

THE DEVELOPMENT AND MANAGEMENT OF WATER RELATED TECHNICAL “PARTNERSHIPS” WITHIN THE DEBSWANA DIAMOND MINING COMPANY

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ABSTRACT

The Mining Industry experiences great peaks and troughs in its development- in times of boom, both Contracting and Consulting services are hard to come by and in times of depression, Contractors and Consultants alike often find it difficult to sustain their businesses. In 2006, the Debswana Diamond Mining Company (Debswana) embarked on a venture, which over two years, resulted in successful Strategic Technical Partnerships being developed in the fields of Groundwater, Mine Dewatering and Depressurization, Water Conservation for mine waste residues and Drilling for the entire Groups operations. Effective and efficient water use is absolutely crucial to the current and future operations of Debswana. For this reason, these significant “mine – water” partnerships were developed to enable continuity, consistency, reliability, sustainability and cost effectiveness and to provide for best practice in water management and to ensure that water supply and mine dewatering were never a production constraint and that these issues were removed from Debswana’s mine risk log – e.g. At Orapa, recently, water supply, has dropped out of the top 10 mine risk log. This paper describes the various methodologies applied in choosing and developing the various partnerships described above and the mechanism adopted to manage them. The advantages of such “Win – Win” partnerships within the Mining Industry - technical, commercial and environmental, are also demonstrated and are proposed as a model for other mining houses to adopt.

1. INTRODUCTION

Debswana is a 50/50 joint venture between the Government of Botswana and De Beers. It owns and operates four diamond mines and one coal mine in Botswana (Figure 1), the latter very important, since it is embarking on considerable increases in production which will significantly increase their current water demands:

- 1) **Jwaneng Mine** – One Open pit, DK2, currently down to +300 meters below ground level (mbgl)
- 2) **Letlhakane Mine** – Two Open Pits, DK1 350 mbgl, DK2 at 80 mbgl
- 3) **Orapa Mine** – One large pit, AK1, currently down to +200 mbgl
- 4) **Damtshaa Mine** – Two small pits, BK9 and BK12, both down to 80 mbgl.
- 5) **Morupule Colliery** – Shallow, Underground coal mine, max depth 110 mbgl.

The Morupule colliery’s proposed strategy to implement the expanded plant has water conservation as a very high priority in its design.

Figure 1 shows the location of the Debswana operations. There are four main areas where water features in Debswana Group operations, namely:

- Water resources development from wellfields which provide for the bulk of water supply for domestic and mine plant requirements at all operations
- Pit dewatering and drainage for pit stability control and depressurization.
- Water in current mine treatment processes and the development of new water conservation methods which are critical to the overall water management strategy
- Protection of water sources and resources from the environmental impacts of mining activities.

Incorporating the above requirements, Debswana produced a Water and Residue Strategic Management Plan in 2005 (Busani, 2005a).

Botswana has a generally semi-arid climate, with a high variability in rainfall in both time and space, ranging from



Figure 1. Location of Debswana Mines

250 mm/yr in the South East to 650mm/yr in the North West. Open water evaporation rates are in excess of 2000mm/yr and there are recurrent droughts. In 2006, the total national water use was 88.3 Mm³/ yr with Debswana operations accounting for 25.6% or a total of 22.6 Mm³/ yr.

It is estimated that there are as many as 25,000 operating boreholes in Botswana and 60% of the total population is supplied by groundwater. It is also predicted that global climate change will have a significant impact on Botswana, with temperature increases of between 0.2 – 0.5 degrees Celsius per decade, raising already high evaporation rates and generally reducing stream flows in the eastern and northern parts of the country. This will also decrease the levels of aquifer recharge. Botswana, by definition, is a water stressed country and a general increase in urbanisation will place further stress on meeting demands for water. It is important to understand and plan for that low rainfall and recurrent droughts are the default climatic regime in Botswana. The current national water demand is 88.3 Mm³ yr, rising to a predicted 186.5 Mm³ yr by 2036 (SMEC & EHES, 2006a). Debswana is a key stakeholder in Botswana's national water resources and in 2006, sponsored a special Master Plan Review study into the Optimisation of the Water Resources of Botswana with a view to supplying Orapa and Jwaneng Mines (SMEC & EHES, 2006b). The largest water source is groundwater, the majority of which is brackish or saline. In some areas of Debswana operations, there are also competing users and comprehensive groundwater monitoring systems have been installed at all wellfields in order to assess impacts locally and regionally.

