Solution collection system for a ROM leach dump: Design criteria to meet best available control techniques rules

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Abstract

Low grade ore dumps subject to leaching operations typically report the pregnant leach solution (PLS) to a downstream collection point, which is subsequently pumped out and processed for copper recovery. Proper design and operation of leaching collection facilities are critical to prevent the run-of-mine (ROM) dump from seepage and unpermitted discharge of these solutions into the environment. Structures making up for the solution collection system may include PLS impoundments, storm water diversions, check dams, lined pre-stacking material, collection channels, ponds and other facilities. This paper outlines the criteria to determine the specific engineering design of such facilities by meeting the use of the best available control techniques to minimize environmental releases and comply with government regulations. Techniques and calculations should be performed to estimate: i) limit-equilibrium slope stability; ii) runoff and storages evaluation under historical storm event scenarios; iii) peak discharge values and reductions, and iv) facilities size optimization. Finally, an application example in support of a copper leaching dump exposed to extreme climate conditions in a surface mine illustrates the proposed design criteria, methods, assumptions and outcomes.

Keywords: Solution collection system, leach dump, best available control techniques

Introduction

In the mining industry, leaching is a hydrometallurgical process that separates valuable minerals from ore by dissolving the mineral with a dilute cyanide solution in the case of gold, or a sulfuric acid to dissolve copper (Hearn RL & Hoye R 1998). Dump leaching is a technique where run-of-mine low grade material is stacked on prepared sites (pads) and wetted with lixiviant chemicals under atmospheric conditions. The metal content is then recovered from the rich 'pregnant leach solution' through mineral processing (Zanbak C 2012). The main environmental concern in permitting dump leaching facilities is that of the pregnant leach solution and its containments, and thus it is absolutely imperative that no leakage takes place from the solution collection systems (Van Zyl D et al. 1998). Other ways of leaking solution can result from dump sliding, broken pipes, dam failure, and the occurrence of overflows due to severe storm events.

Economic and sustainable management of dump leaching operations implies that the mining company should proactively adopt the best available practices in the design, construction, operation, maintenance, closure and post-closure of every component of these facilities. Modern environmental legislation has introduced the concept of 'best available technology', 'best available control techniques' or 'best available demonstrated control technique' which would ensure the elimination or the greatest degree of discharge reduction of pollutants in order to prevent groundwater contamination (Singh MM 2010). While the directives given by environmental authorities must follow a defined general pattern, the applications of the best available practices at particular mines will depend on several site-specific factors, such as the meteorology,

Table 1 General guidance/requirements for leach dump facilities

Criteria	General Guidance
Site characterization	Appropriate when topography, soil properties, vadose zone, surface and subsurface hydrology may influence the dump design
Surface water control	Identify all surface waters locations around the facility (lakes, springs, etc.). Information on 100-year floodplains in the area. Control of runoff and run-on.
Geological Hazards	Identify actual and potential geologic hazards (soil collapse, landslides, subsidence and settlement, liquefaction)
Solution/Waste/Tailings characterization	Identify chemical and physical characteristics of solution, waste and tailings
Pad construction	Site preparation for pad construction. Grubbing, grading and sub-grading the area.
Liner specifications	Design and installation of pad components. Appropriate specifications for non-storm water ponds, PLS impoundments, leaching dumps, tailings impoundments.
Stability design	Provide stability under static and seismic loading conditions. Shear strength evaluation. Recommended minimum factor of safety 1.3 (Non-storm water ponds, PLS Impoundments) and 1.5 static factor of safety for tailings impoundments. For leach dumps and engineered heap leach dumps, te recommended FOS for static analysis is 1.5 (if geosynthetic components are not used), and 1.3 otherwise
Closure /Post-Closure	Present a Closure/Post-closure plan to prevent/control releases

hydrogeology, topography, geology, and magnitude of the mining operation (Hearn RL & Hoye R 1998). A brief description of the general guidance to engineering criteria and best available practices is shown in Table 1.

