- Seattle Creek (North)
- Butte Creek (East)

4 Screening

The Watana Transportation Access Study used a two-tiered screening process. Step 1 was an initial screening based on the initial office study and field reconnaissance. The five corridors (four road and one rail) described in Section 3.3 were evaluated in the Step 1 screening process. This initial screening resulted in the selection of three road corridors for further consideration and the elimination of one road corridor and the one rail corridor. Step 2 screening consisted of a more detailed evaluation of those three potential access corridors. Section 4.1 presents the results of the Step 1 screening and Section 4.2 presents the results of the more detailed Step 2 screening.

4.1 Step 1 Screening

The first level of screening was to perform a preliminary evaluation of each corridor to identify if there were any corridors that were so unsuitable that they would not warrant further consideration to study in more detail. The Step 1 evaluation used the criteria described below to assess each corridor:

Land Status: This criterion evaluates the general land ownership and status along the corridors. In general, all corridors represent a mixture of land ownership including State, Federal, Native, and private properties. The corridors originating from the Denali Highway (Seattle Creek and Butte Creek) generally have State and Federal lands along the majority of the corridor, with Native Corporation land near the proposed dam site. The corridors originating in the Parks Highway/ARRC corridor (Hurricane (West), South Road, and South Rail) have additional impacts to Native land along the routes. While the potential impacts to the various land owners and right of way (ROW) acquisition time varied across the corridors, it was determined land status alone was not sufficient to screen out any corridors during Step 1.

Creek Crossings: All corridors traverse numerous drainages along their routes. These creek crossings were identified in an office study and were evaluated as part of the field reconnaissance. The number of crossings varied by corridor, but no corridor presented a significantly larger number of crossings than the others.

Mode Evaluation–Rail Versus Road: The corridors were screened by mode to evaluate the relative efficiency of roads versus rail to support the construction and operation of the dam. Some of the key differences between the two modes are:

> ***Material handling***. A rail corridor potentially reduces the number of times construction materials would need to be handled. The materials would be loaded on the train in Anchorage (or other Port of Entry/point of origin) then unloaded at the project site. Road access to the project site would require materials shipped by rail to be offloaded at a railroad siding (at Gold Creek, Hurricane, or Cantwell), placed in a large lay down yard, and then loaded and transported by truck to the project site.
>
> ***Ease of Access***. A rail-only access to the project site is not as convenient as road access because travel to the site must be scheduled to prevent rail traffic conflict on the rail line. Rail sidings could be used to manage traffic conflicts, but these improvements come with additional construction and operational costs. To make managing the rail traffic more

efficient, the rail line would need to be signalized and an electronic train management system put in place. Road access is more convenient than rail access, because dispatching a truck can occur at essentially any time and two-way traffic is more easily accommodated. Rail-only access to the project site would restrict public access along the corridor, which has the potential to reduce access-related impacts (such as the increased potential for hunting and fishing) associated with the proposed project.

Steep grades. Due to the terrain in the project area, the track grades along the route are steeper than the existing rail grades between Anchorage and Gold Creek. Therefore, trains would likely need to be split into smaller sections or additional locomotives would be necessary in order to pull the train from Gold Creek to the project site.

Per mile construction cost. The rail alternative is longer than the shortest road route by approximately 20 miles and is approximately 10 miles longer than the closest road route (South Road). On a per mile basis, rail infrastructure is generally more expensive than road infrastructure. While the embankment the track is built on is narrower than the road embankment, the cost for the track, rail, ties, and subballast makes the per-mile cost for the rail line higher than the per-mile cost for the road. For this project, we estimated this cost differential to be approximately $1 million per mile.

Operation costs. Rail transportation (excluding capital expenditures) is generally less expensive per mile of material transported than truck transportation.

Figure 4-1. Sloughing soils in the South Rail alignment

Vehicle cost and availability. The cost of rolling stock is higher than the cost of large trucks. Additional equipment may need to be purchased if ARRC cannot accommodate the project demands with their existing inventory. Additional trucks are easier to acquire than additional rolling stock.

Vehicle maintenance. Truck fleets are more readily serviced and maintained than rail rolling stock and the cost of maintenance is considerably less.

Logistics. A detailed logistics plan was not developed as part of this study, so evaluating the differential cost of construction between road and rail modes could not be assessed. The difference between the conveniences of the two modes could not be quantified at this level of study either, although road transportation would provide more flexibility for construction and operation of the dam.

Range of* M*agnitude (ROM) cost[11]. The cost of constructing a mile of rail was estimated to be $2.5 million and the cost to construct a mile of road was estimated to be $1.5 million.

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[11] A more comprehensive cost estimate for these screened-out corridors that was performed using prorated costs from the remaining corridors substantiated the removal of the South Rail and South Road corridors from further consideration.

These construction costs per mile are representative of the average of all alternatives. Individual alternative costs per mile will vary based on terrain. For a breakdown of terrain classification by alignment, please refer to the cost estimate appendix, Appendix D. For 60 miles of rail, this results in a construction cost of $150 million. The cost to construct 50 miles of roadway is estimated to be $75 million.

Since these costs are ROM metrics, these cost differentials were not deemed sufficient to dismiss the South Rail corridor without support from other additional screening criteria.

Field Reconnaissance: Aerial reconnaissance was performed to validate the corridor selections, and to identify locations where the alignments should be modified or whether there were fatal flaws associated with either alignments or variants on the alignments. Reconnaissance focused on each corridor's terrain, geologic conditions, and drainage characteristics. While the majority of the corridors have similar terrain, the South Rail and South Road corridors have deeply incised drainages (estimated at 200 feet deep) that are not present in the other corridors. The adjacent banks were observed to have sloughing soils and consist generally of poor foundation materials for bridges. The distance from bank to bank was estimated to be greater than 200 feet, and bridge abutments would likely have to be 50 to 100 feet from the top of the bank because of the poor quality founding materials. This would result in bridges with mainspans of 300 to 400 feet. Spans of this length necessitate the use of truss bridges for rail crossings and long steel plate girders or similar bridges for road crossings. While these crossing are technically feasible, the cost of these structures is typically more than two to three times the cost of bridges with span lengths less than 150 feet.

Construction Schedule: Because of the size and complexity of the bridges on the South Rail and South Road corridors, the construction schedule would be severely impacted. At a *minimum*, the South Road and South Rail alignments would take at least one additional year to construct than the other three alignments. It would also take at least two years for a pioneer road to be built along the South Road alignment to the dam site. The completed road is likely to take an additional one to two years after the completion of the pioneer road. A pioneer type of access would not be possible on the South Rail alignment. It would be approximately three to four years before trains could access the Watana dam site.

Conclusion: Based on cost (rail, ballast, major bridge crossings), time for construction of initial access, overall construction schedule, and convenience of travel, it was determined that rail was not the preferable mode of access to the Watana dam site and was dismissed from further consideration.

4.2 Step 2 Screening

The Step 2 screening analysis applied more refined criteria than the Step 1 screening analysis to each of the four remaining corridors (South Road, Hurricane [West], Seattle Creek [North], and Butte Creek [East]). The project team identified screening that could be assessed, either qualitatively or quantitatively, and compared between corridors. In general, the analysis was performed based on the centerline for each corridor, which represents the most likely spot for the access road given the available information. The results of the analysis presented in this report may change as the centerline is refined and more detailed information is collected. Criteria were identified and evaluation was performed for engineering, geological and geotechnical conditions, hydrology, fish streams and waterbodies, terrestrial resources, wetlands and vegetation, resource use, land status, cultural, socioeconomics, costs, and permittability. These evaluation areas were selected because of the potential effect they may present to the project costs, necessary land acquisition, project timeline, environmental considerations, impacts to stakeholders, and project permitting. Each category included a number of specific criteria. Each of the criteria and a summary of each corridor's performance are described below.

4.2.1 Engineering

4.2.1.1 Terrain Types and Roadway Grades

Several studies were conducted to assess the terrain and original ground profiles along the alignments for the corridors[12]. Terrain and ground profiles along the alignments were classified as level, rolling, or mountainous according to the values in Table 4-1. Terrain classification was assigned by meeting either the ground profile or cross slope criteria. For example, terrain may be classified as mountainous if it has a level ground profile but a cross slope of greater than 18 percent.

Table 4-1. Terrain classification criteria

Classification	Ground Profile Along the Alignment (% grade)	Cross Slope Along the Alignment (% grade)
Level	0–7	0–14
Rolling	7–12	14–18
Mountainous	>12	>18

In level terrain, horizontal and vertical alignments are controlled by the appropriate design speed and sight distance. Rolling terrain starts to affect vehicle operation, particularly larger vehicles, as the roadway profile grades rise and fall more steeply. In mountainous terrain, the elevation changes are more severe and usually affect the ability to construct the desired horizontal and vertical geometry. Alignment grades should be minimized, when possible, to maximize the performance and operating efficiency of the access route.

Terrain Slope: GIS was used to shade the corridors based on the steepness of the terrain. This was done to provide a visual representation of the terrain in the roadway corridors. Alignments were adjusted to avoid areas of steep terrain, where possible, to minimize steep grades and sidehill cuts. See Appendix E for terrain slope figures.

Terrain Classification: For estimating purposes, the terrain for the alignments was classified into level, rolling, or mountainous categories. The classification of the terrain for each alignment is shown in Table 4-2 and on Figure 4-2.

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[12] Unless otherwise noted, analyses were conducted on new alignments only.

Table 4-2. Terrain classifications

Corridor	Terrain Classification (in miles)			Total Length
	Level	Rolling	Mountainous	
South Road	12.4	14.5	27.8	54.8
Hurricane (West)	13.5	14.1	24.2	51.7
Seattle Creek (North)	20.9	15.9	6.5	43.3
Butte Creek (East)	25.1	7.8	9.2	42.0

Red = Not preferable **Green = Favorable**

Original Ground Profiles: Profiles of the existing groundline for each corridor was produced using Civil 3D. Profiles for existing groundlines were created along the centerline of the alignment, and 300 feet right and left of the alignment. The purpose for creating a profile 300 feet right and left of the alignments is to give a representation of the terrain in proximity to the alignments. See Appendix F for corridor plan and profile sheets. Information about the length and percent of the alignment for each grade classification is summarized in Table 4-3.

