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Transition Issues and Challenges

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Abstract[1]

Guyana is a country with abundant mineral wealth. Extractive industries, along with agriculture, drive the economy. Mining poses several inherent challenges due to its negative impact on the environment, its relatively high level of capital intensity compared to other main productive activities, and the heavy enforcement demands on understaffed and underfunded regulatory institutions, especially when the vast majority of miners are highly dispersed artisanal, small, medium-scale (ASM) miners. This paper surveys recent developments and trends in the Guyanese gold mining sector, the most important of the five mining subsectors, and analyses the issues surrounding the transition to more environmentally sustainable mining practices. Perverse incentives exist between maximizing private profits, honoring government royalty payments, generating gainful employment, on the one hand, and overcoming the economic and cost constraints of complying with environmentally responsible and sustainable practices in the ASM sector, on the other. The paper makes recommendations on how to better align incentives, especially to bridge the financing and knowledge gaps, to permit optimal extraction of the resource, promote environmental sustainability, and improve public–private collaboration.

JEL Classification: Q32, Q33, Q38

Keywords: extractive, mining, resource boom, exhaustible resources, environmental sustainability, technological adoption, government policy to optimize finite resources

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ACRONYMS

ASM	Artisanal, small, and medium-scale miners
BOG	Bank of Guyana
BMGA	Brazilian Mining and General Association
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
FDI	Foreign direct investment
GDP	Gross domestic product
GFC	Guyana Forestry Commission
GGB	Guyana Gold Board
GGDMA	Guyana Gold and Diamond Miners Association
GGMC	Guyana Geology and Mines Commission
GLSC	Guyana Lands and Surveys Commission
ILMM	Integrated land management model
LCDS	Low-carbon development strategy
MoNRE	Ministry of Natural Resources and the Environment
MoU	Memorandum of Understanding
NPV	Net present value
SMS	Small and medium-scale mining

1. Introduction

Guyana is a small, open, trade-dependent country richly endowed with natural nonrenewable resources, including gold, bauxite, diamonds, uranium, manganese, oil, rare earth metals, and fine-grain sands.[2] Its economy relies primarily on mineral extraction (gold, bauxite, manganese, diamonds, and quarrying of sand and stone), agriculture (rice, sugar), and services.[3] Since the 1990s, the mining sector has emerged as the main source of economic growth and the leading earner of foreign exchange as sugar has declined. In 2015, gold accounted for 42.8 percent of total exports, and the value of export earnings totaled US$501 million. In the same year, rice, the second largest exporter earner, accounted for 18.8 percent of total exports.

During the 2003–2013 "super-commodity boom," which was fueled by rapid industrialization occurring in Asia (China and India), gold prices soared, increasing from US$464.87 in February 2003 to a peak of US$1,910.78 in August 2011 and then falling back to US$1,272 in May 2016.[4] The higher prices and increased demand for gold prompted new entrants into the Guyanese gold mining sector and helped increase the amount of foreign direct investment (FDI) significantly. For example, the number of mining permits granted rose from 280 in 2006 to 1,995 in 2013, and net inflows of FDI as a share of GDP rose from 3.5 percent in 2003 to 7.7 percent in 2014. Most of these net inflows were related to mining investments.[5]

The structure of industry, however, has become bimodal, and this has important implications for national policymakers. From 2006 to 2014, all production was due to medium and small-scale artisanal miners. Then in 2015, two large-scale, foreign-owned open-pit mines—Guyana Goldfields Inc. and Troy Resources Inc.—became operational, accounting for 10 percent of production. These two companies are now expected to account for a third of total production starting in 2016, as they ramp up operations to full capacity. Several other large companies are in exploratory phases but have not announced whether they will commit to establishing a mine.

The main differences between the large-scale and artisanal, small, and medium-scale miners are the following: (i) technology deployed; (ii) compliance with environmental and safety standards; (iii) formal declaration of gold produced and payments of royalties; and (iv) multiplier effects.

Large mines use state-of-the-art technology that recovers between 80 and 95 percent of the gold in material processed, whereas smaller mines use rudimentary technologies, most

[2] It hosts one of the largest underdeveloped gold deposits, which some estimate at 20 million ounces, and has one of the largest deposits of bauxite reserves, estimated at 350 million tons, and oil reserves estimated to contain 700 million barrels.

[3] Oil was discovered in May 2015 and commercial extraction is expected to start 5-8 years in the future.

[4] See MacroTrends database. Available at http://www.macrotrends.net/1333/historical-gold-prices-100-year-chart

[5] Guyana Geological and Mining Commission and World Bank Development Indicators database. Available at http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators.

commonly sluice boxes, that recover between 25 and 40 percent. Large-scale mines are easier to monitor, and transnational corporations are more likely to comply with environmental and safety standards out of concern about maintaining reputations as responsible corporate citizens. Artisanal, small, and medium-scale (ASM) miners have less financial wherewithal and knowledge to comply and more economic incentives to aggressively reduce extraction costs by cutting corners on environmental safeguards and good management practices. This is particularly true when international output prices are falling, since their economic break-even points are much higher than large firms. Since their level of gold recovery is so low, more material must be processed, implying more deforestation, more soil disruption, more tailings be managed, and worse water quality in streams and rivers close to the active mines. Similarly, large mines cannot easily evade making declarations because their operations are geographically concentrated, whereas smaller artisanal mine operations are widely dispersed and more difficult to monitor, making them more likely to under-declare. Since artisanal miners have little or no access to formal credit, they often cancel their debts in gold, and their creditors may or may not enter the gold into the formal economy. In 2015, the government estimated that 15,000 ounces were being smuggled out per week, worth approximately US$912 million to US$1 billion over the course of the year. Lastly, whereas ASMs have much larger economic multipliers, larger mines have low multipliers. Because large mines employ fewer workers and a fair number of those are foreigners, they are much more capital intensive and their mine operations are virtual enclaves, repatriating a large portion of their profits.

Given the differences, tradeoffs, and latent tensions, it becomes extremely difficult for national policymakers to formulate appropriate policies and make strategic choices. On the one hand, gold production has clear and undeniable economic importance in terms of revenue generation for the central government, export earnings, employment generation, and multiplier effects, especially from ASM operations. On the other hand, mining can have major negative environmental, health, and social effects. Mining is inherently disruptive to the environment. To minimize the negative impacts, a combination of good regulations, effective monitoring and enforcement, strict adherence to good mining practices by operators, and appropriate technology is needed. Moreover, because so much of the mining lands are in state-owned forests, mining and forestry interests often clash. Socially, ASM mining can contribute to unsafe working conditions, prostitution, human trafficking, the spread of infectious diseases (particularly malaria and dengue because of the abundance of abandoned water-filled pits that are breeding grounds for mosquito vector-borne diseases), and can trigger land disputes with Indigenous peoples, especially those who have undemarcated and/or untitled land. In Guyana, institutional capacity to monitor and enforce regulations and access to technology and finance are constrained and quite limited.

Therefore, the question for a national policymaker becomes, how to promote sustainable mining development? What is the right mix of regulation and public policy to "push" desired behavior, and what are the "pull factors," such as the availability of clean technologies, human capital, and operating conditions (geology, infrastructure, etc.) that would incentivize change? Does one abandon the ASM sector and focus on promoting only large-scale mines that comply with international good practices and do not evade tax/royalty liabilities? Does one continue with the apparent de facto situation of having a small large-scale sector that is in full compliance alongside an informal ASM sector with compliance challenges and just attempt to maximize revenue capture? Does one actively invest and promote sustainable and efficient mining in the ASM subsector, and if so, how can this be done with limited resources, a high degree of geographic dispersion among small miners, and marked institutional weaknesses? (Masson, Walter, and Priester (2013).

2. Purpose

This paper seeks to: (i) provide an overview of the gold mining subsector in Guyana; (ii) discuss technologies deployed and their associated costs compared to cleaner technologies; (iii) review the policy and regulatory gaps; and (iv) make recommendations as to how to move toward a higher level of sustainability or "greenness," especially in the small and medium-scale gold mining subsector.

The paper is organized in the following manner. Section 3 provides the overview of the gold subsector—main production areas, tenure arrangements, environmental impacts, and economic contributions. Section 4 discusses the technologies used and associated costs and the characteristics and costs of newer technologies that promise to have less environmentally damaging impacts. Section 5 reviews some of the main policy and regulatory shortcomings and considers possible paths forward to attain the goal of wider use of more sustainable practices and technology.

3. Overview of the Gold Subsector

3.1 Geographic Distribution, Tenure, and Gold Declarations

In Guyana, mining is generally permissible in six designated districts, namely, Berbice (Mining District No. 1), Potaro (Mining District No. 2), Mazaruni (Mining District No. 3), Cuyuni (Mining District No. 4), North West (Mining District No. 5), and Rupunnuni (Mining District No. 6). Figure 1 provides a map of Guyana depicting the six mining districts. Together, the mining districts occupy approximately 45.8 million acres. The largest district is the Rupunnuni; the smallest is Potaro (see Table 1). Within all the mining districts, there are Amerindian settlements and areas closed for mining. There are also three national parks within Potaro, North West, and Rupunnuni, which occupy approximately 1.9 million acres of land. It is noteworthy that a significant portion of the mining districts overlaps with the state forest. More than 90 percent of the mining leases issued by the Guyana Geology and Mines Commission (GGMC) are within the state forest boundary, while approximately 60.9 percent of prospecting licenses issued for mining overlap with the state forest.[6]

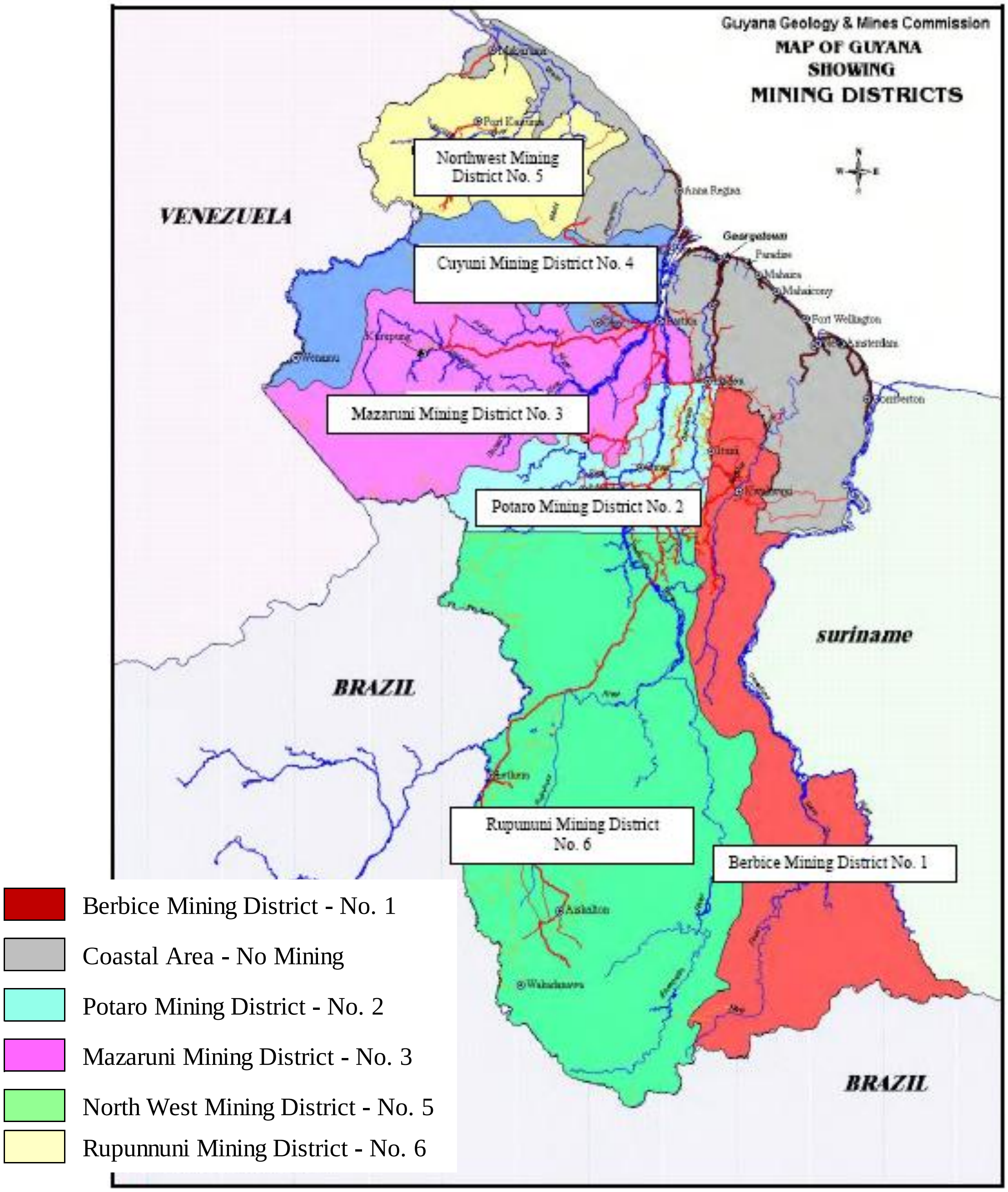
Table 1: Total Acreage per Mining District and Area Available for Mining

Mining districts	Total area	GGMC closed	Amerindian land	National parks	Area available for mining
1. Berbice	8,680,376.3	96,608.7	109,500.0	-	8,474,267.6
2. Potaro	3,511,109.4	1,002,557.3	230,929.6	189,477.5	2,088,145.0
3. Mazaruni	7,780,723.3	347,331.8	1,171,763.0	-	6,261,628.5
4. Cuyuni	4,388,713.7	511,053.0	165,258.0	-	3,712,402.7
5. North West	3,873,683.5	871,020.4	663,174.0	47,349.3	2,292,139.7
6. Rupunnuni	17,607,344.1	86,681.2	4,785,861.8	1,700,186.1	11,034,615.0
Total	**45,841,950.3**	**2,915,252.4**	**7,126,486.5**	**1,937,013.0**	**33,863.198.5**

Source: GGMC.