Although all significant components in a leach dump systems should be evaluated, the present work will only focus on measure operation flow rates, retention check dams, and leach dump slope stability.

Case Study: ROM Leach dump

Final dump design can accommodate the placement and leaching of approximately 212-Million tonnes of ROM material (Figure 1) located in the Western US. This paper evaluates the design and construction of the leach dump and associated leach collection facilities directed to satisfy the long-range mine plans and to meet environmental and civil design requirements. Items within the design criteria include regional design factors (design storm events and flow rates), leaching solution properties, application rate and design process flow rates. The base surface area will be compacted and graded to conduct pregnant leaching solution to the collection area located in the Southeast side of the leach dump. The dump design criterion has been developed to meet the requirements for liner systems, piping layout, and slope stability.

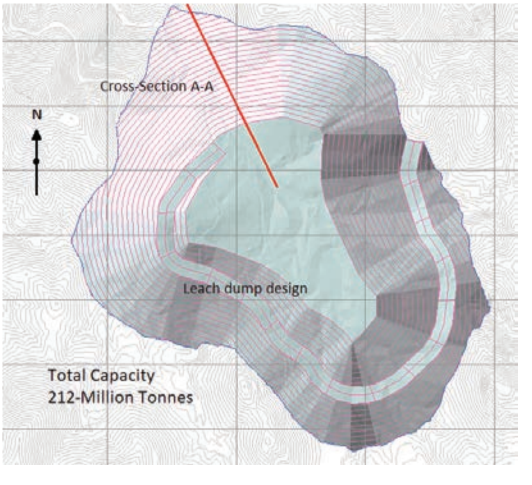

Figure 1 Leach dump design for a total capacity of 212-Million tonnes

Table 2 Summary of hydrology calculation results

Area (sq. miles)	Area (m2)	Depth 100-yr, 24-hr (m)	Volume (m3)	Leach dump Flow Rate (m3/s)
0.2559	662,896	0.0940	62,299	54.0

Operational flow rates

Surface water hydrology analysis around the proposed Leach Dump has been performed to determine the approximate peak stormwater runoff volume for the 100-year, 24-hour storm event. Sub-basin areas are calculated from the projection of the leach dump design to the topography. It is assumed that all rainfall will percolate through the leach dump and eventually will report to a contingency pond for capacity considerations, and the solution collection pipelines will discharge into the pregnant leach solution pond, with overflows reporting to the contingency pond in case of upset conditions. Rainfall depth is 0.094 m and the profess solution flows were calculated assuming nominal solution application rate of 0.00489 m/h (Table 2)

Retention check dams

Check dams are structures installed perpendicular to water channels and are aimed to control wash off, trap sediments from runoff and prevent discharge of pollutants to groundwater (ADEQ 2005). Small check dams can be used to reinforce the surface water control systems in conjunction with major dams or reservoirs. Check dams should be sized to retain the maximum volume of runoff attainable in considerations of site limitations and access and will protect the work during construction of the lined areas of the leach dump infrastructure. Runoff is calculated by amount of precipitation in the catchment area and by infiltration properties of the soil type and moisture (U.S. Depart, of Agriculture 1986). Check dams are placed within the dump limits in locations where high volume precipitation flow could negatively impact the leach dump foundation liners system during construction and prior to leach dump operation. The number of check dams, material quantities and storage capacities are estimated based upon storage requirements for a 100-year, 24-hour design storm event so that the impact on the dump foundation construction activities and downstream system due to precipitation are minimal (Figure 2)

Runoff depths for the 100-year, 24-hours storm for each watershed have been calculated using the TR-55 method (U.S. Depart, of Agriculture 1986). Total estimated runoff depth, then, is the starting point to design the check dams, so that the storage capacity created by check dams can exceed or be equal to

