

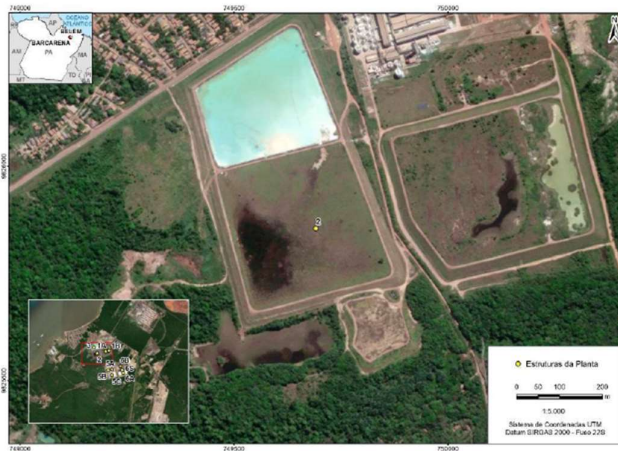
Stability analyses of TSFs

Client: Imerys Mining

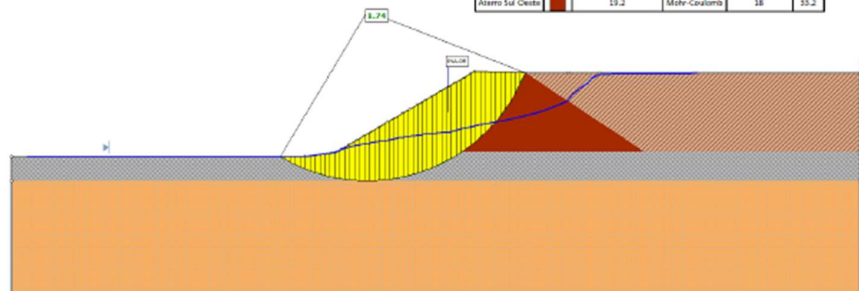
Description: In 2023 Terratek carried out stability analyses of bauxite TSFs (tailings storage facilities) located in Pará, Brazil, including static and dynamic pseudo-static limit equilibrium analyses.

This project included:

- Analyses of existing site investigation data and selecting geotechnical parameters.
- Seismic studies and site response analysis.
- Static limit equilibrium stability analyses under the most severe operation conditions;
- Dynamic pseudo-static stability analysis



Material Name	Color	Unit Weight (kN/m ³)	Strength Type	Cohesion (kPa)	Phi (°)
Fundação 1		18.5	Mohr-Coulomb	25	28.3
Fundação 2		18.5	Mohr-Coulomb	25	27.3
Rejeitos		16.8	Mohr-Coulomb	24	25.4
Atorro Sul Oeste		19.2	Mohr-Coulomb	18	33.2



Liquefaction analyses of tailings dams

Client: Vale

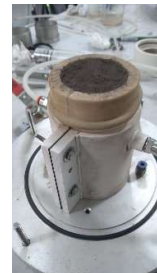
Description: Terratek carried out static liquefaction analyses of tailings dams for decommissioning studies and design. This job includes five dams, namely Sul Superior, Doctor, Campo Grande, Vargem Grande and B3B4 Dams. The aim is to analyse liquefaction potential and factors of safety before and during decommissioning works. The job includes existing data analyses and liquefaction potential assessment, advanced triaxial testing for obtaining NorSand tailings parameters and finite element analyses.

This project includes:

- Analyses of existing site investigation data;
- Recommendation for additional site investigation;
- Advanced triaxial testing with V_s measurements on reconstituted samples;
- Obtaining NorSand parameters;
- FE simulation of dam construction;
- Obtaining factors of safety for each stage using SRM (*Strength Reduction Method*) and FE Stress (stresses from FE analyses + limit equilibrium analyses)
- FE simulation of the decommissioning process.

Laboratory tests

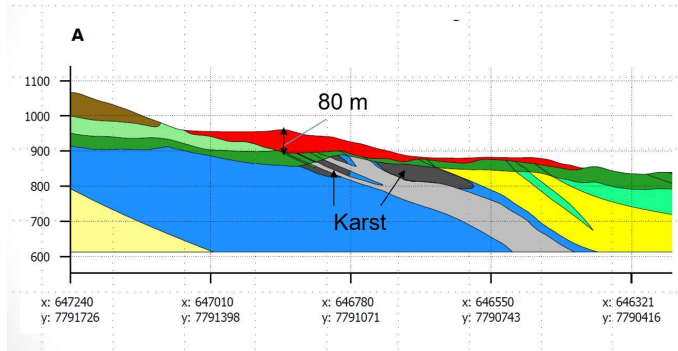
Terratek's laboratory carried out advanced triaxial tests and reconstituted samples of tailings employing the moist tamping technique which yields high void ratios. Saturated specimens are then subjected to a proper range of isotropic and anisotropic consolidation pressures and then drained or undrained shear. Our fully automated triaxial equipment can be fitted with bender elements to allow V_s shear wave velocity measurements.



