KOUGA DAM REHABILITATION
PROJECT

DESKTOP HYDROLOGY
ASSESSMENT

REPORT
KOUGA DAM REHABILITATION PROJECT

DESKTOP HYDROLOGY ASSESSMENT

REPORT

May 2013

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

<table>
<thead>
<tr>
<th>Verification</th>
<th>Capacity</th>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>By Author</td>
<td>Hydrologist</td>
<td>Phillip Hull</td>
<td></td>
<td>29/05/2013</td>
</tr>
<tr>
<td>Checked by</td>
<td>Senior Hydrologist</td>
<td>Professor Jeff Smithers</td>
<td></td>
<td>29/05/2013</td>
</tr>
<tr>
<td>Authorised by</td>
<td>Executive Associate</td>
<td>Magnus Van Rooyen</td>
<td></td>
<td>29/05/2013</td>
</tr>
</tbody>
</table>

Prepared for:

GIBB Pty (Ltd)
2nd Floor, Greyville House
Cnr of Greyville & Cape Rd
PO Box 63703,
Port Elizabeth, Greenacres 6057

Tel: 041 392 7500
Fax: 041 363 9300

Prepared by:

Jeffares and Green
John Jeffares House
6 Pin Oak Ave
Hilton
3201

Tel: 033 343 6700
Fax: 033 343 6701
# TABLE OF CONTENTS

1 INTRODUCTION .................................................................................................................. 2
2 SITE DESCRIPTION ............................................................................................................. 3
3 HYDROLOGY ......................................................................................................................... 6
   3.1 Potential Alluvial Mining Impacts – Scour ................................................................. 6
   3.2 Potential Alluvial Mining Impacts – Sediment Transport ............................................ 8
4 CONCLUSIONS AND RECOMMENDATIONS .................................................................. 10
5 REFERENCES ....................................................................................................................... 12
1 INTRODUCTION

Jeffares & Green (Pty) Ltd have been appointed by GIBB (Pty) Ltd to undertake a hydrological desktop assessment of the potential impacts of the planned alluvial mining activity downstream of the Kouga Dam wall, located approximately 36 km east of Humansdorp in the Eastern Cape. It is planned that the mining activity will provide fill and road construction material for the rehabilitation of the Kouga Dam wall and upgrade of the access road. It is anticipated that the post-mining cavity, below the dam wall, will serve as a stilling basin for the dam, reducing the impacts of flooding to the downstream environment.

It is expected that the Kouga Dam wall rehabilitation and road upgrade will require approximately 315 000 m$^3$ of coarse and fine material aggregate, all of which is anticipated to be supplied by the alluvial mining activities below the dam wall. The mining footprint is anticipated to be 1 200 m long by 120 m wide by 3 m deep. The expected mining process is as follows:

- The identified area to be mined will be fenced off for security and safety reasons. Access will be strictly controlled, including access to the stock piles.
- Topsoil will be stripped away and stockpiled on the upstream side of the mining area, outside of the riverine system.
- The area to be mined will be sub-divided and systematically mined in portions.
- Seepage water entering the mined area will be pumped into settling ponds prior to being allowed to drain into the river downstream of the mine.
- Mined materials will be transported to a crushing plant located outside of the watercourse via excavators and loaders. The aggregate stockpile will also be located outside of the water course.

The objective of this desktop study is to highlight potential negative impacts of the alluvial mining activities on the downstream riverine system. The potential negative impacts assessed included scouring and changes in sediment transport.
2 SITE DESCRIPTION

The Kouga dam located just upstream of the proposed mining area will have a direct impact on flows of the river to be mined, and therefore forms an integral part of the site description. The Kouga Dam and proposed alluvial mining area are situated in the winter and summer rainfall areas of the Gamtoos valley. The main river running through the valley and which flows through the proposed mining area is the Kouga River. The Kouga River flows through the Langkloof Valley, lying between the Tsitsi-Kamma, Kouga and Winterhoek mountains. After joining up with its main tributary, the Baviaanskloof River, it flows through a narrow gorge, the Kougapoort, through the proposed mining area to its confluence with the Groot River, where after the river is called the Gamtoos River. The contributing catchment area to the Kouga Dam and proposed alluvial mining area just downstream of the dam wall is approximately 3,900 km$^2$. This catchment area consists of 12 quaternary catchments and forms part of the tertiary catchment L8, as presented in Figure 2-1.

