

Overview of Two Studies on the Riverine Transport of Tailings from a Possible Tailings Dam Breach at the Mirador Mine in Southeastern Ecuador

E-Tech International, a US-based nonprofit that provides independent technical assistance to communities affected by large-scale development projects, has commissioned a study of a potential tailings dam failure at the Mirador Mine in Ecuador. The study was conducted by Dr. Steven Emerman, an associate professor of hydrology at Utah Valley University in the United States. In December 2011, and at the request of the Ministry of the Environment (MAE), E-Tech submitted an analysis entitled “EIA Beneficio y Respuestas del Ministerio del Ambiente: Observaciones Generales de E-Tech International.” In our 2011 evaluation we raised similar concerns to those expressed in the overview that follows.

As part of the mine permitting processes, consultants for Ecuacorriente, S.A., the mine owners, evaluated the risk level posed by a tailings dam breach of the Quimi tailings impoundment during mine operation. The consultants found that the tailings facility and the earthen tailings dam would have a VERY HIGH (their capitalization) hazard classification and risk of failure due to the high seismicity in the area, the proximity to water resources and human settlements, the significant environmental impact on downstream watercourses if a failure occurs, and the very high economic consequences and socio-economic impact of a failure.¹

The consultants’ evaluation also modeled the release of tailings and created a map showing the extent of tailings from the initial spill and from downstream movement by runoff over the spilled tailings. Their model showed that spilled tailings would only cover the Rio Quimi from the tailings dam to the mouth of the Rio Quimi and would not be transported into the Rio Zamora (Figure 1). E-Tech doubted the validity of this finding and asked Dr. Emerman to examine 1) whether the spilled tailings would enter Rio Zamora, and 2) the rate of transport of the tailings from the dam through the downstream rivers. The first report addresses the movement of the tailings along the stream bed, and the second report examines the movement of tailings that travel with river water as suspended sediment.

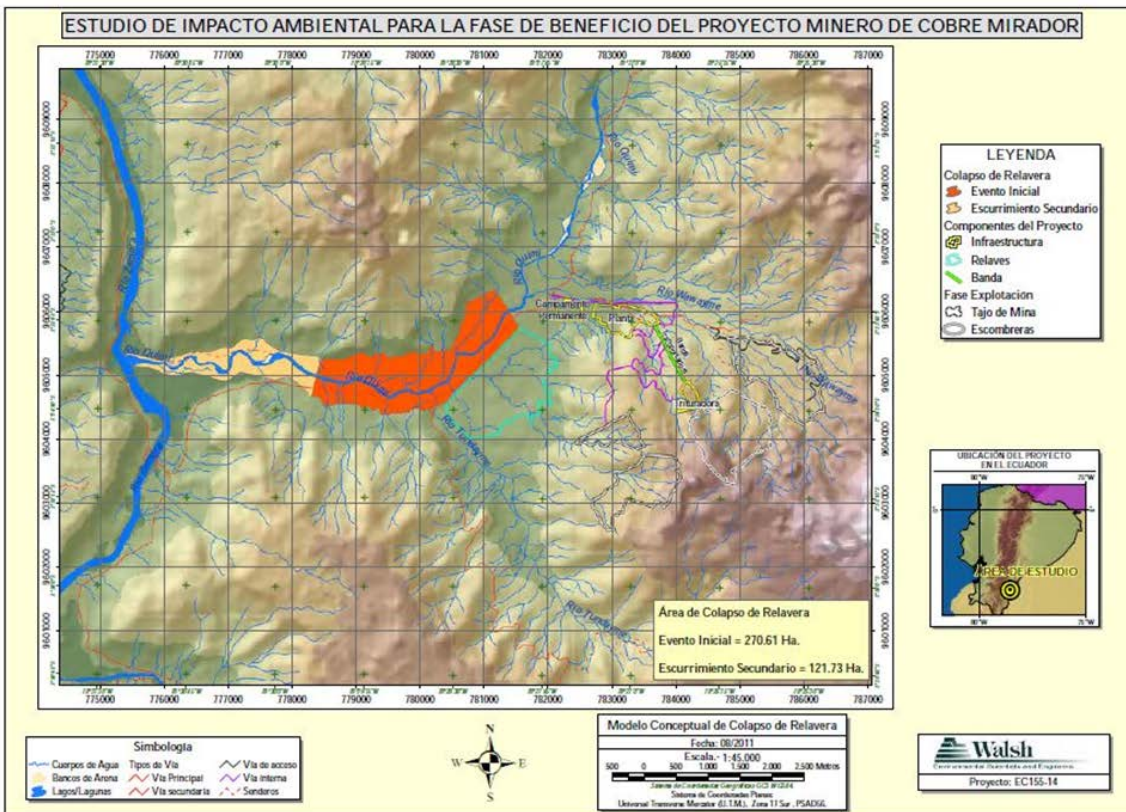
The first Emerman report² examined the transport of tailings along the beds of the streams. Tailings will move much more slowly along stream beds than in the water itself. The transport rates were calculated using an Excel spreadsheet and mathematical equations that describe the movement of particles in rivers. All assumptions and inputs were chosen to minimize the tailings velocity. Therefore, the results represent a best-case scenario in terms of environmental impact and the low end in terms of possible transport velocities. As shown in Table 1, sandy tailings particles are predicted to move along the bed of the Rio Quimi and the Rio Zamora at velocities between 21 and ~300 km/year, depending on the size of the tailings particles. Smaller particles such as silt and clays, which are always present in tailings, would move at a faster rate. It would take approximately 1.5 months for sandy tailings traveling along the bed to reach the Rio Zamora and about two years to travel along the stream bed in the Rio Zamora and reach the confluence with Rio Santiago (Rio Zamora is a tributary of the Santiago), which is ~80 km downstream.

