Placer deposit grain size and water quality sampling program

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ABSTRACT

A program of placer deposit sediment and water sampling was initiated by Indian and Northern Affairs Canada (DIAND) in the summer of 1998 to investigate possible relationships between the grain size distribution of pay gravels and effluent levels at Yukon placer mines. The sedimentology of placer deposits may be characterized in one way by examining the grain size distribution of pay (gold-bearing) gravels. In addition, the amount of clay and silt in gold-bearing gravels has a direct bearing on the treatment necessary for gold liberation during the placer mining process, and the resulting use of water for this process. The program consisted of sampling the pay or sluiced portion of an actively mined placer deposit (bank material), in conjunction with instrument monitoring and sampling the water upstream and at the discharge point of the mine.

Knowledge of the grain size distribution of pay gravels will allow interpretation of the fluvial depositional environment, which can be used as a tool for placer deposit exploration. Sampling and analysis of the water will result in the ability to relate the grain size distribution of the active mine site (bank material) to the suspended solids concentration of the water, and the subsequent impact mining of the deposits has on the water quality in the area. This data will be important for the complete review of the Yukon Placer Authorization in 2001.

RÉSUMÉ

La caractérisation des sédiments des gisements alluvionnaires peut s'effectuer en étudiant la granulométrie des graviers rémunérateurs (aurifères). La teneur en argile et en silt des graviers aurifères influe directement sur le traitement requis pour libérer l'or au cours de l'exploitation des placers et sur l'eau utilisée lors de ce traitement.

Un programme d'échantillonnage des sédiments contenus dans les gisements alluvionnaires et de l'eau a été mis sur pied en 1998 (et se poursuivra en 1999) afin d'étudier les liens pouvant exister entre la granulométrie des graviers rémunérateurs et les débits d'eau chargée en sédiments des mines placériennes.

Le programme comporte l'échantillonnage de la portion rémunératrice ou lavée du gisement alluvionnaire en exploitation (matériaux de la rive) effectué conjointement avec la surveillance au moyen d'instruments et l'échantillonnage de l'eau en amont et au point d'évacuation de la mine.

La connaissance de la granulométrie des graviers rémunérateurs permettra d'interpréter l'environnement fluviatile, ce qui sera un atout pour l'exploration d'autres gîtes alluvionnaires. L'échantillonnage et l'analyse de l'eau permettront de développer une capacité à établir un lien entre la granulométrie d'une mine en cours d'exploitation (matériaux de la rive) et la concentration de matières en suspension dans l'eau, et l'impact ultérieur qu'aura l'exploitation des gisements sur la qualité de l'eau de la région. Ces données seront importantes lors de l'examen complet des placers du Yukon qui se fera en 2001 dans le cadre de la délivrance de permis d'exploitation.

INTRODUCTION

The Yukon Placer Authorization (YPA; Mining Inspection Division, 1993) is the document that sets the standards for placer mine effluent discharge on Yukon streams. This authorization under the Fisheries Act gives powers of enforcement in the regulation of placer mining to Indian and Northern Affairs (DIAND). Standards in the YPA were based on limited information on placer deposit grain size distributions and baseline water quality data, and will be reviewed in 2001.

A database of grain size information for Yukon placer deposits is being developed to aid in this review. This will add to our sedimentological knowledge of these deposits, which may assist us in exploring for similar placer gold-bearing gravels. This information can also be used for mine planning purposes such as settling pond construction.

Simultaneously, a water quality database is being developed to establish baseline information on mined and unmined reaches of creeks throughout the Yukon. This will be used to test the effectiveness of the current YPA standards.

Since some of the YPA standards are not measurable in the field, instrumentation is also being designed and developed which should have this capability.

Two sites were chosen for instrument monitoring in 1998, Duncan Creek in the Mayo area and Nansen Creek in the Carmacks area (Fig. 1).

