## STATE OF ALASKA DOT&PF

## STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# HARD AGGREGATE STUDY

## Part 1
## HARD AGGREGATE SOURCE LOCATION STUDY

The object of this study is to identify and profile alternative sources in Alaska that contain materials potentially suitable for hard aggregate production. The general definition of Hard Aggregate for the purposes of this study is: aggregates meeting or exceeding the Nordic Abrasion Ball Mill Specification for Class II, i.e. Nordic Abrasion test value is less than or equal to 10. The study relies primarily on geologic interpretation. R&M Consultants, Inc. (R&M) used collected expertise and available resources to identify prospects for development of hard aggregate sources.

## Part 2
## CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

The Alaska Department of Transportation and Public Facilities (DOT&PF) is investigating the opportunity to supply hard aggregate for paving projects throughout southcentral Alaska, which would increase the life of road surfaces. Currently there are two out-of-state sources for hard aggregate that can ship (via barge) material to Alaska when specified for a project. DOT&PF is interested in supplementing these sources with an in-state site near Cantwell, if such a site can be developed economically within the near future. This report presents an economic analysis of producing aggregate from Cantwell versus the out-of-state sources.

**ALASKA DEPARTMENT of TRANSPORTATION and PUBLIC FACILITIES**

## STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# HARD AGGREGATE SOURCE LOCATION STUDY

**FEDERAL PROJECT NO. STP-000S(823)**
**AKSAS PROJECT NO. 76149**

Prepared by:

R&M CONSULTANTS, INC.
9101 Vanguard Drive
Anchorage, Alaska 99507

## STATE OF ALASKA DOT&PF

## STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# HARD AGGREGATE SOURCE LOCATION STUDY

**FEDERAL PROJECT NO. STP-000S(823)**
**AKSAS PROJECT NO. 76149**


**ALASKA DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES**
5800 East Tudor Road
Anchorage, Alaska 99507-1286

Prepared by:

R&M CONSULTANTS, INC.
9101 Vanguard Drive
Anchorage, Alaska 99507


**May, 2013**

## NOTE TO READERS

This Hard Aggregate Source Location Study has been prepared to provide useful information to multiple groups of readers, including executive decision-makers, geologists, engineers and planners, and materials end-users. As such, it contains information that may be highly useful to one group, yet too detailed or too broad for the next. The following guidelines are intended to help each group of readers quickly find the information that will be most useful to them.

**Executive decision-makers** will perhaps be most interested in the Executive Summary, the Conclusions (Chapter 7.0), the appended source reports, and the attached plate. Based on available time and interest, this group of readers may also glean useful information from Chapters 1.0 through 3.0.

**Geologists** will find the entire study to be of use. Depending on what their immediate need or interest may be, this group of readers may choose to focus on a particular region or area of study, or on a particular hard aggregate source. Before focusing on a geographic area, however, the geologist reader will be well served by reading Chapters 1.0 through 3.0. This group of readers will also find Chapters 4.0 through 6.0 to be condensed treatments of a broad cross section of geological areas; as such, these latter chapters will provide useful reference material. This group of readers will be able to utilize this study as a starting point for prospecting and planning the development of hard aggregate sources.

**Engineers and planners** will likely wish to focus on the Executive Summary, Conclusions (Chapter 7.0), and the two attached Plates. For project-specific or area-specific interests, this group of readers will also find utility in the appended source reports. Prior to using the information herein, engineers and planners will wish to become familiar with Chapters 1.0 and 2.0, with at least a cursory review of Chapter 3.0.

**Materials end-users** will be most interested in the appended source reports. Next in importance for this group of readers will be the Executive Summary and Conclusions (Chapter 7.0), followed by Chapters 1.0 through 3.0.

# STATE OF ALASKA DOT&PF
# STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# HARD AGGREGATE SOURCE LOCATION STUDY

## TABLE OF CONTENTS

**Page**

## LIST OF TABLES

## LIST OF FIGURES



## ATTACHMENTS

## LIST OF APPENDICES

# HARD AGGREGATE SOURCE LOCATION STUDY

## EXECUTIVE SUMMARY

The Alaska Department of Transportation and Public Facilities (DOT&PF) recognizes that using hard aggregate in pavement products significantly lengthens the performance life of asphalt surfaces. However, the State of Alaska lacks developed sources for supplying hard aggregate, and has had to rely on importation of such materials. The objective of this study is to identify and profile alternative sources in Alaska that contain materials potentially suitable for hard aggregate production. The definition of Hard Aggregate for the purposes of this study is: aggregates meeting or exceeding the Nordic Abrasion Ball Mill Specification for Class II, i.e. Nordic Abrasion test value is less than or equal to 10.

Nordic Abrasion test results are unavailable for many existing or potential material sites in Alaska. Other test results may be available including: Los Angeles Abrasion, Degradation Value, Specific Gravity, Absorption, Unconfined Compressive Strength, and others. These data may be helpful in identifying potential hard aggregate sources, but their correlation to Nordic Abrasion Values are generally poor.

Rock type and characteristics can provide important information on potential suitability of a rock source for producing hard aggregate. Rock weathering, origin, type, grain-size, presence of foliation or mineral orientation, and alteration or degree of metamorphism all affect rock durability and should be considered when identifying potential sources. Research indicates that the best performing hard aggregates are typically fine-grained rock without any foliation or mineral orientation, and are typically igneous or metamorphic in origin. Some of these materials are hornfels, porphyritic basalt, metamorphosed volcanics, amphibolite and quartzite.

Three sites were found in Southcentral Alaska that meet the criteria for hard rock potential and access. Much of the rock in Southcentral Alaska consists of the Valdez and Orca Groups which are generally highly foliated and not suitable. Much of the rock that appears to have potential is in locations that are difficult to access, such as Prince William Sound and the Talkeetna Mountains. Land development has not had a great impact on areas with hard aggregate potential. However, land withdrawals, particularly in Prince William Sound, have had an impact. There are many gravel sources with Nordic Abrasion test results less than 10 in Southcentral Alaska (although the test results are generally not consistent). Only the three potential sites were identified; 2 igneous, 1 hornfels.

The Alaska Peninsula, the Aleutian Islands east of Unalaska, Kodiak Island and the Shumagin Islands have a low potential for producing hard aggregate. The geology of the region is dominated by volcanic, sedimentary, and foliated metamorphic rocks which are generally not likely to be suitable. However, there are some intrusive bodies with associated contact metamorphic aureoles which may have potential for suitable material. With the exception of Kodiak Island and Unalaska, there is little infrastructure in place to mine and transport aggregates, and without port facilities weather conditions can make loading and shipping difficult. Much of the Alaska Peninsula and Aleutian Islands are part of wildlife refuges, monuments, parks, wilderness areas, or other designated restricted development areas. Several of the most promising remaining areas, including Unalaska, Sand Point and Chignik, had previous investigations and additional studies were not prepared for them. The few remaining alternative areas did not have promising potential sources and thus no potential hard aggregate source reports were prepared for the Alaska Peninsula and Aleutian Islands or Kodiak Island.

There appear to be significant numbers of sites with the potential to produce hard aggregate in Southeast Alaska, with many of them having road access and relatively sheltered harbors. Many of the sources in southeast Alaska were within the Tongass National Forest and would require permission of the U.S. Forest Service to use. About half of the potential sources in Southeast Alaska are within parks, monuments, wilderness areas, roadless areas and dedicated recreational areas, and likely would not be attainable. Where ever they could be identified these special use areas were not included in the study. Even with these limitations 27 individual sites were identified, including: 12 hornfels sites, 11 basalt sites, 1 gabbro, 1 possible gabbro, 1 possible syenite, and 1 gravel site with several overlapping areas.

Table 7-1 of this report presents a summary of potential hard aggregate sources. The table includes name of site, highway milepost, site status, ownership, location coordinates, Nordic Abrasion values and also includes an overall characterization of this site. These sources are also depicted on Plate 1 and described in more detail within the individual appendices.

Additionally, a separate feasibility study was performed to evaluate hard aggregate development at a site near Cantwell. That study is presented in a separate project report (Part 2 of this document).

# STATE OF ALASKA DOT&PF
# STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# HARD AGGREGATE SOURCE LOCATION STUDY

## 1.0 INTRODUCTION

### 1.1 Background

The Alaska Department of Transportation and Public Facilities (DOT&PF) recognizes that using hard aggregate in pavement products significantly lengthens the performance life of asphalt surfaces. However, the State of Alaska lacks developed sources for supplying hard aggregate, and has had to rely on importation of such materials.

The object of the study is to identify and profile alternative sources in Alaska that contain materials potentially suitable for hard aggregate production. The general definition of Hard Aggregate for the purposes of this study is: aggregates meeting or exceeding the Nordic Abrasion Ball Mill Specification for Class II, i.e. Nordic Abrasion test value is less than or equal to 10. The definition of alternative sources for the purpose of this study are sites not covered in the previous investigations listed in Table 1-1. Table 1-2 (Hard Aggregate Data Table) contains a non-comprehensive compilation of Nordic Abrasion data that was provided by DOT&PF.

**TABLE 1 - 1**
**PREVIOUS DOT&PF HARD AGGREGATE PROJECTS**

| Investigation Date | Project/Reference | DOT&PF Personnel | Product |
|---|---|---|---|
| 1998-2000 | Draft, Studded Tire Wear Resistant Aggregate Study, Final Report | Pavey and Johnson, May 2000 | Final Report |
| 2003 | Statewide Aggregate Source Investigation | Fritz and Lewis | Draft Report and Pavement Summit Presentation |
| 2004-2005 | Material Site Reconnaissance Report – Denali Highway MP 110 | Boeckman, Jan 2005 | Final Report |
| May 2012 | [Hard aggregate data integration] | Pavey, Finkbiner, Bingham | Web interface: http://10.200.100.100/hardaggregatestudy/ See Table 1-2 |
| Aug 2012 - Current | Cantwell Hard Aggregate Development Feasibility Study | Wright, Saboundjian | Existing Task 7 of AKSAS 79434 |

**TABLE 1 - 2**
**HARD AGGREGATE DATA TABLE**
(From DOT&PF database http://10.200.100.100/hardaggregatestudy/)

| Site ID | Site Description | Nordic Min. | Nordic Max. | Lat. (NAD83) | Lon. (NAD83) |
|---|---|---|---|---|---|
| **INTERIOR/NORTHERN ALASKA** | | | | | |
| 36 | Denali Highway | **6.5** | **8.1** | 63.320909 | -148.234264 |
| 47 | MP 110 Denali Highway | **8.1** | 19 | 63.299565 | -148.139528 |
| 53 | Brown's Hill | 15 | 15 | 64.830704 | -147.474224 |
| 56 | Shaw Creek Quarry | **8** | 17.9 | 64.285378 | -146.130323 |
| 84 | MP 261 Dalton Hwy | **6.8** | **6.8** | 68.318205 | -149.348318 |
| 85 | MS 65-9-021-2 Atigun | 12.5 | 12.5 | 68.31548 | -149.344318 |
| 87 | Nenana River | **9.5** | **9.5** | 64.567336 | -149.100531 |
| 102 | MP 24 Denali Highway | **9.7** | **9.7** | 63.068893 | -146.101916 |
| 103 | MP 20.5 Denali Highway | 10.5 | 10.5 | 63.048127 | -145.99745 |
| 109 | Flag Hill, Fairbanks | **9.6** | **9.6** | 64.409736 | -146.960259 |
| **SOUTHCENTRAL ALASKA** | | | | | |
| 1 | Skookum Pit<br>MP 5.2 Old Glenn Hwy | **7.1** | 22.5 | 61.37775 | -149.493863 |
| 2 | AAA Valley Gravel,<br>Trunk Road | 11.9 | 15.3 | 61.59047 | -149.256618 |
| 3 | Cange-Pittman | **9.3** | 11.7 | 61.583028 | -149.602339 |
| 4 | N. Birchwood on<br>Old Glenn Hwy | **7.4** | 13.4 | 61.392136 | -149.464042 |
| 5 | Birchwood Pit | 12.1 | 12.7 | 61.412783 | -149.499325 |
| 6 | 42 Mile Pit Seward Hwy | 17.5 | 18.7 | 60.589756 | -149.549586 |
| 8 | Ridgeway Pit, Soldotna | 10.4 | 14 | 60.504563 | -151.074751 |
| 9 | Breeden Pit K-Beach Rd,<br>Soldotna | 11.4 | 12.5 | 60.505115 | -151.1432 |
| 11 | New K-Beach Pit,<br>Soldotna | 13.2 | 13.2 | 60.510436 | -151.140794 |
| 12 | Premier Pit,<br>MP 10.4 Old Glenn Hwy | **9.3** | **9.3** | 61.528236 | -148.985341 |
| 13 | MS 584-001-1 MP 6.3,<br>Petersville Road | 16 | 16 | 62.310612 | -150.425766 |
| 14 | Frontier Pit, Soldotna | 12.3 | 12.8 | 60.500691 | -151.070231 |
| 19 | Lucas Pit, Palmer | 15.3 | 42 | 61.594006 | -149.13019 |
| 21 | MP 101.5 Seward Hwy | 13.5 | 18.9 | 60.974901 | -149.471681 |
| 22 | Dyno Nobel Pit, MP 8.1<br>Parks Hwy | 11.9 | 11.9 | 61.856783 | -150.07827 |
| 23 | Spencer Pit | 11.3 | 16.6 | 60.712704 | -149.085201 |
| | | | | | |

| Site ID | Site Description | Nordic Min. | Nordic Max. | Lat. (NAD83) | Lon. (NAD83) |
|---|---|---|---|---|---|
| **SOUTHCENTRAL ALASKA (CONT.)** | | | | | |
| 28 | Palmer | 11.5 | 11.5 | 61.558785 | -149.174042 |
| 31 | MP 217 Parks Hwy | **6.2** | 10.9 | 63.467533 | -148.801696 |
| 32 | Anchorage | **8.1** | 22.1 | 61.56914 | -149.168922 |
| 34 | Eklutna | 15.4 | 56.1 | 61.473461 | -149.259882 |
| 42 | MP 19.7 Hatcher Pass | 13 | 13 | 61.772828 | -149.293447 |
| 43 | MP 22.8 Hatcher Pass | 13.2 | 13.2 | 61.772985 | -149.292793 |
| 45 | Hicks Ck Matanuska R | 26.9 | 26.9 | 61.789191 | -147.936915 |
| 46 | MP 60 Seward Hwy | 11.2 | 11.2 | 60.7514 | -149.38113 |
| 48 | 0.3 Exit Glacier Rd, Seward | 14.5 | 16.9 | 60.153213 | -149.439412 |
| 49 | 4th of July Ck., Seward | **8.5** | 12.6 | 60.096505 | -149.363575 |
| 51 | Best Pit, MP 18.6 K Beach Rd | 24.6 | 24.6 | 60.494816 | -151.155233 |
| 64 | Railroad Quarry, Eklutna | 10.3 | 15.4 | 61.464275 | -149.357482 |
| 65 | Dan's Cove Quarry | 26.4 | 26.4 | 59.450601 | -151.707205 |
| 71 | Wolf Pit, Hyer Rd, Wasilla | 10.2 | 10.2 | 61.572389 | -149.29557 |
| 72 | MP 75.5 Glenn Hwy | **9.8** | 11.4 | 61.774789 | -148.503693 |
| 76 | MP 66.2 Glenn Hwy | 14.7 | 14.7 | 61.737767 | -148.756073 |
| 88 | MS 576-015-1 Old Glenn by Knik River Bridge | 10.2 | 10.2 | 61.499556 | -149.032174 |
| 98 | MP 37 Parks Hwy | **6.3** | **9.6** | 61.56967 | -149.301984 |
| 108 | Eklutna | 12 | 12.2 | 61.45558 | -149.371739 |
| **SOUTHWEST ALASKA** | | | | | |
| 10 | Tununak | 20.7 | 30 | 60.585249 | -165.23494 |
| 15 | Dome Quarry, Sand Point | 14.4 | 14.4 | 55.3278 | -160.502241 |
| 16 | Knoll Quarry, Sand Point | 19.1 | 19.1 | 55.326519 | -160.498517 |
| 39 | Ruth Shaisnikof Pit, Unalaska | **5.9** | **5.9** | 53.826124 | -166.609109 |
| 58 | Castle Bay Quarry | 24 | 24 | 56.203422 | -158.349887 |
| 59 | MP 1 Williamsport to Pile Bay | 17 | 17 | 59.699429 | -153.599434 |
| 63 | Captains Bay Quarry, MP 4.0, Unalaska | **8.1** | **8.1** | 53.835254 | -166.58468 |
| 78 | Manokotak Loop Rd Quarry | **9.1** | **9.1** | 58.926629 | -158.768576 |
| 86 | MP 5 N. Camp Rd, King Salmon | 16 | 16 | 58.665357 | -156.543176 |
| | | | | | |

| Site ID | Site Description | Nordic Min. | Nordic Max. | Lat. (NAD83) | Lon. (NAD83) |
|---|---|---|---|---|---|
| **SOUTHWEST ALASKA (CONT.)** | | | | | |
| 92 | Red Mountain Quarry, Platinum, AK | 10.5 | 24.4 | 58.957351 | -161.746147 |
| 96 | Stebbins Pit, Stebbins | 11.9 | 11.9 | 63.535954 | -162.290341 |
| 100 | Red Cove Quarry, Sand Point | 12.8 | 12.8 | 55.326457 | -160.426161 |
| 106 | Margaret Bay Quarry | 11.3 | 11.3 | 53.884055 | -166.556419 |
| 107 | Ugadaga Quarry | **10** | **10** | 53.849825 | -166.495249 |
| **KODIAK ISLAND** | | | | | |
| 7 | Bells Flats #2 Kodiak | **9.3** | 32.6 | 57.697655 | -152.587538 |
| 17 | Pasagshak Pit MP 9 | 19.7 | 19.7 | 57.453885 | -152.447535 |
| 55 | Shakmanof Bay, Kodiak | 12.7 | 12.7 | 57.91243 | -152.60141 |
| 90 | MP 30.5 Chiniak Hwy, Kodiak | **8.4** | 20.9 | 57.581908 | -152.461077 |
| **SOUTHEAST ALASKA** | | | | | |
| 33 | Lena Point Quarry | 10.7 | 28.4 | 58.391127 | -134.770282 |
| 38 | Gas at Last Pit, Ketchikan | 27.8 | 27.8 | 55.370122 | -131.697651 |
| 62 | Coffman Cove - Rock Ex | **9** | 12.3 | 55.976533 | -132.807419 |
| 74 | Haines 4 Mile Quarry | **9.6** | **9.6** | 59.248258 | -135.535266 |
| 75 | Kake City Pit | 12.6 | 12.6 | 56.96475 | -133.924854 |
| **OUTSIDE ALASKA** | | | | | |
| 18 | DuPont, Washington | **6.1** | 19 | 49.878421 | -127.401103 |
| 60 | Jervis Inlet, B.C., Canada | **6.9** | **9.9** | 51.406161 | -126.822637 |

Note: Bold results indicate Nordic Abrasion results that meet the “hard aggregate” definition.

### 1.2 Scope-of-Work

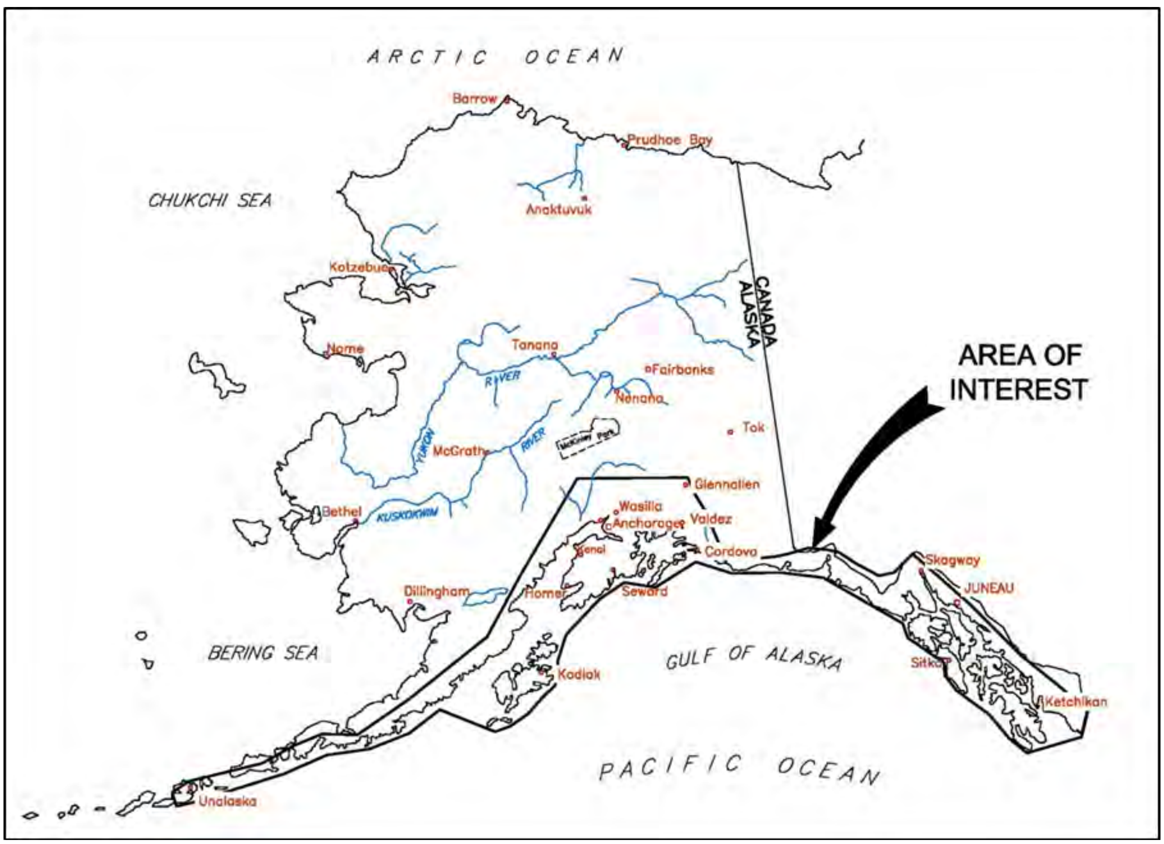
The basic approach to this study relies on geologic interpretation. R&M used collected expertise and available resources to identify prospects for development of hard aggregate sources.

Sites to be identified and profiled had to meet the following criteria:

- Located within the Southcentral Alaska area and accessible by road or railroad.
- Located within the following geographic areas accessible by water:
    - Aleutian Islands (east of Unalaska) and Alaska Peninsula
    - Kodiak Island
    - Prince William Sound
    - Southeast Alaska
- Situated within reasonable proximity to existing or planned roadways, railways or ports.
- Contains materials with demonstrated or anticipated test data that reflect Nordic Abrasion test values less than or equal to 10.

Figure 1-1 shows the area of interest for this study.

**FIGURE 1 - 1**
**PROJECT MAP**



### 1.3 Assumptions

The following assumptions were made during this study.

1. Land ownership was determined based on readily available, web-based public records and did not involve case file searches or formal title searches.
2. In Southcentral Alaska, sites north of Byers Lake on the Parks Highway were not considered, as highway haul would likely be too expensive to utilize them. Likewise sites north of Glennallen on the Richardson Highway, the Denali Highway and Tok Cutoff were also not considered for the same reason. The Hard Aggregate Site at Cantwell was studied in detail previously and was thus omitted from this study.
3. We avoided Wrangell- St. Elias National Park and Preserve, Glacier Bay National Park and Preserve, Admiralty Island National Monument, Misty Fiords National Monument, Kenai Fiords National Park, Lake Clark National Park and Preserve, Katmai National Park and Preserve, and Aniakchak National Monument and Preserve. We also avoided the wildlife refuges, wilderness areas and roadless areas within National Forests.

### 1.4 Contract Authorization

This study was conducted as part of Professional Services Agreement No. 02572001, Statewide Material Site Inventory, Site Inspections & Geological Investigations, between DOT&PF and R&M Consultants, Inc. (R&M). Work was performed under Amendment No 11, NTP No.12 and consists of Subtasks D and E of Task 7 of the agreement.

# 2.0 AGGREGATE / ROCK TESTING

Hard Aggregate is the coarse fraction (retained on the No. 4 sieve) of aggregate intended for asphalt concrete pavement; as mentioned previously, it should have a Nordic Abrasion value of 10 or less. Ideally any potential source would be identified based on Nordic Abrasion test results. However, Nordic Abrasion tests have only been performed on a limited number of material sources in Alaska. Most potential sources will not have available Nordic Abrasion results, so the potential for producing hard aggregate will need to be determined by other means. This section will discuss how other tests and rock properties may be used for predicting Nordic Abrasion values. Table 2-1 summarizes specific laboratory testing which may be available and its reliability for predicting Nordic Abrasion value.

**TABLE 2 - 1**
**RELIABILITY OF SELECTED TESTS FOR PREDICTION OF NORDIC ABRASION VALUE**

| Test | Reliability for Predicting Nordic Abrasion Value |
|---|---|
| LA Abrasion (ASTM C 131) | Moderate |
| Degradation (ATM 313) | Low to Moderate |
| Specific Gravity and Absorption (ASTM C 128) | Low |
| Unconfined Compressive Strength (ASTM D 7012) | Good |

## 2.1 Los Angeles Abrasion (ASTM C 131)

The Los Angeles Abrasion test (ASTM C 131) has been widely used to determine aggregate quality, but the results do not necessarily permit reliable comparisons to be made between different rock units. Therefore, Los Angeles Abrasion test loss specification limits should be assigned with consideration of source performance history, which may not be available for new sources. Where a positive correlation between Nordic Abrasion and Los Angeles Abrasion testing loss values has been established for a particular rock unit, the Los Angeles Abrasion test can be a strong indicator of suitable hard aggregate sources. Where this correlation has not been established, the Los Angeles Abrasion test should only be used as an indicator of potential hardness, and not associated directly with suitability for hard aggregate production. The compiled Los Angeles and Nordic Abrasion values for various rock types are illustrated on Figure 3-1 in Section 3.

## 2.2 Degradation Value of Aggregates (ATM 313)

The degradation value of aggregate test (ATM 313) was developed to determine the durability of an aggregate to resist degrading to detrimental clay-like fines when subjected to a prescribed Abrasion process in the presence of distilled or demineralized water. Materials that maintain high Degradation values will probably be more suitable for use as hard aggregates than those with low Degradation value, but the Degradation test is not specifically measuring hardness, only durability of a material to resist degradation to fine silt and clay particles. The problem with associating this test with hardness is that certain materials may readily break down into particles finer than the desired aggregate but not fine enough to produce poor Degradation results (fine sand size particles for example). As such, the Degradation value should only be used as a general indicator of hardness, and not associated directly with rock hardness.

## 2.3 Specific Gravity and Absorption (ASTM C 128)

The Specific Gravity and Absorption tests (ASTM C 128) are used to determine the density of the solid portion of an aggregate sample and potential of the aggregate to absorb and maintain water within pore spaces. The results of these tests provide an average value representing the Specific Gravity and Absorption for a given aggregate sample. Higher values for Specific Gravity and lower values for Absorption will tend to correlate with harder aggregates. However, Specific Gravity and Absorption tests do not address rock durability, and some rock units with attractive Specific Gravity and Absorption qualities have very low durability, and thus, hardness. Therefore, the results of Specific Gravity and Absorption testing are considered a poor indicator of aggregate hardness.

## 2.4 Unconfined Compressive Strength (ASTM D 7012)

Unconfined compressive strength testing can be useful in screening sites quickly and economically for their potential for producing hard aggregate. Many of the physical properties that result in high strength are also expected to result in low Nordic Abrasion values. Table 2-2 summarizes the classification of rock strengths. Rock in the very to extremely strong range would be expected to be a good candidate for a source of hard aggregate.

**TABLE 2 - 2**
**CLASSIFICATION OF ROCK MATERIALS STRENGTHS (ISRM, 1977)**

| ISRM Grade | Field Identification | Hardness | Description | Approximate Range of Compressive Strength (p.s.i.) |
|---|---|---|---|---|
| R6 | Specimen can only be chipped with geological hammer | Very hard | Extremely strong rock | >36,000 |
| R5 | Specimen requires many blows of geological hammer to fracture it | | Very strong rock | 15,000-36,000 |
| R4 | Specimen requires more than one blow with a geological hammer to fracture it | Hard | Strong rock | 7,000-15,000 |
| R3 | Cannot be scraped with a pocket knife; specimen fractured with single blow of geological hammer | Moderately hard | Medium weak rock | 3,500-7,000 |
| R2 | Can be peeled with a pocket knife; shallow indentations made by firm blow with point of geologic hammer | Medium | Weak rock | 725-3,500 |
| R1 | Crumbles under firm blows with point of geological hammer; can be peeled with pocket knife | Soft | Very weak rock | 150-725 |
| R0 | Can be indented by thumbnail | Very soft | Extremely weak rock | 35-150 |

## 2.5 Selected References

Alaska Department of Transportation and Public Facilities (DOT&PF), 2012, Alaska Test Methods Manual.

American Society of Testing and Materials (ASTM), 2012, Annual Book of ASTM Standards, Vol. 04.02, Concrete and Aggregates.

American Society of Testing and Materials (ASTM), 2012, Annual Book of ASTM Standards, Vol. 04.02, Concrete and Aggregates.

# 3.0 GEOLOGY OF HARD AGGREGATES

Locating potential hard aggregate sources requires finding rock with the appropriate characteristics. These various characteristic are outlined below.

## 3.1 General

Rock type and characteristics can provide important information on potential suitability of a rock source for producing a durable (hard) aggregate. Rock weathering, origin, type, grain-size, presence of foliation or mineral orientation, and alteration or degree of metamorphism all affect rock durability and should be considered when identifying potential sources.

Research in the Nordic countries indicates that the best preforming hard aggregates are typically fine-grained without any foliation or mineral orientation. Their work also indicates that the most durable aggregates are “older” and of metamorphic origin. Some of these materials are hornfels, porphyritic basalt, metamorphosed volcanics, amphibolite and quartzite. Contact metamorphism (metamorphism produced when hot magma comes in contact with country or host rock) is responsible for many of these high quality aggregates (Johnson and Pavey, 2000).

## 3.2 Weathering

Weathering is one of the more important criteria for eliminating or accepting rock units for consideration of potential for hard aggregate sources. Rock formations that weather readily or extensively will not make good sources. Many of the older rocks in Alaska have been extensively weathered in areas without recent glaciation. These rocks generally lie within Alaska’s interior, north of the Alaska Range and outside of this study area. Conversely, many of the very young rocks are poorly consolidated and weather very rapidly. These include the Kenai and Tyonek Formations surrounding Cook Inlet, the Nenana Gravels in the Alaska Range and the Chickaloon Formation in the Matanuska Valley, to name a few.

The degree of weathering on a particular rock unit affects the rock hardness and can vary widely. A rock that may be hard in its fresh state may be prone to weathering and particularly weakened by the weathering. However, rocks that are good sources for hard aggregates tend to resist weathering compared to softer rock units. Therefore, rock masses that classify as anything more than slightly weathered would typically not be a good source for hard aggregate. Table 3-1 provides a description of the various grades of rock weathering.

Weathering action varies regionally across the state. Surficial rock units in interior and northern Alaska are exposed to much colder temperatures than southern portions of the state, therefore the effects of frost penetration intrude deeper within the rock. However, surficial rocks in maritime climates are typically exposed to harsher freeze-thaw conditions and chemical environments which enhance rock weathering. The fracture state of a particular rock unit also has a large effect on rock weathering. Highly fractured or jointed rock will enhance the effects and depth of weathering. Weathering also tends to vary widely across a rock unit. Additional removal of undesirable overburden and rock may be required at one site over another as an effect of different weathering regimes.

As weathering can vary widely across a site, samples must be selected with care to ensure the test rock is representative of the source rock, not showing a varying degree of weathering. To the extent possible, samples should be broken from the fresh rock face of a source or taken from a portion of the deposit, talus slope, stock pile, etc. showing representative weathering characteristics. Weathering and alteration grades of rock are shown in Table 3-1.

**TABLE 3 - 1**
**WEATHERING AND ALTERATION GRADES (ISRM, 1977)**

| Grade | Term | Description | Hard Aggregate Production |
|---|---|---|---|
| I | Fresh | No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces | Possible, Depends on rock hardness characteristics |
| II | Slightly weathered | Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition | Possible, Depends on rock hardness characteristics |
| III | Moderately weathered | Less than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or as corestones | Not suitable |
| IV | Highly weathered | More than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present as a discontinuous framework or as corestones | Not suitable |
| V | Completely weathered | All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact | Not suitable |
| VI | Residual Soil | All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported | Not suitable |

## 3.3 Origin and Type of Rock

Figure 3-1 shows compiled Los Angeles and Nordic Abrasion values by rock type in Norway. The geologic history in Norway is different than Alaska's, and rocks have been subject to different depositional histories and tectonic forces in the two locations. Mylonite is one example of this. Apparently in Norway mylonite is a hard fine-grained rock that would make suitable hard aggregate, whereas in Alaska it typically has been subjected to more shearing forces and has not consolidated to the extent it has in Norway. There are some rock types found in Norway that are uncommon in Alaska such as norite (found in association with gabbro on Chichagof and Admiralty Islands) and some differences in local nomenclature are also evident.

Table 3-2 presents a comparison of typical rock types and the potential for hard aggregate production in Alaska.

**FIGURE 3 - 1**
**COMPILATION OF TEST RESULTS FOR HARD ROCK AGGREGATES IN NORWAY**
(From Erichsen et al., 2008)

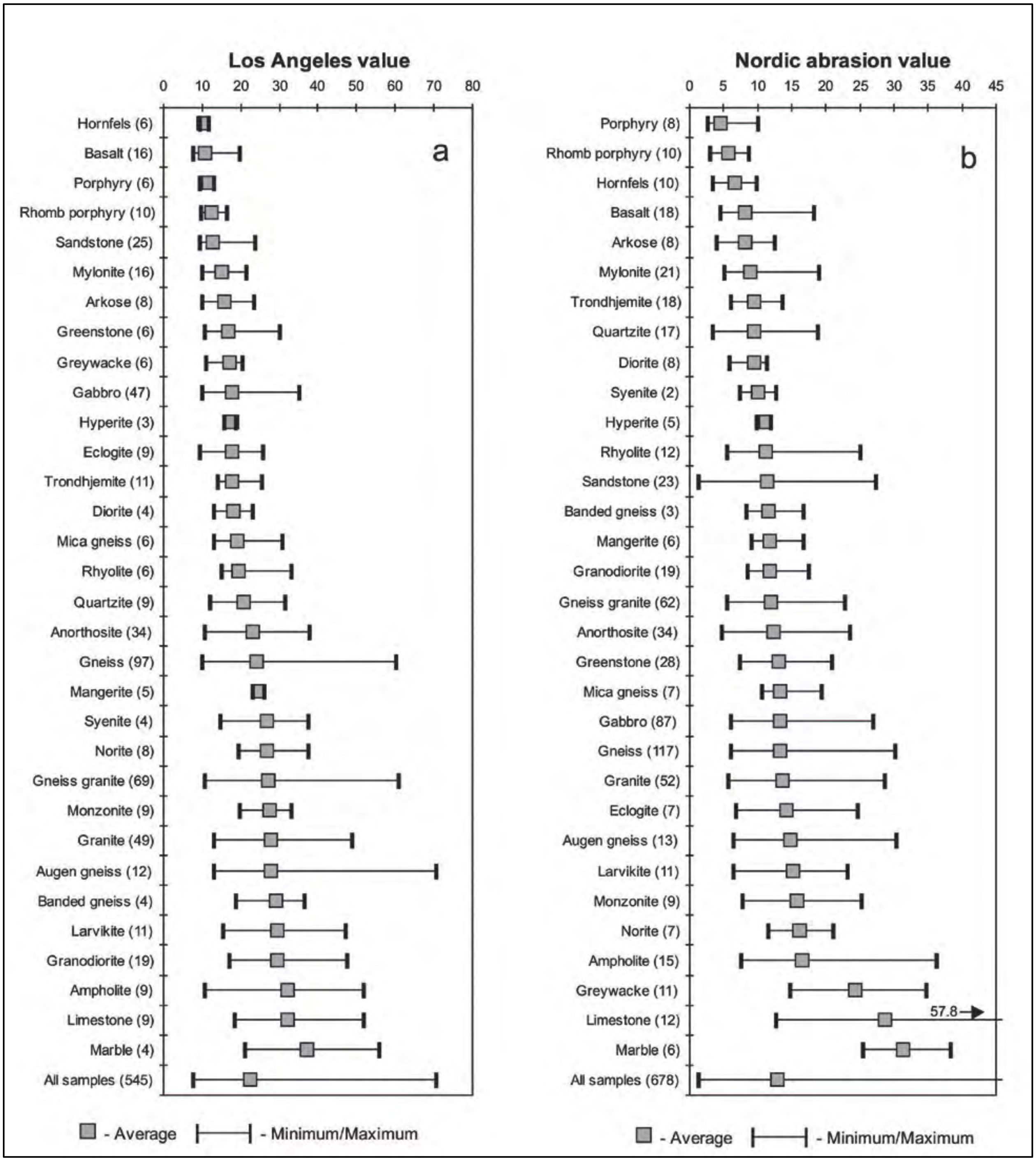


**TABLE 3 - 2**
**TYPICAL ROCK TYPES AND POTENTIAL FOR HARD AGGREGATE DEVELOPMENT IN ALASKA**
(Nordic Abrasion Value 10 or less)

| Rock Origin | Typical Rock Types | Hard Aggregate Potential | Occurrence (In Study Area) |
|---|---|---|---|
| SEDIMENTARY | Conglomerate | Low to High | Common |
| | Sandstone | Low | Common |
| | Siltstone | None | Common |
| | Argillite | None to Low | Common |
| | Shale | None | Common |
| | Limestone | None | Common |
| IGNEOUS (fine-grained*) | Granite | Moderate | Less Common** |
| | Trondhjemite | Moderate | Less Common** |
| | Syenite | Moderate | Less Common** |
| | Monzonite | Moderate | Less Common** |
| | Granodiorite | Moderate | Less Common** |
| | Tonalite | Moderate | Less Common** |
| | Diorite | Moderate to High | Less Common** |
| | Gabbro | Moderate to High | Less Common** |
| | Ultramafics | Moderate to High | Less Common** |
| | Basalt/Andesite | High | Common |
| METAMORPHIC | Hornfels | Moderate to High | Common |
| | Greenstone | Moderate to High | Common |
| | Gneiss | Low to Moderate | Common |
| | Schist | None | Common |
| | Phyllite | None | Common |
| | Slate | None | Common |
| | Quartzite | Moderate to High | Common |
| | Marble | None | Common |
| | Mylonite | None to Moderate | Common |
| UNCONSOLIDATED MATERIALS | Gravel | Low to High | Common |
| | Sand | None | Common |

* Medium and coarse-grained igneous rocks have low hard aggregate potential, but are more common.
** Fine-grained rock only

### 3.3.1 Sedimentary Rocks

For the most part sedimentary rocks are too weakly cemented to be useable. Typically, only where they are cemented by silica do they have the strength necessary to resist fracturing by tire studs. The conglomerates and sandstones found along the Dalton Highway in the Atigun Valley (Brosge et al, 1979) are a good example of this type of material (Dalton Highway Mile 261 - Nordic Abrasion value 6.8). Other sandstones are cemented with calcite and have higher Nordic Abrasion values in the plus 10 range, such as Mile Post 60 on the Seward Highway (11.2), or are subject to minor cataclastic deformation (shearing). This shearing forms weak foliation not visible to the eye which apparently can cause Nordic Abrasion values to reach into the high teens or higher as seen along the Seward Highway (Pavey et al., 2012).

### 3.3.2 Igneous and Volcanic Rocks

For igneous and volcanic rocks, material quality is essentially a function of grain size, mineralogy, weathering and the presence or lack of foliation. Most of the granitic rocks are medium to coarse-grained and generally have Nordic Abrasion values in the teens or low twenties when fresh or slightly weathered. Many of the igneous rocks, particularly in southeast Alaska, are foliated and are thus unsuitable for that reason. The best igneous rocks located in Alaska to date are fine-grained basalts and andesites found in large volcanic flows in the Alaska Range and in southeast and southwest Alaska. Other igneous rocks that have potential are fine-grained diorites and gabbro intrusives, although they appear to be more limited in extent and occurrence. All of these fine-grained igneous rocks can produce consistently low Nordic Abrasion values and can make excellent sources of hard aggregates.

Minerals within igneous rocks that produce low Nordic Abrasion values are generally hard. The most abundant rock in the deep ocean crust and often found in continental crusts is the intrusive gabbro, primarily composed of plagioclase feldspar, clinopyroxine augite and minor olivine. Feldspar, augite and olivine have Mohs hardnesses of 5, 5.5 to 6 and 6.5 to 7, respectfully, making all the minerals fairly hard overall. Basalt, the extrusive equivalent of gabbro, is just as suitable as an aggregate source, if not better because of the fine aphanitic nature of the minerals within the rock. The less mafic intrusive diorite and its equivalent extrusive andesite are typically found in continental areas. These rocks are less iron-rich with amphibole minerals often appearing at the expense of olivine. Hornblende, a typical amphibole mineral, has a Mohs harness of 5 to 6, a bit softer than olivine. Hence these less mafic rocks may produce slightly lower Nordic Abrasion values.

### 3.3.3 Metamorphic Rocks

Most metamorphic rocks in Alaska have developed foliation (cleavage or schistosity) as a result of deformation and will typically produce Nordic Abrasion values in excess of 10. This is particularly true of southern Alaska where terranes have accreted to each other and transform faulting has causing extensive shearing and deformation creating foliation which weakens the rock structure. In southcentral Alaska, this includes the Valdez and Orca Formations which underlie much of the Kenai Mountains and Prince William Sound, and the Kodiak Formation on Kodiak Island. In southeast Alaska, many of the older sedimentary and volcanic rocks have been metamorphosed to phyllite and schist. Exceptions to this process include quartzite, which in Alaska is typically associated with the schists and gneisses of interior Alaska. A discussion of various metamorphic rocks is presented in the following sections.

#### 3.3.3.1 Hornfels

One of the most common types of hard rock in Alaska is hornfels. These are rocks that are formed by contact metamorphism when an igneous rock intrudes into country rock. A contract aureole is formed consisting of fine-grained to aphanitic unoriented mineral grains. Typically hornfels is more developed and harder near the edge of an igneous body, and the rock strength can drop off quickly as one moves away from the edge of the igneous rock. The aureoles are often mapped up to four miles from the igneous bodies, but hard rock capable of providing hard aggregate may only occur within thousands of feet or even hundreds of feet from the igneous bodies.

In contrast to schists and gneisses, hornfelses show little or no foliation or layering. They form under conditions of approximately anisotropic (directionless) stress, so there is no tendency for the crystals to align in any particular direction. Traces of bedding may remain in a hornfels due to chemical differences in the parent (country) rock but is not caused by contact metamorphism.

Hornfelses are defined by the process of origin (contact metamorphism), not by composition, so one must establish that a rock has originated in a contact aureole to classify it as a hornfels. Although hornfelses may be chemically altered by the magma that metamorphoses them, they generally reflect the chemical composition of their parent rocks. A parent rock most suitable for recrystallization into a hornfels will be a sedimentary rock with a wide range of chemical components, such as a mudstone, shale or slate. These rocks are chemically stable at or near the earth’s surface with minerals that have incorporated water in their crystalline makeup. In the presence of intense heat of contact metamorphism the water component is driven off, and hard compact minerals more stable in the new environment are formed. Little hornfelsing occurs when a magma body intrudes a preexisting igneous rock, since the environment of formation for the country rock is similar to the one created by the new intrusive. The minerals stable in hornfelses include feldspar, biotite, muscovite, and pyroxenes. Typically quartz, andalusite, garnet, and cordierite are also present, and these minerals are very hard, all having a Mohs hardness ranging between 6.5 and 7.5. Rocks with simple chemical compositions such as a pure limestone or a clean quartz sandstone change little with thermal metamorphism. The limestone turns into marble and the sandstone to a quartzite, a process largely involving recrystallization into larger mineral grains.

The nature and quality of hornfels for hard aggregate use may vary considerably within a deposit. The presence of soft calcareous zones within a rock may make the hornfels unsuitable. Later regional metamorphism may have imprinted schistosity on the hornfels, or the rock may have developed joint patterns or have been subjected to shearing or crushing by tectonic forces making the hornfels unsuitable.

Problems with pyritic rock were encountered in the construction of a two lane road (FS 3030) near Sweetwater Lake at Coffman Cove. Pyrite in the rock used for fill created an acidic solution that dissolved metals from the rock which contaminated ground and surface waters. Approximately 100,000 cubic yards of road embankment was removed and replaced with limestone to neutralize the acid. Along with the intrusives, and metamorphic rocks in Alaska, many of the hornfels may have mineralized zones associated with them. Therefore, testing for potential acid rock drainage should be conducted at all quarries in which mineralization is apparent.

Contact aureoles are found surrounding many of the igneous intrusives in Alaska and may be potential sources of hard aggregates. During this location study they were located along the Aleutian Peninsula from Lake Iliamna to Unalaska, and in southeast Alaska where over 20 were identified. Hornfels sources have also been noted along the Denali Highway in previous studies. Reports for several of these potential hornfels sources are included in this study, including Copper River Highway, Kruzof Island, Wrangel Island, Kuiu Island, Zarembo Island, Etolin Island, Revillagigedo Island and three sources on Prince of Wales Island.

#### 3.3.3.2 Quartzite and Gneiss

Quartzite is typically associated with the schists and gneisses developed in areas of regional metamorphism within interior Alaska. Quartz is one of the most abundant minerals in continental rocks with a hardness of 7 on the Mohs hardness scale. A sandstone of mostly pure quartz will transition by metamorphism to a quartzite when the rock fractures through the original quartz grains rather than along the original grain boundaries. While the Quartzite may provide a source of hard aggregate, it often occurs interbedded with soft weathered schist and would likely be useable only where found in thicker beds. Shaw Creek Quarry is apparently an example of this type of situation. Nordic Abrasion values range from 8 (quartzite?) to 17.9 (schist?) (Pavey et al., 2012). Quartzite can also grade into siliceous gneisses that can be equally as hard.

#### 3.3.3.3 Greenstone

Greenstone is a term generally applied to mafic, mostly extrusive igneous rocks that have been modified by regional metamorphism, and frequently as well by hydrothermal alteration. The parent rock is generally interpreted to come from ancient oceanic spreading centers and island arc terranes. Through plate tectonics these rocks are frequently accreted to continental crusts. The mafic minerals pyroxene and olivine typically found in these rocks become altered to greenish chlorite, actinolite and other amphibole minerals. In the process the rock loses the distinct grain boundaries of its former parent minerals, and a tough new fibrous mass of much smaller minerals forms, often very resistant to erosion.

### 3.3.4 Unconsolidated Material

One other often overlooked source of hard aggregate is unconsolidated material. The material from DuPont Washington, which has reported Nordic Abrasion values as low as 6.1, is from a glaciofluvial gravel source. The first consideration is that the gravel must be coarse enough to meet the specification. Sand or gravelly sand is not acceptable. The second is that the gravel must meet the Nordic Abrasion value. Several pits in Alaska have recorded Nordic Abrasion values at 10 or less. This may be because there is significant hard rock in the source area of the gravel and the river/outwash has eroded and removed much of the weaker rock. Certain grain sizes may need to be screened out to achieve lower Nordic Abrasion values at otherwise promising sites containing unconsolidated material.

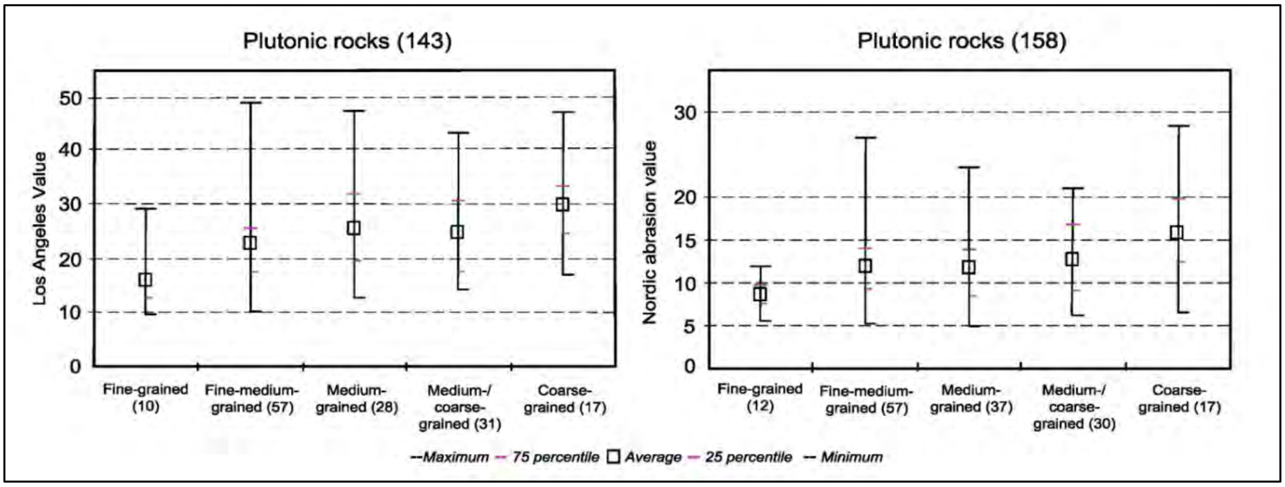
## 3.4 Porosity, Grain-Size, and Grain Shape

Table 3-3 presents the typical unconfined compressive, tensile, and shear strengths for a variety of rock types. From this table, it can be seen that each rock type can exhibit considerable variation. These variations are the result of a number of factors, which include porosity, grain size, grain shape, grain and crystallographic preferred orientation, mineralogy, and moisture content. In most rocks the main factors controlling rock hardness are porosity, grain size, and grain shape. All three of these factors affect the surface area of the interlocking bond forces at mineral grain to grain contacts. In most rocks, the higher the surface area of mineral grain to grain contact, the harder the rock becomes, for example:

1. Decreasing porosity in rock increases the surface area of grain contacts.
2. Decreasing the size of mineral grains in the rock increases surface area of grain contacts.
3. The surface area of equant or irregular grains is greater than that of angular grains.

Sedimentary rocks generally have high porosity, a reflection of the processes of their formation and the nature of the cementing agent. As a result they are generally low in rock hardness and their grains are less tightly held together. Fine-grained and lower porosity igneous rocks, such as basalt and diabase (dolerite) are generally higher in rock hardness than coarser-grained igneous rocks, such as granite, diorite, and gabbro. As a result, the mineral grains of fine-grained igneous rocks are more tightly held together than in coarse-grained igneous rocks. In metamorphic rocks, where strong foliations have developed, rock hardness is generally lower due to the preferred orientation of mineral grains and the structural weaknesses these impose. However, in low-grade metamorphism where foliation does not develop, but the rock becomes more indurated (i.e. more compacted and lower porosity), rock hardness increases. This is the case for slate, which is the indurated metamorphic form of the sedimentary rock shale. Grain-size has been identified as being one of the most important characteristics of a rock in identifying whether or not it will be suitable for hard aggregate.

**FIGURE 3 - 2**
**LOS ANGELES AND NORDIC ABRASION VALUES**
**FOR DIFFERENT GRAIN SIZES OF PLUTONIC ROCK IN NORWAY**
(From Erichsen et al., 2008)




(Nos. in parentheses are number of tests)

**TABLE 3 - 3**
**TYPICAL ROCK PARAMETERS**
(From Attewell and Farmer, 1976)

| Typical Rock Types | Compressive Strength (PSI) | Tensile Strength (PSI) | Shear Strength (PSI) | Bulk Density (PCF) | Porosity % |
|---|---|---|---|---|---|
| Granite | 15,000-36,000 | 1,000-3,600 | 2,000-7,000 | 162-180 | 0.5-1.5 |
| Diorite | 20,000-44,000 | 2,000-4,500 | NA | NA | NA |
| Diabase | 15,000-50,000 | 2,000-5,000 | 3,600-9,000 | 168-190 | 0.1-0.5 |
| Gabbro | 20,000-44,000 | 2,000-4,500 | NA | 175-193 | 0.1-0.2 |
| Basalt | 15,000-44,000 | 1,500-4,500 | 3,000-9,000 | 175-180 | 0.1-1.0 |
| Gneiss | 7,000-30,000 | 700-3,000 | NA | 175-187 | 0.5-1.5 |
| Marble | 15,000-36,000 | 1,000-3,000 | NA | 162-168 | 0.5-2 |
| Slate | 15,000-30,000 | 1,000-3,000 | 2,000-4,500 | 162-168 | 0.1-0.5 |
| Quartzite | 20,000-44,000 | 1,500-4,500 | 3,000-9,000 | 162-168 | 0.1-0.5 |
| Sandstone | 3,000-25,000 | 600-3,600 | 1,000-6,000 | 125-162 | 5-25 |
| Shale | 700-15,000 | 300-1,500 | 450-4,500 | 125-150 | 10-30 |
| Limestone | 4,000-36,000 | 700-3,600 | 1,500-7,000 | 137-162 | 5-20 |
| Dolomite | 4,000-36,000 | 2,000-3,600 | NA | 137-162 | 1-5 |

### 3.5 Selected References


Attewell, P.B., Farmer, I. W., 1976, Principles of engineering geology, Chapman and Hall, 1045 p.

Brosge, W.P., Reiser, H.N., Dutro, J.T., Jr., and Detterman, R.L., 1979, Bedrock geologic map of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 879-B, 2 sheets, scale 1:250,000.

Erichsen, E., Ulvik, A, Wolden, K., Neeb, P-R., 2008, Aggregates in Norway – Properties defining the quality of sand, gravel and hard rock for use as aggregate for building purposes, Geological Survey of Norway, In Stagstad, T.(ed.) Geology for Society of Geological Survey of Norway Special Publication, 11, pp 37-46.

Morian, D.A, Anderson, G.F, Stoffels, Shelley, S.M., Frith, D.J. 2003, Cost effectiveness of hard aggregate sources, Alaska hard aggregate performance study: Final Report, Prepared for Alaska Department of Transportation and Public Facilities, By Quality Engineering Solutions, Inc., Report No. FHWA-AK-RD-02-10., 50p.

Johnson, E.G., Pavey, D.R, 2000, Draft studded tire wear resistant aggregate study, Final Report.

Pavey, Finkbiner, Bingham, 2012, Web interface: http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

# 4.0 SOUTHCENTRAL ALASKA

A series of geologic terranes accreting to Alaska by thrust and right lateral strike-slip faulting have formed about five geologic terranes comprising Southcentral Alaska. These areas can be accessed via the road and railroad systems in the interior, and by marine transport along the southern coastal areas. A vicinity map for southcentral Alaska is presented as Figure 4-1.

## 4.1 General Geology

Along the western Talkeetna Mountains some of the more favorable rocks for producing low Nordic Abrasion values are basaltic to andesitic metavolcanic rocks. Fine-grained intrusives and hornfelses in the southwestern most part of the Talkeetna Mountains and the Petersville area may form suitable aggregate as well. Most of the rocks along the southern margin of the Talkeetna Mountains have been pervasively faulted and sheared from contact with the Chugach Mountains as the terranes grind past one another.

A series of northeast trending steeply fault bounded formations south of the Matanuska River show promising lithologies to suggest the presence of potential hard aggregate rock. Resistant outcrops of fine-grained mafic intrusive that survived glacial scour are exposed in the Burnt Butte area. These mostly mafic rock types look promising, and they extend from Eagle River east to Chickaloon, and possibly beyond.

The western Kenai Peninsula offers outwash gravels that may be suitable as hard aggregate. The Kenai Mountains contain a number of thrust fault bounded formations containing sedimentary and volcanic rocks. Mapped intrusives offer preliminary candidates for hard aggregate sources, especially fault bounded units of ultramafic rocks. The majority of the rocks within the Kenai Mountains are undivided metasedimentary rocks of the Valdez Group. These rocks form a broad arch, also including the core of the Chugach Mountains. Within this arch to the south, surrounding the Prince William Sound, are the undivided sedimentary rocks of the Orca Group. These two groups incorporate basalt and andesite flows, often altered to greenstone, offering potential as hard aggregate sources, if not too deformed by tectonic forces. In Prince William Sound there are a number of large Tertiary intrusives with hornfels aureoles in sedimentary rock sequences up to 0.5 miles wide, which may also offer suitable hard aggregate sites.

## 4.2 Kenai Peninsula

Areas accessible on the Kenai Peninsula by road and railroad include the northern portion of the Kenai Mountains and the lowlands of the peninsula to the west. The northern part of the lowlands is largely covered by glaciolacustrine and glacial outwash deposits as well as moraines from various glacial advances. Nearly horizontal sedimentary bedrock units of the Kenai Group are found south of Tustumena Lake. Along ocean bluffs and in the Homer area rocks of the Beluga Formation are exposed. These are interbedded, poor consolidated sandstone, siltstone, mudstone, calcareous shale, coal and minor volcanic ash of Miocene age. Overlying the Beluga Formation is the Sterling Formation of Miocene to Pliocene age, composed of interbedded, poorly consolidated sandstone, siltstone, mudstone, carbonaceous shale, lignite coal and minor volcanic ash. This formation is exposed in higher topographic areas around Homer (Hartman and et al., 1974). Nordic Abrasion values ranging from 11.4 to 13.2 were reported for alluvial and outwash gravels in the vicinity of Soldotna (Pavey et al., 2012). There are only limited conglomerates in the Kenai Group and what gravels are there tend to be weathered and friable.

The Kenai Mountains, north of the Kenai Fiords National Park, contain two major assemblages of rocks, separated by the Eagle River Fault. Along the western edge of the mountains are the rocks of the McHugh Complex. These rocks are part of the Valdez Group, mapped as undivided, including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the Eagle River Fault and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. There were apparently no Nordic Abrasion values available for the McHugh Complex. It appears that values for the undivided Valdez Group ranged from 11.2 to 18.9 with what appears to be values of 8.5 to 16.9 in alluvial gravels (Pavey et al., 2012). It is possible the 8.5 value at 4$^{th}$ of July Creek near Seward may be a reflection of some of the mafic rocks in the upper drainage. However, there is little room for mining at the site.

Further south, near Seward, is the Resurrection Peninsula, composed of four formations within ophiolitic rocks of Prince William Sound. These rocks contain pillow basalts, sheet basalt dikes, gabbro, and ultramafic rocks. Some of the ophiolites within this assemblage may be of interest, given the proximity to the town of Seward. However, the lack of road access and the precipitous steepness of rocks on the peninsula would make them very difficult to access. The two other nearby units, minor in size, include a tuff in one formation and some interbedded metavolcanic and metasedimentary rocks in a second formation. It appears that there is little to no potential for hard aggregate on the Northern Kenai Peninsula.

**FIGURE 4 - 1**
**SOUTHCENTRAL VICINITY MAP**

## 4.3 Seldovia Area

Rock exposures on the southern part of the Kenai Peninsula in the vicinity of Seldovia are composed of three major assemblages. To the west side of Seldovia are two formations ranging in age from Upper Triassic to Jurassic age. One of those is the Talkeetna Formation consisting of massive volcanic breccia, agglomerate, tuff, andesitic lava flows and volcaniclastic sedimentary rocks. The other is the Port Graham Formation, characterized by dark-gray, carbonaceous limestone and silty limestone. Also included in this formation is tuff, tuffaceous sedimentary rocks and chert. Smaller sedimentary rock outcrops of the typically poorly consolidated Tyonek Formation also occur but none of these bedded formations appear to offer hard aggregate potential.

Three exposures of igneous rocks on the western tip of the Kenai Peninsula are described in the attached Point Bede / Nanwalek Potential Hard Aggregate Source Report. Small igneous exposures are present near Koyuktolik Bay, one consisting of tonalite, the other a light grey felsite. A larger intrusive mass in the Point Bede area is judged as having hard aggregate potential.

Thrust fault bounded rocks of the Valdez Group are found east of Seldovia forming the majority of the Kenai Mountains. The oldest rock assemblages of the Valdez Group form the McHugh Complex. Prior to being metamorphosed, the original rocks were predominantly Triassic, Jurassic and Early Cretaceous in age. The McHugh Complex is mapped as including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, mapped as a graywacke and conglomerate, as is a basalt and chert formation within the McHugh Complex. Fault bounded bodies of gabbro occur within the McHugh Complex, containing dark green medium to coarse-grained gabbro and plagiogranite. One major exposure is found along the shore of Halibut Cove, but the larger grain sizes reported suggests these rocks are unlikely candidates as sources for hard aggregates. South and east of McHugh Complex rocks are the undivided metasedimentary rocks of the Valdez Group of Upper Cretaceous age. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate.

Ultramafic plutonic rocks of probable Triassic to mid-Cretaceous age are accessible by road about 20 road miles from Seldovia. These rocks are predominantly layered, variably serpentinized dunite, with rare to locally abundant layers of chromite and pyroxene, and fault slices of garnet pyroxenite and serpentine. These ultramafic rocks occur in at least seven known bodies within the McHugh Complex, all of them known or interpreted to be fault bounded. Red Mountain, mined in previous years for chrome, is part of an intrusive body bounded on all sides by subvertical, later stage faults. A thrust fault may bound the body at depth. Ultramafic rocks at the Snow Prospect to the west are bounded below and above by such low angle thrust faults. The unweathered ultramafic minerals dunite and associated assemblages are very hard on Mohs hardness scale. With recent glacial scour at higher elevations around Red Mountain, fine-grained unweathered exposures may provide rocks with low Nordic Abrasion values. However, careful inspection of the potential for naturally occurring asbestos and for acid rock drainage problems should be performed prior to any mining.

The peninsula east of McCarty Fiord contains the Nuka Pluton, exposed as a series of rugged mountains and islands. The pluton is an Eocene granodiorite, medium to coarse-grained. While there is a possibility of hornfelsed rocks in one area, it lies within the Kenai Fiords National Monument.

## 4.4 West Chugach Mountains – Anchorage to Eklutna

The western Chugach Mountains lie north of Turnagain Arm east of Knik Arm and south of the Knik River. They form the mountain range immediately to the east of Anchorage.

As shown in Figure 4-2, the Chugach Mountains, east of the Border Ranges Fault, contain two major assemblages of rocks. Along the western edge of the mountains are the rocks of the McHugh and Uyak Complex (blue-KMm). These rocks are part of the Valdez Group, mapped as undivided, including a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the McHugh Complex and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group (green – Kvs) are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. There is a Nordic Abrasion test result of 10.2 in an area mapped as the McHugh Complex (Pavey et al., 2009) near the south abutment of the Old Glenn Highway Bridge over the Knik River. The sample was reported to be from the quarry MS 576-015-1. The rock was reported to be a greenstone and metaconglomerate in a material site file.

West of the Border Range Fault bedrock was mapped outcropping only in the northeast corner of the area near Eklutna.

Geology: Two rock types have been mapped in the northwest corner of the area, near Eklutna. The following units were mapped as shown on Figure 4-2 (Winkler, 1992).

> Jum: (purple) Ultramafic and Mafic and ultramafic rocks undivided (Middle and Early Jurassic). They are mapped as a complexly intermixed series of mafic and intermediate plutonic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite, and tonalite. Generally xenoliths or schlieren of more mafic rock are present in less mafic rock. Xenoliths of gabbro show ductile deformation as though they still were warm when intruded by more silicic magmas, and migmatitic textures are common at contacts between lithologies. Hence, much of the mixing may have been caused by multiple intrusions, and entire series of plutonic rocks may have been mostly coeval (Burns, 1985). This alteration may contribute to the rock being able to produce low Nordic Abrasion values.

> JPzm: (gray) Metamorphic Rocks (Jurassic to Middle Paleozoic?). Diverse metasedimentary and metavolcanic rocks along northern flank of Chugach Mountains, cropping out near the Jum unit. Rocks are strongly to weakly foliated and variably metamorphosed from middle greenschist to amphibolite facies. Rocks are intruded by mafic and intermediate plutons of units Jmip and Jg. Sedimentary protoliths consist of shale chert, tuffaceous arenite, and limestone, and volcanic protoliths are most probably basalt. Diversity of protoliths may indicate tectonic mixing prior to metamorphism. In most places the fabric is cataclastic or recrystallized.

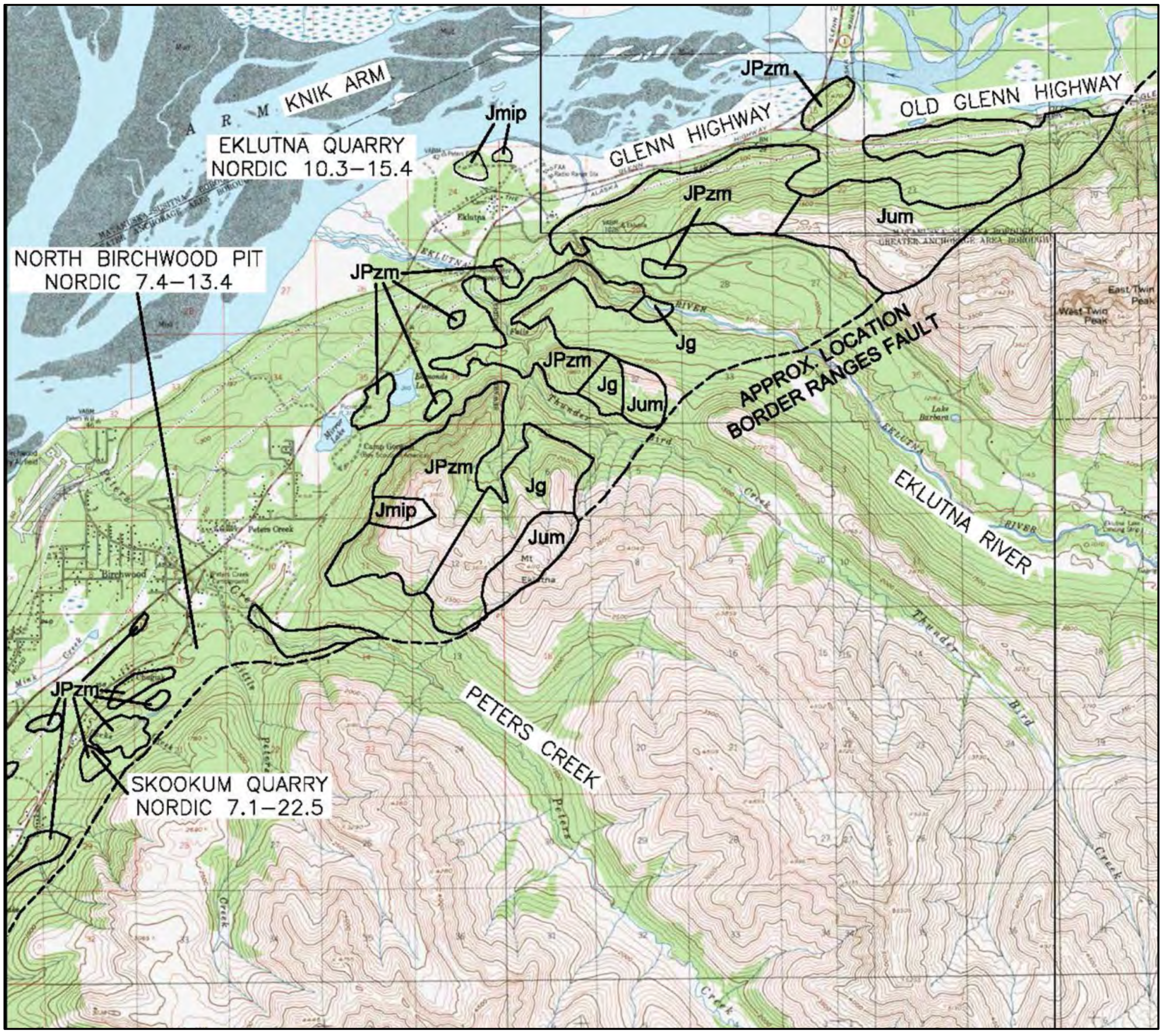
Jmip: Mafic and intermediate plutonic rocks (Middle and Early Jurassic) complexly intermixed series of mafic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite and tonalite.

Jg: Gabbronorite (Middle and Early Jurassic) Fine to coarse-grained gabbroic rocks, exposed as fault-bound slices, or layers and dikes in the Eklutna ultramafic complex. Primarily consist of gabbronorite, leucogabbronorite, and pyroxene-hornblende gabbro.

**FIGURE 4 - 2**
**GEOLOGY OF WESTERN CHUGACH MOUNTAINS**
(From Wilson et al., 2012)

As shown in Figure 4-3, the Eklutna Railroad Quarry is in the Jmip Mafic and intermediate plutonic rock unit and is reportedly a quartz diorite. L.A. Abrasion results varied from 17 to 26, specific gravities from 2.77 to 2.80, absorptions from 0.4 to 0.7, and T-13 Degradations from 69 to 70. Reported Nordic Abrasions values ranged from 10.3 to 15.4 (Pavey et al., 2012).

**FIGURE 4 - 3**
**GEOLOGY OF MAFICS AND ULTRAMAFICS IN EKLUTNA AREA**
(Modified From Winkler, 1992)




The Skookum Quarry is in the JPzm undivided metamorphic rocks in Chugiak on Parks Creek. Nordic Abrasion results ranging from 7.1 to 22.5 have been reported (Pavey et al., 2012). The quarry has reportedly produced high quality rock in the past and it can only be assumed that the quarry is established in one of the intrusives or in the basalt.

The North Birchwood Pit has reported Nordic Abrasion results ranging from 7.4 to 13.4 in what appears to be either glaciofluvial gravel or abandoned terrace gravel of Peters Creek.

The quarries and pits in the Eklutna area, while they have material that can provide Nordic Abrasion values of less than 10, they apparently do not have the geology to provide it consistently. The area is becoming developed and new areas to mine are becoming scarcer and areas to the northeast would likely be more promising for finding sites with more potential for hard aggregate production. Many of the undeveloped rock units that have some potential for hard aggregate production lie within Chugach State Park.

### 4.5 East-Central Chugach Mountains – Knik/Matanuska

The eastern-Central Chugach Mountains lie north of the Knik River and Prince William Sound, south of the Matanuska River and east of the Richardson Highway. For all practical purposes the area considered lies east of Nelchina Glacier as this is the only area close enough to the Glenn Highway to be accessible. The areas of general interest are the igneous intrusives and volcanics that form the Buttes and are found between Palmer and Carpenter Creek, including Wolverine Creek, north of the Borders Range Fault zone.

The east-central Chugach Mountains, south of the Border Ranges Fault, contain the Valdez Group, consisting of two major assemblages of rocks. Along the southern edge of the fault are the rocks of the McHugh Complex. These rocks include a complexly deformed assemblage of argillite, tuff, graywacke, basalt, chert, mesoscale (outcrop–scale) mélange, conglomerate, gabbro, and limestone, and are of Triassic to Mid-Cretaceous in age. Between the McHugh Complex and Prince William Sound extensive sequences of undivided metasedimentary rocks of the Valdez Group are present. These rocks contain turbidic sandstone, siltstone, and slate, plus subordinate conglomerate. The Borders Range Fault is defined as a zone in this area and may contain several faults or shear zones several kilometers wide (Pavlis, 1986).

<u>Geology:</u> Rock types mapped near Matanuska Peak and shown in Figure 4-4 (Winkler, 1992).

