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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Mapping of Geomorphic Features within the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials

2012 Study Technical Memorandum

Prepared for
Alaska Energy Authority

SUSITNA-WATANA HYDRO
Clean, reliable energy for the next 100 years.

Prepared by
Tetra Tech, Inc.

March 2013

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
AOW	Additional Open Water
BAB	Bar/Attached Bar
BIC	Bar Island Complex
Cfs	Cubic feet per second
CL-1	Chulitna River Reach
ER	Entrenchment ratio
EXP	Exposed Substrate
FERC	Federal Energy Regulatory Commission
FIPS	Federal Information Processing Standard
GIS	Geographic Information System
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
LR	Lower River
LR-1	Lower River Reach 1 (PRM 102.4 to PRM 87.9)
LR-2	Lower River Reach 2 (PRM 87.9 to PRM 65.6)
LR-3	Lower River Reach 3 (PRM 65.6 to PRM 44.6)
LR-4	Lower River Reach 4 (PRM 44.6 to PRM 32.3)
LR-5	Lower River Reach 5 (PRM 32.3 to PRM 23.5)
LR-6	Lower River Reach 6 (PRM 23.5 to PRM 3.3)
MC	Main Channel
MR	Middle River
MR-1	Middle River Reach 1 (PRM 187.1 to PRM 184.6)
MR-2	Middle River Reach 2 (PRM 184.6 to PRM 169.6)
MR-3	Middle River Reach 3 (PRM 169.6 to PRM 166.1)
MR-4	Middle River Reach 4 (PRM 166.1 to PRM 153.9)
MR-5	Middle River Reach 5 (PRM 153.9 to PRM 148.4)
MR-6	Middle River Reach 6 (PRM 148.4 to PRM 122.7)
MR-7	Middle River Reach 7 (PRM 122.7 to PRM 107.8)
MR-8	Middle River Reach 8 (PRM 107.8 to PRM 102.4)
NAD	North American Datum
NAVD	North American Vertical Datum
PDF	Portable document file
PRM	Project River Mile
RM	River Mile(s)
SC	Side Channel
SCC	Side Channel Complex

Abbreviation	Definition
SS	Side Sloughs
TD	Tributary Delta
TK-1	Talkeetna River Reach
TR	Tributary
US	Upland Slough
USGS	U.S. Geological Survey
VI	Vegetated Island
YN-1	Yentna River Reach

SUMMARY

The work presented in this technical memorandum involves two primary items. The first is the use of digital images from the 1980s and 2012, collected as part of the habitat-related study, to delineate the geomorphic features of the Middle and Lower Susitna River Segments using Geographic Information System (GIS) software. The second is identification of channel change that has occurred in the Middle and Lower Susitna River Segments between the 1980s and 2012. GIS was used to create overlays of the 1980s and current geomorphic feature mapping and to determine the area for each geomorphic feature for both periods.

Tabulated areas of the geomorphic features and overlays of the 1983 and 2012 aerials were used to analyze channel change over the 30-year period. The channel change analysis addressed both the overall system and specific geomorphic features. The geomorphic features have direct relationships to the aquatic habitat types that were studied in in the 1980s in the Middle River and the Lower River. By creating this linkage between the habitat types and the geomorphic features, the assessment of channel change provides insight into how the features that comprise the important aquatic macrohabitats in the Middle and Lower Susitna River have changed or remained the same over the past three decades.

The technical memorandum *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* provided a comparison of aquatic habitat for 17 Middle River sites and five Lower River sites. The geomorphology effort covers the entire length of both segments, whereas the aquatic habitat mapping effort covered about 50 percent of the Middle River and less than 5 percent of the Lower River. Additionally, the aquatic habitat mapping considered only the wetted portion of a geomorphic feature at a specific flow rate, while the geomorphic feature mapping considered the entire bank to bank area of the feature, including wetted and non-wetted portions.

The results of the geomorphology study indicated that appreciable channel change has occurred in the Middle and Lower Susitna River Segments. In both cases, an increase in vegetation has played an important role in defining the change. The largest changes in the Middle River occurred in the four reaches below Devils Canyon (MR-5 through MR-8) where establishment of new vegetation reduced the combined main and side channel area by an average of 200,000 sq. ft. per mile. Encroachment of vegetation in the main and side channels occurred through enlargement of vegetated islands and along the channel banks. Another major change in the Middle River was the conversion of side sloughs to side channels in geomorphic reaches MR-6, MR-7, and MR-8, where the reduction in side slough area averaged 220,000 sq. ft. per mile.

In the Lower River, channel change was on a larger scale than in the Middle River. All six reaches in the Lower River experienced an increase in the area of vegetated islands ranging from 0.3 million sq. ft. per mile for LR-4 to 5.2 million sq. ft. per mile for LR-6. The dominant form of vegetation encroachment in most reaches of the Lower River was the conversion of open bars to vegetated islands in bar island complexes. Another important finding in the Lower River involved tributaries in the Susitna River floodplain. The backwater habitat at the mouths of tributaries remained fairly constant between 1983 and 2012, except in cases where lateral migration or bank erosion in the mainstem altered the connection with the tributary.

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1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 300-mile-long river in the south-central region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. The results of this study will provide information that will inform the 2013–2014 formal study program, Exhibit E of a license application, and FERC's National Environmental Policy Act analysis for the Project license.

This technical memorandum provides the results from tasks that are part of the following two 2012 Study Plans:

- 2012 G-S2: Aquatic Habitat and Geomorphic Mapping of the Middle River using Aerial Photography
- 2012 G-S4: Reconnaissance-Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel

The 2012 G-S2 Study Plan addresses efforts in the Middle Susitna River Segment. The G-S2 efforts presented in this technical memorandum include the geomorphic feature-related portions of the following tasks and subtasks:

- Digitize Geomorphic Features and River Habitat Types
- Riverine Habitat and Geomorphic Analysis
- Aerial Photography Analysis of Geomorphic Features
- Overall Geomorphic Analysis (PRM 102 to PRM 187)

The riverine habitat-related aspects of these tasks are presented under a separate technical memorandum, *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a).

The 2012 G-S4 Study Plan addresses efforts in the Lower Susitna River Segment. This technical memorandum presents portions of the following tasks:

- Geomorphic Assessment and Present-Day Channel Change and Geomorphic Reach Delineation
- Compare Historic and Present-Day Channel Planform Pattern

The Delineate Geomorphically Similar River Reaches subtask is presented in the 2012 technical memorandum *Initial Geomorphic Reach Delineation and Characterization, Middle and Lower Susitna River Segments* (Tetra Tech 2013b).

The work presented in this technical memorandum involved two primary items. The first was to use the digital images collected as part of the habitat-related study (Tetra Tech 2013a) and Geographic Information System (GIS) software to delineate (map) geomorphic features identified in the 1980s and current 2012 aerials for the entire Middle and Lower Susitna River Segments.

The second aspect of the effort consisted of identifying the channel change that has occurred in the Middle and Lower Susitna River Segments between the 1980s and 2012. As part of this analysis, GIS was used to create overlays of the 1980s and current geomorphic feature delineation. GIS was also used to determine the area for each geomorphic feature for both periods. The geomorphic feature overlays and tabulation of geomorphic feature areas summed was performed by reaches. An assessment of the channel change within each geomorphic reach was developed from this information.

2. STUDY OBJECTIVES

The overall purpose of the work presented in this technical memorandum is to quantify geomorphic features in the Middle and Lower Susitna River Segments, compare the resulting areas, and perform an assessment of channel change between the 1980s and present. The 2012 G-S2 Study Plan states in the objectives that:

> *Understanding the extent to which current (2012) aquatic habitat and geomorphic features are similar to or different from 1980s conditions will not only provide information on the long-term equilibrium of the channel, but will also help inform the extent to which other datasets collected in the 1980s can be relied upon to describe and supplement more recent aquatic habitat and geomorphic data.*

The specific objectives of the G-S2 (Middle River) effort are listed below.

- Identify the surface area of geomorphic features at a single flow.
- Compare existing and 1980s geomorphic feature/units to characterize the relative stability of the river morphology under unregulated flow conditions.

The G-S4 (Lower River) effort presented in this technical memorandum is part of the following objective from the 2012 G-S4 Study Plan:

- Conduct a geomorphic assessment of historic channel change and its drivers as well as determine whether changes have affected the frequency and distribution of macrohabitat units.

The geomorphic assessment portion of the objective is presented in this technical memorandum; the macrohabitat aspects of the objective are covered in a separate technical memorandum (Tetra Tech 2013a).

3. STUDY AREA

3.1. General

The Susitna River, located in south-central Alaska, drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna, and East Fork Susitna glaciers to Cook Inlet (U.S. Geological Survey [USGS] 2012). The Susitna River Basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands, and on the south by Cook Inlet. The highest elevation in the basin is Mt. McKinley at 20,320 feet while its lowest elevation is at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna, and Yentna rivers, which are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29°F.

3.2. Susitna River Segments

The overall study area extends from PRM 0 at Cook Inlet to the Maclaren River confluence at PRM 261.3. Within the geomorphology study area, the Susitna River has been divided into three segments whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle, and Lower Susitna River and are identified in Figure 3.2-1 with the associated extents:

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3 / RM 260) downstream to the proposed Watana Dam site (PRM 187.1 / RM 184)[1]
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1 / RM 184) downstream to the Three Rivers Confluence (PRM 102.4 / RM 98.5)
- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4 / RM 98.5) downstream to Cook Inlet (PRM 3.3 / RM 0)

The study effort for the work presented in this technical memorandum covers the Middle and Lower Susitna River Segments. The Upper River is not part of the 2012 study effort documented in this technical memorandum. The general characteristics of the Middle River (MR) Segment are heavily influenced by bedrock outcrop as well as Quaternary-age glaciations. The morphologic characteristics of the Lower River (LR) Segment are dominated by sediment loading from the major tributaries and variable resistance to erosion of the Pleistocene-age, glacially-derived materials including tills (moraines), glacio-fluvial sediments in various elevation outwash-surfaces, and glacio-lacustrine sediments that control the width of the valley.

[1] Note: Project River Miles (PRMs) are the river mile system used for the current Susitna-Watana Project. River Miles (RMs) were the river mile system used in the 1980s project. The PRM delineation starts about 3 miles farther into Cook Inlet than the RMs and has a slightly different thalweg than that of the 1980s. Thus, PRM values are generally 3 to 4 miles higher than the RM values. Because this analysis is a temporal comparison, both systems are referenced.

4. METHODS

4.1. Deviations from Study Plan

The two primary deviations for the channel change portion of the 2012 G-S2 and G-S4 Study Plans involve collection of the 2012 aerial photographs in the Middle and Lower Susitna River Segments. In both segments, it was the intent to collect aerials at a specific discharge, targeted to correspond to flow at which aquatic habitat was mapped in the 1980s. The targeted flows were 12,500 cubic feet per second (cfs) in the Middle River and 36,600 cfs in the Lower River. The specifics of the deviations in the 2012 aerial photo acquisition and the resulting implications to other portions of the 2012 geomorphology mapping study efforts are identified in the following sections.

4.1.1. Middle River 2012 Aerial Photo Acquisition

It was the intent of the 2012 G-S2 Study Plan to obtain aerial photography in the Middle River in 2012 at 12,500 cfs. This discharge is measured at the Gold Creek gage on the Middle River. The combination of weather conditions and river flows allowed only a portion of the 12,500 cfs (PRM 102.4 to PRM 143.6) to be collected in 2012. Additional aerials were collected at a flow of 17,000 cfs on September 30, 2012 to ensure complete coverage of the Middle River, regardless of flow level. The 12,500-cfs flow level is intended to be collected in 2013. If weather and discharge conditions do not occur to allow for collection of the aerials at the specified discharges by September 1, 2013, a more opportunistic approach to obtaining the aerials will be instituted. Alternate flows may be substituted for the 12,500-cfs discharge to ensure that complete sets of images at medium flow are collected by the end of 2013. The dates, discharges, and PRM extents of the Middle River aerial acquisition in the 1980s and 2012 are summarized in Tables 4.1-1 and 4.1-2, respectively.

4.1.2. Lower River 2012 Aerial Photo Acquisition

The 2012 G-S4 Study Plan called for acquisition of Lower River aerial photographs at a flow of 36,600 cfs. The combination of weather conditions and river flows allowed only a portion of the Lower River from PRM 102.3 to PRM 78 to be collected at a flow approximately equal to the target flow. The actual discharge in the Susitna River during the September 10, 2012 aerial acquisition was 38,200 cfs. The remainder of the Susitna River aerial coverage for 2012 was developed from aerials collected at flows of 53,000 cfs (PRM 78 to PRM 63 7/27/2012), 55,000 cfs (PRM 63 to PRM 33.5 and PRM 22.5 to PRM 0 10/10/2013), and 48,000 cfs (PRM 33.5 to PRM 22.5 9/30/2012). The dates, discharges, and PRM extents of the Lower River aerial acquisition in the 1980s and 2012 are summarized in Tables 4.1-1 and 4.1-2, respectively. In 2013, complete coverage of the Lower River will be obtained at or near the targeted flow of 36,600 cfs.

4.2. Aerial Photography

The digital color aerial photographs were collected in 2012 at a scale of 1:12,000 and with a pixel resolution of 1 foot or better. The processing methodology for the 2012 aerial photography is explained in Tetra Tech (2013a). Aerials from the 1980s were collected for comparative purposes.

4.3. Area of Geomorphic Delineation

An area of geomorphic delineation was developed to define the outer limit of the geomorphic features to be mapped. The limit is referred to as the "geomorphic boundary." It encompasses the active channel area and serves as an estimate of the outer limits of areas that may be affected by the Project in terms of hydraulics and channel morphology. The upstream limit is the proposed Watana Dam site (PRM 187.1) and the downstream limit is Cook Inlet (PRM 3.3). The boundary was defined in coordination with the Riparian Instream Flow Study and the Botanical Resources Riparian Study. The lateral limits of the geomorphic boundary were set using the procedure described below.

The geomorphic boundary was delineated at an approximate scale of 1:3000 using the 2012 color aerials and images from the 2011 Matanuska-Susitna Borough light detection and ranging (LiDAR) survey. The outer limits were initially identified following the riverward edge of a terrace that typically ranged from approximately 20 to 40 feet above the main channel water-surface elevation at the time of this 2011 LiDAR survey. In areas where steep canyon or hillsides existed rather than a terrace, these features were followed at an elevation of approximately 20 to 40 feet above the adjacent channel water-surface elevation. In locations where tributaries joined the main channel and cut through the terrace or canyon walls, the boundary was extended upstream until the tributary water-surface elevation matched that of the main channel terrace at the tributary mouth. The corridor was then narrowed in some locations to reflect man-made features that constrain the river, primarily the railroad embankment. It was assumed that the Alaska Railroad will maintain this alignment, and the Susitna River will not migrate through the embankment; if it does, the Railroad will repair and reestablish the embankment in its original location. In a few locations, where hydrologic connections were judged to continue through the railroad embankment to aquatic habitats on the landward side of the embankment, the low-lying area landward of the railroad was included within the geomorphic boundary. This was done in order to include these habitats that may be affected by changes in water-surface elevations created by the Project. Lastly, a minimum buffer of 150 feet was added along the main channel water's edge, except in locations where the railroad embankment was identified as the outer limits of the boundary. For this exception, the boundary was not offset 150 feet and the railroad embankment formed the geomorphic boundary. The boundary also extended approximately 2 to 3 miles up the major tributaries: the Yenta, Talkeetna, and Chulitna rivers.

4.4. Delineation of Geomorphic Feature Areas

4.4.1. Delineation Procedure

All geomorphic feature delineations were made within the defined geomorphic boundary. While the delineations of geomorphic features reflected the aquatic habitat, they were not always limited to the wetted habitat, but rather encompassed the entire bank to bank extent of the feature. Therefore, the geomorphic features followed defined bank lines and included the wetted habitat, exposed substrate, and other low-lying areas within the banks of the feature. Unlike aquatic habitat types, geomorphic features do not have to have a wetted connection to the Susitna River. This connection does not have to be direct, but could be through one or more additional geomorphic features. For example, an upland slough could connect to a side slough, which connects to a side channel and ultimately the main channel. If the water body was isolated and there was not a connection to the Susitna River, then the wetted area was mapped as additional open water (AOW).

Geomorphic feature delineations were made using ArcGIS 10.0 at a scale of 1:3000. Geomorphic feature delineations from the 2012 aerials were assisted by use of the 2011 Matanuska-Susitna LiDAR to determine elevation differences to better define the boundary between channel areas and floodplain or island areas. The LiDAR was used to determine bank and water-surface elevations in areas of shadows and under vegetation cover in the upper ends of sloughs. The LiDAR has a coordinate system of North American Datum (NAD) 1983 State Plane Alaska 4 FIPS 5004 feet and North American Vertical Datum (NAVD) 88.

Mapping of geomorphic features was performed for all areas within the geomorphic boundaries of the Middle and Lower Susitna River Segments. This is in contrast to aquatic habitat mapping, which was performed for 23 selected habitat sites in the Middle River and five habitat sites in the Lower River. Further, while many habitat types are classified similarly, or the same as, geomorphic types (i.e., main channel and side channel) there were distinctions made pertaining to the wetted connectivity of the area. For example, while a wetted area in a side slough with regions of exposed substrate isolating it from the main wetted slough region would still be classified as part of the side slough by the geomorphic classification system, the isolated wetted region would be classified as an AOW by the habitat classification system. This distinction is due to the lack of a wetted connection through which aquatic organisms can pass. The results of the aquatic macrohabitat mapping are presented in a separate technical memorandum (Tetra Tech 2013a).

4.4.1.1. Geomorphic Feature Classifications

Two sets of geomorphic feature classifications were utilized: one for the sites in the Lower Susitna River Segment and one for the sites in the Middle Susitna River Segment. Geomorphic features include the wetted area along with the exposed substrate contained within the banks of perennial vegetation. The riverine aquatic macrohabitat classifications (main channels, side channels, side sloughs, upland sloughs, and tributaries) apply to the wetted area of the geomorphic feature that has direct or indirect surface water connection to the main channel. The delineation of aquatic macrohabitat is covered in a separate technical memorandum (Tetra Tech 2013a).

4.4.1.1.1. Middle Susitna River Segment

The geomorphic classifications for the Middle Susitna River Segment were based on the same categories as the aquatic habitat types defined in Trihey & Associates (1985a). The wetted perimeter of macrohabitat types (main channel, side channel, side sloughs, upland sloughs) along with the exposed substrate and other low-lying areas within the banks defined the extent of a geomorphic feature. With the inclusion of tributaries, vegetated islands, and additional open water, the classifications were defined in 2012 as follows:

- **Main Channels (MC)** are those channels of the river that normally convey streamflow throughout the entire year. They are visually recognizable by their turbid, glacial water and high velocities. In general, they convey more than 10 percent (approximate) of the total flow passing a given location. Main channels can contain tributary mouth habitat, which is clear water plume that enters from an adjacent tributary.
- **Side Channels (SC)** are also characterized by turbid, glacial water. Velocities often appear lower than in mainstem sites. In general, they convey less than 10 percent (approximate) of the total flow passing a given location. Side channel habitat may exist in well-defined channels or in areas possessing numerous islands and submerged gravel bars. When the upstream berms of side channels are dewatered and the channels contain clear water, they are classified as side sloughs. Side channels can contain tributary mouth habitat which is clear water plume that enters from an adjacent tributary.
- **Upland Sloughs (US)** are off-channel features that typically occur outside the mainstem channel area. They contain clear water and depend on small streams, upwelling, and local surface runoff for their water supply. Upland sloughs possess vegetated upper thalwegs that are rarely overtopped by mainstem discharge.
- **Side Sloughs (SS)** are off-channel features that contain clear water and typically occur outside the main channel. They are single discrete side sloughs. Small tributaries, upwelling groundwater, and local surface runoff are the primary sources of clear water for these areas. Side sloughs have non-vegetated upper thalwegs that are overtopped during periods of moderate to high mainstem discharge. When these areas are overtopped they convey turbid water and are then classified as side channels.
- **Tributary (TR)** habitat is the portion of a tributary channel flowing across the floodplain. Tributaries are typically clear water except in the case of the large channels such as the Yentna, Talkeetna and Chulitna Rivers, which were not classified as tributaries but rather as separate reaches of the Lower Susitna River Segment. Tributaries can contain tributary mouth habitat on their downstream end to the extent of the backwater condition.
- **Vegetated Island (VI)** is a discrete, large vegetated island that exists within or along the main channel. Vegetated islands have perimeters of perennial vegetation edges.
- **Additional Open Water (AOW)** is defined as standing water areas that are not channels or sloughs or rivers. These are isolated bodies of water without a discernible direct or indirect surface connection to the Susitna River.

- **Exposed Substrate (EXP)** is a non-wetted mapping type that is typically composed of gravel and cobble, but can also have annual vegetation or immature perennial vegetation. Exposed substrate is mapped within the boundaries of the geomorphic features, including sloughs, channels, vegetated islands, and tributaries that are above the water-surface elevation. The combination of exposed substrate, wetted macrohabitat, and possibly additional open waters comprise the area within a geomorphic feature.

4.4.1.1.2. Lower Susitna River Segment

For the Lower Susitna River Segment, geomorphic mapping classifications were adapted from the habitat types in R&M Consultants, Inc. and Trihey & Associates (1985a). These included: vegetated areas, exposed substrate, and aquatic macrohabitat types (main channel, side channels, side sloughs, tributaries, and upland sloughs). Features such as the side channel complex (SCC), bar island complex (BIC), bar/attached bar (BAB), tributary delta, and additional open water were added to the set. Within this analysis mainstem is defined as a total of the areas and vegetated islands associated with the main channel, bar island complexes, and side channel complexes. Braid plain is defined as the total of main channel and bar island complexes. The classifications were defined in 2012 as follows:

- **Main Channel** features consist of areas within the river that normally convey streamflow throughout the entire year. They are visually recognizable by their turbid, glacial water and high velocities. In general, they convey more than 10 percent (approximate) of the total flow passing a given location. Vegetated islands, side channel complexes and bar island complexes were not included within the area calculation of the main channel.
- **Side Channel** features occur outside the main channel limits. They are single channels as opposed to the multiple and often interlaced/braided channels of the side channel complexes that occur within the mainstem. They are characterized by turbid, glacial water. Velocities often appear lower than in main channel. In general, they convey less than 10 percent (approximate) of the total flow passing a given location. When the upstream berms of side channels are dewatered and the channels contain clear water, they are classified as side sloughs.
- **Side Channel Complex** is an area within the mainstem that contain multiple side channels separated by vegetated islands. The islands are typically several to many channel widths long. The side channels are typically not separated by gravel bars, though gravel bars may occur within the side channels. Side channels within the side channel complexes convey turbid water. Side channel complexes have vegetated islands which constitute more than 50 percent of the complex area, unlike bar island complexes whose non-wetted areas are dominated by exposed substrate.
- **Bar Island Complex** is an area where there are multiple channels in braided patterns separated primarily by exposed substrate. Both gravel bars (exposed substrate) and vegetated island may occur within these complexes. Vegetated islands form a relativity small percentage of the total area of the complex (in contrast to side channel complexes). The channel braids within the bar island complex convey turbid water. Bar island complexes have

vegetated bars which constitute less than 50 percent of the complex, unlike side channel complexes.

- **Bar / Attached Bar** is an exposed substrate feature that is attached to the banks of the mains channel(s). They are typically single discrete point bars or alternate bars and are not dissected by numerous channel threads. In some case, chute channels may dissect a bar / attached bars. Large alternate bars and point bars may be mapped as bar \ bar islands.
- **Side Slough** features are single discrete channels that contain clear water. These are off-channel features that typically occur outside the main channel. Small tributaries, upwelling groundwater, and local surface runoff are the primary sources of clear water for these areas. Side sloughs do not have mature trees in their upper thalwegs and are overtopped during periods of moderate to high mainstem discharge. When these areas are overtopped, they convey turbid water and are then classified as side channels.
- **Upland Slough** features are off-channel features that typically occur outside the mainstem channel area. They contain clear water and depend on small streams, upwelling, and local surface runoff for their water supply. Upland sloughs possess mature trees in their upstream thalwegs and are rarely overtopped by mainstem discharge.
- **Tributary** features are the portion of a tributary channel flowing across the floodplain. These are typically clear water except in the case of the large channels such as the Yentna, Talkeetna and Chulitna Rivers, which were not included as tributaries, but delineated a few miles upstream of their confluence with the Susitna using the set of geomorphic features classification definitions.
- **Tributary Delta** is an exposed substrate feature of sediment deposited where the tributary meets the mainstem channel area. This would typically be a fan shaped area and the tributary may branch out into several channels across the delta/fan. Tributary fans were delineated as they enter areas from the apex (upstream end of the fan) downstream to its limits with the mainstem channel area.
- **Vegetated Island** is a discrete, large vegetated area surrounded by channels with a perimeter of mature, perennial vegetation trees. If a grouping of vegetated islands is broken by numerous channels, it is defined as a side channel complex rather than several vegetated islands. In this case, the vegetated islands are delineated within and are considered part of the side channel complex.
- **Additional Open Water** features represent standing water areas that are not channels, side channels or sloughs.

4.4.2. Geomorphic Feature Area Tabulation

The surface areas of the geomorphic features were compared between the 1980s and 2012. Area measurements (square feet) were calculated to the sixth decimal point and tabulated to an accuracy of 1,000 sq. ft.

Only portions of the area of geomorphic delineation that were covered by both the 1980s and 2012 aerials could be used for a comparison of geomorphic feature areas. The 1980s and 2012 aerial photography extent within the area of geomorphic delineation was addressed differently for the Middle Susitna River Segment and Lower Susitna River Segment. To account for this difference in the Middle Susitna River Segment, an additional open water body outside the coverage of the 1980s aerial had to be removed from the 2012 AOW category. This additional open water body can be found in the southwest corner of MR-8. On the Lower Susitna River Segment, several areas of its reaches were not covered by the 1980s and 2012 aerial photography. These areas are tabulated per reach separately from the geomorphic features. Geomorphic features that were not covered in the 1980s or 2012 aerial photography sets were not compared.

Each geomorphic feature type within the geomorphic reach and the total area for the reach were summed for comparison. To verify that all geomorphic features were accounted for, each feature was summed and compared to the area within the geomorphic reach boundary. Comparisons between summed features and the total reach boundary area were considered acceptable if the difference was less than one half of a percentage point.

