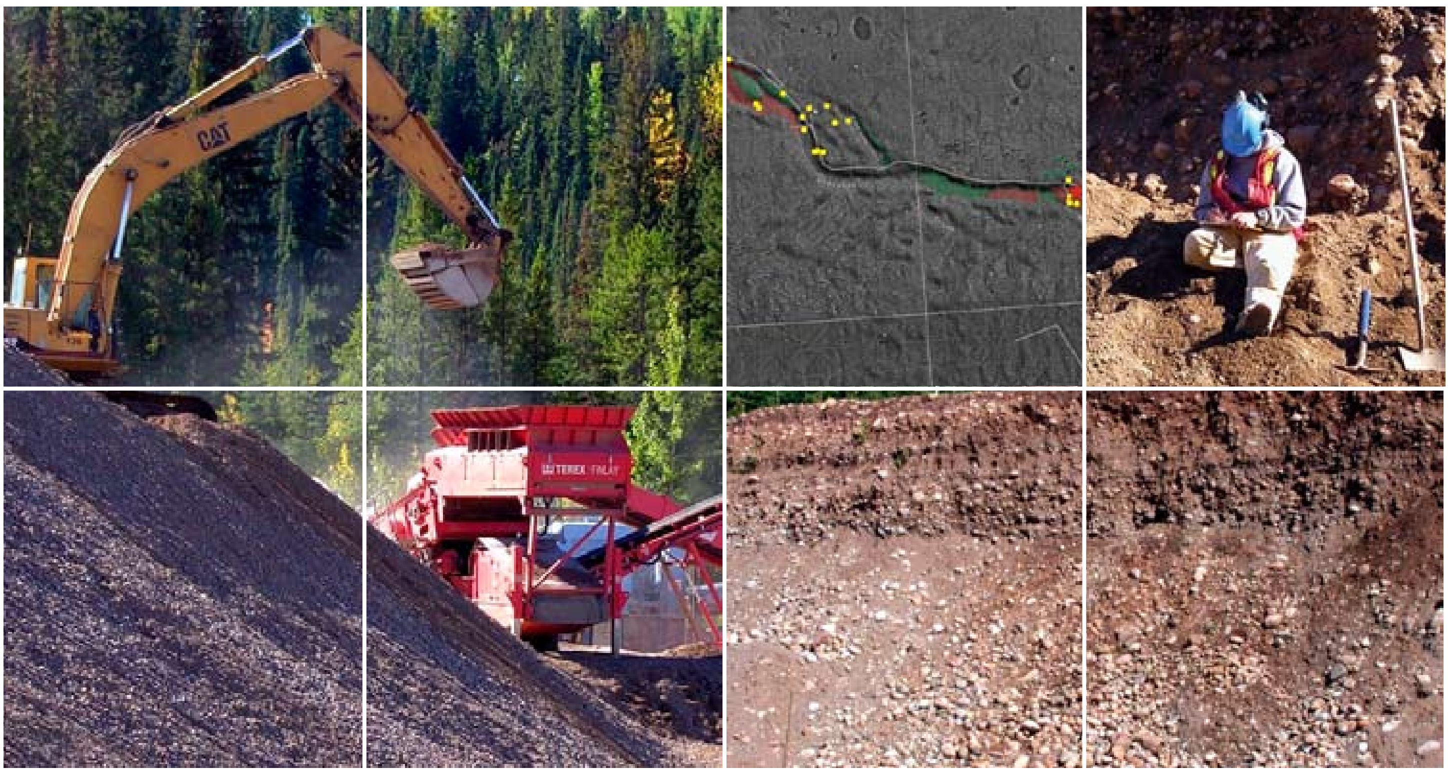
Oil And Gas

Aggregate Potential of the Kimea Creek Area Northeast British Columbia

Aggregate Prospecting Report 2008–1



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AGGREGATE POTENTIAL OF THE KIMEA CREEK AREA, NORTHEAST BRITISH COLUMBIA

by Travis Ferbey[1]

KEYWORDS: aggregate potential, aggregate, construction aggregate, aggregate occurrences, glaciofluvial terrace, kame, esker, ice-proximal deposit, Kimea Creek, northeast British Columbia.

INTRODUCTION

Oil and gas exploration, drilling, and production activity has increased in recent years in northeast British Columbia and currently efforts are being made to extend the drilling season into the summer months. In response to this load levelling effort, petroleum development road (PDR) construction activity has reached an all-time high and the demand for construction aggregates has increased in a region where local sources are scarce. To meet this increase in demand, a focused surficial geology and aggregate potential mapping program has been initiated by the British Columbia Ministry of Energy, Mines, and Petroleum Resources (EMPR) with the goal of identifying new local sources of quality construction aggregate. The program's resources are concentrated in areas of highest demand.

Many new and innovative exploration methods have been developed and implemented by EMPR to efficiently and effectively explore for gravel in the challenging terrain of northeast British Columbia. This, and the development of collaborative agreements with other Provincial and Federal agencies and oil and gas companies, are major contributors to the success of this program. These collaborative efforts have resulted in a multi-disciplinary approach to aggregate exploration, integrating geologic expertise with industry resources.

The study presented here focuses on the aggregate potential of the Kimea Creek meltwater system, within NTS map area 94P, and adjacent areas. The objectives of this study are to: 1) describe the Quaternary history of the Kimea Creek meltwater channel system and adjacent areas; 2) discuss geologic settings within, and near to, this system that have potential to host granular material; and 3) present aggregate potential targets and deposit models for gravel-bearing features occurring within the study area. The goal of this study is to provide to aggregate explorationists working in the area a document that compiles existing surficial geology and aggregate potential data on this system and to comment on where new aggregate occurrences may be found.

LOCATION AND PHYSIOGRAPHY

The Kimea Creek meltwater system is located in the northeast corner of British Columbia, within the Fort Nelson Lowland physiographic region (Figure 1; Holland, 1976). It is part of a larger system that begins in the Bitscho Lake area, Alberta, and winds for over 300 km to its confluence with Liard River in Northwest Territories. This study focuses on the portion of this system within the eastern half of NTS map area 94P (Petitot River). Year-round access to the study area is typically by helicopter, ATV on seismic cutlines, or by a limited number of all-season roads. During the winter months, however, the area can be accessed by snowmobile or by truck on winter ice-roads.

The Kimea Creek portion of the meltwater system (approximately 400 to 550 m above sea level) sits in a broad valley that is bound to the south by the Etsho Plateau (approximately 600 to 700 m above sea level) and by highlands to the north (approximately 650 m above sea level). In general, the study area may be characterized as having flat to subdued topography (Figure 2), which is an expression of the horizontally to subhorizontally bedded sedimentary rocks that underlie the region. The combination of low-relief topography and clay-rich surficial materials results in poor drainage. Shallow water table is present in many areas and small (<5 ha), shallow lakes and narrow (<3 m wide), often meandering, low gradient streams are common throughout the region. With the exception of the Etsho Escarpment (which defines the Etsho Plateau), relief within the study area is minimal.