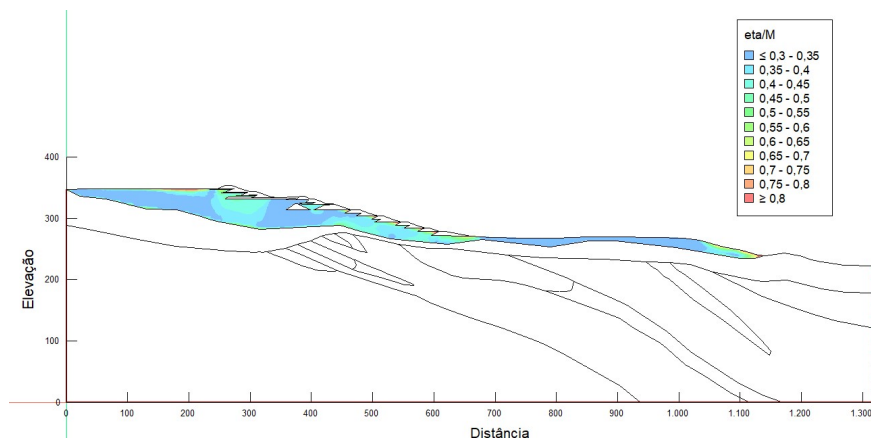
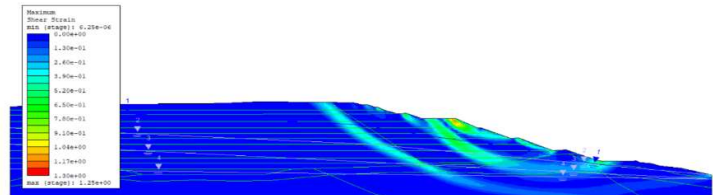
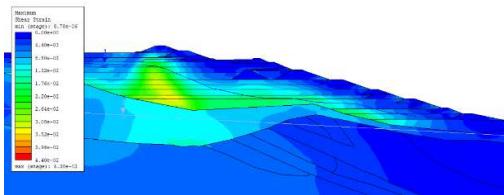
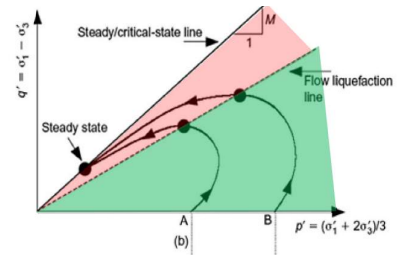
Project datasheet
Mining & Tailings

Sul Superior Dam (SSD)

SSD has started some 30 years ago with a 20 m high starting dyke and has been raised over the years using the upstream method of construction. The dam today is 80 m in height and needs to be decommissioned. Terratek analysed liquefaction potential and carried out stress and deformations through the finite element method.



Liquefaction potential

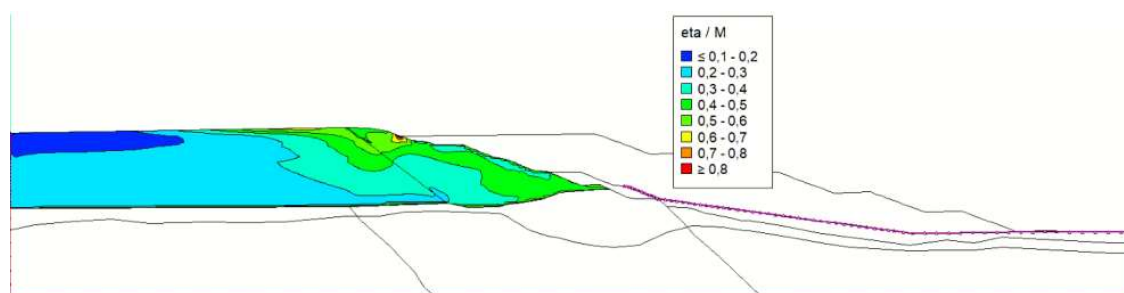
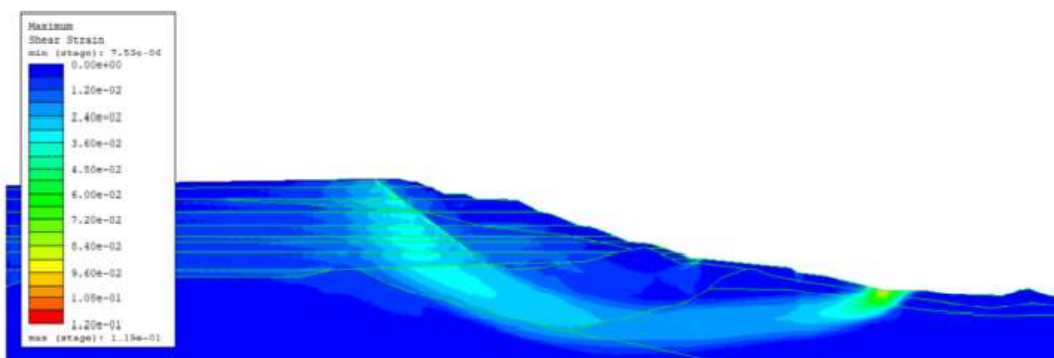
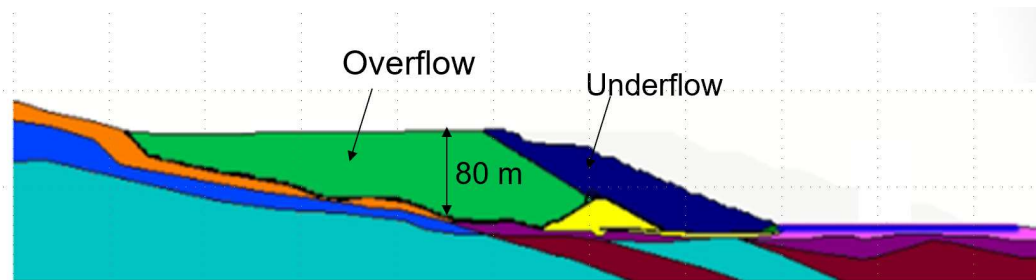


Project datasheet
Mining & Tailings

Doctor Dam (DD)

DD, some 80 m in height, has a starting dyke built with compacted clay, followed by a centreline construction method, where two types of mine tailings were used. The underflow tailings are coarse and compacted materials, while the overflow tailings are loose sands and silts.

Terratek's analyses for the current dam status yielded factors of safety above 2.5 and low potential liquefaction results. Therefore, Terratek recommended a modification of the decommissioning design plan, as the downstream reinforcement berm is not fully necessary. This conclusion leads to significant savings.

