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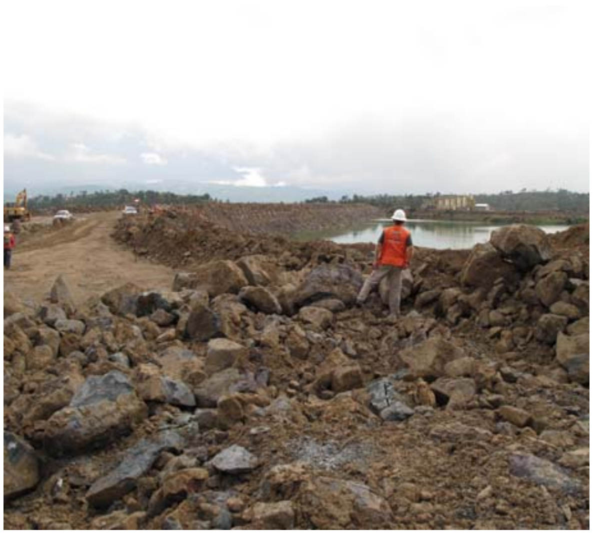
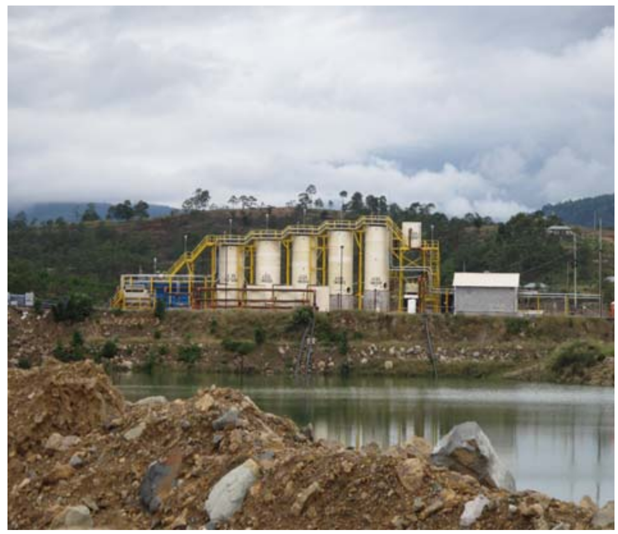
RGC REPORT NO 111001/9

# DAM INSPECTION – November 2009
# TAILINGS DAM REVIEW BOARD REPORT NO 9
# MARLIN PROJECT, GUATEMALA

**Prepared by Dr. Andrew M. Robertson P.Eng.**



**Tailings Dam crest at 1962 m, pond at 1949 m**



**Water treatment plant operational**

## 1.0 TERMS OF REFERENCE AND PROJECT OVERVIEW

This Review Report summarizes the observations, conclusions and recommendations of the writer as a consequence of a site visit and inspection of the Tailings Storage Facility and appurtenant structures (TSF) and Waste Rock Facility (WRF) being operated at the Marlin mine, Guatemala. This report is the ninth in a sequence of review reports issued during on-going review of the evolution of the dam design and construction. It documents the results of a site inspection and review of dam raising, construction control, monitoring and 'as built' record preparation completed to the time of the visit made from November 9 to 13, 2009. *This report should be read in conjunction with Reports No 1 through 8 which document reviews performed during facilities investigation, design, initial construction and early operation.*

Montana Exploradora de Guatemala, S.A. (MEG) operates an open pit and underground gold mine in northwestern Guatemala. The mine began processing of ore in October 2005 at an initial nominal rate of 4,100 tons per day and is progressively increasing production to a planned 6,000 tons per day in a conventional mill utilizing cyanide leach and Merrill-Crowe gold recovery. Tailings from the process are treated with sulfur dioxide to achieve cyanide destruction prior to deposition in a tailings impoundment formed by a 38 m high valley rockfill starter dam which is raised progressively from the Phase 1 crest at 1926 m to a final elevation of 1954 m (80 m ultimate toe to crest height) during the 10-year mine life using mine waste rock placed in downstream staged raises.

The tailings dam and appurtenant structures were designed by Marlin Engineering & Consultanting, (MEC) and the general design and construction specifications were reviewed during previous review meetings. The starter dam (Phase 1) had been constructed to elevation 1926 m in early 2006.

In early 2007 the Engineer of Record for design and construction supervision changed from Mr. Rob. Dorey of MEC to Mr. Clint Stachan of MWH Consultants. The Phase 2A and B construction was completed to 1946 in April 2008 and Phase 3 was under construction at the time of this inspection. The tailings dam design was originally revised by MWH Consultants in 2008 to increase the crest elevation to 1957 m. Construction was to be completed in two phases: 3A to El 1952 and 3B to El 1957. In 2009 MWH again revised the design to a crest elevation of 1962 m. At the time of this inspection construction of the dam was within 1 m of this ultimate elevation.

MEG has retained the writer as an independent expert to perform a review of the tailings impoundment constructed for the Marlin mine in compliance with the principles established in the IFC/World Bank guidance and operating principles OP 4.01 Annex D and OP 4.37.