The area is largely forested with trembling aspen (Populus tremuloides), white spruce (Picea glauca) and lodgepole pine (Pinus contorta var. latifolia). In poorly drained areas, black spruce (Picea mariana) and thick peat deposits dominate.

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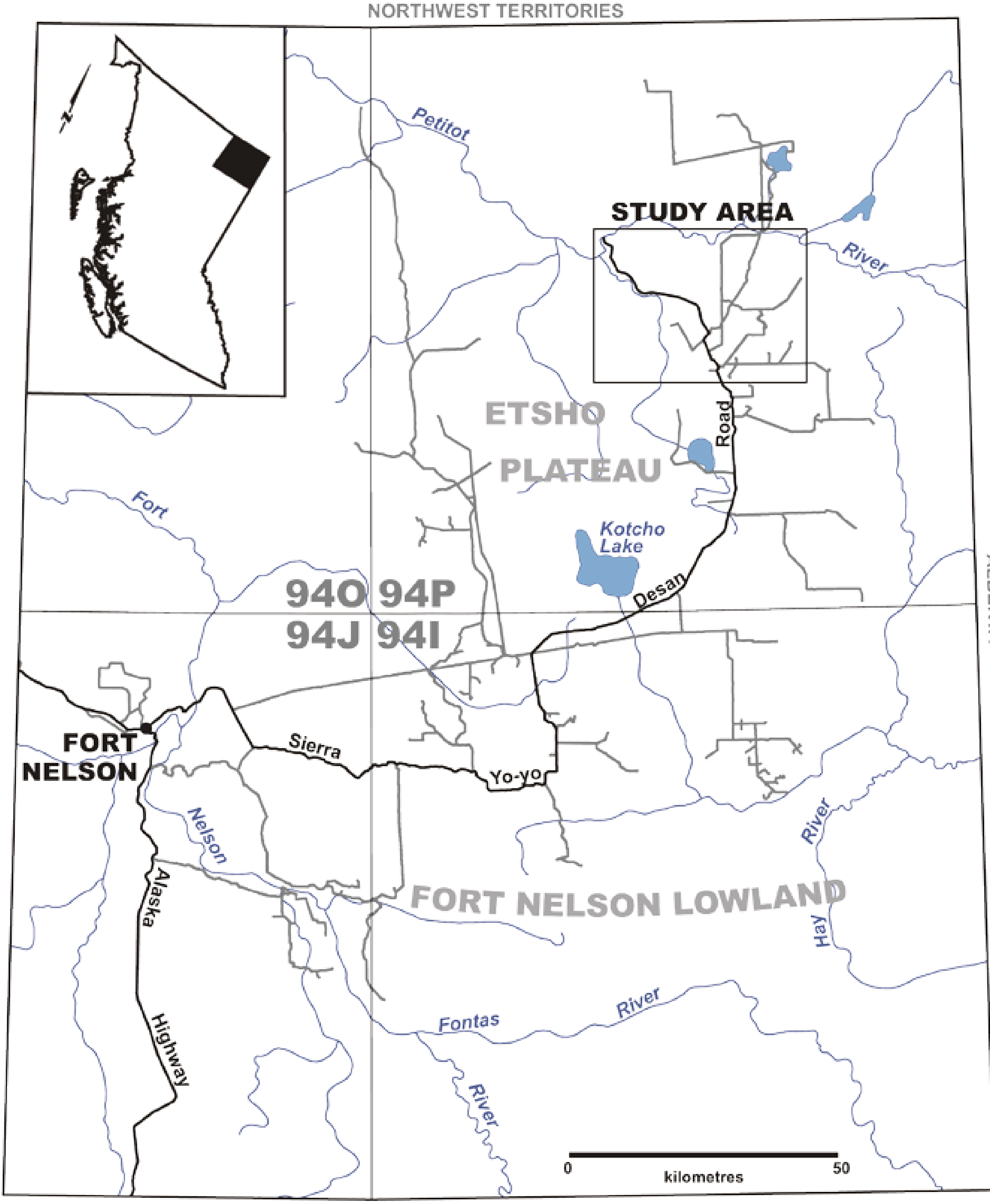

Figure 1. Location of study area.

Figure 2. Photograph of subdued topography, typical of the Fort Nelson Lowland. Photograph taken in the central portion of NTS map area 94I; view is towards the east.

BEDROCK GEOLOGY

The Fort Nelson Lowland is predominantly underlain by marine shales of the Lower Cretaceous Fort St. John Group, belonging to the Shaftsbury Formation (Stott, 1982; Thompson, 1977). These shales are dark grey, and flaky to fissile.

Directly overlying the Fort St. John Group, and forming the resistive cap of the Etsho Plateau, are sandstones of the Duvegan Formation, of the Upper Cretaceous Smoky Group (Stott, 1982; Thompson, 1977). The stratigraphy and sedimentology of the Dunvegan Formation has most recently been discussed in detail by Plint et al. (2001), Plint (2002) and Plint and Wadsworth (2003). Locally, on the Etsho Plateau, these sandstones are fine to medium-grained but they are, however, part of an assemblage of clastic rocks that range texturally from clay-rich shales and mudstones to boulder conglomerates. The lower contact between the Dunvegan and Shaftsbury formations is gradational and consists of sandy siltstones and fine-grained sandstones interbedded with silty shales (Stott, 1982; Thompson, 1977).

Shales have also been observed in borrow pits at higher elevations on the Etsho Plateau, in direct contact with overlying Late Pleistocene till. In general, bedrock outcrop in the region is rare. Limited outcrop does, however, occur along stream cuts and in some borrow pits created during road building activity.

SURFICIAL GEOLOGY

Surficial Materials

Silt and clay-rich morainal deposits are the dominant surficial materials in the study area. They vary in thickness from <1 to >10 m. The fine-grained texture of these deposits is largely due to the underlying fine-grained, weathered, sandstones and shales from which these tills are derived. Morainal deposits are typically clast poor (up to 90% matrix) but meltout facies deposits have been observed in the field. These deposits are generally more clast-rich (up to 60% matrix) and may contain lenses and (or) pods of sand and (or) pebble-sized gravel that are up to 1.5 m thick and that extend laterally for 5 m or more. Meltout tills are invariably underlain by the more commonly occurring dark-grey, silt and clay-rich basal tills that dominate the local stratigraphy. Morainal landforms include low relief plains, crevasse-squeeze ridges, flutes, and rolling, recessional, and interlobate moraines (Levson et al., 2004). Tills are often overlain in more poorly drained areas by organic materials, and less commonly by glaciolacustrine sediments. Typically, organic materials occur as bog or fen peats. Bog peats may be treed or treeless and may be wet as a result of local precipitation and high or perched water tables. Fen peats are found in more open terrain with a mineral-rich, oxygen deficient, water table at or near surface. In either case, organic material may range from <1 m to greater than 3 m thick (Bednarski, 2007a, 2007b). These deposits are extensive in the study area and are typically underlain by more impermeable glaciolacustrine or morainal sediments.

