GUYANA ENVIRONMENTAL CAPACITY DEVELOPMENT PROJECT

(GENCAPD)

MEDIUM SCALE DEMONSTRATION PROJECT

SURVEY OF KABURI RIVER

ALLUVIAL MINES

Prepared for

Canadian International Development Agency (CIDA)
Natural Resources Canada (CANMET)
Guyana Geology and Mines Commission

and

Guyana Gold and Diamond Miners Association

by

Randy Clarkson P.Eng
NEW ERA Engineering Corporation

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1. Executive Summary

The objective of the site inspections was to locate a mine site suitable to conduct a medium scale dry mining demonstration project. The author examined four alluvial and two lode-vein mine sites in the West Kaburi River area. The West Kaburi River is located on the Issano road in central Guyana and is accessible only by three rough bush roads (via Bartica, Rockstone or Omai) which presently require Bedford all-wheel drive bush trucks and a full day of travel. The existing access is not unreasonable by Guyanese standards but it would significantly decrease the demonstration potential of any sites in this area.

Gold has been produced in the Kaburi River area since 1915 from small lode and alluvial deposits (Grantham, 1933). Most of the gold has come from small creek workings and adjacent alluvial flats. Typically the deposits consist of a layer of white sand and clay overburden overlying a shallow layer of gold-bearing, sandy, angular, white quartz gravels. Dennison Mines Guyana Limited completed an extensive geochemical soil and stream silt sampling program, some shallow auger drilling (2 to 6 meters), air-borne magnetometer surveys, and ground based magnetometer and induced polarization surveys in West Kaburi. Cominco and Overseas Platinum Corporation completed some diamond drilling recently at the Hick's mine which indicated fairly rich gold grades in the weathered saprolite, and that the weathering extended to between 20 to 55 meters below the surface.

All of the six mines inspected used hand-held water monitors to erode the alluvial gravels or weathered lode veins. They all used small (6 inch) gravel pumps to pump the gravels to a raised wooden sluicebox, a mining method referred to as "land dredging" in Guyana (photo 9). All of the soils, including barren overburden clays were moved with the gravel pumps and processed by the sluiceboxes (photos 13 & 14). This resulted in excessive dilution of the ore with barren overburden, which could otherwise be stripped (if heavy equipment is available) and moved prior to mining. A lack of exploration and delineation of the deposit by drilling, trenching or pitting, meant that the deposits were advanced on a day-to-day basis. In the two lode vein deposits, the open pit walls tended to be very steep, and often appeared unsafe for the men working at the bottom of the pit (photo 18).

The construction of settling ponds, stream diversions and the recontouring/filling of waste piles and pits is usually difficult or impractical with typical land dredging equipment. However, one operator was able to place his sluicebox over mined areas and direct his sluicebox tailings so that they refilled the newly mined areas. Two other alluvial mine operators were able to direct their sluicebox tailings to promote drainage away from their pits which otherwise were in swampy areas. The sluiceboxes were fitted with bare carpet and, except for the wooden boil boxes and a short section of dredge riffles, had inadequate provision for coarse gold recovery (photos 6, 10 & 19).

Only one operation (George Griffith) had heavy equipment on site with a history of successful operation, and this equipment is small by Canadian standards. All of the other sites would require substantial investments for bulldozers and/or excavators and would require experienced operators and mechanics with an inventory of spares to keep the equipment operational. Without experienced operators and mechanics, any demonstration employing heavy equipment will fail.

At Mr. Griffith's lode vein mine, an excavator was used to dig out the face, break-up the clay, and increase (double) the gravel pump throughput. Mr. Griffith also used a small bulldozer (D6) to widen the pit and construct ramps into the pit. He was unable to use this heavy equipment to its highest potential because he had no advance knowledge (exploration) of the location or grade of the gold-bearing stringers he was mining.

There are several modifications and additions required to transform any of these sites into a Canadian style dry mining demonstration (using heavy mobile equipment). The specific requirements for each site would be variable, and would depend on site conditions, and the financial and technical capabilities of the individual owner/manager. Canadian mining methods and equipment may have to be adapted to typical Guyanese mining conditions such as soft clay soils, a lack of cobble size gravels, and operation during the rainy seasons.

Rough capital cost estimates indicate that between US$253,000 and US$325,000 (depending on stripping ratio) would be required to outfit any of the four alluvial mine sites with the necessary heavy equipment to sustain an operation processing 90 cubic yards of pay gravels per hour. Operating costs are estimated at between US$158,000 and US$207,000 plus US$12,000 to US$24,000 for Banka drilling. Annual gold production is estimated at 4,725 ounces (based on average gold grades of 0.025 ounces per cubic yard and other assumptions detailed in this report).

2. Recommendations

The demonstration deposit should first be drilled to help estimate the location and grade of the deposit. Banka drills such as those owned by the GGMC would only be suitable for the shallow alluvial deposits and for the shallow areas of the lode vein deposits. A larger more powerful and expensive drill would be required to drill the deep holes for the two lode vein mining operations. This requirement and the more complex geology may preclude the use of the two lode vein mines (Griffith and Rausch) as a demonstration site. It is critical that any deep pit excavations have stable pit walls with benches and shallow slopes

The layout of mine areas for the four shallow alluvial deposits should be based on the results of drilling and pitting. The alluvial and lode vein deposits should be prepared by clearing the forest overlying the mining areas and bulldozing the sandy clay barren overburden soils to the sides of the deposits and into mined-out areas. Mining should progress upstream (or up gradient) to facilitate drainage. The mined out pits should be used as settling ponds and for the deposit of stripped waste soils. The overburden stripping would be pushed back into mined-out pits as the operation progresses upstream. Sluiceboxes fitted and operated according to the appended standard recommendations should be more than adequate to recover the size distributions and shapes of free gold particles observed by the author. Settling ponds should be constructed prior to any sluicing of gravels.

Consideration should be given to locating an alluvial mine site which is closer to Georgetown and more easily accessible. This would enhance the demonstration potential of the site. The preferred characteristics of the demonstration site should include:

a) reasonable access to the site and nearness to other mine sites so that it can be viewed by other miners and potential miners, thus enhancing its demonstration potential;
b) presence of operational mobile heavy equipment and a history of successful operation;
c) probability that there is sufficient deposits of economic minerals for future mining; and
d) a cooperative owner/manager who is willing to integrate new technologies to improve productivity, gold recovery and environmental management.

If such a site is available in Guyana it should be considered and inspected before any further investment or analysis is undertaken in West Kaburi area. If there are no sites with heavy equipment and/or experience available, it may be advisable to encourage cooperation/investment from experienced alluvial miners from North America or New Zealand.

Randy Clarkson P.Eng.

3. Objectives and Scope

The objective of the site inspections was to locate a mine site suitable to conduct a medium scale dry mining demonstration project. The demonstration site would host a dry mining operation equipped with mobile heavy equipment and would demonstrate efficiency in mining and gold recovery with a special emphasis on water management and mitigation of environmental impacts. The preferred characteristics of the demonstration site should include:

a) reasonable access to the site and nearness to other mine sites so that it can be viewed by other miners and potential miners, thus enhancing its demonstration potential;
b) presence of operational mobile heavy equipment and a history of successful operation;
c) probability that there is sufficient deposits of economic minerals for future mining; and
d) a cooperative owner/manager who is willing to integrate new technologies to improve productivity, gold recovery and environmental management.

4. Introduction

Further to request from the Guyana Environmental Capacity Development Project (GENCAPD) Project Steering Committee (PSU) and subsequent meetings of November 25, 1999, with the Guyana Geology and Mines Commission (GGMC) and the Guyana Gold and Diamond Miners Association (GGDMA), the author and representatives of the GGMC and GGDMA inspected several small alluvial mines in the West Kaburi River area. The group included:

a) Patrick Harding (the treasurer of the GGDMA and owner of several medium scale leases in the West Kaburi River area);

b) Ronald Glasgow (Mining Engineer with the Environmental Division of GGMC);

c) Rickford Vieira (Senior Mineral Processing Engineer with the GGMC); and

d) George Griffith (an alluvial miner operating in the area who also provided a large all wheel drive bush truck for transportation on the extremely rough roads).

The group departed Georgetown on November 27th and drove via the Omai ferry crossing (the Essequibo River), through the Omai mine area (photo 1), bush roads (photo 2), and arrived late that evening in West Kaburi. Four small-scale mining operations (George Griffith, Victor Daniels, Francis Pestano, and Patrick Harding) operating in the West Kaburi area were inspected on November 28th. Unfortunately neither of the two Pestano brothers' mines were operational. On November 29th, the group inspected alluvial mines at El Paso and at Hick's Mine in the East Kaburi River area. Following further inspections and a wash-down at Mr. Griffith's mine, the group departed for Georgetown on November 30th and arrived late that night in Georgetown. Mr. Vieira also performed several regulatory duties for the GGMC.

The author and Jean-Marc Barbera met with GGMC staff and Mr. Harding to discuss the results and recommendations of the site inspections on December 2, 1999.

5. Background - Kaburi River Area

The West Kaburi River area lies on the Issano Branch Road between the Mazaruni and Potaro Rivers. In the current state of the Issano Road, it requires about 8 hours to travel the 80 miles from Bartica and this road is passable only to the high clearance all-wheel drive Bedford "bush trucks" (photo 1). To go to Bartica from Georgetown, one must travel by road to Parika on the east coast and then take a speedboat up the Essequibo River to Bartica. The Issano Road can also be accessed from the Rockstone Road via a pontoon at Surribanna strock at Shirima crossing. The author took a third route via bush road from Cambior's Omai mine (photo 2).

Gold has been produced in the Kaburi River area since 1915 from small lode and alluvial deposits (Grantham, 1933). Most of the gold has come from small creek workings and adjacent alluvial flats. Typically the deposits consist of a layer of white sand and clay overburden overlying a shallow layer of gold-bearing, sandy, angular, white quartz gravels. These crude gravels overlie a barren white clay, which is weathered bedrock. Some of the gravels also contain ironstone nodules. According to Grantham, the origin of the gold is a stock work of rich quartz stringers in white clay. The white clay is the weathered product of felsic to mafic volcanic and sedimentary rocks, which have been regionally metamorphosed into schists. Granitic rocks and diabase dikes have intruded these rocks.

Dennison Mines Guyana Limited completed some exploration on West Kaburi River concessions in 1989 and 1990. An extensive geochemical soil and stream silt sampling program was undertaken in 1989. This was followed up in 1990 with some shallow auger drilling (2 to 6 meters), air-borne magnetometer surveys, and by ground based magnetometer and induced polarization surveys. Dennison indicated that the Kaburi District is underlain by volcano-sedimentary rocks within the Mazaruni Group Greenstone Belt and was intruded to the south by the Eldorado Granites. The area is bounded on the north by the ironstone plateau and is mostly covered with recent deposits of white sand. Dennison suggested that the gold is related to hydrothermal fluids injected through fault systems and is associated with quartz and amorphous black tourmaline veins (photo 8).

Dennison's crew observed "Pork-Knockers" activity concentrated on alluvial gravels; the unconformity between the red mottled clay/quartz stone and the saprolite derived from volcano-sedimentary rocks; and smoky colored thin lensoid quartz, which occurs in, altered argillaceous-rich rock (photos 14 & 15) . Dennison concluded that "there was no expressive and persistent geochemical values to guide drill targets. They indicated that most of geochemical anomalies were in the low range, that the higher anomalies were isolated and that some are related to the "nugget effect" (erratic high values when a small sample containing free gold is assayed). Dennison dropped the concessions and Patrick Harding acquired them.

Cominco undertook some soils geochemistry and diamond drilling in the early 1970's in the East Kaburi area. Further work was completed in 1988, by Overseas

Platinum Corporation, which indicated fairly rich gold grades in the weathered saprolite, and that the weathering extended to between 20 to 55 meters below the surface. According to the present local manager (Raymond Rausch) on the property of J. Carter, Cathedral Resources and Cambior have also completed some more recent exploration and Cathedral Resources may still maintain an interest in this property.