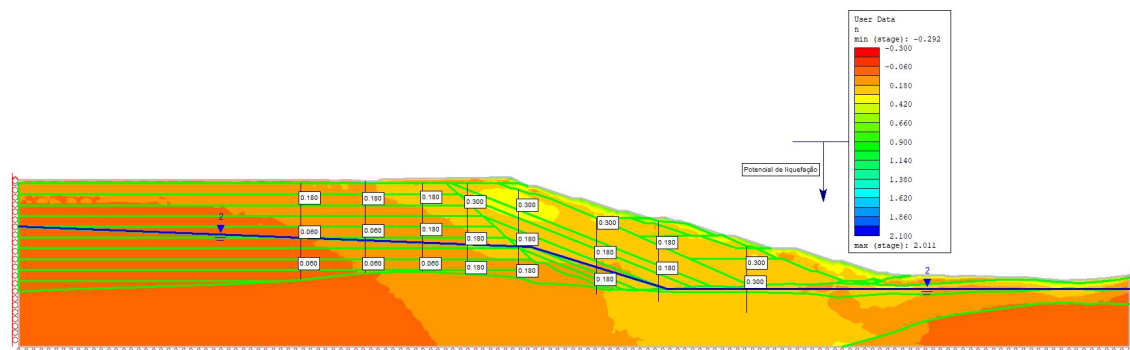
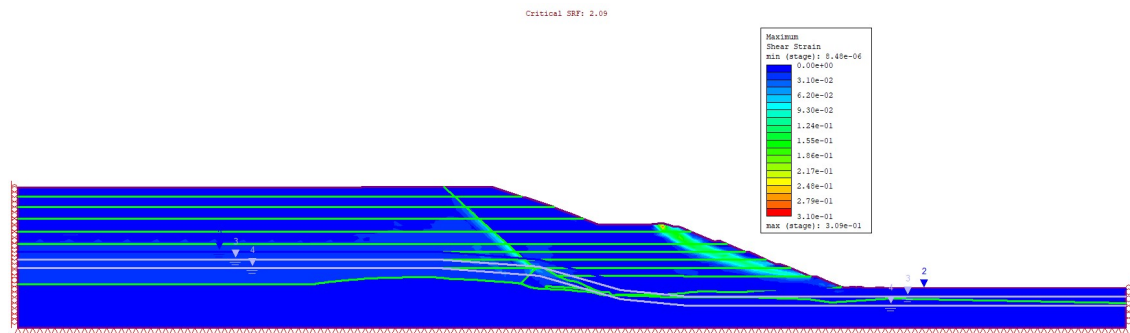
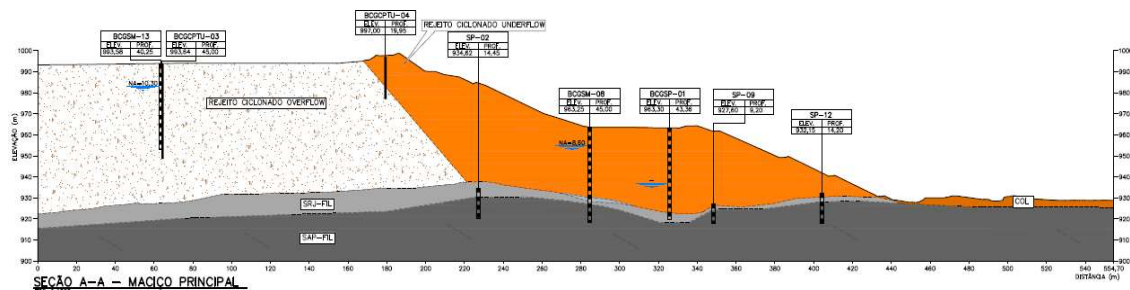


Project datasheet
Mining & Tailings

Campo Grande Dam (CGD)

CGD has a similar design to DD, also some 80 m height and built with underflow and overflow tailings, the first being compacted and presenting a dilatant behaviour, the latter a loose contractive behaviour.

Terratek's analyses for the current dam status yielded factors of safety above 2 and low potential liquefaction results. Therefore, Terratek recommended a modification of the decommissioning design plan, as the downstream reinforcement berm is not fully necessary. This conclusion leads to significant savings.

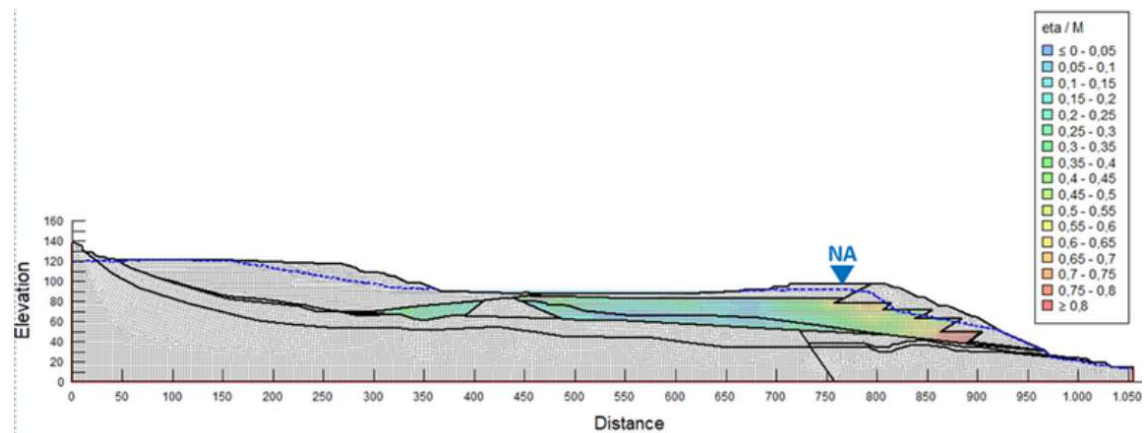
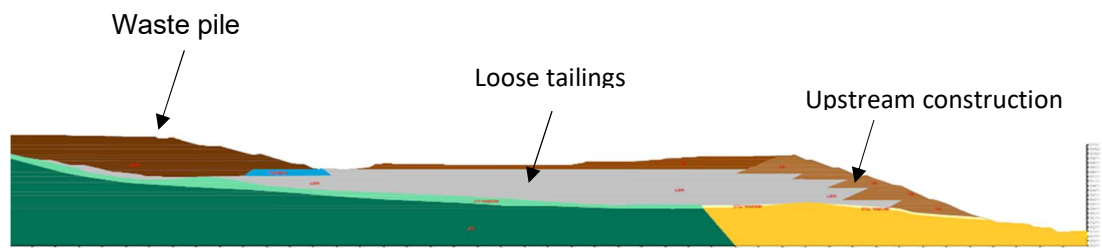


Project datasheet
Mining & Tailings

B3B4 Dam

B3B4 is a large dam also built by the upstream construction method. At the end of the reservoir, a very tall waste pile was built over the tailings, and this leads to an unsafe design. The dam is under decommissioning process and is currently (2022) being excavated.

