# Changes in water management during heap leach lifetime in heavy-rainfall sites

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## Abstract

During the last five years, heap leach pads in Peru operating in rainy environments, successfully face heavy rainfalls, applying technical solutions for the temporary water management in the construction stage because of the creativity and immediate response of the joint work between engineering and construction teams.

Runoff management in heap leach pads may require changes during construction and operation due to different reasons, such as economical, topographical, operational, and geotechnical issues which were not anticipated during design and due to construction of drainage structures being urgently built close to rainy season. These situations make it necessary to modify the projected water management, which can generate additional expenses and important changes in the whole project.

This summary aims to show a current experience of design adaptation during construction of a heap leach pad located in the Peruvian Andes, where each seasonal transition induced setbacks in both construction and operation of the heap leach pad, being heavy rainfall and runoff the major critical factor. To control these issues, a sequential water management system was adopted, which works temporally for each rainy season, coupled to the raise of the heap leach pad and connected to permanent hydraulic structures to catch and divert runoff of impacted valley. The temporary water management used check dams for sediments control, inlets, channels, culverts, energy dissipator ponds, outlets, all lined with either geomembrane or stone masonry, which are considered also temporary liners of low cost and quick installation.

Taking into account the experience in these types of projects, we can conclude that the support of a consultant technical team during both construction and operation stages, increases the probability of success, due to immediate action and response to the unforeseen in stormwater management, avoiding delays in the construction schedule, reducing inefficient cost in drainage infrastructure and earthworks,

avoiding costs of emergency works and operational expenses, and other inconveniences that will affect heap leach pad operation everything that ultimately generates economic losses for the mining operation.

## Introduction

Commercial production of the case study mine began in 2016 with a production of 12,000 tpd, increasing to 36,000 tpd in 2019. Permits and studies for construction were obtained in 2014. The mining project area is located on an eastern zone of the Andes. The leach heap pad is located between gorges 1 and 2, as shown in Figure 1.

Water management for the final footprint of the heap is made up of perimeter channels near the top of the hills, which descend through rapids and end in sedimentation ponds located at the toe of the heap leach pad, from where it is discharged into the natural streams.

## Problem to be faced

In the case study the problem to be solved is how to prevent surface runoff from generating delays in the leach pad construction schedule and economic losses during operation. It must be taken into account that in some cases the detailed engineering studies of a leach pad do not consider the water management design of the scheduled raise year by year but are carried out either for the ultimate configuration or by phases for facilitating the approval of construction and environmental permits of the whole facility. In these cases, the water management solution is designed for the final or the next phase footprint when the heap leach pad reaches its corresponding predicted capacity. However, it takes some or several years until the heap reaches its predicted raise, meanwhile, the operator defines the raise on an annual basis according to the operation schedule or to arrange an area very free of runoff for the construction of the next phase. Besides, the planned designs for water management of the phases further away in time are taken as a relative reference due to the changes that may occur, so intermediate channels at higher levels can be traced by the operator regardless of that design, based on other criteria such as constructability advantages, or to avoid very steep alignments, since it is not necessary to follow a planned edge that may be adjusted or modified.

In Peru, during an annual cycle there is a dry season (from April to October) followed by a wet season (from November to March). According to data from the government meteorological agency (Senamhi), rainfall in the high Andean areas of Peru can present torrential rains in any year.

In the intermediate phases of the heap leach pad, if the water management design is not done in a timely manner, flooding, erosion, and potential instabilities in complementary components to the heap leach pad can be generated during the wet season, which can generate material losses and delays in the operation schedule of the facility, and consequently significant economic losses.

The case concerns those areas of future heap leach pad expansions upstream of the start platform, which are remote from the perimeter access of the heap which contains the permanent perimeter channel, to which the temporary channels are to be connected.


**Figure 1: Heap Leach pad location of the case study**

## Changes in water management of a heap leach pad

The leach pad of the case study in its final stage will contain about 140 Mt and will be divided into intermediate phases with upstream raise. Consequently, it is necessary to review and adjust the performance of surface runoff management from year zero (initial works), intermediate years and final year. The most common situations that present problems in water management during the development and operation of the heap leach pad, which must be addressed by the supervisors and construction team, are the following:

- During the preliminary works: clearing and grubbing, foundation excavation, underdrain, grading and installation of the liner system, as shown in Figures 2 and 3.
- Stages or intermediate phases: the same previous activities plus removal of the previous phase perimeter berm.
- Complementary constructions such as accesses, platforms, and dikes.

The solution of these problems demands the execution of engineering studies called "fast-track" for the design and construction of hydraulic works for water management. For the development of an adequate flow of information to achieve efficient engineering, the following elements must be taken into perspective: update of hydrological information, knowledge of restrictions due to geotechnical conditions, limitations of permits (e.g. authorized water discharge sites) and timely and scheduled planning including integration between specialists and mine reviewers.


**Figure 2: Heap Leach pad - Preliminary works**


**Figure 3: Heap Leach pad - Start of operation**

## Update of hydrological criteria

One of the important aspects is the review of the hydrological criteria, to improve accuracy and representativeness. The maximum rainfall frequency curve was revised, since in areas such as the case study, there is the limitation of a scarce and widely separated network of meteorological stations with a short recording period. With the information from the station installed on the site (Local Station), for comparison, it was inferred that the rainfall on the site is higher than that reported in nearby stations, although without conclusive statistics on its magnitude. So, together with the update with information from nearby stations, instead of the frequency curve it was decided to use the upper limit of the confidence interval, the respective 95% quantile.

The design risk level of the temporary drainage works (channels and culverts) was determined from the risk level of the permanent perimeter channels (in the sense of the duration of the entire operation). According to the practices of the mining industry, in operations of between 10 to 20 years, the return period is estimated at 100 years, which is based on the consequences of the risks. For the temporary channels, a scale was devised according to their operating time, maintaining the level of hydrological risk of the permanent canals (approximately 18%). For the case study, a single scale of 10 years of return period was decided for the design of temporary channels whose function is expected to be 2 to 3 years before being covered by the raise and construction of the intermediate stages of the heap leach pad. