Appendix B3

Interim Crustal Seismic Source Evaluation

14-01-TM_Interim Crustal Seismic Source Evaluation

SUSITNA-WATANA HYDRO

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Technical Memorandum 14-01-TM v0.0

Susitna-Watana Hydroelectric Project Interim Crustal Seismic Source Evaluation

AEA11-022

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Explanation of Abbreviations

AEA	Alaska Energy Authority
AEIC	Alaska Earthquake Information Center
DEM	Digital elevation model
FCL	Fugro Consultants, Inc.
FERC	Federal Energy Regulatory Commission
GIS	Geographic information system
GPS	Global positioning system
INSAR	Interferometric synthetic aperture radar
ka	kiloannum (thousand years)
km	kilometer
LGM	last glacial maximum
LiDAR	Light detection and ranging
m	meter
Ma	Million years
MatSu	Matanuska-Susitna Borough
MWH	MWH Americas, Inc.
PSHA	Probabilistic seismic hazard analysis
RCC	Roller-compacted concrete
RTS	Reservoir-triggered seismicity
TM	Technical memorandum
USGS	United States Geological Survey
WCC	Woodward Clyde Consultants

Explanation of Units

Measurements in this report were made using the International System of Units (SI), and converted to English system for reference. For the conversions, the measurements reported in the English system were rounded off for simplification purposes. Both sets of numbers are presented for the reader, except in cases of very small numbers that are shown only using SI (i.e. metric).

EXECUTIVE SUMMARY

The proposed Susitna-Watana Dam is a hydroelectric power development project planned for the upper Susitna River under the auspices of the Alaska Energy Authority (AEA) and the regulatory authority (among others) of the Federal Energy Regulatory Commission (FERC). Under subcontract to MWH Americas (MWH), Fugro Consultants, Inc. (FCL) is investigating and evaluating the seismic hazard in support of engineering feasibility, and the licensing effort for the Susitna-Watana Hydroelectric Project. This draft technical memorandum presents part of the continued seismic evaluations associated with the proposed dam, specifically a lineament field evaluation.

In 2011, Fugro Consultants, Inc. (FCL) prepared a preliminary seismic hazard source model and probabilistic ground motion assessment based on desktop review of prior studies and recent literature (FCL, 2012). Subsequent to the preliminary seismic hazard ground motions assessment, FCL completed lineament mapping based on interpretation of recently acquired, detailed, topographic data (i.e., INSAR- and LiDAR-derived DEM data). The mapped lineaments were assembled into lineament groups, and evaluated in the office using semi-qualitative criteria to reject or select lineament groups for further investigation during the summer field season of 2013 (TM-8; FCL, 2013). In total, 22 lineament groups and three broader lineament areas were advanced to the field investigation phase in summer of 2013.

The primary objective of the summer 2013 lineament evaluation was to document and interpret available field evidence for the presence or absence of potential shallow crustal seismogenic sources (faults) along features identified through previous lineament mapping, and evaluate the features' significance with respect to Quaternary faulting and their potential as seismic sources of significance to the Susitna-Watana Dam seismic hazard evaluations.

The lineaments inspected were assessed based on geomorphological characteristics observed in the field and field geologic relationships around the lineaments. As guidelines for the field teams conducting the evaluation of individual lineament groups, a series of questions were developed as an aid to focus observations made during the field investigation. To evaluate the field data, a set of questions and criteria similar to those used by FCL (2013) for evaluation of the desktop findings were developed. The principal objective of these criteria is to guide judgments regarding the lineaments' origins in order to evaluate their potential association with Quaternary faulting and potential crustal seismogenic sources.

The 2013 field activities and lineament evaluations highlighted three topics with broad impacts across several aspects of the lineament evaluations. These topics include: 1) insights gained from field investigation and evaluations on the scale and resolution of DEM data, 2) identification of the dominant geomorphic processes acting to modify the landscape, and 3) updated regional age estimates for late

Quaternary landscapes and events in south-central Alaska. Interpretations and evaluations of most lineament groups and individual features within these lineament groups are linked to key principles or limitations posed by data or concepts associated with these topics.

Synthesis of previous studies and research of Alaskan glacial chronologies coupled with field observations on the type and distribution of glacial constructional and erosion landforms suggests that there are three broad age categories within which the landscape may be viewed. These are, from youngest to oldest: late Holocene, mid- to early Holocene, and post-late Wisconsin period of the late Pleistocene. It was judged that the preponderance of surficial geologic deposits are in the mid-to-early Holocene category, and thus are the limiting age for detecting Quaternary deformation.

All lineament groups targeted for 2013 investigation received a low-altitude aerial observation, and ground inspection was completed at selected locations where features of interest were identified and ground access was permitted[1]. Based on the work to-date and access restrictions, the lineament groups are placed into four categories.

- Category I. Lineament groups in category I were not advanced for 2013 field observations (FCL, 2013), but where convenient, brief fly-overs in 2013 visually confirmed their placement in category I, with no further work suggested.

- Category II includes the majority of the lineament groups and features evaluated in 2013. Lineaments in this category are judged to be 1) dominantly erosional in origin, 2) related to rock bedding or jointing, or 3) to a lesser extent, a result of constructional geomorphic processes. This category is subdivided in to categories IIa and IIb. Category IIa lineament groups are those which are not evidently associated with bedrock faults. Category IIb lineament groups that do appear to be associated with bedrock faults (Category IIb). For both categories no further work is suggested.

- Category III consists of lineament groups which are unresolved due to unavailable ground access in 2013, and field activities and further evaluation are deferred. This category includes investigation sites most relevant to evaluations of surface faulting for the dam site area and includes the WCC trench T-1 area, Fog Creek area, and dam site and reservoir vicinities.

- Category IV includes lineament groups that have defensible justification for consideration or inclusion as crustal seismic sources in an updated seismic source model: lineament group 27

[1] Ground access was limited to state and federal lands. For lineament features on ANCSA lands, aerial observations were made during fly-overs however, no landings or ground access was undertaken

(Sonona Creek fault) and the Castle Mountain fault extension are the two lineaments in this category. No further field work is suggested.

At present, this document is an interim work-in-progress pending further “boots on the ground” access. It is anticipated that right-of-way access will be granted in 2014 to allow further investigation of geologic or geomorphic features at and near the dam site to complete the lineament evaluation, evaluate additional LiDAR data under pending acquisition, as well as address potential for fault rupture at the dam site. Accordingly, this document will be updated and finalized based on completion of the field investigations and evaluation of the remaining features.

1. INTRODUCTION

The proposed Susitna-Watana Dam is a hydroelectric power development project planned for the upper Susitna River under the auspices of the Alaska Energy Authority (AEA) and the regulatory authority (among others) of the Federal Energy Regulatory Commission (FERC). The proposed dam would be constructed near about River Mile 184 on the Susitna River, north of the Talkeetna Mountains near the Fog Lakes area. Current concepts envision a RCC dam approximately 715 feet high, impounding a reservoir with a maximum water surface elevation at about 2,050 feet. At this elevation, the dam would impound a reservoir of approximately 5,170,000 acre-feet.

MWH Americas (MWH) is the prime contractor providing engineering and geotechnical services to AEA for the project development and submittal of licensing documents to the FERC. Under subcontract to MWH, Fugro Consultants, Inc. (FCL) is investigating and evaluating the seismic hazard aspects in support of engineering feasibility and the licensing effort for the Susitna-Watana Hydroelectric Project.

1.1 Background

In 2011, Fugro Consultants, Inc. (FCL) prepared a preliminary seismic hazard source model and ground motion assessment based on a desktop review of prior studies and recent literature (FCL, 2012). Subsequent to the preliminary seismic hazard ground motions assessment, FCL interpreted recently acquired, detailed, topographic data (i.e., INSAR and LiDAR) to examine the regional landscape, vis-à-vis digital elevation models (DEM), for evidence of potential lineaments, faults, or geomorphic landforms suggestive of Quaternary faulting. Limited field ground truthing, including low-altitude fly-overs, was performed in late summer of 2012 to inspect and verify features identified by the desktop-based lineament mapping. The mapped lineaments were assembled into lineament groups (Figure 1-1), and analyzed in the office using semi-qualitative criteria to select lineament groups for further investigation during the summer field season of 2013. This analysis included lineaments identified by WCC (1980, 1982) for the two-dam scheme at Devil's Canyon and Watana as originally envisioned in the 1970s and 1980s. In total, 22 lineament groups and three broader lineament areas were advanced to field investigation phase in the summer of 2013. The desktop lineament mapping data, analysis, and selection of lineament groups for further investigation is documented in TM-8 (FCL, 2013), as is a discussion of the regional geologic map data (e.g., Figures 1-2A and 1-2B).

In June 2013, MWH was informed that AEA would not acquire access to Native Village Corporation (ANSCA) lands in 2013 (Figure 1-3). Principally, this resulted in deferral of field studies and investigations at and near the dam site area to summer of 2014 as field activities were limited to aerial inspection. However, low-altitude fly-overs were performed, and investigative field tasks for lineament evaluations (e.g., soil pits) could be conducted on the ground on state and federal lands.

This interim technical memorandum presents part of the continued seismic evaluations associated with the proposed dam, specifically lineament field evaluation. At present this document is a work-in-progress pending further ground access for field investigations and mapping. It is anticipated that right-of-way access will be granted in 2014 to allow further investigation of geologic or geomorphic features at and near the dam site to complete the lineament evaluation, as well as to address the potential for fault rupture at or near the dam site. Accordingly, this document will be updated as necessary based on the additional future data acquired. The 2013 lineament evaluation, field observations and judgments of lineament groups, as well as recommendations for potential 2014 geologic evaluation activities to complete the crustal seismic source evaluation are presented herein.

1.2 Scope of Work

The scope of work for 2013 FCL investigations is defined under MWH Task Orders T10502190-99468-OM dated March 11, 2013 and T10502190-99894-OM dated July 1, 2013. In general, the focus of the studies is continuation of the crustal lineament evaluation. Specific technical activities within the scope of work include development of field plans and logistics, health and safety plan update, geologic mapping, seismometer station site characterization through collection of Vs30 measurements of the rock mass, field geologic inspection of lineaments, assessment of the lineament feature origin, analysis of lineaments as potential crustal earthquake sources of project significance, and identifying and developing recommendations for lineament features that warrant additional field geologic characterization to complete the crustal seismic source evaluation. Other activities specified in the task order include review of earthquake monitoring data, interim probabilistic seismic hazard assessment (PSHA) sensitivity analyses, development of seismic design criteria framework, and work planning studies in support of project licensing. Findings related to most of these activities are reported separately and are not described in this technical memorandum.

As envisioned originally for the crustal lineament evaluation, the 2013 scope of work included wintertime field geologic mapping and fault evaluation at the dam site, a late springtime geologic reconnaissance of lineaments advanced from the desktop study (FCL, 2013), and summertime field investigation of potential crustal seismic sources or fault rupture hazards (e.g. paleoseismic trenching), based on the results of the winter and springtime efforts. Because of the unanticipated field right-of-way access constraints, the full scope of work as originally envisioned was modified to optimize the summer 2013 field season investigation on state and federal lands while ground access to key areas at and near the dam site situated on private lands was resolved.

This interim technical memorandum presents part of the continued seismic evaluations associated with the proposed dam, specifically lineament field evaluation, and is a work-in-progress pending further ground access for field investigations and mapping. The objectives of this interim draft TM are to: (1) document and interpret available field evidence for the presence or absence of potential shallow crustal seismogenic sources (faults) along features identified through previous lineament mapping; (2) ascribe an origin to the lineaments identified, (3) if considered a fault, evaluate field evidence for late Quaternary faulting; and (4) develop a conceptual geo-chronologic model for Quaternary deposits or surfaces in the study area.

2. APPROACH

The approach to the lineament evaluation, in general, consisted of desktop digital terrain mapping and analysis (i.e., FCL, 2013) complemented by field inspection and mapping in the summer of 2013 (this memorandum).

The desktop lineament mapping and analysis report (TM-8; FCL, 2013) describes the approach for mapping of individual lineaments across the Project area, 100 km (~62 miles) radius from the dam site, and assigning morphologic attributes to the individual lineaments. For that effort, criteria were established to provide a basis for delineating lineament groups (that is, aggregates of individual lineaments) that appear to have sufficiently extensive lateral continuity and geomorphic expression consistent with an origin by tectonic processes (FCL, 2013). Additional criteria were developed to exclude lineament groups that were created by erosional or depositional processes (i.e. non-tectonic lineaments), lineament groups that are chiefly related to lithologic controls (i.e., differential erosion), lineament groups that did not meet length and distance criteria, and lineaments that did not show consistent senses of displacement along strike. For completeness, the criteria used to identify and analyze lineament groups is reviewed below in Section 2.2. In total, 22 lineament groups and three broader lineament areas were advanced to further field investigation and evaluation in summer of 2013 (FCL, 2013).

The 2013 field teams consisted of two, two-person groups and involved visual inspection of landscape and geomorphic features within lineament groups via low-altitude helicopter fly-overs and ground data collection in selected locations where access was permitted. The mapped lineament groups were visually inspected in the field to identify positive evidence for (or against) tectonic deformation of the Quaternary deposits (as present in the field) that may overlie, or project toward, the lineaments. The ground-based geologic data collection included walking of parts of mapped lineaments, photo documentation, exposure and logging of shallow soil pits, local mapping, collection of relevant structural measurements (strike, dip), and comparison of existing geologic mapping to field exposures and findings.

Each field team used a ruggedized field laptop computer (Toughbook) with real time GPS tracking and GIS capabilities. The geologic database compiled by FCL during the efforts of FCL (2013) for the seismic studies was loaded onto each Toughbook with LiDAR and INSAR digital elevation and derivative surface models. This approach allowed for: (1) accurately locating position with respect to lineament features in the field in real time, and (2) real-time analyses of the existing geologic mapping and landscape models to the features observed in the field.

The helicopter inspection was conducted chiefly with R-44 type aircraft. Other rotary aircraft were used to a lesser extent during the aerial inspection. Each ruggedized field laptop was carried in the helicopter with the GPS enabled to record a "track" for each team's course, position, and pattern for each flight (Figure 2-1). Minor satellite signal loss occurred during parts of the field investigation, but was supplemented with redundant auxiliary tracks collected by hand-held GPS units. Hand-held GPS units were primarily used to collect way points at selected locations of the ground investigation. The field tracks document the extent and location of low-altitude inspections, and way points document ground locations relevant to the geologic data collection.

Photographs were taken during the low-altitude flyovers and while on the ground, and serve to document the field observations. The photographs were collected with a digital camera whose internal clock was synchronized with the hand-held GPS clock. This allowed geo-referencing of the photographs to the location where the photo was collected, and ensured collected photos were assigned to the correct place, feature, or lineament group. In some instances, inclement weather (rain, clouds) hindered quality of photo documentation. In other instances, glare or distortion from aircraft windows is apparent in the photographs.

The lineament groups and larger areas are depicted in detail on a series of strip maps and plates on which relevant field- and office-generated geologic and geomorphic data are compiled and evaluated. Examples of this field data collection and synthesis effort are shown in Figures 2-2, 2-3, and 2-4. (The map data are presented in-full in Appendices A and B and each lineament group is described below in Section 4.) The content of the strip maps and plates is customized for each lineament group and only the most the relevant field data and geologic map data are shown alongside the mapped lineaments with the most appropriate base imagery, given the local terrain and features of interest (e.g., Figure 2-2). Figure 2-3 demonstrates the annotated field photographs that are linked to the maps while Figure 2-4 provides an example of an explanation sheet that accompanies the maps.

2.1 Geospatial Data

The primary digital data sets utilized by FCL (2013) for the lineament mapping phase and during the 2013 field work consisted of several high-resolution topographic and aerial imagery datasets (Table 2-1). Of the available data, the INSAR and LiDAR (Figure 2-5) were the most valuable due to their high resolution and broad coverage of areas of interest. INSAR coverage is complete for the entire region of study interest within about 100 km of the Susitna-Watana dam site as well as a broader region of south-central Alaska. LiDAR coverages are available for much more restricted areas, and near the Susitna-Watana dam site is generally limited to a narrow corridor along the Susitna River (Figure 2-5). Both INSAR and LiDAR can penetrate through vegetation cover to map the ground surface beneath and can be used to create a "bare earth" digital elevation model (DEM) of the landscape.

In addition to the elevation data, two imagery datasets covered the study area: 1) ortho-imagery (0.3 m) collected as part of the Matanuska-Susitna Borough (MatSu) LiDAR collection project, and 2) regional

Landsat scenes (30 m) (Table 2-1). The MatSu aerial imagery coverage has limited regional extent coincident with the extent of the MatSu LiDAR data (Figure 2-5). Both imagery datasets provide data in the visible spectrum. These imagery datasets were used to provide context and better understand landscape features displayed on the INSAR and LiDAR data and also navigate the terrain during the field work.

Table 2-1. Principal Data Sets Utilized During the Lineament Mapping

Data	Cell Size	Year	Source
INSAR elevation data (bare earth)	5 m (~16 ft)	2010	Data collected by Intermap (50%) and Fugro EarthData. Inc. (FEDI) (50%)*
MatSu LiDAR elevation data (bare earth)	1 m (~3 ft)	2011	Matanuska-Susitna Borough*†
MatSu aerial imagery	0.3 m (~1 ft)	2010	Matanuska-Susitna Borough*†
Landsat satellite imagery	30 m (~100 ft)	2010	NASA/USGS§

*Data downloaded from the Geographic Information Network of Alaska (GINA) at the University of Alaska
†For more information see: http://www.matsugov.us/it/2011-lidar-imagery-project
§ Downloaded from http://glovis.usgs.gov/

2.2 Desktop Approach for Lineament Evaluation

2.2.1 Criteria for Selection of Lineaments Requiring Further Analysis

FCL (2013) defined multiple acceptance criteria to serve as a basis for delineating potentially tectonically-relevant lineament groups (Table 2-2). In general, the lineament groups consisted of individual lineaments having consistently similar orientations that when aggregated together as a group, have a relatively appreciable length and which trend across terrain. Several criteria were established to serve as a relatively inclusive basis for delineating lineament groups within the study area. These criteria from FCL (2013) are described below (Table 2-2), and are presented in generally decreasing degree of confidence in lineament delineation as a potential crustal feature.

Table 2-2. Criteria for Delineating Lineament Groups

Criterion	Reasoning
Lineaments that are expressed in Quaternary deposits, that collectively aggregate to greater than about 10 km (~6 miles) in length.	Quaternary lineaments may strongly represent neotectonism.
Lineaments that appear to represent potential extensions or continuations of known Quaternary faults.	These lineaments may contribute to additional fault source length in ground motion calculations.
Lineaments with possible tectonic geomorphologic evidence that are spatially associated with previously mapped faults or lineaments.	Suggestive, but not conclusive, of neotectonism. Association with previously mapped faults or lineaments supports inference of structure.
Lineaments with possible tectonic geomorphologic evidence that are not spatially associated with previously mapped faults/lineaments.	Suggestive, but not conclusive, of neotectonism.
Lineaments that aggregate to greater than 10 km (~6 miles) in length.	Length criterion is based on an approximately minimal structural length for a seismogenic source capable of ground rupture.
Lineaments that are within 30 km (~18 miles) from the proposed site and reservoir, and are greater than 20 km (~12 miles) in aggregated length.	Seismogenic features within 30 km (~18 miles) of the site may contribute non-trivially to the ground motion calculations.

The lineament groups identified through the inclusion criteria were subsequently screened using semi-objective exclusionary criteria (Table 2-3). The semi-objective criteria included length and distance restrictions, and also geologic process restrictions. The screening process thus required an examination of the identified lineament groups to assess the possible genesis of the features. The screening step eliminated lineaments that show strong evidence of being non-tectonic in origin (e.g. erosional, depositional), or those that likely would not appreciably contribute to the seismic hazard at the proposed dam site.

Table 2-3. Desktop Evaluation Exclusion Criteria

Criterion	Reasoning
Lineament groups that are greater than 100 km (~62 miles) distance from the proposed dam site, excepting potential extensions of the Castle Mountain fault.	Lineaments over 100 km (~62 miles) distant would have very little contribution in hazard calculations. Potential extensions of the Castle Mountain fault may contribute to hazard calculations.
Lineament groups that are greater than 70 km (~43 miles) distance from the proposed site and less than 40 km (~25 miles) aggregate length and with no apparent association to previously mapped structures.	These lineament groups likely would not appreciably contribute to the hazard calculations, based on the Sonona Creek seismic source contribution in the preliminary PSHA (FCL, 2012).
Lineament groups that are greater than 30 km (~18 miles) from the proposed dam site and less than 20 km (~12 miles) in length are excluded from further analysis, where the group cannot be linked to an adjacent group.	Based on the results of the preliminary PSHA (FCL, 2012), it is likely that these lineament groups (if seismic sources) will not appreciably contribute to the hazard calculations.
Lineament groups whose individual features are dominantly erosional and/or depositional with no apparent association with previously mapped faults or lineaments.	Such lineaments are non-tectonic in origin and not considered further.
Lineament groups with inconsistent expression of kinematics along strike.	Inconsistent, contrasting, or discrepant lineament kinematics indicates low likelihood as a potential seismic source.

A second, more subjective, evaluation process (Table 2-4) was applied by FCL (2013) to the remaining lineament groups, based on desktop geological examination of the data compiled on the lineament group strip map. This process served to identify potentially significant lineament groups that would need additional data and evaluation as part of the summer 2013 field studies.

Table 2-4. Criteria for Desktop Geologic Evaluation of Lineament Group

Criterion	Reasoning
Lineaments within groups that appear to have expression in Quaternary units or Quaternary landforms proceed to further analysis.	Quaternary-age lineaments may strongly represent neotectonism, if not erosional or depositional in origin.
Lineament groups that transect or cut across different geologic units proceed to further analysis.	Lineaments that are traceable across different geologic units imply crustal structure exists, as opposed to lineament genesis from lithology, bedding, or jointing.
Lineaments within groups that may be tested for positive evidence of inactivity (e.g., overlain by Tertiary volcanic units) proceed to further analysis.	Determining inactivity via positive evidence will remove lineament group from further study.
Lineament groups that demonstrate relative consistency of geomorphic expression and anticipated structural kinematics along strike proceed to further analysis.	Consistent expression and structural style suggests a common genesis such as neotectonism because many other processes of formation change along the length of their occurrence.
Lineament groups that are explainable in the context of the tectonic model proceed to further analysis.	The tectonic model serves as a guide for anticipating orientation and sense of motion with respect to crustal stresses.

2.2.2 Criteria for Evaluation of Lineaments, Summer 2013 Field Investigation

The lineaments inspected in the field during summer 2013 were assessed based on geomorphological characteristics observed in the field and geologic relationships around the lineaments. As guidelines for the field teams conducting the field investigation of individual lineament groups, a series of questions were developed prior to the field activities as an aid to focus observations and data collected during the field investigation. The intent was for the field teams to discuss and debate during the process of the lineament field evaluations as an ongoing field methodology to help ensure that field observations were sufficiently complete during the limited time available, often with no opportunities for revisitation. Table 2-5 lists these questions and the reasoning which supported the need for collecting the associated field data in order to assess each lineament in a relatively consistent fashion.

Table 2-5. Field Team Geologic Data Collection Guidance

Field Data	Reasoning/Comments
Is a previously mapped bedrock fault structure coincident with or near the lineament group?	Spatial proximity to or association with a previously mapped fault may support the lineament group having a tectonic origin.
Was field evidence of fault structure observed (either directly or indirectly)?	Direct evidence: exposure of shear zone or fault contacts observed. Indirect evidence: apparent rock type juxtapositions, alteration zones, color changes.
What does the trend of the lineament across the topography imply about the geometry of the potential structure?	Topographic expression provides a basis for defining the potential 3D geometry and potential style of faulting or constraints on potential non-tectonic origins.
What types of deposits or geomorphic surfaces is the lineament expressed in?	Quaternary glacial, lacustrine, alluvial, and colluvial deposits or bedrock units? Are the geomorphic surfaces constructional or erosional?
What is the oldest deposit in which the lineament occurs?	Age of deposit may constrain age of activity or limit of reasonable hypotheses of origin.
What is the youngest deposit in which the lineament occurs?	Age of deposit may constrain age of activity or limit of reasonable hypotheses of origin.
Do the mapped lineaments transect or cut across different geologic units or landforms?	Expression of lineament across multiple units or landforms may indicate continuity of geologic process.
What is the scale (magnitude) of expression of the lineaments along strike?	Expression that is proportionally consistent across different age portions of the landscape suggests continuity of process.
Is the lineament discordant with glacial ice flow directions?	Discordance with ice flow direction suggests origins other than ice flow.
Is there field evidence that linear strain markers (such as moraine or ridge crests, esker ridges, terrace risers or treads, lake shorelines, drumlins or other ice scour-generated striae) are cross-cut, deformed or displaced? If deformed, what is the amount?	Disruption of Quaternary strain markers may suggest a recent tectonic origin.
What does the morphology of the lineament imply about the kinematics of a potential fault? What are the apparent structural kinematics needed to produce the morphology of the lineament?	Kinematics need to be consistent along strike.

To evaluate the field data and guide development of documentation for the evaluation of each lineament group, a set of questions and criteria similar to those used by FCL in TM-8 (FCL, 2013) for evaluation of the desktop findings were developed (Table 2-6). In much the same way that the data collection guidelines shown in Table 2-5 were intended to enhance consistency and focus across the range of features visited in the field, the guidance which follows in Table 2-6 is intended to build those observations into a consistent set of discussions for documentation of the evaluation of each lineament group. The principal objective of these criteria is to guide judgments regarding the lineaments' origins in order to evaluate their potential association with Quaternary faulting and crustal seismogenic sources.

Table 2-6. Criteria for Evaluation of Field Data

Criterion	Reasoning
Does the lineament show evidence of geomorphic expression in Quaternary deposits or landforms? What is the character of expression?	Quaternary-age lineaments may strongly represent neotectonism, if not clearly of erosional or depositional in origin.
Does the lineament group transect or cut across different geologic units or landforms?	Lineaments that are traceable across different geologic units may indicate through-going crustal structure exists, as opposed to lineament genesis from local lithology, bedding, or jointing.
Does the lineament group demonstrate relative consistency of geomorphic expression and apparent structural kinematics along strike?	Expression that is proportionally consistent across different age portions of the landscape suggests continuity of process. Consistent expression and structural style suggests a common genesis such as neotectonism because many other processes of formation change along the length of their occurrence.
Are the lineaments' apparent origins dominantly erosional and/or depositional?	Such lineaments are likely non-tectonic in origin.
Are the individual lineaments or lineament groups associated with previously mapped faults?	Spatial proximity to or association with a previously mapped fault may support the lineament having a tectonic origin.