[6] See GLSC/HTPSE/ASTRIUM/SRK Engineering (2013).

Figure 1: Mining District Map



Source: GGMC.

Under the Mining Act 1989 (No. 20 of 1989), the GGMC is vested with the power to issue various licenses to extract and/or prospect for precious minerals (gold, diamonds) and quarry minerals (stone and sand). The licenses to extract gold include land claims (covering an area of 27.58 acres or 11.16 hectares): river claims (covering an area of 1 mile or 1.6 km of navigable rivers); medium and small-scale permits (covering between 150 and 1,200 acres or 61 to 486 hectares); and large-scale mining licenses (covering an area between 500 and 12,800 acres, equivalent to between 202 and 5,180 hectares). The GGMC also issues three categories of prospecting licenses—small-scale, medium-scale, and large-scale—based on the results from geological and geophysical surveys permitted under the Mining Act 1989. Permits and prospecting licenses for small and medium-scale mining are restricted to Guyanese. However, the law also allows Guyanese to enter private contracts (or joint ventures) with foreign investors. Table 2 summarizes the various permits and licenses issued by GGMC between 2006 and 2013. As Table 2 shows, there was a twofold increase in the number of small-scale claims over the period 2006–2013. Medium-scale permits also increased, from 270 in 2006 to 1,979 in 2013. Over 80 percent of the licenses and permits were issued in Potaro (District No. 2), Mazaruni (District No. 3) and Cuyuni (District No. 4). The high concentration of mining activities in these districts depicted in the mineral resources map of Guyana shows that significant alluvial gold occurs in quartz veins and riverbanks, which fall within Potaro, Mazaruni and Cuyuni mining districts (see Figure 2). Most mining activities are concentrated here and most gold declared comes from these districts.

Table 2: Tenure Arrangements, 2006–2013

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Claims (s/s)	9,408	10,563	12,582	13,476	14,335	15,032	18,610	19,471
Prospecting licenses (l/s)	54	65	107	261	136	191	158	74
Prospecting permits (s/s)						991	1,314	1,364
Prospecting permits (m/s)	3,869	3,976	5,413	7,273	4,879	5,149	6,377	6,260
Mining permits (m/s)	270	374	550	646	742	1,161	1,546	1,979
Mining licenses (l/s)	10	10	10	11	7	12	9	16
Reconnaissance	8	13	13	21	3	8	8	3

Source: GGMC.

Note: s/s represent small scale, m/s represent medium scale and l/s represent large scale.

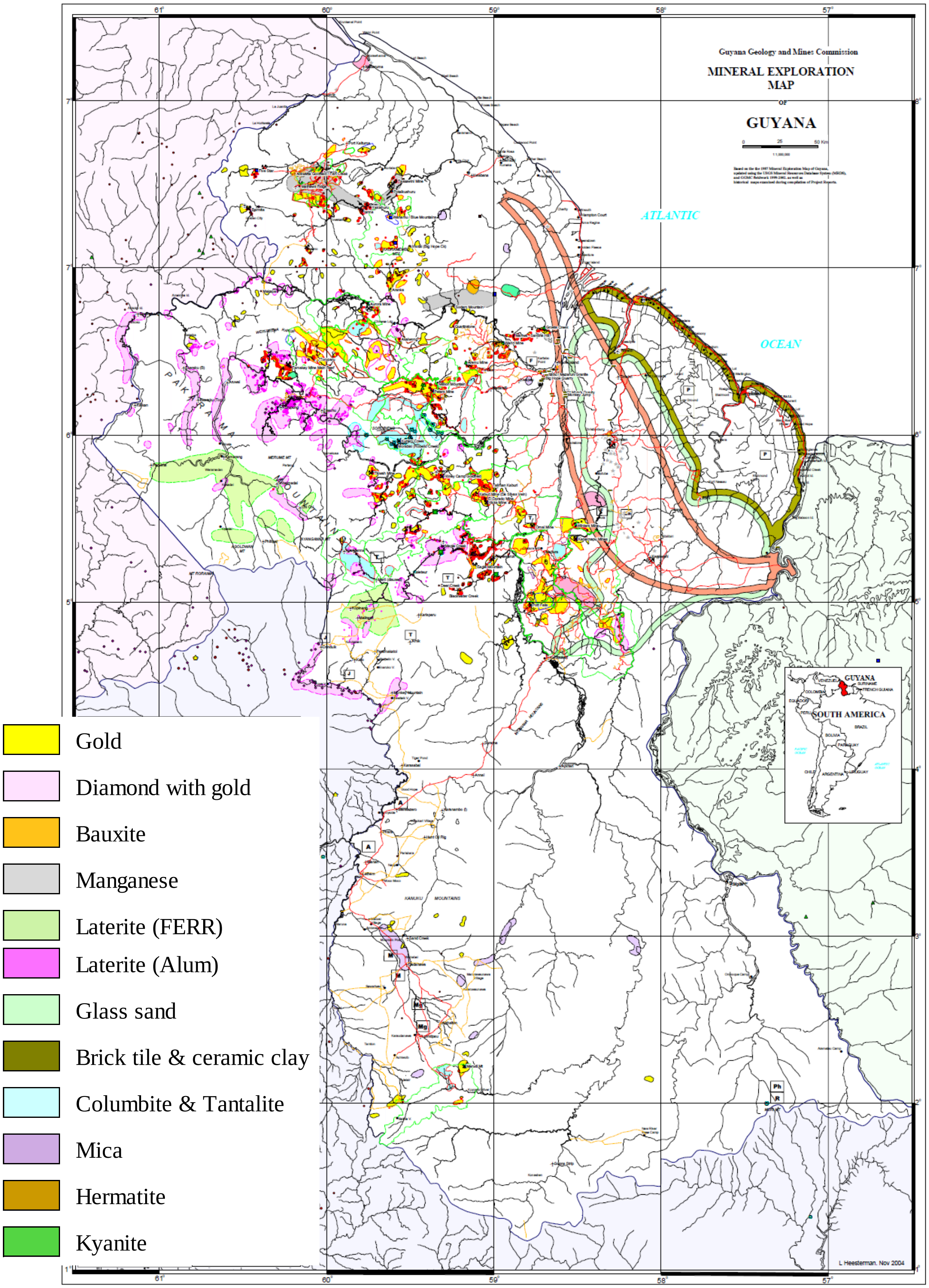
The growth in licenses issued to small- and medium-scale miners was accompanied by the rapid expansion in the volume of gold declared, which increased from 205,900 ounces in 2006 to 481,100 ounces in 2013 (see Table 3). Between 2006 and 2013, more than 70 percent of the declared gold came from Potaro, Mazaruni, and Cuyuni (see Table 3). As indicated earlier, the vast majority of SMS licensed miners operate in these mining districts. The improved technology employed by Brazilian miners coupled with favorable prices contributed significantly to the improved declaration (Thomas, 2009).

Table 3: Gold Declaration by Mining Districts (‘000 ounces)

Mining districts	2006	2007	2008	2009	2010	2011	2012	2013
Berbice	33							
Potaro	24,951	33,624	49,555	48,324	56,420	68,885	103,982	124,385
Mazaruni	103,281	93,561	105,593	92,609	93,403	110,616	110,392	125,279
Cuyuni	29,595	35,965	46,809	83,957	78,133	99,161	94,063	112,291
NWD	46,599	71,816	52,016	53,777	47,459	59,309	78,982	97,165
Rupununi	1,511	11,234	6,414	26,511	33,023	25,112	51,226	21,982
Total	**205,970**	**246,200**	**260,387**	**305,178**	**308,438**	**363,083**	**438,645**	**481,103**

Source: GGMC.

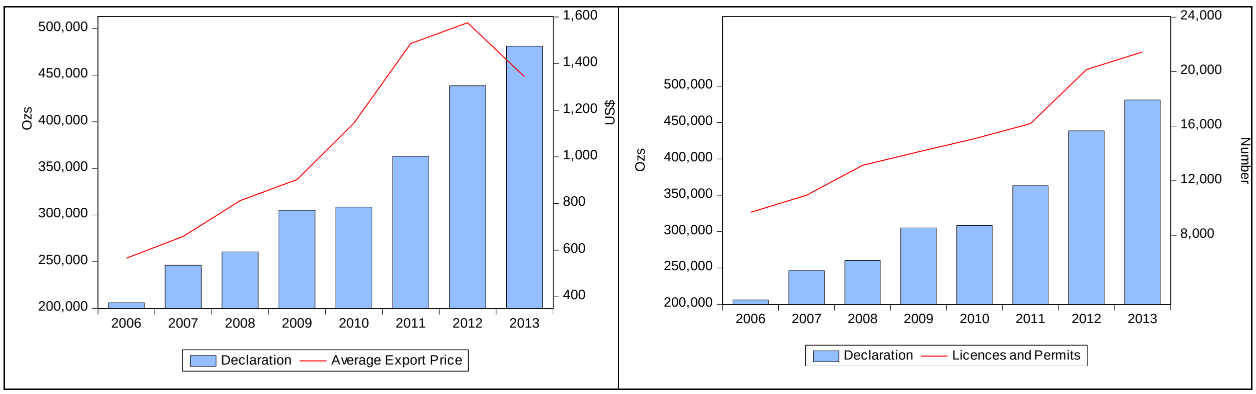
Figure 2: Mineral Exploration Map



Source: GGMC.

The positive impact of gold prices and the expansion of the subsector through the issuance of more licenses to small and medium-scale miners can be gleaned from Figure 3. While gold declaration expanded between 2006 and 2013, diamond declaration tended downwards (see Table 4). This may be attributed to the miners' decision to switch from diamond exploration to gold mining due mainly to favorable gold prices. As can be seen in Table 4, more than 90 percent of the declared diamonds came from Potaro, Mazaruni, and Cuyuni. Diamonds are normally found in similar alluvial deposits and formations as gold, and the technology used by small and medium-scale to mine both are the same. As prices rose for gold, a substitution effect occurred.

Figure 3: Gold Declaration, Average Prices, Licenses, and Permits



Sources: GGMC; Bank of Guyana.

Table 4: Diamond Declaration, 2006–2013 (metric carats)

Mining districts		2006	2007	2008	2009	2010	2011	2012	2013
Berbice		2,038	-			2,353	-	-	-
Potaro		28,979	28,174	47,526	32,524	16,082	13,615	10,312	15,397
Mazaruni		290,027	223,696	95,085	67,542	23,042	22,464	19,523	35,243
Cuyuni		10,062	16,016	25,921	35,152	6,893	16,194	10,424	5,049
NWD		-	-	-	-	-	-	-	-
Rupununi		9,438	1,039	393	8,764	1,550	-	505	241
Total		**340,544**	**268,925**	**168,925**	**143,982**	**49,920**	**52,273**	**40,764**	**55,930**

Source: GGMC.

3.2 Value Chain of the Gold Industry[7]

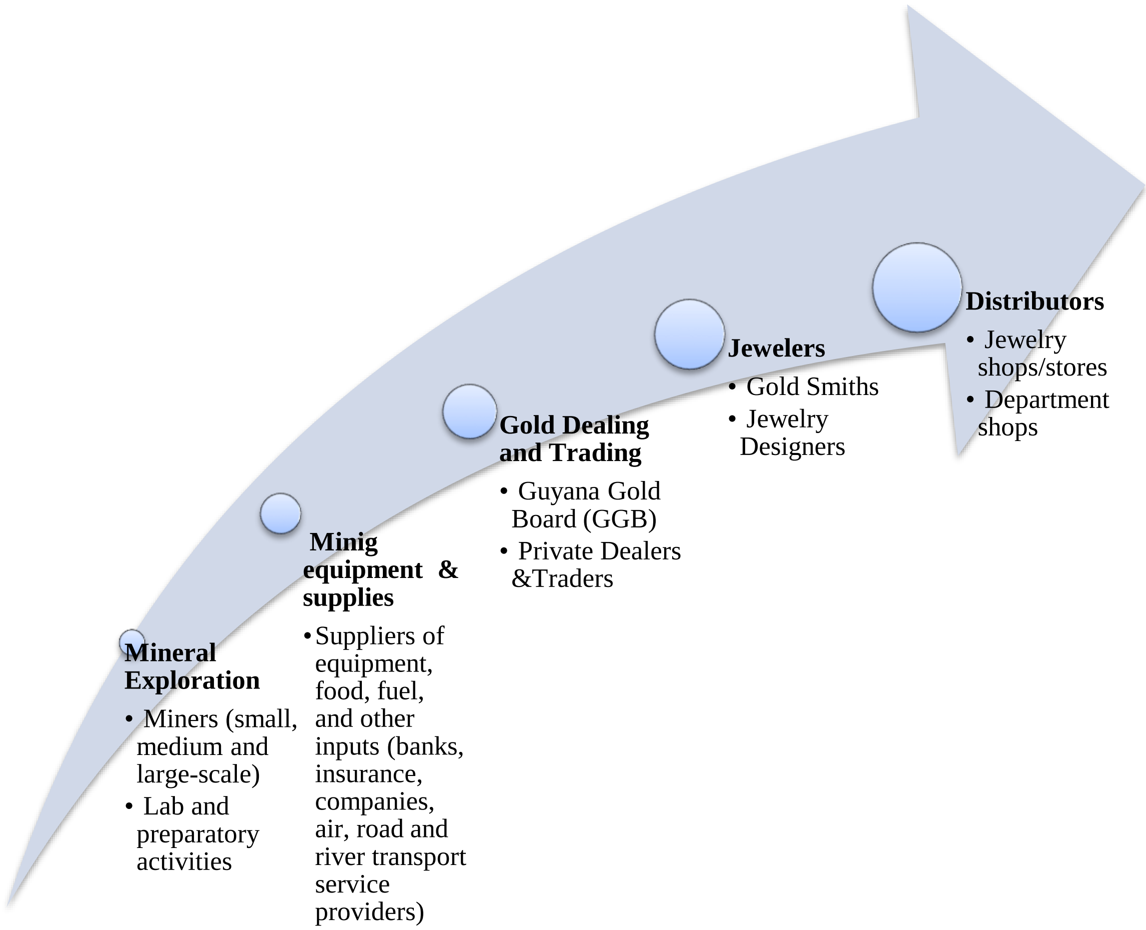
The gold industry has strong backward and forward linkages, especially with regard to the ASM subsector. The ASM miners require an extensive range of supplies/inputs, such as mining

[7] Gold and diamonds are largely extracted with the same technologies and sold using the same distribution channels. However, other minerals produced in Guyana have distinct and more complex production, processing, and distribution channels.

equipment, vehicles (trucks, SUVs, excavators, ATVs, bobcats, backhoes) spare parts, food, fuel, lubricants, and mercury, as well as banking, insurance, security, transport, equipment repair, and metal fabrication (Thomas, 2009). They are also the primary supplier of gold to local jewelers. Large-scale mines have fewer linkages to the local economy since they tend to operate in enclaves and rely on expensive capital goods for extraction and they export all gold produced. Both mining subsectors, through the payment of royalties and other fees, sustain the operation of GGMC (Thomas, 2009). Indeed, more than 50 percent GGMC's income comes from royalties paid by miners.