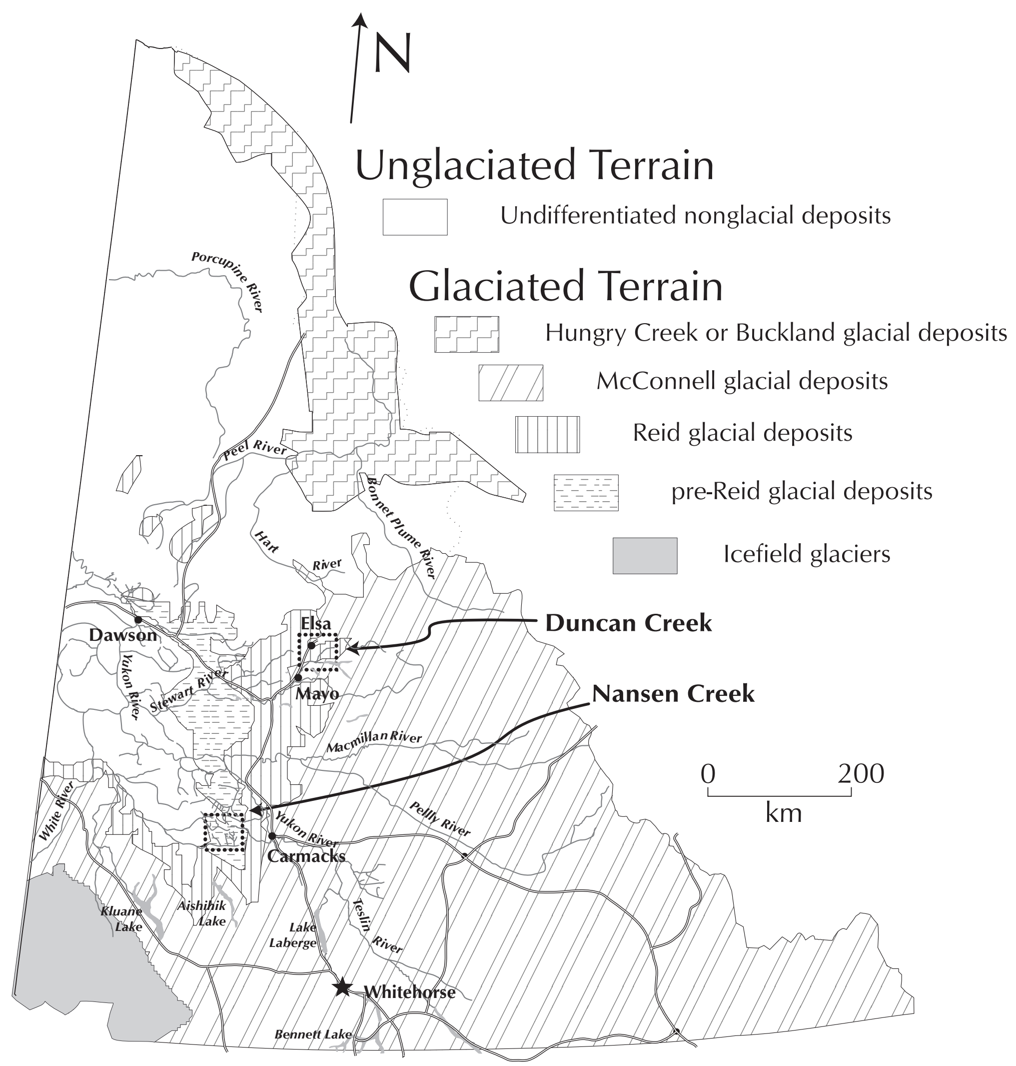

Figure 1. *Location of 1998 water monitoring sites and Cordilleran glacial ice limits in the Yukon.*

PROGRAM OBJECTIVES

The objectives of this program are to learn more about placer deposit sedimentology for exploration purposes, and to characterize the impact of various placer deposit grain size distributions on water quality.

The sedimentology of placer deposits can be distinguished by analyzing their grain size distribution in addition to examining the interaction between these sediments and water, both in a laboratory setting and during the mining process. This will be accomplished by sampling the pay or sluiced portion of an actively mined placer deposit (bank material), in conjunction with monitoring and sampling the water upstream and at the discharge point of the mine.