6. Mine Site Descriptions

6.1 George Griffiths

George Griffith's lode vein mine is located on Mr. Harding's concessions in West Kaburi at 05-38.75 north, 59-06.18 west (624,479 north, 267,050 east). Mr. Griffith was mining a long narrow steep walled (45 degree slopes) pit, which was 50 feet (15 meters) deep, 310 feet (95 meters) long and 85 feet wide (26 meters) at the bottom (photo 3). The free gold particles were contained in several small smoky-colored quartz stringers. The stringers ranged from 1 foot (300 mm) to 1 inch (25 mm) in width and appeared to pinch in and out of the working face in a shear zone. The stringers were difficult to locate and to follow. Free gold particles and visible gold attached to quartz were observed (photo 8). The saprolite was white to light gray in color and though completely weathered, it still displayed rock textures such as crack filling and angular fragments.

A hydraulic excavator (Caterpillar 219) was digging at the face and below the face to follow a stringer (photo 4). A small (Caterpillar D6) bulldozer was used to ramp down and widen the pit walls. The excavated saprolite was washed into a bedrock clay sump with several hand-held monitors. The gravel slurry was about twice as thick (4% versus 2% volume density) when broken up with the excavator. The gravel slurry was pumped with twin 6 by 6 inch Dambrose gravel pumps through about 200 feet (60 m) of 6 inch (150 mm) diameter PVC pipe through a static head of about 60 feet (18 m) to twin sluiceboxes. The sluiceboxes were both 6 feet (1.8 m) wide and about 20 feet (6 m) long. They were fitted with a wooden boil box, a short section of Hungarian dredge riffles and ribbed Brazilian carpeting (photos 5 & 6). The tailings slurry was discharged onto the land and it flowed slowly to the creek.

Mr. Griffith's crew washed down the sluicebox by a process commonly referred to as "puddling" (photo 7). The coarse gravels trapped by the boil box are washed over the ribbed matting in the main section of the sluicebox. Then the carpets are removed and beaten clean on the floor of the wooden sluicebox. Most of the gold is trapped at the bottom end of the sluice with a small wooden board. Most of the sands and some of the gold overflows the board and is lost to the tailings. The remaining concentrate is mixed with mercury in a plastic pail and amalgamated. The amalgam is filtered through a cloth resulting in a thick paste. The remaining mercury is burned off into the atmosphere with a small propane torch. Approximately 6.75 ounces of fine and chip size gold and 2 ounces of coarse nuggets were recovered from the two sluiceboxes after 4 days of mining (photo 8).

Mr. Griffith's crew were advancing the open pit face on a day to day basis and devoted much of their time searching for stringers. He was unable to use his heavy equipment to its full advantage because he did not have any drilling data to determine the location or grades of the stringers in advance of mining. Drill evaluations of this deposit would be difficult due to the presence of coarse gold and due to the small size and erratic distribution of the gold-bearing stringers. A tight spacing of relatively deep drill holes would be required to give an indication of the location and values of the stringers.

6.2 Victor Daniels

Victor Daniels' alluvial mining operation is also located on Mr. Harding's concessions in West Kaburi at 05-38.66 north, 59-06.00 west (624,317 north, 267,405 east) in a swampy area. This alluvial flat appeared to be an ancient stream channel, which had been previously mined by "Pork Knockers" (photo 12). The deposit varied in depth from 8 to 10 feet (3 meters) in the center to 2 to 3 feet (0.6 to 1 m) at the right and left limits (edges). The lowest 2 to 3 feet above the tan colored saprolite bedrock consisted of quartz rich coarse sands, sharp fragments of quartz, and rounded nodules of iron. The overburden consisted of sandy clay and tailings.

Mr. Daniels had mined up one side of the deposit and was completing mining on the other side. He used hand-held monitors to wash the gravels into a sump (photo 9). A Dambrose 6 by 6-inch gravel pump was used to pump the gravels through 6-inch (150 mm) diameter PVC pipe to a wooden sluicebox, which was positioned on the opposite side above his older tailings. The sluicebox was 17 feet (5.2 m) long by 6 feet (1.8 m) wide and was fitted with a wooden boil box, a short (3 feet) section of Hungarian dredge riffles and ribbed Brazilian matting (photo 10). The tailings slurry flowed over the previously mined area and settled in a previously mined pit before it flowed back to the creek (photo 11). The tailings settled relatively quickly due to their high sand content. The mining was completed in a closed circuit and the land was being reclaimed as it was being mined in this manner (photo 12).

Mr. Daniels reported that he recovered very fine gold and nuggets left behind by the Pork Knockers. He was concerned that the saprolite may only be a false bedrock with gravels underneath. He wished he could drill below the saprolite to check for more gold-bearing gravels. However, it would be relatively easy to dig a pit by hand into the saprolite to check for more gold-bearing gravel below

6.3 Francis Pestano

Francis Pestano was also mining alluvial gravels on Mr. Harding's West Kaburi concession at 05-39.07 north, 59-06.17 west (625,065 north, 267,134 east). The site was a swampy alluvial flat next to the present creek. The pit was located in what appeared to be an ancient stream channel, which had been partially mined previously by Pork Knockers. The alluvial deposit was about 12 to 14 feet (3.5 to 4 m) deep with about 1 to 1.5 feet of quartz rich coarse sand and angular gravels resting on an unconformity of saprolite (bedrock). The saprolite was soft but still displayed rock textures. The overburden soils consisted of clay mixed with fine sand.

Mr. Pestano used hand-held monitors to wash the soils into a bedrock sump. He pumped the gravels with a 6 by 6 inch Dambrose gravel pump through 6-inch diameter PVC pipe to a wooden sluicebox. The sluicebox was 6 feet (1.8 m) wide and 22 feet (6.7 m) long. It was fitted with a wooden boil box, a short section of Hungarian dredge riffles, bare Nomad matting and ribbed Brazilian carpet. The tailings were deposited on virgin ground ahead of the mining face. He mined underneath the tailings to advance his pits down slope and towards the present creek while maintaining drainage.

6.4 Patrick Harding

Patrick Harding has his own alluvial land dredging operation on his concession at 05-39.23 north, 59-06.11 west (625,363 north, 267,195 east). This area was a swampy alluvial flat over an ancient stream channel. The alluvial deposit was 13 feet (4 m) deep with 2 to 3 feet of angular quartz-dominant, sandy, angular gravels resting unconformably on white saprolite bedrock (photos 13 & 14). The quartz gravels were both opaque white and translucent smoky in color.

Mr. Harding used hand-held monitors and a 6 by 6 inch Dambrose pump to mine the gravels. He had been mining about 2 to 3 months and had excavated a pit measuring about 300 feet (100 m) long by 80 feet (25 m) wide and 13 feet (4 m) deep. His sluicebox was 6 feet (1.8 m) wide and 20 feet (6 m) long. It was fitted with a wooden boil box, a short section of Hungarian dredge riffles and a long length of bare Nomad carpet (photo 16). Mr. Harding discharged his tailings in front and to the side of his operation to build up the area and promote drainage away from the pit.

6.5 El Paso

The alluvial pit at El Paso was located at 05-38.60 north, 59-07.31 west (624,128 north, 265,010 east). It was 6 to 12 feet (1.8 to 3.6 m) deep, 100 to 150 feet (30 to 45 m) wide and 150 to 200 feet (45 to 60 m) long. It was located on an alluvial flat over an ancient stream channel, which was previously partially mined by Pork Knockers. An angular quartz-dominant, sandy gravel layer about 1 foot thick was located directly above the saprolite bedrock.

The operators used hand-held monitors and a 6 by 6 inch Dambrose gravel pump to mine the gravels. The wooden sluicebox consisted of two sections. The first section was 3 feet wide and 7 feet long and was fitted with bare Nomad matting. The lower section was 6 feet wide and 9 feet long and was fitted with a wooden boil box and bare Nomad matting.

6.6 Raymond Rausch (Hick's Mine)

Raymond Rausch was lode vein mining at Hick's mine on the East Kaburi River at 05-35.78 north, 59-02.67 west (619,014 north, 273,577 east). This deposit is a steeply dipping quartz vein deposit inside a weathered saprolite host rock (photos 17 & 18). Mr. Rausch indicated that fine powder gold is recovered from multiple white and translucent (smoky) quartz stringers in the shear zone. He also indicated that Cathedral Resources had completed some drilling and trenching on the vein and still had an interest in the property. Cambior also did some evaluation of this area to provide a source of oxidized ore for their mill at Omai. However, Cambior are reported to be presently concentrating their exploration efforts on Eagle Mountain.

The vein and surrounding saprolite are mined using hand-held monitors and a 6 by 6 inch Dambrose gravel pump. The owner had a small excavator, which was not operational. The pit was very deep (about 60 to 80 feet, 18 to 24 m) and long and narrow. The slurry flowed through 120 feet (36 m) of 6 inch diameter PVC pipe to a wooden sluicebox about 30 to 40 feet (9 to 12 m) above the pump. The wooden sluicebox was 6.3 feet wide (1.9 m), 19 feet (5.8 m) long, and consisted of a wooden boil box, and bare carpeting (photos 19 & 20). The process water was pumped from a nearby creek and the tailings flowed slowly overland to the same tributary of the Kaburi River.

6.7 Summary of West Kaburi Land Dredging

All of the mines inspected used hand-held water monitors to erode the alluvial gravels or weathered lode veins. They all used small (6 inch) gravel pumps to pump the gravels to a raised wooden sluicebox, a mining method referred to as "land dredging" in Guyana (photo 9). In the deeper lode vein deposits, open pit walls tended to be very steep and often appeared unsafe for the men working at the bottom of the pit. This generally was most severe near the advancing face of the pit (photo 18). All of the soils, including barren overburden clays were moved with the gravel pumps and processed by the sluiceboxes (photos 13 & 14). This resulted in excessive dilution of the ore with barren overburden, which could otherwise be stripped (if heavy equipment is available) and moved prior to mining. This also led to unnecessary discharge of sluicebox effluent from overburden soils, which had clays and high suspended solids.

A lack of exploration and delineation of the deposit by drilling, trenching or pitting, meant that the deposits were advanced on a day-to-day basis. This sometimes resulted in erratic and inefficient mining, the dumping of tailings on virgin gold-bearing areas, unnecessary re-handling of gravels, and/or unnecessary land disturbances.

The sluiceboxes were fitted with bare carpet and, except for the wooden boil boxes and a short section of dredge riffles, had inadequate provision for coarse gold recovery (photos 6, 10 & 19). Victor Daniels was able to place his sluicebox over mined areas and direct his sluicebox tailings so that they refilled the newly mined areas (photos 11 & 12) . Two other alluvial mine operators, Francis Pestano and Patrick Harding's operation were able to direct their sluicebox tailings to promote drainage away from their pits which otherwise were in swampy areas. At George Griffith's lode vein mine, an excavator was used to dig out the face, break-up the clay, and increase (double) the gravel pump throughput . Mr. Griffith also used a small bulldozer (D6) to widen the pit and construct ramps into the pit. He was unable to use this heavy equipment to its highest potential because he had no advance knowledge (exploration) of the location or grade of the gold-bearing stringers he was mining. Drilling, trenching and/or sample pitting in advance of mining would allow all of the alluvial miners to mine more efficiently and safely. The use of heavy equipment, in combination with advance drilling, would also allow them to excavate the pit walls in benches and/or at shallower slopes, thus reducing pit wall failures and improving worker safety.

The basic equipment required for land dredging is a gravel pump and water pump powered by small diesel engines, which is mounted on a skid and/or floating frame (photos 9 & 15). The capital cost of these two pumps and related accessories is about US$25,000 to $30,000. Operating costs are also typically very low with fuel consumption of about 100 liters per day. Labor requirements are very high with large numbers of unskilled and semi-skilled men at each camp. Unfortunately production is also usually relatively low (5 to 12 cubic yards per hour) due to the inability of the jets to rapidly break up and fluidize the gravels, unless the gravels are sandy or previously worked. The barren overburden, which is moved by jetting, dilutes the pay gravels. The construction of settling ponds, stream diversions and the recontouring/filling of waste piles and pits are usually difficult or impractical with typical land dredging equipment.