The value chain of the industry comprises four major segments. These are: (i) mineral exploration; (ii) gold dealing and trading; (iii) jewelry making; and (iv) distribution (see Figure 4). Within the mineral exploration segment, there are many miners (small, medium, and large scale) as well as several suppliers of mining equipment and other inputs. There are also laboratories, which assist miners during the initial mineral exploration stage, providing chemical and mineral analysis of soil and assaying the quality of gold. The ASM miners are the most dominant group within this segment of the value chain, accounting for all the gold declaration from the closure of Omai Gold mine in 2005 until the opening of Goldfields and Troy in 2015. Several large-scale mining companies, such as: Guyana Goldfields, Troy Resources Inc., Sandspring Resources Limited, Guyana Frontier Mining Corporation, Dream Hole Mining Company, and GMV Minerals Inc., have made significant investments in recent years. However, except for the first two, they have yet to commence operation.

Figure 4: Local Value Chain of the Gold Industry



Note: The international value chain is not elaborated. Exported gold can be sold as bullion (ingots) or stamped into coins. Bullion and coins are used either as store of value or for speculative investment purposes. Bullion can also be melted and converted into jewelry or use in industrial purposes such as electrical conductors.

The gold and diamonds mined are sold mainly to the Guyana Gold Board (GGB) and private licensed gold dealers. However, it is common for miners to sell or exchange their gold for supplies provided by shopkeepers or for some licensed dealers (who are also miners) to trade with other dealers. Some traders also rent their claims to small miners, who are obliged to sell the gold recovered to the traders (Swain, 1980). Within the second segment of the value chain, the GBB is legally authorized by the Guyana Gold Board Act 1981 to buy and sell gold.[8] The GBB

[8] Some miners do not declare the gold and diamond mined, while others transact business with unlicensed dealers. However, the actual amount is unknown. Lowe (2000), using a crude model, argues that non-declaration between 1976 and 1997 exceeded 20 percent per annum. Lowe (2003) showed that under-declaration and illegal trade of gold was a feature of the industry, which promoted many legislative initiatives. The Minister of Natural Resources in 2016 announced that 15,000 ounces per week were estimated to be smuggled. See *Stabroek News* January 6, 2016. Available at http://www.stabroeknews.com/2016/news/stories/01/06/around-15000-ozs-gold-smuggled-week-trotman/

purchase gold from miners at a price reflective of its purity. Thus, the prices offered by the GGB are usually lower than the international price because allowance is made for impurities in the gold purchased from local miners. The lower prices are also due to the taxes and royalty deducted by GBB at the point the gold is purchased. Most of the gold purchased by GGB is resold overseas at the London Gold Fix, an exchange for high-value metals. More than 99 percent of the gold is resold overseas, and the remainder goes to local artisans who make gold jewelry (see Table 5).

Table 5: Local and Foreign Sales by Guyana Gold Board: 2002–2012 (ounces)

Sales	2006	2007	2008	2009	2010	2011	2012
Local	63	94	47	41	31	27	72
Foreign	21,203	31,995	41,418	49,666	59,229	67,220	99,111

Source: Guyana Gold Board Annual Reports (various years).

In the value chain, the jewelry manufacturers are the principal agents for adding value to the gold and diamond extracted by local miners. Within this segment there are jewelers who make their products by hand, while other use machine or mold (Thomas, 2009). According to Swain (1980), most of the jewelry is made by hand, and the quality varies from 12 to 22 carats. There are suppliers of molds and design tools for jewelry making in this segment of the chain as well.

Distributors are at the end of the value chain. Some of the distributors are also jewelers who manufacture and sell their products to both local and foreign customers. There are also department stores and small shops which are supplied by local jewelers. Box 1 provides a list of the major players in the value chain.

Box 1: Major Actors in Value Chain of the Gold and Diamond Industry

Segment of value chain	**Major players**
Gold extraction	**Miners** Large-scale: Guyana Goldfields Incorporated, Sandspring Resources Limited, Guyana Frontier Mining Corporation, Dream Hole Mining Company, GMV Minerals Incorporated Medium-scale: numerous medium-scale Small-scale: numerous miners operate in the sector
Ancillary services	**Suppliers of Mining Equipment** Crown Mining Supplies, Farm Supplies Limited, Guyana Sand Port Incorporated, Johil Commercial Mine Services Limited, MKS Import and Export, Mohamed Rahim & Son, Tap Miners Equipment, Triny's Motor Spares, JAPARTS **Laboratory**: ACME labs and ACT labs **Air service**: Fenix Aviation, Golden Arrow, Oxford Aviation, Jags (BK) Aviation, Wings Aviation (Air Guyana), Roraima Airways, Trans Guyana Airways (TGA), Air Service Limited (ASL)

Segment of value chain	Major players
	Road and river transport: road and river transport services are provided by numerous small businesses
Gold trading	**Statutory agency**: Guyana Gold Board (GGB) **Licensed Gold Dealers**: SKS Mineral Trading, Pure Gold Inc., Steve Jewelry, Mohameds Trading
Jewelers	**Jewelry Manufacturer**: DeAbreu's Creations, Elegance Jewelry and Pawn Shop, Gaskin and Jackson Jewelers, King's Jewelry World, L. Seepersaud Maraj and Sons, R. Sookraj Jewelers and Gift Shop, Royal Jewel House, Steve's Jewelry, Topaz Jewelers **Jewelry Design Tools**: R. Seeram's Jewelry
Distributors	All the major jewelers are also distributors. There are several small shops/stalls in the Stabroek Market and Bourda Market which also distribute gold and diamond jewelry.

Source: GGMC.

3.3 Socioeconomic Importance of Artisanal, Small, and Medium-Sized Gold Mining Subsector in Guyana

The mining sector plays an important role in the social and economic development of Guyana. Estimates suggest that the sector directly employed 17,363 people in 2013, 90 percent of whom are employed by small and medium-scale operations involved in gold and diamond extraction (see Table 6). Assuming an average household size of four individuals, the sector supported the livelihood of approximately 69,452 citizens last year. Since the sector employs residents from hinterland communities where poverty is more pronounced, mining plays a significant role in national efforts aimed at reducing poverty in Guyana. Indigenous communities tied to gold mining tend to have higher living standards and incomes than communities not tied to gold mining.[9]

Table 6: Number of People Employed in the Gold and Mining Sector

	2007	2008	2009	2010	2011	2012	2013
SMS miners	7,662	8,124	9,410	10,781	11,672	15,078	15,696
Large scale	1,241	1,282	1,112	1,073	1,072	1,127	1,249
Quarries	267	267	267	316	338	374	418

Source: GGMC.

[9] Preliminary Survey of 11 Indigenous communities. IDB Internal Report. 2015.

The mining sector also contributes significantly to the country's GDP and is a major source of foreign exchange. Gold is the leading subsector within the extractive industry. This subsector accounted for more than 50 percent of the value created by the extractive industry between 1994 and 2013 (see Figure 5). As a result of the increased output and favorable commodity prices, the contribution of gold mining to the country's GDP expanded from 5.3 percent in 2006 to 9.0 percent in 2013 (see Table 7). During this period, export earnings of the sector grew in both absolute and relative terms. Based on Table 7, gold exports increased from US$114.4 million in 2006 to US$648.5 million in 2013 but fell to US$501 million as prices declined. Meanwhile, the share of gold exports as a percentage of total exports grew continuously to reach 47.6 percent in 2013 and then fell back to 42 percent in 2015, up from 19.8 percent in 2006.

Table 7: Contribution of Gold Mining to GDP and Export Earnings

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Gold as percentage of real GDP	5.3	5.7	6.1	6.8	6.7	7.5	8.6	9.0
Gold exports (US$ million)	114.4	158.2	204	281.7	346.4	517.1	716.9	648.5
Gold exports as percentage of total exports	19.8	23.2	25.7	37.2	39.6	46.6	52.2	47.6

Source: GGMC.

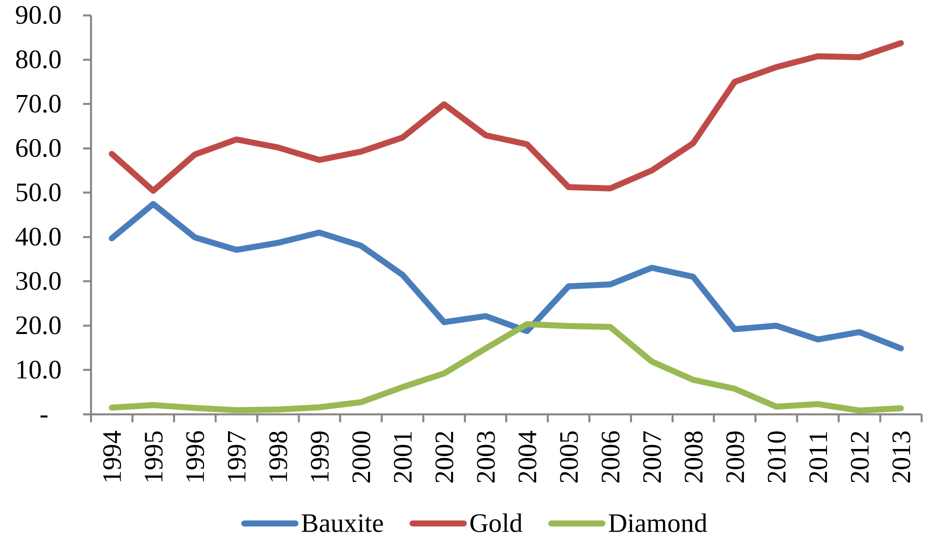
Since the closure of Omai Gold Mines in 2005, small and medium-scale mines (SMS) have dominated the industry. With improved mining techniques,[10] the SMS miners not only sustained the industry but recorded unprecedented gold declaration in 2012 and 2013 (see Figure 6). Nevertheless, these miners face numerous constraints, one of which access to finance (Thomas, 2009). Additionally, the SMS miners are confronted with two important challenges. The first is the need for SMS miners to comply with more stringent regulations to avoid deforestation contained in the Memorandum of Understanding (MoU) between the Government of Guyana and the Kingdom of Norway and the Low-Carbon Development Strategy (GGMC, 2011). The second challenge is the impending ban on the use of mercury, which would force small-scale miners to use environmentally friendly technologies and practices which may be burdensome for these miners to finance (GGMC, 2011).[11]

[10] Thousands of Brazilian immigrants are estimated to be involved in the gold mining sector. They have brought superior mining techniques and equipment with them that has been widely diffused, contributing to much higher outputs. According to one industry observer, approximately 10–12 percent of the small and medium-sized gold miners are Brazilian. See Mangal-Joly (2015).

[11] Mercury is used extensively by miners to separate since it is cheap, easily accessible, and relatively easy to capture gold in the mining process (Thomas, 2009).

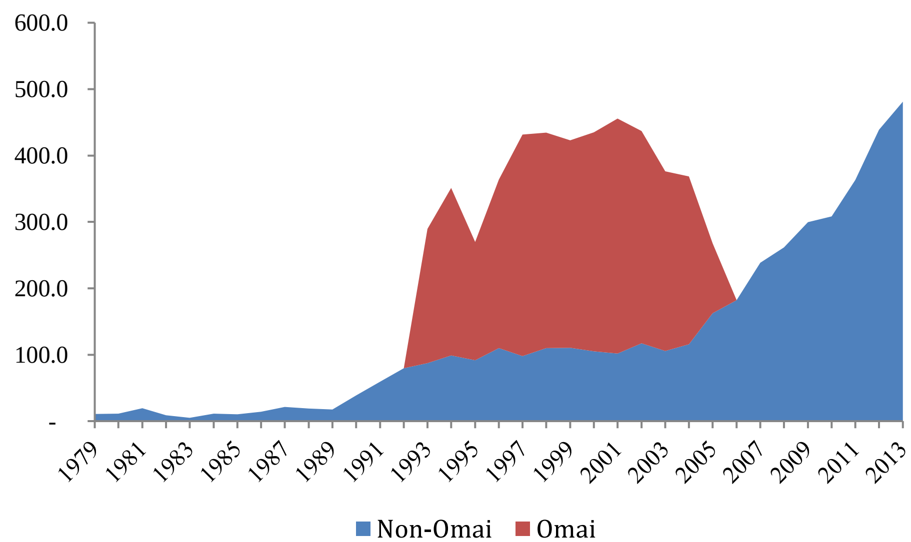
Bauxite is the second most important subsector within the mining industry. Over the past decade, the output level and export earnings from bauxite fluctuated largely due to the variation in global demand for bauxite and mixed impact of investments in the bauxite subsector. Additionally, the bauxite industry's contribution to the mining sector has contracted continuously from 39.7 percent in 1994 to 14.9 percent in 2013 (see Figure 5).

