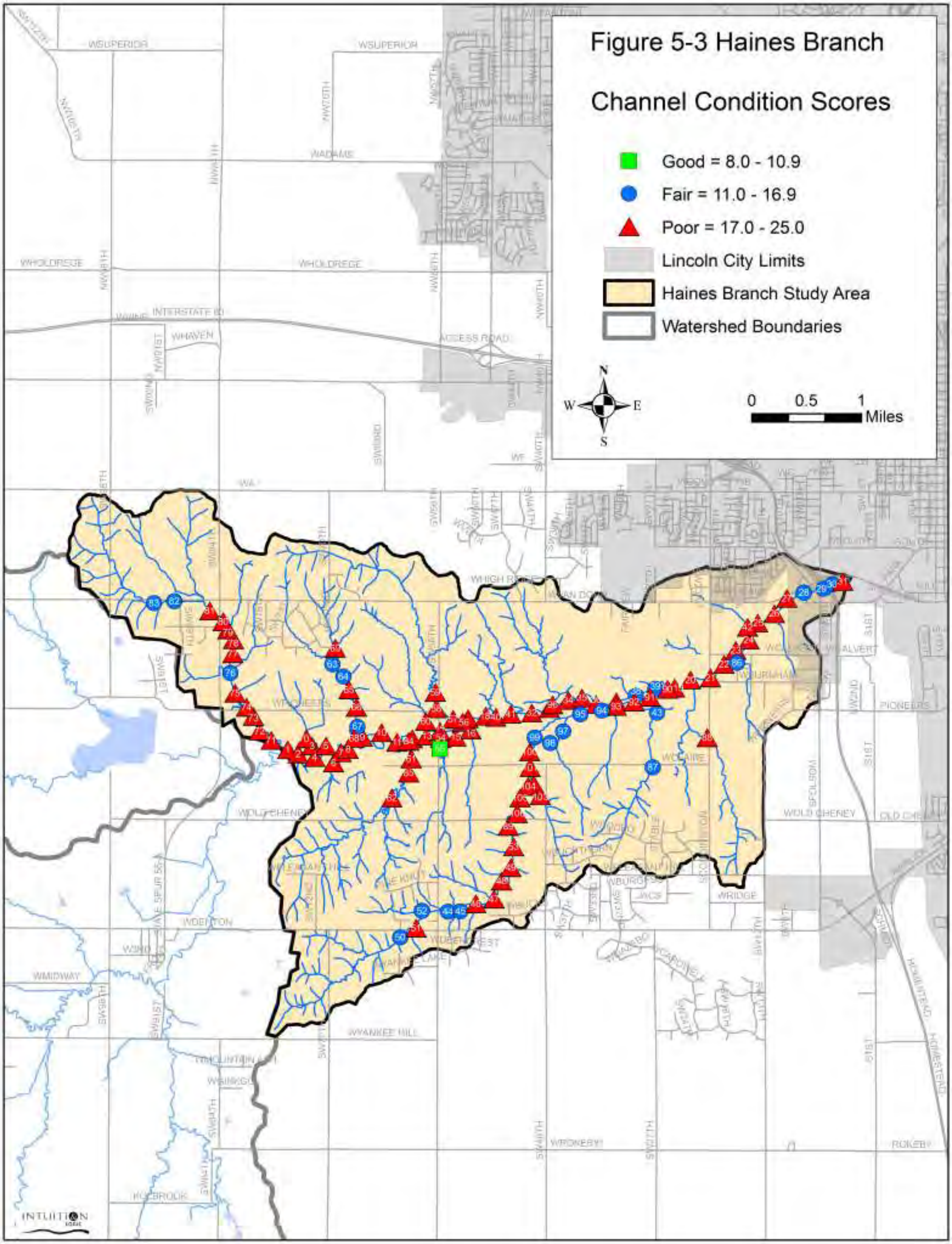

Figure 5-3 Haines Branch
Channel Condition Scores
Good = 8.0 - 10.9
Fair = 11.0 - 16.9
Poor = 17.0 - 25.0
Lincoln City Limits
Haines Branch Study Area
Watershed Boundaries
N
W
E
S
0
0.5
1
Miles

Reach Summaries
42 key indicators of dominant process were evaluated and recorded for each of the 51 Haines Branch reaches walked. The resulting diagnosis for dominant process driving instability in the Haines Branch main stem is incision in the lower reaches, widening through the middle reaches and planform adjustment in the uppermost reach. The dominant process for the tributaries was primarily incision, which is logical as the tributaries adjust and incise to match the main stem flowline. Figure 5-4 illustrates the dominant process by reach.