7. Guyanese versus Canadian Mining Conditions

There are several modifications and additions required to transform any of these sites into a Canadian style dry mining demonstration (using heavy mobile equipment). The specific requirements for each site would be variable, and would depend on site conditions, and the financial and technical capabilities of the individual owner/manager. Canadian mining methods and equipment may have to be adapted to typical Guyanese mining conditions. For example, the soils in Guyana are typically very soft and rich in clays. This could make heavy equipment operation difficult, especially in the rainy seasons (June-July and December-January), however, modifications such as wide tracks and the use of smaller and/or lighter bulldozers (newer D6 or older D7 sizes) and lighter excavators may mitigate this problem to some extent. Pay gravels may have to be stockpiled in advance so that the mines can continue to produce gold through the rainy seasons.

In Guyana, the alluvial gold particles are generally finer sized and more difficult to liberate from the clays. However, very coarse nuggets were recovered on the West Kaburi River mines, even though these sluiceboxes were not well outfitted for the recovery of coarse gold. Guyana's alluvial gravels often contain a very small proportion of stone sized aggregate with greater amounts of clay and sand. In some cases, the limited amount of coarse aggregates may make screening less important for optimum gold recovery. Where screening is warranted, trommel screens should be used due to their superior scrubbing action. Either efficient trommel screens and/or gravel pumps would be required to wash the gravels and free the gold particles from the clays. If trommels are used, some of the stones in the pay gravels may have to be recycled from the trommel discharge back to the feed, or retained within the trommel to help break-up the clays.

Only George Griffith's operation had heavy equipment on site with a history of successful operation, and this equipment is small by Canadian standards. All of the other sites would require substantial investments for bulldozers and/or excavators and would require experienced operators and mechanics with an inventory of spares to keep the equipment operational. Without experienced operators and mechanics, any demonstration employing heavy equipment will fail.

8. Alluvial Exploration

Alluvial deposits by their nature are difficult to "prove" with exploration methods due to the erratic distribution and coarse size of the gold particles. In general, the larger the sample of gravel, the more representative it is. Drilling and/or trenching and/or bulk sampling can be employed by an experienced alluvial mining engineer or alluvial geologist to help determine the location and estimate the grades of the gold-bearing zones. Banka churn drills are commonly used in Guyana for alluvial exploration. These drills are very labor-intensive and relatively slow but they are very portable and usually provide a good quality (although small) samples when operated by experienced and competent drillers, and when supervised by experienced engineers and/or geologists. Generally the maximum drilling depth is about 50 to 60 feet with drilling rates of about 30 to 40 feet per day, depending upon the ground conditions.

Most alluvial deposits are linear in shape and are generally drilled with relatively close spacings between the holes (50 to 200 feet, 15 to 60 m) and much larger spacings between the drill lines (300 to 1000 feet, 100 to 330 m). This would not be the case for the Mr. Griffith's lode vein mine, where closely and equally spaced drill holes and drill lines would be required to outline blocks of ore grade gold-bearing stringers. Some deep holes have already been drilled on Mr. Rausch's lode gold mine in East Kaburi, however additional holes to extend the strike length of the vein may be required once the existing drill information has been examined.

If the deposits are shallow, (less than 20 feet, 6 m), they can often be sampled by digging small pits with an excavator and processing the individual samples on a sampling sluice. With pitting, larger and more representative samples can be obtained and the geology can be examined in detail. If ground water is encountered, a pump may be required to de-water the hole. Trenches would also provide useful samples of lode deposits such as Mr.Griffith's and Mr. Rausch's operations that outcrop near the surface.

9. Program for Dry Mining Demonstration

9.1 Exploration

The demonstration deposit should first be drilled to help estimate the location and grade of the deposit. A Banka drill would be suitable for the shallow alluvial deposits and for the shallow areas of the lode vein deposits. However a more powerful drill would be required to sample the lode veins at depth. Auger drills may work well provided that there is not excessive ground water, and that the walls of the hole remain semi-consolidated while drilling. Other types of drills such as reverse-circulation drills are considerably more expensive to operate and much less portable.

The required saturation of drilling required to estimate the locations and grades of the deposit will vary depending on the site-specific geology encountered. At first a reconnaissance drilling program should be carried to determine the general geology and if the gold grades warrant further exploration. Vieira (1999) indicates that drilling saturation can vary from 1 to 10 holes per acre. For a first estimate, it could be assumed that the shallow alluvial deposits would require a hole density of about 2 to 3 per acre. The depth of the holes would vary with the depth of the alluvial deposit but would be from 10 to 30 feet (3 to 9 m). The deeper lode vein deposits at Griffith's operation would require more holes per acre but each hole could outline a greater depth of deposit. The alluvial deposits were only about 2 to 3 feet thick.

Vieira indicates that about 50 feet (15 m) of Banka drilling could be done per day at a cost of about US$3.70 per foot (US$12 per meter). He also indicates that this cost could increase depending on the location of the project. It is critical that an experienced alluvial mine engineer or geologist provide close supervision of the drilling and interprets the results.

9.2 Mine Planning

Mine areas would be determined based on the results of the exploration and the limits of the mine pits would be surveyed in. The layout of mine areas for the shallow alluvial deposits would be based on the results of drilling and pitting (using the polygon method). The erratic stringers at Griffith's operation would have be evaluated with deep drilling and the use of a block model mine-planning program. The better-defined vein at Rausch's operation should be evaluated with deep drilling and by using a vein model method.

Excavation limits should include an allowance for shallow stable pit walls including benches where the walls are more than 20 feet (6 m) deep. Due to the necessity of shallow pit wall slopes, more and more overburden will have to be stripped with depth, and the economic depth limit of the pits may occur before the bottom of the weathered saprolite (at 80 to 180 feet, 25 to 55 m at the Hick's Mine). It is critical that any deep pit excavations have stable pit walls with benches and shallow slopes. During the rainy seasons, the stability of these pit walls must be monitored closely to prevent unanticipated collapse and possible worker injury or death.

The alluvial and lode vein deposits would be prepared by clearing the forest overlying the mining areas and bulldozing the sandy clay barren overburden soils to the sides of the deposits and into mined-out areas. The deeper alluvial deposits with stripping ratios of greater than 2:1 would required at least two small bulldozers to keep the stripping in pace with mining. Then the gold-bearing gravels could be dug out with a hydraulic excavator. The gravels would either be hauled out or more likely removed with jetting and gravel pumps. An alternative method would use an excavator to feed a trommel scrubber/screen.

Mining should progress upstream (or up gradient) to facilitate drainage. The mined out pits should be used as settling ponds and for the deposit of stripped waste soils. The overburden stripping would be pushed back into mined-out pits as the operation progresses upstream. Settling ponds should be constructed prior to any sluicing of gravels. The initial settling pond construction should require two or three days of construction with a small dozer and excavator (see appended drawings).

All of the operations, except Mr. Griffith's mine, would have to acquire one or two small bulldozers (preferably D7 size) and preferably one small excavator (at least 20 ton). All of the equipment should be fitted with wide (swamp) tracks and/or track extensions. Wide tracks will wear more quickly than standard width tracks but are necessary due to the softness of the clay, which is prevalent in this area.

9.3 Gold Recovery

Most of the alluvial deposits are residual deposits, or are very close to the lode source of their gold. The gold particles are very irregular, some are attached to quartz (photo 8), and they cover the full size range from flour gold (200 mesh, 75 micron) to nuggets. Sluiceboxes fitted and operated according to the appended standard recommendations should be more than adequate to recover the size distributions and shapes of free gold particles observed by the author (a sketch is appended). Where there is significant gold attached to quartz, the oversize should be collected, ground in a ball mill and processed with either gravity, mercury amalgamation, or chemical methods. At the very least, the gold bearing quartz should be stockpiled for later processing.

In most of the alluvial and lode deposits observed by the author, there is not enough cobble size material in the alluvial gravels to warrant the use of a (trommel) screen. A trommel screen is unlikely to wash the clay-rich gravels as thoroughly as a gravel pump. A vibrating screen deck wills likely plug with clays unless very high-pressure jets of water are used.

10. Estimated Costs of Dry Mining

The following capital and operating costs are rough estimates based on Canadian experience, Patrick Harding's estimates, and a report by Rick Vieira regarding Banka drilling methods and costs. Actual mining and processing costs are very site specific and may vary considerably from these preliminary estimates. The cost of mining alluvial deposits with a low stripping ratio (less than 2:1) and a higher ratio (4:1) are estimated below. The costs of mining either of the lode vein deposits (Griffith or Rausch) could only be estimated with any accuracy following a detailed analysis of the results of a deep drilling program.

An older D7 or newer (high drive) D6 bulldozer should be able to strip up to 200 cubic yards per hour provided that the distances are kept short (less than 200 feet, 60 m). Two bulldozers would be required for the deeper mines (20 feet, 6 m) or those with stripping ratios of greater than 2:1. A 20-ton hydraulic excavator should be fitted with a 1 to 1.25 cubic yard digging bucket and wide tracks. It should be able to excavate about 90 cubic yards per hour with a 40 second cycle time. An all -wheel drive service truck would be required.

A 6 by 6 inch Dambrose gravel pump should be able to pump from 30 to 40 cubic yards per hour of gravels provided that the gravels are loosened with heavy equipment and the operator is able to maintain a high solids (10%) density. Two or three pumps would be required to keep up with the hydraulic excavator. Two 6 by 6 inch water pumps should be able to supply sufficient water for hydraulicing unless there is a long distance to the water source.

Two or three small simple wooden sluiceboxes, or one larger box fitted according to the appended standard recommendations with coarse expanded metal and one inch angle iron riffles should be able to recover a high percentage (greater than 90%) of the free gold. An optional trommel may be required to separate gold-bearing quartz for stockpile or further processing.

These estimates assume the following:

a) 300 days per year are suitable for mining;

b) a qualified heavy duty mechanic and well-trained operators are on site;

c) the heavy equipment will have an availability of 70%;

d) diesel fuel can be supplied throughout the mining period, or there is sufficient storage available;

e) a parts inventory will be on hand and other parts can be obtained relatively easily;

f) the exploration is supervised by an experienced alluvial mine engineer or geologist;

f) the soils, gold grades and processing rates observed by the author are typical for this area.

Capital Cost Estimates	**Shallow Alluvial (2:1)**	**Deeper Alluvial (4:1)**
Bulldozer (D7 or newer D6 size)	$72,000	$144,000
Excavator (used 20 ton)	$56,000	
Water Pumps 6by6 (2)	$24,000	
Gravel Pumps 6by6 (3)	$33,000	
Sluicebox	$6,000	
Trommel Screen (Optional)	$30,000	
Service Truck	$15,000	
Camp	$5,000	
Spares	$12,000	
Total	US$253,000	US$325,000

Note: Two bulldozers would be required for the deeper mines (20 feet, 6 m) or those with stripping ratios of greater than 2:1.

Mobilization and demobilization costs are not included.

Operating Cost Estimates	**Shallow Alluvial (2:1)**	**Deeper Alluvial (4:1)**
Depreciation	$20,000	$26,000
Maintenance	$25,000	$37,000
Fuel	$43,000	$64,000
Freight	$8,000	$12,000
Labor	$29,000	$30,000
Camp	$7,000	
Overhead	$12,000	
Subtotal	US$144,000	US$188,000

Contingency	$14,000	$17,000
Total	US$158,000	US$207,000

Note: Annual operating costs for deeper alluvial deposits or those with higher stripping ratios (4:1) would be higher (total of US$207,000).

These do not include exploration and drilling costs (which follow).