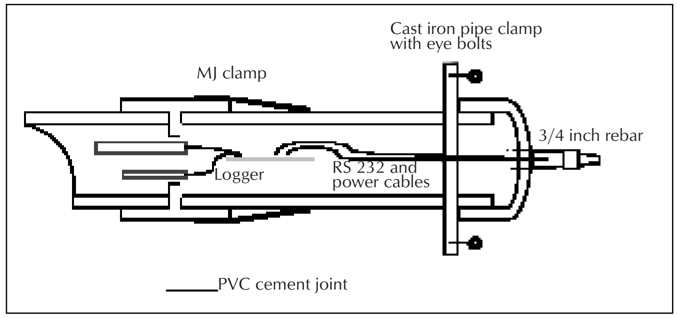

Figure 3. *"Waterpod" instrument developed by Okanagan University College, Kelowna, B.C.*

METHODS

PLACER DEPOSIT SAMPLING PROGRAM

Pay gravels (feed materials) and barren overburden were systematically sampled (Fig. 2), site-specific sedimentologic and stratigraphic data was compiled, and additional information was gathered including amount of overburden stripped, volume of gravels sluiced and gold characteristics. In some areas pay gravels were resampled as they changed character throughout the mining season.

Using methods described in Folk (1974), grain size samples were dried, split and sieved to #10, #18, #35, #60, #120, #230 and minus #230 Tyler screens. After weighing the individual fractions, the #18 to #60 mesh fractions were saved for heavy mineral analysis and the minus #230 portion was sent to Okanagan University College for instrument analysis of the silt/clay ratio.

Figure 2. *Pay gravels and feed materials were sampled for grain-size analysis and gold content.*

WATER QUALITY SAMPLING PROGRAM

The "WaterPod" (Fig. 3) is a water monitoring instrumentation package which was developed by Okanagan University College. It is designed to measure and log various physical and chemical parameters of flowing water in streams and rivers. This equipment allows the continuous collection of water quality data pertaining to individual streams in specific mining areas that, until recently, had been unobtainable (Okanagan University Technical Access Centre, 1998). The "WaterPod" has flexible monitoring capabilities and an on-board 512K memory for data collection and storage. The heart of the WaterPod is a specially designed data logger. The logger is capable of handling up to ten input channels at a time, each channel dedicated to monitoring a specific parameter. All of the components were mounted inside a 6-inch PVC weatherproof housing.

Parameter selective sensors measured the suspended solids concentration, temperature, total dissolved solids (TDS), conductivity, oxygen reduction potential (ORP) and pH in the flowing water. This equipment allowed the continuous collection of background data pertaining to individual streams and specific mining areas that up until now has been unobtainable.

DIAND Water Technologist Mark Nowosad deployed the instrumentation in the field, retrieved the collected data, and gathered individual corroborative water samples upstream and downstream of each of the active placer operations (Figs. 4 and 5). Feed material and process water were simultaneously sampled during placer mine operation.

Data was collected continuously at each site for a period of seven to ten days. The equipment was removed at the end of the season and returned to the university along with copies of the collected data. The university is currently correlating the data collected from the monitoring stations with the data collected from the placer deposit sampling program and the grain size analysis of the gravel samples. This will allow us to relate the surrounding sediment characteristics of the site to the suspended solids concentration of the water, and hence the impact mining of these deposits has on the water quality in the area.

DUNCAN CREEK AND MAYO RIVER

INTRODUCTION AND BACKGROUND

Duncan Creek is a located within the Mayo Mining District (Fig. 6), an area with a long history of placer and hard rock mining dating back to the turn of the century. Several studies have been conducted in this area in recent years, including the multidisciplinary Mayo Placer Research Project (LeBarge, 1996, LeBarge et al., in prep.), and several Master's theses (Giles, 1993, Weston, in prep.). The present study will complement previous research on the relationship between placer mining and suspended sediment in mining streams (Pentz et al., 1996). Each of Duncan Creek and Davidson Creek, both Mayo River tributaries, had one operating placer mine in 1998 (Fig. 7).

PHYSIOGRAPHY AND GLACIAL HISTORY

The Mayo area was affected by all three major episodes of Pleistocene glaciation in the central Yukon. These are (from oldest to youngest): pre-Reid (multiple episodes), Reid, and McConnell. While the Mayo area was completely inundated by the pre-Reid glaciation, it lies at the margins of both of the subsequent Reid and McConnell glaciation (Hughes, 1982, 1987).