Open pit mine stability control is by means of dewatering and depressurization. A total of 84 dewatering production boreholes pump an average 3.66 Mm³ yr from depths of up to 500 mbgl. In addition, an average 3.35 Mm³ yr is

pumped from pit sumps in order to dewater the passive inflows. Dewatering takes place largely by means of ring systems of pit perimeter and, to a lesser extent, in-pit dewatering boreholes, shallow interceptor boreholes, angled drain holes and sump pumping. Storm water is diverted by trenches and channels around the pit perimeters. Using almost one quarter of the nation's total water demand, Debswana needs to be accountable and strives to be a leader in implementing world class standards of water resources management in the country.

Dewatering and slope depressurization are regarded as an integral part of all safe mining operations and, at Orapa Mine, a mine dewatering system was established as early as 1982 with the drilling and equipping of seven dewatering boreholes down to depths of 200m. With mining operations now going deeper and deeper, dewatering boreholes have had to be completed at much greater depths and at larger diameters in order to abstract larger volumes of water. At Letlhakane Mine, seven "ultra-deep" dewatering boreholes have been drilled between 2005-2006, up to a maximum depth of 508 mbgl and with maximum yields of 60m³/hr.

2. STRATEGIC TECHNICAL GROUNDWATER PARTNERSHIP

In 2007, a Strategic Technical Partnership for Groundwater (SGTP) Management, in particular, wellfield resources development, was signed by Debswana for all its operations in order to ensure that the Nations water resources are developed in a sustainable manner (Busani, 2005b).

Orapa, Letlhakane and Damtshaa (OLD) Mines are situated in the centre of Botswana and are totally reliant on groundwater for their water supply. The groundwater is supplied from five wellfields and five open pit dewatering ring systems located around the OLD mines. The Jwaneng Mine is situated in the south eastern part of Botswana and is also totally reliant on groundwater for all its water supply purposes. The groundwater is supplied from the Jwaneng Northern wellfield situated approximately 55km to the north of the Jwaneng Mine.

Morupule Colliery is situated near Palapye in the central District and is currently reliant on groundwater. It is expected that Morupule will be expanded to increase coal production from 1M tons to 4M tons per annum in the next three years. The situation at Morupule is not considered critical at this stage, but should not be ignored as the whole country is facing a water shortage.

As part of the implementation of the Debswana Water and Residue Strategic Management Plan, a SGTP was required to assist Debswana operations with groundwater management to enable continuity, consistency, sustainability and cost effectiveness. This partnership would provide best practice in water management and would help to ensure that water supply is never a production constraint and is removed from the Debswana Mines risk log. During its first year of operation (Water Surveys Botswana, 2008), the partnership concluded 14 separate groundwater resources projects and many other related tasks. The work was completed at very competitive rates and the continuity of the required services enabled the Consultant to plan ahead and build capacity.

The partnership has assisted Debswana with overall groundwater supply and management in order to meet the requirements as set out in the Debswana water & residue medium to long-term strategic management plan (Busani, 2005a) as well as to address the shortcomings stated in the review of the groundwater information for the past 25 years conducted in 2004 and concerns from the Debswana Hydrogeologists and Management in general.

As highlighted in the Debswana Water and Residue Medium to Long Term Strategic Plan, due to the ever increasing demand for water in the Debswana operations and the country in general, holistic and integrated water management has become strategic and key to sustainable operations and development generally. The complexity and costs of managing the diminishing water resources is ever increasing and therefore a sound and competent strategic partner was required to assist Debswana to manage its water resources in a sustainable manner in line with international best practice.

The envisaged negative climatic changes that will result in less rainfall in the southern regions of Africa coupled with negligible groundwater recharge and increasing demand for water will inevitably result in a progressive deterioration of both water quantity and quality. Therefore protection and conservation measures need to be intensified. This can only be done when there is clear technical understanding of the dynamics of all water resources especially groundwater and an effective management system of these resources.