4.4.3. Geomorphic Feature Overlay Analysis

A spatial comparison of the Middle Susitna River Segment and the Lower Susitna River Segment was conducted qualitatively over the entire area of geomorphic feature mapping. This comparison included:

- **Changes in Geomorphic Form** such as channel widths, lengths, and alignment
- **Identification of Geomorphic Processes** such as bank erosion, bar formation, lateral channel migration, meandering, and avulsion
- **Changes in Hydraulic Connections** due to the breaching of side sloughs and side channels
- **Identification of Biogeomorphic Process** such as beaver dam construction and failure
- **Identification of Vegetation Processes** such as encroachment, succession, and removal

4.4.4. Quality Control

The Geomorphology Program Lead and the Geomorphology Task Lead provided training to the senior hydraulic engineers/geomorphologist and the GIS analysts to ensure appropriate identification and application of the classification categories. Senior hydraulic engineers/ geomorphologists reviewed the feature delineations for completeness, adherence to the classifications, and scale criteria. The senior hydraulic engineers/geomorphologists frequently consulted with the Geomorphology Program Lead and the Geomorphology Task Lead on the application of the definitions and for advice when differentiation between geomorphic classifications and/or features was challenging.

Markups were provided to the staff performing the delineation in comments on the GIS files, marked up portable document files (PDFs), and written instructions. Comments were provided for both specific items such as changing the classification of a specific feature or general concerns such as the quality of the digitization and proper interpretation of the definitions. The GIS analysts performed the corrections per the instructions of the reviewers. The reviewers conducted a back-check of the changes made to the classifications and provided additional instructions on changes. The correction/ review cycle was repeated if necessary. Throughout the process, the senior hydraulic engineers consulted with the Geomorphology Program Lead or the Geomorphology Task Lead to refine definitions and help make decisions for unique situations encountered. The files were then reviewed for topology errors such as gaps between delineations (slivers) and overlaps. A final check was run on the tabulated areas for the reaches. The summed areas of the geomorphic features were compared to their outer boundary to ensure complete and non-overlapping coverage.

5. RESULTS

The analysis of channel change in the Middle and Lower River segments is based on comparison of the geomorphic features mapped on aerial photographs from 1983 and 2012. The analysis looks at changes in the geomorphic form, such as channel width, alignment, lengths, size of features present, and types of features present, within each geomorphic reach. The analysis also identifies geomorphic process that results in change including vegetation encroachment, bank erosion, lateral migration, and biogeomorphic processes such as beaver dam construction. One of the tools used to identify and quantify change is the tabulated area for the various geomorphic features within a reach. Comparative terms, such as increase and reduce, are a function of area differences (2012 vs. 1980s) determined from the tabulated geomorphic feature areas.

Aerial photographs with the geomorphic features mapped for the Middle Susitna River Segment are provided in Appendix 1 for 1983 and Appendix 2 for 2012. The Middle Susitna River Segment channel change overlay from the 1980s and 2012 aerials is provided in Appendix 3. The geomorphic mapping for the Lower Susitna River Segment sites is provided in Appendix 4 for 1983 and Appendix 5 for 2012. The Lower Susitna River Segment channel change overlay from the 1980s and 2012 aerials is provided in Appendix 6. Tabulated area for each geomorphic feature is provided in Appendix 7 for the Middle River reaches and Appendix 8 for the Lower River reaches. Appendix 9 provides bar charts for the Middle River geomorphic feature areas by geomorphic reach, with the 1983 and 2012 feature areas displayed side by side for comparison. Appendix 10 contains similar charts for the Lower River.

5.1. Middle Susitna River Segment

The Middle Susitna River Segment can be generally divided into three geomorphic regions: Watana Dam (PRM 187.1) to Devils Canyon (PRM 166.1), Devils Canyon (PRM 166.1 to PRM 153.9), and Devils Canyon to the Three Rivers Confluence (PRM 102.4). From the Watana Dam site to the head of Devils Canyon, the slope is about 11 ft/mile and the channel is bounded by meta-sedimentary and gneissic rocks. The channel slope in Devils Canyon is about 31 ft/mile and the channel is bounded by granitic rocks. From Devils Canyon to the Three Rivers Confluence, the channel slope decreases progressively from about 12 ft/mile to about 7 ft/mile and the reduction in slope correlates to a reduction in the erosion resistance of the bounding materials (Pleistocene- and Holocene-age alluvial terraces) and the transition to an alluvial channel.

These general regions were further divided into eight geomorphically distinct reaches presented in Figure 5.1-1 and listed in Table 5.1-1. Reaches 1 through 3 comprise the upper middle portion. Reach 4 is the Devils Canyon segment, and Reaches 5 through 8 comprise the lower middle portion. Each geomorphic reach was classified based on its geomorphic characteristics including bed slope, bounding geology, average active channel width, channel branching, sediment storage capacity, and sinuosity. Further characteristics for each of the eight reaches are described in the *Initial Geomorphic Reach Delineation and Characterization, Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2013b).

The areas delineated for main channel and side channel show considerable differences between 1983 and 2012. The inconsistency occurs because 10 percent of the total flow proportion that defines the difference between the main channels and the side channels cannot be accurately determined from aerial photography. A surrogate for flow is width, but without knowledge of velocity or depth, width in itself can be a misleading indicator of the flow in a particular channel. In some cases, it can be seen that the flow is shallow based on visual clues such as intermittent exposure of substrate or a different shade of the water. However, in many cases the aerials provide little information besides wetted width for estimating flow in the various channels.

A conservative approach was taken in 2012 to determine side channel flow conveyance based on a comparison of main and side channel widths and assumed similar depths. If shallow side channel depths could be seen in the 2012 aerials, a lower conveyance was assumed per unit width than the main channel. Nevertheless, typically the 1980s classification of side channel features occurred whenever the main channel split from a single channel to multiple channels. When analyzed again, many of these side channels appear to visually convey more than 10 percent of the flow, which would classify them as main channel features. Thus, comparisons between main channel and side channel features in the 1983 and 2012 aerials are inconclusive. For this reason, tables were developed that display the total area of main channel and side channel combined (Tables 5.1-2 through 5.1-9). These areas are graphically represented as bar charts in Appendix 9. From this data, changes in the combined geomorphic feature surface areas were assessed.

The combined total area of main and side channel has not changed appreciably between 1983 and 2012. Similarly, a macrohabitat type analysis described in *Mapping of Aquatic Macrohabitat Types in the Middle and Lower Susitna River Segments from the 1980s and 2012 Aerials*, found there was not an appreciable change in total channel (main and side) area from 1983 to 2012 (4 percent increase) within selected habitat sites in the Middle River (Tetra Tech 2013a). Further, the macrohabitat study found that in all selected habitat sites, the increase in the main channel area by itself was much larger than for the combined total, but was offset by a nearly comparable decrease in side channel area. This is illustrated by the bar charts in Appendix 9.

5.1.1. Middle River Reach 1 (PRM 187.1 to PRM 184.6)

In geomorphic reach 1 (MR-1), the Susitna River flows in a narrow, approximately 780-foot-wide, bedrock-bounded canyon downstream of the Watana Dam site. There is limited sediment storage potential in the reach because of the narrow valley bottom with an entrenchment ratio (ER) of 1.2. Alluvial sediments are stored within vegetated and non-vegetated mid-channel bars that tend to be located in local hydraulic expansion zones. The average number of channels in the reach is 1.2 +/- 0.5.

As expected in a bedrock-bounded section of river, this reach is stable with the only noticeable change associated with erosion around its three vegetated islands. On two of the longitudinally oriented islands (at PRM 185.7 and PRM 185.2) approximately 100 feet of their medial banks was eroded. On the third island, approximately 30 feet of erosion took place on the island’s rounded upstream face. The loss in vegetated islands (1983 area = 376,000 sq. ft., 2012 area = 222,000 sq. ft.) can account for approximately a third of the gains to the main and side channel totals (1983 area = 7,471,000 sq. ft., 2012 area = 7,972,000 sq. ft.). The other two-thirds are likely due to the interpretation of poor aerial imagery quality seen along the river banks.

5.1.2. Middle River Reach 2 (PRM 184.6 to PRM 169.6)

In geomorphic reach 2 (MR-2), the Susitna River flows in a wider, approximately 1,500-foot-wide, bedrock-bounded canyon between the Tsusena Creek confluence (PRM 184.7) and about PRM 173, where the canyon narrows to about 1,000 feet. There are considerably more alluvial sediments stored in vegetated islands, mid-channel bars, and in vegetated discontinuous floodplain segments in this reach with an entrenchment ratio of 2.1. This is particularly true of the wider, upper portion of this reach. In the lower, narrower part of the reach, alluvial sediments are stored within discontinuous vegetated floodplain segments and in unvegetated mid-channel bars.

Based on the aerial analysis of geomorphic features, MR-2 is a relatively stable reach. Geomorphic changes were limited to vegetation encroachment and bank erosion. Vegetation encroachment was the dominant geomorphic change in this reach. Two large (approximately 1,000,000 sq. ft.) vegetated islands at PRM 183 and PRM 181 remained mostly identical to their 1980 extents. A couple of smaller islands downstream of PRM 181 and PRM 180 had vegetation encroachment of 10 and 60 percent of their areas, respectively. A new island (26,805 sq. ft.) was visible at PRM 176.7 in the 2012 aerials due to the lower flow. Vegetated islands increased by 14 percent for the reach. Nearly half (approximately 450,000 sq. ft.) of the vegetation encroachment occurred on the exposed substrate of PRM 174 right. Since 1980, both an upland slough (32,000 sq. ft.) and side slough (11,000 sq. ft.) were lost to vegetation encroachment at PRM 175 right. The tributary area decrease of 8 percent (1980 area = 1,076,000 sq. ft., 2012 area = 987,000 sq. ft.) for Fog Creek (PRM 179.5) is also mostly attributed to vegetation encroachment.

Bank erosion over the 30-year period was limited to a few locations and to 50 feet or less of the 1980s bank line for a length of approximately 1,000 feet. The erosion can be seen along PRM 180 right, PRM 179 left, and PRM 177.5 right.

Overall, MR-2 decreased in main and side channel area by 8 percent due to the higher discharges (31,660 and 35,800 cfs) in the 1980s aerials compared to the 2012 aerials at 17,000 cfs. The higher discharges also account for the 3,400 percent increase for side sloughs and 1,300 percent increase for upland slough due to the flow-based classification of these features. At comparable flow, these numbers should be at least an order of magnitude less and similar to the 2012 areas.

5.1.3. Middle River Reach 3 (PRM 169.6 to PRM 166.1)

The Susitna River throughout geomorphic reach 3 (MR-3) flows in a narrow (about 780 feet wide) bedrock-bounded canyon from PRM 169.6 to PRM 166.1. Because of the relatively narrow canyon (ER=1.3) and steep bed slope (11 ft/mile), the alluvial sediment storage potential in the reach is low. Alluvial sediments are stored within a few vegetated mid-channel bars, and there is little evidence of even discontinuous floodplain segments within the reach.

Geomorphic change within this stable reach was limited to erosion of banks and vegetated islands. Bank erosion of up to 20 feet appears to have occurred at PRM 169 for a length of 1,000 feet. The island at PRM 168.5 was lost to erosion (24,000 sq. ft.). The 1 percent difference in main channel area is primarily due to a 3- to 5-foot difference in the delineation of the vegetated banks lines between the two aerial sets. An increase of the main channel width accounts for 17-percent reduction (2,000 sq. ft.) in the tributary on the left near the upstream limit of MR-3. Total side sloughs increased by 292,000 sq. ft. This is due to a side slough at PRM 169.5 that was a side channel at the higher discharges associated with the 1980s aerials.

5.1.4. Middle River Reach 4 (PRM 166.1 to PRM 153.9)

Geomorphic reach 4 (MR-4) is referred to as Devils Canyon. Within this reach, the Susitna River (310-foot active width) canyon is narrow, 370 feet wide, steep (31 ft/mile), and bounded by bedrock. Because of the narrow canyon (ER=1.2) and steep slope, there is little, if any, alluvial sediment stored within the reach.

Devils Canyon is the most stable reach within the Middle Susitna River Segment. Geomorphic change was minimal; most features did not change. There are only two vegetated islands at PRM 163.5 and PRM 158.8. Both experienced minor erosion amounting to 1,000 sq. ft. Other portions of the islands increased due to establishment of vegetation on bars resulting in an overall 2-percent increase in vegetated island area. The mapped main and side channel area reduced by 4 percent (1980 area = 20,909,000 sq. ft., 2012 area = 20,093,000 sq. ft.). Since no change could be identified in areas that were clearly visible in both sets of aerials, it is believed that the difference is due to shadows obscuring the bank line in Devils Canyon in the 2012 aerials. (This was caused by poor weather conditions earlier in the year when the aerials were flown with less than optimum sun angles.)

5.1.5. Middle River Reach 5 (PRM 153.9 to PRM 148.4)

In geomorphic reach 5 (MR-5), the Susitna River (510-foot active width) flows through a slightly wider (about 850 feet) bedrock-bounded canyon from PRM 153.9 to PRM 148.4. The somewhat wider canyon and lower slope (12.1 ft/mile) compared to MR-4 (Devils Canyon) allow some alluvial sediment storage within the reach, primarily in a few vegetated mid-channel islands and discontinuous floodplain segments in the slightly wider parts of the reach (ER=1.7). The lack of large floodplain areas is a contributing factor to the lack of side sloughs and upland sloughs in the reach.

The major geomorphic change in this stable reach occurred due to vegetation encroachment. An example of this is the vegetated island at PRM 150 right that established since 1983 (45,000 sq. ft.). The island at PRM 149 left expanded its upstream extent (240,000 sq. ft.) and merged two prior islands to form a single large island. Side channel narrowing also occurred downstream of this island due to encroachment of vegetation (approximately 20 feet on either side of the channel). Overall, the reach had a 27-percent increase in vegetated islands (1983 area = 1,636,000 sq. ft., 2012 area = 2,073,000 sq. ft.). This caused a comparable decrease in net main and side channel area (1983 area = 15,039,000 sq. ft., 2012 area = 14,494,000 sq. ft.).

Minor changes in the Portage Creek tributary area amounted to a less than 1-percent reduction (1,000 sq. ft.). In 1983, the tributary had a primary outlet channel that was approximately 50 feet wide and a smaller channel (10 feet wide) to the left. By 2012, there were three outlet channels across the delta, each of which was approximately 30 feet wide. It is expected that many of the tributary deltas are dynamic and change during periods of high flow and/or high sediment delivery.

5.1.6. Middle River Reach 6 (PRM 148.4 to PRM 122.7)

In geomorphic reach 6 (MR-6), the Susitna River flows through a bedrock-bounded canyon averaging 2,350 feet in width. In the wider parts of the reach, alluvial sediments are stored in continuous vegetated floodplain segments and within numerous vegetated islands and bars, as well as in unvegetated mid-channel bars (ER=2.4). Where the valley bottom is wider within the reach, the alluvial deposits tend to be more vegetated, and where the valley bottom is narrower, the alluvial deposits tend to be less vegetated.

The predominant change in the relatively dynamic MR-6 has been the loss of 61 percent of the side sloughs. The primary reasons for this are erosion near the upstream end of the channels and vegetation encroachment. However, in one case at PRM 128, erosion of the main channel into the downstream end of the slough eliminated part of the slough (approximately 150,000 sq. ft.). Erosion of the inlets appears to have reduced the breaching flow and changed the classification of side sloughs to side channels at PRM 144.5 left, PRM 139.5 left, PRM 137 right, PRM 130 left, and PRM 125 left. A large portion (over 2,500,000 sq. ft.) of the side sloughs that changed to side channels are located between PRM 130.5 and PRM 127.5 where breaching flows were common in 2012 in the small channels between the vegetated islands. The channels supplied turbid water to what were previously side sloughs in 1983.

It should be noted that even though the 2012 aerial photography upstream of PRM 143.6 was flown at a higher discharge (17,000 cfs) than the 1983 aerials (12,500 cfs), the difference in flows possibly only affected the classification of one feature in MR-6. This feature was a side slough at PRM 145 left, and in 2012 was mapped as a side channel due to being breached. There are two other side sloughs in the 1983 delineation upstream of PRM 143.6, but they were both mapped as side sloughs in the 2012 delineation. The feature mapped as a side slough at PRM 145 left in 1983 and as a side channel in 2012 impacts the area of side sloughs by 5 percent.

Vegetation encroachment was also a major factor in the loss of side sloughs. Vegetated islands increased by only 12 percent in MR-6 (a 25.7-mile reach); however, this amounts to 7,619,000 sq. ft. which, for comparison, is more than twice the net loss (2,970,000 sq. ft.) within main and side channels. Vegetation encroachment within the side sloughs can account for the remaining area. Vegetation encroachment is present along the edges of all but one of the channels of the Fourth of July Side Channel Complex (PRM 136 to PRM 134). Examples of current large vegetated islands that established since 1983 can be found near PRM 138 and PRM 131 (totaling approximately 1,000,000 and 750,000 sq. ft., respectively). Also, the Gold Creek (upland) slough (PRM 140.3) appears to have been fully encroached upon by vegetation between 1983 and 2012 (35,000 sq. ft.).

Biogeomorphic processes can account for the loss of two upland sloughs at PRM 132.5 (75,000 and 23,000 sq. ft.). These 1983 upland sloughs were classified as AOW in 2012 due to the presence of beaver dams obscuring the downstream connection. (Note: field work in 2013 will be conducted to determine if beaver ponds are actually connected to the downstream channels in terms of fish access.) The 13-percent increase in AOW is mostly due to the biogeomorphic processes of beaver dam construction on former upland sloughs.

The main channel and side channel areas decreased 2 percent between 1983 and 2012. The change is primarily due to the increase in the size of the vegetated islands. In addition to the areas of vegetation encroachment, the bank lines in MR-6 have shown some erosion. The most significant areas of bank erosion noted in MR-6 occurred at PRM 144.5 left, PRM, 139.5 right, PRM 135.5 right, PRM 130.5 right and left, 128.5 left, PRM 127, and PRM 123.5. In general, these areas of bank erosion were on the order of 1,000 to 1,500 feet long and averaged 100 to 150 feet into the banks. MR-6 is characterized as having the most significant level of bank erosion identified in the Middle River over the period of 1983 to 2012.

A 47-percent decrease of tributaries within MR-6 is accounted for by a reduction in tributary area at Gold Creek and Indian River (32,000 and 700,000 sq. ft. lost, respectively). Indian River is not only the largest tributary in this reach, but also the widest. Since 1983, the Indian River has narrowed 200 to 300 feet through the majority of its delineated length across the floodplain.

5.1.7. Middle River Reach 7 (PRM 122.7 to PRM 107.8)

Within geomorphic reach 7 (MR-7), the Susitna River flows through a bedrock-bounded canyon averaging 2,050 feet wide. Because of the relatively wide valley and low slope (8.5 ft/mile), there is a reasonably high sediment storage potential within the reach. Alluvial sediments are stored primarily within continuous vegetated floodplain segments and in vegetated islands and mid-channel bars.

Vegetation encroachment-manifested in the creation of islands on former mid-channel bars, establishment of vegetation on the channel margins, and expansion of existing vegetated islands-was the dominant geomorphic process in this relatively dynamic reach. Vegetation encroachment is most pronounced around the mid-channel bars at PRM 121, PRM 118, and PRM 115. Minor vegetation encroachment did occur along the exposed substrate of the main channel at PRM 119.5 right, the mouth of Lane Creek (PRM 117 left), and PRM 110.7 right. This accounts for the majority of the 39 percent (1983 area = 14,912,000 sq. ft., 2012 area = 20,696,000 sq. ft.) increase in vegetated islands.

The 8-percent decrease in main and side channel area (1983 area = 71,534,000 sq. ft., 2012 area = 65,743,000 sq. ft.) was primarily due to vegetation area increases. The encroachment of vegetation caused an overall decrease in main and side channel area even though there were some areas where the channel widened. Minor channel widening due to erosion was identified near PRM 122 right, PRM 121 left, PRM 118 left, PRM 114.3 left, PRM 111 left, and PRM 110 (both sides).

Side slough areas changed within geomorphic reach MR-7 due to vegetation encroachment, erosion of the inlet inverts, bank erosion, and biogeomorphic processes. The side slough at PRM 121.5 right was mostly lost due to vegetation encroachment and to a lesser degree bank erosion. Most of the side slough immediately east of Lane Creek (PRM 117) was converted to a beaver pond. Lastly, a very small portion of side slough at PRM 116.7 was no longer present in 2012, and appears to have been lost to bank erosion. As geomorphic features measured bank to bank, side slough area decreased by 53 percent in MR-7 (1983 area = 71,534,000 sq. ft., 2012 area = 65,743,000 sq. ft.). A similar loss of 46 percent was noted for side slough aquatic macrohabitat wetted surface area (Tetra Tech 2013a).

Upland slough changes were primarily related to beaver dam construction. Vegetation encroachment was also a factor in the upland slough area reduction of 20 percent (1983 area = 572,000 sq. ft., 2012 area = 455,000 sq. ft.). Large upland sloughs at PRM 116 right and PRM 109 left became beaver ponds and were then classified as AOW. AOW area increased by 10 percent (1983 area = 1,245,000 sq. ft., 2012 area = 1,375,000 sq. ft.) in MR-7.

Geomorphic change was seen in tributary widths and lengths. The exposed banks of Downunda Creek (at PRM 122.5 right) are up to 50 feet wider. The tributary at PRM 119.5 left has increased slightly (10 to 15 feet) in width in 2012 and shifted the river left by approximately 150 feet. Lane Creek (at PRM 117.2) has extended 125 feet in length due to vegetation encroachment of its delta since 1983. Along with an 8,000 sq. ft. tributary presence in 2012 at PRM 115 that was not present in 1983, the tributaries increased in area by 44 percent (1983 area = 84,000 sq. ft., 2012 area = 121,000 sq. ft.).

5.1.8. Middle River Reach 8 (PRM 107.8 to PRM 102.4)

The Susitna River in geomorphic reach 8 (MR-8) averages 1,130 feet in active width with an increase in width as it approaches the Three Rivers Confluence at PRM 102.4. The average gradient of the river decreases about 1 ft/mile to 7.3 ft/mile. In the upper part of the reach, alluvial sediments are stored within continuous floodplain segments, vegetated islands, and mid-channel bars. Just upstream of the confluence, the bulk of the alluvial sediments are stored in active unvegetated braid bars. The large entrenchment ratio (ER=7.9) is largely the result of the wide floodplain created by the transition into the confluence of the Susitna, Chulitna, and Talkeetna rivers. This reach is a transition between the confined single-channel dominated morphology of the Middle River to the multiple channel and braided morphology of the Lower River.

Vegetation encroachment and erosion were the dominant geomorphic processes in this relatively dynamic reach. There have been noticeable shifts in the location of vegetated islands and main channel. Bank erosion can be seen at PRM 107.8 left, PRM 104 right, and PRM 103 left. Vegetation area increases on islands near PRM 104 and in side channels near PRM 103, which were offset by erosion on other sides of the islands. These changes seem to have offset each other since main and side channel area decreased by 2 percent and vegetated island area changed by less than 1 percent.

Side sloughs are present in three primary locations in MR-8. The area associated with side sloughs decreased due to the vegetation encroachment and apparent erosion of inlet inverts. The Whiskers Creek Slough near PRM 105.5 right narrowed (50 ft) due to vegetation encroachment. The side slough at PRM 104.5 left had apparent erosion of its inlet invert which caused it to be breached. There were two side sloughs branches in 1983 at PRM 103.5. A smaller western branch closer to the main channel was encroached by vegetation. The eastern branch converted to an upland slough due to vegetation encroachment within its upstream connection. This geomorphic feature conversion was the primary reason upland slough area increased by 25 percent, while side slough area decreased by approximately 700,000 sq. ft. to only 68 percent of the area found in 1983.

A widening of Whiskers Creek by several feet accounts for the 14-percent increase in MR-8 tributary area (1983 area = 250,000 sq. ft., 2012 area = 285,000 sq. ft.). Whiskers Creek has widened possibly due to changes in its hydrologic regime, biogeomorphic, or vegetation processes.
Several new AOW areas were delineated on the floodplain near PRM 105 right and others increased in size. These changes account for a 51 percent increase in the AOW area in MR-7 since 1983.

5.2. Lower Susitna River Segment

In the Lower Susitna River Segment, from the Three Rivers Confluence (PRM 102.4) to Cook Inlet (PRM 3.3), the bed slope progressively decreases from 6 ft/mile to about 1.5 ft/mile. The channel is bounded primarily by Pleistocene-age glacial, fluvio-glacial, and glacio-lacustrine deposits. Like the Middle River, the Lower River Segment is divided into distinct geomorphic reaches based on bed slope, bounding geology, average active channel width, channel branching, sediment storage capacity, and sinuosity. The Lower River, however, is distinctly different from the Middle River. The character of the river changes dramatically below the Three Rivers Confluence as the width of the river more than triples from the widest portions in the Middle River Segment, and it adopts a braided channel form. Within the Lower River, six geomorphic reaches were identified and classified (Figure 5.2-1). Further geomorphic characterization of the six reaches is provided in the *Initial Geomorphic Reach Delineation and Characterization, Middle and Lower Susitna River Segments Technical Memorandum* (Tetra Tech 2013b). Geomorphic features in the Chulitna, Talkeetna, and Yentna tributaries are also presented in this section.

Tables 5.2-1 through 5.2-9 present the geomorphic feature areas mapped by geomorphic reach for 1983 and 2012 in the Lower Susitna River and Chulitna, Talkeetna, and Yentna tributaries. The tables also include the percent change from 1983 to 2012. A master table of delineated geomorphic feature areas in 1983 and 2012 is found in Appendix 8. The geomorphic feature areas are also presented by reach in a series of bar charts in Appendix 10.

5.2.1. Lower River Reach 1 (PRM 102.4 to PRM 87.9)

Geomorphic reach 1 (LR-1) of the Lower Susitna River (3,340 feet active width) includes the Three Rivers Confluence downstream at PRM 102.4 and extends downstream to a valley bottom constriction at PRM 87.9. The Susitna River triples its width in LR-1 compared with MR-8. This is the result of the added flow and sediment loads from the Chulitna and Talkeetna Rivers. In general, because of the combined sediment delivery from the Three Rivers Confluence, the reach is net aggradational and the bulk of the alluvial sediment is stored in active unvegetated braid bars upstream of the valley floor constriction at PRM 87.9 (ER=2.8). Within the reach, there are also locations where alluvial sediments are stored within vegetated islands and mid-channel bars, and the reach is bounded on each side by a vegetated floodplain of varying width.