Features of the pre-Reid glaciations are difficult to distinguish and mainly consist of erosional scars or glacial erratics on ridges above the Reid ice limit. Ice-contact features, such as moraines and meltwater channels associated with the Reid limit, are more evident but more subdued than the prominent moraines and glaciofluvial terraces associated with the McConnell ice limit.

LOCATION OF STATIONS

Stations were set up in six locations:

1) the confluence of Lightning Creek and Thunder Gulch,

2) immediately upstream of Duncan Creek GoldDusters mining operation,

3) Duncan Creek bridge, downstream of Duncan Creek GoldDusters,

4) Mayo River bridge above the confluence of Davidson Creek and the Mayo River,

5) Mayo River downstream of the confluence with Davidson Creek, and

6) Mayo River downstream of the confluence with Duncan Creek.

NANSEN CREEK

INTRODUCTION AND BACKGROUND

Nansen Creek is located within the Whitehorse Mining District, approximately 60 km west of the village of Carmacks (Fig. 8). Henry S. Back first discovered gold there in July, 1899 on a prospecting trip from Selkirk, when he found gold on Nansen Creek at the mouth of Discovery Creek. Frank H. Back and Tom Bee staked the Discovery claim on Nansen Creek on June 13, 1910 (Cairnes, 1915). Serious mining began to take place shortly thereafter, and nearly all creeks in the area were at one time staked end to end, although most of these claims were eventually allowed to lapse. There were four active mines in 1998, one on Nansen Creek (Fig. 9) and one on Slate Creek, a right limit tributary to Nansen Creek.

Figure 4. *Individual corroborative water samples were gathered upstream and downstream of each of the active placer operations.*

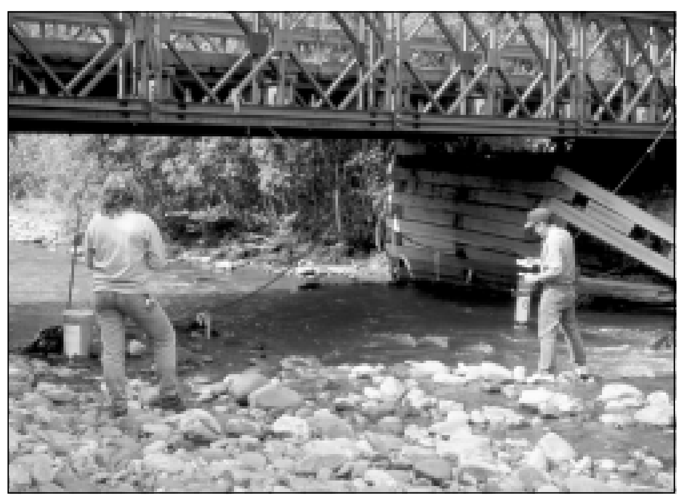

Figure 5. *"Waterpod" instruments were mounted on existing structures, such as bridges, whenever possible.*

