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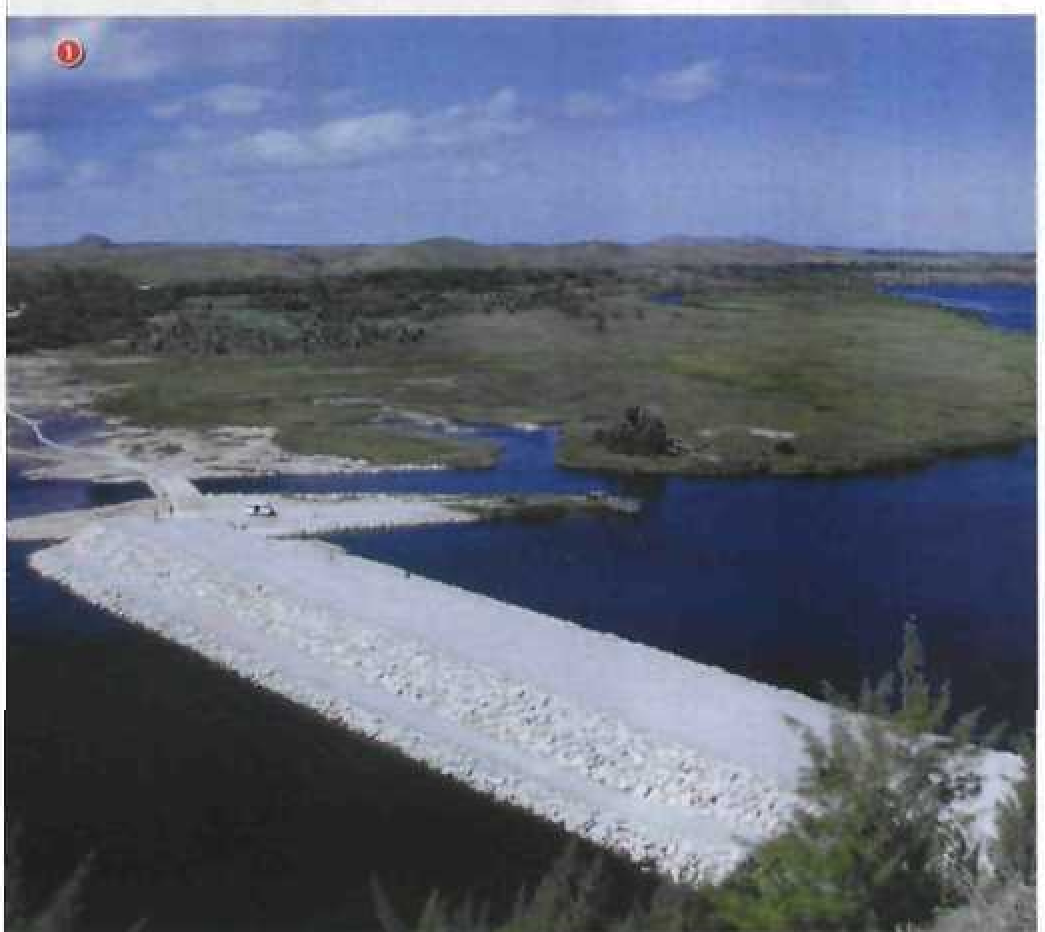
Madagascar

Mandena Mine Salinity Control Weir



MANDENA MINE SALINITY CONROL WEIR, MADAGASCAR

WINNER - International Projects category

KEY PLAYERS

Client Rio Tinto

Consultants SSI Engineers and Environmental Consultants, Mandena Joint Venture (Hatch / Flour)