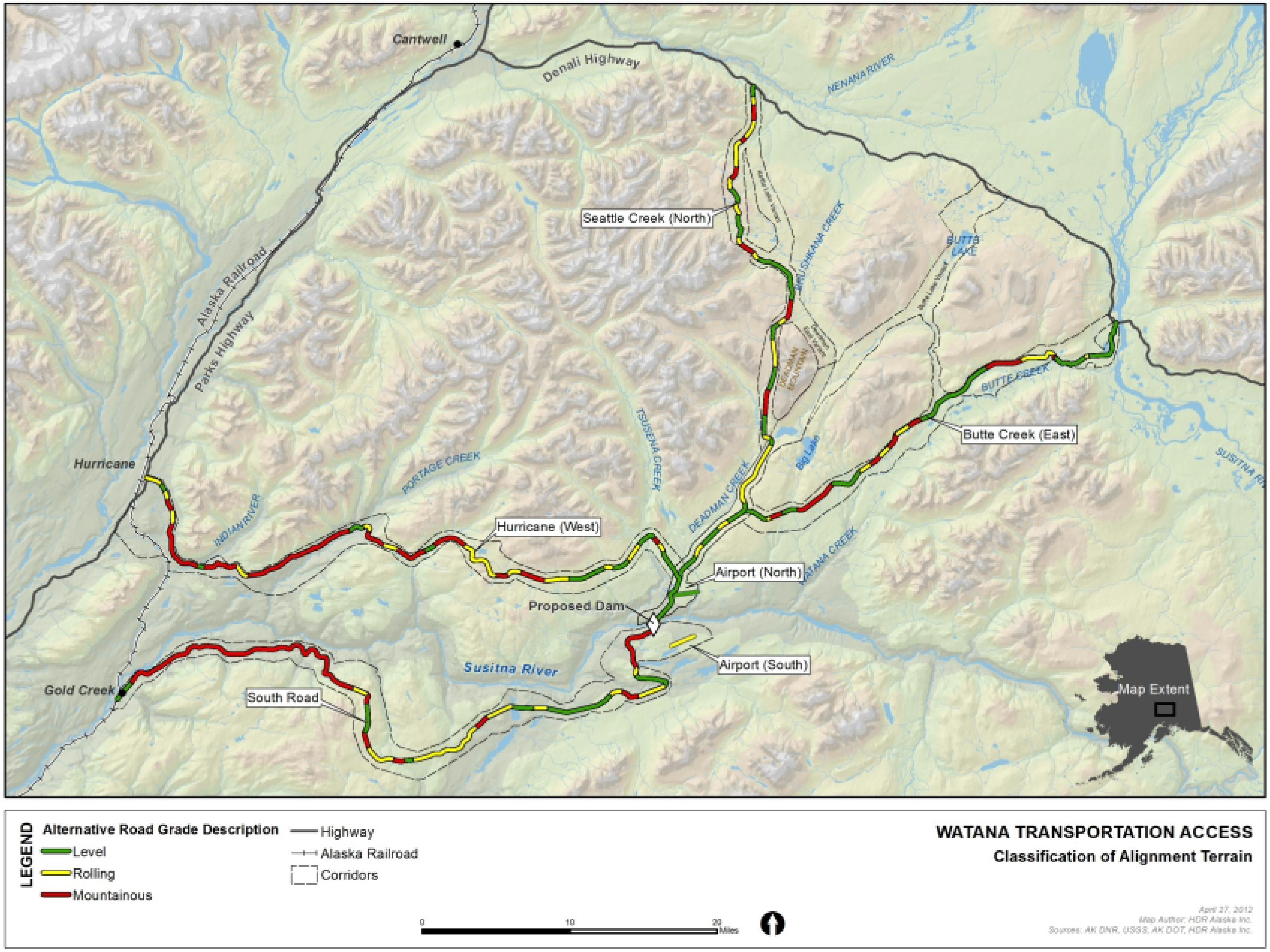
The original ground profiles for Hurricane (West), Seattle Creek (North), and Butte Creek (East) corridors have similar amounts of level, rolling, and mountainous designation (see Table 4-3). The South Road corridor would need to traverse a much greater amount of mountainous terrain (18.4 miles) and much less level terrain (20.7 miles) than the other three corridors. However, classification of the terrain (Table 4-2, Figure 4-2) shows that the South Road and Hurricane (West) alignments have a significantly higher amount of mountainous terrain than the other two corridors. The Seattle Creek (North) alignment has the least amount of mountainous terrain (6.5 miles) and Butte Creek (East) has the most level terrain (25.1 miles). The Seattle Creek (North) alignment has more mountainous terrain than the Butte Creek (East) alignment both in percent and total miles. Overall, the Butte Creek (East) alignment has the flattest profile of the four. The amount of mountainous terrain will likely affect the cost to construct the facility and the operational efficiency of the facility. When more detailed contour information is available, the alignments should be refined to make better use of level/flat terrain.

Table 4-3. Summary of road grade by alignment

Corridor	Grade Classification						Total Length
	Level		Rolling		Mountainous		
	Miles	% of Corridor	Miles	% of Corridor	Miles	% of Corridor	
South Road	20.7	37.7	15.7	28.6	18.4	33.7	54.8
Hurricane (West)	45.92	88.7	4.85	9.36	1.00	1.94	51.7
Seattle Creek (North)	39.46	91.28	3.75	8.67	0.02	0.05	43.3
Butte Creek (East)	37.78	94.69	2.03	5.09	0.09	0.22	42.0

Red = Not preferable **Green = Favorable**

[a] Totals may not match due to rounding



WATANA TRANSPORTATION ACCESS
Classification of Alignment Terrain

April 27, 2012
Map Author: HDR Alaska Inc.
Sources: AK DNR, USGS, AK DOT, HDR Alaska Inc.

Figure 4-2. Classification of alignment terrain

4.2.1.2 Operational Efficiency During Dam Construction

For the purposes of this analysis, it is assumed that the majority of construction materials will be transported to the Watana dam site from a port in Southcentral Alaska although some materials may come from elsewhere in Alaska. While a detailed logistics plan for the Susitna-Watana project has not been established yet, corridors that provide for the more efficient movement of goods between the Southcentral ports and the dam site are preferable.

To quantify the operational efficiency of the corridors, the project team calculated the length and travel time of each corridor from three locations (see Table 4-4):

- From the Parks Highway at Hurricane to the proposed dam site representing the goods transported by road from Southcentral Alaska. The Parks Highway at Hurricane was chosen as a starting point because this location is common to the three corridors accessible from the Parks Highway.
- From the Parks Highway at Cantwell to the proposed dam site to represent goods transported by road from Interior Alaska (Fairbanks area). The Parks Highway at Cantwell was chosen as a starting point because this location is common to the three corridors accessible from the Parks Highway.
- From the proposed railroad staging area (Gold Creek for South Road, Hurricane for Hurricane [West] and Cantwell for Seattle Creek [North] and Butte Creek [East]) for goods moved by rail from Southcentral Alaska.

Table 4-4. Summary of lengths and travel time[a]

	From Hurricane		From Cantwell		From Railroad Siding	
	Travel Length (miles)	**Travel Time[a] (hours)**	**Travel Length (miles)**	**Travel Time[a] (hours)**	**Travel Length (miles)**	**Travel Time[a] (hours)**
South Road	N/A	N/A	N/A	N/A	54.8	1.6
Hurricane (West)	51.7.	1.5	91.0	2.1	52.3	1.5
Seattle Creek (North)	102.6	2.4	63.4	1.8	65.3	1.9
Butte Creek (East)	134.7	3.1	95.5	2.7	97.4	2.8

Red = Not preferable **Green = Favorable**

[a] Estimated, based on the following average running speeds: Parks Highway – 55 mph; Denali Highway – 45 mph; Watana Access – 35 mph

4.2.1.3 Shadow Analysis

For road design and maintenance purposes, it is preferable to have a roadway that is in direct sunlight for more of the time to minimize icing during the winter months. Additionally, roads with better sun exposure typically freeze up later in the fall and thaw more quickly in the spring, reducing snow-clearing costs. For each corridor, a shadow analysis was performed using GIS to identify the length of centerline that was in shadow on September 21 (equinox) and October 21. For each date, shadows were calculated for three time periods (see Table 4-5): one hour after sunrise, solar noon, and one hour before sunset. This analysis includes the effects of shadows cast from surrounding terrain to provide a more realistic assessment of real-world lighting conditions for each corridor.

Table 4-5. Time and date parameters, calculated altitude, angle, and azimuth angle

Date	Time of Angles	Altitude	Azimuth
September 21	8:33	5.78	99
	13:47	27.77	180
	18:56	6.4	258
October 21	9:54	4.79	125
	13:38	16.39	180
	17:19	5.11	234
November 21	11:22	2.87	148
	13:40	7.21	180
	15:54	3.07	211
December 21	12:19	1.77	159
	13:52	3.74	180
	14:48	1.92	200

The analysis was done by using the identified date and time information to generate a hillshade from a 30-meter Digital Elevation Model (DEM) using the Spatial Analyst extension in ArcGIS 10. In this analysis, all hill-shades were created with modeled shadows for each date and time period specified. Once these hill-shades were generated, the areas in light or shadow for each alternative were calculated. Table 4-6 and the maps in Appendix G show the final results for the shadow analysis for each time modeled.

Table 4-6. Approximately length and percentage of each corridor in morning shadow, noon shadow, and evening shadow

	September 21						October 21					
	AM		Solar Noon		PM		AM		Solar Noon		PM	
Alternative	Length (mi.)	%	Length (mi.)	%	Length (mi.)	%	Length (mi.)	%	Length (mi.)	%	Length (mi.)	%
South Road	12.2	22.5	0.1	0.1	10.3	19.1	30.5	56.5	3.2	5.9	22.0	40.8
Hurricane (West)	18.8	36.3	0.7	1.4	13.5	26.1	21.2	40.9	2.7	5.2	14.2	27.4
Seattle Creek (North)	14.6	33.7	0.3	0.7	14.1	32.6	16.6	38.3	1.2	2.8	0.0	0.0
Butte Creek (East)	4.5	10.7	0.0	0.0	8.9	21.2	13.3	31.7	0.0	0.0	6.5	15.5

Red = Not preferable **Green = Favorable**

At solar noon, all four alignments have similar amounts of the roadway in shadow in September and October. In the AM, the Hurricane (West) corridor has slightly more shading in September and October than the Seattle Creek (North) corridor but has more than Butte Creek (East). However, the South Road corridor has more shading in October than Hurricane (West). In the PM, Seattle Creek (North) and Hurricane (West) have more shadow in September, while South Road has the most in October. Overall, the South Road and Hurricane (West) have slightly more shadow than the other two corridors. However, as detailed terrain information was not available for the analysis, these data may change if more accurate information is used.

4.2.1.4 Construction Seasons

The Susitna-Watana Hydroelectric Facility is one of Alaska's most important capital projects. The dam itself will take many years to construct. AEA stated the importance of establishing early access to the dam site with a pioneer road so construction work on the dam and airport can begin as early as possible. The pioneer road would then be upgraded concurrent with dam construction. Corridors that can be constructed in fewer construction seasons[13] would be considered preferable because that would reduce the overall project construction schedule.

Based upon the project team's experience with previous roadway construction projects, it is assumed that in one construction season, 20 miles of roadway could be build in level terrain,

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[13] For the purposes of this analysis, winter construction is not assumed because of the need to achieve compaction with moisture and density controls.

15 miles in rolling terrain, and 12 miles in mountainous terrain. The estimated number of construction seasons for the three corridors is shown in Table 4-7.

Table 4-7. Construction season estimate

Corridor		**Level**	**Rolling**	**Mountainous**	**Total Construction Seasons**
South Road	Miles	20.7	15.7	18.4	—
	Construction seasons	1.0	1.0	1.5	**3.6**[a]
Hurricane (West)	Miles	45.9[b]	4.9	1.0	—
	Construction seasons	2.3	0.3	0.1	**2.7**
Seattle Creek (North)	Miles	39.5	3.8	0.0	—
	Construction seasons	2.0	0.3	0.0	**2.3**
Butte Creek (East)	Miles	37.8	2.0	0.1	—
	Construction seasons	1.9	0.1	0.0	**2.0**

Red = Not preferable Green = Favorable

[a] Total does not match due to rounding

[b] Rounded to the nearest tenth of a mile

The South Road alignment will take longer (between three and four construction seasons) to construct than the other three corridors. Hurricane (West), Seattle Creek (North) and Butte Creek (East) are expected to take between two and three construction seasons to complete. The Butte Creek (East) corridor would have the shortest total construction period. With the existing information, a more detailed analysis about construction schedules could not be produced.

4.2.1.5 Avalanche

An avalanche is the sudden release of snow down a slope, occurring due to either natural triggers or human activity. In order for an avalanche to occur, terrain must be level enough to build adequate snow mass, yet steep enough to mobilize the static snow mass into a dynamic slide. Mitigation of many avalanche hazards can be proactive through alignment modifications, modification of surrounding terrain, or initiation of controlled slides during facility operations. If left unaddressed, avalanches can pose safety risks to facility users, temporary closures due to avalanche debris, and high maintenance costs to address snow and debris removal.

Using ArcGIS, the terrain in the project area was evaluated and shaded according to the values presented in Table 4-8. The proposed corridors were then overlaid on the map. The corridors and terrain are presented on Figure 4-3.

Table 4-8. Avalanche potential related to terrain slope

Avalanche Potential	Terrain Slope (%)	Color
Low	0–25	Green
Moderate	25–30	Yellow
High	30–45	Red
Moderate	45–50	Yellow
Low	50–90	Green

Source: Colorado n.d.

Based on the ArcGIS analysis, there are five regions of potential concern for the proposed alignments. These regions are identified in Table 4-9 and also presented on Figure 4-3.

While some planning-level quantifiable results were developed during this assessment, it is important to note the limitations of this assessment of the avalanche hazard for the proposed corridors. This analysis only identifies terrain where avalanches could potentially occur. Identification of specific avalanche paths or chutes and calculation of avalanche run-out was not performed. The avalanche hazard for Region 3 may be largely mitigated or even eliminated if Tsusena Butte is re-contoured as a result of material extraction for either the dam or road construction. While Region 4 shows a small amount of terrain that could produce avalanches, the contributing area may not be capable of sustaining enough snow load to produce a significant avalanche. Region 5 shows some areas that could produce avalanches, but it appears there are terrain features (gullies and benches) between the potential slide areas and the road corridor that would arrest or redirect any avalanches away from the proposed road. Region 6 has some avalanche potential, but hazard is deemed low as avalanches would most likely not reach the road because there is significant run out area and the snow accumulation zone is not very large. In Region 7, the road corridor is in close proximity to 30 to 45 percent slopes; however, the accumulation zone is small.