3. FIELD DATA EVALUATION FRAMEWORK

The 2013 field activities and lineament evaluations revealed three topics with broad impacts across several aspects of the lineament evaluations. These topics include: 1) insights gained from field investigation and evaluations on the scale and resolution of DEM data, 2) identification of the dominant geomorphic processes acting to modify the landscape, and 3) updated regional age estimates for late Quaternary landscapes and events in south-central Alaska. Interpretations and evaluations of most lineament groups and individual features within these lineament groups are linked to key principles or limitations posed by data or concepts associated with these three topics.

3.1 Post-Field Data Evaluation of DEM Data

As noted in Section 2.1, two sets of topographic data were used for the desktop lineament mapping: INSAR and LiDAR (FCL, 2013). The INSAR (Interferometric Synthetic Aperture Radar) data covered the largest area for the project and has a 5 m (~16 ft) horizontal cell-size (Table 2-1). The LiDAR, with a 1 m (~3 ft) horizontal cell-size, captured a smaller aerial extent that chiefly focused on the Susitna River corridor (Figure 2-5). Both INSAR and LiDAR can penetrate through vegetation cover to map the ground surface beneath and can be used to create a "bare earth" model of the landscape.

The INSAR-derived DEM data was the basis for mapping lineaments at regional extents (e.g. the 100-km [~62 miles] radius), and is a significant improvement in accuracy and detail of elevation as compared to any previously available regional data in south-central Alaska, and compared to DEM models derived from typical 1:24,000-scale topographic quadrangles throughout the mainland United States. However, after comparing the elevation model data along mapped lineaments to the geomorphic features observed on the ground during the field work, several trends became apparent. First, for example, what visually appear to be relatively small features on the INSAR data actually are rather large features in the field. Features such as slope breaks that appeared sharp and abrupt on hill shaded maps, generally were found to be larger than expected in overall size and relief with less abrupt and more rounded slope geometries. Considering that the investigation team's objective was to detect and identify potential earthquake-related geomorphic features (i.e., fault rupture scarps), the INSAR-based lineament mapping (FCL, 2013) may have over-mapped features that – in hindsight after two weeks of field investigation – likely would not be considered tectonic in origin. Nevertheless, all lineaments were mapped impartially, and subsequently tested via observation and reasoning.

Secondly, some relatively small features were observed on the landscape and on the ground during the field investigation which were not captured by the INSAR data, and thus not identified as lineaments in FCL (2013). This condition is challenging to characterize because the ability of the INSAR to image small features seems to be a function of the features' relief relative to that of the landscape (small feature in flat terrain vs. small feature in a ravine or valley) and the features' inherent geomorphic expression (steeply sloped margins vs. gently sloped margins and also continuity or length). To mitigate this apparent resolution limitation, derivative surface elevation models from the bare earth model were analyzed during the field investigation using the ruggedized field laptop GIS platform. Slope maps (change of elevation), and slope of slope maps (change of slope), were used to highlight subtle changes in elevation or slope that accentuate features that may be generally non-apparent in traditional hillshade elevation maps. These derivative surface elevation models were locally helpful in identifying smaller landscape features such as solifluction scarps and terraces.

Overall, the field investigation highlighted the previously known limitations of the INSAR based lineament mapping, notably that the base resolution of a 5 m (~16 ft) DEM is still relatively coarse with respect to the scale of geomorphic features that might be expected to be associated with single earthquake surface ruptures. As noted in FCL (2012), surface rupture features associated with the 2002 Susitna Glacier fault rupture are subtle, but recognizable in the 5 m INSAR DEM data. Conversely, the previously mapped lineament along the Talkeetna fault trenched by WCC (1982) and discussed later in Section 4.1, is not resolved on the INSAR DEM, but does represent the type and scale of feature that would be of interest as a potential tectonic feature. When considered together with the role of active surface modification processes (discussed below in Section 3.2), these two features show that while there may be significant limits to the preservation of small tectonic features over time periods of thousands of years due to geomorphic surface modifications, such features can be stable and preserved in the Holocene landscape. Our field observations confirm that this limitation is likely most severe in areas of more irregular and high relief terrain, and somewhat less so in areas with more gentle, rounded, and uniform slopes. In short, the terrain and the style of faulting will together affect how apparent potential fault-derived features will be in the INSAR data.

The scale of features mapped in areas where LiDAR DEM data are available is much finer, but no direct comparisons of the field scale of these features have been done to date, as most of the areas in which mapped features of potential interest occur, and where there is overlap of the INSAR and LiDAR data, were not available for ground access in 2013. Direct on-ground comparisons of mapped features in areas with data overlap may provide a basis for specific definition of the overall resolution of scale of features detectable through the mapping on the INSAR and LiDAR DEM data sets.

3.2 Role of Geomorphic Processes for Creating Apparent Lineaments

Another insight stemming from the 2013 lineament field investigation is that a preponderance of the individual lineaments mapped within many of the lineament groups are the result of glacial and/or periglacial processes. Therefore, a discussion of the various geomorphic processes and resulting landforms is warranted in order to provide a context for their extensive presence on the landscape, as well as a technical basis for evaluation of lineament groups within the project area. Based on the field observations, the dominant erosional features observed are common in glacial and periglacial environments and include: subglacial (sub-ice) channels carved into rock or soil; solifluction-related scarps and lobes; roche moutonee, drumlins, and nivation-related scarps. The erosion-related landforms tend to produce slope breaks and linear features that are similar in landscape expression to tectonically produced lineaments. These processes are briefly described below.

3.2.1 Subglacial Channels and Basal Erosional Processes

Subglacial erosional processes appear to be significant factors in the origin of many of the larger lineament features identified through the desktop DEM analyses in FCL (2012). Unfortunately, the specific genesis of subglacial erosion that creates subglacial channels (also called meltwater channels) is generally poorly understood because their process of origination cannot be directly observed. Moreover, the classification and nomenclature for describing landforms and origins of various types of subglacial channels is relatively non-uniform and inconsistent, which further confounds clear terminology.

In essence, subglacial channels may develop by eroding upward into ice, eroding downward into the underlying substrate, or a combination of both. Channels that erode upward into ice may eventually become plugged with sediment and, when the ice recedes, remain on the landscape as eskers.

Subglacial channels that form by eroding downward under the ice into the underlying geologic substrate are relevant to this lineament evaluation because this action produces sub-linear erosional features on the landscape (Figures 3-1 to 3-3). Geomorphic characteristics common to subglacial channels include: an often abrupt beginning or termination in places where normal river channels do not start or end (e.g., across interfluves), uneven longitudinal profiles, channels that tend not to widen downstream, and steep channel side-walls oriented down slopes at a right angle to the contour lines (Gray, 2001; Gao, 2011). The geomorphic expression usually is a ravine that starts for seemingly no reason and then continues towards the bottom of a valley where it may terminate abruptly. Where the channels have formed in solid rock, the substrate rock typically is deeply incised or gorged, with narrow and steep-sided walls (Figure 3-2).

The subglacial channels described above may also be referred to as a tunnel valley. A tunnel valley is a large, long, valley originally cut under the margin of former continental ice sheets (Figure 3-3; Jorgensen and Sandersen, 2006; Gao, 2011). The processes forming the valleys appear to advantageously occupy pre-existing (open and buried) valleys for the renewed erosion. Thus, old subglacial erosion pathways may have been re-used several times. The Finger Lakes in New York State are attributed to tunnel valley processes (Jorgensen and Sandersen, 2006). Tunnel valleys appear in the technical literature under several terms, including tunnel channels, subglacial valleys, iceways, snake coils and linear incisions.

Roche moutonnee (a.k.a. sheepback) landforms result from the passage of glacier ice over bedrock that creates an asymmetric erosional form as a result of abrasion on the up-ice side of the rock and plucking on the down-ice side (Ritter et al., 1995). This process generally produces isolated "knobs" of rock that may protrude through glacial drift or alluvial cover, and appear similar to a tectonically bounded or emplaced sliver because of its generally infrequent occurrence on the landscape.

Drumlins form by ice-flow and substrate abrasion or scour, and typically are elongate, linear ridges oriented parallel to the direction of ice flow (Ritter et al., 1995). On a drumlin, the steep side is facing the approaching glacier, rather than trailing it, and thus may appear as an apparent truncation if the slope is appreciably steep.

3.2.2 Solifluction

Solifluction (also called gelifluction) is a slow-rate hillslope mass wasting process that commonly occurs in periglacial environments during the thaw (i.e., summer) season. It is distinct from the frost heave process. (Frost heave is a particle's movement perpendicular to slope because of volumetric ice expansion.) The term solifluction describes the gravity-driven downslope movement of water-saturated unconsolidated surface material (regolith) that flows down slopes of moderate to very low gradient because meltwater saturates the upper layers but cannot penetrate the frozen ground beneath (Bloom, 1988). The process produces arcuate erosional (and scarp-like) features up-slope as well as arcuate lobate constructional landforms on the downslope. The arcuate landforms tend to produce apparent slope breaks on the landscape that may be interpreted as potential fault-related features. In many cases, it appears that solifluction related scarp-like features and slope breaks of sufficient size to be identified and mapped in the INSAR based DEM were included as individual features within the lineament groups. These occurrences are most common in landscapes with more uniform and moderate slopes, where extensive areas of solifluction features have developed. Because of similarities at the outcrop scale of the size, morphology, and continuity of these features to surface rupture features associated with large tectonic earthquakes, evaluation of lineament groups and features in these types of landscapes poses significant challenges and added uncertainty for interpretations.

3.2.3 Other Processes and Landforms

Nivation processes are difficult to define because the process includes both physical weathering coupled with hillslope erosion. In general, nivation is the acceleration and/or intensification of ground weathering and erosion associated with patches of snow that persist into the summer season in a periglacial environment (Bloom, 1988). Snow patches that persist in sheltered (shaded) positions on hillslopes below the altitude of permanent snow fields may produce nivation depressions or "hollows." The weathering becomes intensified in the saturated ground beneath a compacted snow patch (i.e., névé: a young, granular type of snow which has been partially melted, refrozen and compacted yet precedes the form of ice). The saturated snow mass produces a flow of water on the ground surface that erodes particles of soil beneath the snow. In addition, freezing and thawing of the snow mass can impart physical breakdown of soil as well as heave and downslope soil erosion processes.

Nivation scarps and related geomorphic features are most common and apparent in the higher elevation portions of the landscape above treeline, most often in portions of valleys most recently occupied by glacial ice. In these areas, low-level aerial and ground observation facilitated differentiation of nivation-related landforms from landforms generated by other processes. Importantly, the identification of lineaments, whether nivation-related or not, in areas most recently occupied by glaciers implies a very young age. Many of the features ultimately interpreted as nivation-related were prominent in the DEM models, but found with field observations to be much larger than credible for features of tectonic origin given their occurrence within the youngest portions of the regional landscape.

3.3 Age Datums and Detectability Limits

Understanding the Quaternary geologic history in the Susitna River basin region is relevant to understanding the geomorphic processes, resultant surficial geologic deposits, as well as relationships amongst deposits, both stratigraphically and chronologically. Quaternary stratigraphy and chronology form a basis to establish a geologic datum for evaluating tectonic (fault) activity during the late Quaternary.

3.3.1 Quaternary Geology Model

At their maximum extent during the Quaternary, glacial ice caps coalesced and covered essentially the entire 100 km (~62 miles) radius about the Susitna-Watana dam site (Wahrhaftig, 1965; Hamilton, 1994; Kaufman et al., 2011). Even during the late Wisconsin or last glacial maximum (LGM) in south–central Alaska, recent regional compilations (Kaufman et al., 2011) show that the glacial extent was slightly restricted relative to the Quaternary maximum extent, but still only a few relatively high elevation or isolated areas within 100 km (~62 miles) of the Susitna-Watana dam site remained ice free (Figure 3-4). Most remaining lower elevation areas in that region, such as the northwestern Copper River Basin, were largely occupied by proglacial lakes, confined by ice blockages between the mountain ice caps. In the Susitna-Watana dam site area, prior investigations (e.g., Acres, 1981, 1982) document the stratigraphic record left by alternating ice advances and glacial lakes associated with the most recent glaciations.

Age control for the late Wisconsin glacial advances in the Susitna-Watana dam region is limited, and largely based on recent cosmogenic dating of moraines and landforms on either side of the Alaska Range, north of Susitna-Watana dam site (Figure 3-4). Most recent age compilations (e.g., Kaufman et al., 2011; Briner and Kaufman, 2008) now suggest that the timing of Oxygen Isotope Stage 2 (LGM) maximum advances in Alaska may have varied by thousands of years across the state, but retreat from the maximum extent in south-central Alaska likely started about 22 to 20 ka. Ice extent probably remained near the maximum extent for a few thousand years, with several readvances and periods of stabilization through about 15 ka. The last significant readvances of glaciers in the Alaska Range occurred between 14 to 12 ka, and 12 to 11 ka (Briner and Kaufman, 2008), followed by rapid deglaciation.

Near Anchorage and in the upper Cook Inlet, about 200 km (~125 miles) to the southwest of the site, the late Wisconsin advance is locally termed the Naptowne, and occurred between about 30 to 11 ka (Reger et al., 2007). During the maximum advance, ice from the Alaska Range flowed south and southeast and filled much of the Cook Inlet at about 23 ka. Ice remained near this limit until about 19 ka, then retreated gradually to less extensive advances or stillstands until about 17 ka, when there was significant retreat. A final re-advance, which built the Elmendorf moraine complex, began after 16 ka, and extended to about 11 ka.

For fault and lineament evaluations, the ages for the regional glacial chronology imply that the vast majority of the landscape within about 100 km (~62 miles) of Susitna-Watana dam site was covered beneath glacial ice or glacial lakes as late as about 15 ka, with a slow reduction in ice and lake extent through 12 to 11 ka. During this later period, significant ice and lakes remained in most of the glaciated valleys within the northern and central Talkeetna Mountains, and potentially included the last glacial advances of the Tsusena and Deadman Creek glacial lobes into the Susitna-Watana dam site vicinity, and intervals of glacial lakes in the Watana Creek area. Thus, geomorphic surfaces on which a record of potential surface faulting might be preserved prior to about 12 to 11 ka within about 100 km (~62 miles) of the Susitna-Watana dam site were likely limited to isolated high peaks above the ice limits, and small ice-free areas above the limits of glacial lakes. Potential ice free areas during the later stages of the late Wisconsin advance lie mostly east of Watana Creek along either side of the Susitna River, and along the southeastern margin of the Talkeetna Mountains above the limits of Lake Ahtna in the Copper River Basin (Figure 3-4). As ice receded during the late Wisconsin advance, areas near Talkeetna, along the Chulitna River from Susitna River to the Broad Pass area, and the low hills and valleys southwest of the Alaska Range glaciers on Monihan Flats, but northeast of Susitna-Watana dam site may have been ice free closer to 15 ka.

Following the last late Wisconsin advances at about 12 to 11 ka, there was rapid deglaciation and retreat of the glaciers of southern Alaska to high altitude limits and positions not far from present glacial extents (e.g., Reger and Pinney, 1997). Moraines and deposits just beyond the limits of current and recently active deposits have ages of less than 2 to 1 ka (e.g., Dortch et al., 2010a), suggesting glacial extents during the Holocene have remained near present limits. Near the Susitna-Watana dam site, the rapid transition to non-glacial conditions is evidenced by several radiocarbon ages on peats and bog deposits which began to accumulate in the post-glacial environment and which yield radiocarbon ages ranging up to about 11 to 10 ka (e.g., WCC, 1982; Reger et al., 1990). Radiocarbon ages from the lake deposits in Copper River Basin, suggest final lowering and drainage of the large glacial lake there during the same time period (Williams and Galloway, 1986). Thus, beginning around 11 ka, large areas of the formerly ice and glacial lake-covered landscape began to stabilize and present geomorphic surfaces which might record faulting emerged. Published radiocarbon chronologies from archaeological studies indicate that some parts of the Upper Susitna area may have been habitable by 12 ka (Potter, 2008). The upper Susitna basin was first occupied by somewhere between 11.5 and 8 ka (Potter, 2008).

At least three Holocene tephra units are known to overlie glacial deposits in some areas near the Susitna-Watana dam site. These deposits are thought to have originated from eruptions in the Tordrillo Mountains to the southwest of the Watana site (Riehle et al., 1990). Three tephra units described near the Watana site are reported to be about mid to late Holocene age, based on radiocarbon analyses of 42 samples (Dixon et al., 1983, 1985).

For fault and lineament evaluations in the Susitna-Watana dam site region, the review of previous studies and research of Alaskan glacial chronologies, coupled with field observations of the type and distribution of glacial constructional and erosion landforms suggests that there are three broad age categories within which the landscape may be viewed. These are, from youngest to oldest: late Holocene, mid- to early Holocene, and post-late Wisconsin period of the late Pleistocene. Geomorphic surfaces and deposits associated with maximum phases of the late Wisconsin glaciation, and older glaciations, were generally either modified or buried by effects of the last phases of late Wisconsin glaciation. Thus, for geomorphic evaluations of the faults and lineaments in the region, these older deposits are generally of limited use because the surface expression of older faulting has been removed.

4. OBSERVATIONS AND INTERPRETATIONS OF LINEAMENT GROUPS

The following section discusses each of the individual lineament groups and larger areas visited during the summer 2013 lineament investigation. The groups and larger areas are depicted in detail on a series of strip maps and plates on which relevant field and office geologic and geomorphic data are compiled and evaluated (Appendix A). The lineament groups identified for summer 2013 field work are shown on Appendix A, Figure A0.1, and a series of supporting figures[2]. The larger areas showing the Broad Pass fault, Clearwater Mountains, northeastern Castle Mountain fault, are shown on Plates A-BP, A-CWM, and A-CME, respectively. Appendix B contains a series of figures presenting map and field data for numerous photogeologic lineaments mapped by Reger et al. (1990) on the Healy A-3 Quadrangle (see Figure B-01 and discussion below). The strip maps and plates facilitate discussion and evaluation of the data collected in the field with respect to the features' relevance to the seismic hazard evaluation for the proposed Susitna-Watana dam site and potential needed further study.

Lineament Group 1: Observations and Evaluation

Lineament group 1 is an east-northeast-trending group of lineaments defined by a series of aligned, linear to sub-linear drainages and uphill-facing slope breaks, approximately 51 km (~32 miles) north of the proposed Susitna-Watana dam site (Appendix A, Figures A0.1, and A1.1). Individual mapped lineament feature lengths range from approximately 200 m to 4 km (~650 feet to 2 miles), with an aggregate length of approximately 20 km (~12 miles). No previously mapped faults or lineament features coincide with the group (Figure A1.1), and no evidence of fault structure was observed during low-level aerial investigation. Along the eastern portion of the group, the morphology of the lineaments and their very linear trend across the high relief terrain suggests that any potential fault structure that may exist would have a steep dip and apparently north-down, south-up sense of motion. The feature has a similar trend to the relatively proximal Denali fault (Figure A0.1). Discrete lineaments that make up the aggregate group occur in the Cretaceous Kahlitna flysch sequence (map unit KJf, Wilson et al., 1998) and to a lesser extent, Tertiary intrusives of felsic and intermediate composition (map unit Thf). Late Quaternary deposits along the Jack River, of late Wisconsin and post-glacial age intersect the projected trace of the group 1 lineaments near the center of the group 1 ellipse. These late Quaternary deposits show no apparent expression of the lineament (Figures A1.1 and A1.2).

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[2] Note that for ease of reference, Appendix A figure numbers correspond to lineament group numbers. For example, Figure A1.1 shows the extent of lineament group 1. The content of the strip maps and plates is customized for each lineament group and only the most the relevant geologic data are shown on the most appropriate base imagery, given the local terrain and features of interest. The explanation of symbols and relevant existing geologic mapping shown on the figures has been compiled into a series of explanation sheets (Figures A0.2, A0.3, A0.4, and A0.5) that follow the index map of lineament groups and precedes the figures for lineament group 1.

Observations made during aerial field investigation suggest that the topographic expressions of the lineaments within the Cretaceous flysch (map unit KJf), in the eastern portion of the group, may be erosional features along unmapped bedrock structure, or possibly large sackung features. In either case, the absence of continuity of the individual lineaments from steep bedrock slopes into areas adjacent areas of lower slopes where Quaternary deposits are present is evidence of non-tectonic origin for these features. Although the lineament group has a similar trend to the Denali fault located about 18 km (~11 miles) to the north, no previously mapped faults or lineament features coincide with the group (Figure A1-1), and no evidence of fault structure was observed during low-level aerial investigation. The lineaments that were identified in the western portion of group 1 are associated with a large, narrow, linear canyon, with no change in rock type or expression across the valley. Additionally, the lineament segments of Group 1 do not align across the Jack Creek drainage at larger (more detailed) map scales, suggesting the lineament group may represent two shorter sets of unrelated features. Based on the above evidence, the lineaments of group 1 are likely non-tectonic in origin, are judged to be primarily erosional and/or landslide features, and are not considered further.

Lineament Group 2: Observations and Evaluation

Lineament group 2 is an east-northeast-trending series of aligned, linear drainages, slope-breaks, and V-notched saddles (Figure A2.1) located approximately 46 km (~29 miles) north-northwest of the proposed Susitna-Watana dam site (Figure A0.1). No previously mapped geologic faults or lineament features coincide with the lineaments of group 2, although the group has a similar trend to the relatively proximal Denali fault (located 25 km [~15 miles] to the north-northwest). No evidence of fault structure was observed during low-level aerial investigation. Individual features range in length from a few hundred meters to approximately 2 km (<985 feet to ~1 miles), with an aggregate length of approximately 12 km (~7 miles). The youngest unit expressing lineament features are Tertiary volcanic rocks (map unit Tvu), and the oldest unit is the Cretaceous Kahlitna flysch (map unit KJf) sequence (Wilson et al., 1998; Figure A2.1). Individual lineaments within the group have a clear expression in both bedrock units. Mapped Quaternary surficial sediments, fluvial deposits in several unnamed drainages, a glacial moraine, and an alluvial fan deposit show no apparent deflection or deformation where overlying the projected trace of the lineament group (Figures A2.1 and A2.2). Glacial valley orientations are orthogonal, or sub-orthogonal to the lineament group, suggesting that Quaternary glacial processes likely had little role in the formation of the features. From west to east, the mapped linear segments present both down-to-the-north and down-to-the-south apparent senses of vertical deformation with a variable scale of vertical relief ranging from less than 10 m to about 50 m (~33 to 164 ft).

Discrete lineaments within group 2 occur primarily in Tertiary volcanic rocks (map unit Tvu), with one feature showing an apparent expression in both the Tertiary and Cretaceous rocks, and an additional aligned linear drainage expressed in Cretaceous rocks (Figure A2.1). No FCL mapped lineament from group 2 has expression in Quaternary units or Quaternary landforms based on field observations. As mapped, the Wilson et al. (1998) map compilation in this area is generalized and does not accurately depict the full extent of Quaternary surficial deposits (map unit Qs) along the position of FCL-mapped lineaments. Field investigation confirmed that Quaternary surficial deposits should be mapped through the floor of the Jack River valley and on both the north and south sides of the linear drainage shown in Figure A2.2 Photograph A) and that much of these deposits consist of till and other glacial deposits, likely of late Wisconsin age. In all instances, lineaments with clear expression in bedrock lose expression at contacts with Quaternary deposits and landforms. In the eastern portion of the lineament group, the lineament appears to consist of erosional scarps and linear drainage sections that follow the course of the Jack River. At a rectilinear bend in the river (near A on Figure A2.2), late Wisconsin glacial deposits in the valley bottom overlie the projected trace of the linear river segment, and did not show any expression indicative of deformation related to faulting. West of the Jack River, the lineament consists of discontinuous, but aligned linear slope breaks in Tertiary volcanic bedrock (map unit Tvu) separately by Quaternary units in which the lineament is not expressed. The western-most of the lineaments extends into KJf (Cretaceous Kahiltna flysch), based on the Wilson (1998) mapping, but is again separated from other lineaments by Quaternary units with no expression of the lineament. The limited and ambiguous expression of lineament features outside of the Tertiary volcanic rocks within the Cretaceous flysch, suggests that the observed trend may represent erosion along internal bedrock structure or features with the Tertiary volcanic rocks, as opposed to a through-going crustal structure. The geomorphic expression of this lineament group presents an inconsistent expression of apparent vertical displacement. Along the trace of this lineament group both down-to-the-north and apparent down-to-the-south sense of displacement is expressed. The case for lateral displacement is unlikely because of the absence of deflected drainages and other features related to lateral deformation (shutter ridges, sag ponds, etc.) along the projection of the lineament trend. Based on the field observations, notably the irregular characteristics of the lineaments along strike, lack of western continuity into the Cretaceous Kahiltna flysch units, and absence of expression in Quaternary units along the feature, the likelihood of a tectonic origin for the lineaments in group 2 is judged to be low and they are not considered further.

Lineament Groups 3a & 3b: Observations and Evaluation

Lineament group 3a is an east-west trending group consisting of a series of linear to sub-linear aligned drainages, approximately 40 km (~25 miles) northwest of the proposed Susitna-Watana dam site (Figure A3a.1). Lineament group 3b, east of group 3a, consists of east-west trending lineaments manifested by a series of aligned, linear to sub-linear drainages, slope-breaks, and steep V-shaped notched canyons, approximately 27 km (~17 miles) north-northwest of the proposed dam site (Figure A3b.1).

These two groups were considered for evaluation in summer 2013 largely because they share a generally similar orientation/trajectory on the landscape and they are spatially proximal, thus introducing the possibility that groups 3a and 3b could represent a through-going (i.e. linked) structure of appreciable length. In fact, considered separately, group 3a and group 3b would have failed, or nearly failed, the lineament exclusionary criteria (Table 2-3). There are no previously mapped faults that coincide with either group 3a or group 3b lineament, however, each group is depicted (Clautice, 1990; Wilson, 2009) with bedrock faults crossing each lineament group at high angles (Figures A3a.1 and A3b.1). The northeast trending fault in group 3b was not observed. The faults bounding Triassic metamorphic rocks (Trnm) in group 3a did appear to bracket rock types based on somewhat different surface textures.