Figure 5: Sectoral Contribution of Three Leading Mining Subsectors



Sources: Bank of Guyana Annual Report (various years).

Figure 6: Gold Declaration, 1979–2013



Source: GGMC.

Meanwhile, the diamond subsector has consistently placed third in the industry, only overtaking the bauxite industry for second place once in 2004 (see Figure 5). With the shift from diamond exploration to gold mining, the export earnings and value-added contribution of the diamond subsector has trended downwards between 2006 and 2013 (see Table 8 and Figure 5).

Table 8: Diamond Declaration, Export Value, and Volume

	2006	2007	2008	2009	2010	2011	2012	2013
Diamond declaration (‘000 carats)	340.5	268.9	168.9	144.0	49.9	52.3	40.8	64.0
Diamond Exports (US$ ‘000)	8,975	7,114	5,487	4,337	1,586	3,066	1,468	2,156
Diamond Exports % of Total Exports (%)	7.8	5.2	3.9	1.9	0.8	0.9	0.6	0.9

Source: GGMC.

3.4 Environmental Challenges of Gold and Diamond Industry[12]

Notwithstanding its economic importance, the environmental, social, and health impacts of mining have not gone unnoticed. Indeed, there are a bevy of studies that highlight some of the adverse consequence of ASM mining in Guyana, especially in indigenous communities. Based on the extant literature, the adverse environmental impacts fall under three broad categories, namely: land degradation, vegetation/biological degradation, and water degradation.

Rawana (1998) surveys Bartica and several mining communities along the Essequibo River. The author reported that the “destruction of forests and river banks, generation of heavy sediment loads in rivers, and widespread mercury contamination were the major environmental hazards posed by dredge-mining” (Rawana, 1998: 108). Rawana also revealed that respondents in the mining communities surveyed indicated that gold mining affected their health and socio-economic wellbeing. Forte (1998), on the other hand, examined the impact of gold mining from the earliest colonial times. The author confirmed that mining has contributed to the pollution of rivers and adversely impacted the traditional way of life of the Guyanese Amerindians. Forte also argued that the expansion in mining would likely contribute to the spread of malaria and sexually transmitted diseases in the interior locations. While pointing out that limited data are available on scale of drug cultivation and trafficking, the author cited reports of the involvement of Amerindians in these criminal activities.

[12] Because gold and diamonds are normally found in same alluvial deposits and medium and small-scale miners use the same technology and practices, the environmental impacts are largely the same. Other main mining subsectors are bauxite and quarrying and different technologies are use and the operations tend to be large scale and concentrated. Those environmental impacts are outside the scope of this paper, which focuses on the gold subsector.

Meanwhile, the International Human Rights Program, Harvard (2007) observed that mining has contributed to deforestation and degradation of soil and water quality of some of the country's rivers. The study reported high incidences of mosquito infestation and malaria as well as many social issues in mining settlements, including: prostitutions, trafficking in person, rape, and violence against women. Additionally, the study showed that mining was responsible for land conflicts between miners and Amerindian communities.

Development Policy and Management Consultants (2008) examined the status of soil and biological degradation of five mining districts based on a flyover survey. The study found significant soil, vegetation, and biological degradation in all the mining districts. While reporting evidence of forest growth in some mining districts, the authors conjectured that the degraded land would not recover without the implementation of interventions prescribed by the GGMC. Some of the recommended interventions to restore land were capacity building, re-vegetation activities, and provision of technical assistance to miners.

Box 2: Environmental Impacts of Different Types of Mining

Impacts of Land Mining

- Deforestation and forest degradation – The main causes of deforestation include: clearing of forest for mining operations (mine pits, processing facilities, tailings pond), living quarters, wood for fuel, and construction of access roads. In Guyana, an estimated 45,000 has of forest was cleared for gold mining activities between 1990 and 2009. Studies conducted in Suriname indicate that forest recovery rates following small-scale gold mining activities are extremely slow and qualitatively inferior compared to other anthropogenic disturbances. Deforestation and forest degradation results in the loss of wildlife habitat and/or a reduction of wildlife carrying capacity and ultimately in the reduction in local wildlife numbers. Threatened and endangered species are especially vulnerable to forest disturbance or removal because in many cases they share the common characteristic of having narrow ecological niche specialization, limited reproductive potential, and/or vulnerability to predation or disease at a critical life stage. Hunting to support mining camps will also contribute to reduction in local wildlife populations.
- Topsoil removal – Land mining involves the removal of a large quantity of overburden to expose the ore carrying gravel. It is estimated that a single land dredge in Guyana can move up to 130 tons of material daily. Material deposited on the river banks affects the hydrological continuity between the river channel and the floodplain. Wetlands in the riparian zone and floodplain provide habitats for invertebrate and birds. Some species of birds make their nests in river banks. Dredging is therefore likely to disturb or destroy suitable feeding and nesting sites. Amphibians may also, lose habitat diversity and spawning areas.
- Sediments – Increased sediment load occurs from direct and indirect discharge of tailings into rivers and streams, soil erosion from dredging activities, and deforestation. The impacts on riverine ecology will be similar to those described for river dredging.
- Mercury pollution – Pollution of watercourses occurs in the same way as that described for river dredging.

Impacts of River Dredging on Aquatic Organisms

- Crushing fish and macroinvertebrates with dredging equipment or burying them under disturbed materials.
- Destruction or alteration of physical habitat needed by fish and macroinvertebrates.
- Substrate removal results in a loss of spawning sites for many species of fishes.
- Removal or disturbance of bank vegetation cover and shade makes fish more susceptible to predators.
- Possible inhibition of upstream migration by creation of deep-water low velocity areas that create a behavioral barrier for migrating fish.
- Deposition of dredged material on the bankside effectively creates a barrier between the flood plain and the river.
- Dredged material deposited on river banks may also contribute to longer term sediment load in the river if it erodes back into the river when left unconsolidated.

Source: Singh et al. (2013).

Gold mining is also regarded as the principal driver of deforestation and forest degradation in Guyana, putting the country's Low-Carbon Development Strategy (LCDS) at risk.[13] This situation is due to the overlapping boundaries between the state forest and mining districts and the fact that significant mining occurs in the country's state forest. The latter may be gleaned from Appendix A, which describes gold mining activities in areas classified by the Guyana Forestry Commission (GFC) as state forest. The prolific use of mercury by miners also presents serious environmental challenges and risks. The Government has signed the Minamoto Treaty and plans to eliminate the use of mercury by 2020 but limited progress has been made toward mercury free mining. Equally important is the need for tailings management and reclamation and re-vegetation to be made mandatory for small-scale miners.

4. Transition Issues

4.1 Technology Employed in the Gold Subsector

The gold and diamond harnessed by small and medium-scale miners have always come from placer deposits which occur along riverbanks and land adjacent to riverbanks (Abrams, 2004). These deposits are easy to locate and relatively easy to process. The small and medium-scale miners employ various gold recovery or concentrator technologies, some of which are purely manual (or non-mechanized) while others are semi-mechanized or fully mechanized. On one extreme of the continuum, there is the gold pan, which is considered a purely manual technique. This technique was used in the past by "pork knockers" to process gold in the local mining sector. The miners who opted for this technique had limited access to financial resources. There is also semi-mechanized technology of which the most dominant are sluice boxes of varying dimensions. Indeed, sluice boxes are the most dominant gold concentration technology utilized in the sector since they require relatively less investment compared with the other more advanced and fully mechanized-type technologies, such as shaking table, jigs, and centrifugal concentrators (see Appendix D).

4.2 Cost of Operation

No agency regularly tracks the costs incurred by small and medium-scale miners. This may be attributed to the difficulty of acquiring such data from this class of miners who do not maintain financial or accounting records. Three studies were conducted by staff members of the GGMC to determine the cost of operation. The earliest study was Glasgow (2003), which estimated the

[13] See GFC (2010), which shows approximately 94 percent of the deforestation that occurred between 2010 and 2011 was due to mining.

average operating expenditure for small-scale mining operations in six mining districts for 1998, 2001, and 2002. The study found that the average weekly cost ranged between $71,300 and $198,000 in 2002 (see Table 9).

Table 9: Average Cost per Week, 2002

Mining districts	Average operating cost per week	Food	Fuel	Transport	Repairs/ maintenance
Berbice – 1	N/A				
Potaro - 2	G$161,000	36.7%	47.8%	4.1%	11.5%
Mazaruni - 3	G$198,000	na	na	na	na
Cuyuni - 4	G$198,000	22.0%	41.4%	11.6%	25.0%
NWD - 5	G$121,000	35.3%	40.2%	7.1%	17.4%
Rupununi - 6	G$71,300	24.5%	29.8%	39.6%	6.1%

Sources: Glasgow (2003) and author's calculations.

Using an inflation rate of 15 percent due to the fallout of the September 11, 2001 terrorist attack in the United States, the author computed the average cost for 2002 by increasing the weekly averages for 2001 by 15 percent.

Extending the previous study, Abrams (2005) estimated the average weekly operating cost by including wages, royalties and taxes, tributes, licenses, medical expenses, and depreciation in his computation. The study used a sample of 69 mining operations in the top four mining districts, which accounted for 100 percent and 97 percent of the gold declared and diamond declared, respectively, in 2005. The weekly weighted average cost ranged between $259,500 and $518,733, with the lowest cost estimated for Potaro, while the highest cost was estimated for Cuyuni. According to the author, the price difference among the mining districts reflected the variation in ore body and overburden common in each district as well as the mining methods (e.g., land dredging, dry mining, hydraulic, river dredging, underground mining, quartz mining), and technology commonly employed in each district. Abrams (2005) also showed that the percentage share of the major cost elements varied among the mining districts as shown in Table 10. Additionally, the study reported the average cost associated with setting up operation (or mobilization cost) in the various mining districts; which ranged between G$311,400 in Potaro to G$915,600 in Cuyuni (see Table 10).

Table 10: Average Weekly Operating Cost by Mining District

Mining Districts	Average Mobilization Cost (G$)	Average operating cost per week (G$)	Major expense items (percent share)			
			Wages	Fuel and Lubricants	Transport	Share of 3 items out of total
Potaro – 2	$311,400	$259,500	21.5%	18.9%	7.6%	48.0%
Mazaruni – 3	$444,510	$370,425	18.3%	22.8%	15.1%	56.3%
Cuyuni – 4	$915,600	$763,000	11.9%	27.8%	27.6%	67.3%
North West - 5	$622,480	$518,733	21.7%	25.8%	9.7%	57.2%
Average	$573,498	$477,914				

Source: Abrams (2005).

Samaroo (2012) estimated the annual production cost for the traditional sluice box operation at $95,932,320 (see Table 11). Unlike previous studies, Samaroo also estimated the annual production cost for the RG-200 Plant and SG-200 Plant at G$65,209,483 (US$315,784) and G$62,624,308 (US$303,265), respectively (see Table 11). Both are mercury-free technologies which utilize the Centrifugal Concentrator as the primary concentrator and Gemini. However, the RG-200 plant is more suitable for clay materials while the SG-200 plant is ideal for sandy material. While the annual production cost of the sluice box is higher than the RG-200 and SG200, the initial investment of the former is substantially below the latter.

Table 11: Annual Production Costs of Sluice Box and Green Technologies (G$)

Cost	RG-200 Plant	SG-200 Plant	Sluice Box
Exploration cost	2,094,000	1,694,000	
Site preparation	1,234,400	383,100	
Installation and Commissioning	9,827,080	6,706,200	
Capital Investment			
Fixed investment	63,944,308	43,427,047	
Working capital	6,394,431	4,342,705	
Total	70,338,739	47,769,752	17,617,600
Annual Production Cost	65,209,483	62,624,308	95,932,320

Source: Samaroo (2012).

A dataset collected from the GGMC on the output and cost of 133 miners, the average cost per ounce of gold for production period 2013–14 based on different dredge sizes was computed and presented in the Table below. It can be gleaned that dredge size is positively related to both variable and fixed costs. This is not surprising, since the capital costs (or rental) are higher for larger operations. The key variable costs such as wages and fuel are also understandably higher for larger dredge, which requires more workers and utilizes larger quantities of fuel.

Table 12: Cost per Ounce of Gold per Production Period and Break-even Quantities

Dredge size	Fixed per oz. (Col. 1)	Variable per oz. (Col. 2)	Total per oz. (Col. 3)	Contribution margin per oz. Selling Price – Col. 2	Break-even units (oz)
2”	G$54,705.58	G$33,297.06	$88,002.64	G$207,428.25	0.26
4”	G$78,856.66	G$56,193.27	$123,795.77	G$184,532.04	0.51
5”	G$119,072.53	G$140,000.00	$259,072.53	G$100,725.31	1.18
6”	G$141,449.58	G$144,555.56	$286,055.13	G$96,169.75	1.45
8”	G$158,796.86	G$161,65.49	$320,447.35	G$79,074.82	10.92

Source: Authors' calculations.
Notes: Contribution margin = Selling Price – Variable Cost per unit.
Break-Even Units = Fixed Cost per unit/Contribution Margin per unit

Assuming a selling price of G$240,725.31 per ounce, the minimal output level required to break even ranges from 0.28 oz. for 2” dredges to 10.92 oz. for 8” dredges (Table 12). It therefore follows that for larger operations to survive they must produce substantially more gold relative to their smaller counterparts or harness higher quality gold to benefit from more favorable selling price.