Table 4-9. Regions of potential avalanche hazard

Region	Route	Location	Description
1	Hurricane (West)	MP 4.5–9.5	Avalanche potential is on the western side of the access corridor. Alignment is side-hilling as it wraps around terrain features.
2	Hurricane (West)	MP 13.5–20.5	Area where the alignment is side-hilling in the Portage Creek drainage.
3	Hurricane (West)	MP 45.0	Corridor may potentially be affected by avalanches on the southern face of Tsusena Butte.
4	Seattle Creek (North)	MP 11.5–13.0	Corridor is potentially affected by avalanches on the east side of adjacent terrain.
5	Seattle Creek (North)	MP 25.5–26.5	Area adjacent to the southwestern face of Deadman Mountain.

Table 4-9. Regions of potential avalanche hazard

Region	Route	Location	Description
6	South Road	MP 0.6-4.1	Road corridor is south of the Susitna River on the northern slope (side-hilling) of terrain with avalanche potential.
7	South Road	MP 9.8-12.1	Road corridor is south of the Susitna River on the northern slope (side-hilling) of terrain with avalanche potential.

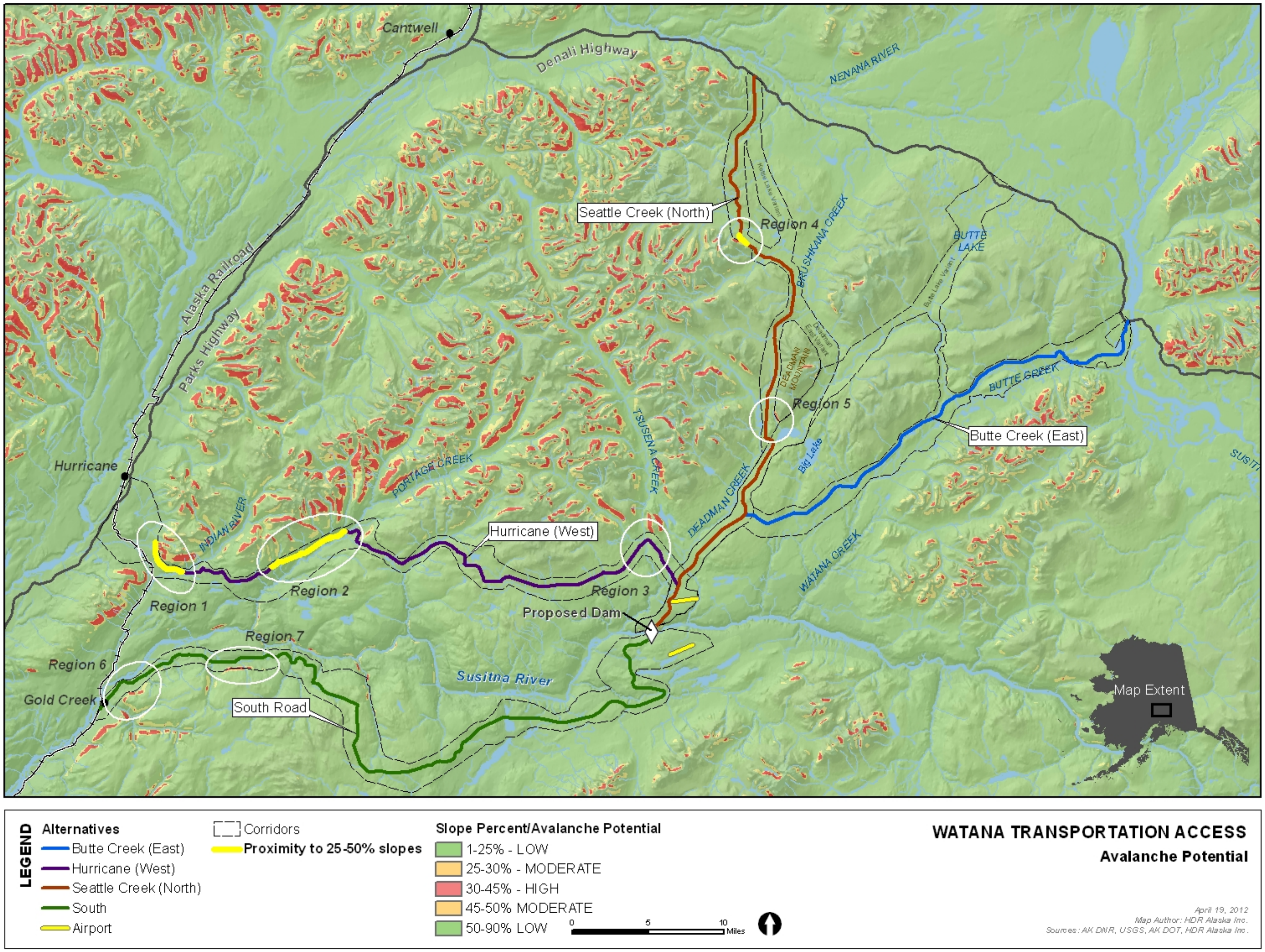

Figure 4-3. Avalanche potential

Based on this initial identification of potential avalanche terrain, the project team determined it was more appropriate to evaluate avalanche hazards based on the miles of roadway in proximity to a moderate or high slope. The basis for this recommendation is that a more detailed analysis may result in minimal or reduced true avalanche hazard, rendering the true avalanche hazard equal for all corridors.

The potential for avalanches for the Hurricane (West) corridor is higher than for the South Road, Seattle Creek (North) and Butte Creek (East) alternatives. Based on this initial screening, the avalanche potential for the Butte Creek (East) alternative appears to be non-existent, the potential for avalanche for the Seattle Creek (North) alternative is slight (0.8 miles), and the potential for the Hurricane (West) alternative is low to moderate (8.7 miles).

4.2.1.6 Railroad Siding and Staging Area

Based on the project team's assumed construction logistics plan for the dam, each alternative must be able to accommodate a rail siding and staging area. The project team developed conceptual railroad staging yard diagrams to determine if there was adequate space available for the needed facilities. The Hurricane (West) alignment would require a staging area in Hurricane (ARRC MP 281). The Seattle Creek (North) and Butte Creek (East) alignments would require a staging area in Cantwell (ARRC MP 319). Both Hurricane and Cantwell have existing sidings that are part of current ARRC operations. These sidings need to be upgraded for use by this project. Improvements at each siding location include the addition of approximately 4,800 feet of siding track, approximately 40 acres of staging area; and storage tanks/silos[14] for fuel, cement, and fly ash. The Hurricane and Cantwell sidings include an access road to the highway (with a traffic light on the Parks Highway).

The South Rail alignment would upgrade the existing Gold Creek siding (ARRC MP 263). Because the South Road alignment would rely on goods, material, and people being brought to the area by rail, the Gold Creek siding would require more extensive improvements than the other alignments. The anticipated upgrades[15] include:

- A passenger siding
- Two sets of double track sidings with appropriate offsets for unloading material, and storage spurs
- Approximately 115 acres of staging area will be needed to support construction staging, material and fuel storage, and track infrastructure.
- A 10,000-square-foot multiuse building for bunking facilities, project office space, and miscellaneous storage

All three of these locations are considered feasible for a railroad siding and staging area; therefore this criterion did not contribute directly to the relative ranking of the corridors. The cost differential for upgrading the sidings was captured under the construction cost criterion.

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[14] The silos represent a conceptual location. It is anticipated that silo height will be consistent with airspace restrictions. Without a detailed logistics plan, the sizing and configuration of the silos are unknown and additional silos may be required.

[15] A detailed logistics plan needs to be prepared before the list of improvements at the Gold Creek siding can be fully identified.

Upgrades to the Gold Creek, Hurricane, and Cantwell sidings are shown on Figure 4-5 and Figure 4-6, respectively.

All four alternatives appear to have adequate space for a railroad staging and siding area.