Terratek's analyses for the current dam status yielded low factors of safety around 1.3 during excavations works.

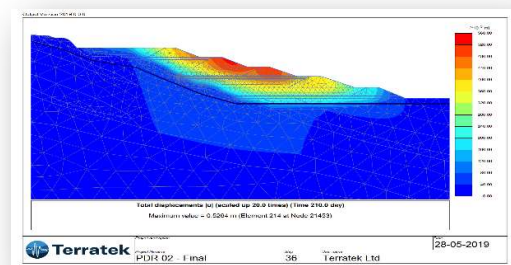
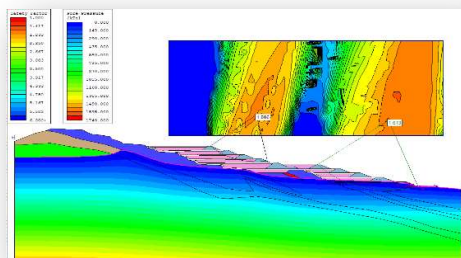
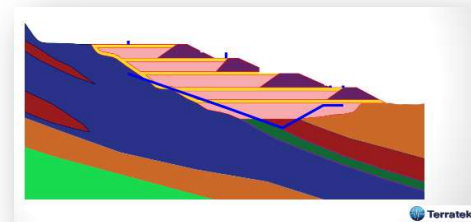
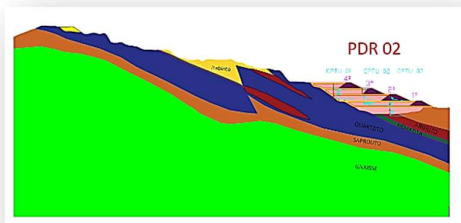


Design of waste pile

Location: Minas Gerais, Brazil

Client: J Mendes Mining

Description: In 2020 Terratek carried out the design of a huge, 80 m high, waste pile on sloping ground. The work included analysis of existing site investigation data, specs for additional site investigation, stability and Plaxis 2D deformation analysis, as well as a proposal for a monitoring programme.

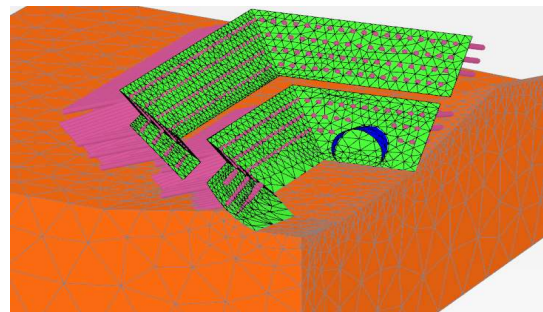


Project: Design of Access Tunnels, Bonsucesso Underground Mine

Location: Paracatu, MG, Brazil

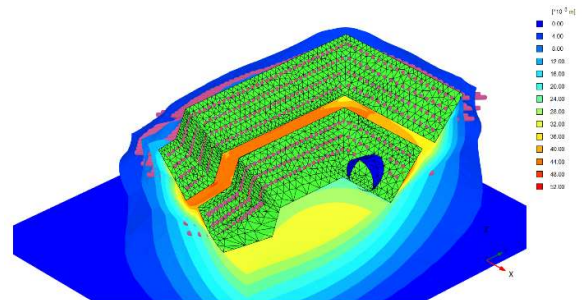
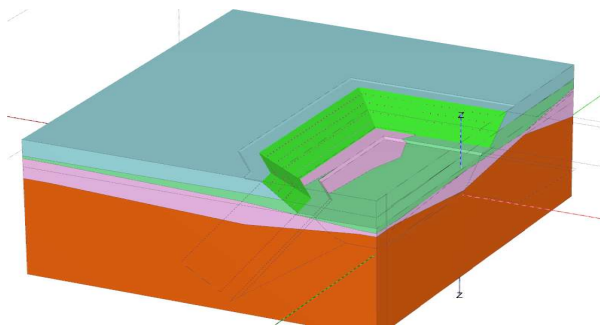
Client: Nexa Resources

Description: The project consists of the design of two 20 m deep trenches and four tunnels to access the ore. Inside the trench, there are two portals giving access to two tunnels. Each tunnel has a 40 m² sectional area. The geotechnical solution for the trenches was soil reinforcement utilizing the soil nailing technique. For the tunnels, the solution was a NATM type solution in which the sandy materials will be stabilised by employing horizontal jet-grouting (HJG) columns. Terratek also designed an umbrella-type crown reinforcement with HJG. The tunnel's primary lining was 25 cm thick sprayed concrete. The secondary lining was 30 cm thick cast in situ concrete.



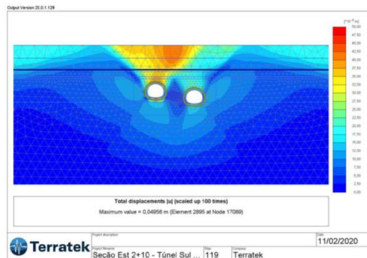
Services provided by Terratek:

Terratek was the designer and also carried out the site investigation



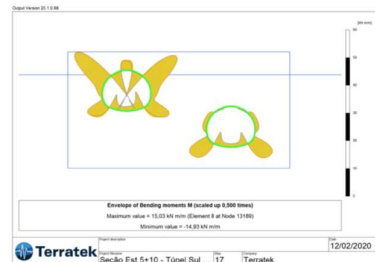
Total displacements u (scaled up 100 times)
Maximum value = 0.05583 m (Element 39586 at Node 9562)

Terratek
Project name: Trincheira Sul v32
Job: 275
Company: Terratek Ltd
Date: 03-02-2020



Total displacements u (scaled up 100 times)
Maximum value = 0.04959 m (Element 2895 at Node 17095)

Terratek
Project name: Córrego Est 2+10 - Túnel Sul ... T19
Company: Terratek
Date: 11/02/2020