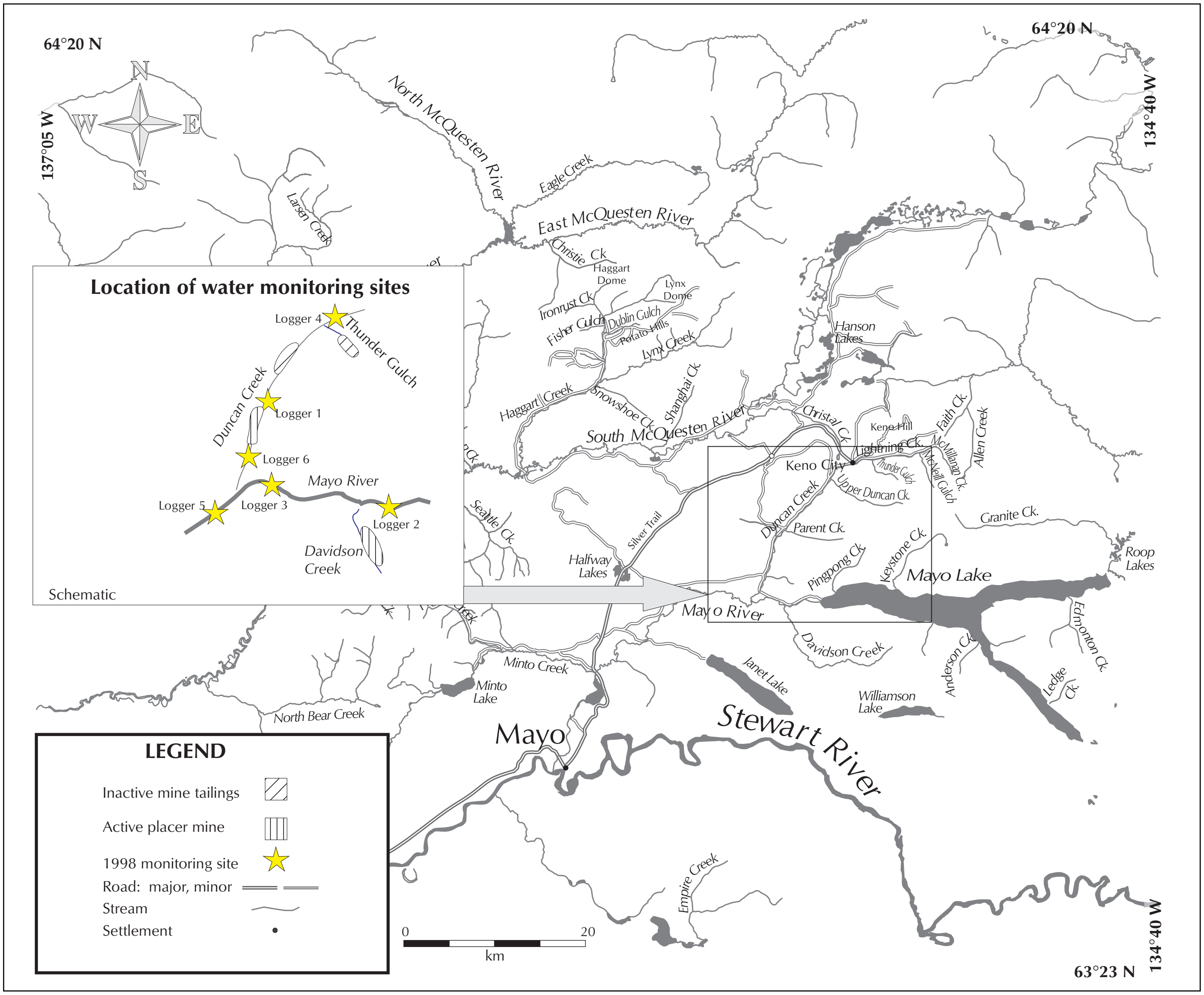

Figure 6. *Location of 1998 water monitoring sites, Duncan Creek area.*

Figure 7. *Duncan Creek Golddusters mined on Duncan Creek in 1998.*

Physiography and Glacial History

Nansen Creek and its tributaries lie outside of the limits of the McConnell and Reid glaciations, however they are within the limits of at least two of the much earlier, pre-Reid glacial episodes (Bostock, 1966, Hughes, 1987). The economic placers in Nansen Creek occur upon a “boulder clay” horizon which may represent a till left by one of these early glaciations (Bostock, 1966). Placer gold also occurs within this till or diamicton, primarily at the diamicton/bedrock contact (LeBarge, 1993, 1995). Gravels are frozen, range in thickness from 1 to 8 m (averaging 5 to 6 m), with a moderate amount (0.5 to 3 m) of organic material. Many of the Mt. Nansen area gold placers lie above the treeline.