The objectives from the Debswana Medium to Long Term Strategic Management Plan were further developed and enhanced to form the basis for terms of reference for the SGTP. These were then used as the basis for inviting tenders to enable Debswana to appoint a SGTP to forge a long term win-win partner relationship. A process of pre-qualification of Botswana based groundwater consultants was undertaken during 2005 and three Consultants were short listed and invited to tender in 2006, based on the following major inputs: Company Profile, Staffing Resources, Capacity Capabilities, Partnership outsourcing / sub-contracting, Commercial offer (hourly professional fees fixed for the first 12 – months of the two year partnership contract, with possibility of fees increase in the second year and contract extension after two years). The SGTP was appointed to assist Debswana as set out in the following categories in order to satisfy the objectives of the medium to long term water and residue strategic management plan as stated above.

- Groundwater Data
- Impact on Private boreholes
- Groundwater Quality
- Aquifer development, management and maintenance
- Groundwater modelling
- Technical investigations
- Regional Involvement
- Groundwater education and awareness
- Identify and evaluate borehole drilling specialists

The technical partner's developed scope is as follows:

- a. Conduct groundwater modelling to ensure that information on groundwater availability is updated annually and that the level of confidence on the information is improved on an ongoing basis.
- b. Ensure that the existing well fields are fully understood, developed and that legal, environmental and planning considerations are taken into account during the life cycle of each aquifer development.
- c. Assist with the identification of alternative future water sources for Debswana Mines and with desktop trade off studies - with input from the Department of Water Affairs and other affected and interested parties.
- d. Provide information for updating infrastructural requirements including costs of sustainable and consistent supply of water to the mines and townships given the projected demands as per strategic business plans – including advice on infrastructure for treatment of water to meet quality requirements.
- e. Recommend specialist skills required for specific water related work as required including pit dewatering, pollution control and ground water recharge.
- f. Technical investigations and feasibility studies on all areas related to groundwater and water supply to the mines including recharge studies, pollution control, artificial recharge of aquifers etc.

- g. Groundwater management and provision of annual audited reports with recommendations and actions as and when required.
- h. Liaison with the mine and or any consultant appointed by the mine on pit dewatering and the effects of pit dewatering on surrounding wellfields.

3. STRATEGIC TECHNICAL DEWATERING PARTNERSHIP

In late 2007, Debswana decided that a similar technical partnership was required for a high level Consultancy specialised in mine water control, dewatering and pit slope depressurization. The partnership would run for a period of 2 years, after which, it would be reviewed for possible extension.

The Strategic Mine Dewatering Technical Partnership's (SMTDP) scope includes provision of independent strategic reviews and full technical support at a higher level for all the Debswana operations (Brook, 2008a). The strategic technical partnership was established in order to conduct the following work for all Debswana operations.

- Joint strategic planning
- Interactive operational planning
- Dewatering
- Slope depressurisation
- Water supply (open pit environment)
- Design of monitoring and aquifer / rock mass analysis instrumentation
- Development of hydrogeological monitoring systems in cooperation with geotechnical monitoring programs
- Development of conceptual hydrogeological models
- Liaison, cooperation collaboration with local Botswana Water Consultants engaged in low-mid level mine dewatering / depressurization activities for Debswana
- General Training for various aspects of the applied methodology
- Predictive modelling and training to Debswana Hydrogeologists and Geotechnical Engineers
- Database support
- Engineering of pumping equipment
- Environmental and reclamation planning
- Instrumentation of the pit slopes
- Development of a practical approach to digital modelling and provision of regular outputs of predicted pore pressures and water levels in relation to targets and the mining plan
- Input of pore pressures into geotechnical models
- Develop a close working relationship with geotechnical, hydrogeological and mining staff groups at the various operations.
- Set pore pressure targets to meet slope design criteria

The exact work program to be followed for each operation was submitted by the technical partner as an inception study which was required to be submitted for each operation by the end of the second month of commencement of the partnership contract. The inception report (Golders Africa, 2008) contained a detailed work program and Gantt chart of activities and responsibilities for each of the Debswana operations. Once the inception report had been reviewed by the client, a program of work would be put in place and the following partnership approach would be followed:

- Six monthly review
 - Update strategic plan, goals and timing
 - 12-month rolling detailed work plan
- Support of operations
 - Field support for technical installations
 - Data interpretation
 - Interactive short term planning
- Digital Modelling – jointly with Debswana staff
- Field training and technical courses
- Other aspects as required
 - engineering
 - environmental

Based on the general scope of services outlined above, it is expected that the SMDTP shall undertake the following detailed activities at all of the Debswana diamond operations and shall assess the need, early on, for any immediate inputs required at Morupule colliery. Table 1 below provides a definition of the various "levels" of consultancy required for Mine Dewatering and Depressurization at Debswana's operations.

4. STRATEGIC WATER & RESIDUE TECHNICAL PARTNERSHIP

The Debswana Water Optimisation Study objective is a major (50%) reduction in water used in processing from 2003-2008 through adopting an Integrated Water Resources Management approach (Mbada, 2007).

Since 2005, Debswana have committed significant resources to the development of a new water management strategy. Its vision is a finished residue that minimises new water intake and which is deposited in a safe, environmentally acceptable and cost effective manner over the next 25 years. It is focussed on the following main areas:

- Water sources and water resources management
- Residue disposal
- Disposal Rehabilitation and closure
- Research & Development
- Stakeholder Management

Table 1. Levels of Mine Dewatering Consultants Inputs

| ACTIVITY | LEVEL OF CONSULTANCY |
|--|---|
| On site routine monitoring | Low –local (Botswana) consultant / Debswana |
| Drilling, test pumping, other hydrogeological investigations etc | Low – Mid – local consultant / Debswana |
| Data analysis & Conceptual Modelling | Mid local consultant in cooperation with high level partner |
| Digital modelling for mine dewatering and depressurization | High Level Partner |
| High level dewatering / Depressurization analysis, review, | High level Partner |

The strategic objective is to have enough water to satisfy all of Debswana’s production and domestic water requirements for life of the respective mines and that all water from all sources will be used in a responsible and sustainable manner. There is no doubt that the Debswana Group is faced with considerable challenges in meeting the requirements of its own strategic plan for water & residue management and its objective of a 50% reduction in ore process water used per ton of head feed treated by the end of 2008, but results shown below are extremely encouraging, with a 36% reduction across the operations to date (Figure 2).

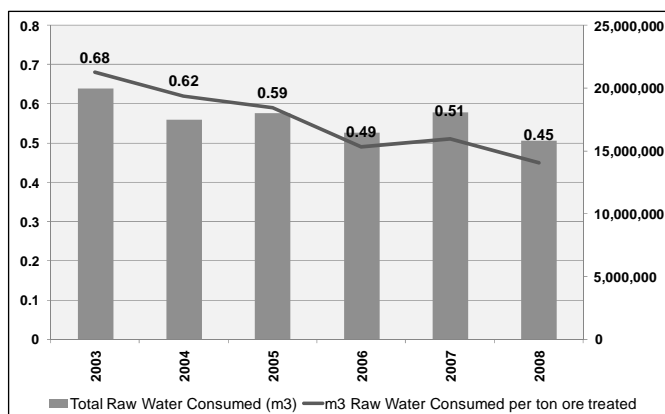


Figure 2. Raw Water Use per ton ore treated 2003-2008

Table 2. Debswana Water Conservation Targets (m³ per m³ per ton ore treated)

| PLANT | m ³ new water per ton treated 2003 | m ³ new water per ton treated 2006 | m ³ new water per ton treated 2008 Target |
|------------|---|---|--|
| JWANENG | 0.92 | 0.63 | 0.64 |
| ORAPA No 1 | 0.40 | 0.37 | - |
| ORAPA No 2 | 0.60 | 0.59 | 0.45 |
| LETLHAKANE | 0.21 | 0.18 | - |
| DAMTSHAA | 0.33 | 0.32 | - |
| MORUPULE | 0.03 | 0.0325 | - |

The strategic water and residue partnership, which was signed in 2007, was to focus on a slimes dewatering Technology Roadmap (Busani, 2005c) for Debswana in which several water saving technology concepts were to be studied in order to fulfil the long-term water saving objective and Debswana strategic vision of “a finished residue product that minimises new water intake and is deposited in a safe, environmentally acceptable and cost effective manner”. A platform was established from which new research and development projects could be initiated and progressed.