The main purpose of the Kouga dam just upstream of the proposed alluvial mining area is flood control, water supply to irrigation schemes in the Gamtoos valley, and water supply to the city of Port Elizabeth. The construction of the Kouga Dam was completed in 1969, and the wall type is a double curvature arch wall with a height of 94.5 m. The dam wall crest is 204 m long and the capacity of the dam is 133 million m$^3$. The design flood used to size the spillway is 4,249 m$^3$/s (1:200 year return period flood event). The spillway consists of two components, namely, a radial gate-controlled chute spillway on the left flank of the dam wall (to allow for draw down in the dam in anticipation of a flood event) and an uncontrolled spillway 64 m above apron level.

The proposed alluvial mining site is located immediately downstream of the Kouga Dam wall, and extends to a point approximately 1,200 m downstream of the wall, as presented in Figure 2-2. The area to be mined is to be approximately 120 m wide and will be approximately 3 m deep.
Figure 2-1  Locality Plan of the Kouga Dam Rehabilitation Project
Figure 2-2  Extent of the proposed alluvial mining area
3 HYDROLOGY

The project site is located on the Kouga River at the outlet of quaternary catchment L82H, but within the quaternary catchment L82J. According to the Water Resources of South Africa 2005 study (WR2005), the Kouga River at the outlet of quaternary catchment L82H receives a Mean Annual Runoff (MAR) equal to 218 Million Cubic Meters (MCM). Details of the quaternary catchments contributing to the Kouga River at the project site are provided in Table 3-1.

Table 3-1 Quaternary Catchment Details

<table>
<thead>
<tr>
<th>Quaternary Catchment</th>
<th>Catchment Area (km²)</th>
<th>Evaporation Zone</th>
<th>Rain Zone</th>
<th>Water Management Area</th>
<th>MAR (MCM)</th>
<th>MAR Depth (mm)</th>
<th>MAP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L81A</td>
<td>332</td>
<td>24C</td>
<td>L8A</td>
<td>15</td>
<td>15.55</td>
<td>53.3</td>
<td>527</td>
</tr>
<tr>
<td>L81B</td>
<td>261</td>
<td>24C</td>
<td>L8A</td>
<td>15</td>
<td>7.34</td>
<td>32.2</td>
<td>428</td>
</tr>
<tr>
<td>L81C</td>
<td>332</td>
<td>24C</td>
<td>L8A</td>
<td>15</td>
<td>10.19</td>
<td>34.3</td>
<td>437</td>
</tr>
<tr>
<td>L81D</td>
<td>308</td>
<td>24C</td>
<td>L8A</td>
<td>15</td>
<td>7.49</td>
<td>26.6</td>
<td>393</td>
</tr>
<tr>
<td>L82A</td>
<td>269</td>
<td>24C</td>
<td>L8B</td>
<td>15</td>
<td>17.71</td>
<td>55.8</td>
<td>595</td>
</tr>
<tr>
<td>L82B</td>
<td>405</td>
<td>24C</td>
<td>L8B</td>
<td>15</td>
<td>36.89</td>
<td>77.8</td>
<td>678</td>
</tr>
<tr>
<td>L82C</td>
<td>362</td>
<td>24C</td>
<td>L8B</td>
<td>15</td>
<td>33.92</td>
<td>79.0</td>
<td>686</td>
</tr>
<tr>
<td>L82D</td>
<td>591</td>
<td>24C</td>
<td>L8C</td>
<td>15</td>
<td>41.54</td>
<td>53.0</td>
<td>578</td>
</tr>
<tr>
<td>L82E</td>
<td>365</td>
<td>24C</td>
<td>L8C</td>
<td>15</td>
<td>24.62</td>
<td>50.7</td>
<td>584</td>
</tr>
<tr>
<td>L82F</td>
<td>169</td>
<td>24C</td>
<td>L8D</td>
<td>15</td>
<td>7.34</td>
<td>33.7</td>
<td>512</td>
</tr>
<tr>
<td>L82G</td>
<td>265</td>
<td>24C</td>
<td>L8D</td>
<td>15</td>
<td>9.36</td>
<td>26.8</td>
<td>472</td>
</tr>
<tr>
<td>L82H</td>
<td>230</td>
<td>26A</td>
<td>L8D</td>
<td>15</td>
<td>6.81</td>
<td>23.0</td>
<td>451</td>
</tr>
</tbody>
</table>