Drilling and Exploration Costs	**Shallow Alluvial (2:1)**	**Deeper Alluvial (4:1)**
Average Depth of Holes	10 feet (3 m)	20 feet (6m)
Estimated Saturation	800 feet	1600 feet
Unit Cost per foot	$7.42	
Drilling Costs	$6,000	$12,000
Contingency	$6,000	$12,000
Total	US$12,000	US$24,000

Production Estimates

Throughput	90 loose cubic yards per hour
Operating Hours	10 hours per day
Operating Days	300 days
Availability	70%
Gravel Thickness	3 feet (0.9 m)
Average Grade	0.025 ounces/cubic yard
Annual Gold Production	4,725
Annual Gold Value	US$250 per ounce (net of royalties)
Annual Revenue	US$1.2 million

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Photo 1 - Bedford Bush Truck with the first of two flat tires on Omai mine site road.
Patrick Harding, Ronald Glasgow and Rickford Vieira look on.

Photo 2 - Corduroy Bush Road in West Kaburi Area
View from Bedford Truck Cab
Photo 3 - Overview of Pit and White Hole at George Griffith's Lode Vein Mine

Note the miners jetting red clays in the foreground

Photo 4 - Excavator digging out face of Griffith's pit to assist gravel pumping
Photo 5 - Twin sluiceboxes operating at Griffith's lode vein mine

Photo 6 - End view of twin sluiceboxes at Griffith’s mine
Photo 7 - Puddling sluicebox concentrates at Griffith’s mine

Photo 8 - Irregular gold nuggets and gold on quartz at Griffith's lode vein mine
Photo 9 - Pumping gravel from sump at Victor Daniel's alluvial mine

Photo 10 - Victor Daniels' wooden sluicebox
Photo 11 - Fresh tailings in a settling pond at Victor Daniels' alluvial mine
Note how the tailings are refilling an old mine pit, Ronald Glasgow and Mr. Daniels

Photo 12 - Mined and refilled/reclaimed area at Victor Daniels' alluvial mine
Patrick Harding and Ronald Glasgow in foreground
Photo 13 - Alluvial pit wall at Harding's operation
Note clay bedrock on bottom, 2 feet of gravel, and sandy clays above

Photo 14 - Close-up of clay bedrock and alluvial gravel contact
Photo 15 - Water intake pump in creek at Patrick Harding's alluvial mine
Note the water is discolored from upstream discharges

Photo 16 - Patrick Harding's wooden sluicebox
with tailings directed to raise land for drainage purposes
Photo 17 - Steep walled pit at Hick's mine (Rausch's lode vein mine).
Dambrose gravel pump in the background

Photo 18 - Alternate view of steep walled pit, Rausch's lode vein mine
Note jetting in the middle of the photo
Photo 19 - Rausch's wooden sluicebox, note absence of riffles

Photo 20 - Rausch's sluicebox running at low density

Appendix 1 Standard Sluicebox Recommendations

STANDARD RECOMMENDATIONS

Field and laboratory test work has indicated that sluicebox runs should be designed to the following specifications for optimum recovery levels:

a) every sluice run should have a section of expanded metal riffles and a section of angle iron riffles in series;

b) the expanded metal section should be sized to handle 8 loose cubic yards per foot of width and consist of coars e expanded metal mesh (4 to 6 lbs/ft2) fitted tightly on top of Nomad matting;

c) optimum slurry velocities for the expanded metal riffles section will range from 5 to 6 feet per second (1.5 to 1.8 m/s);

d) the expanded metal section of the sluicebox should preferably be at least 16 feet long and followed or preceded by an 8 feet long section of angle iron riffles;

e) the angle iron riffle section should be approximately one half the width of the expanded metal riffle section and may have to be set at a steeper gradient of up to 3 inches/foot to achieve a slurry velocity of 6 to 8 feet per second (1.8 to 2.4 m/s), care must be taken to reduce rooster tails where runs are narrowed;

f) the one-inch angle iron riffles should be aligned at 15 degrees from the sluicebox's vertical towards to top of the box and they should be located with a clear distance of 2 to 2.5 inches (50 to 65 mm) between each riffle;

g) the angle iron riffles should be fitted tightly on top of Nomad matting (light expanded metal may be inserted between the riffles and the matting to prolong the life of the matting); and

h) nuclear tracers indicated that the gold particles can migrate down the sluice run (especially during start up periods) therefore sluice runs that are easily washed down will allow more frequent clean ups (preferably every 24 hours) to further reduce gold losses.

Appendix 2 Kaburi River Mines Data, Sluicebox Data and Calculations

George Griffith's Operation West Kaburi River

Location:	05-38.75N	59-06.18W	SAM 69
	624,479N	267,050E	SAM 69

PROCESSING EQUIPMENT DIMENSIONS (Imperial) 1 m = 3.2808 feet

Description	Length ft	Width ft	Depth ft	Area ft2	Volume yd3	
Boil Box	2.5	8.0		20	0.49	Wooden Box 8" deep
Top Sluice	3.0	8.0		24	0.22	Hungarian 3x1x4.5 O
Bottom Run	14.0	8.0		112	0.09	Bare Ribbed Carpet
Combined	19.5	8.0		156	0.80	Total Con Volume yd:
Bucket Vol	4.3	3.3	2.10		1.08	Struck
					1.40	Heaped
Feed Rate					8	yd3/hour each sluicebox
					15	yd3/hour both sluiceboxes
			10 hours		115	yd3/day
Clean up Volume			75% operation		0.80	yd3
Concentration Ratio		30 hours		1:	215	Extremely Low
						Due to low feed rat
Gravel Pump	6 by 6	Dambrose Gravel Pump				and Low Density
Pipeline	6	inch PVC	200 ft length		45	ft lift

Notes: These data are similar for both of the twin sluiceboxes.

The extremely low density of the pumped slurry has resulted in low combined feed rates of 15 cubic yards per hour or about 115 cubic yards per day when low flow pumping periods (about 25% of the time) are considered.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

Victor Daniels' Operation **West Kaburi River**

Location	05-38.66N	59-06.00W	SAM 69
	624,319N	267,405E	SAM 69

One Sluicebox

PROCESSING EQUIPMENT DIMENSIONS (Imperial)

Description	Length ft	Width ft	Depth ft	Area ft2	Volume yd3	
Boil Box	2.3	6.2		14	0.51	Wooden Box 12" dee
Top Sluice	3.0	6.2		19	0.17	Hungarian 3x1x4.5 O
Bottom Run	11.0	6.2		68	0.05	Bare Ribbed Carpet
Combined	16.3	6.2		100	0.74	Total Con Volume yd:

Feed Rate			12	yd3/hour
		10 hours	61	yd3/day
Wash-down volume		50% operation	0.74	yd3
Concentration Ratio	30 hours	1:	250	Extremely Low Due to Low Feed Rat Low Density
Gravel Pump	6 by 6	Dambrose Gravel Pump		
Pipeline	6 inch PVC	80 ft length	12	ft lift

Notes: There is only one sluicebox.

The extremely low density of the pumped slurry has resulted in low feed rates of 12 cubic yards per hour or about 61 cubic yards per day when low flow pumping periods (about 50% of the time) are considered.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

Francis Pestano's Operation West Kaburi River

Location:	05-39.07N	59-07.17W	SAM 69
	625,065N	267,134E	SAM 69

PROCESSING EQUIPMENT DIMENSIONS (Imperial)

Description	Length ft	Width ft	Depth ft	Area ft2	Volume yd3	
Boil Box	2.0	6.0		12	0.44	Wooden Box 12" dee
Top Sluice	3.0	6.0		18	0.17	Hungarian 3x1x4.5 O
Center Run	5.0	6.0		30	0.07	Bare Nomad Carpet
Bottom Run	8.5	6.0		51	0.04	Bare Ribbed Carpet
Combined	18.5	6.0		111	0.72	Total Con Volume y
Feed Rate					N/A	yd3/hour
Clean up Volume					0.72	yd3
Concentration Ratio		30 hours		1:	N/A	Unknown

Gravel Pump	6 by 6	Dambrose Gravel Pump			
Pipeline	6	inch PVC	80 ft length	20	ft lift

Notes: There is only one sluicebox.

The density of the pumped slurry was not measured.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

Patrick Harding **West Kaburi River**

Location:	05-39.23N	59-06.11W	SAM 69
	625,363N	267,195E	SAM 69

PROCESSING EQUIPMENT DIMENSIONS (Imperial)

Description	Length ft	Width ft	Depth ft	Area ft2	Volume yd3	
Boil Box	2.0	6.0		12	0.44	Wooden Box 12" dee
Top Sluice	3.0	6.0		18	0.17	Hungarian 3x1x4.5 O
Center Run	8.0	6.0		48	0.11	Bare Nomad Carpet
Bottom Run	7.0	6.0		42	0.03	Bare Ribbed Carpet
Combined	20.0	6.0		120	0.75	Total Con Volume yd:

Feed Rate		10	hours	36	yd3/hour
		50%	operation	179	
Clean up Volume				0.75	yd3
Concentration Ratio	30 hours		1:	710	Very Low
Gravel Pump	6 by 6	Dambrose Gravel Pump			
Pipeline	6	inch PVC	120 ft length	20	ft lift

Notes: There is only one sluicebox.

The pumped slurry has a higher density because these pay gravels are easier to wash into the sump. This resulted in higher feed rates of 36 cubic yards per hour or about 179 cubic yards per day when low flow pumping periods (about 50% of the time) are considered.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

Other Operations at El Paso

Location:	05-58.62N	59-07.29W	SAM 69
	624,173	265,057	SAM 69

PROCESSING EQUIPMENT DIMENSIONS (Imperial)

Description	Length ft	Width ft	Depth ft	Area ft2	Volume yd3	
Top Sluice	7.0	3.0		21	0.05	Bare Nomad Matting
Drop Box	2.5	7.0		18	0.32	Wooden Boil Box
Bottom Run	9.0	7.0		63	0.15	Bare Nomad Carpet
Combined	18.5	5.7		102	0.52	Total Con Volume yd:

Feed Rate			10	hours	N/A	yd3/hour
			50%	operation	N/A	
Clean up Volume					0.52	yd3
Concentration Ratio		30	hours	1:	N/A	Unknown
Gravel Pump	6 by 6	Dambrose Gravel Pump				
Pipeline	6	inch PVC	200	ft length	30	ft lift

Notes: There is only one sluicebox.

The density of the pumped slurry was not measured.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

Raymond Rausch's Operation at East Kaburi

Location:	05-35.80N	59-02.65W	SAM 69
	619,014N	273577E	SAM 69

PROCESSING EQUIPMENT DIMENSIONS (Imperial)

Description	Length	Width	Depth	Area	Volume	
	ft	ft	ft	ft2	yd3	
Boil Box	2.7	6.3		17	0.31	Wooden Box 6" deep
Top Sluice				0	0.00	
Bottom Run	16.5	6.3		105	0.08	Bare Carpet
Combined	19.2	6.3		121	0.39	Total Con Volume yd:
Feed Rate			10	hours	5	yd3/hour
			50%	operation	24	
Clean up Volume					0.39	yd3
Concentration Ratio		30 hours		1:	179	Extremely Low
						Due to Low Feed Rat
Gravel Pump	6 by 6	Dambrose Gravel Pump				and Low Density
Pipeline	6	inch PVC	120	ft length	40	ft lift

Notes: These data are similar for both of the twin sluiceboxes.

The extremely low density of the pumped slurry has resulted in low feed rates of 5 cubic yards per hour or about 25 cubic yards per day when low flow pumping periods (about 50% of the time) are considered.

The sluicebox has only the boil box and a short section of dredge riffles for coarse gold recovery.

SLUICE SLOPES

	Griffith	Griffith	Daniel's	Pestano	Harding	Rausch
Percent	N/A	N/A	N/A	20%	19%	19%
Degrees	N/A	N/A	N/A	11	11	11
in/ft	N/A	N/A	N/A	2.4	2.3	2.3

MASS FLOWS

WATER FLOW RATES

The water and pay gravel feed rates were derived from sampler data and time studies. These were compared to recommended values for expanded metal riffles derived from previous research: feed rate at 8 loose cubic yards/hr and water rate of 160 Igpm of water per foot of sluice width. (One inch angle iron riffles require 320 Igpm and can be loaded at up to 16 loose cubic yards/hr per foot of sluice width.