Glaciofluvial landforms are relatively uncommon in the region but eskers, kames, fans, deltas and terraces may occasionally be observed. Some recently discovered aggregate deposits, underlying a diamicton, are interpreted to be subglacial channel deposits overlain by a basal or meltout till. During deglaciation, numerous meltwater channels were incised by streams generally flowing west, away from the retreating Laurentide ice sheet. Although sands and gravels were locally deposited, many of these channels appear to be entirely erosional and may have formed subglacially (Levson et al., 2004).

Quaternary History

During the Late Pleistocene the Laurentide ice sheet advanced westward up the regional slope into northeast British Columbia and the entire study area was ice-covered during the glacial maximum. The configuration of advancing and retreating ice fronts was complex as indicated by cross-cutting relationships observed in large-scale landforms (e.g. flutes and recessional moraines). Although the entire region may have been covered by the Laurentide ice sheet at some time, perhaps during the glacial maximum, the preserved large-scale landform record indicates that at least during the later stages of glaciation multiple ice lobes, rather than a single ice sheet, were active in the region.

During retreat of the Laurentide ice sheet, glacial lakes commonly developed along the ice margin as drainage down the regional slope to the east was blocked by ice (Mathews, 1980). This, in combination with the region's flat topography, resulted in the widespread deposition of glacial lake sediments over pre-existing Late Pleistocene deposits. These glacial lakes may have prevented the development of extensive outwash, and the fine-grained deposits may mask glaciofluvial material, contributing to the scarcity of surface sand and gravel deposits in the region.

Three northwest trending, ice-proximal systems occur within the study area (Figure 3). The extent of these systems has been estimated using aerial photographs and a limited number of field stations. These systems are related to deglaciation of the area and mark the retreat of an ice-front(s) towards the northeast during Late Wisconsinan time. Compositionally, the landforms associated with these systems are variable and may contain silt and clay-rich diamtictons and (or) granular material such as sand and (or) gravel. Construction aggregate has been mined from features within these systems (e.g. Helmet 3 deposit, North Helmet Airstrip) and there is potential for other deposits to be discovered.

Dating of Late Pleistocene sediments in the area has been facilitated by the discovery of an interglacial peat underlying a thin Late Wisconsinan-age till approximately 55 km southeast of the study area. Radiocarbon analyses on two wood pieces found within the peat yielded dates of >38 690 (Beta 183832) and >40 590 radiocarbon years BP (Beta 183831). Another fragment of wood recovered from gravels stratigraphically underlying till in the Elleh Creek area, 130 km southwest of the survey area, was dated at 24 400 ±150 radiocarbon years BP (Beta 183598) (Levson et al., 2004). Collectively, these dates, and others provided by Trommelen (2006) for the lower Prophet River area, provide new constraints on the Late Pleistocene history of the region and indicate that the area was ice-free from before 40 000 until after about 24 000 years BP (Levson et al., 2004).

PREVIOUS WORK

As part of a collaborative surficial geology mapping program between EMPR and the Geological Survey of Canada (GSC), the Kimea Creek meltwater system, and neighbouring areas, are included in on-going 1:50 000-scale mapping (e.g. Bednarski, 2005a, 2005b, 2007a, 2007b). To the south and east in Alberta, similar mapping is being conducted (e.g. Plouffe et al., 2006; Smith et al., in press) under a collaborative effort between the GSC and the Alberta Geological Survey (AGS). For this mapping, a process-based approach has been taken. In addition to documenting the spatial distribution of surficial materials, this work also provides detailed interpretations of the area's Quaternary history, including the configuration and movement of glaciers during the Late Pleistocene. These studies include the assessment of local sources of construction aggregate material (e.g. Smith et al., 2005) .

The Kimea Creek meltwater system is included in Mathews (1980) report on the deglacial history of northeast British Columbia and northwest Alberta. Mollard (1984) and Blythe et al. (2003a, 2003b, 2003c) included the study area in their aggregate potential assessments of the Sierra-Yoyo-Desan Road corridor. These assessments were conducted with aerial photographs and, in the case of Blythe et al. (2003a, 2003b, 2003c), limited field checking. They included terraces and kame or ice-proximal features along, an adjacent to, the Kimea Creek meltwater system in their assessment of gravel potential (Figure 4).

Edwards et al. (2004) and Smith et al. (2005) have conducted aggregate potential and aggregate resource studies in northwest Alberta, and included in their studies the headwaters of the Petitot River. Many of the same geomorphic landforms have been identified in northeast British Columbia and northwest Alberta as having high potential to host granular material.