Main Stem Incision Reaches - The lower Haines Branch main stem (incorporating reaches HB005 through HB025) is incising from a point approximately 2,600 feet upstream of S Coddington Ave downstream to the confluence with Salt Creek about 1,500 feet east of the intersection of W Van Dorn St and Highway 77. The dominant indicators of incision in these reaches include:

- Wedge failures along both banks
- Steep near vertical banks
- Perched bankfull floodplain or abandoned terraces
- Lower limit of woody vegetation high with exposed roots
- Undercut or perched infrastructure

Main Stem Widening Reaches – The Haines Branch main stem is widening from a point approximately 2,600 feet upstream of S Coddington Ave upstream to a point 2,000 feet west of SW 56th St (incorporating reaches HB030 to HB055). The dominant indicators of widening through these reaches include:

- Scouring or bank failures along both banks
- Residual failure material at bank toes - The residual failure material at the bank toes is a key indicator that the geomorphic process has progressed from incision to widening.
- Lower limit of woody vegetation high with exposed roots
- Numerous surfing or overhanging trees

Main Stem Plan Form Adjustment Reaches – The Haines Branch main stem was observed to be in plan form adjusting from a point approximately 2,000 feet west of SW 56th St to a point approximately 2,000 feet south of W Pioneers Blvd at the rail road track crossing (incorporating reaches HB 060 to HB070). The dominant indicators of plan form adjustment in the upper reach include:

- Cutbanks with active scour lines opposite of advancing bar formations
- Circular failures along alternating banks or at the outside of bends
- Bar formations are consolidated with an unconsolidated leading edge
- Bar is irregularly shaped and more than 1/3 across the channel
- Bar parameters such as consolidation and shape are the key indicators that the geomorphic process has progressed from widening to plan form adjusting.
- Poorly sorted bed material

The channel degradation on the main stem is in the latter stages of incision, widening and planform adjustment. The main stem appears to have gone through previous cycles of incision - widening - planform adjustment based on the depth of the channel and the presence of multiple slump levels and terraces higher on the banks.

Active erosion and mass wasting along Haines Branch main stem is still evident by recent slumps and treefalls. Recent slumps and wedge failures were observed to have fresh, loose exposed dirt, orange colored exposed roots, grass and vegetation on the slump/wedge with clean cut lines where the slump/wedge separated from the bank. The recent tree falls were observed to have loose dirt on the root mass and green un-wilted leafy vegetation.

Tributary Incising Reaches - The dominant process driving instability in the tributaries, with one exception, is incision. The dominant indicators of incision in the tributaries include:

- V" or "U" shaped channel cross section
- Persistent scouring on both banks toe to mid slope
- Steep near vertical banks
- Lower limit of woody vegetation high with exposed roots

Tributary Plan Form Adjustment Reach - Reach HB080R005 is the lower portion of Tributary 80 on the western limits of the Haines Branch Study area from W Pioneers Blvd to the confluence with Haines Branch Main Stem. The dominant indicators of planform adjustment along tributary HB080R005 include:

- Circular failures along alternating banks or at the outside of bends
- Alternating pattern of scour and deposition
- Bar material unsorted with fines downstream
- Bar is irregularly shaped and more than 1/3 across the channel
- Poorly sorted bed material

Tributary Early Stage Incision Reaches – Several of the tributaries display signs of early stage incision. The dominant indicators of early stage incision in the tributaries include:

- Channel is less than 4 feet deep
- Scour in the channel
- Lower limit of woody vegetation high with exposed roots

Tributary Managed Swale Reaches – Two of the Haines Branch tributaries, HB030R005 and HB025R005, are managed swales. Typical indicators of tributary managed swale reaches include:

- Growth of crops across swale
- Trapezoidal shape
- Mowed or managed vegetation
- No natural channel features

Tributaries are experiencing various stages of impacts in response to changes in the mainstem. The incision on the tributaries is active and varies from shallow, early-stage incision to deep, late-stage incision. In general, the deep, late-stage incision started at the main stem confluence where the tributaries incised to match the deeply incised main stem flowline. Road crossing culverts and various grade controls placed by land owners help slow incision on some of the tributaries. Figure 5-4 illustrates the dominant process by reach.