Descriptior	Factor	Griffith **w/o** excavator	Griffith **with**	Daniels	Harding	El Paso	Rausch	Avg.
Slurry Velocity m/s		1.3	1.33	1.56	1.37	1.43	1.17	1.4
Slurry Velocity ft/s		4.3	4.35	5.12	4.50	4.71	3.83	4.5
Depth of Water cm		2.10	2.10	2.22	2.70	3.18	1.91	2.37
Depth in inches		0.83	0.83	0.88	1.06	1.25	0.75	0.93
Width of Sluice Run m		2.4	2.4	1.9	1.8	0.9	1.9	1.9
Width in feet		8.0	8.0	6.2	6.0	3.0	6.3	6.3
Slurry cms	0.800	0.054	0.054	0.052	0.054	0.033	0.034	0.047
Slurry Flowrate Igpm		715	715	688	715	440	453	621
Slurry Flowrate USgpm		859	859	826	859	528	544	746
% Recommend by Width		56%	56%	70%	75%	92%	45%	0.7
For Angle Iron Riffles		28%	28%	35%	37%	46%	22%	0.3

Note: Water flow rates less than 100% or greater than 150% of recommended values usually low gold recoveries.

All of these sluiceboxes would have to be narrowed to between 2/3 to 1/2 of their present widith if they were refitted with coarse expanded metal riffles.

The slurry velocities would have to be increased to between 5 to 7 feet per second.

PAY GRAVEL FEED RATES

Description	Factor	**Griffith** **w/o** excavator	**Griffith** **with**	**Daniels**	**Harding**	**Rausch**	**Average**
Solids %		2%	4%	5%	14%	3%	6%
Solids cms	1.00	0.0011	0.0022	0.0026	0.0076	0.0010	0.0029
Sluice Solids Lyd3/hr		5	10	12	36	5	14
% Recommend by Feed		8%	16%	25%	74%	20%	29%
For Angle Iron Riffles		4%	8%	12%	37%	10%	14%

Notes: Pay gravel feed rates which exceed 100% of recommended values are one of the greatest factors contributing to gold losses. Pay gravel feed rates below 100% of recommended values may improve gold recovery slightly.

None of these boxes, except Patrick Harding's is operating near its potential feed rate.

Appendix 3 - Placer Mining Design Handbook

1.0 Introduction and Overview

For centuries man has known that gold settles out of flowing water more rapidly than most other materials. The sluice is technology as old as that basic knowledge. Cloth or fleece linings were found to help retain the settled solids and these also make the cleaning of the box easier.

The sluice box itself is very simple; it is a sloping flat-bottomed channel that is usually lined. A mixture of ore and water flows down the channel and the dense material (including gold) sinks and is retained on the bottom of the box. Simple construction and easy operation have led to the sluice box being widely used all over the world but, like many apparently simple things, there is an underlying complexity that, if properly understood, can be exploited to improve performance. Lack of understanding of the mechanisms involved has led to inefficiency and the loss of much gold during sluicing operations. High losses in the past have meant that many old tailings dumps contain substantial amounts of recoverable gold and miners become locked into a constant cycle of re-treatment of tailings that does not allow the land to recover. The fact that miners continue to recover economic quantities of gold from tailings that may already have passed over a sluice box two or three times is clear evidence of past inefficiencies.

Sluice boxes come in a wide variety of sizes and methods of construction. This handbook will explain some of the complexity of the sluice box and it will give some guidance on how to improve performance.

Photos of large sluice from Guyana and small sluice from Zimbabwe

2.0 Ore Delivery

There are many ways of delivering the mined ore to the sluice box however for optimum performance the sluice box requires controlled, steady delivery at an appropriate rate. Sluice box feed has two components, ore and water, and these must be thoroughly mixed and in the correct proportion for the sluice box to work at its best. The delivery method used will depend upon the source of the ore, the source of the water, the availability of technology, the capital resources and sources of power.

2.1 Slurry Pumping

This is one of the better options where large volumes of ore are to be processed. In a typical operation two pumps are used: one to pump water to the mine and the other to pump the ore slurry to the sluice box. The use of pumps may not be feasible in many situations, as they are a relatively high cost, high technology solution. Pumping does, however, offer a number of significant operational benefits:

- it actively mixes ore and water to help form a slurry
- it helps to disaggregate lumps and clay balls

- it delivers a relatively constant feed to the sluice, which promotes efficient operation.

NB this depends on a sufficient water supply and steady suction at the pump intake.However, if operation of the pump is varied, causing surges in the delivery of ore slurry, the efficiency of the sluice box will be compromised. Surges in the slurry flow will lead to heavy concentrate being lost over the end of the sluice, whereas slower slurry flow will lead to clogging of the sluice bed with mud and tailings. The pumping of slurry requires a more robust pump than those used for clean water.

2.2 Separate Delivery of Ore and Water to the Sluice box

Water is easier to pump than ore slurry. This favours the practice of mixing the ore and water in a box at the head of the sluice box. It is recommended that the ore slurry is screened, before passing over the sluice box, to remove coarse unliberated ore, rock lumps and clay balls. An inclined grizzly usually works well for this purpose and punched plates can also be used.

The ore can be fed directly into the mixing box by bucket, shovel, sack-load or by mechanical means. The water should be delivered at a constant rate. Water comprises between 85% and 95% of the feed volume. Therefore, small variations in the rate at which the ore is added will not have a significant impact on the rate at which the feed slurry is delivered to the sluice box.

There are, however, situations where both the water and ore are added batch-wise. In these cases it is recommended that the water and ore be mixed (ideally 5 to 15% ore by volume) before feeding onto the sluice box. This will enable the operators to retain control over the water:ore ratio and to maintain a relatively constant rate at which the feed slurry is delivered to the sluice box.

The rate at which the feed is delivered to the sluice should be such that the flowing slurry stream should be deep enough to allow stratification of the mineral components. If the stream is too shallow it is likely that less-dense material will come into contact with the bottom of the sluice box and be retained within the capture zone. If the stream is too deep it is likely that stratification will not occur close to the capture zone and gold will be lost into the tailings. Ideally the stream depth should be between 20 and 30mm (¾ to 1¼ inches). The depth can be adjusted by varying the feed rate to the sluice box, its width and/or its slope. This is the first example of the many interrelated variables that control efficient operation of a sluice box.

3.0 Sizing

3.1 Why Screen?

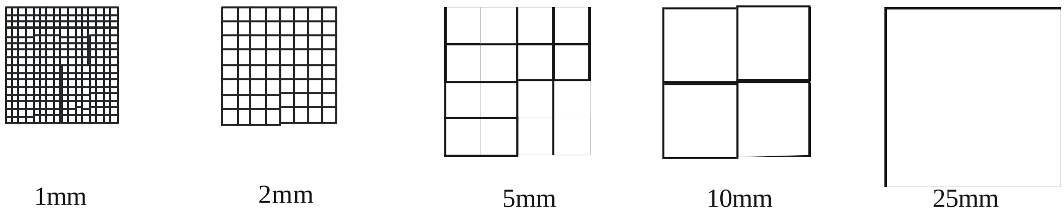
Sluice boxes (Section 4.0) work because dense particles such as gold (density = 19.25 kg/l) settle much more rapidly than less dense particles, of a similar size, like quartz (density = 2.65 kg/l). This simple separation principle works very well provided all particles are of a similar size. However, for material with a wide particle-size range this separation principle does not hold. In the dynamic conditions created by slurry flowing down a sluice box coarse-grained, less-dense particles can behave in a similar way to fine-grained, dense particles. Also, very large particles have a greater effect on the flow characteristics of the stream and can create sufficient turbulence to inhibit separation.

Screening is the process of sorting particles according to size. Feed material that has been screened will consist of particles of a similar size, or within a certain size range, that are more likely to separate out based upon differences in their densities.

3.2 Screening Options

The simplest methods of sizing feed material are based on fixed aperture screens. Particles finer than the screen aperture (otherwise known as undersize) will pass through whereas particles that are coarser (otherwise known as oversize) will not. The main purpose of screening the feed depends on the type of ore. For alluvial ore it is necessary to remove the very coarse material such as pebbles and lumps of rock or clay as these are much coarser than any gold particles but disturb the operation of the sluice box. A size around 25 mm (1 inch), might be appropriate. For crushed bedrock ore the size of particles will be much smaller and the range of sizes much narrower. It is necessary to remove larger particles from which the gold might not have been liberated and return them for further crushing. A size of 5mm or even smaller might be appropriate. Sieves and screens come in a wide range of sizes; they can be described by the size of the gaps in mm or inches or the mesh size. The British and American systems for describing mesh sizes for sieves are slightly different and the common sizes are shown in the following table.

Particle-size		**British Standard Mesh** BS410: 1986	**American Standard Mesh** ASTM E11-87
Geological usage	Technical/Industrial usage		
	25 mm (1 inch)	-	-
	2.36mm	7	8
2mm		8	10
	1.18mm	14	16
1mm		16	18
	600µm	25	30
500µm		30	35
	300µm	52	50
250µm		60	60
	150µm	100	100
125µm		120	120
	75µm	200	200
63µm		240	230
	38µm	400	400
32µm		440	450



1mm 2mm 5mm 10mm 25mm

Screening equipment that is currently available uses different shaped apertures, different slopes, and different mechanisms: static, vibrating or rotating. This section will only discuss those methods that are judged to be the most appropriate for simple sluicing systems; hand-held screens, grizzlies (static) and trommels (rotating).

Box 3.1 Hand-Held Screens

Small sluice box operations may not have the resources to invest in screening equipment. In this case, when the throughput is low, the miner may be able to size the feed using a hand-held screen.

Simple screens can be made from wire mesh mounted in a wooden or steel frame for support and ease of use. Screens can also be made from metal sheets with holes punched through them.

Box 3.2 Grizzlies

A grizzly is an inclined, static screen consisting of parallel bars set apart by a spacing equivalent to the size of the material to be rejected. Oversize material will not pass through whereas undersize material does and forms the feed to the sluice box. It is recommended that the grizzly bars be set approximately 25 millimetres (1 inch) apart.

Grizzlies should be inclined at an angle that will allow oversized material to roll or slide off and prevent blocking of the screen. If the screen becomes blocked (choked) fine material will be prevented from passing through and will either be rejected or build up on the screen. As grizzlies are prone to blockages they do require regular cleaning to prevent gold being lost with misplaced material.

The bars of a grizzly are usually made of steel, for example old rails or high tensile steel reinforcing rods. Wooden grizzlies require more attention but they are relatively cheap and appropriate in wooded regions.

Diagram of grizzly

Box 3.3 Trommels

A trommel is a cylindrical screen, which is open-ended, slopes down toward the discharge end and rotates as material is fed through it. Material is introduced at the top end of the trommel and is caused to tumble due to the rotation. The feed particles either pass through the screen apertures as undersize or travel the length of the trommel to be discharged over the end as oversize.

Unlike static screens, trommels rely on a dynamic screening method. As a result of this, the undersize material produced by a trommel is finer than that produced by the same aperture size in a static screen. Therefore in order to produce oversize material coarser than 25 mm it is recommended that an aperture size of approximately 35 mm is used. The speed of rotation has a similar effect. The faster the drum rotates the smaller the effective size of the holes.

The rolling and tumbling of the feed in a trommel does help to break up clay lumps / balls and weakly consolidated material. Ideally, trommels are operated with wash water and this ensures that any gold particles on the surface of larger lumps are washed into the sluice box feed stream.

Diagram of trommel

Screens do present their own problems to the operator but, in general, the gains from improved sluice box performance will more than offset the inconveniences and the cost of the screening system. The perceived disadvantages of most screens are the cost (trommels) and the need for additional labour (hand screening and grizzlies).