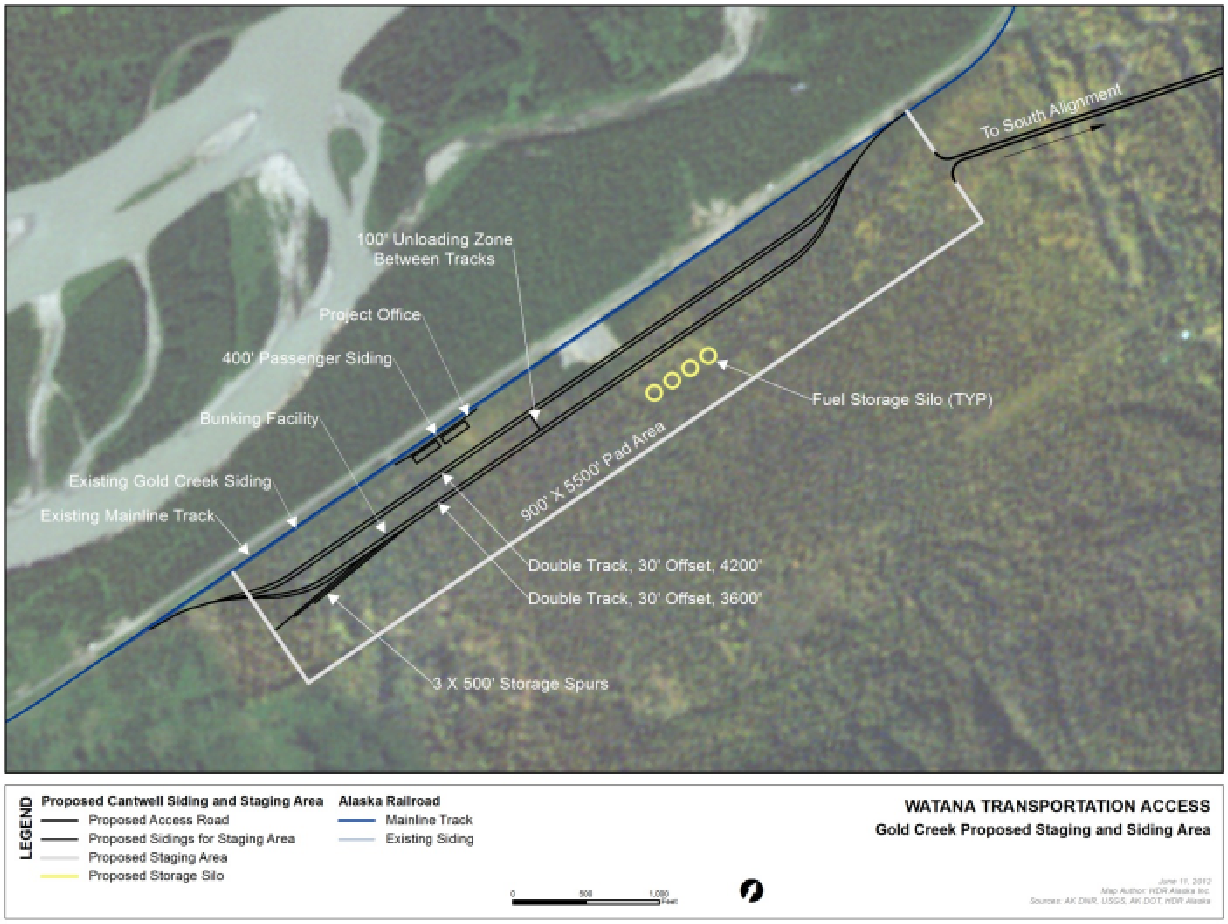

Figure 4-4. Conceptual Gold Creek railroad staging and siding area

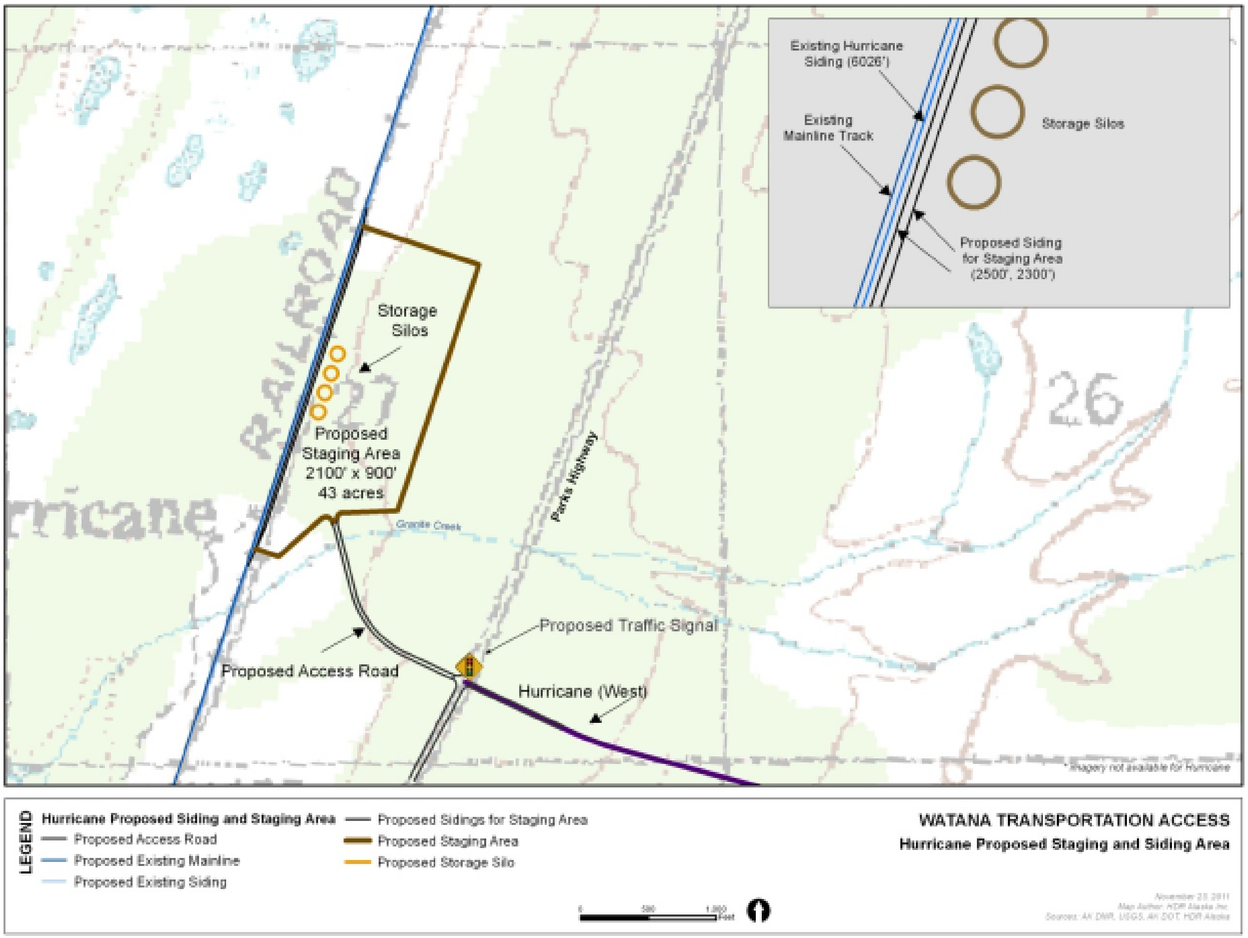

Figure 4-5. Conceptual Hurricane railroad staging and siding area

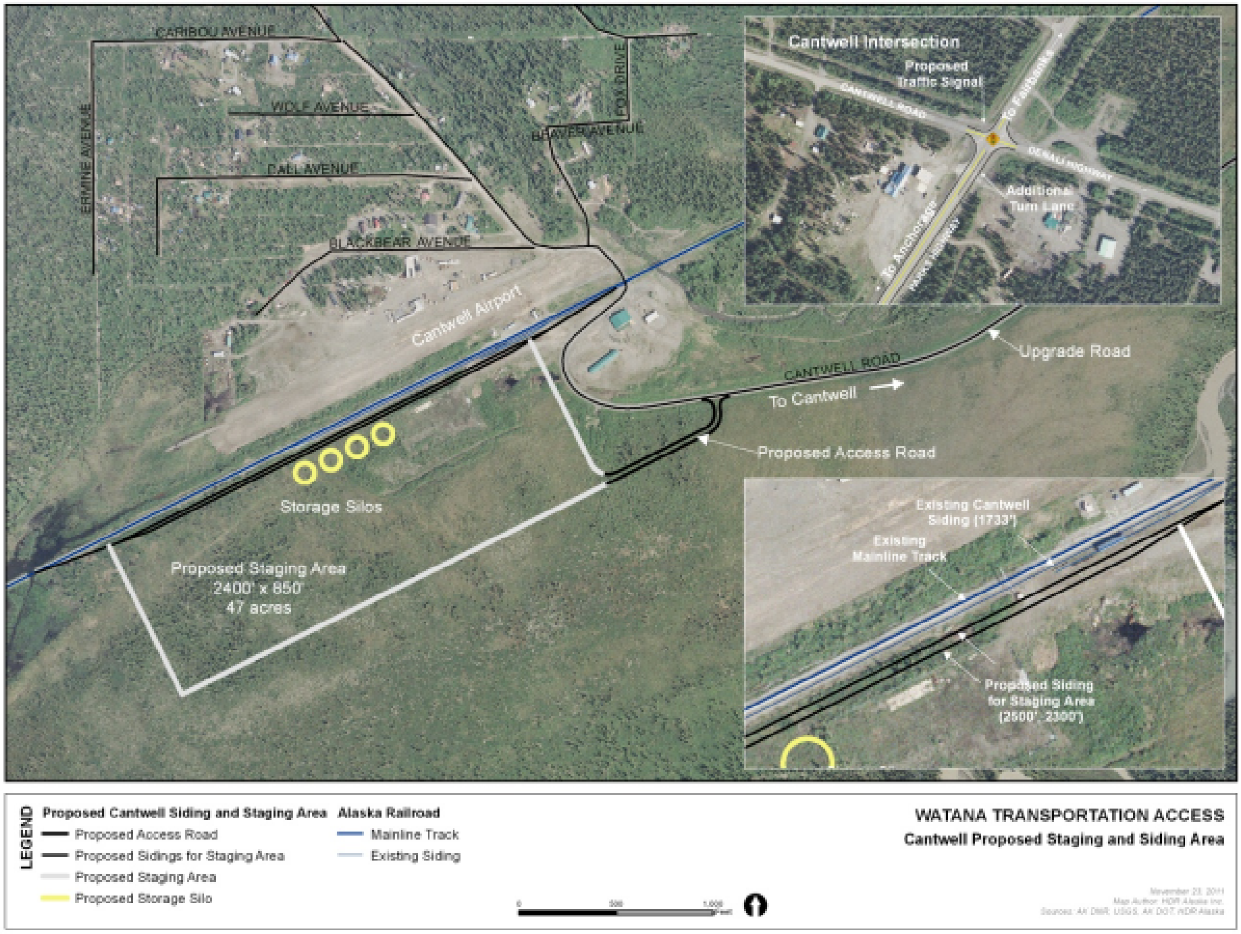

Figure 4-6. Conceptual Cantwell railroad staging and siding area

4.2.1.7 Potential for Co-location of Transmission Lines

As part of the Watana Hydroelectric project, there would be a transmission line connecting the dam to the Railbelt Intertie. While AEA has not identified the ultimate location of the transmission line, there are several advantages to having the transmission line in close proximity to the access corridor, including lower transmission line construction and maintenance costs and reduced project footprint. Currently, AEA is studying transmission lines in the proximity of the South Road, Hurricane (West) and Seattle Creek (North) corridors. AEA has indicated that the elevation of the transmission line should be less than 3,000 feet although short segments that exceed that elevation may be acceptable. Table 4-10 shows the length of alignment (new road only) that exceeds 3,000 feet in elevation.

Table 4-10. New road above 3,000 feet

Corridor	Length above 3,000 feet (Miles)	Transmission line in close proximity to corridor
South Road	5.0	Yes
Hurricane (West)	12.5	Yes
Seattle Creek (North)	32	Yes
Butte Creek (East)	6.4	No

Red = Not preferable **Green = Favorable**

4.2.2 Geologic and Geotechnical

The geological and geotechnical criteria were evaluated based on work done in the 1980s combined with aerial reconnaissance and a hand-sampling of selected locations along each corridor by a geotechnical engineer in October 2011 during field reconnaissance. For more detailed information about the geological and geotechnical analysis, please see Appendix H.

Due to the lack of quantifiable data to evaluate the geologic and geotechnical conditions, the project team decided to develop a set of specific development criteria assign each criterion a value between 1 and 5, with 1 being most favorable. These values, assigned by a geotechnical engineer, represent the overall suitability of the criteria for a road corridor and are shown in Table 4-12 (located at the end of this section). The remainder of this section describes each criterion considered.

Other regional geological hazards at the site include regional seismicity and volcanism. While these hazards could impact the project, the project team does not believe that the effects from seismicity or volcanism will be substantially different from one alignment to another. The various evaluation criteria such as subgrade support, foundation support, and slope stability inherently include consideration of seismicity and its effects (such as liquefaction, seismically induced settlement, and lateral spreading). Other wide-area effects such as ground motions should not be appreciably different from one corridor to another. Based on our review of existing data, there are no significant fault alignments that cross the proposed corridors. Additionally, volcanism may impact the project area, but the effects would likely be limited to ash fall events from the closest active volcanoes, which are over 150 miles to the south-southwest of the area.

4.2.2.1 Rock Borrow Availability

Rock borrow availability addresses the proximity of rock materials to the corridors studied for this project. Rock materials will be an important resource for the construction of the proposed access road and associated facilities and structures. Material produced from quarries can be used in a wide variety of applications from embankment development, concrete and/or asphalt aggregate, revetment, rip-rap, and surfacing material. The proximity of the rock materials is important because the distance that the material must be hauled during construction will have a direct impact on the cost of construction. If rock material is not available adjacent to the roadway, additional access roads may be needed to access potential sources, which would also have an impact on the cost of the improvements and will increase the footprint of the project. For successful completion of this project, it will be essential that the final corridor selected have multiple sources of rock material along its full length. These sources will ideally be located adjacent to the final road alignment and will require minimal development of access branch roads to access them.

Each of the corridors appears to have regular sources of potential rock borrow with the exception of the east end of the South Road alignment (between MP 30 and the dam site) and the first several miles of the western end (between MP 0 and MP 10) of the Hurricane (West) alignment. Based on the information available, all four corridors have similar rock material sources available, although Seattle Creek (North) and Butte Creek (East) appear to be slightly more favorable.

4.2.2.2 Rock Borrow Quality

Rock borrow quality addresses the rock material types along each corridor that will be available for construction of the road and associated facilities. Rock material quality is important to the project because some of the uses for the rock will require that the material be durable (i.e., resistant to mechanical degradation). In general, rock material used in the construction of this project must meet the various durability requirements defined in DOT&PF specifications for the material's application (e.g., aggregate or rip-rap). The highest quality, most durable materials should be used in the production of aggregates and rip-rap, while lower quality materials can be used in embankment construction as shot-rock fill.

Typically, intrusive igneous rocks such as granite and diorite yield very high durability values. Extrusive igneous rocks (such as basalt) and lightly metamorphosed rocks (such as phylite) typically have somewhat lower durability characteristics. Highly metamorphosed rocks, such as schist, and sedimentary rocks usually have the lowest durability values. The selected corridor should have rock sources that produce high durability materials that can be developed into rock materials of a wide variety of sizes. High quality sources will reduce the need to import higher durability materials from long distances, thereby reducing the construction costs.

The quality of rock available on each alignment varies, and each alignment has a mixture of high- and low-quality rock. The highest quality rock materials were found to consist of coarse granites and diorites. When found in outcrops, this material was blocky and resistant to weathering. Biotite-rich gneiss and diorite, as well as isolated areas of basalt and phyllite materials, were found north of the dam site along the Seattle Creek (North) alignment. These formations may provide good materials for road construction, but may be somewhat less durable than the granitic rock in other areas. As such, they may not be as reliable as the granite for use as aggregate.

The South Road corridor appeared to cross terrain that likely consists of metamorphosed sedimentary rocks (such as argillite, shale, greywacke quartzite, and conglomerate) and volcanic flow rocks (such as lava, tuff, and agglomerate). Mapping does indicate granite and granodiorite intrusive bodies near the beginning of the project and in the upland portions of the alignment between approximate MP 15 and 30. It is likely that the intrusive igneous rock formations would yield relatively high-quality, durable material for use in this project. Metamorphosed sedimentary rocks may provide construction materials, but would be less reliable as sources of high-quality materials for use as aggregate.

Very poor shaley rock was generally observed in the western half (between MP 5 and MP 13) of the Hurricane (West) alignment. This rock was found to be weak and highly weathered in some places. This material will likely be usable as embankment fill, but will most likely not be able to meet durability requirements for aggregate. Rock materials found between MP 13 and the dam site are likely higher quality and will likely be usable for embankment development and potentially aggregate production.

Biotite rich gneiss and diorite, as well as isolated areas of basalt and phyllite materials were found north of the dam site along the Seattle Creek (North) Corridor between MP 22 and MP 30. These formations may provide good materials for construction of the road, however, they may be somewhat less durable than the granitic rock found in other areas. As such, they may not be as reliable for use as aggregate.

Along the Butte Creek (East) corridor, rock quality is expected to be variable, but generally good, with no obvious areas of rock that is very poor or very low durability.