Since the fixed costs are higher for larger dredge, they are more sensitive to changes in selling price and sales volume. In other words, they have higher *operating leverage*. This can be demonstrated by computing the operating leverage of the various dredges based on the following assumptions:

- Production level is 2 oz.
- Selling price is G$240,725.31 per oz.
- Contribution margin per unit remain unchanged

Table 13: Operating Leverage Circa 2013–14

Size of Dredge (inches)	Contribution margin per oz. [Column 1]	Contribution margin [Column 2] (Col. 1 x 2 oz.)	Operating income [Column 3] (Selling Price x 2 oz.)	Degree of operating leverage [Column 4] (Column 3/Column 2)
2”	G$207,428.25	G$414,856.50	G$481,450.62	1.16
4”	G$184,532.04	G$369,064.08	G$481,450.62	1.30
5”	G$100,725.31	G$201,450.62	G$481,450.62	2.39
6”	G$96,169.75	G$192,339.50	G$481,450.62	2.50
8”	G$79,074.82	G$158,149.64	G$481,450.62	3.04

Source: Authors' calculations.
Note: Degree of operating leverage = operating income divided by contribution margin.

Based on the results in Table 13, when operating sales are 2 ounces, a percentage change in sales and contribution margin will cause income for an 8” dredge operation to change by 3.04 times compared to 1.16 times change in a 2” dredge operation. This degree of operating leverage will however generally fall as the level of sales needed to achieve the breakeven point. Thus, larger-scale operators, despite a very high initial investment in capital and mobilization costs, can weather lower international world prices for gold much better than the smaller scaled operators.

Given miners' sensitivity to changes in sales revenue or operating income, they may have a greater incentive to hoard gold when prices are low because when the prevailing prices are low they cannot cover their expenses. The small and more marginal the miner, the less capacity there is to withhold gold because they have financial obligations to meet (payouts for fuel, food, and salaries). They may also discontinue operations when prices are relatively low.

4.3 How Technology is Financed

There is a paucity of data on how miners finance their operations. However, anecdotal evidence suggests that informal capital is primarily used to finance the operations of small and medium-scale miners. To a lesser extent, miners use supplier credit and bank credit to acquire fixed assets (or equipment), while shopkeepers finance some operational expenses. This situation may be attributed to the riskiness of the sector. The limited support provided by formal banking institutions to the mining sector is clearly reflected in Table 9; which shows that less than 6 percent of the loan portfolio of the commercial banks was directed to the mining sector. Therefore, the overwhelming majority of miners self-finance or use informal sources of finance (family, friends, suppliers, shopkeepers, traders).

Table 14: Sectoral Distribution of Loans to the Private Sector (percent)

	2007	2008	2009	2010	2011	2012	2013
Agriculture	9.1	9.6	12.1	13.3	14.9	13.8	14.0
Mining and quarrying	2.5	4.1	3.6	5.1	4.3	5.2	5.5
Manufacturing	32.3	28.3	24.8	25.3	25.8	27.1	28.3
Services	56.2	58.0	59.5	56.4	54.9	53.8	52.2
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Bank of Guyana.

4.4 Efficiency of the Technology Employed

Gold extraction involves several important processes. These are: crushing and grinding, concentration and concentrate refinement. In this process, small and medium-scale miners employ a variety of techniques and methods depending on factors such as the "availability and exposure to the technology; cost of inputs, availability of and exposure of technology; cost of inputs; geological and other physical conditions; and mining culture and tradition" (Lowe, 2000: 13).

In the local mining sector, dredging emerged as the most dominant method in the crushing and grinding phase of the mining process from the 1960s (Lowe, 2000).[14] Dredges are of two principal types, namely, land and river. According to Abrams (2004), land dredges are normally outfitted with two engines and two suction pumps with diameters ranging from 3 to 6 inches, while river dredges employ suction pumps with diameters from 8 to 22 inches. Mining from hard rock (quartz) is not commonplace in Guyana. Most surface alluvial deposits were exhausted in the 1990s and most mining is open pit mines now.

Box 3: Types of Dredges

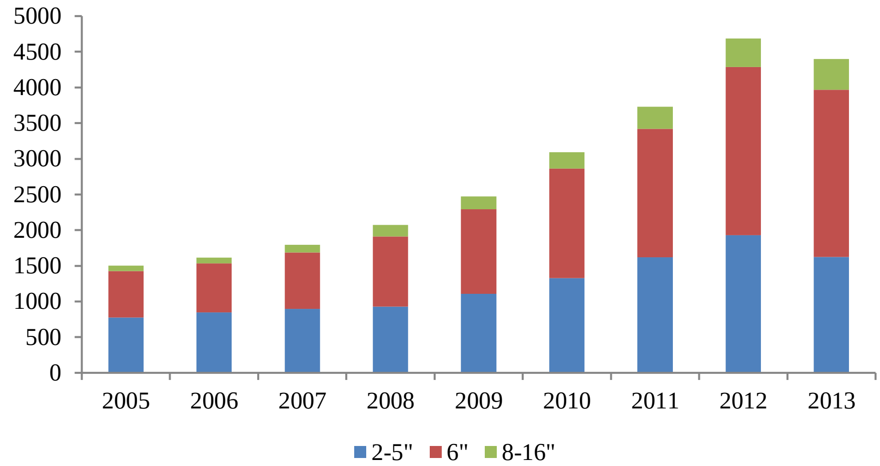
Land dredging (hydraulic mining) involves the loosening and moving of ore using jets of water under pressure. This method works well in loose, unconsolidated material such as sand, loam, clay, and gravel since the force of the water jets easily washes out these materials. The material extracted with the water forms slurry, which moves downslope by gravity or is lifted upslope and away from the working face using gravel (suction) pumps known as Marac pumps. The gravel pumps carry away the slurry to sluice boxes, which separate the lighter clay and sand from the heavier black sands and gravelly material (pay dirt) that are associated with gold and diamond. River dredging operations use suction pumps to vacuum material from the riverbed. The material (slurry) is then transported to a barge based sluice box of various dimensions; with contain riffles and matting to retain gold particles or a 'lavador' [washer] for the separation and retrieval of diamond.

Adapted from Abrams (2004: 3).

Over the past eight years, the number of registered dredges has increased exponentially, reflecting the upsurge in both land and river operations. The six-inch dredges appear to be the most popular choice for land operations; while the eight-inch and twelve-inch dredges seem to be the most option for river operations.

[14] For a comprehensive discussion of the type of dredging employed in the local mining sector, see Lowe (2000).

Figure 7: Annual Dredge Registration by Number and Size, 2005–2013



Source: GGMC.

The sluice box is the principal recovery technology employed by local miners since it is relatively inexpensive. This technology is generally used twice in the mining process as a primary concentrator and secondary concentrator. Apart from its affordability, the sluice box is the preferred technology because it is easier and less expensive to operate and has high capacity (Wotruba et al., 1998). Notwithstanding the many benefits this technology offers, it is extremely inefficient. According to Lowe (2000), the sluice box only traps coarse liberated gold and is incapable of capturing gold particles, such as fine gold, gold entrapped in clay balls, gold entrapped in stone fraction, and gold occupied in black sands. The recovery rates using this technology range from 20 to 40 percent in Guyana (Lowe, 2000). Thus, only 20 to 40 percent of the gold originally in the ore is captured in the concentrate, and the remainder (60 to 80 percent) is disposed in the tailings and/or middling.[15] Additionally, the sluice box requires the use of mercury in the gold recovery process at the primary and secondary concentration phases, to amalgamate the fine gold dust. Notwithstanding the existence of mining regulations that encourage the safe use of mercury, it is common for local minors to apply this poisonous substance improperly, with adverse environmental and health impacts. The International Human Rights Program at Harvard (2007), for instance, reported cases of mercury poisoning caused by mining in some Amerindian communities. The study also revealed that miners polluted creeks with mercury, forcing Amerindians to stop fishing in waterways. Glasgow (2000), on the other

[15] A recovery rate of 20 percent means that 20 percent of the gold originally in the ore is captured in the concentrate and other 80 percent is disposed in the tailings and/or middling. Since the maximum recovery rate from the sluice box is 40 percent it therefore follows that at least 60 percent of gold is lost in the tailings when this technology is employed.

hand, reported the discharge of hazardous materials in nearby waterways and limited use of retort by miners. Meanwhile the Singh, Watson, and Mangal (2001) reported evidence of significant mercury contamination in two mining communities in the Mazaruni Basin.

In view of the harmful environmental and health impacts of mercury and given the country's commitment its use in the mining sector, there is an urgent need for miners to move to modern 'mercury free' technologies with proven application for the recovery of placer gold. Some of the modern technologies, which are ideal for small and medium-scale operations, include: jigs, cones, spirals, centrifugal concentrator (Davis, 1986; Lowe, 2000; Wotruba et al., 1998). Apart from the high recoveries, these technologies offer numerous advantages, as shown in Box 4 and Appendix D.

Box 4: Mercury-free Technologies

Recovery technologies	Advantages
Jigs: Hydraulic	Simple to construct, does not require power, and has low investment and maintenance costs.
Jigs: Mechanical	Can be adapted to all types of materials, does not require much attention
Shaking table	Continuous discharge of products; obtain a range of products (concentrate, middling and tails); visible behavior of material on the deck, relatively low cost, great flexibility; relatively simple operation and supervision; possibility of recovering other valuable accompanying minerals; high safety of work conditions; good recovery and high level of enrichment; possibility of manufacture in developing countries.
Spiral concentrators	Simple operation; good recovery; requires no power; high capacity and moderate price.
Centrifugal concentrator	Good recovery even of ultrafine and flaky gold; high capacity; compact equipment and high theft security.

Source: Adapted from Wotruba et al. (1998).

5. Policy, Legal, and Regulatory Environment

The mining industry is not guided by any sector-specific policy. Rather, it is governed by several laws and regulations, which have evolved over the years. The laws and regulations are focused on five basic issues, namely: ownership and authority over mineral resources; protection of private property, claims and capital; regulation of labor, Amerindian (Indigenous) rights, and environmental impact; revenue and other economic considerations; and dispute resolution (Mars, 1998). Lowe (2003) provides a detailed historical perspective of the evolution of the legal and regulatory framework. Currently, the main legislation governing the sector is the Geology and Mines Commission Act 1989. Under this Act, the GGMC is vested with the power to exercise rights over all minerals on state lands. The Act empowers the GGMC to issue permits and entrusts the authority with the responsibility to supervise and regulate mineral exploration in accordance with the Mining Act 1989; Guyana Geology and Mines Commission Act 1969; Geological Surveys Act 1997; Environmental Protection Act 1996; and Industrial Aid and Encouragement Act 1951.

In addition to these laws, the sector is governed by the Mining (Amendment) Regulations 2005 and ten legally enforceable Codes of Practices. The latter provide specific details on how the Regulations should be observed. Together, the Regulations and Codes of Practices cover an extensive range of environmental issues, including: mercury use, tailings management, mine reclamation and closure plans, mine effluent, waste management and disposal, and contingency and emergency response planning.

While the legal and regulatory framework is robust, the absence of a clearly defined policy for the industry is a major shortcoming. According to Thomas (2009), the legislation that govern the sector cannot substitute for the policy. If international best practices are to be observed, then a mining policy is necessary.[16]

6. Regulatory Enforcement Gaps and the Way Forward

Best practices for promoting sustainable alluvial mining comprises mining methods and practices that minimize the environmental impact of mining while simultaneously improving the socioeconomic impact of this economic activity. The Mining (Amendment) Regulations 2005 and accompanying Codes of Practices conform to international best practices since they promote environmentally friendly mining activities.

Notwithstanding the robust and modern regulatory framework, there are reported incidents of environmental degradation. The International Human Rights Program at Harvard (2007) attributed this situation to regulatory flaws (such as overlapping jurisdiction, the laxity of the regulations with respect to small-scale miners, under-enforcement due to the small number mines officers who are greatly outnumbered by miners, the complexity and time-consuming nature of the administrative tasks assigned to mines officers), and structural impediments to effective oversight (such as the failure of the judicial system to adequately enforce the laws, porous borders, and a political climate marked by rent seeking). Among the starkest challenges are the lack of coordination and the lack of an implemented comprehensive land use plan among key resource-based agencies—Lands and Surveys, the Guyana Forestry Commission, the Ministry of Agriculture, the Ministry of Natural Resources, the Environmental Protection Agency,

[16] See for instance, United Nation Economic Commission for Africa (2002) which argues that several factors are important for the success of SMS among which include: the establishment of a mining policy which makes special provision for SMS; the enactment and enforcement of robust and clear legislation tailored to promote SMA; improving access to more efficient technology by SMA; promotion of environmental management, health and safety practices among SMS; the improvement in minerals marketing by establishing a one-stop-shop and auction market for gemstone; improvement of regulatory oversight by establishing offices close to major mining areas; and improving access to finance by SMS.

and the Ministry of Indigenous Affairs, which represents people who base their livelihood on the forest. Many actions of these agencies conflict with the interests of land users. Maps used by one entity do not coincide or properly indicate uses, concessions, or titled lands. A second example is that mining concessions are often let or auctioned without prospecting. Small and medium-sized concessionaires assume higher risks and costs, acquiring parcels whose true mineral wealth is unknown. This adds to the economic and cost constraints of following sustainable and responsible practices and cleaner technology. In this setting, the incentive is to minimize outlay in technology and to economize in all ways possible.