This reach has experienced changes in the geomorphology, which include a reduction in number of main channel flow splits, lateral channel migration, and vegetated island establishment. These processes appear to be acting together to store and route sediment delivered at the Three Rivers Confluence. Increases in vegetated islands and commensurate reduction in gravel bars create a more stable channel form.

Vegetation island development is occurring primarily within bar island complexes and side channel complexes, but also the main channel. Total vegetated island area within bar island complexes from PRM 100 to PRM 95 has doubled since 1983 (1983 area = 10,264,000 sq. ft., 2012 area = 20,497,000 sq. ft). For LR-1, vegetated increased within bar island complexes by 83 percent (1983 area = 16,328,000 sq. ft., 2012 area = 29,960,000 sq. ft.). At PRM 99, the bar island complexes on the river right in 1983 converted to a side channel complex by 2012. Another side channel complex developed at PRM 100 left that was not apparent in 1983. The combination of vegetated islands within the main channel, side channel complexes, and bar island complexes increased by 51 percent (1983 area = 49,186,000 sq. ft., 2012 area = 74,107,000 sq. ft.).

Vegetation encroachment within existing side channel complexes acts to consolidate smaller vegetation islands. The portion of the 1983 side channel complex at PRM 94 was lost to lateral channel migration in 2012. However, the downstream portion of this side channel complex approximately doubled in proportion of vegetated to non-vegetated area because of vegetation encroachment of its side channels. Several of the side channels of Sunshine Slough side channel complex were encroached upon by vegetation since 1983. Side channel complexes increased by 10 percent (from 55,639,000 to 61,120,000 sq. ft.).

Compared to 1983, the 2012 main channel has progressed to have more single channel sections and fewer split channel sections. In 1983, approximately 5 miles or 35 percent of the reach was single channel. In 2012, the single channel sections had increased to 7 miles or 50 percent. This change from a split channel in 1983 to single channel in 2012 can be seen in the channel change (overlay) mapping between PRM 100 to PRM 97.3. For the first 7 miles below the Chulitna River (PRM 102 to PRM 95), the number of main channel flow splits reduced from five in 1983 to two in 2012. For comparison, the remaining portion of LR-1 (PRM 95 to PRM 87.9) had five bar island complexes within the main channel split channels in both 1983 and 2012.

Main channel lateral migration after 1983 at three consecutive bar island complexes (PRM 94.5, PRM 92, and PRM 89.5) is evident within the 2012 main channel. The main channel at PRM 94.5 and PRM 89.5 has migrated approximately 2,000 feet river left, while the west branch of the main channel at the middle bar island complex (PRM 92) has migrated approximately 2,000 feet east toward river right. At PRM 95, the left lateral channel migration bisected Birch Creek side slough. The overall width of the channel remained relatively constant with a 7 percent decrease in the braid plain width.

Three minor tributaries (the Chulitna, Talkeetna, and Yentna Rivers are considered major tributaries) empty into the Susitna River or connecting sloughs in LR-1: Trapper Creek at PRM 95.1, Birch Creek at PRM 93.3, and Sunshine Creek at PRM 89.4. The entire length of Trapper Creek within the extent of the aerial photography remained almost entirely unchanged between 1983 and 2012. At the mouth of Trapper Creek, the large bar island complex has developed more vegetation since 1983, and the adjacent braided channels have become more defined. Birch Creek appears to have widened slightly by 10 to 20 feet. The downstream half of Birch Creek Slough is approximately 40 feet wider in 2012 than in 1983. This is likely due to main channel migration near PRM 95, where the main channel has shifted east about 2,000 feet. This bisected the slough, creating a new connection to Birch Creek slough. As with Trapper Creek, Sunshine Creek appears to be mostly unchanged from 1983 to 2012. Sunshine Slough, into which Sunshine Creek empties, is also mostly unchanged, with only a small amount of vegetation having developed on a gravel bar adjacent to PRM 89.7.

5.2.2. Lower River Reach 2 (PRM 87.9 to PRM 65.6)

The geomorphic reach 2 (LR-2) of the Lower Susitna River (3,120 feet active width) can be further subdivided into upper and lower subreaches. The upper reach (PRM 87.9 to about PRM 74.4) stores alluvial sediments primarily in vegetated islands, bars, and continuous floodplain segments. Between PRM 74.4 and PRM 65.6, the planform of the river changes to anastomosed as a result of the imposed base level control (Smith and Smith 1980, Knighton and Nanson 1993, Makaske 2001). The bulk of the alluvial sediments within the lower subreach are stored in longitudinally extensive, relatively stable vegetated floodplain segments.

LR-2 is a fairly dynamic reach. The bars within bar island complexes are coalescing and becoming vegetated. Both bar island complexes and side channel complexes are increasing their proportions of vegetated islands, and side channel complexes are converting to floodplains with single side channels. The coalescing of bars to vegetated islands is particularly evident for the bar island complexes within the main channel flow splits at PRM 78 to PRM 76 and PRM 74 to PRM 67. In the section between PRM 76 and PRM 74, vegetated islands developed, changing it from a bar island complex to a side channel complex. Several other bar island complexes had converted to side channel complexes by 2012 due to vegetation establishing new islands. Bar island complexes decreased 38 percent (1983 area = 247,246,000 sq. ft., 2012 area = 152,952,000 sq. ft.) while side channel complexes increased by 8 percent (1983 area = 257,762,000 sq. ft., 2012 area = 279,331,000 sq. ft.). The side channel complex increase does not offset the bar island complex decrease, because two large side channel complexes that were present in 1983 are no longer complexes but vegetated islands separated from the riparian zone by a single side channel. These vegetated islands are increasing in stability now that the main channel has migrated further away. They are located downstream of Goose Creek (PRM 77 left to PRM 73 left; 2012 area = 44,368,000 sq. ft.) and PRM 78.5 left to PRM 77 left (2012 area = 62,289,000 sq. ft.). Side channels (not part of side channel complexes) and their associated vegetated islands increased by 460 percent (1983 area = 12,617,000 sq. ft., 2012 area = 70,635,000 sq. ft.).

The side channel complexes occur approximately every 2 miles between PRM 75 and PRM 68 on alternating sides of the channels. Beginning with the side channel complex at PRM 75left, it follows another at PRM 73 left, then PRM 71 right, PRM 70 left, and 68 PRM right. The vegetated island within the side channel complex at PRM 78 left underwent succession (the side channel at PRM 80 right encroached left), and a new island formed within the bar island complex at PRM 81 left. The pattern of alternating vegetation island formation extends upstream with two more bar island complexes that converted to side channel complexes (PRM 83.5 right and PRM 85 left). The complex at PRM 87 right exhibited vegetation encroachment in its northern side channel and succession on its downstream island. Vegetation encroachment also occurred in the side channel complex within the mainstem from PRM 71 to PRM 67.

Rabideux Creek at PRM 87.2, Montana Creek at PRM 80.8, Goose Creek at PRM 77.7, Sheep Creek at PRM 71.7, and Caswell Creek at PRM 67.2 enter the Susitna River or connecting sloughs in LR-2. Three of the five tributaries, Rabideux Creek, Sheep Creek, and Caswell Creek appear to be mostly unchanged between 1983 and 2012. More vegetation has developed on the bar on the left side of the mouth of Rabideux Creek (1983 area = 2,486,000 sq. ft., 2012 area = 4,020,000 sq. ft.). The mouths of Sheep and Caswell Creeks appear to have changed little from 1983 to 2012. Larger changes were apparent in Montana and Goose Creeks. Since 1983, Montana Creek has migrated approximately 200 feet north between the Parks Highway bridge and the railroad bridge. There were fewer gravel bars present in 2012 as compared to 1983; vegetation has developed on the gravel bar immediately downstream of the Parks Highway Bridge. The flow characteristics of the two channels at the mouth of Montana Creek and the main channel have changed significantly between 1983 and 2012, with more flow passing through the two side channels, and a more direct connection to the main channel, reducing the backwater at the mouth of the tributary. Since 1983, vegetated islands have separated the mouth of Goose Creek from the main channel. The mouth of Goose Creek is now in a side channel. In 1983, Goose Creek had split with a majority of the flow going south and discharging into a secondary side channel over 3,000 feet south of where the tributary mouth was located in 2012. The side channel into which Goose Creek had emptied in 1983 had evolved into a side slough by 2012.

5.2.3. Lower River Reach 3 (PRM 65.6 to PRM 44.6)

In geomorphic reach 3 (LR-3), a valley floor constriction at PRM 44.6 forms a downstream base level control for the river (4,040 feet active width), and consequently, the river planform is anastomosed for most of the reach (Smith and Smith 1980, Knighton and Nanson 1993, Makaske 2001. The bulk of the alluvial sediments within reach are stored in longitudinally extensive, relatively stable vegetated floodplain segments that are referred to as the Delta Islands.

Vegetation encroachment and island development has occurred along the mainstem margins and within the side channel complexes of this dynamic reach. Conversion of a bar island complex to a side channel complex as a result of vegetation being established on bars and converting them to islands has occurred in multiple locations in LR-3. From PRM 64 right to 62 right, the side channel complex (2012 area = approximately 28,000,000 sq. ft.) has developed from a bar island complex. Another example of bar island complex to side channel complex conversion is PRM 55 right to 53 right (1983 area = approximately 12,000,000 sq. ft., 2012 area = approximately 30,000,000 sq. ft.). Total bar island complex area decreased by 37 percent (1983 area = 283,125,000 sq. ft., 2012 area = 178,537,000 sq. ft.) while total side channel complex area increased by 16 percent (1983 area = 610,421,000 sq. ft., 2012 area = 707,998,000 sq. ft.). Vegetated islands within side channel complexes increased by 12 percent (1983 area = 489,845,000 sq. ft., 2012 area = 547,959,000 sq. ft.).

Several smaller side channels within the Delta Island side channel complex are no longer present. A main channel section that divided the side channel complex into two sections has since reduced flow conveyance and is now part of the side channel complex in 2012. The inlet and outlet of this channel are at approximately PRM 54 and PRM 50, respectively. This appears to be a consequence of a bar island complex that replaced a 1983 left main channel split at PRM 56 left. This has caused a reduction in the flow to the left side of the side channel complex at PRM 55.

Conversions of single main channels to split channels also occur in this reach. Vegetated islands at PRM 62 now divide the main channel between east and west branches. These branches have eroded into the side channel complex on the left and the riparian zone on the right. Changes in the locations of main channel flow splits and increased vegetation have created erosion (ranging from 750,000 to 3,000,000 sq. ft.) at PRM 53.5 left, PRM 51 right, PRM 49.5 right, and PRM 48 right.

Four named tributaries join the Susitna River or connecting sloughs in LR-3: Kashwitna River at PRM 65.3, Little Willow Creek at PRM 54.4, Willow Creek at PRM 54, and Deshka River at

PRM 45. Migration of the main channel has moved the mouth of Kashwitna River in 2012 approximately 200 feet upstream of its 1983 location. Approximately 2,500 feet upstream of the mouth, the Kashwitna River has migrated 200 feet southeast. By 2012, many of the Kashwitna River's point bars that were bare in 1983 had been encroached by vegetation. Both Little Willow Creek and Willow Creek appear to be slightly wider, and point bars that had been present in 1983 were not visible in the 2012 aerial photographs. However, discharge data were not available for either tributary; the wider channels and point bars not being visible may be due to higher discharges in both tributaries. Otherwise, no discernible change was detected from the aerials for both Little Willow Creek and Willow Creek between 1983 and 2012. The high level of stability for these two tributaries is consistent with R&M Consultants and Trihey & Associates (1985b). The Deshka River, upstream of its mouth, has remained relatively the same between 1983 and 2012. The mouth of the Deshka River appears to be approximately 80 feet wider in 2012 aerials than 1983 aerials; however, this may be due to a higher discharge in the main channel in 2012. Slightly more vegetation has developed on the side channel complex upstream of the tributary mouth (1983 area = 2,509,000 sq. ft., 2012 area = 3,166,000 sq. ft.).

5.2.4. Lower River Reach 4 (PRM 44.6 to PRM 32.3)

In geomorphic reach 4 (LR-4), the Yenta River is at the downstream limit of the Susitna River (2,750 feet active width) in which the Susitna River flows between Upper Pleistocene-age lacustrine deposits on both the east and west sides of the valley. Valley floor constriction is created by the Yentna River alluvial fan and the Upper Pleistocene-age moraine on the east side of the river and the moraine-draped, Late Cretaceous-age, granodiorite outcrop on the west side of the river at Susitna Station (PRM 30.1 downstream of the reach boundary). The bulk of the alluvial sediments in the reach are stored in vegetated islands, mid-channel bars, and continuous vegetated floodplains on both sides of the river.

Significant channel change detected from the comparison of the 1983 and 2012 aerial photography was limited to vegetation encroachment, a main channel cutoff, and erosion in this fairly stable reach. Vegetation encroachment has occurred within the three side channel complexes at PRM 42 left, PRM 37 right, and PRM 35 right, and vegetated island area has increased by 13 percent (1983 area = 109,562,000 sq. ft., 2012 area = 124,246,000 sq. ft.). Over the entire reach, vegetative areas increased by 8 percent (1983 area = 119,293,000 sq. ft., 2012 area = 129,187,000 sq. ft.) with only a 1-percent increase (from 106,234,000 to 106,874,000 sq. ft.) in the braid plain. A significant change is the main channel across the side channel complex at PRM 37.7. Here the main channel has captured several smaller side channels and divided a vegetated island. This appears to have resulted in erosion of vegetated floodplain on the river right at PRM 35 (200 feet by 1500 feet) and PRM 36 (300 by 1,500 feet). Erosion (300 by 4,500 feet) at PRM 38.5 right appears to be from main channel meandering.

Higher flows in the 2012 aerials (55,000 cfs for PRM 33.5 to PRM 44.6 in 2012 compared to 36,600 cfs in 1983) may account for the 72 percent decrease in mid-channel bars and bar island complexes (1983 area = 55,295,000 sq. ft., 2012 area = 15,544,000 sq. ft.) as opposed to those shown the 1983 aerials. The small increase of 1 percent in braid plain area (1983 area = 106,234,000 sq. ft., 2012 area = 106,874,000 sq. ft.) indicates that the change in bar island complex area is due to the bars being inundated at the 2012 discharge rather than a change in the area of the channel dimension.

5.2.5. Lower River Reach 5 (PRM 32.3 to PRM 23.5)

In geomorphic reach 5 (LR-5) between the Yentna River confluence at PRM 32.3 and the downstream limit of the reach at PRM 23.5, the Susitna River (3,250 feet active width) is confined by Upper Pleistocene-age glacio-lacustrine deposits on the east bank as well as the Late Cretaceous-age granodiorite outcrop on the west side of the river at Susitna Station (PRM 30.1). This is the only reach with the Lower River to be classified as having a single channel form (Tetra Tech 2013b). The relatively constricted valley limits the sediment storage potential within the reach, and the bulk of the sediment is stored in mid-channel bars, vegetated islands, and discontinuous floodplain segments (ER=2.7). The Yentna River is the only named tributary that enters this reach of the Lower River and contributes approximately 40 percent of the mean annual flow measured at Susitna Station (Tetra Tech 2013d).

Within the relatively stable geomorphic reach LR-5, the primary channel changes were vegetation encroachment and side channel meander migration. Vegetation encroachment into the bar island complex from vegetated islands occurred to a limited degree (1983 area = 39,585,000 sq. ft., 2012 area = 40,414,000 sq. ft.) on the inside bend at PRM 25 left, PRM 26 left, and the side channel inlet at PRM 27.5 left. Sufficient vegetation encroachment occurred within what had been a bar island complex in 1983 at the downstream limit of the reach such that the area was classified as a side channel complex in 2012, accounting for the increase in side channel complex area of approximately 1,200,000 sq. ft. Erosion and vegetation encroachment of the mainstem (1983 area = 192,265,000 sq. ft., 2012 area = 195,134,000 sq. ft.) was minor and amounted to an increase of 1 percent.

Higher flows in the 2012 aerials (48,000 cfs) may account for the decrease in mid-channel bars visible on the aerials and the associated bar island complexes delineated as opposed to those shown the 1983 aerials (36,600 cfs). This is supported by the 73 percent decrease in bar island complex area (1983 area = 68,312,000 sq. ft., 2012 area = 18,261,000 sq. ft.), and is mostly reflected in the 49-percent increase in main channel area (1983 area = 86,976,000 sq. ft., 2012 area = 129,912,000 sq. ft.), indicating that the bar island complexes were inundated at the higher 2012 discharge.

5.2.6. Lower River Reach 6 (PRM 23.5 to PRM 3.3)

From PRM 23.5 to the Cook Inlet at PRM 3.3 in geomorphic reach 6 (LR-6), the Susitna River (5,280 feet active width) forms a delta-distributary system with longitudinally continuous, vegetated, and relatively stable inter-distributary channel delta plain segments (ER=5.9). The average gradient in this reach was estimated at 1.5 ft/mile.

This reach is tidally influenced. The primary geomorphic changes within LR-6 are related to the increase in proportion of flow in the west distributary. Processes of channel widening, bank erosion, and vegetation encroachment appear to have contributed to the change in flow distribution between the channels.

Vegetation processes in the side channel complexes are prominent in this reach. Vegetation encroachment has narrowed the side channels by as much as 400 to500 feet within the side channel complex through PRM 23 and PRM 19. The bar island complex at PRM 12 has converted to a side channel complex through establishment of vegetation. Another bar island complex on the left main channel distributary branch lost half its area (1983 area = 4,841,000 sq. ft.) to main channel and the other half to vegetation encroachment at PRM 7. The inlet to the west branch of the side channel complex has narrowed to about half its width due to encroachment since 1983. This would have reduced the amount of flow entering the west branch. The corresponding increase in flow to the east branch may explain the large amounts of bank erosion and meander migration.

The area of greatest change occurred at PRM 11 right with the enlargement of a minor distributary channel that was classified as a side channel in 1983 and reclassified as a main channel in 2012. Since 1983, the channel has widened from approximately 200 to 1,000 feet. This channel is now estimated to convey more than 10 percent of the mainstem discharge. Therefore, the vegetated island at PRM 7 is no longer bounded or part of a side channel complex, but is classified as a single vegetated island. On the opposite side of the mainstem, a chute cut-off has shortened the main channel length by approximately 2,700 feet at PRM 11 left.

Significant bank erosion can be seen at PRM 21 left (2,300,000 sq. ft.), PRM 14 right (6,000,000 sq. ft.), PRM 12 left (2,300,000 sq. ft.), and PRM 11 (2,000,000 sq. ft.). The bend at PRM 16.5 appears to be migrating. Since 1983 the inside bend has shifted southeast with the extension of bar island complexes (by 2,000,000 sq. ft.) and establishment of vegetated islands (3,400,000 sq. ft.). The outside bend received a comparable amount of bank erosion (5,000,000 sq. ft.).

Differences in the discharges of the 1983 (36,600 cfs) and 2012 (55,000 cfs) aerials and tidal influences may account for apparent changes in the area and extent of non-vegetated features. The timing of the tidal ebb and flow could also influence the turbidity and geomorphic classification of sloughs and channels in terms of whether they are turbid or clearwater features.

The only named tributary in LR-6 is Alexander Creek. Aside from a 230,000 sq. ft. patch of vegetation having developed in 2012 on the gravel bar near the mouth of Alexander Creek, it remained mostly unchanged between 1983 and 2012.

5.2.7. Chulitna River Reach

The Chulitna River Reach (CL-1) joins the Susitna River at PRM 102 at the Three Rivers Confluence. The reach extends approximately 18,000 feet upstream of the Susitna River to encompass over three miles of this major tributary. The average annual sediment load of the Chulitna River was estimated to be 9.9 million tons/year (Tetra Tech 2013c). This is 66 percent of the total sediment load estimated for the Three Rivers Confluence. The remainder of the estimated average annual load is composed of 3.3 tons/year from the Susitna River or 22 percent and the 1.9 tons from the Talkeetna River or 12 percent. In contrast, the percentage of average annual flow contributed at Three Rivers Confluence is 36, 46, and 17 for the Chulitna, Susitna, and Talkeetna rivers, respectively (Tetra Tech 2013d). The dominance of the Chulitna River in terms of sediment supply is reflected in the channel from downstream of the Three Rivers Confluence, which resembles the Chulitna River much more so than the Susitna River even though their flow contributions are similar.

The river planform changes from a single channel to multiple channels at the reach's upstream end as the river exits a more confined area. The Chulitna River Reach is net aggradational and the bulk of the alluvial sediment is stored in active unvegetated braid bars (Tetra Tech 2013b). Within the reach, there are also locations where alluvial sediments are stored within vegetated islands and mid-channel bars, and the reach is bounded on each side by a vegetated floodplain of varying width.

The dominant change in this reach between 1983 and 2012 was vegetation encroachment on the mid-channel bars and lateral channel migration into the vegetated floodplain. The right edge of the river has experienced approximately 2,000 feet of vegetation encroachment and changed from a bar island complex in 1983 to a side channel complex in 2012. The braid plain (1983 area = 44,399,000 sq. ft., 2012 area = 32,463,000 sq. ft.) has reduced by 27 percent. Further vegetation encroachment has narrowed the channels that were present in 1983 side channel complex by approximately 33 percent. The area of side channel complex, including its vegetated islands, increased by 50 percent. In the lower 7,000 feet of the Chulitna River, the side channel complex has shifted the braid plain north by approximately 2,000 feet since 1983. The left edge of the braid plain has eroded into the floodplain that separates the Middle Susitna River Segment from the Chulitna River.

5.2.8. Talkeetna River Reach

The Talkeetna River Reach (TK-1) joins the Susitna River at PRM 101, which is the Three Rivers Confluence. It was bounded approximately 25,000 feet upstream of the Susitna River and covers the lower five miles of the Talkeetna River (1983 aerials only cover the lower 10,000 feet of the reach). The Talkeetna River is the smallest of the three rivers at the confluence and on an average annual basis contributes 12 percent of the sediment load and 17 percent of the flow at the Three Rivers Confluence (Tetra Tech 2013c, 2013d). The planform changes from a single channel to anastomosed about a quarter of the way downstream through the reach. The bulk of the alluvial sediments within the reach are stored in longitudinal vegetated floodplain islands and attached bars.

The Talkeetna near the Three Rivers Confluence is a relatively stable reach. It has vegetated islands and attached bars, as opposed to highly dynamic bar island complexes where the channel braids shift regularly and the main channel may often migrate. Vegetated islands within the Talkeetna have converted from parts of side channel complexes to islands within the main channel. Consequently, vegetated islands within side channel complexes decreased by 40 percent (1983 area = 5,185,000 sq. ft., 2012 area = 3,103,000 sq. ft.), while vegetated islands within the main channel increased by 188 percent (1983 area = 5,580,000 sq. ft., 2012 area = 16,097,000 sq. ft.).

A noticeable change occurred near the upstream end of the 1980s aerial coverage where a main channel branch captured a 1,000-foot-long former side channel and reversed its flow direction.

The flow direction is now southeast to northwest at a point 8,000 feet up the middle main channel branch. The former side channel was estimated to convey more than 10 percent of the flow in 2012 and was reclassified as a main channel.

5.2.9. Yentna River Reach

The Yenta River Reach (YN-1) joins with the Susitna River at PRM 32.3 and defines the reach break between geomorphic reaches LR-4 and LR-5. The Yenta River Reach extends nearly three miles above the confluence. Review of the average annual flow and estimated sediment load for Susitna Station indicates that the Yentna River contributes 40 percent of the total mean annual flow of 48,600 cfs at the Susitna Station and 46 percent of the total sediment load of 34.1 million tons/year (Tetra Tech 2013c, 2013d). The bulk of the alluvial sediments in the reach are stored in vegetated islands, mid-channel bars, and continuous vegetated floodplains on both sides of the river.

Geomorphic changes in the Yentna River channel include the alternating of side channel and main channels, and vegetation encroachment. The main channel has occupied and widened (from 200 to 800 feet) approximately one mile of former side channel that was along the right side of the mainstem in 1983. At the same time, the former main channel has decreased its flow capacity to less than 10 percent of the total flow based upon the nearly perpendicular angles of it inlets and the presence of mid-channel bars. Consequently, it was classified as a side channel for 2012. Vegetation encroachment (1983 area = 4,259,000 sq. ft., 2012 area = 7,596,000 sq. ft.) has transformed a bar island complex and several smaller islands into a single large island.

6. SUMMARY AND CONCLUSIONS

This 2012 study effort utilized aerial photographs from 1983 and 2012 to perform an analysis of channel change over the approximately 30-year period. The analysis included classification of various components of the system into geomorphic features. The geomorphic features have direct relationships to the aquatic habitat types that were studied in in the 1980s in the Middle River (Trihey & Associates 1985a) and the Lower River (R&M Consultants, Inc. and Trihey & Associates 1985a). By creating this linkage between the habitat types and the geomorphic features, the assessment of channel change provides insight into how the features that comprise the important aquatic macrohabitats in the Middle and Lower Susitna River have changed or remained the same over the past three decades.

The technical memorandum *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013a) provided a comparison of aquatic habitat for 17 sites in the Middle River and five sites in the Lower River. This current technical memorandum differs in that it covers the entire length of both segments, whereas the aquatic habitat mapping effort covered about 50 percent of the Middle River and less than 5 percent of the Lower River. Additionally, the aquatic habitat mapping considered only the wetted portion of a geomorphic feature at a specific flow rate while the geomorphic feature mapping effort considers the entire bank to bank area of the feature including wetted and non-wetted portions.

The conclusions are divided into a discussion of the Middle Susitna River Segment and the Lower Susitna River Segment. The Middle River discussion is organized around the individual features including main channel/side channels, vegetated islands, side sloughs, upland sloughs, and tributaries. The main channel and side channels were combined into the one category for discussion since the 1980s demarcation between main channel and side channel of 10 percent or greater flow conveyance is subjective when using only aerial photographs. For the Lower River, the discussion is organized around grouping of geomorphic features that highlight key physical processes or isolate important aquatic habitat types. The first grouping is the primary conveyance features, which includes the main channels, side channel complexes, bar island complexes, and side channels. The second grouping consists of the vegetated islands within the previously mentioned channel features. The third grouping consists of a relatively small portion of the geomorphic features, but comprises the important clearwater habitats. The clearwater grouping includes the side sloughs, upland sloughs, and tributaries.

6.1. Middle Susitna River Segment Geomorphic Features

To support the discussion of the change in geomorphic features between 1983 and 2012 a summary of the area for each geomorphic feature for both years and the change in area from 1983 to 2012 is presented in Tables 5.1-2 through 5.1-9 and Appendix 7. Figure 6.1-1 plots the change in area for each feature by geomorphic reach In Figure 6.1-1 the relative magnitude of the area change per mile is represented as the height of the bars for main and side channels, side sloughs, upland sloughs, tributaries and vegetated islands. At the end of this section, plots of the relative proportion of the various geomorphic features between 1983 and 2012 are provided to help assess the potential application of the habitat mapping from the 1983 aerials for identifying the distribution and frequency of aquatic macrohabitat for current conditions.