3.1 Potential Alluvial Mining Impacts – Scour

Natural alluvial rivers are constantly in a process of trying to reach a state of equilibrium. The proposed alluvial mining activities are likely to distort the natural quasi-equilibrium state of the Kouga River, and in the process of restoring the equilibrium, either scouring or deposition or both can potentially occur. Generally, the use of fundamental principles of river hydraulics, detailed hydraulic models and mathematical models are required in the analysis of altered conditions of a river due to alterations of its river bed. However, this study is only a high level investigation of potential implications of the planned alluvial mining. No hydraulic or mathematical models have thus been applied.

With the establishment of the alluvial mining activities, the river system will attempt to restore, or move towards, a state of pseudo-equilibrium. The time scales involved for the river system to reach a state of pseudo-equilibrium, once mining activities have concluded,
are usually large, especially when compared to the timescales of the actual mining process. It is therefore very important to understand the hydrological and hydraulic responses to a change in morphological conditions of the river bed, prior to the initiation of the mining process.

In order to assess the potential level of impact of the alluvial mining on scour of the river bed, conditions upstream and downstream of the alluvial mining site need to be accounted for. As presented in Section 2, the alluvial mining area is located directly downstream of the Kouga Dam wall and extends to a point approximately 1 200 m downstream of the wall.

As a result of the Kouga Dam, flows in the Kouga River downstream of the dam are significantly altered. It has been noted that generally, on a day to day basis, there is little to no flows downstream of the dam due to the large quantities of water supplied from the dam for irrigation in the Gamtoos valley. The result of this is that the energy requirements for scour to occur in the river on a day to day basis (excluding extreme events) is limited, and therefore scour is unlikely. However, due to the size of the contributing catchment area (approximately 3 900 km$^2$), the flow rates and associated energy levels of extreme flood events are likely to be significant. It is noted that the Kouga Dam wall has been designed for a flood event equal to 4 249 m$^3$/s. The energy associated with a flood event of even a quarter of that for which the dam wall has been designed will be associated with significant levels of energy, and therefore a high likelihood of scour. The level of scour that will occur during a flood event is dependent on the flow rates and energy levels in the river, the underlying river geology, material of the river bed, as well as the shape of the beginning and end of the mined area. Initially it was thought that the alluvial mining would serve as a stilling basin for the uncontrolled spillway (there is a drop of 64 m from the spillway crest to the apron). It is, however, cautioned that in the event of an extreme flood, scour could occur in a direction upstream of the mined area. This may undermine and/or compromise the integrity of the dam wall. It is therefore suggested that a more detailed study is undertaken to determine a buffer area between the dam wall and where the alluvial mining is not to be undertaken. In addition, it may be found that there is a requirement for stabilisation of the upstream face of the mined area to prevent scouring in an upstream direction.

Located approximately 3 900 m downstream of the proposed alluvial mining area is the confluence of the Kouga and Groot Rivers. It is not likely that the Groot River will have any impact on the proposed alluvial mining area. However, it is expected that any potential
Impacts of scour due to the alluvial mining are likely to be limited to the area between the dam wall and the Kouga River and Groot River confluence.

3.2 Potential Alluvial Mining Impacts – Sediment Transport

There are two dominant types of sediment transport, namely, Bedload Transport and Suspended Load Transport. Bedload Transport is associated with the transport of fine sand through the river system. Suspended solids are normally in low concentrations, with spikes in levels associated with the peak flow periods. The bedload component of the sediment transport is dependent primarily on flow velocities. The role of vegetation and sediment transport are integrally linked. Sediment deposition provides establishment opportunities for vegetation, which in turn retards streamflow velocities. The reduction in streamflow velocity leads to more sediment deposition, thereby perpetuating the cycle. In deeper, faster flowing channels, the bedload moves too fast for vegetation to establish itself, thereby allowing sediments to keep moving down the channel (McCarthy et. al., 1992). Based on these assumptions, a bedload transport equation, dependent of streamflow velocities was developed (McCarthy et. al. 1992). The bedload equation is as follows:

\[ Q = 0.154 \times 3.40 V \]

where:

- \( Q \) = Bedload discharge per unit width of channel (kg.m\(^{-1}\).s\(^{-1}\)); and
- \( V \) = flow velocity (m.s\(^{-1}\)).