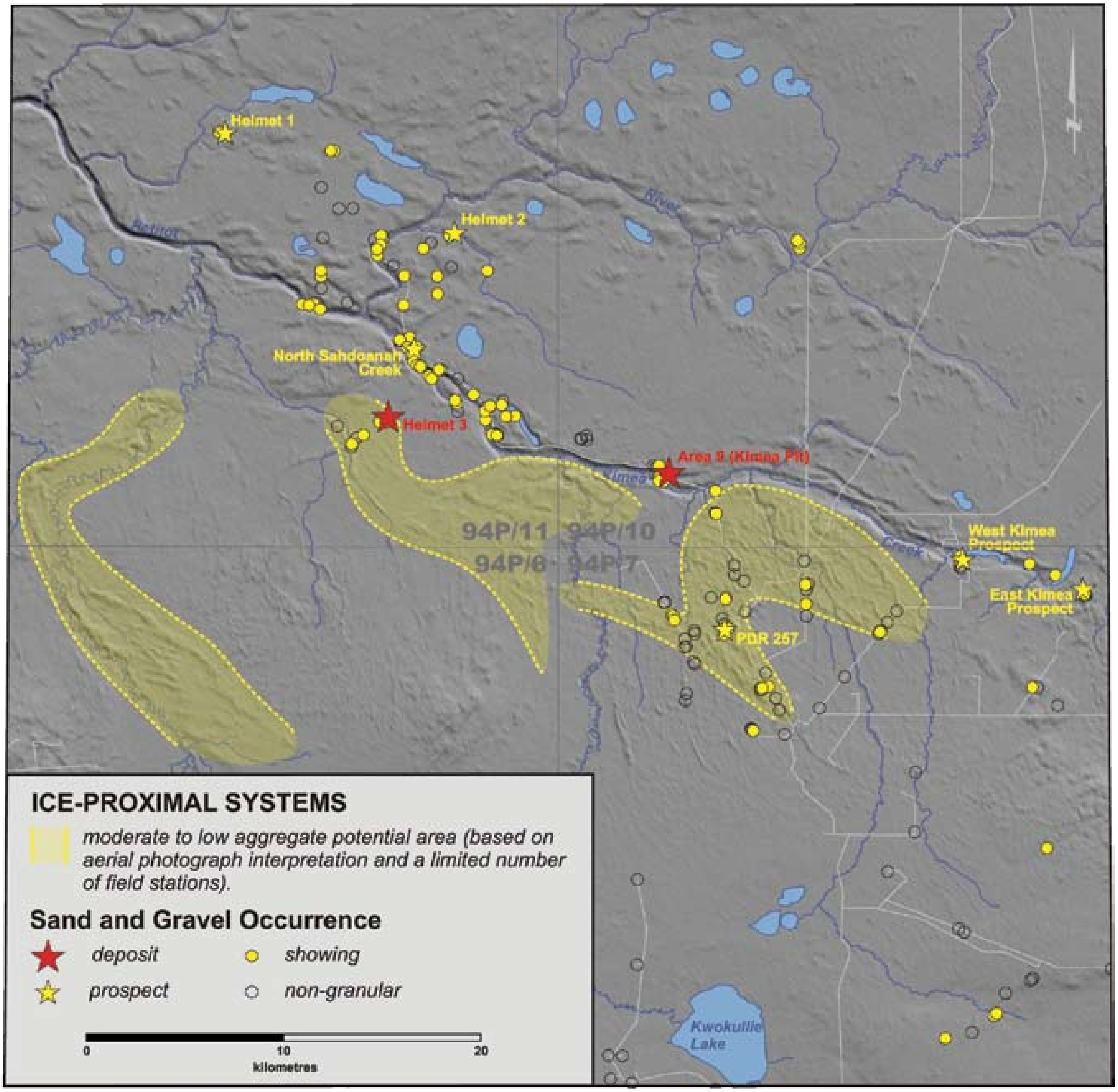

Figure 3. Ice-proximal systems identified within the study area. The extent of these systems has been estimated using aerial photographs and a limited number of field stations.

AGGREGATE EXPLORATION METHODS

Methods used during this study can be divided into two general categories – reconnaissance and detailed-scale. Reconnaissance-scale methods and data types were used in the office to identify areas that have potential to host aggregate occurrences. Such methods and data types include aerial photograph interpretation, light detection and ranging (LiDAR) and shuttle radar topography mission (SRTM) digital elevation models (DEMs), satellite imagery such as land remote-sensing satellite (Landsat), and seismic shot hole data.

Areas identified as having potential to host aggregate occurrences were followed up with more detailed field methods. Often a detailed field description, based on information obtained from a hand-dug pit or auger hole, was sufficient. In some cases, information on material occurring at depths beyond the reach of a hand shovel or auger, or material occurring over a large area, was required. In these instances, other field methods were used, and included (in increasing order of detail), ground geophysics (e.g. capacitively coupled resistivity, ground penetrating radar), hydraulic powered auger drilling, and test pit programs. Although not used as part of this study, EMPR has

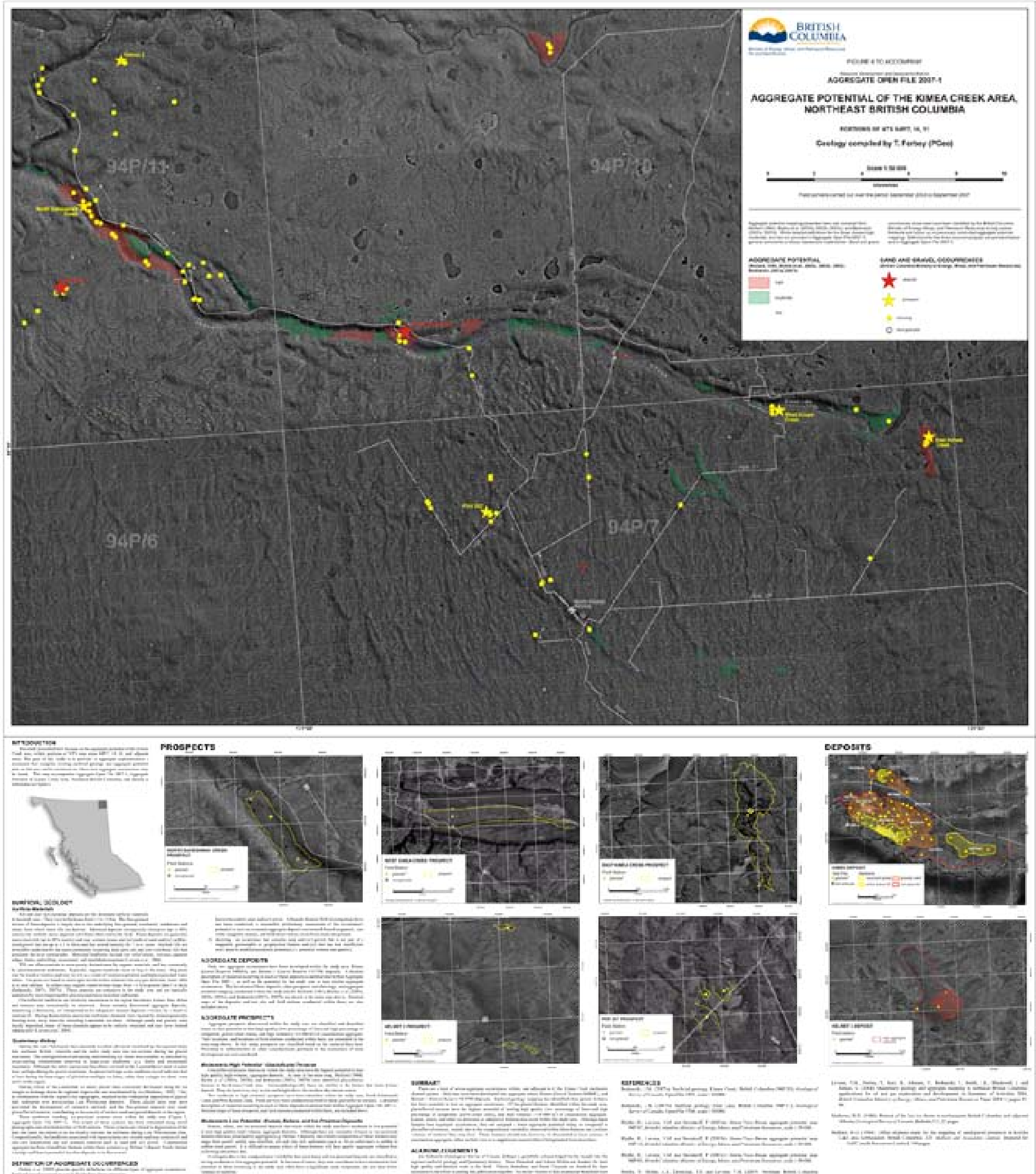

Figure 4. Aggregate potential of the Kimea Creek area, northeast British Columbia (see full-size fold out version inserted at back of publication).

successfully used airborne electromagnetics to investigate aggregate potential (Best et al., 2006). Collection of these airborne data are costly and are therefore only conducted when it is determined that the benefits of this method outweigh the cost efficiencies of other methods.

At all scales of analysis and interpretation, other existing geologic data such as regional-scale surficial geology, soils, and landform maps were included to obtain a more complete geologic picture. Interpretations made with this more complete geologic picture are inevitably more robust.