As screening removes coarse-grained material that does not contain recoverable gold, it can be considered to be a concentration stage. Screening reduces the volume of material to be treated by the sluice box and increases the proportion of gold in the sluice box feed. Eliminating clay balls, that would otherwise pick up gold particles and misplace them with the tailings, also improves the overall performance of sluice box process.

Ultimately the choice of size for the screen is a compromise between efficiency and throughput. The desire to have the feed as fine as possible, without loosing gold grains, to make the box as efficient as possible, has to be balanced against the time it takes for the screen to get clogged with oversize material and reduce throughput, requiring either regular cleaning during operation or temporary halts in production.

4.0 Sluice box Principles

Particles in a slurry stream, flowing under non-turbulent (laminar) conditions, will tend to settle to the bottom of the stream. The rate at which a particle settles depends upon its density, size and shape; large, dense, spherical particles will be the first to settle out, whereas smaller, less-dense and platy particles will be the last. Any fine currents in the stream will have a greater effect on less-dense particles than heavy ones and cause them to rise; the overall result is a stratified (layered) stream with dense material at the bottom and less-dense at the top. The dense material thus comes into contact with the bottom of the channel and, with an appropriate trapping mechanism, it will stay there.

This is the theory but the reality is usually somewhat different. The ability of the sluice box to retain the settled gold is often not as great as miners believe. There are many reasons for this and some of the main ones are described here:

- The slurry may contain a broad range of particle sizes. Without screening to remove oversize material the sluice box trapping mechanism may become blocked with coarse-grained less-dense material.
- Sometimes large clay balls enter the sluice box with the feed. These may reduce the amount of gold recovered by collecting small gold grains on their surface as they roll down and also by causing local turbulence which could dislodge gold grains.
- Excessive flow can causes losses by washing away gold that is not effectively trapped.
- Infrequent cleaning out of the sluice box which results in blocking of the trapping mechanism, which limits its ability to retain gold.
- Many sluice boxes have leaks along the bottom through which fine-grained dense material and gold may escape.
- Poor distribution of the flow over the width of the box may result in sections with insufficient depth to permit settlement.

The sluice box is a robust process, which is tolerant of poor operation and can usually be relied upon to recover some gold in any given situation. This makes sluice boxes very popular but it lulls the operator into believing that a box is working well when it is not.

Simple diagram of sluice box

Although a sluice box is relatively simple, it still has many operational parameters and, like all equipment, it has an optimal set up. The parameters fall into three distinct categories: the feed, the design of box itself and the gold trapping mechanism.

The ore “feed” parameters (Section 5.0) are:

- Flow velocity (speed) down the box.
- Solids to water ratio of the feed.
- Particle size of gold
- Particle size range in the feed.

The “sluice box” design parameters (Section 6.0) are:

- Length of the sluice box.
- Width of the sluice box.
- Gradient (slope) of the box.

The parameters relating to the “gold trapping system” (Section 7.0) are:

- The type of lining.
- Enhancements such as riffles.

It is good practice to measure and record the values of these parameters whenever the sluice box is set up. Monitoring of these parameters will enable the sluice box operators to control the performance of the sluice box and quickly pinpoint the cause of process problems as they arise.

5.0 The Feed

5.1 Flow Velocity (Speed) Down the Box

Flow velocity is dependent upon the volumetric feed rate and the geometry of the sluice box. For a given box width and gradient, the flow velocity will increase as the feed rate increases. Narrowing the box or steepening the gradient will result in a higher flow velocity at a fixed feed rate. In general it is not important to know the velocity of the flow accurately, it is only necessary to check the box to see that the flow is fast enough to wash away the less dense material. If there is a reasonable trapping mechanism it is unusual for gold to be lost due to unnecessarily high flow velocity of the feed.

Where water is in short supply it is recommended that a narrow sluice box is used to ensure that the flow velocity is sufficient to keep the gold trapping mechanism clear of less dense material.

Measurement of the flow velocity in a sluice box is relatively straightforward. The method outlined below will give a good indication but it is not absolutely accurate because velocity varies with depth, proximity to surfaces and internal currents.

Flow Velocity Measurement

1. Measure the length (metres) of a section of the sluice box.
2. Obtain some pieces of paper or wood that will be visible in the slurry stream.
3. Obtain a stopwatch. A watch with a second hand will suffice but the operation may require two people rather than one.
4. Drop the paper/wood into the stream at the top of the section and record the time (in seconds) it takes to reach the bottom. If a normal watch is being used, the person watching the stream will call out at the start and finish.
5. The velocity is the length divided by the time (metres/seconds, or m/s^{-1}).
6. Repeat steps 4 and 5 to obtain a mean value.

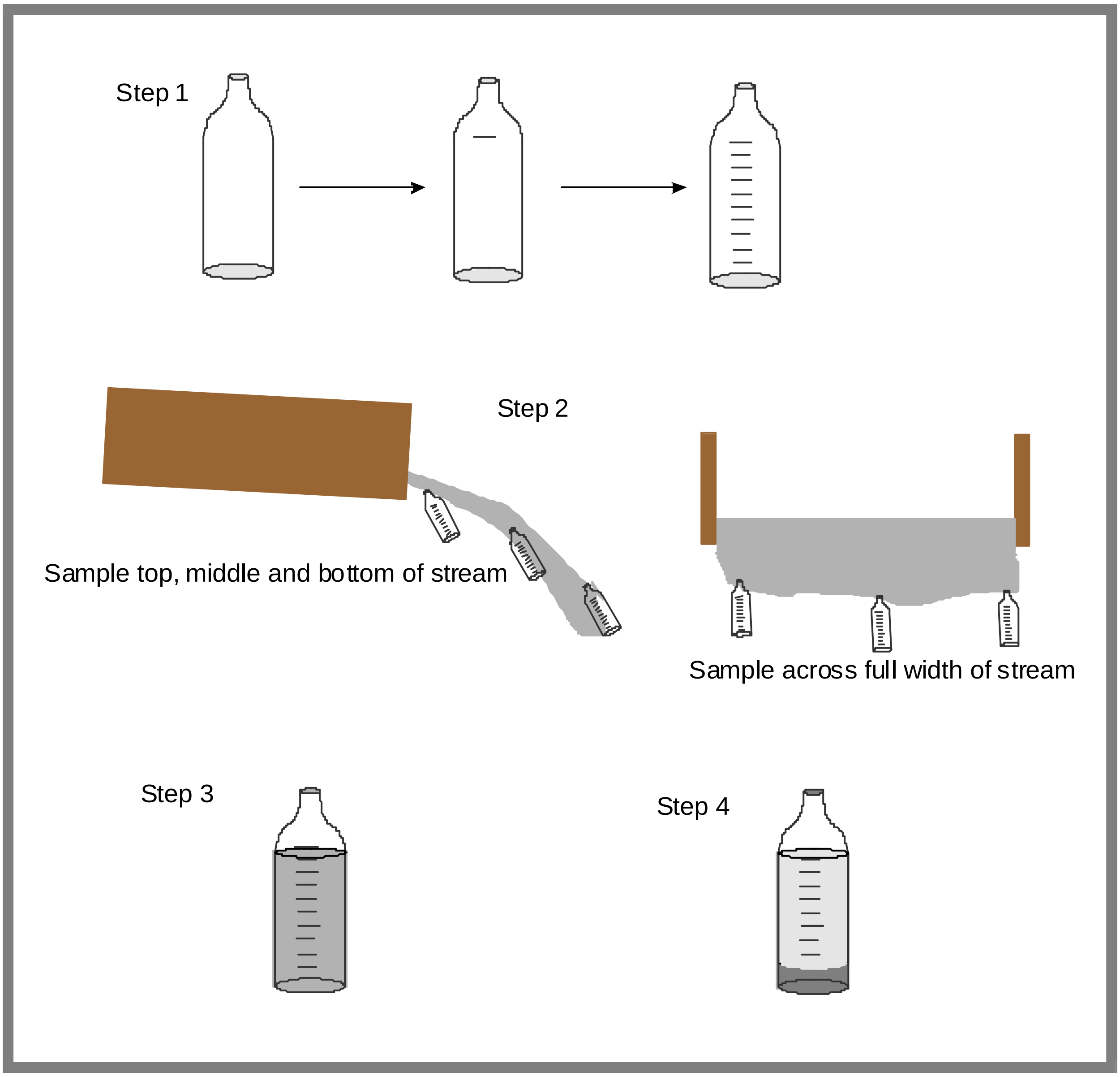
Slurry velocity is especially important where riffle systems have been implemented to improve sluice box performance; this will be discussed in a later chapter.

5.2 Solids to Water Ratio in the Feed

A key factor affecting the stratification and settling of material is the consistency of the feed slurry. If the slurry is too ‘thick’, i.e. the proportion of solids in the slurry is too high, stratification and settling of the material in the feed slurry may be hindered. Particles will collide with each other, fine-grained dense particles may be buoyed up by coarse grained less dense particles and vice versa. For good operation it is essential to have sufficient water. Ideally, there should be less than 15% solids (by volume) in the feed. This can be measured accurately enough using the following simple method:

Percentage Solids Measurement

1. Obtain a large (at least 500 ml) straight-sided, graduated measuring cylinder. If such a vessel is not available then obtain a fairly large, 500 ml (1 pint) or more, straight-sided, clear bottle with a relatively small opening. Mark the top of the straight section with a scratch or using an indelible marker. Then divide the length of the parallel section into 10 equal lengths, marking them out in the same way. The top mark will represent 100% and the remaining marks will represent 90% down to 10%.
2. Take the cylinder/bottle to the discharge of the sluice box and hold it in the stream until it is full to the top mark. It is important to sample across the full width of the stream and from the top, middle and bottom of the stream (stratification will cause a variation).
3. Allow the cylinder/bottle to stand, undisturbed for five or ten minutes and then pour off the liquid until left with a fairly thick sludge. The water that is poured off may be quite dirty but do not worry about this.
4. Read off from the scale on the cylinder/bottle the percentage solids (by volume) estimating when the level does not correspond directly with one of the marked lines.
5. A solids content of 15% or less is the optimum for the feed slurry.



5.3 Particle Size of Gold

The size (and the shape) of gold particles influences the rate at which they settle and the proportion recovered from a slurry stream. This is a parameter that the miner cannot change. However, an understanding of the particle size and shape characteristics of the gold will enable the miner to tailor the design and operation of the sluice box to match the gold he is attempting to recover. For instance, some types of riffles (angle iron) are very good for recovering gold bigger than one millimetre in diameter and while others (expanded metal) are better for capturing finer gold.

Screening was covered in section 3.0. Gold particle size is an important consideration when selecting your screen aperture size. It is important to be sure that the screen aperture size is larger than the coarsest gold particles present to ensure that gold is not lost to oversize.

The particle size of gold in the feed material can be determined in various ways. A simple field test involves carefully hand-panning gravel from the main ore sources to observe the size of gold grains present. For a more accurate and representative figure, large volumes of gravel would have to be processed. This can be carried out using a carefully operated test sluice (see section on testing ore deposits). Samples (several kilograms) can be collected for laboratory test work consisting of sieving into several size ranges and determining the gold content of each size range.

5.4 Particle Size Range in Feed

The sluice box is a gravity concentration device and, as such, it relies upon dense particles settling more rapidly than light ones. A difficulty is that large less dense particles can behave very similarly to fine dense particles and where there is a wide range of particle sizes in the feed this can lead to inefficient sluice box performance. It is recommended that sluice box feed should, if possible, be screened to ensure that all particles are within a relatively narrow size range.

A further advantage of screening is that sticky clay balls, which can pick up gold, can be excluded from the feed.

6.0 The Sluice box

6.1 Construction of the Sluice box

A sluice box is a sloping channel with a flat bottom. The material of construction is not critical except that the box should be rigid enough to resist twisting and sagging. Typically, sluice boxes are made of wood or steel or they are dug into the ground.

Removal of the gold –bearing concentrate from a sluice involves cleaning out the gold trapping mechanism. In order to minimise the clean out period, which puts the sluice box out of operation, it is important that the trapping mechanism can be removed and reinstalled rapidly. Figure **** shows a simple methods for holding the trapping mechanism in place in the sluice box.