Based on the available information, Butte Creek (East) and South Road have the best rock quality and Hurricane (West) has the worst rock quality. Table 4-11 shows the results of durability tests conducted on four samples collected during surface reconnaissance activities. The samples were selected to represent the variety of material that exists along the alignments. As can be seen by the testing results, the highest quality material is from the igneous rock types along the alignment. The poorest material was encountered at Observation Point 20 on the Seattle Creek (North) Alignment (see Geotechnical Report in Appendix H for the location) in a coarse-grained granodiorite material. While this, material is igneous in origin, it is biotite rich and appears to be susceptible to mechanical weathering.

Table 4-11. Durability test results

Observation Point	Los Angeles Abrasion Loss	Los Angeles Abrasion Loss Specification	Soundness loss %	Soundness Specification
12	31	<45	1	<9
20	75	<45	11	<9
22	14	<45	1	<9
30	22	<45	2	<9

4.2.2.3 Soil Borrow Availability

Soil borrow availability addresses the proximity of soil materials to the corridors studied for this project. Soil borrow materials will be an important resource for the construction of the proposed access road and associated facilities and structures. Soil borrow materials will likely be most widely used to provide embankment fill materials and as structural fill for the roadway. It could also likely be used in producing fine aggregates and as structural fill around drainage structures, culverts, and bridges, and in utility trenches. As with rock materials sources, the proximity of the soil borrow sources with respect to the proposed roadway will have a direct impact on construction costs. Sources that are farther from the proposed roadway will have longer haul times and will increase the footprint of the project.

To complete the construction of this project, the final corridor selected will need multiple sources of soil borrow along its full length. As with the rock material sources, the soil borrow sources should be located adjacent to the final road alignment to minimize the need for additional access roads.

Soil sources are available along each alignment. The sparsest areas of viable soil deposits along the alignments are likely to be the middle portion of the South Road corridor (between MP 15 and 30) and the middle quarter of the Seattle Creek (North) corridor (approximately between MP 18 to 26) where the corridors traverse high, rocky terrain and the first several miles (approximately between MP 1 and 5) of the Hurricane (West) corridor as it crosses lowlands that may contain shallow groundwater or thick organic deposits.

Based on the information available, all four corridors have similar soil borrow material source availability. The proximity of these sources is slightly favorable for Butte Creek (East) corridor. Slight modifications in the alignments once additional information is gathered may reduce the distance to these sources. Based on the level of detail available, it was concluded that the four corridors perform similarly enough that this criterion individually should not be used as an evaluation criterion.

4.2.2.4 Soil Borrow Quality

Soil borrow quality addresses the soil material types available in the soil borrow sources along each corridor. While soil availability is important, the quality of available material will also impact the cost of the project. Ideally, soil borrow will consist of clean (low fines content), well-graded sand and gravel. Granular or non-frost-susceptible material will most likely be found in outwash and/or alluvial deposits as well as some moraine deposits. This material would lend itself well to development of structural sections for the road as well as structural fill around bridge and culvert foundations. Poorly graded soils or soils with higher fines content (such as those found in glacial till or moraine) may also be acceptable for use, but their applications will be limited to deep embankment development. Regardless of the gradation of the soil fill used, it should not contain significant amounts of free ice, organic detritus, or a significant amount of plastic fines.

Higher quality soil borrow resources along the project corridor will have a positive impact on the construction cost. The high-quality materials will require less processing (washing, screening, etc.) and if they are located at regular intervals along the alignment, they will not need to be imported from long distances. Ideally, the final selected corridor will have multiple high-quality soil borrow sources along its full length.

Soil sources are available along each alignment. A wide variety of material is available from each alignment ranging from glacial till, moraine, and outwash deposits to alluvial materials. The Butte Creek alternative appears to have the highest quality and quantity of soil deposits available of the three considered alignments. The majority of this alignment traverses alluvial terraces and outwash deposits that appear to be relatively clean (low fines content) and well graded. The western quarter of the alignment (near the dam site) begins to transition into glacial till materials that likely include higher fines content.

The South Road will likely have soil deposits that are of glacial origin. While the soils may be naturally dense and compact, they likely contain significant amounts of fines and may be difficult to use effectively in embankment and/or structural section construction. In addition, between approximately MP 15 and MP 30, the soil thickness over bedrock will likely be relatively thin. As the alignment crosses into generally lower-lying areas to the east, soil materials will likely be more abundant. Based on R&M terrain mapping and landforms evident on available satellite imagery, the soil deposits are mostly glacial tills with sporadic lacustrine and alluvial deposits. Significant surface deposits of organics may also be present in the eastern half of the alignment between MP 35 and the dam site which could make mining soil deposits more difficult. The northern half of the Seattle Creek (North) corridor traverses terrain that is likely a mixture of outwash and moraine material between MP 0 and MP 18. While this soil appeared to have relatively low fines content in the areas that we visited, it is likely to have a higher variability in fines content. The southern portion of the Seattle Alignment between MP 18 and MP 26 generally traverses terrain that is shaped by glacial action and therefore is likely dominated by till soils that likely contain relatively high fines content. The portion of the corridor between MP 26 and the dam site appears to traverse terrain dominated by a mixture of outwash, alluvium, and moraine soils.

The portion of the Hurricane (West) corridor between MP 5 and MP 20 traverses soil terrain that likely consists of outwash, alluvial, and moraine soils (where bedrock is not exposed). Many of the outwash soils in this area appear to be high energy deposits, and are likely intermixed with colluvium where they exist on steep side slopes. This material was difficult to observe in the field due to vegetative cover, however given the depositional environment, it is likely to be of variable quality (i.e., variable fines content). Alluvial material is typically relatively clean (low fines content), however, moraine materials can have a wide range of grain sizes including higher fines content. The remaining portion of the Hurricane (West) alignment between MP 20 and the dam site traverses wide, U-shaped valleys that are likely dominated by glacial till deposits with the potential for alluvial deposits in the valley floors. Till soils will likely consist of relatively dense sand and gravel with high silt content.

On average, the Butte Creek (East) alignment appears to have the highest quality and quantity of soil deposits available of the four considered alignments. A majority of this alignment traverses alluvial terraces and outwash deposits that appear to be relatively clean (low fines content) and well graded. The western portion of the alignment between MP 25 and the dam site likely transitions into glacial till materials that may have higher fines content.

Based on the information available, the Butte Creek (East) alignment crosses terrain that will likely yield the highest quality soil borrow of the four alignments (most of the borrow is anticipated to meet Selected Material Type A or B). The Seattle Creek (North) alignment will likely have a mixture of material types available along its corridor, most of which will likely be Selected Material Type B or C with scattered areas of Selected Material Type A. The remainder of the alignments traverse terrain that will likely yield (on average) relatively low-quality Selected Material Type C. In terms of borrow soil quality, the Butte Creek (East) alignment is preferable to the other three alignments.

4.2.2.5 Subgrade Support

Subgrade support addresses the general support capabilities of the subsurface materials along each corridor. In general, favorable subgrade support conditions consist of shallow bedrock and/or firm, well-drained mineral soils. Poor conditions include thaw-unstable permafrost and thick deposits of soft and compressible (mineral or organic) soils.

Favorable subgrade support conditions will have a positive impact on construction costs in several ways. Firm subgrade support typically provides more ideal construction conditions and presents fewer constructability challenges since conventional equipment can be used. Furthermore, firm subgrade support circumvents the need for costly subgrade improvement such as excavation and replacement of unsuitable soils, and typically results in thinner embankments and structural sections. Additionally, ideal subgrade support conditions allow for steeper embankment slopes that require less material to construct and result in a smaller project footprint.

On average, the majority of the alignments cross ground that is relatively competent and capable of supporting the proposed roadway. The exceptions to this condition are the lowland areas on the extreme west end of the Hurricane alignment and isolated areas of the Butte Creek (East) alignment. The lowlands on the Hurricane alignment exhibit widespread soft conditions that may include thick organic soil deposits. The Butte Creek (East) alignment will likely require crossing isolated, widely spaced, soft, poorly drained features that are typically less than 200 feet long.

Based on the information available, all four corridors have similar subgrade support conditions. Based on the level of detail available, it was concluded that the four corridors perform similarly enough that this criterion should not be used for evaluation.

4.2.2.6 Permafrost Conditions

Permafrost[16] conditions address the state and nature of frozen ground under the various corridors studied for this project. The proposed improvements will have an impact on the thermal regime along each corridor that will likely result in warming of the ground around and under the new road. Based on the location of this project, it is likely that the majority of the ground beneath each alignment is frozen continuously throughout the year. As such, permafrost conditions are most ideal if the subsurface consists of materials that do not lose a significant amount of strength when they are thawed. Such conditions will likely include shallow bedrock and dense soils that have low fines content.

Unfavorable conditions include poorly drained soils, fine-grained soils, and permafrost conditions with large amounts of segregated ice. Such soils are subject to long-term creep under foundation and/or slope loading and typically lose a significant amount of strength when thawed. Having favorable permafrost conditions along the selected corridor will have a cost benefit, as measures (such as insulation and refrigeration) will not need to be taken to maintain the thermal balance under the roadway and associated structures.

Based on field observations and the project location, it is likely that permafrost soils are present over most of each alignment. The most critical zones of permafrost are likely found along the slopes above the bottoms of the wide, U-shaped valleys in the higher regions of each alignment. These areas exhibit characteristics of solifluction[17], which may impact roadways built on these

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[16] Permafrost is soil, sediment, or rock that remains at or below 32°F for a minimum of 2 years.

[17] Solifluction is “the slow viscous downslope flow of waterlogged soil and other unsorted and saturated surficial material, normally at 0.5-5.0 cm/yr; esp. the flow occurring at high elevations in regions underlain by frozen ground (not necessarily permafrost) that acts as a downward barrier to water percolation, initiated by frost action and augmented by meltwater resulting from alternate freezing and thawing of snow and ground ice” (Neuendorf et al. 2005).

slopes. Most other areas along each alignment are likely underlain by thaw-stable alluvial or outwash soils or shallow bedrock.

Based on the available information and field observations, the Butte Creek (East) corridor appears to have the least extent of thaw-unstable[18] permafrost conditions, while the Seattle Creek (North) corridor has a moderate extent of thaw-unstable permafrost conditions. On a relative scale, the South Road and Hurricane (West) alignments appear to be between the two other alternatives.

Based on the information available, the Butte Creek (East) alignment is expected to have the least amount of permafrost or it has thaw-stable conditions. Permafrost conditions are less favorable on the South Road, Hurricane Creek (West), and Seattle Creek (North) alignments.

4.2.2.7 Drainage

Drainage addresses the general surface and near-surface drainage characteristics of each corridor. Well-drained conditions are usually found in free-draining soils and in topography that is sloped to allow for the conveyance of surface water. Poor drainage is typically encountered in flat terrain with soils that do not allow for infiltration of surface water (such as in peat bogs or in permafrost terrain). In general, well-drained ground conditions typically result in favorable support conditions for new roads and structures. Development of roadways in poorly drained areas results in higher costs associated with designing and constructing additional drainage provisions in the form of culverts and/or porous embankments. Additional costs may also be associated with development of embankments and structures with poor subgrade support in these areas.

Most of the areas that the four corridors traverse appear to be relatively well drained with the exception of the west end of the Hurricane alignment, the Seattle Creek - Kettle Lake variant, and some areas near the dam site in all four alignments. All of these areas appear to have groundwater near the ground surface and will likely require special provisions for drainage to facilitate construction and area drainage after construction is complete.

Based on the information available, all four corridors have similar drainage characteristics. Based on the level of detail available, it was concluded that the four corridors perform similarly enough that this criterion individually should not be used as an evaluation criterion.

4.2.2.8 Rock Slope Stability

Rock slope stability addresses the stability of rock slopes that are likely to exist along each corridor. In the context of this report, rock slope stability is related only to new rock slopes that will be developed during construction of the road, as most of the rock slopes observed during field reconnaissance appeared to be relatively stable. In general, rock slope stability is determined primarily by the rock material quality and the orientation of major rock structure (joints, bedding, foliation, and shear zones) with respect to the orientation of the rock cut face.

Favorable rock slope conditions will allow for steeper rock slopes and fewer requirements for slope retention (e.g., dowels, bolting, shotcrete) and rock fall mitigation (e.g., catchment basins,

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[18] Thaw unstable refers to “Poorly drained, fine grained soils, especially silts and clays. Such soils generally contain large amounts of ice. The result of thawing can be loss of strength, excessive settlement and soil containing so much moisture that it flows”.

barricades, fencing, netting). Unfavorable conditions will necessitate shallower rock slope angles and/or increased measures for retention and rock fall mitigation. In general, favorable rock conditions will have a positive impact on construction costs as less material will need to be removed from rock cuts and fewer engineering measures will need to be taken to ensure that safe conditions persist through the life of the project. The final selected corridor will likely have few rock cuts needed and those that are required will be in areas with favorable conditions.