6.1.1. Main Channel / Side Channel

The greatest change in terms of main channel and side channels was that channels in the lower reaches of the Middle Susitna River Segment below Devils Canyon are being encroached by vegetation. Channel (main and side) area decreased (by an average of approximately 200,000 sq. ft. per mile) in the lower four Middle River reaches (MR-5 to MR-8). The change of main and side channel area in MR-5 (99,000 sq. ft. per mile) and MR-7 (144,000 sq. ft. per mile) was due to conversion to vegetated islands since 1983. In MR-8, the main and side channel area was reduced by 144,000 sq. ft. per mile (or 2 percent) because the channels were narrowed by vegetation encroachment along their banks. The amount of main and side channels in MR-6 increased due to the breaching of side sloughs, but decreased by a greater amount with conversion to vegetated islands and riparian zone.

Above Devils Canyon, the combination of main channel/side channel either remained stable or experienced slight widening. The changes seen in Figure 6.1-1 for MR-1 difference represents about a 5-percent increase in area of the main channel/side channel. However, about 2 percent of that increase is due to erosion of vegetated islands, so the actual channel widening based on the change in areas is about 3 percent. This represents a reach average increase in channel width of about 15 feet. Some of the area difference may be due to difficulty in accurately identifying the top of banks in areas with shadows. The change in MR-2 is due to higher flows in the 1980s

(30,000 cfs) aerials inundating with turbid water and creating a side channel feature in an area which at a lower flow in 2012 (17,000 cfs) is a large side slough. The minor erosion trend continued in MR-3 where the area of the combined main channel and side channel increased slightly, despite a side channel, similar to MR-2, being reclassified as a side slough due to the lower flows in the 2012 aerials. The difference in MR-4 is due to difficulty in delineating the banks in this bedrock controlled reach with steep canyon walls.

6.1.2. Vegetated Islands

Vegetated islands increased overall for the Middle Susitna River Segment. Substantial increases occurred since 1983 within MR-6 (approximately 300,000 sq. ft /mile) and MR-7 (approximately 400,000 sq. ft /mile). Reaches MR-3, MPR-4, and MR-8 did not have appreciable changes, since the change in the area of vegetated islands was less than 15,000 sq. ft. per mile. However, MR-8 did experience encroachment by vegetation along the banks as mentioned in the previous section. Moderate increase in vegetated island area occurred in MR-2 and MR-5 with an increase of approximately 80,000 sq. ft. per mile. Only one reach, MR-1, experienced net erosion of vegetated islands with a reach average reduction in vegetated island area of 60,000 sq. ft. per mile.

6.1.3. Side Sloughs

Over the Middle Susitna River Segment, a significant change between 1983 and 2012 was the decrease in side slough frequency and area. The geomorphic processes by which side sloughs change include the erosion of the slough inlet elevations (breaching), erosion of the entire feature, and vegetation processes of encroachment and succession. Deposition in the main channel could also create a reduction in side sloughs. The analysis of side sloughs focuses on geomorphic Reaches MR-6 through MR-8 where the vast majority of side sloughs occur. In fact, no side sloughs were identified from either the 1980 or 2012 aerials in MR-1, MR-4 and MR-5. Due to the high flows in the 1980s aerials in MR-3, no side sloughs were present and only a minor amount in MR-2.

Within MR-6, MR-7, and MR-8, side slough geomorphic feature area has decreased by an average of 222,000 sq. ft. per mile (or 61 percent) since 1983. The aquatic macrohabitat area for Sites 1 to 13 (including the sites within MR-8, MR-7 and section of sites within MR-6 that had comparable discharges), side slough wetted habitat area was shown to decrease by 42 percent (Tetra Tech 2013a). Therefore, by two different measures, side sloughs were determined to have decreased on the order of 50 percent since 1983.

The trend of side slough conversion to side channel in the Middle River over the past 30 years has not always been the case. Labelle et al. (1985) studied channel changes within the Middle River from 1949 to 1982 using a series of aerial photographs. The results of that effort indicated that 12 sloughs and side channels changed classification type. Of these 12 (Table 2 of Labelle et al. 1985) six side channels became side sloughs, five side sloughs changed to upland sloughs and one upland slough converted to a side slough. In general all but one change, the side slough to a side channel, involved a change to a less connected classification. Labelle et al. (1985) hypothesized that this was a result of a general trend toward main channel degradation (lowering) in the Middle River. However, the results of the current study indicate that between 1983 and 2012, in reaches with comparable flow, side slough geomorphic area decreased between 53 percent and 68 percent (Table 5.1-7 through Table 5.1-9). Therefore it appears that for both periods, there was considerable change in classification of the sloughs and side channels and that the two 30-year periods exhibited opposite trends. This suggests a fairly high level of natural variability associated with whether a particular lateral habitat will be a side channel or side slough and possibly even an upland slough over a period of decades.

6.1.4. Upland Sloughs

As with side sloughs, the vast majority of upland sloughs occur in the portion of the Middle River below Devils Canyon in geomorphic reaches MR-6, MR-7, and MR-8. Above Devils Canyon only MR-2 had an appreciable area of upland sloughs at 440,000 sq. ft., but high flows in the 1980s aerials make meaningful comparison between the two dates impossible.

In the Middle Susitna River Segment, upland sloughs within MR-6 and MR-7 decreased due to conversion to additional open water areas through biogeomorphic processes. The decrease in upland slough geomorphic feature area was approximately 5,000 sq. ft. per mile for MR-6 and 7,000 sq. ft. per mile for MR-7. A similar trend was determined for the upland slough wetted aquatic macrohabitat area within reaches MR-6 and MR-7 that were shown to decrease by 25 percent (Tetra Tech 2013a). In MR-8, geomorphic upland slough area increased since 1983 by 37,000 sq. ft. per mile (25 percent) due to vegetation encroachment in a 1983 side slough that converted it to an upland slough by 2012. The wetted aquatic macrohabitat area for the only upland slough site analyzed in MR-8 was shown to increase by 85 percent (Tetra Tech 2013a).

6.1.5. Tributaries

Several general observations concerning the behavior of the tributary confluences can be made from the analysis of the 1983 and 2012 aerials. Many of the tributaries along the confined single channel morphologies of MR-1 to MR-7 go through cycles of fan expansion and vegetation encroachment. Vegetation encroachment on the Lane Creek delta (PRM 117.2, MR-7) has extended its downstream geomorphic limits farther into the receiving side channel. Some of the most noticeable fan differences occurred on the larger of the Middle River tributaries, Fog Creek (PRM 179.3 left, MR-2) and Indian River (PRM 140.0, MR-6). The number of channel braids on these tributaries has reduced. The single channel portions have a significantly narrower active channel width in 2012 compared to the braided portions of the 1980s. The channel pattern appears to have changed due to vegetation encroachment.

Floodplain deposition has widened Downunda Creek (PRM 122.5 right, MR-6 and MR-7) and Fourth of July Creek (PRM 134.3, MR-6) to twice their 1983 bankfull width. Widening occurred with the conversion from a single channel to multiple braided channels. The different extents of the fans between 1980 and 2012 indicate that sediment delivery varies and is likely the result of, large, infrequent sediment delivery events. Such an event may have occurred in September 2012 and was reported to have contributed considerable amounts of sediments to some of the tributaries. The response to the 2012 event will be further investigated in 2013. Review of aerials form the 1950s and field investigations in 2013 will provide further insight into the behavior of the tributary confluences that will help guide efforts in the Fluvial Geomorphology Modeling Study to identify potential Project effects.

6.2. Lower Susitna River Segment Geomorphic Features

The Lower River is distinctly different from the Middle River as the character of the Susitna River changes dramatically below the Three Rivers Confluence. The width of the river more than triples from the widest portions in the Middle River Segment, and it adopts a braided channel form. Consequently, the presentation of the conclusions for the Lower Rive is organized differently than for the Middle River. Unlike the Middle River conclusions which were presented for each individual geomorphic feature, the presentation of the Lower River conclusions is organized around grouping of geomorphic features that highlight key physical processes or isolate important aquatic habitat types. The first Lower River grouping is the “primary conveyance features” which includes the main channels, side channel complexes, bar island complexes and side channels. The second grouping consists of the “vegetated islands features” within the previously mentioned channel features. The third grouping consists of a relatively small portion of the geomorphic features, but comprises the important “clearwater features.” The clearwater grouping includes the side sloughs, upland sloughs and tributaries.

To support the discussion of the change in geomorphic features in the Lower River Segment, summaries of the areas of features for both years and the change in areas from 1983 to 2012 are presented in Tables 6.2-1 and 6.2-2. Table 6.2-1 presents the information for both the primary conveyance feature grouping and the vegetated island feature grouping. Similar area information for the clearwater feature grouping is presented in Table 6.2-2. Figures 6.2-1 through 6.2-3 display the change in area from 1983 to 2012 for the various geomorphic features within a feature grouping for each geomorphic reach. The information for the primary conveyance features is provided in Figure 6.2-1, the information for the vegetated islands within the primary conveyance features in Figure 6.2-2 and the information for the clearwater features in Figure 6.2-3. The relative magnitude of the area change in units of one million square feet per mile is represented as the height of the bars for each feature type. Each feature type is part of a stacked bar and each reach has its own set stacked bars. Stacked bars for features which reduced in area between 1983 and 2012 are plotted on the negative portion of the graph and features that increased in area are plotted on the positive portion of the graph. Each reach has an adjacent bar that represents the net difference between the negative bars (loss of area), and the positive bars (gain in area).

6.2.1. Primary Conveyance Features

The primary conveyance features include the main channels, side channel complexes, bar island complexes and side channels of the Lower Susitna River Segment. The vegetated islands inside these features are excluded from the area determinations for the features. Figure 6.2-1 plots the changes in the areas of the channel features in order to help understand what features may be increasing in areas and what features may be decreasing within the various reaches. This information, combined with the similar plot for vegetated islands in Figure 6.2-2, is useful in discerning the exchange between channel reduction and widening processes, and vegetation encroachment and removal processes (erosions). Channel change was also estimated based upon visual review of the overlaid 1983 and 2012 aerials. The overlay analysis helped in identification of the spatial distribution of geomorphic processes such as bank erosion, channel deposition or erosion resulting in changing flow distribution at flow splits, the apparent erosion of side channel inlets, lateral channel migration, and vegetation encroachment.

Across the geomorphic reaches, the Lower Susitna River Segment the most apparent trend is the reduction in the area of the primary conveyance features. Five of the six reaches showed net losses ranging from 700,000 sq. ft. per mile for LR-4 to 2,900,000 sq. ft. per mile for LR-2. These values represent a reach averaged reduction in channel width ranging from 130 feet to over 500 feet. The exception to trend of increasing primary conveyance feature areas between 1983 and 2012 was LR-5 which showed a net increase in the area of primary conveyance features of 400,000 sq. ft. per mile.

Vegetation encroachment within the bar island complexes accounts for much of the vegetation that has developed in former portions of the primary conveyance features. A good example is the 1983 bar island complex in LR-1 between PRM 96 and PRM 94 right. At this location, the development of the vegetated islands shifted the main channel flow to the left and the channel eroded through the forested floodplain and breached Birch Creek Slough near PRM 95. The development of the vegetated islands also changed the classification of the 1983 bar island complex to a side channel complex in 2012.

In LR-2, a pattern of bar island complexes transforming to side channel complexes on alternating sides of the channel is apparent form the aerial overlays. This may only be a short term trend and it is noted that there are still areas of significant braid plain and even in areas where a dominant main channel may be developing; numerous smaller side channels still exist. Review of the 1950s aerials in 2013 will help discern longer term trends in the evolution of the channel form within the Lower River.

Though vegetation encroachment is widespread throughout the Lower River, there are areas of bank erosion and channel widening. For example, LR-5 experienced a net increase of 400,000 sq. ft. per mile in the area of primary conveyance features. For the 8.8 mile long reach, this represents an average increase in width of 75 feet. This is in contrast to LR-2 which had the largest average decrease in width of the primary conveyance features on the order of 500 feet. The overlay analysis also identified localized areas of bank erosion and channel widening. One example is the approximately 7,000,000 sq. ft. of erosion that occurred at PRM 11 right with the enlargement of a minor distributary channel. Since 1983, the 9,000 foot long channel has widened from approximately 200 to 1,000 feet.

Even in reaches where there is a net loss in the area of the primary conveyance features, there is some bank erosion if the net increase in area of vegetated islands is greater than the reduction in area of the primary conveyance features. This occurred to the greatest extent in reaches LR-6 where an average of 500 feet of bank erosion partially offsetting the increase in vegetated island area. Reaches LR-3 and LR-5 also fall into this category with 50 and 150 feet of bank erosion partially offsetting the increase in vegetated island area. Conversely, when the net increase in vegetated islands is not as great as the net reduction in the area of primary conveyance features in a reach, the difference represents additional loss of the primary conveyance area due to floodplain development along the channel banks. The reach with the most significant floodplain development offset was LR-1 which had a reach average 230 feet. Reaches LR-2 and LR-4 had minor floodplain building offsets of 20 and 70 feet, respectively.

6.2.2. Vegetated Island Features

The most consistent channel change in terms of vegetated islands identified in the Lower Susitna River Segment was the consistent increase in area of vegetated islands. All of the reaches showed a net increase in vegetated island features, as shown in Figure 6.2-2, with the most significant increase occurring in LR-2, LR-3, and LR-6. The increase in vegetated islands in LR-6 was over 5,200,000 sq. ft. per mile. In terms of the average width of island building in the Lower River Segment, the net values translate to a high of nearly 1,000 feet of island width increase in LR-6 to a low of 50 and 80 feet in LR-4 and LR-5, respectively.

When channel area is transformed to vegetated islands, sediment is stored in the vegetated islands. In LR-1, sediments are stored within the vegetated islands of bar island complexes and side channel complexes, and to a lesser degree main channel vegetated islands. The bar chart also shows that vegetated islands bounded by discrete side channels decreased in LR-1, but increased in LR-2. Such vegetated islands could be considered forested floodplains that are very stable locations for sediment storage. LR-2 had the greatest increase (2,300,000 sq. ft. per mile) in side channel vegetated islands. Sediment storage within the side channel complexes is the greatest for LR-3, which includes the Delta Islands. The side channel complex vegetated islands are significant and add stability to LR-1, LR-2, and LR-4 as well. The most significant storage of sediment is occurring in LR-6 and is occurring in islands adjacent to or within the main channel.

6.2.3. Clearwater Geomorphic Features

The overall changes in clearwater features in each reach of the Lower River are presented in Figure 6.2-3. All of the reaches showed a net increase in clearwater feature area, with the exception of LR-6, which showed a net decrease of 45,000 sq. ft. per mile. The increase of clearwater feature area ranged from 51,000 sq. ft. per mile in LR-2 to 150,000 sq. ft. per mile in LR-5. Clearwater features had minor changes primarily due to vegetation encroachment, and larger changes due to main channel migration causing increased or decreased connectivity. Of the clearwater geomorphic features in the Lower River, side sloughs changed the most from the 1980s to 2012. In reaches LR-1, LR-2, and LR-3, side slough area increased between 26,000 sq. ft. per mile in LR-3 and 50,000 sq. ft. per mile in LR-1. No side sloughs were present in LR-4, and side slough area decreased by 3,000 sq. ft. per mile in LR-5 and 75,000 sq. ft. per mile in LR-6. The loss of side slough habitat in LR-5 is also attributed to vegetation encroachment, as the one side slough which had been present in the 1980s was vegetated over in 2012. The increase in side slough area is primarily attributed to side channels and side channel complexes losing connectivity to the primary conveyance features, reducing flow and causing those features to evolve into side sloughs. Lateral main channel migration bisected a large side slough in LR-6 at PRM 16.5, directly connecting the main channel to the slough downstream of the bisection. The feature changed classification to side channel complex due to the increase in flow through the channel. Upland sloughs changed the least of the clearwater geomorphic features, ranging from a decrease of 9,000 sq. ft. per mile in LR-3 to an increase of 62,000 sq. ft. per mile in LR-4.

In addition to the major tributaries in the Lower River (Chulitna, Talkeetna, and Yentna Rivers), there were 13 minor tributaries in the Lower River, as studied in R&M Consultants, Inc. and Trihey & Associates (1985b): Trapper Creek, Birch Creek, Sunshine Creek, Rabideux Creek, Montana Creek, Goose Creek, Sheep Creek, Caswell Creek, Kashwitna River, Little Willow Creek, Willow Creek, Deshka River, and Alexander Creek. Relatively little change aside from slight vegetation development was observed in any of these tributaries, with the exception of Montana and Goose Creeks. Montana Creek had migrated slightly north, and flow had increased through two side channels converging at the mouth of the tributary, and the main channel is more directly connected at the mouth, reducing backwater. The majority of the Goose Creek flow no longer splits south, instead meeting a side channel which had previously been the main channel, but has since been separated by the development of a vegetated island.

In summary, while there were a number of minor changes throughout the Lower River, the most significant changes observed in clearwater features were related to changes in connectivity to the main channel.

6.3. Comparison of the Relative Proportion of Geomorphic Feature Types from 1983 to 2012

The relative proportion of the geomorphic features within each reach was determined for both the Middle River and Lower River Segments. This information was developed to help in assessing the relative change that has occurred in the distribution among the areas associated with the various geomorphic features within each reach. Geomorphic features are closely linked to the habitat types; this information is useful in determining whether the 1980s aquatic macrohabitat mapping information can be used to help represent the distribution of aquatic macrohabitat under current conditions. Similar comparisons were made between the macrohabitat mapping developed for the 1980s and 2012 conditions (Tetra Tech 2013a). That information was based on a sampling of sites that represented about 50 percent of the Middle River's length and over 50 percent of the habitat sites mapped in the 1980s in the Lower River (only a small portion of the Lower River habitat was mapped in the 1980s). The information presented below for the relative proportion of geomorphic features types is based on mapping the entire extent of each reach rather than sampling a fraction of the reach.

6.3.1. Middle Susitna River Segment

Figures 6.3-1 through 6.3-8 provide the relative proportion (percentages) of geomorphic features for each of the eight geomorphic reaches in the Middle River. Two sets of charts are provided for each reach, one in which the main channel and side channel are shown separately, and the other with the two features combined into a single percentage. The combined figure was included because of the large differences in the application of the main channel versus side channel criteria between the 1980s and the current effort.

Main channel and side channel features comprise from 88 to 100 percent of the geomorphic feature area in Middle River reaches in both the 1980s and 2012. Of all the Middle River reaches, MR-1, MR-4 and MR-5 maintained the same relative proportions in main channel and side channel feature areas between the 1980s and 2012. This can be misleading as these reaches are comprised almost entirely of main channel and side channel features with the combination representing 100, 99.7 and 96.9 percent of the geomorphic feature areas, respectively. The largest percent change in relative proportion for the combined main channel and side channel feature area occurred in MR-2 at an increase of 8.6 percent. (Note: The percent change is not based on the percentage of change in the proportion. For example if side slough features represented 5.0 percent of the area in a reach in the 1980s and 2.5 percent in 2012, the percentage change is 50 percent, not 2.5 percent.)

It is in the other geomorphic features classifications, side sloughs and upland sloughs, that there are appreciable changes in the proportions between the two periods in some of the geomorphic reaches. These features are also of the most interest since they are associated with the important clearwater aquatic macrohabitat types. Clearwater geomorphic features comprise less than 12 percent of the total area of any reach, and in most reaches, less than 5 percent of the total area. Most of the changes in relative proportions in the Middle River were in the side slough geomorphic features. In MR-2, side slough areas increased in relative proportion approximately by 3,000 percent; however this was largely due to higher flows in the 1980s aerials. In reaches with comparable flows, side sloughs decreased in relative proportion in MR-6, MR-7, and MR-8 by 58, 47, and 66 percent, respectively. Where changes occurred in relative proportion of upland slough, those changes ranged from a decrease of 13 percent (MR-7), to an increase of 1000 percent (MR-2). Where changes in tributary features occurred, those changes ranged from a 20 percent decrease (MR-5) to 58 percent increase (MR-7).

6.3.2. Lower Susitna River Reach

Figures 6.3-9 through 6.3-17 provide the relative proportion of geomorphic features in the Lower River. Each reach in the Lower River shows two sets of charts, one displaying all of the geomorphic features, and another set displaying only clearwater geomorphic features (side sloughs, upland sloughs and tributaries). Overall, the Lower River was more dynamic than the Middle River, in that there were no geomorphic features in any of the Lower River reaches that maintained consistent relative proportions between the 1980s and 2012. For example, side slough features varied by as much as a 100 percent decrease (LR-5) to a 108 percent increase (LR-2) in relative proportion. Upland slough areas varied by as much as a 1 percent decrease (LR-6) to a 170 percent increase (LR-4) in relative proportion, and tributary features varied from a 2 percent increase (LR-2) to a 67 percent increase (LR-3) in relative proportion.

6.3.3. Use of 1980s Aerials for 2013 and 2014 Studies

The level of change in proportion of the various geomorphic features, particularly the clearwater features, between the 1980s and present, supports the recommendations in Tetra Tech (2013a) that the 1980s surface area mapping of the aquatic macrohabitats should not be the sole or primary information used to represent the current aquatic macrohabitat conditions. This is true for both the Middle and Lower Susitna River Segments. Use of the geomorphic features for comparison eliminated some of the problems with trying to interpolate wetted areas between aerials taken at differing flows. In addition, this effort looked at the change for the entire area within each geomorphic reach rather than sampling of only a fraction of the reach as was the case for the macrohabitat mapping evaluated in Tetra Tech (2013a). The results in this study still showed relatively large changes of up to a 68-percent decrease in the proportion of clearwater geomorphic features within a geomorphic reach.

6.4. 2013 Study Efforts

In 2013, additional effort will be conducted in the Geomorphology Studies to expand upon the work provided in this technical memorandum. This will include additional aerial photo analysis, field verification, studies at tributary mouths and possible adjustment of feature definitions.

Two types of additional aerial analyses are planned for 2013. The first is to obtain a set of aerial photographs for the entire Middle Rive at a flow of approximately 12,500 cfs and for the Lower River at a flow of approximately 36,600 cfs. Current 12,500 cfs aerial coverage in the Middle River spans from PRM 102 to PRM 143.6. The remaining portion of the Middle River was flown at 17,000 cfs in 2012. In the Lower River the coverage at a 38,200 cfs, which is sufficiently close to 36,600 cfs to meet the study needs, is available from PRM 78 to PRM 102. The remaining length of the Lower River was flown at flows ranging from 48,000 to 55,000 cfs. In 2013 aerial photo coverage at 12,500 cfs will be obtained from PRM 143.6 to PRM 187.1 and at 36,600 cfs in the Lower River from PRM 0 to PRM 78.

Analysis of the aerial photography for conditions from 1980s to the present indicated considerable change in certain aspects of the system had occurred. For example, in the Middle River, there was substantial loss of side slough geomorphic features as a result of increased connectivity and conversion to side channels. In both the Middle and Lower River, vegetation tended to increase. This was most noticeable in the Lower River as the area of vegetated islands increased as large open areas of exposed substrate in bar island complexes were encroached upon by vegetation and the bar island complexes were converted to side channel complexes. In 2013 it will be important to discern whether these are long-term trends or shorter-term responses to specific conditions over the past three decades. Labelle et al. (1985) identified the opposite trend in an analysis of aerial photographs spanning the three decade period from the early 1950s to the early 1980s. The results of that effort indicated that 12 sloughs and side channels changed classification type. Of these 12 (Table 2 of Labelle et al. 1985) six side channels became side sloughs, five side sloughs changed to upland sloughs and one upland slough converted to a side slough. In general, all but one change, the side slough to a side channel, involved a change to a less connected classification. To provide the longer term perspective on channel change, in 2013 aerial photographs from the 1950s will be acquired and analyzed. This technical memorandum will be updated with the results of that analysis and the analysis of the 2013 aerials for the portions of the Middle River and Lower River where 2012 aerials were not collected at 12,500 and 36.600 cfs, respectively.

In 2013, coordination will occur with the Fish and Aquatics Instream Flow Study (IFS) to determine if any definitions of habitat types will be changed from the 1980s to provide more functional definition in the current study. For example, a specific breaching flow could be assigned to determine the difference between a side channel and a side slough rather than allowing the feature to switch classifications when it is breached. There is also potential to improve the definition of side channels versus main channels or to at least use a more quantifiable procedure to determine whether a channel feature has more than 10 percent of the flow and identify a reference flow for this determination.

Determination of the rate that area occupied by the channel is converted to floodplain and islands, and area occupied by floodplain and islands is converted to channel will provide information useful in identifying LWD recruitment rates and characterizing floodplain dynamics important to the Riparian IFS. Therefore, a "turnover" analysis is included as part of the 2013 Geomorphology Study effort. The turnover analysis will also assist the Geomorphology Study in developing a better understanding of vegetation establishment and encroachment within both the Middle and Lower River Segments. This effort is described in the Revised Study Plan (RSP) Section (AEA 2012). The turnover analysis will be conducted in 2013 and will include analyses of the period from the 1950s to the 1980s and from the 1980s to 2012. This effort will be coordinated closely with the Riparian IFS.

Results of the study effort presented in this technical memorandum indicated that portions of the tributaries in the area of their confluence with the mainstem can be dynamic features. This is true in both the Middle and Lower River Segments. Studies of the tributary confluences were already included in the RSP for the Lower River in Section 6.6. 4.1.2.6 (AEA 2012). As part of the decision to expand the Study effort in the Lower Susitna River Segment in 2013, five tributaries will be studied in the Lower River as part of the Geomorphology Study. These tributaries are: Trapper Creek, Birch Creek, Sheep Creek, Caswell Creek and the Deshka River (R2 2013).

The delineation of the geomorphic features will be improved through field assessments conducted in 2013. These will include surveys of breaching elevations at inlets to side sloughs in the Middle River and verification of the connection or lack of connection between many of the upland sloughs and adjacent beaver ponds.

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8. TABLES

Table 4.1-1. Summary of 1980s aerial dates, discharges, and project river mile extents.