In terms of OP 4.37, a Tailings Dam Review Board is required to review the development of the dam designs, construction and initial dam filling. The writer constitutes the Review Board to satisfy the terms of this OP.

The documentation provided or made available to the writer for the purposes of this review was:

For tailings dam design and construction:

- MWH 'As Built' QC test results
- MWH TSF Expansion Elev 1962 II - Drawings
- Quarterly instrumentation review report
- Hydrology Report Final, Dec 2008
- Marlin Dam Breach March 2009
- The construction records available on site for review
- Two memoranda from Rob Dorey to MWH dated June 22, 2009, relating a site visit and review of the tailings dam and waste rock dumps.

In addition to the above documentation extensive discussions were held with Mr. Clint Strachan, the Engineer of Record (EOR) for the tailings dam, who produced documentation from on site construction records in response to questions or requests by the writer.

For water quality:

- Results of geochemical classification testing program for mine waste (field cell and other geochemical testing results) in on site database and selected graphs there from, and

- o Results of water quality testing for tailings pond, seepage return dam, select downstream monitoring wells, and underground mine dewatering water from on site data base.

In addition to this documentation discussions were held with Lisa Wade, Goldcorp Environmental Director for Central and South America and Peter Hughes – Marlin mine Environmental Manager.

The site inspection and review comprised a five day site visit (November 9 to 13, 2009), and included an extensive tour of all TSF and WRF facilities. Photographs of key elements, taken during this site inspection, are included in Appendix A. In addition meetings, site tours were conducted with Clint Strachan, Jim Obermeyer (Head Mining Division) and Rodrigo Perez (Marlin Dam Construction Manager) of MWH and Manuel Aparicio (Supervisor Civil Construction for MEG). Rob Dorey, the original dam designer and EOR for the Marlin tailings impoundment until 2007 was on site and participated extensively in discussions and site tours.

Meetings were held with Lisa Wade and Peter Hughes on water quality and geochemistry testing and acid mine drainage management.

Additional meeting were held with Dan England (Goldcorp Maintenance Manager – Central and South America) and German Paz (Marlin mine Process Manager), regarding investigations and evaluations that were on-going related to tailings dewatering to produce filtered tailings with the objective of developing a 'stacked' tailings disposal system. These evaluations are at an early stage and discussed further in this site inspection and review.

A debriefing on the writer's findings from this review was presented on November 13, 2009, to the Marlin Mine General Manager, MEG staff and the EOR prior to departing from the mine site.

In Guatemala the writer provided a similar debriefing to Tim Miller (Goldcorp VP Central and South America and Eduardo Villacorta (Goldcorp Executive Director Central and South America).

On November 14 the writer continued with report preparation and departed Guatemala. A report was submitted on November 18, 2009. After receiving comments from Marlin Mine personnel, necessary edits were made and a final report submitted on April 21, 2010.

***Key Findings***

The meetings were held in an open and frank manner and all information available on site was made available to the writer.

The TSF and WRF continue to be designed and operated in accordance with good international standards of engineering practice by a staff with adequate experience and under a management structure and oversight appropriate to structures of this nature.

The critical need for the construction of a water treatment plant mentioned in the previous report has been satisfied by completion of construction and testing of the water treatment plant. It has not been necessary to operate this plant and discharge water as yet.

The Marlin mine tailings impoundment is approaching the end of its service life in about 18 months. It will continue to be used as a water storage and control dam for an indefinite period while Marlin mine continues to mine and process remaining reserves. The waste dump will essentially achieve its end of operating life in approximately 4 years. There is urgent need to revise the Closure Plan for the tailings dam and waste dump, taking into consideration any future activities, so that the closure topography drainage systems and progressive reclamation can be implemented during the remaining service life. The requirements for the Closure Plan revision are discussed further below in Section 3.4.

The transfer of EOR responsibility for the tailings dam from Rob Dorey to Clint Strachan has been successfully completed. Other design and operational guidance provided by Rob Dorey for general engineering and for major geotechnical structures such as the waste storage facility (WRF) and open pit, site wide water balance and water quality management, earth/rockfill construction material management etc. have not been transferred to MWH. Continued design and operational aspects of these general engineering and geotechnical (including geochemical and water balance/quality management) structures and operations have become fragmented within the Marlin mine management and operating staff. Integration of design and management is suffering at a time when there is urgent need for both integration and comprehensive geotechnical input to planning the transition from the current TSF and WRF to new facilities (2011 for TSF and 2015 for WRF). *It is recommended that either Rob Dorey be requested to again provide this integration and planning service, working with MEG management and staff, or an engineer with suitable qualifications, broad mine engineering and geotechnical experience and team leadership capabilities be appointed to satisfy this service requirement and be given the appropriate authority.*

## 2. SITE INSPECTION AND REVIEW ACTIVITIES

The writer flew to site on the **9$^{th}$ November** and was briefed by Clint Strachan on the changes and progress on TSF development. This was followed by a site inspection of the crest of the tailings dam and of the decant structure in the company of MWH staff. In the afternoon presentations were made to the writer on the options for developing future tailings storage capacity for future mine and mill tailings production for total capacity of 20 Mt.