The trend of lineaments within group 3a across the topographic contours is linear, and does not follow a pattern expected from a dipping plane intersecting the ground surface. The lineaments are expressed in mapped undifferentiated Quaternary deposits (map unit Qs – likely post glacial age) as short linear gullies tributary to Crooked Creek along the eastern part of group 3a (Figure A3a.2), however no scarp-like feature was observed in the field during low-level aerial investigation. The lineaments also are expressed in Cretaceous Kahiltna flysch sequences (map unit KJf) as a raised ridge with an apparent color contrast on either side of the ridge (Photograph B, Figure A3a.2). However, this observation could not be extended laterally to the west; the adjacent, older, Triassic metamorphic rocks (map unit Trnm) show no expression of faulting. The 3a lineaments cross several different geologic units and landforms, and are largely discordant to the likely ice flow direction. The lineaments' morphology largely are v-shaped notches and slope breaks whose scale is variable along strike of the group. Near the Crooked Creek drainage, the lineaments have both small and moderate magnitude notches. Farther west, and into the Triassic rocks, the notches become relatively larger in magnitude. The magnitude of expression at the west end of group 3a is least of the entire group.

The lineaments mapped in Quaternary (post-glacial) deposits along group 3a do not show neotectonic expression or offset. While the group 3a lineaments are mapped across several different geologic units, there is no apparent offset of mapped bedrock contacts along the trend of the lineaments. Most of the lineaments are interpreted to be either erosional in origin or related to slope processes due to their expression as short linear gulleys or presence on slopes where solifluction or nivation processes are dominant. The exception to this is the ridge in the Cretaceous Kahiltna flysch in which field observations found a color contrast (Figure A3a.2) that may be structurally-controlled, or may just as equally be stratigraphically controlled.

The lineaments within group 3b are nearly entirely within Eocene granitics (map unit Tegr, Figure A3b.1). The lineaments within group 3b are mapped along the invert of v-shaped notches, and thus the trend of the lineaments across topographic contours is nearly orthogonal. No Quaternary deposits are mapped, but ground-based observations indicate that there are youthful (Holocene) deposits in cirques and drainage valleys, as well as rock glacier deposits (Figure A3b.2). Although these are very young deposits, there are no expression of lineaments in these deposits. The lineaments are somewhat oriented parallel to ice flow direction along the eastern part of the group, but are positioned mostly in cirques and near ridgelines. Rock glaciers are present along the western part of group 3b, and interrupt the mapped lineaments without offset or deformation (Photograph D, Figure A3b.2). The morphology of the lineament is inconsistent along strike, showing north-facing slope breaks, south-facing slope breaks, as well as v-shaped notches.

The lineaments show an absence of evidence of expression in the Quaternary drainages, and in particular, the toes of rock glaciers where they interrupt the mapped lineaments. While the rock glaciers are likely no older than post-glacial, they may also be as young as early Holocene. Given the relatively large expression of the north-facing slope break along the eastern part of group 3b, it is reasonable to expect some signature in the Quaternary deposits despite their potential youthfulness.

Overall, lineaments within groups 3a and 3b are not associated with previously mapped faults, are predominantly erosional in origin, and show no evidence of offsetting Quaternary deposits. When considered individually, there is little evidence to support the lineaments as a fault structure. When considered collectively, there is little similarity in their landscape expression across the two groups to support positive interpretation of a linked, through-going crustal structure. Lineament groups 3a and 3b are interpreted to not represent an active crustal structure and no further work is deemed necessary.

Lineament Group 4: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) and strip maps for this group are not included herein (Figure A0). However, a limited number of low-altitude fly-overs in 2013 appear to confirm the desktop conclusion that the group 4 features are pre-Quaternary. Rock-type contrasts were observed across the previously mapped NE-trending thrust fault but no prominent tectonic geomorphology to suggest Quaternary activity was observed along strike in post-glacial surficial deposits nor in the bedrock.

Lineament Group 5: Observations and Evaluation

Lineament group 5 is an east-northeast trending lineament group defined by aligned V-shaped troughs, side-hill benches, and slope breaks, approximately 40 km (~25 miles) west-northwest of the proposed Susitna-Watana dam site, near Chulitna Pass (Figures A5-1.1 and A5-1.2). The eastern extent of the lineament group coincides with a previously mapped, unnamed lineament feature (Wilson et al., 2009), however lineament group 5 does not coincide with any previously mapped faults (FCL, 2013). Low altitude aerial observation found no evidence for the presence of a fault structure along group 5. Along its eastern extent, the trend of individual lineament groups is generally parallel to ice-flow direction expressed as fluted and grooved topography in a general east-west orientation. The trend of the lineaments across the topography is near straight, implying a vertical to steep geometry of a hypothetical structure. The lineaments primarily are expressed in Cretaceous turbidite rocks of the Kahiltna flysch sequence (map unit KJs) and, to a lesser extent, Tertiary granitics and Quaternary (probable late Wisconsin) glacial sediments. While the lineaments traverse different age rocks and sediments, the lineaments mapped in Quaternary sediments are restricted to likely floodplain or terrace deposits of the Indian River that could be as young as Holocene and coincide with terrace risers (Figure A5-2.2). The magnitude of the lineaments expression along strike is variable, with greater expression in the older bedrock units and substantively less expressed within the Quaternary units. The lineaments within the Quaternary deposits are relatively concordant with the ice-flow direction as expressed in the ice-scoured surfaces. There is no evidence that the ice-scoured surfaces are cross-cut or otherwise offset by the lineaments. Along the eastern extent of the group, the lineaments' morphologic expression as side-hill benches would imply an extensional-type kinematics (i.e., down-to-the-south); along the western extent the morphologic expression varies as both uphill and downhill facing scarps, linear grooves, and drainages that would imply a translational-type kinematics.

Low altitude aerial field observation revealed no evidence of lineament expression within the Quaternary deposits or surfaces. While the lineament group does traverse different geologic units and landforms suggesting a continuity of structure, the lineaments show an inconsistent kinematic expression along strike (i.e., extensional on the east, translational on the west) within the same rock unit (Cretaceous turbidites; map unit KJs) that tends to not support the presence of a tectonic structure for creating the lineaments. The lineament group is associated with a previously mapped lineament along the eastern extent, however, the lineament does not continue westerly past Indian Creek drainage. Given the above, it is likely that individual lineaments apparent origin is dominantly erosional. Along the western part of the group near Little Coal Creek, field observations indicated that a side-hill bench and linear drainage (Figure A5-2.2) likely are the result of bedded turbidite sediments dipping into the hillslope (Figure A5-1.1), with differential weathering accentuating the erosion features. The lineaments in the Quaternary sediments of Indian River valley appear to be the result of erosion along generally west-flowing creeks that are dissecting the geomorphic surfaces creating apparent scarps in the fluvial deposits. From the above, it is judged that the lineaments along group 5 are the result of bedding orientations in the Cretaceous turbidite units and elsewhere from fluvial or glacial erosion, and do not represent a tectonic fault.

Lineament Group 6: Observations and Evaluation

The northeast-trending linear drainage of Watana Creek is a prominent landscape feature; this and smaller lineaments along Watana Creek are grouped as Lineament 6 (Figure A6.1). The lineaments primarily define a northeast-trending, linear to sub-linear drainage, approximately 14 km (~9 miles) east of the proposed Susitna-Watana dam site. Traces of the Talkeetna fault previously-mapped (as concealed and/or inferred) pass within the ellipse defining group 6. In addition, Watana Creek was the target of focused project-specific geologic mapping and data collection by WCC (1980, 1982) and Acres (1981, 1982). However, the previous studies result in a fair degree of disagreement as to the (inferred) location and character of the Talkeetna fault in the area of lineament group 6. Importantly, the published map traces (as concealed and/or inferred) are placed along the western upland margin of Watana Creek, and are not shown as crossing or intersecting Watana Creek (Figure A6.1). During multiple low altitude overflights, field evidence of a fault structure was not observed along or in the immediate vicinity of lineament group 6, and no evidence was observed along the projection of the fault trace across Delusion Creek. A shear zone is mapped near the mouth of Watana Creek (Orange line in Acres mapping shown in Figure A6.1), and may coincide with an observed juxtaposition of Triassic basalt and inferred Tertiary sediment (Photograph A in Figure A6.2). However, the trend and extent of the shear zone do not seem to correspond to other map traces of the Talkeetna fault. Because the lineaments are chiefly mapped along Watana Creek itself, as well as linear drainages tributary to the creek, the trend of the lineaments as mapped reveals little about hypothetical fault structure geometries. The lineaments are expressed as linear drainages or erosional gullies oriented sub-orthogonal to the Talkeetna fault trace(s), and principally are developed in late Quaternary glacial drift (till) and glacio-lacustrine (lake) deposits. Lineament group 6 occurs at a high angle to regional ice-flow direction, suggesting that Quaternary glacial processes had little influence on the formation of the feature. The lineaments themselves are thus attributed to surface erosion and drainage development on the Quaternary upland surface, with one exception. A linear feature of about 700 m length (~2,300 ft) with distinctly positive relief was observed and mapped as a lineament segment near where Watana Creek turns easterly into the uplands. This feature, parallel and nearby to the inferred locations of the Talkeetna fault, was inspected from the air and on the ground, and a shallow test pit was opened to examine the stratigraphy to better understand the origin of the feature (Figures A6.1 and A6.4). The shallow subsurface texture generally was sand with gravel, grading upward into silt, and was interpreted as an esker landform. Tephra deposits (wind-laid volcanic ash) were observed near the top of the pit, and three different tephras could be present. Discussions with project archaeologists and review of published literature indicate that the tephras likely represent the Mt. Hayes, Watana, and possibly the Oshetna tephra deposits (Dixon, 1990). It is interpreted that the esker is at least a few to several thousand years old based on the presence of the tephras, but an upper age limit is undetermined at present.

There is an appreciable lack of mapped lineaments coincident with the (concealed and/or inferred) locations and orientations of published Talkeetna fault traces, even within LiDAR imagery area. The LiDAR-derived DEM data reveal an absence of scarp-like features along the map traces in Quaternary surfaces (Figure A6.1) that was confirmed during field investigation (Figure A6.2 and A6.3). The INSAR-derived DEM data also reveal an absence of lineaments in the post-glacial valley bottom sediments to the northeast of GPS waypoints 017 and 183. Field observations of Quaternary stratigraphic outcrops along Watana Creek suggest that the contact between the overlying lake and underlying till deposits is planar, unbroken, and apparently untilted (Figure A6.2). A prominent ridge consisting of bedded Tertiary sediments (map unit Tsu) appear as gently northwest-dipping (A6.3).

This is generally consistent with structural data collected in Oligocene (Tertiary) outcrops along Watana Creek by WCC (1982) that was used as a basis to argue for northeast-southwest compression and related flexural deformation of the Tertiary units. Though gently northwest-dipping, the stratigraphy of the ridge appears undisrupted along its length and provides additional evidence that the Talkeetna fault likely does not run down the Watana Creek canyon. This style of deformation is inconsistent with reverse thrusting along this part of the Talkeenta fault while regional stress field data allows for the potential reactivation of this lineament as a northeast-oriented thrust fault. The lineaments mapped within group 6 are judged to be the result of erosion of tributary drainages and fluvial erosion to create terrace risers along the creeks and are not likely tectonically-related. Further, there is an absence of tectonic geomorphology along the inferred locations of the Talkeetna fault in Quaternary deposits and surfaces present along the uplands adjacent to Watana Creek. However, additional LiDAR data is being collected to provide complete coverage for the area of lineament group 6 and the concealed and/or inferred locations of the mapped Talkeetna thrust fault. Additional future work for lineament group 6 should include review of these new high-resolution data to confirm that the current interpretations are still supported.

Lineament Group 7: Observations and Evaluation

Lineament group 7 is a northeast-oriented lineament group defined by an aligned series of linear to sub-linear drainages, faceted ridges, and saddles (Figure A7.1), approximately 28 km (~17 miles) east of the proposed Susitna-Watana dam site (Figure A0.1). Mapped bedrock fault structures are depicted within the lineament group by some, but not all existing maps (FCL, 2013). For example, mapping by Kline et al. (1990) shows a shear zone within lineament group 7. One of the bedrock faults juxtaposing Triassic (Nikolai) greenstone (map unit Trn) against Paleozoic volcanic rocks (map unit Pv) was indirectly observed as a color and vegetation change coincident with a topographic notch in the ridgeline (Photograph A, Figure A7.2). These are the oldest rocks within which the lineaments occur. The youngest deposits that the lineaments are mapped in are latest Pleistocene (late Wisconsin?); the lineaments transect young valley floor glacial sediments as well as elevated bedrock ridgelines. The topographic expression of the individual lineaments implies a high angle to near vertical orientation for a fault because they cut steeply across topographic contours. Along the northern part of the group, the lineaments are not mapped nor are expressed in the glacial valleys; along the southern part of the group the lineaments are oriented along the drainage direction toward the Susitna River. Aerial investigation revealed no field evidence that linear strain markers were deformed or displaced, however the glacial sediments are from rock glacier processes, and few older landforms such as moraines, eskers, or terraces were observed along this group. The expression of the lineament is inconsistent along strike with an apparent stronger expression where mapped along fluvial drainages, and no expression in WNW-oriented cirque-floors or valleys. An additional lineament feature less than 2 km [~1 mile] away from the group 7 also was inspected, although this was not formally included as part of group 7. This feature trends slightly west of north, and is expressed as a large notch near rock glacier deposits. Low altitude fly-overs allowed a visual inspection of the notch that was estimated to be about 15 meters tall (~50 ft). No corresponding notch or groove was observed in the ridgeline on projection to the north, thus the groove was probably created by non-tectonic surface processes.

Lineament group 7 does not show consistent field expression in Quaternary deposits or landforms. The largest magnitude relief along the lineament is along the south-flowing drainages, and relief is not expressed topographically across the WNW trending cirque valley floors. Because the lineament expression in Quaternary deposits is chiefly linear gullies (erosion) with no apparent difference in relief across the gulley, the expression does not suggest either normal or reverse-type faulting. A translational kinematic sense of motion cannot be ruled out; however there is little along-strike expression to assess the sense or magnitude of potential relative lateral motion. There are previously mapped faults along the mapped lineament (Wilson et al., 2009; Figure A7.1). However, there are large scale topographic changes (i.e. reverses) along the length of the fault (and lineament) that leads to an inconsistency in location, magnitude, and type of lineament expression. These inconsistencies, coupled with the fact that the Quaternary deposits in the valley floors are not disrupted, strongly indicates that erosional process of creek incision and downcutting into surface deposits along the south-flowing drainages are likely responsible for creating the mapped lineament feature. Where mapped in bedrock, lineaments of group 7 generally coincide with mapped bedrock structures within fault-line-valleys but lineaments in late Quaternary deposits are inconsistently expressed and likely relate to processes of erosion. No evidence of Quaternary deformation along the mapped lineaments was observed and no further work is deemed necessary.

Lineament Group 8: Observations and Evaluation

The lineaments of group 8 are north-northwest-oriented features expressed topographically as aligned V- and U-shaped, linear to sub-linear drainages, aligned with several discontinuous slope breaks and linear fronts (Figures A8-1.1 and A8-2.2), approximately 38 km (~24 miles) west of the proposed dam site (Figure A0.1). The lineament group coincides with a north-trending promontory around which the Susitna River makes a prominent bend in course (Figure A8-1.1). The middle portion of lineament group coincides with an unnamed, inferred fault mapped by Wilson et al. (2009) that juxtaposes Tertiary undivided volcanic rocks (map unit Tvu) against Paleocene granite (map unit Tpgr) and also granodiorite (map unit Tgd) against turbidites of the Kahiltna flysch (unit KJs) (Figure A8-2.1). WCC lineament feature KD5-44 also coincides with lineament group 8 (FCL, 2013). WCC described their feature KD5-44 as a linear stream valley north of the Susitna River, and south of the Susitna River as a linear valley (Cheechako Creek and a tributary creek) and "a shallow, broad, linear depression on the upland plateau…" (WCC, 1982). No direct evidence of fault exposures were observed during ground and low level aerial investigation but indirect evidence in the form of changes in lithology across the linear valley was observed near the middle of the lineament group (Photograph C, Figure A8-2.2). The linear trend of the lineament group across the terrain suggests any potential fault that may exist has a very steep to near-vertical dip. The lineaments are expressed in ice-scoured bedrock uplands and a thin cover of glacial and colluvial deposits subject to solifluction. The bedrock ranges in age from Cretaceous-Jurassic flysch (map unit KJf) to Tertiary volcanics (map unit Tvu). The glacial deposits are likely latest Pleistocene to early Holocene (~11 to 12 ka) in age while the colluvium is latest Holocene to modern in age. The mapped lineaments transect across several different bedrock units (Figure A8-1.1 and A8-2.1). The magnitude of expression ranges from none in broad, flat-lying terrain, to 1- to 2-m-high (3- to 6-ft) scarps in solifluction-prone colluvial slopes, to deeply incised linear streams and 50- to 100-m-high (~164 to ~328 ft) linear fronts (Figures A8-2.2 and A8-2.3). The lineament group lies roughly perpendicular to the direction of glacial striae. Glacial striae north of the Susitna River do not appear consistently deformed or displaced across the trend of the lineament and, although the Susitna River does take a tight bend-in-course along the projection of some of the mapped lineaments, several small streams that cross the lineaments near GPS waypoints 177 and 195 are not consistently laterally offset or deflected (Figure A8-2.1). Aerial investigation did reveal the oxidized mafic dike on the northern canyon wall of the Susitna River that WCC (1982) observed projecting across the observed lineament trend but discovered the same ambiguous and poor exposure conditions described by WCC. The 2013 aerial investigation efforts discovered no new evidence to confirm or refute WCC's (1982) interpretation that the dike is not truncated by the linear drainage (FigureA8-2.3); ground access may be required. Based on the preponderance of east-facing bedrock escarpments, the morphology of the lineament group overall suggests down-to-the-east or dip-slip motion on high-angle faults, but a few west-facing escarpments do exist. In addition, mapped fault relations that juxtapose units (Wilson et al., 2009) along the middle of the lineament group are not entirely consistent with the contact of turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) and Paleocene granite (map unit Tpgr) being apparently undeformed across the northern portion of the lineament (Figure A8.1).

Portions of lineament group 8 are expressed in very thin Quaternary (i.e., latest Holocene) colluvial and glacial deposits that overlie bedrock, but the lineaments are not consistently expressed in Quaternary strain markers (i.e., stream channels). In two locations, on the north side of Susitna River and along its southern extent, individual lineaments of the group appear to be overprinted by glacial or flood-derived striae (Figure A8-1.1 and A8-2.1). The orthogonal orientation of the lineaments to the regional ice-flow direction suggests that most of the lineament features likely do not result from ice scour or abrasion. However, other ice-related processes such as plucking might explain some of the short lineaments north of the Susitna River where the small east-facing (and up-ice stream-facing) knobs of turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) might have been preferentially erodible due to the highly bedded nature of the unit. Lineament group 8 does transect different mapped geologic units but does not exhibit relative consistency of geomorphic expression along strike. For example, in the middle of the group, both east- and west-facing topographic scarps in undivided Tertiary volcanics (map unit Tvu) range up to 50 to 200 m high (~164 to 656 ft) but apparent scarps in thin colluvium overlying Tertiary granodiorite (unit Tgd) near GPS waypoints 177 and 195 are less than several meters high (Figure A8-

2.2 and A8-2.3). Furthermore, the lack of spatially-connected and through-going lineaments across the ice-striated terrain north of the Susitna River is inconsistent with the magnitude of expression the deeply-incised linear streams and tall linear fronts to the south. In addition, the apparent structural kinematics (dip-slip) based on mapped contact relations compiled by Wilson et al. (2009) for the middle and southern portion of the group are not consistent with the undeformed contact relations between turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) and Paleocene granite (map unit Tpgr) near the Susitna River and also the lack of deformation in turbidite rocks (map unit KJs) north of the river. Lineament group 8 is spatially coincident with previously mapped lineaments (feature KD5-44 of WCC (1982)) and faults (Wilson et al., 2009) but making kinematic sense of the mapped fault and unit contact relations is challenging. No positive evidence of active tectonism was observed and the discrepancy in magnitude in the apparent tectonic geomorphology along the group is inconsistent with a genesis by active faulting; a fault capable of producing topographic displacement on the order of 50 or more meters (~164 ft) should leave a more consistent, through-going pattern of deformation on the landscape. Overall, the evidence supports the presence of a fault-line-scarp (an erosional feature aligned with a mapped fault) along the middle and southern portions of group 8 where glacial erosion may have preferentially eroded along pre-existing faults or lithologic contacts.

Lineament Group 9: Observations and Evaluation

Lineament group 9 consists of north-northwest oriented features expressed principally as a prominent V-shaped linear drainage greater than 5 km (~3 miles) in length, along with smaller, sub-linear aligned drainages, aligned knobs, and short east-facing slope breaks (Figures A9-1.1 and A9-2.1 through A9-2.4) approximately 31 km (~19 miles) west of the proposed dam site (Figure A0.1). The southern portion of the lineament group coincides to an inferred fault mapped by Wilson et al. (2009) that lies within the prominent linear V-shaped drainage and juxtaposes Paleocene granitics (map unit Tpgr) against turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) (Figure A9-2.1). The lineament group also coincides with WCC fault KC5-5. WCC (1982) described the feature as a linear stream drainage north of the Susitna River and a prominent linear canyon and shallow linear depression south of the Susitna River that is fault-controlled in several locations. Indirect evidence of fault structure was observed along the prominent linear V-shaped drainage in the form of contrasting rock types (Figure A9-2.4). With the exception of the southern end, the strongly linear trend of most of the lineament group implies that any potential tectonic structure would have a steep to near-vertical dip. At the southern end of the lineament, the mapped lineaments that curve around a hill near WCC segment 4 (Figure A9-2.1) suggest that a fault in this area would have a moderate to shallowly west-dipping orientation. Individual lineaments are expressed in several Cretaceous to early Tertiary bedrock units exposed in the glaciated uplands: turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs), Paleocene granitics (map unit Tpgr), and at the contact between units those units where the inferred fault trace is mapped (Wilson et al., 2009). North of the Susitna River, lineaments are expressed as short, discontinuous, and weakly-aligned, bedrock knobs, and in the southernmost portion of the group as 1- to 4-m-high (~3- to ~13 ft), east-facing slope breaks in thin colluvium overlying bedrock. The mapped lineaments do transect mapped bedrock units, but are not expressed in the limited extent of Quaternary surficial deposits present along the group. No lineaments were observed in post-glacial (early Holocene) fluvial deposits within a broad depression (Figure A9-2.1) or across the extent of a post-glacial landslide located in WCC segment 3. The scale of expression of the lineaments is variable along trend. The 1- to 4-m-high (~3- to ~13 ft), east-facing slope breaks in the south contrast with the >300-m-deep (~985 ft) linear V-shaped canyon, and the absence of any lineaments in above-mentioned late Quaternary deposits. The orthogonal orientation of the lineament group to the regional ice-flow direction (Figures A9-1.1 and A9-2.1) suggests that the lineament group as whole likely does not result from ice-flow or scour, but individual knobs in the north could relate to plucking by flowing ice. No field evidence of consistently deformed linear strain markers was observed along the lineament group during low altitude aerial or ground investigation. A sharp bend in the Susitna River exists where the lineament group projects across the river (Figure A9-1.1) but south of the river lies an apparently undeformed contact between turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) and Paleocene granitics (map unit Tpgr), while the southern portion of the lineament group corresponds to an inferred fault mapped by Wilson et al. (2009) that juxtaposes those same rock types (Figure A9-2.1). Based on the mapped geologic contacts along the southern portion of the group, the apparent sense of offset is right-lateral with possible unknown oblique component. However, this is kinematically inconsistent with the mapping north of the Susitna River because the mapped contact between Cretaceous Kahiltna flysch (map unit KJs) and Paleocene granitics (map unit Tpgr) is apparently undeformed and undisplaced where the lineament group projects across the contact.

WCC's evaluation of their feature KC5-5 led them to recognize four segments of the feature (WCC, 1982) (Figures A9-1.1 and A9-2.1). Segment 1 is the linear drainage that lies north of the Susitna River. WCC acknowledged that the drainage may be fault-controlled but WCC did not observe any evidence that conclusively confirmed or precluded a fault origin (WCC, 1982). Low-level aerial investigation revealed that the drainage is only weakly linear and did not reveal any evidence to refute WCC's observations.

Segment 2 is the V-shaped linear drainage >5 km (~3 miles) in length directly south of the Susitna River. Here, WCC observed fault zones via helicopter aerial reconnaissance in three different locations running parallel to the overall lineament orientation. The fault zones are a few inches (few centimeters) to a few feet (few meters) in width, near vertical in orientation, light gray in color, and form sharp, distinct boundaries within intrusive rocks and locally separate intrusive from metamorphic rocks. No evidence to determine the sense of displacement was observed (WCC, 1982). These fault zones may be similar to the zones of light-colored, fractured, and highly weathered rock in Cheechako Creek along lineament group 8 observed by both WCC and FCL during aerial inspection. One or more of these fault zone location may lie within the view captured in photograph J of Figure A9-2.4.

Segment 3 is a broad and shallow curvilinear depression in the bedrock upland south of segment 2. Mapping completed by WCC revealed that a contact mapped by Csejtey et al. (1978) between Cretaceous argillite and greywacke metasediments on the west and Tertiary intrusive rocks on the east, which was previously thought to coincide with the depression, is too irregular to match the contact. Rather, WCC describes that the fault zone lies entirely within the Tertiary intrusive rocks (WCC, 1982). However, more recent compilations of mapping (i.e., Wilson et al., 2009) show this area as turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) (Figure A9-2), suggesting an apparent discrepancy in the understanding of the geologic units. Field investigation in July of 2013 confirmed the presence of granodiorite (presumably equivalent to Paleocene granitics; unit Tpgr) in a nearby drainage previously mapped as exposing turbidite rocks of the Cretaceous Kahiltna flysch (map unit KJs) (Figure A9-2.1 and A9-2.4), confirming the interpretation that contact relations from this ground inspection are more complicated than shown by Wilson et al. (2009).

Regardless of the bedrock lithologies present, WCC observed sediments in the broad depression which they interpreted to be approximately 40,000 to 75,000 years in age. Their aerial inspection revealed no evidence of deformation of the sediments and they interpreted that the observed fault zones had not experienced displacement within the last 40,000 years (WCC, 1982). Based on an updated view of the Quaternary glacial history of the region (Section 3.3), these sediments are likely much younger, as deglaciation of this area is possibly as young as 15,000 to 11,000 years. Our low-level aerial and ground inspection confirmed the absence of any apparent deformation or lineaments observed by WCC (1982) (Figure A9-2.4).