To address some of regulatory flaws, the following measures should be considered:

Progressive reclamation and re-vegetation

One of the measures that could minimize the impact of mining on the environment is progressive reclamation and re-vegetation. The Mining Regulations of 2005 require the submission of a Mine Reclamation Plan and Closure Plan. However, it is not compulsory for small-scale miners to reclaim or re-vegetate the mine site after ceasing operations. This is in stark contrast with some countries, where progressive reclamation and re-vegetation are mandatory (Franklin and Agard, 2008; Goodchild and Husbands, 2010). In this regard, the Regulations should be amended to make land reclamation compulsory.

The GGMC should also consider providing technical and financial support to promote compliance. The GGMC has successfully piloted several reclamation and re-vegetation projects (GGMC, 2011). However, these activities could be accelerated by encouraging private businesses to reclaim and/or re-vegetate mines operated by small-scale miners.

Adoption of more efficient and environmentally friendly technologies

With the impending ban on the use of mercury, it is imperative that mercury-free technology be promoted. Studies conducted by staff of the GGMC revealed that mercury-free technologies, such as the Knelson Concentrator, are financially feasible. Samaroo (2012), for instance, examines the RG-200 and SG-200 processing plants. The study shows that the net present value (NPV) of the RG-200 and SG-200 amounted to G$889.3 million (US$4.3 m) and G$403.5 million (US$1.9 m), respectively. The analysis also showed that the sluice box yields lower economic returns. Table 15 summarizes the findings of Samaroo (2012).

Table 15: Economic Returns on Different Mining Technologies

Technology	Service life of mining operations (years)	NPV at 20 percent (G$m)
RG-200	3	G$889.3
SG-200	2	G$403.5
Sluice box (on RG-200 site)	1	G$298.2
Sluice box (on SG-200 site)	0.7	G$131.7

Source: Samaroo (2012).

Notwithstanding the economic feasibility of the mercury free technology, small miners are likely to resist the use of green technology since the costs of employing them are prohibitive. Recognizing this constraint, the Ministry of Natural Resources and the Environment is in the process of establishing a revolving loan fund to provide miners with concessional finance to procure mercury-free technology. While this initiative is commendable, other financing options should also be considered, such as leasing arrangements, equity-based financing schemes, and donor and government supported schemes.

Integrated land management model

The mineral extractive industry is always in constant competition with the forestry sector. The sector is also a major source of land conflict with Indigenous communities. To address these conflicts, it is important to situate mining within an integrated land management model (ILMM) with all the other land use sectors. This would, however, require the development of a national land use policy and information management system. Apart from addressing land conflict, an ILMM would provide the framework for sustainable mineral extraction (Ali, 2013).

Use of technology to aid regulation

As highlighted by several studies, the GGMC is incapable of regulating mining activities given the number of miners who operate in the sector vis-à-vis the number of mines officers. This problem may be addressed in several ways:

- The monitoring system should be extended to include local actors (e.g., residents in mining communities, community-based organization, and local authorities such as the Regional Democratic Council and/or Neighborhood Democratic Council) as active watchdogs.
- Rather than granting miners' claims that are far apart, they could be concentrated in specific locations. Alternatively, claims could be granted to small groups (clusters) rather than individuals. This would reduce the number of people to be regulated.

- Technologies such as drones, Geographic Information Systems (GIS), and geo-referencing tracking devices could be used to monitor miners and random checks carried out where the environmental risks are higher.
- Increasing awareness and providing training to miners on environmentally friendly practices. The awareness exercises should be undertaken periodically. For instance, before claims are issued or renewed, miners should be required to attend awareness sessions that focus on environmentally technologies and practices. There should also be a toolkit.[17]

Small-scale miners should be organized into clusters

Rather than issuing claims to small miners whose operations are scattered across mining districts, the Government should encourage clusters in designated areas with proven minerals. To make the clusters more attractive, the GGMC with the support from international agencies should undertake geological surveys in areas identified for small-scale mining. Currently, small miners lack the capacity to finance these surveys and resort to the 'hit or miss' approach. Given the risk associated with this approach, small-scale miners invest in technologies that require minimal capital outlays to minimize potential losses if the operation is subsequently found to be uneconomical. Some also move to other locations outside their claims, thereby making it difficult to effectively regulate their operations.

Once the minerals are available in sufficient quantities, the GGMC should then identify the best technology for harnessing them. At this stage, the GGMC should develop an appropriate environmental management plan and/or environmental impact assessment to ensure that the environmental impact from mining is minimized.

The total cost for setting up the operation should then be determined and miners brought together to share expenses by forming a private limited company or partnership. Alternatively, the initial cost should be financed through the issuance of shares to the public, allowing small-scale miners to invest in the operation. The latter approach may allow the establishment of large-scale mining operations with small-scale miners and Guyanese generally. By organizing small-scale miners into clusters, several benefits may accrue. First, it would allow the miners to benefit from economies of scale while sharing risk. Second, it would make monitoring easier for the regulatory agency (GGMC). Third, since the cost will be lower for each investor (miner), it would enhance the attractiveness of greener technologies. Fourth, the cluster arrangement would allow the Guyanese people to benefit optimally from the wealth created by the mineral sector. Fifth, miners may be better positioned to negotiate for more fiscal concessions (e.g., tax waiver on fuel, parts).

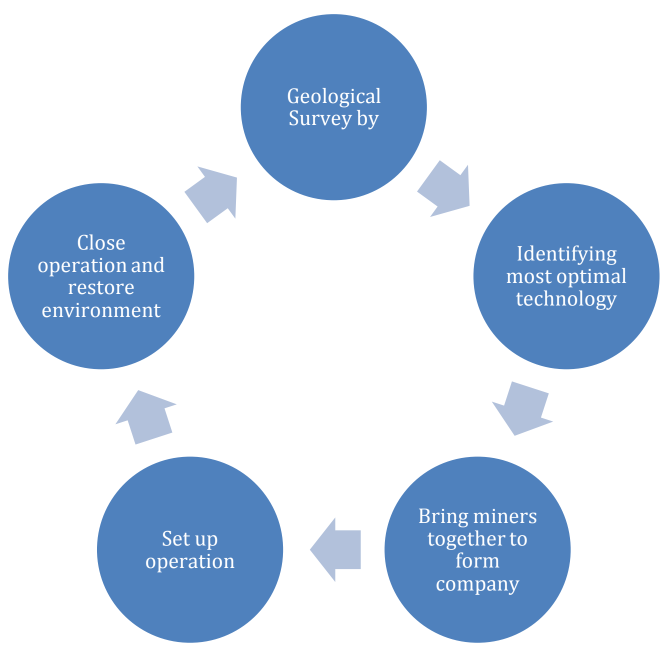
[17] The Ministry of Natural Resources and the Environment (MNRE) is developing a toolkit for miners. At the time this report was written, it was in draft form.

To improve access to credit to finance the needed investments a revolving credit could be established as well as a partial guarantee scheme with commercial banks. Once the financing is raised, the operation should be established with appropriate technologies and systems (e.g., tailing ponds) to harness the minerals. Sixth and last, organizing smaller miners into clusters, companies, or cooperatives would allow those who implement "green practices" to certify and brand themselves in the international marketplace and demand a price premium for sustainably mined gold, i.e. "green gold".

Knowledge and research agenda

Information and research available on extractive industries is quite limited. An agenda of statistical collection and economic, social, and environmental analysis is needed to create the necessary conditions for evidence-based decision making. Besides a geo-referenced dataset to facilitate the creation of an integrated land management system mentioned above, a series of knowledge creation activities are needed. These include economic profiles of miners, data on production costs, health assessments of miners and residents of communities affected by mining, occupational safety assessments of various types and scales of mines, evaluations of the efficiency gains from using differing technologies, feasibility studies for creating technology financing funds, and reclamations/reforestation initiatives, among others.

Figure 8: Cluster Development Cycle



The clusters should be developed with both backward and forward linkages aimed at encouraging greater value-added activities locally.

7. Conclusion

Guyana is a mineral-rich state, and gold production is the leading economic sector, accounting for the greatest share of total exports. It directly employs approximately 17–18,000 persons and indirectly benefits 69–70,000 persons. Nonetheless, the dominance of ASM miners poses serious environmental, social, and health challenges that need to be addressed. In an environment of moderating gold prices, greater efficiency in recovery methods is needed and better management practices should be adopted to minimize negative environmental impacts and improve worker safety standards.

Despite Guyana's modern regulatory framework for mining, enforcement capacity is weak. Government authorities are also experiencing a high degree of revenue leakage due to smuggling across international borders. The authorities must choose between depending on a well-managed large-scale sector and a restricted ASM sector, or promoting sustainable and good practices in all both sectors. The investments in capital, technical knowledge transfer, and improved institutional capacity will be high, and access to formal finance has been problematic for ASM.

Some recommendations on how to promote the adaption of more environmentally friendly and efficient technology were made, such as prospecting before granting concessions, establishing revolving loan funds, clustering and equipment sharing, and forming holding companies or mining cooperatives. The main idea would be to cluster and organize the smaller-scale operators so they can share the use of expensive technology and incentivize the branding of "green" or "certifiable sustainable gold" to earn price premiums in the marketplace. Better organization of miners would also facilitate better training and outreach. One immediate change could be to harmonize Guyana's royalty rates with those of neighboring states (Brazil and Suriname) to remove opportunities for arbitrage in smuggling gold to lower royalty and tax jurisdictions.

Epilogue

Field work for this study was completed in 2014 The study reports figures up to 2013 and mentions developments in 2014 and 2015. Since then, gold declaration has increased, setting a record in 2016 of 705,000 ounces and accounting for US$798 million in exports. Prices rebounded due to Brexit in June 2016, and the production of two large gold mines, which began operating in 2015, reached maximum output levels in 2016. The improved price outlook and the increased large mine output combined to yield strong performance in 2016. Into the first quarter of 2017, gold continues to be the main driver of the economy. A marked duality in the sector has emerged, with two large, foreign-owned mines using efficient technology accounting for 35 percent of declared production and artisanal, small, and medium-scale miners using inefficient technology accounting for 65 percent. The same regulatory, policy, institutional, economic, and environmental challenges mentioned in the 2013-2014 analysis remain.

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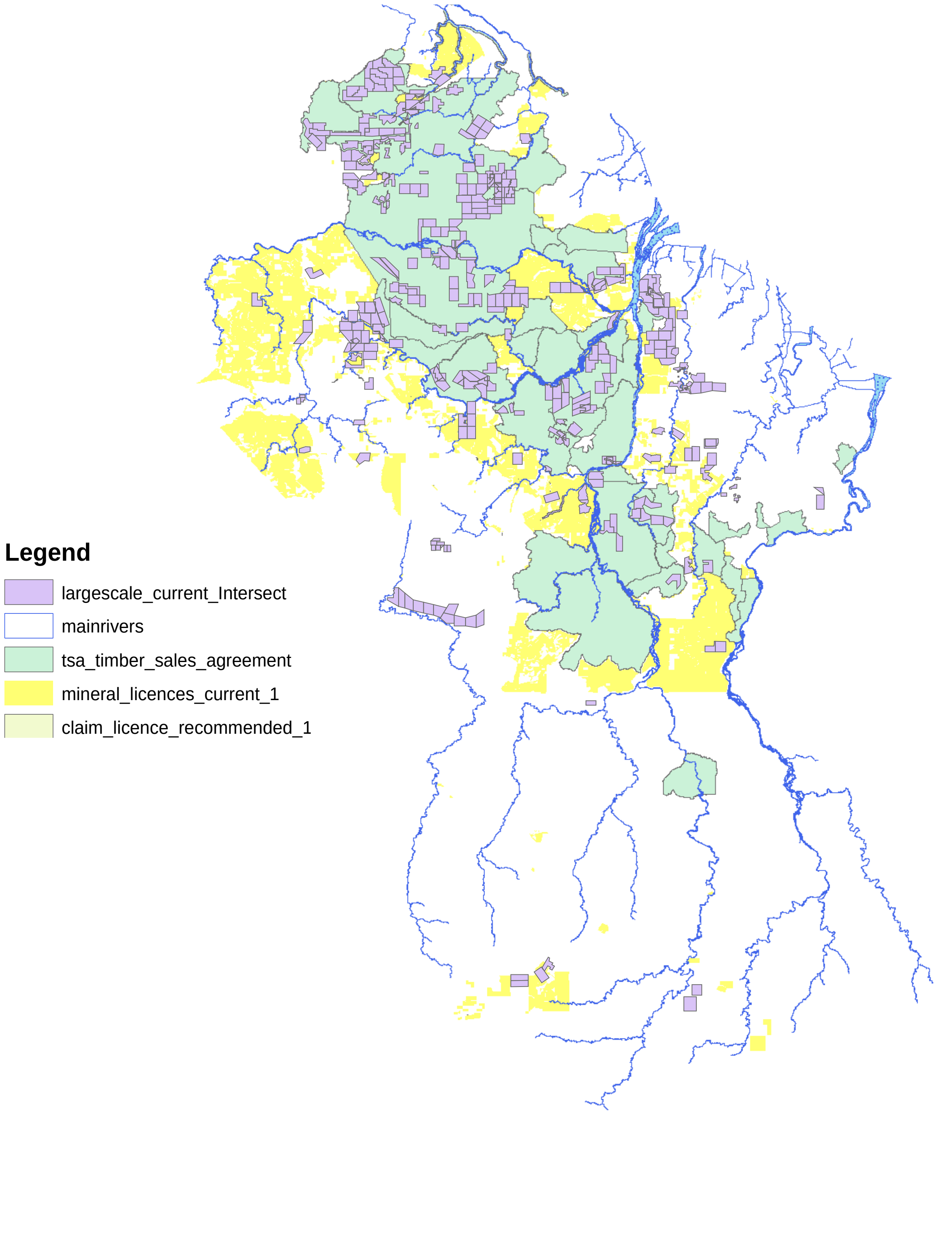
APPENDIX A