On **10$^{th}$ November** inspections were completed with MWH staff of the downstream face of the tailings dam, including the seepage return facilities; tailings impoundment; the East Saddle dam; an overview of the potential East Tailings dam site; inspection of rockfill sources in the open pit; and a brief overview of the WRF. Design change drawings were inspected and design changes and analyses discussed with MWH staff. In the afternoon an inspection was made of the WRF in the company of Lisa Wade, Peter Hughes, MEG dump operating staff and MWH. A meeting was also attended with Dan England and German Paz on initial testing and alternative options for the development of a dewatered tailings stacking project being evaluated by MEG.

On **11$^{th}$ November** a working session was held on the options and requirements for closure planning for the TSF. Further review of the tailings dam construction quality control and quality assurance documentation and results was made with MWH staff assisting. This was followed by an inspection of the ‘barrel farm’ where long term kinetic field cell testing of waste rock and tailings is being performed. The downstream toe of the tailings dam was visited to verify that the lock preventing access to the valve preventing discharge from the TSF decant pipe could be opened by MEG staff in a timely manner.

During the morning of **November 12th**, Lisa Wade and Peter Hughes presented the results of water quality monitoring from the kinetic field cell program, discussed acid rock drainage investigations predictions and control measures. This was followed by a presentation and review of the water quality results from the site water quality database of all monitoring points relevant to this review. During the afternoon additional discussions on tailings dewatering (filtration) and 'dry stacking' options were held with Dan England and German Paz. The rest of the afternoon was spent starting the preparation of this report.

Report preparation continued **November 13th** and a close-out session was held with Marco Meneses ,the Marlin mine General Manager, MEG staff and consultants mentioned in this report, at mid day. The writer then travelled to Guatemala City and the MEG offices where the writer debriefed Tim Miller (Goldcorp VP Central and South America and Eduardo Villacorta (Goldcorp Executive Director Central and South America) on the finding of this review.

Observations from the site inspections are as follows:

***TSF***

The tailings dam crest elevation is approaching the final crest elevation of EL1962 m (see Photo 1). The tailings pond water was at El 1949. The dam impoundment is expected to be filled by mid 2011.

The rockfill being placed on 9th November had excessive fines (Photo 1). MWH report that the excessive fines fill was permitted only because placement was near dam crest in the freeboard zone of dam. Rockfill placed on 10th November was of good quality and grading. The Marlin pit was visited to inspect the rockfill source (Photo 17). The weathering and rock strength characteristics of the mined rock changes rapidly over short distances. The difficulty of selectively mining good quality rock is apparent (Photo 18). The underground has priority for good quality rock which is used for underground mine backfill. The consequence of the poor quality rockfill in the tailings dam are increased settlement and a need for long term monitoring and maintenance. The stability of the dam is not in question.

Rockfill on the upstream face was observed to have a high percentage of rock particles and boulders that was weathering (slaking) to soil sized particles. This raises some concern relating to the long term behavior of the rockfill.

Other placement and compaction operations were in accordance with good practice and specifications.

The extended decant structure to allow for the El 1962 design was seen (Photo 3) and was designed and constructed identical to the prior channel. The silicone caulking of the previously placed stoplogs was observed to have deteriorated (Photo 4), a condition that MWH was aware of and were in the process of stripping out to allow replacement.

The downstream face of the dam was being progressively covered with a meter depth of material understood to come from scraping of the road surfaces during wet weather road maintenance. Two bench faces had been covered at the time of the visit and vegetation had been established on the lower bench slope (see Photo 5). This soil has a high fines content which is readily erodible. It does not satisfy filter criteria with respect to the material onto which it is placed and it can be expected that fines will wash and pipe from this layer into the rockfill, potentially migrating to the internal base drain and blinding the drain filter.

The seepage collection pond was pumped drown and the current inflow of groundwater and tailings seepage collected in the dam under drain is less than 2 l/s. It was noted that there are two pumps in the pond with one plumbed to allow direct discharge of seepage water to the tailings pond. Alternatively water from the seepage pond is pumped to a tank (Photo 7) from where it is pumped to the tailings pond. The controls and power distribution facilities are seen in Photo 8.

The tailings decant pipe has a valve near the discharge end which is normally kept closed to prevent discharge of tailings pond water to the environment (Photo 9). Access to the valve is prevented by a steel enclosure to prevent vandalism. The enclosure is fitted with a lock. The writer requested a test to determine who had the key and if it could be opened in a timely manner. The first key is with German Paz – Marlin mine Process Manager who obliged by producing the key and unlocking the door to the steel enclosure. Three keys are maintained with various project personnel so that one is always available to effect unlocking. A bypass pipe has been installed to allow the small amount of leakage past the stoplogs to discharge by gravity in the seepage pumpback tank (Photos 10 and 11). The decant is operating effectively.