Most of the rock materials along the various corridors are generally well suited for developing steep cuts with a few exceptions. The rocks along the western third of the Hurricane (West) alignment are relatively weak and prone to weathering, resulting in slopes that will not stand steeply, will be difficult to support with conventional rock retention systems, and will require significant maintenance. The South Road alignment may encounter challenging slope conditions between MP 0 and 20 where the alignment traverses across and up substantial natural slopes. Most of the natural slopes appear to be incised by stream erosion, but due to organic and vegetative cover, it is difficult to determine if shallow rock conditions exist. If shallow rock exists in the natural slopes, cutting steep slopes in the hillsides to establish a road bench should be readily achievable. However, if deep soil deposits exist, poor slope stability conditions (requiring structural reinforcement of slopes and/or development of retaining walls) will persist as these slopes are likely at or near the natural angle of repose for soil. Along the lower lying portions of the South Road alignment, adjacent to stream crossings, steeply incised channels with actively eroding bluff features and poor rock and/or soil conditions may pose significant challenges to designing crossings and may require substantial stabilization measures and/or long bridge spans.

Rock along the Seattle Creek (North) and Butte Creek (East) alignments is expected to be relatively competent on average and likely capable of being developed at steep angles with relatively few long-term maintenance concerns. While the competency of rock in the Seattle Creek (North) and Butte Creek (East) corridors is similar, the Butte Creek (East) alignment appears to have significantly fewer rock cuts than would be necessary for the construction of the Seattle Creek (North) alignment.

The western portion of the Hurricane (West) corridor contains areas with rock quality that may be well suited for developing steep cuts. The Seattle Creek (North) and Butte Creek (East) corridors contain better quality rock for developing steep cuts. Based on this evaluation, the Seattle Creek or Butte Creek corridors are preferable over the Hurricane (West) corridor.

4.2.2.9 Soil Slope Stability

Soil slope stability addresses the stability of natural soil slopes. Soil slope stability is directly related to the material and strength properties of the soil exposed in the face of the slope as well as the soils behind the slope face, and the slope angle. Under ideal conditions (well-drained slopes consisting of angular, coarse soils over a well-drained, stable subgrade) permanent soil slopes can stand at angles approaching 1.5 horizontal (H) to 1 vertical (V) if vegetation is well established on the slope face. Shallower slope angles are needed if vegetative cover is poor or if support or slope soils are fine grained, soft, rounded, or poorly drained. Natural slope conditions may be unstable if the slope is near the maximum slope angle and vegetation is disturbed during construction. Furthermore, natural slopes can be unstable if they are composed of colluvium or if they are in an erosive environment such as undercut slopes in an incised stream channel.

Ideally, the selected corridor will traverse ground that does not require development on steep and/or unstable soil slopes. The construction costs for a roadway that traverses unstable slope conditions will be significantly higher through the need for constructing slope retention.

Unfavorable soil slope conditions exist on each alignment. However, it appears that in most areas, those conditions are avoidable given appropriate route selection. Areas that should be avoided are locations that would require traversing across the fall line on soil slopes that are between 2:1 and 1.5:1. These slopes are found throughout the project area and are largely stable due to established vegetative cover. Disturbing this cover could destabilize the entire slope and cause significant sloughing failures well outside the project limits. Other areas are relatively gentle slopes above the bottoms of the wide U-shaped valleys in the upper elevations of the three alignments and should be relatively stable. Potential solifluction in these areas may not cause dramatic failure events, but could result in long-term maintenance issues over the life of the project. Difficult slope conditions do occur in the western portion of the Hurricane (West) alignment.

The area along Portage Creek where the alignment traverses relatively steep side slopes and crosses deeply incised tributary channels may require additional mitigation to maintain slope stability. This area exhibits oversteepened soil slopes and the potential for significant instability if the vegetative cover is disturbed. Retaining structures will likely be required in this area to reduce the risk of slope failure during construction and the life of the project.

Based on available information, soil slope stability appears to be the best on the Butte Creek (East) alignment and worst on the Hurricane (West) alignment.

4.2.2.10 Waste Area Availability

For the purposes of this analysis, it is assumed that that quarry/borrow pits can be used for waste soil disposal. The distance between the roadway and the quarry/borrow pits will be the primary factor and is accounted in the rock material source availability and soil borrow source availability criteria. Some sites will be less desirable than others due to limited space to store waste during production of materials. In addition, some waste materials may be used to flatten foreslopes, which could be beneficial in thaw unstable permafrost soils where widened embankments can improve driving surface performance.

Additional information would be required to evaluate this criterion in more detail.

Available information is not sufficient to evaluate the corridors based on the availability of waste areas. At this level of evaluation it can be assumed that quarry/borrow sites for any selected corridor will be adequate for soil waste areas.

4.2.2.11 Foundation Support

Foundation support addresses the overall likely subgrade support for structure foundations along the various corridors. From a foundation support standpoint, the most ideal condition is a foundation supported on shallow, competent bedrock. Less ideal conditions range from soft bedrock and/or dense soil support to thick deposits of soft and/or compressible mineral and organic soils that require deep foundations. Other less ideal conditions include thaw unstable permafrost and liquefiable soils. In general, the poorer the foundation support conditions are, the deeper the foundation systems will need to be to transmit structural loads to the subsurface. The cost advantages to selecting a corridor with ideal foundation support conditions is obvious in that shallower foundations require significantly less materials and effort to construct. Ideally, the corridor that is selected will traverse ground that lends itself to development of relatively shallow foundations on bedrock and/or dense, stable, mineral soils.

The South Road alignment appears to have relatively good foundation support between MP 0 and 30 in the alpine areas where bedrock is relatively shallow. In the lowland areas between MP 0 and MP 15 as well as between MP 30 and the dam site, structure foundations will likely bear on glacial till soils. Glacial till soils, while typically dense and adequate for support of structures, may require development of deep foundations if they are overlain by thick organic or lacustrine deposits or to support very high loading. Likewise, challenging slope conditions adjacent to incised channels between MP 30 and the dam site could provide poor foundation support. Based on field observations, the Seattle Creek (North) alignment appears to have favorable foundation support characteristics where the majority of the stream crossings will likely involve developing foundations on dense soil and/or rock substrata. It is likely that soil conditions will be favorable for shallow foundations along the Seattle Creek (North) alignment depending on the size of the crossing.

The Butte Creek (East) alignment is also expected to have relatively good foundation support conditions; however, there will likely be few crossings along this alignment that will be founded on bedrock. As with the Seattle Creek alignment, the soils along the Butte Creek (East) alignment may also be suitable for supporting shallow bridge foundations, depending on the loading requirements.

Foundation support along the Hurricane (West) alignment is expected to be variable with poor conditions in the low lands on the west end of the alignment and good conditions in the eastern two thirds of the corridor. Deep foundations will likely be needed on the extreme west end of the corridor to penetrate soft and compressible surface deposits. Foundations may also be difficult to establish around the deeply incised slopes around the tributaries of Portage Creek.

The South Road with the exception of abutments spanning rivers with deeply incised channels, Butte Creek (East), and Seattle Creek (North) alignments are expected to have the best foundation support conditions. The foundation support conditions for the Hurricane (West) alignment is expected to be variable, with some locations having poor conditions requiring deep foundations for structures.

4.2.2.12 Summary

Overall, based on an assessment of known existing geologic and geotechnical conditions, the Butte Creek (East) corridor is preferred from a geotechnical standpoint. The South Road and Seattle Creek (North) corridors appears to have acceptable geological and geotechnical conditions. The Hurricane (West) corridor presents the greatest number of technical challenges relating to this evaluation criteria (see Table 4-12).

Table 4-12. Summary of geologic and geotechnical conditions

Factor	**South Road**	**Hurricane (West)**	**Seattle Creek (North)**	**Butte Creek (East)**
Rock borrow availability[a]	2	2	1	1
Rock borrow quality	2	4	3	2
Soil borrow availability[a]	3	2	2	1
Soil borrow soil quality	4	4	3	1
Subgrade support	3	2.5	2	1.5
Permafrost conditions	2	2	3	1
Drainage[a]	2	2.5	1.5	1.5
Rock slope stability[a]	3	3	2	2
Soil slope stability	2	3	2	1
Foundation support[a]	2	3	2.5	2

Red = Not preferable Green = Favorable

[a] Not used as evaluation criteria.

4.2.3 Hydrology

Stream crossings were originally identified on USGS topographic maps and aerial imagery. The watershed area draining to each crossing was estimated using 20m Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)[19] contour intervals and USGS mapping. An approximate 50-year (2 percent) flood discharge was estimated using the watershed area, precipitation, and lake area data and the regression equations of Curran et al. (2003). None of the streams identified have gages on them.

Field reconnaissance consisted of flying each access route in a helicopter, identifying each stream crossing (those previously mapped and those that did not appear on the USGS map), landing[20] at selected crossings to estimate channel width and incision depth, and identifying more efficient crossing locations where they existed. The likely structures needed were selected

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[19] ASTER is an imaging instrument flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System.

[20] No crossings were field verified along the South Road alignment.

based on field observations and estimated design discharge. Most streams were assumed to be fish-bearing unless earlier studies identified them as otherwise.

Generally, streams with an active channel over 20 feet wide or with an estimated peak design flow greater than 650 cubic feet per second (cfs) were assigned bridges (see Appendix B). Culverts were assigned to smaller streams, according to the following criteria: large fish culverts were assigned to fish-bearing streams with peak flows between 200 and 650 cfs; small fish culverts were assigned to fish-bearing streams with flows less than 200 cfs; and drainage culverts were assigned to non-fish-bearing streams. Large fish culverts were defined as those greater than 10 feet in diameter based on design discharge. Small fish culverts have diameters ranging between 48 inches and 9 feet (again, depending upon design discharge), whereas drainage culverts have a diameter less than 48 inches. In some cases, it may be possible through further study or minor route adjustments to use different structures than those indicated.

4.2.3.1 South Road

The South Road alignment crosses 23 streams, including four large fish culverts and four bridges. From the Gold Creek Station adjacent to the Susitna River, this road alternative traverses the north-facing slopes above the Susitna River. The first bridge crossing is a 200-foot structure over Gold Creek near MP 0.5. The stream channel is relatively broad and shallow compared to the incised channels elsewhere on the South Alignment.

The alignment crosses numerous smaller streams flowing north into the Susitna River before encountering Cheechako Creek at MP 15. Cheechako Creek requires a structure with a clear span on the order of 300 to 500 feet, due to the wide and deep canyon formed by the stream.

The alignment jogs south to the headwaters draining into Chinook Creek in order to avoid Chinook’s deep ravine. Descending from MP 22 on an eastward course, the alignment navigates between two small lakes downstream of Stephan Lake and crosses additional small streams before approaching Fog Creek near MP 44.

Fog Creek is a large tributary of the Susitna River and is the last drainage requiring bridges before the South Road alignment descends to the proposed dam site on the Susitna River at MP 54.5. The lower reaches of Fog Creek flow through a deep canyon with steep walls and unstable soils. The canyon walls are intermittent vertical, jagged rock formations and with observed rockslides. Rather than attempt to span the canyon, the South Road alignment skirts along the southern rim before crossing the more docile terrain to the east. The first structure in the Fog Creek drainage crosses a major tributary to Fog Creek near MP 45. This structure will have a length between 100 and 300 feet. Near MP 48, another bridge is needed to cross Fog Creek. This bridge is approximately 150 feet in length. At this location, the topography slopes more gradually across the creek, allowing for a shorter bridge and more agreeable access conditions for the movement of equipment and materials making it preferable to crossing Fog Creek closer to the Susitna River. From there the alignment follows the north ridge above the stream approximately three miles back to the west to tie in with the original South Road alignment. The structures associated with the South Road corridor are documented in Appendix B.

4.2.3.2 Hurricane (West)

The Hurricane (West) alignment crosses the most streams of the four alternatives (36 in all, with six bridges and two large fish culverts). The route begins on the Parks Highway, and traverses a hillslope drained by multiple small tributaries to the Chulitna River. The alignment then enters the Indian River drainage, and crosses Indian River with a 150- to 200-foot bridge. Indian River is incised into the surrounding landscape, but several locations were identified where an appropriately graded road could descend into the river valley and back out the other side. Indian River is a steep, bouldery stream, and the crossing should be located at a relatively stable and preferably straight reach, as a bend is more likely to migrate.