Numerous contributing factors can alter the sediment transport dynamics of a system. Such factors relevant to this study include changes in energy dynamics of the river (changes in water flow velocities) as well as changes in vegetation cover on the banks of the river (area in which mining is to occur). Based on the above, the potential for sediment transport will differ between the period in which active mining occurs and that once mining has concluded.

The likelihood of sediment transport during the period in which alluvial mining is underway, is increased. This is due to the fact that during mining activities there will be an increase in fine materials available for transport as there will be less vegetation cover binding soil and fine materials together. This will be especially true for the river banks. However, it should be noted that as per the mining plan, stripped topsoil will be stockpiled outside of the riverine system, upstream of the mining area. This should limit the amount of sediment available for transport. In addition, it is likely that flow in the Kouga River will be limited during the mining
activities, as water is likely to be released to the irrigation canal system rather than through the Kouga River.

Once the alluvial mining has concluded and the banks of the mined area have been rehabilitated and vegetated, it is likely that sediment transport in the Kouga River will be reduced, from what would ordinarily occur prior to mining. This is due to the fact that flow velocities over the mined area will be reduced as a result of the expanded area in which water can flow, as well as the pool of water within the mined area. The pool (area that was mined and will, at a post mining stage, be filled with water) will most likely function as a sediment trap. Sediments trapped in the pool are likely to only be washed downstream during a flood event once flow velocities through the pool are sufficiently increased. It is, however, important to note that the Kouga Dam is effectively a major sediment trap in the Kouga River system, due to the size and length of the dam. The sediments spilling over the dam wall are likely to be limited and therefore the amount of sediment trapped in the mined cavity or “pool” would be negligible. The impact of the alluvial mining on sediment transport, once the mining has been concluded, will likely be a very small reduction in the amount of sediment transported downstream of the Kouga Dam.
4 CONCLUSIONS AND RECOMMENDATIONS

A hydrological desktop assessment of the potential impacts of the planned alluvial mining activity downstream of the Kouga Dam wall was undertaken. The assessment included potential impacts relating to scour and sediment transport. It should be noted that generally the use of hydraulic and mathematical models are required in the analysis of altered conditions of a river due to alterations of its river bed. However, this study is a high level investigation of potential implications of the planned alluvial mining, therefore no hydraulic or mathematical models have been applied.

The following conclusions were formulated, based on the potential for scour of the river bed and mined area:

- The proposed alluvial mining activities are likely to distort the natural quasi-equilibrium state of the Kouga River, and in the process of restoring the equilibrium, scour is likely to occur.
- The scour will, however, be limited to times where there is sufficient flow and therefore energy in the system i.e. flood events.
- The potential for scour as a result of the mining activities are likely to be limited to the area between the Kouga Dam wall and the confluence between the Kouga River and Groot River.

Based on the assessment of changes in sediment transport as a result of the mining activities, the following is concluded:

- Sediment transport around the mining area to the downstream environment is likely to increase during the alluvial mining activities. This is due to the inherent disturbances of the river bank and increase in the fine materials available for transport.
- Sediment transport from the mining area to the downstream environment is likely to decrease slightly once mining has concluded. This is due to the fact that the mining cavity will serve as a sediment trap during low flows. It should, however, be noted that sediment in the Kouga River downstream of the dam wall is limited due to the Kouga Dam serving as a sediment trap in itself.

It is recommended that a more detailed hydraulic and geotechnical study is undertaken on the potential for scour, especially in the area directly below the Kouga Dam wall. It is anticipated that these studies will determine a buffer area below the dam wall in which alluvial mining should not occur and determine if the upstream face of the mined area will
require stabilisation to prevent upstream scour. These studies will ensure that the integrity of the dam wall is not compromised during flood events due to scour.
5 REFERENCES