The soil placed on the downstream face is erodible (Photo 12) and should be vegetated as soon as possible. Additional erosion is occurring from unreclaimed slopes adjacent to the toe. Severe erosion is observed in the road (Photo 13). Water drains from these slopes and passes through two sediment ponds downstream of the seepage collection pond. It was observed that these sediment ponds are nearly full and *they should be cleaned out to restore sediment settlement efficiency.* It is understood that a regular program of sediment removal is followed.

Longitudinal cracking was observed along the tailings pipe bench onto and along the upstream crest of the East Saddle dam. In the opinion of the writer this cracking is caused by settlement and some shear displace of the loose fill that has been placed over the upstream crest of the dam fill. This deformation is expected to continue during the next wet season and could affect the performance of the pipes. *Consideration should be given to widening the bench in the downstream direction once water treatment plant relocation is complete, but before the next wet season.*

The tailings pond was observed to contain an excessive amount of water (Photos 1 and 21). With the excessive water volume there was only a modest area of 'beach above water' on which tailings segregation and drying can occur. As a consequence almost the entire tailings deposit in the TSF has been deposited as 'beach below water' with a low density. One of the consequences is a reduced average tailings density. This reduces the storage volume of the impoundment and increases the post closure settlement that can be expected.

The water treatment plant has been constructed and is operational (Photo 15), however it is due to be moved to higher ground to allow the completion of the East Saddle dam. The water evaporators were functioning during the inspection (Photo 14).

It was noted that a dike had been constructed around the reclaim water system. This was required to control fines flow towards the pumps.

The tailings delivery line and flume is being reconstructed to deliver tailings along the right flank of the impoundment, dam crest and a short distance up the left flank of the impoundment. The tailings line rests on the berm constructed on the upstream crest of East Saddle dam (see Photo 16). The line will be extended over the dam crest once construction Main Dam is completed.

***Potential East Dam Impoundment***

A tailings dam, to be located in the valley adjacent to the right flank of the TSF, has been proposed by MEG. MEG is proposing a geomembrane liner for this dam and impoundment. Photo 19 is a view of the right flank of the impoundment. The deep gulley's and apparent side valley slumps would result in challenging liner installation conditions.

***WRF***

The placement and compaction of PAG in layers and the construction of low permeability compacted clayey waste was observed in the WRF. This procedure is suitable for minimizing air convection (hence the rate of oxidation) as well as water migration (hence leach in of contaminants in waste rock. It also reduces the dump settlement and therefore potential for cracking of internal 'barrier layers' and the cover of the waste rock (reducing potential infiltration). The writer considers these measures appropriate.

Photo 20 shows NAG oxide waste being placed by end tipping over the PAG berm crest to form a 10 m isolation layer over the PAG. Field inspection of the NAG waste indicted it to be very coarse grained and it would have a very high permeability in the lose state. This cover would be highly conducive to infiltration. The writer questioned the MEG staff on anticipated future supply of low permeability NAG waste and was told that this was becoming increasingly scarce. *It is recommended that consideration be given to changing the cover design to 3 m of well compacted low permeable cover material to limit infiltration and leaching.* This design in considered further in Section 5 below.

The construction of a concrete lined surface water drainage ditch on the left flank was seen but not inspected (see Photo 22).

The bottom 3 benches of the WRF have been completed and re-sloping and reclamation soil placement was in progress.

The tailings pond has risen to the level that it now floods the WRF toe at El 1949. At final pond storage level of El 1958.6, the flooded depth will approach 20 m.

Photo 23 shows the relocated kinetic field cells (barrel farm) for acid rock drainage (ARD) evaluation and classification. The test setup was inspected and found to be suitable.

# 3. TAILINGS STORAGE FACILITY

## 3.1 Design Life

The Marlin tailings dam is approaching the end of its design life. The original design to a crest elevation of 1954 m has been modified twice to El 1957 m and El 1962 m respectively by MWH. It is anticipated that maximum capacity for this crest height will be achieved about mid 2011. In this section (Section 3) it is assumed that there will be no further increase in the dam crest elevation.

MRG exploration activities have demonstrated potential for additional reserves and they are seeking to evaluate options for additional tailings disposal to a total of 20Mt and possibly 25 Mt.

Three options are under consideration:

- Raising the current dam for some additional storage
- Developing a tailings impoundment in the valley east of the current dam (East TSF)
- Dewatering of tailings by filtration and forming a ‘dry stack’, with or without co-disposal with waste rock

These options are in the process of being evaluated.

## 3.2 Design for Crest elevation of 1962 m

The writer reviewed the drawings for the dam to El 1962. These indicate maintenance of essentially the same dam slopes as for previous designs with an extension of the filter and drainage layers. The dam alignment is kinked on the left abutment to avoid intrusion onto the airstrip runway and the grout curtain has not been extended. The raising of the East Saddle Dam involves the removal of downstream rock shell material and downstream raising of the low permeability fill zone and placement of the downstream rock shell zone with the footprint being extended some distance down the east slope of East Ridge on which the East Saddle Dam is located. No drain or filter layers are provided in the East Saddle Dam. The decant channel has been extended using the same design as previously.