Envelope of Bending moments M (scaled up 0.300 times)
Maximum value = 15.233 kN.m (Element 8 at Node 13195)
Minimum value = -14.833 kN.m

Terratek
Project name: Córrego Est 5+10 - Túnel Sul ... T7
Company: Terratek
Date: 12/02/2020



Design of sheet piling tailings dams

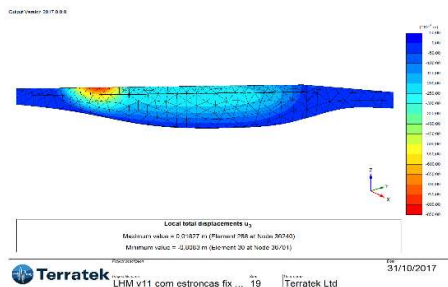
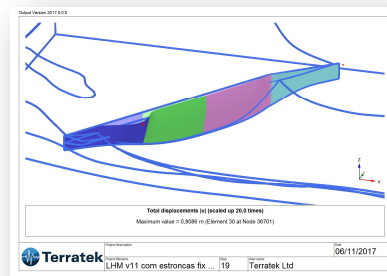
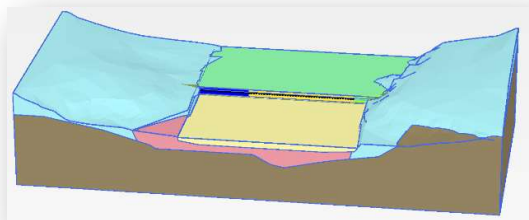
Location: Doce River, MG, Brazil

Client: Renova

Description: Fundão dam failure in 2015 led the tailings to flow and pollute the Doce River. Vale and BHP Mining, owners of Fundão Dam, created the Renova Foundation to design and implement mitigation solutions for the disaster. One of them is three sheet piling dams across the Doce River, to contain the tailings and enable dredging. Terratek was hired for a detailed Plaxis 3D analysis of the preliminary design and a monitoring programme with IPis (in-place inclinometers). Plaxis 3D analysis showed a flaw in the preliminary design which would lead to large horizontal deformation on the sheet piling close to the right abutment and led to a thorough design review.

Terratek carried out:

- Analysis of existing site investigation;
- Plaxis 3D model of the sheet piling dam;
- Analysis of the results
- Monitoring programme.



Design of waste pile with geotubes

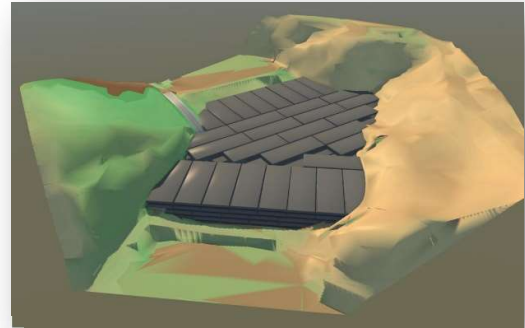
Location: Doce River, MG, Brazil

Client: Renova

Description: In the wake of the Fundao Dam failure in 2015, the dam tailings flowed along the Doce River and sedimented along its way. Vale and BHP, the owners of Samarco Mining, created the Renova joint-venture which in turn hired Terratek to design an innovative type of waste pile to be filled with tailings pumped from the Doce River.

Terratek carried out:

- Analysis of existing site investigation;
- Pile waste design;
- Monitored pilot test of geotube filling;
- Site supervision;
- Instrumentation and monitoring programme.

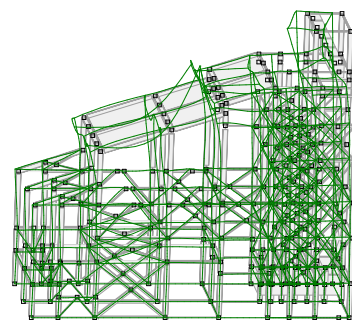


Structural Integrity Assessment

Location: Mirai, MG, Brazil

Client: Empa Contractors and Votorantim Mining

Description: In 2008 Terratek carried out structural integrity monitoring of seven mining structures consisting of a scrubber building, primary and secondary crusher structures, and the transfer and sampling towers. The job included dynamic measurements on selected locations on the structure, numerical modelling and model calibration, analyses of the results and design of reinforcements when needed.



Decommissioning of Mundo Mining Tailings Dams.

Location: Rio Acima, MG, Brazil

Client: MG State Public Works Dept

Description: Between 2017 and 2018 Terratek carried out the decommissioning design for the abandoned gold mine. One tailings dam and the other is an arsenic-contaminated reservoir. These dams are located 2 km upstream of the water intake structure for the City of Belo Horizonte, and their failure would result in an enormous environmental disaster.

Services provided by Terratek

- Site investigation: drilling, sampling, lab testing, CPTU
- Geotechnical consultancy and design review;
- Contaminated water treatment design and plant;
- Drainage design;
- Geomembrane design over the existing tailings.



Project name: SAG Mill Foundation

Location: Paracatu, MG,
Brazil

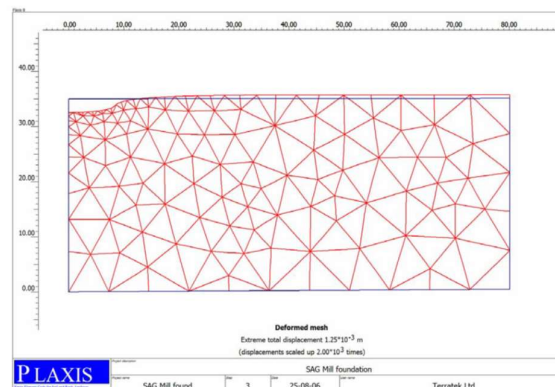
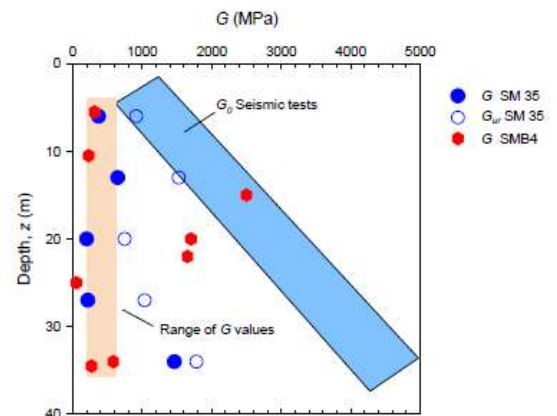
Client: Kinross Mining

Description: Back in 2007, RPM Mining, now Kinross Mining, carried out a large expansion project and the deployment of a new SAG Semi-Autogenous Grinding mill, 18 m in diameter



Services provided by Terratek

- Site investigation: drilling and sampling, PMT and seismic tests;
- Geotechnical analysis report;
- Dynamic numerical modelling of the foundation;
- Vibration monitoring for the commissioning of the structure.