Figure A1. Overlaps between Forest and Mining Licenses



Source: www.geoserver.ggmc.gov.gy

APPENDIX B

Table B1. Declaration of Minerals, 1979–2013

Period	Gold (000 oz.)			Bauxite (000 tons)	Diamond (000 carats)	Quarry Stones (000 tons)	Sand (000 tons)	Loam (000 tons)	Laterite (000 tons)	Clay (000 tons)
	Non-Omai	Omai	Total							
1979	10.6		10.6	1,533	15.8	na	na	na	na	
1980	11.0		11.0	1,626	10.2	89.9	0.0	na	na	
1981	19.3		19.3	1,503	9.5	71.8	0.4	na	na	
1982	8.7		8.7	1,174	11.5	28.1	1.1	na	na	
1983	5.0		5.0	1,091	12.4	41.6	0.5	na	na	
1984	11.1		11.1	1,333	7.4	39.0	0.2	na	na	
1985	10.3		10.3	1,573	11.9	22.1	2.0	na	na	
1986	14.0		14.0	1,470	9.5	33.8	2.4	na	na	
1987	21.4		21.4	1,359	7.7	24.3	2.7	na	na	
1988	18.8		18.8	1,339	4.4	11.8	9.5	na	na	
1989	17.3		17.3	1,322	8.1	61.5	11.2	na	na	
1990	38.7		38.7	1,456	15.3	3.3	44.0	na	na	
1991	59.3		59.3	2,204	23.1	63.4	17.0	na	na	
1992	79.6		79.6	2,336	44.8	13.3	90.0	na	na	
1993	87.1	202.2	289.3	2,110	50.1	69.3	166.2	na	na	
1994	99.1	251.8	350.9	2,091	37.4	92.5	751.4	na	na	
1995	91.5	178.4	269.8	2,036	52.4	98.1	171.9	na	na	
1996	110.2	253.4	363.6	2,369	48.5	336.5	118.9	na	na	-
1997	98.0	333.6	431.6	2,491	35.6	176.9	149.0	na	na	-
1998	110.1	324.2	434.3	2,489	33.5	32.4	290.6	na	na	-
1999	110.6	312.1	422.7	2,539	45.4	128.5	211.3	19.2	na	-
2000	105.3	329.6	434.9	2,667	81.7	120.2	261.8	14.6	1.0	-
2001	101.8	354.1	455.9	1,953	179.5	117.9	243.1	43.3	12.0	-
2002	117.3	319.4	436.7	1,686	248.4	54.7	186.3	10.7	4.5	0.2
2003	105.7	270.7	376.4	1,846	412.5	154.1	253.7	10.7	5.2	0.2
2004	115.9	252.6	368.5	1,506	454.9	285.6	142.1	17.3	3.0	-
2005	162.5	105.1	267.7	1,648	356.9	316.0	573.1	4.0	12.0	-
2006	182.2		182.2	1,453	340.5	204.0	285.0	21.0		
2007	238.3		238.3	2,239	268.9	368.0	715.5	34.6		
2008	261.4		261.4	2,109	168.9	449.6	683.9	13.3		
2009	299.8		299.8	1,448	144.0	340.0	478.5	2.0		
2010	308.4		308.4	1,100	49.9	505.9	569.1	na		
2011	363.1		363.1	1,828	52.3	539.1	674.9	12.1		
2012	438.6		438.6	2,210	40.8	483.9	1,478.2	92		
2013	481.1		481.1	1,694	64.0	654.0	2,334	95		

APPENDIX C

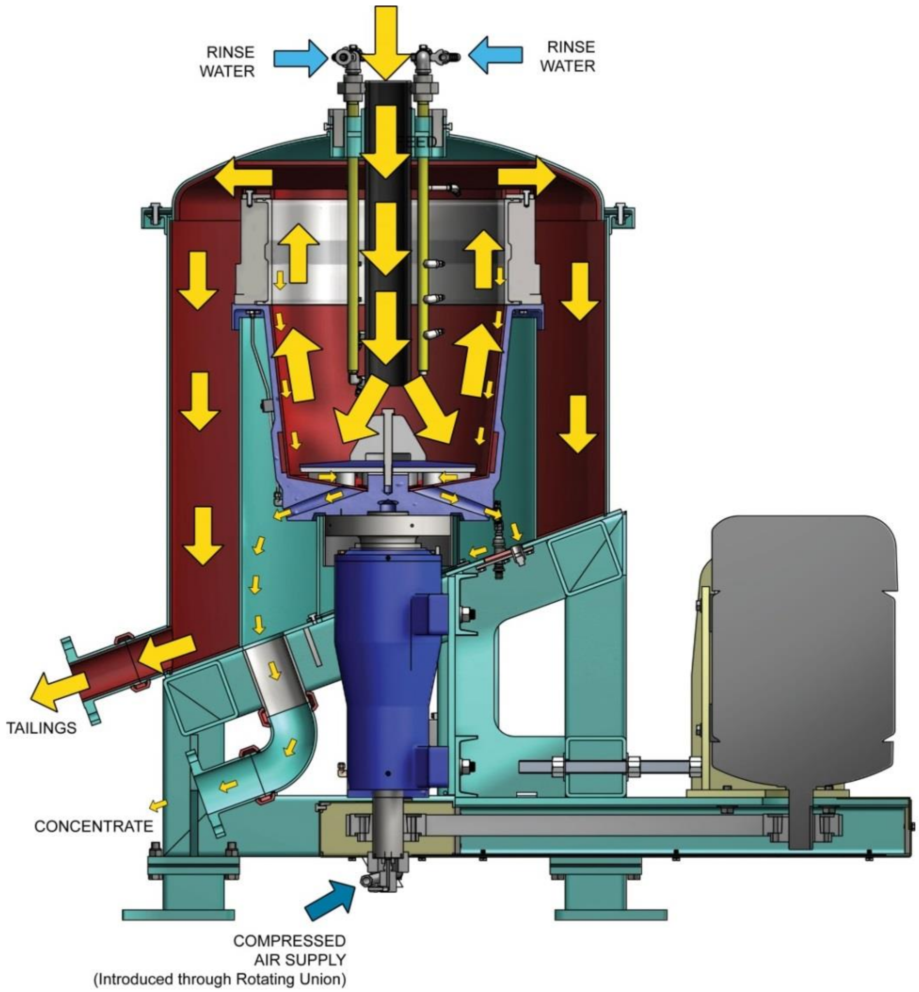
Table C1. Mineral Exports, 1979–2013

Period	Gold (US$ Mln)	Bauxite (US$ Mln)	Diamond (US$ Mln)	Total exports (US$ Mln)	Gold % of total exports	Bauxite % of total exports	Diamond % of total exports
1979	-	128		289	-	44.4	-
1980	-	188		383	-	49.1	-
1981	-	153		341	-	44.8	-
1982	-	94		232	-	40.6	-
1983	-	73		188	-	38.9	-
1984	4	92		214	2.1	43.2	-
1985	4	98		206	1.9	47.7	-
1986	15	98		222	6.5	44.2	-
1987	17	86		266	6.4	32.4	-
1988	18	82		230	8.0	35.8	-
1989	7	76	0	224	3.0	33.8	0.0
1990	18	80	0	250	7.1	32.1	0.2
1991	21	82	2	254	8.4	32.4	0.7
1992	25	97	3	363	6.8	26.7	0.8
1993	100	91	4	404	24.7	22.5	1.0
1994	128	76	3	448	28.6	17.1	0.6
1995	95	83	3	479	19.8	17.3	0.6
1996	103.5	70	na	553	18.7	12.6	na
1997	139.8	89	na	573	24.4	15.6	na
1998	124.0	78.5	na	525	23.6	15.0	na
1999	108.7	77.2	na	505	21.5	15.3	na
2000	123.3	76.3	4.8	503	24.5	15.2	1.0
2001	127.0	61.0	13.3	487	26.1	12.5	2.7
2002	136.3	35.3	20.0	492	27.7	7.2	4.1
2003	130.9	40.4	29.7	501	26.1	8.1	5.9
2004	145.1	44.7	48.8	578	25.1	7.7	8.4
2005	111.9	62.8	43.6	536	20.9	11.7	8.1
2006	114.4	65.5	44.9	578	19.8	11.3	7.8
2007	158.2	101.5	35.5	681	23.2	14.9	5.2
2008	203.7	131.1	31.2	792	25.7	16.5	3.9
2009	281.7	79.5	14.1	757	37.2	10.5	1.9
2010	346.4	114.2	7.1	874	39.6	13.1	0.8
2011	517.1	133.3	10.4	1,110	46.6	12.0	0.9
2012	716.9	150.8	8.2	1,374	52.2	11.0	0.6
2013	648.5	134.7	12.1	1,362	47.6	9.9	0.9

Source: GGMC.

APPENDIX D: BRIEF NOTES ON MERCURY-FREE TECHNOLOGIES ADAPTED FROM VARIOUS SOURCES

Figure D1. Centrifugal Gold Concentrator (US$5,000–6,000)


RINSE
WATER
RINSE
WATER
TAILINGS
CONCENTRATE
COMPRESSED
AIR SUPPLY
(Introduced through Rotating Union)

Descriptions

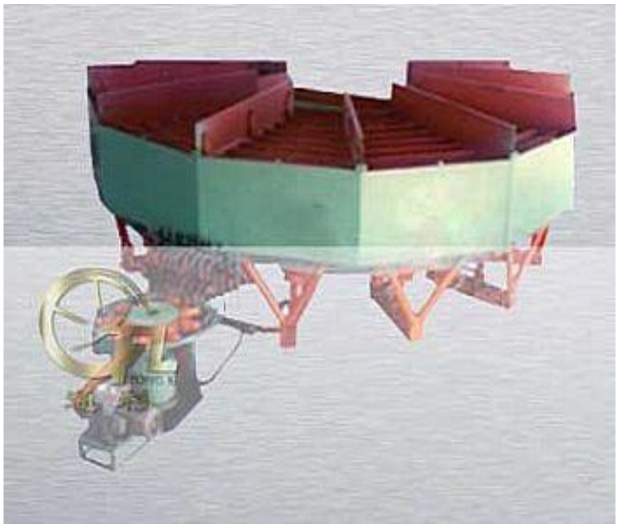
The Centrifugal Concentrator is a relatively new type of gravity concentration apparatus. The machines use the principles of a centrifuge to enhance the gravitational force experienced by feed particles to effect separation based on particle density. The key components of the unit are a cone-shaped "concentrate" bowl, rotated at high speed by an electric motor and a pressurized water jacket encompassing the bowl. Feed material, typically from a ball mill discharge or cyclone underflow bleed, is fed as slurry toward the center of the bowl from above. The feed slurry contacts the base plate of the vessel and due to its rotation, is thrust outward. The outer extremities of the concentrate bowl house a series of ribs and between each pair of ribs is a groove. During operation, the lighter material flows upward over the grooves and heavy mineral particles (usually of economic value) become trapped within them. Pressurized water is injected through a series of tangential water inlets along the perimeter of each groove to maintain a fluidized bed of particles in which heavy mineral particles can be efficiently concentrated.

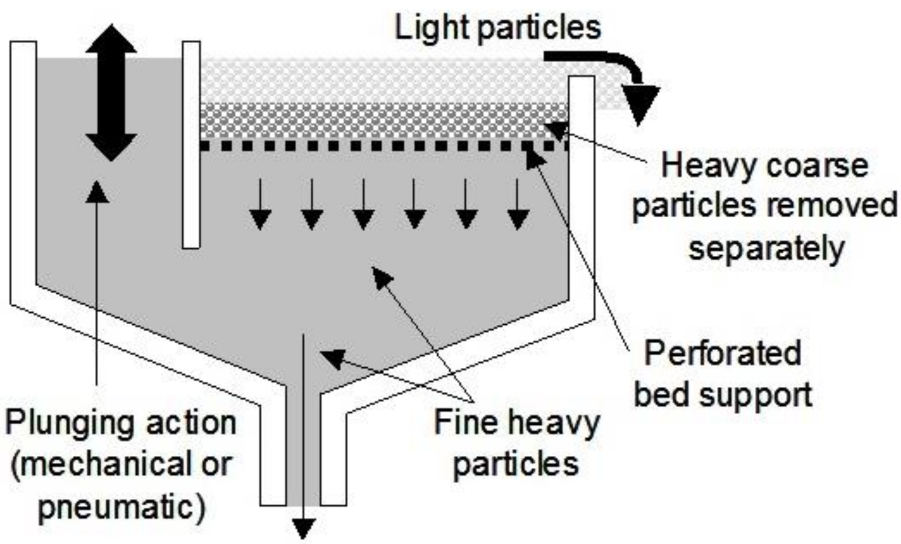
The Centrifugal Concentrator was patented in China. It is efficient equipment for recovering free gold in all particle size ranges, especially for recovery of fine gold which is lost during the operation of the gravitational concentrators (sluice boxes and jigs). It can be used not only for placer gold mining, but also for hard rock mining to recover the natural gold, replacing amalgamation, and recover gold from the old tailings. Application shows that the recovery can be as high as 99 percent, and the concentrating ratio is up to 1, 000 times. In recovering the natural gold in lode ore with size -0.074mm, the gold is up to 98 percent, and for 0.04mm in particle size, the gold recovery is 97 percent

- in processing of low-grade gravity concentrates produced at sluices of refinery plants, in reprocessing of tailings of jig units, concentration tables and magnetic-liquid separators, containing fine, fine-dispersed and dust gold at placer gold-concentrating sites of prospectors' teams.
- in processing (considerable grade raising) of low-grade gravity concentrates produced at sluices of refinery plants, industrial centrifugal concentrators of classifying type (KNELSON, FALCON, ITOMAK, etc.), as well as in reprocessing of tailings of jig units and concentration tables and in processing of old tailings in prospectors' teams and at gold recovery plants.
- Most alluvial gold mining done with use sluices results in half gold mined lost in tailings. Most gold particles lost are in sizes from 5 to 100 microns.