The modified design results in the core terminating at elevation 1960. The filter zone terminates at El 1957 and the transition zone at 1956. The design is therefore not tolerant of overtopping of the core as core erosion would progress rapidly to elevation 1956. If core erosion occurred to this elevation the seepage flow rates to the high fines downstream rockfill could be excessive and lead to downstream slope instability and a dam breach. *This potential failure mode should be taken into consideration in establishing the design freeboard.*

Design calculations to support the 1962 crest level for stability, seepage and freeboard were provided to the writer for review. These stability analyses yield factors of safety for the Main Dam section that meet the operating period design criteria for the dam. The stability of East Saddle Dam is dependent on the pore pressures that may develop in the foundation under the core and downstream colluvial soils under full impoundment operating conditions. In this regard the writer notes the East Saddle Dam design does not include a chimney or blanket drain to reduce these pore pressures under the downstream portion of the dam. The phreatic surface, and therefore the stability analyses, are anticipated to be sensitive to the permeability contrast between the low permeability 'core' zone material and the underlying volcanic ash 'rock' of the foundation. *It is recommended that a review be made of the 'ash' bedrock permeability and the core low permeability zone material separately from the core and foundation bedrock under the Main Dam. If such a review indicates that these values should be different from those applicable to the Main Dam, then a re-analysis of the saddle dam seepage, phreatic surface and downstream stability is appropriate.*

The writer further understands that it is intended that the closure spillway will be constructed across the East Ridge at the southern end of the East Saddle Dam. This relocation is required to avoid conflict with the airstrip runway which passes over the location on the Main Dam left abutment where the closure spillway was previously intended to be constructed. No design information or drawings were provided for review. This new spillway location has the advantage of being located close to tailings water reclaim barges, hence a location where the tailings surface is naturally low. The rock into which the spillway will be cut is relatively soft and erodible cemented ash. With the high flood flows that will be passed through this spillway, and the large elevation drop to the base of East valley, it is essential that the spillway be a concrete lined channel with adequate energy dissipation to avoid erosion. *The writer looks forward to being able to review the closure spillway design during the next review meeting.*

Additional studies performed to support the current design that were provided to the writer include a dam breach analysis and hydrological studies.

#### *Dam breach analysis*

The dam breach analysis performed by MWH is appropriate and a state-of-the-art evaluation. The severe consequences of a breach are down valley flooding at depths exceeding 20 m and very high flow rates down to and into the Rio Cuilco. Since the impacts are severe the dam design is required to ensure that this probability remains extremely low; effectively to avoid any such possibility. This is achieved by ensuring stability of the dam, and TSF operation with adequate freeboard and flood discharge capacity.

To eliminate the potential of a breach of the Main Dam as the dam approaches full tailings storage *it is recommended that the closure spillway be constructed prior to the TSF operating pond level reaching its maximum operating elevation.*

#### *Hydrological Study*

The hydrological assessment and 100 year 24 hour flood assessment made by MWH are appropriate, taking into account site specific records and the increased time for which rainfall records are available. They estimate rainfall using standard methodology for statistical evaluation of the 39 years of rainfall records at Huehuetenango. For the 100 year 24 hour precipitation estimate MWH estimate a value of 113 mm, and for the PMP they estimate 219 mm. This result is somewhat similar to results obtained by MEG during initial dam design using equivalent statistical methodology. However the MEG values adopted for TSF design were determined from conservative estimates based on the assumption that Marlin mine was located in an area affected by hurricanes and tropical storms. This assumption yielded much greater precipitation estimates of 350 mm and 1400 mm respectively.

The current decant structure design is based on the MEG values and is therefore conservative. It is assumed that freeboard design for the 1962 m dam design is based on the MWH precipitation estimate. It is the writers opinion that adoption of the MWH estimate for the 100 year 24 hour storm is appropriate for determining TSF pond operating elevation to avoid pond water discharge through the decant. *Given the high hazard nature of this dam and the results of the dam breach analysis, the writer considers it appropriate that the freeboard applicable for dam overtopping should be conservative and should not be based on the MWH PMP estimate until a site specific PMP assessment using climatological models is used to refine the PMP estimate. Due consideration must be given to the period represented by closure and reasonable allowance made for climate change.*

*Since the tailings dam is achieving its ultimate crest level it is recommended that the design of the closure spillway be expedited and that it be installed prior to the tailings pond reaching its closure elevation.*

### 3.3 Construction

The rockfill observed being placed on November 9 appeared to have excessive fines (see Photo 1). It was explained to the writer that such high fines rockfill was being tolerated because it was the last half meter of dam rockfill placement. The rockfill observed placed on the $10^{th}$ November appeared to be consistent with the specified grading.

The Dorey inspection memo of June 2009 indicates that excessive rockfill lift thicknesses may have been done in the Stage 3A and B construction. This was not occurring during the inspection by the writer.

A review of the quality control test results indicated that both rock fill and other materials placed on the dam met both grading and compaction specifications.