Other evidence of the pre-Reid glaciations includes scattered erratics on ridges and variously buried glaciofluvial terraces, meltwater channels and glacial till, some of which have a

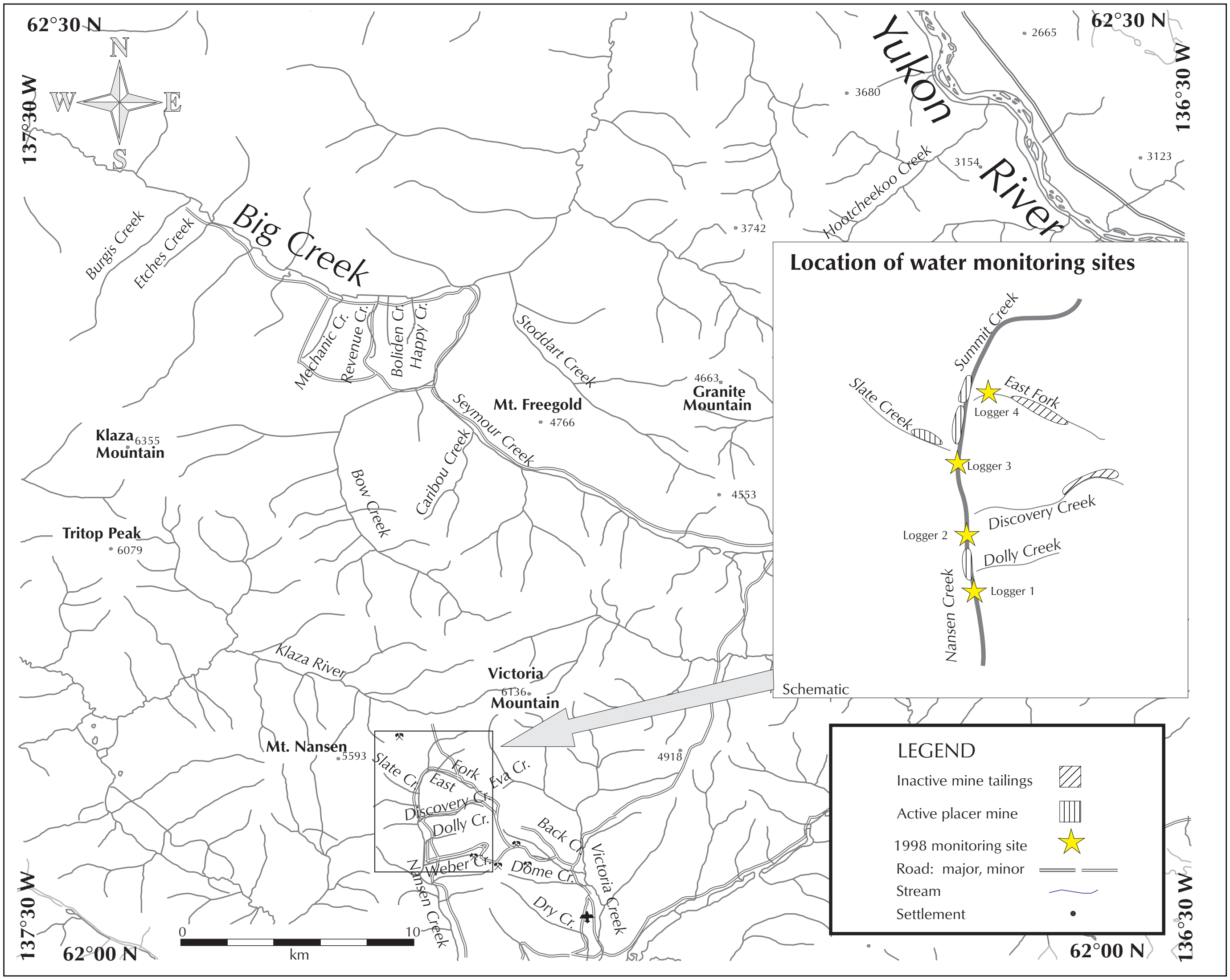

Figure 8. *Location of 1998 water monitoring sites, Nansen Creek area.*

characteristic deep-red weathering surface known as the Wounded Moose paleosol (Foscolos et al., 1977). Large, sandy periglacial fans that formed during the Reid glacial period, just outside of the Reid ice limit, dominate the lower reaches and the major tributaries of Nansen and Victoria creeks. McConnell glacial deposits consist of wind-blown silt or loess which caps many of the gravel deposits.

LOCATION OF STATIONS

Monitoring stations were set up in four locations:

1) immediately downstream of Johnson Brothers mining operation on Nansen Creek,
2) approximately 300 m upstream of Johnson Brothers mining operation on Nansen Creek,
3) at the confluence of Slate Creek and Nansen Creek, and
4) at the confluence of Summit Creek and Nansen Creek.