After ascending out of the Indian River drainage, the alignment crosses into the Portage Creek drainage, crossing six small tributaries incised into steep gullies. Each of these gullies appears to have relatively stable side slopes at the crossing locations. Stability was judged by assessing the condition of the adjacent vegetation (which was dense and undisturbed). Two of the larger gullies have exposed bedrock cliffs in places. These stream crossings will require relatively deep fill to maintain grade.

Portage Creek is a large tributary to the Susitna River. Thoroughfare Creek joins Portage Creek in the vicinity of the crossing location. There is a large gravel bar immediately downstream of the Thoroughfare/Portage Creek confluence, indicating that this is an active deposition area. We recommend crossing Thoroughfare Creek and Portage Creek upstream of the confluence. Although two bridges would be necessary, Portage Creek appears to be in a more stable channel upstream of the confluence.

After leaving Portage Creek, the alignment crosses Devil Creek, a stable, confined channel incised about 40 feet into bedrock. The alignment then traverses a moderate hill slope and crosses several small streams. One moderately sized stream cut into a gully will likely require a bridge, owing to the depth of incision and large amounts of sediment moving through. The final major crossing is Tsusena Creek, which is the largest drainage on the Hurricane (West) route, and will require a 150- to 200-foot-long bridge to cross.

4.2.3.3 Seattle Creek (North)

There are 15 stream crossings[21] on the Seattle Creek (North) route with the western option, including four bridges and five large fish culverts. The Seattle Creek (North) route leaves the Denali Highway and traverses the Lily and Seattle Creek drainages, both tributaries to the Nenana River. Both Lily Creek and Seattle Creek are crossed in the upper reaches with large fish culverts. The alignment traverses a mild slope into the Brushkana Creek drainage and then crosses Brushkana Creek and a major tributary with short (50-foot) bridges.

The route leaves the Brushkana drainage and enters the Deadman Creek drainage, crossing Deadman Creek three times. The first crossing of Deadman Creek is in a flat, grassy area near the headwaters, and will require a large fish culvert or a short bridge. The second crossing, at the outlet to Deadman Lake, will require a 50- to 75-foot bridge. The creek is steep and incised at this location but banks appear stable. The third crossing of Deadman Creek is the largest creek crossed by any of the alignments and will require a 100- to 150-foot bridge. Deadman Creek alternates between broad, shallow reaches several hundred feet wide and deeper reaches of 90 to 100 feet wide. As the alignment is further refined, specific crossing locations of Deadman Creek at narrower sections should be identified.

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[21] This number refers to the stream crossings on the new roadway. There may be additional crossing associated with the Denali Highway.

4.2.3.4 Butte Creek (East)

The Butte Creek (East) route crosses 29 streams, including four that will require bridges and two requiring large fish culverts. The route begins by crossing the outlet to Snodgrass Lake and Wickersham Creek (both would require large fish culverts or short bridges). The alignment then traverses a poorly drained hillside north of Butte Creek, and crosses Butte Creek with a 100-foot bridge. The alignment leaves Butte Creek and continues along a north-facing slope in the Watana Creek drainage, crossing multiple small streams and swampy beaver dam areas. One creek will require a 30-foot bridge, and Delusion Creek will likely require a large fish culvert. The Butte Creek alignment then joins the Seattle Creek alignment and crosses Deadman Creek with a 100- to 150-foot bridge.

4.2.3.5 Summary

All four corridors require similar numbers of bridges (four on South Road, six on Hurricane [West] and four on Seattle Creek [North] and Butte Creek [East]) for the new road alignment. Collectively, the bridges on the South Road and Hurricane (West) alignments are substantially greater (1,000 and 800 feet respectively) than the Seattle Creek (North; 200 feet) and Butte Creek (East; 300 feet) alignments. The Seattle Creek (North) corridor appears to need 4 large fish culverts while the South Road alignment needs 3 and the Hurricane (West) and Butte Creek (East) alignments need only 2 each. The Seattle Creek (North) alignment needs substantially fewer small fish culverts and drainage culverts (7) compared to South Road (15), Hurricane (West; 27) or Butte Creek (East; 21). In addition to the structures along the stretches of new road, the Seattle Creek (North) and Butte Creek (East) alignments will also require the replacement or upgrade of culvert and bridge structures on their respective portions of the Denali Highway, according to the information presented in Appendix C. Overall, the Seattle Creek (North) alternative is preferable. Table 4-13 summarizes the hydraulic conditions of each alignment. For more information about structures, please see Appendix B.

Table 4-13. Summary of hydraulic conditions on new roadway

Factor	South Road	Hurricane (West)	Seattle Creek (North)	Butte Creek (East)
Number of bridges	4	🟥 6	3	4
Linear feet of bridge	🟥 1,000	🟥 800	🟩 200	300
Drainage culverts	🟩 0	2	🟥 4	🟩 0
Small fish culverts	15	🟥 25	🟩 3	🟥 23
Large fish culverts	🟥 4	2	🟥 4	2

Red = Not preferable **Green = Favorable**

4.2.4 Fish Streams/Waterbodies

Fish are an important resource in Alaska and maintaining access to fish habitat is important for the health of this resource. Historically, road culverts have been a barrier to fish passage as they have restricted the ability for fish to access upstream spawning and rearing areas. DOT&PF has a Memorandum of Agreement (MOA) with ADF&G to ensure that road culverts are adequately sized to accommodate fish passage. Fish passage culverts tend to be larger (and more expensive) than drainage culverts and can have an impact on a project's construction cost. The crossing of fish-bearing waters also requires a Title 16 Fish Habitat Permit (see Section 4.2.12.3).

The access corridor study area includes streams and waterbodies within both the Susitna River and Tanana River watersheds (see Figure 4-7). However, most of the streams that may be crossed ultimately drain into the Susitna River watershed. Many of the streams that would be crossed are small, high-gradient tributaries in the upper reaches of larger watersheds (Schmidt 1983). However, each alignment would also cross larger streams as well as small, swampy tundra streams. Most of these tributary streams are small and shallow with variable discharge (Schmidt et al. 1983). Schmidt et al. (1983) reported that rubble, cobble, and boulders dominated the substrate in many of the tributary streams.

A total of 14 fish species have been documented to occur throughout the streams and lakes within the proposed access corridor study area, as listed below. Biologists documented the presence of both resident[22] and anadromous fish species[23] within the access corridor study area (Schmidt et al. 1983; ADF&G 1983, 2011; FERC 1984; Yanusz et al. 2011).

Arctic grayling (*Thymallus arcticus*)

Dolly Varden (*Salvelinus malma*)

Coho salmon (*Oncoryhynchus kisutch*)

Chinook salmon (*O. tshawytscha*)

Pink salmon (*O. gorbusha*)

Chum salmon (*O. keta*)

Sockeye salmon (*O. nerka*)

Rainbow trout (*O. mykiss*)

Lake trout (*S. namaycush*)

Slimy sculpin (*Cottus cognatus*)

Burbot (*Lota lota*)

Round whitefish (Prosopium cylindraceum)

Longnose sucker (Catostomus catostomus)

Humpback whitefish (*Coregonus oidschian)*

Overall, Arctic grayling was the most abundant and perhaps the most widely distributed fish species documented during various baseline studies conducted within the access corridor study area in the early 1980s. Dolly Varden, slimy sculpin, and burbot were also fairly abundant and widespread (ADF&G 1983, Schmidt et al. 1983).

The five species of Pacific salmon indigenous to Alaska all occur in the Susitna River downstream of Devils Canyon (ADF&G 2011, Yanusz et al. 2011). The Susitna River is among the most important salmon-producing systems in upper Cook Inlet (UCI; HDR 2011a). Fisheries resources contribute to the Cook Inlet commercial harvest as well as the important sport and subsistence fisheries (Jennings 1984, Oslund and Ivey 2010, Shields 2010).

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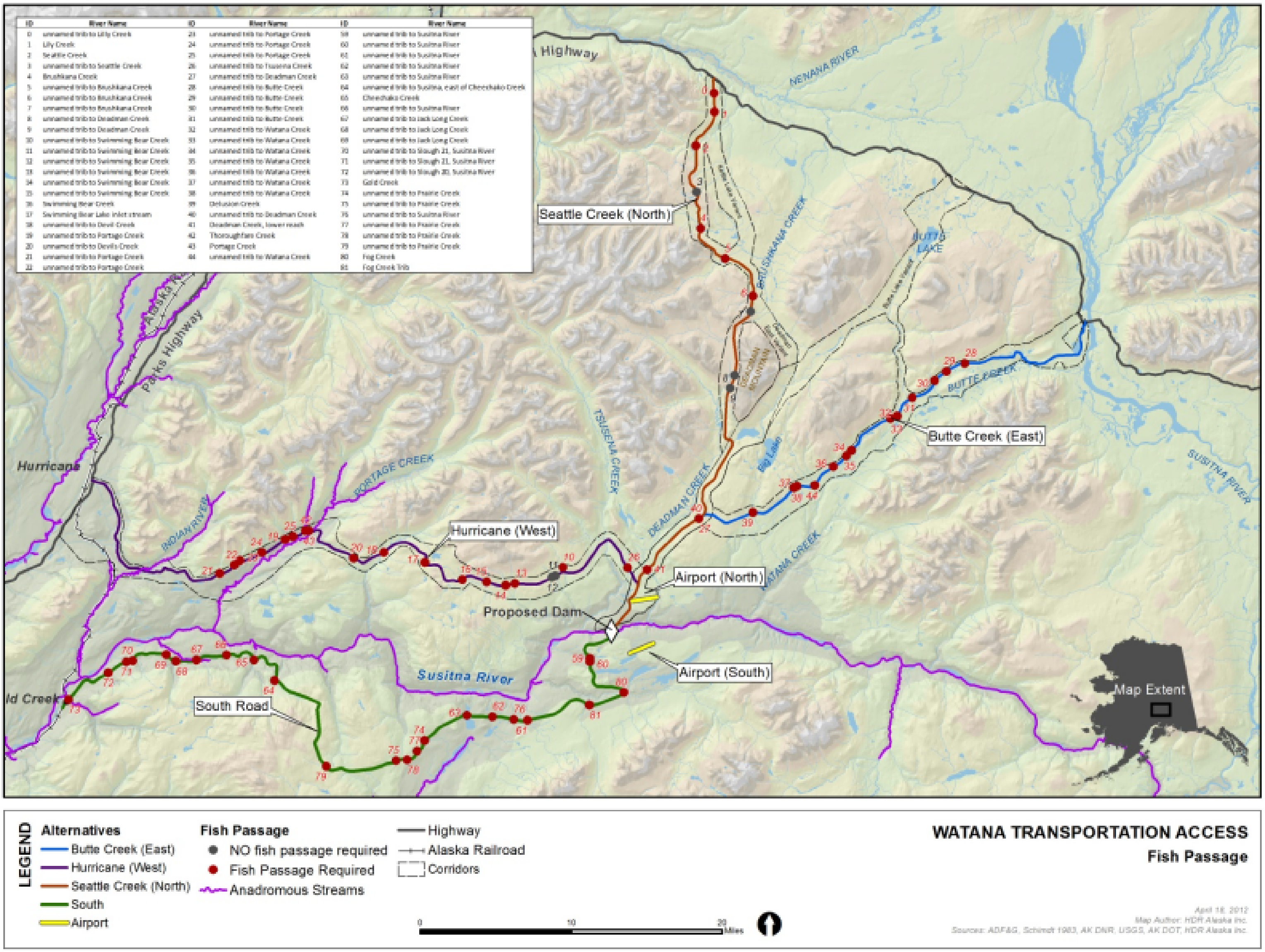
[22] Resident fish spend their entire lives in freshwater. Dolly Varden and rainbow trout have both anadromous and resident forms. Resident Dolly Varden are most often found upstream from barriers (i.e., natural falls, manmade dams) that prevent the upstream migration of anadromous fish (Ihlenfeldt 2005).

[23] Additional species have been documented farther downstream in the Susitna River, including, but not necessarily limited to, eulachon (*Thaleichthys pacificus*), northern pike (*Esox lucius*), Pacific lamprey (*Lampetra tridentate*), and Arctic lamprey (*Lethenteron camtschaticum;* HDR 2011a).