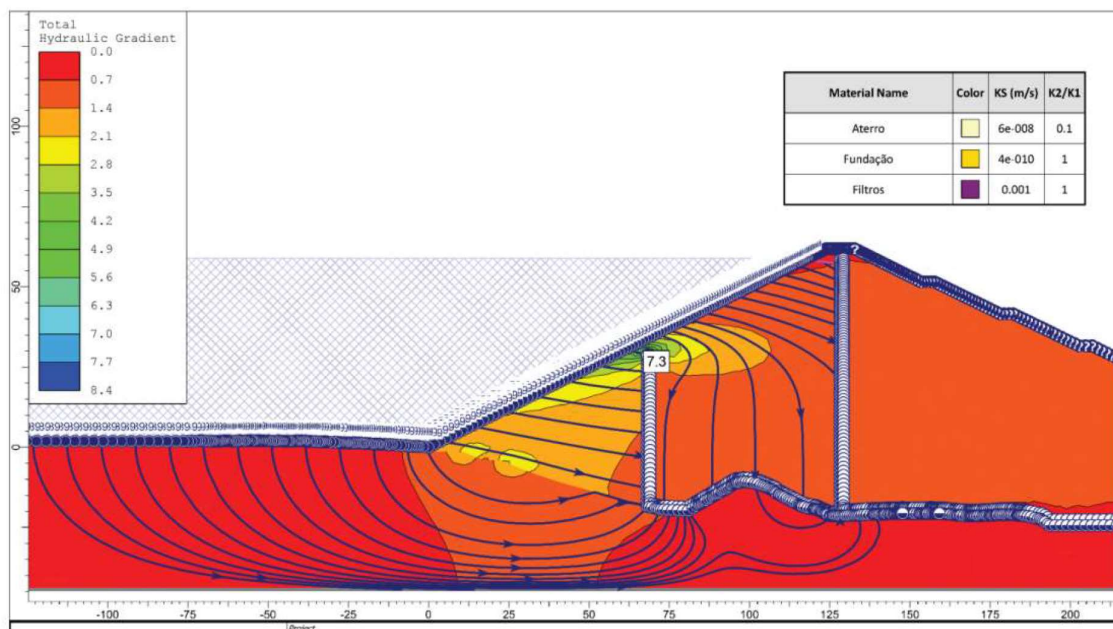


Design review of Maravilhas III Tailings Dam

Location: Nova Lima, MG, Brazil

Client: Construcap Contractors

Description: This is a tailings dam built by the downstream method and owned by Vale Mining. Construcap hired Terratek for the design review involving site visit and seepage, deformation and stability analyses. This work showed the need to redesign the rip-rap and high seepage gradients close to the top of the sand filter. Our recommendations also included improvement for the instrumentation programme.

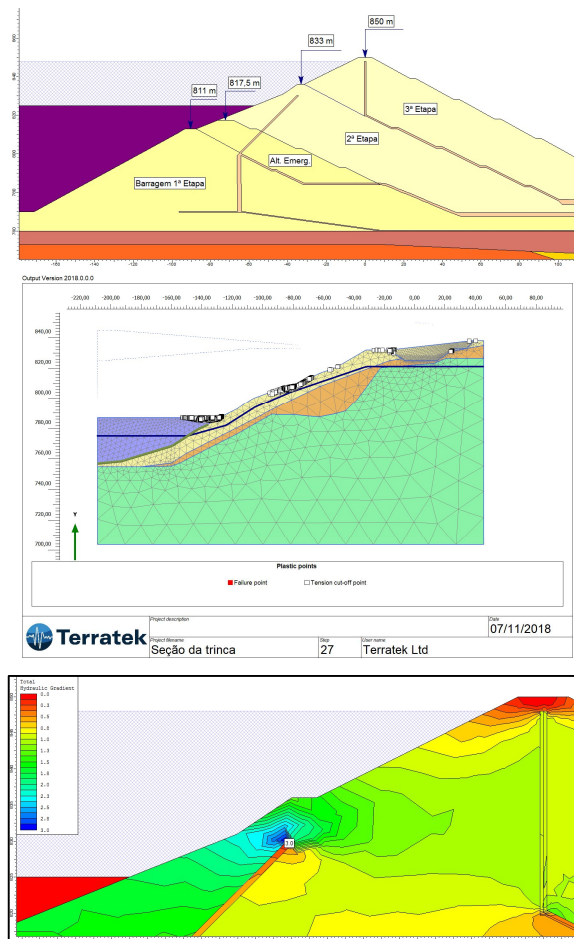


Itabiruçu Tailings Dam Design Review

Location: Itabira, MG, Brazil

Client: Empa Contractors

Description: This is a tailings dam built by the downstream method and owned by Vale. Empa was awarded the contract to carry out the second lift and hired Terratek for the design review. The work included a site visit when the Terratek team observed a cross and another longitudinal crack through the compacted embankment dam. Terratek carried out document review and seepage, deformation and stability analyses. The deformation analysis showed tensile stress zones where the observed cracks took place. This work showed high seepage gradients close to the top of the sand filter. Our recommendations also included the improvement of the instrumentation programme.