¹ Knight Piésold Consulting, 2007. Ecuacorriente – Tailings Management Facility. Appendix 7D. Knight Piésold – Rio Quimi Tailings Management Facility Feasibility Study.

² Emerman, S.H. 2014. Prediction of Transport of Mine Tailings following Failure of an Earthen Dam on the Rio Quimi, Ecuador. June 22.

The studies found that the spilled tailings would absolutely move into the Rio Zamora. Rio Quimi and Rio Zamora are high-gradient mountain rivers, and spilled tailings and the mine water covering the tailings would move rapidly to the Quimi-Zamora confluence and into Rio Zamora.

Figure 1. Predicted area of impact from a collapse of the Mirador tailings dam. The initial spill was predicted to cover 271 hectares (ha) of the Rio Quimi drainage; movement of tailings by runoff after the initial spill could cover an additional 122 ha. Unlike shown in the figure, the tailings would enter the Rio Zamora and travel downstream toward Rio Santiago.



The second Emerman report³ estimated spilled tailings transport velocities for particles suspended in the water column. Suspended tailings particles would travel about as fast as the water itself – and the transport velocities will depend on stream discharge rather than grain size (Table 1). Using a range of velocities representing mean annual streamflow, annual peak flow, and maximum flooding, suspended tailings particles would travel much faster than tailings moving along the stream bed. As shown in Table 1, spilled tailings would reach the Rio Zamora confluence in as little as 18 to 78 minutes, depending on whether the spill occurred during average flow conditions, annual peak flows, or maximum flood discharges (Table 1). After tailings entered Rio Zamora, they would travel from the Quimi confluence to the Rio Santiago confluence, the next important downstream Zamora tributary, in only 7 to 28 hours.

³ Emerman, S.H. 2015. Prediction of Transport of Mine Tailings in the Suspended Load following Failure of an Earthen Tailings Dam on the Rio Quimi at the Mirador Mine, Ecuador. May 17.

Table 1. Calculated transport velocity and travel times for tailings spilled from a predicted tailings dam breach at the Mirador Mine (Emerman 2014 and 2015)

	Tailings Velocity	Rio Quimi: Time to reach Rio Zamora confluence [3.8 km]	Rio Zamora: Time to reach Rio Santiago confluence [~80 km]
Stream Bed Transport	Fine sand: 17-298 km/yr Medium sand: 105 km/yr Coarse sand: 21-62 km/yr	~1.5 months	~2 years
Water Column Transport	Mean discharge: 2.88 km/hr Annual peak: 6.52 km/hr Maximum flood: 11.2 km/hr	18 – 78 minutes	7 – 28 hrs

Summary and Recommendations

After a spill, tailings would reach the Rio Zamora quickly and move both along the stream bed and as suspended particles in the water column. The tailings suspended in the water will travel much faster than those moving along the river beds. The Emerman reports estimate that spilled tailings traveling in the bed load would reach the confluence of the Zamora and Santiago rivers, located about 80 km downstream of the mine, in two years or less; spilled tailings traveling in the suspended load would reach this location in hours. The initial breach would cause tailings to completely cover a portion of the Rio Quimi. If the tailings are not removed, they would feed mine waste into Rio Quimi and the Zamora for at least tens of years into the future.

After these reports were completed, EcuCorriente submitted a revised Environmental Impact Study for double the ore production at the Mirador Mine. Doubling ore production will double tailings production, and a larger tailings impoundment has been proposed. A number of devastating of mine water and tailings spills have occurred in 2014 and 2015, including at the Mt. Polly Mine in British Columbia, Canada; la Mina Buenavista del Cobre in Cananea, Mexico; the Gold King Mine in Colorado, USA; and the BHP Billiton-Vale Samarco iron mine in Brazil. Water quality effects have been reported 200 km downstream from the spill in Brazil. Given the substantial potential for failure of a tailings impoundment and dam in the Cordillera del Condor area, E-Tech International has the following recommendations related to the Mirador Mine tailings impoundment(s):

- Realizar un Análisis de Modos de Falla, Efectos y Criticidad (AMFEC) para la facilidad Río Quimi u otras facilidades de gestión de relaves antes de que sean otorgados los permisos correspondientes y que se consideren las alternativas a la propuesta actual para reducir el riesgo potencial a la vida humana y el medio ambiente.
- En el AMFEC, incluir una evaluación del potencial para deslaves o licuefacción debido a cargas sísmicas utilizando métodos aceptados en la práctica geotécnica. Hay potencial para los flujos de lodo o deslizamientos de tierra que se iniciara a partir de carga sísmica.

- Evaluate a number of locations for the tailings management facility, and select the location(s) with the lowest hazard ranking.
- Increase monitoring of tailings dam stability and seepage throughout and after the mine life.
- Incluya la participación de interesados de profesionales técnicos calificados que representen a grupos de interés público.

It is E-Tech's hope that MAE will increase the vigilance on the Mirador Project, seriously evaluate the environmental risks, and choose best practices that will minimize the potential for adverse environmental effects.