Aerial Coverage (PRM)		Date	Discharge (cfs)	
From	To	(MM/DD/YYYY)	Gold Creek	Sunshine Station
Upper Susitna River Segment				
251	187	7/19 and 7/20/1980	35,800 & 31,600	---
Middle Susitna River Segment				
187	152	7/19 and 7/20/1980	35,800 & 31,600	---
158	102	9/11/1983	12,500 (12,200 published)	---
Lower Susitna River Segment				
102	0	9/6/1983	---	36,600

Table 4.1-2. Summary of 2012 aerial dates, discharges, and project river mile extents.

Aerial Coverage (PRM)		Date	Discharge (cfs)	
From	To	(MM/DD/YYYY)	Gold Creek	Sunshine Station
Upper Susitna River Segment				
266.5	231.5	10/20/2012	7,410	---
231.5	187	9/30/2012	17,000	---
Middle Susitna River Segment				
187	143.6	9/30/2012	17,000	---
143.6	102	9/10/2012	12,900	---
119	102	7/27/2012	22,200	---
Lower Susitna River Segment				
102	63	7/27/2012	---	53,000
102	78	9/10/2012		38,200
78	69	9/30/2012	---	48,000
69	33.5	10/10/2012	---	55,000
33.5	22.5	9/30/2012		48,000
22.5	0	10/10/2012	---	55,000

Table 5.1-1: Geomorphic reach delineations and classifications

Reach Designation	Reach Breaks (PRM / *RM*)[1]		Reach Classification	Slope (ft/mi)	Lateral Constraints
	Upstream	Downstream			
Upper Susitna River Segment (UR)					
UR-1	261.3 / *260.0*	248.6 / *247.7*	SC2	NA	Quaternary Basin Fill
UR-2	248.6 / *247.7*	234.5 / *233.0*	SC1	NA	Quaternary Basin Fill
UR-3	234.5 / *233.0*	224.9 / *223.1*	SC1	NA	Quaternary Basin Fill
UR-4	224.9 / *223.1*	208.1 / *205.7*	SC2	NA	Granodiorite
UR-5	208.1 / *205.7*	203.4 / *200.8*	SC1	NA	Quaternary Basin Fill
UR-6	203.4 / *200.8*	187.1 / *184.3*	SC2	NA	Quaternary Basin Fill
Middle Susitna River Segment (MR)					
MR-1	187.1 / *184.3*	184.6 / *181.9*	SC2	9	Tertiary-Cretaceous Gneiss
MR-2	184.6 / *181.9*	169.6 / *166.4*	SC2	10	Cretaceous Kahiltna Flysch Tertiary-Cretaceous Gneiss
MR-3	169.6 / *166.4*	166.1 / *163.0*	SC2	17	Paleocene Granites
MR-4	166.1 / *163.0*	153.9 / *150.3*	SC1	30	Paleocene Granites
MR-5	153.9 / *150.3*	148.4 / *144.9*	SC2	12	Cretaceous Kahiltna Flysch
MR-6	148.4 / *144.9*	122.7 / *118.9*	SC3	10	Cretaceous Kahiltna Flysch with undifferentiated Upper Pleistocene moraines, kames, lacustrine deposits
MR-7	122.7 / *118.9*	107.8 / *104.1*	SC2	8	Cretaceous Kahiltna Flysch with undifferentiated Upper Pleistocene moraines, kames, lacustrine deposits
MR-8	107.8 / *104.1*	102.4 / *98.6*	MC1/SC3 (Reach is a transition from SC3 to MC1 as the Three Rivers Confluence is approached)	8	Upper Pleistocene moraines, outwash and Holocene Alluvial Terrace deposits

Reach Designation	Reach Breaks (PRM / *RM*)[1]		Reach Classification	Slope (ft/mi)	Lateral Constraints
	Upstream	Downstream			
Lower Susitna River Segment (LR)					
LR-1	102.4 / *98.6*	87.9 / *83.8*	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-2	87.9 / *83.8*	65.6 / *61.4*	MC2/MC3	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-3	65.6 / *61.4*	44.6 / *40.3*	MC3	4	Upper Pleistocene Glaciolacustrine deposits
LR-4	44.6 / *40.3*	32.3 / *28.3*	MC2	2	Upper Pleistocene Glaciolacustrine deposits
LR-5	32.3 / *28.3*	23.5 / *19.4*	SC2	2	Upper Pleistocene Glaciolacustrine and Moraine deposits and Late Cretaceous granodiorite
LR-6	23.5 / *19.4*	3.3 / *0.0*	MC4	1.4	Upper Pleistocene Glaciolacustrine and Holocene Estuarine deposits

Notes:

1 First Value is in current Project River Miles (PRM). Second value, in italics, is in the 1980s River Mile (*RM*) System.

Table 5.1-2: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 1.

MR-1 (PRM 187.1 to PRM 184.6)								
Year	**Total Main Channel[1]**	**Total Side Channel[1]**	**Total Main Channel and Side Channel[1]**	**Total Side Slough[2]**	**Total Upland Slough[2]**	**Total Tributary[1]**	**Vegetated Island**	**Additional Open Water**
	ft^2							
1983	7,010,000	461,000	7,471,000	0	0	0	376,000	0
2012	7,240,000	610,000	7,850,000	0	0	0	222,000	0
Percent Change	3%	32%	5%	0%	0%	0%	-41%	0%

Notes:

1. Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).
2. Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-3: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 2.

MR-2 (PRM 184.6 to PRM 169.6)								
Year	**Total Main Channel[1]**	**Total Side Channel[1]**	**Total Main Channel and Side Channel[1]**	**Total Side Slough[2]**	**Total Upland Slough[2]**	**Total Tributary[1]**	**Vegetated Island**	**Additional Open Water**
	ft^2							
1983	51,619,000	4,644,000	56,263,000	136,000	32,000	1,076,000	8,375,000	213,000
2012	50,726,000	1,035,000	51,761,000	4,719,000	438,000	987,000	9,527,000	295,000
Percent Change	-2%	-78%	-8%	3370%	1269%	-8%	14%	38%

Notes:

1. Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).
2. Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-4: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 3.

MR-3 (PRM 169.6 to PRM 166.1)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft²							
1983	10,627,000	0	10,627,000	0	0	12,000	410,000	0
2012	10,697,000	9,000	10,706,000	292,000	11,000	10,000	368,000	0
Percent Change	1%	N/A	1%	N/A	N/A	-17%	-10%	0%

Notes:

1 Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).

2 Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-5: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 4.

MR-4 (PRM 166.1 to PRM 153.9)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft²							
1983	20,874,000	35,000	20,909,000	0	0	66,000	45,000	0
2012	20,064,000	29,000	20,093,000	0	0	67,000	46,000	4,000
Percent Change	-4%	-17%	-4%	0%	0%	2%	2%	N/A

Notes:

1 Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).

2 Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-6: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 5.

MR-5 (PRM 153.9 to PRM 148.4)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft²							
1983	14,208,000	831,000	15,039,000	0	0	482,000	1,636,000	0
2012	14,155,000	339,000	14,494,000	0	0	481,000	2,073,000	0
Percent Change	0%	-59%	-4%	0%	0%	0%	27%	0%

Notes:

1. Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).
2. Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-7: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 6.

MR-6 (PRM 148.4 to PRM 122.7)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft²							
1983	85,064,000	45,830,000	130,894,000	14,573,000	700,000	1,472,000	66,124,000	523,000
2012	100,493,000	27,431,000	127,924,000	5,660,000	566,000	775,000	73,743,000	592,000
Percent Change	18%	-40%	-2%	-61%	-19%	-47%	12%	13%

Notes:

1. Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).
2. Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-8: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 7.

MR-7 (PRM 122.7 to PRM 107.8)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft^2							
1983	55,385,000	16,149,000	71,534,000	1,083,000	572,000	84,000	14,912,000	1,245,000
2012	60,502,000	5,241,000	65,743,000	512,000	455,000	121,000	20,696,000	1,375,000
Percent Change	9%	-68%	-8%	-53%	-20%	44%	39%	10%

Notes:

1 Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g. Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).

2 Total values are a summation of the geomorphic feature's wetted region and exposed region.

Table 5.1-9: Comparison of mapped geomorphic feature area from 1980s and 2012 in Middle River geomorphic reach 8.

MR-8 (PRM 107.8 to PRM 102.4)								
Year	Total Main Channel[1]	Total Side Channel[1]	Total Main Channel and Side Channel[1]	Total Side Slough[2]	Total Upland Slough[2]	Total Tributary[1]	Vegetated Island	Additional Open Water
	ft^2							
1983	26,891,000	5,774,000	32,665,000	1,077,000	795,000	250,000	9,844,000	595,000
2012	29,495,000	2,395,000	31,890,000	348,000	994,000	285,000	9,874,000	900,041
Percent Change	10%	-59%	-2%	-68%	25%	14%	0%	51%

Notes:

1 Total Values are summation of the geomorphic feature's wetted region, exposed region, and tributary mouth (e.g., Main Channel + Exposed Main Channel + Main Channel Tributary Mouth).

2 Total values are a summation of the geomorphic feature's wetted region and exposed region.

3 A delineated AOW from 2012 that was not delineated in 1983 was subtracted from the 2012 MR-8 AOW summation and added into Background.

Table 5.2-1: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 1.

LR-1 (PRM 87.9 to PRM 102.4)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	73,434,000	22,858,000	163,389,000	0	236,824,000	308,867,000	615,000	1,190,000	5,579,000	634,000	0	77,000	32,781,000	16,328,000	93,727,000
2012	71,135,000	18,218,000	148,951,000	0	220,086,000	312,410,000	730,000	1,911,000	3,207,000	590,000	0	1,245,000	42,902,000	29,960,000	99,799,000
Percent Change	-3%	-20%	-9%	0%	-7%	1%	19%	61%	-43%	-7%	0%	1517%	31%	83%	6%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-2: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 2.

LR-2 (PRM 65.6 to PRM 87.9)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	132,878,000	79,412,000	216,331,000	0	349,209,000	638,439,000	752,000	1,159,000	1,288,000	1,174,000	373,000	553,000	178,349,000	30,915,000	221,147,000
2012	142,407,000	84,228,000	130,472,000	0	272,879,000	577,607,000	1,061,000	2,057,000	7,846,000	1,105,000	351,000	2,917,000	195,102,000	22,480,000	283,288,000
Percent Change	7%	6%	-40%	0%	-22%	-10%	41%	77%	509%	-6%	-6%	427%	9%	-27%	28%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-3: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 3.

LR-3 (PRM 44.6 to PRM 65.6)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	112,019,000	120,577,000	247,828,000	0	359,848,000	1,005,566,000	2,631,000	680,000	3,253,000	13,171,000	0	0	489,845,000	35,297,000	590,870,000
2012	126,610,000	160,038,000	155,122,000	0	281,732,000	1,015,174,000	2,451,000	1,225,000	5,343,000	15,374,000	0	2,029,000	547,959,000	23,415,000	633,028,000
Percent Change	13%	33%	-37%	0%	-22%	1%	-7%	80%	64%	17%	0%	NA	12%	-34%	7%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-4: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 4.

LR-4 (PRM 32.3 to PRM 44.6)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain¹	Mainstem²	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	60,670,000	65,136,000	45,564,000	0	106,234,000	290,662,000	481,000	0	8,557,000	325,000	0	0	109,562,000	9,731,000	345,500,000
2012	94,451,000	55,676,000	12,423,000	0	106,874,000	291,737,000	1,248,000	0	9,294,000	520,000	0	1,820,000	124,246,000	3,121,000	348,877,000
Percent Change	56%	-15%	-73%	0%	1%	0%	159%	0%	9%	60%	0%	NA	13%	-68%	1%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-5: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 5.

LR-5 (PRM 23.5 to PRM 32.3)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain¹	Mainstem²	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	86,976,000	0	61,382,000	0	NA	192,265,000	1,508,000	29,000	853,000	3,567,000	0	36,952,000	25,000	6,930,000	45,390,000
2012	129,912,000	926,000	16,816,000	0	NA	195,134,000	1,664,000	0	4,811,000	4,737,000	0	45,716,000	319,000	1,444,000	49,103,000
Percent Change	49%	NA	-73%	0%	NA	1%	10%	-100%	464%	33%	0%	24%	1176%	-79%	8%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-6: Comparison of mapped geomorphic feature area from 1980s and 2012 in Lower River geomorphic reach 6.

LR-6 (PRM 3.3 to PRM 23.5)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain¹	Mainstem²	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	189,444,000	210,871,000	199,858,000	0	NA	1,173,918,000	4,027,000	6,043,000	0	7,774,000	0	72,970,000	494,000,000	6,775,000	1,870,378,000
2012	298,210,000	106,821,000	142,664,000	0	NA	1,216,890,000	3,700,000	4,524,000	7,410,000	8,715,000	0	247,264,000	411,584,000	10,348,000	678,966,000
Percent Change	57%	-49%	-29%	0%	NA	4%	-8%	-25%	NA	12%	0%	239%	-17%	53%	-64%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-7: Comparison of mapped geomorphic feature area from 1980s and 2012 in Chulitna River.

CL-1 (PRM 102)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	7,696,000	3,956,000	36,703,000	0	44,399,000	59,759,000	1,234,000	0	1,971,000	0	0	0	11,382,000	21,000	13,783,000
2012	4,464,000	10,570,000	27,999,000	0	32,463,000	55,454,000	279,000	139,000	629,000	0	0	0	12,421,000	0	21,864,000
Percent Change	-42%	167%	-24%	0%	-27%	-7%	-77%	NA	-68%	0%	0%	0%	9%	-100%	59%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-8: Comparison of mapped geomorphic feature area from 1980s and 2012 in Talkeetna River.

TK-1 (PRM 101)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	3,933,000	1,615,000	934,000	2,463,000	NA	17,275,000	68,000	636,000	674,000	0	0	5,580,000	5,185,000	27,000	19,755,000
2012	4,914,000	1,275,000	0	2,613,000	NA	25,389,000	164,000	10,000	769,000	315,000	0	16,097,000	3,103,000	0	20,390,000
Percent Change	25%	-21%	-100%	6%	NA	47%	141%	-98%	14%	NA	0%	188%	-40%	-100%	3%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 5.2-9: Comparison of mapped geomorphic feature area from 1980s and 2012 in Yentna River.

YN-1 (PRM 32)															
Year	Main Channel	Side Channel Complex	Bar Island Complex	Bar Attached Bar	Braid Plain[1]	Mainstem[2]	Upland Slough	Side Slough	Side Channel	Tributary	Tributary Delta	Vegetated Island (Main Channel)	Vegetated Island (Side Channel Complex)	Vegetated Island (Bar Island Complex)	Vegetated Island (MC + SCC + BIC+ SC)
	ft²														
1983	9,363,000	2,000	19,665,000	0	29,028,000	33,690,000	0	0	4,538,000	0	0	0	108,000	4,659,000	9,021,000
2012	9,144,000	0	0	0	9,144,000	11,910,000	0	1,691,000	16,426,000	0	0	2,766,000	0	0	9,706,000
Percent Change	-2%	-100%	-100%	0%	-68%	-65%	0%	NA	262%	0%	0%	NA	-100%	-100%	8%

Notes:
1 Braid Plain = Main Channel + Bar Island Complex
2 Mainstem = Main Channel + Bar Island Complex + Side Channel Complex

Table 6.2-1 Summary of difference in area per river mile for the primary conveyance features and the vegetated islands within the features.

Reach	Difference in Area, 2012 minus 1983 (ft^3x10^6/mi)														
	Main Channel			Bar Island Complex			Side Channel Complex			Side Channel			Net		
	Channel	Vegetated	Total	Channel	Vegetated	Total	Channel	Vegetated	Total	Channel	Vegetated	Total	Channel	Vegetated	Total
LR-1	-0.16	0.08	-0.08	-1.00	0.94	-0.06	-0.32	0.70	0.38	-0.16	-1.30	-1.46	-1.64	0.42	-1.22
LR-2	0.43	0.11	0.53	-3.85	-0.38	-4.23	0.22	0.75	0.97	0.29	2.31	2.60	-2.91	2.79	-0.13
LR-3	0.70	0.10	0.79	-4.41	-0.57	-4.98	1.88	2.77	4.65	0.10	-0.29	-0.19	-1.74	2.01	0.27
LR-4	2.75	0.15	2.89	-2.69	-0.54	-3.23	-0.77	1.19	0.43	0.06	-0.53	-0.47	-0.65	0.27	-0.39
LR-5	4.88	1.00	5.88	-5.06	-0.62	-5.69	0.11	0.03	0.14	0.45	0.02	0.47	0.38	0.42	0.79
LR-6	5.38	8.63	14.00	-2.83	0.18	-2.65	-5.15	-4.08	-9.23	0.37	0.48	0.85	-2.23	5.21	2.97

Table 6.2-2 Summary of difference in area per river mile for the clearwater geomorphic features

Reach	Difference in Area, 2012 minus 1983 (ft^3x10^3/mi)			
	Side Slough	Upland Slough	Tributary	Net
LR-1	50	8	-3	55
LR-2	40	14	-3	51
LR-3	26	-9	105	122
LR-4	0	62	16	78
LR-5	-3	18	133	147
LR-6	-75	-16	47	-45

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9. FIGURES

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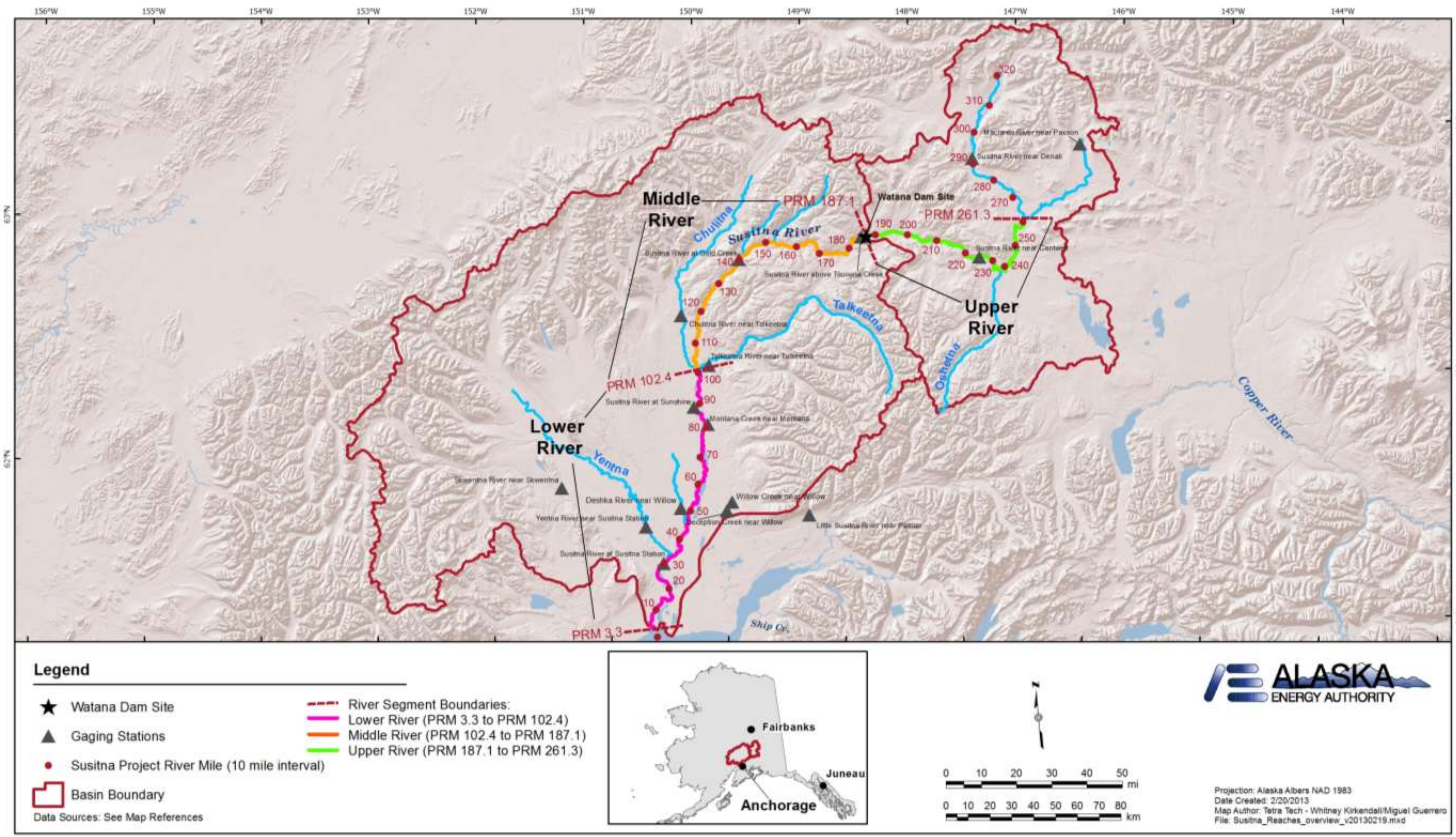

Figure 3.2-1. Susitna River geomorphology study area and large-scale river segments.

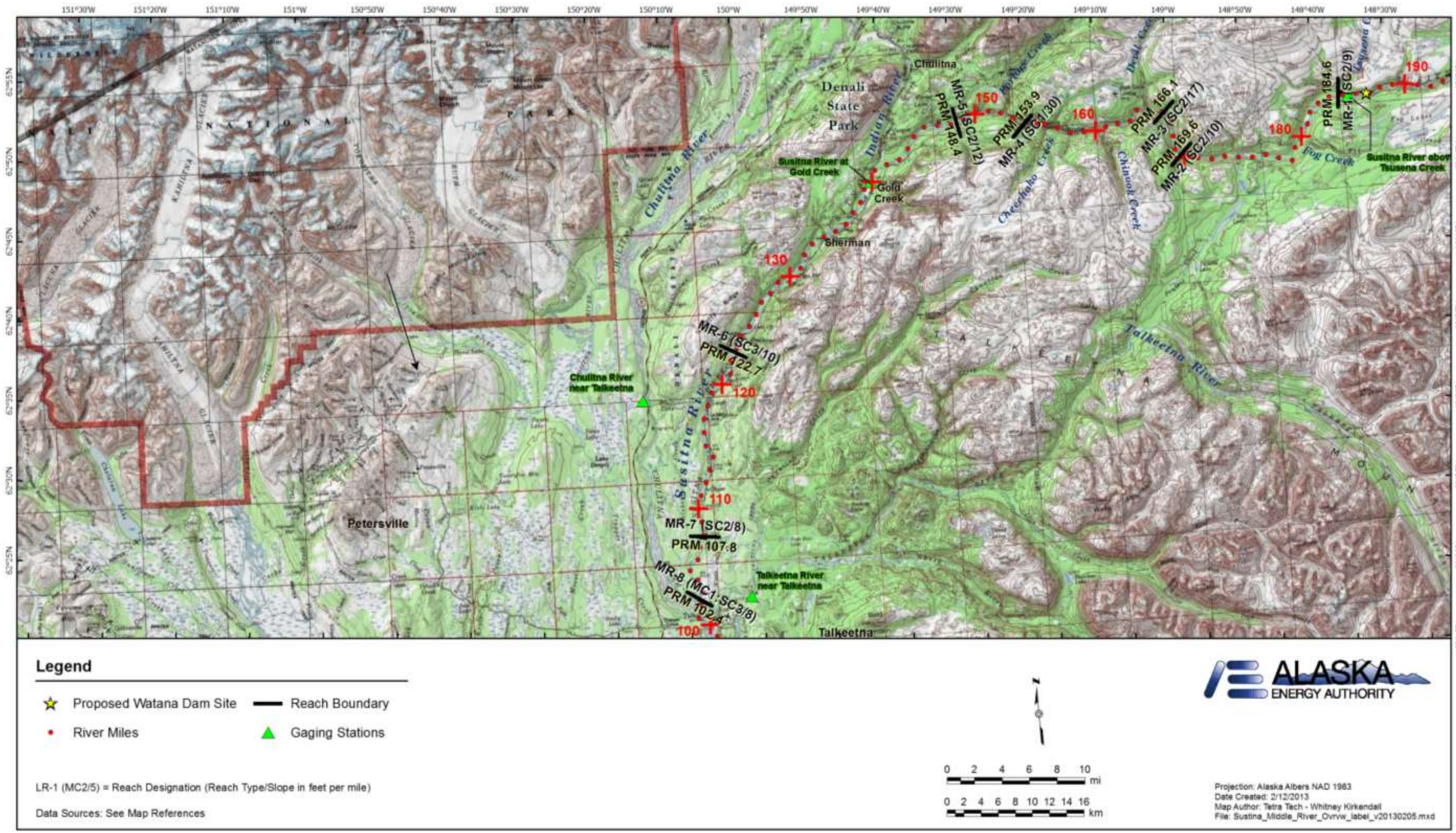

Figure 5.1-1 Map of the Middle Susitna River Segment showing the geomorphic reaches.