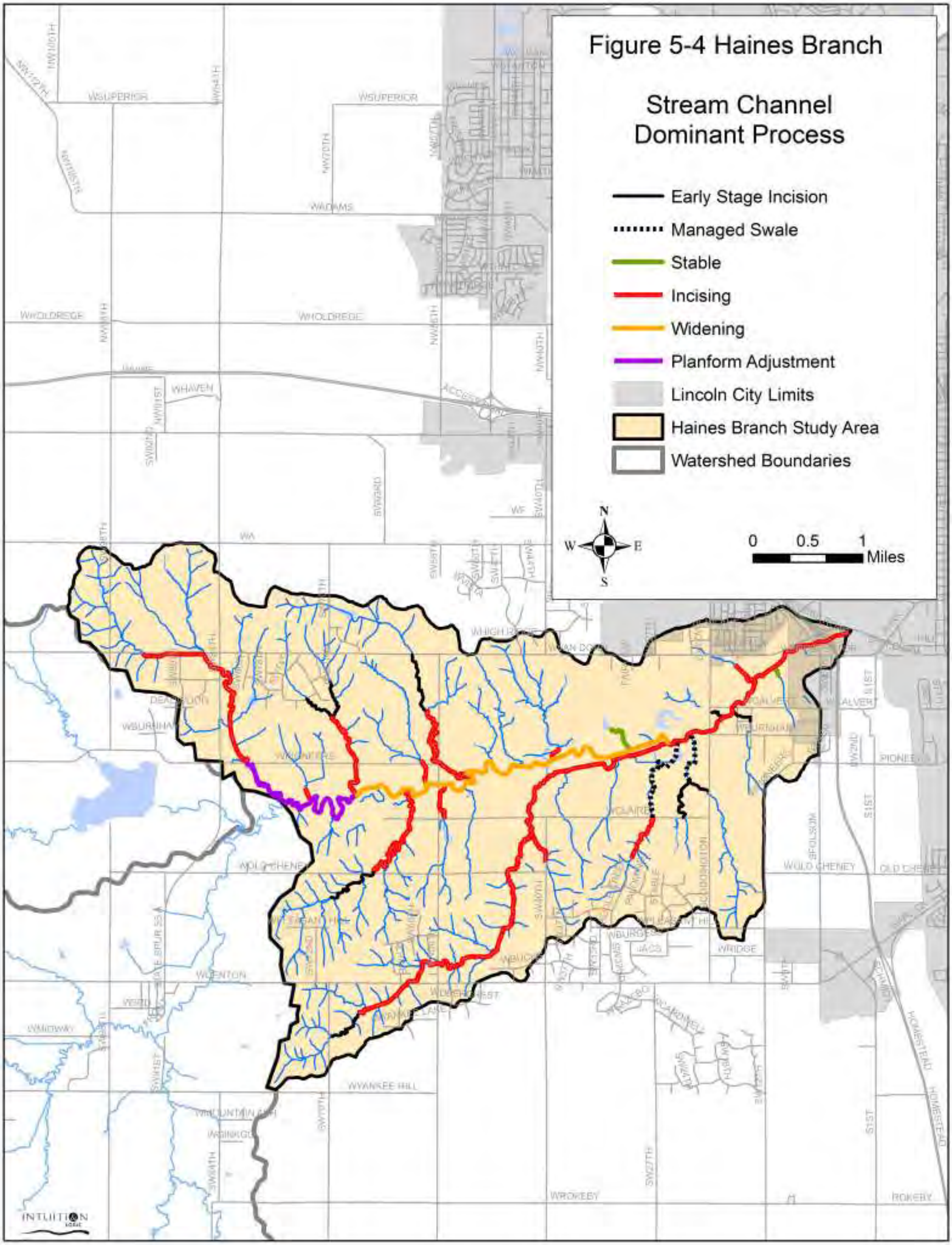
Figure 5-4 Haines Branch
Stream Channel Dominant Process
Early Stage Incision
Managed Swale
Stable
Incising
Widening
Planform Adjustment
Lincoln City Limits
Haines Branch Study Area
Watershed Boundaries
N
W
E
S
0
0.5
1
Miles

5.4 Stream Recommendations

In general, the recommended approach to stabilizing Haines Branch and its tributaries is to stop the process of incision, widening and planform adjustment. Each of these processes is attempting to lower the stream slope and reduce energy in the system in response to changes in the watershed. At several locations on the tributaries, active incision is threatening upstream reaches that are in relatively good shape.

Grade controlling the channel will arrest the downward migration of the channel bed and will allow the reaches to adjust to a stable planform. Grade controls are recommended at existing knickpoints and at locations where projects are necessary to protect infrastructure from the channel erosion. Bank stabilization is recommended in conjunction with grade controls at locations where mass wasting and plan form adjustment are threatening infrastructure.

Section 7 provides additional details on the recommended improvements to address the high priority stream stability problem areas.