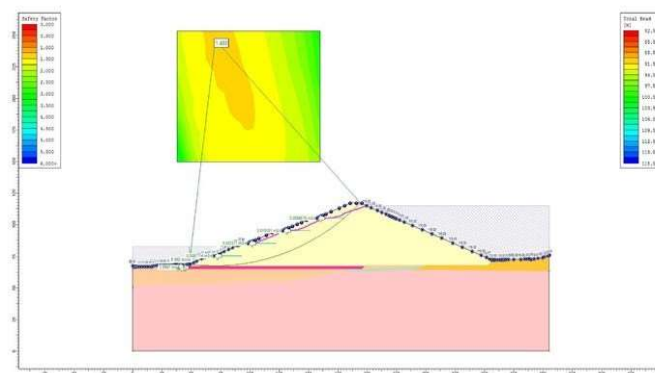
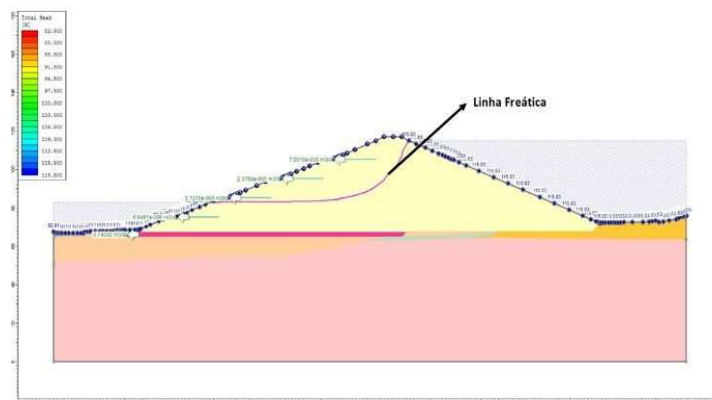


Design Review Sabão 1 & 2 Dams

Location: Serra do Salitre, MG

Client: Construcap Contractors

Description: These are water reservoir dams belonging to Norsk Yara Fertilizers Mining. Construcap is the contractor and hired Terratek for the design review. The work included a site visit, document review and seepage and stability analyses. Our analyses showed that the seepage analyses carried out by the designer were wrong due to the conceptual mistaken selection of compacted clay permeabilities, taken equally in the vertical and horizontal directions. This misconception led to recommendations to change the dams drainage system to avoid the phreatic water level crossing the downstream slope of the dams.



Design & Construction Review Avanco Dam

Location: Carajás, Curionópolis, PA

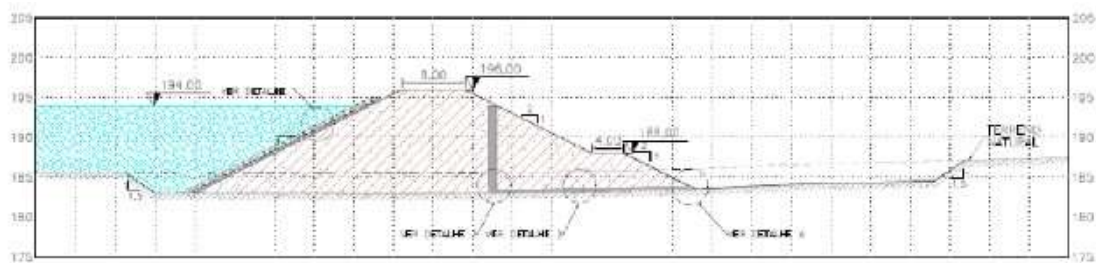
Client: Avanco Mining

Description: Avanco Copper Mining in the Amazon built from 2015 to 2016 a tailings dam, 11 m high, 320 m long embankment dam using the downstream lifting method. The drainage system consists of a horizontal sand blanket filter connected to the vertical chimney filter



Terratek provided the following services

- Site visit and safety inspection;
- Design review;
- Site resident engineering services;
- Final review & signoff report.



Germano Mining Dry Waste pile

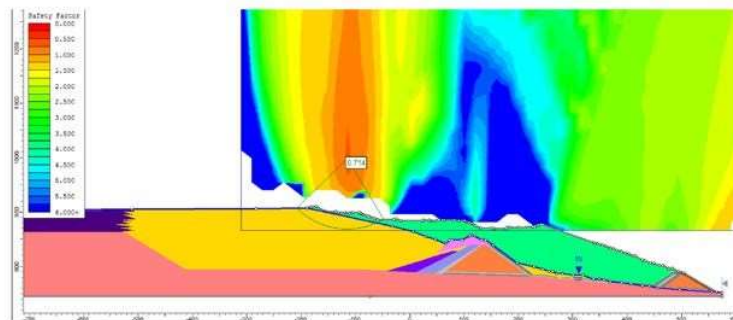
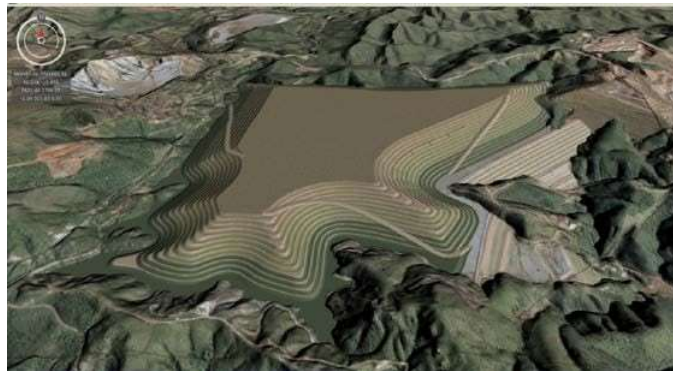
Location: Mariana, MG, Brazil

Client: Samarco Mining

Description: In 2013 Samarco Mining awarded Terratek a contract to carry out feasibility studies for a stockpile for the disposal of dry mine tailings.

Terratek provided the following services:

- In situ (CPTU, Seismic CPT, VST) and lab testing;
 - Design and construction of a trial embankment on fine mine tailings;
 - Probabilistic seismic hazard studies;
 - Static and dynamic liquefaction susceptibility;
- Stability analyses.