Segment 4 consists of an alignment of east-facing linear bedrock scarps, some of which coincide with the location of several springs (Figures A9-2.2 and A9-2.3). These topographic escarpments are readily apparent in the INSAR data along the southernmost portion of the lineament group (Figure A9-2.1) and are the most suspiciously fault-like geomorphic features in the group. WCC's field investigations suggested that the scarps could relate to differential erosion controlled by jointing but that the scarps are not controlled by lithologic contacts. WCC could not identify direct evidence of faulting along segment 4 of their Fault KC5-5 but did acknowledge the segment could be fault controlled (WCC, 1982). Ground access restrictions prevented thorough study of all the features but aerial inspection revealed the lineaments are generally 1- to 4-m-high, east-facing slope breaks that are each several hundred meters or more long (Figures A9-2.2 and A9-2.3). The features align in a subtle curve across the topography, suggesting that any fault here would have a moderate to shallowly west-dipping orientation. Detailed review of the geomorphology along the features revealed apparent morphological and kinematic inconsistencies; in adjacent drainages both left-lateral and right-lateral apparent sense of motion indicators were observed, which is further inconsistent with the apparent west-up/east-down thrust movement suggested by adjacent features along trend and the apparent the west-dipping orientation of the features as they cross topography.

After evaluating all four segments of their Fault KC5-5, WCC concluded that together the observed features represented a fault without recent displacement, noting "the absence of any compelling evidence of recent displacement (e.g., systematic stream drainage offsets, scarps in recent sediments, or offset of youthful geomorphic units)" (WCC, 1982; p. 4-44). Low altitude aerial and ground inspection in July of 2013 of the lineaments of group 9 revealed similar evidence and concluded that the features are likely a fault-line scarp. For example, no evidence of expression in Quaternary units, landforms, or strain markers was observed. Furthermore, although a rock-type contrast does exist across portions of the lineament, the current mapping compilation may be too simplified and more irregularity of bedrock unit contacts likely exists along the linear V-shaped drainage and mapped fault. Although the lineament group does coincide with a previously mapped fault and also cuts across several bedrock units, the magnitude of expression and apparent sense of deformation observed in the field is inconsistent along trend. Lineament group 9 is interpreted to represent a fault-line scarp and not a Quaternary tectonic feature.

Lineament Group 10: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) that the lineament group is over 70 km (~44 miles) from the proposed dam site and is less than 40 km (~25 miles) long (Table 5-2), and likely would not appreciably contribute to the hazard calculations. Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). During limited flyovers in 2013, no features were observed that suggested a need to revise those conclusions.

Lineament Group 11: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) suggesting that surficial processes are likely exploiting existing topographic position and/or local weaknesses in the underlying Cretaceous Khalinta flysch bedrock to create the lineaments. Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). Limited overflight of these features in 2013 appears to confirm this conclusion. In addition, the group is greater than 30 km (~19 miles) from the proposed site and is less than 20 km (~12 miles) in length (Table 5-2), and likely would not appreciably contribute to the hazard calculations.

Lineament Groups 12a & 12b: Observations and Evaluation

Lineament 12a traverses part of the southeastern-facing Paleozoic volcanic hills in the Fog Creek area, about 14 km (~9 miles) southeast of the proposed dam site (Figures A0.1 and A12a.1). Aerial and ground inspection of group 12a confirmed the presence several southeast-facing slope breaks near the lower flanks of the hillside of the northern part of the group (Figure A12a.2). There are no previously mapped faults within this group; however, field observations of color contrasts within the Paleozoic rocks (map unit Pzv) suggest the possible presence of northeast-oriented bedrock structures. No evidence of a fault was observed along the lineament group trend. A prominent notch with an uphill-facing slope break was observed within the Paleozoic rocks along the nose of a ridge (Photograph C, Figure A12a.2). The topographic expression of this lineament feature on the ridge topography implies a northwest-dipping structure geometry. Bedded rock exposed on the other side of the mountains within the northwest-facing cirque walls appear to have a generally northwest dip and a moderate (~45?) degree dip angle. The topographic expression of the lineaments about 1.2 km (~3/4 mile) to the north of the notch may allow an inferred northwest-dipping geometry but with a much shallower dip plane as compared to the notch feature; suggesting a substantive change in dip should the lineaments represent a structural fault. The individual lineaments mapped along the north part of the group chiefly are within probable latest Wisconsin-age glacial deposits near the valley margin, and are oriented along the ice flow direction. To the southwest, the lineaments rise in elevation and are mapped in the Paleozoic rocks (map unit Pzv) above the contact with glacial sediments (map unit Qs). There are no lineaments expressed in the Quaternary deposits along about the southern half of group 12a, and there is visual evidence that right-lateral moraine and kame terrace features at the southern end of the group are not offset. The relief of the lineaments along strike is variable, and generally is greater in magnitude within the bedrock than the unconsolidated deposits. However, the morphology of the features is kinematically inconsistent along strike, with south-east facing downhill slope breaks found on the lineaments in the Quaternary deposits, and an uphill facing slope break on the bedrock notch feature.

Although the individual lineaments of group 12a are mapped within late Quaternary deposits along the valley margin, there is no expression of deformation or offset of late Wisconsin landforms in kames or delta surfaces within the valley of Fog Creek directly north. Similarly, there is no expression of deformation or offset of late Wisconsin landforms in lateral moraines or delta surfaces within the Clear Valley directly south of group 12a. The individual lineaments appear to traverse both Paleozoic rocks as well as late Quaternary deposits, however, as noted above there is an inconsistent morphologic expression of those features along strike, as well as inconsistent relative structural kinematics (apparent dip, scarp direction) along the lineaments. The slope breaks within the Quaternary sediments along the northern part of the group appear to be a result of solifluction and to a lesser extent, nivation processes, and thus are dominantly erosional in origin. The observation of multiple slope breaks on the hillslope in the vicinity of the mapped lineaments, as well as the general lineament orientation being parallel to ice flow directions, suggests the lineament group was not produced by tectonic processes, rather glacial deposits that are now undergoing solifluction and nivation processes. From these observations and interpretations, it is judged that the lineaments within group 12a are the result of both past glacial processes, ongoing hillslope erosion processes, and potentially bedding relationships within the Paleozoic rocks, and do not represent a tectonic fault.

Lineament group 12b is approximately 16 km (~10 miles) southeast of the proposed Susitna-Watana dam site, and is about 2 km (~1.5 miles) northwest of lineament group 12a and directly west of Mount Watana. Lineaments within group 12b are coincident with an unnamed, kinematically-undefined fault (Clautice, 1990) within the Paleozoic Slana Spur volcanic rocks (map unit Pzv) (Figure A12b.1), however no direct or indirect field evidence of the fault was found from low-altitude inspection; the morphologic expression of the feature is incised drainages and a very broad and deep valley within which a small creek now flows (Photograph C, Figure A12b.2). The trend of the lineament group across topography is essentially linear, implying a vertical geometry that cuts directly across contours. The lineaments are expressed chiefly in Paleozoic rocks, however, a thin cover of Holocene regolith mantles the rocks, consisting of unmapped talus, solifluction of glacial material, colluvium, and alluvium, in which the lineaments also are mapped. The lineaments show no field evidence of offsetting or deforming those sediments. The scale of expression of the lineaments varies along strike: it is rather large at the middle and northern end of the lineament group where it is coincident with an unnamed northeast-flowing drainage; the expression decreases along the southern end of the lineament group. The middle and northern part of the lineament group is oriented parallel to a glacial ice flow from cirques toward the Susitna River. The southern part of the lineament group is less certainly assessed with respect to ice flow because of its topographic position on the landscape. None of the glacial geomorphic surfaces in Fog Creek valley (e.g. eskers, deltas) along the southwestern projection of the lineaments were observed to be offset or deformed, and no evidence of deformation was observed at the Susitna River margin along the northeastern projection. Along the south-center part of the lineament group, a northwest-facing break in slope morphology may suggest reverse-type movement (i.e. northwest vergence), however, the ends of the group do not exhibit any strong kinematic indicators.

The lineaments within group 12b did not show field evidence of expression in Quaternary deposits or landforms serving as strain markers, notably along the southwestern projection of the group into Fog Creek valley with late Wisconsin landforms. The lineament is chiefly constrained to within the Paleozoic volcanics (map unit Pzv), and is coincident with the previously mapped fault of Clautice (1990), suggesting a potential structural control and preferential erosion along the pre-existing structure. Alternatively, internal lithologic control on the geomorphic expression of the lineament (e.g. bedding) is plausible given the lack of lineament continuity beyond the Paleozoic rocks. The lineament group appears to have a variable geomorphic expression along strike, has weak kinematic indicators along strike, and has its largest surface expression in drainages flowing away from the area of kinematic indicators. In total, the field observations and data evaluation suggest that glacial and post-glacial fluvial erosional processes are a likely explanation for the origin of the lineament features. Individual lineaments may represent fault-line scarps or fault-line-valleys but due to the lack of expression in Quaternary deposits, the lineament group is not considered a Quaternary tectonic structure and no further work is deemed necessary.

Lineament Group 13: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). FCL (2013) interpreted that lineament group 13 was the result of erosion, but also discussed that the lineament group lies greater than 40 km (~25 miles) distant from the proposed dam site and is less than 20 km (~12 miles) in aggregate length (Table 5-2) and would therefore likely have limited contribution to the hazard calculations. During limited flyovers, no features were observed that suggested a need to revise those conclusions.

Lineament Group 14: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). The group is greater than 30 km (~19 miles) from the site and less than 20 km (~12 miles) in aggregate length, (Table 5-2) thus meeting lineament exclusion criteria. A limited fly-over in 2013 revealed no features that that suggested a need for additional analysis.

Lineament Group 15: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). FCL (2013) excluded the group from further analysis on the basis of its large distance from the proposed damsite (~43 km [~27 miles]) and short aggregate length (~6 km [~4 miles]) (Table 5-2). A limited fly-over in 2013 revealed no features that that suggested a need for additional analysis.

Lineament Group 16: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). This group is sub-orthogonal to the map trace of the Talkeetna fault (Csejtey, 1978; Wilson et al., 2009), directly north of the WCC trench T-2 site (Figures 2-1 and 5-3). The group was excluded from further analysis on basis on its significant distance to the proposed damsite (~60 km [~37 miles]) and relatively short aggregate length (~19 km [~12 miles]) (Table 5-2). During limited flyovers, no features were observed that suggested a need for additional analysis.

Groups 17a, 17b, & 17c: Observations and Evaluation

Lineament group 17a is a north-northwest trending lineament, approximately 24 km (~15 miles) west of the proposed Susitna-Watana dam site (Figure A0.1). Lineament group 17b is a north-northwest trending lineament group, approximately 36 km (~22 miles) southwest of the proposed Susitna-Watana dam site. Lineament group 17c is approximately 45 km (~28 miles) south-southwest of the proposed

Susitna-Watana dam site, and is the southernmost extent of lineament the 17a, 17b, and 17c series (Figures A0.1 1). Lineament group 17a is not coincident with previously mapped faults, however, the southerly extent of 17b and parts of 17c are (Figure A17b.1 and A17c.1). Wilson (2009) depicts a lineament coincident with 17a and another coincident with 17b. Although aerial field inspection did not find evidence to directly confirm the presence of a fault within group 17b and 17c, contrasting rock types and units were observed in the field in general consistency with previous geologic mapping, allowing the possibility of a bedrock fault structure along these groups.

Lineaments within group 17a are mapped along a northerly segment of the Susitna River, a north-trending canyon tributary, and in the Quaternary deposits south of the canyon (Figure A17a.1). No evidence of a fault was observed at the northern end of the lineament group along the south-facing wall of the Susitna River, nor along strike to the north. Low altitude aerial field inspection revealed that the lineaments in Quaternary deposits at the south end of group 17a do not show scarp-like morphologies; rather one is a discordant, small, creek drainage and the other appears to be a depositional contact of likely late Holocene grassy swale (bog) sediments against a near-surface ice-sculpted bedrock buttress (Figure A17a.2). Lineament group 17a is somewhat off-trend of lineament groups 8 and 9, and also appears to follow a bedrock jointing pattern that is expressed on the landscape. Based on the absence of compelling evidence for Quaternary tectonism, lineament group 17a is judged to not represent a tectonic fault.

As noted above, lineaments within the group 17b are somewhat coincident with previously published inferred faults and lineaments. Aerial field inspection indicated that the morphologic break in slope along the FCL-mapped lineaments at the base of the uplands near the western margin of the valley is not as sharp and abrupt in the field as implied on the INSAR-derived DEM. The most prominent morphologic feature is actually a narrow drainage that is fed by a perched lake; review of USGS topographic maps confirmed this linear feature as a creek. The trend of the lineaments across topographic contours is straight, but also parallel to contour because it is in the valley bottom; this would imply either a vertical or horizontal hypothetical fault dip geometry. The lineaments are chiefly mapped in thin glacial-derived sediments that primarily reflect erosion by small creek drainage, and are probably Holocene age. Near the south end of group 17b, the lineaments are mapped as extending out of the glacial deposits and traversing Tertiary volcanics (map unit Tvu) and Paleozoic volcaniclastic rocks of the Slana Spur formation (map unit Pzv) (Figure A17b.2) directly north of the Talkeetna River. Field investigation found no direct evidence of a fault along this trend. The lineaments appear to coincide with the trend of glacial ice flow directions that were valley parallel. The southeasterly oriented inferred fault of Csejtey (1974) also was not confirmed in the field; this area appears to be sculpted bedrock knolls that have been slightly dissected and mantled by a thin veneer of youthful glacial deposits (Figure A17b.2). South of the Talkeetna River, the southern part of group 17b coincides with a short inferred fault of Wilson (2009). Low altitude fly-overs of this area discovered a positive relief “mole track-like” features present on the ground along the FCL-mapped lineament. Ground inspection resulted in the conclusion that the feature in fact is a pro-talus rampart; a geomorphic feature constructed by talus collecting in a snow covered field that results in talus deposition a short distance away from the base of the slope (Figure A17b.3). The ground inspection supports the interpretation that glacial ice was present in the valley by the observation of an out-of-place glacial erratic. Although there may be a bedrock structure along part of this group that separates Paleozoic (map unit Pzv) and Mesozoic rocks (map unit Tvu), lineament group 17b is judged to be created at the local scale by fluvial erosion as well as in part by glacial ice erosion of the linear valley and periglacial processes.

Along part of its northern and southern ends, lineament group 17c is partially coincident with faults previously mapped by Wilson (2009), although none are recognized by Csejtey (1974) and Clautice (1990). None of the faults depicted on Wilson (2009) are shown extending across or displacing Quaternary glacial or moraine deposits. No evidence was found during low altitude aerial field investigation to confirm the northern (dashed and inferred) previously mapped fault in group 17c. Near the southern end of 17c, the depicted rock juxtaposition between units Tertiary volcanic rocks (map unit Tvu) and Eocene mafic volcanic rocks (map unit Tem) (i.e. bedrock fault) was not lithologically well expressed in the field with apparently similar bedded volcanic rocks exposed on either side of the canyon walls (Figure A17c.1), and the presence of the previously mapped fault is unconfirmed. The lineament trends across topography irrespective of contours in steep terrain, suggesting a near vertical geometry for a hypothetical structure. The lineaments are mapped across Tertiary volcanic rocks as well as in young (likely Holocene) rock glacier deposits; the expression within the rock glacier deposits correspond to relatively deep drainages eroded into the rock glacier deposits (Figure A17c.2). The scale of the lineaments’ expression along strike varies; along the north end of group 17c cirque ridges that are traversed by previously mapped structure are not offset and little relief is expressed topographically. Along the middle of the group the lineaments are expressed as ridgeline saddles with adjacent ridge peaks standing about 75 meters (~246 ft) above the saddle whereas on the INSAR DEM the lineaments are attributed as linear v-shaped troughs. Along the south end of lineament group 17c, the relief along the lineament in the Quaternary rock glaciers is lesser than the middle part of the group, however, the relief in the rock glacier drainage is about 25 meters (~82 ft); much larger than would be expected for a relatively low-slip rate fault structure in young post-glacial deposits. While the presence of a bedrock fault cannot be ruled out along lineament group 17c, it is judged that the mapped lineament is the result of erosion into the rock glacier deposit.

Lineament groups 17a, 17b, and 17c are each independently judged as formed by erosional processes (fluvial and/or glacial) as described above, based on field observations and interpretations. Collectively, these groups do not form a continuous geologic structure based on an absence of faults observed (directly or indirectly) in the field, and the inconsistent and variable geomorphic expression of the lineaments in the landscape along 17a, 17b, and 17c as a whole.

Lineament Group 18: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) which concluded that the group's large distance to the proposed damsite and short overall length (Table 5-2) would likely not appreciably contribute to the hazard calculations. Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013).

Lineament Group 19: Observations and Evaluation

Lineament group 19 is a semi-arcuate, northeast-trending group of linear features that is nearly 44 km (~27 miles) long, located approximately 54 km (~34 miles) southeast of the proposed Susitna-Watana dam site (Figure A0.1). This feature is defined by a series of aligned, gently-sloping linear range-fronts, slope breaks, linear valleys, and a few aligned saddles (Figures A19-1.1, A19-2.1, and A19-3.1).

Existing geologic mapping (Wilson et al., 2009; Csejtey et al., 1978) suggests that this lineament group may represent a bedrock contact zone between various Jurassic age bedrock units (mostly Trondhjemite [map unit Jtr] vs. a migmatite border zone of granodiorite [map unit Jpmu]). An inferred fault mapped by Clautice (1990) lies east of the aligned features along a parallel orientation and nearly converges with the lineament group near the northern projection of the lineament (Figures A19-1.1, A19-2.1, and A19-3.1). Indirect evidence of a fault structure was observed in the southwestern portion of the lineament where apparent rock type contrasts were observed via aerial inspection across an alignment of linear drainages (Figures A19-1.2 and A19-1.3). The trend of this rock type contrast/rock contact across the topography is very linear, suggesting that any tectonic feature present would have a near-vertical to steeply-dipping orientation. The features making up lineament group 19 are expressed in bedrock valleys, bedrock plateaus, valley-margin glacial deposits, and colluvial deposits. The ages of deposits in which lineament features are expressed ranges from the Jurassic age bedrock exposed in the linear valleys shown in Figures A19-1.2 and A19-1.3 to thin colluvial deposits of latest Holocene age. Low-level aerial inspection revealed that the lineaments of group 19 do transect several different geologic units and landforms, but are not present in the post-glacial (Holocene) alluvium of the Goose Creek or adjacent drainages (Figure A19-2.1). The magnitude of expression of the lineaments ranges from ~10-m-high (~33 ft) downhill-facing slope breaks in glacial deposits of the Black River to gently sloping ~125-m-high (~410 ft) (Photograph A, Figure A19-2.2; Photograph A, Figure A19-3.2) bedrock escarpments. The lineament group is roughly parallel to glacial ice flow directions in the Black River canyon and spatially coincident with left-lateral ice margins as mapped by Williams and Galloway (1986) (Figures A19-1.1, A19-2.1, and A19-3.1). Field inspection did not reveal any displaced or deformed linear strain markers along the lineament. The morphology of the lineament and its expression in the landscape suggests that, if it were a tectonic fault, it would be a strike-slip fault.

Low altitude aerial observations showed variable evidence of lineament expression within the Quaternary deposits along lineament group 19. Lineaments are expressed in the glacial deposits of the Black River, but not in Holocene age rock glacier and glacial moraine deposits at the head of Kosina Creek (Photographs E and F, Figure A19-1.3), nor in the Holocene-age deposits of the Goose Creek adjacent drainages (Figure A19-2.1). (The lineaments in the glacial deposits of the Black River valley occur parallel to the ice-flow direction and their geomorphic position high on the left side of the valley suggests that the lineaments are most likely left lateral moraine or kame terraces.) The large magnitude of relief across the lineaments in the northeastern portion is inconsistent with the apparent lack of topographic offset across the lineaments in the southwest portion of the group. Specifically, the surfaces of the exceptionally planar bedrock plateau across which the aligned linear valleys run (Figure A19-1.1) show no evidence of the vertical displacement apparent along the lineament group to the northeast. This inconsistency in relief does not support the existence of a tectonic structure along lineament group 19. Bedrock exposures observed during ground inspection in creeks along the lineament showed evidence of pervasive jointing (Photograph C, Figure A19-3.2) which is the likely genesis of the linear troughs and swales at the northeast-most portion of the group (Photograph D). Lateral ice margins mapped by Williams and Galloway (1986) coincide with many of the mapped lineaments (Figures A19-2.1 and A19-3.1), providing a non-tectonic origin alternative. In addition, a series of sub-ice fluvial channels located just north of Goose Creek (Photograph B, Figure A19-3.1) cross the lineament and do not appear to be displaced. For these reasons, lineament group 19 is not interpreted to be the result of Quaternary tectonic faulting; a fault or bedrock contact may exist in the southwest portion of the group, but there is no direct evidence of Quaternary tectonic activity anywhere within the group. It is judged that lineament group 19 is a result of a combination of bedrock jointing and glacial and post-glacial erosion processes, and does not represent at Quaternary fault.

Lineament Group 20: Observations and Evaluation

Lineament group 20 is a northeast-trending lineament group defined by a series of sub-linear, aligned drainages, saddles, broad U-shaped troughs, and V-notched linear canyons expressed in an area of gently rolling hills and terrain of relatively modest-relief (Figures A20.1, A20.2, A20.3, and A20.4), approximately 94 km (~58 miles) southeast of the proposed Susitna-Watana dam site (Figure A0.1). Some of the lineaments in this group coincide with mapped, unnamed faults with apparent vertical throw (Grantz, 1960) that lie along the northeastern projection of the Castle Mountain fault (Figure A0.1, Plate A-CME). Early mapping by Grantz (1960) shows stratigraphic offsets within Tertiary (Eocene) units as well as between Tertiary (Eocene), Cretaceous, and Jurassic age rocks. However, more modern compilations (Wilson et al., 1998) show the same faults juxtaposing Jurassic-age sedimentary rocks against one another as well as Jurassic sedimentary rock units against Tertiary sedimentary units, suggesting a revised understanding of the geologic units with further study. No direct evidence of any of the mapped faults was apparent in the field during aerial or ground inspection but indirect evidence in the form of apparent rock type contrasts across mapped faults was observed near GPS way point 018 and locations to the southwest of GPS way point 018 (Figure A20.1). The trend of the lineaments across topography is very linear, suggesting any potential fault structures would be steeply dipping. Grantz's (1960) map unit Jns (Jurassic sandstone) is the oldest unit in which the linear drainages and aligned saddles occur in while the youngest map unit to express lineaments is Eocene fluviatile conglomerate and coaly sandstone (map unit Tf) (Figure A20.1). Very few Quaternary units were observed during field investigation of this group; colluvium is relatively thin and thin alluvial deposits are restricted to narrow watercourses. The area appears to be a region of erosional or residual terrane with gentle slopes with relatively non-resistant bedrock and few solifluction features. None of the mapped lineaments are concordant with glacial ice-flow directions; there is no field evidence of erosion from glacial ice within the area of the lineament group 20 (Figure A20.5) although the presence of glacial lake sediments and glacial erratics suggests the presence of glacial lakes (Figure A20.1). The magnitude of expression of the lineaments is not consistent along trend. For example, the mapped lineaments often alternate between weakly expressed and subtle slope breaks and broad troughs and deep and well-defined linear valleys. A prime example is the U-shaped swale shown in photographs A and B of Figure A20.1 which is not matched by similar features along trend to the southwest (Photograph C).

Based on the bedrock map units alone, a short fault mapped by Grantz (1960) as running through the middle of the lineament group 20 ellipse and which is mapped as displacing Eocene fluviatile conglomerate and coaly sandstone (map unit Tf) in a down-to-the-southeast sense. GPS way point 001 lies on this fault. (Wilson et al.'s (1998) compilation of the area does not include this fault, but whether this difference is due to the regional scale of their compilation, or the discovery of additional evidence to refute the fault's existence is unknown. Consequently, review of the original mapping is warranted.) As noted above, a mapped lineament feature is spatially associated with this fault where the fault passes through a saddle but the lineament is not consistently expressed along trend. Specifically, a prominent linear ridge and the geologic unit contacts within it are not obviously displaced (Photograph C) and the southeast-flowing stream valley to the north also does not express the lineament. Close inspection of the INSAR-derived DEM revealed that no separation of geologic units may exist across the fault (Figure A20.6). Grantz (1960) mapped an apparent ~100 feet (~33 m) offset in the Tf-Jns contact but a detailed slope map of the area apparently shows the basal contact of Tf with the underlying Jns in a different position than depicted by Grantz and that does not suggest any offset. Southeast of the mapped fault, Grantz's (1960) Tf-Jns contact is approximately 100 feet too low on the hillside and northwest of the fault the contact is ~100 feet too high elevation.

The prominent swale coinciding with the mapped fault may have a genesis related to spillways and wave-cut benches developed during the presence of an ice-marginal glacial lake. Glacial meltwater was likely impounded by the left lateral moraines of the Little Nelchina ice lobe to the east and by the ice in Daisy Creek to the north (Figure A20.5). Ground investigation discovered a presumably ice-rafted granitic glacial erratic in terrain mapped as Jurassic sedimentary rocks (unit Jnbc) at an elevation of ~3925 feet (at GPS waypoint 018 on Figure A20.1), about 100 feet higher in elevation than the swale shown in Photographs A and B of Figure A20.2. Williams and Galloway (1980) show a spillway transecting part of lineament group 20 at similar elevations that would have sent water over a drainage divide to Fourth of July Creek (Figure A20.5). Development of a similar spillway could be the genesis of the swale shown in Photograph A. In addition, several planar and horizontal benches at similar elevations may indicate the presence of a relatively long-lived lake, but could also relate to differential erodibility of the nearly horizontal stratigraphy in the area.

In summary, some of the individual lineaments along the northwestern margin of group 20 do appear to coincide with previously mapped bedrock faults and are likely fault-line scarps developed along bedrock faults, but the remaining lineaments are interpreted to be the result of erosion and not tectonically-related. Low-level aerial and ground inspection did not reveal any evidence for Quaternary faulting along the mapped lineaments or previously mapped faults. However, the validity of some of the faults is in question when evaluated with modern high-resolution elevation data. The mapped lineaments are not consistently expressed across the landscape and nearly all are spatially associated with erosional features. For the above reasons, no further work for lineament group 20 is deemed necessary.