Main contractors Colas Madagascar

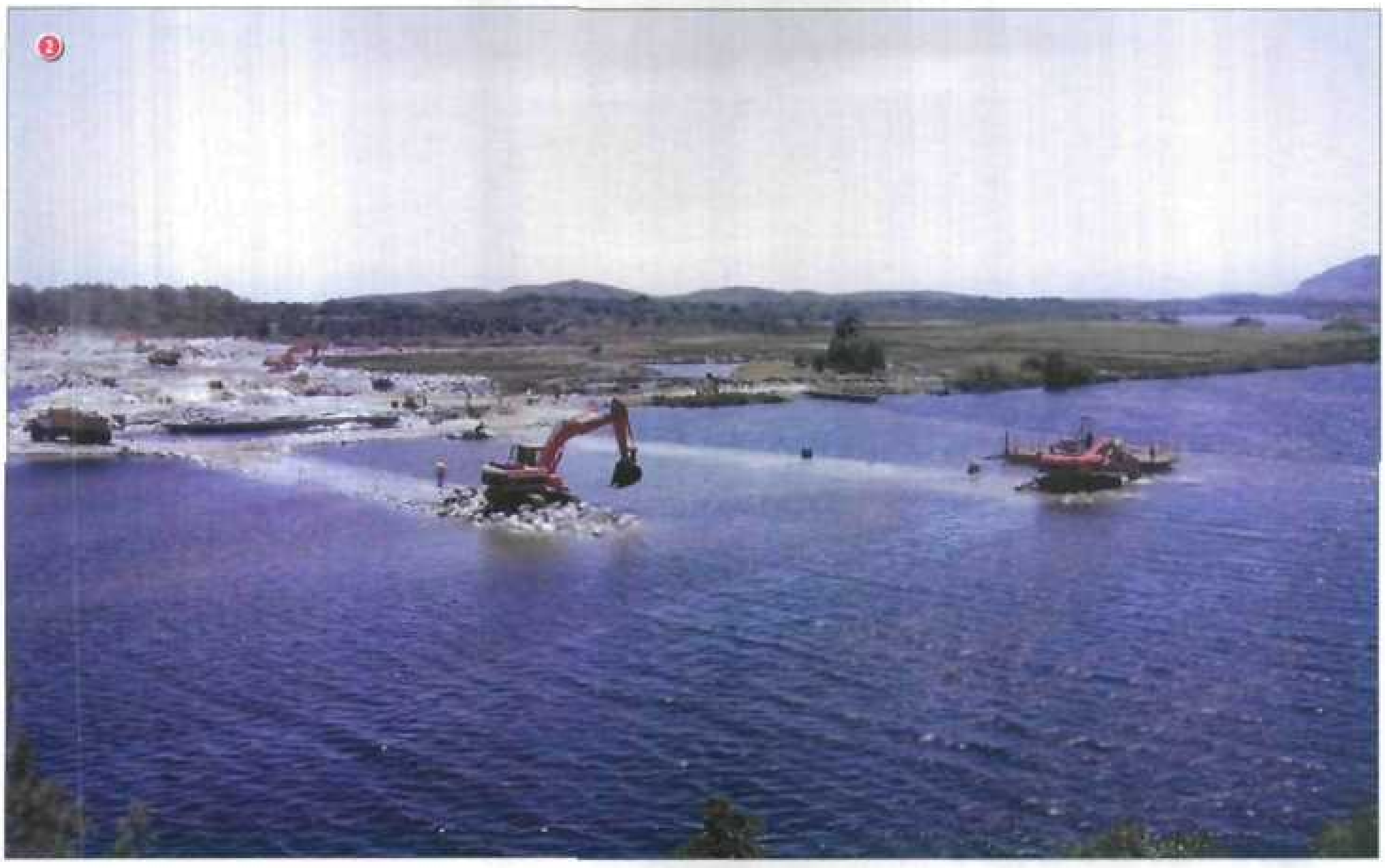
Major sub-contractors & suppliers Genmac – gate manufacturer, Kentz – gate installation

INTRODUCTION

Rio Tinto recently commissioned its Mandena mine, situated about 10 km north of the small town of Tolagnaro in southern Madagascar. The mine extracts titanium dioxide from mineral sands using the water-intensive dredge-mining process. This requires up to 20 Mℓ of water per day.

The mining site is located approximately 5 km from the sea and is bordered by rivers and shallow estuarine lakes. Water resources studies done by SSI Engineers and Environmental Consultants confirmed that the saline lake system fed by the rivers would supply adequate water for mining. However, the environmental impact of dredge-mining using saline water is unacceptable. Therefore it was decided that a low level salinity barrier should be provided at a downstream site on the Anony River to prevent tidal flows upstream into the lake system, but allowing normal rainfall and flood events to pass with minimal increases in flood level.

SSI was tasked with the detailed design and supervision of the salinity control weir. The environmental impact assessment and monitoring was performed by the on-site environmental team of QIT Madagascar Minerals (QMM). Engineering, procurement and construction management of the project was carried out by a joint venture of Hatch and Flour (Mandena Joint Venture). Eventual construction of the weir was undertaken by Colas Madagascar, with 3CR12 gate fabrication and installation by Genmac and Kentz respectively.



DESIGN CHALLENGES

General weir arrangement

The basic concept for the salinity barrier, to be erected just downstream of Lake Ambavarano, was a wide spillway on the left bank, excavated in a rocky outcrop, and a rockfill weir embankment across the Anony River, constructed using the material excavated for the spillway. At this point overall width of the river is about 120 m with a maximum water depth of 4 m. The wide spillway would allow for the passage of floods.

However, a conflicting requirement was to have the spillway crest level as high as possible so as to minimise the risk of saline flow reversal when downstream estuarine water levels were higher than the spillway level under storm surge conditions. The rockfill weir needed to be impermeable enough to limit seepage of water through the embankment and ensure that no piping occurred in either direction.

The remoteness of the site, its environmental uniqueness and the unusual operating conditions required that each aspect of the structure had to be subjected to rigorous analysis and review to ensure that it would work under a multitude op operating conditions and flow situations.