> <u>Jmip</u>: Mafic and intermediate plutonic rocks (Middle and Early Jurassic) – Mapped as a complexly intermixed series of mafic and intermediate plutonic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite, and tonalite. Diorite is the predominate lithology in the Wolverine Creek area. These rocks form the southern half of Bodenburg and Burnt buttes and project northeast into Matanuska Peak. Xenoliths of gabbro show ductile deformation. Migmatitic textures are common at contacts between lithologies. Hence, much of the mixing may have been caused by multiple intrusions, and entire series of plutonic rocks may have been mostly coeval (Burns, 1985). The rocks on Bodenburg's south side have also been hydrothermally altered, turning the mafic minerals a lighter green with diffuse grain boundaries. This alteration may contribute to the rock reportedly being extremely strong and almost impossible to break with a rock hammer.
>
> <u>Jqt:</u> Quartz diorite and tonalite (Middle Jurassic) – Series of discordant intermediate plutons. Plutons are relatively homogeneous, fine to medium-grained quartz diorite and tonalite. Large areas are sheared and altered.
>
> <u>Kt/Kit:</u> Leucotonalite and trondhjemite (Early Cretaceous) – Medium-grained plugs and elongate, irregular-shaped, sill-like bodies of leucocratic plutonic rocks in a zone about 5 km wide near Border Ranges fault. Rocks generally are foliated and contain less than 10

percent mafic minerals including muscovite, biotite, or hornblende. Due to the foliation these rocks typically would make poor hard aggregate sources.

Jg: Gabbronorite (Middle and Early Jurassic) - Fine to coarse-grained gabbroic rocks, exposed as fault-bound slices, or layers and dikes in the Wolverine ultramafic complex. Primarily consist of gabbronorite, leucogabbronorite, and pyroxene-hornblende gabbro.

Jum: Ultramafic and mafic rocks (Middle and Early Jurassic) - A small exposure of Late Cretaceous ultramafics rocks is exposed just east of Bodenburg Butte.

TKc: Cataclasite (Eocene and Early Cretaceous) – Chlorite-rich fine-grained granular rocks formed by cataclasis alteration of mafic and ultramafic plutonic rocks and mafic volcanic rocks. May represent central zones or major strands of Border Ranges fault system where rocks from both upper and lower plates were cataclastically deformed, mixed, and metamorphosed.

JTRk: Talkeetna Formation (Early Jurassic and Late Triassic) – Andesitic, dacitic, and basaltic flows, flow breccia, tuff, shallow sills, and agglomerate. Contains subordinate interbedded volcaniclastic sandstone, conglomerate, and fossiliferous marine siltstone and shale. The Talkeetna is altered in many places. An isolated exposure (Sec. 17 and 18, T18N, R4E, SM) in Lower Wolverine Creek, contains fine-grained, highly altered, massive greenstones that presumably are a mafic part of the Talkeetna Formation (Pavlis, 1986).

JPzm: Metamorphic Rocks (Jurassic to Middle Paleozoic?). Diverse metasedimentary and metavolcanic rocks along northern flank of Chugach Mountains, cropping out near the Jum unit. Rocks are strongly to weakly foliated and variably metamorphosed from middle greenschist to amphibolite facies. Rocks are intruded by mafic and intermediate plutons of units Jmip and Jg. Sedimentary protoliths consist of shale chert, tuffaceous arenite, and limestone, and volcanic protoliths are most probably basalt. Diversity of protoliths may indicate tectonic mixing prior to metamorphism. In most places the fabric is cataclastic or recrystallized.

Tc: Chickaloon Formation (Eocene and Paleocene) Predominately fluvatile and alluvial carbonaceous mudstone, siltstone, conglomeratic sandstone, and polymictic conglomerate; contains beads of bituminous coal.

Rock exposures in the northeastern trending sequence containing Bodenburg Butte and Burnt Butte show promising rock lithologies likely to produce low Nordic Abrasion values. The rock exposures are readily accessible by existing roads. While Bodenburg Butte is a State Park, Burnt Butte in on land apparently owned by Eklutna, Inc. (subsurface), CIRI (subsurface). A Potential Hard Aggregate Source Report was prepared for Burnt Butte.

Rocks in the Chugach Range between Wolverine Creek and Carpenter Creek to the east may also contain rock units that would produce hard aggregate. The land in the flats surrounding the mountains is generally owned by private and municipal entities, the foothills by Native Corporations and the interior of the mountains themselves by the State of Alaska. Access may be a problem, however the area is open to mining under the Susitna-Matanuska Area Plan.

Some of the glaciofluvial gravels in the area may also contain hard gravels that can produce low Nordic Abrasion values. Premier Pit near Mile 10.4 of the Old Glenn Highway had a reported Nordic Abrasion value of 9.3. Other gravel pits in the area had Nordic Abrasion values ranging from 8.1 to 15.3 (Pavey et al., 2012). It may be possible to find gravel pits that with processing can consistently meet low Nordic Abrasion values.

**FIGURE 4 - 4**
**GEOLOGY OF MAFICS AND ULTRAMAFICS IN WOLVERINE CREEK AREA**
(Modified from Winkler, 1992)

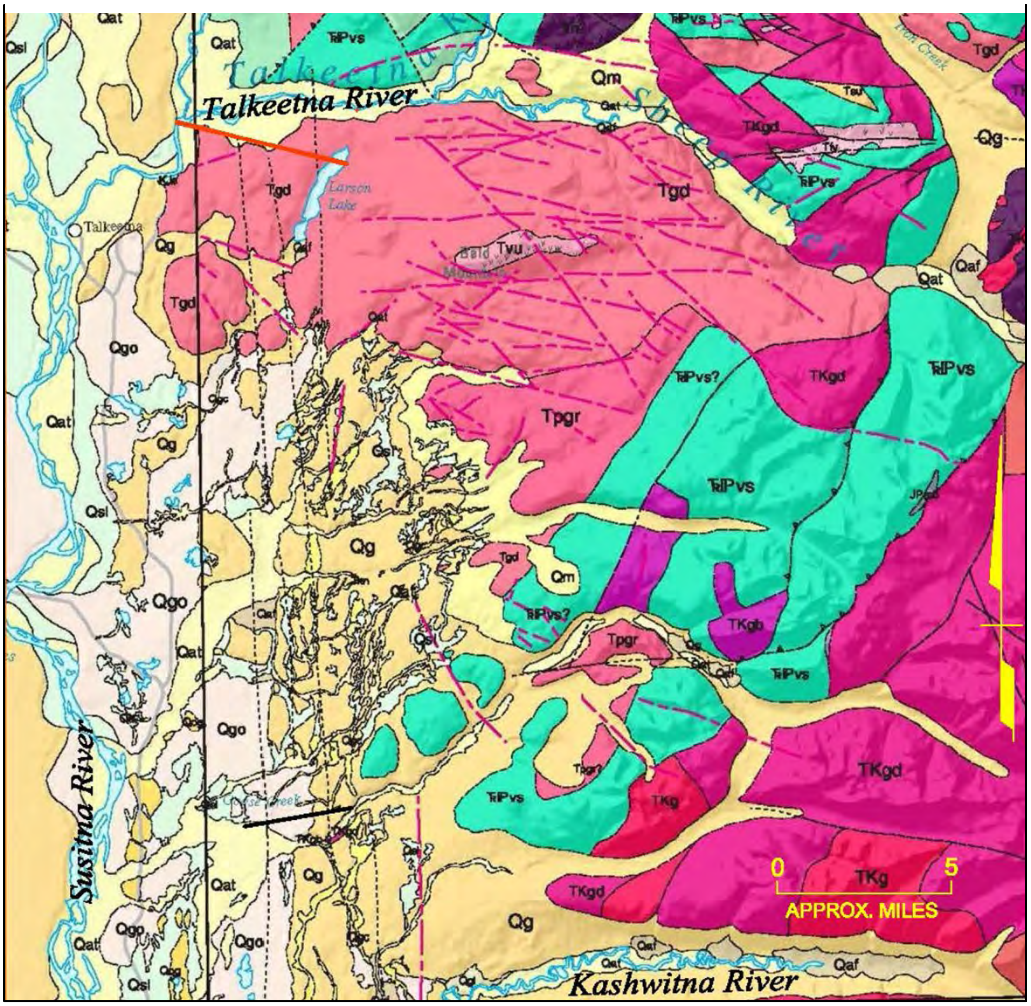
## 4.6 Western Talkeetna Mountains

The George Parks Highway provides access to hard aggregate deposits from Cantwell to Houston along the western slopes of the Talkeetna Mountains. From Cantwell to Talkeetna, sedimentary rocks of the Kahiltna flysch sequence (earliest Late Cretaceous to Late Jurassic?) are exposed. These rocks are a sequence of intensely deformed and locally highly metamorphosed turbidites described by and Reed and Nelson (1980). They include dark-gray to black argillite, fine- to coarse-grained, generally dark-gray graywacke, dark-gray polymictic pebble conglomerate, subordinate black chert pebble conglomerate, a few thin layers of dark-gray to black radiolarian chert and thin, dark-gray impure limestone interbeds. Locally, the presence of interbedded light tuffaceous deposits indicates contemporaneous volcanism. The northern portion of these exposures between Cantwell and Honolulu Creek encompass a large folded klippe or thrust sliver that may be as large as 30 by 60 km, perhaps a remnant of a much larger thrust sheet (Csejtey, et al., 1992).

From Honolulu Creek south to Talkeetna the flysch sequences are intruded by large, mostly Tertiary to Cretaceous granitic plutons. Major sequences include biotite-muscovite granite to quartz monzonite (Wilson et al., 1998). Most of the plutons are likely too coarse-grained to produce acceptable hard aggregate. Although no discussions of developed hornfels zones were found in literature, such zones are likely to exist in flysch sequences exposed to contact metamorphism from plutons, and might provide promising locations for hard aggregate extraction.

From the northern banks of the Talkeetna River south to the Kashwitna River there are a series of basaltic to andesitic metavolcanics of Mesozoic to Cenozoic age ($T_R$Pvs) (Figure 4-5). These units are interlayered heterogeneous, dominantly marine sequences over 15,000 feet thick (Csejtey et al., 1978). They consist primarily of metamorphosed flows and tuffs of basaltic and andesitic composition, subordinate mudstone, bioclastic marble, and dark-gray to black phyllite. These extrusive rocks are in fault and intrusive contacts with plutons, varying between granite, granodiorite, quartz diorite, tonalite and diorite, ranging in age between Mesozoic to Cenozoic. The metavolcanics are likely to have a “greenstone” appearance, and they may produce acceptable Nordic Abrasion values.

**FIGURE 4 - 5**
**GEOLOGY TALKEETNA TO KASHWITNA RIVER AREA**
(From Wilson et al., 2009)

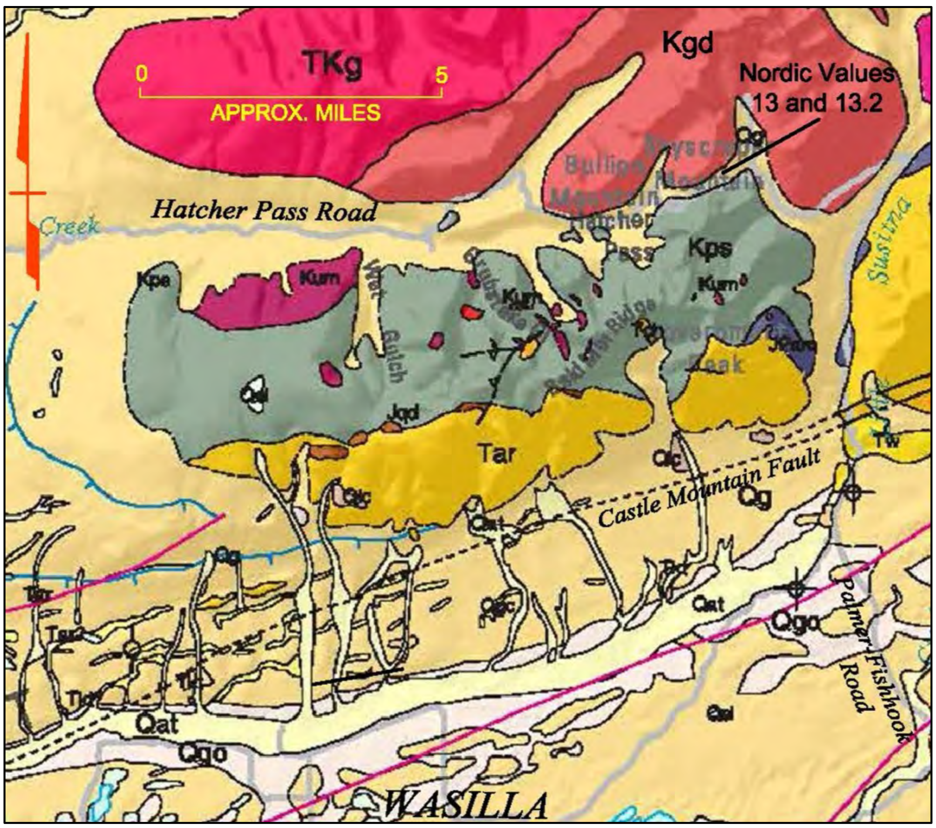



TRPvs – Metavolcanics (blue-green on map)

South of the Kashwitna River to Willow Creek, the majority of bedrock exposures are from the Arkose Ridge Formation, Lower Eocene to upper Paleocene in age. These outcrops are composed of fluviate and alluvial feldspathic and biotic sandstone, conglomerate, siltstone, and shale containing abundant plant fragments (Csejtey et al., 1978 and Winkler, 1992). Coarsening upward, the sequence was deposited on alluvial fans and by braided streams carrying sediment derived from rapid erosion of uplifted mountains to the north (Winkler, 1992). Thickness is as much as 2,300 feet. Granitic rocks are exposed in Willow Creek and further to the east, but no mention of hornfelsed rocks was encountered in the literature.

Between Willow and Houston, the southern portion of the western Talkeetna Mountains includes Bald Mountain Ridge. The Arkose Ridge Formation (Tar), Lower Eocene to Upper Paleocene, is exposed along the southern slopes of Bald Mountain Ridge (Figure 4-6). The ridge crest and most of the northern slopes contain a pelitic schist formation (Kps) (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al., 1983 and Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks (Tkg), Late Cretaceous serpentinized ultramafic rocks (Kum), as well as a Lower Jurassic or older unit comprising dark gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz-rich amphibolite, and mafic schist (JPam). A series of small Jurassic hornblende-biotite tonalite intrusions (Jqd) are present near the main pelitic schist (Kps) /Arkose Ridge Formation (Tar) boundary (Wilson et al., 2012). Hornfelses may have developed adjacent to the sedimentary rocks. These hornfelses and the fine-grained intrusions within the ridge may produce low Nordic Abrasion values. The ridge is accessible via Hatcher Pass Road.

**FIGURE 4 - 6**
**GEOLOGY BALD MOUNTAIN RIDGE (HATCHER PASS ROAD)**
(From Wilson et al., 2009)




The Arkose Ridge Formation is exposed along the southern slopes. The ridge crest and most of the northern slopes contain Pelitic schist (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al. and 1983, Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks, Late Cretaceous serpentinized untramafic rocks, as well as Lower Jurassic or older dark-gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz rich amphibolite, and mafic schist. The amphibolite is intruded by a foliated Jurassic hornblende-biotite tonalite. This latter intrusive rock is mapped along the ridge together in the same formation as other outcrops containing quartz diorite, tonalite and diorite (Wilson et al., 2012). Hornfelses may have developed adjacent to intrusives in the Arkose Ridge Formation and the pelitic schist. The fine-grained intrusions within the ridge may also produce low Nordic Abrasion values. The ridge is directly accessible via Hatcher Pass Road. Two Nordic Abrasion values of 13 and 13.2 were reported for the granodiorite (Kgd) in Hatcher Pass (Pavey et al., 2012) as shown in Figure 4-6.

## 4.7 Petersville Road

The Petersville area, located approximately 50 miles west of the George Parks Highway, is covered by numerous placer and hard rock metallic mineral mines. Capping both the Dutch and Peters hills are the turbiditic sedimentary rocks of the Kahiltna Flysch sequence (Cretaceous, Aptian and Valanginian or younger to Upper Jurassic?). These rocks are a sequence of intensely deformed and locally highly metamorphosed turbidites (Csejtey et al., 1992, and Reed and Nelson, 1980). Included are dark-gray to black argillite, fine- to coarse-grained, generally dark-gray graywacke, siltstone, and shale turbidites, thinly bedded and dense cherty argillite, dark-gray polymictic pebble conglomerate, subordinate black chert pebble conglomerate, a few thin layers of dark-gray to black radiolarian chert and thin dark-gray impure limestone interbeds. Sandstone includes greywacke in beds up to six feet thick and feldspathic sandstone. These rocks are locally metamorphosed along the margin of intrusives. A pluton is mapped atop the northern portion of the Dutch Hills. This intrusive is part of predominantly medium-grained series of composite plutons classified as granite, syenite, tonalite, quartz monzonite, quartz monzodiorite, quartz diorite, granodiorite, and minor diorite. Biotite is the chief mafic mineral. The plutons are locally weakly foliated or contain flow structures (Wilson, 2012). These plutonic rocks are likely present at shallow depth underneath both the Dutch and Peters hills, giving rise to the metallic mineralization as well as hornfelses. These hornfelses may be shown to have low Nordic Abrasion values.

Along the flanks of the Dutch and Peters hills is the younger Sterling Formation of Pliocene and Miocene age. These rocks are weakly lithified massive sandstone, conglomeritic sandstone and interbedded siltstone and claystone. The unit includes interbedded lignite coals typically less than three feet thick in the upper part of the unit, but may be as much as ten feet thick in the lower parts (Calderwood and Fackler, 1972). Along the lower flanks and valley bottoms of the Dutch and Peters hills is the Tyonek Formation of Miocene to Oligocene. Present is carbonaceous nonmarine conglomerate and subordinate sandstone, siltstone, and local coal (Winkler, 1992 and Bradley et al., 1998). The Tyonek Formation is identified by massive sandstone beds and lignite to subbituminous coal beds as much as 30 feet thick (Calderwood and Fackler, 1972). Contact with the overlying Beluga Formation is believed to be a disconformity where the sandstone beds and coal beds become markedly thinner (Calderwood and Fackler, 1972). Prominent older but modified morainal deposits of Knik and Eklutna glaciations are found along the eastern flanks of the Peters Hills (Karlstrom, 1964).

## 4.8 Southern Talkeetna Mountains

From Bald Mountain Ridge, the Glenn Highway follows the southern Talkeetna Mountains past Slide Mountain and onto broad interior lowlands before reaching Glennallen. On Bald Mountain Ridge the Arkose Ridge Formation, Lower Eocene to Upper Paleocene, is exposed along the southern slopes. The ridge crest and most of the northern slopes contain a pelitic schist formation (Cretaceous?). This schist is a quartz-muscovite-albite-chlorite schist which is remarkably uniform in lithology. No correlative rocks are known (Albanese et al., 1983 and Winkler, 1992). Mineralogy indicates greenschist metamorphism, which Winkler (1992) interpreted as probably a retrograde from amphibolite facies metamorphism. Smaller outcrops contain Tertiary or Cretaceous granitic rocks, Late Cretaceous serpentinized ultramafic rocks, as well as a Lower Jurassic or older unit comprising dark-gray to dark-green, fine- to coarse-grained hornblende-plagioclase amphibolite, quartz rich amphibolite, and mafic schist. A series of small Jurassic hornblende-biotite tonalite intrusions are present near the main pelitic schist /Arkose Ridge Formation boundary (Wilson et al., 2012). Hornfelses may have developed adjacent to the sedimentary rocks. These hornfelses and the fine-grained intrusions within the ridge may produce low Nordic Abrasion values. The ridge is accessible via Hatcher Pass Road. (See section on Western Talkeetna Mountains for more information).

To the east and bounded by the Little Susitna River and Moose Creek is Arkose Ridge, predominantly underlain by the Arkose Ridge Formation. The Castle Mountain Fault cuts across the southern slope of the ridge, marking the boundary with the Chickaloon Formation further to the south. This latter formation is Lower Eocene and Upper Paleocene in age, predominantly a fluviatile and alluvial carbonaceous mudstone, siltstone, conglomeratic sandstone, and polymictic conglomerate. Locally, upper and middle parts of the unit contain numerous beds of bituminous coal and fossils. Lower parts of the unit largely include conglomerate and lithic sandstone derived from Talkeetna Formation (Winkler, 1992).

Further east and south of the Castle Mountain Fault is Wishbone Hill, capped by the Tsadaka Formation of Miocene to Oligocene age. This unit is a poorly sorted cobble to boulder conglomerate, interbedded with lenses of feldspathic sandstone, siltstone, and shale (Winkler, 1992). Underlying the Tsadaka Formation is the Wishbone Formation of Eocene age, a fluviatile conglomerate having thick interbeds of sandstone, siltstone, and claystone, and it contains local partings of volcanic ash (Winkler, 1992). South of these formations, along the gentler slopes of the Matanuska Valley bottom, the valley is covered by outwash, valley trains, fans and eskers related to outburst floods from Glacial Lake Atna (Wiedmer et al., 2010).

From Knob Hill to Red Mountain there are extensive units of the upper Cretaceous Matanuska Formation, a well-indurated, thinly bedded, dark-gray fossiliferous shallow marine shale containing conspicuous calcareous concretions, volcanic-lithic siltstone, sandstone, greywacke, and subordinate conglomerate (Winkler, 1992). This formation is overlain by the Chickaloon Formation. Granitic plutons of Paleocene to Late Cretaceous age form the core of Red Mountain, composed of fine-to coarse-grained, epizonal, biotite and biotite-hornblende granite, quartz monzonite and alkali granite (Winkler, 1992).

Exposed at the crest of Castle Mountain, Puddingstone Hill and along the flanks of Anthracite Ridge are Tertiary volcanic rocks, composed of andesite, basalt, and dacite lava flows, tuff, lahar deposits, volcanic breccia, and hypabyssal intrusions. These units include small lenses of fluviate conglomerate. Crude stratification has been reported where felsic rocks and pyroclastic rocks occur stratigraphically lower in the section. Basaltic and andesitic flows occur in the upper part of the section (Csejtey et al. and 1978, Winkler, 1992). Both Castle Mountain and Puddingstone Hill are surrounded by rocks of the Wishbone Hill Formation, and further downslope by the Chickaloon Formation. Anthracite Ridge, farther to the east, is capped by the Matanuska

Formation, with coal rich Chickaloon Formation rocks along its southern flanks. There are numerous Paleocene to late Cretaceous granitic outcrops exposed within the Chickaloon Formation. No mention of hornfelsed zones in sedimentary rocks near intrusives from Red Mountain to Anthracite Ridge was found in the literature. Many of the igneous contacts are along erosional or fault contacts. Some of the intrusives are very coarse-grained with concentrations of large hornblende crystals, suggesting a view of the lower reaches of a batholith system.

Flanking the terminus of the Matanuska Glacier, the Glenn Highway passes through rocks of the Matanuska Formation before skirting Lion Head, an intrusive stock, which is one of a cluster of stocks in the area. From Caribou Creek, the highway passes along the base of Sheep and Gunsight mountains before entering the Glennallen Lowlands. Rocks along this stretch alternate between those of the Matanuska Formation and the Talkeetna Formation. This latter formation contains greenstones and tuff, forming the large orange and brown stained "stratigraphic color anomaly" seen near Sheep Mountain. The rocks vary from volcanics and volcaniclastic rocks consisting of lava, agglomerate, breccia, tuff, and interbedded sandstone and shale. Where more distal from volcanic sources the formation contains volcanic-sources sedimentary rocks. The unit is the extrusive product of an early Jurassic island arc, of which the Jurassic phase of the Alaska-Aleutian Range batholith is the plutonic core. Further east scattered outcrops of undifferentiated sedimentary rocks are present in the Glennallen Lowlands (Wilson et al., 1998).

Fine-grained intrusives and possible adjoining hornfelsed zones in the far southwestern portion of the Talkeetna Mountains around Bald Mountain may produce promising Nordic Abrasion values as discussed in more detail in Section 4.6. The Matanuska Valley forms the boundary between the Talkeetna and Chugach Mountains. Nordic Abrasion values ranging from 9.8 to 11.4 were reported for a small igneous bedrock source near Milepost 75.5 on the Glenn Highway that was mapped as dikes or sills. Two Nordic Abrasion values of 14.7 and 26.9 were reported for gravel at MP 66 (Kings River) and MP 96 (Hicks Creek), respectively (Pavey et al., 2012). In general, it appears that the southern Talkeetna Mountains do not have any potential sources of hard aggregate.

## 4.9 Prince William Sound

Prince William Sound lies between the Kenai Peninsula and the Chugach Mountains and is surrounded by some of the most rugged coast lines in Alaska. Geology is dominated by the sedimentary and volcanic rocks of the Valdez and Orca Groups. The two groups are very similar and can be difficult to differentiate. The Orca Group is thought to be less metamorphosed than the Valdez Group and contains both greenstones and conglomerates. Also, the Orca Group contains basalt and andesite flows (locally called greenstones) that are of potential interest for hard aggregates. However, the rocks are very highly deformed therefore it may not be possible to find large enough blocks of greenstone that can be utilized for hard aggregate. There are also several large Tertiary granite intrusives with thick contact aureoles around the edges of the sound that may provide suitable sources.

The western and northern edges of Prince William Sound are underlain by the Upper Cretaceous Valdez Group, an accretionary belt of rocks approximately 1,000 miles long that extends from southeastern Alaska to Kodiak and the Shumagin Islands. The entire belt is folded, deformed and metamorphosed to grades ranging from zeolite to lower greenschist and to the amphibolite facies. In this area the Valdez Group is composed of interbedded sandstone, siltstone with minor mudstone that pebble conglomerate. Mafic volcanic rocks consist of greenstone, basalt with intermixed metasedimentary rocks and tuffaceous units (Nelson et al., 1985).

Central and eastern portions of Prince William Sound are mapped as being underlain by a complexly deformed sequence of Eocene and Paleocene flysch and mafic volcanic rocks of the Orca Group in fault contact with the southern margin of the Valdez Group. The Orca Group is thought to be an accretionary sequence that may underlie the contiguous continental shelf. Sedimentary rocks of the Orca Group are made up of sandstone, siltstone, and mudstone showing abundant sedimentary structures. Tholeiitic basalt is the most common type of volcanic rock in the Orca Group, occurring as massive flows, interlayered with pillowed flows in some areas.

Intrusive plutons of Prince William Sound were associated with two main events, one Eocene and the other Oligocene. The intrusives are composed primarily of granite and granodiorite with smaller gabbro and diorite stocks and dikes. These intrusive rocks intrude both the Valdez and Orca Groups. Thermal aureoles extend outward from the pluton contacts up to 0.5 miles into the country rock (Nelson et al., 1985).

The principal landowner in Prince William Sound is the Federal Government. Most of the land is part of the Chugach National Forest and is managed by the U.S. Forest Service. The western part of Prince William Sound (west of Montague Island and Valdez Arm) lies within the Nellie-Juan-College Fiord Study Area. Large sections of this area have been recommended for preservation wilderness. The regional native corporation in Prince William Sound is the Chugach Alaska Corporation. There are three village corporations Tatitlek Corporation, Chenega Corporation, and Eyak Corporation within the area. Each of these entities own lands with different levels of ownership within the National Forest. The State of Alaska also owns small parcels surrounding Prince William Sound, primarily near Whittier, Valdez and Cordova. A number of these areas have been designated as state parks.

<u>Knight Island Greenstones:</u> Knight Island is a rugged, glacially sculpted island on the east side of Prince William Sound. The island lies within Chugach National Forest with most of the land owned by the Federal Government. However, there are two large parcels of land at the south end and in the middle of the island owned or selected by native corporations. The predominate rock types on the island are basaltic and andesitic volcanics (sometimes referred to as greenstones) of the Orca Group (Kog) as shown in Figure 4-7. Orca Group sedimentary rocks (Kos) were mapped by Moffit on the south end of the island and included siltstone, mudstone and sandstone. A small area of conglomerate (Koc) was mapped on the south tip of the island (Moffit, 1954).

Knight Island volcanics were further subdivided as follows in 1985 by Nelson et al. in the Geologic map of the Chugach Forest:

1. Pillow Basalt (Top), associated broken pillow breccia, and massive flows make up large parts of Knight Island. This unit may be more than 5,000 feet thick on Knight Island where it is part of a larger mafic igneous complex. Interpillow material consists of siliceous mudstone, sandstone, or carbonate rocks. Pillow basalts are phophyritic with altered brown-colored volcanic glass making up much of the matrix, especially in the outer shells of the pillows. This unit grades into;

2. Pillow Basalt and Sedimentary Rocks (Tops) consisting of similar basalts interbedded with sandstone, siltstone and shale, which further grades into;

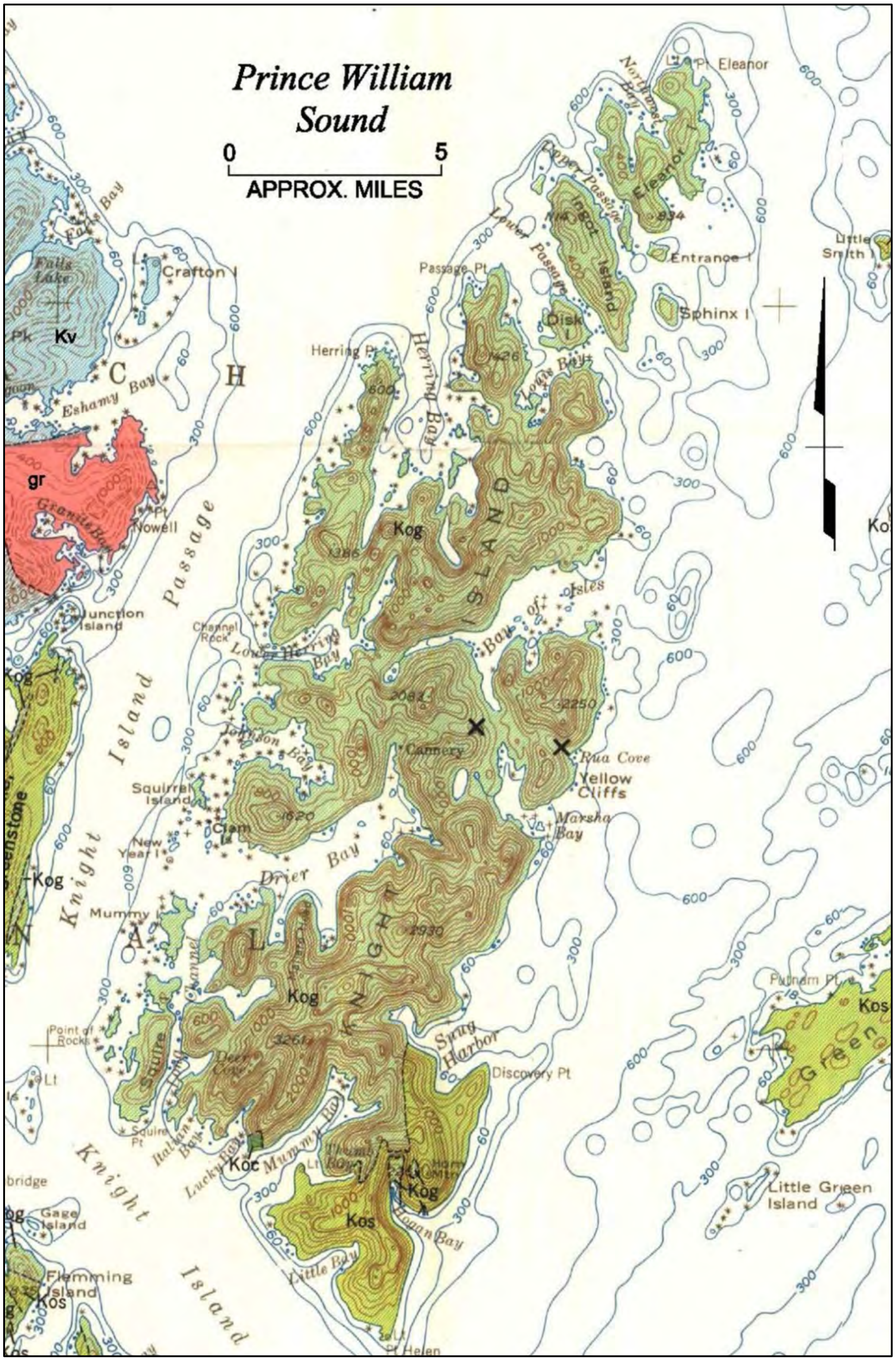
3. Interbedded Sedimentary and Mafic Volcanic Rocks (Tosv) consisting of massive basalt flows and sills intercalated with shale and argillite.

There are a number of shear zones running the length of the island from north to south (Richter, 1975). These shear zones would tend to weaken the rock, making it harder to find areas with the potential for producing hard aggregate. Large numbers of dikes and sills are noted intruding the country rock. Loarse-grained gabbro and diorite dikes were also reported. There were only a few reports of contact metamorphic alteration described in several reports.

While there is a possibility of locating an area where the basalt or andesite still has the durability to produce hard aggregate, it is not possible to predict where on the island this may occur. Even if an area is located, it may not be in a location where it would be accessible or where a permit to mine could be obtained.

Greenstones similar to those on Knight Island are also mapped on Bainbridge, Evans and Elrington Islands to the south of Knight Island Passage. There is a lower percentage of the volcanic rocks here than on Knight Island. They are also more interbedded with the sedimentary rocks.

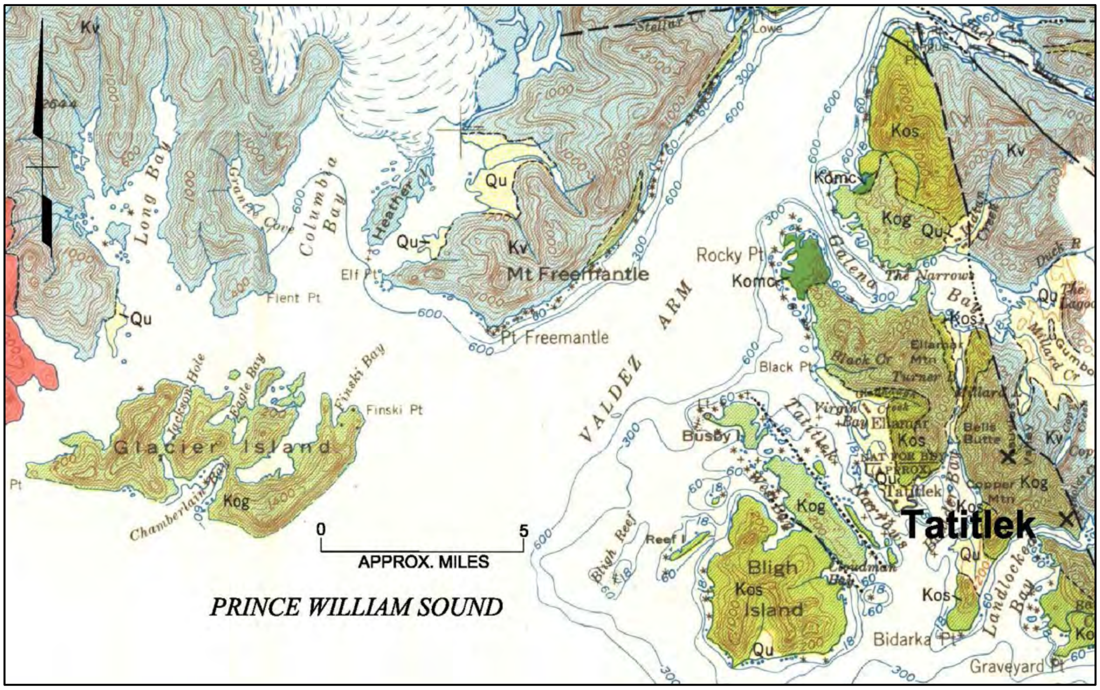
**FIGURE 4 - 7**
**GEOLOGY OF KNIGHT ISLAND**
(From Moffit, 1954)




Kog – Greenstones Kos – Sedimentary rocks Koc - Conglomerate

Tatitlek Greenstones: There are two large bodies of greenstone near Tatitlek, one on the west side the Tatitlek Narrows and the other east of the village between Landlocked Bay and Galena Bay Predominate rock types are basaltic and andesitic volcanics of the Orca Group (Kog) as shown in Figure 4-8. Orca Group sedimentary rocks (Kos) were mapped by Moffit on Bligh Island and included siltstone, mudstone and sandstone. A small area of conglomerate (Komc) was mapped on the south tip of the island. Similar rocks were mapped on Glacier Island along with a basaltic sheeted dike complex near Chamberlain Bay (Moffit, 1954).

**FIGURE 4 - 8**
**GEOLOGY OF TATITLEK AND GLACIER ISLAND**
(From Moffit, 1954)




The greenstones in Prince William Sound appear to exhibit alteration and weathering and therefore may not be retain enough of their original hardness to produce hard aggregate. There may be some areas where the rock is still hard enough to produce hard aggregate, but it is difficult to identify from mapping. While there may be some potentially useable rock in this area for producing hard aggregate, the land status near Tatitlek is unclear. Conservation easements in several areas including Bligh Island makes it difficult to determine if and where mining could occur. Glacier Island appears to be on Forest Service Land. It appears to be used as a sea lion pull out and therefore may not be available for mining.

Igneous Intrusives: There are nine (9) larger granitic plutons in Prince William Sound as shown on the following Figures 4-9 through 4-13 including several smaller gabbro stocks or dikes. The granitic plutons intrude both the Valdez and Orca sedimentary and volcanic rocks. Marginal zones of the granitic plutons contain inclusions of country rock with thermal aureoles extending outward from the pluton for distances up to 0.5 miles into the country rock.

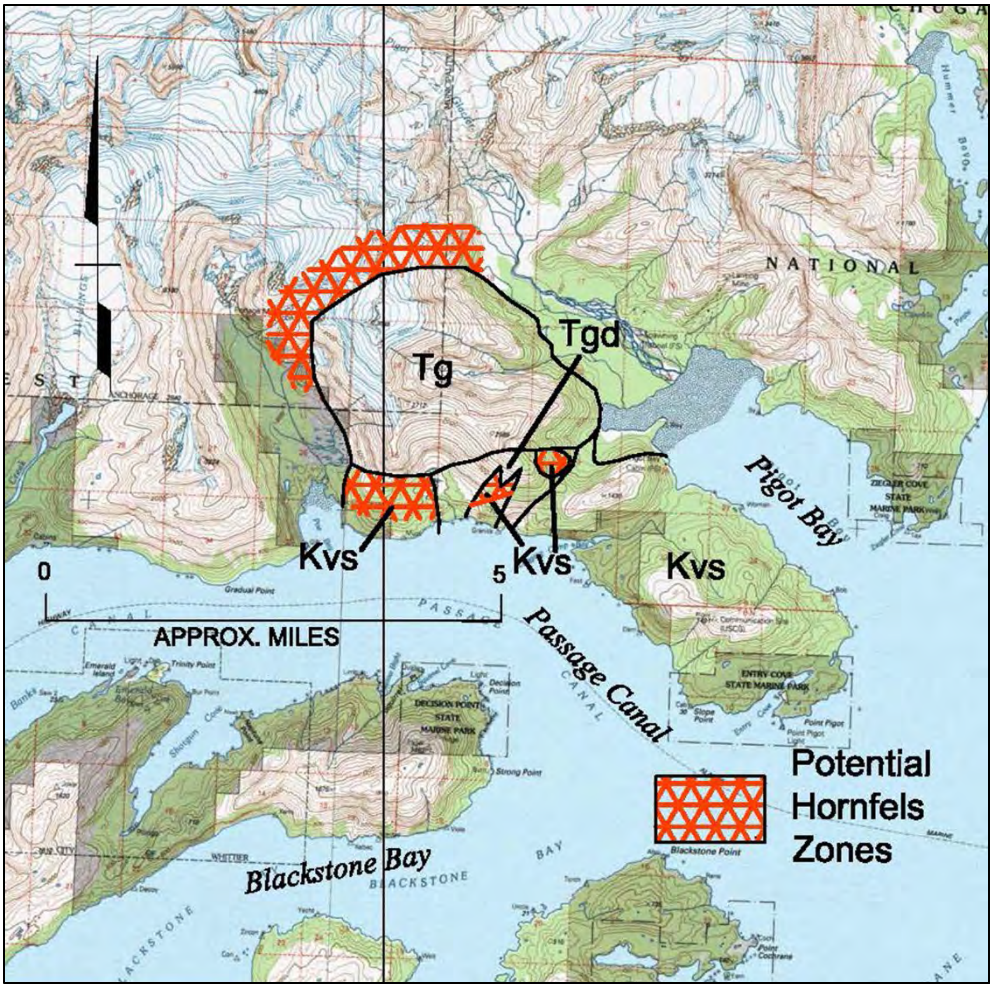
These Prince William Sound granite intrusive have been further subdivided as per Nelson et al., (1985):

> Tg: Granites and Granodiorite (Oligocene), "The central parts of the plutons are dominantly light-gray, medium to coarse-grained granite with color index ranging from 3 to 8. The plutons grade outward to fine to medium-grained, more mafic mineral-rich (color indices of 10 to 20) margins of granitic, granodiorite, and sometimes tonalite compositions" (Nelson et al., 1985). One-half mile thermal aureoles spread out from edges of plutons. Found near Billings Glacier on Passage Canal, on Ester Island, Perry Island, and Cupper Island,
>
> Tgg: Granites and Granodiorite (Eocene). The older of the two intrusive events is represented by plutons in the central parts of Prince William Sound, and intrudes both the Orca and Valdez Groups. Surface exposures range from less than 0.3 mile (Ragged Mountain) to greater than 55 miles at the Sheep Bay pluton. Faults truncate a few of the bodies, but elsewhere the plutons are surrounded by contact-metamorphic aureoles. Plutons of this unit are generally medium to coarse-grained, hypidiomorphic-granular biotite-granite with border phases of biotite- hornblende-granite to granodiorite and tonalite. Found on Wells Bay, Sheep Bay, and at Sheridan Glacier.
>
> Tgd: Gabbro and Diorite. "These rocks are dominantly medium to coarse-grained gabbro and subordinate diorite with finer-grained borders of quartz gabbro and quartz diorite. The color index varies from a range of 30 to 70 in the gabbro and diorite to a range of 20 to 40 in the quartz diorite" (Nelson et al., 1985). There is no mention of thermal aureoles surrounding the gabbros and diorites. Found on Ester Island, Eshamy Lagoon and Passage Canal.

Billing Glacier Intrusive: (Figure 4-9). The Bering Glacier Intrusive is one of the smallest granite (Tg) plutons in Prince William Sound and lies on the north side of Passage Canal. Potential hornfels zones lie on the southern, eastern and northern edges of the pluton. A gabbro (Tgd) is mapped on the south side of the pluton. Most of the potential hornfels zone is on Chugach National Forest land although some hornfelsmay be on State of Alaska land along the southeast and eastern edge of the pluton (dark green area on map).

Ester, Culross, and Perry Island Intrusives: (Figure 4-10). Granitic plutons are found on Ester, Culross and Perry Islands. They lie outside the portion of the Port Nellie-Juan College Fiord Wilderness Study Area that has been recommended as wilderness. There are two small State Parks on Esther Island, both of which appear to lie outside of the potential hornfels zone.

**FIGURE 4 - 9**
**BILLING GLACIER INTRUSIVE**
(Modified from Nelson et al., 1985)




Tg – Granite  Tgd – Gabbro  Kvs – Valdez Group sedimentary rock

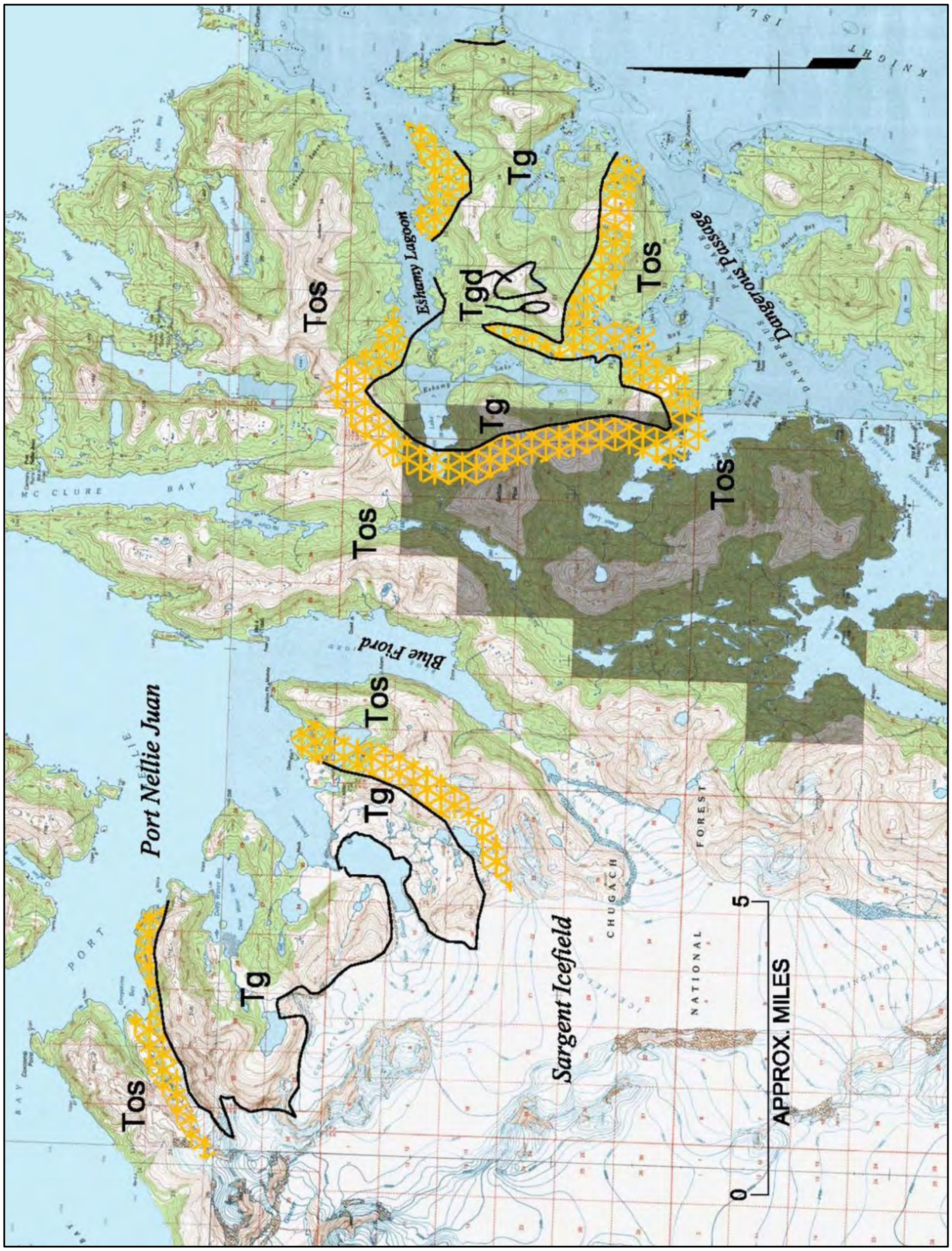
Port Nellie Juan and Eshamy Lagoon Intrusives: (Figure 4-11) The Port Nellie Juan Pluton lies between Port Nellie Juan and Blue Fiord. It is within the Port Nellie-Juan College Fiord Wilderness Study Area which has been recommended for inconclusion as wilderness. The area will likely not be permitted for mining. The Eshamy Lagoon pluton is a granitic intrusive that lies south of Eshamy Lagoon and north of Dangerous Passage. The surface estate was purchased by the State of Alaska from the Chenega Bay Corporation. The subsurface estate is owned by the Chugach Native Corporation. Covenants in the warranty deed to the State of Alaska appear to preclude any mining operations in the Eshamy Lagoon area (OSL 1159).

Wells Bay Intrusive: (Figure 4-12) The Wells Bay Pluton lies between Wells Bay and Glacier Island. It is within the Port Nellie-Juan College Fiord Wilderness Study Area. Therefore the area will likely will not be permitted for mining.

**FIGURE 4 - 10**
**NORTHWEST PRINCE WILLIAM SOUND INTRUSIVES**
(Modified from Nelson et al., 1985)

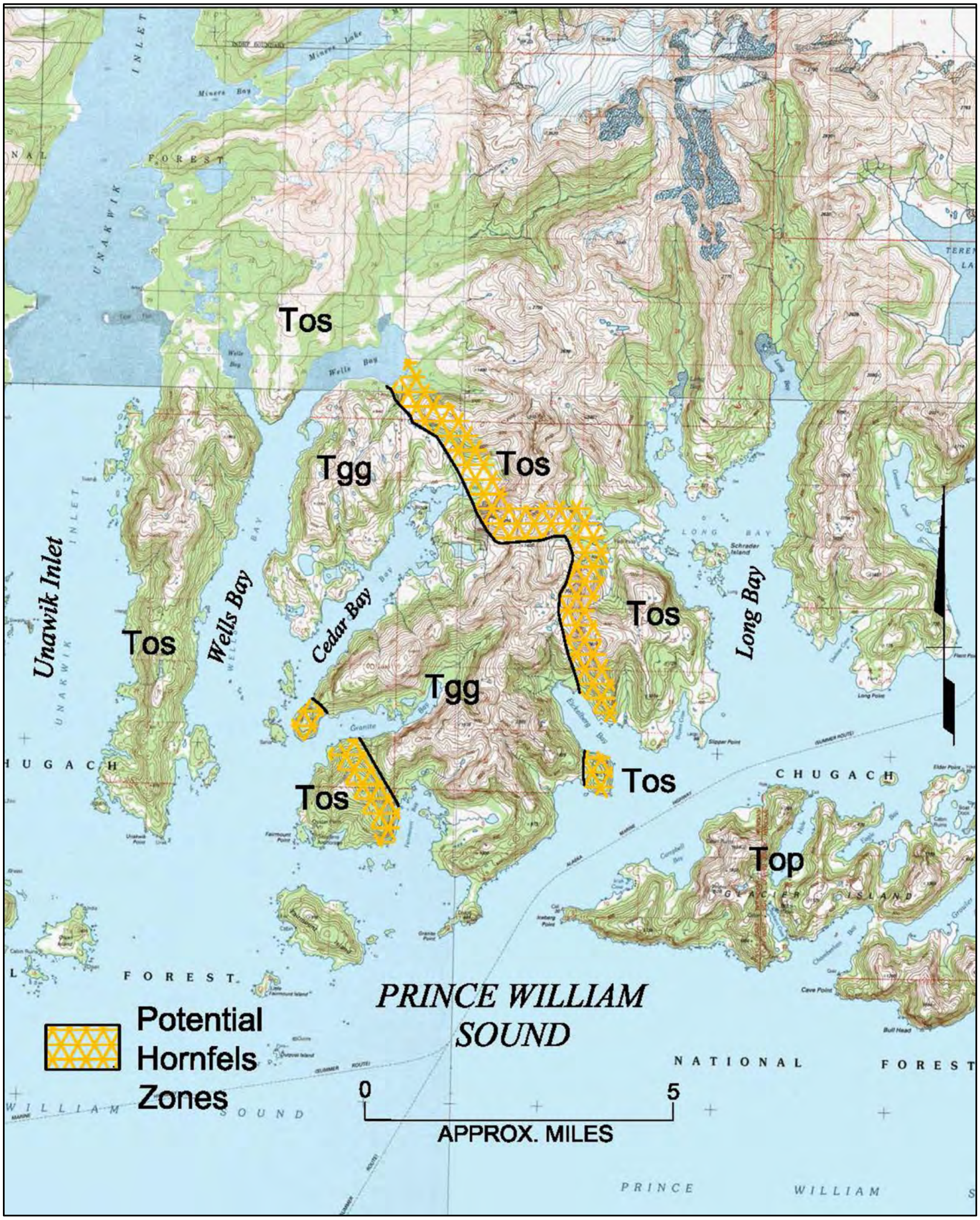

Tg – Granite Pluton   Tgd – Grabbro
Kvs – Valdez Group sedimentary Rocks   Tos – Orca Group sedimentary rocks

**FIGURE 4 - 11**
**PORT NELLIE JUAN & ESHAMY LAGOON INTRUSIVES**
(Modified from Nelson et al., 1985)



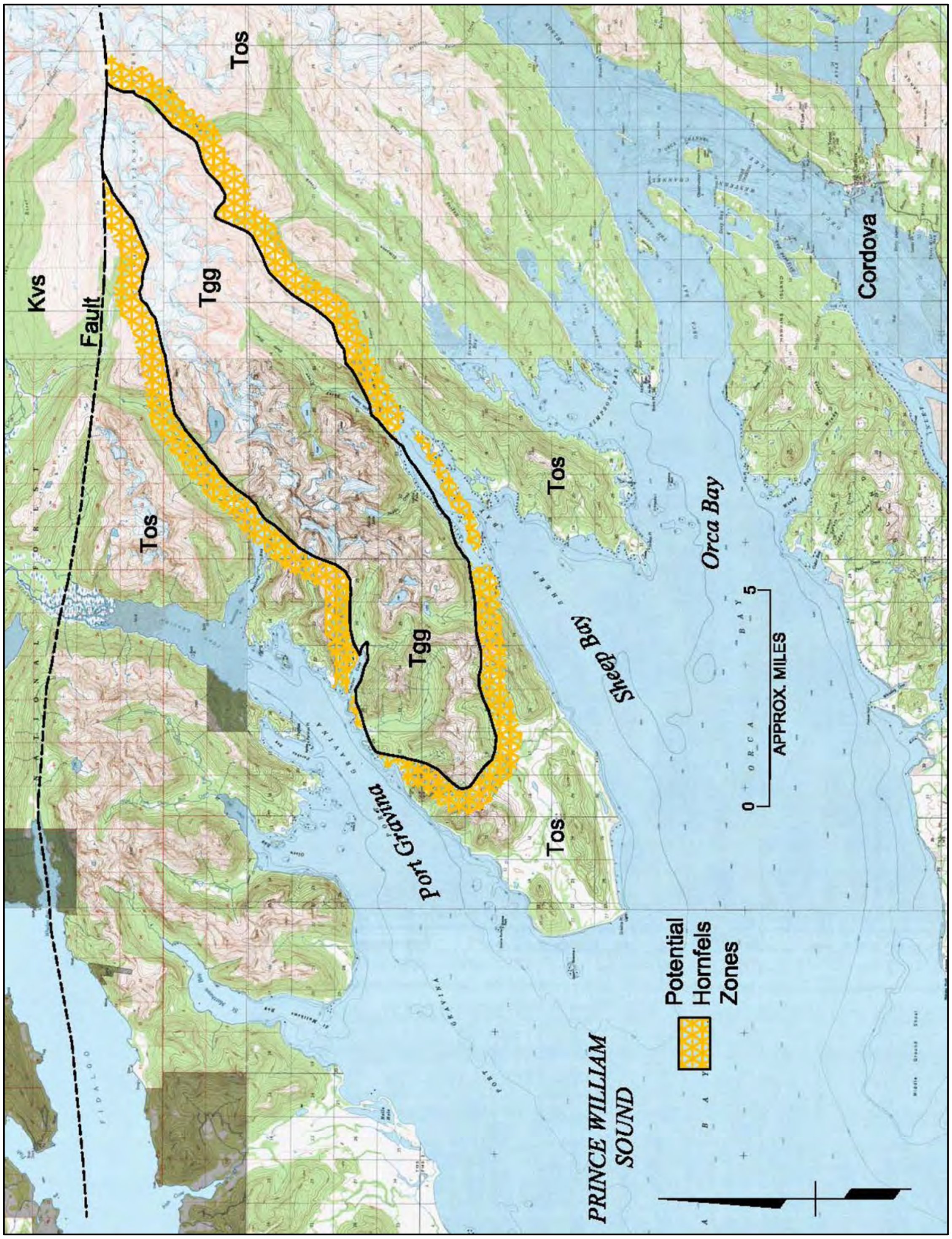

Tos – Orca Group sedimentary rocks  Tg – Granite  Tgd - Gabbro
The western intrusive lies within a wilderness study area. The eastern intrusive at Eshamy Lagoon lies on land with use restrictions that will not allow mining.

**FIGURE 4 - 12**
**WELLS BAY INTRUSIVE**
(Modified from Nelson et al., 1985)




Tos – Orca Group sedimentary rocks    Top – Orca Group greenstone
The Tgg intrusive and associated hornfelses lie within a wilderness study area.

**FIGURE 4 - 13**
**SHEEP BAY INTRUSIVE**
(Modified from Nelson et al., 1985)




Tgg – Granite/Granodiorite    Tos – Orca Group sedimentary rocks
Kvs – Valdez Group volcanic rocks

Sheep Bay Intrusive: (Figure 4-13) The Sheep Bay Pluton is a large elongated granitic intrusive on a peninsula between Sheep Bay and Port Gravina approximately 10 miles north of Cordova. The east end of the pluton is cut by a fault. Hornfels may be potentially found around the southern and northern margins of the pluton. The State of Alaska appears to own land at the west end of the peninsula and the Chugach Native Corporation owns a parcel of land in the center of the pluton. The remainder of the pluton appears to be owned by the Federal Government which is part of the Chugach National Forest. Of all the plutons in the regions this area appears to have the most potential for providing a quarry to produce hard aggregate.

Sheridan Glacier Intrusive: The Sheridan Glacier Pluton is located on the east side of the Sheridan and Sherman Glaciers at MP19 of the Copper River Highway. The contact zone between the igneous granite and granodiorite and the Orca Group sedimentary rock (Tos) lies between two creeks and is mapped between the highway and the headwaters of Salmon Creek. The area lies on Chugach National Forest land and is apparently within the Scott-Sheridan Travel Management Area, which is open to motorized vehicles use yearlong, according to the U.S. Forest Service Motor Vehicle Use Map for Chugach National Forest Map #3. A Potential Hard Aggregate Source Report was prepared for this site.

## 4.10 Selected References


Albanese, M., Kline, J.T., Bundtzen, T.K., and Kline, K., 1983, Reconnaissance geology and geochemistry of the Willow Creek-Hatcher Pass area, Alaska: Alaska Division of Geological and Geophysical Surveys Public-Data File 83-9, 1 sheet 1:63,360.

Bradley, D.C., Parrisch, Randall, Clendenen, William, Lux, Daniel, Layer, P.W., Heizler, Matthew, and Donley, Thomas, 1998, New geochronological evidence for the timing of early Tertiary ridge subduction in southern Alaska, *in* Kelley, K.D. and Gough, L.P., Geological Studies in Alaska by the U.S. Geological Survey, 1998: U.S. Geological Survey Professional Paper 1615, p. 5-21.

Bradley, D.C., Kusky, T.M., Haeussler, P.J., Karl, S.M., and Donley, D.T., 1999, Geologic map of the Seldovia Quadrangle, south-central Alaska: U.S. Geological Survey Open-File Report 99-18.

Burns, L.E., Pessel, G.H., Little, T.A., Palvis, T.L., Newberry, R.L., Winkler, G.R., and Decker, J.E., 1991, Geology of the northern Chugach Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 94, 63 p., 2 sheets, scale 1:63,360.

Burns, L.E., Little, T.A., Newberry, R.J., Decker, J.E., and Pessel, G.H., 1983, Preliminary geologic map of parts of the Anchorage C-2, C-3, D-2, and D-3 quadrangles, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 83-10, 3 sheets, scale 1:25,000.

Calderwood, K.W., and Fackler, W.C., 1972 Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet basin, Alaska: American Association of Petroleum Geologist Bulletin, v. 56, no. 4, p. 739-754.

Clark, S.H.B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 350, 1 sheet, scale 1:250,000.

Clark, S.H.B., 1983, Reconnaissance geologic map of the Chugach Mountains in the Anchorage C-5 and C-6 quadrangles, Alaska: U.S. Geological Survey Open-File Report 83-336, 1 sheet, scale 1:63,360.

Clautice, K.H., Newberry, R.J., Blodgett, R.B., Bundtzen, T.K., Gage, B.G., Harris, E.E., Liss, S.A., Miller, M.L., Reifenstuhl, R.R., Clough, J.G., and Pinney, D.S., 2001, Bedrock geologic map of the Chulitna region, southcentral Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2001-1A, 31 p., 1 sheet, scale 1:63,360.

Csejtey, Bela, Jr., Mullen, M.W., Cox, D.P., and Stricker, G.D., 1992, Geology and geochronology of the Healy quadrangle, south-central Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1961, 63 p., 2 sheets, scale 1:250,000.

Csejtey, Bela, Jr., Nelson, W.H., Jones, D.L., Silberling, N.J., Dean, R.M., Morris, M.S., Lanphere, M.A., Smith, J.G., and Silberman, M.L., 1978, Reconnaissance Geologic map and geochronology, Talkeetna Mountains quadrangle, northern part of Anchorage quadrangle, and southwest corner of Healy quadrangle, Alaska: U.S. Geological Survey Open-File Report 78-558A. 62p., 1 sheet, scale 1:250,000.

Hartman, D.C., Pessel, G.H., and McGee, D.L., 1974, Stratigraphy of the Kenai group, Cook Inlet: Alaska Division of Geological & Geophysical Surveys Alaska Open-File Report 49, 7 p., 11 sheets, scale 1:500,000.

Karlstrom, T.N.V., 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional paper 443, 69 p., 7 plates, 1:250,000 and other scales.

Kelley, J.S., 1984, Geologic map and sections of the southwestern Kenai Peninsula west of the Port Graham Fault, Alaska: U.S. Geological Survey Open-File Report 84-152, 1 sheet, scale 1:63,360.

Moffit, F.H., 1954, Geology of the Prince William Sound region, Alaska: U.S. Geological Survey Bulletin 989-E, p. 225-310, 1 sheet.

Nelson, S.W., Dumoulin, J.A., and Miller, M.L., 1985, Geologic map of the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1645-B, 16 p., 1 sheet, scale 1:250,000.

Pavey, Finkbiner, Binghan, 2012, Web interface http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

Pavlis, T.L., 1986, Geologic map of the Anchorage C-5 Quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Public Data File 86-7, 57 p., 3 sheets, scale 1:63,360.

Reed, B.L., and Nelson, S.W., 1980, Geologic map of the Talkeetna quadrangle, Alaska: U.S. Geological Survey, Miscellaneous Investigation Series Map I-1174, 15 pages, 1 plate, scale 1:250,000.

Richter, D.H., 1965, Geology and mineral deposits of central Knight Island, Prince William Sound, Alaska: Alaska Division of Mines and Minerals Geologic Report 16, 40 p., 1 sheet, scale 1:40,000.

Tysdal, R.G. and Case, J.E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1150, 12 p., 1 sheet, scale 1:250,000.

Wiedmer, Michael, Montgomery, D.R., Gillespie, A. R., and Greenberg, Harvey, 2010, Late Quaternary megafloods from Glacial Lake Atna, southcentral Alaska, U.S.A., Quaternary Research 73, p. 413-424, http://gis.ess.washington.edu/grg/publications/pdfs/Wiedmer_etal_2010.pdf.

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K., and Haeussler, P.J., 1998, Geologic map of Central (Interior) Alaska: U.S. Geological Survey Open-File Report 98-133-A.

Wilson, F.H., Hults, C.P., Labay, K.A., and Shew, Nora, 2008, Preliminary integrated geologic map databases for the United States: digital data for the reconnaissance geologic map for Prince William Sound and the Kenai Peninsula, Alaska: U.S. Geological Survey Open-File Report 2008-1002, 1 p.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeusler, P.J.., Schmidt, J.M., Yehle, L.A., Labay, K.A. (Map Compilers) Wilson, F.H., Hults, C.P., Labay, K.A., Shew, N. (Digital Files Preparers), 2009, Preliminary Geologic Map of the Cook Inlet Region, Alaska-including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale quadrangles, U.S. Geological Survey Open-File Report 2009-1108, Version 1.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeussler, P.J., Schmidt, J.M., Yehle, L.A., and Labay, K.A., 2012, Geologic map of the Cook Inlet region, Alaska, including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak quadrangles: U.S. Geological Survey Scientific Investigations Map 3153, 76 p., 2 sheets, scale 1:250,000.

Winkler, G.R., 1992, Geologic map, cross sections and summary geochronology of the Anchorage 1 degree x3 degrees Quadrangle, southern Alaska, U. S. Geological Survey Miscellaneous Investigations Series Map I-2283, 1 sheet, scale 1:250,000.

Winkler, G.R. and Plafker, George, 1993, Geologic map of the Cordova and Middleton Island quadrangles, Southern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1984, 1 sheet, scale 1:250,000.

# 5.0 ALASKA PENINSULA, ALEUTIAN ISLANDS, AND KODIAK ISLAND

There is little to no local demand for hard aggregate in the Alaska Peninsula, Aleutian Islands or Kodiak Island. Kodiak Island has demand for acceptable paving aggregate, but it doesn't necessarily have to be hard aggregate. With the exception of Kodiak and Unalaska, there is little infrastructure in place to mine and transport aggregates and without port facilities, weather conditions can make loading and shipping difficult. For these reasons and the land issues discussed below, it is unlikely that hard aggregates for paving will be produced in significant quantities in this part of Alaska. The major demand for hard rock will likely be for armor stone.

Much of the Alaska Peninsula and Aleutian Islands are part of the Alaska Maritime National Wildlife Refuge (Aleutian Island and Alaska Peninsula Units), Aniakchak National Monument and Preserve, Katmai National Park and Preserve, Izembek National Wildlife Range, and the Becharof National Wildlife Refuge, plus several wilderness areas and other designated restricted development areas. These areas were precluded from this study. Several of the most promising remaining areas including Unalaska, Sand Point and Chignik had previous investigations, therefore additional studies were not prepared for them. The few remaining alternative areas did not have promising potential sources and thus no potential hard aggregate source reports were prepared for southwest Alaska or Kodiak Island.

Vicinity maps for the Alaska Peninsula, Aleutian Islands and Kodiak Island are presented as Figures 5-1 and 5-2.

## 5.1 General Geology

The Alaska Peninsula is part of the Aleutian arc which forms the northern rim of the Pacific Basin. Bedrock on the peninsula includes mostly Mesozoic to Holocene volcanic and plutonic rocks as well as shallow marine and continental deposits rich in volcanic detritus. The rocks are part of the Peninsular Terrane which occurs along the southern edge of South Central Alaska between the Alaska Peninsula and the Copper River Basin. Along the Alaska Peninsula the Peninsular Terrane is intruded by the Alaska Aleutian Range Batholith. Tertiary granitic intrusives and associated hornfels found throughout the Alaska Peninsula, Aleutian Islands and Kodiak Island are the primary potential source of hard aggregates in this part of Alaska. The more recent Cenozoic volcanic and sedimentary rocks generally are not expected to produce rock of the necessary hardness to produce hard aggregates.

## 5.2 Unalaska

Four existing quarries having Nordic Abrasion test values were found in close proximity to the town of Unalaska (Figure 5-3).

1. <u>Ruth Shaishnikoff Quarry (USS 8378):</u> This site appears to be located along the shoreline, 5.0 miles southwest of Unalaska.

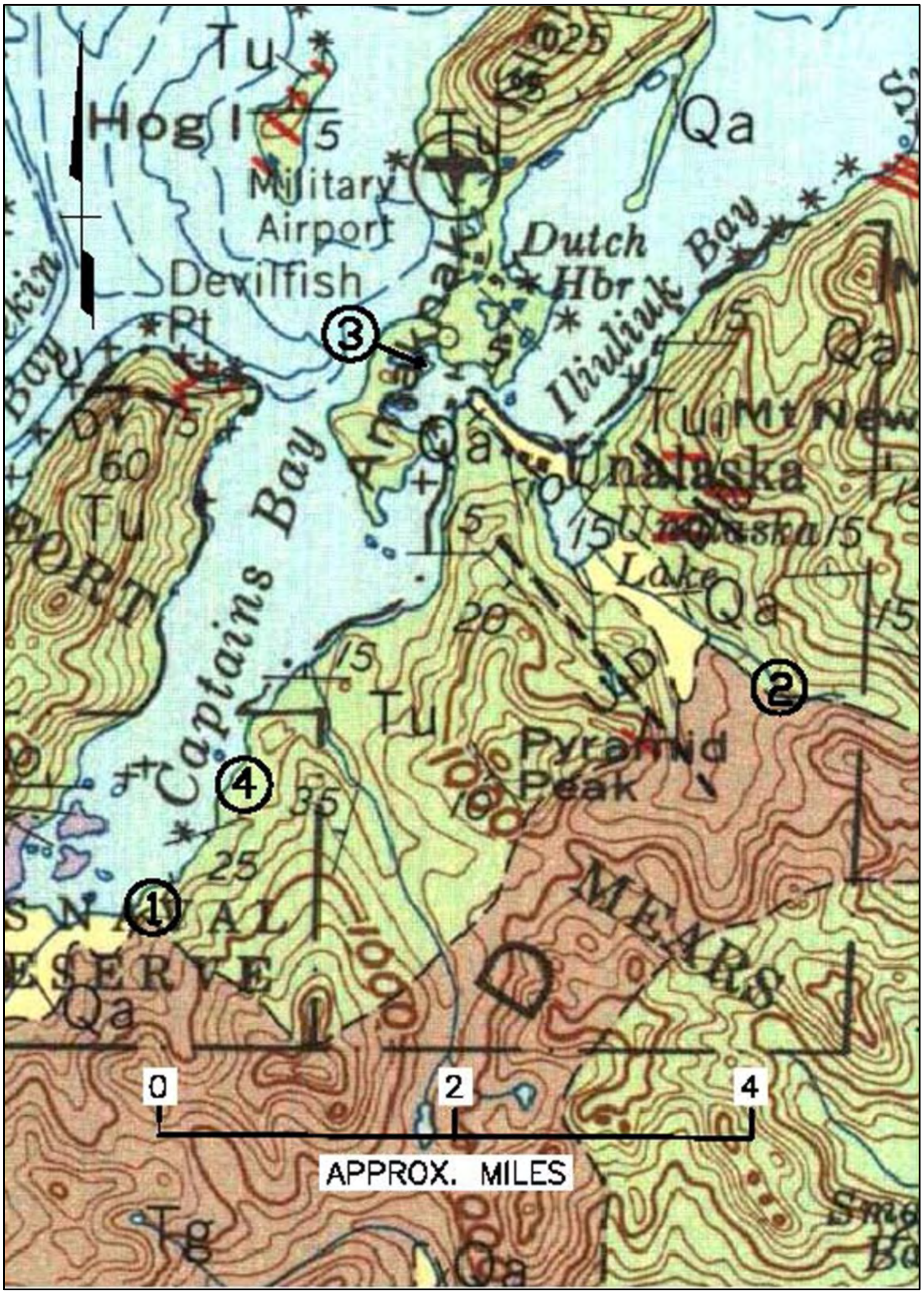
2. <u>Ugadaga Quarry:</u> Located atop a ridge about five miles by road southeast of Unalaska by road.

3. <u>Margarets Bay Quarry:</u> Located one mile southwest of the Unalaska Airport on Amaktak Island. This site is in a developed area that would be difficult to continue quarrying.

## FIGURE 5 - 1
## EASTERN ALASKA PENINSULA AND KODIAK ISLAND VICINITY MAP

## FIGURE 5 - 2
## WESTERN ALASKA PENINSULA AND ALEUTIAN ISLANDS VICINITY MAP

**FIGURE 5 - 3**
**GEOLOGIC MAP OF UNALASKA**
(Modified from Drewes et al., 1961)




Note: Numbers on map are keyed to the text.

4. Bering Shai Quarry: This quarry is located along the shore of Captains Bay, approximately 4 miles southwest of Unalaska. The quarry is apparently also known as the Captains Bay Quarry. Deep water is reported just offshore (U.S. Army Corps of Engineers, 2010).

Geology: Little documentation is available describing the lithology of rocks quarried in three of the four locations. That is particularly true of the rocks subjected to the Nordic Abrasion test for each site.