6.2 Width of the Sluice box

The width of the sluice box is a critical operational parameter that is often overlooked. Miners have a tendency to use the same width of box irrespective of the feed-rate and/or the ore type. If the feed rate remains constant, changing the width of the box will change the velocity and depth of the feed slurry stream, which in turn will affect the amount of gold recovered.

In general, a sluice box should be built to suit the rate at which the feed is delivered to the sluice box. Constructing a sluice box with the most appropriate width, for the feed rate and ore type, will ensure that the velocity and depth of the slurry stream are within the ranges required for optimum gold recovery. The main adjustment of the speed of flow is by altering the width, while fine-tuning of the slurry stream velocity and depth can be achieved by varying the slope of the sluice box.

Considering that the width of the sluice box is the primary parameter controlling the slurry stream velocity, it is recommended that narrow sluice boxes be used when water is in short supply. This will enable sufficient flow velocities to be achieved.

There are many types of gold trapping mechanisms used in sluice boxes, each of which requires different velocities and depths of slurry stream. Therefore, in order to achieve optimum sluice box performance the width of the sluice box must be matched to the type of trapping mechanism used. One type of trap for coarse gold may need high velocity and be in a narrow part of the box while a system for finer gold might need slower speed and be positioned in a wider section.

6.3 Slope of the Sluice box

Most sluice boxes are used with a slope of around 10 to 15 degrees. The exact slope is worked out in combination with other parameters whilst fine-tuning the performance of the sluice box. The flow velocity and depth of the slurry stream can, for a given sluice box width and feed rate, be adjusted by minor alteration of the slope.

6.4 Length of the Sluice box

The sluice box needs to be long enough to capture all of the recoverable gold. Miners have learnt from experience that most of the gold recovered is found on the first two or three metres of the sluice box. This was confirmed by a study which indicated that successive sections of a sluice box, split into three equal parts, contain 90%, 9% and 1% respectively of the gold recovered (Fricker, 1984). However, contrary to popular belief, this does not give an indication of sluice box efficiency. It would seem logical to assume that the sluice box is working efficiently if the proportion of gold recovered diminishes further down the box. However, trials have shown that irrespective of the overall recovery efficiency of the sluice box, whether it is as low as 30% or as high as 80%, most of the gold recovered would still be found in the first 1/3 of the sluice box length.

For a large alluvial gold operation with high throughput it is recommended that sluice box sections should be at least three metres long and preferably up to five metres long. If more than one riffle type is being used each should be three to five metres long. It is also recommended that a smooth, riffle-free, section (slick plate) is inserted between each riffled section, to allow the slurry stream to re-stratify.

7.0 The Gold Trapping Mechanism

The gold trapping mechanism is the means used to recover gold from the slurry stream and retain it on the sluice box. A sluice box with a flat bottom is the simplest but least effective trapping mechanism. As the slurry stream is fed over the sluice box gold settles to the bottom of the channel. The gold then travels along the channel unhindered and would eventually be discharged over the end of the sluice box. In order to trap the gold as it travels along the sluice some kind of lining such as sacking, matting or fleece is used. More sophisticated trapping mechanisms use riffles to create localised flow disturbances which, when coupled with an appropriate lining material, can enhance the trapping efficiency of the sluice box. This section discusses various types of riffles and gives an indication of the optimum operating conditions for each and the situation when they are most applicable.

An important operational consideration of any gold trapping mechanism is that it should be easy to assemble and dismantle so that down time for clean ups can be reduced to a minimum. Complex or difficult fixings may discourage the operators from cleaning regularly. This may mean that clean ups only occur long after the box efficiency has deteriorated to the point where gold losses are high. Another important consideration when designing the fixing assembly is that the lining must be well secured to prevent gold from escaping underneath the lining. This is especially important when using unbacked matting. If the riffles are not held down tightly over the matting, the sluice box concentrate may penetrate the matting and migrate underneath the matting to the end of the sluice box.

7.1 The Lining

A good lining enables the sluice box to retain more concentrate than bare wood, rock or steel. Also it is removable and this makes the cleaning of the sluice box faster and more efficient.

In many places the choice of lining is dictated by the availability of materials, for example old sacking, animal hide or old matting. These all have an ideal structure for the trapping, and retention, of small particles.

Research has shown that the best lining materials have an open fibrous structure that allows easy access of particles. However, this also means that the particles can easily be lost. Retention of the particles within the matting is improved by the protection that the riffles provide.

Photos/diagrams of Nomad matting and black Monsanto matting

7.2 Riffle Systems

The need to secure the lining onto a sluice box may inadvertently have led to the development of the first riffle systems. Cross pieces nailed to hold a sack or a mat in place on the base of the sluice box may have led to the belief that their use resulted in the localised recovery of gold. Rudimentary riffles do not improve sluice box performance significantly. This is because they may cause local turbulence that can break up the stratification of the slurry stream and even reduce the amount of gold recovered. However, coarse or nugget gold can be trapped behind them and this causes great excitement and the perception of improved performance.

Different types of riffle systems are used for recovering different gold particle sizes. For ore with a range of gold particle sizes, more than one riffle system should be used; one type for coarse gold and another for fine gold. As different riffle systems require different operating conditions it may be necessary to modify the width and slope of the sluice box to maintain optimum sluice box performance.

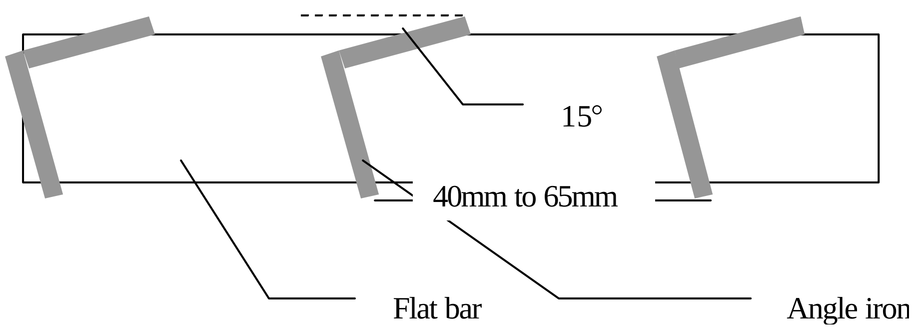
Stratification is an underlying requirement of all efficient sluice box recovery systems. By their very nature, riffles create local turbulence in the slurry stream which is designed to improve recovery. As well as riffles it is important that smooth sections are inserted between the riffled sections to allow the slurry stream to re-stratify and maintain optimum flow conditions are gold recovery. These smooth sections are called “slick plates”.

7.2.1 Angle Iron Riffles

Angle iron riffles are mainly used for trapping coarse gold. The two most important parameters for effective use of these riffles are the flow velocity and riffle spacing. Assuming optimum flow velocity and spacing, a rotational or ‘rolling’ turbulence is created between the riffles that keeps the fine less dense material moving and also prevents the lining from becoming blocked with solids. At the same time, centrifugal forces generated by the rotational turbulence push the gold particles down into the open structure of the matting. Standard 25mm (1inch) angle iron is ideal for many sluice boxes but smaller sizes can be used.

To construct the riffles, the angle iron should be cut to a length about 25mm shorter than the width of the box section where the riffles are to be installed. These lengths should then be welded to flat bar (same length as the riffles), with a gap between each riffle length of 40mm to 65mm and the flat top of the riffle at approximately 15° to the horizontal top of the flat bar.

Cross section through angle-iron riffles



7.2.2 Expanded Metal Riffles

Expanded metal is made from sheet steel that has a series of holes cut through it and it is then stretched along the axis perpendicular to the cuts to produce an open structure with lozenge-shaped holes. This produces shallow riffles that are more suitable than angle iron for trapping fine gold.

A secondary purpose of the riffles is to hold the lining down firmly against the bottom of the sluice box to prevent the trapped gold from being lost under the matting. It is, therefore, important to use a gauge of steel that is appropriate for the size of the sluice box. Too light a grade of steel can bow and leave gaps between it and the matting. Narrow sluice boxes can use much lighter steel than wide ones. If the expanded metal does warp then this can be remedied by nailing down a wooden batten along or near the centre line of the box.

Photos/diagrams of expanded metal riffles

Process Parameters	***Gold Trapping System***	
	Angle Iron Riffles	***Expanded Metal Riffles***
Gold particle size	Coarse gold recovery (+1mm particles))	Fine gold recovery (-1mm particles)
Flow velocity		
Depth of stream above riffles	25mm to 30mm	15mm to 20mm
Riffle spacing	40mm to 60mm gap (25mm angle iron)	Fixed by grade of expanded metal (20 to 30 kg/m^2 recommended).
Length of section	3m to 5m minimum	3m to 5m minimum
Slope (Gradient)	12° to 15° (210 to 265mm vertical drop per 1m horizontal length).	7° to 12° (120 to 210mm vertical drop per 1m horizontal length).

8.0 Clean up (Wash down)

This is the process whereby the concentrate accumulated in the sluice box is recovered. Clean up should be performed whenever the gold trapping mechanism is loaded (filled with sediment). Overloading will cause a deterioration of performance. Different gold trapping mechanisms have different characteristics and capacities and the operator should familiarise him/herself with the appearance and feel of the system at various stages in its cycle. Systems with angle iron or expanded metal riffles over “Nomad” matting are best assessed by feel. When first installed, the matting has plenty of ‘give’ (i.e. it feels relatively flexible) but, as the matting is loaded with sediment, it becomes harder. If the matting is monitored frequently the operator will become familiar with the feel of its open structure and it will be evident when the matting needs to be cleaned up.

The main objective of the clean up is to ensure that none of the concentrate is lost. The clean up operation is therefore carried out, where possible, in a ‘closed system’.

It is normal practice to clean the oversize and general debris from the sluice box before attempting to recover the trapped concentrate. The sluice box is then blocked off at the bottom such that any concentrate that escapes, as the box is cleaned down from top to bottom, is retained.

The general procedure is to remove the fixings (wedges, nailed retaining strips, etc) and wash them. The riffles should then be washed and removed before the matting is carefully taken out and placed in a closed tank of water.

The matting should be cleaned using an appropriate technique. For example, the open structure of "Nomad" matting allows it to be cleaned by hosing with water or slapping small areas sharply against the surface of water. However, "Nomad" matting is not robust and if the treatment is too vigorous it can tear. Other types matting are relatively tough and can be treated far more roughly. Gold particles either occur on the surface or buried within the mat such that fairly aggressive shaking and slapping on the water is required for its release.

9.0 Gold Recovery

Once the gold-bearing concentrate has been recovered from the sluice box it can be treated in various ways:

- Further concentration, using a small sluice box or a pan, followed by mercury amalgamation.
- Immediate amalgamation of the concentrate.

The use of mercury in the amalgamation process, and its subsequent burning off to recover the gold, is the main environmental concern associated with small-scale gold mining; more serious than deforestation and the pollution of rivers with particulates. Therefore, all efforts must be made to minimise the use of mercury. The amount of mercury used for amalgamation is roughly proportional to the volume of concentrate processed. A reduction in the volume of the concentrate processed by amalgamation would have the 'knock on' effect of reducing the amount of mercury used. To this end it is recommended that a secondary concentration stage be introduced to reduce the volume of concentrate by using a small sluice box or a pan.

The mercury amalgamation process, and the recycling of mercury using retorts, is described in detail in the *Amalgamation Manual*.

10.0 Water Recycling and Tailings Disposal

The main arguments for water recycling by small-scale miners are as follows:

- **Water Availability –** In many areas where small-scale mining is practised, water is either scarce or its source is a long way from where it is needed. If considerable effort and cost has been invested in getting water to the treatment location then it makes good practical and economic sense to make the best possible use of it.

- **The Environment –** The tailings produced by mining can be a serious environmental hazard. Tailings slurry discharged directly into a watercourse can increase the amount of suspended solids in the water to the point where any life present is suffocated. This will effect local people who rely on fish as a major food source. Also, the solids may settle out (a process known as "siltation") into the watercourse and may accumulate to the point where the flow of water changes direction or dries up completely. Drawing water from one stream and discharging tailings into another may exacerbate this process.