DEFINITION OF AGGREGATE OCCURRENCES

Ferbey et al. (2005) provide specific definitions for different types of aggregate occurrences. Sand and gravel occurrences can be divided into three categories:

1) deposit–an occurrence that can be mined economically (typically assessed by a detailed test pit program) and (or) is a current or past producer of construction aggregate.
2) prospect–an occurrence within a mappable geomorphic or geophysical feature that is known to contain sand and (or) gravel. Although detailed field investigations have not been conducted, a reasonable preliminary assessment of the occurrence's potential to host an economic aggregate deposit can be made based on genesis, size of the mappable feature, and field observations on surficial materials present.
3) showing–an occurrence that contains sand and (or) gravel, but is not part of a mappable geomorphic or geophysical feature and (or) that has had insufficient work done to establish economic potential (i.e. potential volume and quality).

SOURCES OF CONSTRUCTION AGGREGATE

Only two aggregate occurrences have been developed within the study area, Kimea (Gravel Reserve 048041), and Helmet 3 (Gravel Reserve 915798) deposits. The following summary includes a detailed description of material occurring in each of these deposits. This summary also comments on the potential for the study area to host similar aggregate occurrences. The locations of these deposits, other prospects and showings, and aggregate potential mapping conducted within the study area by Mollard (1984) and Blythe et al. (2003a, 2003b, 2003c) are included in Figure 4.

Kimea deposit (Gravel Reserve 048041)

Kimea deposit is located at km 23 on Wildboy Road and is hosted within a glaciofluvial terrace on the northeast bank of the Kimea Creek channel (Figure 4). The terrace is approximately 2200 m long, 650 m wide, and elevated 8 to 15 m above Kimea Creek. This deposit has been mined intermittently for construction aggregate for approximately 20 years. Tenure on this deposit is currently held by the British Columbia Ministry of Energy, Mines, and Petroleum Resources and it has been set aside for upgrade and maintenance of Sierra-Yoyo-Desan Road.

Distribution of sand and gravel in this deposit is variable and ranges from a well sorted, sub-horizontally bedded coarse sand to a poorly sorted, crudely stratified boulder-sized gravel (Figure 5). Clast lithologies include weathered schist, sandstone, mafic volcanics, and Canadian Shield-derived gneiss, granite, and syenite. Sub-angular to rounded boulders up to 50 cm are found throughout the coarse portions of the deposit. In general, over a 3 m exposure, the deposit appears to coarsen upwards. The occurrence of coarser gravels closer to the modern day channel (the southern boundary of the gravel reserve) is supported by test pit log data (Beeson, 1985a, b; Dewar, 2003). These coarse gravels were likely deposited in the main channel of the meltwater system that produced this deposit.

Figure 5. Photograph of vertical exposure at Kimea deposit. Note shovel in bottom left corner is for scale.

The glaciofluvial terrace that hosts Kimea pit has been studied in detail. The British Columbia Ministry of Transportation (MoT) recognized the aggregate potential of Kimea Creek meltwater system in the summer of 1984, following work conducted by Mollard (1984), and the observation of gravel exposed in a stream cut along this terrace. Detailed geotechnical investigations followed and included a ground electromagnetics (EM) survey using an EM-31D (Beeson, 1985a, b). Vertical orientation resulted in apparent resistivity values that ranged from 25 to 1173 ohm m which are consistent with values typical for sand and gravel

(Reynolds, 1997). A test pit program was then designed to confirm the presence of granular material within this terrace. Sand and gravel was reported to be in excess of 3 m thick (Beeson, 1985a, b).

A comparison of test pit and EM-31D data (vertical orientation), shows a good correlation between apparent resistivity values >200 ohm m and the occurrence of sand and gravel. Also, a positive relationship exists between apparent resistivity values and grain size of granular material. Areas within the terrace that host the coarsest material have apparent resistivity values greater than 500 ohm m, and include the maximum apparent resistivity value recorded as part of this EM survey (1173 ohm m). The MoT estimated the total resource of Kimea deposit to be 635 000 m^3; 485 000 m^3 of this is gravelly sand, while 150 000 m^3 is sand and gravel (material was categorized using the modified unified soils classification system).

More recently, Kimea deposit was included in gravel inventories conducted along the Sierra-Yoyo-Desan Road corridor to determine if known gravel reserves could meet the volume of gravel needed for future upgrades and maintenance of the road (e.g. Smith, 2001, 2002). The most recent of these inventories was conducted by AMEC Earth and Environmental Limited (AMEC) on behalf of the British Columbia Ministry of Energy, Mines, and Petroleum Resources (Dewar, 2003a). This program assessed the quality of material occurring at Kimea, and, based on laboratory results (e.g. gradation, sand equivalent and degredation tests), recommended the most suitable use for material occurring there.

Seventy-five test pits were excavated, 55 of which contained granular material (defined by Dewar (2003a) as material with <15% silt and clay by weight; Figure 4). Based on test pit and laboratory results, the deposit was divided into nine sections (1A, 1B, 2, 3A, 3B, 4A, 4B, 5, and 6; Figure 4). Eight sections contain granular material (1A, 1B, 3A, 3B, 4A, 4B, 5, and 6; Figure 4). Of these eight sections, six are predominantly gravelly sand or sand with some gravel (1A, 1B, 3A, 3B, 4A, and 4B; Figure 4), containing only 1 to 10% gravel or are thin. The remaining two sections (5 and 6; Figure 4) are composed of sand and gravel (i.e. 40 to 45% gravel). Average gradation values from these eight sections are summarized in Table 1. The total estimated granular resource for all eight sections is 3 269 000 m^3; 2 342 000 m^3 of this is gravelly sand or sand with some gravel, while 927 000 m^3 is sand and gravel (Table 2; Dewar, 2003a).

As with the MoT investigation, most test pits dug as part of this study bottomed in granular material (Dewar, 2003a). Unlike the MoT investigation, however, water was encountered in a number of test pits; this could be a function of differences in annual precipitation values in the years these test pit programs were conducted. The discrepancy between MoT and AMEC volume calculations is a result of different numbers used for gravel thicknesses and area of gravel-bearing ground. A better estimate likely lies somewhere between these. For example, MoT did not include in their calculations the area in Section 5 occupied by the active pit, whereas AMEC did. Also, AMEC tested to greater depths and their number for average thickness of sand and gravel for Section 5 (5.1 m) is greater than that used by MoT.

Aggregate quality tests were conducted on material collected from AMEC sections 1A/B and 5 (Table 3; Dewar 2003a) while petrographic analyses were conducted by Beeson (1985a, b; Table 4). Based on laboratory analyses, Dewar (2003a) categorized the material into MoT road material classes (Table 5). The coarsest aggregate occurring within Kimea deposit is found in sections 5 and 6 and it is appropriate for crushing and processing. To date, all material mined from Kimea deposit has been removed from section 5 (Figure 6).