Lineament Group 21a: Observations and Evaluation

Lineament group 21a is a northwest-trending small group of lineaments expressed as weakly aligned features within a terminal moraine complex, and a few topographic slope breaks and linear drainages (Figures A21a.1 and A21a.2), approximately 41 km (~25 miles) northeast of the proposed Susitna-Watana dam site (Plate 1). No previously mapped fault or lineament feature coincides with the orientation of the lineament group and no direct evidence of fault structure was observed during low-level aerial investigation. However, the Mesozoic-age Honolulu thrust fault (Csejety, 1961) does cut across the lineament group but does not align or coincide with any mapped lineaments. The weakly linear alignment of lineaments across the relatively low-relief terrain (Figure A21a.1) does not constrain the geometry or kinematics of any potential tectonic structure. Lineament group 21a lies entirely with glaciated terrain at the confluence of possibly four different ice streams (Figure A21a.2) and although Cretaceous flysch is mapped nearby (Csejtey et al., 1992; Wilson et al. 2009), field inspection confirmed that most of the area has either a surficial cover of glacial moraine and/or glacial lake deposits from a series of glacial lakes (Reger et al., 1990). The youngest deposits containing lineaments are likely late Holocene linear streams while the oldest surficial deposits in which lineaments are expressed are likely latest Pleistocene glacial deposits (Reger et al., 1990). The lineaments do not cut across different age deposits or landforms; they lie almost entirely within the Quaternary deposits in the valley bottoms. Aside from a 120-meter-tall rock-cored drumlin, the lineaments all have a relatively consistent magnitude expression of < 15 meters tall and are both parallel and discordant with ice flow directions. The most prominent lineaments are three lineaments that trend highly obliquely to the rest of the group and which have morphology and position suggestive of being either a terminal moraine ridge from northwest flowing ice or an esker (Figure A21a.2). No field evidence of displaced or deformed terrace risers or moraine ridges was observed along the trend of the lineaments.

Several lines of evidence point to a non-tectonic origin for the lineaments in group 21a. Although expressed in Quaternary deposits and of a scale consistent with a low slip-rate fault, the lineaments of group 21a do not traverse across portions of the landscape of different ages which would help support the existence of through-going tectonic structure. The apparent origins of the lineaments are both constructional (terminal moraine complex and eskers) and erosional (linear streams and short slope breaks in dissected glacial moraine ridges). In addition, part of the importance of group 21a as a potential tectonic structure is the group's spatial proximity and along-trend parallel orientation with group 21b, for which a non-tectonic explanation is likely (see below). Overall, the lineaments of group 21a are few in number, weakly expressed, weakly aligned, and do not coincide with a previously mapped structure. These factors, and the recent dominance of both active and stagnant ice processes in the area, point to a non-tectonic, glacial origin for the lineaments of group 21a and the lineaments are not considered further.

Lineament Group 21b: Observations and Evaluation

Lineament group 21b is a northwest trending group of lineaments expressed as a series of linear slope breaks and aligned linear drainages (Figure A21b.1) located approximately 43 km (~27 miles) north-northeast of the proposed Susitna-Watana dam site. Lineament group 21a is separated from group 21b by about 5 km (~3 miles). The only previously mapped fault or lineament feature that coincides with lineament group 21b is a photographic lineament mapped by Reger et al. (1990) that is discussed below and shown on Figure B-15. No fault exposures were observed during aerial and ground field investigation along lineament group 21b. The portion of the lineament group located west of Butte Creek climbs east-sloping terrain in a straight-line manner (Figure A21b.1) that suggests any potential tectonic structure would have a steep to near vertical dip and strong lateral kinematics. The lineaments of group 21b occur as downhill-facing slope breaks in mapped Quaternary glacial deposits (unit Qdt_3 of Smith et al. (1988)) and as linear streams and gulleys eroded into Cretaceous flysch, and to a lesser extent, Cretaceous granite (Csejtey et al., 1992; Wilson et al., 2009). Map unit Qdt_3 is considered to be of late Wisconsin age (11,800 to 25,000 year B.P.) (Smith et al., 1988). The mapped lineaments coincide with a concealed bedrock contact between units Ks (schist) and Kph (phyllite) of Smith et al. (1988) but cut across the map unit contacts of Wilson et al. (1998) (Figure A21b.1). Low-level aerial and ground inspection revealed the scale of the lineaments ranges from 2- to 4-m-high slope breaks (Photograph A, Figure A21b.2) to 5- to 10-m-deep linear stream channels. The lineament group is oriented perpendicular to the ice flow directions within the Butte Creek valley.

Field investigation did confirm the expression of the 3-km-long, downhill-facing slope break in Quaternary glacial deposits (Photograph A, Figure A21b.2) but did not reveal any exposures of the spatially-coincident concealed schist-phyllite contact mapped by Smith (1988). Inspection of the stream banks and terrace risers located to the west along the trend of the feature did not reveal any displaced terrace risers or surfaces (Figure A21b.3). Exposures in the left bank of Butte Creek at GPS waypoint 009 consisted of east-southeast striking, vertically-dipping phyllite which coincide with the projection of a lineament formed by a short, low-relief downhill-facing slope break (small arrows in Photograph A, Figure A21b.2) on the adjacent strath terrace surface. More resistant, sandy beds within the phyllite are interpreted to form the short slope break along the margin of the strath terrace and serve as an analogy for the much larger lineament located upslope. For example, rather than a being formed by a tectonic fault, the 3-km-long lineament mapped from INSAR data most likely relates to the rock type contrasts mapped by Smith et al. (1988) where higher grade (and more resistant) schist lies upslope of the slightly lower grade (and less resistant) phyllite and is overlain by a thin veneer of Quaternary glacial deposits. The linear streams and gulleys to the west of Butte Creek are therefore interpreted to be serendipitously-aligned erosion features. Alternatively, the reconnaissance mapping compiled by Wilson et al. (2009) for this area may be inaccurate, and the contact relations shown by the more detailed mapping of Smith et al. (1988) may continue westward, controlling the drainage patterns to produce linear streams along the strike direction of the phyllite. In either case, the lineaments of Group 21a are judged to be non-tectonic in origin and likely relate to differential erosion along depositional contacts within bedded metasedimentary rocks.

Lineament Group 22: Observations and Evaluation

Lineament group 22 is a northwest-trending group of lineaments defined chiefly as a series of aligned, linear V-shaped troughs and slope breaks (Figure A22), approximately 27 km (~17 miles) northwest of the proposed Susitna-Watana dam site (Plate 1, Figure A0.1). Group 22 spatially coincides with several northwest-trending photogeologic lineaments discussed below as features 7, 8, and 9 in the section on Reger et al.'s (1990) northwest-trending photogeologic lineaments of the Healy A-3 quadrangle. These features are depicted as extending across Quaternary glacial sediments as well Tertiary and Cretaceous intrusives that have variable strikes and dips. The lineaments are mapped in Reger et al.'s (1990) till of late Wisconsin age (unit Qd3; 9,500 to 25,000 years old) (Reger Public Data file 90-1), and are expressed in the field as linear erosional gullies. The geomorphic features east of Deadman Creek are smaller and less prominent in Mesozoic and Tertiary rocks as compared to those in Cretaceous rocks that are west of the creek, indicating an inconsistent scale of expression along strike (Figure A22.1). No field evidence of a fault was found during low-level aerial inspection, and much of the hillsides appear to be influenced by solifluction processes (Figure A22.2). The trend of the lineament on the landscape would suggest a hypothetical steeply-dipping geometry because the lineaments trend at high angles across contours. Along Deadman Creek, the lineaments are nearly orthogonal to the ice flow direction

(Reger et al., 1990, sheet B), and no offsets in the lateral moraines were observed. Along the far western part of the lineament group, the lineaments are parallel to the ice flow direction.

The lineaments of group 22 show a dearth of expression in Quaternary deposits, other than being associated with two linear drainages. While the lineaments transect several different geologic units, suggesting some continuity, we find that the magnitude of expression along strike is quite variable supporting an erosional genesis to the lineaments. The absence of substantive Quaternary lineaments further supports an erosional origin. Because of its geomorphic expression as linear drainages, there is insufficient landform information to assess potential kinematics (e.g., uphill facing scarp). Because there is no fault previously mapped along this group and no evidence of a fault was observed, coupled with the field observations of hillslope processes as well as a distinct lack of faulting expression in the late Wisconsin glacial deposits, it is judged that lineament group 22 is not a fault.

Lineament Group 23: Observations and Evaluation

Lineament group 23 is an arcing group of roughly east-west-trending lineaments defined by a series of aligned slope-breaks, low mounds, and short linear ridges (Figure A23.1), approximately 62 km (~39 miles) southeast of the proposed Susitna-Watana dam site. The features along the lineament trend occur entirely within mapped Quaternary glacial and lake deposits of the Copper River Basin (Williams and Galloway, 1986; Wilson et al., 2009). Potential ages for these deposits range from mid to late Pleistocene for the glacial till deposits to latest Pleistocene for the glacial lake deposits (Williams and Galloway, 1986). The lineaments do not coincide with any previously mapped faults or lineaments (FCL, 2013) and low altitude aerial inspection did not reveal any direct evidence of tectonic structures anywhere along the lineament, including in the near-vertical cut banks of Tyone Creek. The aligned slope-breaks, low mounds, and short linear ridges that make up the lineament group are of mostly broad and low relief, ranging in height from approximately 30 m high (~100 ft) in the west to 10 to 15 m high in the center and east portions. The orientation of the mapped lineaments is parallel to several north-south oriented drumlins mapped by Williams and Galloway (1986), and perpendicular to regional ice-flow directions, but parallel to and locally coincident with terminal moraine crests.

Several pieces of evidence beyond the spatial coincidence with the terminal Tysus Moraines of Williams and Galloway (1986) point to a non-tectonic explanation for lineament group 23. For example, no direct evidence of tectonic structures was observed during very low altitude aerial inspection, including in key exposures where the lineament alignment crosses Tyone Creek. The arcing alignment and the consistently low relief morphology of the aligned slope-breaks, low mounds, and short linear ridges does appear similar to a terminal moraine complex. The positive relief of these features suggests constructional or depositional geomorphic processes, rather than tectonic processes, may have played a role in their formation and their subtle expression could derive from being obscured by overlying glacial lake deposits. For example, the lineament group lies within published glacial lake extents and elevations in the Copper Basin for lake elevations of 975 m, 914 m , 800 m, and partly for the 775 m lake level (Kaufmann et al., 2011), suggesting Quaternary lake glacial processes may have influenced the formation of these features. The discordance of the lineaments located east of Tyone Creek with the orientation of terminal moraine ridges mapped by Williams and Galloway (1986) may result from differences in the scale and quality of the aerial photography used by Williams and Galloway (1986) compared to modern hi-resolution INSAR data. For example, the discordance could be the result of receding lake shorelines being interpreted as terminal moraines. Overall, the preponderance of evidence described above points to a genesis via glacial processes for the lineaments of group 23, and does not support a tectonic genesis. It is judged that lineament group 23 does not represent a tectonic fault, and no further work is recommended for lineament group 23.

Lineament Group 24: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). The lineament group is short (~15 km [~9 miles]) and lies a great distance from the damsite (~120 km [~75 miles]), and likely would not appreciably contribute to the hazard calculations (FCL, 2013).

Lineament Group 25: Observations and Evaluation

This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). Strip maps for this group are not included herein (Figure A0) but were presented as part of FCL (2013). The lineament group was interpreted to be the result of erosional and depositional processes (FCL, 2013), chiefly the apparent alignment of several large, curvilinear glacial valleys. During limited flyovers, no features were observed that suggested a need to revise those conclusions.

Lineament Group 26: Observations and Evaluation

Lineament group 26 is a northwest-trending lineament group expressed as a series of aligned slope-breaks, U-shaped troughs, and linear drainage segments (Figure A26.1), approximately 2 km (~1 miles) west of the proposed Susitna-Watana dam site (Figure A0.1). Much of the lineament follows an unnamed tributary to the Susitna River that lies directly west of Tsusena Creek. Previously mapped bedrock structures, lineaments, or faults are not coincident with or near this lineament group. Similarly, field evidence of fault structures were not observed along this lineament group during low altitude aerial inspection. The trend of the lineaments across topography implies a hypothetical near vertically-oriented geometry because the lineaments cut across topographic contours at high angles. South of the Susitna River, the lineaments are mapped in glacially-sculpted terrain that shows geomorphic landforms indicative of stagnant ice (e.g. eskers). The thickness of unconsolidated deposits on the south side of the river seems to be relatively thin. At the confluence of the Susitna River with Tsusena Creek, the lineament is mapped across Quaternary till deposits that overlie bedrock. North of the Susitna River, the lineaments principally are mapped in a linear drainage in whose upper banks are exposures of till that overlies lacustrine and fluvial deposits. The lineaments are mapped as cutting across Tertiary volcanics and intrusives as well as Quaternary sediment, however field observations did not find evidence to confirm presence of a lineament(s) expression in the bedrock or sediment. The scale of the expression of the lineaments along strike is variable, with little to no apparent relief across lineaments on the south side of the river. North of the Susitna River, the lineaments are depicted along a deeply incised canyon. The lineament group is relatively discordant with the ice flow direction, however, an esker deposit on the south side of the river trends oblique to the lineaments and showed no evidence of being offset or deformed based on low-altitude flyovers (Figure A26.2). Assessment of kinematics of the lineament morphology is indeterminate because there a near absence of geomorphic expression of tectonic-related features.

The lineament group does not show evidence of expression in late Quaternary units or landforms, including the till deposits at the confluence of the Tsusena Creek and Susitna Rivers. The till that seems to overlie the lake deposits along the upper banks of the unnamed drainage also appears to have a horizontal basal contact (Figure A26.2). Most clearly, the esker landform on the south side of the Susitna River appears to be continuous where it extends across the mapped lineament, indicating no deformation since its emplacement. While the lineament group is mapped across different geologic units, there is very little consistency of expression north of the Susitna River as compared to the south. North of the river, the lineaments appear to be dominantly erosional based on their mapped position at the bottom of a sub-linear canyon. South of the river, the lineaments that are mapped largely follow ice-flow directions. The few that are not concordant with ice-flow direction seem to be related to near-surface bedrock that is expressed as drumlin-like landform features. Because of the absences of previously mapped structures or faults, the lack of field evidence of faults, and the apparent positive evidence for non-faulting or displacement vis-à-vis the undeformed esker deposit (>11 ka in age), it is preliminarily judged that the lineament group is erosional in origin and likely does not represent a fault structure. However, ground access for this lineament group was restricted during the 2013 field inspection, and due to the close spatial proximity to the dam site, this lineament group warrants additional study to confirm the absence of bedrock structure along these features.

Lineament Group 27: Observations and Evaluation

Lineament group 27 is a northeast-trending series of aligned lakes and subtle topographic troughs/swales that project towards a large and linear U-shaped valley (Figures A27-1.1 through A27-3.1), approximately 80 km (~50 miles) southeast of the proposed Susitna-Watana dam site (Figure A0.1). This group is expressed in mapped Quaternary sediments within the Copper River Basin and partially coincides with the mapped Sonona Creek fault (Williams and Galloway, 1986; Wilson et al., 2009), although no fault exposures were directly observed in the field during aerial and ground reconnaissance. The geometry of any potential tectonic structure is difficult to resolve with certainty because the linear trend of the lineament across the very low relief (i.e., basically flat) portion of the Copper River Basin could result from several fault geometries. The lineament is expressed in late Quaternary glacial drift and glacial lake deposits as a series of aligned lakes, linear lakes and swales, vegetation lineaments, low-relief (~2-m-high) ridges, all of which project toward a 1 km right stream deflection in Tyone Creek (Figures A27-3.1 and A27-3.2). These lineament features were not mapped throughout all the Tolson Creek Moraine complex of Williams and Galloway (1986) but do exist in the glacial lake deposits (and underlying basal till under the center of the ice lobe?) located to the east. Williams and Galloway's (1986) depiction of the Sonona Creek fault is somewhat equivocal regarding the constraining age of potential faulting; they show the fault as truncating, cutting across, and also terminating into different ridges of the Tolson Creek moraine complex. The magnitude of lineaments' expression is relatively consistent along strike as shallow, ~2- to 3-m-deep lakes and ~2-m-high linear ridges, but the apparent sense of displacement is not consistent. In some locations (Photograph D, Figure A27-3.2) the apparent sense of displacement is south-down/north-up, whereas elsewhere the apparent displacement is south-up/north-down, and at other locations there is no discrete topographic expression of any displacement. The orientation of the lineament group is roughly perpendicular to the northwest-flowing ice in the Copper River Basin, but parallel to ice flowing down a northeast-trending segment of the Oshetna River Valley. No observations of displaced linear strain markers such as moraine ridges or terrace risers were found during low-level and ground investigation or from desktop analysis of the INSAR data. This suggests that the ~1 km (~0.6 miles) of apparent right-lateral stream deflection cannot be due to lateral fault motion, but it does not eliminate the possibility of stream deflection due to damming or diversion by a south-facing topographic scarp created by a north-up/south-down sense of vertical movement.

Field investigation revealed that the very few lineaments mapped in the western half of the group within the broad glacially-sculpted Oshetna River valley (Figures A27-1.1 and A27-2.1) are either rock or drift drumlins or coincide with ice-marginal features such as kame terraces, and are not likely tectonically related. The most prominently expressed features of group 27 are located in the eastern portion of the group amongst features that appear to be derived from stagnant ice (Figure A27-3.1) and coincide with the mapped Sonona Creek fault, but these aligned lakes, linear lakes and swales, and vegetation lineaments do not appear to transect across features of different ages. Specifically, ground investigation and aerial inspection of the Tolson Creek moraines did not reveal any lateral or vertical deformation along the projection of the mapped fault—only the presumably younger areas of ice-related deposition contained lineaments. The expression of lineaments in a portion of the landscape judged to be the youngest, and the absence of observed deformation (lateral or vertical) in the adjacent Tolson Creek Moraines, which are older, is inconsistent with an origin by faulting. (If the youngest portions of the landscape express prominent tectonic geomorphology, the older portions would likely also show evidence of recent tectonic activity too.) However, the lineament group's orientation does align with an apparent regional structural grain in the landscape, based on the orientation of the Castle Mountain fault 30 km to the south. Field investigation did not reveal any definitive evidence to strongly refute nor strongly support the presence of the mapped portion of the Sonona Creek fault and a late Pleistocene/early Holocene earthquake event cannot be refuted.

The initial Susitna-Watana PSHA (FCL, 2012) included the Sonona Creek fault as a seismic source based on the mapping of Williams and Galloway (1986) that depicts a late Quaternary faulted moraine. The aerial and ground field observations from this study did not verify this feature, however, the field data are not sufficiently detailed or extensive to preclude the potential of a latest Pleistocene to early Holocene co-seismic surface rupture. This would require developing a new detailed map along the Sonona Creek fault trace and confirmation of the relative age relationships of the presumed unfaulted deposits in that area. The Sonona Creek fault was not a significant contributing seismic source in the FCL (2012) PSHA evaluation due to its low slip rate and distance (~70 km) from the Watana site. Based on the 2013 field observations, the Sonona Creek fault should likely be retained in the seismic source model, but with an updated source characterization which considers a weighted non-tectonic interpretation of this lineament suggested by the new field observations. Reasons for maintaining this feature in the seismic source model are: (1) it is depicted on a previous publication as a late Quaternary fault, and, (2) the present study scope does not provide sufficient field evidence to positively refute its existence. In the absence of further field studies of the Sonona Creek fault, inclusion of a non-tectonic alternative for this fault would encompass a broad range of alternative interpretations within the crustal source model. No further field studies of the Sonona Creek fault or features in lineament group 27 for the Watana dam seismic hazard evaluation are recommended.

Broad Pass Area Faults: Observations and Evaluation

The Broad Pass area includes, for this investigation, the northeast-trending northwest-dipping thrust fault previously mapped by Csejtey (1961), approximately 56 km (~35 miles) northwest of the proposed Susitna-Watana dam site, along the western extent of the Chulitna River valley (Plate A1); as well as other bedrock faults mapped within and near the Chulitna valley (e.g., Honolulu thrust fault of Csejtey (1961)); and most recently several northeast-southwest oriented faults depicted by Wilson et al., (1998)). Faults oriented approximately northeast-southwest in this area are likely favorably oriented for (re)-activation in the existing crustal stress field near the Denali fault. A strong fabric of northeast-trending glacial features characterizes the geomorphology in the Chulitna valley, with numerous landforms such as drumlins, and glacial striae occurring throughout the valley. Existing geologic mapping (Wilson et al., 1998) depicts pre-Quaternary faults that apparently place Paleozoic and Mesozoic rocks against each other, or Paleozoic and Mesozoic rocks against Tertiary sedimentary rock units. These older rocks are in turn overlain by Quaternary glacial and fluvial sediments that are no older than late Wisconsin age.

Several locations were investigated as part of the assessment of previously mapped faults in the Chulitna River valley (Plate A-BP). Faults mapped as bounding Tertiary units could not be confirmed due to lack of exposure (e.g., Figure A-BP.1). A ground traverse was made orthogonal to the mapped fault and no exposures were present and a fault was not observed during the hike. Low altitude fly-overs of the partly-forested, partly-wetland surface of the Chulitna valley found no evidence of Quaternary faulting, and the surficial geomorphology observed was uninterrupted and undeformed. Exposures of Quaternary terrace units exposed along the western bank of the West Fork of the Chulitna River appear to be chiefly fluvial in origin and show lenticular beds that are not entirely planar in geometry. On the east side of the West Fork of the Chulitna River, an important outcrop exposes late Quaternary till that unconformably overlies Tertiary sediments with an apparently horizontal basal contact geometry for the length of the exposure (Figure A-BP.1). Similar contact relations and horizontal geometries were observed in the East Fork Chulitna River and several tributaries. This observation argues that the till deposit has not experienced tectonic deformation since its emplacement, supporting an interpretation of no late Quaternary or post-glacial faulting.

Other locations within the Chulitna River valley were visually inspected (Plate A-BP; Figures A-BP.2 and A-BP.3). Field investigation found no evidence to directly confirm the faults as mapped. In all instances, late Quaternary cover overlying the fault appeared undisturbed and not offset. Based on the extensive glacial ice features that are prevalent in the valley, the late Quaternary deposits and landforms are probably from the last glacial maximum. The lineaments mapped within the Chulitna River valley are oriented along the direction of ice flow, and generally are located along the margins of geomorphic features (e.g. drumlins, kettle edges) that are genetically related to glacial flow and related processes. Thus, none of the lineaments mapped in this area are considered tectonic in origin. The field evidence did not directly confirm the previously mapped pre-Quaternary faults, nor did it confirm faulting of Tertiary deposits at locations inspected. However, observations of field exposures and late Quaternary surficial deposits showed no evidence of faulting.

Clearwater Mountains: Observations and Evaluation

FCL (2013) identified the Clearwater Mountains as an area of interest because the western extent of the Broxson Gulch fault lies within the Clearwater Mountains, and was inferred as Quaternary-active by Nokleberg et al. (1994). Conceptually, the region could be analogous to the area around the Susitna Glacier fault, where a WSW-trending fault splays from the Denali fault and results in southward-directed uplift on a north-dipping fault. West-southwest trending fault splays may be favorably oriented for (re)-activation within the existing crustal stress field and if active would potentially provide a structural connection between the Denali fault and the Talkeetna thrust fault. In order to better understand the potential genesis of the Clearwater Mountains and potential connections between the Broxson Gulch fault and Talkeetna thrust fault, Plate A-CWM displays the area surrounding the

Clearwater Mountains. The potential junction of the Broxson Gulch fault and Talkeetna thrust faults lies approximately 83 km (~52 miles) northeast of the proposed dam site.

Several different iterations of geologic mapping exist for the area of the southern Clearwater Mountains and these data are described in detail by FCL (2013). For the purposes of the current discussion, it is sufficient to reiterate that three maps in particular demonstrate the range of depictions of the faults in the area: Smith (1981), Silberling at al. (1981), and Csejtey et al. (1992). Importantly, the three maps show different configurations for the potential junction of the Broxson Gulch, Black Creek, and Talkeetna thrust faults in the Pass Creek area (Plate A-CWM). Smith et al. (1981) show the Talkeetna thrust fault as a continuation of the Broxson Gulch fault, which together truncate the Black Creek fault. Silberling et al. (1981) also show the Talkeetna thrust fault as a continuation of the Broxson Gulch fault but do not present mapping of the Black Creek fault. In contrast, Csejtey et al. (1992) shows the Broxson Gulch fault continuing westward as the Black Creek fault and the Broxson-Black Creek fault system as truncating the Talkeetna thrust fault. Based on their own work, and upon review of previous work, including the work of Nokleberg et al. (1994), O'Neill et al. (2001) conclude that the Black Creek/Broxson Gulch fault truncates the Talkeetna thrust fault, and that the Broxson Gulch fault and Talkeetna thrust faults are not kinematically or structurally related.

Based on the results of FCL (2013), two specific areas within the Clearwater Mountains were deemed candidates for field inspection (Plate A-CWM): 1) the junction area of the Talkeetna thrust, Broxson Gulch thrust, and Black Creek faults (lineament group CMW1) and, 2) a collection of lineaments on the south side of the Clearwater Mountains (lineament group CMW2).

Lineament group CWM1 does contain a few lineaments that lie proximal to mapped faults in the saddle between the Windy Creek and South Fork Pass Creek valleys (Plate A-CWM, Figure A-CWM.1) and in other locations along the Black Creek fault (Plate A-CWM). In the saddle between the Windy Creek and South Fork Pass Creek valleys, the trend of most mapped lineaments across the terrain was somewhat inconclusive while the trends of others suggested the potential geometry of fault structures would be steeply dipping. Indirect evidence of fault structure was observed in several locations in the high elevation bedrock terrain above the valley floor in the form of contrasting rock-type juxtapositions (Figure A-CWM.1 and A-CWM.2) that corroborate the general locations of the mapped faults. The FCL-mapped lineaments are expressed as linear gullies and streams in both late Cretaceous to early Jurassic bedrock and glacial deposits, broad and shallow U-shaped linear troughs in glacial deposits, and locally as side-hill benches within latest Pleistocene glacial deposits on the margins of the valleys. The lineaments do not appear to cut across different geologic units and have a consistent magnitude of expression. The lineaments are both discordant and concordant with glacial ice-flow directions; some lineaments may be expressing the ice-limit elevations at the bedrock-glacial moraine contact (Figure A-CWM.1). No field evidence of deformed Quaternary-age linear strain markers along the trend of mapped lineaments or faults was observed during aerial inspection. Furthermore, no evidence of through-going tectonic geomorphology was observed along the mapped lineaments in the saddle between the Windy Creek and South Fork Pass Creek valleys, nor any expression of deformation in the Quaternary sediments of the north-trending glaciated valleys across which the Black Creek fault cuts (Figure A-CWM.2).

The FCL-mapped lineaments in the area of group CWM2 do not coincide with previously mapped faults, lie at elevations below the maximum ice elevation, and are oriented mostly parallel to the direction of ice flow (Plate A-CWM). The lineaments are expressed as side-hill benches within Quaternary glacial deposits (and spatially coincide locally with kame terraces) (Figure A-CWM.3) and as downhill-facing scarps in areas subject to solifluction. The magnitude of expression varies from relatively broad side-hill benches 10s of meters wide and 100s of meters long to smaller topographic scarps with only a few meters of relief that are difficult to trace laterally in thick vegetation. Extensive low-level and ground investigation revealed that the lineaments are not laterally continuous across different geologic units or landforms; eskers and post-glacial alluvial fans are not apparently deformed along the projection of the lineaments (Figure A-CWM.3). No evidence of displaced or deformed linear strain markers was observed.