The advantage of a water recycling system is that it prevents much of the environmental damage to watercourses and provides a water source close to the point of need.

The main requirement for a recycling system is an area that will retain water, for example a natural depression in the land or an old worked out pit. Other options include the excavation of a hillside and the construction of a retaining wall or dam (see diagrams) to produce a settling pond.

The principle of operation is simple. Tailings slurry is delivered to the settling pond. The solids settle to the bottom and a layer of clear water develops on top. All particles take a finite amount of time to settle and, where the particles are of similar density, the rate at which they settle is determined by their particle size. Therefore, it takes longer to produce clear water from suspensions of very fine particles such as clays. It is fortunate that sluice boxes can be operated with water that is not perfectly clear. The main drawback of using water with a small amount of fine-grained suspended solids is that the solids are abrasive and accelerate wear of the pump parts. This will, in time, reduce water pump efficiency.

The clear water can be returned to the mine or the sluice box. It recommended that the point at which the clear water is removed be as far away as possible from the point at which the tailings slurry is introduced to the settling pond. However, the water that extracted may still contain an unacceptable amount of suspended solids. To overcome this it is possible to "fool" the system by building a barrier that would increase the effective distance between the tailings delivery point and the clear water extraction point.

Diagrams of water clearing and recycling ponds etc.

11.0 Problems and Remedies (Operational Considerations)

Sluice box packed with solids

- Riffled sluice box. The sluice box may become packed with solids if the slurry flow is too low or the gap between the riffles is not set at the correct distance. The slurry flow can be modified by altering the slope and/or width of the sluice box. Steeper and/or narrower to increase flow. Shallower and/or wider to decrease flow. If the problem persists it may be solved by changing the gap between the riffles.
- Unriffled sluice box. The sluice box may become packed with solids if the flow rate is insufficient to keep large particles in suspension. This could be resolved by increasing the slope and/or by narrowing the width of the sluice box to increase the slurry flow rate. However, in preference to this, it is recommended that the feed be screened to remove coarse particles before the feed slurry is fed onto the sluice box.

Uneven Distribution of Feed across Width of Box

- The feed slurry stream may flow along one side of the sluice channel instead of flowing evenly across its entire width. This may be caused by the sluice box tilting to one side or by introduction of the feed slurry to one side.
- The feed slurry stream may be diverted away from certain areas of the sluice box due to a build up of material. Regular cleaning of the sluice box, or pre-screening to remove coarse particles, will solve this problem

Clay Balls

- A reduction in the amount of gold recovered can be caused by the presence of 'clay balls'. These can physically remove gold by rolling over the gold particles which then become stuck to the sticky surface of the clay or reduce the efficiency of the gold trapping system by disturbing the normal operation of the sluice box. The 'clay balls' can either be removed by screening or by dispersing them (breaking them down to their constituent particles) on a screen, in a scrubber, in a pump or in a trommel.
- If the slurry flow rate is too low the 'clay balls' can also adhere to the sluice box riffles. This has the effect of reducing the amount of gold recovered because the gaps between the riffles are blocked. This problem can be avoided by either increasing the slurry flow rate (by either adding more water; reducing the width of the sluice box ;or by increasing the slope of the sluice box) or by screening out the 'clay balls'.

12.0 Monitoring and Sampling

In order to maintain a sluice box at optimum process efficiency it is important to measure, and continually monitor, its operating parameters.

Methods for the measurement of many of the important operating parameters (percentage solids, slope of the sluice box and slurry flow rate) have already been described in this handbook. These parameters should be measured and recorded as part of the regular operating routine. Other parameters that should also be included in this routine include the depth of the slurry stream; the "fixed" parameters like the length, width and type of gold trapping system; and physical observations like packing between riffles (if used), the presence of 'clay balls' and the build-up of material.

Careful study of the monitoring record will make it easier to diagnose and solve any problems that may occur during the operation of the sluice box. For example, it would be readily apparent that variations in the slurry flow rate are responsible for blocked riffles and that the solution to this problem would be to increase the flow rate. However, other problems may be less obvious to identify and, in cases like this, it may be necessary to measure the gold recovery efficiency.

Many miners are aware that their gold mining operations are not perfect however, very few can put a number on their current operating inefficiency i.e. the proportion of gold recovered from that present in their ore. One means of evaluating performance is to relate the amount of gold lost to tailings to the total amount of gold recovered in the sluice box concentrate. Observations on the size and shape of the gold particles occurring in the concentrate and tailings can also be very informative. Information on the amount of gold produced from a sluice box concentrate will be readily available. However, it would still be useful for at least part of the sluice box concentrate to be panned down to pure gold. The pan tails should also be sampled and carefully panned to indicate the panning efficiency.

Tailings are harder to evaluate because of their shear volume and low gold content. Because of the low gold content a large sample of tailings is required to produce a significant amount of gold.

It should be noted that the perfect sample does not exist unless the whole product is taken. However, it is possible, given adherence to certain guidelines, that a close approximation to the 'perfect sample' can be taken; this is known as representative sampling.

It is important that a sample must represent the whole period of operation and the full process stream. It is recommended that a small sample should be taken from the tailings stream every hour throughout the operational period. This should be used to make up a composite sample. The vessel used for measuring the percentage solids of the slurry can be used as a sampling vessel. The sample will only be representative if it is taken from across the full width of the stream and from the full depth of the stream (top, middle and bottom).

This tailings sample should, like the concentrate, be reduced to a manageable volume by using either a mini sluice box (for example, a 'warrior') or a pan. Careful panning should then be carried out to produce a final concentrate consisting mainly gold.

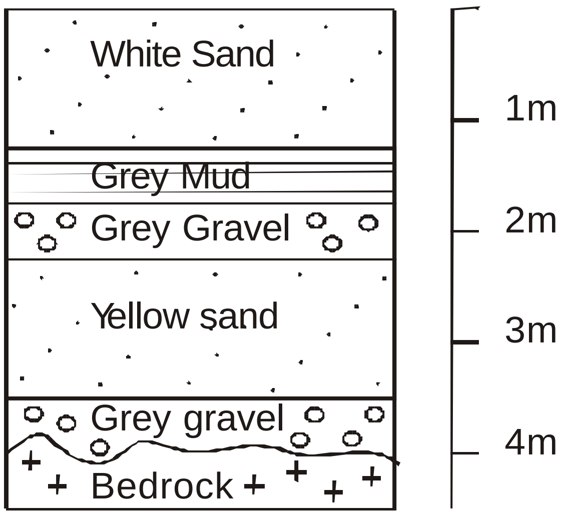
The amount, and the characteristics (mainly shape), of gold recovered from the tailings will give an indication of the operating efficiency of the sluice box. A direct correlation of the amount of gold found to occur in the tailings and concentrate gold to the total gold content of the ore will be difficult to achieve. However, systematic record keeping will reveal trends in the amount of gold recovered that could be related to the operating efficiency of the sluice box and also to natural variability of the ore deposit itself.

13.0 Assessment of alluvial gold deposits

The distribution of gold in alluvial deposits is extremely variable from place to place. In a river valley there is usually a main channel where the river deposits coarser sediments, sand and gravel and a flood plain where sand and mud are deposited in times of flood. In general most gold is found in the coarser channel deposits. Over a period of years the channel trends to change its course so that beneath the current river channel there are flood plain deposits and beneath the flood plain there are probably older buried channel deposits. A pit dug through the sediments will reveal a profile of various types of sediment overlying the bedrock and the detail of the succession and proportions of the type of sediment will vary from one place to another.

The assessment of the gold potential of an area of alluvial sediments is extremely difficult due to this large variability. Even when drilling equipment is available and large number of holes are drilled it is difficult to make accurate predictions. Simpler methods can be used to find some idea of the gold potential. Probably the most accurate way to estimate the total amount of recoverable gold at a particular site is to set up the actual equipment that is going to be used and to carry out a trial mining operation excavating a large pit down to the bedrock. Using this method it will be difficult to get an estimate of the gold content of the different layers unless the sluice box is cleaned after each layer has been excavated.

Profile through alluvial sediments



An alternative is to dig smaller hand dug pits, which gives much better control over the source of the sediment from particular layers. The sediment is then either hand panned or processed with a small test sluice. A sluice similar to the one shown can process at least half a ton, 1 cubic metre, per hour. This would enable representative sampling to be done as the pit is dug. Ideally the same volume of sediment from each horizon should be processed to make comparison easy. Large (20 litre) plastic buckets make a convenient measure and 15 buckets, gives a weight of about 500 kg which is a good size sample. It is important to record the thickness of the various sediment layers and to wash down the test sluice after the material from each layer has been processed. The heavy concentrate from each layer can then be very carefully hand panned to produce a gold-rich concentrate.

The most accurate way to determine the gold content of these gold-rich concentrates would be to make assay analysis but reasonable estimate can be made using a small set of sieves to separate the gold into specific size ranges and then counting the gold grains in each sieve. The coarser grains can be counted using a hand lens but the smaller ones require a simple binocular microscope. This may not be possible at the mine site but concentrates could be examined at the local mine station.

Sieve mesh (UK size)	Particle size (mm)	Weight conversion factor
8	-2.4 + 2.0	0.06041
16	-2.0 + 1.0	0.02299
30	-1.0 + 0.5	0.00191
60	-0.5 + 0.25	0.00029
120	-0.25 + 0.125	0.00009
240	-0.125 + 0.063	0.00003
	<0.063	0.00001

After the gold grains collected on each sieve have been counted the table above can be used to calculate the weight of gold in each size range by multiplying the number of grains by the weight conversion factor. The weight conversion factor has been calculated by sieving gold samples , collecting a large number of grains on each sieve, weighing the grains and calculating the average weight of a gold grain in that sieve size. The following table shows the results from an actual test of a sample of 'pay gravel' from the Mahdia gold deposits in Guyana. The sample was seven buckets giving a weight of about 250 kg.

Particle size (mm)	Sieve mesh (UK size)	Weight conversion factor	Number of grains	Weight of grains (gm)	% by weight
-2.4 + 2.0	**8**	**0.06041**	**0**	**0**	**0**
-2.0 + 1.0	**16**	**0.02299**	**3**	**0.06898**	**33.6**
-1.0 + 0.5	**30**	**0.00191**	**19**	**0.03635**	**17.7**
-0.5 + 0.25	**60**	**0.00029**	**192**	**0.05622**	**27.4**
-0.25 + 0.125	**120**	**0.00009**	**434**	**0.03920**	**19.1**
-0.125 + 0.063	**240**	**0.00003**	**131**	**0.00394**	**1.9**
<0.063		**0.00001**	**58**	**0.00058**	**0.3**
		Total	**837**	**0.20526**	

This data gives a lot of important information.

- The grade is 0.9 grams per ton (2 gm/cubic metre or 1 pennyweight/cu yard), which is a good grade for an alluvial deposit.
- The recovery efficiency of sluice boxes drops off rapidly for gold finer than 100 microns. In this example only a small proportion is less than 125 microns so a well set up sluice box should get very good recovery.
- Although there are only a few larger gold grains these form a large proportion of the total amount of gold, three grains account for 33% of the gold. It is very important to have a gold trapping system that is effective for coarser gold or losses could be high.

From a series of pits a good idea of the distribution of gold in the area can be built up. It will show which types of sediment contain the most gold, possibly gravel, and when this type of material is being mined particular care should be taken to make sure the box is working properly. If this is at the bottom of the profile the box might be clogged with mud and silt from the overlying sediment and it could be advisable to clean the mats before passing the richest ore. The upper parts of the profile might be very low grade and in this case it may be possible to remove this overburden before passing the richer material over the sluice.

It is very important to take adequate safety precautions when digging pits. If the alluvial sediments are thick, 3 metres or more, the pits will have to be quite large so that the sides are not too steep and liable to collapse. They may need to be supported with timber planks to make them safe.