In the Kimea Creek meltwater system, glaciolfluvial terraces are generally considered to have moderate to high

TABLE 1. AVERAGE GRADATION RESULTS FOR (DEWAR, 2003A). SECTION BOUNDARIES SHOWN IN FIGURE 4 ARE BASED ON THESE GRADATION RESULTS. THE MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS IS USED TO CLASSIFY MATERIAL FROM EACH SECTION.

Section	Fines <0.075 mm (%)	Sand <4.75 mm (%)	Fine Gravel < 25 mm (%)	Coarse Gravel 25 - 75 mm (%)	Additional Oversize[1] >75 mm (%)
1A/1B	5	62	23	10	5
3A/3B	6	85	7	2	1
4A/4B	5	65	20	10	8
5	2	61	21	16	17
6	7	52	25	16	2

[1]*Field estimate.*

TABLE 2. VOLUME ESTIMATES FOR THE EIGHT SECTIONS DEFINED BY DEWAR (2003A) FOR KIMEA DEPOSIT.

Section	Average Thickness (m) Overburden	Average Thickness (m) Granular Material	Potential Volume (m^3) Overburden	Potential Volume (m^3) Granular Material
1A/1B	1.2	4.7	86 000	338 000
3A/3B	0.6	4.3	88 000	628 000
4A/4B	0.3	4.0	103 000	1 376 000
5	0.1	5.1	14 000	704 000
6	0.1	1.7	13 000	223 000

TABLE 3. RESULTS OF SAND EQUIVALENT AND DEGRADATION TESTS, CONDUCTED BY DEWAR (2003A), FOR GRANULAR MATERIAL OCCURRING AT KIMEA DEPOSIT. LABORATORY ANALYSES WERE CONDUCTED ON MATERIAL FROM ONE TEST PIT FROM EACH SECTION (DEWAR, 2003A).

Test	Section	Value	MoT Secifications
Degradation	1A	40	>35 for all aggregates
	1B	20	
	5	46.7	
Sand Equivalent	1B	49	>40 for 25 and 50 mm base course aggregates; >20 for sub-base aggregate and surface aggregates
	5	46.5	

aggregate potential. Two other glaciofluvial terraces have been visited in the field by EMPR. They are discussed in more detail in the proceeding section, Potential Sources of Construction Aggregate (Moderate to High Potential – Glaciofluvial Terraces).

Helmet 3 deposit (Gravel Reserve 915798)

Helmet 3 deposit is located approximately 6 km west of km 32 on Wildboy Road, southwest of the Sahdoanah Creek channel, and is hosted within a feature of glaciofluvial origin. The feature is approximately 550 m long, 500 m wide, and 12 m high (Figure 4). Tenure on this deposit is currently held by a private operator.

A detailed geotechnical investigation was not conducted on Helmet 3 deposit and so gradation and aggregate-quality data are not available. This deposit was, however, visited in the field. A 3 to 4 m pit face revealed a crudely stratified, silty, pebble to cobble-sized gravel (Figure 7). Tabular cross-beds were observed in this pit face and within the coarser portions of this unit silty sand to coarse sand laminae occasionally occur.

Only a small volume of material has been removed from this feature. Other features exist in the area that are geomorphologically similar to the one that hosts Helmet 3 deposit and they appear to be part of a larger, northwest trending, ice-proximal system (Figure 3). Other similar systems occur to the east (in the vicinity of the North Helmet Airstrip) and to the west (portions of which are occupied by Thetlaandoa River). The Helmet 3 deposit, and the occurrence of granular material at the south end of the North Helmet Airstrip, suggests that there is potential for similar features in the area to be composed of sand and gravel. Two such features are discussed in the proceeding section, Potential Sources of Construction Aggregate (Moderate to Low Potential – Kames, Eskers and Ice-Proximal Deposits).

POTENTIAL SOURCES OF CONSTRUCTION AGGREGATE

In the following discussion, aggregate prospects discovered within the study area are classified and described based on their potential to host high quality (low percentage of fines and high percentage of competent, gravel-sized clasts), and high volumes (>10 000 m^3) of construction aggregate. Their locations, and locations of field stations conducted within them, are presented in Figure 4. In this study, prospects are classified based on the material they host. Proximity to infrastructure or other considerations pertinent to the economics of mine development are not considered. Prospects identified in this study are placed into the following two classifications:

1. Moderate to high potential – Included are features with a glaciofluvial origin occurring exclusively as glaciofluvial terraces in this particular meltwater system. These features are elevated above the modern day

TABLE 4. RESULTS OF PETROGRAPHIC ANALYSES, CONDUCTED BY THE MINISTRY OF TRANSPORTATION (MOT), FOR GRANULAR MATERIAL OCCURRING AT KIMEA DEPOSIT (BEESON 1985A, B).

Rock Type	Southeast Corner Section 5 (%)	South-central Section 3a (%)
Sedimentary		
carbonate (fair) – soft, slight to moderate weathering, sound	23	22.2
sandstone (fair) – medium hard, slight to moderate weathering, firmly cemented, sound	1	-
shale (poor) – soft, friable	0.2	-
siltstone (fair) – medium hard, slight to moderate weathering, firmly cemented, sound	8.1	7.2
Metamorphic		
quartzite (good) – hard, sound	22.6	16.3
quartzite (fair) – medium hard, slight to moderate weathering, sound	13.9	9.7
Igneous		
plutonics (good) – hard, fresh, sound	9.4	10.3
plutonics (fair) – medium hard, slight to moderate weathering, sound	11.3	11.2
volcanics (good) – hard, fresh, sound	5.6	13.6
volcanics (fair) – medium hard, slight to moderate weathering, sound, slightly porous	4.9	9.5
good	37.6	40.3
fair	62.2	59.7
poor	0.2	-

stream course by 2 m or more and although there is typically some component of sand they are likely to host pebble to boulder-sized gravels.

2. Moderate to low potential – Included are features similar in form and genesis to those having high potential. Moderate to low potential glaciofluvial terraces, however, are more likely to be situated in areas that are closer in elevation to modern-day stream courses; shallow water is likely to be encountered during subsurface excavations. Some features included in this category may be compositionally variable (laterally and vertically) and may host, at least locally, deposits of diamicton such as till or colluvium. Features included in this classification are likely to host smaller volumes and may have a sand component >65%.

The locations of prospects discussed here, and the locations of other showings and aggregate potential mapping conducted within the study area by Mollard (1984) and Blythe et al. (2003a, 2003b, 2003c) are included in Figure 4.

TABLE 5. MATERIAL OCCURRING AT KIMEA DEPOSIT CATEGORIZED INTO MINISTRY OF TRANSPORTATION (MOT) ROAD MATERIAL CLASSES (DEWAR, 2003A).