In summary, some mapped lineaments mapped by FCL (2013) in the central Clearwater Mountains area coincide with previously mapped bedrock faults but no evidence of deformed or displaced Quaternary deposits was observed. No field evidence of Quaternary activity along the mapped traces of the Talkeetna thrust, westward extension of the Broxson Gulch, or Black Creek faults was observed and consequently the specific geometries and contact relationships between these three faults were not evaluated in the field. The lineaments mapped along the southern slopes of the Clearwater Mountains are interpreted to be of non-tectonic origin. The geomorphology on the southern slopes of the Clearwater Mountains is heavily influenced by glacial processes and the presence of left-lateral moraine deposits. Field investigation did not reveal any through-going and laterally continuous aggregations of individual lineaments or tilted tectonic markers (such as shorelines or terraces) at the southern foot of the mountains that could be definitively linked to a tectonic origin. Post-glacial landforms and deposits did not express any lineaments and appear undeformed.

Castle Mountain Fault Extension: Observations and Evaluation

The Castle Mountain fault is a Quaternary seismogenic structure, as well as a major structural boundary which was included as a seismic source in the initial Watana Dam PSHA evaluation (FCL, 2012). The eastern extent of the Castle Mountain fault, as mapped in the Alaska Quaternary fault and fold database (i.e., Koehler et al., 2012), bifurcates to the east toward the Copper basin, ending in two splays (Plate A-CME). The northern splay ends at an unnamed glacial valley west of Caribou Creek; and the southern splay ends at the confluence of Billy Creek, and the larger Caribou Creek drainage. Northeast of the mapped end of the southern splay of the Castle Mountain fault, along Billy Creek, a group of lineaments projects to the northeast along a trend similar to the Castle Mountain fault (Plate A-CME). Lineament features aligned with the Castle Mountain fault could potentially increase the overall rupture length of the fault, and may extend slightly closer to the Watana dam site than previously mapped.

Field evidence for faulting observed during low altitude aerial and ground inspection included: apparent bedrock type juxtapositions, bedrock color change associated with alteration zones, and deformation of bedrock units. All apparent evidence was observed in bedrock and no linear expression or evidence of faulting was observed in Quaternary deposits, although Quaternary deposits were scarce. The mostly straight to overall gently arcuate trend of the lineaments across high-relief mountainous terrain occur within a swath of parallel to sub-parallel features. The landscape in this swath exhibits a clear northeast-trending structural grain which suggests a steeply dipping structure(s) within a zone of deformation. To the southwest, the lineaments coalesce and join the right-lateral Castle Mountain fault. Considering the oblique orientation of these faults to the east-west trending right-lateral Castle Mountain fault system, the kinematics of these features can be implied as being right-lateral oblique with a larger vertical component than lateral. Observed lineament features occur in multiple bedrock lithologies, including: the Jurassic Talkeetna (Jtk), the undivided Chinitna and Tuxedni formations (Jtxc), and Naknek formations (Jn), Cretaceous Matanuska Formation (Km), Tertiary age Chickaloon formation (Tch) and undifferentiated Tertiary volcanic rocks (Tvu) (Plate A-CME). These features are only expressed in upland bedrock terrain and slopes and do not occur in alluvial deposits or glacial landforms. The orientation of these lineaments is perpendicular to regional ice-flow direction. It is unlikely that glacial processes played a major role in the formation of these lineaments.

Quaternary deposits in the vicinity of the Castle Mountain fault extension lineament group have limited spatial coverage and most commonly occur as fluvial deposits found within in narrow canyons. Bubb Creek, Flume Creek, Greta Creek, and other unnamed drainages intersect, and are nearly orthogonal to, the lineament alignment and mapped features of Csejtey et al. (1978). Each waterway is relatively narrow with little to no Quaternary deposits. The Little Nelchina River valley is a broad glacial valley, and it provides the best exposure of continuous, flat-lying, and undeformed Quaternary terraces across the lineaments and mapped features. The scale of aligned features such as saddles, linear U- and V-shaped valleys, side-hill benches and breaks-in-slope remain consistent along strike and across variable terrain. Although a core group of lineaments within this group coincide with mapped faults, others do not. The mapped lineaments that do not coincide with previously mapped faults are attributed to be linear drainages (erosion features) and lineaments related to structural grain of the bedrock (lithologic control). The fault-related lineaments appear to be related to the Castle Mountain-Caribou fault systems of late Cenozoic age (Csejtey et al., 1978). Because of limited exposure of Quaternary deposits and the segmented and splayed characteristics of the mapped faults in this area, it is difficult to declare that all segments of this fault exhibit no Quaternary activity. No definitive evidence was encountered that precludes a scenario where this segment of aligned features ruptures as an extension of the Castle Mountain fault. If the group of aligned features acts as an extension of the Castle Mountain fault, the group of features could extend the fault by approximately 21 km (~13 miles) to the northeast of the current mapped extent of the fault as shown in Koehler et al. (2012). Based on the observations that these features are clearly related to faulting of late Cenozoic age, we suggest adding this segment of fault-related features to the crustal seismic source model as a northeast extension of the Castle Mountain fault rupture scenario.

North-South Features near Talkeetna River-Susitna River Confluence: Observations and Evaluation

This area was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) on the basis of the features' large distance (i.e., >70 km [>40 miles]) to the proposed dam site and their poor expression in the surrounding Quaternary sediments and Tertiary granodiorite outcrops as manifested in the INSAR data. This group was not visited during the 2013 field inspections and no observations were made that suggested a need for additional analysis. A plate showing available geologic data for this group is not included herein but was presented as part of FCL (2013).

Photogeologic Lineaments Mapped by Reger et al. (1990) in the Healy A-3 Quadrangle

In addition to investigation of the lineaments mapped by FCL (2013), lineaments appearing in Reger et al. (1990) were also evaluated in the field. In their study, Reger et al. (1990) mapped geologic units, glacial features, glacial lake shorelines, faults and lineaments within the extent of the Healy A-3 quadrangle. These features are presented in several thematic map sheets and described in the associated report. In the report, Reger et al. (1990) mention that "several photogeologic lineaments transect or offset moraines…" and are "likely candidates for active faults." Reger et al. (1990) describe one specific lineament as intersecting an east facing cirque in the headwaters of Butte Creek and being coincident with an offset cirque floor. Three lineament groups mapped by FCL (2013) and evaluated as part of this study (groups 21a, 21b, and 22) fully or partly overlap the Reger et al. (1990) map area (Figure B-01). None of the features identified in these three lineament group areas are interpreted to be associated with late Quaternary faulting. However, closer examination of the Reger et al. (1990) map showed a number of locations where the map depicted faults and solid lines either through or extending into Quaternary units. Based on these observations and the statements in the associated text, the features shown on the Reger et al. (1990) map were highlighted for further field review.

Lineaments and faults appearing in Reger et al., (1990), Sheet 1 of 2, were digitized as shapefile lines at a scale of 1:63,360, or better, and attributed appropriately. The locations where these lineaments and faults were mapped across or extended into Quaternary units were identified, saved as shapefile points and given a feature number (Figure B-01). The line and point shapefiles were loaded into an ArcGIS-enabled ruggedized field laptop with real-time GPS tracking. Field investigation of each feature was conducted via helicopter overflight with limited ground inspection, using the evaluation process described in Section 2 and Section 3 above. Discussion of these features follows below, but due to the large number of features shown by Reger et al. (1990), figures presenting the map and field data for the features are presented as Appendix B.

Feature 1:

Feature 1 is a northeast trending photo-lineament mapped over orthogneiss and migmatite (TKgm) bedrock in its central and northern portions. The southern portion of the lineament is mapped over Quaternary age landslide (Qct) and rock glacier (Qcg) deposits in a narrow south facing cirque (Figure B-02). Low altitude aerial inspection of this location revealed that the mapped trace of the lineament is coincident with a linear alignment formed by the toe of a rock glacier advancing downslope from the eastern cirque wall. The lineament is enhanced because it is in close proximity, and parallel to, the axial drainage channel. Additionally, the lineament is absent in the Quaternary sediments on the valley floor of the down-drainage intersecting valley. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 2:

Feature 2 is a northwest trending photo-lineament mapped over a quartz monzonite gneiss (TKqmg) and paragneiss (TKpng) bedrock ridge. The lineament is terminated in Wisconsin age till (Qd3) at its northwest extent (Figure B-03). The mapped trace of the feature overlies obliquely oriented linear glacial striations within the bedrock. Low altitude aerial inspection revealed no clear linear expression in the terrain with the same orientation as the mapped trace of Feature 2. Quaternary deposits at the northwest and southeast extent of this feature were visually inspected, and no evidence of linear expression was observed. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 3:

Feature 3 is a west-northwest trending photo-lineament mapped across Wisconsin age till (Qd3), moraine (Qm3), and abandoned meltwater channel alluvium (Qac) deposits (Figure B-04). Low altitude aerial inspection revealed that this feature correlates with linear expressions related to glacial features rather than tectonic features. The western and central segments of this lineament are coincident with two prominent breaks-in-slope on the northeastern margin of a U-shaped glacial valley. The eastern portion of the feature is coincident with a linear to semi-arcuate moraine. In addition, the lineament has no expression within the Qac deposits near the center of the mapped trace. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Features 4 & 5:

Features 4 and 5 are mapped as sub-parallel northwest striking faults across a broad Kahiltna Terrace argillite, sandstone, and siltstone (JKs) bedrock ridge (Figure B-05). Both of these faults are depicted as intersecting Wisconsin age till (Qd3) deposits on the flanks of the ridge. A clear expression of these faults was not observed in the bedrock during low altitude aerial inspection. In addition, the Quaternary (Qd3) deposits were observed to have no linear expression or fault related deformation. Lacking evidence of Quaternary age deformation, these features are not considered to be active structures.

Feature 6:

Feature 6 is an arcing north-northwest trending photo-lineament mapped across granodiorite (Tgdf) bedrock and Quaternary age paludal (Qs) and Wisconsin age till (Qd3) deposits (Figure B-06). The central portion of the mapped lineament correlates to a prominent break in slope and juxtaposing bedrock and Quaternary deposits. The northern extent of the lineament is expressed by a subtle west facing slope and linear valley. The southern extent is mapped over the crest of a bedrock knob and has no clear expression. Low altitude aerial inspection revealed that this lineament exhibits an opposite sense of vertical displacement in the north (apparent down-to-the-west) compared to the middle and southern segments (apparent down-to-the-east), an unlikely combination of geomorphic expressions for a tectonic feature with vertical displacement. Geomorphic expression indicative of oblique or strike-slip faulting was not observed. Additionally, this lineament has no expression within Quaternary deposits. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 7:

Feature 7 is a sinuous east-northeast trending photo-lineament mapped over quartz monzonite gneiss (TKqmg), quartz monzonite (Tqm) bedrock, and Wisconsin age till (Qd3) deposits (Figure B-07a/b). A pegmatite vein is mapped, unbroken, across this feature at its intersection with the Feature 8 lineament. Low altitude aerial inspection revealed that linear expression within the Quaternary deposits was observed to be a linear drainage (western segment) and an alignment of solufluction lobes (eastern segment). In aggregate, this lineament is a collection of aligned and unrelated non-tectonic features: linear drainages, linear erosional features, and aligned solufluction lobes. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 8:

Feature 8 is a slightly arcing west-northwest trending photo-lineament mapped over a quartz monzonite gneiss (TKqmg) bedrock ridge and Wisconsin age till (Qd3) deposits (Figure B-07a/b). The mapped trace of Feature 8 intersects Feature 7 on the eastern flank of the bedrock ridge. On the western side of the ridge, the feature intersects the northern extent of a mapped fault that has no expression in Quaternary deposits. Two pegmatite veins are mapped unbroken across this feature. This lineament is made prominent by a very large southwest facing topographic scarp along a linear drainage on the west side of the ridge, and a linear drainage on the eastern side of the bedrock ridge. Low altitude aerial observations revealed that the topographic scarp is approximately 10-20m in height and likely an erosional feature related to solifluction. The scarp has a limited extent and is not expressed in any other bedrock segment or Quaternary deposit along Feature 8. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

The western portion of this mapped feature (from the fault intersection to the west) corresponds with the FCL mapped lineaments of lineament group 22 discussed above.

Feature 9:

Feature 9 is a northwest trending photo-lineament that is mapped over Wisconsin age till (Qd3), alluvial fan (Qaf), and moraine (Qm3) deposits (Figure B-08). The eastern portion of this lineament is the same feature as the lineaments included in FCL lineament group 22 discussed above. Low-altitude aerial inspection revealed that feature is formed by an alignment of non-tectonic glacial features: linear moraine, solufluction features, and glacial striations in the bedrock on the valley margin slopes. At one location near the center of its mapped trace, the lineament is overprinted with a Quaternary age alluvial fan. No trace of the lineament was observed within the alluvial fan deposit. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 10:

Feature 10 is a long (~10.5-km) north-northwest trending photo-lineament mapped over quartz monzonite (Tqm) and granite (Tgr) bedrock, and Wisconsin age till (Qd3) and alluvium (Qa) deposits (Figure B-09a/b). Low altitude aerial inspection showed that the lineament is mostly composed of linear drainages, linear moraines, and breaks in slope. The breaks in slope in the north and south display an opposite sense of displacement (down-to-the-east) than the middle slope (down-to-the-west), an argument against a through-going, tectonic feature with vertical displacement. Geomorphic features indicative of oblique or strike-slip faulting were not observed. Alluvial deposits within the intersecting glacial valley (southern portion of the trace) and the glaciated plain (mid to northern segment of the trace) show no clear evidence of linear expression. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 11:

Feature 11 is a northwest trending photo-lineament mapped over granite (Tgr) and quartz monzonite (Tqm) bedrock and over Wisconsin age till (Qd3) and Quaternary landslide (Qct) and rock glacier (Qcg) deposits (Figure B-10). Observations made during low altitude aerial inspection showed that the mapped trace of this lineament is coincident with an alignment of moraine crests and linear erosion features. The lineament was not observed in any of the intersecting Quaternary deposits. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 12:

Feature 12 is an east-northeast trending photo-lineament mapped in Quartz Monzonite (Tqm) bedrock and Quaternary age rock glacier (Qcg) deposits (Figure B-10). The western and central segments of this lineament are coincident with linear drainages (erosion features). In its eastern extent, the mapped trace of the lineament is coincident with the linear flank of a rock glacier over an older rock glacier. Observations from low altitude aerial inspection and existing data indicate that this feature is likely non-tectonic in origin.

Feature 13:

Feature 13 is a north-northwest trending fault mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and terminates at Quaternary age rock glacier (Qcg) and Quaternary landslide (Qct) deposits (Figure B-11a). The mapped trace is intermittent within the Quaternary deposits, and dike swarms (Tgr-d) are mapped unbroken across the project path of this feature. Observations from low altitude aerial inspection showed no expression of faulting within Quaternary deposits. Lacking evidence of Quaternary age deformation, these features are not considered to be active structures.

Feature 14:

Feature 14 is a north-northwest trending photo-lineament mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and Quaternary age landslide (Qct) and rock glacier (Qcg) deposits (Figure B-11a). This feature is along strike with, and appears to be mapped as a possible northern extension of, the Feature 13 fault. This lineament is formed by a linear drainage within a rock glacier in a narrow, south facing, cirque and an aligned saddle. Low altitude aerial inspection observed no evidence for faulting along this linear alignment. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 15:

Feature 15 is a north-northwest trending fault mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and Quaternary glacial till (Qd) deposits (Figure B-11a). Low altitude aerial inspection observed the fault in bedrock outcrops on the mountain slopes and through a saddle. No expression of the fault or fault related deformation was observed in Quaternary (Qd) deposits in the valley floor or in an overlying rock glacier. Lacking evidence of Quaternary age deformation, these features are not considered to be active structures.

Feature 16:

Feature 16 is a northwest trending fault juxtaposing Tertiary Quartz Monzonite (Tqm) against Cretaceous Kahiltna Terrane Argillite, Sandstone, and Siltstone (KJs) bedrock and over Quaternary landslide (Qct) and till (Qd) deposits (Figure B-11a/b). This fault is along strike with, and north of, the Feature 15 fault. The two features are separated by a glacial valley. Low altitude aerial and ground inspection observed evidence of faulting in bedrock at a ridgeline saddle near photograph location C, confirming the presence of the fault along the mapped trace. The Quaternary deposits (Qct, Qd) on the floor and lower flank of the glacial valley were observed, and no linear expression or evidence of tectonic deformation was observed. Lacking evidence of Quaternary age deformation, this feature is not considered to be an active structure.

Feature 17:

Feature 17 is a northeast trending photo-lineament mapped in Kahiltna Terraine Argellite, Sandstone, and Siltstone (KJs) bedrock and across Quaternary landslide (Qct) and an unlabeled unit (late Wisconsin till and/or moraine?) (Figure B-12a/b). The mapped trace of the lineament crosses the till and moraine(?) deposits, however no clear through-going linear expression was observed during low altitude aerial inspection. The mapped trace is most likely defining aligned and subtle slopes and drainages within the Quaternary deposit. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 18:

Feature 18 is a northwest trending photo-lineament mapped in Kahiltna Terraine argellite, sandstone, siltstone (KJs) bedrock and Wisconsin age till (Qd3), and an unlabeled unit (late Wisconsin till and/or moraine?) (Figure B-12a/b). The mapped trace of the lineament is coincident with a topographic break-in-slope (apparent down-to-northeast) in bedrock. This lineament is parallel/sub-parallel, and along strike to the northwest, to a (down-to-northeast) normal fault mapped by Reger et al (1990). The two features are separated by a northeast trending glaciated valley. Low altitude aerial inspection observed an apparent fault exposure in bedrock at a topographic break-in-slope along the ridgeline. This evidence indicates that this lineament is likely a continuation of the fault trace mapped to the southeast. The Quaternary deposits between Features 18 and 20 were inspected and found to be undeformed and lacking any linear expression. Lacking evidence of Quaternary age deformation, this feature is not considered to be an active structure.

Feature 19:

Feature 19 is a northeast tending photo-lineament mapped in unlabeled unit (late Wisconsin till and moraine?) (Figure B-12a/b). Low altitude aerial inspection showed that the mapped linear trace correlates with a vegetated linear drainage. The lineament is made more prominent by the color contract between the vegetation and the surrounding rocky ground surface. Observed to be an erosional feature, this lineament is likely non-tectonic in origin and not considered further.

Feature 20:

Feature 20 is a northwest striking photo-lineament mapped across orthogneiss and migmatite (TKgm) bedrock and Quaternary age undifferentiated colluvium (Qc) deposits (Figure B-12a/b). Low altitude aerial inspection confirmed that the mapped linear trace correlates with a linear drainage and has expression only in bedrock. No linear expression was observed in Quaternary deposits along the projected path of the feature. Lacking evidence of Quaternary age deformation, this feature is not considered to be an active structure.

Features 21:

Feature 21 is a northwest trending photo-lineament mapped over quartz monzonite (Tqm) bedrock and morainal deposits of Late Wisconsin age (Qm3) (Figure B-13). Low altitude aerial inspection showed that this lineament is composed of a collection of aligned features. The northern and central segments of this feature are a bedrock ridge crest leading to a linear drainage. The southern extent, in Quaternary deposits, was observed to be the crest of a debris flow levee which bounds the linear drainage. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 22:

Feature 22 is an east-northeast trending photo-lineament mapped within a deposit of colluviated till of Illinoian age (~120 to 170 ka) (Figure B-14a). Low altitude aerial reconnaissance observed no clearly defined linear expression to correlate with the mapped lineament. It is likely that the mapped trace represents a color contract created by glacial till along the crest of a low-relief ridge separating two drainages. Field observations and existing data indicate that this feature is likely non-tectonic in origin

Feature 23:

Feature 23 is an east-northeast trending photo lineament mapped across paragneiss (TKpgn) bedrock and morainal deposits of late Wisconsin age (Qm3), and till of Illinoian age (Qd2) (Figure B-14a/b). This lineament is to the east of, and along strike with, Feature 22. The two features are separated by a broad landscape mantled with Qd2. Low altitude aerial inspection observed that the mapped trace of the lineament correlates with topographic scarps and linear solifluction features. Along strike, the topographic scarps were observed to express opposing expressions of vertical displacement (down-to-northwest and down-to-southeast), an unlikely combination of geomorphic expressions for a through-going tectonic feature with vertical displacement. Geomorphic expression indicative of strike-slip or oblique faulting was not observed. No linear expression or scarps were observed within the intersecting

Quaternary deposits. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 24:

Feature 24 is a northwest trending photo-lineament mapped in paragneiss (TKpng) bedrock for most of its length except for the northern extent where it is mapped within Quaternary age talus (Qct) deposits (Figure B-15). Reger et al. (1990) describes this lineament as one which corresponds to an offset in the floor of an east-facing cirque, the floor of which is mapped as Tkpgn. Low altitude aerial inspection of the lineament revealed that in bedrock the mapped trace consists of an alignment of variably-scaled, linear swales more likely related to glaciation rather than active tectonics. In the Quaternary deposits, the lineament corresponds to a linear drainage. Scarps and vertical displacement were not observed in the cirque floor described by Reger et al. (1990) and no evidence of tectonic origin was noted for this feature. Field observations and existing data indicate that this feature is likely non-tectonic in origin

Feature 25:

Feature 25 is an angled northwest trending photo-lineament. The lineament is mapped over paragneiss (TKpgn) bedrock and late Wisconsin age till (Qd3) (Figure B-15). Low altitude aerial inspection revealed that the mapped trace is coincident with a shallow linear drainage that is highlighted by an apparent vegetation color contrast. Being an erosional feature, these field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 26:

Feature 26 is an east-to-west trending photo lineament mapped over bedrock for its entire trace except for the far western end (Figure B-16). At this location, it is mapped over Quaternary age talus deposits before it terminates against a bedrock knob in the center of the cirque. Visual inspection of the lineament via low altitude aerial inspection revealed no clear linear trace through the talus deposits. Within the cirque, the only along-strike linear trend is attributed to a linear drainage incised into bedrock.

Feature 27:

Feature 27 is an east-to-west trending photo-lineament mapped over paragneiss (TKpgn) bedrock in its middle portion and Quaternary talus (Qct) deposits on its eastern and western extents (Figure B-16). Within bedrock, no continuous linear features were observed that correspond with the mapped trace of Feature 27. Within Quaternary talus, the only linear expressions observed via low altitude aerial inspection were related to linear drainages. Field observations and existing data indicate that this feature is likely non-tectonic in origin.

Feature 28:

Feature 28 is a north-northwest trending photo-lineament mapped over orthogneiss and migmatite (TKgm) bedrock and Quaternary age colluviated till (Qdc3) (Figure B-17). During low altitude aerial inspection, the feature was observed to be characterized by a shallow linear trough oriented at an oblique angle to linear solifluction features and moraines, possibly indicating that this feature is related to bedrock structure. However, it has no expression in overlying Quaternary deposits or within adjacent Quaternary till deposit to the southeast. Lacking evidence of Quaternary age deformation, this feature is not considered to be an active structure.

Summary of Reger et al. (1990) Lineaments

This study evaluated 28 locations where photo-lineaments and faults, appearing in Reger et al., (1990) Map 1, intersect Quaternary deposits to determine if any of these features display morphology indicative of post-glacial surface rupture and faulting. The aerial reconnaissance of these 28 features did not identify evidence of post-glacial surface rupture associated with these features. The prominence of these features on some aerial photography, linear traces, and local topographic expression can be explained through juxtaposition of different rock types with physical or erosional contrasts, linear erosion features along existing bedrock structures or down slopes, linear features associated with glacial landforms such as moraines and eskers. In addition to the visual inspection of these features, Dr. Reger was contacted, and through personal communication (Reger, 2013), commented that he does not believe that any linear features identified in Reger et al., (1990), Map 1 are related to active faulting. This study also judges that Reger et al. (1990) lineaments are not the result of late Quaternary faulting.

4.1 Discussion of the Talkeetna Fault Trench Locations of WCC (1982)

The Talkeetna fault was characterized as a major tectonic feature near the Watana dam site by WCC (1982) although no evidence of Quaternary faulting was located during their investigations. FCL (2012, 2013) reached similar conclusions, based on the initial literature review for seismic source characterization (FCL, 2012) and subsequently based on lineament mapping using LiDAR and INSAR derived DEM's (FCL, 2013). The WCC (1982) investigations included paleoseismic trenching at two locations along the Talkeetna fault. As part of the 2013 field evaluation, aerial inspection and focused review of the INSAR data for those sites was conducted. Two trenches were excavated along parts of the Talkeetna fault: trench T-1 and trench T-2. Trench T-1 is located directly southwest of the Fog Lakes, and lies about 15 km from the proposed dam site (Figures 5-1 and 5-2). Trench T-2 is located much farther to the southwest, about 65 km from the proposed dam site, and is slightly west of the confluence of the Talkeetna River and Iron Creek (Figure 4-3).

Low altitude aerial inspection was performed near the WCC trench T-1 site along the map trace of the Talkeetna fault, to confirm the location of the trench and observe the geology and geomorphology in the area (Figure 4-1). Ground access was not available during the 2013 summer season. From the air, the slightly west of north-facing break-in-slope is a geomorphic feature that would expected from a potential southeast-dipping, reverse to oblique-slip fault (Figure 4-1). From subsurface excavations, WCC (1982) concluded that the exposures in trench T-1 were not faulted, and the slope break "scarp" is related to the melting edge of a late Wisconsin ice margin. This scarp trenched by WCC (1982) is relatively unique compared to the other lineaments inspected during the summer 2013 field investigations and it is reasonable that this location was selected by WCC for paleoseismic investigation. However, this scarp is not readily discernible on the INSAR DEM (Figure 4-2), and thus was not captured by the lineament mapping. This area lies south of the existing detailed LiDAR data extent along the Susitna River, and additional LiDAR coverage in this area is necessary to inspect and interpret features that could be related to the scarp at the WCC T-1 trench site that are not readily apparent on the INSAR data.

A brief aerial inspection of the WCC paleoseismic trench T-2 area was performed to confirm, as best as practical, the location of the excavation, and observe the geology and geomorphology at the location (Figure 4-3). No distinct features were associated with the excavation site (e.g. tree lines, backfill mounds), so the exact trench spot was only approximately located. In general, there are linear topographic grooves along the mapped location of the Talkeetna fault. In this area, the fault juxtaposes Cretaceous sedimentary rocks (map unit KJs) on the northwest against Paleozoic volcanic rocks on the southeast. The northeast projection of the fault is shown as terminating at a hill composed of intrusive Tertiary volcanics (map unit Tvu) that were dated at slightly older than 50 ma (Csejtey, 1978). WCC (1982) observed that these volcanic rocks have not been displaced. Our field inspection confirms the conclusion that the volcanic rocks show no evidence of displacement (Figure 4-3), suggesting that the fault, at least in this part of the study area, shows no evidence of movement post volcanic emplacement (early Eocene).