The quarries include rocks of the Unalaska Formation (Tu) and igneous rocks, predominantly granodiorite in composition (Tg), with contrasting border facies and assorted plutons (Drewes et al., 1961). The Unalaska Formation is composed of slightly altered andesite and basalt extrusive rocks, sills, and sedimentary rocks derived from similar igneous rocks. Conglomerates, graywackes and coarse breccias are the dominant sedimentary rocks in the northern and eastern part of the island. Finer epiclastic and pyroclastic rocks, particularly argillite, are dominant to the south. Belts of hydrothermal wallrock alteration surround the batholiths, which were themselves slightly altered by deuteric solutions, and several areas of wallrock have been dynamically metamorphosed when the adjacent batholiths were intruded. Significant hydrothermal alteration commonly occurs up to a distance of five miles from the nearest batholith. Minerals formed as a result of hydrothermal alteration include primarily epidote, albite, chlorite and uralite. Chalcedonic and cherty masses, as well as crystalline quartz masses, are common in some pillow lavas. Hornfelsed zones in sedimentary rocks have been reported in argillites adjacent to more mafic gabbros of the pluton.

1. Ruth Shaishnikoff Quarry, (USS 8378). The geologic map by Drewes et al. (1961), shows that the pit is located along the intrusive contact between the Unalaska Formation and a granodiorite batholith. The reported Nordic Abrasion test value was 5.9.

2. Ugadaga Quarry. This site is mapped as a cluster of three quarries atop a ridge overlooking the town of Dutch Harbor. Drewes et al. (1961), show the pits located along the intrusive contact between the Unalaska Formation and a granodiorite batholith. A reported Nordic Abrasion test value was 10.

3. Margarets Bay Quarry. Now inactive, the quarry is located in part of series of parallel glaciated bedrock ridges referred to as the Arch Rock Complex. The quarry is mapped by Drewes et al. (1961), as being composed rocks of the Unalaska Formation. Christie (1974), reported color anomalies caused by oxidation of disseminated pyrite in volcanic breccia, cut by small swarms of feldspar porphyry andesite and hornblende-biotite porphyry basalt (lamprophyre) dikes. Weakly mineralized dikes are oriented 010° dipping 80° E. Small quartz veins occur adjacent to some dikes, one of which has been reported as gold-bearing (Drewes et al, 1961). Rocks are regionally prophylitically altered or metamorphosed to low grade, locally highly iron stained with moderate to intense leaching. F.H. Wilson (1996) reported that an entire ridge at this location was being quarried for riprap and fill and being removed for commercial port development. The quarry site is now occupied by a series of buildings. The reported Nordic Abrasion test value was 11.3

4. Bering Shai Quarry: This site is located along the shore of Captains Bay and is mapped as being within a granodiorite pluton. Material has been reported to be a diorite but limited amounts of unweathered rock were reportedly observed in the quarry face in 2010 (U.S. Army Corps of Engineers, 2010). The reported Nordic Abrasion test value was 8.1.

The low Nordic Abrasion test results reported for the Unalaska Island sites appear to come from predominantly fine-grained igneous rocks that have been recrystallized by heat, including deuteric and hydrothermal solutions. One area likely to produce hard aggregates is the alteration zones along the boundary between the Unalaska Formation and the granodiorite batholith as seen in the Ruth Shaishnikoff and Ugadaga Quarries. However, alteration zones may occur within 5 miles of the batholith with low Nordic values such as that found in the Bering Shai Quarry. Thus, thorough field investigations are likely to uncover additional sites with low Nordic Abrasion test values in the vicinity of Unalaska.

## 5.3 False Pass, Cold Bay and King Cove

Bedrock in this area is dominated by Tertiary and Quaternary volcanic deposits which unconformably overlie Tertiary sedimentary rocks. Numerous small Tertiary intrusive bodies have been mapped in the area. These are described as small dikes, sills, and stocks of andesite, quartz diorite, or diorite containing phenocrysts of pyroxene or hornblende in a fine-grained groundmass. Additionally, a few outcrops of hypabyssal intrusions are described as being altered or hornfelsed.

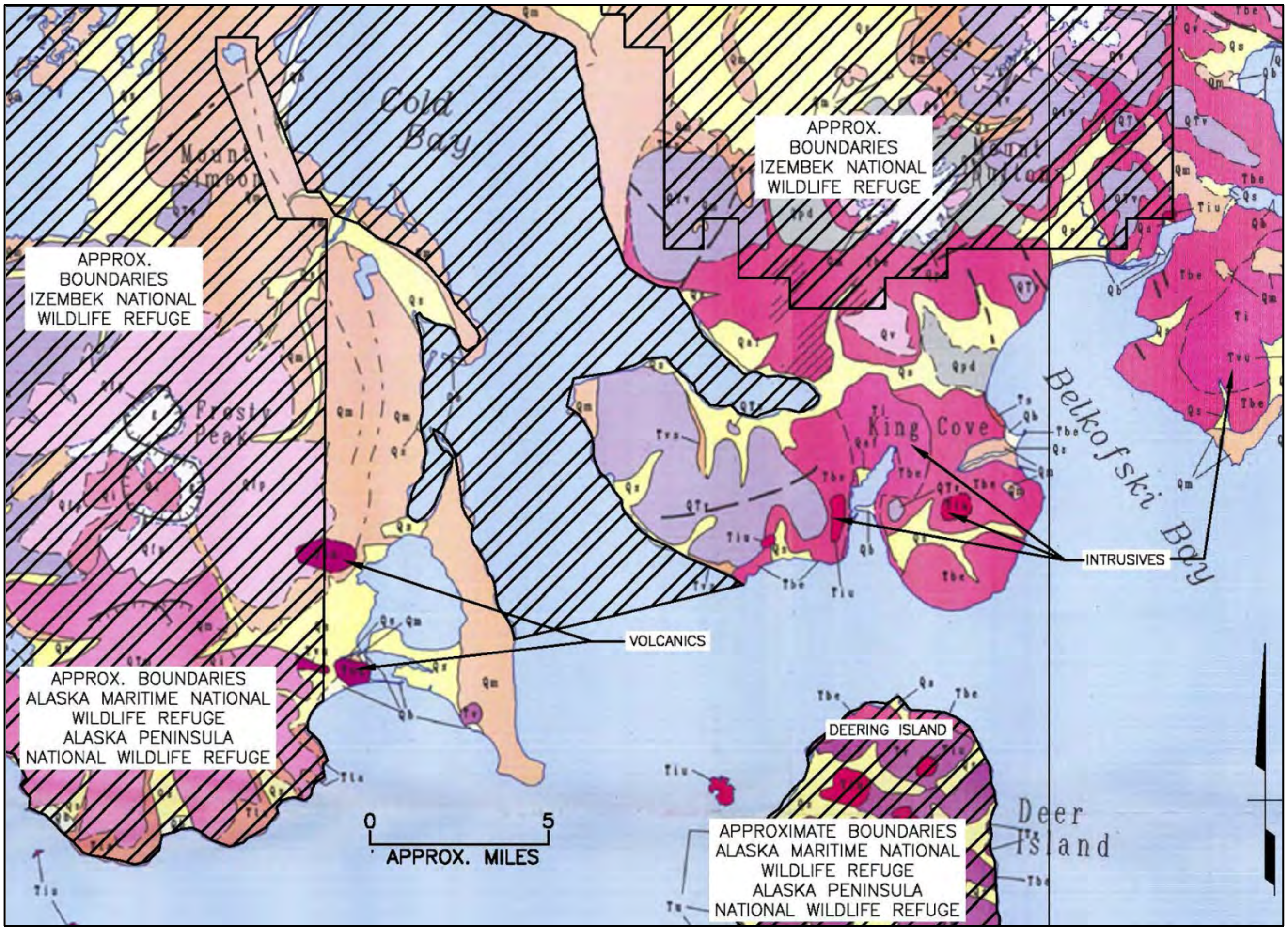
The most likely sources for hard aggregate in this area are the hydrothermally altered or Tertiary hornfelsed volcanic rocks (Tv or Tvu) or intrusive rocks surrounded by well-developed hornfels zones (Ti or Tiu) of Wilson et al. (1997). Many of these outcrops are within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge and are likely unavailable. The only mapped outcrops of the volcanic rocks lying outside the refuge are south of Cold Bay in the vicinity of Thinpoint Lake as shown on Figure 5-4. These volcanics are noted as consisting of andesites, dacite, basalts, tuffs, lahar deposits, volcanic breccia and hypabyssal intrusions, all locally hornfelsed.

Tertiary intrusive rocks consisting of medium to coarse-grained, equigranular, granodiorite to quartz diorite plutons with stocks containing hornblende, biotite, and pyroxene and mafic minerals, are mapped in the vicinity of the village of King Cove, and on the east side of Belkofski Bay (Moss Cape pluton), as shown in Figure 5-4. These intrusives are typically surrounded by well-developed hornfels zones and sporadic hydrothermal alteration in country rock.

## 5.4 Sand Point and Shumagin Islands

Sand Point is located on Popof Island, part of the Inner Shumagin Islands. Bedrock on Popov Island is dominated by Tertiary volcanics, including lava flows, lahar deposits, debris-flow deposits, ash-flow tuff, and tuff. Tertiary sedimentary rocks of the Stepovak Formation are also present, consisting of siltstone and sandstone rich in volcanic debris. Several small intrusive bodies of Tertiary quartz diorite or diorite rocks are mapped on the east side of the island as shown in Figure 5-5.

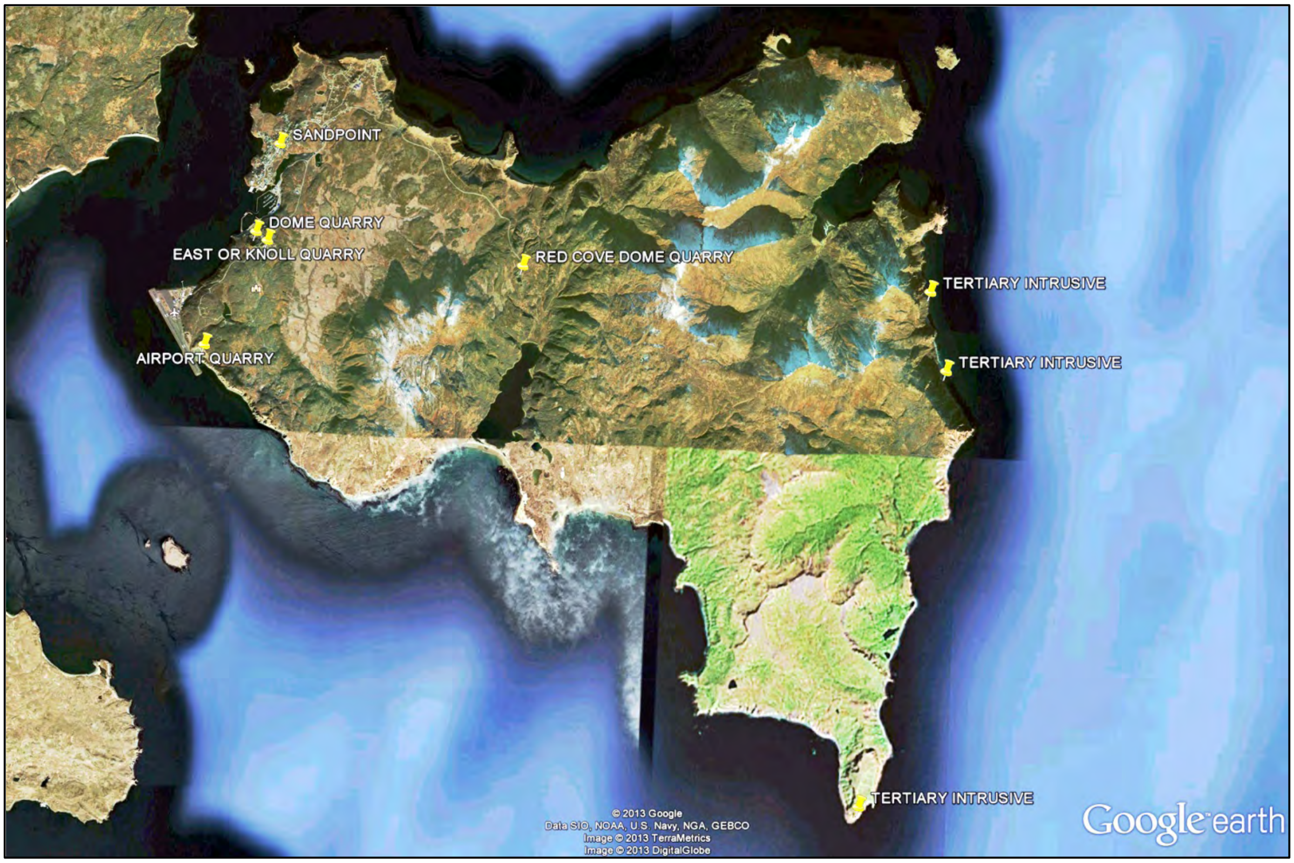
**FIGURE 5 - 4**
**COLD BAY-KING COVE-BELKOFSKI-BAY VOLCANICS AND INTRUSIVE ROCKS**
(Modified from Wilson et al., 1997)




Nordic Abrasion test results are available for three quarries on Popov Island as reported in Table 1-2. The three quarries (Dome Quarry, Knoll Quarry and the Red Cove Quarry) are all weathered basalt plugs with Nordic Abrasion values ranging from 12.8 to 19.1. The only rocks on Popof Island with potential for producing hard aggregate are interpreted to be the Tertiary intrusives. However, these rocks are of very limited extent, and there is no available information regarding the material properties or the presence of contact hornfels. Tertiary intrusions also appear to lie within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge.

The Shumagin Islands are located to the southeast of Sand Point and consist primarily of the sedimentary Shumagin Formation and Tertiary granitic plutons. Minor hornfels were reported on the islands (Wilson et. al, 1995). The difficulty of access, and being in the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge make this an area of low potential for hard aggregate.

**FIGURE 5 - 5**
**POPOV ISLAND AND SAND POINT**




## 5.5 Perryville

Bedrock in the immediate vicinity of Perryville is dominated by Tertiary volcanic and sedimentary rocks. There is no indication from published mapping that these materials have been metamorphosed, nor are there any mapped intrusive rocks.

Well-developed hornfels and sporadic hydrothermal alteration in associated country rocks was noted surrounding Tertiary granodiorite to quartz diorite plutons at American Bay (approximately 40 miles to the southwest of Perryville) and on Mitrofania Island (approximately 14 miles east of Perryville) (Wilson et. al, 1995). However, both locations appear to lie within the Alaska Peninsula Unit of the Alaska Maritime National Wildlife Refuge and are likely unavailable for mining.

## 5.6 Chignik

Bedrock geology of the Chignik Bay area is dominated by a sequence of Upper Jurassic to Eocene sedimentary rocks which are unconformably overlain by Late Eocene to Early Oligocene volcanic rocks. The Tertiary formations consist predominately of non-marine, volcaniclastic, and carbonaceous sedimentary rocks. The underlying Mesozoic rocks are predominately marine sandstone, siltstone, and shale. These layered rocks are intruded by the Miocene age Devils Bay Batholith, consisting of medium to coarse-grained quartz diorite. A well-developed hornfels zone is mapped along the margins of the batholith as shown on Figure 5-6. The Devils Bay Batholith is mapped along the coast from Kuiukta Bay to Cape Kumlium, approximately 25 miles north of Chignik. Other small igneous intrusive bodies are mapped in the area, including andesite and basalt domes.

A Nordic Abrasion value of 24 was obtained from a sample of the Castle Bay Quarry at the head of Castle Bay. It appears that the sample came from an area that the sample was thermally altered, however the type of rock tested is not known. The mapped presence of hornfels in the Chignik area suggests that there is potential for hard aggregate in this area and further investigation is warranted.

## 5.7 Kamishak Bay to Iliamna Bay

Geology along the coast of Kamishak Bay is a complex mixture of sedimentary, metamorphic and igneous rock. The Bruin Bay Fault extends along the shoreline, dividing the area into two distinct geologic areas. Rocks west of the fault are dominated by the Alaska-Aleutian Range batholith and roof pendants of meta-volcanic, meta-sedimentary and sedimentary origin. East of the fault bedrock is entirely sedimentary, consisting of conglomerate, sandstone, siltstone and shale. These sediments have not been intruded or otherwise altered, and are therefore not a likely source for hard aggregate. Further discussion will be limited to the rocks west of the Bruin Bay Fault.

Jurassic age rocks of the Alaska-Aleutian Range batholith consist of medium to coarse-grained quartz monzonite and quartz diorite. These rocks are not expected to be a source for hard aggregate; however, the contact metamorphic zone in the country rocks around the pluton may contain potential sources. The most promising units are the Triassic age Cottonwood Bay greenstone (TRC), and the Jurassic age Talkeetna Formation. Outcrops of the Cottonwood Bay greenstone are present in Pile Bay, Cottonwood Bay, Iliamna Bay, and Ursus Cove (Figure 5-7). This rock unit is described as mainly mafic volcanic rocks altered to hornfels and chloritic greenschist, is extremely hard and forms massive, rugged outcrops. The Talkeetna Formation (Jtk) is a thick unit of volcanic rock outcropping in many locations along the coast of Kamishak Bay. While most of this formation consists of relatively unaltered volcanic breccia, agglomerate, lava flows and tuff, and is unlikely to produce hard aggregate, some of the lower portions close to the batholith may have been altered to hornfels (Detterman and Reed, 1980).

The other mapped units in the area are likely to be either too foliated, as is expected in the Kakhonak Complex, or too soft, as is expected in the sedimentary Kamishak Formation.

**FIGURE 5 - 6**
**GEOLOGIC MAP OF CHIGNIK AND CASTLE BAYS**
(Modified from Detterman et al., 1981)

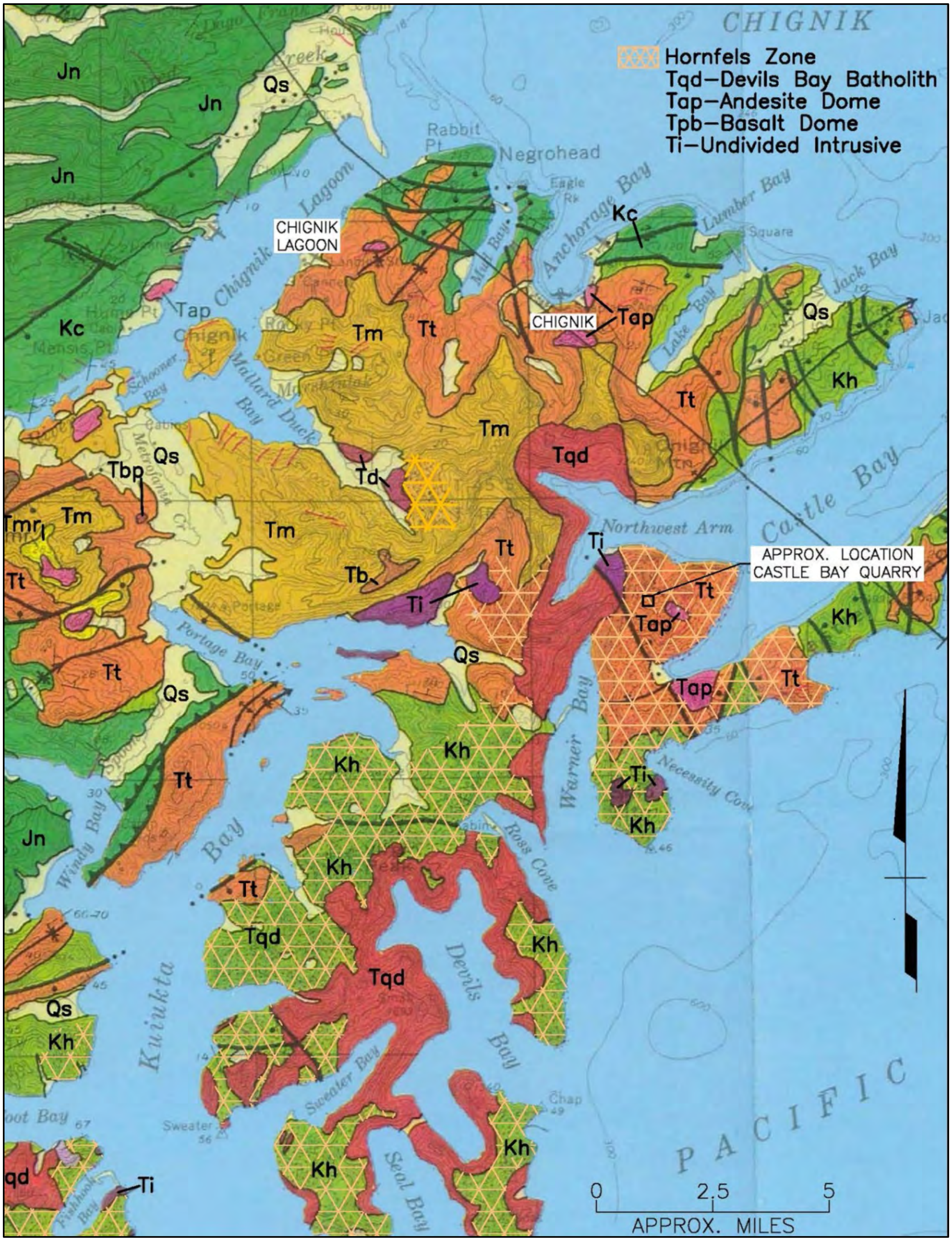
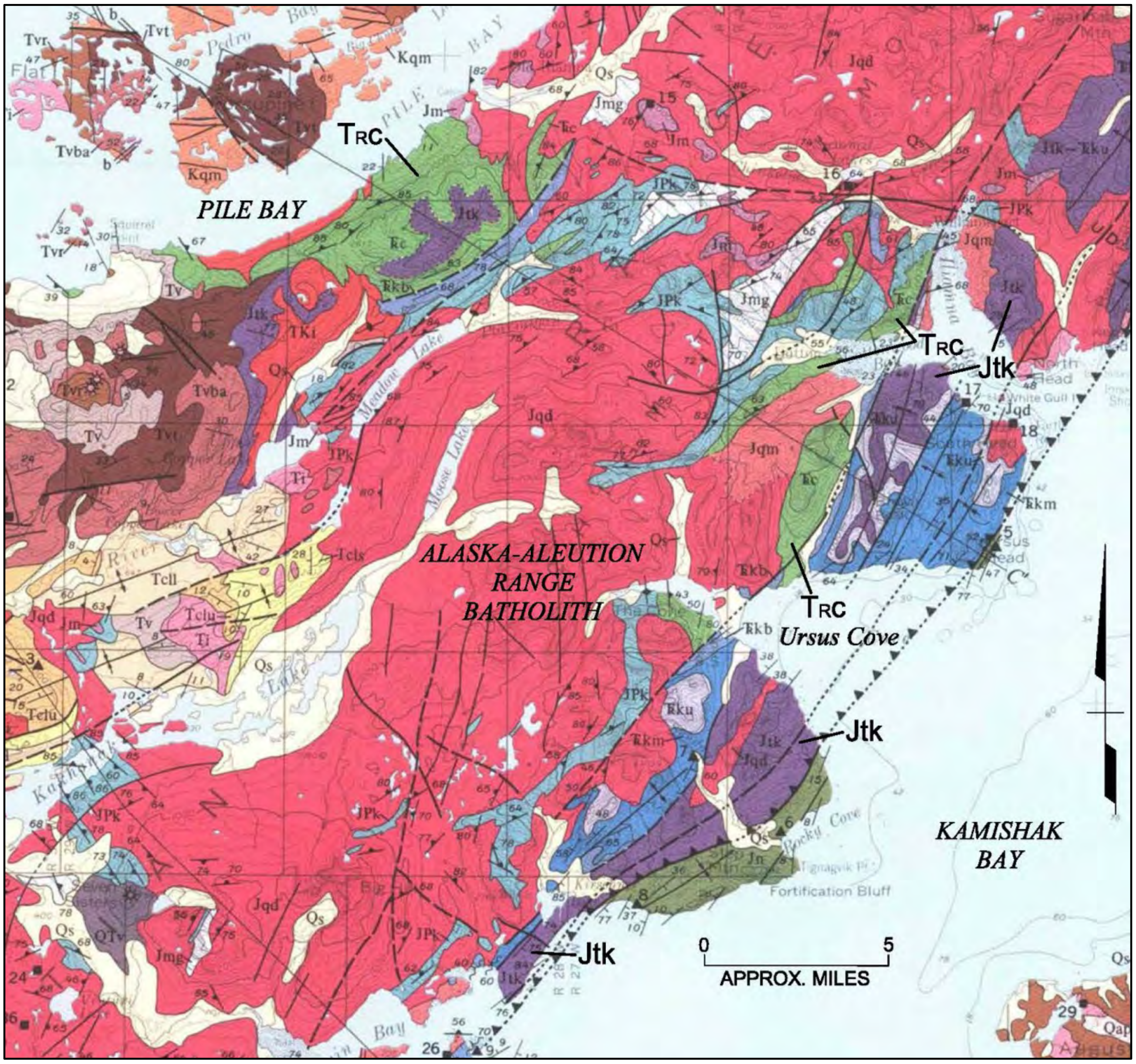


**FIGURE 5 - 7**
**GEOLOGIC MAP OF KAMISHAK BAY TO PILE BAY**
(Modified from Detterman et al., 1980)




Cottonwood Formation – TRc     Talkeetna Formation – Jtk

## 5.8 Kodiak Island

Kodiak Island can be separated into three different belts of bedded rock. The southeastern belt is composed of Tertiary sediments separated from a sequence of Cretaceous rock by a northeast-trending normal fault. These sediments in turn are separated from older Triassic-Jurassic rocks by a northeast-trending thrust fault to the west. All three groups have been intruded by Tertiary granodiorite masses (Moore, 1967).

Tertiary sediments lie to the southeast of the Contact Fault, a major northeast trending normal fault extending from Kalsin Bay to Portage Bay and probably beyond to the south. The sediments include the entire Tertiary sequence from Paleocene to Pliocene. Both marine and continental sediments are represented including shales, sandstones, and conglomerates. Sandstones consist of subangular to rounded grains of predominantly quartz with minor feldspar, chert and other rock types. Conglomerates contain pebbles of chert, graywacke, limestone and granitic rocks. Northwest of the Contact Fault, rocks are predominately Upper Cretaceous flysch deposits consisting of turbidite sequences of argillite and graywacke. These sediments have been variably metamorphosed to zeolite to low-greenschist facies, and have been moderately to highly deformed. These unsorted sediments are bounded on the northwest by the Uganik and Border Ranges Faults, and cover extensive areas in the western part of Kodiak Island. Northwest of the Uganik and Border Ranges Faults, rocks consist of a Middle Cretaceous to Lower Jurassic mélange assemblage of basalt, schist, and oceanic sedimentary rocks. An elongate granodiorite mass occupies the axial core of Kodiak Island and is continuous from Kizhuyak Bay on the north to Alitak Bay on the south. Petrographic examination of samples from this granodiorite mass shows that the texture is coarse to medium-grained, consisting of quartz and light colored plagioclase feldspars with common darker minerals, predominantly biotite mica. The smaller intrusives are similar both in texture and chemical composition to the large granodiorite mass and represent satellite intrusives or genetically related rock masses. One of these intrusives is the proposed Shakmanof Cove Quarry on Kizhuyak Point between Anton Larsen Bay and Shakmanof Cove northwest of Kodiak. Nordic Abrasion values ranging from 10.3 to 20 were reported from this site (U.S. Army Corps of Engineers, Alaska District, 2010). Numerous dikes and sills that have similar chemical properties to the intrusives, but are of finer-grained texture, were noted and mapped by Capps (1937). These dikes and sills are usually associated with the intrusive bodies, but some occur without a direct relationship.

Generally, the geology of Kodiak Island does not appear conducive to hard aggregate production. Most of the island is composed of relatively soft sedimentary rock, or highly foliated low-grade meta-sediments. The igneous intrusives are generally too coarse-grained to have low Nordic Abrasion values. One area that may be suitable for the production of hard aggregate would be on the margins of the Tertiary granodiorite intrusive where contact metamorphism may have resulted in alteration to hornfels. To date these types of contact deposits have not been noted in the literature.

### 5.9 Selected References


Capps, S.R., 1937, Kodiak and adjacent islands, Alaska: U.S. Geological Survey Bulletin 880-C, p. 111-184, 1 sheet.

Collier, A.J., 1905, Auriferous quartz veins on Unalaska Island: U.S. Geological Survey Bulletin 259, p. 102-103.

Christie, J.S., 1974, Aleut-Quintata-Duval 1974 joint venture final report: unpublished Quintana Minerals Corporation report available from the Aleut Corporation, 24 p., appendices, 2 maps in pocket.

Detterman, R.L. and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna quadrangle, Alaska. U.S. Geological Survey Bulletin 1368-B.

Detterman, R.L., Miller, T.P., Yount, M.E., and Wilson, F.H., 1981, Geologic map of the Chignik and Sutwik Island quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1229, 1 sheet, scale 1:250,000.

Drewes, H.F., Fraser, G.D., Snyder, G.L., and Barnett, H.F., Jr., 1961, Geology of Unalaska Island and adjacent insular shelf, Aleutian Islands, Alaska: U.S. Geological Survey Bulletin 1028-S, p. 583-676, 4 sheets, scale 1:250,000.

Green, K. and Warren, G, 2007, Investigation of sources for armor stone and site conditions for Unalaska Airport Project: Prepared by CH2M HILL as part of Unalaska Airport Master Plan Update, 94 p.

Moore, G.W., 1967, Preliminary geologic map of Kodiak Island and vicinity, Alaska: U.S. Geological Survey Open-File Report 67-161, 2 sheets, scale 1:250,000.

Simpson, D.F., 1986, Aleutian Islands project 1985 final report, Kennecott-Alaska Exploration: unpublished report available from The Aleut Corporation, 54 p.

U.S. Army Corps of Engineers, Alaska District, 2010, Rock quarry potential, A preliminary investigation, State of Alaska: In cooperation with State of Alaska Department of Transportation and Public Facilities, 82p.

Wilson, F.H., 1996, Alaska resource data file; Unalaska quadrangle: U.S. Geological Survey Open-File Report 96-270, 48 p.

Wilson, F.H., Detterman, R.L., Miller, J.W., and Case, J.E., 1995, Geologic map of the Port Moller, Stepovak Bay, and Simeonof Island quadrangles, Alaska Peninsula, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 2272, 2 sheets, scale 1:250,000.

Wilson, F.H., Weber, F.R., Dochat, T.M., Miller, T.P., and Detterman, R.L., 1997, Revised geologic map of the Cold Bay and False Pass quadrangles, Alaska Peninsula: U.S. Geological Survey Open-File Report 97-866, 34 p., 1 sheet, scale 1:250,000.

Vallier, T.L., Scholl, D.W., Fisher, M.A., Bruns, T.R., Wilson, F.H., von Huene, Roland , and Stevenson, A.J., 1994, Geologic framework of the Aleutian arc, Alaska, in Plafker, George, and Berg, H.C., The Geology of Alaska: Geological Society of America, p. 367-388.

# 6.0 SOUTHEAST ALASKA

Many of the potential hard aggregate sites in southeast Alaska are found along State highways, Forest Service roads or logging roads that can be used to access the coast and barge landings. Potential sites were generally located in the Tongass National Forest and on lands managed by the U.S. Forest Service. Areas in national parks and monuments, wilderness areas, and roadless areas, were eliminated from the potential study areas. A vicinity map for southeast Alaska is presented as Figure 6-1.

## 6.1 General Geology

Southeast Alaska is underlain by a complex and heterogeneous assemblage of rocks, and is cut by an intricate network of faults. The rocks record a long and complete geologic history beginning in the Proterozoic and continuing into the Holocene. These rocks can be subdivided into ten assemblages, five of which are terranes and five of which are in depositional or intrusive contact with the terranes. Stratified rocks in southeast Alaska consist of a series of northwest belts of various depositional ages and degrees of deformation and metamorphism. These belts occur along the east and west flanks of the Coast Mountains. The rocks along the east flank consist of schist, gneiss and marble with sedimentary and volcanic rocks extending eastward into British Columbia. Rocks along the west flank include an assemblage of metasedimentary and metavolcanic rocks. An extensive assemblage of pre-Jurassic strata occurs on the islands to the west, where a section of sedimentary and volcanic rocks is found that ranges in age from the Cambrian through the Late Triassic. Intrusive rocks mostly range from Cretaceous to Tertiary and occur on many of the islands west of the Coast Mountain batholith. Several phases of deformation and/or metamorphism have punctuated the evolution of southeastern Alaska, the most widespread event occurring during the Late Cretaceous and early Tertiary (Gehrels and Berg, 1994).

The northern cordillera of British Columbia and Alaska comprise the Coast Range and the Rocky Mountains. The Coast Range is underlain by the metamorphic plutonic rocks of the Coast Plutonic Complex. Less metamorphosed rocks lie west of the Coast Range in the insular superterrane and to the east in the intermontaine superterrane. The Coast Range is divided into three parallel belts that extend the length of southeast Alaska; the western metamorphic belt, the central pluton-gneiss belt and the eastern metamorphic belt. Rocks along the western metamorphic belt underlie the mountains along the inside passage and crop out along the Gravina Belt of the Insular super terrane. The central pluton-gneiss belt was created by collision of the insular and intermontaine super terrane of British Columbia, followed by magma intrusion during later subduction. Folding and faulting during the subduction and upthrust created metamorphic layering (foliation) that is generally subvertical.

The insular superterrane in southeast Alaska consists of four terranes west of the Coast Range. Three of these are parts of island arcs; the Alexander Terrane, the Wrangellia Terrane, and the Gravina Belt. The older Alexander Terrane may be between 500 and 240 million years old and stretches between the middle of the Alexander Archipelago from Prince of Wales Island through Admiralty Island through Haines. The Wrangellia Terrane may be between 150 and 250 million years old, and occurs in southeast only in the central portion of Chichagof Island. The youngest of the terranes is the Chugach, composed of sedimentary and metamorphic rocks,

**FIGURE 6 - 1**
**SOUTHEAST ALASKA VICINITY MAP**

which forms the western portion of Chichagof and Baranof Islands. Gravina Belt rocks formed a narrow marine basin on the eastern side of the Alexander Terrane (Stowell, 2006).

Moving toward the Coast Range, the rock generally becomes subject to more thermal alteration and recrystallization, which should make it harder, but it appears that it also subjects it to cataclastic deformation which weakens the rock. Foliation is common in rocks from Haines to Ketchikan. Foliated rocks are generally not strong enough to produce hard aggregates.

The best potential sources of hard aggregates in southeast Alaska are basalts with the two most extensive deposits along the Chilkat River near Haines and on Kupreanof Island. Pits in talus cones near the airport at Haines are being mined at present. Small quarries on Kupreanof Island have also been mined in the past. There are also scattered fine-grained intrusive igneous rocks throughout southeast Alaska, the most prominent being a gabbro near Herring Bay on Revillagigedo Island that may also provide sources of hard aggregate.

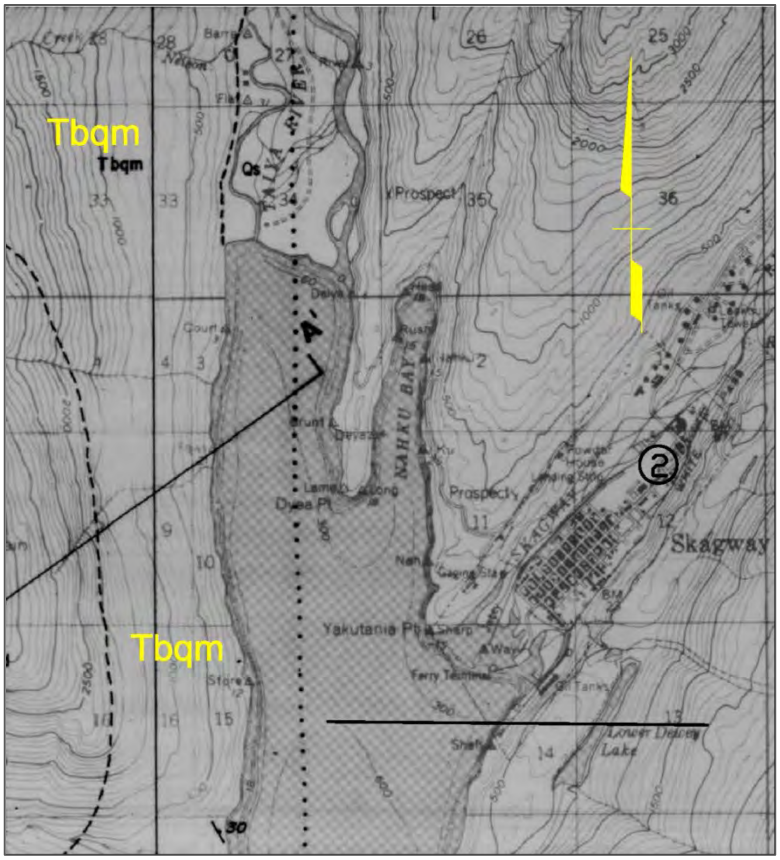
Hornfels is found in contact aureoles surrounding many of the igneous intrusives in southeast Alaska, making the most common potential sources of hard aggregate. Eight out of ten reports for potential sources included in this study involve hornfels, including, Kuiu Island, Zarembo Island, Etolin Island, Wrangell Island, Revillagigedo Island and three sources on Prince of Wales Island. Reports were not included for several other sources as they are located in wilderness areas, national monuments, roadless areas, or areas that would make for very difficult access.

### 6.2 Skagway Area

Bedrock in the Skagway area consists primarily of granitic rocks. Two mapped units were identified as fine-grained enough to have the potential for providing hard aggregates, but there is no test data available for either. A monzonite (Tbqm) near Dyea is accessible to the coast and may be worthy of further consideration. A fine to medium-grained granite (Tgr) is generally inaccessible. The two units are described below with further information being found in the referenced publications.

> Tbqm: Biotite quartz monzonite of the Burrow Creek Pluton. Rock is fine to medium-grained, subhedral granular with characteristic large poikoilitic plagioclase phenocrysts. Rock is 20% quartz, 15% biotite, 25% K-feldspar, and 40% plagioclase (Redman et. al., 1984). Found along the west side of Taiya Inlet near Dyea. See Figure 6-2.
>
> Tgr: Pink to buff, medium to fine-grained, equigranular biotite granite. Locally, near margins includes xenoliths of fine-grained diorite, diabase, and biotite gneiss, and is intruded by pegmatite dikes (Gilbert et al., 1990). This unit is found along the Canada border in locations that are generally inaccessible.

**FIGURE 6 - 2**
**GEOLOGIC MAP OF SKAGWAY (Tbqm)**
(Modified from Redman et al., 1984)

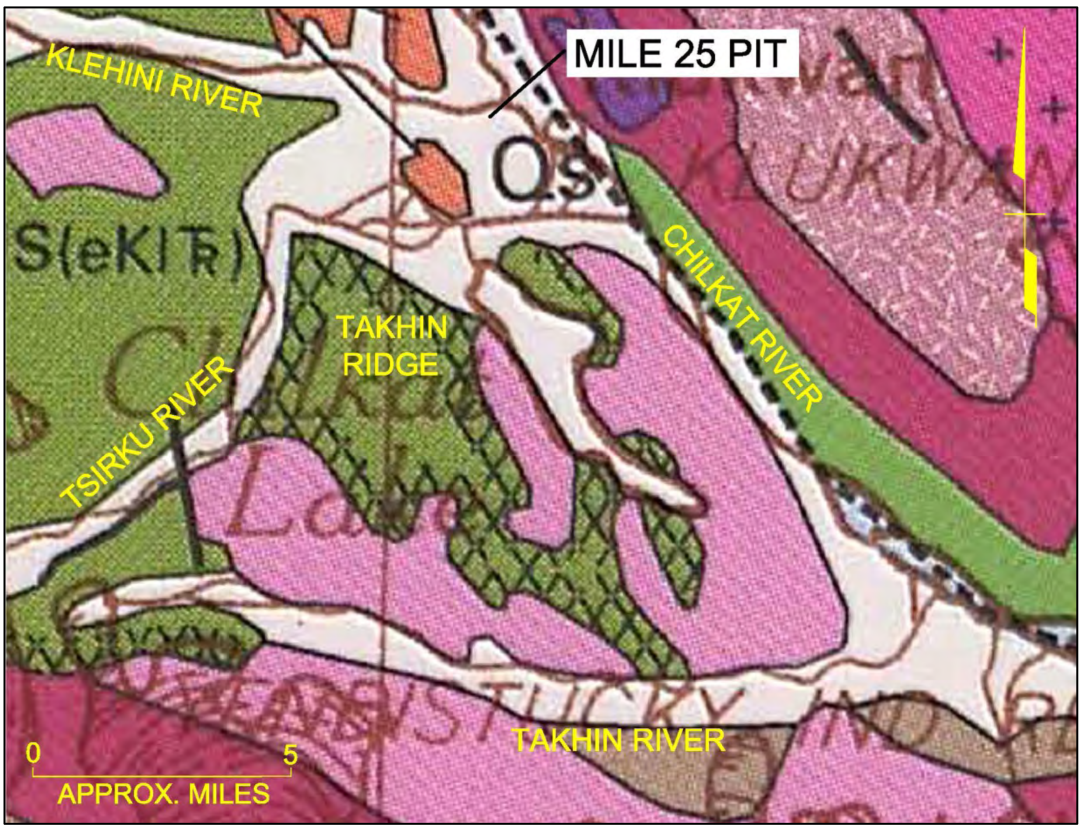



## 6.3 Haines Highway Area

Between Haines Airport and Klukwan, a metabasalt is exposed in a northwest-trending belt as much as one-half a mile wide along the base of the Takshanuk Mountains bordering the northeast side of the Chilkat River where it is in gradational contact with the gabbro-diorite complex. Most of the metabasalt in the Skagway B-3 Quadrangle near Klukwan is reportedly characterized by near-vertical foliation that strikes northwestward approximately parallel to the Chilkat River fault and the Takshanuk Mountains. A complex of altered gabbro and diorite occupies an extensive northwest-trending belt, as much as two miles wide, along the southwest flank of the Takshanuk Mountains. It is intruded by pyroxenite along sharp, steep contacts that strike mainly northwestward and generally transect foliation of the gabbroic rocks (MacKevett, Jr. et.al., 1974).

There are three known pits with Nordic Abrasion test values equal to or lower than 10 along this stretch of the highway. Potential Hard Aggregate Source Reports were prepared for these sources and are included in this report. It may also be possible to find other sources between 5.5 Mile and the Chilkat River Bridge. Two sites near Haines appear to be mining talus slopes and alpines fans composed of material fallen from the Takshanuk Mountains that is likely composed of metabasalt and diorite rocks. This material is a fine-grained igneous rock that typically can give low Nordic Abrasion values. However, the Nordic Abrasion values are not as low overall as one might expect for the rock types mapped, which may be due to local weakening of the rock during cataclastic processes that created the foliation throughout the region. Statements made by MacKevett, Jr. (1974) indicate that foliation may increase upriver and thus Nordic Abrasion values may increase as you go up river toward Klukwan. The area around Milepost 25 is in the floodplain of the Klehini River where a Nordic Abrasion value of 10 was achieved. This relatively low value in the Klehini floodplain may be due to hornfels eroded from Takhin Ridge into the abandoned Tsirku River floodplain between the two rivers, and thus into the Klehini River (see Figure 6-3). Other locations in the Tsirku and Takhin River floodplains to the south may have gravels with Nordic Abrasion values of less than 10. Portions of the Chilkat River floodplain may also be a potential source of hard aggregate.

**FIGURE 6 - 3**
**TAKHIN RIDGE HORNFELS – KLEHINI RIVER MILE 25 PIT**
(Modified from Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Takhin Ridge. Cross hatch patterns are interpreted hornfels zones. These hornfels zones are subject to differing interpretations by different authors.

Most of the land adjacent to the Haines Highway along the Chilkat River is in Unit 7A of the Haines State Forest therefore land use issues may arise if mining is attempted on State lands. However, there are numerous private parcels along the highway.

Bedrock between Milepost 24 and the Canadian Border is highly foliated and thus would likely be too weak to be used in hard aggregate production (MacKevett, Jr. et al., 1974) and (R&M Consultants, Inc., 1992).

### 6.4 Juneau and Admiralty Island Area

The Juneau-Admiralty Island area stretches from Admiralty Island to Skagway along Stephens Passage and Lynn Canal and includes Douglas Island. The rocks along part of the coast consist of sedimentary, volcanic and igneous rocks of the Gravina Belt along Stephens Passage, against the metamorphosed and highly deformed Taku Terrane and the Coast Mountain Batholith to the east. The area around Juneau to Berners Bay is primarily mapped as mélange. Steep mountain slopes exist along the east side of Lynn Canal underlain by igneous rocks. Migmatites are found northeast of Haines. Potential hard aggregate sites were not identified within this area.

Most of Admiralty Island lies in the Admiralty Island National Monument and was thus excluded from this study.

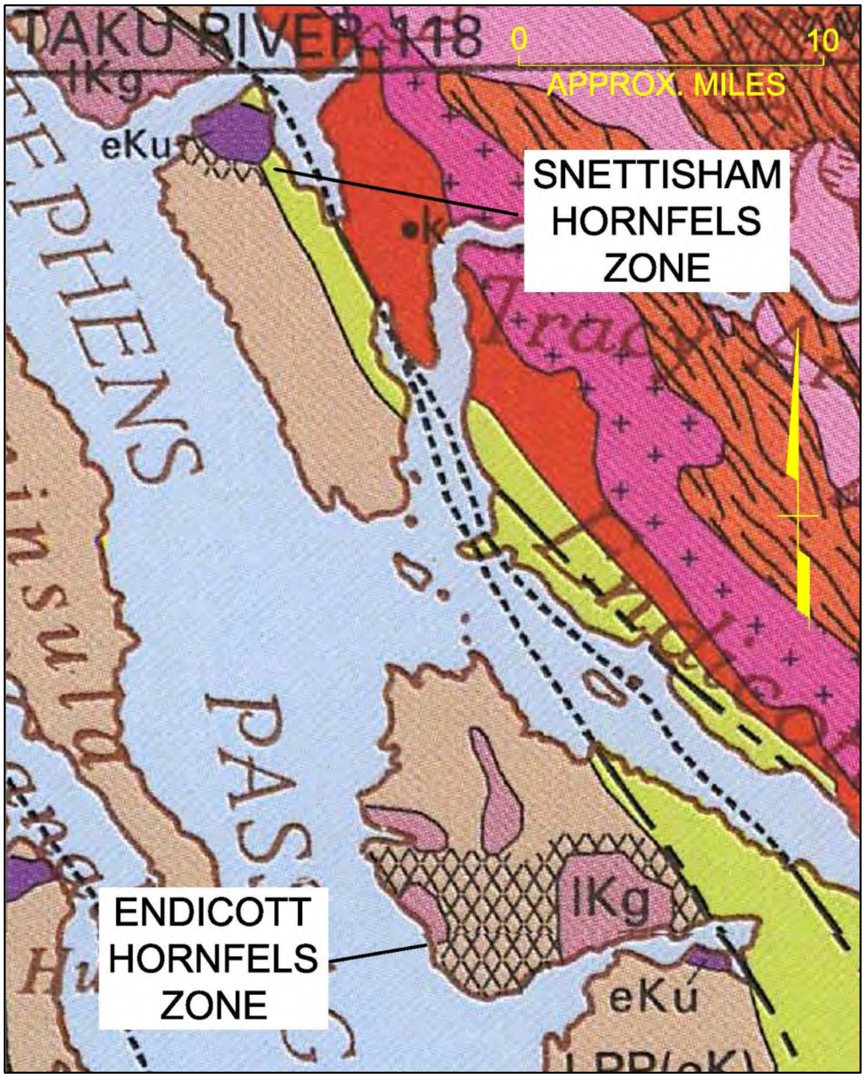
### 6.5 Snettisham and Endicott Peninsula Area

A hornfels contact metamorphic aureole one kilometer wide or more has been mapped adjacent to an ultramafic pluton on Snettisham Peninsula (Dusel-Bacon et al., 1996) as shown in Figure 6-4. Contact metamorphism was caused by the intrusion of a magnetically high ultramafic pluton (Brew et al., 1984) coming into contact with volcanic rocks and possibly sedimentary rocks (Gehrels et al. 1992). These thermally metamorphosed (or hornfelsed) rocks may have low Nordic Abrasion values. The area where the hornfels are mapped is steep and there are apparently no roads. The area is generally accessible only with great difficulty and thus has low potential for hard aggregate production.

An assemblage of low-grade metamorphic rocks on the Endicott Peninsula between Sumdum and Windham Bay have been mapped as having being hornfelsed to a width of approximately one kilometer or more by a series of intrusive plutons (Dusel-Bacon et al., 1996) as shown in Figure 6-4. These contact metamorphosed rocks as well as fine-grained volcanic and intrusive rocks appear to have the potential to produce low Nordic Abrasion values. The challenge will be to find rocks where recrystallization from thermal overprinting has removed foliation produced by regional metamorphism. These rock exposures of interest occur on the peninsula west of the Chuck River Wilderness.

The Endicott Peninsula is part of the western metamorphic complex in Southeast Alaska. Rocks consist of low-grade metamorphosed detrital and volcanic rocks of probable Paleozoic or early Mesozoic age cut by complicated granite, diorite, and hornblendite intrusions with locally “extensive contact-metamorphic effects” (Brew and Grybeck, 1984). There are no existing roads on this part of the peninsula as the terrain dips steeply onto the coast. Investigation of new sources and access to such sources may be difficult.

**FIGURE 6 - 4**
**SNETTISHAM-ENDICOTT PENINSULA METAMORPHIC FACIES MAP**
(Modified from Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Snettisham and Endicott Peninsulas. The pink/purple units are igneous intrusives, the green/yellow/orange/gray units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatch among the intrusives are interpreted hornfels zones. These hornfels zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

### 6.6 Chichagof, Baranof and Kruzof Islands Area

Stratified bedrock on Chichagof, Baranof and Kruzof Islands consists of a wide range of sedimentary and volcanic rocks and metamorphic rocks ranging from Silurian to Cretaceous in age. Some fine-grained volcanic rocks are found on Kruzof Island but they appear to be too weathered to produce hard aggregate. Three belts of northwest trending granitic intrusives occur on the islands, some of which have hornfels aureoles (Looney et al., 1975).

On the west side of Chichagof, Baranof and Kruzof Islands hornfels aureoles were mapped or noted in three major locations. In the south, on the north side of Crawfish Inlet pluton, a hornfels is mapped on the north side of Redoubt Lake along on a steep mountain side. Early maps (Looney et al., 1975) show extensive hornfels throughout south Baranof Island. However, later maps (Dusel-Bacon et al., 1996) show much less. Most of the mapped hornfels lies within the South Baranof Wilderness.

Hornfels are mapped surrounding Tertiary gabbro and diorite plutons in the Yokobi Island area, but they lie within the West Chichagof Yokobi Wilderness (Dusel-Bacon et al., 1996). Some hornfels are also mapped north of Mount Edgecumbe on Kruzof Island that may be accessible using Forest Service roads. A Potential Hard Aggregate Source Report was prepared for this area and is included in this report.

### 6.7 Mitkof, Kupreanof and Kuiu Island Area

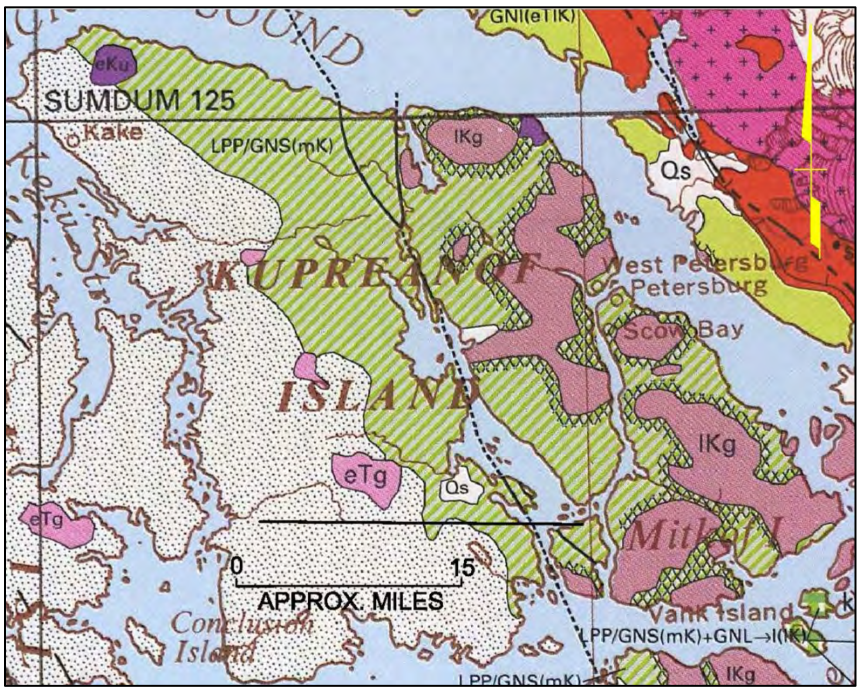
Bedrock mapping on Mitkof Island and eastern Kupreanof Island (east of the Duncan Canal Fault Zone) generally shows Cretaceous phyllite derived from fine-grained sedimentary rocks and schist intruded by igneous Cretaceous diorite and tonalite plutons (Brew et.al., 1984). Some strongly hornfelsed rocks close to plutons were noted by Brew, although the locations were not indicated on the maps. Dusel-Bacon et al. mapped the presence of hornfels surrounding all the intrusives (see Figure 6-5). Much of the area on Mitkof Island is accessible by logging roads. The central portion of the eastern part of Kupreanof Island is designated as Petersburg Creek Duncan Salt Chuck Wilderness, but the remainder of the area appears to be accessible by logging roads.

Mapping on western Kupreanof Island generally shows Devonian to Cretaceous phyllites and schists derived from fine-grained volcanic and sedimentary rocks on the north end of the island and Tertiary to Quaternary volcanics on the southern portion of the island (Brew et al., 1984). With the exception of the Quaternary basalts on the south part of the island, most of these rocks do not appear to have the potential for producing hard aggregate. The Quaternary basalts as mapped by Brew et al. (1984) and Brew (1997) are generally dense to very dense and aphanitic. A Potential Hard Aggregate Source Report was prepared for these sources and is included in this report.

Bedrock mapping on Kuiu Island generally show Silurian sedimentary rocks and Quaternary volcanics with Cretaceous and Tertiary intrusives (Brew et al., 1984). Reconnaissance maps prepared by Muffler (1967) and Brew et al. (1984) show that two small plutons have intruded the sandstones between Rowan Bay and Security Bay on the northwest corner of Kuiu Island. Hornfels were mapped between the intrusives. A Potential Hard Aggregate Source Report was prepared for this source and is included in this report. Brew also mapped small granitic intrusives on the southern portion of the island but does not map hornfels surrounding them. There were no other obvious potential sources of hard aggregate found on Kuiu Island during our research.

Figure 6-5 shows interpreted hornfels zones on Kupreanof and Mitkof Islands. The purple units are igneous intrusives, the green units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatch areas along the intrusives are interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

**FIGURE 6 - 5**
**KUPREANOF-MITKOF ISLANDS METAMORPHIC FACIES MAP**
(Modified from Dusel-Bacon et al., 1996)




## 6.8 Wrangell, Zarembo and Etolin Islands Area

Mapping on Wrangell Island generally shows Cretaceous phyllite derived from fine-grained sedimentary rocks and schist intruded by igneous tonalite plutons (Brew et al., 1984). Some strongly hornfelsed rocks were noted as being close to plutons in the northern part of the island (Dusel-Bacon et al., 1996). If these hornfels can be located, they may be possible sources of rock for the production of hard aggregates. Two Nordic Abrasion test values (7 and 17) were found for the Wrangell Airport quarry. A Potential Hard Aggregate Source Report was prepared for this source and is included in this report. Much of Wrangell Island is accessible by existing roads. Hornfels are indicated for the northern portion of the island and on the southern portion on some maps, but not on others.

Zarembo Island is located to the west of Wrangell Island and south of Kupreanof Island. Bedrock on Zarembo Island can be separated into two parts; a northern portion generally composed of Cretaceous granodiorite to diorite intrusives surrounded by semischist and phyllite and a southern portion generally composed of Tertiary to Quaternary volcanic and igneous rocks. The two parts are separated by a wide valley that cuts across the island from northwest to southeast. Hornfels zones are mapped along the edges of the intrusives in the northern part of the island (Dusel-Bacon et al., 1996). A Potential Hard Aggregate Source Report was prepared for this source and is appended to this report. Mapping also shows some hornfels on the south shore of the island.

Etolin Island is located to the southwest of Wrangell Island and southeast of Zarembo Island. The island is generally composed of Cretaceous and Tertiary granitic rocks of the Kuiu-Etolin Volcanic Plutonic Belt, surrounded by semischist and phyllite of the Seymour Canal Formation. Hornfels are inferred along the edges of the intrusives (Dusel-Bacon et al., 1996). A Potential Hard Aggregate Source Report was prepared for this source and is appended to this report.

Parts or all of Wrangell, Zarembo and Etolin Islands are within the Tongass National Forest and appear to be managed by the U.S. Forest Service. There are numerous existing quarries shown on the U.S.G.S. topographic maps. The U.S. Forest Service may have information available concerning these sites. There appear to be numerous logging roads and several harbors on the islands.

### 6.9 Cleveland Peninsula, Revillagigedo and Annette Islands Area

Mapping indicates that the bedrock geology on the Cleveland Peninsula, Revillagigedo, Gravina and Annette Islands consists of igneous intrusives, metasedimentary and metavolcanic rocks. These intrusives are more variable in composition than the igneous rocks in Wrangell, Kupreanof and surrounding islands, and they appear to be more foliated. Thermal alteration was mapped surrounding only one stock (Dusel-Bacon et al., 1996), a gabbro intrusive near Ketchikan where a spotted hornfels was observed. There were few igneous intrusives noted on Gravina Island and most of those on Annette Island have been metamorphosed with the rock thus apparently weakened. Much of the area east of these islands, including the eastern edge of Revillagigedo Island, was excluded from this study as it lies within the Misty Fiords National Monument.

### 6.10 Prince of Wales Island Area

Bedrock geology on Prince of Wales Island and associated islands (lying south of Sumner Strait and west of Clarence Strait) consists primarily of Devonian to Silurian sedimentary rocks including the Bay of Pillars Formation, the Descon Formation, and the Karheen Formation. There are extensive limestone formations including the Heceta Limestone in addition to volcanic and volcaniclastic deposits. Also, there are smaller igneous intrusive bodies than elsewhere in southeast Alaska, although the extent of thermal alteration appears to be similar or greater than most places. Hornfels has been mapped in the northern part of the island, near Coffman Cove, at a small area near Klawock, and on Sukkwan Island. Potential Hard Aggregate Source Reports were prepared for the first of these hornfels sources and appended to this report. The Sukkwan Island source was excluded as it lies within a roadless area.

### 6.11 Selected References


Barker, Fred, 1957, Geology of the Juneau (B-3) quadrangle, Alaska: U.S. Geological Survey Geologic Quadrangle Map 100, 1 sheet, scale 1:63,360.

Berg, H.C., 1972, Geologic map of Annette Island, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map 684, 8 p., 1 sheet, scale 1:63,360.

Berg, H.C., 1973, Geology of Gravina Island, Alaska: U.S. Geological Survey Bulletin 1373, 41 p., 1 sheet, scale 1:63,360.

Berg, H.C., Elliott, R.L., and Koch, R.D., 1988, Geologic map of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1807, 27 p., 1 sheet, scale 1:250,000.

Brew, D.A. and Grybeck, Donald, 1984, Geology of the Tracy Arm-Fords Terror Wilderness Study Area and vicinity, Alaska, in U.S. Geological Survey, Mineral resources of the Tracy Arm-Fords Terror Wilderness Study Area and vicinity, Alaska: U.S. Geological Survey Bulletin 1525, p. 19-52.

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Brew, D.A. and Ford, A.B., 1985, Preliminary reconnaissance geologic map of the Juneau, Taku River, Atlin, and part of the Skagway 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 85-395, 23 p., 1 sheet, scale 1:2,500,000.

Brew, D.A., 1996, Geologic map of the Craig, Dixon Entrance, and parts of the Ketchikan and Prince Rupert quadrangles, Southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 2319, 53 p., 1 sheet, scale 1:250,000.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-F, 20 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-G, 19 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-J, 21 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-K, 18 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg D-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-M, 22 p., 1 sheet, scale 1:63,360.

Decker, John, 1980, Geologic map of western Chichagof Island, southeastern Alaska: U.S. Geological Survey Open-File Report 80-150, 2 sheets, scale 1:63,360.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E., 1992, Geologic map of the southern Prince of Wales Island, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 2169, 23 p., 1 sheet, scale 1:63,360.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Gehrels, G.E. and Berg, H.C., 1994, Geology of southeastern Alaska: In the Geology of North America Chapter 13, Vol. G-1, The Geology of Alaska, The Geologic Society of America.

Gilbert, W.G., Burns, L.E., Redman, E.C., and Forbes, R.B., 1987, Preliminary bedrock geology and geochemistry of the Skagway B-3 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 87-2, 2 sheets, scale 1:36,200.

Gilbert, W.G., Clough, A.H., Burns, L.E., Kline, J.T., Redman, E.C., and Fogels, E.J., 1990, Reconnaissance geology and geochemistry of the northeast Skagway quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 90-5, 2 sheets, scale 1:125,000.

Herreid, G.H., 1975, Geology of the Craig A-2 quadrangle and vicinity, Prince of Wales Island: Alaska Division of Geological & Geophysical Surveys Alaska Open-File Report 35, 2 p., 1 sheet, scale 1:63,360.

Johnson, B.R. and Karl, S.M., 1985, Geologic map of western Chichagof and Yakobi Islands, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1506, 15 p., 1 sheet, scale 1:125,000.

Johnson, B.R. and Karl, S.M., 1982, Reconnaissance geologic map of the western Chichagof and Yakobi Islands Wilderness Study Area, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1476-A, 1 sheet, scale 1:125,000.

Karl, S.M., 1996, Preliminary geologic map of Northeast Chichagof Island, Alaska: U.S. Geological Survey Open-File Report 96-53, 12 p., 1 sheet, scale 1:63,360.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance Geologic Map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30p., 1 sheet, scale 1:150,000.

Koch, R.D., and Elliott, R.L., 1984, Late Oligocene gabbro near Ketchikan, southeastern Alaska, in Coonrad, W.L., and Elliot, R.L., eds., The U.S. Geological Survey in Alaska: Accomplishments during 1981: U.S. Geological Survey Circular 868, p. 126-128.

Lathram, E.H., Pomeroy, J.S., Berg, H.C., and Loney, R.A., 1965, Reconnaissance geology of Admiralty Island, Alaska: U.S. Geological Survey Bulletin 1181-R, p. R1-R48, 2 sheets, scale 1:250,000.

Loney, R.A., Berg, H.C., Pomeroy, J.S., and Brew, D.A., 1963, Reconnaissance geologic map of Chichagof Island and northwestern Baranof Island, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map 388, 7 p., 1 sheet, scale 1:250,000.

Loney, R.A., Brew, D.A., Muffler, L.J.P., and Pomeroy, J.S., 1975, Reconnaissance geology of Chichagof, Baranof, and Kruzof Islands, southeastern Alaska: U.S. Geological Survey Professional Paper 792, 105 p., 4 sheets, scale 1:250,000.

Loney, R.A., Condon, W.H., and Dutro, J.T., Jr., 1963, Geology of the Freshwater Bay area, Chichagof Island, Alaska: U.S. Geological Survey Bulletin 1108-C, p. C1-C54, 2 sheets, scale 1:63,360.

MacKevett, E.M., Jr., Robertson, E.C., and Winkler, G.R., 1974, Geology of the Skagway B-3 and B-4 quadrangles, southeastern Alaska: U.S. Geological Survey Professional Paper 832, 33 p., 1 sheet, scale 1:63,360.

Muffler, L.J. Patrick., 1967, Stratigraphy of the Keku Islets and neighboring parts of Kuiu and Kupreanof Islands, southeastern Alaska: U.S. Geological Survey Bulletin 1241-C, p. C1-C52, 1 sheet, scale 1:63,360.

Redman, E.C., Retherford, R.M., and Hickok, B.D., 1984, Geology and geochemistry of the Skagway B-2 quadrangle, southeastern Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 84-31, 34 p., 4 sheets, scale 1:40,000.

Redman, E.C., Gilbert, W.G., Jones, B.K., Rosenkrans, D.S., and Hickok, B.D., 1985, Preliminary bedrock-geologic map of the Skagway B-4 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 85-6, 1 sheet, scale 1:40,000.

R&M Consultants, Inc., 1992, Haines Highway rock slope evaluation Milepost 24 to Border Haines Highway, Alaska, Prepared for Alaska Department of Transportation and Public Facilities, 2 volumes.

Smith, J.G., 1977, Geology of the Ketchikan D-1 and Bradfield Canal A-1 quadrangles, southeastern Alaska: U.S. Geological Survey Bulletin 1425, 49 p., 1 sheet, scale 1:63,360.

Stowell, H.H., 2006, Geology of Southeast Alaska, Rock and Ice in Motion, University of Alaska Press, 140p.

# 7.0 CONCLUSIONS

## 7.1 General Overview

A detailed review of the geology of three areas in southern Alaska, including Southeast Alaska, the Alaska Peninsula (including Kodiak Island and Unalaska) and southcentral Alaska (including Prince William Sound) has revealed a significant number of sites with the potential for hard aggregate production that meet the criteria laid out in the scope-of-work. A potential hard aggregate report was prepared for each of these sites (Appendix A thru N). Many of the sites listed in Table 1-2 were discussed in context with other sites or sites covering much larger areas. Other sites that did not meet all of the criteria but might interest someone in the future were discussed in the text. Sites that were in areas that appeared to be unavailable for mining such as national parks and wilderness areas were mentioned where they were encountered, but no special effort was made to identify specific locations. There were approximately two to three potential hard aggregate sites found that did not meet the criteria in the scope-of-services for each one that did.

The majority of the potential hard aggregate source locations consisted of hornfels. Several locations were basalts or fine-grained igneous rocks. Fourteen (14) locations were identified and Potential Hard Aggregate Source reports were prepared for individual sites or groups of potential sites within these 14 areas. A total of 27 individual sources were identified within the 14 locations. Thirteen new Nordic Abrasion values (not part of Table 1-2) were available for these sites, most having been supplied by Mr. Mitch McDonald of DOT&PF Southeast Region.

Three sites were found in Southcentral Alaska that meet the criteria for hard rock potential and access. Much of the rock in Southcentral consists of the Valdez and Orca Groups which is generally highly foliated and not suitable. Much of the rock that appears to have potential is in locations that are difficult to access such as Prince William Sound and the Talkeetna Mountains. Land development surprisingly has not had a great impact on areas with hard aggregate potential. However, land withdrawals, particularly in Prince William Sound, have had an impact. There are many gravel sources with Nordic Abrasion test results less than 10 in Southcentral Alaska, although the test results are generally not consistent. Only the three potential sites were identified; 2 igneous, 1 hornfels.

With the exception of Unalaska, there do not appear be any potential sites for hard aggregate production along the Alaska Peninsula or Kodiak Island. While there does appear to be material suitable for making the hard aggregate, much of it is located within wildlife refuges, monuments or preserves and was therefore excluded from this study. What remained outside the refuges, etc. was in areas with limited local infrastructure, and with the exception of Kodiak Island and Unalaska has little to no local demand. The quarries in Unalaska that have rock with low Nordic Abrasion test values are a great distance from areas requiring hard aggregate.

A significant number of sites with the potential to produce hard aggregate were found in Southeast Alaska, with many of them having road access and relatively sheltered harbors. Many of the sources in Southeast Alaska were within the Tongass National Forest and would require permission from the U.S. Forest Service for their use. About one-half of the sources in Southeast Alaska are located within parks, monuments, wilderness areas, roadless areas or dedicated recreational areas and likely would not be attainable for use. Wherever they could be identified, these areas were removed from the current study. Even with these limitations, we identified eleven groups of sites with 27 individual sites that included 12 hornfels quarries, 11 basalt quarries, 1 gabbro quarry, 1 possible syenite quarry, and 1 gravel pit with several areas overlapping.

## 7.2 Summary of Potential Hard Aggregate Sources

The following potential hard aggregate sources (Table 7-1) were identified in this study as meeting the criteria as laid out in the scope-of-work (See Section 1). These sources are also depicted on Plate 1 (attached) and described in detail in the appended Potential Hard Aggregate Source reports (Appendices A thru O).

Additionally, a separate feasibility study was performed to evaluate hard aggregate development at a site near Cantwell. That study is presented in a separate project report (Part 2 of this document).