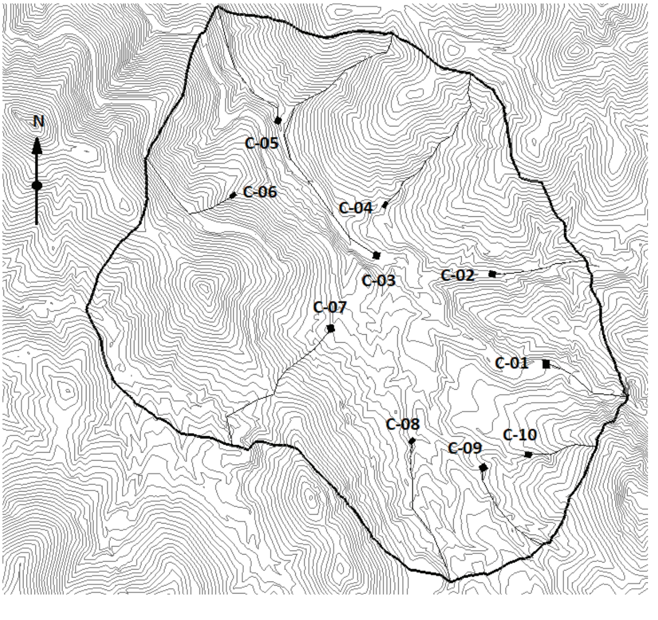

***Figure2** Check dam watershed site plan*

Table 3 Check dam analysis

P = Rainfall 100-yr (m)	Curve number CN (m)	S=1000/CN - 10 (m)	Q=(P-0.25S)2/(P+0.8S) (m)	Overexcavation depth (m)
0.094	2.210	0.038	0.060	1.5

Table 4 Check dam storage volume for the Optimized check dam model (10 total locations)

Check Dam #	Area Upstream of Dam (m2)	Estimated Runoff (m3)	Dam Height (m)	Dam Length (m)	Storage Volume Available (m3)
C-01	19,974	1,199	1.5	167.6	2,370
C-02	38,090	2,286	4.6	174.3	8,104
C-03	65,961	3,959	4.6	576.1	26,759
C-04	56,950	3,418	4.6	306.3	14,297
C-05	42,364	2,543	3.0	249.3	6,957
C-06	100,335	6,022	7.6	216.4	21,178
C-07	82,962	4,979	3.0	319.4	8,945
C-08	45,151	2,710	1.5	278.0	3,899
C-09	23,133	1,388	1.5	188.1	2,676
C-10	15,979	959	1.5	134.4	1,911

the estimated runoff volume. The optimized model is subject to successive iterations by strategically placing each check dam to maximize its ability to retain stormwater. The optimization was performed iteratively using 5' contours to estimate storage capacity for each check dam at an upstream and downstream check dam slope of 2H: 1V.

The results for the optimized stormwater check dam placement are shown in Table 3-4 below. Note that P is rainfall in inches (NOAA 2018); CN is the curve number, S is the potential maximum retention after runoff begins (inches), and Q is runoff. Values for S and Q are calculated based on the TR-55 method (U.S. Depart, of Agriculture 1986).

In order to reduce the risk of damage to the dump foundation, construction of check dams is completed upstream of construction activities. Once the leach dump has been established and ready to receive run-of-mine material from the mine, checks dams will be covered. Because of the its temporary nature, check dams are exempt from freeboard and spillway construction

Leach dump slope stability

Leach dumps usually become these large mining structures for which slope stability studies must be considered in their designs. Appropriate procedures for stability analysis of leach dumps are determined by the type of rock the dump is composed, whether it is classified as hard or soft rock, and other dump design considerations that include: maximum height, volume, slope angle, foundation material and conditions, and berms at the edges of lifts (Marcus 1997). Leach dumps built with hard, durable broken rock will be stable under static conditions and will only require evaluating slope stability if failure can occur through potentially weak foundation. On the other hand, for dumps built with soft rock, static and seismic stability analysis should be performed. The factor of safety (FOS) is the minimum ratio of available shear strength to the shear stress required for equilibrium. The recommended FOS is 1.3 for leach dumps where site specific testing and geosynthetic material have been used, otherwise the recommended FOS is 1.5 (ADEQ 2005).