The objective is to reduce water consumption on Debswana Mines by 50 % by 2008. This was to be achieved through optimisation of the current processes and paste thickening. It was also proposed that beyond 2008 new technologies must be developed to further reduce water by another 50 % by 2013. Overall group water demands have decreased over the last 5 years, despite significant increases in production (Figure 3).

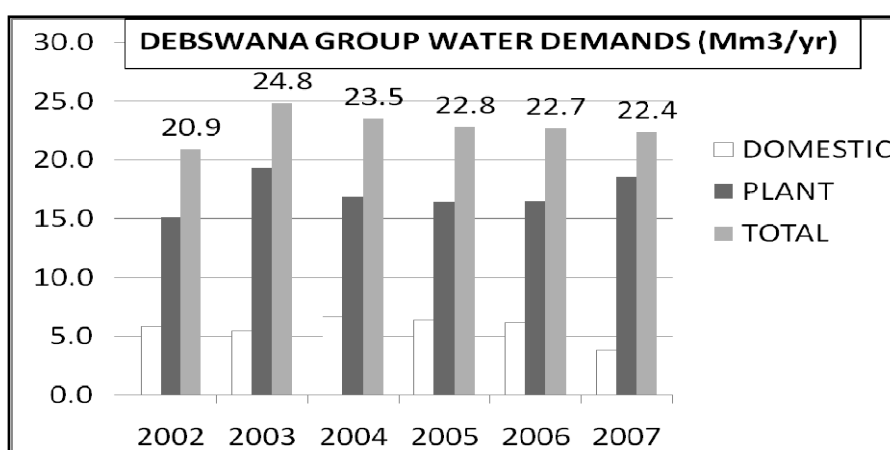


Figure 3. Total Debswana Group Water Demand (2002-2007) – Mm³/yr

This partnership is aimed at finding the most cost effective technology that will reduce process water consumption to a technologically feasible minimum (Paterson and Cooke, 2007). The partnership was strengthened even further with Debswana hosting its first ever International Conference – “Paste 2008” in Kasane, Botswana. Quality and environmental issues are also important for the management plan. Water quality must meet the respective Botswana Bureau of Standards limits and residue and waste disposal has to be handled in an environmentally acceptable manner in order to meet Debswana’s vision of a “global benchmark operation”. Debswana will work with identified technology suppliers, partners and research institutions until a suitable solution is identified, tested, proven and applied. In doing this work, citizens and local institutions will be meaningfully engaged in finding solutions in order to build ownership, capacity and expertise in the identified technologies.

5. STRATEGIC DRILLING TECHNICAL PARTNERSHIP

Currently , Debswana lets numerous drilling contracts each year for all types of boreholes to be drilled at varying depths and diameters, including for geological, geotechnical, ore evaluation, resources delineation, pit dewatering / depressurization, water supply wellfields and environmental (e.g. pollution control and monitoring) purposes. The 2006-2008 situation of the boom in the development of the mineral resources sector has meant that there was intense competition for drilling resources locally, regionally and internationally. For Debswana, this often results in delayed project delivery, extended tenders preparation and difficult management, shortage of resources and ultimately, costly projects to complete e.g. duplication of resources during mobilization to site etc. This current situation is inefficient and

costly and is no longer acceptable to the Debswana Group and there is now a great opportunity to develop a Strategic Drilling Partnership (SDP) between a drilling consortium and Debswana to meet virtually all of Debswana's drilling requirements in an efficient and cost effective way (Brook,2008b). Such a close partnership will enable continuity, consistency, sustainability and cost effectiveness. Additionally it will provide for best practice in drilling activities and to ensure that water supply, pit water control etc. will not be a constraint to production, subsequently removing it from Debswana's mine risk log. The duration of the drilling partnership proposed is fixed at three years, with a possibility to extend the partnership for a period of two additional years.