## TABLE 7 - 1
## SUMMARY OF POTENTIAL HARD AGGREGATE SOURCES

| | MS NUMBER | COMMON NAME | MILEPOST | PERMIT NO. (1) | SITE STATUS / EXPIRATION DATE (1) | OWNER (1) | GEOGRAPHIC COORDINATES WGS84 (2) | | UTM COORDINATES WGS84-METERS (2) | | | STATE PLANE COORDINATES NAD83-US SURVEY FEET (2) | | | NORDIC VALUES(3) | CATEGORIZATION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LAT. | LONG. | ZONE | NORTH | EAST | ZONE | NORTH | EAST | | CLASSIFICATION | STATUS | |
| | **SOUTH CENTRAL ALASKA** | | | | | | | | | | | | | | | | | |
| 1 | HA-A1 | Chugach Mountains / Burnt Butte | --- | --- | --- | CIRI | 61.561286 | -148.968555 | 6 | 6,826,888 | 395,424 | 4 | 2,764,014 | 1,820,253 | --- | UNKNOWN | POTENTIAL | 1 |
| 2 | HA-B1 | Nanwalek / Point Bede | --- | --- | --- | CHUGACH ALASKA | 59.311215 | -151.986317 | 6 | 6,575,146 | 557,711 | 4 | 1,945,695 | 1,269,321 | --- | UNKNOWN | POTENTIAL | 2 |
| 3 | HA-C1 | Copper River Highway / Sheridan Glacier | 19 | --- | --- | USFS | 60.473414 | -145.262355 | 6 | 6,705,397 | 595,526 | 3 | 2,395,685 | 2,494,731 | --- | UNKNOWN | POTENTIAL | 3 |
| | **SOUTHEAST ALASKA** | | | | | | | | | | | | | | | | | |
| 4 | HA-D1 | Haines Highway / Mile 4.5 Site | 4.5 | --- | --- | Private | 59.253884 | -135.538934 | 8 | 6,568,447 | 469,265 | 1 | 2,715,162 | 2,335,421 | **6.6, 8, 9.3**, 11.4, 17.5 | ACTIVE | POTENTIAL | 4 |
| 5 | HA-D2 | Haines Highway / Mile 5.5 Site | 5.5 | --- | --- | Private | 59.260689 | -135.558706 | 8 | 6,569,214 | 468,144 | 1 | 2,717,750 | 2,331,791 | **6.8** | ACTIVE | POTENTIAL | 5 |
| 6 | HA-D3 | Haines Highway / Mile 25 Klehini River Site | 25 | --- | --- | SOA | 59.407787 | -135.964659 | 8 | 6,585,858 | 445,236 | 1 | 2,773,823 | 2,257,684 | **10** | UNKNOWN | POTENTIAL | 6 |
| 7 | HA-E1 | Kupreanof Island / Area “A” – Sumner Straits | --- | --- | --- | USFS | 56.445424 | -133.650459 | 8 | 6,256,472 | 583,194 | 1 | 1,684,212 | 2,689,223 | --- | UNKNOWN | POTENTIAL | 7 |
| 8 | HA-E2 | Kupreanof Island / Area “B” – Sumner Straits | --- | --- | --- | USFS | 56.439241 | -133.520885 | 8 | 6,255,949 | 591,196 | 1 | 1,681,985 | 2,715,443 | --- | UNKNOWN | POTENTIAL | 8 |
| 9 | HA-E3 | Kupreanof Island / Area “C” – Totem Bay | --- | --- | --- | USFS | 56.455001 | -133.460536 | 8 | 6,257,784 | 594,877 | 1 | 1,687,774 | 2,727,638 | --- | UNKNOWN | POTENTIAL | 9 |
| 10 | HA-E4 | Kupreanof Island / Area “D” – Totem Bay | --- | --- | --- | USFS | 56.505468 | -133.437401 | 8 | 6,263,433 | 596,175 | 1 | 1,706,224 | 2,732,255 | --- | UNKNOWN | POTENTIAL | 10 |
| 11 | HA-E5 | Kupreanof Island / Area “E” SE Kupreanof Island | --- | --- | --- | USFS | 56.457785 | -133.196343 | 8 | 6,258,490 | 611,150 | 1 | 1,689,055 | 2,781,068 | --- | UNKNOWN | POTENTIAL | 11 |
| 12 | HA-E6 | Kupreanof Island / Area “F” – Kah Sheets Bay | --- | --- | --- | USFS | 56.515122 | -133.129981 | 8 | 6,264,980 | 615,065 | 1 | 1,710,098 | 2,794,326 | --- | ACTIVE | POTENTIAL | 12 |
| 13 | HA-E7 | Kupreanof Island / Area “G” – Duncan Canal | --- | --- | --- | USFS | 56.672651 | -133.170506 | 8 | 6,282,444 | 612,104 | 1 | 1,767,579 | 2,785,725 | --- | UNKNOWN | POTENTIAL | 13 |
| 14 | HA-E8 | Kupreanof Island / Area “H” – Duncan Canal | --- | --- | --- | USFS | 56.708212 | -133.253637 | 8 | 6,286,268 | 606,910 | 1 | 1,780,458 | 2,768,928 | --- | UNKNOWN | POTENTIAL | 14 |
| 15 | HA-E9 | Kupreanof Island / Area “I” – Forest Service Quarry | --- | --- | --- | USFS | 56.763233 | -133.523917 | 8 | 6,292,003 | 590,234 | 1 | 1,800,336 | 2,714,582 | **7** | ACTIVE | POTENTIAL | 15 |
| 16 | HA-F1 | Kuiu Island / Security Bay | --- | --- | --- | USFS | 56.808520 | -134.360498 | 8 | 6,296,254 | 539,047 | 1 | 1,817,555 | 2,546,908 | --- | UNKNOWN | POTENTIAL | 16 |
| 17 | HA-F2 | Kuiu Island / Rowan Bay | --- | --- | --- | USFS | 56.695866 | -134.296529 | 8 | 6,283,753 | 543,082 | 1 | 1,776,279 | 2,559,348 | --- | UNKNOWN | POTENTIAL | 17 |
| 18 | HA-G1 | Wrangell Island / Wrangell Airport Quarry | --- | --- | --- | DOTPF | 56.487009 | -132.386582 | 8 | 6,263,345 | 660,916 | 1 | 1,701,819 | 2,944,632 | **7**, 17.1 | ACTIVE | UNKNOWN | 18 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **SOUTHEAST ALASKA (CONTINUED)** | | | | | | | | | | | | | | | | | |
| 19 | HA-H1 | Zarembo Island / Northern Zarembo Island | --- | --- | --- | USFS | 56.401017 | -132.785403 | 8 | 6,252,914 | 636,673 | 1 | 1,669,140 | 2,864,445 | --- | UNKNOWN | POTENTIAL | 19 |
| 20 | HA-I1 | Etolin Island / Northern Etolin Island | --- | --- | --- | USFS | 56.246532 | -132.470702 | 8 | 6,236,395 | 656,722 | 1 | 1,613,684 | 2,929,165 | --- | UNKNOWN | POTENTIAL | 20 |
| 21 | HA-I2 | Etolin Island / Central Etolin Island | --- | --- | --- | USFS | 56.144496 | -132.464071 | 8 | 6,225,058 | 657,550 | 1 | 1,576,442 | 2,931,166 | --- | UNKNOWN | POTENTIAL | 21 |
| 22 | HA-J1 | Kruzof Island / Kruzof Island | --- | --- | --- | USFS | 57.200676 | -135.713812 | 8 | 6,339,950 | 456,872 | 1 | 1,966,213 | 2,280,066 | --- | UNKNOWN | POTENTIAL | 22 |
| 23 | HA-K1 | Revillagigedo Island / Ketchikan | --- | --- | --- | SOA | 55.333238 | -131.507959 | 9 | 6,134,739 | 340,919 | 1 | 1,285,043 | 3,135,353 | --- | UNKNOWN | POTENTIAL | 23 |
| 24 | HA-L1 | Prince of Wales Island / Coffman Cove | --- | --- | --- | SOA/Private | 56.010422 | -132.818347 | 8 | 6,209,387 | 636,016 | 1 | 1,526,394 | 2,859,538 | **5.6**, 13.7 | UNKNOWN | POTENTIAL | 24 |
| 25 | HA-M1 | Prince of Wales Island / Red Bay Mountain | --- | --- | --- | USFS | 56.217549 | -133.382180 | 8 | 6,231,470 | 600,327 | 1 | 1,601,095 | 2,743,849 | --- | UNKNOWN | POTENTIAL | 25 |
| 26 | HA-M2 | Prince of Wales Island / Tokeen Peak | --- | --- | --- | USFS | 56.117709 | -133.406904 | 8 | 6,220,324 | 599,051 | 1 | 1,564,606 | 2,738,956 | --- | UNKNOWN | POTENTIAL | 26 |
| 27 | HA-N1 | Prince of Wales Island / Klawock River Quarry | --- | --- | --- | KLAWOCK HEENYA | 55.545702 | -133.096303 | 8 | 6,157,165 | 620,110 | 1 | 1,356,068 | 2,804,085 | **8.4** | ACTIVE | POTENTIAL | 27 |
| | **ALASKA RANGE (CANTWELL AREA) (4)** | | | | | | | | | | | | | | | | | |
| 28 | --- | Athna Pit | 216 | --- | --- | AHTNA | 63.464594 | -148.792723 | 6 | 7,038,605 | 410,649 | 4 | 3,460,349 | 1,837,900 | **9.1, 7.3** | INACTIVE | POTENTIAL | 28 |
| 29 | --- | Cantwell Hard Aggregate Site (Caswell Pit) | 216 | --- | --- | SOA | 63.464919 | -148.788904 | 6 | 7,038,636 | 410,840 | 4 | 3,460,480 | 1,838,523 | **6.2, 8.0, 7.0, 5.6, 9.1, 7.6, 6.2, 6.9, 8.6, 8.1, 7.3, 8.2,** 13.7, **6.2** | ACTIVE | POTENTIAL | 29 |
| 30 | 52-2-046-2 | Panorama Mtn. #1 | 217 | F-29729 | Indef. | AHTNA | 63.467089 | -148.807934 | 6 | 7,038,905 | 409,899 | 4 | 3,461,215 | 1,835,396 | --- | ACTIVE | OPEN | 30 |
| 31 | 52-2-068-2 | Panorama Mtn. #2 | 217 | F-33438 | Indef. | AHTNA | 63.470705 | -148.813608 | 6 | 7,039,315 | 409,627 | 4 | 3,462,520 | 1,834,443 | --- | ACTIVE | UNKNOWN | 31 |
| 32 | --- | Site uphill of MS 52-2-068-2 | 217 | --- | --- | AHTNA | 63.471288 | -148.811878 | 6 | 7,039,378 | 409,715 | 4 | 3,462,738 | 1,834,722 | **7.0, 8.1, 7.9** | ACTIVE | POTENTIAL | 32 |
| | **OUTSIDE ALASKA (4)** | | | | | | | | | | | | | | | | | |
| 33 | --- | DuPont, Washington | --- | | | Commercial | 47.122228 | -122.642356 | 10 | 5,218,809 | 527,129 | | | | **6.1, 19** | ACTIVE | OPEN | 33 |
| 34 | --- | Jervis Inlet, B.C., Canada | --- | | | Commericial | 49.840299 | -123.87524 | 10 | 5,521,242 | 437,068 | | | | **6.9, 9.9** | ACTIVE | OPEN | 34 |

Notes:

1. Permit status and land ownership were taken from Central Region - R.O.W. spreadsheet Central Region MatSite Inventory 6-18-08.xls, BLM and DNR plats and case file abstracts.
2. Coordinates listed are taken from Google Earth Pro and are approximate. Minus numbers designate west longitude.
3. Test Results in bold are 10 or less.
4. Data for sites on lines 28, 29, 32, 33 & 34 are discussed in more detail in Part 2 of this report. Data for sites 30 and 31 were obtained from the Statewide Material Site Inventory.

STATEWIDE MATERIAL SITE INVENTORY

# POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# CHUGACH MOUNTAINS BURNT BUTTE

March 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: Bedrock that is resistant to erosion, including those located on Bodenburg and Burnt buttes and Matanuska Peak, align themselves in a northeastern trend. The buttes resisted glacial scouring during the Pleistocene in an area where the Matanuska and Knik glaciers merged. Rocks on Bodenburg Butte are unweathered, hard, and show only limited fracturing and jointing. Bedrock on Burnt Butte has the potential to be similar. These rocks and similar rocks projecting to the northeast into the Chugach Mountains may be a promising source of hard aggregate. Two miles south of the Buttes, near MP 10.4 of the Old Glenn Highway, the Premier Pit has yielded a Nordic abrasion value of 9.3 in glacial outwash gravels. Other gravels in the area may also have low Nordic Abrasion values.

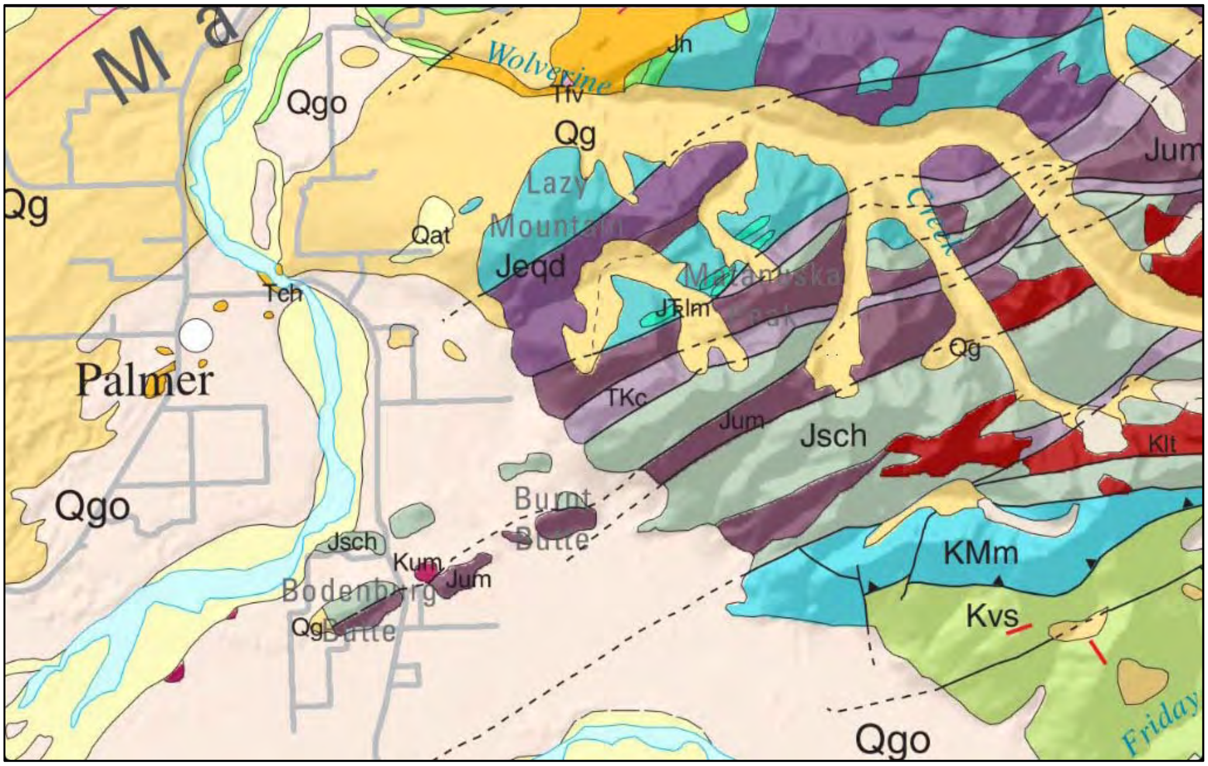
Burnt Butte lies on lands owned by Eklutna, Inc. (surface PA 50-88-0395) and Cook Inlet Region, Inc. (CIRI) (subsurface 50-88-0396).

LOCATION OF BURNT BUTTE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-A1 | Burnt Butte | 61.561286 | -148.968555 |

Access: A series of roads near the community of Butte provide access to within a mile of all of the butte areas as well as the southeastern side of Matanuska Peak. Additional access to similar rock types may be possible by constructing a road up along Wolverine Creek to the northeastern side of Matanuska Peak. Similar rock types continue to project to the northeast. The construction of other roads parallel to Wolverine Creek may lead to viable deposits.

**GEOLOGIC MAP MATANUSKA PEAK AREA**
(From Wilson, et al., 2009)




<u>Geology:</u> The following rock types are mapped near Matanuska Peak (Winkler, 1992 and Wilson et al., 2009).

> <u>Jmip/Jum</u>: Mafic and intermediate plutonic rocks. (Middle and Early Jurassic) – These are mapped as a complexly intermixed series of mafic and intermediate plutonic rocks. Plutons consist of gabbronorite, hornblende gabbro, diorite, quartz diorite, and tonalite. Diorite is the predominate lithology in the Wolverine Creek area. These rocks form the southern half of Bodenburg and Burnt buttes, projecting northeast into Matanuska Peak. Xenoliths of gabbro show ductile deformation. Migmatitic textures are common at contacts between lithologies. Hence, much of the mixing may have been caused by multiple intrusions, and entire series of plutonic rocks may have been mostly coeval (Burns, 1985). The rocks on Bodenburg Butte's south side have also been hydrothermally altered, turning the mafic minerals a lighter green with diffuse grain boundaries. This alteration may contribute to the rock reportedly being extremely strong and almost impossible to break with a rock hammer.

Jqt/Jeqd: Quartz diorite and tonalite (Middle Jurassic) – Series of discordant intermediate plutons. Plutons are relatively homogeneous, fine to medium-grained quartz diorite and tonalite. Large areas are sheared and altered.

Kt/Kit: Leucotonalite and trondhjemite (Early Cretaceous) – Medium-grained plugs and elongate, irregular-shaped, sill-like bodies of leucocratic plutonic rocks in a zone about 5 km wide near Border Ranges fault. Rocks generally are foliated and contain less than 10 percent mafic minerals including muscovite, biotite, or hornblende. Due to the foliation these rocks typically would make poor hard aggregate sources.

Jg: Gabbronorite (Middle and Early Jurassic) Fine to coarse-grained gabbroic rocks, exposed as fault-bound slices, or layers and dikes in the Wolverine ultramafic complex. Primarily consist of gabbronorite, leucogabbronorite, and pyroxene-hornblende gabbro.

Jum: Ultramafic and mafic rocks (Middle and Early Jurassic) - A small exposure of Late Cretaceous ultramafics rocks is exposed just east of Bodenburg Butte.

TKc: Cataclasite (Eocene and Early Cretaceous) – Chlorite-rich fine-grained granular rocks formed by cataclasis alteration of mafic and ultramafic plutonic rocks and mafic volcanic rocks. May represent central zones or major strands of Border Ranges fault system where rocks from both upper and lower plates were cataclastically deformed, mixed, and metamorphosed.

JTRk: Talkeetna Formation (Early Jurassic and Late Triassic) – Andesitic, dacitic, and basaltic flows, flow breccia, tuff, shallow sills, and agglomerate. Contains subordinate interbedded volcaniclastic sandstone, conglomerate, and fossiliferous marine siltstone and shale. The Talkeetna Formation is altered in many places. An isolated exposure (Sec. 17 and 18, T18N, R4E, SM) in Lower Wolverine Creek, contains fine-grained, highly altered, massive greenstones that presumably are a mafic part of the Talkeetna Formation (Pavlis, 1986).

JPzm/Jsch: Metamorphic Rocks (Jurassic to Middle Paleozoic?). Diverse metasedimentary and metavolcanic rocks along northern flank of Chugach Mountains, cropping out near the Jum unit. Rocks are strongly to weakly foliated and variably metamorphosed from middle greenschist to amphibolite facies. Rocks are intruded by mafic and intermediate plutons of units Jmip and Jg. Sedimentary protoliths consist of shale chert, tuffaceous arenite, and limestone, and volcanic protoliths are most probably basalt. Diversity of protoliths may indicate tectonic mixing prior to metamorphism. In most places the fabric is cataclastic or recrystallized.

Tc: Chickaloon Formation (Eocene and Paleocene) Predominately fluvatile and alluvial carbonaceous mudstone, siltstone, conglomeratic sandstone, and polymictic conglomerate; contains beds of bituminous coal.

Conclusions: Rock exposures in the northeastern trending sequence containing Bodenburg Butte and Burnt Butte show promising rock lithologies likely to produce low Nordic abrasion values. The rock exposures are readily accessible by existing roads. Rocks in the Chugach Range to the east may also contain rock units that would produce hard aggregate. Some of the glaciofluvial gravels in the area may also contain hard gravels that can produce low Nordic Abrasion values. Processing of the gravels will likely be required to decrease the value.

References:


Burns, L.E., Pessel, G.H., Little, T.A., Palvis, T.L., Newberry, R.L., Winkler, G.R., and Decker, J.E., 1991, Geology of the northern Chugach Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 94, 63 p., 2 sheets, scale 1:63,360.

Burns, L.E., Little, T.A., Newberry, R.J., Decker, J.E., and Pessel, G.H., 1983, Preliminary geologic map of parts of the Anchorage C-2, C-3, D-2, and D-3 quadrangles, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 83-10, 3 sheets, scale 1:25,000.

Clark, S.H.B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 350, 1 sheet, scale 1:250,000.

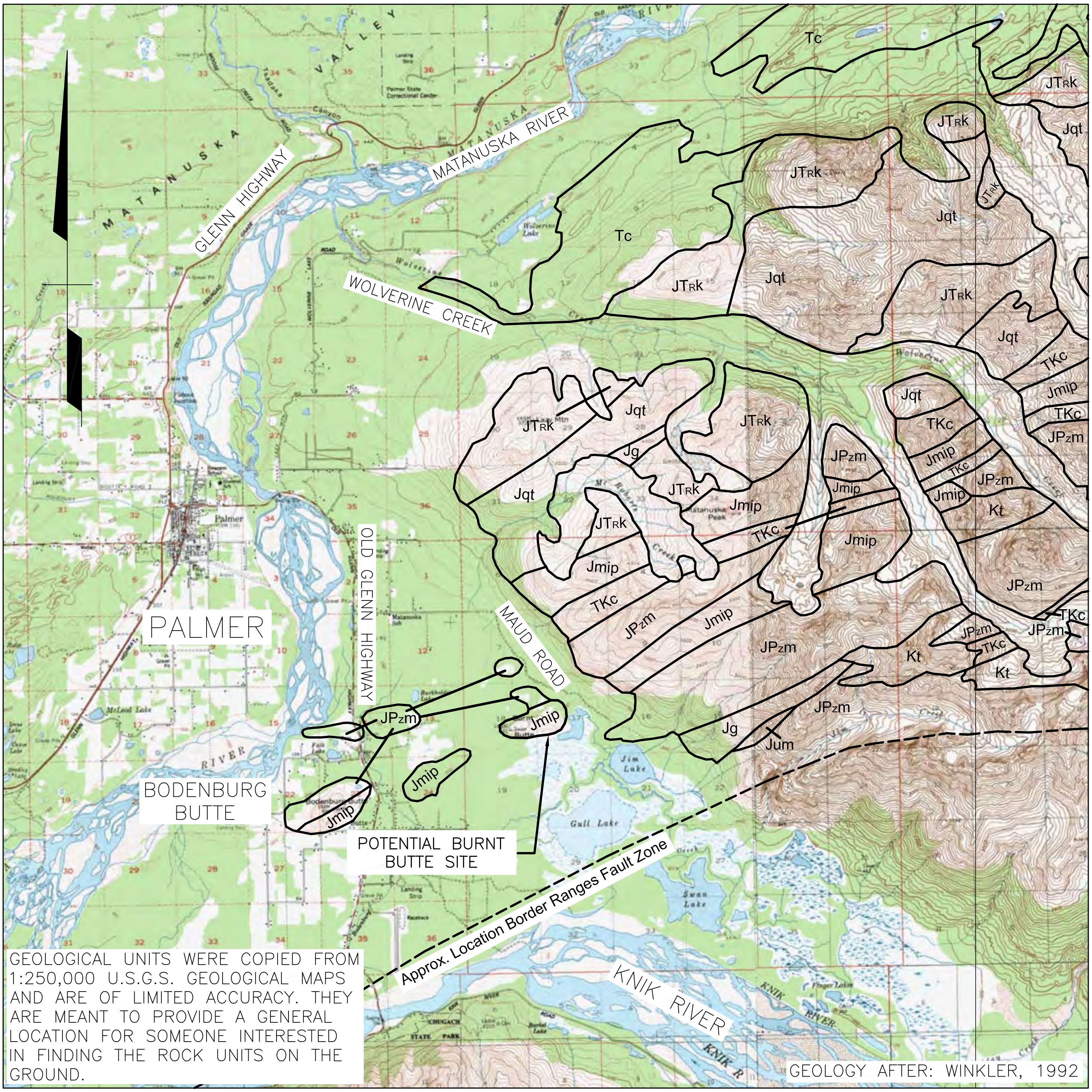
Clark, S.H.B., 1983, Reconnaissance geologic map of the Chugach Mountains in the Anchorage C-5 and C-6 quadrangles, Alaska: U.S. Geological Survey Open-File Report 83-336, 1 sheet, scale 1:63,360.

Pavlis, T.L., 1986, Geologic map of the Anchorage C-5 Quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Public Data File 86-7, 57 p., 3 sheets, scale 1:63,360.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeusler, P.J.., Schmidt, J.M., Yehle, L.A., Labay, K.A. (map compilers) Wilson, F.H., Hults, C.P., Labay, K.A., Shew, N. (Digital Files Preparers), 2009, Preliminary geologic map of the Cook Inlet Region, Alaska-including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale quadrangles, U.S. Geological Survey Open-File Report 2009-1108, Version 1.

Winkler, G.R., (map compiler), 1992, Geologic map and summary geochronology of the Anchorage 1x3° quadrangle, southern Alaska, U. S. Geological Survey Miscellaneous Investigations Series Map I-2283, 1 sheet, scale1:250,000.

# LOCATION MAP (HA-A1)




U.S.G.S. QUADRANGLE: ANCHORAGE (B-5), (B-6), (C-5) & (C-6)

# POTENTIAL HARD AGGREGATE SOURCE CHUGACH MOUNTAINS

0 1 2 4 6

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

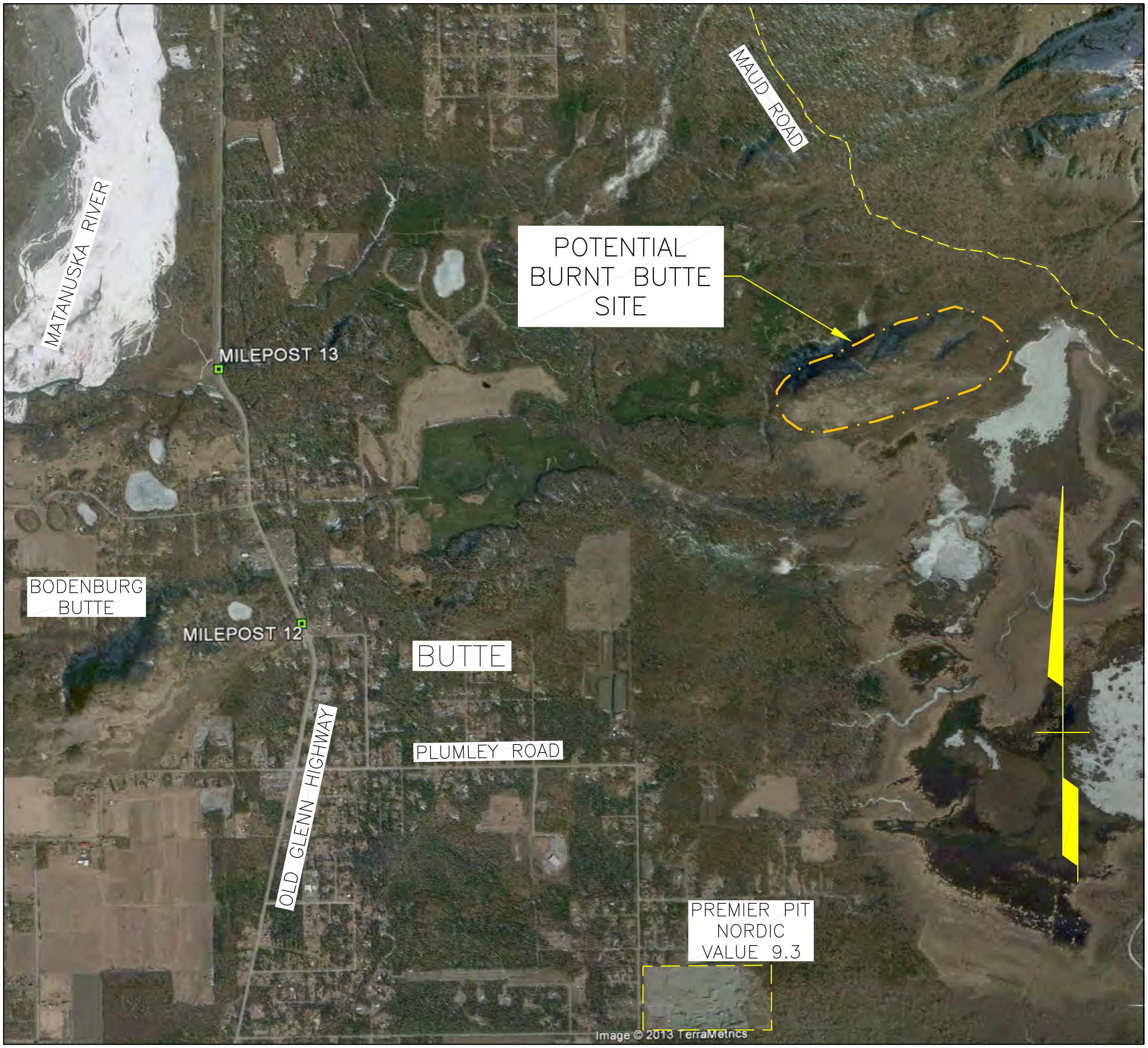
STATEWIDE MATERIAL SITE INVENTORY
BURNT BUTTE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2 |
| | CHECKED C.H.R. | DATE MAR 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Chugach Mountains\Acad\MS_Topo_Map_Chugach_Mtn.dwg

Plotted 3/28/2013 3:52 PM by Pete Hardcastle

# SITE MAP (HA-A1)




BASE MAP IS APRIL 14, 1997 GEOEYE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE CHUGACH MOUNTAINS

0 1500 3000 6000 9000

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/3/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

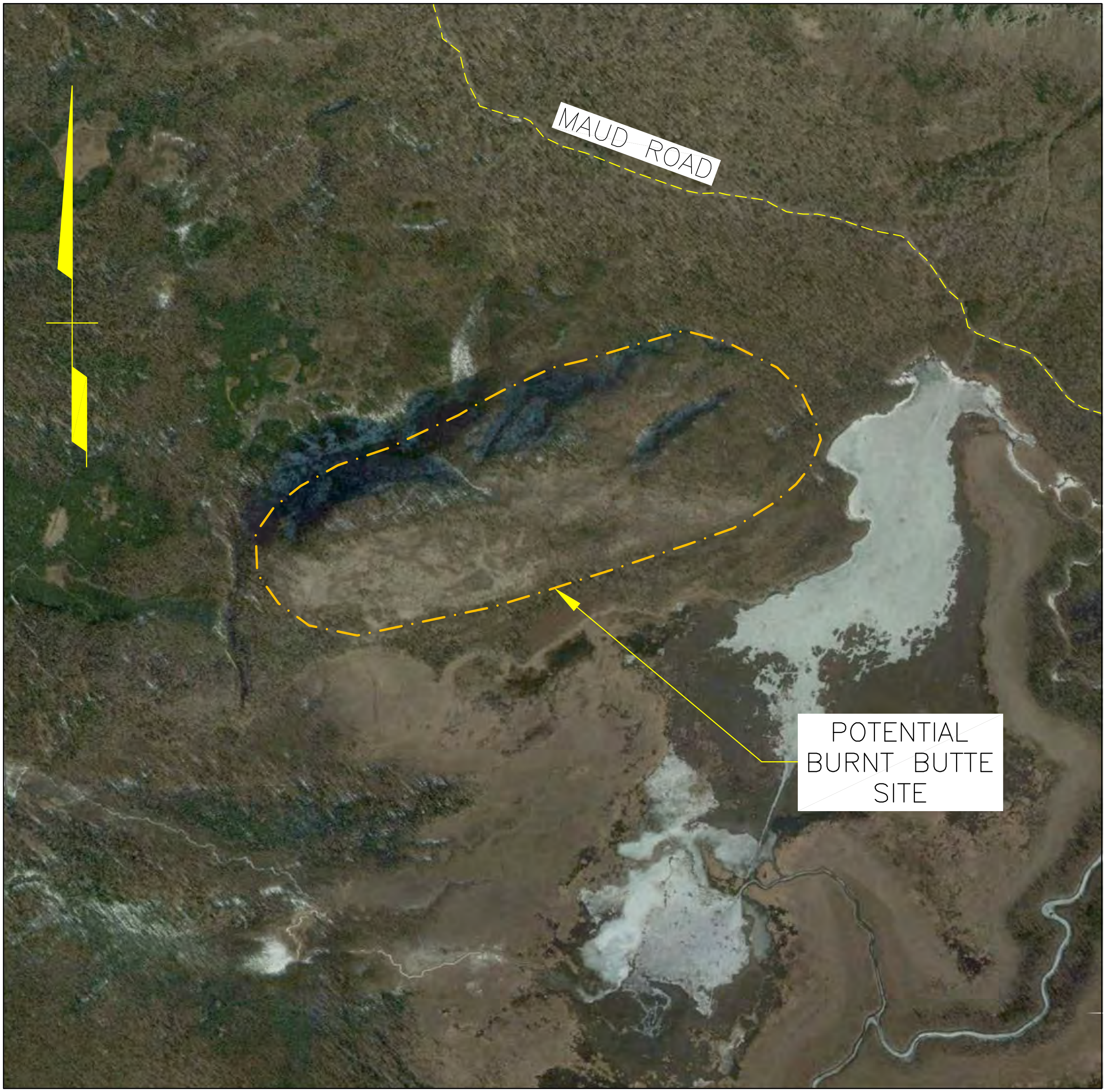
STATEWIDE MATERIAL SITE INVENTORY

BURNT BUTTE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3A |
| | CHECKED C.H.R. | DATE MAR 2013 | |

Plotted 3/28/2013 3:56 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Chugach Mountains\Acad\MS_Site_Map_Chugach.dwg

# SITE MAP (HA-A1)




BASE MAP IS APRIL 14, 1997 GEOEYE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE CHUGACH MOUNTAINS

0 600 1200 2400 3600

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/3/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY

BURNT BUTTE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3B |
| | CHECKED C.H.R. | DATE MAR 2013 | |

# STATEWIDE MATERIAL SITE INVENTORY

# POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# NANWALEK
# POINT BEDE

February 16, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: There are three exposures of potentially usable hard aggregate along the shoreline within the Seldovia Quadrangle. The larger deposit (quartz diorite) is located along the coast around Point Bede, seven miles southwest of the town of Nanwalek. Two smaller exposures of fine-grained felsite are located five miles further south near the tip of a peninsula, south of Koyuktolik Bay (Bradley et al, 1999).

POINT BEDE POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-B1 | Point Bede | 59.311215 | -151.986317 |

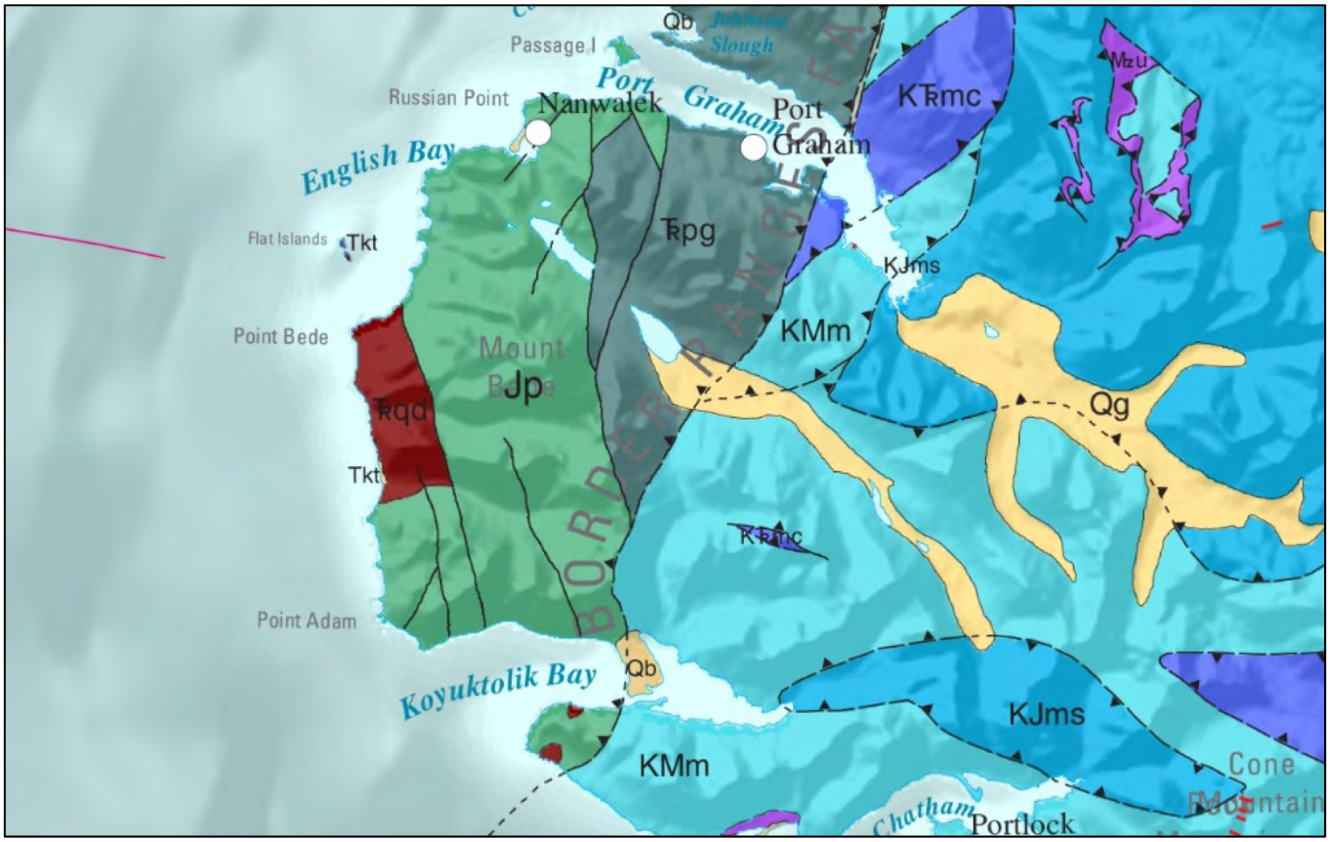
It is our understanding that the English Bay Corporation owns the surface rights (PA 50-98-0487) and Chugach Alaska Corporation owns the subsurface rights (PA 50-98-0488) in the vicinity of Point Bede.

Access: There are no protected harbors along the shore near Point Bede. The nearest is at Nanwalek, but a better port would be Port Graham to the north. Koyuktolik Bay to the south could also be used. Access would require construction of a new 3 to 4 mile road following existing roads and trails to Nanwalek or a new 10 mile road south to Koyuktolik Bay (also called Dog Fish Bay).

Geology: The $T_R$qd (Jbd) unit is a fine to medium-grained, nonfoliated quartz diorite consisting chiefly of plagioclase, quartz, chloritized biotite, and chloritized hornblende (Wilson et al., 2009 and Kelley, 1984).

**GEOLOGIC MAP POINT BEDE AREA**

(From Wilson et al., 2009)




Unit $T_R$qd is the quartz diorite of interest.

Conclusions: There are shoreline outcrops of probable Jurassic intrusives by Point Bede and near Koyuktolik (Dogfish) Bay. The diorite ($T_R$qd) of Point Bede is a fine-to medium grained, nonfoliated quartz diorite consisting chiefly of plagioclase, quartz, cholitized biotite, and chloritized hornblende. A small exposure of tonalite, is reported along the shores of Koyuktolik (Dogfish) Bay. These rocks are medium-grained and nonfoliated consisting of plagioclase, quartz, and chloritized biotite. The chloritic alteration is very similar to that in the Point Bede diorite. Along the shore just south of the tonalite outcrop is another small igneous outcrop, a fine-grained, aphanitic, light grey felsite. The fine-grained outcrop at Point Bede may have the potential for producing hard aggregates with low Nordic Abrasion values.

References:

Bradley, D.C., Kusky, T.M., Haeussler, P.J., Karl, S.M., and Donley, D.T., 1999, Geologic map of the Seldovia quadrangle, south-central Alaska: U.S. Geological Survey Open-File Report 99-18, 1 sheet, scale 1:250,000.

Kelley, J.S., 1984, Geologic map and sections of the southwestern Kenai Peninsula west of the Port Graham fault, Alaska: U.S. Geological Survey Open-File Report 84-152, 1 sheet, scale 1:63,360.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeusler, P.J.., Schmidt, J.M., Yehle, L.A., Labay, K.A. (Map Compilers) Wilson, F.H., Hults, C.P., Labay, K.A., Shew, N. (Digital Files Preparers), 2009, Preliminary geologic map of the Cook Inlet Region, Alaska-including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Iliamna, Seldovia, Mount Katmai, and Afognak 1:250,000-scale quadrangles, U.S. Geological Survey Open-File Report 2009-1108, Version 1.

# LOCATION MAP (HA-B1)


U.S.G.S. QUADRANGLE: SELDOVIA (A-5), (A-6), (B-5) & (B-6)

# POTENTIAL HARD AGGREGATE SOURCE NANWALEK

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

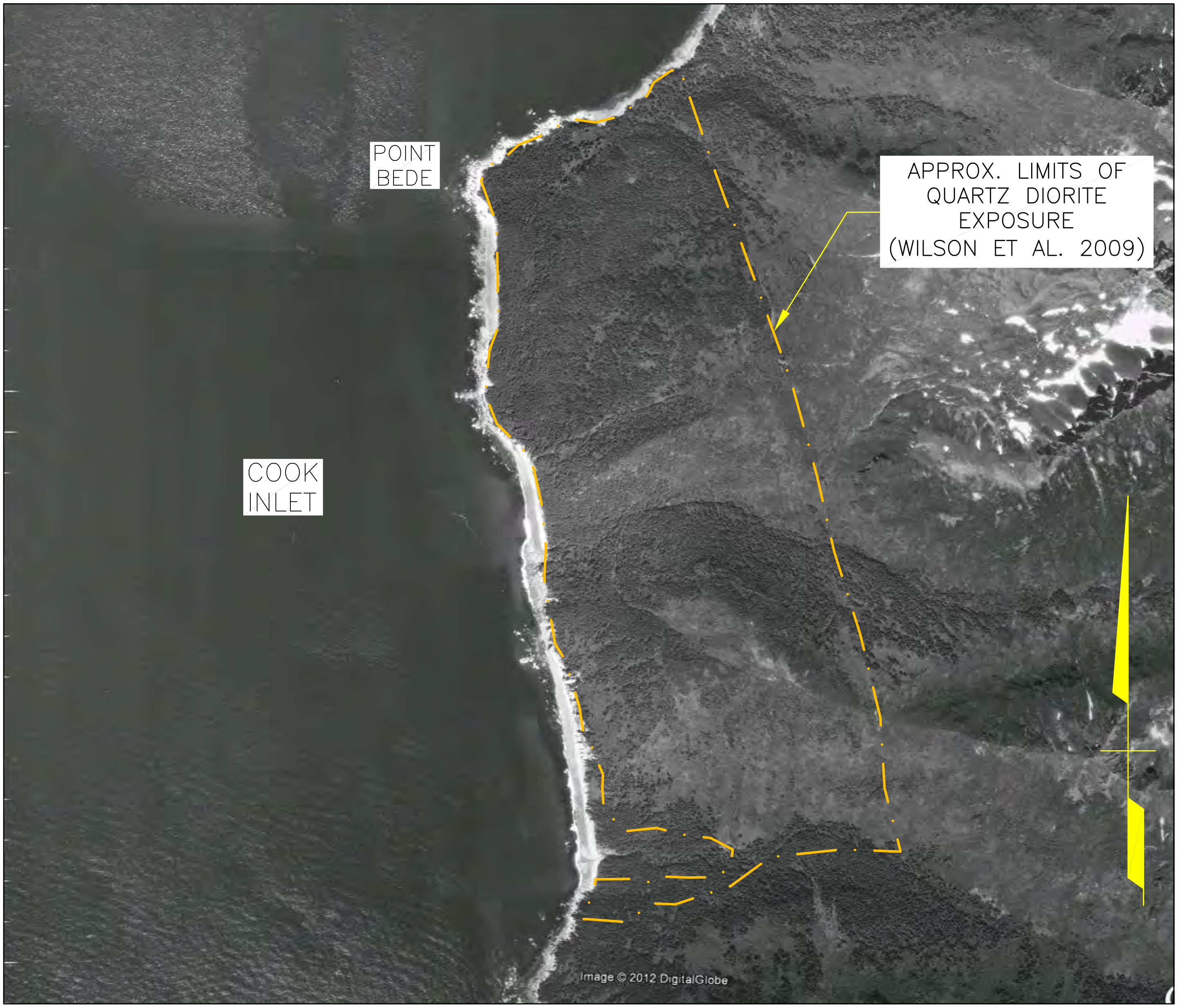
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
POINT BEDE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 12:23 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Nanwalek\Acad\MS_Topo_Map_Nanwalek.dwg

# SITE MAP (HA-B1)




BASE MAP IS JUNE 25, 1997 U.S.G.S. AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE NANWALEK

0 0.25 0.5 1 1.5

GRAPHIC SCALE IN MILES

BASE MAP FROM GOOGLE EARTH PRO 2/3/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
POINT BEDE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Nanwalek\Acad\MS_Site_Map_Nanwalek.dwg

Plotted 3/28/2013 12:25 PM by Pete Hardcastle

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# COPPER RIVER HIGHWAY
# SHERIDAN GLACIER

March 20, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: The Sheridan Glacier site is located on the east side of the Sheridan and Sherman Glaciers at 19 mile of the Copper River Highway. It is a potential thermal contact (hornfels) deposit along the eastern edge of a Tertiary igneous pluton.

The site lies on Chugach National Forest land and is apparently within the Scott-Sheridan Travel Management Area, which is open to motorized vehicles use yearlong, according to the U.S. Forest Service Motor Vehicle Use Chugach National Forest Map #3.

SHERIDAN GLACIER POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-C1 | Sheridan Glacier | 60.473414 | -145.262355 |

Access: From the Copper River Highway to Cordova.

Geology: Bedrock at the Sheridan Glacier Site is mapped (Nelson et al., 1985 - Map 2B /Winkler & Plafker, 1993 - Map 2A ) as:

> Tgg/ Tg: Granites and Granodiorite (Eocene). The older of the two intrusive events is represented by plutons in the central and eastern parts of Prince William Sound, and intrudes both the Orca and Valdez Groups. Surface exposures range from less than 0.3 mile (Ragged Mountain) to greater than 55 miles at the Sheep Bay pluton. Faults truncate a few of the bodies, but elsewhere the plutons are surrounded by contact-metamorphic aureoles. Plutons of this unit are generally medium to coarse-grained hypidiomorphic-granular biotite-granite with border phases of biotite- hornblende-granite to granodiorite and tonalite. Found on Wells Bay, Sheep Bay, and at Sheridan Glacier.
>
> Tos/Tos: Tertiary sedimentary rocks of the Orca Group.
>
> Qu/Qs, Qm, Qsm, Qls: Undifferentiated Surficial deposits / Surficial deposits, Glacial Moraines, Supraglacial moraines, and Landslides.

Potential contact metamorphism (hornfelsing) is mapped where sedimentary rocks predominate adjacent to the intrusive igneous rocks. The Contact zone between the igneous granite and granodiorite (Tgg) and the Orca Group sedimentary rock (Tos) lies between two creeks and is mapped between the highway and the headwaters of Salmon Creek.

Conclusions: There are no test results or other direct observations to verify the presence of rock capable of producing hard aggregate near Sheridan Glacier. However, the conditions exist for these types of rock (hornfels) to occur to the east of the glacier. Access to these potential hornfels sites is from the Copper River Highway. It is unknown how much hornfels rock is available, or where it is available. This source appears to warrant consideration.

A source at Sheep Bay may be considered if this site is not selected. However, the Sheep Bay site does not have highway access and much of the peninsula is steep and rugged, therefore difficult to access.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

<u>References:</u>


Moffit, F.H., 1954, Geology of the Prince William Sound region, Alaska: U.S. Geological Survey Bulletin 989-E, p. 225-310, 1 sheet.

Nelson, S.W., Dumoulin, J.A., and Miller, M.L., 1985, Geologic map of the Chugach National Forest, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1645-B, 16 p., 1 sheet, scale 1:250,000.

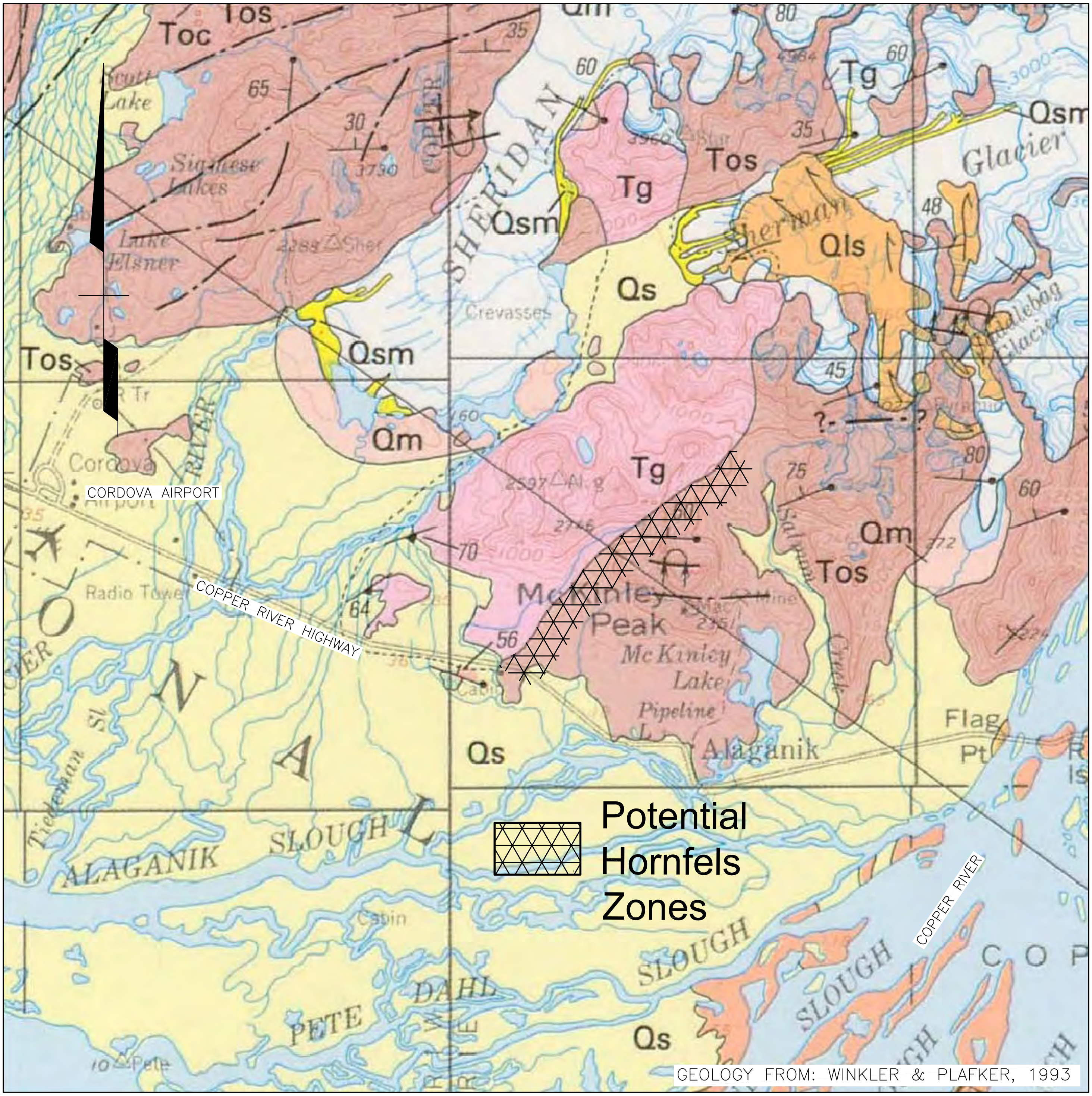
Richter, D.H., 1965, Geology and mineral deposits of central Knight Island, Prince William Sound, Alaska: Alaska Division of Mines and Minerals Geologic Report 16, 40 p., 1 sheet, scale 1:40,000.

Tysdal, R.G. and Case, J.E., 1979, Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1150, 12 p., 1 sheet, scale 1:250,000

Wilson, F.H., Hults, C.P., Labay, K.A., and Shew, Nora, 2008, Preliminary integrated geologic map databases for the United States: digital data for the reconnaissance geologic map for Prince William Sound and the Kenai Peninsula, Alaska: U.S. Geological Survey Open-File Report 2008-1002, 1 p.

Winkler, G.R. and Plafker, George, 1993, Geologic map of the Cordova and Middleton Island quadrangles, southern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1984, 1 sheet, scale 1:250,000.

# LOCATION MAP (HA-C1)




U.S.G.S. QUADRANGLE: CORDOVA

Tg-Granite
Tos-Orca Sedimentary Rock
Qls-landslide
Qs- Surficial Deposits
Qm/Qsm-Glacial Deposits

# POTENTIAL HARD AGGREGATE SOURCE COPPER RIVER HWY.

0 1 2 4 6

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
SHERIDAN GLACIER

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2A |
| | CHECKED C.H.R. | DATE MAR 2013 | |

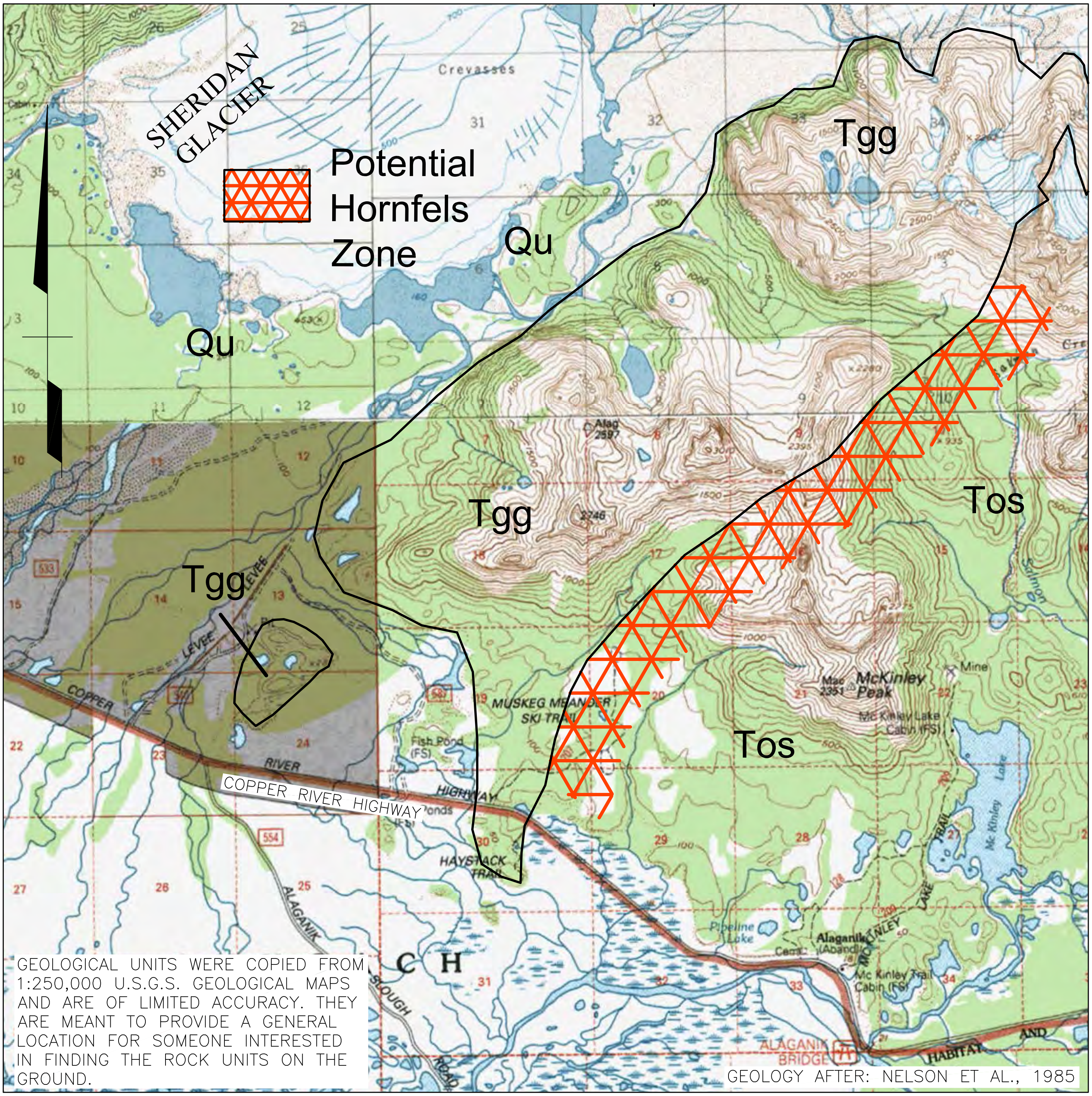
Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince William Sound\Acad\MS_Topo_Map_Knight_Island.dwg

Plotted 3/28/2013 11:24 AM by Pete Hardcastle

# LOCATION MAP (HA-C1)




U.S.G.S. QUADRANGLE: CORDOVA (B-4) & (C-4)

Tgg-Granite & Granodiorite
Tos-Orca sedimentary rock
Qu-Undivided Surficial

# POTENTIAL HARD AGGREGATE SOURCE COPPER RIVER HWY.


STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
SHERIDAN GLACIER

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2B |
| | CHECKED C.H.R. | DATE MAR 2013 | |

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

Plotted 3/28/2013 11:25 AM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince William Sound\Acad\MS_Topo_Map_Knight_Island.dwg

# STATEWIDE MATERIAL SITE INVENTORY

# POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# HAINES HIGHWAY MILE 4.5, 5.5 AND 25 SITES

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS:

General Site Description: There are three sites along the Haines Highway noted for having hard aggregate. Sites at MP 4.5 and 5.5 are reportedly owned by Mr. Roger Schnabel of Southeast Roadbuilders. These sites appear to be at the base of steep alpine fans or talus cones along the southern end of the Takshanuk Mountains. A request (ADL 108049) for a material sale, apparently to expand the MP 5.5 site into the northwest quarter of Section 19, T30S, R59E, CRM, was denied due to inconsistencies with the Haines State Forest Management Plan.

A third site is located south of the Haines Highway at MP 25, on the Klehini River floodplain. This site appears to be on State land.

HAINES HIGHWAY POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Nordic Values | Latitude | Longitude |
|---|---|---|---|---|
| HA-D1 | Mile MP 4.5 Site | 6.6, 8, 9.3, 9.6, 11.4, 17.5 | 59.253884 | -135.538934 |
| HA-D2 | Mile 5.5 Site | 6.8 | 59.260689 | -135.558706 |
| HA-D3 | Mile 25 Klehine River Site | 10 | 59.407787 | -135.964659 |

Access: Access to all three sites is from the Haines Highway.

Geology: It should be noted that some of the geologic symbols change between references when identifying similar rock types as one goes up the Chilkat River. Geologic symbols on Location Map 2A are from (Redman et al., 1984 - Skagway B-3) while geologic symbols on Location Map 2B are from (MacKevett, Jr. et al., 1974 - Skagway B-3).

As shown on Location Maps 2A and 2B, metabasalt (Kmb) is exposed in a northwest-trending belt as much as one-half a mile wide along the base of the Takshanuk Mountains, bordering the northeast side of the Chilkat River where it is in contact with a gabbro-diorite complex (Kgd/Kkhd). Most of the metabasalt in the Skagway B-3 Quadrangle near Klukwan (Location Map 2B) is reportedly characterized by near-vertical foliation that strikes northwestward approximately parallel to the Chilkat River and the Takshanuk Mountains. The gabbro-diorite complex occupies an extensive northwest-trending belt, as much as 2 miles wide, along the southwest flank of the Takshanuk Mountains. It is in gradational contact with the metabasalt and quartz diorite to the east, and is intruded by pyroxenite (Kp/Kum) along sharp, steep contacts that strike mainly northwestward and generally transect foliation of the gabbroic rocks (MacKevett, Jr. et al., 1974).

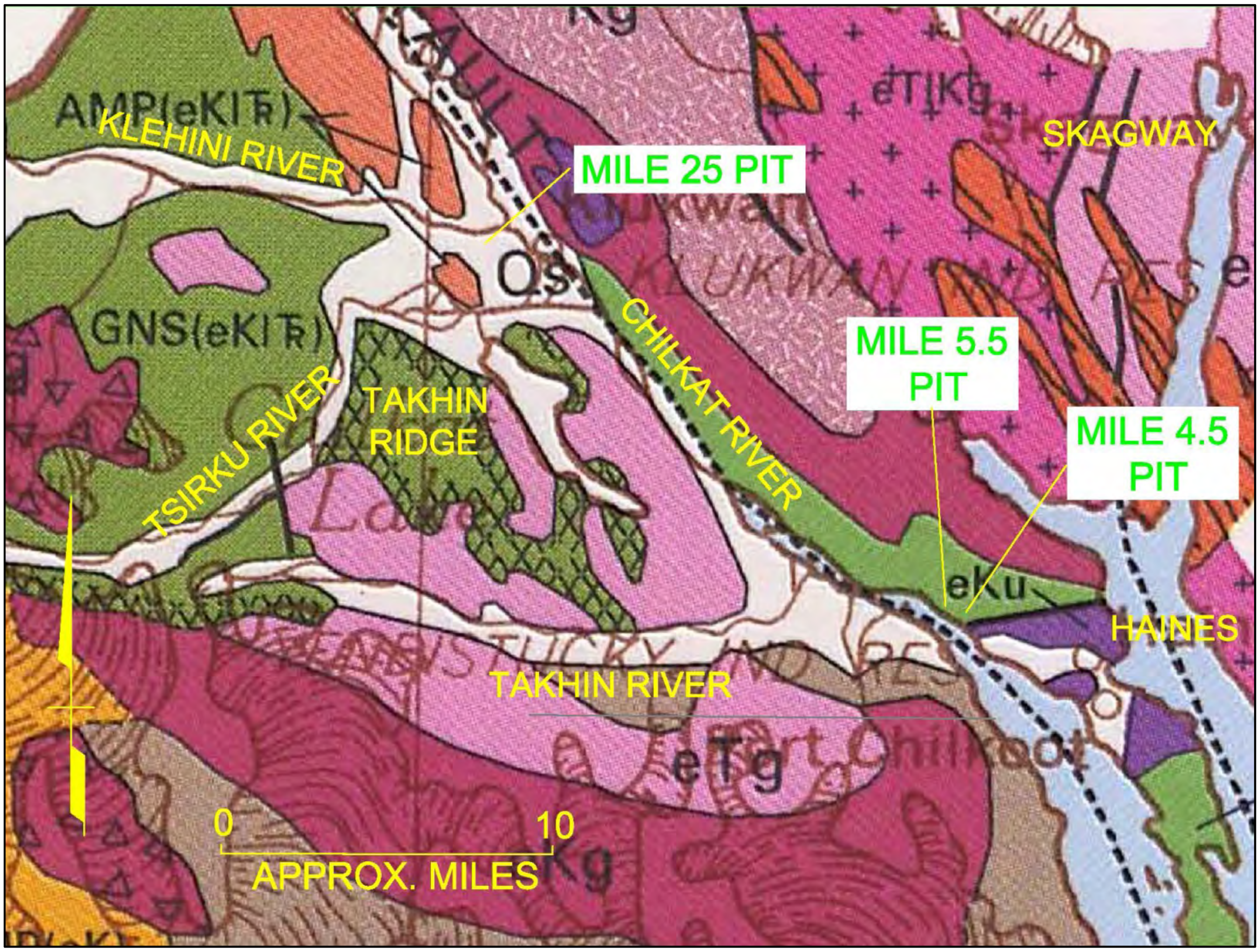
Kmb: Metabasalt. Rock occurs as black to dark-green, massive, dense, metabasalt flows, with local phyllitic interbeds. Rocks have undergone Abukuma-type high temperature, low pressure metamorphism. It is commonly flow-banded, porphyritic, and/or amygdaloidal and contains rare pillows. Rocks are composed of almost equal amounts of hornblende and plagioclase, with minor chlorite and epidote. Pods, zones and veins of replacement epidote are common (Redman et. al., 1984).

Kgd/Kkhd: A complex of gabbro and diorite occupies an extensive northwest-trending belt as much as two miles wide, along the southwest flank of the Takshanuk Mountains. It is a gradational contact with the metabasalt (Kmb) downslope and is intruded by pyroxenite (Kp). Rocks of the gabbro and diorite complex exhibit various degrees of alteration. The alteration is most intense near the pyroxenite (Kp) where the gabbroic rocks are strongly epidotized and saussuritized. The gabbro and diorite are light to medium greenish gray, fine or medium-grained, and mainly equigranular (MacKevett, Jr. et al., 1974).

Kp/Kum: Pyroxenite forms an irregular main outcrop approximately one mile wide and 4 miles long with several small isolated outcrops, high on the southwest flank of the Takshanuk Mountains northeast of Klukwan. The pyroxenite is well exposed throughout vertical extents of as much as 3,000 feet. It intrudes rocks of the gabbro and diorite complex along sharp, irregular contacts that mainly dip steeply northeastward and generally crosscut foliation of the invaded rocks. The pyroxenite is dark green to black, medium or coarse-grained, and mainly xenomorphic granular in texture (MacKevett, Jr. et al., 1974).

As shown on the following Chilkat River/Haines Metamorphic Facies Map, hornfels zones are mapped south of the Klehini River on Takhin Ridge, between the Tsirku River and the Takhin Rivers (Dusel-Bacon et al., 1996). Erosion of these zones may have carried hornfels down into the floodplains of the surrounding rivers and into the Klehini River floodplain.

**CHILKAT RIVER/HAINES METAMORPHIC FACIES MAP**
(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Takhin Ridge. The pink, red and purple units are igneous intrusives, the green, orange and brown units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatches are the interpreted hornfels zones. The hornfels zones are subject to differing interpretations by different authors.

Nordic Abrasion Values were made available by Mr. Mitch McDonald of DOT&PF Southeast Region. He provided the five (5) laboratory reports that are attached giving Nordic Abrasion values of 6.6, 9.3, 11.4 and 17.5 for the 4.5 mile site and a value of 10 for the 25 mile site. Mr. McDonald also reported a value of 6.8 for the 5.5 mile site. An undocumented value of 8 was also provided by DOT&PF on a map of Alaska as part of background data, which was assumed to be for the 4.5 mile site.

<u>Conclusions:</u> There are three known sites with Nordic Abrasion values equal to or lower than 10 along this stretch of the highway, but other sources may be found between 5.5 mile and Klukwan at MP 22. Operations in two sites at MP 4.5 and 5.5 near Haines appear to be mining talus slopes and alpines fans composed of material fallen from the Takshanuk Mountains. These loose materials are likely composed of metabasalt and gabbro or diorite rubble. This rubble is

apparently fine to medium-grained igneous rocks that typically can give low Nordic Abrasion values. However, the Nordic values are not as low overall as one might expect for the rock types mapped. This may be due to local weakening of the rock during cataclastic processes or the material being coarser grained than reported. Geologic reports indicate more foliation may be present upriver of these two sites (MacKevett, Jr. et al., 1974) and thus Nordic values may increase as you near Klukwan. The area around Milepost 25 is in the floodplain of the Klehini River and a Nordic Abrasion value of 10 was achieved on a sample of the river gravel. One interpretation of this low result is that hornfels south of Klehini River makes up a significant amount of the material in the gravel of this part of the Klehini floodplain. If this is the case, it may be possible that other gravel in the Tsirku and Takhin River floodplains may have low Nordic Abrasion values.

Most of the land adjacent to the Haines Highway along the Chilkat River is in Unit 7A of the Haines State Forest, therefore land use issues may arise if mining is attempted on State lands. However, there appear to be numerous private parcels along the highway.

References:


Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of Southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Gilbert, W.G., Burns, L.E., Redman, E.C., and Forbes, R.B., 1987, Preliminary bedrock geology and geochemistry of the Skagway B-3 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 87-2, 2 sheets, scale 1:36,200.

MacKevett, E.M., Jr., Robertson, E.C., and Winkler, G.R., 1974, Geology of the Skagway B-3 and B-4 quadrangles, southeastern Alaska: U.S. Geological Survey Professional Paper 832, 33 p., 1 sheet, scale 1:63,360.

Redman, E.C., Retherford, R.M., and Hickok, B.D., 1984, Geology and geochemistry of the Skagway B-2 quadrangle, southeastern Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 84-31, 34 p., 4 sheets, scale 1:40,000.

Redman, E.C., Gilbert, W.G., Jones, B.K., Rosenkrans, D.S., and Hickok, B.D., 1985, Preliminary bedrock-geologic map of the Skagway B-4 quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 85-6, 1 sheet, scale 1:40,000.