A limit-equilibrium analysis was performed to assess the global stability of the leach dump for the ultimate design. The slope stability method calculates the minimum shear stress to maintain the slope stable. The maximum shear resistance is calculated for the corresponding shear surface using rock strength properties and pore water pressures. One cross-section has been analysed that best

Table 5 Material Properties

Material name	Unit Weight (kN/m3)	Effective Cohesion (KPa)	Friction angle (degrees)
Foundation	22	900	35
Low Grade ROM	21	0	37
Oxide ROM	21	0	37

represent the most adverse slope conditions using a two-dimensional, limit equilibrium modelling software Geo Studio Slope/W (GeoSlope 2012). Morgenstern-Price method of analysis was used to evaluate every cross-section, considering both static and seismic conditions. An effective friction angle of 37degrees (angle of repose) that corresponds with a slope of approximately 1.3H: 1V sustains slope inclination of the ROM leach dump. Prior to ROM material deliveries, dump footprint will be covered by a liner protection system (liners and geomembranes). Afterwards and during the entire dumping operation, a consistent leaching solution flow, runoff and rain water should be maintained through the leach dump and collection channels.

Based on the mine plans, the dump consists of three main components: a liner system at the dump foundation, low grade ROM material until a horizontal level is established to place Oxide ROM material on top. The slope geometries of the cross sections used in the analysis is provided in Figure 3. Stratigraphy and material properties used in slope stability are summarized in Table 5. In addition, the hydrostatic head in the proposed dump design is assumed to be 1 m.

Conclusions

Environmental quality standards may be violated around active leach dump facilities by leachates discharges that can seep into the groundwater. Therefore, the applications of efficient water management practices in mining are mandatory for permitting approval and renewal. Modern environmental regulations that adopt the concept of 'best available technology' work dynamically and are open to using state-of-the-art technology that has proven to be the best available in the industry.

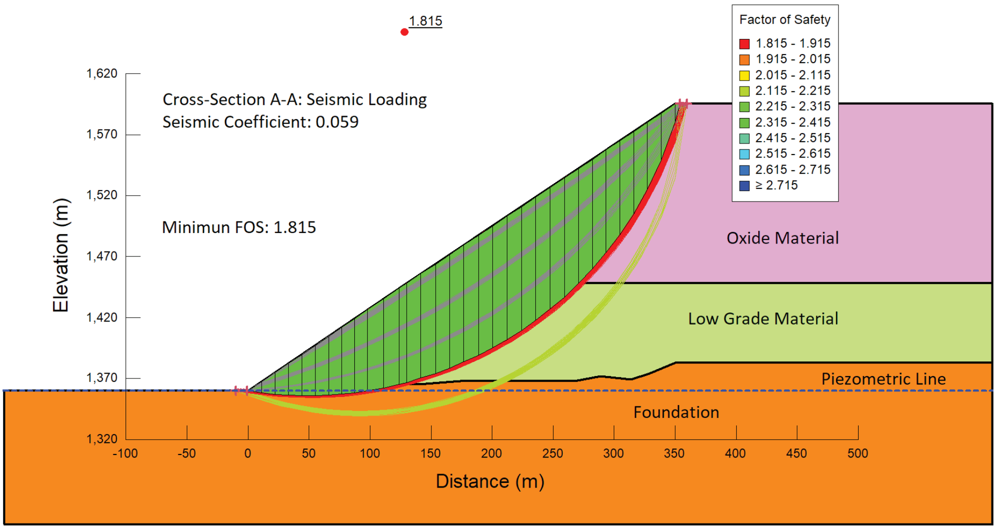

Figure 3 Slope Stability Analysis. Cross-Section A-A

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