Crusher wall design

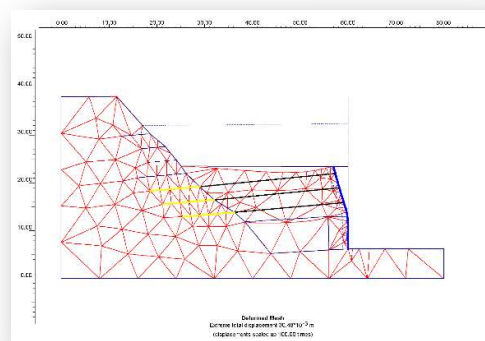
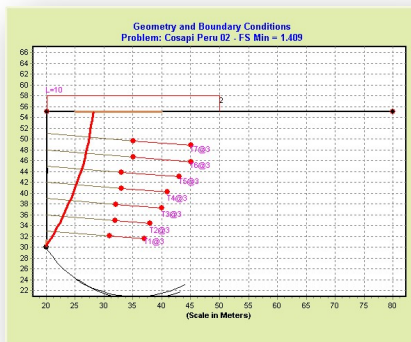
Location: Toquepala, Peru

Client: Cosapi Contractors / Southern Peru Copper Co.

Description: A joint venture between Logus Ingeniería and Terratek carried out in 2004 the detailed design of a large and 35 m tall tieback wall for the Toquepala Mine new crusher. The mine is located in the Peruvian desert at highs exceeding 3000 m.

Terratek provided the following services:

- Site visit,
- Stability analyses,
- Plaxis 2D deformation analysis
- Structural design
- Earthquake analysis
- Instrumentation and monitoring



Design Review: Alemães Tailings Dam

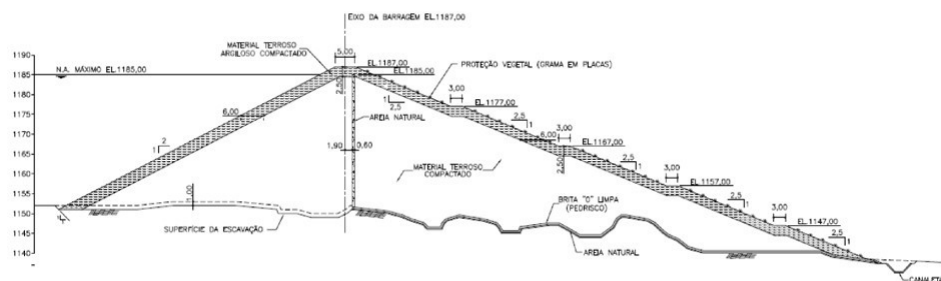
Location: Miguel Burnier Mine, MG, Brazil

Client: Gerdau Steel

Description: This earth structure is a tailings dam constructed by the downstream method. The starting dam is a 50 m high structure, 180 m long on phyllites.

Terratek provided the following services:

- Site visit,
- Stability analyses,
- Instrumentation analysis;
- Design review and sign-off report



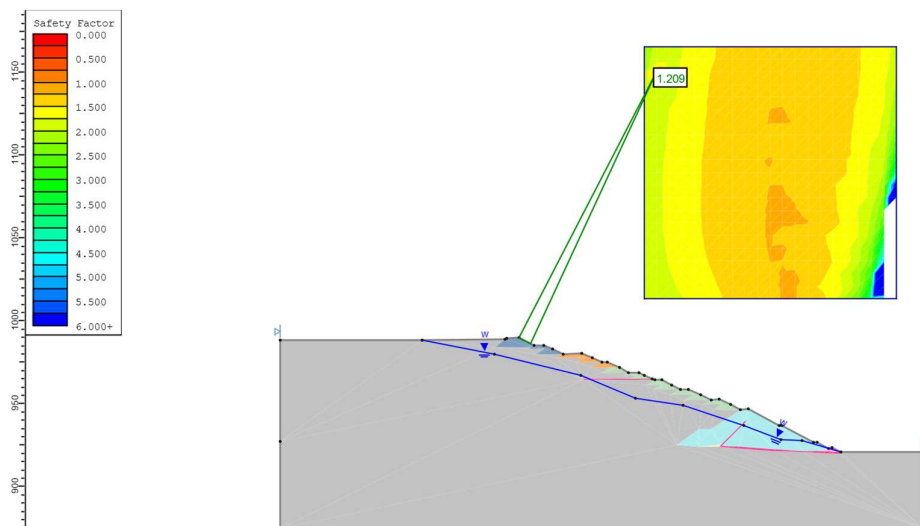
Itatiaiuçu Tailings Dam Review

Location, Itatiaiuçu, MG, Brazil

Client: Arcelor Mittal

Description: In 2009 Terratek was hired to investigate the stability of the tailings dam, about 100 m high and built by the upstream construction method. The work involved site investigation including in situ and lab testing and analyses. This work showed loose silty sandy tailings and a very high water level in the dam, close to the dam slope. Undrained laboratory testing showed liquefiable tailings with a cohesionless behaviour and a drained friction angle of 26 degrees. Stability analyses yielded a very low factor of safety $FS = 1.25$.

Terratek's final report did not ensure dam stability.



Project name: Morro do Ouro Tailings Dam

Location: Paracatu, MG, Brazil

Client: Kinross Mining

Description: Morro do Ouro tailings dam is 4 km long and 120 m high, and is among the world's largest dams of its type. Terratek provided geotechnical services from 2002 to 2008. It involves the dam and other structures such as the SAG mill foundation, slope stability of the pit,



Services provided by Terratek

- Safety inspection;
- Geotechnical consultancy and design
- In situ testing, seismic piezocone
- Geophysical testing
- Flume tests to simulate tailings beach
- Safety review and sign-off reports
- Design and construction of a trial embankment over tailings
- Stability and liquefaction assessment
- Instrumentation and monitoring



Project name: Germano Tailings Dam

Location: Mariana, MG, Brazil

Client: Samarco

Description: Germano tailings dam is 110 m high and, by the time of its completion in 2020 will be 140 m high. Terratek installed an automated monitoring system

Services provided by Terratek

- Supply of instruments; piezometers, hydraulic settlement cells, inclinometers, flowmeters, dataloggers
- Installation
- Datalogging
- Argus web-based monitoring system for all electrical instruments