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

PRECONSTRUCTION ☐ CONSTRUCTION ☑
ACCEPTANCE ☐ QUALITY ☑
ASSURANCE ☐ INFORMATION ☐

TEST OF HOT MIX ASPHALT (PROCESSED AGGREGATE FOR) ITEM NO. 401 LAB NO. 08C-92

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | STP-0003(104) | PROJECT NAME | HNS UNION ST REFURBISHMENT & THIRD AVE RECONSTRUCTION | | |
| SAMPLED FROM | SOURCE | EXAMINED FOR | DEG, LA, NORDIC, SPG, ABSORPTION | | |
| DEPTH | | FIELD NO. | | DATE SAMPLED | 11/02/07 |
| SOURCE | HAINES 4 MILE PIT | SUBMITTED BY | Z. FERRIN | DATE RECEIVED | 01/29/08 |
| LOCATION | HAINES, ALASKA | REPRESENTS | SOURCE | DATE REPORTED | 04/23/08 |

AS RECEIVED

| % PASSING SIEVE | QUALITY | ACCEPTANCE | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | 100 | | |
| 1/2" | 85 | | |
| 3/8" | 69 | | |
| #4 | 45 | | |
| #8 | 30 | | |
| #10 | | | |
| #16 | 20 | | |
| #20 | | | |
| #30 | 14 | | |
| #40 | | | |
| #50 | 10 | | |
| #80 | | | |
| #100 | 8 | | |
| #200 | 6.0 | | |
| 0.02 MM | | | |
| .005 MM | | | |

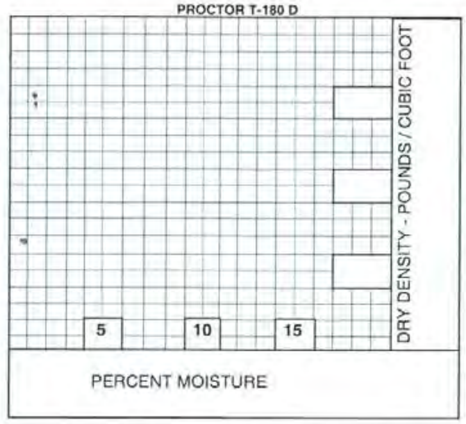
| PROPERTIES | |
|---|---|
| LIQUID LIMIT | NV |
| PLASTIC INDEX | NP |
| DELETERIOUS | FREE |
| FRACTURE % | 100 |
| THIN ELONGATED % | 1 |
| FINENESS MODULUS | |
| ORGANIC CONTENT % | |
| AASHTO CLASS | |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 84 | |
| L.A. ABRASION % B | 11 | |
| NORDIC ABRASION % | 9.3 | |
| BULK SPG | 3.012 | |
| BULK SSD SPG | 3.029 | |
| APPARENT SPG | 3.064 | |
| ABSORPTION % | 0.6 | |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




REMARKS: SENT TO ANCHORAGE FOR SODIUM SULFATE SOUNDNESS

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: MATERIALS LAB COORDINATOR

SIGNATURE: REGIONAL MATERIALS ENGINEER

THE MATERIAL AS SUBMITTED CONFORMS TO SPECIFICATIONS

YES ( ) NO ( ) N/A ( )

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

25-229
R-1/2007
S.E. REGION

# STATE OF ALASKA
# DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
# LAB REPORT (U.S. STAND.)

| | | | |
|---|---|---|---|
| PRECONSTRUCTION | [ ] | CONSTRUCTION | [X] |
| ACCEPTANCE | [ ] | QUALITY | [X] |
| ASSURANCE | [ ] | INFORMATION | [ ] |

TEST OF CRUSHED AGGREGATE BASE, GRADING D-1 ITEM NO. 301 LAB NO. ~~10C-215~~ 255

| | | | |
|---|---|---|---|
| PROJECT NO. | AARA-0956(032) | PROJECT NAME | HNS FRONT STREET TO UNION STREET |
| SAMPLED FROM | STOCKPILE | EXAMINED FOR | LA ABRAS, DEGRADATION, NORDIC ABRAS, SPG'S, ABSORPTION |
| DEPTH | | FIELD NO. | Q-BC-1 |
| | | DATE SAMPLED | 07/13/10 |
| SOURCE | HNS HWY 4.5 MILE PIT | SUBMITTED BY | S. MEREDITH |
| | | DATE RECEIVED | 07/13/10 |
| LOCATION | HAINES, ALASKA | REPRESENTS | SOURCE |
| | | DATE REPORTED | 07/21/10 |

| % PASSING SIEVE | AS RECEIVED QUALITY | ACCEPTANCE | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #20 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| 0.02 MM | | | |
| .005 MM | | | |

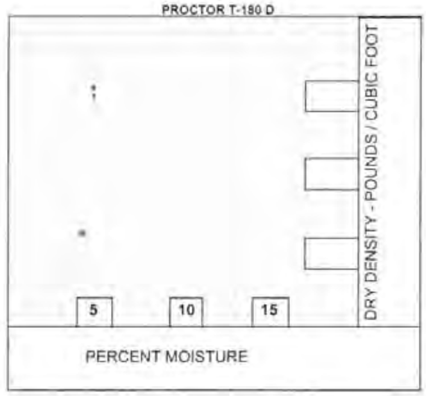
**PROPERTIES**

| | | | |
|---|---|---|---|
| LIQUID LIMIT | | | |
| PLASTIC INDEX | | | |
| DELETERIOUS | | | |
| FRACTURE % | | | |
| THIN ELONGATED % | | | |
| FINENESS MODULUS | | | |
| ORGANIC CONTENT % | | | |
| AASHTO CLASS | | | |

**MOISTURE / DENSITY RELATIONS**

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 51 | |
| L.A. ABRASION % B | 12 | |
| NORDIC ABRASION % | 11.4 | |
| BULK SPG | 3.011 | |
| BULK SSD SPG | 3.022 | |
| APPARENT SPG | 3.043 | |
| ABSORPTION % | 0.4 | |

REMARKS: SENT TO ANCHORAGE FOR SODIUM SULFATE SOUNDNESS

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffrey A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: [signature]
For REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

| | | | |
|---|---|---|---|
| PRECONSTRUCTION | | CONSTRUCTION | X |
| ACCEPTANCE | | QUALITY | X |
| ASSURANCE | | INFORMATION | |

TEST OF **ASPHALT CONCRETE, TYPE II; CLASS B (BLENDED AGG FOR)** ITEM NO. **401(1)** LAB NO. **12C-248**

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | NH-0956(33) | PROJECT NAME | HNS 2ND AVENUE - UNION STREET TO MAIN STREET | | |
| SAMPLED FROM | SOURCE | EXAMINED FOR | VARIOUS QUALITY TESTS | | |
| DEPTH | | FIELD NO. | | DATE SAMPLED | CONTRACTOR |
| SOURCE | 4.5 MILE HNS HWY - KIANA PIT | SUBMITTED BY | CONTRACTOR FOR MIX DESIGN | DATE RECEIVED | 02/06/12 |
| LOCATION | HAINES, ALASKA | REPRESENTS | SOURCE | DATE REPORTED | 06/06/12 |

| % PASSING SIEVE | AS RECEIVED QUALITY | QUALITY | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | 100 | | |
| 1/2" | 90 | | |
| 3/8" | 83 | | |
| #4 | 63 | | |
| #8 | | 49 | |
| #10 | | | |
| #16 | | 38 | |
| #20 | | | |
| #30 | | 29 | |
| #40 | | | |
| #50 | | 19 | |
| #80 | | | |
| #100 | | 12 | |
| #200 | | 7.0 | |
| 0.02 MM | | | |
| .005 MM | | | |

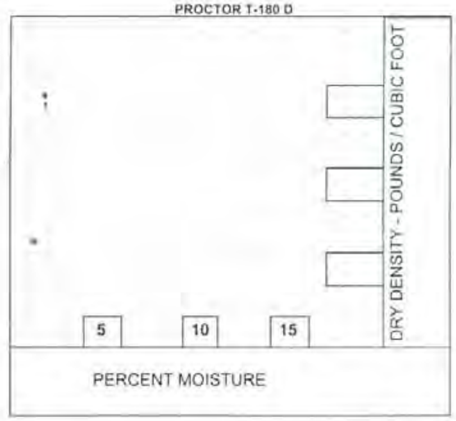
| PROPERTIES | | |
|---|---|---|
| LIQUID LIMIT | | NV |
| PLASTIC INDEX | | NP |
| DELETERIOUS | | FREE |
| FRACTURE % | | 100 |
| THIN ELONGATED % | | 2 |
| FINENESS MODULUS | | |
| FINE AGG ANGUL. | | 44.3 |
| SAND EQUIVALENT | | 44 |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 79 | |
| L.A. ABRASION % B | 19 | |
| NORDIC ABRASION % | 17.5 | |
| BULK SPG | 3.007 | 3.044 |
| BULK SSD SPG | 3.030 | 3.076 |
| APPARENT SPG | 3.077 | 3.146 |
| ABSORPTION % | 0.8 | 1.1 |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO. | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




REMARKS: SENT TO ANCHORAGE FOR SODIUM SULFATE SOUNDNESS

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffry A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: [illegible] for Bruce Brunette
REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

| | | | |
|---|---|---|---|
| PRECONSTRUCTION | ☐ | CONSTRUCTION | ☑ |
| ACCEPTANCE | ☐ | QUALITY | ☑ |
| ASSURANCE | ☐ | INFORMATION | ☐ |

TEST OF **CLASS A CONCRETE (COARSE CONCRETE AGGREGATE FOR)** ITEM NO. **501(1)** LAB NO. **08C-96**

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | **HRM-0003(114)** | PROJECT NAME | **HNS SAWMILL CREEK CULVERT** | | |
| SAMPLED FROM | **STOCKPILE** | EXAMINED FOR | **DEG, LA, NORDIC, SPG, ABSORPTION** | | |
| DEPTH | | FIELD NO. | **CA-Q-1** | DATE SAMPLED | **04/22/08** |
| SOURCE | **NORTHERN CONSTRUCTION PIT** | SUBMITTED BY | **J. STOCKBRIDGE** | DATE RECEIVED | **04/24/08** |
| LOCATION | **HAINES, ALASKA** | REPRESENTS | **SOURCE** | DATE REPORTED | **04/29/08** |

| % PASSING SIEVE | AS RECEIVED QUALITY | ACCEPTANCE | SPECS |
|---|---|---|---|
| | | | |
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | 100 | | |
| 3/4" | 92 | | |
| 1/2" | 59 | | |
| 3/8" | 40 | | |
| #4 | 2 | | |
| #8 | 1 | | |
| #10 | | | |
| #16 | 0 | | |
| #20 | | | |
| #30 | 0 | | |
| #40 | | | |
| #50 | 0 | | |
| #80 | | | |
| #100 | 0 | | |
| #200 | 0.2 | | |
| 0.02 MM | | | |
| .005 MM | | | |

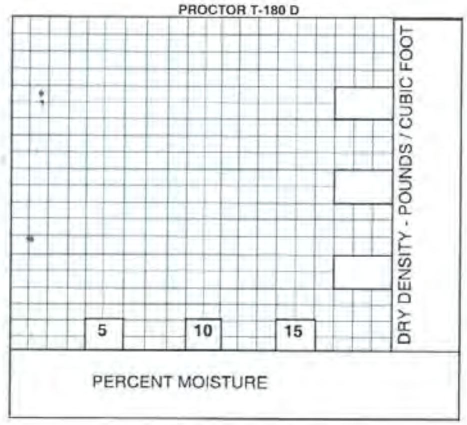
| PROPERTIES | |
|---|---|
| LIQUID LIMIT | |
| PLASTIC INDEX | |
| DELETERIOUS | FREE |
| FRACTURE % | |
| THIN ELONGATED % | |
| FINENESS MODULUS | |
| ORGANIC CONTENT % | |
| AASHTO CLASS | |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 85 | |
| L.A. ABRASION % B | 14 | |
| NORDIC ABRASION % | 6.6 | |
| BULK SPG | 2.858 | |
| BULK SSD SPG | 2.878 | |
| APPARENT SPG | 2.915 | |
| ABSORPTION % | 0.7 | |

**MOISTURE / DENSITY RELATIONS**

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

**PROCTOR T-180 D**




**REMARKS:** SENT TO ANCHORAGE FOR CONCRETE AGGREGATE TESTS

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

**CHECKED BY:** [signature]
MATERIALS LAB COORDINATOR

**SIGNATURE:** [signature]
REGIONAL MATERIALS ENGINEER

THE MATERIAL AS SUBMITTED CONFORMS TO SPECIFICATIONS

YES ( ) NO ( ) N/A ( )

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

PRECONSTRUCTION [ ] CONSTRUCTION [X]
ACCEPTANCE [ ] QUALITY [X]
ASSURANCE [ ] INFORMATION [ ]

TEST OF SIDEWALK, CURB & GUTTER (COARSE CONCRETE AGG FOR) ITEM NO. 608 & 609 LAB NO. 12C-141

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | NH-0956(33) | PROJECT NAME | HNS 2ND AVENUE - UNION ST TO MAIN ST PAVEMENT REHAB | | |
| SAMPLED FROM | STOCKPILE | EXAMINED FOR | LA ABRAS, NORDIC ABRAS, DEG, SPG, ABSP, GRAD, UNIT WT | | |
| DEPTH | N/A | FIELD NO. | Q-CA-1 | DATE SAMPLED | 04/27/12 |
| SOURCE | KLEHINI 25 MILE PIT | SUBMITTED BY | T. SWEN #175 | DATE RECEIVED | 05/02/12 |
| LOCATION | HAINES, AK | REPRESENTS | SOURCE | DATE REPORTED | 05/07/12 |

AS RECEIVED

| % PASSING SIEVE | QUALITY | ACCEPTANCE | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | 100 | | 100 |
| 3/4" | 91 | | 90 - 100 |
| 1/2" | 51 | | |
| 3/8" | 32 | | 20 - 55 |
| #4 | 2 | | 0 - 10 |
| #8 | 1 | | 0 - 5 |
| #10 | | | |
| #16 | 0 | | |
| #20 | | | |
| #30 | 0 | | |
| #40 | | | |
| #50 | 0 | | |
| #80 | | | |
| #100 | 0 | | |
| #200 | 0.3 | | 1.0 MAX |
| 0.02 MM | | | |
| .005 MM | | | |

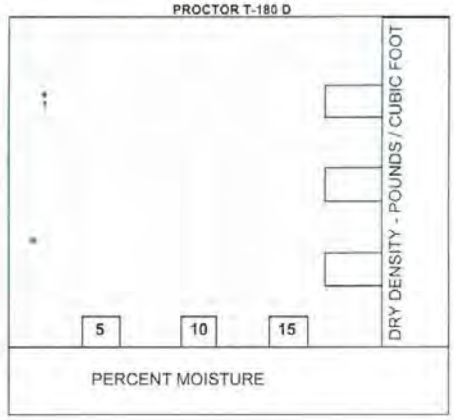
| PROPERTIES | | | |
|---|---|---|---|
| LIQUID LIMIT | | | |
| PLASTIC INDEX | | | |
| DELETERIOUS | FREE | | FREE |
| FRACTURE % | | | |
| THIN ELONGATED % | | | |
| DRY RODDED UNIT WT | 116.0 | | |
| ORGANIC CONTENT % | | | |
| AASHTO CLASS | | | |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 77 | |
| L.A. ABRASION % B | 19 | |
| NORDIC ABRASION % | 10.0 | |
| BULK SPG | 2.770 | |
| BULK SSD SPG | 2.785 | |
| APPARENT SPG | 2.812 | |
| ABSORPTION % | 0.5 | |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO. | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




REMARKS: SENT TO ANCHORAGE FOR FURTHER TESTING

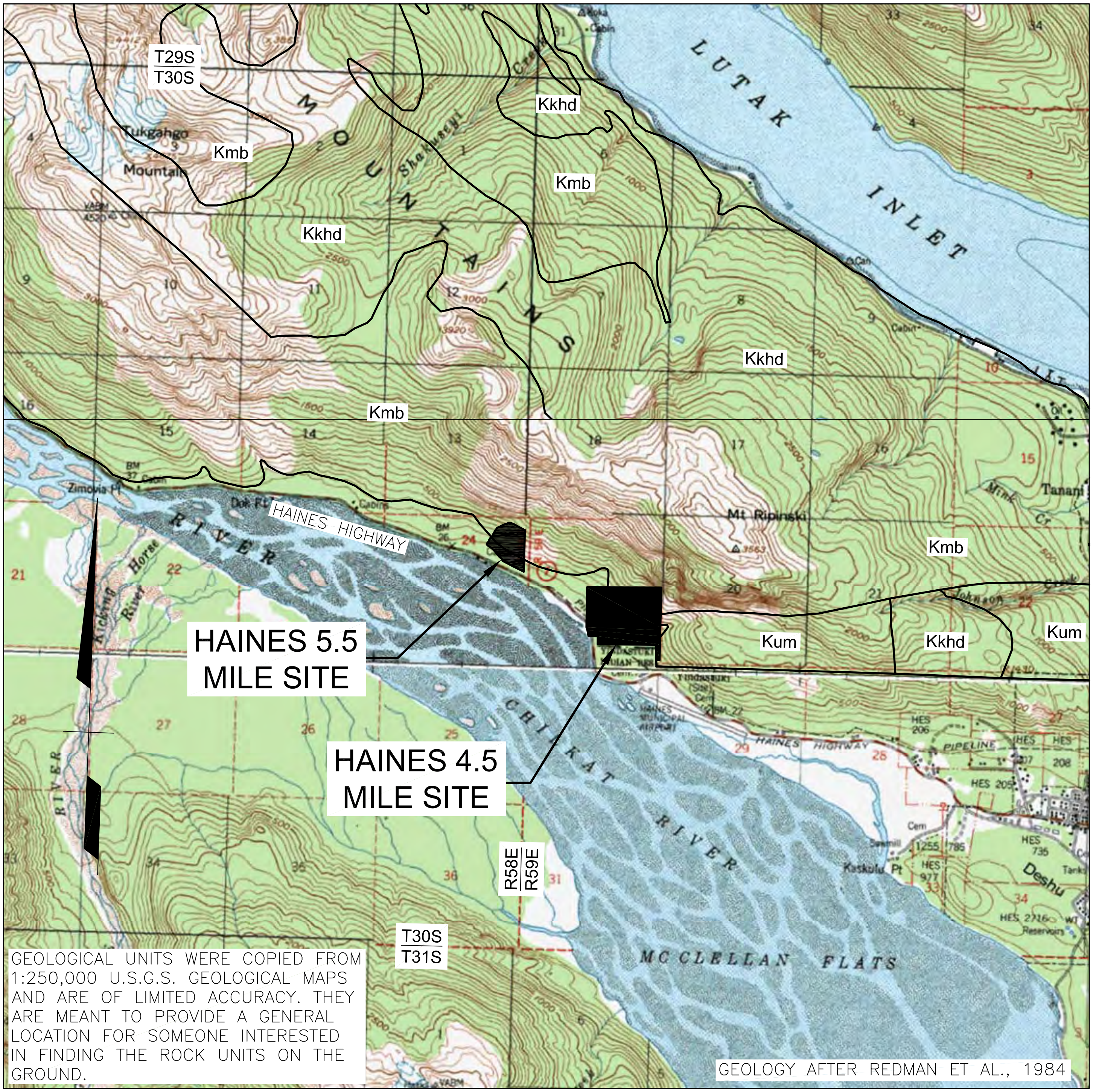
INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffrey A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: Bruce [illegible]
REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

# LOCATION MAP (HA-D1 & HA-D2)




U.S.G.S. QUADRANGLE: SKAGWAY (B-2)

Kmb-Metabasalt
Kkhd-Diorite
Kum-Pyroxenite

# POTENTIAL HARD AGGREGATE SOURCE HAINES HIGHWAY

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

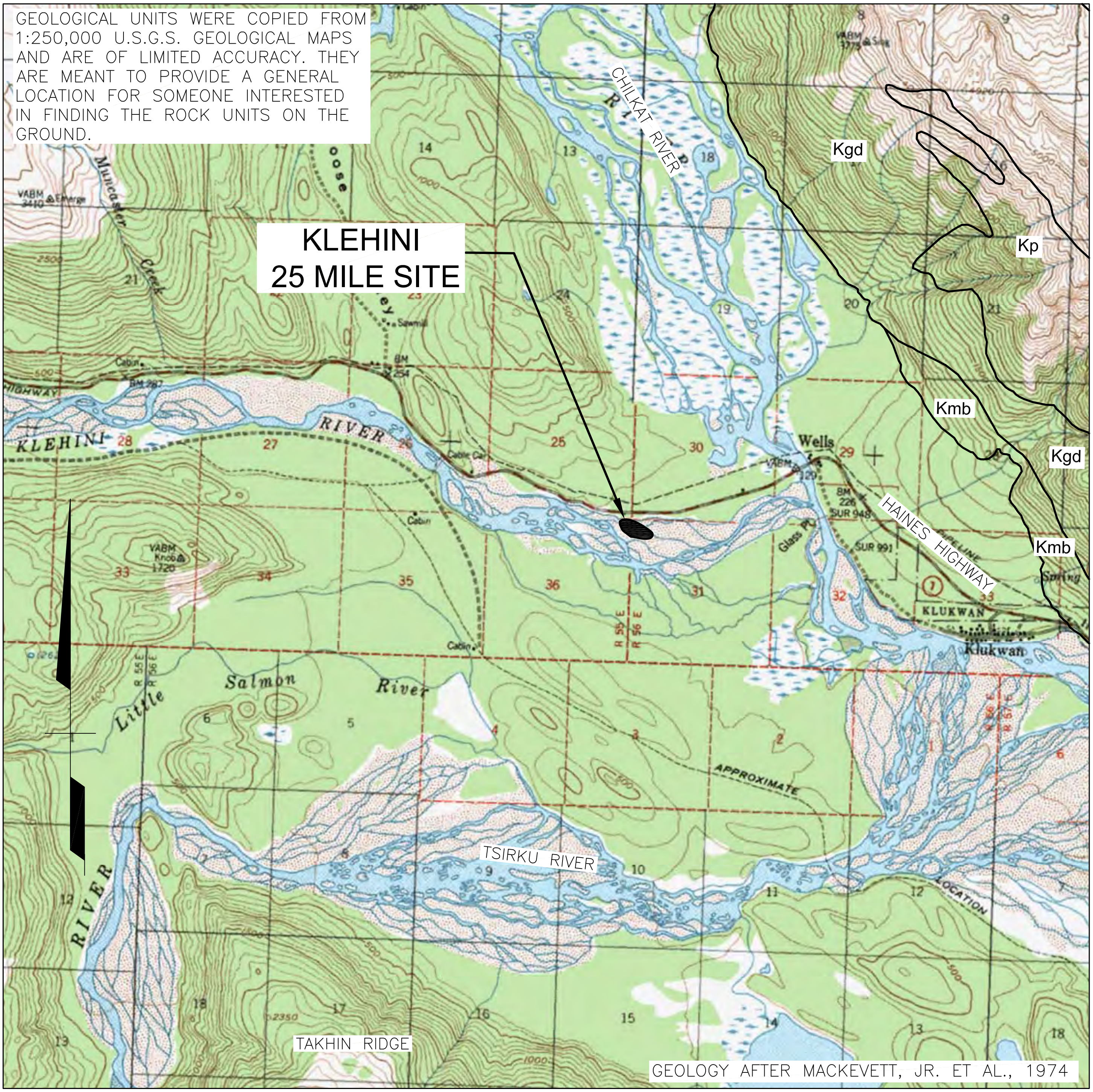
HAINES 4.5/5.5 MILE SITE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Haines\Acad\MS_Topo_Map_Haines.dwg

Plotted 3/28/2013 3:37 PM by Pete Hardcastle

# LOCATION MAP (HA-D3)




U.S.G.S. QUADRANGLE: SKAGWAY (B-3)

Kmb-Metabasalt
Kgd-Diorite/Gabbro
Kp-Pyroxenite

# POTENTIAL HARD AGGREGATE SOURCE HAINES HIGHWAY

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
KLEHINI 25 MILE SITE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Plotted 3/28/2013 3:37 PM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Aggregate Feasibility Study\Earth\Hard Aggregate Location Study\Haines\Acad\MS_Topo_Map_Haines.dwg

# SITE MAP (HA-D1)


BASE MAP IS JULY 18, 2004 DIGITALGLOBE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE HAINES HIGHWAY

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/6/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY

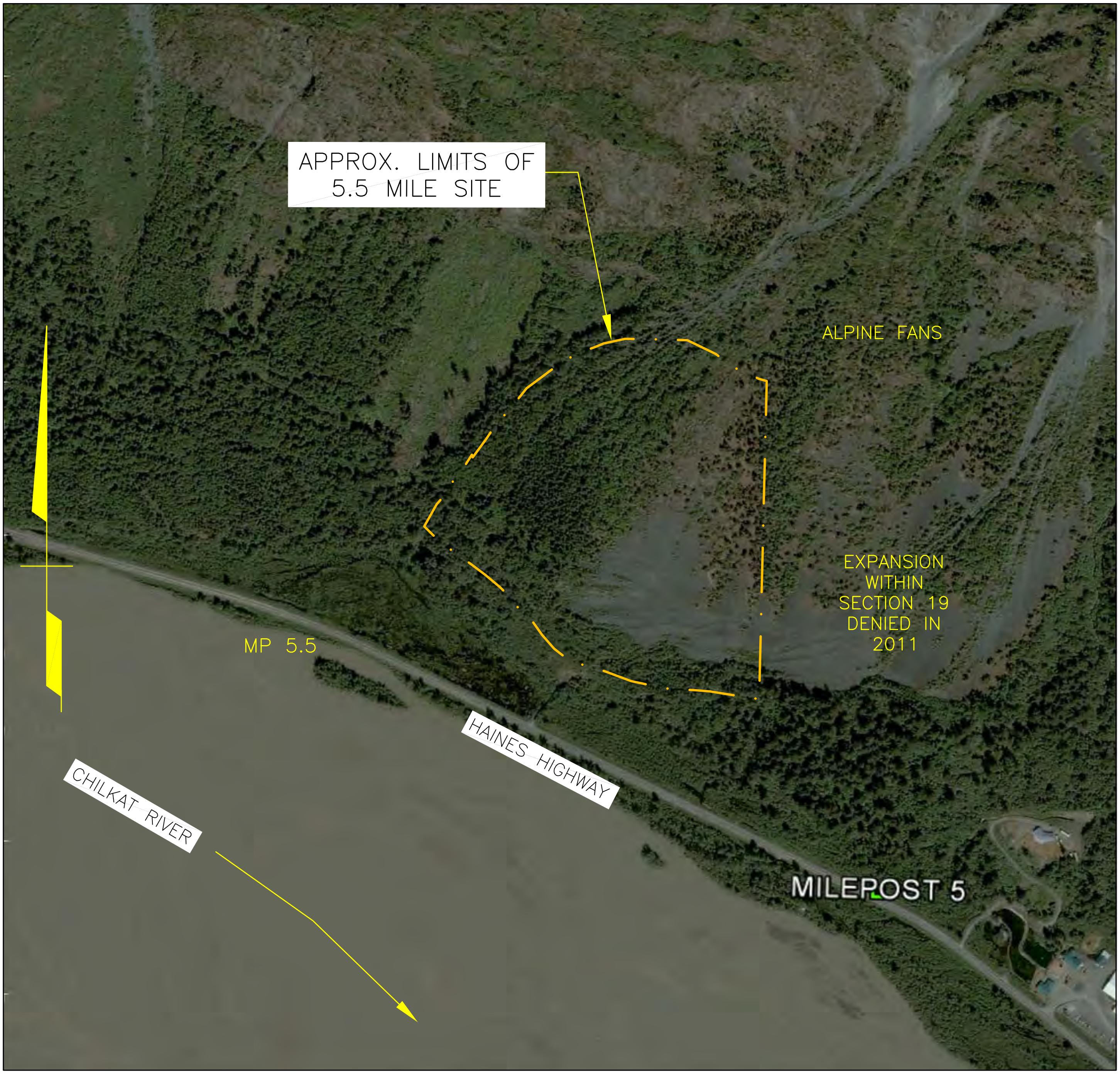
HAINES 4.5 MILE SITE

| SCALE | DESIGNED P.K.H. | DRAWN P.K.H. | PAGE 3A |
|---|---|---|---|
| AS SHOWN | CHECKED C.H.R. | DATE JULY 2010 | |

Plotted 3/28/2013 3:41 PM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Haines\Acad\MS_Site_Map_Haines_4.5.dwg

# SITE MAP (HA-D2)




BASE MAP IS JULY 18, 2004 DIGITALGLOBE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE HAINES HIGHWAY

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/6/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

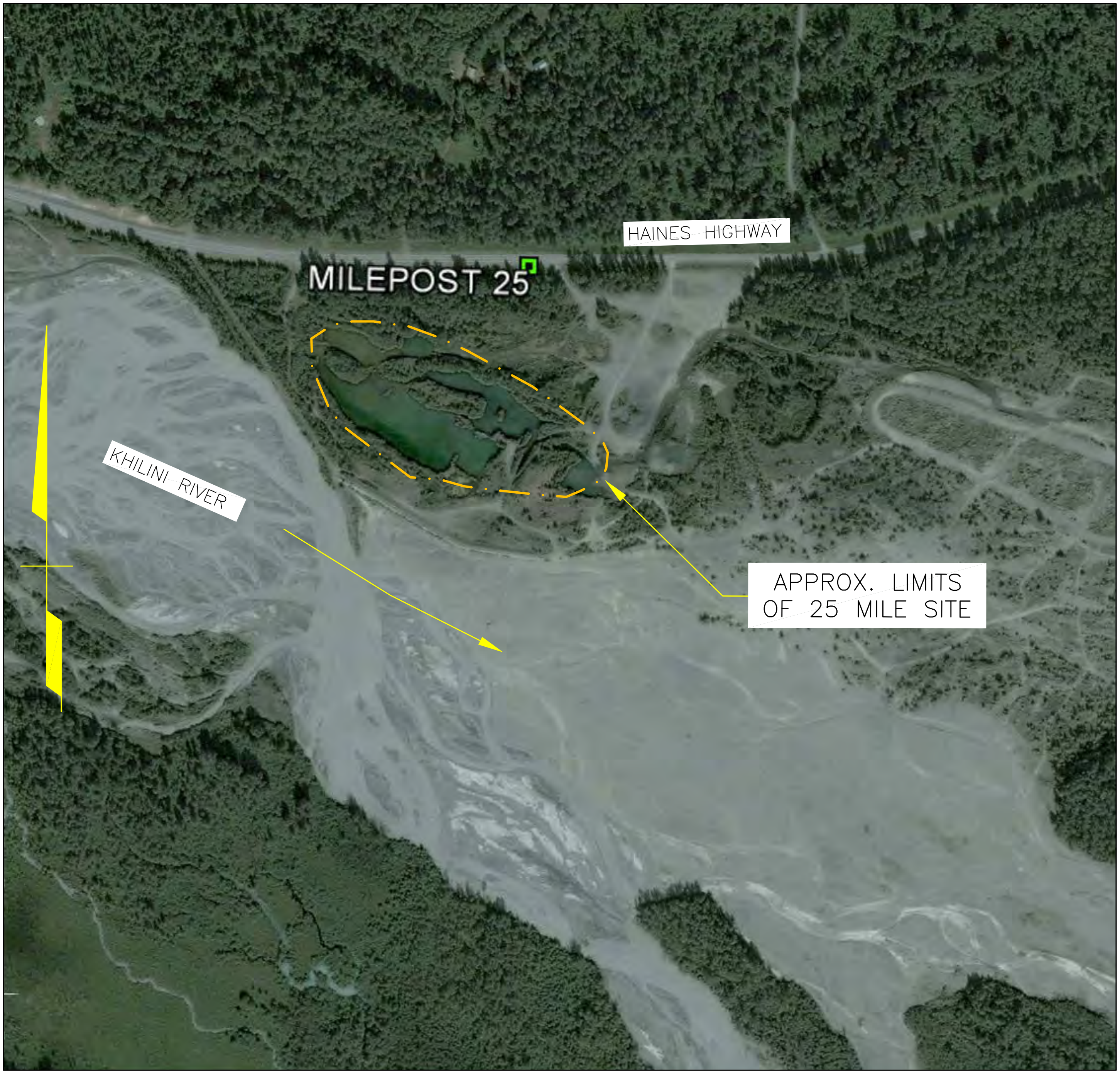
STATEWIDE MATERIAL SITE INVENTORY

HAINES 5.5 MILE SITE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3B |
| | CHECKED C.H.R. | DATE JULY 2010 | |

Plotted 3/28/2013 3:49 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Haines\Acad\MS_Site_Map_Haines_5.5.dwg

# SITE MAP (HA-D3)




BASE MAP IS JULY 18, 2004 DIGITALGLOBE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE HAINES HIGHWAY

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/6/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

MILE 25 KLEHINI SITE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3C |
| | CHECKED C.H.R. | DATE JULY 2010 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Haines\Acad\MS_Site_Map_Haines_25.dwg

Plotted 3/28/2013 3:46 PM by Pete Hardcastle

# STATEWIDE MATERIAL SITE INVENTORY

# POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# KUPREANOF ISLAND
# AREA “A” THRU AREA “I”

February 15, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: Potential hard aggregate sources on Kupreanof Island are located along the southern and eastern shores of the island (Areas “A” thru “H”) but also include an existing Forest Service quarry (Area “I”) in the interior of the island. The sources lie within the Tongass National Forest, although portions of the basalt are mapped underlying Sumner Strait, Duncan Canal and Kah Sheets Bay. Besides the existing quarry in the interior of the island, there was an existing quarry on Kah Sheets Bay that was reportedly mined as early as the 1970’s for paving aggregate.

Access: Portions of the area apparently can be accessed by gravel surfaced Forest Service roads from Kake, although most of the areas are accessible only from the coast.

Geology: The deposits have been divided into eight (8) areas based on geologic mapping and one (1) area based on exposure in an existing quarry.

KUPREANOF ISLAND POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Site Description | Latitude | Longitude |
|---|---|---|---|---|
| HA-E1 | Area “A” | Sumner Straits | 56.445424 | -133.650459 |
| HA-E2 | Area “B” | Sumner Straits | 56.439241 | -133.520885 |
| HA-E3 | Area “C” | Totem Bay | 56.455001 | -133.460536 |
| HA-E4 | Area “D” | Totem Bay | 56.505468 | -133.437401 |
| HA-E5 | Area “E” | SE Kupreanof Island | 56.457785 | -133.196343 |
| HA-E6 | Area “F” | Kah Sheets Bay Quarry | 56.513813 | -133.126340 |
| HA-E7 | Area “G” | Duncan Canal | 56.672651 | -133.170506 |
| HA-E8 | Area “H” | Duncan Canal | 56.708212 | -133.253637 |
| HA-E9 | Area “I” | Forest Service Quarry | 56.763233 | -133.523917 |

The only known laboratory testing data from this rock unit was from an exposure unmapped by the U.S.G.S. in a U.S. Forest Service quarry in the interior of the island (Area “I”). Generally, the rock in this existing quarry was dense, very fine-grained, relatively unaltered Quaternary basalt that had a petrographic description similar to the rock described along the south coast of Kupreanof Island by Brew in 1997. Alaska T-13 degradation results from the existing interior quarry reportedly ranged from 81 to 91. The rock in the Forest Service quarry was almost impossible to break with a rock hammer and could not be split with a point load testing apparatus. Unconfined compressive strength was estimated to exceed 29,000 psi (extremely strong). There was an undocumented Nordic abrasion test result of 7 provided by DOT&PF for the quarry.

Geology: The Geologic Unit Description (Brew, 1997) from the rock described along the south coast is as follows:

> Qb - Extrusive Basaltic Rocks and Underlying Sediments (Holocene and (or) Pleistocene) - Fresh, locally polygonally jointed, dark greenish-gray, dense, very fine-grained to aphanitic, magnetite-bearing, olivine basalt and minor pyroxene basalt. Individual flows are as much as 10 meters thick and are columnar jointed; most flows are less than 1 meter thick. Underlain locally by aa (lava) flows and mafic volcanic breccia in layers up to 0.5 meters thick and by locally derived, poorly sorted, well-bedded brown- to gray-weathering conglomerate, pebbly sandstone, sandstone, and minor siltstone deposited in fluvial or beach environment.

The Qb unit is similar to extensive flows of the QTb basalt unit found in the interior of the island. Brew stated that it may be included within the QTb unit “particularly along Rocky Pass and near the mouth of Irish Creek”. Observations during Forest Service road construction found the QTb basalt unit to be more vesicular and highly weathered, traits that would be unsuitable for hard aggregate production. It appears from the geologic literature that the mapping of the two units may not be well defined.

Conclusions: This basalt has potential for making hard aggregate and may have been used for paving aggregates in the past. Some variability in the rock within the unit may create problems locating the best rock sources. Additionally, conflicts with dedicated Forest Service uses of the land may make locating potential quarries difficult. Finding a site with access to a sheltered deep water harbor may also be problematic. However, there appears to be potential for developing a quarry that may produce hard aggregate as well as other aggregates (including riprap) that can be transported throughout southeast Alaska as well as into central and western Alaska.

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-F, 20 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg B-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-G, 19 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-4 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-J, 21 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg C-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-K, 18 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg D-5 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-M, 22 p., 1 sheet, scale 1:63,360.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance geologic map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30p., 1 sheet, scale 1:150,000.

# LOCATION MAP (HA-E1 & HA-E2)


U.S.G.S. QUADRANGLE: PETERSBURG (B-5) & (C-5)

Qb-DenseBasalt

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

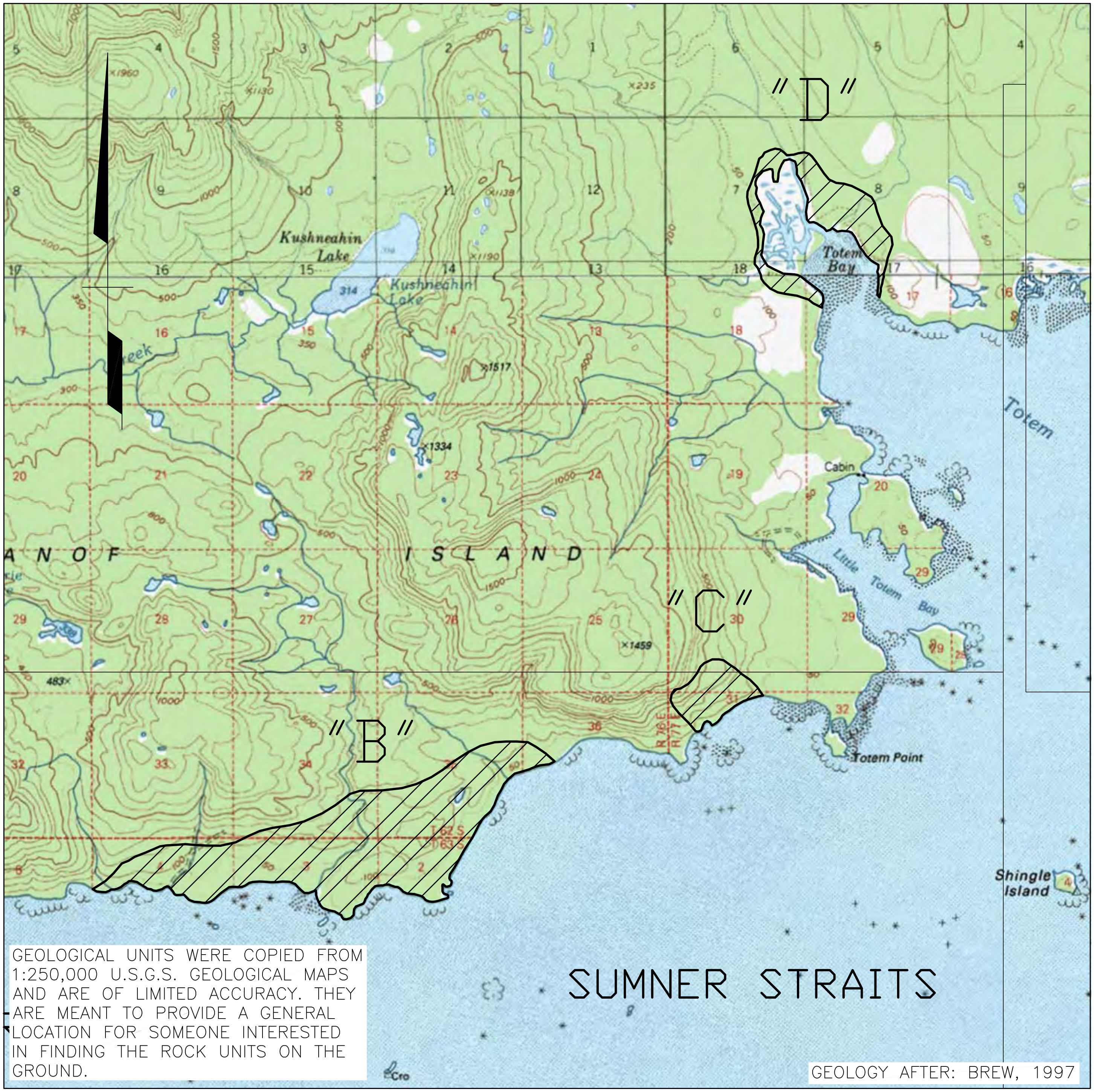
Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
SUMNER STRAITS

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2A |
| | CHECKED C.H.R. | DATE JAN 2013 | |

# LOCATION MAP (HA-E3 & HA-E4)




U.S.G.S. QUADRANGLE: PETERSBURG (B-5)

Qb-DenseBasalt

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

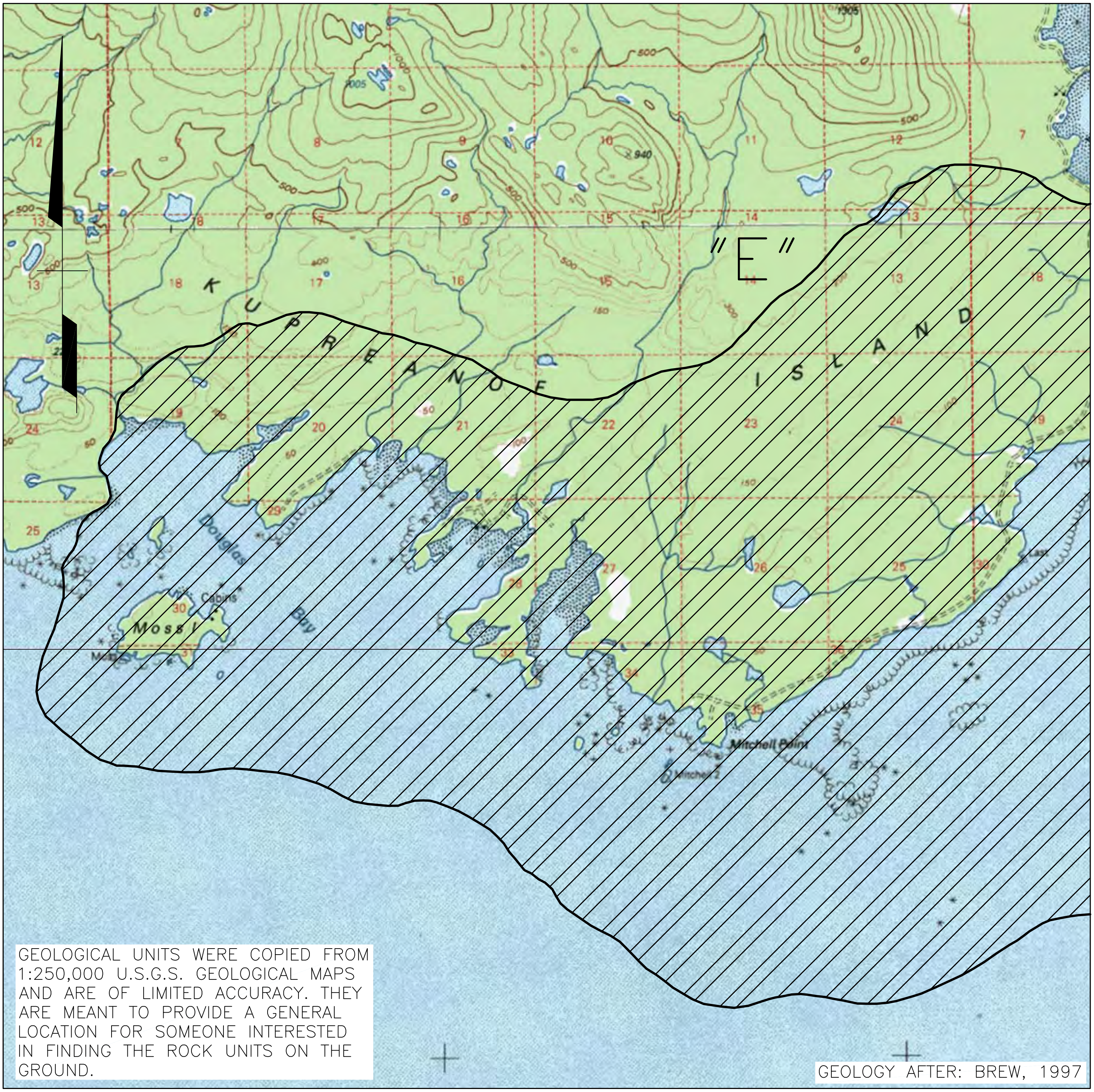
STATEWIDE MATERIAL SITE INVENTORY
TOTEM BAY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2B |
| | CHECKED C.H.R. | DATE JAN 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Topo_Map_Kake_Inland.dwg

Plotted 3/28/2013 3:14 PM by Pete Hardcastle

# LOCATION MAP (HA-E5)




U.S.G.S. QUADRANGLE: PETERSBURG (B-4) & (B-4)

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

Qb-DenseBasalt

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
SE KUPREANOF ISLAND

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2C |
| | CHECKED C.H.R. | DATE JAN 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Topo_Map_Kake_Inland.dwg

Plotted 3/28/2013 3:15 PM by Pete Hardcastle

# LOCATION MAP (HA–E6)


U.S.G.S. QUADRANGLE: PETERSBURG (B–4) & (C–4)

Qb–DenseBasalt

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

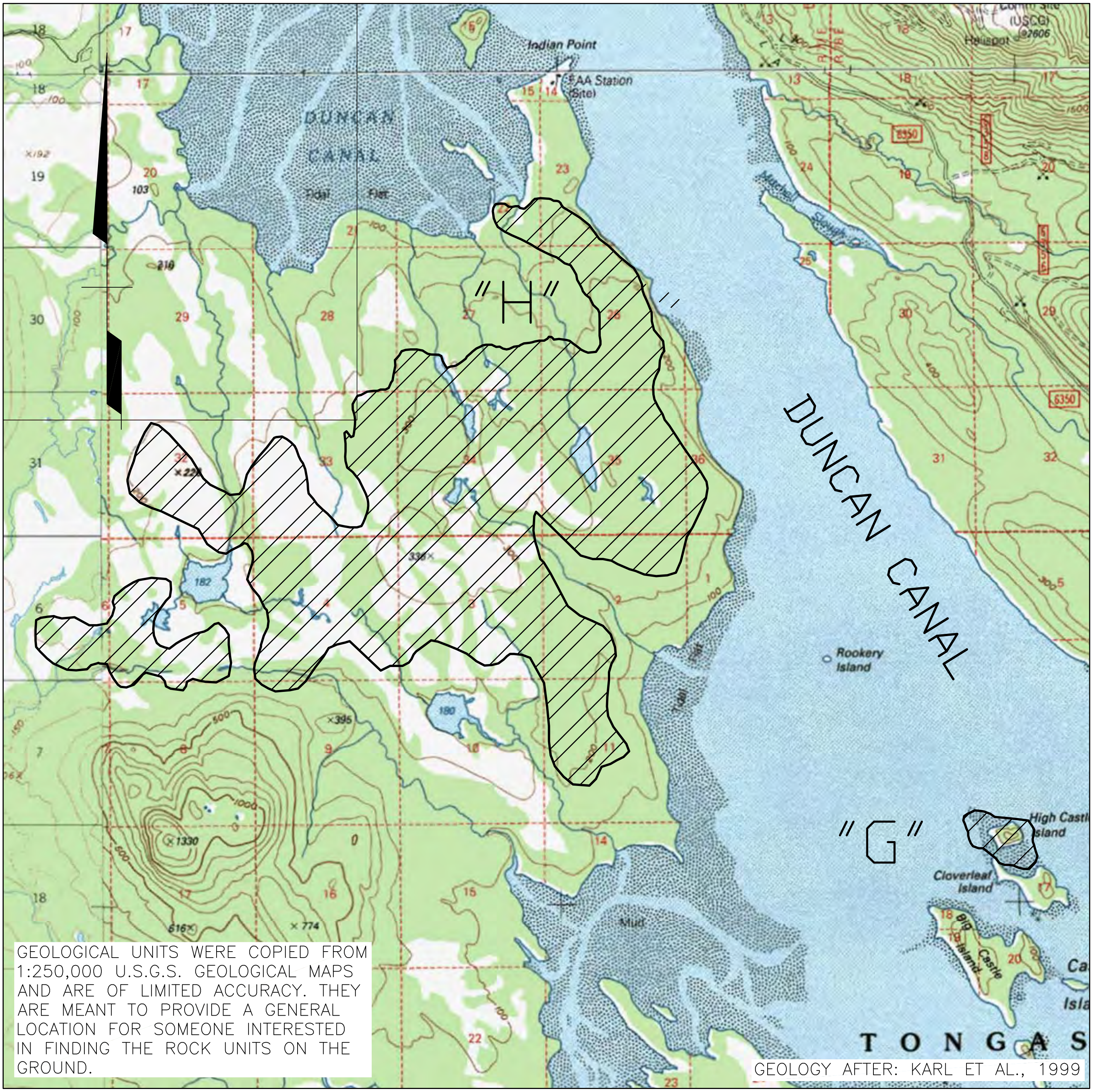
STATEWIDE MATERIAL SITE INVENTORY
KAH SHEETS QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. / CHECKED C.H.R. | J.D.N. / DATE JAN 2013 | 2D |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Topo_Map_Kake_Inland.dwg

Plotted 3/28/2013 3:16 PM by Pete Hardcastle

# LOCATION MAP (HA-E7 & HA-E8)




U.S.G.S. QUADRANGLE: PETERSBURG (C-4), (C-5), (D-4) & (D-5)

Qb-DenseBasalt

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

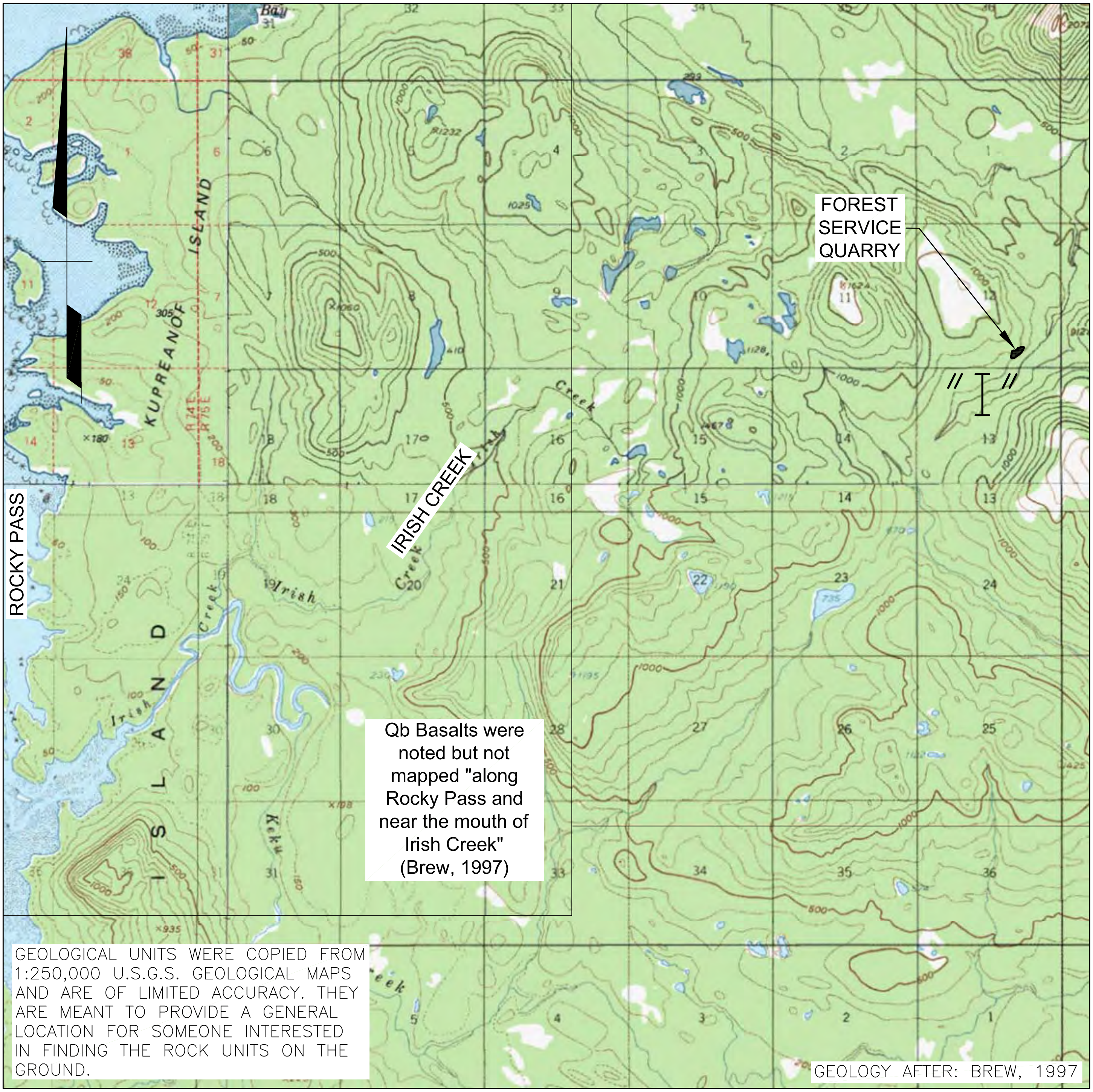
STATEWIDE MATERIAL SITE INVENTORY
DUCAN CANAL

| SCALE | DESIGNED / CHECKED | DRAWN / DATE | PAGE |
|---|---|---|---|
| AS SHOWN | DESIGNED P.K.H. CHECKED C.H.R. | DRAWN J.D.N. DATE JAN 2013 | 2E |

Plotted 3/28/2013 3:16 PM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Topo_Map_Kake_Inland.dwg

# LOCATION MAP (HA-E9)




U.S.G.S. QUADRANGLE: PETERSBURG (C-5) & (D-5)

Qb-DenseBasalt

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

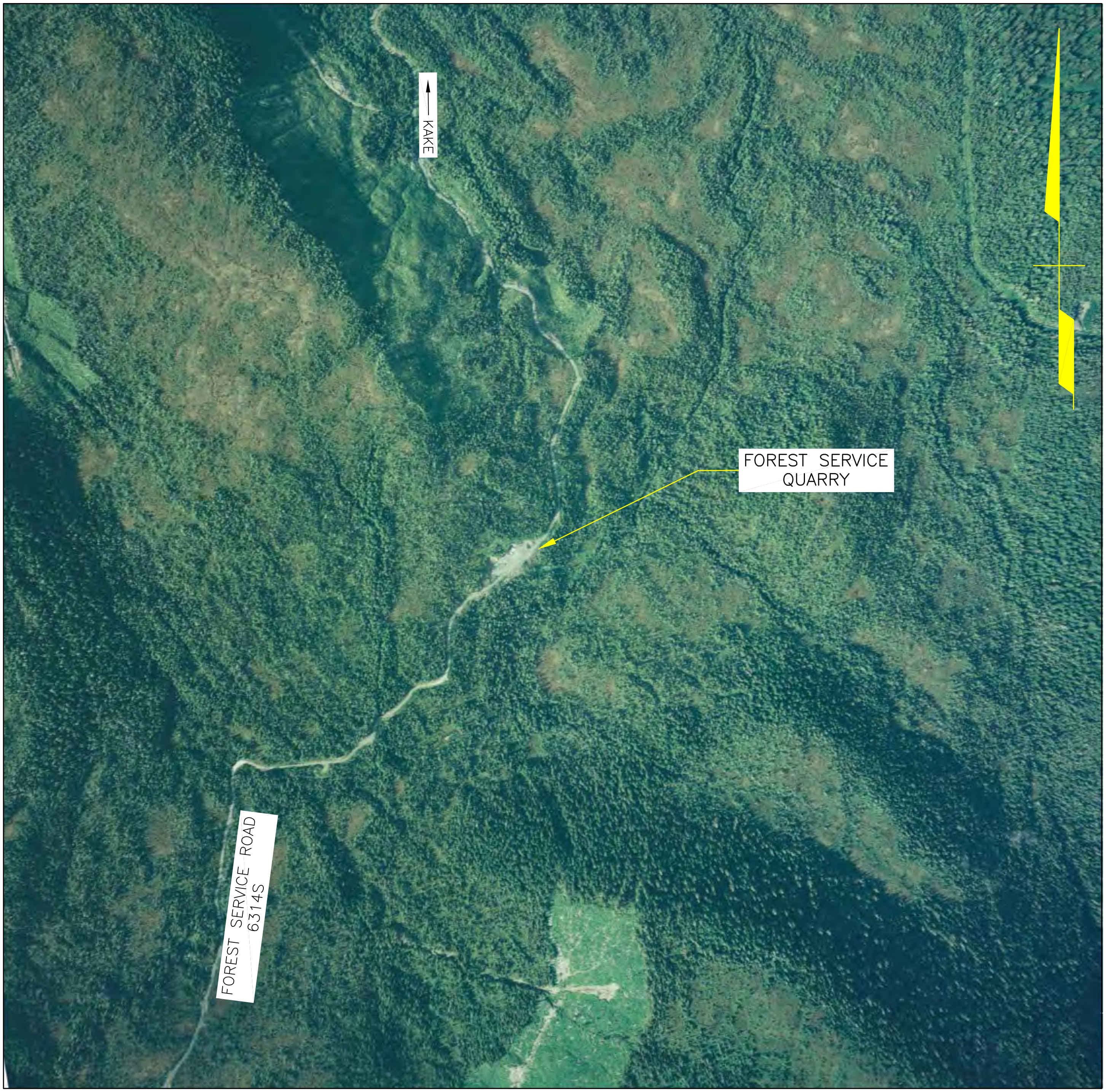
STATEWIDE MATERIAL SITE INVENTORY
FOREST SERVICE QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2F |
| | CHECKED C.H.R. | DATE JAN 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Topo_Map_Kake_Inland.dwg

Plotted 3/28/2013 3:17 PM by Pete Hardcastle

# SITE MAP (HA-E9)




BASE MAP IS AUGUST 14, 2012 AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 600 1200 2400 3600

GRAPHIC SCALE IN FEET

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

FOREST SERVICE QUARRY

| SCALE | DESIGNED | DRAWN | |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | PAGE 3A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Site_Map_Kake.dwg

Plotted 3/28/2013 2:40 PM by Pete Hardcastle

# SITE MAP (HA-E9)


BASE MAP IS AUGUST 14, 2012 AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 150 300 600 900

GRAPHIC SCALE IN FEET

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

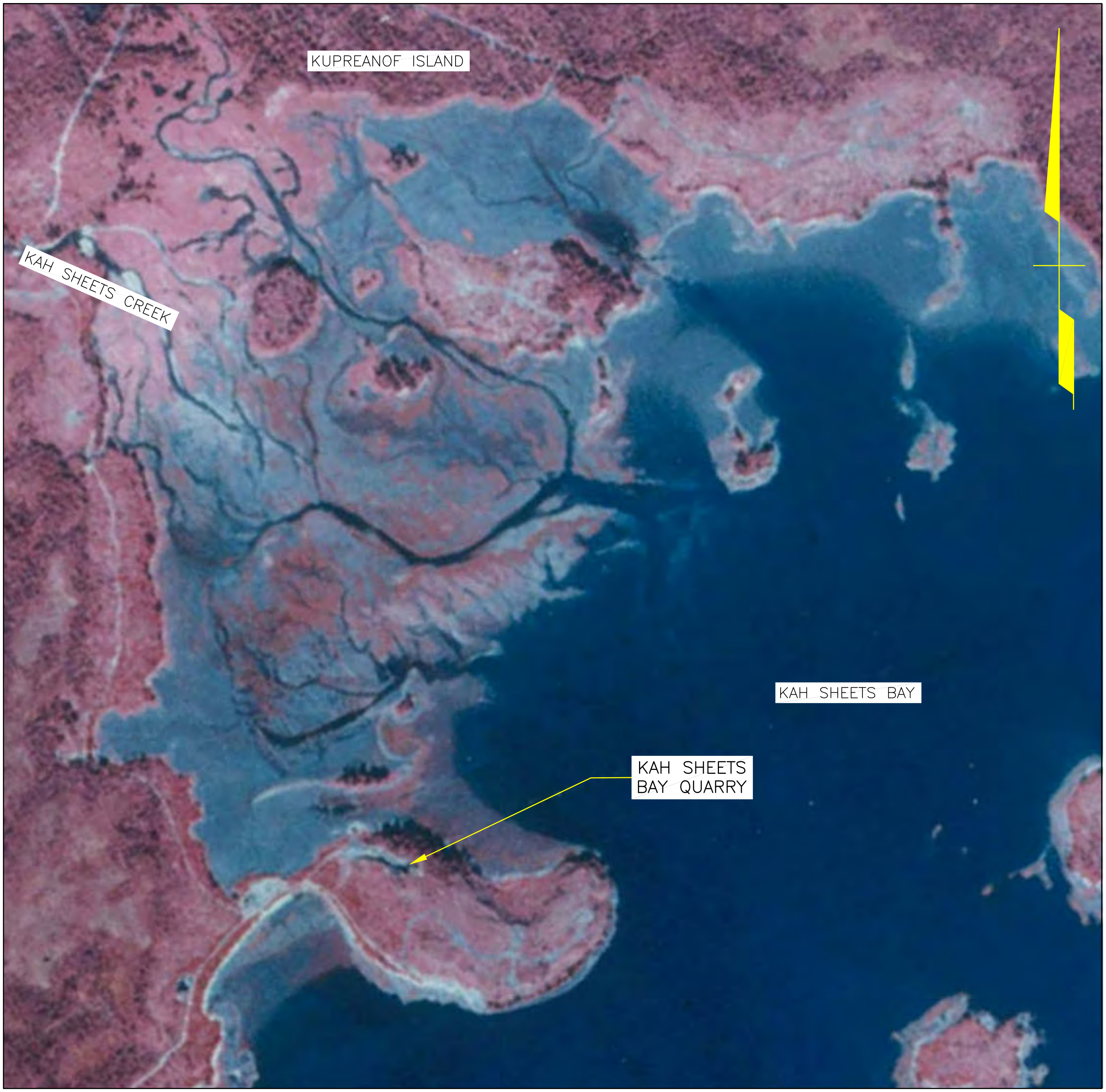
STATEWIDE MATERIAL SITE
INVENTORY

FOREST SERVICE QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 2:44 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Site_Map_Kake.dwg

# SITE MAP (HA-E6)




BASE MAP IS AUGUST 1979 CIR AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 600 1200 2400 3600

GRAPHIC SCALE IN FEET

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

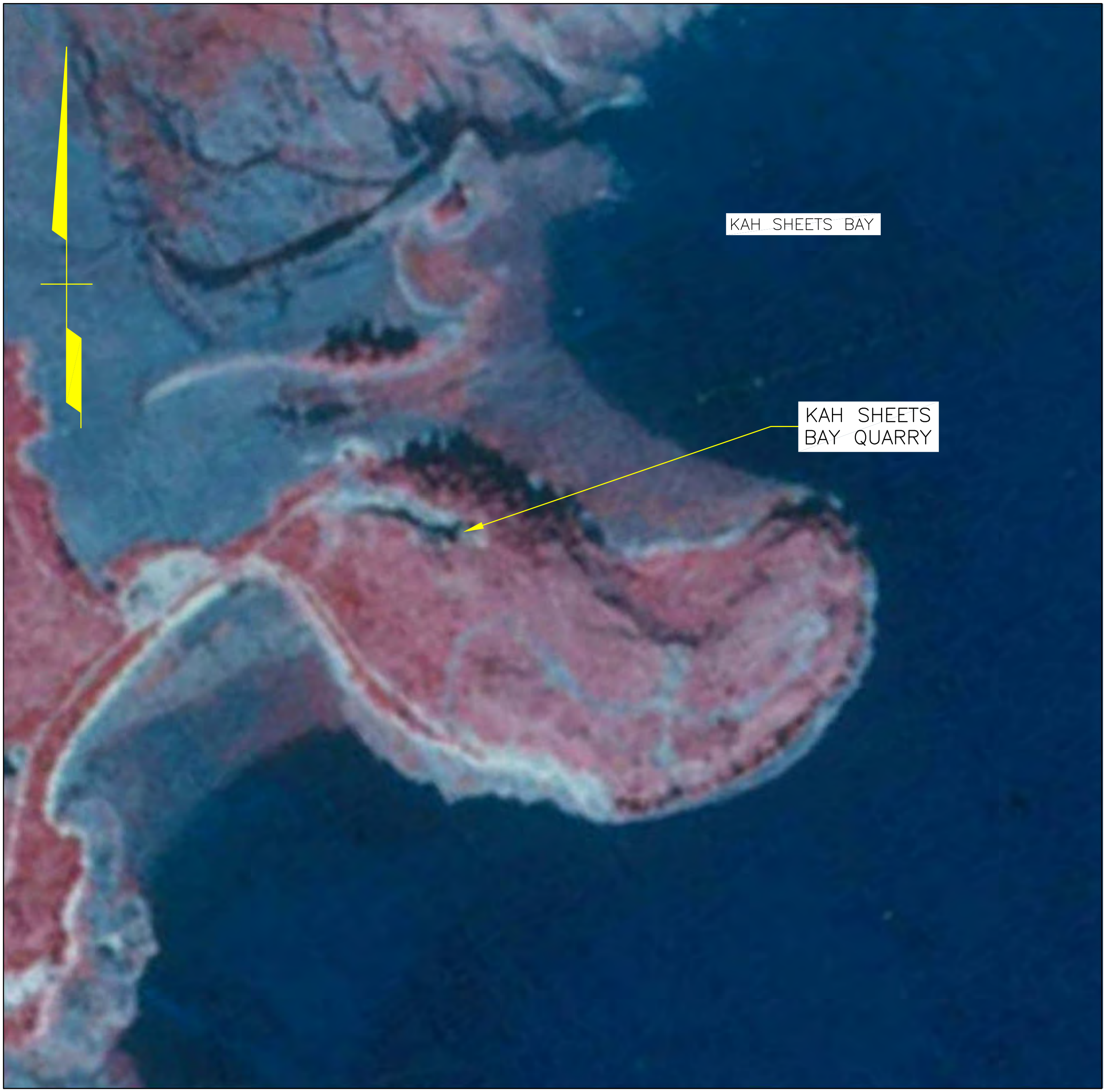
STATEWIDE MATERIAL SITE
INVENTORY

KAH SHEETS BAY QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3C |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 2:52 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Site_Map_Kake.dwg

# SITE MAP (HA-E6)




BASE MAP IS AUGUST 1979 CIR AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE KUPREANOF ISLAND

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

KAH SHEETS BAY QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3D |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kake\Acad\MS_Site_Map_Kake.dwg

Plotted 3/28/2013 2:58 PM by Pete Hardcastle

# STATEWIDE MATERIAL SITE INVENTORY

## POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# KUIU ISLAND ROWAN AND SECURITY BAY

February 15, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: The potential hard aggregate sources on Kuiu Island are located along the northwestern coast of the island between Rowan Bay and Security Bay. Potential sources include two granodiorite/gabbro intrusives in a sandstone country rock. The potential hard aggregate sources are hornfelses associated with the intrusives. Locations of these hornfelses are mapped as being along the boundary of the two intrusives as shown on the following maps. The two sources lie entirely within the Tongass National Forest on lands managed by the U.S. Forest Service.

KUIU ISLAND POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-F1 | Security Bay | 56.808520 | -134.360498 |
| HA-F2 | Rowan Bay | 56.695866 | -134.296529 |

Access: Access to and from the potential sources would be from logging roads to the coast at Washington, Rowan, Security or Saginaw Bays.

Geology: Two small plutons have intruded the sandstones between Rowan Bay and Security Bay on the northwest corner of Kuiu Island. Hornfelses were mapped as occurring along the edge of and between the two intrusive bodies. Geologic mapping was obtained from two sources (Muffler, 1967 and Brew et al., 1984). Within the following text, are instances where these two sources used differing bedrock symbols for similar rock types, Muffler's is shown first with Brew's succeeding. Muffler does not map the hornfels units. All bedrock symbols presented on the location maps are derived from Brew et al.

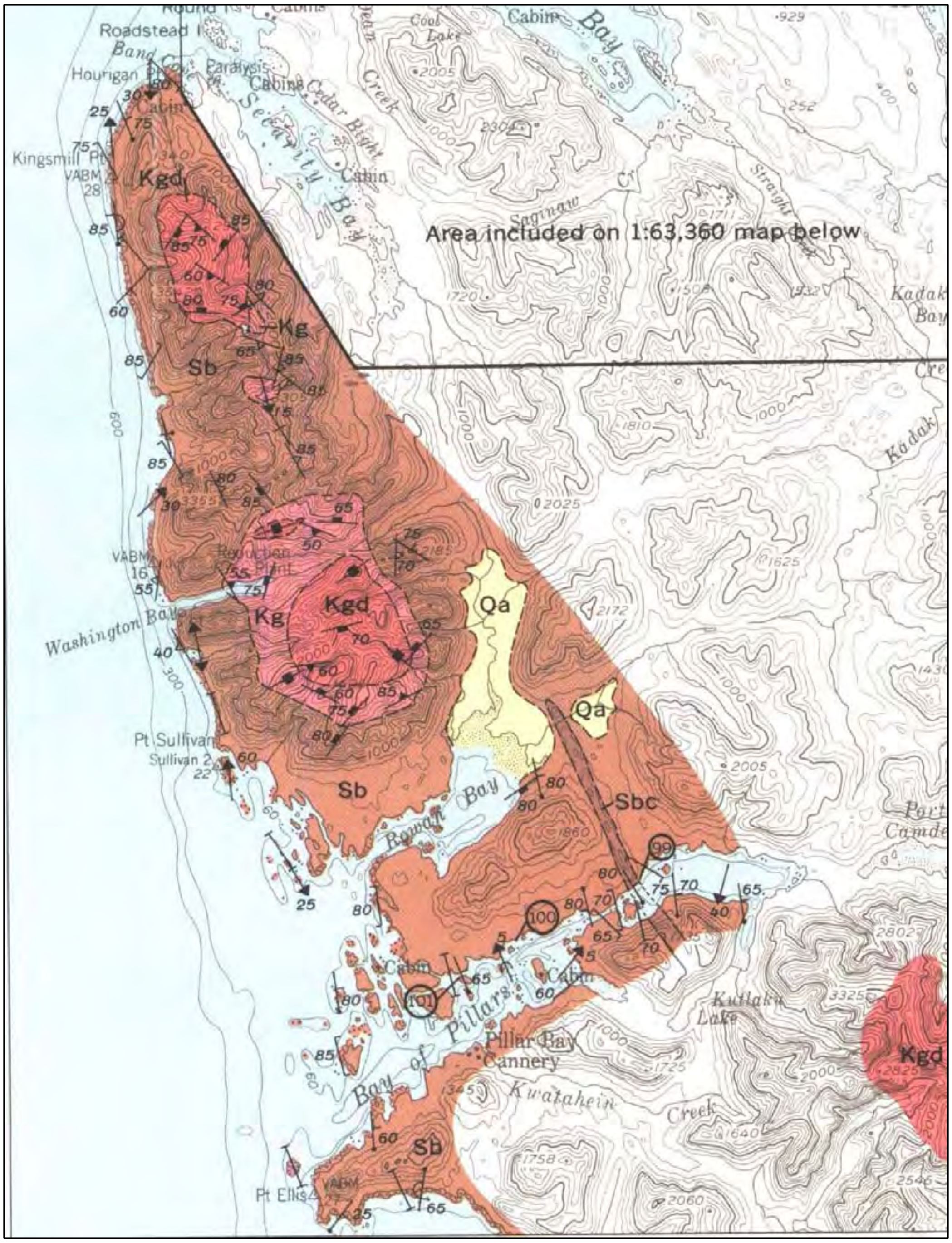
The Bay of Pillars Formation (Sb/Stbg) is composed primarily of medium-grained light-gray calcareous lithic sandstone. The sand grains are subangular to subrounded and consist of volcanic rock, calcite, slate, plagioclase (ranging in composition from albite to andesine), and quartz. Matrix usually makes up less than 15 percent of the rock, and calcite cement is commonly subordinate to the matrix.

The pluton southeast of Washington Bay is a composite Gabbro/Diorite (Kg/Tmdk) deposit and forms a roughly elliptical outer ring one-quarter to one and one-half miles wide. Foliation, where detected in gabbro, dips toward the center of the pluton. Where the ring is widest, at the northwestern part of the pluton, the rocks are predominantly fine to medium-grained layered hypersthene-augite-olivine gabbro. Biotite is a minor interstitial and secondary constituent that is conspicuous on weathered surfaces. The eastern and southern parts of the outer ring are composed of amphibole-bearing augite gabbro that contains minor biotite. The amphibole is light brownish green in thin section and is only slightly pleochroic; it replaces clinopyroxene. The core of this composite pluton is fine to medium-grained hornblende-biotite adamellite and granodiorite. The plagioclase is oligoclase. The hornblende is euhedral and is pleochroic from dark green to light tan.

A pluton west of Security Bay is dominantly fine to medium-grained quartz-bearing hornblende diorite (Kgd/Kwgd). Biotite-hornblende adamellite crops out at the south margin, and hornblende granodiorite near the northeast margin. Medium-grained hornblende gabbro forms the southeast projection of the pluton. The hornfels along the ridge between these two major plutons are intruded by numerous irregularly shaped plutonic bodies, most of which are too small to show at the map scale. Quartz-bearing hornblende-pyroxene diorite is dominant; biotitic hornblende-pyroxene gabbro and hornblende adamellite are subordinate (Muffler, 1967).

Hornfelsed Bay of Pillars Formation rocks of albite-epidote to hornblende hornfels (Tbh) and biotite-quartz-feldspar-hornfels (Kbh) facies metamorphic rocks; dominantly biotite-quartz-feldspar hornfels, fine to medium-grained, brownish-gray; original sedimentary structures and bedding of graywacke and mudstone turbidite sequence locally preserved; includes minor metaconglomerate. Metamorphosed from the Graywacke and Mudstone Turbidite Unit in Bay of Pillars Formation (Brew et al., 1984).

**RECONNAISSANCE GEOLOGIC MAP, NW KUIU ISLAND**
(Muffler, 1967)



Conclusions: There are no test results or other direct observations to verify the presence of rock capable of producing hard aggregate. However, the conditions exist for these types of rock (hornfels) to occur. Access to roads and locations on the coast where materials can be loaded on barges also appears to be available. These sources appear to warrant further consideration. Large-scale mapping indicates that similar intrusives intrude the Bay of Pillars Formation in the southern portion of the island but there is no detailed mapping available and it is unclear if hornfelses have formed (Gehrels and Berg, 1992).

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate, testing for acid rock drainage should be performed when using these sources.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Muffler, L.J. Patrick., 1967, Stratigraphy of the Keku Islets and neighboring parts of Kuiu and Kupreanof Islands, southeastern Alaska: U.S. Geological Survey Bulletin 1241-C, p. C1-C52, 1 sheet, scale 1:63,360.

# LOCATION MAP (HA-F1)


U.S.G.S. QUADRANGLE: PORT ALEXANDER (D-1) & (D-2)

Stbg-Sandstone
Tmdk-Gabbro/Diorite
Tbh/Kbh-Hornfels
Kwgd-Granodiorite

# POTENTIAL HARD AGGREGATE SOURCE KUIU ISLAND


BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
SECURITY BAY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kuiu Island\Acad\MS_Topo_Map_Rowan_Bay.DWG

Plotted 3/28/2013 2:22 PM by Pete Hardcastle

# LOCATION MAP (HA-F2)


U.S.G.S. QUADRANGLE: PORT ALEXANDER (C-1), (C-2), (D-1) & (D-2)

Stbg-Sandstone
Tmgk-Granite
Tmdk-Gabbro/Diorite
Tbh-Hornfels

# POTENTIAL HARD AGGREGATE SOURCE KUIU ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
ROWAN BAY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kuiu Island\Acad\MS_Topo_Map_Rowan_Bay.DWG

Plotted 3/28/2013 2:28 PM by Pete Hardcastle

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# WRANGELL ISLAND
# WRANGELL AIRPORT QUARRY

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: The Wrangell Airport Quarry is located at the north tip of Wrangell Island at the north end of the Wrangell Airport. It lies on a bedrock knob that forms Point Highfield. It consists of a tonalite intrusive, part of a series of Cretaceous tonalite (and other igneous) intrusives that stretch from Admiralty Island to Revillagigedo Island (Gehrels and Berg, 1992). The Wrangell Airport Quarry appears to be on Airport managed property. Two other intrusives near the City of Wrangell appear to be on state or private lands. Intrusives further to the south are in the Tongass National Forest.