5. SUMMARY OF FINDINGS

The purpose of the lineament mapping and evaluation is two-fold: (1) to identify potential seismic sources (i.e., crustal faults) that could appreciably contribute to the seismic hazard at the proposed hydroelectric project and affect dam design; and (2) to identify faults and assess their potential for surface fault rupture at or near the proposed dam site area. However, because of unanticipated lack of ground access to private land (e.g., ANCSA) in 2013 (Figure 1-3), not all planned activities were completed during the summer field season. Certain parts of select lineament groups and features in the dam site area will need to be investigated and evaluated to complete this study and to reduce remaining uncertainties.

All lineament groups targeted for 2013 field work received a low-altitude aerial observation, and ground inspection was completed at selected locations (i.e. state and federal lands) where features of interest were identified and ground access was permitted. Based on the work to date and the current access restrictions, the lineament groups are placed into four categories:

- Lineament groups in category I were not advanced for 2013 field observations (FCL, 2013), but where convenient, brief fly-overs in 2013 were performed to visually confirm their placement in category I, with no further work suggested.
- Category II includes the majority of the lineament groups and features evaluated in 2013. Lineaments in this category are judged to be 1) dominantly erosional in origin, 2) related to rock bedding or jointing, or 3) to a lesser extent, a result of constructional geomorphic processes. This category is subdivided in to categories IIa and IIb. Category IIa lineament groups are those which are not evidently associated with bedrock faults. Category IIb lineament groups that do appear to be associated with bedrock faults (Category IIb). For both categories no further work is suggested.
- Category III consists of lineaments which are presently unresolved due to unavailable ground access in 2013, and for which field activities and further evaluation are deferred. This category includes investigation sites most relevant to evaluations of surface faulting in the dam site area and includes the WCC trench T-1 area, Fog Creek area, and dam site and reservoir vicinities.
- Category IV includes lineament groups that have defensible justification for consideration or inclusion as crustal seismic sources in an updated seismic source model. No further field work is suggested.

The overall evaluation and grouping of the lineament groups and features are summarized in Table 5-1 below. Category I includes several lineament groups not advanced for further study based primarily on distance from the site considerations derived from the evaluations in FCL (2012, 2013). Table 5-2 presents a summary of lineament data, observations, and evaluations from the detailed discussions in Section 4.0.

Table 5-1. Summary of Lineament Groups and Areas

Category	Category Description	Lineament Groups
I	Lineament groups that were not advanced for field investigation in 2013 based on FCL (2013) desktop evaluations. Most were not inspected during 2013 field activities.	4, 10, 11, 13, 14, 15, 16, 18, 24, 25, North-South Features near Talkeetna River-Susitna River Confluence
IIa	Lineament groups evaluated during 2013 field studies, and judged to be non-tectonic (dominantly erosional, depositional, or jointing/bedding in origin). No further work is recommended for evaluation as potential crustal seismic sources.	1, 2, 3a, 3b, 5, 12a, 17a, 21a, 21b, 22, 23, select Reger et al. (1990) features
IIb	Lineament groups evaluated during 2013 field studies, and also judged to be of non-tectonic origin, but which appear to be spatially associated with previously mapped bedrock faults. No evidence of Quaternary faulting was observed, and no further work is recommended for evaluation as potential crustal seismic sources	7, 8, 9, 12b, 17b, 17c, 19, 20, Broad Pass area, Clearwater Mountains area, select Reger et al. (1990) features
III	Lineament groups or other areas unresolved due to unavailable ground access in 2013. Field activities and further evaluation are deferred.	6, 26, WCC T-1 area, Fog Creek area, dam site and reservoir vicinities
IV	Lineament groups that have defensible justification for consideration or inclusion as crustal seismic sources in an updated seismic source model.	27 (Sonona Creek fault), Castle Mountain extension

Many of the lineament groups visited in 2013 are judged to be dominantly erosional in origin, or to a lesser extent, related to rock bedding or jointing, are not evidently associated with tectonic faults, and are thus assigned to Category IIa (Table 5-1). These include features in lineament groups 1, 2, 3a, 3b, 5, 12a, 17a, 21a, 21b, 22, and 23. Most of the Reger et al. (1990) photolineament features fall in Category IIa as well. A second set of lineament groups do appear to be coincident with previously mapped pre-Quaternary (i.e. bedrock) faults, but are also interpreted as erosional in origin as no evidence was found for offset or deformation of Quaternary deposits or surfaces. These are assigned to Category IIb, and include lineament groups 7, 8, 9, 12b, 17b, 17c, 19, 20, the remaining Reger et al. (1990) features, lineaments in the Broad Pass area, and lineaments in the Clearwater Mountains area.

Category III features are those that remain relatively unresolved because of the unanticipated lack of access during the summer 2013 field season. This category includes lineament group 6, lineament group 26, as well as WCC T-1 area, Fog Creek area, dam site area and reservoir vicinities. The Category III features are discussed further in Section 5.1.

Category IV lineaments have defensible justification for consideration or inclusion as crustal seismic sources in an updated seismic source model, and consist of lineament group 27 (Sonona Creek fault) and lineaments of the Castle Mountain extension.

Part of lineament group 27 is shown on previously published maps as offsetting Quaternary moraine landforms (i.e. Sonona Creek fault; Figure A27-3.1) and this relationship could not be confirmed nor refuted during aerial and ground field inspection. However, field investigation showed no justification for laterally extending the fault farther than already mapped. Because the Sonona Creek fault was previously included in the preliminary PSHA as a seismic source (FCL, 2012), and did not result in significant contributions to the seismic hazard at the Watana site due to its low slip rate and distance from the site (~ 70 km), there is little value for further field investigation of this lineament group. Based on the new field data, the updated seismic source characterization for the Sonona Creek fault should include an alternative evaluation in which the Sonona Creek fault is considered non-tectonic in order to fully represent the potential uncertainty associated with this fault.

The Castle Mountain extension area includes several lineaments along mapped bedrock structures which appear to constitute a northeastern extension of this known Holocene active fault (Koehler et al., 2012). While Quaternary deposits of appreciable extent and age along these lineaments are lacking, the sharpness of geomorphic expression within the bedrock units was notable. Based on these two observations, it is prudent to consider the lineaments as part of the Holocene-active fault system, and include this within the alternatives considered for an updated crustal seismic source model. Castle Mountain fault provided modest contributions to the total hazard for the Watana site (FCL, 2012), and extension of the Castle Mountain system to the northeast would increase the total fault length of this system and result in minor reduction in the closest distance to the Watana site (~100 km in FCL, 2012). Based on the results from this study, an updated seismic source characterization might consider alternative seismic source models which include potential northeastern extensions of the Castle Mountain fault.

5.1 Unresolved Lineaments and Areas

The unanticipated lack of ground access in certain areas has resulted in a number of potential seismically significant features that remain to be fully addressed during the future studies. These features are shown in Table 5-1 as Category III, and mostly relate to features along the projection of the map trace of the Talkeetna fault, and features identified in areas proximal to the dam site and reservoir vicinity.

Lineament group 6 (~14 km [~9 miles] from the dam site) and the WCC trench T-1 site are along the projection of the map trace of the Talkeetna fault, and ground access was unavailable for the T-1 site area as well as the southern part of lineament group 6 near the Susitna River. To facilitate a thorough investigation of these areas, new additional LiDAR data should be acquired for as an expansion to the existing project LiDAR coverage. Review and interpretation of the LiDAR data will further assist in the evaluation of landscape expression of the Talkeetna fault along lineament group 6 and the WCC T-1 area, and provide a platform for closing the gap on the remaining uncertainties of this mapped fault. This would include evaluation of features in the Fog Creek area, mid-way between lineament group 6 and the WCC T-1 area, where key bedrock outcrops mapped by Acres (1982) appear to define limits on the Talkeetna fault trace.

Based on the work to date, lineament group 26 (2 km [~1 miles] from the dam site) appears to be of erosional origin and not associated with bedrock faults. However, based on its proximity to the dam site, coupled with the lack of access to potentially important stratigraphic exposures in the vicinity of Tsusena Creek, lineament group 26 has been assigned to category III.

Evaluation of the dam site area for potential surface faulting and studies on the reservoir area were not able to be accomplished during the summer 2013 season, and remain to be investigated as access becomes available. For evaluation of potential surface faulting at the dam site and near the reservoir, a key issue is the underlying resolution of the lineament mapping observations from the INSAR and LiDAR DEM data. As noted in Section 3.1 and the individual feature discussions in Section 4, many of the features mapped on the INSAR base map are of a scale larger than would be expected to be associated with low- to moderately-active tectonic features. One aspect of the evaluations of lineaments near the dam site that will be needed for future studies will be more direct on-ground comparisons of the scales of features mapped, and not mapped, on the LiDAR and INSAR DEM datasets in areas where they overlap. These comparisons would be most useful in the areas nearby the dam site and reservoir, along the Talkeetna fault, and in areas such as Fog Creek, and near the WCC T-1 trench site lineament. Such on-ground comparisons would provide a direct basis for evaluation of the resolution of the INSAR and LiDAR DEM data for detection of potential lineaments and tectonic features in key areas near the dam site. The acquisition of additional LiDAR data and geologic mapping on the existing and new LiDAR base maps will be useful to completing this assessment.

Table 5-2. Lineament Data Summarized from Section 4.0

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
1	N	--	51	20	Late Quaternary deposits along the Jack River, of late Wisconsin and post-glacial age intersect the projected trace of the group 1 lineaments near the center of the group 1 ellipse. These late Quaternary deposits show no apparent expression of the lineament. No evidence of fault structure was observed during low-level aerial inspection.	The absence of continuity of the individual lineaments from steep bedrock slopes into areas adjacent areas of lower slopes where Quaternary deposits are present is evidence of non-tectonic origin for these features. The lineaments of group 1 are likely non-tectonic in origin, are judged to be primarily erosional and/or landslide features.	IIa
2	N	--	46	12	Mapped Quaternary surficial sediments, fluvial deposits in several unnamed drainages, a glacial moraine, and an alluvial fan deposit show no apparent deflection or deformation where overlying the projected trace of the lineament group. In all instances, lineaments with clear expression in bedrock lose expression at contacts with Quaternary deposits and landforms.	Based on the irregular apparent throw of the lineaments along strike, lack of western continuity into the Cretaceous Kahiltna flysch, and absence of expression in Quaternary units along the feature, the likelihood of a tectonic origin for the lineaments in group 2 is judged to be low. The limited and ambiguous expression of lineament features outside of the Tertiary volcanic rocks within the Cretaceous flysch, suggests that the observed trend may represent erosion along internal bedrock structure.	IIa
3a	N	--	40	12	The lineaments mapped in Quaternary (post-glacial) deposits along group 3a do not show neotectonic expression or offset. While the group 3a lineaments are mapped across several different geologic units, they appear erosional in origin. The exception to this is the ridge in the Cretaceous Kahiltna flysch in which field observations found a color contrast (Figure A3a.2) that may be structurally-controlled, or may just as equally be stratigraphically controlled.	Lineaments within groups 3a and 3b are not associated with previously mapped faults, are predominantly erosional in origin, and show no evidence of offsetting Quaternary deposits. When considered individually, there is little evidence to support the lineaments as a fault structure. When considered collectively, there is little similarity in their landscape expression across the two groups to support positive interpretation of a linked, through-going crustal structure.	IIa
3b	N	--	27	19	No Quaternary deposits are previously mapped, but ground-based inspection indicate that there are youthful (Holocene) deposits in cirques and drainage valleys, as well as rock glacier deposits. Although these are very young deposits, there are no expression of lineaments in these deposits. The morphology of the lineament is inconsistent along strike, showing north-facing slope breaks, south-facing slope breaks, as well as v-shaped notches.	Lineaments within groups 3a and 3b are not associated with previously mapped faults, are predominantly erosional in origin, and show no evidence of offsetting Quaternary deposits. When considered individually, there is little evidence to support the lineaments as a fault structure. When considered collectively, there is little similarity in their landscape expression across the two groups to support positive interpretation of a linked, through-going crustal structure.	IIa
4	Y	Unnamed fault of Wilson et al. (2009)	23	11	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013)	A limited number of low-altitude fly-overs in 2013 appear to confirm the desktop conclusion that the group 4 features are pre-Quaternary. Rock-type contrasts were observed across the previously mapped NE-trending thrust fault but no prominent tectonic geomorphology to suggest Quaternary activity was observed along strike in post-glacial surficial deposits nor in the bedrock.	I
5	Y	Partial coincidence with an unnamed lineament of Wilson et al. (2009)	40	23	Along its eastern extent, the trend of individual lineament groups is generally parallel to ice-flow direction expressed as fluted and grooved topography in a general east-west orientation. There is no evidence that the ice-scoured surfaces are cross-cut or otherwise offset by the lineaments. Along the eastern extent of the group, the lineaments' morphologic expression as side-hill benches would imply an extensional-type kinematics (i.e., down-to-the-south); along the western extent the morphologic expression varies as both uphill and downhill facing scarps, linear grooves, and drainages that would imply a translational-type kinematics.	While the lineament group does traverse different geologic units and landforms suggesting a continuity of structure, the lineaments show an inconsistent kinematic expression along strike within the same rock unit (Cretaceous turbidites) that tends to not support the presence of a tectonic structure for creating the lineaments. It is judged that the lineaments along group 5 are the result of bedding orientations in the Cretaceous turbidite units and elsewhere from fluvial or glacial erosion, and do not represent a tectonic fault	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
6	Y	Talkeetna thrust fault of Csejtey et al. (1978); WCC, (1982); and Wilson et al. (2009)	14	17	Previous studies result in a fair degree of disagreement as to the location and character of the (inferred) Talkeetna fault in the area of lineament group 6. Field evidence of a fault structure was not observed along or in the immediate vicinity of lineament group 6, and no evidence was observed along the projection of the fault trace and Delusion Creek. The lineaments are expressed as linear drainages or erosional gullies oriented sub-orthogonal to the Talkeetna fault trace(s), and principally are developed in late Quaternary glacial drift (till) and glacio-lacustrine (lake) deposits. Field observations of Quaternary stratigraphic outcrops along Watana Creek suggest that the contact between the overlying lake and underlying till deposits is planar, unbroken, and apparently untilted.	The lineaments mapped within group 6 are judged to be the result of erosion of tributary drainages and fluvial erosion to create terrace risers along the creeks and are not likely tectonically-related. Further, there is an absence of expression of the Talkeetna fault in Quaternary deposits and surfaces present along the uplands adjacent to Watana Creek. However, additional LiDAR data is being collected to provide complete coverage for the area of lineament group 6 and the mapped Talkeetna thrust fault. Additional future work for lineament group 6 should include review of these new high-resolution data to confirm that the current interpretations are still supported.	III
7	Y	Unnamed shear zone of Wilson et al. (2009), a mapped thrust fault (Turner and Smith, 1974; Belkman et al., 1975; Kachadoorian and Moore, 1979; and Clautice, 1990), and a northeast-trending anticline axis Csejtey et al. (1978)	28	17	The lineaments transect young valley floor glacial sediments as well as elevated bedrock ridgelines. There was no field evidence that linear strain markers were deformed or displaced, however the glacial sediments are from rock glacier processes, and few older landforms were observed along this group. The expression of the lineament is inconsistent along strike with an apparent stronger expression where mapped along fluvial drainages, and no expression in WNW-oriented cirque-floors or valleys.	The geomorphic inconsistencies, coupled with the fact that the Quaternary deposits in the valley floors are not disrupted, strongly indicates that erosional process of creek incision and downcutting into surface deposits along the south-flowing drainages are likely responsible for creating the lineaments. Lineaments of group 7 generally coincide with mapped bedrock structures within fault-line-valleys but lineaments in late Quaternary deposits are inconsistently expressed and likely relate to processes of erosion. No evidence of Quaternary deformation was observed.	IIb
8	Y	Coincidence with feature KD5-44 of WCC (1982); Partial coincidence with an unnamed fault of Wilson et al. (2009)	38	26	The lineaments are expressed in ice-scoured bedrock uplands and a thin cover of glacial and colluvial deposits subject to solifluction. Glacial striae north of the Susitna River do not appear consistently deformed or displaced across the trend of the lineament and several small streams that cross the lineaments are not consistently laterally offset or deflected. Aerial inspection did reveal the oxidized mafic dike on the northern canyon wall of the Susitna River that WCC (1982) observed projecting across the observed lineament trend but discovered the same ambiguous and poor exposure conditions described by WCC.	Lineament group 8 does not exhibit relative consistency of geomorphic expression along strike. The apparent structural kinematics (dip-slip) based on mapped contact relations (Wilson et al., 2009) for the middle and southern portion of the group are not consistent with the undeformed contact relations between turbidite rocks of the Cretaceous and Paleocene rocks near the Susitna River, and also the lack of deformation in turbidite rocks north of the river. The evidence supports the origin as a fault-line-scarp (an erosional feature aligned with a mapped bedrock fault).	IIb
9	Y	Coincidence with feature KC5-5 of WCC (1982); Partial coincidence with an unnamed lineament and an unnamed fault of Wilson et al. (2009)	31	24	The mapped lineaments transect mapped bedrock units, but are not expressed in the limited extent of Quaternary surficial deposits present along the group. No lineaments were observed in early Holocene fluvial deposits within a broad depression or across the extent of a post-glacial landslide. Although a rock-type contrast does exist across portions of the lineament, the current mapping compilation may be too simplified and more irregularity of bedrock unit contacts likely exists. The magnitude of expression and apparent sense of deformation observed in the field is inconsistent along lineament group trend.	Based on the mapped geologic contacts along the southern portion of the group, the apparent sense of offset is right-lateral with possible unknown oblique component. This is kinematically inconsistent with the mapping north of the Susitna River because the mapped the contact there between Cretaceous Kahiltna and Paleocene granitics is apparently undeformed and undisplaced where the lineament group projects across the contact. No evidence of expression in Quaternary units, landforms, or strain markers was observed. Lineament group 9 is interpreted to represent a fault-line scarp and not a Quaternary tectonic feature.	IIb
10	N	--	70	27	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) that the lineament group is over 70 km (~44 miles) from the proposed dam site and less than 40 km (~25 miles) long, and likely would not appreciably contribute to the hazard calculations.	During limited flyovers, no features were observed that suggested a need to revise those conclusions.	I
11	Y	Coincidence with an unnamed lineament and an unnamed fault of Wilson et al. (2009)	40	18	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) suggesting that surficial processes are likely exploiting existing topographic position and/or local weaknesses in the underlying Cretaceous Khalinta flysch bedrock to create the lineaments.	Limited overflight of these features in 2013 appears to confirm this conclusion. In addition, the group is greater than 30 km (~19 miles) from the proposed site and is less than 20 km (~12 miles) in length, and likely would not appreciably contribute to the hazard calculations.	I

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
12a	N	--	14	12	The individual lineaments mapped along the north part of the group chiefly are within probable latest Wisconsin-age glacial deposits near the valley margin, and are oriented along the ice flow direction. A prominent notch with an uphill-facing slope break was observed within the Paleozoic rocks along the nose of a ridge. The topographic expression of this lineament feature on the ridge topography implies a northwest-dipping structure geometry, similar to bedded rock exposed on the other side of the mountains. The morphology of the features is kinematically inconsistent along strike, with south-east facing downhill slope breaks found on the lineaments in the Quaternary deposits, and an uphill facing slope break on the bedrock notch feature.	There are no lineaments expressed in the Quaternary deposits along about the southern half of group 12a, and there is visual evidence that right-lateral moraine and kame terrace features at the southern end of the group are not offset. There is no expression of deformation or offset of late Wisconsin landforms in kames or delta surfaces within the valley of Fog Creek directly north. Multiple slope breaks on the hillslope in the vicinity of the mapped lineaments, as well as the lineament orientation parallel to ice flow directions, suggests the lineament group was produced by glacial deposits that are now undergoing solifluction and nivation processes. It is judged that the lineaments within group 12a are the result of both past glacial processes, ongoing hillslope erosion processes, and potentially bedding relationships within the Paleozoic rocks, and do not represent a tectonic fault.	IIa
12b	Y	Unnamed fault of Clautice, (1990)	16	11	The lineaments are expressed chiefly in Paleozoic rocks, however, a thin cover of Holocene regolith mantles the rocks. The morphologic expression of the feature is incised drainages and a very broad and deep valley within which a small creek now flows. None of the glacial geomorphic surfaces in Fog Creek valley (e.g. eskers, deltas) along the southwestern projection of the lineaments were observed to be offset or deformed, and no evidence of deformation was observed at the Susitna River margin along the northeastern projection. The lineament group appears to have a variable geomorphic expression along strike, has weak kinematic indicators along strike.	The lineament is chiefly constrained to within the Paleozoic rocks, and is coincident with the previously mapped bedrock fault, suggesting a potential structural control and preferential erosion along a pre-existing weakness. Internal lithologic control on the geomorphic expression of the lineament also is plausible given the lack of lineament continuity beyond the Paleozoic rocks. The evaluation suggests that glacial and post-glacial fluvial erosional processes are a likely explanation for the origin of the lineament features. Individual lineaments may represent fault-line scarps or fault-line-valleys, but due to the lack of expression in Quaternary deposits, the lineament group is not considered a Quaternary tectonic structure.	IIb
13	Y	Coincidence with unnamed fault of Wilson et al. (2009)	67	15	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) . Also, because of the large distance from the site, the group would therefore likely have limited contribution to the hazard calculations.	During limited flyovers, no features were observed that suggested a need to revise the conclusions of FCL (2013).	I
14	Y	Coincidence with unnamed fault of Wilson et al. (2009)	62	18	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). The group is greater than 30 km (~19 miles) from the site and less than 20 km (~12 miles) in aggregate length, thus meeting lineament exclusion criteria.	A limited fly-over revealed no features that that suggested a need for additional analysis.	I
15	Y	Coincidence with unnamed fault of Wilson et al. (2009)	43	6	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) due to its large distance from the proposed damsite (~43 km [~27 miles]) and short aggregate length (~6 km [~4 miles]).	During limited flyovers, no features were observed that suggested a need for additional analysis.	I
16	Y	Partial coincidence with an unnamed lineament of Wilson et al. (2009)	60	19	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). The group was excluded from further analysis on basis on its significant distance to the proposed damsite (~60 km [~37 miles]) and relatively short aggregate length (~19 km [~12 miles]).	During limited flyovers, no features were observed that suggested a need for additional analysis.	I
17a	Y	Unnamed lineament of Wilson et al. (2009)	24	11	Field investigation revealed that the lineaments in Quaternary deposits at the south end of group 17a do not show scarp-like morphologies; rather one is a small, discordant, creek drainage and the other appears to be a depositional contact of likely late Holocene grassy swale (bog) sediments against a near-surface ice-sculpted bedrock buttress.	Lineament group 17a appears to follow a bedrock jointing pattern that is expressed on landscape, and potentially enhanced by fluvial erosion. Based on the absence of compelling evidence for Quaternary tectonism, lineament group 17a is judged to not represent a tectonic fault.	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
17b	Y	Unnamed lineament of Wilson et al. (2009); and dashed fault of Csejtey (1974)	30	20	The most prominent morphologic expression of the lineaments is a narrow creek drainage that is fed by a perched lake. The lineaments appear to coincide with the trend of glacial ice flow directions that were valley parallel. No direct evidence of a fault along this trend was found in the field.	The ground inspection supports the interpretation that glacial ice was present in the valley. Although there may be a bedrock structure along part of this group that separates Paleozoic and Mesozoic rocks, lineament group 17b is judged to be created at the local scale by fluvial erosion as well as in part by glacial ice erosion of the linear valley and periglacial processes.	IIb
17c	Y	Unnamed fault of Wilson et al. (2009)	45	8	The lineaments are mapped across Tertiary volcanic rocks as well as in young (likely Holocene) rock glacier deposits; the expression within the rock glacier deposits correspond to relatively deep drainages eroded into the rock glacier deposits. None of the faults depicted on Wilson (2009) are shown extending across or displacing Quaternary glacial or moraine deposits.	Along the south end of 17c group the relief along the lineament in the Quaternary rock glaciers is lesser than the middle part of the group, however, the relief in the rock glacier drainage is about 25 meters (~82 ft); much larger than would be expected for a relatively low-slip rate fault structure in young post-glacial deposits. While the presence of a bedrock fault cannot be ruled out along lineament group 17c, it is judged that the mapped lineament is the result of erosion into the rock glacier deposit.	IIb
18	Y	Partial coincidence with two unnamed faults of Wilson et al. (1998)	52	10	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) which concluded that the group's large distance to the proposed damsite and short overall length would likely not appreciably contribute to the hazard calculations.	This group was not visited during the 2013 field inspections and no observations were made that suggested a need for additional analysis.	I
19	Y	Partial coincidence with unnamed fault of Clautice (1990)	54	44	The lineaments of group 19 transect several different geologic units and landforms, but are not present in the post-glacial alluvium of Goose Creek or adjacent drainages. The magnitude of expression of the lineaments ranges from ~10-m-high (~33 ft) downhill-facing slope breaks in glacial deposits of the Black River to gently sloping ~125-m-high (~410 ft) bedrock escarpments. Bedrock exposures in creeks along the lineament showed evidence of pervasive jointing. The lineament group is roughly parallel to glacial ice flow directions in the Black River canyon and spatially coincident with left-lateral ice margins.	The large magnitude of relief across the lineaments in the northeastern portion is inconsistent with the apparent lack of topographic offset across the lineaments in the southwest portion of the group. Specifically, the surfaces of the exceptionally planar bedrock plateau across which the aligned linear valleys run show no evidence of the vertical displacement apparent along the lineament group. It is judged that lineament group 19 is a result of a combination of bedrock jointing and glacial and post-glacial erosion processes, and does not represent at Quaternary fault.	IIb
20	Y	Partial coincidence with unnamed normal fault of Wilson et al. (2009) and fault mapped by Grantz (1960)	94	14	No direct evidence of any of the mapped faults was apparent in the field but indirect evidence in the form of apparent rock type contrasts across mapped fault traces. There is no field evidence of erosion from glacial ice within the area of the lineament group. The mapped lineaments often alternate between weakly expressed and subtle slope breaks and broad troughs and deep and well-defined linear valleys.	Low-level aerial and ground inspection did not reveal any evidence for Quaternary faulting along the mapped lineaments or previously mapped faults. Some of the individual lineaments along the northwestern margin of group 20 do appear to coincide with previously mapped bedrock faults and are likely fault-line scarps developed along bedrock faults, but the remaining lineaments are interpreted to be the result of erosion and not tectonically-related.	IIb
21a	N	--	40	12	Lineament group 21a lies entirely with glaciated terrain at the confluence of possibly four different ice streams. Field inspection confirmed that most of the area has either a surficial cover of glacial moraine and/or glacial lake deposits from a series of glacial lakes. No field evidence of displaced or deformed terrace risers or moraine ridges was observed along the trend of the lineaments. The lineaments of group 21a are few in number, weakly expressed, weakly aligned, and do not coincide with a previously mapped structure.	The lineaments of group 21a do not transect portions of the landscape of different ages which challenges the existence of through-going tectonic structure. The apparent origins of the lineaments are both constructional (terminal moraine complex and eskers) and erosional (linear streams and short slope breaks in dissected glacial moraine ridges. Limited and poor expression of lineaments coupled with both active and stagnant ice processes in the area, point to a non-tectonic glacial origin for the lineaments of group 21a.	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
21b	N	Coincides with a photographic lineament mapped by Reger et al. (1990)	42	12	The lineaments occur as downhill-facing slope breaks in mapped Quaternary glacial deposits (unit Qdt_3 of Smith et al. (1988)) and as linear streams and gulleys eroded into Cretaceous flysch, and to a lesser extent, Cretaceous granite. Map unit Qdt_3 is considered to be of late Wisconsin age (11,800 to 25,000 year B.P.). The lineament group is oriented perpendicular to the ice flow directions within the Butte Creek valley. Inspection of the stream banks and terrace risers located to the west along the trend of the feature did not reveal any displaced terrace risers or surfaces.	Field investigation did confirm the expression of the 3-km-long, downhill-facing slope break in Quaternary glacial deposits but did not reveal any exposures of the spatially-coincident concealed schist-phyllite contact mapped by Smith (1988). The group 21b lineament most likely relates to the rock type contrasts mapped by Smith et al. (1988) where higher grade (and more resistant) schist lies upslope of the slightly lower grade (and less resistant) phyllite and is overlain by a thin veneer of Quaternary glacial deposits. The lineaments of Group 21a are judged to be non-tectonic in origin and likely relate to differential erosion along depositional contacts within bedded metasedimentary rocks.	IIa
22	N	Spatially coincides with several northwest-trending photogeologic lineaments from Reger et al. (1990)	27	17	The lineaments are mapped in Reger et al.'s till of late Wisconsin age (unit Qd3; 9,500 to 25,000 years old) (Reger Public Data file 90-1), and are expressed in the field as linear erosional gullies. Much of the hillsides appear to be influenced by solifluction processes. Along Deadman Creek, the lineaments are nearly orthogonal to the ice flow direction, and no offsets in the lateral moraines were observed.	The lineaments of group 22 show a dearth of expression in Quaternary deposits, other than being associated with two linear drainages. While the lineaments transect several different geologic units, suggesting some lateral extent, we find that the magnitude of expression along strike is highly variable. Because there is no fault previously mapped along this group and no evidence of a fault was observed, coupled with the field observations of solifluction processes as well as a distinct lack of faulting expression in the late Wisconsin glacial deposits, it is judged that lineament group 22 is not a fault.	IIa
23	N	--	62	17	The features along the lineament trend occur entirely within mapped Quaternary glacial and lake deposits of the Copper River Basin. The lineaments do not coincide with any previously mapped faults or lineaments (FCL, 2013) and low-level aerial inspection did not reveal any direct evidence of tectonic structures anywhere along the lineament, including in the near-vertical cut banks of Tyone Creek. The orientation of the mapped lineaments is parallel to several north-south oriented drumlins, and perpendicular to regional ice-flow directions, but parallel to and locally coincident with terminal moraine crests	The arcing alignment and the consistently low relief morphology of the aligned slope-breaks, low mounds, and short linear ridges does appear similar to a terminal moraine complex. The positive relief of these features suggests constructional or depositional geomorphic processes, rather than via tectonic processes, may have played a role in their formation. The lineament group lies within published glacial lake extents and elevations in the Copper Basin. The evidence points to a genesis via glacial processes, and does not support a tectonic genesis. It is judged that lineament group 23 does not represent a tectonic fault.	IIa
24	Y	Partial coincidence with lineament of Wilson et al. (2009)	120	14	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) that the lineament group is short (~15 km [~9 miles]) and lies a great distance from the damsite (~120 km [~75 miles]), and likely would not appreciably contribute to the hazard calculations.	This group was not visited during the 2013 field inspections and no observations were made that suggested a need for additional analysis.	I
25	N	--	23	32	This lineament group was not advanced for field work in 2013 based on the desktop analysis of FCL (2013). The lineament group was interpreted to be the result of erosional and depositional processes, chiefly the apparent alignment of several large, curvilinear glacial valleys.	During limited flyovers, no features were observed that suggested a need to revise those conclusions.	I
26	N	--	16	13	Neither direct nor indirect field evidence of fault structures were observed along this lineament group. South of the Susitna River, the lineaments are mapped in glacially-sculpted terrain that shows geomorphic landforms indicative of stagnant ice. North of the Susitna River, the lineaments principally are mapped in a linear drainage in whose upper banks are exposures of till that overlies lacustrine and fluvial deposits. The lineament group is relatively discordant with the ice flow direction. Assessment of kinematics of the lineament morphology is indeterminate because there a near absence of geomorphic expression of tectonic-related features.	An esker landform on the south side of the Susitna River appears to be continuous where it extends across the mapped lineament, indicating no deformation since its emplacement. Because of the absences of previously mapped structures or faults, the lack of field evidence of faults, and the apparent positive evidence for non-faulting or displacement vis-à-vis the undeformed esker deposit (>11 ka in age), it is judged that the lineament group is erosional in origin and does not represent a fault structure. However, ground access for this lineament group was restricted during the 2013 field investigations, and due to the close spatial proximity to the dam site, this lineament group warrants additional study to confirm the absence of bedrock structure along these features.	III