Section	SGSB[1]	WGBCA[2]	HFGSA[3]	Comments
1A/1B	yes	no	yes	crushing may be required which could generate additional fines; fines may need to be added to meet HFGSA specifications
3A/3B	no	no	no	material could be used for winter sand or general fill
4A/4B	yes	no	yes	crushing may be required which could generate additional fines; fines may need to be added to meet HFGSA specifications
5	yes	yes	yes	crushing is required which could generate additional fines; considerable fines would need to be added to meet HFGSA specifications
6	yes	no	yes	limited test pit data available for this section; further testing required to confirm suitability of material

[1]Select Granular Sub-base (Ministry of Transportation, 2000)
[2]25 mm Well Graded Base Coarse Aggregate (Ministry of Transportation, 2000)
[3]High fines granular surfacing aggregate (Ministry of Transportation, 2000)

Figure 6. Photograph of summer 2005 mining and processing activities at Kimea deposit. View towards the south, with the south side of Kimea Creek valley in the background.

Figure 7. Photograph of vertical exposure at Helmet 3 deposit. Pick is 70 cm long.

Moderate to High Potential – Glaciofluvial Terraces

Glaciofluvial terraces that occur within the study area have the highest potential to host high quality, high volume, aggregate deposits. Mollard (1984) and Blythe et al. (2003a, 2003b) have identified glaciofluvial terraces throughout Kimea Creek meltwater channel (Figure 4). Geomorphologically these are similar to the terrace that hosts Kimea deposit. They do, however, vary in size and height above the modern-day stream course. Field surveys were conducted on two glaciofluvial terraces and the details of these prospects are discussed below.

North Sahdoanah Creek prospect

North Sahdoanah Creek prospect is located at approximately km 38 on Wildboy Road and is hosted within a glaciofluvial terrace on the northeast bank of the Sahdoanah Creek channel. The terrace is 1600 m long, 200 to 300 m wide, and elevated approximately 7 m above the present day Sahdoanah Creek (Figure 4). A foot traverse was carried out on this terrace and field observations are summarized below.

Natural exposures on this terrace are limited to local tree-throws. These, and hand-auger and shovel holes, were used to characterize the material occurring in this terrace. Pebble to cobble-sized gravel, with a silty fine to medium sand matrix, was observed at five field stations (Figure 8; granular field stations). Clasts here are typically subangular to rounded. The coarse material at these stations prevented auger-holes from exceeding 50 cm below surface. Sandy silt to silty very fine-grained sand was observed at four other field stations (non-granular field stations). Auger holes at these field stations were completed up to 1 m below surface. In all but one of these four other field stations, pebble to cobble-sized clasts did occasionally occur. Material in

Figure 8. Photograph of hand-dug pit at North Sahdoanah Creek prospect (pencil for scale).

one auger hole (most southerly non-granular field station) coarsened with depth and ended in a gravelley sand.

Pebble to cobble-sized gravel is also exposed at well a-l-G/94P-11 in side cuts adjacent to the well pad and in a test pit dug in the southwest corner of the pad. It is interesting to note the occurrence of boulders at surface at this pad, with b-axis lengths of up to 100 cm. It is not known whether these boulders were brought to surface when the pad was built or levelled, or perhaps whether they were brought to the site as fill. Similar sized boulders do occur naturally at Kimea deposit. Further comparisons of field and aerial photograph observations suggest that the North Sahdoanah Creek prospect could be similar in composition to Kimea deposit. A more detailed subsurface investigation conducted with a tracked excavator is required to confirm.

West Kimea Creek prospect

West Kimea Creek prospect is located approximately 12 km northeast of the North Helmet Airstrip and is hosted within a glaciofluvial terrace. The terrace is 1700 m long, 200 to 300 m wide, and elevated approximately 5 m above Kimea Lake (Figure 4). This terrace is the lower of a series of three terraces that occur on the south shore of Kimea Lake. Truck access to this prospect is by winter road only. A foot traverse was carried out across the terraces along a seismic cutline. Field observations made at five field stations along this traverse are summarized below.

All three terraces are treed and natural exposures could not be found, so hand-auger and shovel holes were used to characterize surficial materials. Based on observations at a limited number of field stations, the lower terrace is composed of sand and gravel while the upper terrace is composed of a clayey silt diamicton, likely till. The material occurring in the lower terrace is a pebble to cobble-sized gravel with a silty fine to coarse sand matrix. The coarse material prevented auger-holes from exceeding 50 cm depth. Information is not available for middle terrace.

Only reconnaissance-scale work has been conducted on this prospect and more detailed work is required to better understand the lateral extent of gravel in the lower terrace. A more detailed subsurface investigation conducted with a tracked excavator is required to characterise the material that occurs at depth.

Moderate to Low Potential – Kames, Eskers and Ice-Proximal Deposits

Kames, eskers, and ice-proximal deposits that occur within the study area have moderate to low potential to host high quality, high volume, aggregate deposits. Although there are examples of kame or ice-proximal features that host good quality aggregate (e.g. Helmet 3 deposit), the overall composition of these features may range from poorly sorted, non-stratified, silt and clay-rich sediments (such as till or colluvium) to pebble to cobble-sized gravel. It is difficult to assess which of these features will host quality aggregate without first collecting subsurface data.

It is largely due to this compositional variability that most kame and ice-proximal deposits are classified as having moderate to low aggregate potential. In the case of eskers, they are considered to have moderate to low potential as they often have a significant sand component and (or) host lower volumes of material.

East Kimea Creek prospect

East Kimea Creek prospect is located approximately 17 km northeast of the North Helmet Airstrip and is hosted within an ice-proximal feature, likely a kame. This feature is 1100 m long, 300 to 550 m wide, and approximately 35 m in height (Figure 4). Truck access to this prospect is by winter road only. This feature was mapped by Mollard (1984) as having potential to host aggregate. A foot traverse was carried out along a seismic cutline that cuts across the highest point of this feature. Field observations

Figure 9. Photograph of hand-dug pit at East Kimea prospect, showing cobble-sized clasts that occur at surface (shovel blade in lower right corner for scale).

Figure 10. Photograph of road cut through PDR 257 prospect.

made at five field stations at the top of the feature, and along its upper flanks, are summarized below.

Gravel is exposed at surface at all five field stations. Due to the coarse nature of material occurring here, investigations were conducted to a maximum depth of 50 cm. Material occurring here is typically a cobble-sized gravel with a silty, fine to coarse sand matrix (Figure 9). Locally, large cobble-sized clasts were observed (up to 23 cm). Typical clast lithologies include granite, gneiss, syenite, and occasional quartzite. Local sandstone and shale lithologies were not observed at the five field stations conducted here. The feature that hosts East Kimea prospect was likely deposited in an ice-proximal, or perhaps sub-glacial, environment during the southward retreat of an ice lobe that occupied the area.

Despite the occurrence of sand and gravel, East Kimea prospect is assigned a moderate to low aggregate potential rating due to compositional variability that is typical of features deposited in ice-proximal environments. More detailed work is required in order to better assess the amount, type and quality of aggregate occurring within this prospect (e.g. foot traverses and subsurface investigations).