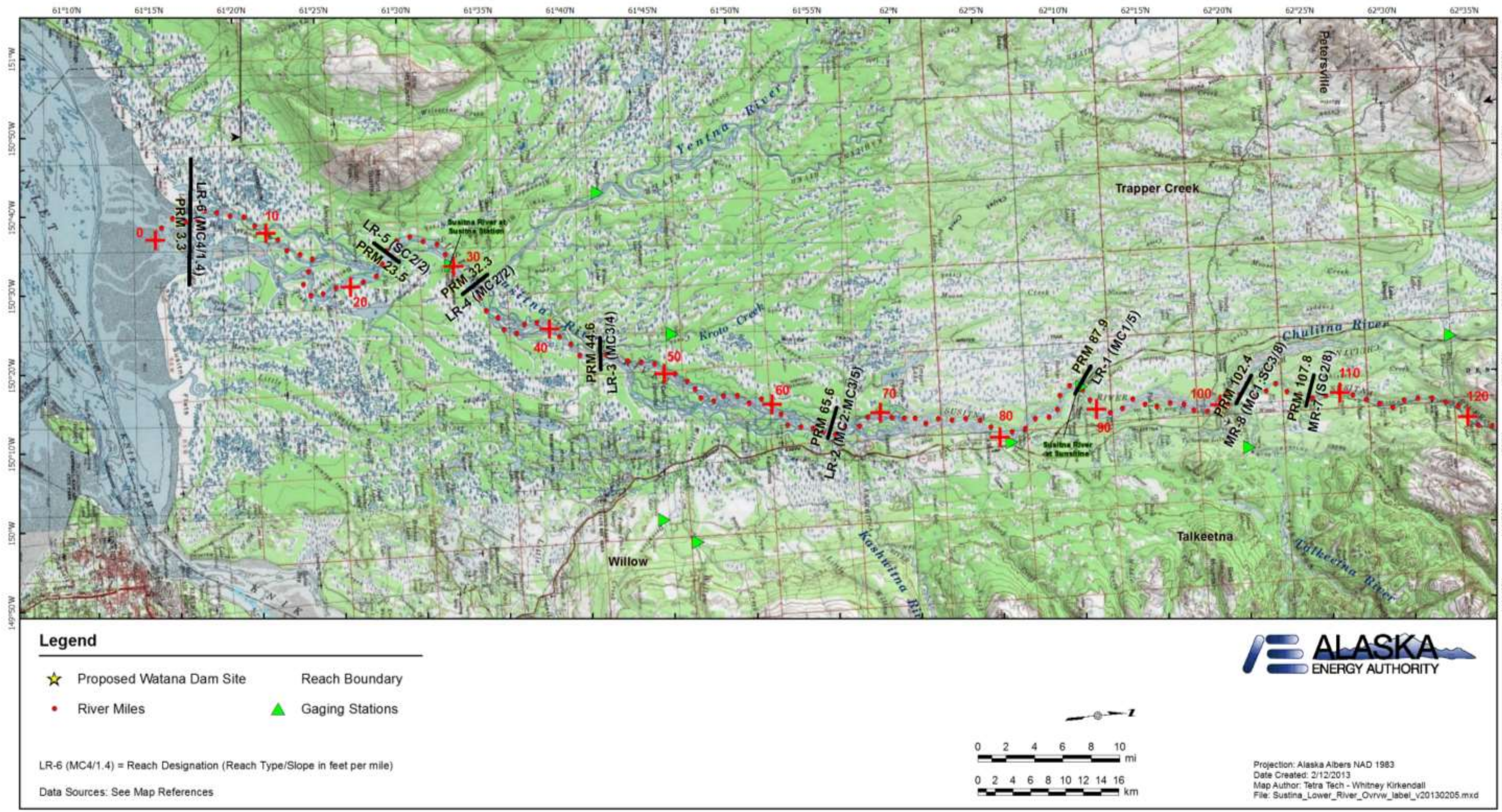

Figure 5.2-1: Map of the Lower Susitna River Segment showing the geomorphic reaches.

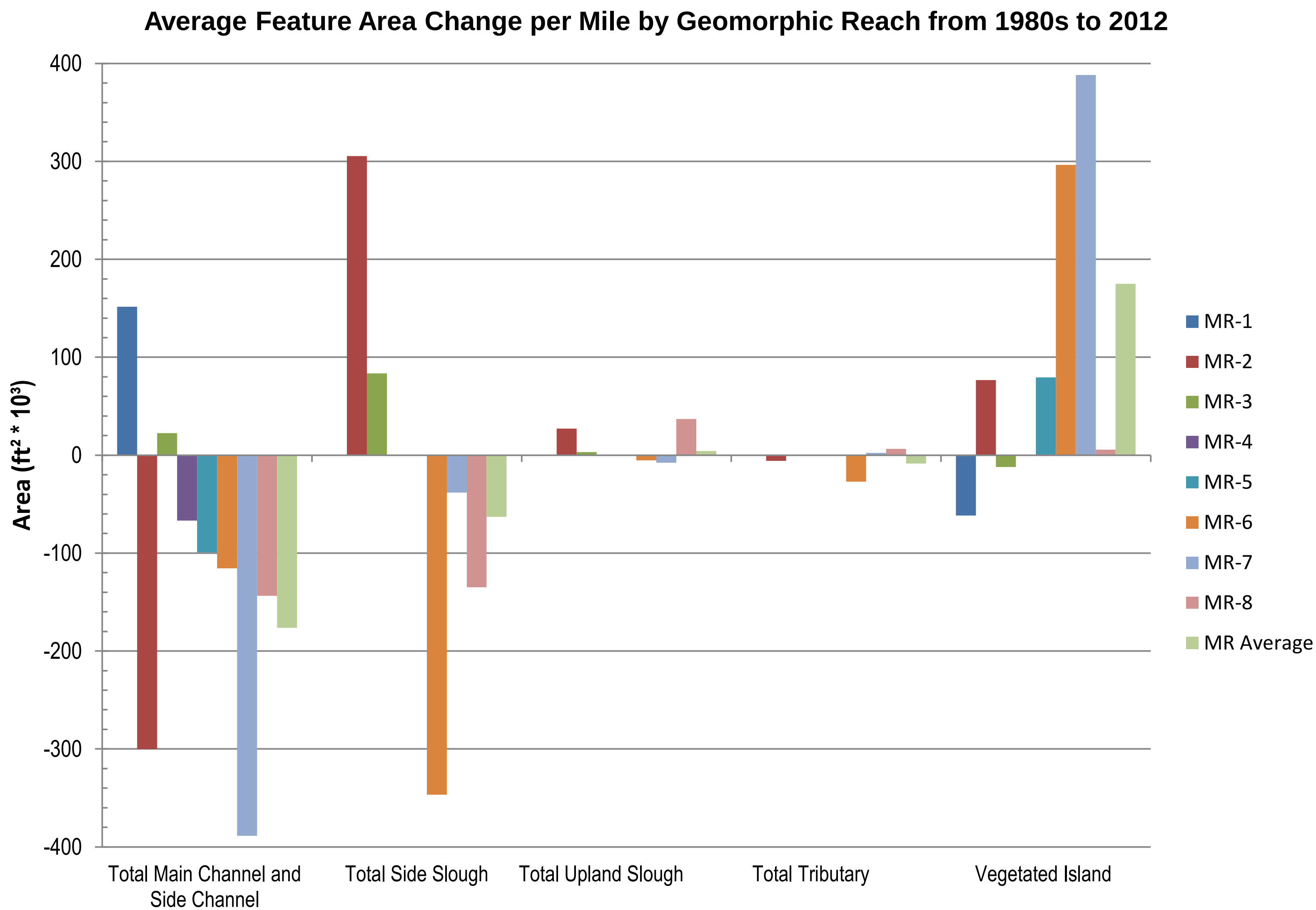

Figure 6.1-1: Average geomorphic feature area change per mile for Reach MR-1 through Reach MR-8 and average change per mile for the entire Middle River segment (MR Average).

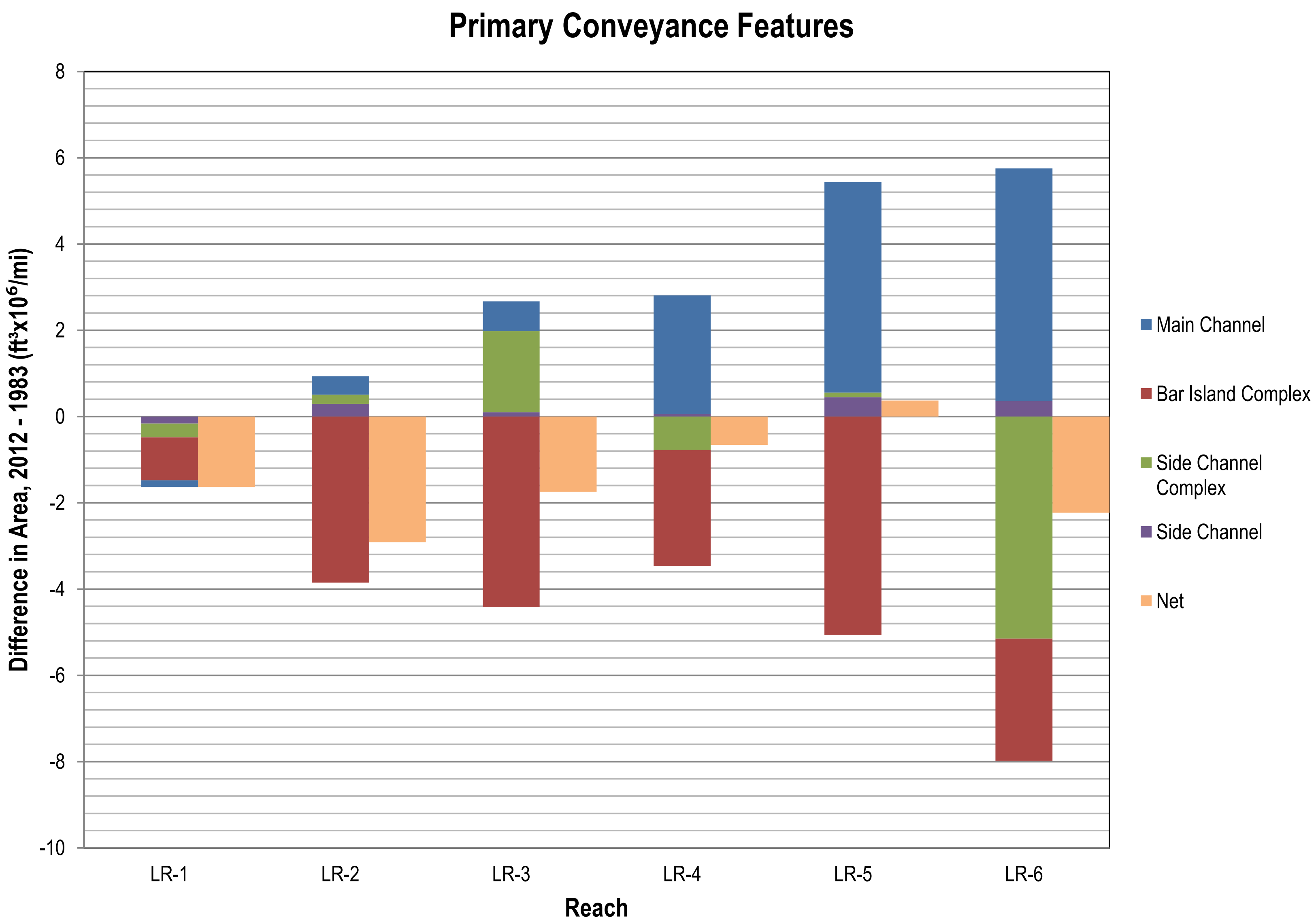

Figure 6.2-1: Difference in 1983 and 2012 areas per river mile for the primary conveyance features.

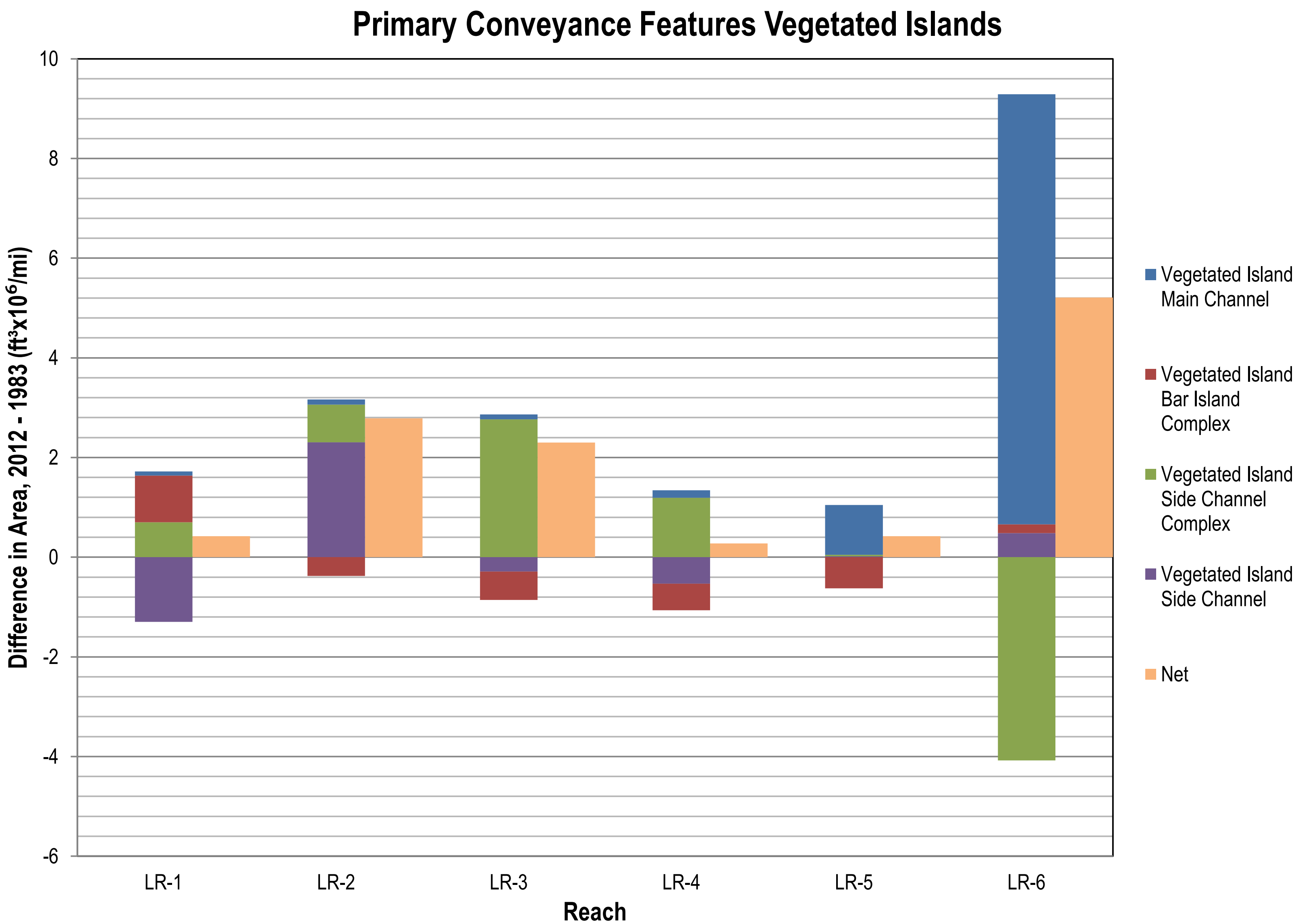

Figure 6.2-2: Difference in 1983 and 2012 areas per river mile for the vegetated islands within the primary conveyance features.

Figure 6.2-3: Difference in 1983 and 2012 areas per river mile for the clearwater features.

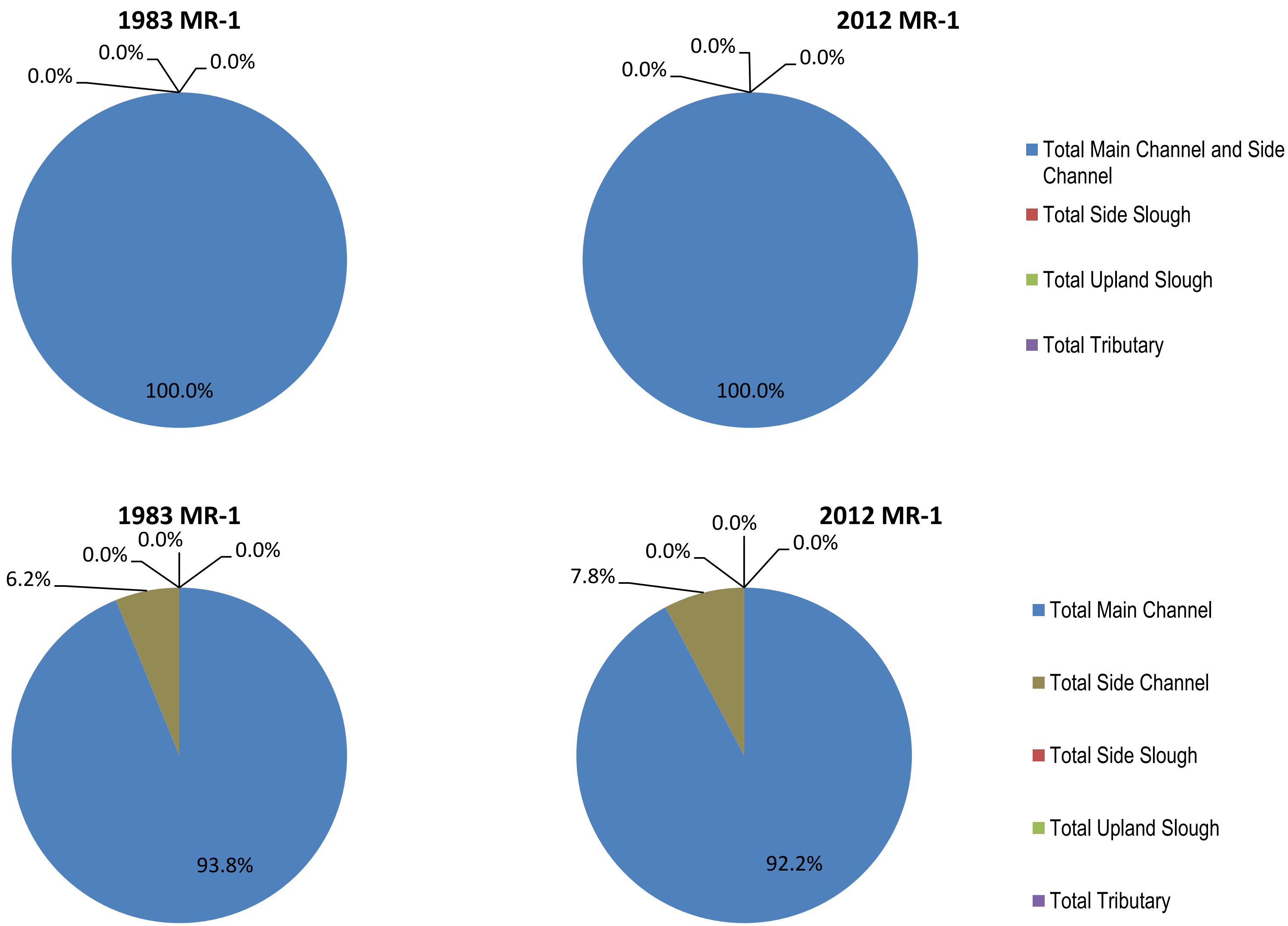

Figure 6.3-1: Relative proportion of geomorphic features in MR-1 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

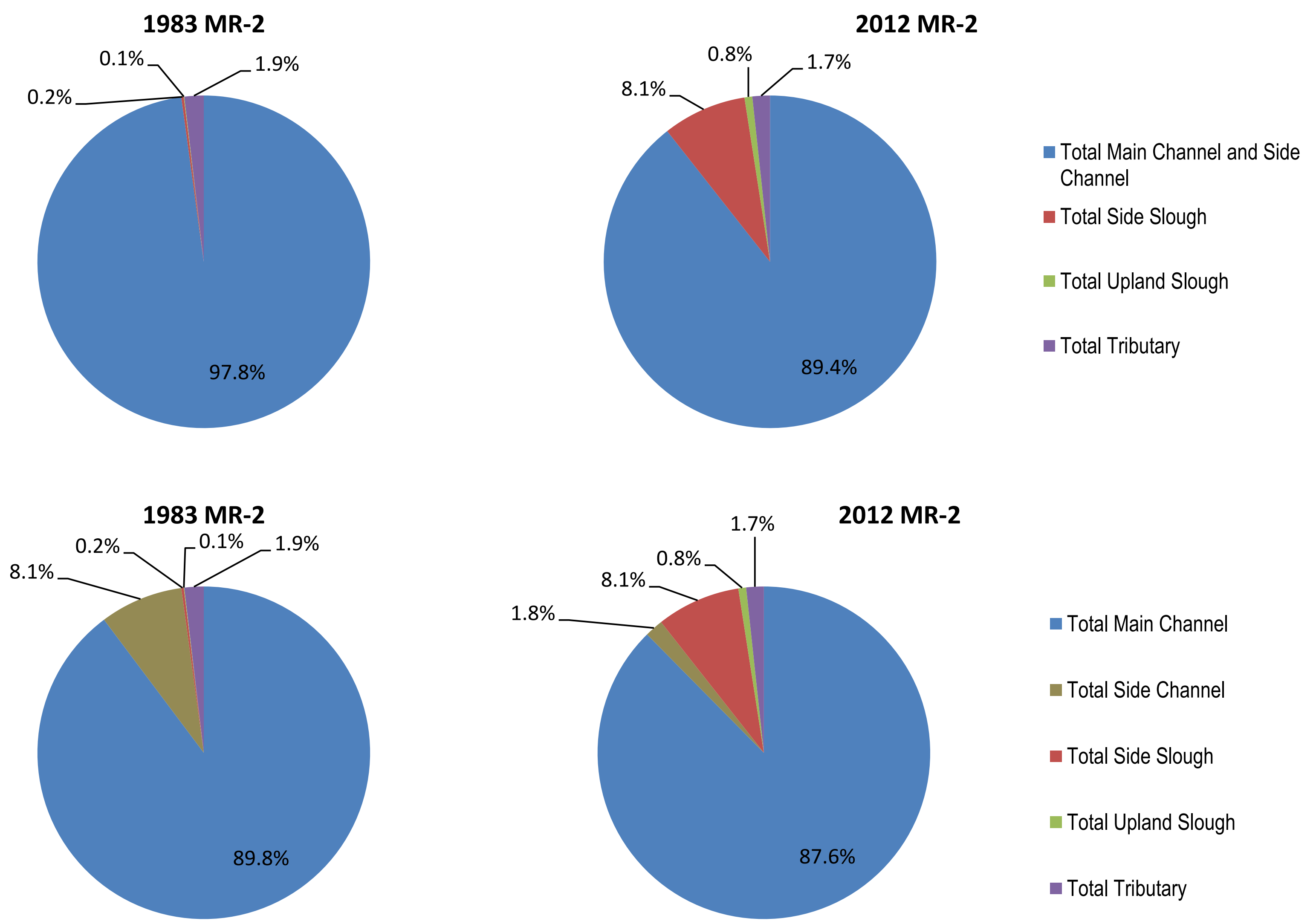

Figure 6.3-2: Relative proportion of geomorphic features in MR-2 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

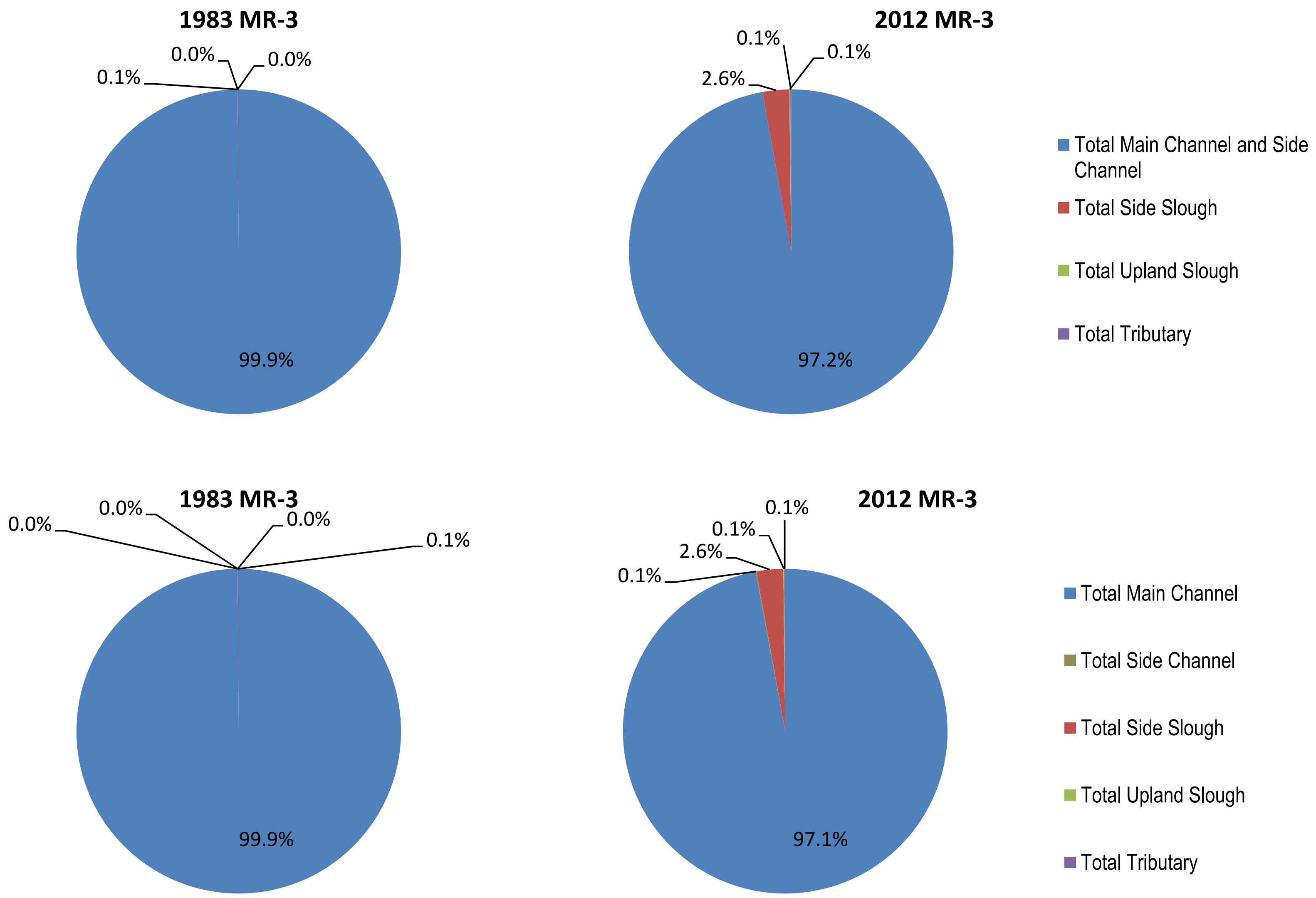

Figure 6.3-3: Relative proportion of geomorphic features in MR-3 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