The rockfill exposed on both the upstream and downstream dam face contained a substantial quantity of boulders that were slaking (weathering under wet dry cycles – see Photo 2). The rock hardness of many of the boulders were in R1 to R2 range - below the desirable R3 minimum strength. The combination of low strength and poor durability, together with the increased fines will result in a rockfill with a relatively low deformation modulus. It is understood that to accommodate poor quality rockfill supply to the dam, a zone for the placement of such rockfill was provided. This zone is not indicated on the 1962 Dam design drawings. *It is recommended that this zone be well defined on 'as built' drawings so that it can become part of the 'as built' record. It should also be accounted for in any deformation analyses.*

### 3.4 Closure Preparation

Post closure the Marlin tailings dam will continue to contain tailings that would liquefy under seismic loadings or a dam breach. It will therefore remain classified as a high hazard dam. The spillway will have to continue to operate in perpetuity. Dam erosion will be ongoing. Instrumentation reading to ensure the internal drainage system continues to function will have to be maintained, though a less comprehensive more robust instrument set may be appropriate. It may be necessary to operate the seepage pump back system for an extended period. At least 5 yearly stability inspections and periodic maintenance will be required. Care and maintenance in perpetuity is required which may be provided by Goldcorp or a successor custodian (community?). The nature of the dam and waste dump closure will have a large effect on the degree of post closure care and maintenance required as well as the willingness of the succeeding custodian to assume responsibility for the dam.

Dam construction is reaching the terminal crest elevation of 1962 m. Initial progressive reclamation of the dam and area has started. The rock quality used for construction is poor as a consequence of a lack of better quality materials in the Marlin pit or the number of specially formed quarries that have been tried. The rock fill is expected to deteriorate with time. Rock fill dams experience time dependent settlement and the Marlin tailings dam can be expected to have substantial long term settlement. Such settlement lowers the crest of the core and dam requiring periodic raising. Crest and core settlement are also anticipated under earthquake loadings. It is an appropriate practice to build the dam with a hogback to allow for such future settlement and avoid the need to mobilize for periodic dam raising. *It is recommended that such a hogback be constructed now while the men and equipment are on site, and construction materials are available. At this time such construction can be done cost effectively and it also avoids future disturbance of the reclaimed dam surface. It is recommended that a deformation review, and deformation analysis, be done to estimate long term settlement allowing for both static and dynamic effects*. The settlement monitoring done to date provides a basis for current rock deformation characteristic estimate calibration. *These properties should also be adjusted for the slaking nature of the rockfill and 'potential softening' with time.* The results of this evaluation should be used to design the amount of overbuild required for the core and crest. *The writer requests that the selection of rock deformation properties and the deformation modeling be discussed with and submitted for review by Dr Peter Byrne who has reviewed this aspect of the dam design on behalf the writer in the past.*

It is not certain at this time if a dry tailings beach would produce acidic runoff or neutral leaching. The low strength tailings would not support vehicle traffic for cover placement. There is merit in considering closing the dam with a water cover and using the dam as a water storage facility for the remainder of the Marlin operating period, changing to a community water storage and supply dam on closure.

The average density of the tailings deposit has been increasing slowly over time but remains low at a little less than 1 $t/m^3$. Over time (tens of years) these tailings will consolidate. Up to 5 to 10 meters of settlement can be anticipated in the zones of deepest tailings deposition. This makes the development of a dry surface discharging to a spillway very difficult. If water were drained from the tailings surface this would remain very weak and special costly techniques would be required to place cover. *Consideration should be given to a water cover for closure*; in which case the post closure settlement is not of concern.

To maximize the amount of tailings placed into the tailings impoundment will require that tailings be discharged from as much of the perimeter of the impoundment as possible. To place tailings solids in the center of the dam (to fully utilize all available capacity) may require a floating tailings line. *It is recommended that MWH be requested to produce a* *tailings infilling plan and that this tailings placement should commence as soon as possible.*

*A revised comprehensive closure plan is required urgently to ensure that closure requirements can be met. Included in the development of the closure plan should be:*

- *A materials balance plan to ensure that there is enough NAG and low permeability materials available or stockpiled so that these materials will be available to implement the closure plan in accordance with the closure plan schedule.*

- *A water balance, water quality and water management plan that takes into account on-going operational requirements and utilization of the tailings pond for water quality management both during operations and post closure.*

- *Revision of the WRF design to provide for a low permeability cover; progressive reclamation and installation of surface drainage controls; taking into account the potential for expanding the dump footprint to provide volume and geometry for dewatered tailings stacking co-disposed with mine waste.*

- *Revision of the Marlin and Cochis pits closure plans; taking into consideration the potential use of Marlin open pit for future use as a TSF for dewatered tailings.*

- *Revision of the TSF closure plan.*

### 3.4 Performance assessment

The average dry density of the tailings deposited in the TSF has been increasing steadily with time. Average dry densities have reached a little below 1.0 t/m$^3$ compared with the 1.35 value assumed for original design. The impoundment was observed to contain a large volume of water ~ 1 M m$^3$. This is an impediment to beach development which, in turn, is a contributory cause to the low tailings densities. There should be some reduction in the pond volume during the dry season that has now commenced, but it is anticipated that the drying effects on beaches will be marginal.