WRANGELL ISLAND POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Nordic Values | Latitude | Longitude |
|---|---|---|---|---|
| HA-G1 | Wrangell Airport Quarry | 7, 17.1 | 56.487009 | -132.386582 |

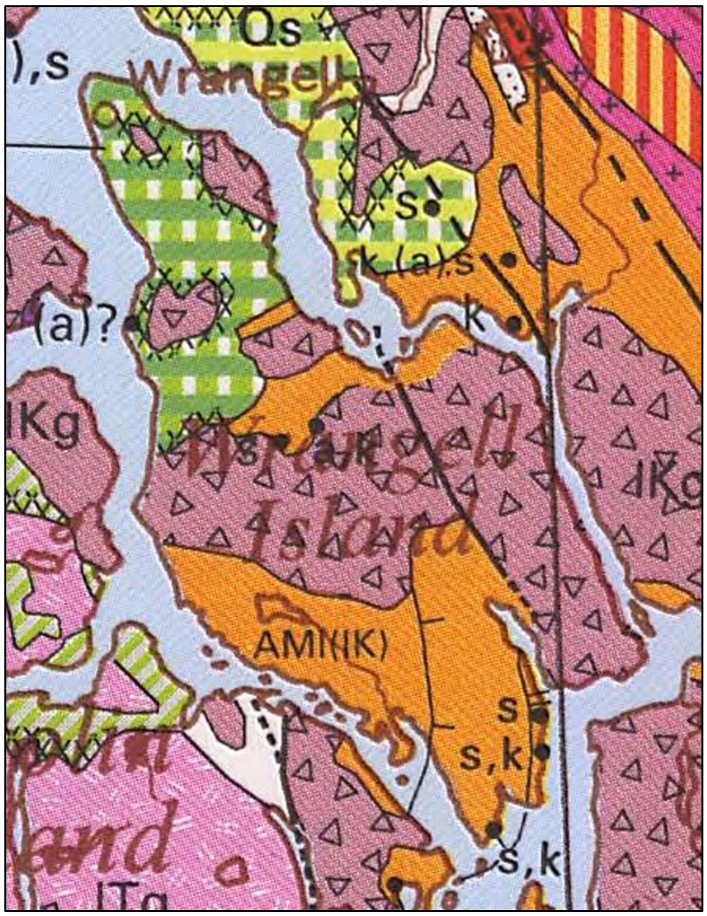
Access: By road from Wrangell. The other intrusive bodies on the island are accessible from a series of roads that run the length of the island or from the coast.

Geology: Bedrock on Wrangell Island has been described as follows (Brew et al., 1984)

Ktoc: Garnet biotite tonalite and minor granodiorite. Nonfoliated plagioclase rock; inequigranular to porphyritic; very fine to medium-grained; color index 14 to 29; medium-gray fresh; weathers light-gray; forms small elongate bodies less than 3 square kilometers in area; also makes up one larger body on northern Wrangell Island. Mineralogy includes reddish brown garnet, clinozoisite and local muscovite. Biotite and quartz is commonly interstitial to closely-spaced and includes plagioclase laths.

**WRANGELL ISLAND METAMORPHIC FACIES MAP**

(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Wrangell Island. The pink/purple units are igneous intrusives, the green/orange units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatched areas along the intrusives are the interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

Ktef: Hornblende biotite tonalite and granodiorite, quartz monzodiorite, and quartz diorite. Foliated to massive equigranular; average grain size is medium, fine-grained near some margins; color index 17 to 50; light to medium gray fresh, weathers to brownish to dark gray. Foliation varies both in direction and development and ranges from moderately developed on the west side to very well-developed on the east side of Wrangell Island; locally semischistose and cataclastic.

Ksp: Phyllite. Subgreenschist and greenschist facies metamorphic rocks inferred to be derived from fine-grained sediments; original textures and structures generally obscure; dominantly very fine-grained, dark-gray weathering, carbonaceous chlorite-quartz-feldspar phyllite; some interlayered graywacke and graywacke semischist; locally extensive layers and lenses of very fine-grained, light to dark-green weathering chlorite-rich phyllite interpreted to have been metamorphosed from fine-grained volcanic sediments.

Kss: Schist and Greenschist. Subgreenschist to greenschist facies rocks within the phyllite unit (Ksp); fine to medium-grained, relict pyroxene phenocrysts bearing epidote albite chlorite greenstone; poorly foliated, weathers dark greenish gray, grayish-green fresh; probably derived from intermediate composition volcanic breccias; forms poor rounded outcrops.

The units are shown on the maps on pages 2, 3A and 3B of this report. Hornfelses are noted by Brew et al. as occurring along the edges of the tonalite intrusives although he doesn't map them. Hornfelses are mapped in the phyllites and schists surrounding the tonalite intrusives on the north end of the island as shown on the metamorphic facies map above. They are not mapped surrounding the intrusives in the amphibolite-facies schist and gneiss on the south end of the island (Dusel-Bacon et al., 1996). Karl et al. in 1999 indicated hornfels can be found over the entire island. Nordic abrasion values of 7 and 17.1, apparently from the Wrangell Airport Quarry, have been reported. The value of 7 was taken from a map of Alaska provided by DOT&PF. The 17.1 value was provided by DOT&PF Southeast Region with the laboratory report being attached to this report. The location, weathering and type of rocks tested are unknown. It is possible the 17.1 value may represent a test in the tonalite and the 7 may represent a test in the hornfels, or the test may represent different grain sizes in the tonalite.

Conclusions: There appears to be some rock capable of producing hard aggregate at the Wrangell Airport Quarry, however further investigations will be necessary to delineate where and how much is available. Additional rock with potential for hard aggregate production may be available on the Wrangell Island.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. eological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance geologic map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30 p., 1 sheet, scale 1:150,000.

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

| | | | |
|---|---|---|---|
| PRECONSTRUCTION | | CONSTRUCTION | X |
| ACCEPTANCE | | QUALITY | X |
| ASSURANCE | | INFORMATION | |

TEST OF **BORROW 10" MINUS SHOT ROCK (QUARRY ROCK FOR)** ITEM NO. **203(19)** LAB NO. **11C-438**

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | **HPRM-0003(135)** | PROJECT NAME | **WRG WRANGELL ROAD AND UTILITY IMPROVEMENT** | | |
| SAMPLED FROM | **STOCKPILE** | EXAMINED FOR | **QUALITY** | | |
| DEPTH | | FIELD NO. | **Q-SR-1** | DATE SAMPLED | **08/25/11** |
| SOURCE | **AIRPORT PIT** | SUBMITTED BY | **B. KLEIN** | DATE RECEIVED | **08/25/11** |
| LOCATION | **WRANGELL, ALASKA** | REPRESENTS | **SOURCE** | DATE REPORTED | **09/12/11** |

| % PASSING SIEVE | AS RECEIVED QUALITY | QUALITY | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #20 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| 0.02 MM | | | |
| .005 MM | | | |

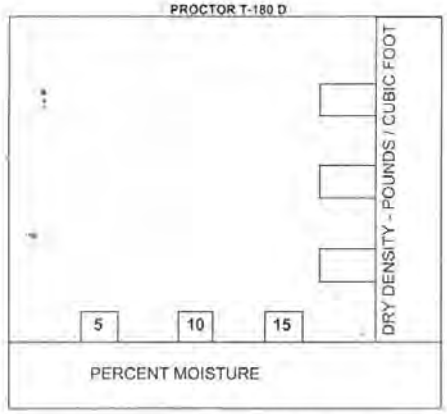
| PROPERTIES | | | |
|---|---|---|---|
| LIQUID LIMIT | | NV | |
| PLASTIC INDEX | | NP | 6 MAX |
| DELETERIOUS | FREE | FREE | FREE |
| FRACTURE % | 100 | | 50 MIN 2 FACES |
| THIN ELONGATED % | | | |
| FINENESS MODULUS | | | |
| ORGANIC CONTENT % | | | |
| AASHTO CLASS | | | |

| QUALITY | COARSE | FINE | |
|---|---|---|---|
| DEGRADATION VALUE | 81 | | |
| L.A. ABRASION % B | 34 | | 30 MAX |
| NORDIC ABRASION % | 17.1 | | |
| BULK SPG | 2.678 | | |
| BULK SSD SPG | 2.701 | | |
| APPARENT SPG | 2.742 | | |
| ABSORPTION % | 0.9 | | |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO. | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




REMARKS: **SENT TO ANCHORAGE FOR FURTHER TESTING**

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffrey A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: 9/26/11
REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED.
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES.

State of Alaska
Department of Transportation & Public Facilities
Central Materials Lab
5750 East Tudor Road
Anchorage, AK 99507
Phone (907) 269-6200 FAX (907) 269-6201

**Laboratory Report**

Quality
Laboratory No.: 2011A-3004

Name: WRG Wrangell Road and Utility Improvements
Project No.: 68828 / HPRM-0003(135)
Sample: Borrow 10 Inch minus shot rock
Item/Specification No.: 203(19)
Field No.: 11C-438
Sampled From: Stockpile at Crusher
Date Sampled: 08/25/2011
Source: Airport Quarry
Quantity Represented: Source
Date Received: 09/01/2011
Location: Wrangell
Submitted By: J. Hart
Date Completed: 09/08/2011
Examined For: Sulfate Soundness
Date Reported: 09/08/2011

| Sieve Analysis | Lab | Field | Specs |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1 1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| 1/4" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| .02 mm | | | |
| .002 mm | | | |
| Fineness Modulus | | | |
| % Fracture | | | |
| Single Face | | | |
| Double Face | | | |
| Atterburg Limits | | | |
| Liquid Limit | | | |
| Plastic Limit | | | |
| Plastic Index | | | |
| Flat / Elongated | | | |
| 1:3 | | | |
| 1:5 | | | |

| | Lab | Specs |
|---|---|---|
| % Organic | | |
| % Natural Moisture | | |
| pH of Soil | | |
| % Sticks & Roots | | |
| Dry Unit Weight, pcf | | |
| % Lightweight Particles | | |
| Uncompacted Voids of FA | | |
| Specific Gravity of Soil | | |
| Sand Equivalent | | |
| Expansion Breakdown | | |

| | | Coarse Lab | Coarse Specs | Fine Lab | Fine Specs |
|---|---|---|---|---|---|
| | Friable Particles | | | | |
| AASHTO T104 | Sulfate Soundness, % Loss | 1 | 9 max | | |
| | Agg. Specific Gravity, Bulk | | | | |
| | Agg. Specific Gravity, SSD | | | | |
| | Agg. Specific Gravity, App. | | | | |
| | % Absorption | | | | |
| | LA Abrasion, Total % Loss | | | | |
| | @ 100 revs % Loss | | | | |
| | Degradation | | | | |
| | Nordic Abrasion | | | | |

FSV Class
AASHTO Class
Unified Class

% +3"
% Gravel
% Sand
% Silt/Clay
% Clay

California Bearing Ratio
Organic Impurities Plate #3
Mortar Making Properties of Sand - Compressive Strength

| Age | Sample | Control | Ratio | Spec |
|---|---|---|---|---|
| 7 Day | | | | |
| 28 Day | | | | |

**Remarks:**

DRAFT

Signature:

Newton J. Bingham, PE
Regional Materials Engineer

D5 The Material as Submitted Conforms to Specifications
Yes [X] No [ ] NA [ ]

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED

# LOCATION MAP (HA-G1)


U.S.G.S. QUADRANGLE: PETERSBURG (B-1), (B-2), (C-1) & (C-2)

Ktoc/Ktif-Tonalite

Ksp-Phyllite

Kss-Schist

# POTENTIAL HARD AGGREGATE SOURCE WRANGELL ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
WRANGELL AIRPORT QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

Plotted 3/28/2013 11:11 AM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Wrangell\Acad\MS_Topo_Map_Wrangell_Island.dwg

# SITE MAP (HA-G1)


BASE MAP IS JULY 24, 2012 GEOEYE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

Ktoc-Tonalite
Kss-Schist

# POTENTIAL HARD AGGREGATE SOURCE WRANGELL ISLAND

0 600 1200 2400 3600

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/4/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY

WRANGELL AIRPORT QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 11:15 AM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Wrangell\Acad\MS_Site_Map_Wrangell_Island.dwg

# SITE MAP (HA-G1)


BASE MAP IS JULY 24, 2012 GEOEYE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

Ktoc-Tonalite
Kss-Schist

# POTENTIAL HARD AGGREGATE SOURCE WRANGELL ISLAND

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 2/4/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

WRANGELL AIRPORT QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Wrangell\Acad\MS_Site_Map_Wrangell_Island.dwg

Plotted 3/28/2013 11:18 AM by Pete Hardcastle

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# ZAREMBO ISLAND
# NORTHERN ZAREMBO ISLAND

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: Zarembo Island is located to the west of Wrangell Island and south of Kupreanof Island. The bedrock on Zarembo Island can be separated into two parts, a northern portion generally composed of Cretaceous granodiorite to diorite intrusives surrounded by semischist and phyllite and a southern portion generally composed of Tertiary to Quaternary volcanic and igneous rocks. The two parts are separated by a wide valley that cuts across the island from northwest to southeast. Hornfels zones are mapped along the edges of the intrusives in the northern part of the island (Dusel-Bacon et al., 1996). These areas may be sources of hard aggregates. The approximate locations of the mapped hornfels zones are shown on the Location Maps attached to this report.

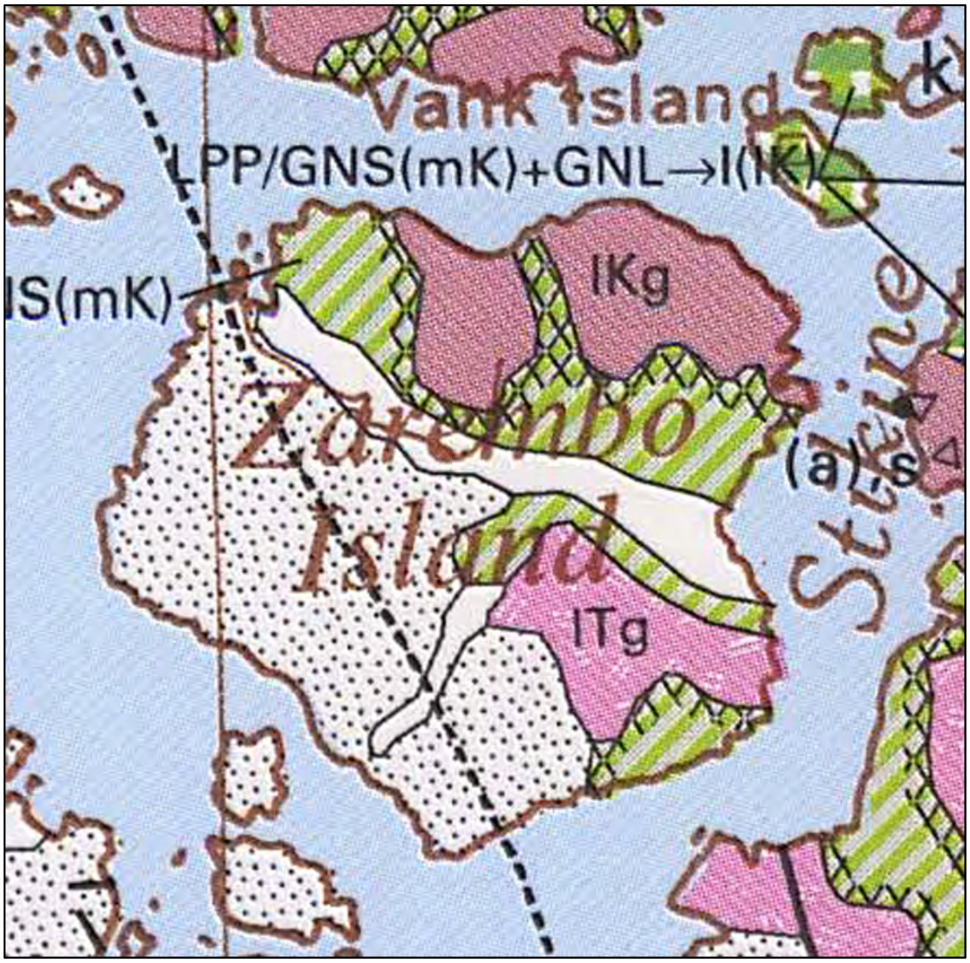
ZAREMBO ISLAND POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-H1 | Northern Zarembo Island | 56.401017 | -132.785403 |

Zarembo Island is within the Tongass National Forest. All lands appear to be managed by the U.S. Forest Service. There are numerous existing quarries shown on the U.S.G.S. topographic maps. The U.S. Forest Service may have information available about these quarries.

Access: There appears to be numerous Forest Service roads crossing the island, particularly on the northern part (See Location Map 2B) and several small harbors where aggregate could be loaded.

**ZAREMBO ISLAND METAMORPHIC FACIES MAP**
(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Zarembo Island. The purple units are igneous intrusives, the green units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross hatch along the edges of the intrusives are the interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

<u>Geology:</u> Bedrock on northern Zarembo Island has been described as follows (Brew et al., 1984).

<u>Ktif (IKg):</u> Hornblende-biotite tonalite, granodiorite, quartz monzodiorite, and quartz diorite: Equigranular to sparsely porphyritic, massive to weakly foliated; medium-grained; color index 14 to 52; light gray fresh, weathers yellowish-gray, elongate very fine-grained dioritic and local ultramafic inclusions.

<u>Kqop (IKg):</u> Biotite-epidote-hornblende-quartz-monzodiorite: Locally foliated; plagioclase phophyritic with medium and coarse-grained phenocrysts (to 12mm), fine to medium-grained

groundmass to 3mm and a color index range of 17 to 48; weathers brownish-gray, gray and white fresh; body margins are commonly more mafic and have a very fine to fine-grained ground groundmass.

Mzs: Semischist and phyllite: Metamorphosed from graywacke and siltstone; Low grade (probably sub-greenschist facies) metamorphic rocks; locally highly folded; generally poorly foliated but finer-grained phases have good cleavage; brownish-gray fresh, gray to brown weathered; relict textures and sedimentary structures indicate derivation from a graywacke and siltstone or mudstone turbidite sequence.

Mzv: Greenschist and greenstone: Metamorphosed from intermediate to mafic volcanic rocks. Greenschist, greenstone, phyllite, minor semischist; weathers light to dark green, locally brownish pillow breccia, agglomerate flows, and possible tuffs.

KJsv: Brothers Volcanics/Douglas Island Volcanics: Augite bearing flows, volcanic breccias and intercalated tuff, volcanic graywacke, phyllite and slate. Andesitic to probably basaltic composition; weathers dark greenish-gray, gray, and green; generally lighter colored where fresh; relict augite phenocrysts conspicuous in most outcrops.

Units are outlined on the Location Map on Page 2A of this report. Hornfelses are mapped by Dusel-Bacon et al. as occurring along the edges of the intrusives as shown on the Zarembo Island Metamorphic Facies Map on Page 1B. There were no Nordic Abrasion test results found for Zarembo Island.

Conclusions: Rock in the hornfels zones on the northern part of Zarembo Island may be capable of producing hard aggregate, however additional investigations will be necessary to delineate where and how much material is available.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of Southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance geologic map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30p., 1 sheet, scale 1:150,000.

# LOCATION MAP (HA-H1)


U.S.G.S. QUADRANGLE: PETERSBURG (B-2) & (B-3)

# POTENTIAL HARD AGGREGATE SOURCE ZAREMBO ISLAND

Ktif/Kqop-Intrusives
Mzs/Msv-Schist, Phyllite & Greenstone
KJvs-Volcanics
Hornfels zone

0 0.75 1.5 3 4.5

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
NORTHERN ZAREMBO ISLAND

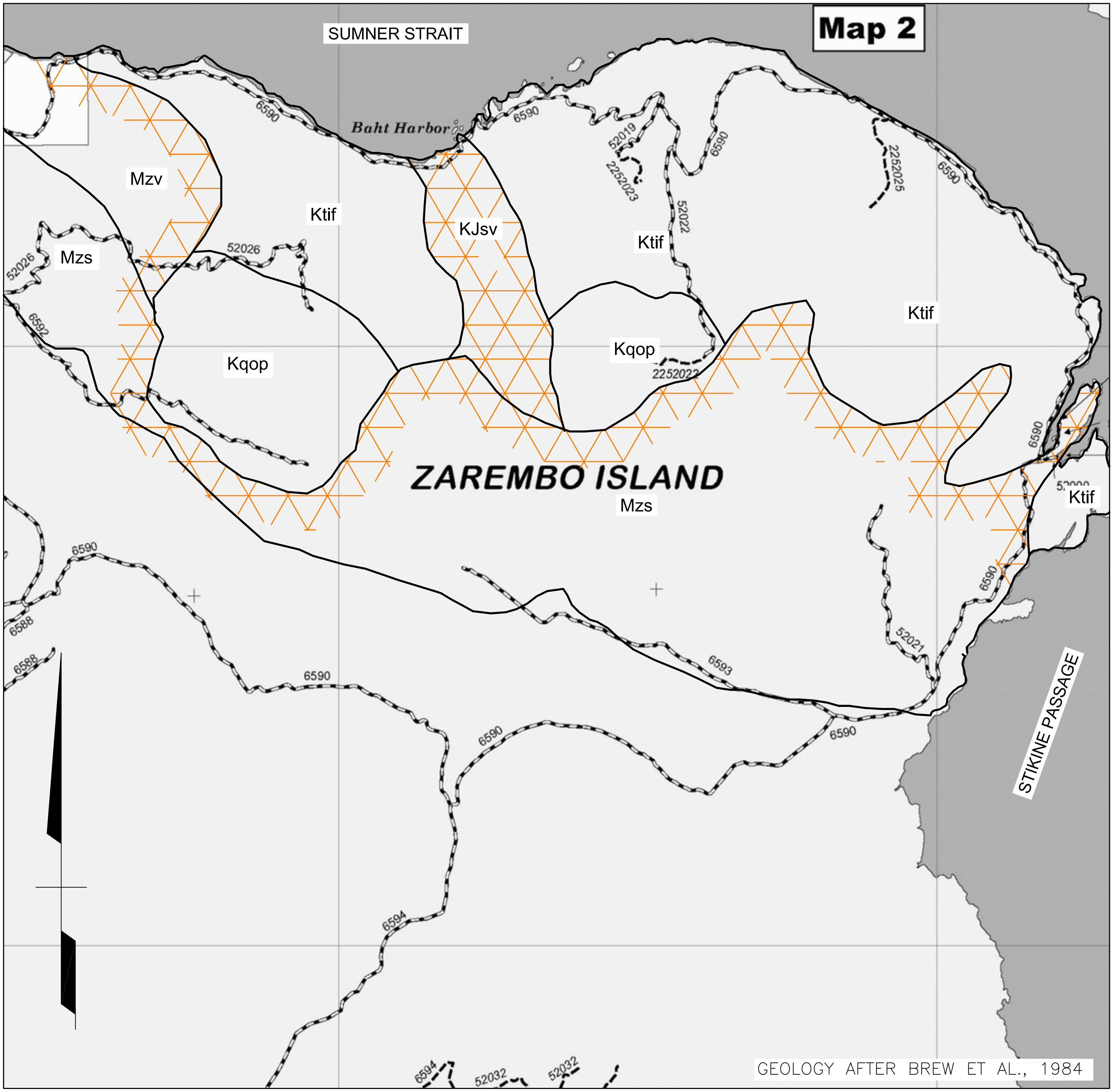
| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

Plotted 3/28/2013 11:07 AM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Aggregate Feasibility Study\Earth\Hard Aggregate Location Study\Zarembo\Acad\MS_Topo_Map_Zarembo_Island.dwg

# LOCATION MAP (HA–H1)




ROAD LAYOUT FROM U.S.FOREST SERVICE MAP, JANUARY,2013

# POTENTIAL HARD AGGREGATE SOURCE ZAREMBO ISLAND

Ktif/Kqop-Intrusives
Mzs/Msv-Schist, Phyllite & Greenstone
KJvs-Volcanics
Hornfels zone

0 0.75 1.5 3 4.5

GRAPHIC SCALE IN MILES

BASE MAP FROM MOTOR VEHICLE USE MAP
TONGASS NATIONAL FOREST WRANGELL RANGER DISTRICT

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

NORTHERN ZAREMBO ISLAND

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Zarembo\Acad\MS_Topo_Map_Zarembo_Island.dwg

Plotted 3/28/2013 11:06 AM by Pete Hardcastle

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# ETOLIN ISLAND
# NORTHERN AND CENTRAL ETOLIN ISLAND

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: Etolin Island is located to the southwest of Wrangell Island and southeast of Zarembo Island. The island is generally composed of Cretaceous and Tertiary granitic rocks of the Kuiu-Etolin Volcanic Plutonic Belt surrounded by semischist and phyllite of the Seymour Canal Formation. Hornfelses are inferred along the edges of the intrusives (Dusel-Bacon et al., 1996). These may be sources for hard aggregates. Locations of the mapped hornfelses are shown on the location map attached to this report and on Etolin Island Metamorphic Facies Map shown on Page 1C. The island is in the Tongass National Forest and is managed by the U.S. Forest Service. The south end of the island has been designated as the South Etolin Wilderness and was not considered for hard rock sources during this study.

ETOLIN ISLAND POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-I1 | Northern Etolin Island | 56.246532 | -132.470702 |
| HA-I2 | Central Etolin Island | 56.144496 | -132.464071 |

Access: There appear to be numerous forest service roads on the island, particularly on the north half in addition to several small harbors. There are numerous existing quarries shown on the U.S.G.S. topographic maps. The U.S. Forest Service may have information available about these sites.

Geology: Bedrock on Etolin Island has been described as follows (Brew et al., 1984 and Karl et al., 1999):

Ktef: Hornblende-biotite-tonalite and granodiorite, quartz monzodiorite, and quartz diorite: Foliated to massive equigranular; average grain size is medium, fine-grained near some margins; color index 17 to 50; light to medium gray fresh, weathers to brownish to dark gray. Foliation varies both in direction and development, and ranges from moderately developed on the west side to very well developed on the east side; locally semischistose and cataclastic.

Tmae: Alkali granite to granite: Biotite amphibole alkali granite, granite, and alkali quartz syenite with minor amounts of quartz syenite to syenite. Massive, nonfoliated; equigranular to seriate; medium to very coarse-grained; color index 01 to 13; weathers from a distinctive pale orange to white; generally homogeneous at outcrop scale.

Tmge: Granite: Hornblende biotite granite, alkali granite, quartz syenite, and alkali quartz syenite: Massive, nonfoliated; equigranular to seriate; medium to coarse-grained; color index 01 to 07; weathers from a distinctive pale orange to white; often rusty weathering; generally quite homogenous at outcrop scale.

Tmme: Migmatitic granitic rock: Hornblende biotite pyroxene quartz monzodiorite, quartz monzonite, granodiorite, quartz diorite, and diorite as well as granite, alkali granite, and quartz syenite. Massive, extremely heterogeneous, and generally nonfoliated; equigranular to seriate to porphyritic; generally fine to medium-grained; color index 03 to 50.

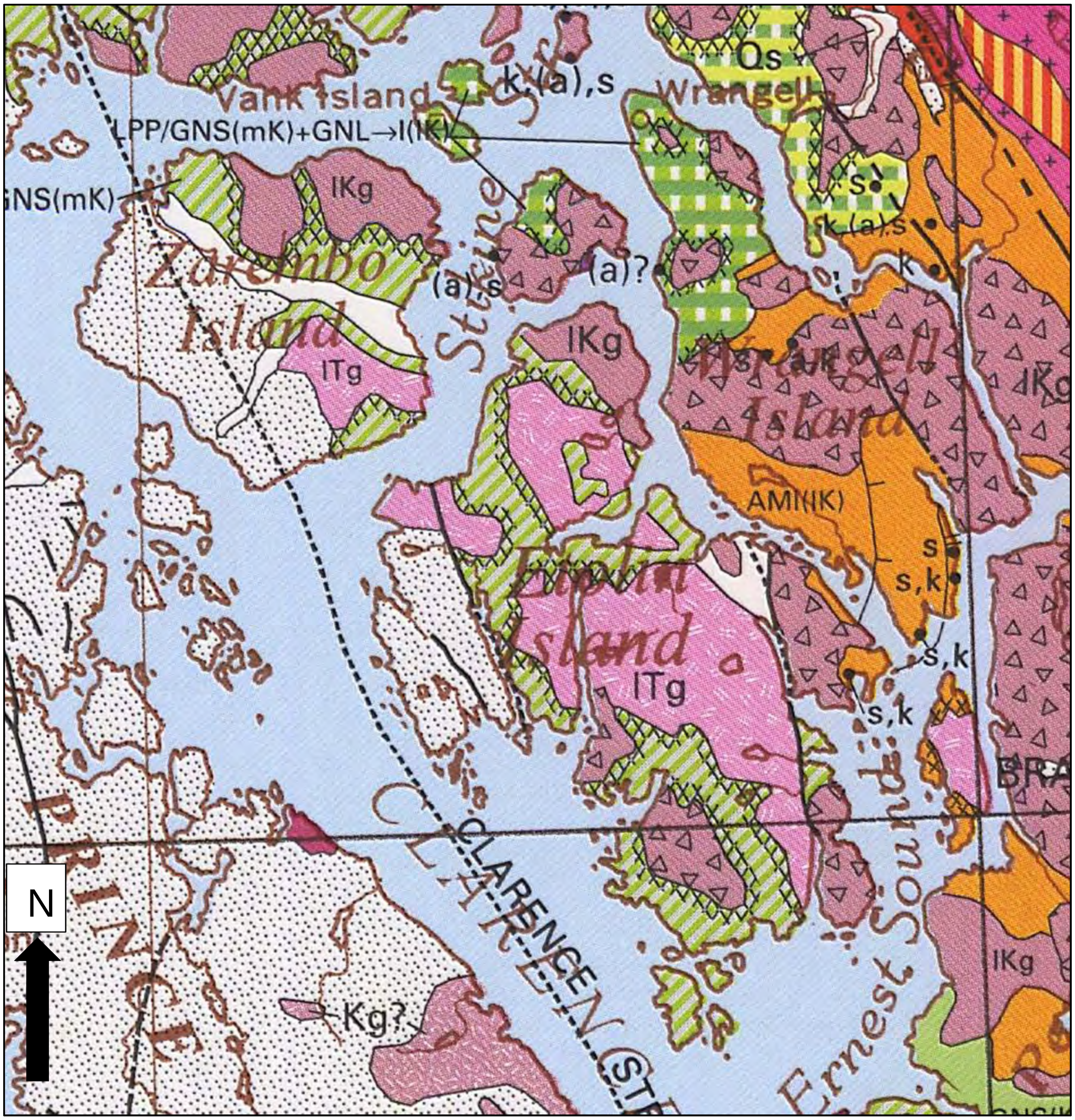
Ktgp: Biotite tonalite quartz diorite, and granodiorite: Porphyritic and foliated: medium to coarse-grained; color index 11 to 35; cut by pegmatite and basalt dikes; local cataclastic texture; inclusions of country rock; foliation parallels that of the country rock; petrographic features include zoned, complexly twinned plagioclase, quartz, interstitial K-feldspar, partly chloritized biotite, epidote, minor local hornblende; and garnet, sphene, apatite and allanite as accessories.

KJsv: Brothers Volcanics/Douglas Island Volcanics: Augite bearing flows, volcanic breccias and intercalated tuff, volcanic graywacke, phyllite and slate. Andesitic to probably basaltic composition; weathers dark greenish-gray, gray, and green; generally lighter colored where fresh; relict augite phenocrysts conspicuous in most outcrops.

KJss: Seymour Canal Formation: Graywacke, slate, and minor conglomerate. Composed largely of volcanic debris, except for the conglomerates, which are polymictic and contain granitic clasts; most are turbidites, but nothing more is known of the depositional environment: weathers dark greenish-gray, brownish gray, and very dark gray; graywacke and slate/argillite are locally calcareous and lighter colored; sedimentary structures common, although few directional features have been noted.

These units are outlined on the Location Map on Page 2A of this report. Hornfelses were mapped by Dusel-Bacon et al. as occurring along the edges of the intrusives as shown on the map on Page 1C. There were no Nordic Abrasion test results available for this island.

**ETOLIN ISLAND METAMORPHIC FACIES MAP**
(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Etolin Island. The pink/purple units are igneous intrusives, the green units are metamorphic rocks generally derived from sedimentary and volcanic units and the cross-hatched areas along the intrusives are the interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas are unmetamorphosed rocks.

Conclusions: There appears to be rock capable of producing hard aggregate on Etolin Island, however additional investigations will be necessary to delineate where and how much material is available.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance geologic map of the Duncan Canal-Zarembo Island area, southeastern Alaska: U.S. Geological Survey Open-File Report 99-168, 30 p., 1 sheet, scale 1:150,000.

# LOCATION MAP (HA-I1)


U.S.G.S. QUADRANGLE: PETERSBURG (A-2), (A-3), (B-2) & (B-3)

Ktef/Kqop-Intrusives
Mzs/Msv-Schist, Phyllite & Greenstone
KJsv-Volcanics
Hornfels zone

# POTENTIAL HARD AGGREGATE SOURCE ETOLIN ISLAND

0 0.75 1.5 3 4.5

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
NORTHERN ETOLIN ISLAND

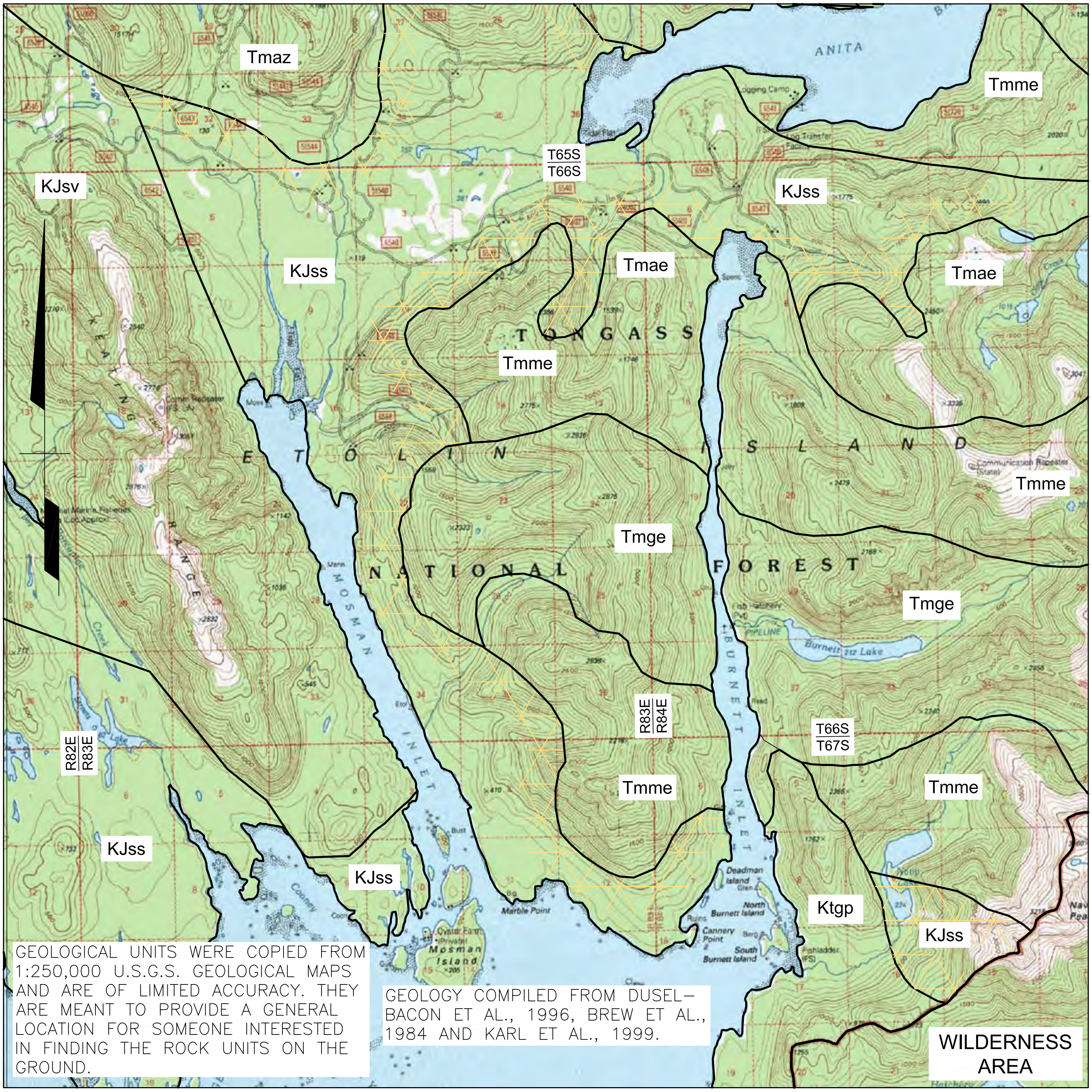
| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Plotted 3/28/2013 3:29 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Etolin Island\Acad\MS_Topo_Map_Etolin_Island.dwg

# LOCATION MAP (HA-12)




U.S.G.S. QUADRANGLE: PETERSBURG (A-2), (A-3), (B-2) & (B-3)

# POTENTIAL HARD AGGREGATE SOURCE ETOLIN ISLAND

Ktgp/Tmme/Tmge/Tmae/Tmaz - Granitic Rocks
KJss-Sedimentary Rocks
KJsv-Volcanics
Hornfels zone

0 0.75 1.5 3 4.5

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
CENTRAL ETOLIN ISLAND

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. / CHECKED C.H.R. | P.K.H. / DATE FEB 2013 | 2B |

Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Etolin Island\Acad\MS_Topo_Map_Etolin_Island.dwg

Plotted 3/28/2013 3:30 PM by Pete Hardcastle

# STATEWIDE MATERIAL SITE INVENTORY

## POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# KRUZOF ISLAND HORNFELS

March 8, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: This site is located in the middle of Kruzof Island to west of Sitka. Mount Edgecumbe, an active volcano, lies on the south end of the island. Bedrock on the south end of the island consists of Quaternary volcanic rocks and on the north end there are sedimentary rocks of the Sitka Graywacke formation and metamorphic rocks of the Khaz Formation. A Tertiary igneous pluton intruded the central portion of the island where extensive hornfelses are mapped along its northern boundary (Loney et al., 1975). The central part of the island appears to be located in the Tongass National Forest and is managed by the U.S. Forest Service, Sitka Ranger District.

KRUZOF ISLAND POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-J1 | Kruzof Island | 57.200676 | -135.713812 |

Access: Based on the USGS geologic maps and Forest Service road maps, Forest Service roads reach up from the south to the north edge of the intrusive (See Location Map 2B). There is also an existing road in the valley to the north. Forest Service roads may not be useable as haul roads. Access to the island is by sea approximately 12 miles from Sitka. There do not appear to be any port facilities; barges would be required to land on the beach.

Geology: Bedrock on Kruzof Island has been described as follows (Loney et al., 1975):

Tegd: A pluton composed of Tertiary biotite granodiorite, muscovite-bearing biotite adamellite, and muscovite-bearing biotite albite granite cut by albite dikes and biotite-bearing alaskite.

Tet: Tertiary Hornblende-biotite tonalite.

Qe: Edgecumbe Volcanics consist of gently dipping flows, composite cones and air-fall ash and lapilli from the eruptions of Mount Edgecumbe.

KJsh: A Hornfels Zone.

KJs: The Sitka Graywackes are poorly sorted fine to coarse-grained sandstones. The poor sorting results from the amount of silt and clay size matrix material present. Most of the matrix has been neocrystallized to quartz, muscovite, albite, chlorite, epidote, sphene, calcite, tourmaline and prehnite. There are interbedded shale or argillite beds. The Sitka Graywacke is tightly and complexly folded.

JTRk: The Khaz Formation is a chaotic formation composed largely of greenstone, greenschist, graywacke, and phyllite with minor limestone. The deposit was intensely deformed. Typical cataclasites consist of streaked greenschist and phyllite in which lenses of more resistant rock swim in a highly foliated mylonitic matrix. The matrix consists of epidote, chlorite, muscovite, sphene, calcite, and angular grains of quartz and plagioclase.

Qu: Undifferentiated Surficial deposits.

Contact metamorphism is mapped as prevalent where sedimentary rocks predominate. The sedimentary rocks are classified as clastic sedimentary, volcanic, and carbonaceous rocks, undivided of Cretaceous to Permian age. The fine-grained contact metamorphic rocks as well as fine-grained margins of the plutonic rocks may show promise for a source of hard aggregate.

Conclusions: There are no test results or other direct observations to verify the presence of rock capable of producing hard aggregate at Kruzof Island. However, the conditions exist for hard aggregate rock (hornfels) to occur across the middle of the island. Access to these potential hornfelses along Forest Service roads and then access to locations on the coast where materials can be loaded on barges may be available. It is unknown how much hornfels rock is available. These sources appear to warrant further consideration.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as you move away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Loney, R.A., Brew, D.A., Muffler, L.J.P., and Pomeroy, J.S., 1975, Reconnaissance geology of Chichagof, Baranof, and Kruzof islands, southeastern Alaska: U.S. Geological Survey Professional Paper 792, 105 p., 4 sheets, scale 1:250,000.

# LOCATION MAP (HA–J1)


GEOLOGICAL UNITS WERE COPIED FROM 1:250,000 U.S.G.S. GEOLOGICAL MAPS AND ARE OF LIMITED ACCURACY. THEY ARE MEANT TO PROVIDE A GENERAL LOCATION FOR SOMEONE INTERESTED IN FINDING THE ROCK UNITS ON THE GROUND.

GEOLOGY AFTER: LONEY ET AL., 1975

U.S.G.S. QUADRANGLE: SITKA (A–5), (A–6), (B–5) & (B–6)

KJsh–Hornfels Zone
Tegd/Tet/Qe–Igneous Rock
KJs–Sitka Graywacke
JTRk–Khaz Formation
Qu–Suficial Deposits

# POTENTIAL HARD AGGREGATE SOURCE KRUZOF ISLAND

0 1 2 4 6

GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
KRUZOF ISLAND

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2A |
| | CHECKED C.H.R. | DATE MAR 2013 | |

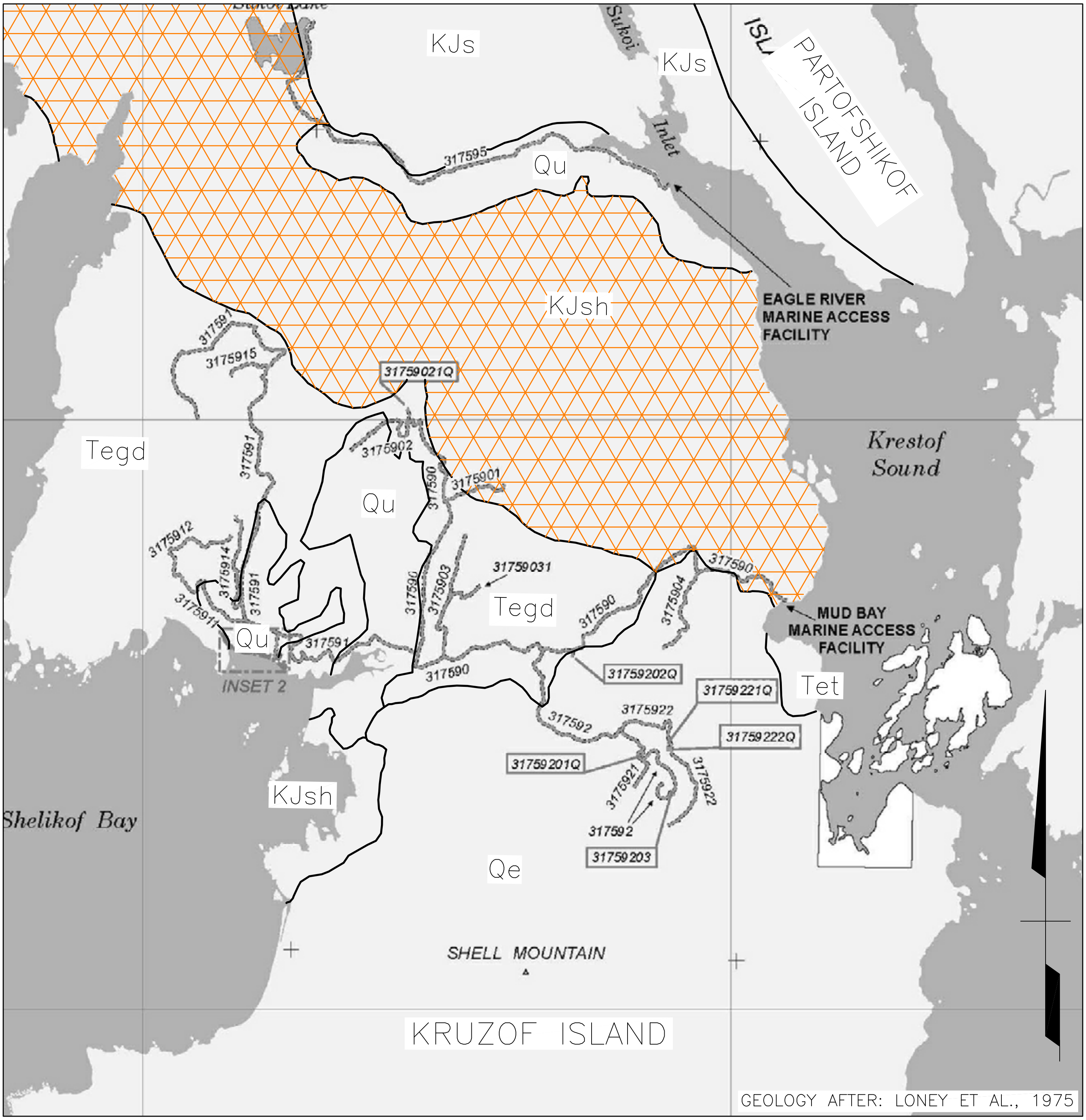
Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Plotted 3/28/2013 1:51 PM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kuzof Island\Acad\MS_Topo_Map_Kruzof_Island.dwg

# LOCATION MAP (HA-J1)




ROAD LAYOUT FROM U.S.FOREST SERVICE MAP, JANUARY,2013

# POTENTIAL HARD AGGREGATE SOURCE KRUZOF ISLAND

0 0.75 1.5 3 4.5

GRAPHIC SCALE IN MILES

KJsh–Hornfels
Tegd/Tet/Qe–Igneous
KJs–Sitka Graywacke
Qu–Suficial Deposits

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
KRUZOF ISLAND

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2B |
| | CHECKED C.H.R. | DATE MAR 2013 | |

BASE MAP FROM MOTOR VEHICLE USE MAP
TONGASS NATIONAL FOREST SITKA RANGER DISTRICT

Prepared By:
R&M CONSULTANTS, INC.

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Kuzof Island\Acad\MS_Topo_Map_Kruzof_Island.dwg

Plotted 3/28/2013 1:53 PM by Pete Hardcastle

# STATEWIDE MATERIAL SITE INVENTORY

## POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# REVILLAGIGEDO ISLAND KETCHIKAN

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

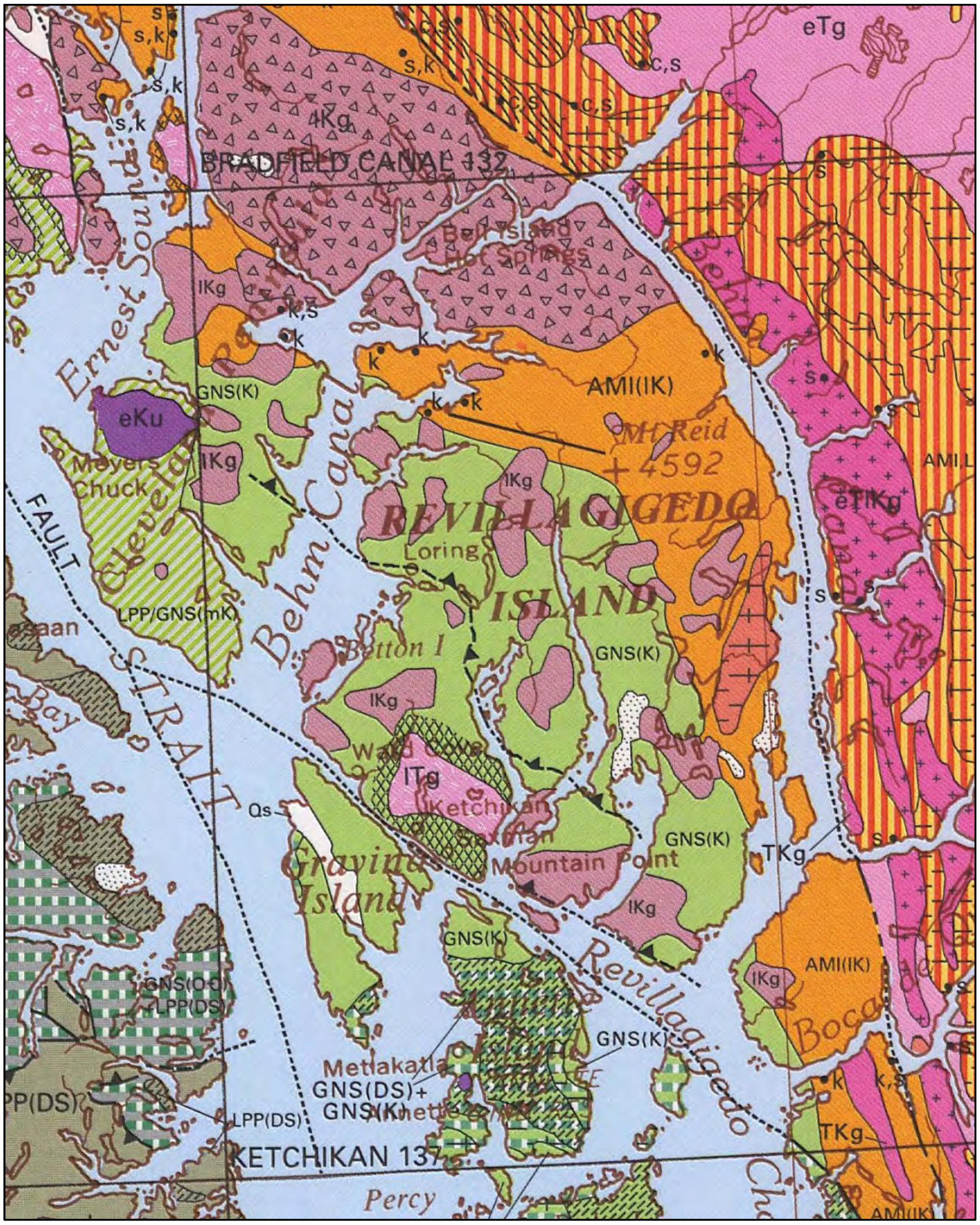
General Site Description: The site is located on southern Revillagigedo Island near Milepost 9 of the South Tongass Highway, northeast of Herring Bay. A new aquarium is being constructed nearby. A gabbro pluton has been intruded into the metamorphosed sedimentary and volcanic rocks at this location. The altered rock consists of a spotted hornfels adjacent to the gabbro pluton surrounded by spotted schists. Generally, the alteration decreases with distance from the edge of the gabbro pluton. The site north of Herring Bay appears to be on State Land.

REVILLAGIGEDO ISLAND POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-K1 | Ketchikan | 55.333238 | -131.507959 |

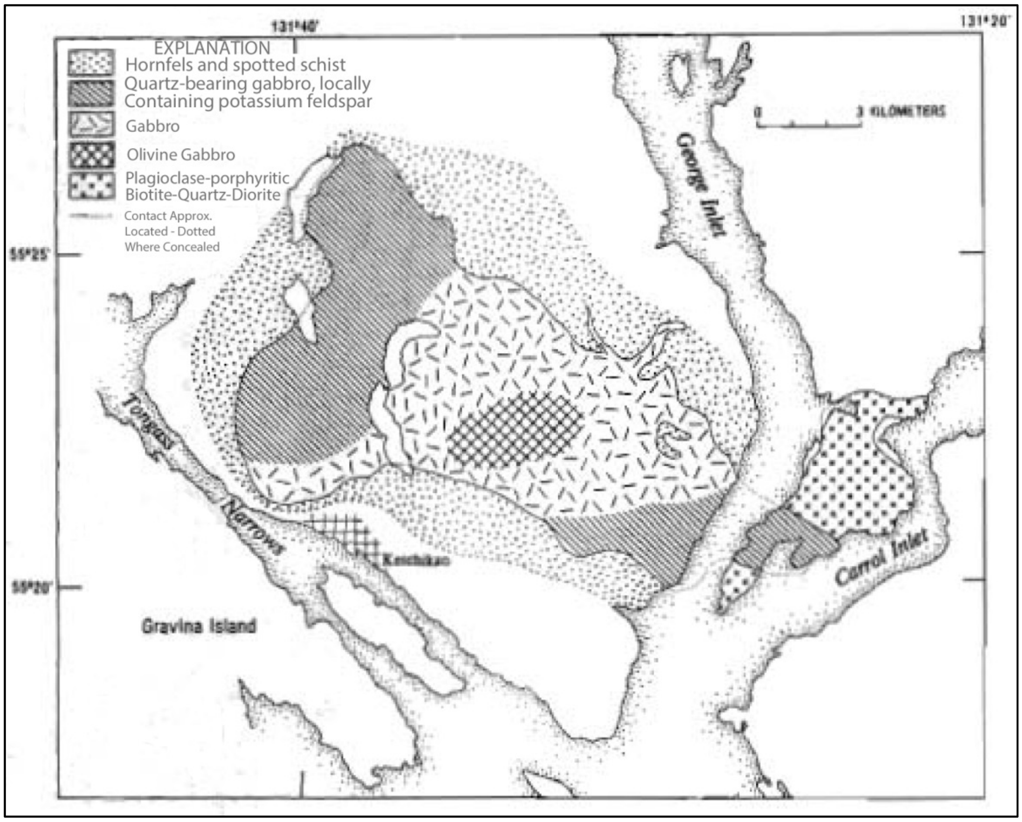
Access: Directly from the South Tongass Highway or from the beach. The water depth increases quickly in front of the beach.

**REVILLAGIGEDO ISLAND AREA METAMORPHIC FACIES MAP**
(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on Revillagigedo Island. The pink/purple units are igneous intrusives, the green/gray-green and orange units are metamorphic rocks generally derived from sedimentary and volcanic units, and the cross hatched area along the intrusives are the interpreted hornfels zones. These zones are subject to differing interpretations by different authors.

**KETCHIKAN GABBRO PLUTON MAP**
(Modified from Koch & Elliott, 1984)




<u>Geology:</u> Bedrock at the Ketchikan Hornfels site has been described as follows (Berg et al., 1988):

> <u>Tgb (ITg):</u> A gabbro complex that forms an elongate pluton. An olivine-bearing two-pyroxene gabbro that makes up the core of the complex: biotite-hornblende two-pyroxene gabbro surrounds the core; and a discontinuous zone of quartz-bearing gabbro underlies two areas at the ends of the complex. The gabbro intrudes the metasedimentary and metavolcanic rocks and quartz diorite intrusive rocks. Thermal metamorphism has produced a zone of spotted hornfels and spotted schist apparently as wide as 3 kilometers in the adjoining country rocks. Generally, the spotted schist still maintains its schistosity, while the hornfels is fine-grained and massive.
>
> <u>MzPzms:</u> Metasedimentary rock: Rocks derived from pelitic and semipelitic flysch interbedded with relatively minor amounts of andesitic or basaltic volcanic or volcaniclastic rocks. The prevailing lithology is dark-gray and silvery-gray phyllite and fine-grained semischist; there are subordinate layers of green phyllite and semischist.
>
> <u>MzPzmv:</u> Metavolcanic rocks: Rocks derived primarily from submarine andesitic or basaltic lava flows, tuff, and agglomerate and from subordinate gradationally intertonguing pelitic and semipelitic flysch. In this area the unit consists chiefly of dark-green, silvery-green, greenish-gray phyllite, semischist, and schist, minor marble, with some gray phyllite and semischist.

Units are outlined on the Location Map on Page 2 of this report. Hornfelses are noted by Berg et al. as occurring along the edges of the intrusive. A wider zone was shown by Dusel-Bacon et al. on the Revillagigedo Island Area Metamorphic Facies Map shown on Page 1B. There were no Nordic Abrasion test results available for this source. Limited testing of the spotted hornfels gave unconfined compressive strengths of approximately 30,000 psi and for the spotted schists of approximately 21,000 psi. The gabbro is fine to medium-grained (Koch and Elliott, 1984). The distribution of various rock types are shown on the Ketchikan Gabbro Pluton Map on Page 1C. Along the South Tongass Highway near Milepost 9 the hornfelses were observed to be approximately 600 feet wide. Diorite boulders were noted in the area.

Conclusions: Very strong hornfels rock that has the potential for producing hard aggregate is available in this area. The gabbro may also be durable enough to make hard aggregates. The quantities of available rock are unknown; therefore further investigations will be required.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Berg, H.C., Elliott, R.L., and Koch, R.D., 1988, Geologic map of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1807, 27 p., 1 sheet, scale 1:250,000.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Koch, R.D., and Elliott, R.L., 1984, Late Oligocene gabbro near Ketchikan, southeastern Alaska, in Coonrad, W.L., and Elliot, R.L., eds., The U.S. Geological Survey in Alaska: Accomplishments during 1981: U.S. Geological Survey Circular 868, p. 126-128.

# LOCATION MAP (HA-K1)


U.S.G.S. QUADRANGLE: KETCHIKAN (B-5)

Tgb-Gabbro Pluton
MzPzms-Sedimentary Rocks
MzPzmv-Volcanic Rocks
Hornfels zone

# POTENTIAL HARD AGGREGATE SOURCE REVILLAGIGEDO ISLAND

0 0.5 1 2 3
GRAPHIC SCALE IN MILES

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
KETCHIKAN

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Prepared By:
R&M CONSULTANTS, INC.

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Ketchikan\Acad\MS_Topo_Map_Ketchikan.dwg

Plotted 3/28/2013 4:58 PM by Pete Hardcastle

# SITE MAP (HA-K1)


BASE MAP IS MAY 26, 2010 GEOEYE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE REVILLAGIGEDO ISLAND

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 7/18/2010

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY

KETCHIKAN

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3 |
| | CHECKED C.H.R. | DATE JULY 2010 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Ketchikan\Acad\MS_Site_Map_Ketchikan.dwg

Plotted 3/28/2013 5:00 PM by Pete Hardcastle

# STATEWIDE MATERIAL SITE INVENTORY

## POTENTIAL HARD AGGREGATE SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# PRINCE OF WALES ISLAND COFFMAN COVE

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: The potential hard aggregate source is located in an area surrounding Coffman Cove on Prince of Wales Island in Southeast Alaska. There are several Nordic Abrasion test values from this area (5.6, 9, 12.3, and 13.7), although it is not known from which quarries the samples were taken or from which rock types. Sample results for two of the sample results (5.6 and 13.7) are attached to this report. The other two (9 and 12.3) from a location referred to as Coffman Cove Rock-Ex were included in the GIS database provided by DOT&PF (Pavey et al., 2012). Much of the area has been developed and subdivided and may now be in private hands. There are numerous small quarries noted on the maps. Due to the subdivision roads that have been built, there may be more small quarries in Coffman Cove than elsewhere in the forested areas.

PRINCE OF WALES POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Nordic Values | Latitude | Longitude |
|---|---|---|---|---|
| HA-L1 | Coffman Cove | 5.6, 13.7 | 56.010422 | -132.818347 |
| 62 | Coffman Cove Rock Ex | 9, 12.3 | 55.976533 | -132.807419 |

Access: Most of the area is connected by road to Coffman Cove.

Geology: The area has been mapped on two different quadrangles (Petersburg and Craig) at two different times and means by the same author, and the mapping, while generally similar, does not match precisely. This appears to have been due to the more detailed 1:63,360 scale of mapping in the Petersburg Quadrangle and the compilation mapping at 1:250,000 in the Craig Quadrangle.

Bedrock in the area is mapped as a Silurian Graywacke (SOtgd), part of the Descon Formation (Brew, 1997); a grayish green, buff weathering, volcaniclastic graywacke and siliceous shale. It consists of massive amalgamated beds, graded beds, thin rhythmic beds, slump deposits, sedimentary breccia and conglomerate, suggesting a proximal depositional environment. Sandstones and conglomerates include mainly mafic volcanic rock fragments, with feldspar, quartz, graywacke, mudstone, chert, limestone, and plutonic rock fragments in a chloritic matrix. Graptolites are found on partings in siliceous argillite. Some greenschist facies sandstones are pyritic.

In the area immediately underlying and surrounding Coffman Cove, bedrock is mapped (Brew, 1997) as a biotite-feldspar-quartz hornfels (Kdh): fine to coarse-grained, brown and gray; with original textures and structures obliterated; includes minor calc-silicate hornfels layers. The Kdh unit is mapped only in the Petersburg Quadrangle but may also be found in the Craig Quadrangle.

There is a hornblende quartz monzodiorite (Brew, 1997) with minor tonalite, granodiorite, quartz diorite, diorite, quartz monzonite, and monzodiorite (Kwqo) in the northern Coffman Cove area: massive to foliated, equigranular to locally porphyritic; medium-grained; color index 2 to 48, averaging about 15; pyroxene commonly altering to hornblende and biotite to chlorite; accessories are apatite and sphene. This unit is mapped within the hornfels unit in the Petersburg Quadrangle. Thermal alteration caused by the intrusion may have created the hornfels (Kdh). A second monzodiorite intrusive was mapped (Brew, 1996) in the Craig Quadrangle. Hornfels were not mapped surrounding it, although it is likely that some thermal alteration occurred. It is possible other intrusives and associated hornfels occur south of Coffman Cove.

Problems with pyritic rock were encountered in construction of a two lane road (FS 3030300) near Sweetwater Lake. Pyrite in the rock used for fill created an acidic solution that dissolved metals from the rock, which contaminated ground and surface waters. Approximately 100,000 cubic yards of road embankment was removed and replace with limestone to neutralize the acid. It is not known which quarry or quarries the pyritic rock was mined from.

Conclusions: It is likely the hornfelses are the source of most of the lower Nordic Abrasion test values in the north Coffman Cove area. Based on what we have found elsewhere, lower Nordic values may be encountered along the boundary between the Kdh and Kwqo units. However, these boundaries primarily appear to lie in tidal zones or in developed areas. Alteration can be found a significant distance away from an igneous intrusive, therefore hornfelses may be found outside the area shown on the attached location map.

It is unknown how much hornfels rock is available, how consistent the character of the rock is, and which quarries are still available to mine. Due to the inability to tie sample data to known quarries and rock types, the existing Nordic Abrasion test data is of limited value. If hard aggregate is desired from Coffman Cove it may be worth the effort to map the numerous existing quarries and road cuts, noting the rock types and strength, obtaining samples and performing petrographic analysis and Nordic tests on the most promising rock. Testing for the potential for acid rock drainage should be conducted for all quarries in which mineralization is apparent.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., (compiled by), 1996, Geologic map of the Craig, Dixon Entrance, and parts of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 2319, 53 p. 1:250,000.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg A-2 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-A, 20 p., 1 sheet, scale 1:63,360.

Brew, D.A., 1997, Reconnaissance geologic map of the Petersburg A-3 quadrangle, southeastern Alaska: U.S. Geological Survey Open-File Report 97-156-B, 24 p., 1 sheet, scale 1:63,360.

Condon, W.H., 1961, Geology of the Craig quadrangle, Alaska: U.S. Geological Survey Bulletin 1108-B, B-1 – B-43, 1 sheet, scale 1:250,000.

Eberlein, G.D., Churkin, Jr. C.C., Berg, H.C. and Ovenshine, A.T., 1983 Geology of the Craig quadrangle, Alaska: U.S. Geological Survey Open-File Report 83-91, 52 p. 1 sheet, scale 1:250,000.

Karl, S.M, Haeussler, P.J., and McCafferty, A., 1999, Reconnaissance geologic map of the Duncan Canal-Zarembo Island area, southeastern Alaska: US. Geological Survey Open-File Report 99-168, 30 p. 1 sheet, scale 1:150,000.