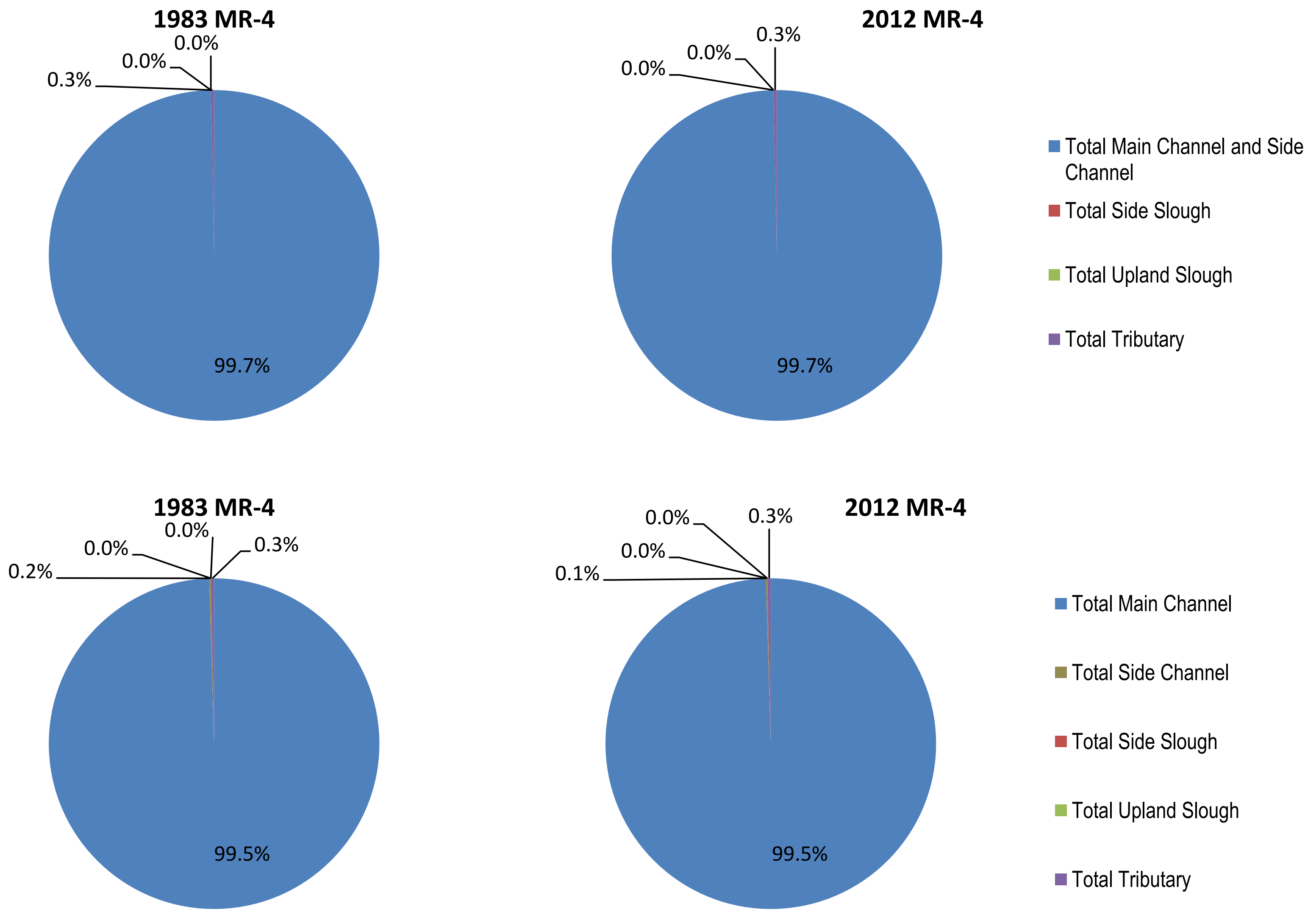

Figure 6.3-4: Relative proportion of geomorphic features in MR-4 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

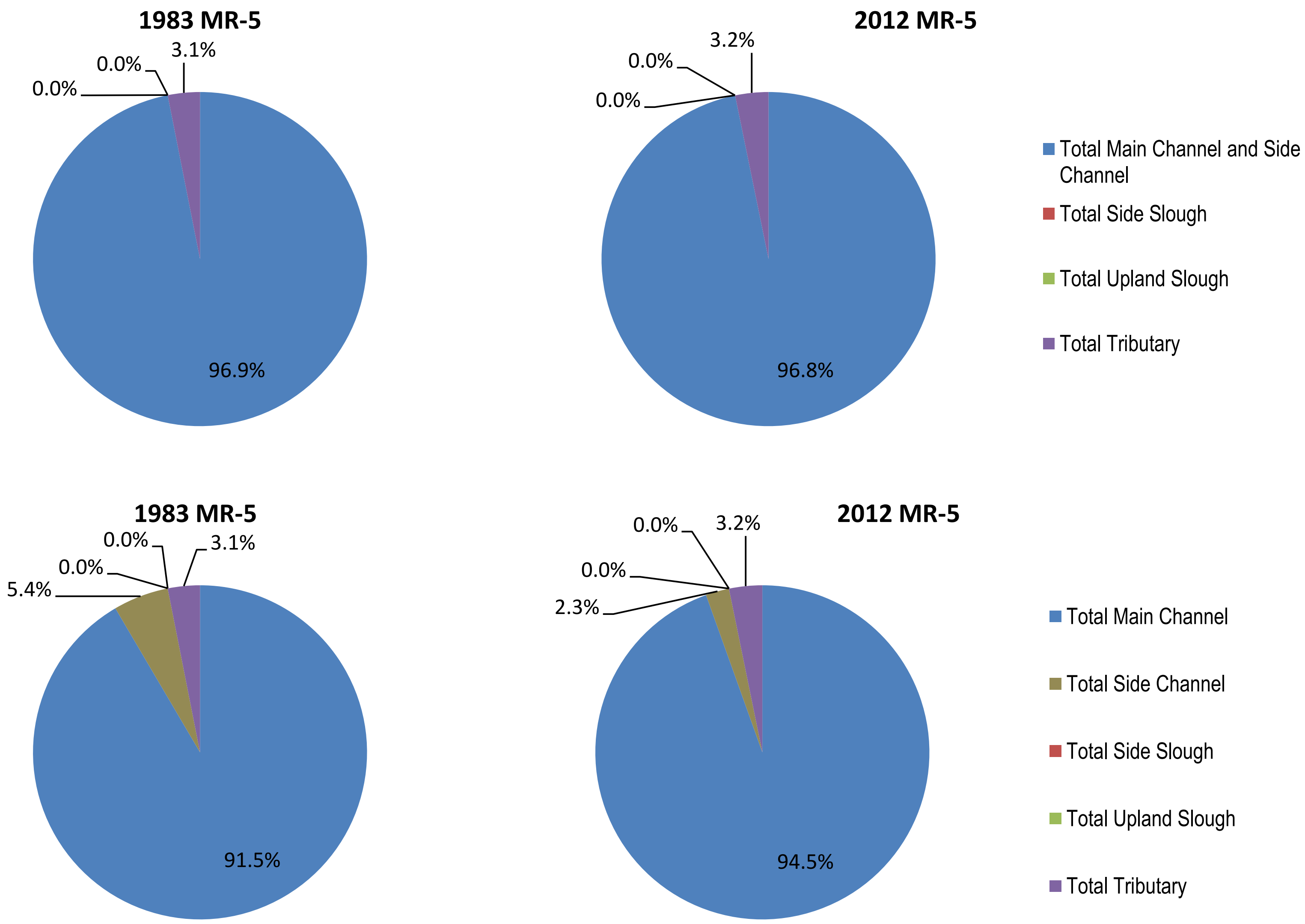

Figure 6.3-5: Relative proportion of geomorphic features in MR-5 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

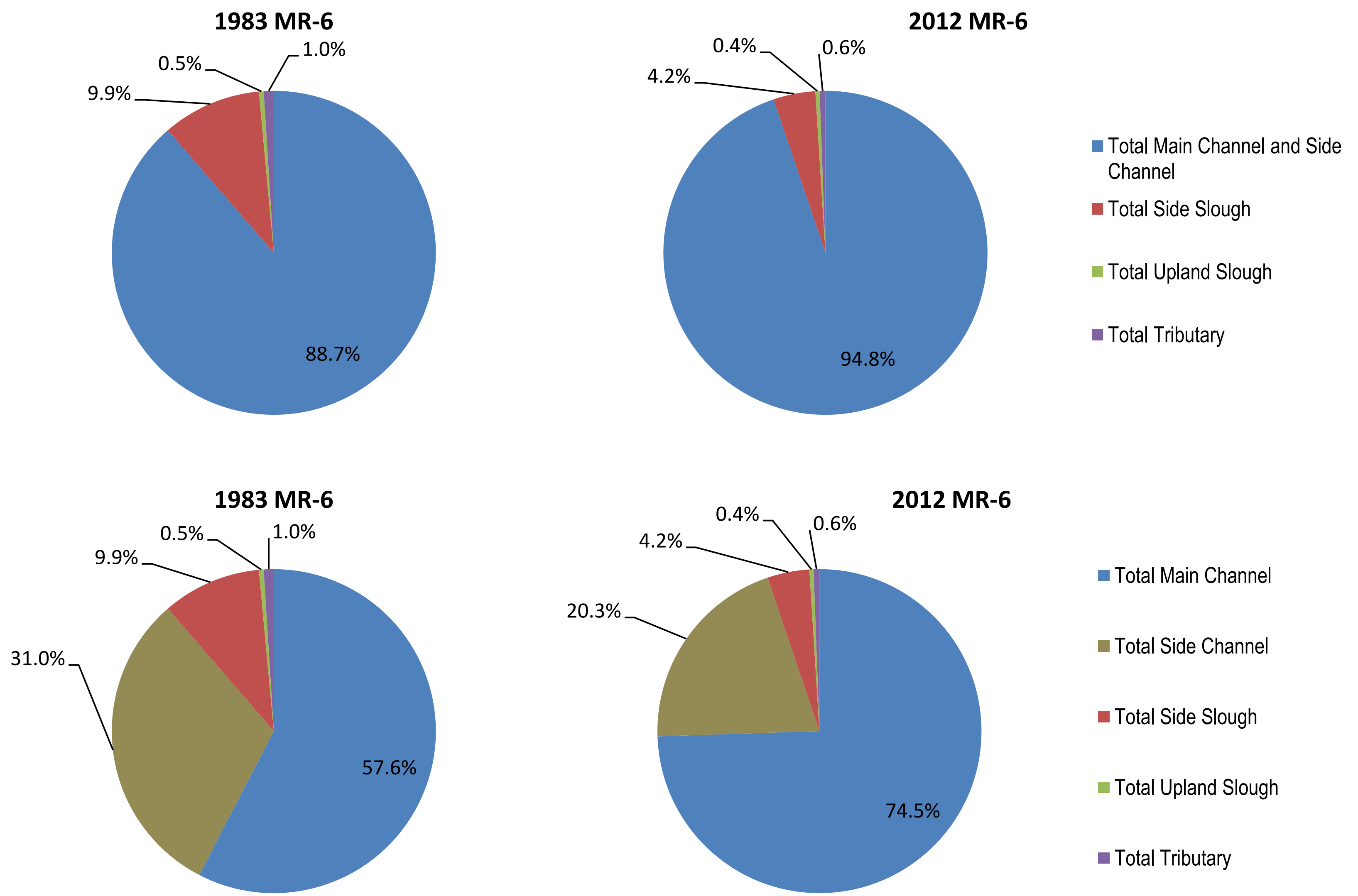

Figure 6.3-6: Relative proportion of geomorphic features in MR-6 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

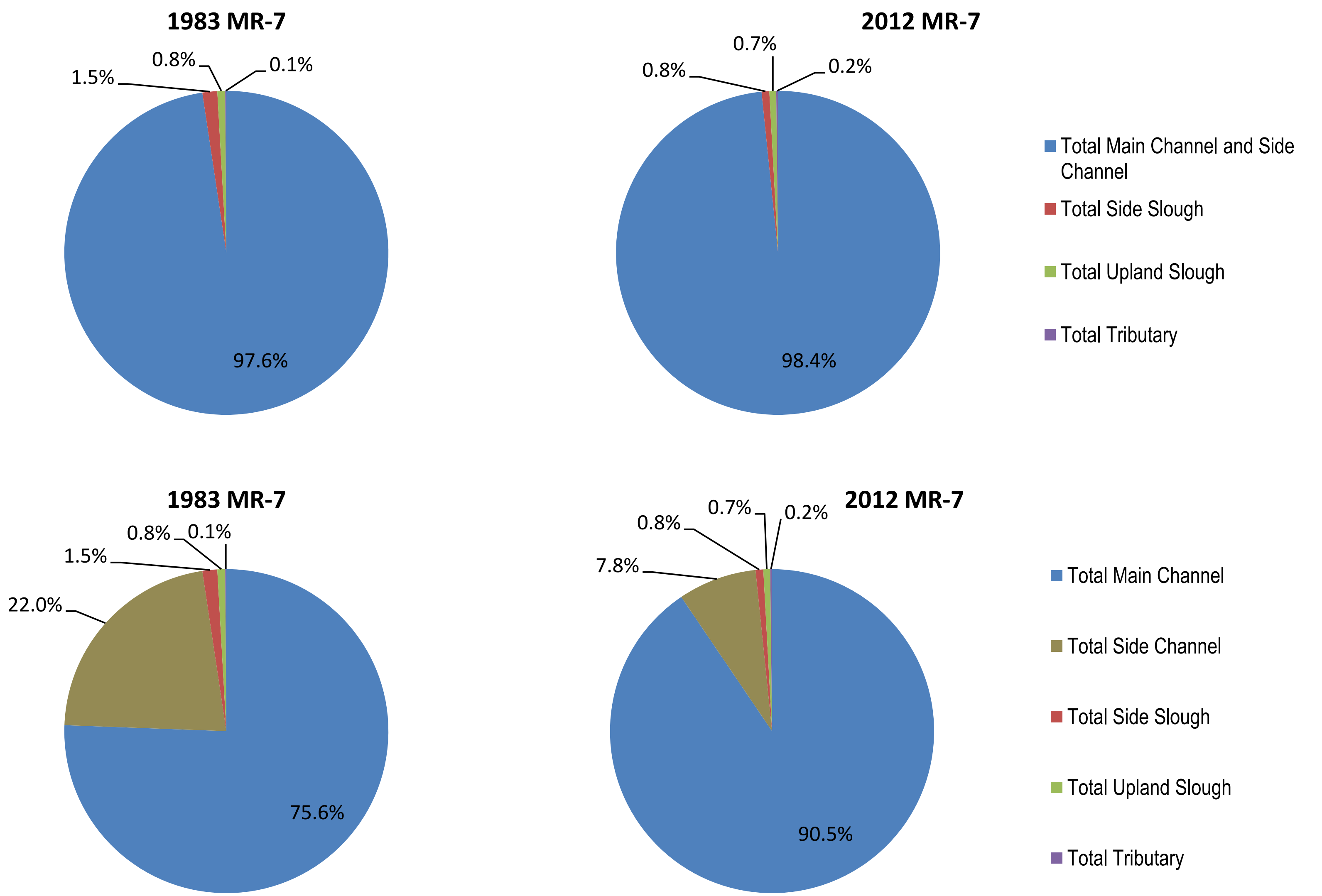

Figure 6.3-7: Relative proportion of geomorphic features in MR-7 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

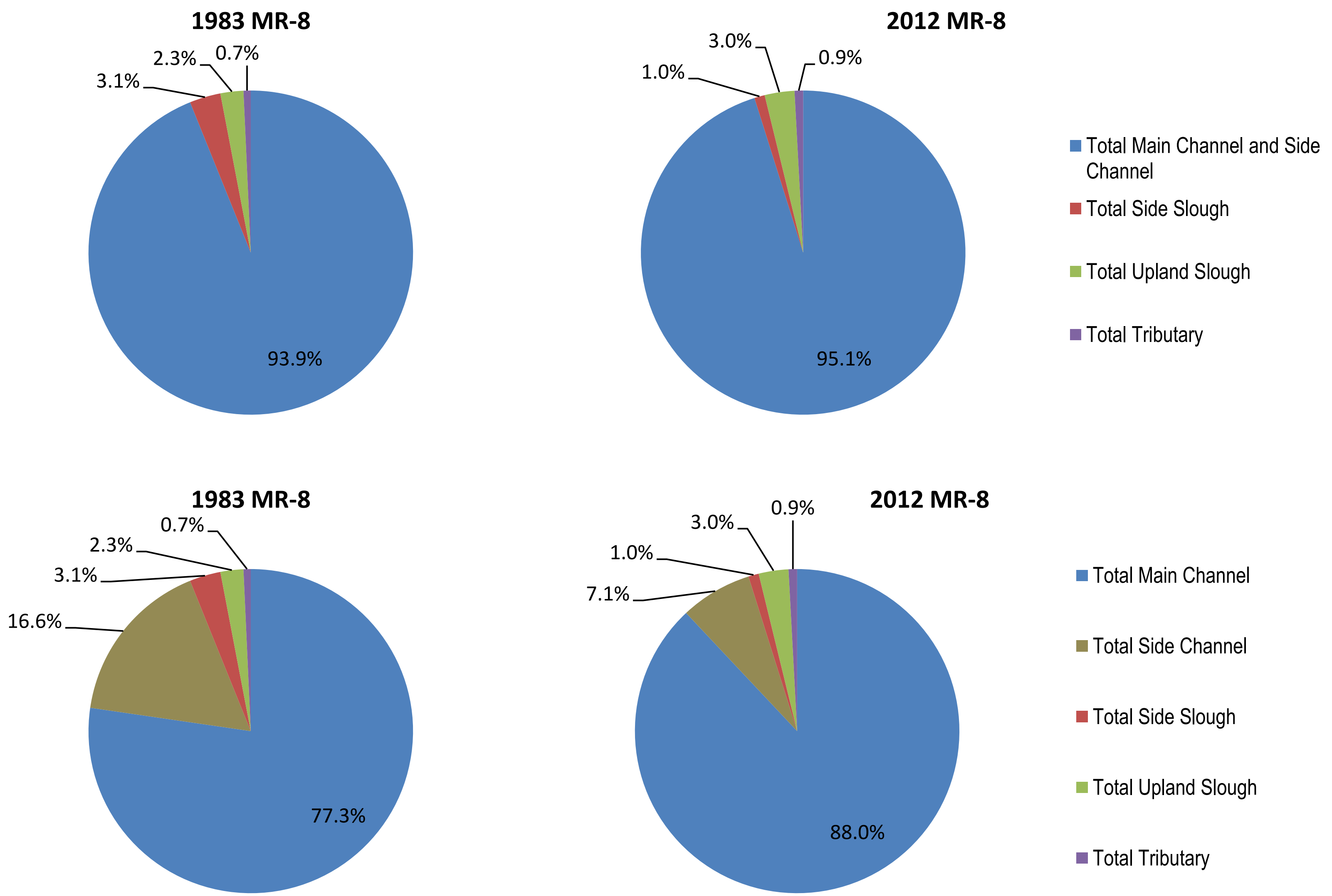

Figure 6.3-8: Relative proportion of geomorphic features in MR-7 of the Middle Susitna River Segment for 1983 and 2012 (top charts main channels and side channels combined / bottom charts main channels and side channels tracked separately).

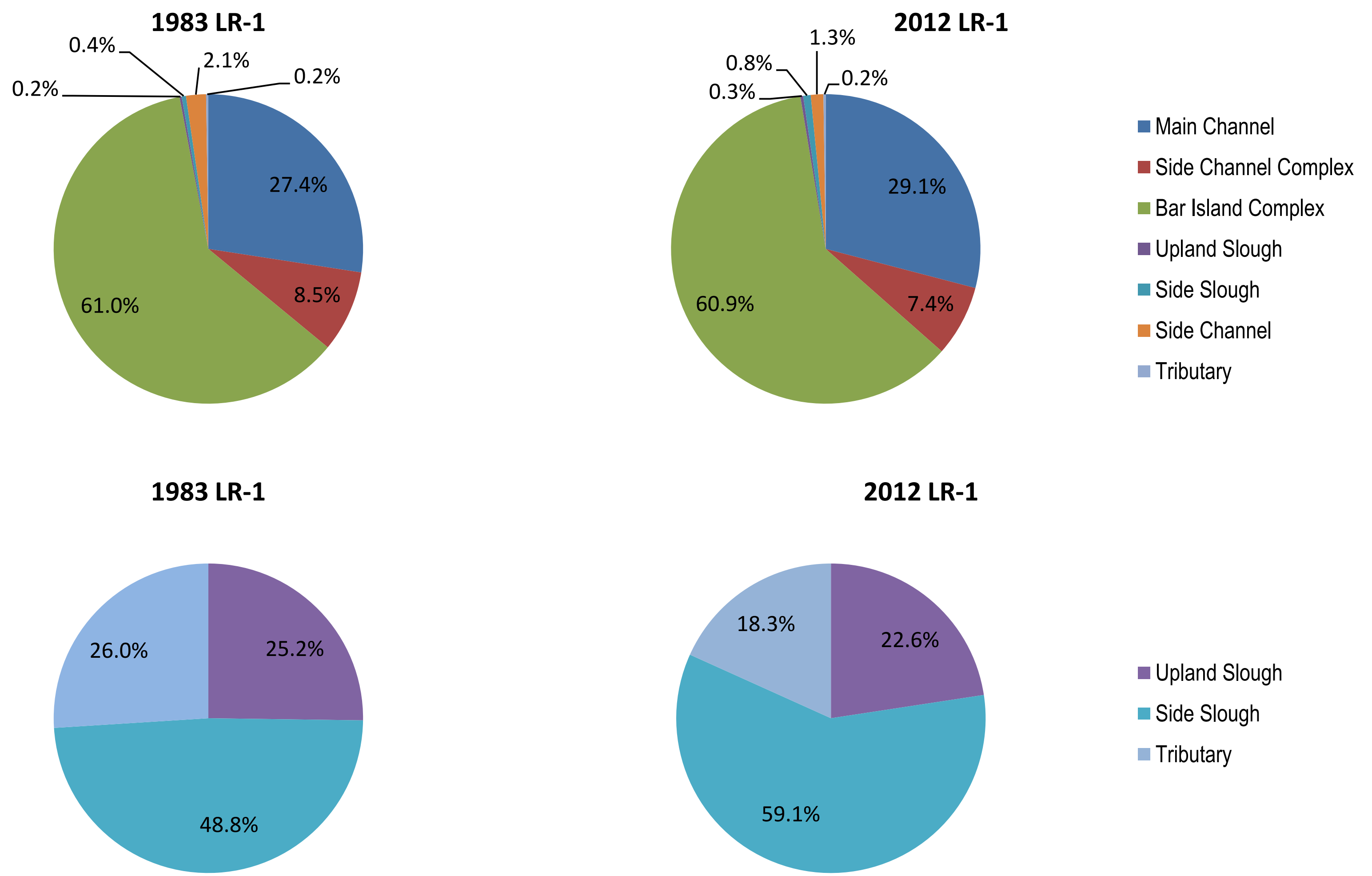

Figure 6.3-9: Relative proportion of geomorphic features in LR-1 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

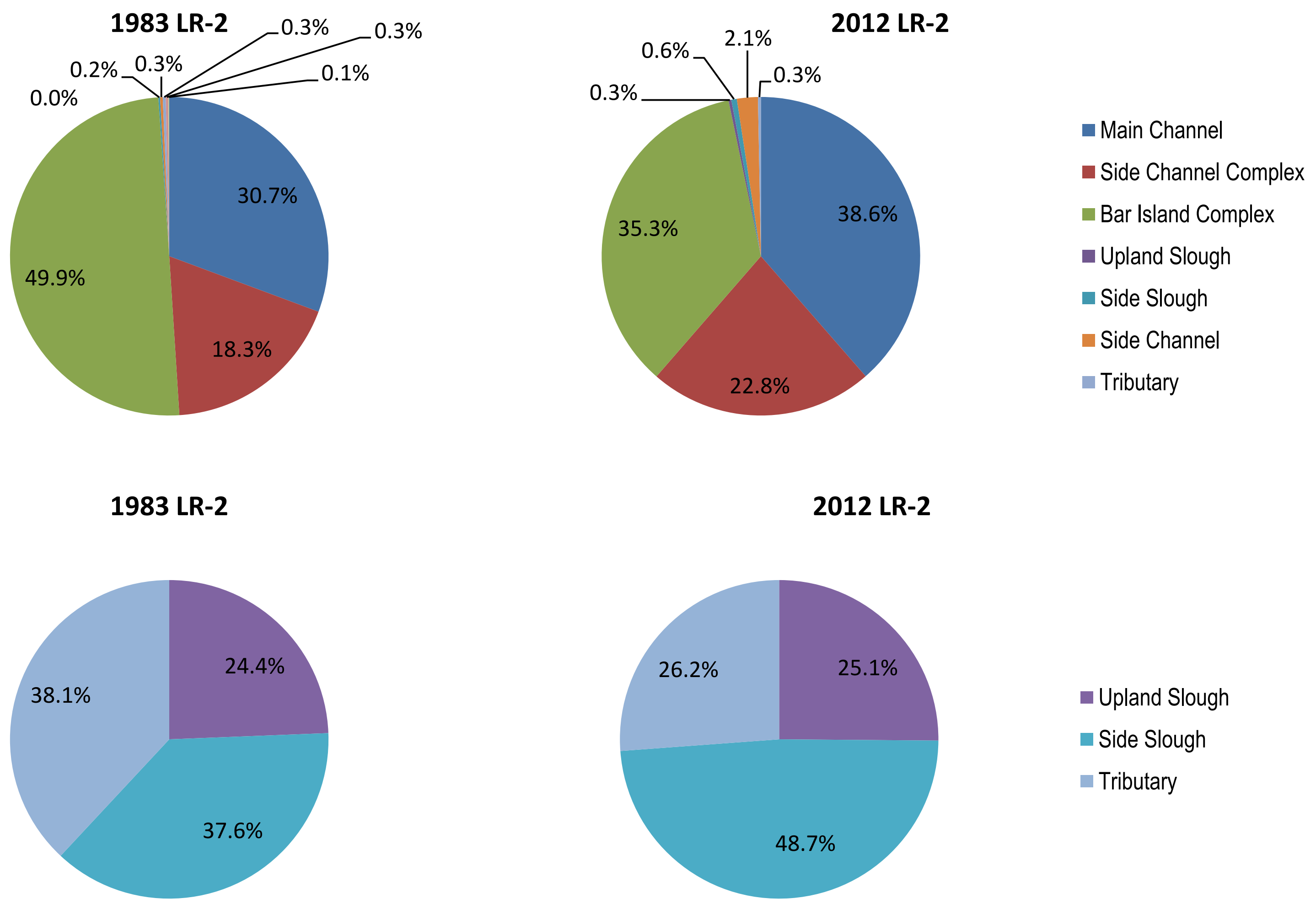

Figure 6.3-10: Relative proportion of geomorphic features in LR-2 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