PDR 257 prospect

PDR 257 prospect is located approximately 5 km northwest of the North Helmet Airstrip, and is cut by a lease road that is accessible year-round by truck (Figure 4). The only field station conducted on this feature was at this road cut.

PDR 257 prospect is hosted in a linear, north-northwest-trending ridge that is approximately 180 m long and 75 m wide (Figure 4). As observed at the road cut, this ridge is approximately 6 m high and is composed of interbedded sands and gravelly sands. Approximately 1 m of medium-grained sand overlying <1 m of silt is exposed in a road cut 300 m to the south (Figure 10). Although it is hosted within a mappable geomorphic landform, PDR 257 prospect is classified as moderate to low potential due to a lack of coarse-grained aggregate.

PDR 257 prospect is hosted within a larger, ice-proximal system (Figure 3). Within this system are features that are geomorphologically similar to the one that hosts this prospect, suggesting that there is potential for other aggregate occurrences within this system.

Helmet 2 prospect

Helmet 2 prospect is located approximately 4 km east of the Petitot River bridge, at the west end of Wildboy Road (Figure 4), and is accessible year-round by ATV and during the winter months by truck. Three features are delineated at this prospect, the most northern of which is the only one to have been visited in the field (Figure 4).

Helmet 2 prospect is hosted in a sinuous, west-trending ridge that is approximately 400 m long, 15 to 25 m wide, and 5 to 10 m high. This feature, interpreted as an esker, is composed of a pebble to cobble-sized gravel with a sandy matrix (Figure 11). At the southern-most section of the Helmet 2 prospect, a second sinuous ridge with similar dimensions (also interpreted as an esker) has been identified using aerial photographs and satellite imagery. There are other eskers that occur approximately 12 km northwest of Helmet 2 prospect. Although eskers in the study area are more commonly found northeast of the Kimea Creek meltwater channel, it is possible that detailed aerial photograph mapping could identify more within the study area.

Helmet 2 prospect is assigned a moderate to low aggregate potential rating mostly due to the limited volume of construction aggregate these features are likely to contain, but also because they often have a significant sand component.

Figure 11. Photograph of trench cut through Helmet 2 prospect, showing pebble to cobble-sized material that occurs at surface.

BEDROCK AS A SOURCE FOR CONSTRUCTION AGGREGATE

Without exception, bedrock occurring within NTS map area 94P is unsuitable for use as a running surface on all-season roads. Typically consisting of mudstones and fine to medium-grained sandstones, the friable and easily weathered bedrock quickly breaks down leaving unconsolidated or unlithified fine to medium-grained sands or muds (i.e. its main constituents). Some material may be suitable for use as select granular sub-base or simply borrow. Silt and clay-rich till, however, is more abundant and more commonly used as a base for this purpose.

The unsuitability of local bedrock for use as a running surface is supported by results from a test pit program conducted 60 km to the south of the study area, on an erosional remnant above the south shore of Kotcho Lake (Area 4, Dewar 2003b). Although durability tests were not conducted on sandstones encountered here (e.g. Micro-Deval abrasion test), Dewar (2003b) does comment that this material would not be suitable for use as rip-rap or crushed material.

Other exposures of sandstone and mudstone have been observed in the region, typically in vertical-walled borrow pits up to 4 m below surface. Rocks in these exposures are weathered and in some cases may be sampled with a shovel. It is, however, not known how deep this weathered horizon extends and if more competent bedrock exists at greater depths.

It is also possible for Duvegan Formation distributary channel facies to occur within the study area. The closest known occurrence of this facies is approximately 100 km to the east, at approximately km 100 on the Liard Highway (Highway 77). As observed here, this facies is typically a well sorted, heterolithic, pebble conglomerate with abundant granule-sized clasts. As the study area is believed to be located within the distal portion of the Dunvegan Formation deltaic sequence the chance of finding coarser grained material, such as this pebble conglomerate, is unlikely.

AGGREGATE POTENTIAL TARGETS AND DEPOSIT MODELS

Glaciofluvial terraces within the Kimea Creek- Petitot River meltwater system have the highest potential of hosting high volume, high quality, construction aggregate deposits. These glacial features are level, elevated above modern-day stream courses, and are located within, and throughout the length of, the meltwater system. Detailed geotechnical investigations conducted at Kimea deposit have provided some insight into the composition of these glaciofluvial terraces. Observed there, coarse material such as cobble to boulder-sized gravels occur near the terrace edge, while sand to gravelly sand dominates closer to the back of the terrace (i.e. valley wall). Areas near terrace edges should be included in any test pit program conducted on these features.

Eskers do occasionally occur within the study area. Although eskers identified south of the study area appear to be more typically composed of sand or gravelly sand (cf. Area 3; Dewar, 2003b), those occurring within the study area are known to host pebble to cobble-sized gravels and field observations suggest compositional variability in these particular features is minimal. Based on typical dimensions of eskers identified in aerial photographs, and observations made in the field, however, total volumes hosted by these features would be low as compared to those hosted by glaciofluvial terraces. These features should not be discounted as a local source of construction aggregate. Aerial photograph mapping during the planning stages of infrastructure development could identify eskers near a proposed route. Construction aggregate hosted by these features could be used to supplement material being brought in from a more distant source to surface all-season gravel roads.

Kames or ice-proximal features are commonly found in the study area. These typically elongate mounds or hills are variable in composition. For example, a feature that hosts sand and (or) gravel may occur directly adjacent to a feature that is composed of diamicton (e.g. till). It is also possible for individual features to be composed of both sand and (or) gravel and diamicton. It should be noted that kames or ice-proximal features have the potential to host volumes of construction aggregate equal to or greater than those hosted within glaciofluvial terraces. As with eskers, kames or ice-proximal features should not be discounted as a local source of construction aggregate. They occur within northwest trending ice-proximal or perhaps subglacial systems that are areally extensive. Within these northwest trending systems there are many raised, elongate features. Subsurface investigations are required to assess what portion of a feature, if any, is composed of sand and (or) gravel. As with eskers, these features could also be used to supplement material being brought in from a more distant source to surface all-season gravel roads.

SUMMARY

There are a total of seven aggregate occurrences within, and adjacent to the Kimea Creek meltwater channel system. Only two have been developed into aggregate mines, Kimea (Gravel Reserve 048041), and Helmet 3 (Gravel Reserve 915798) deposits. Surficial geology mapping has identified other glacial features that have potential to host an aggregate occurrence. Of the glacial features identified within the study area, glaciofluvial terraces have the highest potential of hosting high quality (low percentage of fines and high percentage of competent, gravel-sized clasts), and high volumes (>10 000 m^3) of construction aggregate. Kames, eskers, and other ice-proximal or subglacial features also occur within the study area. Although these features host aggregate occurrences, they are assigned a lower aggregate potential rating, as compared to glaciofluvial terraces, mainly due to the compositional variability observed within these features and (or) the low volumes of material they may host. These features should not, however, be discounted as local sources of construction aggregate, either on their own or to supplement material that is being hauled from elsewhere.

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