Pavey, Finkbiner, Bingham, 2012, Web interface: http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

25-225
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

PRECONSTRUCTION ☐ CONSTRUCTION ☐
ACCEPTANCE ☐ QUALITY ☐
ASSURANCE ☐ INFORMATION ☒

TEST OF: ASPHALT CONCRETE, TYPE II; CLASS B (QUARRY ROCK FOR) ITEM NO. 401(1) LAB NO. 09C-653

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | HPRM-0003(124) | PROJECT NAME | POW COFFMAN COAVE ROADS PAVING | | |
| SAMPLED FROM | SOURCE | EXAMINED FOR | LA ABRAS., DEGRADATION, SPG & ABSORPTION, NORDIC ABRAS. | | |
| DEPTH | | FIELD NO. | | DATE SAMPLED | CONTRACTOR |
| SOURCE | QUARRY @ MINKE LOOP | SUBMITTED BY | CONTRACTOR | DATE RECEIVED | 12/22/09 |
| LOCATION | COFFMAN COVE, ALASKA | REPRESENTS | SOURCE | DATE REPORTED | 01/04/10 |

AS RECEIVED

| % PASSING SIEVE | INFORMATION | ACCEPTANCE | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #20 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| 0.02 MM | | | |
| .005 MM | | | |

PROPERTIES

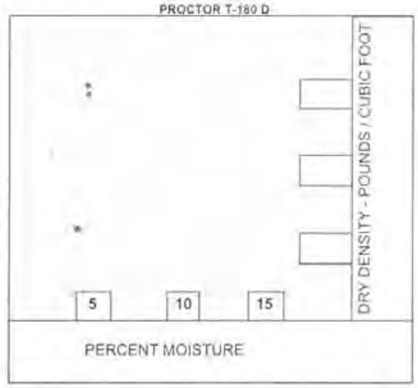
| | |
|---|---|
| LIQUID LIMIT | |
| PLASTIC INDEX | |
| DELETERIOUS | |
| FRACTURE % | |
| THIN ELONGATED % | |
| FINENESS MODULUS | |
| ORGANIC CONTENT % | |
| AASHTO CLASS | |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 79 | |
| L.A. ABRASION % B | 10 | |
| NORDIC ABRASION % | 5.6 | |
| BULK SPG | 2.913 | |
| BULK SSD SPG | 2.930 | |
| APPARENT SPG | 2.965 | |
| ABSORPTION % | 0.6 | |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




REMARKS: Not For Source Acceptance For Project

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffrey A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: Bruce E. Brunette
REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

25-229
#R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

| | | | |
|---|---|---|---|
| PRECONSTRUCTION | | CONSTRUCTION | X |
| ACCEPTANCE | | QUALITY | X |
| ASSURANCE | | INFORMATION | |

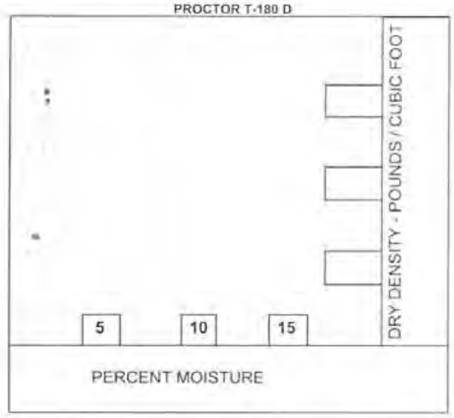
TEST OF **ASPHALT CONCRETE, TYPE II, CLASS B (QUARRY ROCK FOR)** ITEM NO. **401(1)** LAB NO. **11C-240**

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO | HPRM-0003(124) | PROJECT NAME | POW COFFMAN COVE ROADS PAVING | | |
| SAMPLED FROM | SOURCE | EXAMINED FOR | LA ABRAS, NORDIC ABRAS, DEG, SPG, ABSP, LIMITS, FRACT, F/E | | |
| DEPTH | | FIELD NO | | DATE SAMPLED | 06/13/11 |
| SOURCE | CHAMBERLAIN QUARRY | SUBMITTED BY | E. STICKLE | DATE RECEIVED | 06/15/11 |
| LOCATION | COFFMAN COVE, ALASKA | REPRESENTS | SOURCE | DATE REPORTED | 06/30/11 |

| % PASSING SIEVE | AS RECEIVED QUALITY | QUALITY | SPECS |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #20 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| 0.02 MM | | | |
| .005 MM | | | |

| MOISTURE / DENSITY RELATIONS | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




| PROPERTIES | | | |
|---|---|---|---|
| LIQUID LIMIT | | NV | |
| PLASTIC INDEX | | NP | 4 MAX |
| DELETERIOUS | FREE | FREE | FREE |
| FRACTURE % | 100 | | 80 MIN 1 FACE |
| THIN ELONGATED % | 0 | | 8 MAX |
| FINENESS MODULUS | | | |
| ORGANIC CONTENT % | | | |
| AASHTO CLASS | | | |

| QUALITY | COARSE | FINE | |
|---|---|---|---|
| DEGRADATION VALUE | 62 | | 30 MIN |
| L.A. ABRASION % B | 14 | | 45 MAX |
| NORDIC ABRASION % | 13.7 | | |
| BULK SPG | 2.880 | | |
| BULK SSD SPG | 2.895 | | |
| APPARENT SPG | 2.922 | | |
| ABSORPTION % | 0.5 | | |

REMARKS: SENT TO ANCHORAGE FOR FURTHER TESTING

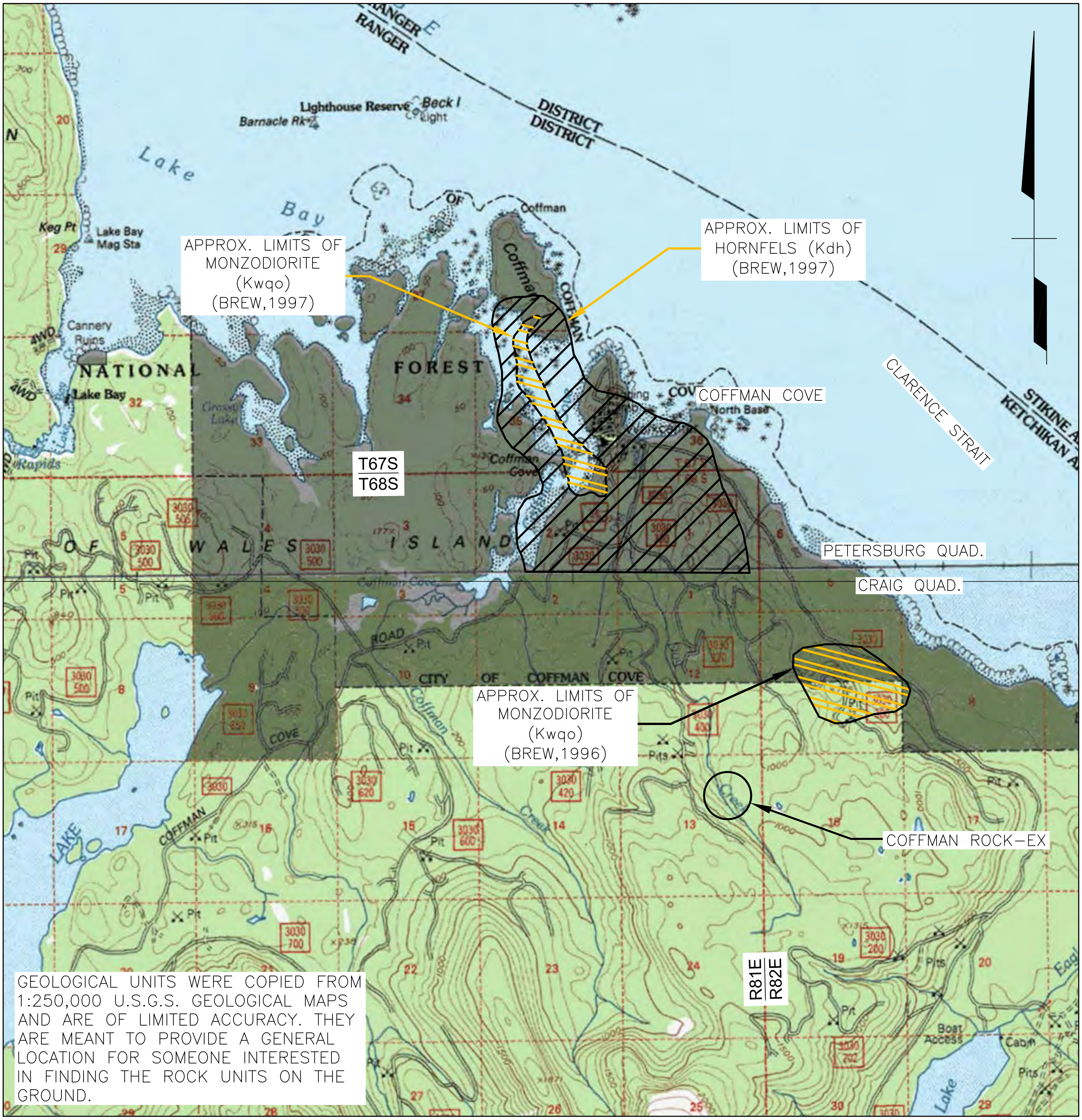
INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
ACCEPTABLE UNACCEPTABLE

CHECKED BY: Jeffrey A. Hart
MATERIALS LAB COORDINATOR

SIGNATURE: Bruce [signature]
REGIONAL MATERIALS ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

# LOCATION MAP (HA-L1)




U.S.G.S. QUADRANGLE: PETERSBURG (A-3) & CRAIG (D-3)

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

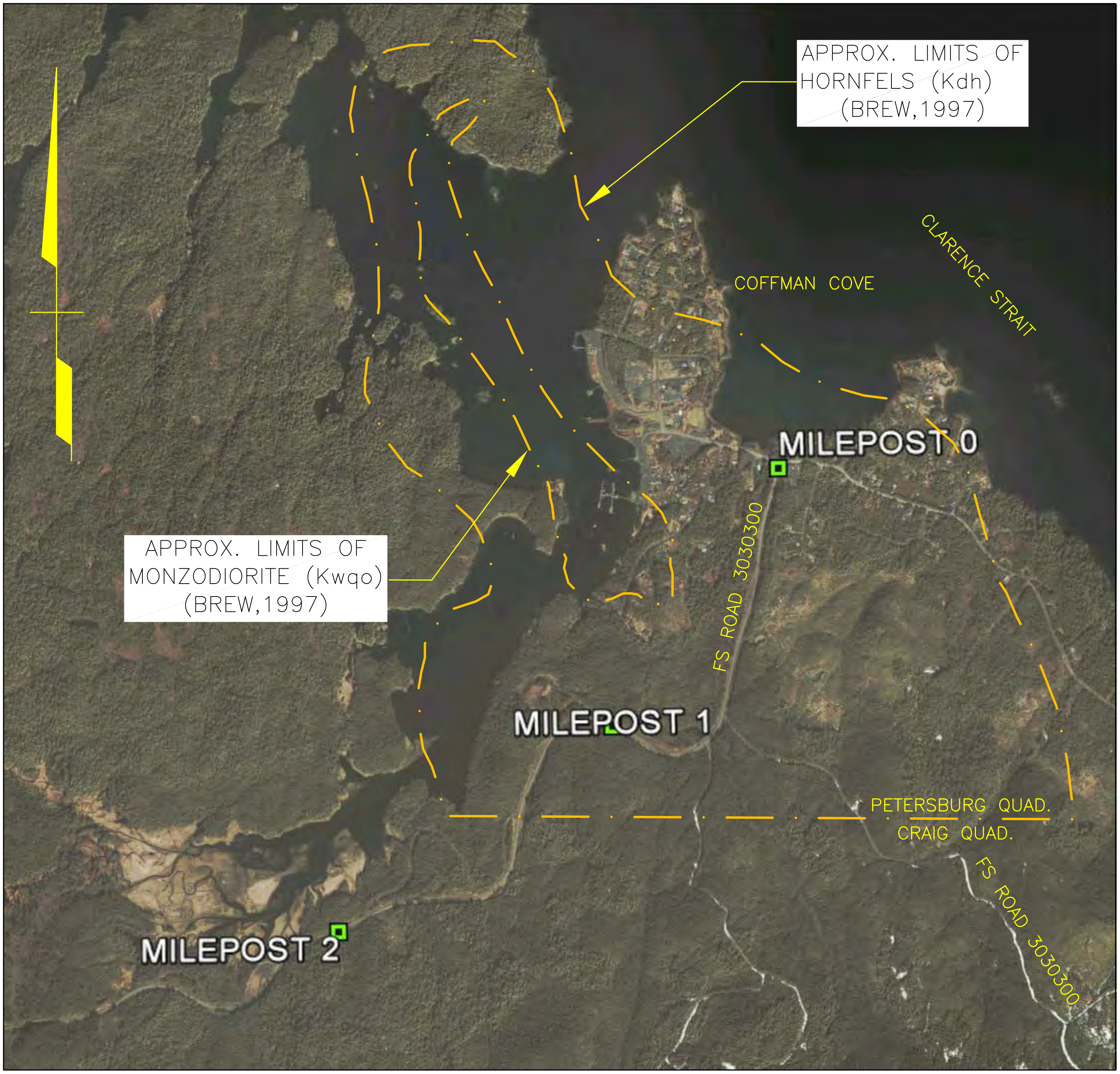
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
COFFMAN COVE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 11:40 AM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\Coffman Cove\Acad\MS_Topo_Map_Coffman_Cove.dwg

# SITE MAP (HA–L1)




BASE MAP IS APRIL 15, 2012 DIGITALGLOBE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 1,000 2,000 4,000 6,000

GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 3/1/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY

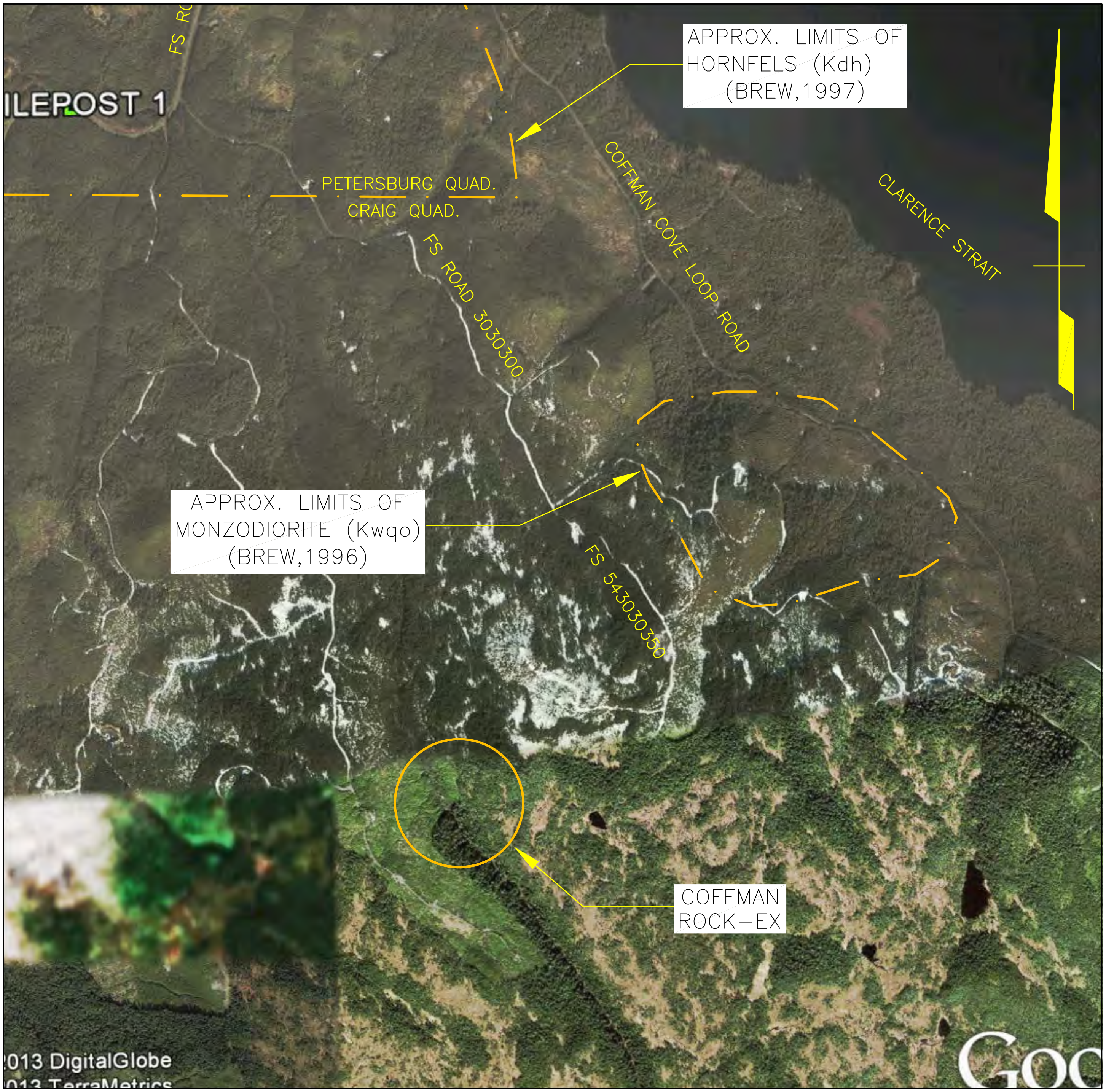
COFFMAN COVE

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3A |
| | CHECKED C.H.R. | DATE MAR 2013 | |

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\Coffman Cove\Acad\MS_Site_Map_Coffman_Cove.dwg

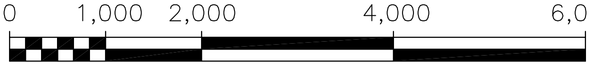
Plotted 3/28/2013 11:43 AM by Pete Hardcastle

# SITE MAP (HA-L1)




BASE MAP IS APRIL 15, 2012 DIGITALGLOBE SATELLITE IMAGERY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND




GRAPHIC SCALE IN FEET

BASE MAP FROM GOOGLE EARTH PRO 3/1/2013

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY
COFFMAN COVE

| SCALE | DESIGNED P.K.H. | DRAWN P.K.H. | PAGE 3B |
|---|---|---|---|
| AS SHOWN | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 11:47 AM by Pete Hardcastle

Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\Coffman Cove\Acad\MS_Site_Map_Coffman_Cove.dwg

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# PRINCE OF WALES ISLAND
# RED BAY MOUNTAIN AND TOKEEN PEAK

February 24, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: Potential hard aggregate sources on the north end of Prince of Wales Island are located south of Sumner Strait, east of El Capitan Passage and north of Tokeen Bay. The potential sources include three monzodiorite intrusives and related aureoles in a sedimentary country rock (see Page 1C). Potential hard aggregate source(s) are hornfelses associated with the intrusives. Locations of these hornfelses are mapped as being along the boundary of the three intrusives as shown on the following maps. The three sources are within the Tongass National Forest and except for small blocks of land along El Capitan Passage (see dark blocks of land on Location Map 2B) are managed by the U.S. Forest Service. Portions of the southern intrusive appear to lie within Mt. Calder/Mt. Holbrook LUD II Lands.

PRINCE OF WALES ISLAND POTENTIAL HARD AGGREGATE SOURCES

| Site ID | Source Name | Latitude | Longitude |
|---|---|---|---|
| HA-M1 | Red Bay Mountain | 56.217549 | -133.382180 |
| HA-M2 | Tokeen Peak | 56.117709 | -133.406904 |

Access: Access to and from the potential sources would appear to be on logging roads to the area from El Capitan Passage, Red Bay and Tokeen Bay.

Geology: Three small plutons have intruded the sandstones between Tokeen Bay and Sumner Strait on the north end of Prince of Wales Island. Hornfels and marble were mapped as occurring along the edge of and between the three intrusive bodies. The units shown on Page 1D were described (Brew et al., 1984) as follows and shown in more detail on Location Maps 2A through 2C.

> Kwqo: Hornblende quartz monzodiorite with minor tonalite, granodiorite, quartz diorite, quartz monzonite, and monzonite: Massive to foliated; equigranular to locally porphyritic; medium-grained; color index 2 to 48, average (approx.) 15; locally hornblende porphyritic; local rounded fine-grained mafic inclusions; includes common aplite, less common pegmatite, and several mafic dikes. Lacks garnet and epidote.

Metamorphic Rocks in the Chilkat-Prince of Wales Plutonic Province: Aureoles around plutons of the Chilkat Prince of Wales plutonic province on Kosciusko and northern Prince of Wales Islands; are divided into:

> Khh: Marble: Medium to coarse-grained, white fresh, light gray weathering; original bedding and structures largely obliterated. Metamorphosed from the Heceta Limestone (Sch).

> Kch: Biotite-Quartz-Feldspar-Hornfels: Metapolymictic conglomerate with 1 to 35 cm diameter rounded clasts of syenite (?), granodiorite, feldspar porphyry, chert, intermediate volcanic rock, and mudstone in 1 to 10 meter thick beds. Metamorphosed from the Polymictic Conglomerate Unit of the Bay of Pillars Formation (Stbg).

> Kbh/Koh: Biotite-Quartz-Feldspar-Hornfels: Fine to medium-grained, brownish-gray; original sedimentary structures and bedding of graywacke and mudstones turbidite sequence locally preserved; includes minor metaconglomerate like that described in Kch Unit. Metamorphosed from the Graywacke and Mudstone Turbidite Unit in the Bay of Pillars Formation (Stbg).

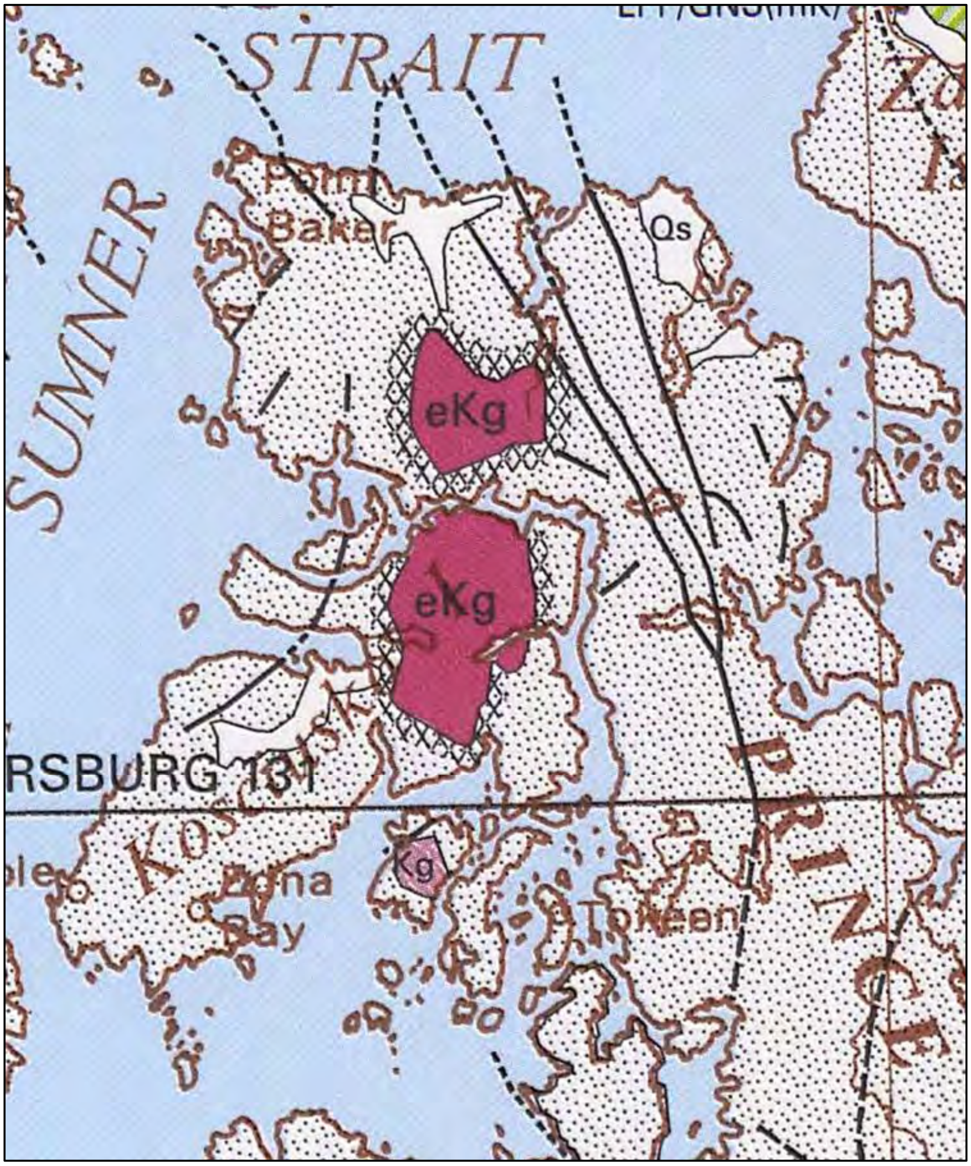
Conclusions: There are no test results or other direct observations to verify the presence of rock capable of producing hard aggregate. However, the conditions exist for these types of rock (hornfels) to occur. Access to roads and locations on the coast where materials can be loaded on barges also appear to be available. It is unknown how much hornfels rock is available, and where it is available. These sources appear to warrant consideration.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as you move away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

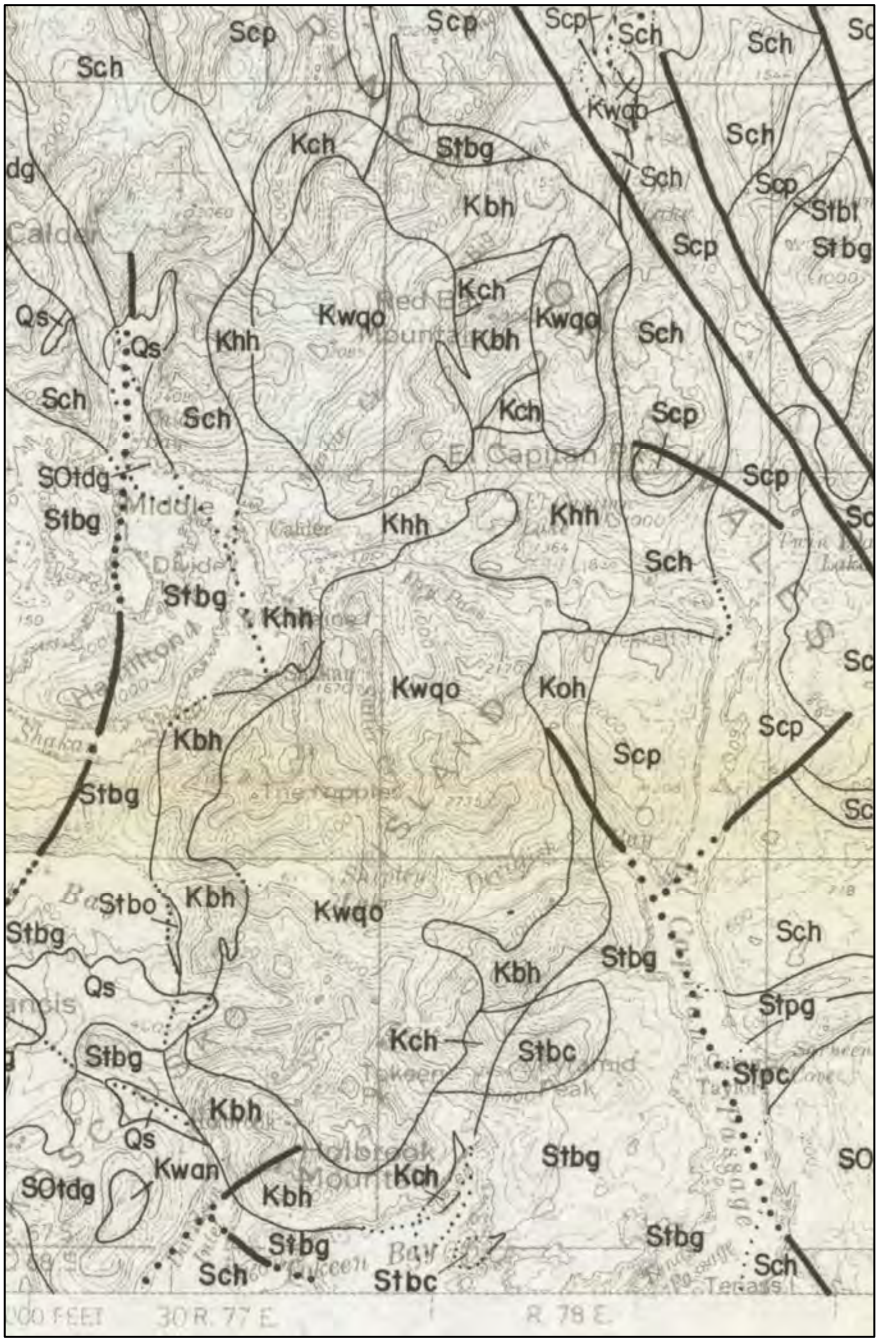
**NORTH PRINCE OF WALES ISLAND METAMORPHIC FACIES MAP**

(From Dusel-Bacon et al., 1996)




Map showing the interpreted hornfels zones on North Prince of Wales Island. The pink units are igneous intrusives and the cross-hatch along the edge of the intrusives are the interpreted hornfels zones. These zones are subject to differing interpretations by different authors. The dotted areas without cross-hatching are unmetamorphosed rocks.

**GEOLOGIC MAP OF NORTH PRINCE OF WALES ISLAND**
(From Brew et al., 1984)




Kwqo - Monzodiorite Kbh/Kch/Koh – Hornfels Khh - Marble
Kwan – Andesite Stbg – Bay of Pillars Formation Sch- Hecta Limestone
Scp – Polymictic Conglomerate Stbg/Stbo/Stbl – Turbidites
SOtdg – Descon Formation Qs – Surficial Deposits

References:

Brew, D.A., Ovenshine, A.T., Karl, S.M., and Hunt, S.J., 1984, Preliminary reconnaissance geologic map of the Petersburg and parts of the Port Alexander and Sumdum 1:250,000 quadrangles, southeastern Alaska: U.S. Geological Survey Open-File Report 84-405, 43 p., 2 sheets, scale 1:250,000.

Dusel-Bacon, Cynthia, Brew, D.A., and Douglass, S.L., 1996, Metamorphic facies map of southeastern Alaska; distribution, facies, and ages of regionally metamorphosed rocks: U.S. Geological Survey Professional Paper 1497-D, p. 1-42, 2 sheets, scale 1:1,000,000.

Gehrels, G.E. and Berg, H.C., 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1867, 24 p., 1 sheet, scale 1:600,000.

Plotted 3/28/2013 12:15 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\North Prince Of Wales\Acad\MS_Topo_Map_North_Prince_of_Wales.DWG

# LOCATION MAP (HA–M1)


U.S.G.S. QUADRANGLE: PETERSBURG (A–4), (A–5), (B–4) & (B–5)

Kwqo–Monzodiorite
Khh–Marble
Kbh/Kch–Hornfels

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

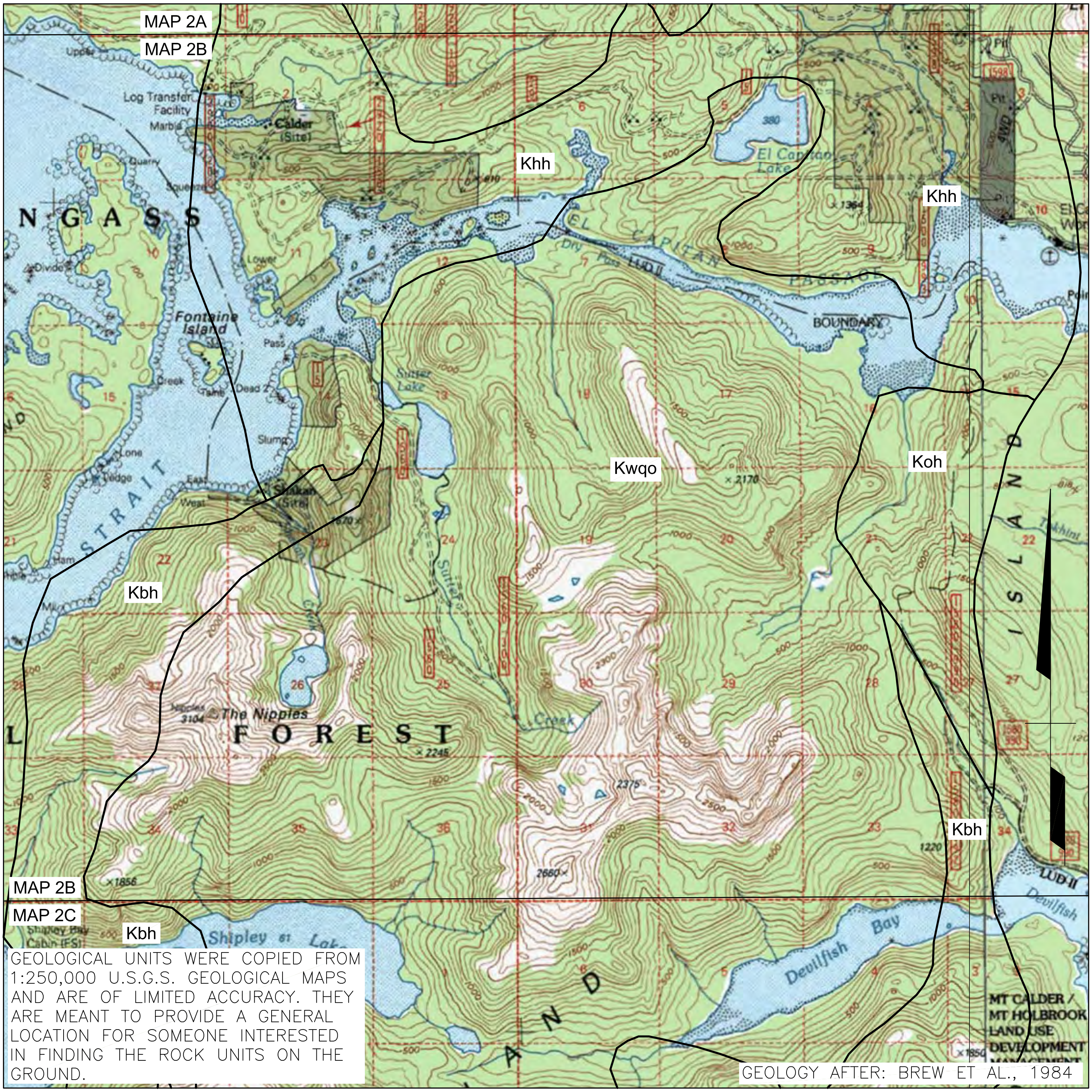
Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
RED BAY MOUNTAIN

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2A |
| | CHECKED C.H.R. | DATE FEB 2013 | |

# LOCATION MAP (HA–M2)




U.S.G.S. QUADRANGLE: PETERSBURG (A–4) & (A–5)

Kwqo-Monzodiorite
Khh-Marble
Kbh/Koh-Hornfels

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE
INVENTORY
TOKEEN PEAK

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2B |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 12:16 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\North Prince Of Wales\Acad\MS_Topo_Map_North_Prince_of_Wales.DWG

# LOCATION MAP (HA–M2)


U.S.G.S. QUADRANGLE: PETERSBURG (A–4) & (A–5) AND CRAIG (D–4) & (D–5)

Kwqo–Monzodiorite
Khh–Marble
Kbh/Kch–Hornfels

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

STATEWIDE MATERIAL SITE INVENTORY
TOKEEN PEAK

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | J.D.N. | 2C |
| | CHECKED C.H.R. | DATE FEB 2013 | |

STATEWIDE MATERIAL SITE INVENTORY

POTENTIAL HARD AGGREGATE
SOURCE REPORT

Federal Project No. STP-000S(823)
AKSAS Project No. 76149

# PRINCE OF WALES ISLAND
# KLAWOCK RIVER QUARRY

February 23, 2013

CONTENTS PAGE



## SITE CONDITIONS

General Site Description: This potential hard aggregate source appears to consist of two existing quarries located on a low ridge south of the Klawock River and along the Craig to Klawock Highway. The rock is mapped as being an igneous leucosyenite intruded into sedimentary limestones, sandstones and siltstones (Brew, 1996). A Nordic Abrasion test value of 8.4 percent was obtained from a sample in this area in 2008 (see the sample result attached to this report). It is not known from which quarry the sample was obtained.

The quarries appear to lie on lands owned by the Klawock Heenya Corporation (PAT 50-2007-0080).

PRINCE OF WALES ISLAND POTENTIAL HARD AGGREGATE SOURCE

| Site ID | Source Name | Nordic Values | Latitude | Longitude |
|---|---|---|---|---|
| HA-N1 | Klawock River Quarry | 8.4 | 55.545702 | -133.096303 |

Access: The area is connected by road to Klawock and Craig.

Geology: Bedrock is reportedly a leucosyenite intrusive found at Klawock and on Sukkwan Island (Early Permian and Late Pennsylvanian): A biotite and hornblende bearing syenite (PIPsy) with color index 15 was described near Klawock. There was no mention of a hornfels at the Klawock site (Brew, 1996).

There is a sphene-apatite-amphibole/augite-bearing biotite leucosyenite mapped on Sukkwan Island which was described as surrounded by extensive hornfels aureole (Brew, 1996). This second potentially larger hornfels deposit on Sukkwan Island was removed from this study when it was found that Sukkwan Island was in a roadless area within the Tongass National Forest.

Conclusions: It is not known from exactly which quarry the Nordic test result (8.4) included in this report came. It is assumed that the hornfelses that are mentioned at Sukkwan Island also occur at Klawock. These hornfels may have given the low Nordic Abrasion test value at Klawock. It is unknown how much hornfels rock is available, and in which locations it is available. The southern extent of the leucosyenite is also unknown, but there are several small quarries to the south of the Klawock Quarry that could be used to trace the extent of the intrusive.

Grain size of the syenite at Klawock is not known. It is possible that the syenite rock was responsible for the low Nordic Abrasion test value. If this is so, the deposit would be much more useful and easier to mine.

Contact metamorphic rocks are commonly associated with mineralization that can cause acid rock drainage when disturbed. Testing for acid rock drainage should be performed when using these sources, even though the mineralized zones in the contact aureoles are generally not durable enough to provide rock for hard aggregate.

The rock within the contact zones or aureoles varies considerably in composition and strength, especially as one moves you move away from the intrusive. Generally, the most durable rock that has the greatest potential for producing hard aggregate is found closest to the intrusive body.

References:

Brew, D.A., (compiled by), 1996, Geologic map of the Craig, Dixon Entrance, and parts of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 2319, 53 p. 1:250,000.

Condon, W.H., 1961, Geology of the Craig quadrangle, Alaska: U.S. Geological Survey Bulletin 1108-B, B-1 – B-43, 1 sheet, scale 1:250,000.

Eberlein, G.D., Churkin, Jr. C.C., Berg, 1983, H.C. and Ovenshine, A.T., 1983 Geology of the Craig quadrangle, Alaska: U.S. Geological Survey Open-File Report 83-91, 52 p. 1 sheet, scale 1:250,000.

25-229
R-1/2007
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

# LAB REPORT (U.S. STAND.)

PRECONSTRUCTION ☐ CONSTRUCTION ☑
ACCEPTANCE ☐ QUALITY ☒
ASSURANCE ☐ INFORMATION ☐

TEST OF **HOT MIX ASPHALT TYPE II, CLASS C (QUARRY ROCK FOR)** ITEM NO. **P-401** LAB NO. **08C-22**

| | | | | | |
|---|---|---|---|---|---|
| PROJECT NO. | **DTFAWA-06-A-00013** | PROJECT NAME | **KLW AIRPORT PROFILE IMPROVEMENTS AND OVERLAY** | | |
| SAMPLED FROM | **SOURCE** | EXAMINED FOR | **DEG, LA, NORDIC, SPG, ABSORPTION** | | |
| DEPTH | | FIELD NO. | | DATE SAMPLED | **03/07/08** |
| SOURCE | **KLAWOCK RIVER QUARRY** | SUBMITTED BY | **S. MIELKE** | DATE RECEIVED | **03/10/08** |
| LOCATION | **KLAWOCK, ALASKA** | REPRESENTS | **SOURCE** | DATE REPORTED | **03/20/08** |

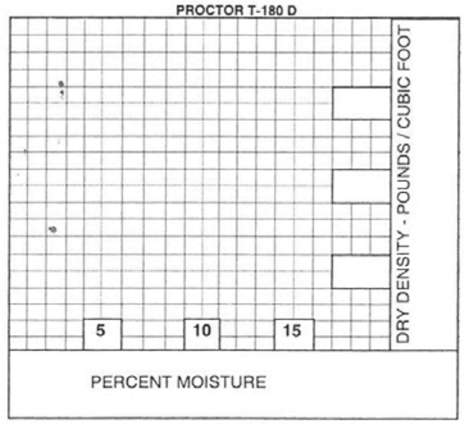
AS RECEIVED

| % PASSING SIEVE | QUALITY | ACCEPTANCE | SPECS |
|---|---|---|---|
| | | | |
| 4" | | | |
| 3" | | | |
| 2" | | | |
| 1-1/2" | | | |
| 1" | | | |
| 3/4" | | | |
| 1/2" | | | |
| 3/8" | | | |
| #4 | | | |
| #8 | | | |
| #10 | | | |
| #16 | | | |
| #20 | | | |
| #30 | | | |
| #40 | | | |
| #50 | | | |
| #80 | | | |
| #100 | | | |
| #200 | | | |
| 0.02 MM | | | |
| .005 MM | | | |

MOISTURE / DENSITY RELATIONS

| | ASSURANCE | ACCEPTANCE | SPECS |
|---|---|---|---|
| DEPTH OF PROBE | | | |
| LAB STD NO | | | |
| STANDARD TYPE | | | |
| OPT. MOISTURE % | | | |
| DENSITY STD | | | |
| CORRECTED STD | | | |
| FIELD DENSITY | | | |
| FIELD MOISTURE % | | | |
| PLUS 3/4" / #4 % | | | |
| BULK SPG +3/4" / #4 | | | |
| COMPACTION % | | | |

PROCTOR T-180 D




| PROPERTIES | |
|---|---|
| LIQUID LIMIT | |
| PLASTIC INDEX | |
| DELETERIOUS | |
| FRACTURE % | |
| THIN ELONGATED % | |
| FINENESS MODULUS | |
| ORGANIC CONTENT % | |
| AASHTO CLASS | |

| QUALITY | COARSE | FINE |
|---|---|---|
| DEGRADATION VALUE | 62 | |
| L.A. ABRASION % B | 14 | |
| NORDIC ABRASION % | 8.4 | |
| BULK SPG | 2.676 | |
| BULK SSD SPG | 2.701 | |
| APPARENT SPG | 2.745 | |
| ABSORPTION % | 0.9 | |

REMARKS: **SENT TO ANCHORAGE FOR SODIUM SULFATE SOUNDNESS**

INDEPENDENT ASSURANCE / ACCEPTANCE
TEST RESULT COMPARISON
______ ACCEPTABLE UNACCEPTABLE ______

CHECKED BY: *[signature]*
MATERIALS LAB COORDINATOR

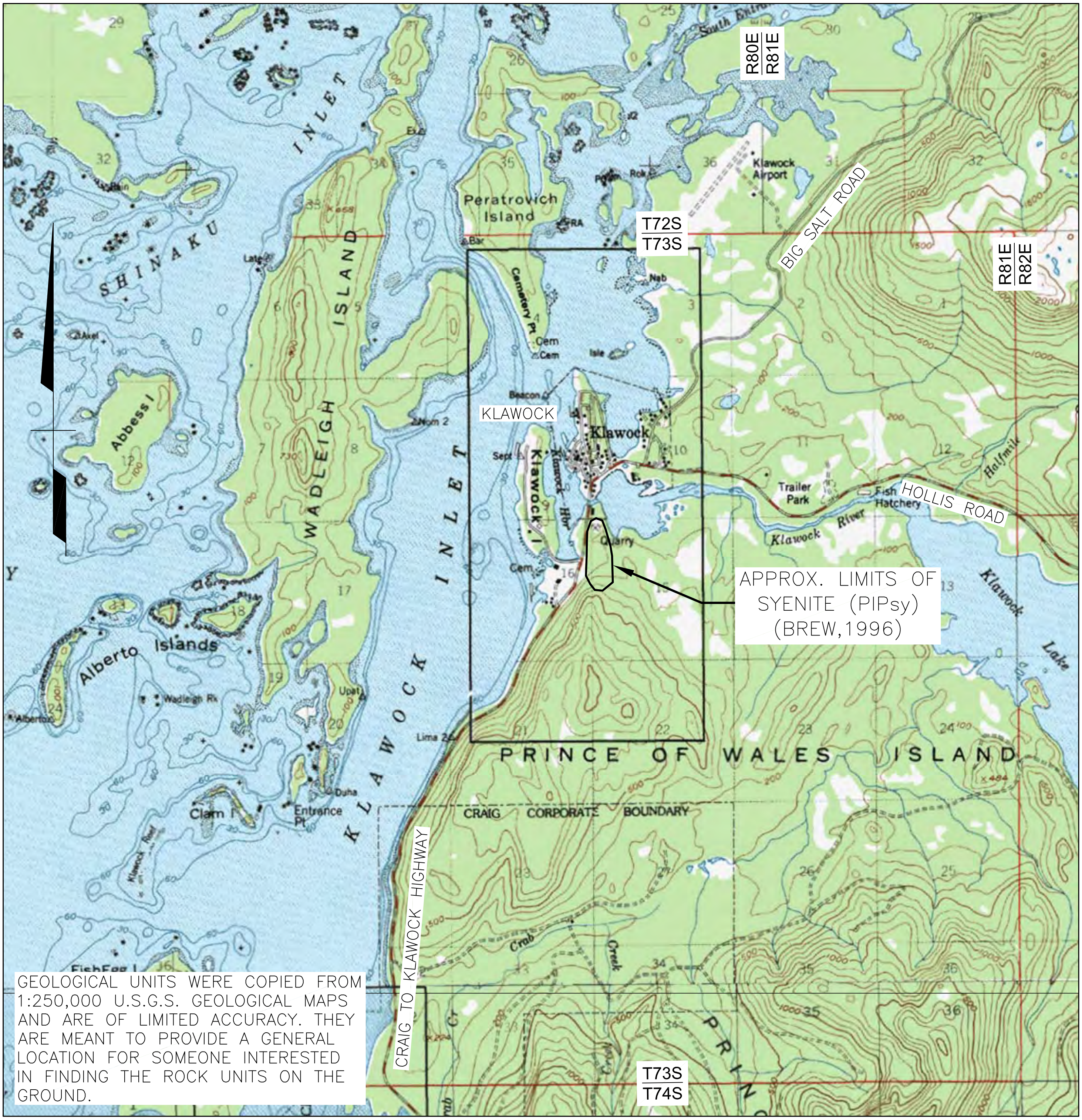
SIGNATURE: Bruce E. Brunette
REGIONAL MATERIALS ENGINEER

THE MATERIAL AS SUBMITTED CONFORMS TO SPECIFICATIONS

YES ( ) NO ( ) N/A ( )

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIAL AS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/FAA APPROVED ATM TEST PROCEDURES

# LOCATION MAP (HA–N1)




U.S.G.S. QUADRANGLE: CRAIG (C–4)

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 0.5 1 2 3

GRAPHIC SCALE IN MILES

BASE MAP CREATED WITH TERRAIN NAVIGATOR PRO

Prepared By: R&M CONSULTANTS, INC.

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

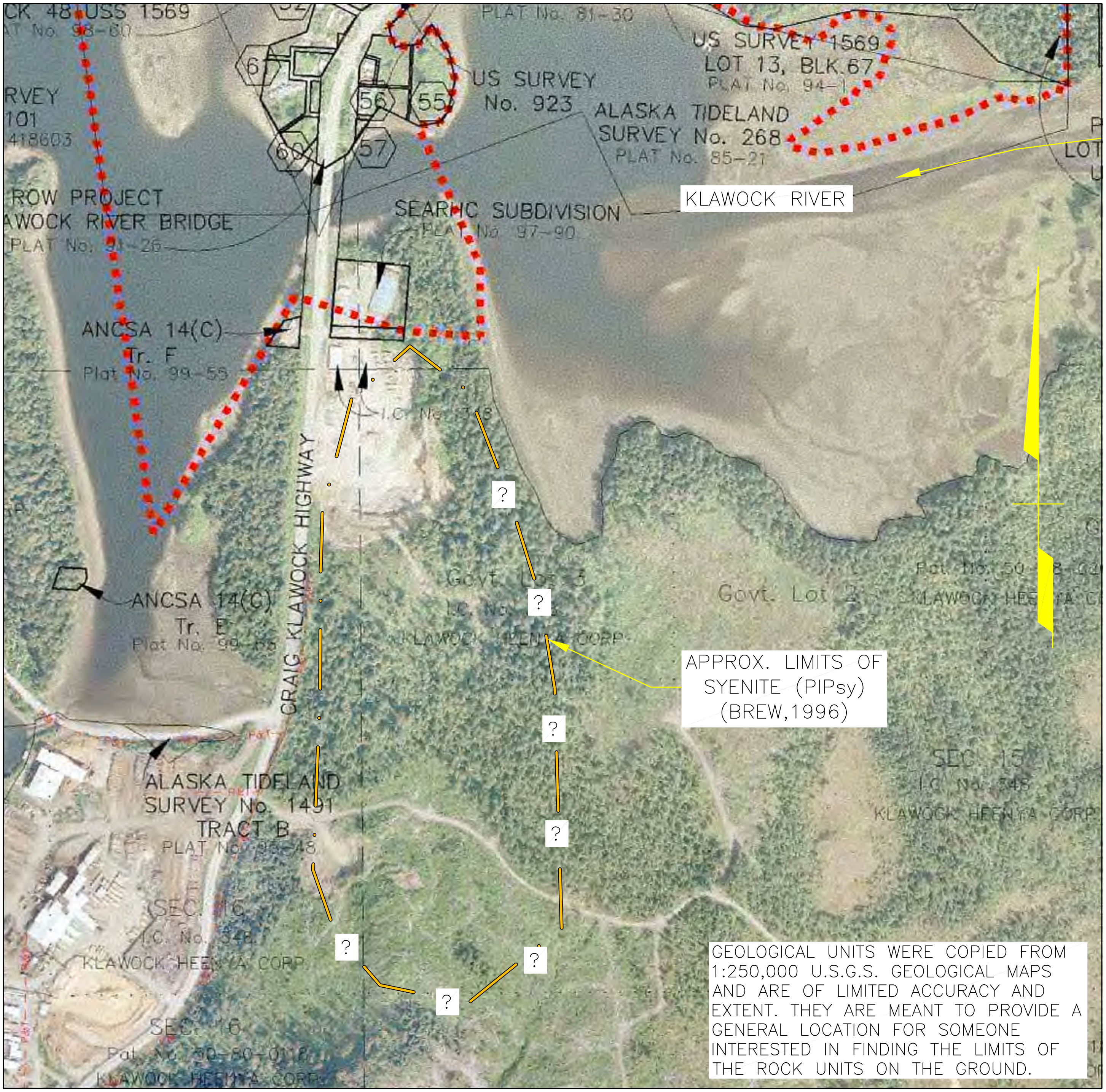
STATEWIDE MATERIAL SITE INVENTORY

KLAWOCK RIVER QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 2 |
| | CHECKED C.H.R. | DATE FEB 2013 | |

Plotted 3/28/2013 11:50 AM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\Klawok River Quarry\Acad\MS_Topo_Map_Klawok_River_Quarry.dwg

# SITE MAP (HA-N1)




BASE MAP IS MAY 22, 2004 AERIAL PHOTOGRAPHY.
THIS IS A PLANNING DOCUMENT ONLY.

# POTENTIAL HARD AGGREGATE SOURCE PRINCE OF WALES ISLAND

0 300 600 1200 1800

GRAPHIC SCALE IN FEET

BASE MAP FROM SOA DCRA KLAWOCK COMMUNITY PROFILE MAP

Prepared By:
R&M CONSULTANTS, INC.

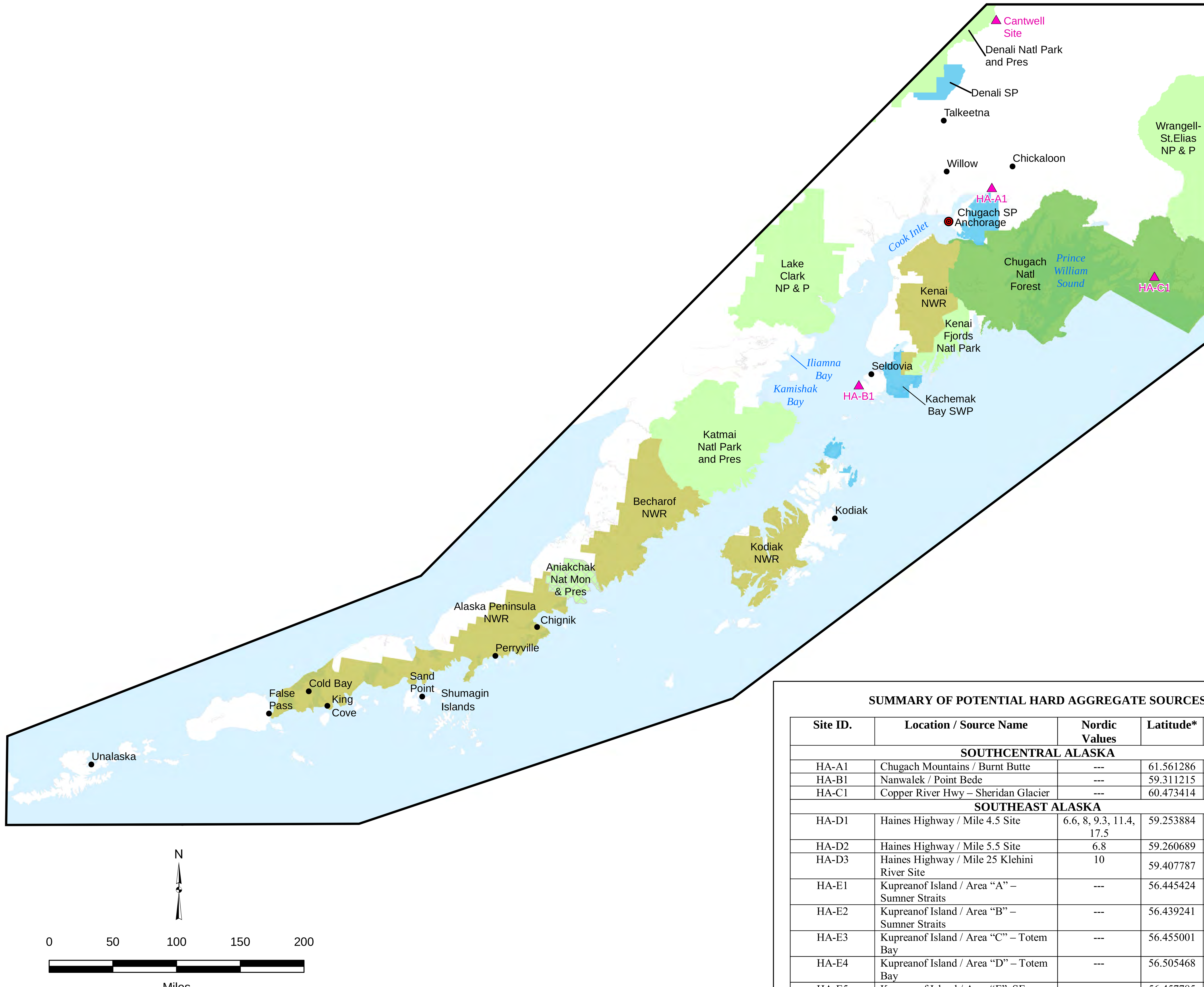
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

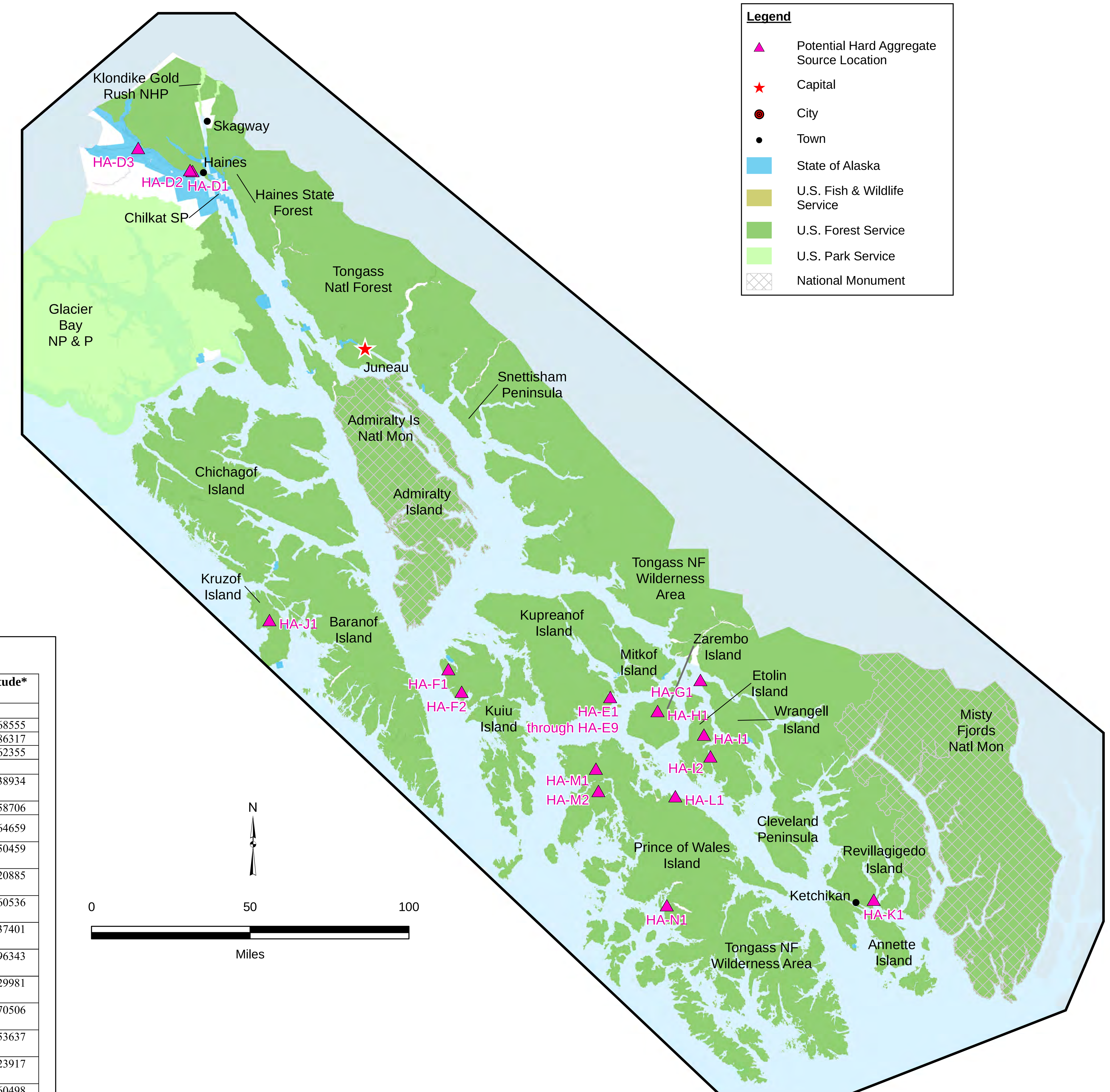
STATEWIDE MATERIAL SITE INVENTORY

KLAWOCK RIVER QUARRY

| SCALE | DESIGNED | DRAWN | PAGE |
|---|---|---|---|
| AS SHOWN | P.K.H. | P.K.H. | 3 |
| | CHECKED C.H.R. | DATE FEB. 2013 | |

Plotted 3/28/2013 4:03 PM by Pete Hardcastle Z:\project\1443.07 DOT_SWM Cantwell Agreegate Feasibility Study\Earth\Hard Aggregate Location Study\Prince Of Wales Island\Klawock River Quarry\Acad\MS_Site_Map_Klawok_River_Quarry.dwg




**SUMMARY OF POTENTIAL HARD AGGREGATE SOURCES**

| Site ID. | Location / Source Name | Nordic Values | Latitude* | Longitude* |
|---|---|---|---|---|
| **SOUTHCENTRAL ALASKA** | | | | |
| HA-A1 | Chugach Mountains / Burnt Butte | --- | 61.561286 | -148.968555 |
| HA-B1 | Nanwalek / Point Bede | --- | 59.311215 | -151.986317 |
| HA-C1 | Copper River Hwy – Sheridan Glacier | --- | 60.473414 | -145.262355 |
| **SOUTHEAST ALASKA** | | | | |
| HA-D1 | Haines Highway / Mile 4.5 Site | 6.6, 8, 9.3, 11.4, 17.5 | 59.253884 | -135.538934 |
| HA-D2 | Haines Highway / Mile 5.5 Site | 6.8 | 59.260689 | -135.558706 |
| HA-D3 | Haines Highway / Mile 25 Klehini River Site | 10 | 59.407787 | -135.964659 |
| HA-E1 | Kupreanof Island / Area “A” – Sumner Straits | --- | 56.445424 | -133.650459 |
| HA-E2 | Kupreanof Island / Area “B” – Sumner Straits | --- | 56.439241 | -133.520885 |
| HA-E3 | Kupreanof Island / Area “C” – Totem Bay | --- | 56.455001 | -133.460536 |
| HA-E4 | Kupreanof Island / Area “D” – Totem Bay | --- | 56.505468 | -133.437401 |
| HA-E5 | Kupreanof Island / Area “E” SE Kupreanof Island | --- | 56.457785 | -133.196343 |
| HA-E6 | Kupreanof Island / Area “F” – Kah Sheets Bay | --- | 56.515122 | -133.129981 |
| HA-E7 | Kupreanof Island / Area “G” – Duncan Canal | --- | 56.672651 | -133.170506 |
| HA-E8 | Kupreanof Island / Area “H” – Duncan Canal | --- | 56.708212 | -133.253637 |
| HA-E9 | Kupreanof Island / Area “I” – Forest Service Quarry | 7 | 56.763233 | -133.523917 |
| HA-F1 | Kuiu Island / Security Bay | --- | 56.808520 | -134.360498 |
| HA-F2 | Kuiu Island / Rowan Bay | --- | 56.695866 | -134.296529 |
| HA-G1 | Wrangell Island / Wrangell Airport Quarry | 7, 17.1 | 56.487009 | -132.386582 |
| HA-H1 | Zarembo Island / Northern Zarembo Island | --- | 56.401017 | -132.785403 |
| HA-I1 | Etolin Island / Northern Etolin Island | --- | 56.246532 | -132.470702 |
| HA-I2 | Etolin Island / Central Etolin Island | --- | 56.144496 | -132.464071 |
| HA-J1 | Kruzof Island / Kruzof Island | --- | 57.200676 | -135.713812 |
| HA-K1 | Revillagigedo Island / Ketchikan | --- | 55.333238 | -131.507959 |
| HA-L1 | Prince of Wales Island / Coffman Cove | 5.6, 13.7 | 56.010422 | -132.818347 |
| HA-M1 | Prince of Wales Island / Red Bay Mountain | --- | 56.217549 | -133.382180 |
| HA-M2 | Prince of Wales Island / Tokeen Peak | --- | 56.117709 | -133.406904 |
| HA-N1 | Prince of Wales Island / Klawock River Quarry | 8.4 | 55.545702 | -133.096303 |
| **ALASKA RANGE (CANTWELL AREA)** | | | | |
| --- | Cantwell Site/Parks Hwy. Mile 216 | 5.6, 6.2, 6.2, 6.2, 6.9, 7, 7, 7.3, 7.3, 7.6, 7.9, 8, 8.1, 8.1, 8.2, 8.6, 9.1, 9.1, 13.7 | 63.464919 | -148.788904 |

* – Coordinates are geographic, reported in the NAD83 datum and were obtained from Google Earth.

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
**DEPARTMENT OF TRANSPORTATION & PUBLIC FACILITIES**

HARD AGGREGATE
SOURCE LOCATION STUDY
FEDERAL PROJECT NO. STP-000S(823)
AKSAS PROJECT NO. 76149

HARD AGGREGATE SOURCE LOCATIONS & POLITICAL BOUNDARY MAP

| SCALE | DESIGNED | DRAWN | |
|---|---|---|---|
| AS SHOWN | PH | LB | PLATE 1 |
| | CHECKED ATB | DATE MAY 2013 | |

# ALASKA
# DEPARTMENT of
# TRANSPORTATION
# and
# PUBLIC FACILITIES

## STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

**AKSAS PROJECT NO. 79434**

Prepared by:

R&M CONSULTANTS, INC.
9101 Vanguard Drive
Anchorage, Alaska 99507

**STATE OF ALASKA DOT&PF**

# STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

**AKSAS PROJECT NO. 79434**

**ALASKA DEPARTMENT OF TRANSPORTATION**
**& PUBLIC FACILITIES**
5800 East Tudor Road
Anchorage, Alaska 99507-1286

Prepared by:

R&M CONSULTANTS, INC.
9101 Vanguard Drive
Anchorage, Alaska 99507

**July, 2013**

# STATE OF ALASKA DOT&PF
# STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

## TABLE OF CONTENTS

**Page**

## LIST OF TABLES



## LIST OF FIGURES



## ATTACHMENT

# CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

## EXECUTIVE SUMMARY


Alaska Department of Transportation & Public Facilities (DOT&PF) is conducting a feasibility study to determine the cost effectiveness of producing hard materials for paving aggregates from the existing Hard Aggregate Site on Panorama Mountain near Cantwell, Alaska. As part of this study, a cost comparison was performed between using the Panorama Mountain source and two commercial west coast (outside) sources.

The west end of Panorama Mountain is interpreted to be underlain by basalt flows with associated sills and dikes of diabase and gabbro. Nineteen (19) Nordic abrasion samples tested from this area since 1996 have returned values between of 5.6 and 9.1 with one outlier at 13.7. Without a subsurface investigation, a surface evaluation indicates that there are an estimated 1,000,000 tons of material for producing hard aggregate at the Cantwell Hard Aggregate Site.

For each of the aggregate source possibilities, there are variations in the delivery methods to be considered. Utilizing the out of state sources requires barging the materials into either the Port of Anchorage or a private facility in Anchorage. From either of these delivery points, the aggregates have to be unloaded and transported to the batch plant by truck.

For the Panorama Mountain source, the primary option is to deliver the aggregate to the batch plant by rail. There are multiple locations to consider for a loading facility which will be required to load the aggregate into hopper cars. The considerations involved for each location are described in the body of this report.

This evaluation assumed that material from the Hard Aggregate Site at Panorama Mountain would be processed on-site and then transported to a loading facility at a relatively nearby point on the Alaska Railroad (ARR). The Alaska Railroad has repeatedly stated that a permanent loading facility will require a separate siding and that loading must be accomplished using a conveyor system with a method to accurately weigh the material loaded into each gravel hopper. However, this season a contractor was given tentative approval to load a dedicated gravel train along the main line utilizing loaders to fill hopper cars with aggregate obtained from DOT&PF MS 52-2-046-2 approximately 1 mile to the north of our evaluation site. Alaska Railroad has confirmed that this is a one-time allowance and this approach is not an option for future operations. Ultimately the contractor did not utilize this loading site, but instead used existing ARR facilities at Healy.

Three primary loading facility options near Cantwell are considered in this report:

- The existing Healy facility approximately 36 miles to the north of the site,
- A new siding and loading facility at a point approximately 12 miles to the south of Cantwell, and

- A new siding and loading facility at a previously utilized site 26 miles south at approximately Milepost 190 along the Parks Highway.

The only facility currently operational near Cantwell that the Alaska Railroad would allow to be utilized to load aggregate without special allowances being made is the Healy facility to the north. Based on the crushing costs and hauling per ton per mile costs utilized in this analysis, the costs per ton delivered to the batch plant in Anchorage would be on the order of $83.50 per ton.

The estimated range costs of aggregate delivered to a batch plant in Anchorage from a new siding and loading facility near the Cantwell site would be on the order of $64.00 to $76.00 per ton. The siding location closest to Cantwell would result in lower costs per ton but with higher capital improvement costs. This average cost per ton is based on one of the two new siding locations being operational and does not include estimated capital costs for the siding or loading facility construction.

The range of estimates received from outside sources including Port of Anchorage dry barge berth fees and contractor truck hauling costs is approximately $66.00 to $82.00 per ton. A local private freight company submitted an estimate to barge the material from either outside source and unload the barge at their facility into contractor trucks. However the final estimated costs utilizing this approach were substantially higher.

At the estimated average approximate rates, it would take approximately 11-51 years to recover the roughly $4,100,000 associated with developing a new siding and loading facility. When all variables were considered, the range of recovery time was between 5 and 145 years depending on which comparisons were used. This assumes an annual need for 20,000 tons of aggregate to be delivered. The overall range of estimated costs for each source and details regarding delivery method costs is included.

Based on this analysis, without special allowances being made from ARR to allow for loading materials on existing rail, it appears to be more economical to barge materials to Anchorage from outside sources, utilize the Port of Anchorage's dry barge berth, allowing the contractor to unload the barge and haul to the batch plant with their own equipment and personnel.

# STATE OF ALASKA DOT&PF
# STATEWIDE MATERIAL SITE INVENTORY, SITE INSPECTIONS & GEOLOGICAL INVESTIGATIONS

# CANTWELL HARD AGGREGATE DEVELOPMENT FEASIBILITY STUDY

## 1.0 INTRODUCTION

### 1.1 Background

The Alaska Department of Transportation and Public Facilities (DOT&PF) is investigating the opportunity to supply hard aggregate for paving projects throughout southcentral Alaska, which would increase the life of road surfaces. Currently there are two out-of-state sources for hard aggregate that can ship (via barge) material to Alaska when specified for a project. DOT&PF is interested in supplementing these sources with an in-state site near Cantwell, if such a site can be developed economically within the near future. A Vicinity Map showing the location of the site in relation to Anchorage and the Parks Highway/Alaska Railroad corridor is provided as Figure 1.

### 1.2 Contract Authorization

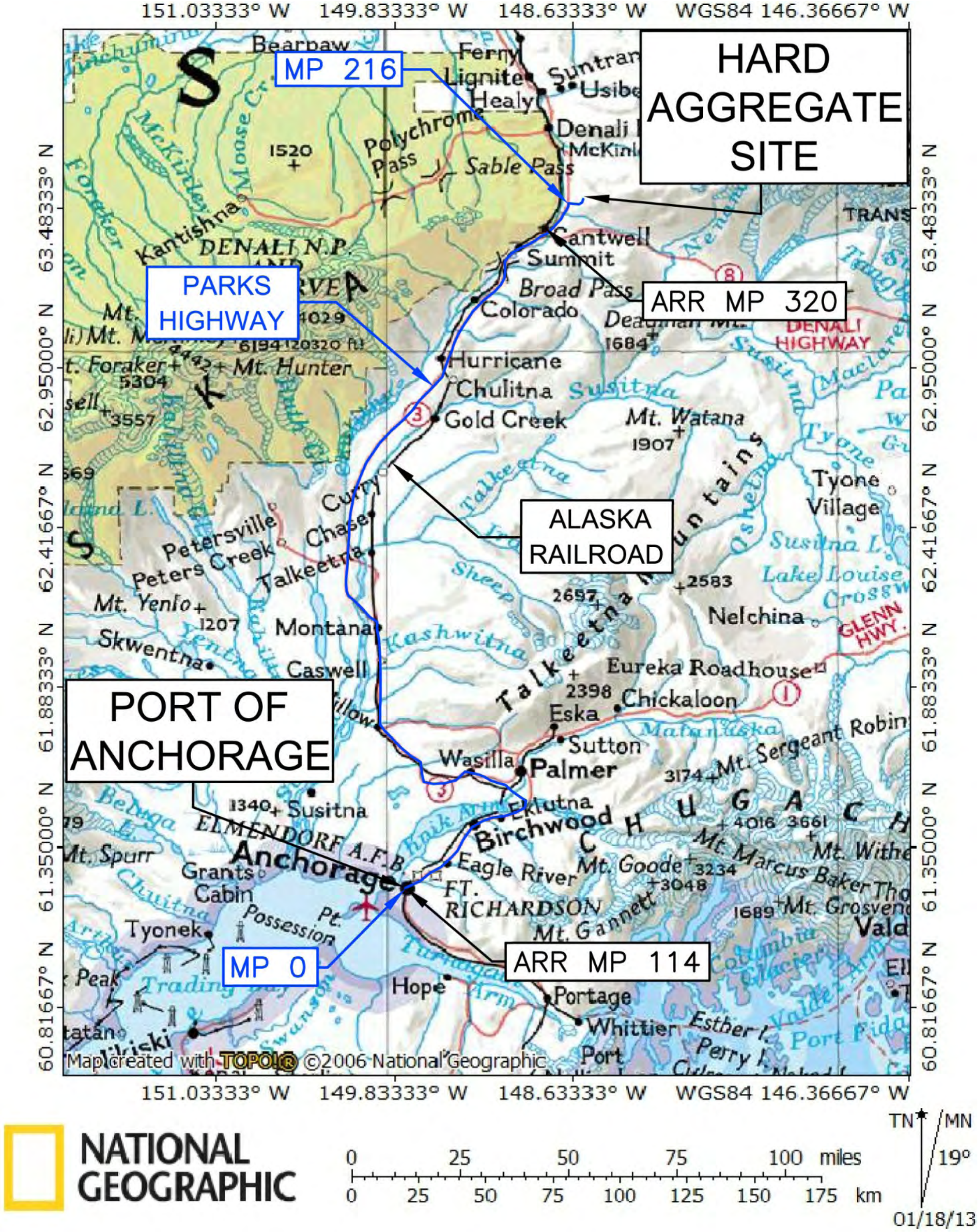
This study was conducted as part of Professional Services Agreement No. 02572001, Statewide Material Site Inventory, Site Inspections & Geological Investigations, between DOT&PF and R&M Consultants, Inc. Work was performed under Amendment No 9, NTP No.10 and consists of Subtasks A, B and C of Task 7 of the agreement.

### 1.3 Scope-of-Work

The Panorama Mountain area north of Cantwell is a potential area for an in-state hard aggregate material site. The area lies adjacent to the Parks Highway and is within about 25 miles of Alaska Railroad sidings close to the communities of Cantwell and Healy. There are three existing sites within this area (see Plate 1-A). The site of interest to this study is the Hard Rock Aggregate Site which lies to the north and northeast of Milepost (MP) 216 on the Parks Highway. The site covers approximately 35 acres and is owned partially by Ahtna Native Corporation and partially by the State of Alaska. A material site has been developed at this location by Mr. Jim Caswell (Alaska Lime Co., Inc.) on the state portion of the site. Previous testing by DOT&PF indicates that the Hard Aggregate Site has the potential to compete (in quality) with other out-of-state sources, however development and transportation costs were unknown at the start of this study.

This project was intended to compare the costs per ton of a developed Cantwell site to the two (2) existing out-of-state sources.

**FIGURE 1**
**VICINITY MAP**



Our initial scope-of-services included four tasks as outlined below:

1. Conduct a brief reconnaissance of the Cantwell material site on state land to determine site surface conditions and collect 10 rock samples for laboratory testing. Prepare maps using existing aerial or satellite imagery.
2. Perform Nordic Abrasion testing (ATM 312) on the samples.
3. Provide a conceptual mining plan for the site including costs for processing the rock to meet specification. Provide a transportation plan, including development of a loading facility along the Alaska Railroad for loading and unloading of this material with their existing rail cars.
4. Provide a cost per ton of processed hard aggregate delivered to the Port of Anchorage from the Cantwell site, and the two outside sources. Perform an economic analysis to determine the break-even point between the Cantwell site and the two outside sources.

Our revised scope-of-services (Amendment No. 14 dated April 22, 2013) includes the tasks as outlined below:

1. Provide a conceptual mining development plan for the Cantwell site including processing the material to meet specification, and associated costs for the on-site production of approximately 20,000 tons/year of hard aggregate (size range 4.75 mm to 10 mm) to be obtained from the site

2. Provide a conceptual aggregate material transportation plan (using train, truck, or a combination) from the Cantwell site to a loading facility along the Parks Highway corridor [including: 1) railhead site near Cantwell that may require the development of a loading facility for the Alaska Railroad (RR), and 2) private loading facility (PF) that may require development/leasing fees], and associated costs to deliver the aggregate to a hot-mix batch plant (BP) in the Anchorage area (e.g. AS&G Lang Street facility). At least three delivery options shall be considered to determine aggregate cost per ton:

   2a- Cantwell site to RR loading facility: by truck; RR loading facility to BP: by train
   2b- Cantwell site to PF: by truck; PF to BP: by train
   2c- Cantwell site to BP: by truck.

3. Provide a cost per ton of hard aggregate from the two existing out-of-state sources delivered to an Alaska port, unloaded then transported to the same BP considered above.

4. Compare costs and determine cost-effectiveness of developing the Cantwell site and transporting the produced aggregate to the Anchorage area versus importing aggregate from the two outside sources.

5. Estimate the number of years (assuming ~ 20,000 tons/year usage) and total number of tons of aggregate that will make the construction of a Cantwell rail siding economical, and make the Cantwell source competitive with outside sources.

6. Estimate the cost savings that may be realized by producing several years' worth of hard aggregate at one time and stockpiling in Cantwell for future use.

7. Submit a draft report describing work done in Tasks 7A, 7B, 7C, 7D, and 7E to the Project Manager for review and comments. The report shall include the Cantwell hard aggregate economic study and the hard aggregate source location study results.

8. Submit a final report that addresses review comments to the Project Manager.

## 1.4 Assumptions

Several assumptions were made during this study.

1. While only surficial sampling was conducted, all of the material at the Cantwell Hard Aggregate Site is assumed to be satisfactory for the desired purpose.
2. That the existing access road into Mr. Caswell's site at ADL 417419 would be available for use with no additional right-of-way cost. Upgrade and maintenance of the road would be required.
3. The two outside sources are CalPortland's DuPont Pioneer Aggregate Plant in DuPont, Washington and Jack Cewe's Jervis Inlet Site in British Columbia, Canada.

# 2.0 SITE CONDITIONS

The following information is based on a brief field reconnaissance by R&M Consultants, Inc. conducted in September 2012 and data acquired by DOT&PF during field programs between 1996 and 2003. Site photographs are provided as Figure 2.

Detailed exploration has not been performed at the site, therefore verification of the projected quality and quantities should be accomplished prior to mining.

## 2.1 Location

The Cantwell Hard Aggregate Site lies along the George Parks Highway corridor northeast of MP 216 on the north side of the Nenana River Crossing at Windy. This site is situated on the southern base of Panorama Mountain at the confluence of the Nenana and Jack Rivers (Plate 1-A). Denali National Park lies immediately to the west across the Nenana River from the Parks Highway.