DISCUSSION

The Mining Inspection Branch of DIAND has collected Yukon creek and river water samples for analysis for a number of years. The data collected from these samples, and the subsequent analysis of that data, indicates a non-conforming relationship exists between the turbidity level in some waters versus the suspended solids concentration. Some of the creeks (e.g., McBurney, Blackhills and Hunker) have a very high suspended solids concentration without a high turbidity value. Alternatively, several creeks (Henderson, Duncan and Little Gold) have high NTU (Nephelometric Turbidity Units) readings despite the fact that the suspended solids concentration is low (Mining Inspection Division, 1992-1997).

In these instances, apparent background colour and the texture class of the sediment in solution (sand vs. silt vs. clay) has a detrimental effect on turbidity readings[1]. Dissolved and

Figure 9. *Joex Mining (Johnson brothers) was the largest placer mine on Nansen Creek in 1998.*

suspended material, both organic and inorganic, can cause colouration of the water and reflect light (Hammer and Hammer, 1996). This can lead to high turbidity values and the mistaken assessment that the creek bears substantial suspended solids, when in fact their concentration is low. Turbidity is not a direct measure of suspended particles in water but instead, a measure of the scattering effect these particles have on light. The amount of light scattered by any particle depends on the particle's size, shape, composition and refractive index.

To further complicate the picture, only superior design allows sensors to compensate for the interference of background colour and varying particle matrix. Site specific field calibration is one method of improving the sensing of these fractions that have creek to creek variations. With the added effects of colouration and clay concentration, NTU values easily rise while the creek may have negligible suspended solids concentration. The alternate case of low NTU readings in conjunction with high suspended solids concentrations is more easily correlated as the NTU readings are not skewed by colour and particle interferences and therefore remain positively correlated with suspended solids.[2]

The Yukon Placer Authorization standards for suspended solids are measured in mg/L. Since DIAND would like to be able to predict these values using a suitable sensor, direct measurement of suspended solids using suspended solids sensors is recommended rather than trying to convert from turbidity readings. At this time, the alternate field measurement technique using turbidity as a standard has not been approved by the Minister.

TENTATIVE 1999 PROGRAM

The 1999 Program will expand the number of monitored sites to several new regions across the Yukon, in a number of different physiographic and geologic settings. There will be several more WaterPods available, and as many as 10 WaterPod stations per region may be deployed. The new Waterpods will incorporate a modified sensor, which is capable of in-situ sand/silt/clay fractional determination, while at the same time monitoring suspended and settleable solids. A newly designed floating hull system will also be deployed.

CONCLUSIONS

Placer mining is an important Yukon industry which must be sustained in a world of increasingly difficult environmental constraints. It is therefore important to have adequate relevant baseline data, which in the case of placer deposits is information on the types of sediment mined and the water quality before, during, and after mining. It is also important to have accurate, state of the art technology for monitoring and regulating mining activity, whether to meet regulatory standards or to achieve mine planning goals.

New equipment and technology allows field measurement of suspended solids concentrations of up to 20,000 mg/L. These measurements in conjunction with their corresponding sand/silt/clay fractional analysis will allow the prediction of settleable solids values as set out in the Yukon Placer Authorization. This will be important for the review of the 2001 YPA standards.

In addition, the careful analysis of grain size information and background water quality data collected from areas with no active mining could be compared to data collected from active placer operations. This would provide the potential to forecast the impact of placer mining on a virgin area.

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[1] Laboratory analysis of three *identically* coloured solutions, each having the same suspended solids concentration but one made from sand, one made from silt, and one made from clay, displayed different turbidity values when measured with standard lab turbidity instrumentation. The turbidity of the solution made from pure silt was 100% higher than that of the solution made from pure sand, while the turbidity of the solution made from pure clay was 150% higher than the solution made from the silt.

[2] Laboratory analysis of *different* coloured solutions, each having the same suspended solids concentration and created from sediment of the same particle size (i.e., silt only), displayed different turbidity values when measured with standard lab turbidity instrumentation. The turbidity of darker coloured solutions generally was higher than that of lighter coloured solutions.

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