A grand total of 162 km of drilling is anticipated over the three year period, however, it has been agreed that approximately 90% of this, or 146 km will be assigned to this drilling partnership contract. The remaining 10% or so will continue to be tendered by normal Debswana tender process. The drilling partner shall not be eligible to tender for this remaining 10%. This drilling component, excluded from the drilling partnership, shall be for only percussion drilling, normally water supply or dewatering production boreholes at any of the operations.

Table 3 shows a summary of the types of work which currently requires drilling in one form or another at the Debswana operations. Various types of drilling are required as follows:

- Medium and large diameter vertical dewatering production & monitoring boreholes, varying in depth from 250m-600m, and at diameters ranging from 6 to 12-inch completions
- Medium depth well field production boreholes at 8-12 inch completion to depths of 350m
- Core drilling for ore evaluation, geotechnical investigation and hydrogeological testing – normally HQ/NQ size, or any other size specified. Geotechnical and ore evaluation borehole depths go down to 1000m.
- Horizontal drain holes, usually cored at HQ/NQ, or any other size specified / percussion at 4-inch diameter ranging from 100 -300m lengths
- Angled drain holes at 5 degrees to 45 degrees and at lengths required of up to 300m
- Small and large diameter (up to 23-inch) bulk sampling
- Environmental investigation boreholes, usually small diameter to 100- 200m depth

It is also proposed that Debswana will procure necessary casing and screens for the drilling works and supply to the drilling contractor as per each drilling activity requirement. For the first year, however, the Drilling Contractor shall be asked to supply and install the casing and screen as per the bill of quantities provided. These rates shall be fixed. The Contractor is to supply the whole quantities specified for the first 12-months of drilling. Thereafter it is proposed that Debswana shall procure the casing and screens directly from vendors; this will be reviewed through the first year of drilling.

The partnership shall form one tender document and the contract shall be awarded on the basis of a call – off contract, with basic scopes of work and detailed Bills of Quantities developed and agreed for individual drilling activities at the operations. Scopes detailing the number and type of boreholes to be drilled and completed will be prepared by the operations and provided to the drilling partner, along with a proposed time frame for completion. Site inspections and pre-mobilization meetings will be held at the respective operation as per current procedures.

Figure 4 provides a graph of the estimate of drilling lengths required by all the Debswana Group operations between 2009 and 2011. Diamond drilling constitutes about 76% of the total drilling requirement for the drilling partnership. The majority of the 24% percussion drilling will be for wellfield water supply production and monitoring borehole completions, in the Orapa and Jwaneng region. A total of about 422 boreholes will be required to be drilled in the course of the three year partnership. The estimates of drilling given in this enquiry will be updated on an annual basis during the course of the partnership.

Drilling is required at the following Debswana operations:

- within the current and expanded lease area of Morupule Coal Mine
- The Jwaneng Mine current cut 7
- For Jwaneng Mine future cut 8 & 9
- The Jwaneng Northern (water supply)Wellfield and its expansion
- Saline water investigation for Jwaneng Mine
- Orapa Wellfields 2,3,4,5,6,7,8 and 9 – all water supply wellfields
- Mopipi North (Orapa region) saline water area (new investigation area)
- Orapa Mine AK1
- Letlhakane Mine DK1 and DK2
- Damtshaa Mine BK9 and BK12
- Village Borehole Water Supply (Debswana Corporate Social Responsibility Program)