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
27	Y	Coincidence with Sonona Creek fault mapped by Williams and Galloway (1986)	62	50	The lineament is expressed in late Quaternary glacial drift and glacial lake deposits as a series of aligned lakes, linear lakes and swales, vegetation lineaments, low-relief (~2-m-high) ridges, but the apparent sense of displacement is not consistent along the lineament group. Williams and Galloway's (1986) depict the Sonona Creek fault as truncating, cutting across, and also terminating into different ridges of the Tolson Creek moraine complex. Ground investigation and aerial inspection of the Tolson Creek moraines did not reveal perceptible lateral or vertical deformation along the projection of the mapped fault	The expression of lineaments in a portion of the landscape judged to be the youngest, and the absence of observed deformation (lateral or vertical) in the adjacent Tolson Creek Moraines, which are older, is inconsistent with an origin by faulting. Field investigation did not reveal any definitive evidence to strongly refute nor strongly support the presence of the mapped portion of the Sonona Creek fault. The field observations from this study favor a non-tectonic interpretation for this feature, but are not sufficiently strong to rule out the potential of late Quaternary faulting.	IV
Broad Pass Fault Area	Y	Coincidence with dashed faults mapped by Csejtey (1961) and Wilson et al. (1998)	56	Several; various lengths	A strong fabric of northeast-trending glacial features characterizes the geomorphology in the Chulitna Valley, with numerous landforms such as drumlins, and glacial striae occurring throughout the valley. Existing geologic mapping depicts pre-Quaternary faults that apparently place Paleozoic and Mesozoic rocks against each other, or Paleozoic and Mesozoic rocks against Tertiary sedimentary rock units. These older rocks are in turn overlain by Quaternary glacial and fluvial sediments that are no older than late Wisconsin age. Several locations were investigated as part of the assessment of previously mapped faults in the Chulitna River valley. Faults mapped as bounding Tertiary units could not be confirmed due to lack of exposure.	Low altitude fly-overs of the partly-forested, partly-wetland surface of the Chulitna valley found no evidence of Quaternary faulting, and the surficial geology and geomorphology observed was uninterrupted and undeformed. This argues that the deposit has not experienced tectonic deformation since its emplacement, supporting an interpretation of no late Quaternary or post-glacial faulting. The lineaments mapped within the Chulitna River valley are oriented along the direction of ice flow, and generally are located along the margins of geomorphic features (e.g. drumlins, kettle edges) that are genetically related to glacial flow and related processes. Thus, none of the lineaments mapped in this area are considered tectonic in origin.	IIb
Clearwater Mtns Area	Y	Coincidence with faults mapped by: Smith (1981), Silberling at al. (1981), and Csejtey et al. (1992)	63	Several; various lengths	The lineaments are both discordant and concordant with glacial ice-flow directions; some lineaments may be expressing the ice-limit elevations at the bedrock-glacial moraine contact. No field evidence of deformed Quaternary-age linear strain markers along the trend of mapped lineaments or faults was observed. Field investigation did not reveal any through-going and laterally continuous aggregations of individual lineaments or tilted tectonic markers (such as shorelines or terraces) at the southern foot of the mountains that could be definitively linked to a tectonic origin. Post-glacial landforms and deposits did not express any lineaments and appear undeformed.	Indirect evidence of fault structure was observed in several locations within the core of the Clearwater Mountains in the high elevation bedrock terrain above the valley floor in the form of contrasting rock-type juxtapositions that corroborate the general locations of the mapped faults. No field evidence of Quaternary activity along the mapped traces of the Talkeetna thrust, westward extension of the Broxson Gulch, or Black Creek faults was observed. The lineaments mapped along the southern slopes of the Clearwater Mountains do not coincide with previously mapped faults and are interpreted to be of non-tectonic origin, and likely is originated by glacial processes and the morphology of left-lateral moraine deposits.	IIb
Castle Mtn extension	Y	The Castle Mountain fault is a Quaternary seismogenic structure (Koehler et al., 2012)	100	21	Field evidence for faulting observed during low-level aerial inspection includes: apparent bedrock type juxtapositions, bedrock color change associated with alteration zones, and deformation of bedrock units. All apparent evidence was observed in bedrock and no linear expression or evidence of faulting was observed in Quaternary deposits, although Quaternary deposits were scarce. Quaternary deposits in the vicinity of the Castle Mountain fault extension lineament group have limited spatial coverage and most commonly occur as fluvial deposits found within in narrow canyons. Because of the limited exposure of the Quaternary deposits and the segmented and splayed characteristics of the mapped faults in this area, it is difficult to declare that all segments of this fault exhibit no Quaternary activity.	Although a core group of lineaments within this group coincide with mapped faults, others do not. The mapped lineaments that do not coincide with previously mapped faults are attributed to be linear drainages (erosion features) and lineaments related to structural grain of the bedrock (lithologic control). No definitive evidence was encountered that precludes a scenario where this segment of aligned features ruptures as an extension of the Castle Mountain fault. If the group of aligned features acts as an extension of the Castle Mountain fault, it could extend the fault by approximately 21 km (~13 miles) to the northeast of the current mapped extent of the fault as shown in Koehler et al. (2012). Based on the observations that these features are clearly related to faulting of late Cenozoic age, we suggest adding this segment of fault-related features to the crustal seismic source model as a northeast extension of the Castle Mountain fault rupture scenario.	IV

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
North-South Features near Talkeetna River-Susitna River Confluence	Y	Unnamed, normal faults are identified in previous mapping by Wilson et al. (1998; 2009)	85	43	This area was not advanced for field work in 2013 based on the desktop analysis of FCL (2013) on the basis of the features' large distance (i.e., >70 km [>40 miles]) to the proposed dam site and their poor expression in the surrounding Quaternary sediments and Tertiary granodiorite outcrops as manifested in the INSAR data.	This group was not visited during the 2013 field inspections and no observations were made that suggested a need for additional analysis.	I
Reger's (1990) Photogeologic Lineament Features							
R1	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	20	2.25	At its southern extent, this lineament is mapped across Quaternary age landslide (Qct) and rock glacier (Qcg) deposits within a narrow south facing cirque. On the ground, this lineament is expressed as a mild inflection in the slope angle. Down drainage, to the south, the lineament has no expression in the valley floor sediments.	This linear feature is coincident with the linear toe of a rock glacier advancing downslope from the eastern cirque wall. The linear trace through the Quaternary deposits shows no evidence of being caused by a tectonic feature.	IIa
R2	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	25	1	A northwest trending photo-lineament mapped over a quartz monzonite gneiss (TKqmg) and paragneiss (TKpng) bedrock ridge and terminated in Wisconsin age till (Qd3) at its northwest extent. The mapped trace of the feature overlies obliquely oriented linear glacial striations within the bedrock. No clear linear expression with the same orientation as the mapped lineament was observed in the terrain. Quaternary deposits at the northwest and southeast extent of the mapped lineament were visually inspected, and no linear expression was observed.	It appears likely that the lineament represents a collection of small and unrelated linear features such as: vegetation lineaments, glacial features, joints/bedding rather than having a tectonic origin.	IIa
R3	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	25	3	A west-northwest trending photo-lineament mapped across Wisconsin age till (Qd3), moraine (Qm3), and abandoned meltwater channel alluvium (Qac) deposits. The western and central segments of this lineament are coincident with two prominent breaks-in-slope on the northeastern margin of a U-shaped glacial valley. The eastern portion of the feature is coincident with a linear to semi-arcuate moraine. The lineament has no expression within the Qac deposits near the center of the mapped trace.	The mapped lineament is expressed by two prominent slope breaks and a linear trace coincident with a moraine crest. This evidence indicates that the mapped trace correlates with glacial features and is likely non-tectonic in origin.	IIa
R4 & R5	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	28	1	A clear expression of these sub-parallel faults was not observed in the bedrock during low altitude aerial inspection. Intersecting Quaternary (Qd3) deposits were observed to have no linear expression or fault related deformation.	Lacking evidence of Quaternary age deformation, these features are not considered to be active structures.	IIa
R6	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	34	4.5	The central portion of the lineament correlates to a prominent break in slope and juxtaposing bedrock and Quaternary deposits (apparent down-to-east). The northern extent of the lineament is expressed by a subtle west facing slope and linear valley. The southern extent is mapped over the crest of a bedrock knob and exhibits an apparent down-to-east sense of motion. No expression of the lineament was observed within Quaternary deposits.	The inconsistent expression of apparent vertical displacement along the mapped trace and a lack of geomorphic expression indicative of strike-slip faulting suggest that a tectonic origin is highly unlikely. This lineament appears to represent a collection of unrelated features.	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
R7	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	27	5	A sinuous east-northeast trending photo-lineament mapped over quartz monzonite gneiss (TKqmg), quartz monzonite (Tqm) bedrock and Wisconsin age till (Qd3) deposits. A pegmatite vein is mapped, unbroken, across this feature at its intersection with the Feature 8 lineament. Linear expression within the Quaternary deposits was observed to be a linear drainage (western segment) and an alignment of solufluction lobes (eastern segment)	In aggregate this lineament is a collection of aligned and unrelated non-tectonic features: linear drainages, linear erosional features, and aligned solifluction lobes.	IIa
R8	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	29	5	A slightly arcing west-northwest trending photo-lineament mapped over a quartz monzonite gneiss (TKqmg) bedrock ridge and Wisconsin age till (Qd3) deposits. On the western side of the ridge, the feature intersects the northern extent of a mapped fault that has no expression in Quaternary deposits. Two mapped pegmatite veins are mapped, unbroken, across this feature. This lineament is made prominent by a very large southwest facing topographic scarp along a linear drainage on the west side of the ridge, and a linear drainage on the eastern side of the bedrock ridge	Low altitude aerial observations revealed that the topographic scarp is approximately 10-20m in height and likely an erosional feature related to solifluction. The scarp has a limited extent and is not expressed in any other bedrock segment or Quaternary deposit along Feature 8.	IIa
R9	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	29	5.75	A northwest trending photo-lineament that is mapped over Wisconsin age till (Qd3), alluvial fan (Qaf), and moraine (Qm3) deposits. The feature is coincident with numerous glacial related features. At one location near the center of its mapped trace, the lineament is overprinted with a Quaternary age alluvial fan. No trace of the lineament was observed within the alluvial fan deposit.	The lineament is created by an alignment of non-tectonic glacial features: a linear moraine, solifluction features, and glacial striations in bedrock and along the valley margin.	IIa
R10	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	26	10.5	The lineament is mostly composed of linear drainages, linear moraines, and breaks in slope. The breaks in slope in the north and south display an opposite sense of displacement (down to east) than the middle slope (down to west). Geomorphic features indicative of oblique or strike-slip faulting were not observed. Alluvial deposits within of the intersecting glacial valley (southern portion of the trace) and the glaciated plain (mid to northern segment of the trace) show no clear evidence of linear expression.	The opposing sense of apparent vertical displacement along the trace of the fault and lack of geomorphic indicators for strike-slip faulting is an argument against this feature having a tectonic origin. The mapped trace appears to depict a linear alignment of unrelated non-tectonics features.	IIa
R11	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	32	3.25	Observations made during low altitude aerial inspection showed that the mapped trace of this lineament is coincident with an alignment of moraine crests and linear erosion features. The lineament was not observed in any of the intersecting Quaternary deposits	This lineament represents the alignment of glacial features.	IIa
R12	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	34	1.25	The western and central segments of this lineament are coincident with linear drainages (erosion features). In its eastern extent, the mapped trace of the lineament is coincident with the linear flank of a rock glacier over an older rock glacier.	This lineament represents both erosional and glacial features.	IIa
R13	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	37	0.25	A north-northwest trending fault mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and terminates at Quaternary age rock glacier (Qcg) and Quaternary landslide (Qct) deposits. Dike swarms (Tgr-d) are mapped across the project path of this feature, unbroken. Observations from low altitude aerial inspection showed no expression of faulting within Quaternary deposits	Lacking evidence of Quaternary age deformation, this feature is not considered to be a Quaternary structure.	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
R14	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	38	1	A north-northwest trending photo-lineament mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and Quaternary age landslide (Qct) and rock glacier (Qcg) deposits. This feature is along strike with, and it appears to be mapped as a possible northern extension of the Feature 13 fault. This lineament is formed by a linear drainage within a rock glacier in a narrow, south facing, cirque and an aligned saddle. Low altitude aerial inspection observed no evidence for faulting along this linear alignment	Field observations indicate that this feature is a linear drainage and is erosional in origin.	IIa
R15	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	39	1.5	A north-northwest trending fault mapped in Basalt, Rhyolite, and Agglomerate (Tvfa) bedrock and Quaternary glacial till (Qd) deposits. Low altitude aerial inspection observed the fault in bedrock outcrops on the mountain slopes and through a saddle. No expression of the fault or fault related deformation was observed in Quaternary (Qd) deposits in the valley floor or in an overlying rock glacier.	Lacking evidence of Quaternary age deformation, this feature is not considered to be an Quaternary structure.	IIa
R16	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	42	0.75	A northwest trending fault juxtaposing Tertiary Quartz Monzonite (Tqm) against Cretaceous Kahiltna Terraine Argellite, Sandstone, and Siltstone (KJs) bedrock and over Quaternary landslide (Qct) and till (Qd) deposits. This fault is along strike with, and north of, the Feature 15 fault. The two features are separated by a glacial valley. Low altitude aerial inspection observed evidence of faulting in bedrock at a ridgeline saddle near the center of the lineament, confirming the presence of the fault along the mapped trace. The Quaternary deposits (Qct, Qd) on the floor of the glacial valley and lower flanking slopes were observed, and no linear expression or evidence of tectonic deformation was observed.	Lacking evidence of Quaternary age deformation, this feature is not considered to be a Quaternary structure.	IIa
R17	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	42	2.25	A northeast trending photo-lineament mapped in Kahiltna Terraine Argellite, Sandstone, and Siltstone (KJs) bedrock and across Quaternary landslide (Qct) and unlabeled (till and/or moraine?) quaternary deposits. The mapped trace of the lineament crosses the till and moraine(?) deposits; however no clear through-going linear expression was observed during low altitude aerial inspection.	The mapped trace is coincident with, and most likely defining aligned and subtle slope inflections and linear drainage channels within the Quaternary deposits. The field observations found no evidence to support a tectonic origin for this feature.	IIa
R18	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	42	0.5	A northwest trending photo-lineament mapped in Kahiltna Terraine argellite, sandstone, and siltstone (KJs) bedrock and Wisconsin age till (Qd3), and unlabeled (till and moraine?) deposits. The mapped trace of the lineament is coincident with a topographic break-in-slope (apparent down-to-northeast) in bedrock. This lineament is parallel/sub-parallel, and along strike to the northwest, to a (down-to-northeast) normal fault mapped by Reger et al (1990). The two features are separated by a northeast trending glaciated valley. Low altitude aerial inspection observed an apparent fault exposure, in bedrock, at a topographic break-in-slope along the ridgeline. Quaternary deposits between Features 18 and 20 were inspected and found to be undeformed and lacking any linear expression.	Evidence indicates that this lineament is likely a continuation of the bedrock fault trace mapped to the southeast. However, lacking evidence of Quaternary age deformation, this feature is not considered to be an active structure.	IIa
R19	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	43	1	A northeast tending photo-lineament mapped in unlabeled. Quaternary (till and moraine?) deposits. Low altitude aerial inspection showed that the mapped linear trace correlates with a vegetated linear drainage. The lineament is made more prominent by the color contract between the vegetation and the surrounding rocky ground surface.	Observed to be an erosional feature this lineament is likely non-tectonic in origin and not considered further.	IIa

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R20	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	41	1	A northwest striking photo-lineament mapped across orthogneiss and migmatite (TKgm) bedrock and Quaternary age undifferentiated colluvium (Qc) deposits. Low altitude aerial inspection confirmed that the mapped linear trace correlates with a linear drainage and has expression only in bedrock. No linear expression was observed in Quaternary deposits along the projected path of the feature.	Observed to be an erosional feature this lineament is not considered further.	IIa
R21	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	38	2.25	A northwest trending photo-lineament mapped over quartz monzonite (Tqm) bedrock and morainal deposits of Late Wisconsin age (Qm3). Low altitude aerial inspection showed that this lineament is composed of a collection of aligned feature. The northern and central segments of this feature are a bedrock ridge crest leading to a linear drainage. The southern extent, in Quaternary deposits, was observed to be the crest of a debris flow levee which bounds the linear drainage	This lineament represents a collection of aligned, non-tectonic features and is not considered further.	IIa
R22	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	45	0.75	An east-northeast trending photo-lineament mapped within a deposit of colluviated till of Illinoian age. Low altitude aerial inspection observed no clearly defined linear expression to correlate with the mapped lineament.	It is likely that the mapped trace represents a color contrast created by glacial till along the crest of a low-relief ridge separating two drainages. Likely non-tectonic in origin this feature is not considered further.	IIa
R23	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	46	3.75	An east-northeast trending photo lineament mapped across paragneiss (TKpgn) bedrock and morainal deposits of late Wisconsin age (Qm3), and till of Illinoian age (Qd2. Low altitude aerial inspection observed that the mapped trace of the lineament correlates with topographic scarps and linear solifluction features. Along strike, the topographic scarps were observed to express an opposing sense of vertical displacement (down-to-northwest and down-to-southeast). Geomorphic expression indicative of strike-slip or oblique faulting was not observed. No linear expression or scarps were observed within the intersecting Quaternary deposits.	The geomorphic expression of this lineament is composed of an unlikely combination of features to support a through-going tectonic structure with vertical displacement, and it lacks geomorphic expression to support strike-slip faulting. This lineament appears to be a collection of coincidentally aligned linear features and caused by solifluction and erosion.	IIa
R24	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	44	4	A northwest trending photo-lineament mapped in paragneiss (TKpng) bedrock for most of its length except for the northern extent where it is mapped within Quaternary age talus (Qct) deposits in an east-facing cirque. Low altitude aerial inspection of the lineament revealed that in bedrock the mapped trace consists of an alignment of variably-scaled, linear swales. In the Quaternary deposits the lineament corresponds to a linear drainage. Scarps and vertical displacement were not observed in the cirque floor described by Reger et al. (1990) and no evidence of tectonic origin was noted for this feature.	This lineament represents a collection of aligned non-tectonic features. The linear swales appear to be glacial in origin, and other segments of this lineament are formed by a linear drainage (erosional feature).	IIa
R25	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	43	1.25	An angled northwest trending photo-lineament. The lineament is mapped over paragneiss (TKpgn) bedrock and late Wisconsin age till (Qd3). Low altitude aerial inspection revealed that the mapped trace is coincident with a shallow linear drainage that is highlighted by an apparent vegetation color contrast.	Being an erosional feature, these field observations indicate that this feature is likely non-tectonic in origin.	IIa

Group Number	Previously Mapped? *	Source of Previous Mapping	Approximate Distance to Dam Site† (km)	Approximate Length of Group (km)	2013 Lineament Summary Observations	2013 Lineament Summary Interpretations	Lineament Category
R26	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	41	3.25	An east-to-west trending photo lineament mapped over bedrock for its entire trace except for the far western end. At this location it is mapped over a Quaternary age talus deposits before it is terminated against a bedrock knob in the center of the cirque. Visual inspection of the lineament revealed no clear linear trace through the talus deposits.	Within the cirque the only along-strike linear trend is attributed to a linear drainage incised into bedrock. The mapped trace appears to represent an erosional feature and is not considered further.	IIa
R27	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	40	2	An east-to-west trending photo-lineament mapped over paragneiss (TKpgn) bedrock in its middle portion and Quaternary talus (Qct) deposits on its eastern and western extents. Within bedrock, no continuous linear features were observed that correspond with the mapped trace of Feature 27. Within Qct, the only observed linear expressions were related to linear drainages.	The only linear expression observed in the vicinity of the mapped trace was a linear drainage (erosional feature) and non-tectonic in origin. This feature is not considered further.	IIa
R28	Y	Reger, 1990, Geologic Map of the Healy A-3 Quadrangle, Alaska. Alaska Division of Geological and Geophysical Surveys, Public Data File 90-1 sheet 1 of 2	39	2.5	A north-northwest trending photo-lineament mapped over orthogneiss and migmatite (TKgm) bedrock and Quaternary age colluviated till (Qdc3). During low altitude aerial inspection the feature was observed to be characterized by a shallow liner trough oriented at an obliquique angle to linear solufluction features and moraines, possibly indicating that this feature is related to bedrock structure. However, it has no expression in overlying Quaternary deposits or within adjacent Quaternary till deposit to the southeast.	Lacking evidence of Quaternary deformation, this feature is not considered to be an active structure.	IIa

Notes: *Y = yes, N = no.

†Distance value represents the approximate distance to the portion of the lineament group nearest to the dam.

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