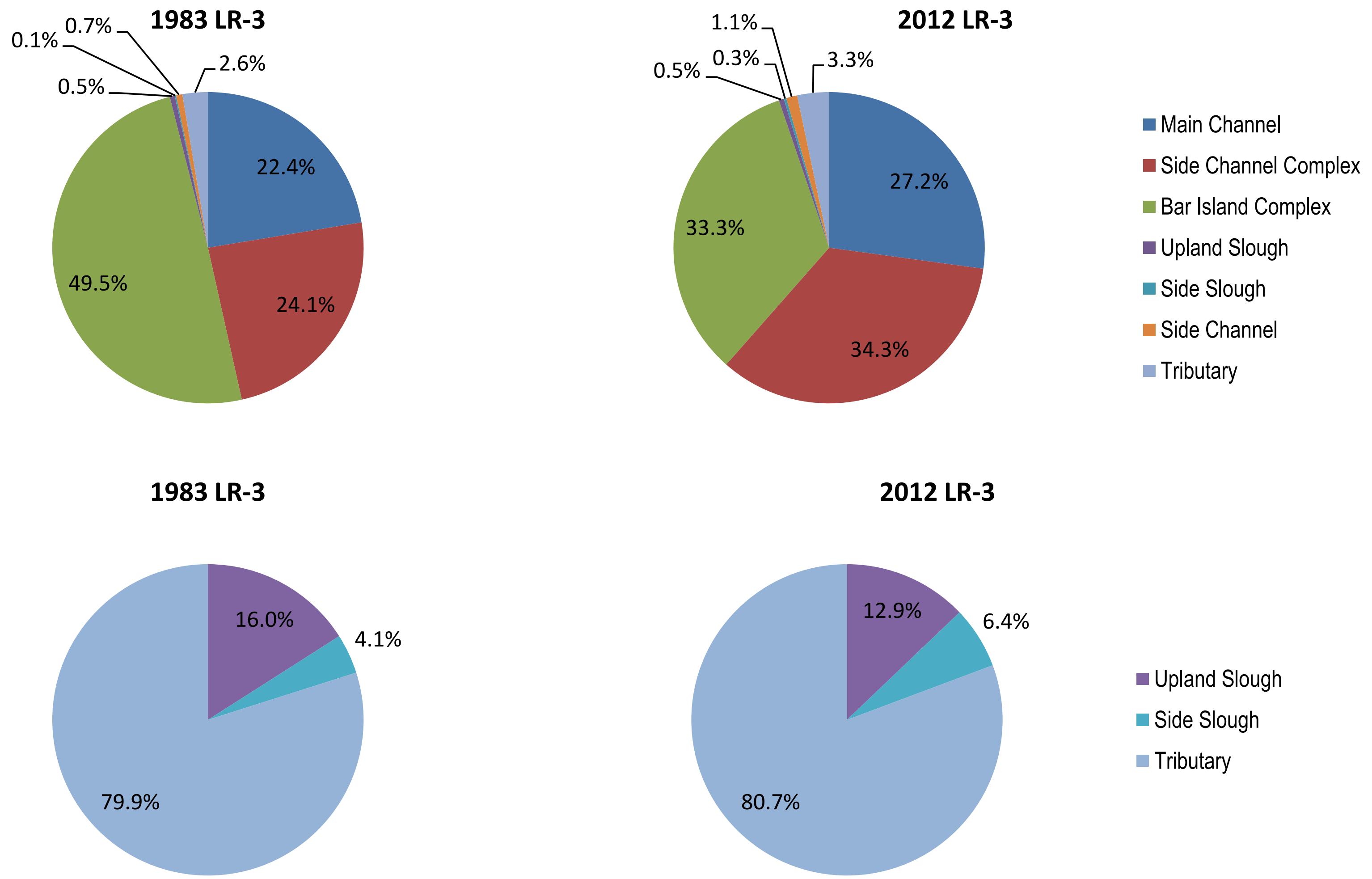

Figure 6.3-11: Relative proportion of geomorphic features in LR-3 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

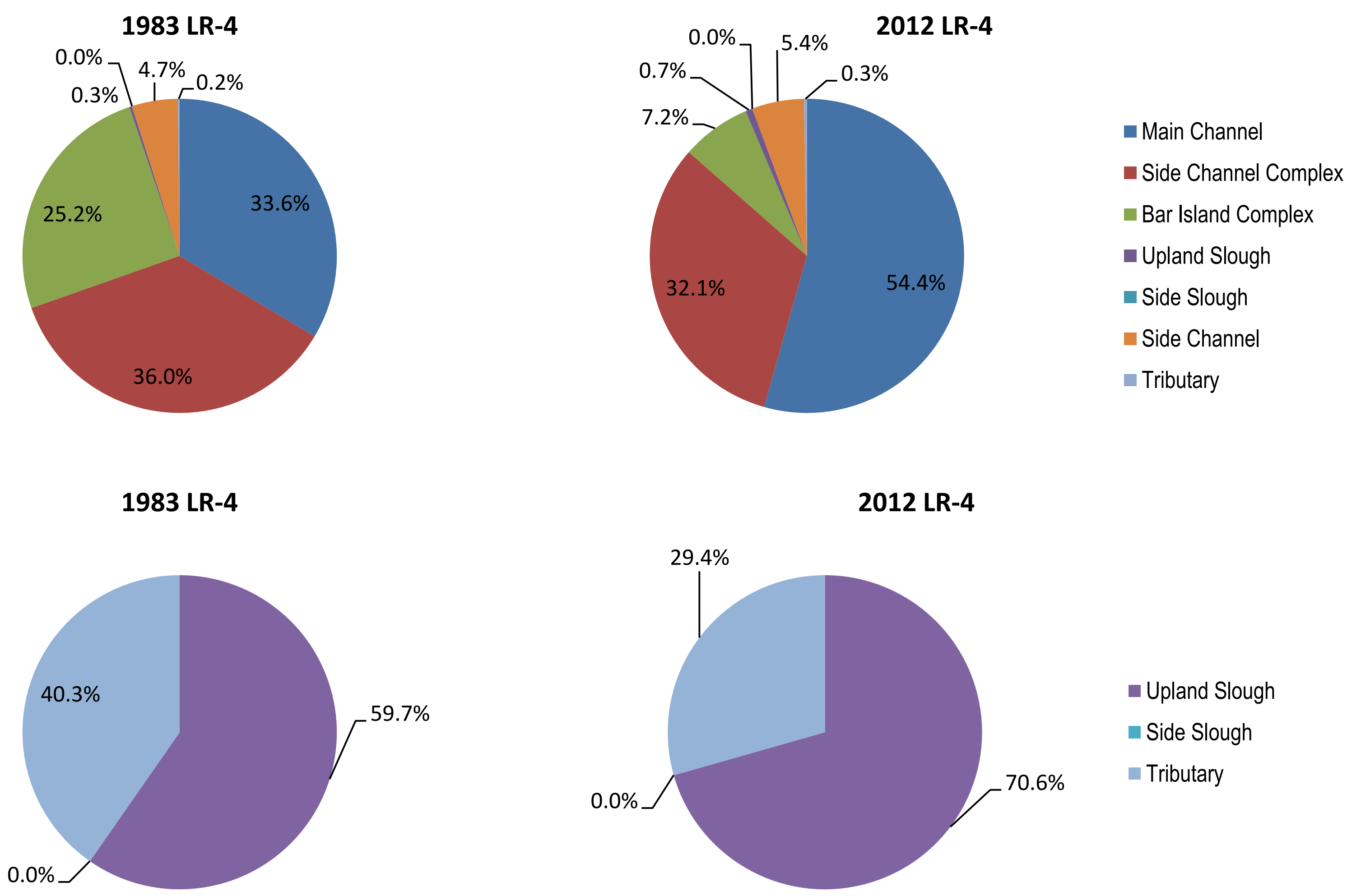

Figure 6.3-12: Relative proportion of geomorphic features in LR-4 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

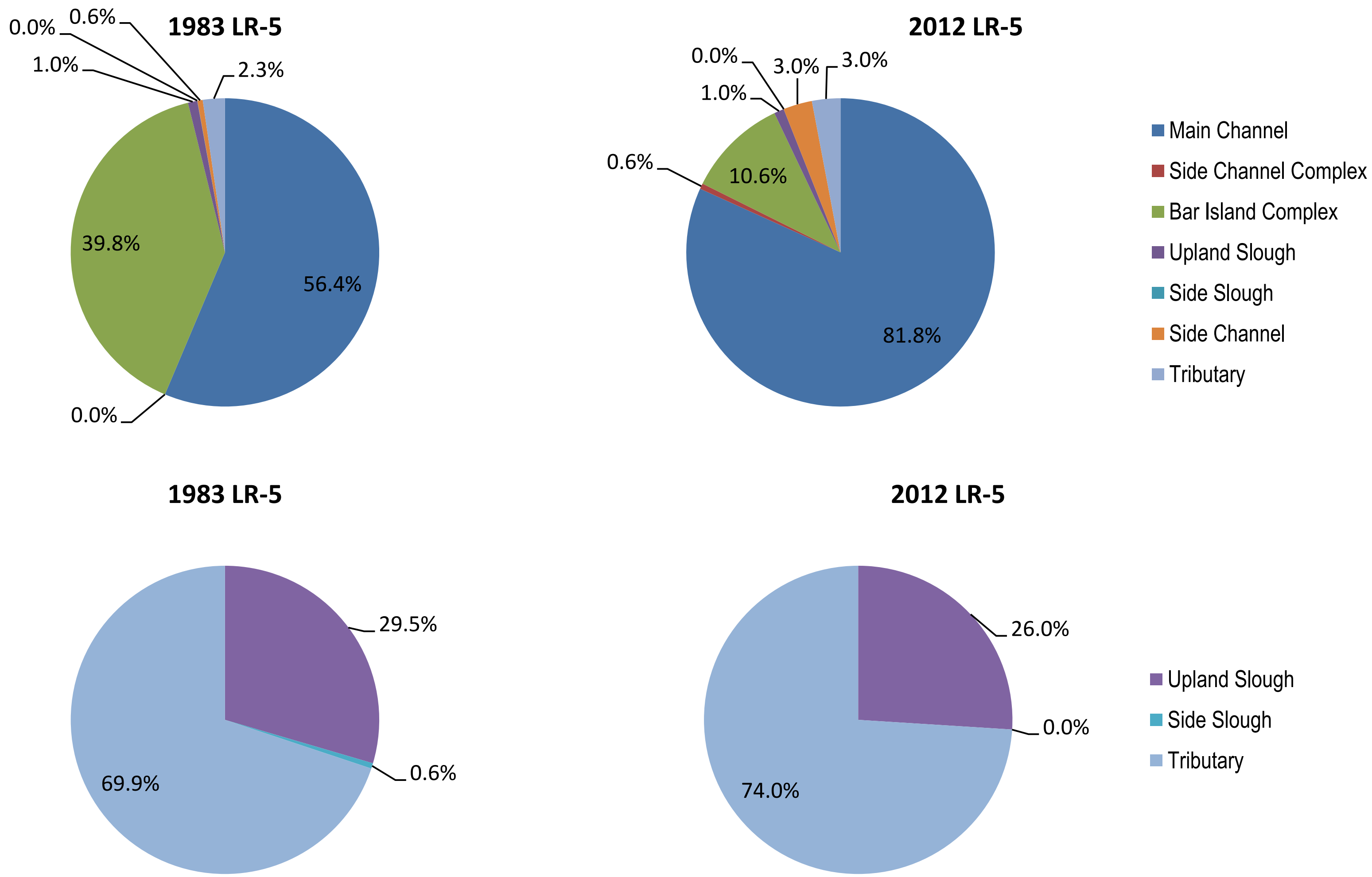

Figure 6.3-13: Relative proportion of geomorphic features in LR-5 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

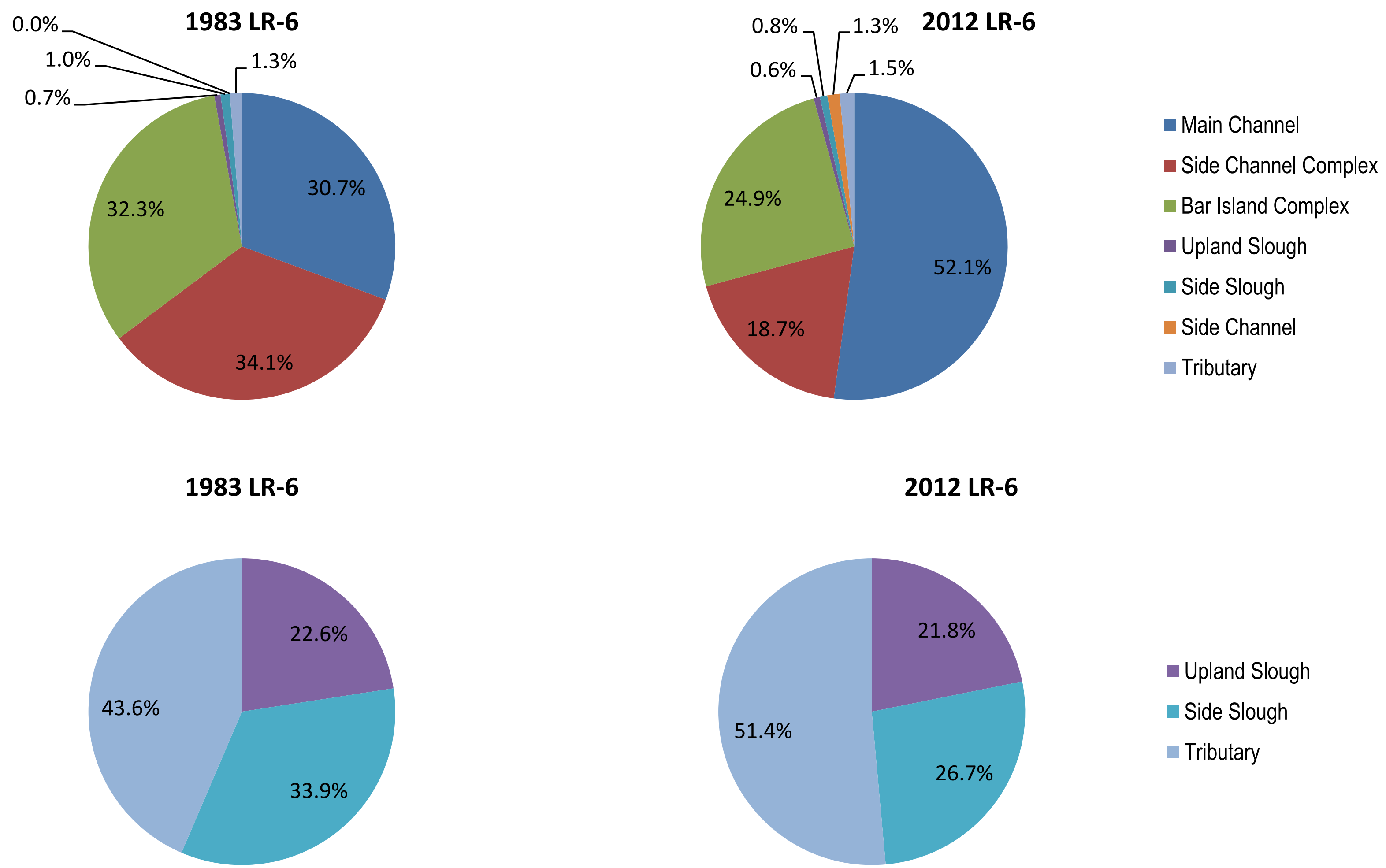

Figure 6.3-14: Relative proportion of geomorphic features in LR-6 of the Lower Susitna River Segment for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

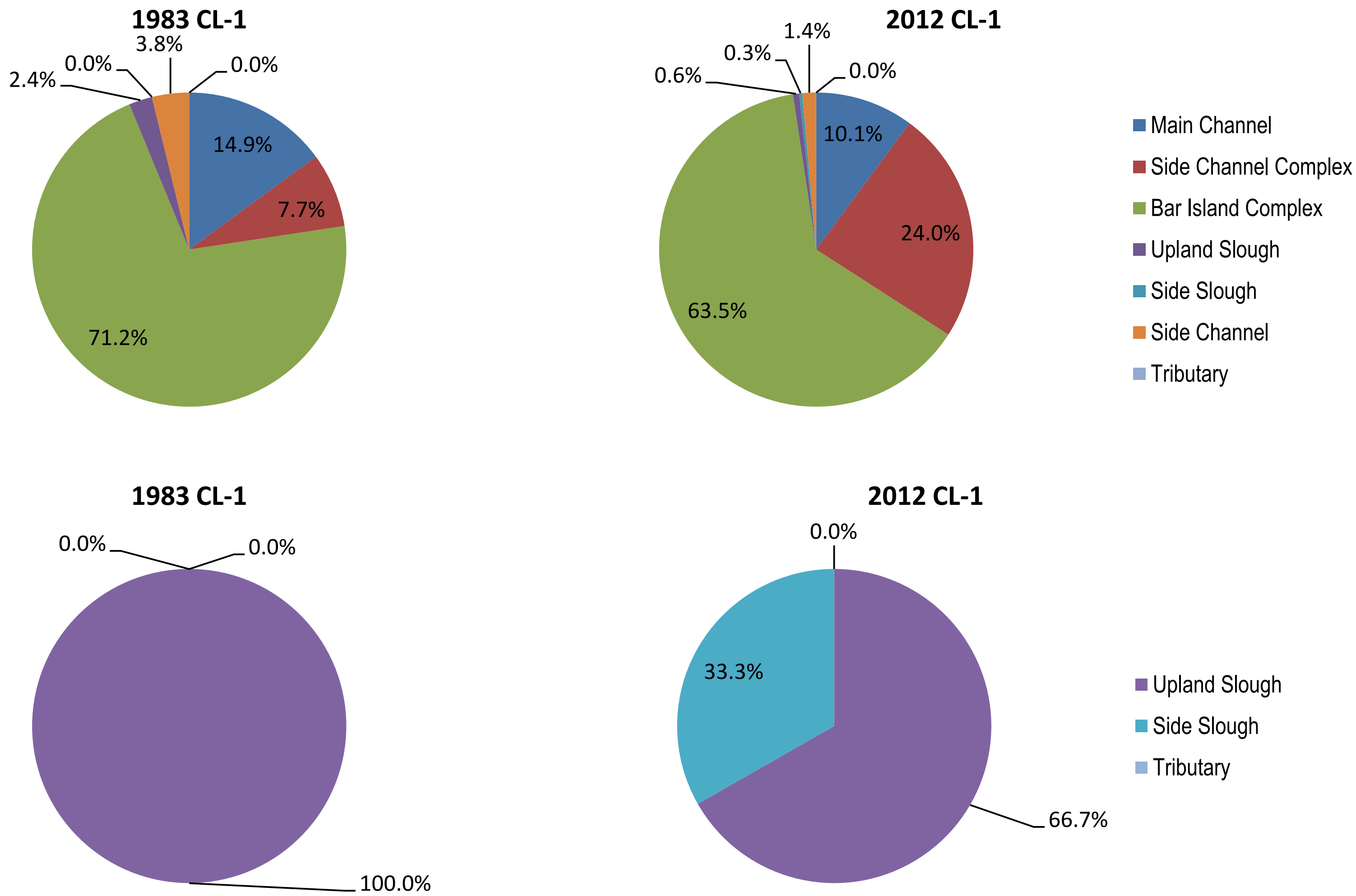

Figure 6.3-15: Relative proportion of geomorphic features in CL-1 of the Chulitna River for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

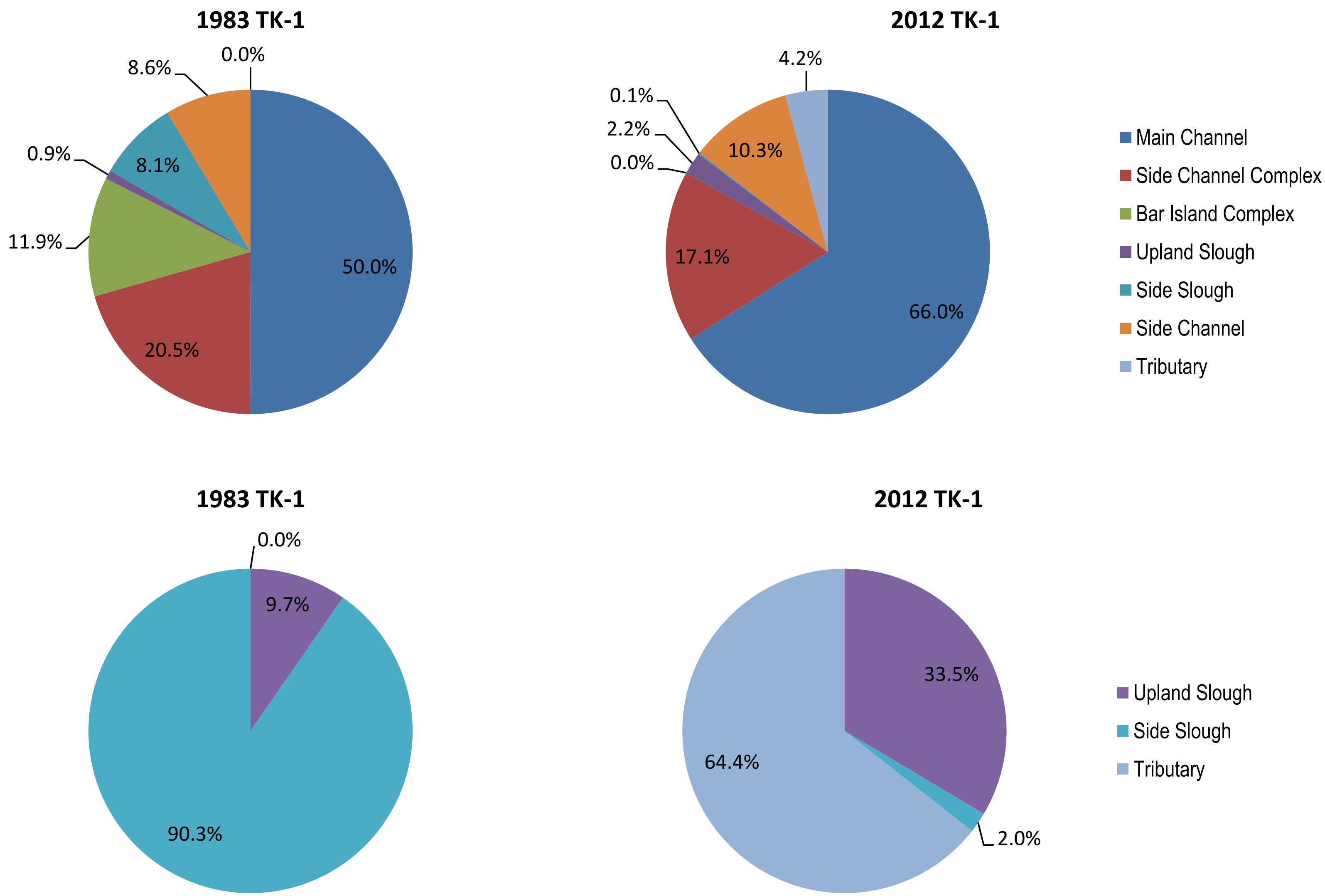

Figure 6.3-16: Relative proportion of geomorphic features in TK-1 of the Talkeetna River for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).

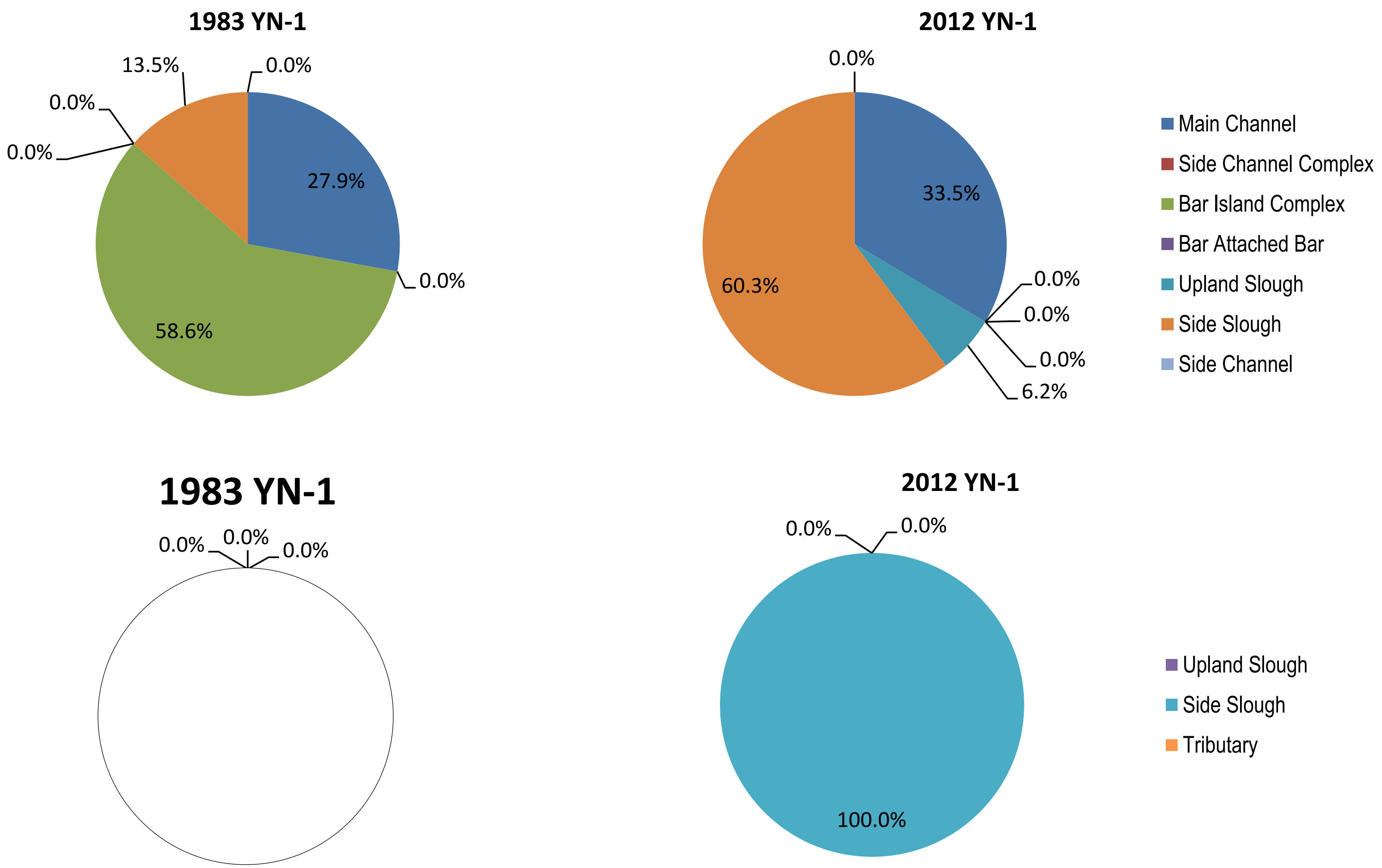

Figure 6.3-17: Relative proportion of geomorphic features in YN-1 of the Yentna River for 1983 and 2012 (top charts are geomorphic features with wetted and exposed regions / bottom charts are geomorphic features with primary aquatic habitat).