Figure D2. Hydraulic Radial Jig (US$8,000–100,000)

http://www.alibaba.com/product-detail/hydraulic-jigging-machine_377929418.html?s=p





Hydraulic radial jigs are widely used on mining vessel at home and aboard as roughly selected equipment to sort ores such as alluvial gold, tin, diamond, tungsten, and hematite.

Hydraulic radial jigs are developed from circular jigs. They are composed of two parts: the drive and the tank. The drive is of the mechanical hydraulic type, powered by a motor. Through a speed-change mechanism, the output shafts of the speed reducer bring along the rotation of the cam, which drives the cyclical alternating movement of every plunger of the drive cylinder to convert electric energy to mechanical energy and then to hydraulic energy. Through hydraulic pipes and all kinds of valves, the movement of the cylinder is driven and the fluctuation of the jig's cone. The tank is of the unit combination type. Every unit consists of three jigs. Every room is equipped with one trapezoidal jig. It can be made circular or fan shaped according to the handling capacity and configuration requirements of the equipment. The advantage of adopting the combination type is its ease of fabrication, transportation, and installation.

Ore dressing by hydraulic radial jigs is capable of handling almost full sizes of mineral materials in addition to very fine material. It features a simple process operation, heavy-duty equipment-handling capacity, with final products obtained through one-time separation. Therefore, it has found a wide application in production. It is regarded as one of the main means to process metallic ores such as iron and manganese ores of coarse, moderate, and fine sizes and has found significant use in beneficiating tin and tungsten ores. Moreover, the jigging method also can achieve a good result in processing primary ores bearing gold, tantalum niobium, titanium, zirconium, and chrome and sand stones.

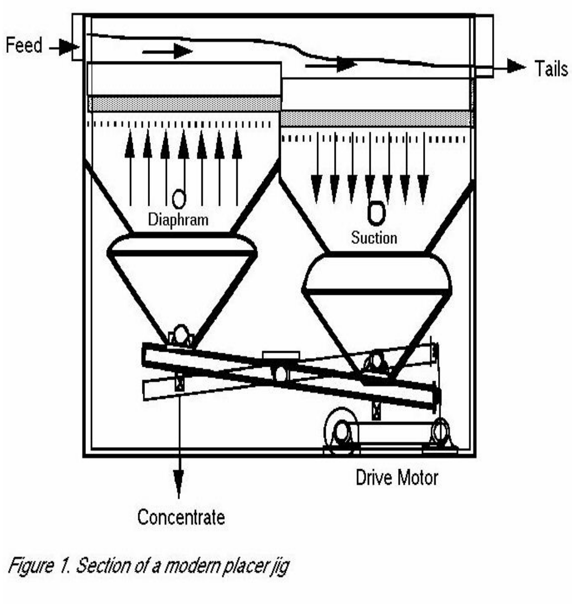
The greater the density of the minerals to be separated in ores, the wider the range of the feed sizes. For a gold-bearing placer, when the feed grain size is less than 25mm, separation may be carried out without size classification with the lower limit of recovery up to 0.05mm. For ordinary metallic ores, size-classified separation is conducted to effectively improve indexes for separation and to enhance the handling capability of the equipment.

Table D1. Technical Parameters

Model	Area (m^2)	Stroke (mm)	Times of stoke (r/min)	Feed size (mm)	Capacity (t/h)	Power (KW)	Weight (T)
DYTA7750-3 PYTA7750-3	9.9	20-30	0-90	<25	50–75	5.5	6
DYTA7750-4 PYAT7750-4	13.2	20-30	0-90	<25	66–100	7.5	7.5
DYTA7750-6 PYTA7750-6	19.8	20-30	0-90	<25	100–150	7.5	12.5
DYTA7750-8 PYTA7750-8	26.4	20-30	0-90	<25	132–197	11	16
DYTA7750-9 PYTA7750-9	29.7	20-30	0-90	<25	150–220	11	17.5
DYTA7750-12 PYTA7750-12	39.6	20-30	0-90	<25	220–300	15	21
DYTA7750 type (electromagnetic stepless adjustment). PYTA7750 type (belt variable wheel speed)							

Figure D3. Hydraulic Mineral Separator Jig Machine for Mineral Separation (US$2,000–8,000)

http://www.alibaba.com/product-detail/Hydraulic-mineral-separator-jig-machine-for_650886828.html?s=p



Structure of side way action diaphragm jig (also called an up way action diaphragm jig): the double compartment side way action diaphragm jig is composed of two jigging chambers connected with each other with a certain difference. The structure of each chamber is the same, consisting of framework, driving and moving mechanism, jigging chamber, and pyramid bottom box.

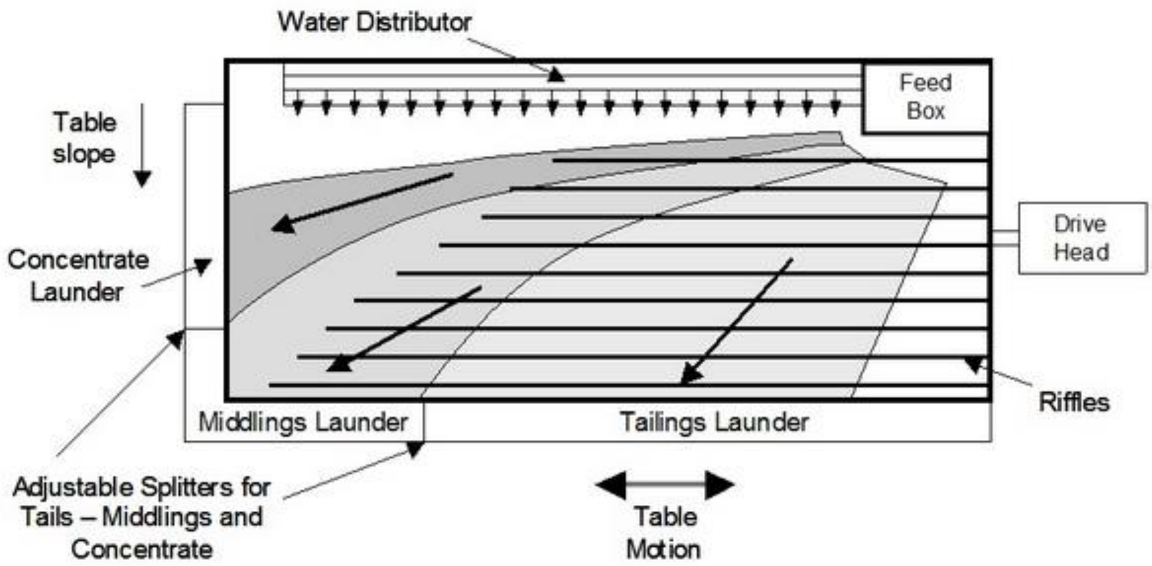
The working process of the double compartment side way action diaphragm jig: Crude ore is fed to jigging chamber from the first feed launder. The diaphragm produces vertical alternating current under the action of the eccentric link mechanism, which makes the ores separate according to their density. The principle is the same as the previous mechanism.

The diaphragm jig has double rooms under the single plug-fuse type. It makes use of water as medium, and separates according to the proportion of the gangue minerals (density). It is the beneficiation equipment. The jig machine does the sine wave motion. It has the advantage of high recovery, large capacity of treatment, and continuous operation. It is widely used in processing tungsten, tin, antimony, mercury, alluvial gold deposits, manganese ore, barites, fluorite, lapis lazuli, ore, pyrite, limonite, and ore dressing and hematite, as well as all kinds of smelting slag metal recycling. Since this machine is small, it can also be used as a test machine in a laboratory.

Table D2. Technical Specification

Model	Size of supplying minerals (mm)	Output (t/h)	Washing times (r/min)	Regulation limits of rout (mm)	Density of supplying mineral (%)	Measure of additional water(t/h)	motor		Dimension (L*W*H) (mm)	Weight (kg)
							Model	Power (kw)		
300*450	1~12	2.1~6.1	322~420	0~25.3	15~50	2.1~3.8	Y90S-4	1.1	1290*1270*1750	745
400*600	<=10	2~5	76.7~767	0~18	15~50	2.1~5.4	TZT222-4	1.5	996*1263*1789	500
600*900	<=10	2~5	300	0~25	15~50	2.1~6	Y112M-6	2.2	1638*1230*2148	1400

Figure D4. Shaking Table

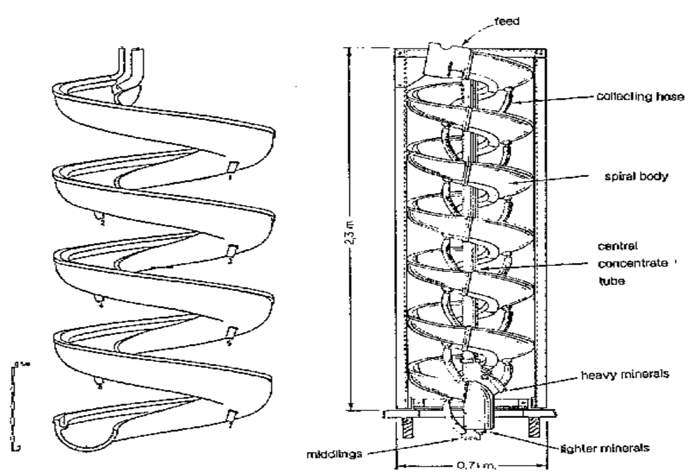


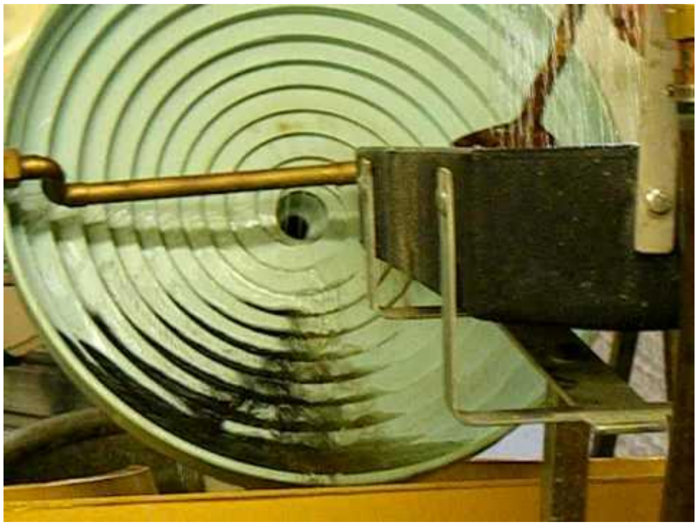
Shaking tables, also known as wet tables, consist of a sloping deck with a riffled surface. A motor drives a small arm that shakes the table along its length, parallel to the riffle and rifle pattern. This longitudinal shaking motion consists of a slow forward stroke followed by a rapid return strike. The riffles are arranged in such a manner that heavy material is trapped and conveyed parallel to the direction of the oscillation (see Figure D4). Water is added to the top of the table perpendicular to the table motion. The heaviest and coarsest particles move to one end of the table while the lightest and finest particles tend to wash over the riffles and to the bottom edge. Intermediate points between these extremes provides recovery of the middling (intermediate size and density) particles.

Shaking tables find extensive use in concentrating gold but are also used in the recovery of tin and tungsten minerals. These devices are often used downstream of other gravity concentration equipment such as spirals, reicherts, jigs, and centrifugal gravity concentrators for final cleaning prior to refining or sale of the product.

Figure D5. Spiral Concentrators (US$3,000–100,000)

http://www.alibaba.com/product-detail/Gold-Recovery-New-Spiral-Concentrator_60035258902.html?s=p





The Spiral Separator is a new equipment representing the domestic advanced level, successfully invented by Beijing General Research Institute of Mining and Metallurgy.

Spiral separators are made of high-quality polyurethane with fiberglass banking and a wearable corundum inner surface. Generally, there are five turns in one start and four starts in one column. They can be used for mineral particles sized from 0.02 to 0.3 mm, with processing capacity from 2 to 4 t/h per column. Four or six columns can be joined to form a bank with distributor on the top to suit capacity requirements.

The advantages of the Spiral Separator are that it has a small footprint, without power; it is moisture proof, anti-rust, wear proof, anti-corrosion, makes no noise, and is suitable for different feeding particle sizes. It is especially useful for concentrating sand ore in beach, riverside, seashore, and stream.

The Spiral Chute works by the force of water flow, gravity, inertial centrifuge, and friction. Slurry is pumped to the top of the spiral, and it enters a feed distributor that evenly distributes the feed to each spiral concentrator. The design and shape of the spiral make it work, when combined with gravitational acceleration. As the slurry travels the spiraling path down the spiral, mineral grains settle and start sorting by size, density, and, to a lesser extent, shape. Low-density particles are carried with the bulk of the water toward the outside of the spiral, while particles with the greatest density migrate toward the inside of the spiral.

It is applicable for the separation of granularity ranging from 4mm to 0.02mm metallic minerals such as iron, ilmenite, chromite, tungsten-tin ore, niobium-tantalum ore, gold placer, seashore monazite, rutile, and zircon, as well as other metallic and non-metallic minerals with adequate difference of specific gravity. For the seaside, riverside, sand beach, the stream of placer mining, it is the best equipment of all.