The George Parks Highway (numbered Interstate A-4 and Alaska Route 3), usually called the Parks Highway, traverses 323 miles (520 km) from its junction with the Glenn Highway 35 miles (56 km) north of Anchorage to Fairbanks in the Alaska Interior. The highway, originally known as the Anchorage-Fairbanks Highway, was completed in 1971, and given its current name in 1975. The highway, along with the Alaska Railroad, follows one of the most important transportation routes in Alaska. It is the main route between Anchorage and Fairbanks (Alaska's two largest metropolitan areas), the principal access to Denali National Park and Preserve and Denali State Park, and the main highway in the Matanuska-Susitna Valley.

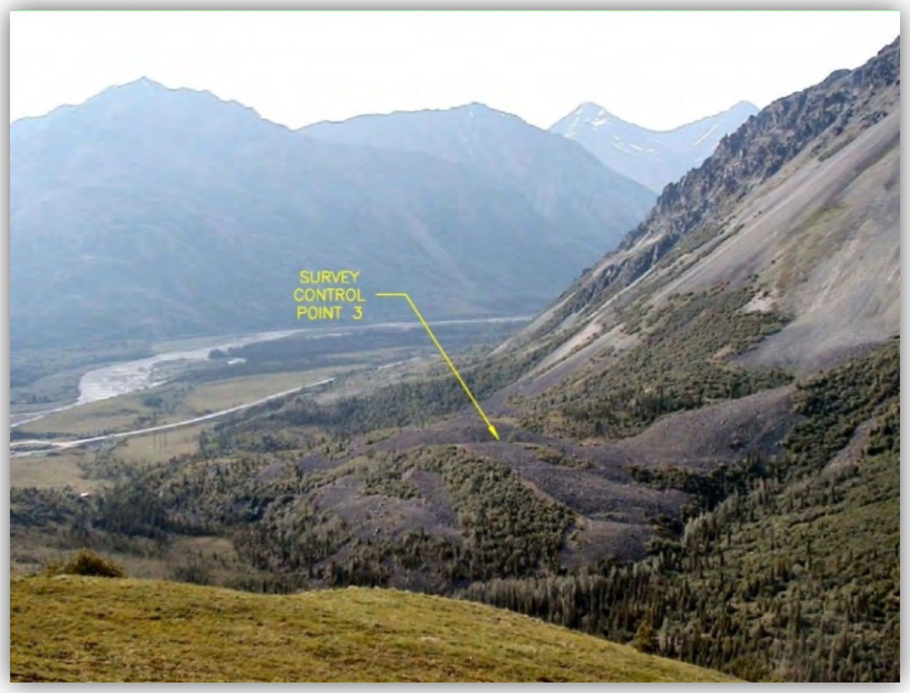
Mileposts along the Parks Highway do not begin with 0 (zero). Instead, they begin with Mile 35 (km 56), continuing the milepost numbering of the Glenn Highway where the two highways intersect near Palmer. The 0 (zero) mile marker for the Glenn Highway is at its terminus in downtown Anchorage at the intersection of East 5th Avenue and Gambell Street. Thus, mileposts along the Parks Highway reflect distance from Anchorage, which is not actually on the Parks Highway.

## 2.2 Geology

According to “Geology and Geochronology of the Healy Quadrangle” (Csejtey et al., 1992), the west end of Panorama Mountain is underlain by basalt flows with associated sills and dikes of diabase and gabbro with subordinate sedimentary rocks. Petrographic analysis of two samples from rubble at the base of the mountain was performed by Stevens Exploration in 2003 with the samples being identified as andesite and diorite (Figures 3 and 4). The low flat ridge along the south base of the mountain is underlain by a Cretaceous mélange, within which blocks of massive limestone are encountered. The Alaska Lime Company facility is located on one of these limestone blocks. The low ridge is bounded by the McKinley fault, part of the Denali fault system.

**FIGURE 2**
**SITE PHOTOGRAPHS**

Boulders on the surface of the Cantwell Hard Aggregate Site at Control Point 3 (2003).




Rock glaciers, looking west towards Parks Highway, Nenana River in background (DOT&PF, 2003).

**FIGURE 3**
**PETROGRAPHIC ANALYSIS REPORT RUBBLE 6**

## PETROGRAPHIC ANALYSIS REPORT

Client: DOT & PF – John Fritz

Thin Section Number: Rubble No. 6 (3)

Project Number : 04 36 5016

Field Classification: Moderately dark gray-green diorite with CI 35-40. No effervescence.

**COMPOSITION**

| Constituent | Optical/Physical Properties | Estimated % |
|---|---|---|
| **Plagioclase ($An_{38-50}$: Andesine)** | feldspar laths randomly intergrown in subophitic (?) texture; twinning & cleavage typical; mostly clear, unaltered, except for some patches of incipient epidote (?) (or leucoxene?), which is whitish in reflected light. Large laths have inclusions of the (sometimes altered) mafic. ≤4 mm. in length. | 42% |
| **Pyroxene/Augite** | colorless, no pleochroism in plane light; high relief, low interference colors; high extinction angle; variously altered to chlorite and tremolite-actinolite (both green in plane light); ≤4 mm. in length. Chlorite includes some pennine with anomalous "Berlin blue" interference colors; fills interstices as well as being alteration products of mafics. | 40% |
| **Epidote-Clinozoisite** | Clinozoisite minor, with high relief, 1st order anomalous interference colors; epidote usually occurs as high relief, semi-opaque whitish (in reflected light) granular patches which are secondary; incipient patches fairly common. | 8% |
| **Opaques** | those white in reflected light = leucoxene. Ilmenite/leucoxene occurs as skeletal crystals with ilmenite cores surrounded by leucoxene. | 10% |

**TEXTURES AND STRUCTURES**

Grain Size: Both pyroxene and plagioclase are ≤4 mm. in length; opaques (ilmenite/leucoxene) up to 2 mm. in diameter.

Textures: Subophitic, with plagioclase crystals better-formed, sometimes somewhat clumped together; pyroxene formed later, is more interstitial, yet not markedly so. Ilmenite formed even later; definitely interstitial.

Structures: Several small microfractures noted, mostly around edge of specimen. (These may have formed when the specimen was prepared-?) This is a fairly cohesive rock.

**PETROGRAPHIC CLASSIFICATION:** **Diorite**

**PETROGENESIS:** Igneous, possibly shallow intrusive.

**COMMENTS:**

Evelyn LH. Stevens 8/14/03 David L. Stevens 8/14/03

Petrographer Date Approved by Date

**FIGURE 4**
**PETROGRAPHIC ANALYSIS REPORT RUBBLE 7**

## PETROGRAPHIC ANALYSIS REPORT

Client: DOT & PF - John Fritz

Thin Section Number: Rubble No. 7 (4)

Project Number : 04 36 5016

Field Classification: Moderately dark greenish-gray, fine-grained porphyritic volcanic with CI ≈ 40 = andesite(?). No effervescence noted.

**COMPOSITION**

| Constituent | Optical/Physical Properties | Estimated % |
|---|---|---|
| **Plagioclase ($An_{10\text{-}30}$: Oligoclase)** | largest grains ≤4 mm; some glomerophenocrysts; occur as larger discrete grains up to ≈ 2 mm. as clumped phenocrysts up to ≈ 3.5 mm. diameter, and as much smaller laths ≈ .37 mm. in length. | 25% |
| **Mafics/Augite?** | chloritized; possibly/probably some hornblende? | 15% |
| **Chlorite + Actinolite** | Pennine chlorite with anomalous "Berlin blue" colors occurs as interstitial patches (that may have once been volcanic glass?); also chlorite occurs as pleochroic shred and patches intimately mixed with higher-relief shreds of actinolite, all being alteration products of the pyroxene (augite?). | 38% |
| **Epidote** | includes clinozoisite also. High relief, moderately high interference colors, pistachio green in plane light. Occurs as colorful granular clumps (occasionally), and as cloudy but colorful incipient epidote patches ubiquitous throughout the rock. Sometimes/often seemingly associated with ilmenite-cored leucoxene (white in reflected light.) | 10% |
| **Opaques** | ilmenite altering to leucoxene, possibly altering to epidote? | 10% |
| **Calcite** | high relief, high birefringence, typical rhombohedral cleavage; probably alteration products of Ca-plagioclase feldspars; ≤ 1.5 mm. diameter. | <2% |

**TEXTURES AND STRUCTURES**

Grain Size: < .3 mm. diameter to ≈ 4 mm. diameter.

Textures: Glomeroporphyritic igneous rock with moderately fine-grained matrix; volcanic.

Structures: One open microfracture noted; another is filled with incipient epidote.

**PETROGRAPHIC CLASSIFICATION:** **Deuterically-altered Porphyritic Andesite**

**PETROGENESIS:** Volcanic flow that was subsequently buried and deuterically altered.

**COMMENTS:**

Carolyn [illegible] Stevens — Petrographer
8/4/03 — Date
Donald [illegible] Stevens — Approved by
8/14/03 — Date

The existing Cantwell Hard Aggregate Site is located on the southern base of Panorama Mountain, along the north side of the Nenana River crossing near Windy. The site is at the bottom of an extensive complex of talus chutes that originate high up on the mountain. The Hard Aggregate Site encompasses the upper portion of a group of large tongue-shaped inactive rock glaciers (Wahrhaftig and Cox, 1959). These rock glaciers are composed of angular blocks of rock ranging up to 6 feet in diameter (see Figure 2) which stretch out to the south from the base of the mountain from the Cantwell Hard Aggregate Site to the two developed DOT&PF material sites (MS 52-2-046-2 and MS 52-2-068-2) that lie to the west of site (Plate 1-A).

According to Wahrhaftig and Cox (1959), the rock glaciers formed during post-Wisconsin time (less than 10,000 years ago). Fronts of active (moving) rock glaciers are bare of vegetation, are generally at the angle of repose and make a sharp angle with the upper surface. Inactive rock glaciers can be distinguished by gentle slopes that are rounded on top along with lichen and turf growth which not only covers, but joins boulders together, and typically takes more than 300 years to grow. Since these types of vegetation can be observed on the southern Panorama Mountain rock glaciers, it may be concluded that these rock glaciers were not active during the last cold period (A.D.1600 to 1900).

Rocky material found in the rock glacier has fallen from the steep cliffs on the mountain above and forms talus cones which flow into the rock glaciers. The material may become finer-grained at depth due to percolation of fine-grained material through the coarser surface material, or reducing of grain size by grinding movement near the base of the rock glacier. Typically, the top one-quarter of the thickness of a rock glacier is reportedly coarse rubble, below which is coarse rubble mixed with silt, sand, and fine gravel.

The existing Cantwell Hard Aggregate Site lies on the south side of the Alaska Range with permafrost ranging from isolated patches to sporadic occurrences. However, there may be remaining isolated pockets of permafrost underlying the inactive rock glaciers. Groundwater is generally associated with poorly drained low lying areas or with rivers and streams. Locally, groundwater can be perched on glacial till or bedrock.

The rock has been tested for hardness during at least three sampling programs since 1996. Known sample results are shown on Tables 1 through 3.

The first recorded sampling program was in 1996 as part of the “Studded Tire Wear Resistant Aggregate Study” (Johnson and Pavey, 2000). A material site referred to in that study as MS 52-2-058-2 (Plate 1-A) was sampled but no site boundaries were delinated. The tested site was located uphill of DOT&PF Material Site 52-2-068-2 on Ahtna Corporation lands. The contractor for the aggregate study reportedly arranged for purchase of the material from Ahtna. However, an undeveloped site formerly designated MS 52-2-058-2 already existed elsewhere and should not be confused with the site referenced in the aggregate study report.

**TABLE 1**
**SUMMARY OF DOT&PF SAMPLE RESULTS**
**For MS 52-2-058-2* (Uphill of MS 52-2-068-2)**
(No Sample Locations Available)

| Location Name | Depth | Individual Nordic Abrasion Values | Average Nordic Abrasion Value | Degradation Value (ATM 13) | Los Angeles Abrasion Loss % |
|---|---|---|---|---|---|
| 1996 | | | | | |
| R96-8 | Surface | 6.9, 7.3, 6.9 | 7.0 | 79 | 9 |
| R16 | Surface | 8.0, 8.2, 8.1 | 8.1 | --- | --- |
| R17 | Surface | 8.4, 7.5, 7.9, | 7.9 | 79 | --- |

*The samples were all field identified as augite/andesite with a grain size of less than 1 mm.

**TABLE 2**
**SUMMARY OF DOT&PF SAMPLE RESULTS FROM 2003**

| Location Name | Depth | Individual Nordic Abrasion Values | Average Nordic Abrasion Value | Location** | |
|---|---|---|---|---|---|
| | | | | North Latitude | West Longitude |
| July 10, 2003 | | | | | |
| Rub 06 | Surface | Not Reported | 9.1 | 63.464520 | 148.794479 |
| Rub 07 | Surface | Not Reported | 7.3 | 63.464259 | 148.794096 |
| September 23, 2003 | | | | | |
| Rub 71 | Surface | Not Reported | 6.2 | 63.464802 | 148.791291 |
| Rub 72 | Surface | Not Reported | 8.0 | 63.465487 | 148.789275 |
| Rub 73 | Surface | Not Reported | 7.0 | 63.465482 | 148.787799 |
| Rub 74 | Surface | Not Reported | 5.6 | 63.464591 | 148.789106 |

**Samples locations (NAD83) were derived from annotated maps and re-plotted in Google Earth to obtain coordinates (NAD83).

Rubble No. 6 was identified in thin section as a diorite (see Figure 3).
Rubble No. 7 was identified in thin section as a deuterically-altered porphyritic andesite (see Figure 4).

R&M's Bob Pintner, P.E. and Brian Mullen, E.I.T. collected 10 rock samples (~50 lb. each) from the surface of the state portion of the Cantwell Hard Aggregate Site using hand tools (sledge hammers) to break the rock into manageable pieces. The sampling took place on September 19, 2012. Access to the sampling area was along the existing access road to the Caswell site. Samples were submitted to R&M's Anchorage laboratory for further examination and testing. Test results are shown below. Additionally, Mike Wariner, P.E. of R&M and Barry Benko, C.P.G. of DOT&PF visited the site on November 20, 2012 to observe development and transportation conditions.

**TABLE 3**
**SUMMARY OF R&M SAMPLE RESULTS**
(Collected September 19, 2012)

| Location Name | Depth | Individual Nordic Abrasion Values | Average Nordic Abrasion Value | Location* | |
|---|---|---|---|---|---|
| | | | | North Latitude | West Longitude |
| 1C | Surface | 8.7, 9.0, 9.5 | 9.1 | 63.46391 | 148.79081 |
| 2G | Surface | 7.5, 7.8, 7.5 | 7.6 | 63.46486 | 148.79029 |
| 3B | Surface | 5.3, 6.4, 6.8 | 6.2 | 63.46360 | 148.78974 |
| 4E | Surface | 6.9, 6.7, 7.1 | 6.9 | 63.46435 | 148.78902 |
| 4I | Surface | 8.1, 8.7, 8.9 | 8.6 | 63.46552 | 148.78914 |
| 5A | Surface | 8.5, 8.0, 7.9 | 8.1 | 63.46324 | 148.78840 |
| 6C | Surface | 6.5, 7.6, 7.9 | 7.3 | 63.46388 | 148.78792 |
| 6J | Surface | 8.3, 8.2, 8.2 | 8.2 | 63.46575 | 148.78804 |
| 7E | Surface | 13.7, 13.6, 13.8 | 13.7 | 63.46443 | 148.78730 |
| 7G | Surface | 5.9, 5.9, 6.8 | 6.2 | 63.46497 | 148.78731 |

*Samples locations (NAD83) were recorded using recreational grade GPS units.

Other laboratory data for the material in this area, including Los Angeles abrasion loss, sodium sulphate soundness loss, specific gravity and degradation values are available from DOT&PF.

## 3.0 PREVIOUS WORK AND ESTIMATED QUANTITIES

The area around the south base of Panorama Mountain has been investigated and developed for material sources since the construction of the Denali Highway in the 1950's. The material has primarily been used for embankment construction, aggregates and riprap. Since the 1990's, DOT&PF has been considering exploiting the hardness of the material in this area for paving aggregate that can resist the wear caused by studded tires.

### 3.1 Construction of Denali Highway

Material sites were opened along the base of Panorama Mountain during 1957 for construction of the Denali Highway (Plate 1-A). A free use permit was issued to the Bureau of Pubic Roads for MS 52-2-046-2 in 1956. An indefinite right-of-way grant was issued to DOT&PF by BLM in 1962. This portion of the Denali Highway became part of the Parks Highway in 1971 when the Parks Highway was completed. An indefinite right-of-way grant was issued to DOT&PF for MS 52-2-068-2 by BLM in 1964.

### 3.2 Alaska Lime Company and Existing Rubble Quarry

An interim conveyance (IC 443) was issued in 1981 by BLM to Ahtna, Incorporated (subsurface) and Cantwell Yedatene NA, Corporation (surface) for the land in Township 17 South, Range 7 West, Fairbanks Meridian. Tentative approval (TA F-034875) was given in 1982 to the State of Alaska for lands in Township 17 South, Range 6 West, Fairbanks Meridian.

Mr. James Caswell established the Alaska Lime Company, an agricultural limestone quarry operation and processing plant, on the low ridge along the front of Panorama Mountain during the early 1990s (Plate 1-A).

According to information provided to R&M by DOT&PF, the proposed Hard Aggregate Site lies on State Land in Section 6, T17S R6W, FM. It lies entirely within the boundaries of a negotiated material sale contract issued to Mr. James Caswell of Cantwell (ADL 417419) on September 19, 2008. According to DNR case file abstracts, the contract presently expires on September 18, 2013. Mr. Caswell reported mining 2,319 cubic yards of material in 2010 and 2011. Mr. Caswell has also built a road to provide access to the site. A public easement to the site (ADL 417426) was authorized in 2007.

### 3.3 DOT&PF Investigations

In the 1990's, DOT&PF conducted a "Studded Tire Wear Resistant Aggregate Study" (Johnson and Pavey, 2000). Material from MS 52-2-058-2 on Panorama Mountain was hauled to Anchorage and processed into paving aggregate. Test sections were placed along the Seward Highway and on 5th and 6th Avenues. The sections were then compared with those made of aggregate from the Matanuska Valley. The Panorama Mountain aggregate reportedly exhibited 45 percent less wear than the aggregate from the Matanuska Valley.

DOT&PF also conducted a field investigation of the area around the Cantwell Hard Aggregate Site in 2003. Nordic abrasion tests and petrographic analyses were performed. A survey control point (CP-3) was also placed on the township line between State of Alaska and Ahtna Lands by R&M in 2003.

### 3.4 Estimated Available Quantity of Material

Conservatively, there is an estimated 1,000,000 tons of material available for manufacturing hard aggregate at the Cantwell Hard Aggregate Site. Even with no subsurface exploration, it has been assumed for the purposes of this estimate that an average of 15 feet of material will be useable from the site. The estimated quantity of material available is based on a 15-foot working depth over both the State and Ahtna portions of the site and uses a factor of 1,000 c.y. per acre to estimate the quantity, i.e. (Acres) x (Average working depth) x (Factor) = (Quantity Available in Cubic Yards).

**TABLE 4**
**ESTIMATED QUANTITIES**

| Area (acres) | Average Working Depth (ft.) | Factor | ~ Quantity (c.y.) | ~ Quantity (tons) |
|---|---|---|---|---|
| State Land | | | | |
| 18.4 | 15 | 1,000 c.y./acre | 276,000 | 480,000 |
| Ahtna Land | | | | |
| 19.1 | 15 | 1,000 c.y./acre | 287,000 | 500,000 |

There may be significantly more material available. Working depths of greater than 60 feet may be achievable, however quantity and quality has <u>not</u> been verified. The surface of rock glaciers tend to be characterized by blocks and smaller stones but all sizes and shapes are possible. The surface appearance is misleading, however, in that the interior of rock glaciers, where known, usually consist of a diamicton in which fines may be plentiful (Washburn, 1980).

A conceptual site development plan is presented on Plate 1-B.

## 4.0 MINING, PROCESSING AND HAULING TO RAIL LOADING FACILITY

This study assumes that the aggregate will be crushed on site and then will be hauled from the Hard Aggregate Site to Anchorage either by Alaska Railroad trains or over the Parks Highway via trucks.

Options considered for transportation by rail were dedicated trains consisting of 86 gravel hopper cars or adding approximately 15-20 hopper cars to scheduled trains that had capacity traveling to Anchorage. Depending on the loading option to be utilized, the crushed material would either be stockpiled on site until a train was available for loading or hauled to the loading site for stockpiling there prior to loading the rail cars.

Consideration was given to multiple potential areas for railroad loading sites as follows.

1. The closest site would have involved constructing a bridge across the Jack River to the south of the Nenana River. This would have had the shortest haul distance (~2 miles) to the railroad of any potential area. However, suitable land adjacent to the railroad is apparently owned by the National Park Service and would not likely be made available.
2. A second loading option abuts the existing railroad right-of-way at the community of Cantwell with a haul distance of approximately 8.7 miles. However, construction of one mile of siding would require building a new bridge and crossing a bog. It also would interfere with the existing sidings and railroad facilities in Cantwell. Additionally, aggregate would have had to be hauled through a 40 mph speed zone within the community. The combination of these conditions eliminated this location from consideration.
3. A third loading option is approximately 12.7 miles to the south near a point where the railroad crosses the Parks Highway at MP 204 (Plate 1-C). The surrounding land is apparently owned and managed by the Ahtna/Yedatene NA Corporation (Cantwell). This location would require the construction of access roads, stockpile area, loading facility and a railroad siding. A photograph of the area is included as Figure 5.
4. The Alaska Railroad has a loading facility near Healy that could be utilized to stockpile and load aggregate into hopper cars. This facility is approximately 36 miles to the north of the Cantwell Site. The railroad provided information regarding utilization of this location for loading aggregate. This loading site was reportedly used by a hard aggregate producer during Spring of 2013 when a site at MP 190 of the Parks Highway still contained winter snow.
5. An upgrade to the existing Alaska Railroad site at track mile marker 301-302 or approximately Parks Highway Milepost 190 may also be a possibility (Plate 1-D). This location was scheduled to be utilized by a contractor to load Cantwell aggregate onto a dedicated gravel train during the 2013 season for projects in Anchorage, however the existing Healy site was ultimately used. For this specific project the railroad was allowing gravel hopper cars to be loaded on the mainline utilizing front loaders under very strict guidelines. However, it has been

repeatedly reiterated by the Alaska Railroad that for any future loading a conveyor system will be required to load the hoppers and that loading must be completed on a siding.

Due to the length of haul to the railhead and the quantities (20,000 tons annually) being considered for production, it was felt that crushing of the aggregate on-site is the more economical solution. It should be noted that for smaller quantities, it may not be worth mobilizing a crusher to the site, i.e. for the 100 tons required for the 1998 test sections the material was transported to Anchorage and then processed (Johnson and Pavey, 2000).

### 4.1 Mining, Processing and Stockpiling at Hard Aggregate Site

The on-site material is very coarse, angular and dense. This will require large equipment to excavate and move this material. It may also be necessary to selectively remove and set larger boulders aside. The hardness of the rock may cause wear and tear to excavating equipment in excess of that which would normally be expected in a typical mining operation.

There is sufficient room on the site (or adjacent to the site) to place a crusher. Stockpiled aggregate could also be placed on-site or adjacent to the site (Plate 1-B). There appears to be sufficient room to stockpile 100,000 tons should that be required. It would appear that the most economical approach to on-site activities would be to crush and stockpile the needed quantity of material on the state land that could then be hauled to the railroad loading station as needed each season. The overall cost savings of producing more than one season's materials at a time are relatively minor because the majority of the costs associated with utilizing this site are due to the trucking and haling activities, not the crushing operations. Also, if individual contractors are going to utilize this material as a source for different projects, this may not be practical. For the cost analysis in this study, it is assumed that the individual contractor will mobilize as needed to mine, crush and stockpile only the material needed for each project. As described in our scope-of-work, we will use 20,000 tons of material for cost analysis purposes.

Based on our experience in crushing operations and conversations with multiple contractors regarding the approach and equipment typically used for this size operation, we would expect the following equipment to be used to accomplish the on-site operations. Crushing and separation of materials would likely be completed by a 42"x28" Jaw Crusher and a 300 HP Cone Crusher feeding a screening plant. With expected capacity of approximately 200 cy/hr and anticipated net density of material to be approximately 126 pounds per cubic foot after accounting for void space in loader buckets, our anticipated output would be 340 tons per hour. Support equipment would consist of a dozer, two front-end loaders and minimal materials lab equipment.

The percent of materials crushed that meet the particle size requirements to be used as coarse aggregate in paving activities varies for each operation. During our research we had multiple conversations with representatives from a local contractor who is currently utilizing a DOT&PF site approximately 1 mile north of the study site and they indicated that they are realizing 30% generation of acceptable material. For this analysis, we used the 30% factor because it represents actual work accomplished. This payable yield percentage translates into approximately 66,667 total tons to be processed to provide 20,000 tons of acceptable aggregate.

The operation described above including necessary personnel should be able to accomplish the crushing of 20,000 tons of acceptable material in approximately 3 weeks of crushing activities.

Utilizing typical industry wage scales and hourly costs of operations for the listed equipment, we calculated a crushing cost for a useable ton of coarse aggregate to be $22.04 per ton.

This could likely vary by as much as $4.00 per ton depending on equipment production rates, useable yield percentages during crushing, the size of staff utilized and the daily work schedule of the contractor.

**TABLE 5**
**ESTIMATED COST FOR EXCAVATION, PROCESSING & STOCKPILING ON SITE**

| Crushing Equipment | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Equipment** | **Each** | **Hours / Day** | **Days / Months** | | **Unit Rates** | **Markup** | **total** |
| 42"x28" jaw crusher | 1 | - | 1 | Month | $31,000.00 | 15% | $35,650.00 |
| 300HP cone crusher | 1 | - | 1 | Month | $38,000.00 | 15% | $43,700.00 |
| Screening Plant | 1 | 12 | 16 | Days | $75.00 | 0% | $14,400.00 |
| Materials Lab | 1 | 0 | 1 | Month | $2,000.00 | 0% | $2,000.00 |
| Dozer | 1 | 12 | 16 | Days | $195.00 | 15% | $43,056.00 |
| 5 CY Front Loader | 2 | 12 | 16 | Days | $155.00 | 15% | $68,448.00 |
| Pickup | 1 | 12 | 16 | Days | $17.00 | 15% | $3,753.60 |
| Mob/Demob | 1 | - | - | - | $55,000.00 | 0% | $55,000.00 |
| | | | | | | **Equipment Total:** | **$266,007.60** |
| | | | | | | | |
| **Labor Costs** | | | | | | | |
| **Position** | **Each** | **Rate/hr** | **Hrs/Day** | **Days** | **Straight** | **Overtime** | **Total** |
| Dozer Operator | 1 | $115.00 | 12 | 16.0 | $14,720.00 | $ 11,040.00 | $25,760.00 |
| Loader Operator | 2 | $118.00 | 12 | 16.0 | $30,208.00 | $ 22,656.00 | $52,864.00 |
| Crusher Operator | 1 | $118.00 | 12 | 16.0 | $15,104.00 | $ 11,328.00 | $26,432.00 |
| Materials QC | 1 | $90.00 | 12 | 16.0 | $11,520.00 | $ 8,640.00 | $20,160.00 |
| Laborer I | 1 | $105.00 | 12 | 16.0 | $13,440.00 | $ 10,080.00 | $23,520.00 |
| Crew per diem | 6 | $210.00 | 0 | 96 | $20,160.00 | | $20,160.00 |
| | | | | | | **Labor Total:** | **$168,896.00** |
| | | | | | | **Total Crush & On-site Stockpile:** | **$434,903.60** |
| | | | | | | **Royalty:** | **$5,878.89** |
| | | | | | | | |
| **Cost to crush** | 11,758 | CY of Rock for 20,000.00 Tons of Usable Material | | | | | |
| | | | | | | | |
| | | | **$ 22.04** | **Per Ton of Usable Material** | | | |

## 4.2 Truck Hauling of Acceptable Aggregate to Rail Loading Sites

In order for the aggregate to be transported to Anchorage via railcars, the acceptable crushed aggregate will have to be hauled from the site near Panorama Mountain by truck over the Parks Highway to the loading point determined to be the most beneficial. Three different railroad loading options appear to be feasible.

- A potential site located approximately near Parks Highway Milepost 204, 12.7 miles to the south of the hard aggregate site.
- An existing Railroad access area at approximately Parks Highway Milepost 190 on the Parks Highway, 26 highway miles south of the hard aggregate site.
- The existing Healy facility approximately 36 highway miles to the north of the hard aggregate site.

Each location has advantages and challenges and varying associated costs. The site specific conditions for each are discussed in the following section. In order to provide a relatively consistent comparison of the costs associated with trucking useable materials to each location, we kept the hauling operation consistent with regard to the pieces of equipment utilized, crew staffing and length of shifts worked. This approach ties the haul costs directly to the number of miles the haul trucks are required to drive at specific speed limits between the source location and the unloading area.

The proposed operation would consist of one loader, 15 haul trucks, 1 water truck and a grader along with associated personnel. The haul team schedule would consist of 12 hour work days, 5 days per week with overtime pay for the personnel taking effect after 8 hours each day. An evaluation of these conditions utilizing typical operating costs and personnel wages results in the following haul times and associated costs per ton:

- Potential Site at MP 204: 6 Days Hauling; $21.12/Ton Hauled
- Improved Site at MP 190: 9 Days Hauling; $31.67/Ton Hauled
- Healy Site: 11 Days Hauling; $38.71/Ton Hauled

## 4.3 Required Site Development

A major factor in the evaluation of each location is the requirement from the Alaska Railroad that loading of railcars be accomplished with the cars on a siding to avoid conflict with scheduled rail traffic. Additionally, all loading at an established location must be completed using a conveyor system including a scale to accurately weigh aggregate to avoid overloaded railcars. The existing Healy facility has the infrastructure in place to accomplish this. The other two potential locations would require improvements including the construction of a new siding and conveyor loading system.

### Healy Location

In order to utilize the existing rail loading site that ARR operates in Healy, there would not be additional infrastructure development required. This site would require close coordination with the railroad regarding stockpiling material prior to loading the railcars and scheduling trains so as not to interfere with previously scheduled deliveries. The most likely windows of opportunity for scheduling deliveries would be late fall or very early spring. Consideration was given to hauling smaller shipments via railcars added to existing trains already scheduled to come from the Healy site. However, after evaluation of this suggestion by ARR, they determined that this piece meal approach would dramatically increase the overall cost per ton of aggregate and would be extremely limited in hopper availability since the majority of the gravel hoppers are committed to the two designated gravel trains already in operation. The Healy location could be utilized to load dedicated 86-car gravel trains already in operation.

**Potential New Site at Parks Highway Milepost 204**

There is an area adjacent to Parks Highway Milepost 204 which could provide a potential location for a siding and stockpile area to be developed. As part of the evaluation of this location we assumed a 4-acre parcel of land would be purchased or leased. The access roads and necessary improvements required would be made to the area to allow for stockpiling of the materials and to construct a siding of at least 1 mile in length. We anticipate utilizing materials from the Cantwell source to level the site and develop a pad for stockpiling pay materials prior to loading onto the railcars. The total anticipated cost to develop this site to the point it would be useable for stockpiling and loading would be on the order of $4,094,000.

**FIGURE 5**
**PHOTOGRAPH OF POTENTIAL LOADING AREA**
**AT PARKS HIGHWAY MP 204**


Looking West toward Potential Stockpiling/Loading Site in the Trees (Google Earth, 9/2011).

### Improved Site at Parks Highway Milepost 190

At approximately Milepost 190 on the Parks Highway, there is an area that has previously been utilized by the railroad as an aggregate source. This area could be utilized as a stockpile area and for construction of a siding for loading purposes. This site provides the benefits of having an existing access road and already having a larger roughly level area. Some site work would still be required to develop a siding of sufficient length to allow for the full gravel train (approximately 5,200 feet) to be loaded without affecting the mainline traffic. The total anticipated cost to develop this site to the point it would be useable for stockpiling and loading would be on the order of $4,074,000.

### General Site Considerations

For both the potential new loading sites, the following information was incorporated into the development costs for each location.

An estimate was obtained from Thor Global for a conveyor with an inline scale that will provide the capacity needed to load the train in the time allotted. The same belt system would be used at either location.

**FIGURE 6**
**EXAMPLE CONVEYOR LOADER/STACKER**

A hopper would be placed at one end for loaders to feed the belt.
From: http://www.thorglobal.ca/data/product-photos/52-176.jpg

Calculation of the cost to build the siding were completed using material costs developed for the Cantwell crushing operation and construction costs for the actual track and switches provided by

ARR. According to the railroad, each mainline switch costs $500,000 to install which dramatically increases infrastructure development costs along the mainline. A siding of a circular nature similar to the Healy site would be a potential for each location. The railroad indicated that construction of the track costs approximately $200 per linear foot installed once grade is established. As shown by the estimated construction totals for both potential sites, the majority of the costs are associated with the switches, track work and loading equipment.

During several discussions related to this study, ARR representatives responded to questions regarding loading on the mainline with front loaders by an Anchorage contractor for their project this season. The railroad team responded by stating that this was a one time trial run and that the loading time was limited to only 6 hours. They went on to reiterate that any location set up to be a regular loading facility would require a conveyor system with an inline scale as previously described.

## 5.0 HAULING TO ANCHORAGE

### 5.1 Hauling to Anchorage by Railroad

For the purpose of this portion of the study, we are assuming that the aggregate will be hauled to Anchorage in existing gravel trains consisting of two engines on each end with 86 gravel hopper cars between. Trains will be scheduled at the Alaska Railroad's convenience, thus allowing the Alaska Railroad to incorporate the aggregate trains into its gravel train schedule. Each gravel hopper is capable of hauling 100 tons of aggregate. Assuming that consideration will be taken to avoid overloading a hopper, we utilized 95 tons per car in our cost estimations. Figure 7 includes a photograph of Alaska Railroad's hopper cars.

**FIGURE 7**
**ALASKA RAILROAD HOPPER CARS**

From http://alaskarailroad.com/Portals/6/Images/Web_Truck-vs-Train.jpg

Based on an assumed 126 pounds per cubic foot for the crushed aggregate, each car would contain approximately 60 cubic yards of material and thus each train would hold approximately 5,160 cubic yards of aggregate.

### 5.2 Operational Costs for One 86 Hopper Car Train

The total estimated operational cost for loading one 86-car train is based on the operational effort involved in loading the train within the 8-hour time frame required by ARR. Loading operations would be accomplished by two front loaders feeding a conveyor system with 1,200 tons per hour capacity. At this load rate, assuming that each car is loaded with 95 tons of aggregate in order to avoid any overage penalties, it would take approximately 4.5 minutes to load each car. For the estimate, we assumed 1 minute would be required to move between cars. Actual time may be less. This assumption results in an overall load time of 5.5 minutes per car or just under 8 hours per 86 car train. Based on our estimate of operational costs for the loading equipment and the referenced schedule, a cost of approximately $1.46 per ton was calculated.

Updated hauling costs were requested and provided by ARR. The most recent update includes a discounted rate for utilizing the existing facility in Healy while rates for the two greenfield sites are equal.

**FIGURE 8**
**ALASKA RAILROAD QUOTE**

PO Box 107500
Anchorage, Alaska 99510-7500
907-265-2485

**Alaska Railroad Rate Quote Worksheet**

ALASKA RAILROAD CORPORATION
*Business Development*

DATE: 06/21/2013

| | |
|---|---|
| CUSTOMER NAME: | Mike Wariner |
| COMPANY NAME: | R & M Consultants |
| CUSTOMER PHONE: | 907-646-9674 |
| PRODUCT DESCRIPTION: | Aggregate |
| ORIGIN: | MP 301 |
| DESTINATION: | Anchorage, AK |
| DIMENSIONS: | LENGTH: WIDTH:<br>HEIGHT: WEIGHT: |
| EQUIPMENT: | Hopper |
| BILLABLE UNIT: | Per Ton (PT) |
| RATE: | $12.50 PT |
| ROUTING: | ARR |
| PREPARED BY: | Tim Williams, 907-265-2669<br>Director, Freight Sales & Marketing |

NOTES:

1 - Rate is from siding to siding. Shipper responsible for loading railcar at origin and consignee responsible for unloading railcar at destination.
2 - Rate is based on moving a minimum of 80 railcars per train and 100 ton minimum per railcar.
3 - Rate is based on availability of railcars. Depending on timing for moving aggregate, approval may have to be obtained from AS&G or QAP to use consist.
4 - Rate includes fuel surcharge.
5 - Rate is based on maximum of 2 days to cycle each train, to include train movement, loading and unloading. (Assumes 8 hours to load)
6 - Gross weight of railcar cannot exceed 263,000 lbs.
7 - Alaska Railroad Real Estate Department must be contacted to obtain approval and permit to stage aggregate in Alaska Railroad right-away for loading railcars.
8 - Rate valid for 60 days.
9 - Subject to Rules, Regulations and Provisions as provided in Tariff ICC-ARR 3016 and 9003.
10 - Payment shall be made to the Alaska Railroad Corporation, ATTN: Treasury, P.O. Box 103515, Anchorage, AK 99510-3515 NOTE: NET terms only on credit approved accounts.

Unloading costs were estimated utilizing the existing unloading facilities at the AS&G facility at O'Malley and Old Seward Highway in Anchorage.

Combined transportation costs are presented in Table 6.

**TABLE 6**
**RAILROAD TRANSPORTATION COST COMPARISON**

| | **Cantwell Crushing and Stockpiling Cost Estimate** | | | | | | |
|---|---|---|---|---|---|---|---|
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| | $ 22.04 | Per ton | $ 22.04 | Per ton | $ 22.04 | Per ton | |
| | | | | | | | |
| | **Truck Haul to Rail Loading Facility Estimate for Crushed Rock** | | | | | | |
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| | $ 21.12 | Per Ton | $ 31.67 | Per Ton | $ 38.71 | Per Ton | |
| | | | | | | | |
| | **Rail Car Loading Facility Estimate for Crushed Rock** | | | | | | |
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| | $ 1.46 | Per Ton | $ 1.46 | Per Ton | $ 1.46 | Per Ton | |
| | | | | | | | |
| | **Rail Hauling Estimate for Crushed Rock** | | | | | | |
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| | $ 12.50 | Per Ton | $ 12.50 | Per Ton | $ 12.00 | Per Ton | |
| | | | | | | | |
| | **Rail Car Unloading Facility Estimate for Crushed Rock** | | | | | | |
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| | $ 1.19 | Per Ton | $ 1.19 | Per Ton | $ 1.19 | Per Ton | |
| | | | | | | | |
| | **Summary Costs For Cantwell Area Utilizing Railroad** | | | | | | |
| | MP 204 Greenfield Site | | MP 190 Improved Site | | Healy Existing Site | | |
| Crush | $ 22.04 | Per Ton | $ 22.04 | Per Ton | $ 22.04 | Per Ton | Crush |
| Haul to Rail | $ 21.12 | Per Ton | $ 31.67 | Per Ton | $ 38.71 | Per Ton | Haul to Rail |
| Loading | $ 1.46 | Per Ton | $ 1.46 | Per Ton | $ 1.46 | Per Ton | Loading |
| Rail costs | $ 12.50 | Per Ton | $ 12.50 | Per Ton | $ 12.00 | Per Ton | Rail costs |
| Unloading | $ 1.19 | Per Ton | $ 1.19 | Per Ton | $ 1.19 | Per Ton | Unloading |
| Oversight | $ 5.83 | Per Ton | $ 6.89 | Per Ton | $ 7.54 | Per Ton | Oversight |
| **Totals** | **$ 64.14** | **Per Ton** | **$ 75.75** | **Per Ton** | **$ 82.95** | **Per Ton** | **Totals** |

## 5.3 Hauling to Anchorage by Highway

A second transportation alternative assumes that the aggregate would be hauled directly from the Hard Aggregate Site to the AS&G facility in trucks. The haul distance is approximately 233 miles one-way including the distance from the site to the highway and from there to the AS&G facility. Despite several discussions with multiple trucking companies, we could not obtain estimates from local trucking companies for this project. Therefore, we estimated the costs based on established unit rates. The haul vehicle was assumed to be a tractor-belly dump or side dump with a 25-ton highway legal load and Davis-Bacon wages were assumed. These calculations showed an expected cost per ton delivered to be in the range of $141.34.

We attempted to obtain estimates from hauling companies to utilize tandem trailers or any other means possible to obtain an estimate for this scope. The freight companies indicated that the workload elsewhere was more beneficial to them when comparing time and effort with revenue. One company did indicate that they could potentially place the aggregate in containers, load them on flatbed trailers and transport them to the Anchorage facility, but we did not pursue this option due to the immediate added complexity and handling charges that would have been involved.

# 6.0 BARGING FROM OUTSIDE SOURCES TO ANCHORAGE

Two outside sources of hard aggregate for paving have been used in the past for DOT&PF projects; one in DuPont, Washington and the other in Jervis Inlet, British Columbia, Canada.

## 6.1 Outside Sources and Barging

### CalPortland DuPont Pioneer Aggregate Plant

The CalPortland DuPont Pioneer Aggregate Plant (Figure 9) is a large commercial aggregate site in DuPont, Washington. DOT&PF (Pavey et al., 2012) has records showing Nordic abrasion values ranging from 6.1 to 19 for the site.

**FIGURE 9**
**CALPORTLAND PIONEER AGGREGATE PLANT**

From: http://clui.org/sites/default/files/imagecache/ludb-image/ludb/wa/6548/5662906375_6d49cbe9c5_o.jpg

The DuPont operation is one of the largest sand and gravel operations in the United States, and is a major source for building material in Washington State. Seven miles of conveyors move material around the site and out to a barge loading dock, from where most of the material is shipped to customers. Gravel from this operation was quoted at a per ton cost of $10.98 which includes a $1.00 per ton Environmental Compliance Charge.

Island Tug and Barge provided a quote to utilize a 7,500-ton barge to transport material from the DuPont location to the Port of Anchorage. Based on their submittal, the barging costs for material from DuPont would be on the order of $46.67 per ton.

**Jack Cewe Ltd.**

Jack Cewe Ltd. of Coquitlam, British Columbia maintains a bedrock quarry on the southeast shore of Jervis Inlet in British Columbia, Canada (Figure 10). The rock is reportedly a granitic rock. DOT&PF (Pavey et al., 2012) has records showing Nordic abrasion values ranging from 6.9 to 9.9 for the site.

**FIGURE 10**
**JACK CEWE LTD. SITE ON JERVIS INLET**

From: http://www.cewe.com/road_construction/wp-content/uploads/2012/07/aggregate_supply_2.jpg

Cewe's quoted cost was $9.50 per ton. Jack Cewe Ltd.'s submittal included estimated barging costs from Western Towboat for a 9,500-ton barge at a unit rate of $33.34 per ton delivered to the Port of Anchorage.

The barging costs included in both of these estimates are highly dependent on fuel prices and are expected to fluctuate if the price of fuel changes more than 1% from prices shown in each estimate. Additionally, up to one year lead time may be needed to schedule certain barges.

## 6.2 Port of Anchorage Fees

During our investigation, we had several conversations and met with representatives from the Port of Anchorage. They were excited about the opportunity to provide docking and wharfage services through their new dry barge berth and provided current rates and optional services associated with the utilization of that facility. From a financial perspective an advantage of utilizing the new dry barge berth is the opportunity for contractors to unload materials with their own equipment and personnel since there is not a precedence set which requires the utilization of the longshoreman associated with the established port facilities. This provides the contractor the opportunity to realize savings on multiple levels including utilizing their own equipment and their standard labor rates for the operators, and not having to handle the material twice to load it into their trucks after another entity unloads the barge and stockpiles it in the yard.

Port fees added to the docking costs for either barge described below would include a wharfage fee of $1.00 per ton and a security fee of $0.58 per ton for a total added expense of $1.58 per ton on top of the docking fees.

Current docking fees at the dry barge berth for the 7,500-ton barge proposed to be utilized by Island Tug hauling materials from the DuPont plant would be $1,098 per 24-hour period. This combined with the per ton fees shown above result in POA costs of $1.73 per ton for DuPont materials.

Current docking fees at the dry barge berth for the 9,500-ton barge proposed to be utilized by Western Towboat hauling materials from the Jack Cewe plant would be $1,206 per 24-hour period. This combined with the per ton fees shown above result in POA costs of $1.71 per ton for Jack Cewe materials. Utilizing a larger barge reduces the cost per ton.

An additional service that the Port of Anchorage offered that doesn't directly apply to the process we are investigating at this time, but could provide for several alternatives, is a storage area near the dry barge berth for a large aggregate stockpile. The rates associated with this area are $0.105 per square foot per month. The configuration of any stockpiled materials would dramatically effect the cost per ton for aggregate storage, but if a specific need arises, it would be a relatively straightforward calculation to determine the footprint of a specifically sized stockpile and calculate the associated storage rates for that stockpile.

### 6.3 Unloading and Hauling Costs

Estimating costs associated with unloading the barges and hauling aggregate to the Anchorage facility used as a reference point for our study was controlled by needing sufficient equipment and personnel to unload either barge within the initial 24 hours of docking. By utilizing 2 loaders with 5 cy buckets and 23 haul trucks with 10 cy of capacity the unloading and hauling of aggregate from either barge could be accomplished.

It was estimated that the 7,500-ton Island Tug barge for use with the DuPont aggregate could be unloaded and hauling completed in just less than 15 hours. The unloading costs for this shift would be on the order of $1.20 per ton and the haul costs would be approximately $14.27 per ton.

It was estimated that the 9,500-ton Western Towboat barge for aggregate from the Cewe facility could be unloaded and hauling completed in just less than 19 hours. The unloading costs for this shift would be on the order of $1.16 per ton and the haul costs would be approximately $13.88 per ton.

### 6.4 Private Local Barging and Unloading

As part of our evaluation of other options for transportation and unloading of aggregate to the Anchorage area, we contacted a private local transportation contractor in Anchorage. They agreed to perform an evaluation of the services they could provide and submit rates for as large a portion of this scope as possible. Multiple members of their team participated in the analysis and in the end they provided an estimate for a barge carrying 9,200 tons of materials from either source location to their private dock in Anchorage. At that facility they would unload the materials to a stockpile or into contractor's trucks for hauling to the batch plant location. Their submittal indicates that their costs per ton to haul the material and unload it at their facility would be $67.50 per ton for the Cewe materials and $74.50 for material from the DuPont facility.

Based on our estimated cycle times for a 10 cy end dump truck, 35 trucks would be needed to match the pace at which they plan to unload the barge. Utilizing 35 trucks for 12 hours at standard equipment and operator rates maintained throughout our analysis, we estimate that hauling the material to the AS&G facility would cost approximately $13.88 per ton.

**TABLE 7**
**BARGING DELIVERY SUMMARY**

| | Jack Cewe / Western Towboat | | DuPont / Island Tug | | Cewe / Private | | Dupont / Private | |
|---|---|---|---|---|---|---|---|---|
| **Agg** | $ 9.50 | Per ton | $ 10.98 | Per ton | $ 9.50 | Per ton | $ 10.98 | Per ton |
| **Barge** | $ 33.34 | Per ton | $ 46.67 | Per ton | $ 67.50 | Per ton | $ 74.50 | Per ton |
| **Port Costs** | $ 1.71 | Per ton | $ 1.73 | Per ton | | | | |
| **Unloading** | $ 1.16 | Per ton | $ 1.20 | Per ton | | | | |
| **Haul to BP** | $ 13.88 | Per ton | $ 14.27 | Per ton | $ 13.88 | Per ton | $ 13.88 | Per ton |
| **Oversight** | $ 5.96 | Per ton | $ 7.48 | Per ton | $ 9.09 | Per ton | $ 9.94 | Per ton |
| **Total** | **$ 65.54** | **Per ton** | **$ 82.32** | **Per ton** | **$ 99.96** | **Per ton** | **$109.29** | **Per ton** |

### 6.5 Barging to the Alaska Railroad Facility in Seward

As part of our evaluation of other options for transportation of aggregate to the Anchorage area, we investigated the possibility of barging the material to the AAR's facility in Seward which is typically utilized to ship coal from Alaska to outside markets. Initially, enthusiasm was high related to this option with the hopes that the rail shipping costs would be greatly reduced by backhauling with coal trains. However, discussions with the railroad lead to the conclusion that this would not be a possibility due to the large quantity of coal residue left in the hopper cars after unloading. This residue coating and contaminating the aggregate would likely make it unusable in asphalt mixes. The costs and efforts associated with cleaning the cars combined with the delays in schedule rendered the coal car backhaul option to be unrealistic.

We contacted the outside barging companies regarding shipping to Seward and surprisingly the costs per ton were approximately $1.00 higher to ship to the Seward facility rather than the Port of Anchorage. We also asked the railroad to provide information regarding a dedicated gravel train to haul aggregate from Seward to the AS&G facility in hopes that the rail shipping costs would be low enough to overcome the unloading, truck haul and POA expenses for the Anchorage deliveries. Their evaluation of the equipment and engines required to deliver aggregate from Seward resulted in the maximum number of hopper cars to be 70 cars. At the anticipated 95% capacity level, this would limit each train's load to 6,650 tons. With the smallest barge being considered for delivery at 7,500 tons, a customer would either have to pay for the barge and only haul the tonnage limited by the railroad or stockpile materials in Seward until the quantity of stockpiled excess material grew sufficiently to require a dedicated train. With these complications and the minimal area available in the Seward facility to stockpile materials, this approach was eliminated as a feasible option.

## 7.0 COST COMPARISON AND CONCLUSIONS

### 7.1 Cost of Cantwell Material Delivered to AS&G Facility in Anchorage

As expected, the options available for the transportation of acceptable hard aggregate materials from the Cantwell site results in a wide range in the cost per ton of aggregate delivered. The factor most dramatically affecting the delivery costs are the costs associated with trucking the materials from the proposed Cantwell stockpile to the loading site. Additionally, the initial capital investment required to develop sites capable of servicing the proposed scope at 2 of the 3 locations is substantial. Based on the research we performed and the estimates outlined in the body of this report, approximate costs per ton for each of the 3 options are shown below.

**TABLE 8**
**AGGREGATE DELIVERY COMPARISON SUMMARY**

| | **Summary Costs For Cantwell Area Utilizing Railroad** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | MP 204 Greenfield Site | | | MP 190 Improved Site | | | Healy Existing Site | | | |
| Crush | $ | 22.04 | Per Ton | $ | 22.04 | Per Ton | $ | 22.04 | Per Ton | Crush |
| Haul to Rail | $ | 21.12 | Per Ton | $ | 31.67 | Per Ton | $ | 38.71 | Per Ton | Haul to Rail |
| Loading | $ | 1.46 | Per Ton | $ | 1.46 | Per Ton | $ | 1.46 | Per Ton | Loading |
| Rail costs | $ | 12.50 | Per Ton | $ | 12.50 | Per Ton | $ | 12.00 | Per Ton | Rail costs |
| Unloading | $ | 1.19 | Per Ton | $ | 1.19 | Per Ton | $ | 1.19 | Per Ton | Unloading |
| Oversight | $ | 5.83 | Per Ton | $ | 6.89 | Per Ton | $ | 7.54 | Per Ton | Oversight |
| **Totals** | **$** | **64.14** | **Per Ton** | **$** | **75.75** | **Per Ton** | **$** | **82.95** | **Per Ton** | **Totals** |

Over the road truck hauling directly from the Cantwell site is estimated to cost $141.34 per ton.

### 7.2 Cost of Outside Material Delivered to AS&G Facility in Anchorage

The two sources for hard aggregate approved for use on DOT&PF projects provided estimates on a cost per ton basis for acceptable aggregate. Two shipping options were evaluated for each source. Initial evaluations utilizing independent barging companies delivering materials to the new dry dock berth at the Port of Anchorage and then a contractor unloading the barge and trucking the materials to the AS&G facility.

Additionally, an Anchorage private freight company provided an estimate to haul the material to their facility in Anchorage and then have a contractor haul the materials to the AS&G facility utilizing dump trucks. Approximate costs for each delivery method are as follows.

| Source | Outside Barging | Private Freight |
|---|---|---|
| Jack Cewe, BC | $65.54/Ton | $99.96/Ton |
| DuPont, WA | $82.32/Ton | $109.29/Ton |

## 7.3 Break Even Quantity for Cantwell Hard Aggregate Site

The Cantwell Hard Aggregate Site appears to be competitive with hard aggregate barged in from outside sources. The most significant issue now becomes the initial investment required to construct the infrastructure for hauling on the railroad or negotiating a lease to utilize the Healy site. For comparison purposes we will assume that any increases in fuel costs will affect each mode of transportation equally and that the demand for 20,000 tons per year will remain consistent. Additionally, our break even analysis only considers costs associated with shipping from the two sites where capital improvements will be required to utilize that site.

**TABLE 9**
**COST COMPARISON AND BREAK EVEN CALCULATIONS IN YEARS**

| Values | Rail | Barge | Savings/Ton | Years |
|---|---|---|---|---|
| Average Values (Including Private Freight) | $69.95/Ton | $89.28/Ton | $19.33 | 11 |
| Greatest Difference (Including Private Freight) | $64.14/Ton | $109.29/Ton | $45.15 | 5 |
| Average Values (Outside Barges / Contractor Unloading) | $69.95/Ton | $73.93/Ton | $3.98 | 51 |
| Greatest Difference (Outside Barges / Contractor Unloading) | $64.14/Ton | $82.32/Ton | $18.18 | 11 |
| Lowest Cost Difference | $64.14/Ton | $65.54/Ton | $1.40 | 145 |

**The overall average recovery time for capital improvement costs based on 20,000 tons per year and assumptions, calculations and estimates provided in this report would be between 11 and 51 years.**

Thus, the crux of the issue is that if the aggregate from the Cantwell area is to be utilized as a competitive source, a railroad siding and loading yard will need to be constructed. The costs incurred by trucking the aggregate from the Cantwell source to the existing ARR loading facility in Healy elevates the cost per ton to equal or higher prices than the outside sources appear to provide.

In addition to hard aggregates, the sites on the south side of Panorama Mountain can also provide high quality material for highway construction and maintenance within the local area or be hauled to other project sites including the Fairbanks area. Additional uses for the aggregate could include riprap, normal aggregates, and general fill. With the addition of infrastructure at Cantwell, it may be feasible to haul riprap by rail to other locations in Alaska. The material sites may also become a source of material for the proposed Susitna Dam Project or its ancillary projects. Any facilities built to haul materials out can also be used to haul materials into the area. For instance the siding and loading areas can be used to support construction of the proposed Susitna Dam, mining projects, or other construction projects in the area.

# 8.0 REFERENCES

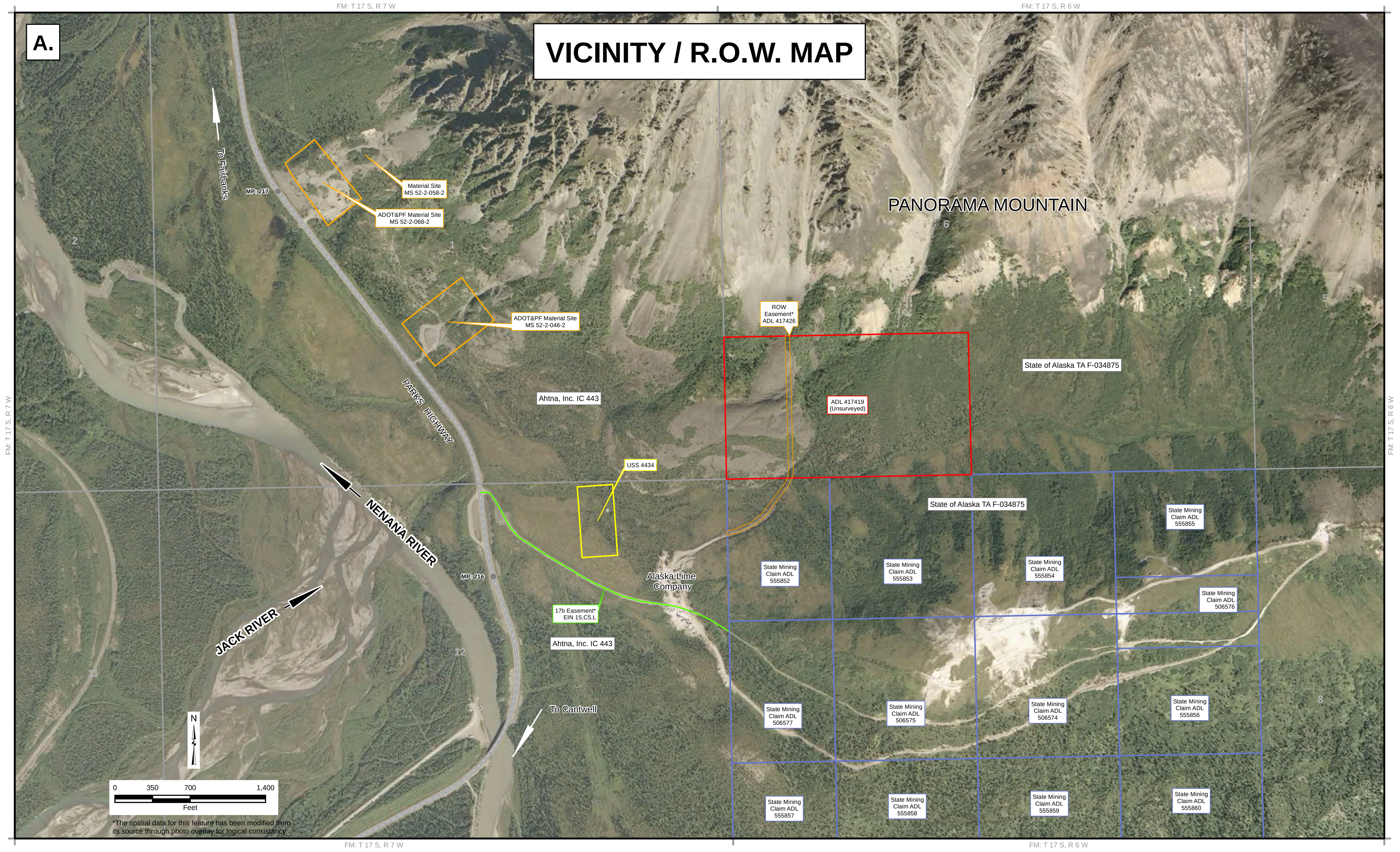

Csejtey, Bela, Jr., Mullen, M.W., Cox, D.P., and Stricker, G.D., 1992, Geology and geochronology of the Healy Quadrangle, south-central Alaska: U.S. Geological Survey Miscellaneous Investigations 1961, 63 p., 2 sheets, scale 1:250,000.

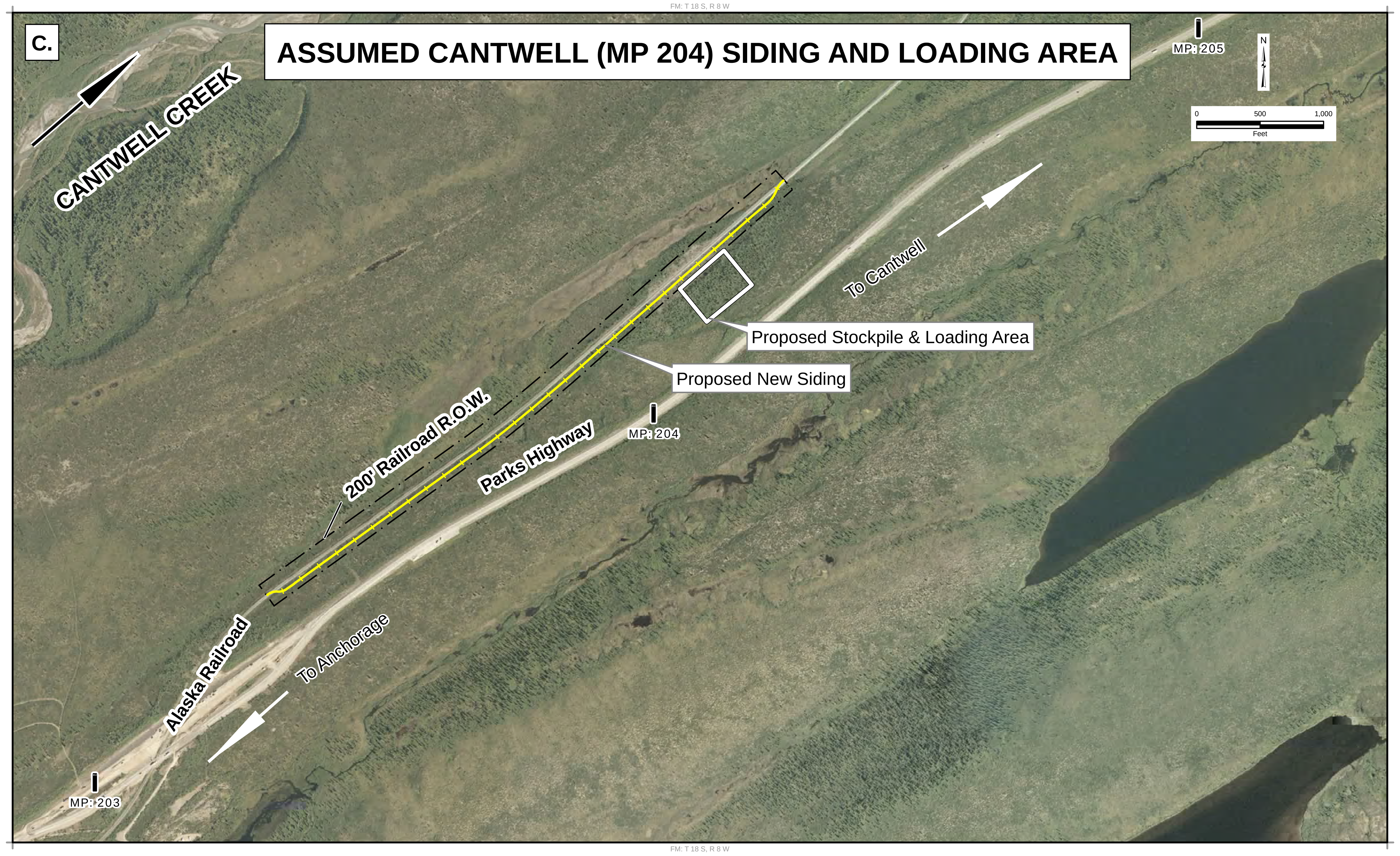
Johnson, E.G. and Pavey, D. R., 2000, Studded Tire Wear Resistant Aggregate Study Final Report: Alaska Department of Transportation and Public Facilities, 22 p.

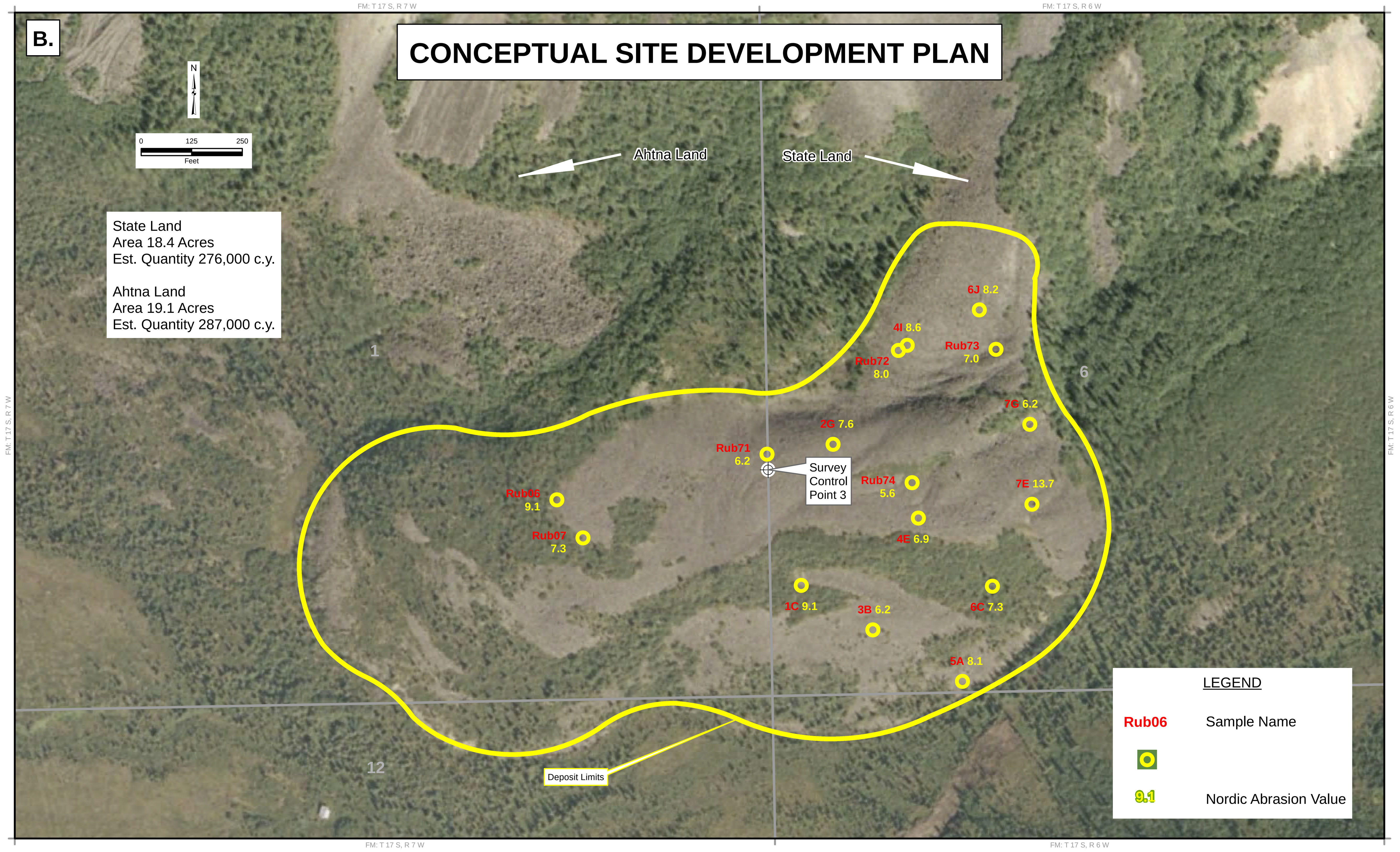
Pavey, Finkbiner, Bingham, 2012, Web interface: http://10.200.100.100/hard/aggregatestudy/ (Note this web interface is available only to DOT&PF personnel).

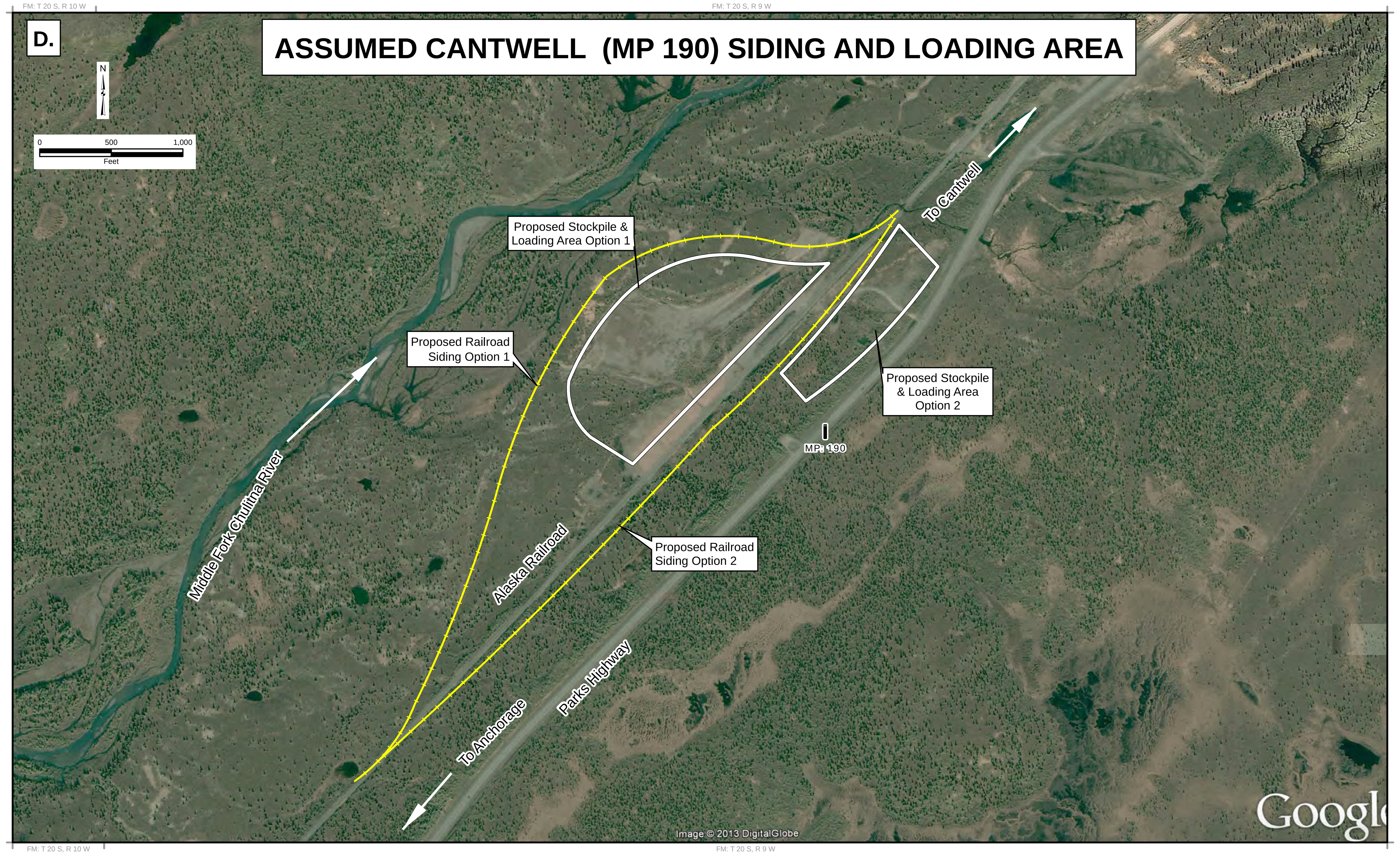
Wahrhaftig, Clyde, and Cox, Allan, 1959, Rock Glaciers in the Alaska Range: Bulletin of the Geological Society of America, Vol. 70, No. 4, Pages 383 to 436.

Washburn, A.L., 1980, Geocryology – A Survey of Periglacial Processes and Environments, John Wiley & Sons, New York.




Notes:
Data for ADL 417419, ADL 417426, ADL's 55852-56 & 506574-77, from ADNR Alaska Mapper (http://dnr.alaska.gov/MapAK).
Data for USS 4434 and ARRC ROW (USS 9051) from US BLM SDMS (http//sdms.ak.blm.gov/isdms/imf.jsp?site=sdms).
Land status infomation for IC 443, TA F-034875, and 17b Easement* EIN 15, C, L from US BLM SDMS (http://sdms.ak.blm.gov/isdms/imf.jsp?site=sdms).
Data for material sites MS 52-2-064-2 and MS 52-2-068-2 from ADOT&PF statewide material site inventory conducted by R&M Consultants, Inc.
Data for conceptual mining plan sample points from ADOT&PF statewide material site inventory Cantwell Hardrock Quarry material site sampling report by R&M Consultants, Inc.

# CONCEPTUAL MINING AND TRANSPORTATION PLAN

Prepared By:
R&M CONSULTANTS, INC.

STATE OF ALASKA
**DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES**

CANTWELL HARD AGGREGATE
DEVELOPMENT FEASIBILITY STUDY

| SCALE | DESIGNED | DRAWN | |
|---|---|---|---|
| AS SHOWN | LB | LB | PLATE 1 |
| | CHECKED CHR | DATE MAY 2013 | |

Saved 5/31/2013 1:31:01 PM by jnelson