It is understood that there is currently a 7 m difference in the depth of water above tailings – ranging from 0 at the edge of the discharge delta to about 7 m at the reclaim barge. To achieve tailings placement to the maximum elevation over the entire pond requires that tailings be discharged around most of the periphery of the impoundment and that a floating line be used for filling ‘holes’ in the center of the pond. During an earthquake in 2006, the tailings in the TSF liquefied and flowed such that the upper surface of the tailings became level. This is expected to occur under earthquake loadings in the future. *It is recommended that a ‘filling plan’ be developed to achieve the maximum tailings deposition in the TSF. In developing this plan, due consideration should be given to the potential for tailings surface flattening when making provision for freeboard.*

The current bathymetry to determine top of tailings is being done with an echo sounder. With high clay tailings there is often a zone of very low density extra-fine tailings above the more consolidated tailings. If this occurs the echo sounder may locate either the top of extra-fine tailings, or consolidated tailings, or both, depending on the frequency setting of the sound wave. Given the critical nature of the pond volume during filling it is essential that it be determined what surface is being identified by the echo sounder. If it is the consolidated tailings elevation and there is a substantial depth of extra-fine tailings above this elevation then the current remaining capacity estimates may be too high. *The writer has previously recommended that the results of the echo sounder be calibrated against physical pluming of the depth to tailings.* Plumbing should be done with plumbs with different buoyant density to ensure that the presence of a layer of extra-fine low dry density tailings, if it exists, will be detected. *At minimum, depth sounding with a large lead ball (SG about 11) and with a plastic bottle filled with water and sand to a have a total density of 1.1 (buoyant density of 0.1) t/m$^3$, should be done and correlated with the echo sounder results.*

The settlement sensors in the dam indicate that a strain of about 3% has occurred to date under incremental loading. Secondary settlement will occur with yet additional settlement due to the slaking of some of the poor quality shell rock under both static and dynamic loads.

The piezometers in the dam and dam foundation are all indicating pore pressures consistent with what was contemplated in the design. Two of the four piezometers in the Main Dam downstream shell have ceased to function. *In view of the potential of impairment (clogging) of filters to the underdrain by fines from the high fines rockfill and cover materials being placed on the downstream face it is recommended that at least two additional piezometers be installed in the downstream shell, located a few meters above the underdrain.*

Of the water level monitoring holes installed in the East ridge only PW–7 is showing at this time a rise in the phreatic surface in this ridge. The permeability of the ash deposit which forms the ridge appears to be very low. The increase in phreatic surface in PW-7 is about 10 m. It is apparent that the transient water table that will establish through the East Ridge is still developing. The water table is expected to increase as the tailings pond water level rises. The increase observed in PW-7 indicates that there is a more permeable zone in the vicinity of PW-7 and the transient water table has risen more rapidly than at other PW well locations. As PW-7 is the last in a row, it is not known how wide the seepage zone is or where the maximum elevation of the phreatic surface is located. Rob Dorey pointed out the strike of a fault that may pass through the East Ridge in the vicinity of PW-7.

*It is recommended that additional water level indicator wells be installed near to PW-7 to determine the lateral and vertical extent of this elevated phreatic surface. Permeability testing should also be done in these wells to determine if the higher permeability zone exists. This drilling should be done as part of a comprehensive hydrogeological assessment of the East Ridge and should be directed by an experienced specialist hydrogeologist.*

The writer was pleased to hear that a GoldSim water balance model had been developed for site wide water quantity, quality and balance modeling. This will allow pond elevations, freeboard, and water treatment to be more securely managed. There is currently a steady accumulation of water in the TSF. MEG staff report that there is an increase in underground drainage water quantity as the mine development is deepened. It is reported that underground workings become more consistently wet below elevation 1900 m. MEG is evaluating the potential for treating mine water so that it can be utilized in the mine, avoiding some fresh water intake. *The writer looks forward to a presentation of the water balance modeling results and predictions of future tailings pond elevations, as well as water treatment requirements at the next review meeting. Both best case (dry year) and worst case (wet year) scenarios should be modeled.*

# 4. WASTE ROCK FACILITY

## 4.1 Design

The WRF is being constructed generally in accordance with the design prepared by MEC. The design has not been revised. Revision and updating is needed.

*It is recommended that the WRF design be reviewed by Dorey and/or MWH and the design be updated and advanced to comprehensively address the cover placement and long term surface drainage ditch layout, slopes and design.*

## 4.2 Operation

The non-acid generating rock, (NAG), buffer zone required between the sulfide waste and the valley walls, was observed to have been placed in the WRF. This zone of NAG waste rock should not be compacted, so as to preserve its permeability and allow free drainage of seeps and springs from the valley sides to drain to the base drain.

Waste containing sulfides (PAG rock) was being compacted in layers in the interior of the dump and was being covered by compacted fine grained NAG with high fines content. This is appropriate for minimizing long term settlement, reducing air permeability and minimizing potential for leaching of contaminants that may be produced in sulfide waste.

The three lowest WRF benches had been completed and were in the process of having re-vegetation cover material placed (Photos 21 & 22). A concrete channel, to conduct water down the dump face at the abutment, was under construction (Photo 22).