Table 3. Types of work requiring drilling at Debswana Operations

| Discipline | Types of work requiring drilling |
|--|--|
| Geological | <ul style="list-style-type: none"> • Kimberlite delineation / Ore Evaluation – Core drilling, micro- diamond analysis, Reverse circulation drilling • Large diameter evaluation drilling (bulk sampling) • Detailed exploration and assessment outlier kimberlite pipes e.g.AK20 at Orapa, DK7 at Jwaneng etc. |
| Geotechnical | <ul style="list-style-type: none"> • Confirming our various geotechnical models – core drilling,confirmation of vertical / inclined structures, rock mass characterization and laboratory rock testing sample collection • Geological contact investigations • Rock and slope stability monitoring installations e.g. TDR |
| Hydrogeological -Mine water control | <ul style="list-style-type: none"> • Vertical pit perimeter dewatering boreholes • In-pit dewatering boreholes • Piezometer installations – pore pressure monitoring • In – pit Angled and horizontal drain holes • Shallow pit interceptor / scavenger production boreholes |
| Hydrogeological -Water Resources and Supply | <ul style="list-style-type: none"> • Wellfield water supply boreholes • Wellfield monitoring boreholes • New wellfield assessment and investigations e.g. brackish / saline water resources • Village water supply (Debswana Corporate Social Responsibility) |
| Environmental | <ul style="list-style-type: none"> • General pollution monitoring • Hydrocarbon storage facility monitoring • Hydrocarbon reclamation • Other requirements e.g. EIA |

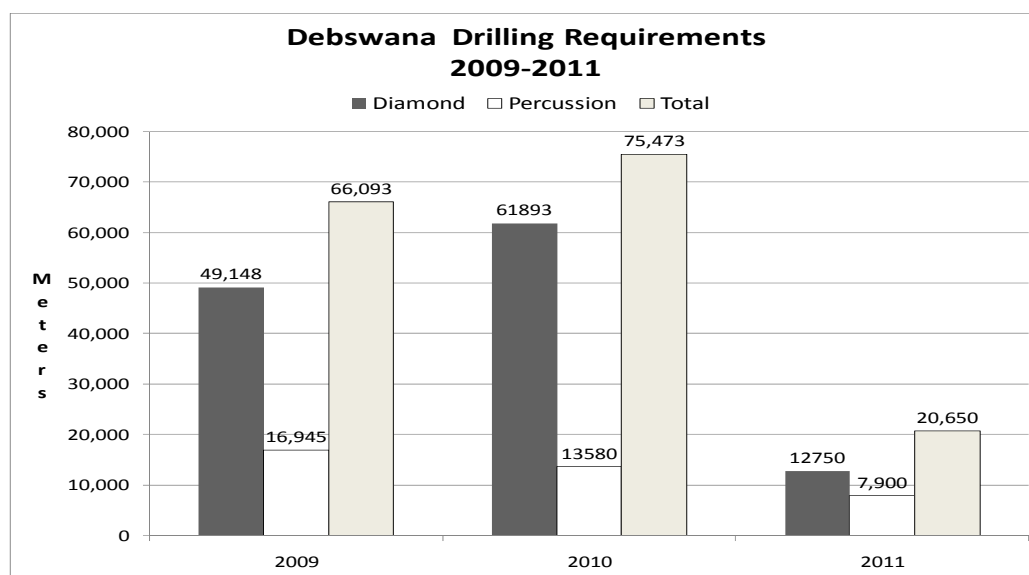


Figure 4. Debswana Drilling Requirements 2009-2011

As such, and given the magnitude and timing / duration of the drill works expected over the next three years, the drilling partner is encouraged to establish bases at the operations in order to facilitate the management of the local drilling requirements and the storage of equipment and materials. As a minimum, the Contractor will be required to establish a base camp with all necessary office requirements at both Orapa and Jwaneng Mines.

6. CONCLUSIONS

Great strides have been made by Debswana in most aspects of Water Resources Management over the last 5 years. The efficient and effective Integrated Management of Botswana’s precious groundwater resources has been facilitated by the development and subsequent management of four significant Mine – Water related partnerships in the fields of groundwater, residue and waste, dewatering / depressurization and Drilling. These “Win-Win” partnerships have benefited both client and private company partner alike and have resulted in continuity, consistency, reliability, sustainability and cost effectiveness and to provide for best practice in water management. Being of sufficient duration, the partnerships have enabled capacity building both in terms of staffing and equipment for the companies involved and have enabled both partners the opportunity of a closer working relationship within which goals and objectives are

shared with equal commitment and rewards. The client has saved considerably on mobilisation, tendering and contract administration costs in all partnerships and the call off nature of the contracts has provided the flexibility required for conducting the various activities.

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