Geometry of the main spillway

The 164 km^2 catchment generates a 1:100 year flow of 1 550 m^3/s and a PMF of 5 230 m^3/s. Flood levels in the river system for the various spillway options were estimated using a HECRAS unsteady flow model.

With a 300 m long spillway with a crest level of RL 1,1 m, the increase in flood levels as a result of the weir ranged from 0,76 m at the structure itself, to 0,28 m at the nearest human settlement, which is considered to be acceptable.

A low flow spillway with a capacity of around 20 m^3/s was provided to carry the normal river flow. This spillway is equipped with flap gates to prevent reverse flow when the downstream water level is higher than the upstream level.

Embankment design

The embankment had to be stable under all flow situations, protected from piping failures, and had to be constructed from local materials. Various embankment design options were investigated, and the choice eventually fell on a sand core rockfill embankment.

Allowing for boat passage

Fishing, transport and recreational boats use the river frequently. Two options were considered to allow for the passage of boats – a boat lock and a ramp slipway. Because of the remote location of the site and the fact that the spillway is prone to frequent flooding, any option needed to be operated without a power supply. For reasons that it could pass larger boats with relatively little effort the boat lock option was selected. The width of this was sized on the largest boat currently operating in the river system (4,5 m wide).

1 The completed Mandena salinity control weir and low flow spillway, Madagascar

2 Construction of the two initial embankments

Boat lock gates and low flow gates

The boat lock gates are balanced with a top hinge radial bearing that takes both the vertical and horizontal loading on the gate. The bottom hinge is a vesconite-faced bearing. The gates are counterbalanced using concrete blocks to reduce friction in the system and to make them easier to open by hand. The counterbalance also gives the operator purchase to push the gate open once the water levels are equalised. The gates are designed so that they can be removed without having to send divers into the boat lock.

The low flow gates had to be designed to prevent any reverse flow of sea water, but at the same time had to be light enough to open easily and not restrict the normal river flow. This challenge was met by providing a counterbalanced gate constructed of 3CR12 steel, which was also epoxy-coated to protect it from the aggressive environment.

CONSTRUCTION CHALLENGES

The following is a summary of some of the key construction challenges, and the solutions developed:

Blasting and excavation of the rock cut spillway

The contractor had to submit a blast design, including hole arrangement and charges for each blast in advance of drilling. This was reviewed and approved by a blasting specialist to ensure that no mistakes were made. The actual rockfill excavated was well graded and the contractor removed larger stones for riprap protection on the upstream and downstream face of the rockfill embankment.

Accurately laying the grade A7 geotextile underwater

The geotextile was laid on the river bed using a purpose-made barge that rolled the geotextile out as the barge progressed on an alignment set by a preset cable across the river.

Closure of the embankment against the right bank

To limit damage from river flows to the right bank, just prior to closing the embankment, the contractor artificially closed the estuary mouth with sandfill. This effectively prevented all river and tidal flows from entering the river and allowed the embankment to be carefully completed against the right bank.

Floods

In February 2008, 400 mm of rain fell in four days. The partially completed embankment was overtoped on the left bank and the entire spillway construction area was flooded to a depth of about 1 m. Although damage to the embankment was minimal, a 1 to 2 m deep channel was eroded on the downstream side of the main spillway rock excavation where bare excavation had not yet been reinstated with native grasses and reeds.

ENVIRONMENTAL CONTROLS

QMM employed a team of specialists who were responsible for investigating the impacts of the weir on the natural surroundings. Effects considered

3 Closing the rockfill embankment against the right bank sand dune
4 Laying geotextile underwater during the construction of the weir
5 The low flow spillway with balanced gates

included the changes in fish populations, effects on flora and fauna, sedimentation and the effects of the structure on the local community.

Fish populations

The QMM fish specialist confirmed that there are numerous fish species that live in salt water and numerous fish species that live in fresh water, but very few that can live in brackish water. On that basis he estimated that the number of fish in the system would increase after completion of the weir.

Fish passage through the boat lock

The fish specialist recommended that the means of letting water through the boat lock compartments be changed from the originally designed piped system to a sluice in the actual boat lock gate. Apparently fish and eels can sense a flow and then swim towards this flow, allowing them to pass through the opening during boat lock operation. Because of the relatively low head difference, these gates can also be left partly open at night to allow the passage of fish through the openings.

Sedimentation

A floating geotextile silt fence was established in the river on either side of the rockfill embankment to limit the amount of silt that washed into the river during end tipping of rockfill in the river. Professor Albert Rooseboom, from the University of Stellenbosch, visited the site and reviewed the potential for increased sediment deposition as a result of the embankment construction. He concluded that sediment transport within the catchment was very low and the weir would result in a negligible change to the current situation.

COMPLETION

SSI commenced work on the detailed design of the weir in late 2004. The project was completed on time in mid-2008, and has since been operating effectively. The final account for the weir, USD 2,9 million, was well within the original budget, given escalation over the period. □