A 10 meter wide NAG zone was being placed by end tipping over the 4$^{th}$ bench face as is seen in Photo 20. This NAG was observed to be coarse and very permeable and would do little to inhibit infiltration into the WRF. This 'cover layer' was not being effectively compacted. MEG staff also report that quantities of fine grained NAG suitable for low permeability cover material are decreasing. *It is recommended that consideration be given to revision of the WRF cover design by reducing its thickness (to 3 m say) while increasing the selective placement of fine grained NAG and compacting it in layers (0.3 to 0.5 m thick) to minimize the permeability. To facilitate compaction it would be necessary to re-slope the bench face to a slope on which a compactor can operate (3H to 1V).* Additional NAG can be placed over the low permeability cover layer to maintain bench slopes and berms.

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*The placement of the 3 m low permeability NAG cover, as well as the construction of drainage ditches should be done to civil engineering standards to ensure that future potential for infiltration and erosion is minimized.* This includes quality control of the selected cover material as well as testing of compaction to determine densities and permeability's achieved. MWH staff on site can provide both engineering guidance and quality control.

### 4.3 Closure

*The establishment of concrete lined drainage ditches on each bench with positive drainage to the lateral vertical drains is recommended to minimize post closure erosion*

The field cell (barrel) test program has demonstrated some of the sulfide waste is highly acid generating and substantiates the need for the WRF ARD control measures that have been implemented. In particular the NAG base layer will prevent seeps from the valley sides leaching sulfide waste, and the improved low permeability cover over the entire WRF should reduce the amount of infiltration. Together with the internal sulfide cover layers, it is anticipated that potential for contaminant leaching is minimized. However it should be anticipated that some contaminated seepage will migrate to the base drain and impact the water quality of this drainage. This drainage discharges to the tailings impoundment and is expected to flow onto the tailings and mix with tailings pond water, impacting tailings pond water quality.

It is anticipated that if most of the tailings are under a water cover, that the tailings pond water could achieve discharge water quality. There may be an advantage to isolating the dump toe seepage from the tailings pond water. This would allow the dump toe drainage to be treated before discharge, protecting tailings pond water, if required. *It is recommended that the potential for such isolation/separation be investigated and, if it is demonstrated to be feasible, be allowed for in the Closure Plan.*

## 5. WATER MANAGEMENT

The writer was informed that a site wide GoldSim water balance model has been constructed for MEG by MWH. The water quality modeling functionality of the model is being developed. This should be a very useful tool for evaluating water quantity accumulation and quality improvement by alternative water management strategies. An example of a strategy under consideration is replacement of some of the fresh water distributed underground by treated underground drainage water. The model allows requirements for water treatment and discharge to be more reliably predicted.

The tailings pond currently has almost 1 million $m^3$ of water in storage. This represents the volume occupied by 6 months of tailings production storage in the TSF. This volume is urgently needed to maintain production over the next 18 months prior to the implementation of the future TSF. Water treatment and discharge will have the lowest downstream impact if performed during the upcoming wet season. The potential for such treatment and discharge is restricted by the requirement for treatment plant relocation. *An evaluation of the most suitable time for treatment and discharge is recommended.*

## 6. ARD CHARACTERIZATION

The field cell kinetic test program has, and continues to, yield valuable data on the kinetics of oxidation, acid generation and contaminant leaching from mine waste types.

The program of testing to date has focused on determining what contaminants will be released. The number and variety of tests completed for the open pit waste rock is adequate for determining potential contaminants. Since the open pit mining will be complete in about 4 years time there is little benefit in initiating additional tests. *It is recommended that the current field cell test series be maintained to observe leachate quality changes as the oxidation state of the samples mature. It is also recommended that the quantities of waste rock in the WRF represented by the types tested be estimated to allow a quantitative estimate of the distribution of waste types in the WRF.* This estimate is relevant to an assessment of the mix of leachate types that will be generated in the WRF.

Additional field cells, established for underground mine waste testing, should be initiated when new waste types are encountered.

Once a revision of WRF cover design is complete, an estimate of infiltration can be made using a cover modeling code such as 'SOILCOVER' or 'HELP'. Using the available field cell test results, and making allowance for the restricted air movement through the WRF, an estimate can be made of seepage water quantity and quality from this facility. This estimate will be useful in anticipating the level of toe seepage control and water treatment (wetland or chemical) that should be provided for the long-term.

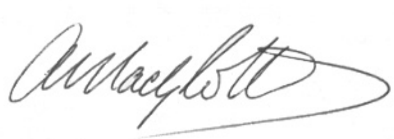
## 7.0 NEXT REVIEW MEETING

It is recommended that the next review meeting be undertaken in approximately six months. The meeting will be during the wet season allowing site conditions under maximum erosion to be inspected. The revised closure plan should be well advanced or completed and there should be considerable progress in the selection and implementation of the selected option for continued tailings disposal post mid 2011.

The next inspection and review meeting has been tentatively scheduled for May 17 to 21 2010.

I would welcome the opportunity of answering any questions you may have with respect to this report.

Yours truly



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