ID	River Name	ID	River Name	ID	River Name
0	unnamed trib to Lilly Creek	23	unnamed trib to Portage Creek	59	unnamed trib to Susitna River
1	Lilly Creek	24	unnamed trib to Portage Creek	60	unnamed trib to Susitna River
2	Seattle Creek	25	unnamed trib to Portage Creek	61	unnamed trib to Susitna River
3	unnamed trib to Seattle Creek	26	unnamed trib to Tsusena Creek	62	unnamed trib to Susitna River
4	Brushkana Creek	27	unnamed trib to Deadman Creek	63	unnamed trib to Susitna River
5	unnamed trib to Brushkana Creek	28	unnamed trib to Butte Creek	64	unnamed trib to Susitna, east of Cheechako Creek
6	unnamed trib to Brushkana Creek	29	unnamed trib to Butte Creek	65	Cheechako Creek
7	unnamed trib to Brushkana Creek	30	unnamed trib to Butte Creek	66	unnamed trib to Susitna River
8	unnamed trib to Deadman Creek	31	unnamed trib to Butte Creek	67	unnamed trib to Jack Long Creek
9	unnamed trib to Deadman Creek	32	unnamed trib to Watana Creek	68	unnamed trib to Jack Long Creek
10	unnamed trib to Swimming Bear Creek	33	unnamed trib to Watana Creek	69	unnamed trib to Jack Long Creek
11	unnamed trib to Swimming Bear Creek	34	unnamed trib to Watana Creek	70	unnamed trib to Slough 21, Susitna River
12	unnamed trib to Swimming Bear Creek	35	unnamed trib to Watana Creek	71	unnamed trib to Slough 21, Susitna River
13	unnamed trib to Swimming Bear Creek	36	unnamed trib to Watana Creek	72	unnamed trib to Slough 20, Susitna River
14	unnamed trib to Swimming Bear Creek	37	unnamed trib to Watana Creek	73	Gold Creek
15	unnamed trib to Swimming Bear Creek	38	unnamed trib to Watana Creek	74	unnamed trib to Prairie Creek
16	Swimming Bear Creek	39	Delusion Creek	75	unnamed trib to Prairie Creek
17	Swimming Bear Lake inlet stream	40	unnamed trib to Deadman Creek	76	unnamed trib to Susitna River
18	unnamed trib to Devil Creek	41	Deadman Creek, lower reach	77	unnamed trib to Prairie Creek
19	unnamed trib to Portage Creek	42	Thoroughfare Creek	78	unnamed trib to Prairie Creek
20	unnamed trib to Devils Creek	43	Portage Creek	79	unnamed trib to Prairie Creek
21	unnamed trib to Portage Creek	44	unnamed trib to Watana Creek	80	Fog Creek
22	unnamed trib to Portage Creek			81	Fog Creek Trib

Figure 4-7. Fish and water body map

The ADF&G has confirmed the presence of Chinook salmon in the Susitna River and some of its tributary streams upstream of Devil's Canyon (ADF&G 2011). Chinook salmon is the only pacific salmon species documented upstream of Devils Canyon in the Susitna River or its tributaries to date (ADF&G 2011).

The Susitna River Chinook salmon stock is the fourth largest in Alaska (Ivey et al. 2009). Although Susitna River Chinook salmon make a relatively small contribution to commercial fisheries, they are important to recreational and guided sport fisheries (HDR 2011a). In February 2011, the Alaska Board of Fisheries (ABF) declared Willow Creek and Goose Creek Chinook salmon as stocks of concern due to declining escapement numbers (HDR 2011a). Both of these creeks flow into the Susitna River well downstream of the access corridor study area.

Sockeye salmon also occur as far upstream as Devils Canyon (Yanusz et al. 2011, ADF&G 2011). Sockeye salmon is the most abundant and economically valuable salmon species in the Susitna River system (HDR 2011a). The Susitna River is the third largest producer of sockeye salmon in the UCI, following the Kenai and Kasilof river systems (HDR 2011a).

Sockeye salmon stocks in the Susitna River have reportedly declined over the past decade (Shields 2010). In 2008, the ABF deemed the Susitna River Sockeye salmon as a stock of yield concern. As a result, an action plan to develop conservation management measures was set in place by the ADF&G. Although sockeye salmon have been extensively studied in the Susitna River, additional information is necessary to identify spawning locations within the middle and portions of the lower Susitna River (HDR 2011a).

The Susitna River coho, chum, and pink salmon stocks are also important to both the commercial and sport fisheries in the UCI area (HDR 2011a). Coho salmon are abundant in the middle reach of the Susitna River from Talkeetna to Devils Canyon (HDR 2011a). Recent studies have been undertaken to identify the spawning distribution of both coho and chum salmon (Merizon et al. 2010) and determine bank orientation of migrating pink salmon within the Susitna River system (Willette 2011).

Arctic grayling, Dolly Varden, lake trout, and rainbow trout are important for the recreational sport fishery in Alaska and in some areas are important subsistence species. Burbot and various whitefish species are also important food sources for subsistence harvest. A subsistence harvest data gap analysis was recently completed for the Watana Hydroelectric Project (Simeone et al. 2011).

Maintaining natural fish populations also plays an important role for the overall genetic biodiversity of each species. Fish species can act as indicator species for changes in the environment. For example, slimy sculpin has been identified as a good indicator species for acidification in lakes and ponds and possibly for streams (Mansfield 2011).

4.2.4.1 South Road

The South Road alignment would require a total of 23 stream crossings. All streams and waterbodies intersected by this alignment drain into the Susitna River watershed. The Susitna River (including side channels and sloughs) are known to provide habitat for Pacific Salmon (ADF&G 2011). Many of the streams that would be crossed are unnamed tributaries of the Susitna River. Fish data are available for a number of streams that would be crossed. However, much of the available fish data were collected downstream from (i.e. not in the direct vicinity of) the proposed crossing sites (ADF&G 1981, 2011; Schmidt et al. 1983).

A total of 8 of the 23 streams intersected by the southern alignment are known to provide habitat for anadromous fish downstream of the proposed crossing sites (ADF&G 1981, 2011; Schmidt et al. 1983). The South Road alignment is presumed to provide fish passage at all 23 proposed stream crossings.

4.2.4.2 Hurricane (West)

The Hurricane alignment would require a total of 36 stream crossings. All streams and waterbodies intersected by this alignment drain into the Susitna River watershed. The majority of streams that would be crossed by the Hurricane (West) alignment are smaller tributary streams to larger systems. However, the Hurricane alignment would also cross a number of larger streams, such as Pass Creek, the Indian River, and Thoroughfare, Portage, Devil, Tsusena, and Deadman creeks.

The Hurricane (West) alignment would cross Granite Creek west of the Parks Highway to facilitate access to the existing railroad line. The ADF&G *Anadromous Waters Catalog* (*AWC*) lists Granite Creek (AWC No. 247-41-10200-2381-3600) as providing habitat for anadromous fish (ADF&G 2011). Bader and Sinnott (1989) captured juvenile Chinook and coho salmon at a point downstream of the proposed crossing (Bader and Sinnott 1989, ADF&G 2011).The *AWC* nomination does not identify the presence of passage barriers; therefore, anadromous fish presence at the Hurricane (West) alignment crossing site is assumed. Fish passage at the crossing site would be provided via either bridge or culvert.

Pass Creek, located southwest of the Hurricane route crossing, is specified as an anadromous stream in the *AWC* (AWC No. 247-41-10200-2381-3236) and is designated to provide habitat for all five species of Pacific salmon (ADF&G 2011). However, a waterfall located downstream of the Hurricane alignment crossing presents a barrier to upstream migration of anadromous fish (ADF&G 2011). The Hurricane alignment intersects nine small, unnamed tributaries to Pass Creek. A limited electro-fishing assessment conducted by ADF&G found Dolly Varden and slimy sculpin at the one location sampled (Buckwalter et al. 2003). Since no other data regarding fish presence are available for these small tributary streams, culverts would be designed to pass resident fish (e.g., Dolly Varden and slimy sculpin).

Three additional streams—Indian River (AWC No. 247-41-10200-2551), Thoroughfare Creek (AWC No. 247-41-10200-2582-3201), and Portage Creek (AWC No. 247-41-1020-2585)—are cataloged (ADF&G 2011) to provide habitat for anadromous fish at the crossing sites. Passage for anadromous fish, including salmon, would need to be provided at each crossing. The Hurricane alignment would include bridges to span the width of the four anadromous fish streams.

The Hurricane (West) alignment would also cross 10 small, unnamed tributaries of Portage Creek, the mainstem of Devil Creek and 3 of its tributaries, and 7 smaller tributaries to the upper Susitna River (in the Swimming Bear drainages; Schmidt et al. 1983). The Hurricane (West) alignment would also cross Tsusena Creek and 2 of its tributaries.

Since fish presence sampling has not been conducted in many of these tributary streams and passage barriers have not been identified to date, fish presence should be assumed. The Hurricane (West) alignment would be required to provide fish passage at all 36 proposed stream crossings.

4.2.4.3 Seattle Creek (North)

The Seattle Creek (North) alignment would cross streams within both the Nenana River and Susitna River watersheds. Seattle Creek and Brushkana Creek are the two major drainages crossed within the Nenana River watershed. Deadman Creek is the major stream crossed within the Susitna River watershed.

The Seattle Creek (North) alignment would require a total of 15 stream crossings. In the 1980s, biologists conducted fish presence surveys in the vicinity of 10 of the 15 stream crossing sites and recorded general habitat and water quality conditions (Schmidt et al. 1983). Resident fish species were confirmed to be present in the vicinity of 9 proposed crossing locations (Schmidt et al. 1983). Schmidt et al. (1983) identified three crossing sites as having intermittent flow and deemed them unsuitable for long-term fish use; therefore, these three sites were not sampled for fish presence at that time.

Biologists documented the presence of Dolly Varden, slimy sculpin, and Arctic grayling (Schmidt et al. 1983). All three species were relatively widespread (Schmidt et al. 1983). No anadromous fish habitat was identified along the Seattle Creek alignment (Schmidt et al. 1983). Biologists captured sculpin near nine of the proposed crossing locations and Dolly Varden and Arctic grayling near six of the proposed crossings. Fish were captured from all but one of the sites sampled. No data are available for one of the 15 stream crossings.

Based on field data reported by Schmidt et al. (1983), the Seattle Creek alignment would be required to provide fish passage at 12 of the 15 stream crossings. Fish passage would not be required at the three crossing sites where intermittent flow was identified. Habitat descriptions for streams crossed within the study area are provided by Schmidt et al. (1983).

4.2.4.4 Butte Creek (East)

The Butte Creek (East) alignment would require a total of 29 stream crossings. The Butte Creek (East) alignment would cross streams and waterbodies that ultimately drain into the Susitna River. Butte Creek, Watana Creek, Delusion Creek, and Deadman Creek are the major streams crossed by the Butte Creek (East) alignment.

In the 1980s, biologists conducted fish presence surveys in the Watana Creek and Deadman Creek drainages (ADF&G 1983, Schmidt et al. 1983). Arctic grayling, burbot, longnose suckers, and sculpin were found to occur within both drainages (ADF&G 1983). Additionally, Dolly Varden presence was confirmed throughout Deadman Creek, while lake trout were captured from its middle and upper reaches (Schmidt et al. 1983). The presence of round whitefish was confirmed in the lower portion of Watana Creek (ADF&G 1983). No fish data were identified for Butte Creek.

The presence of anadromous fish has not been identified in any one of the streams that would be crossed by the Butte Creek (East) alignment (Schmidt et al. 1983; ADF&G 1983, 2011). However, Chinook salmon presence has been confirmed in the Susitna River just upstream from Delusion Creek (ADF&G 2011).

The majority of fish data available for streams intersected by the Butte Creek (East) alignment was not collected in the vicinity of the proposed crossing sites. Since data are not available for the proposed crossing sites, fish presence was assumed. Therefore, the Butte Creek (East) alignment would be required to provide fish passage at all 29 proposed crossing sites.

4.2.4.5 Summary

The Hurricane (West) alignment has the highest number of crossings compared to the other alternatives and the highest number of crossings over anadromous waters (see Table 4-14). However, proposed crossings over the four major anadromous streams would be designed with full span bridges.

The Seattle Creek (North) alignment has the fewest number of stream crossings and does not cross anadromous streams. However, the Seattle Creek (North) alignment would span between two watersheds: the Susitna and the Tanana. Impacting fewer watersheds is preferable because potential impacts (such as introduction of an invasive species) would affect a smaller geographic area if they were to occur. Additional research would be needed to identify potential impacts. The Butte Creek (East) alignment has a total of 29 stream crossings.

Table 4-14. Summary of fish crossings

	South Road	**Hurricane (West)**	**Seattle Creek (North)**	**Butte Creek (East)**
Salmon stream crossings	8	4	0	0
Stream crossings requiring passage for resident fish	23	32	15	29

Red = Not preferable **Green = Favorable**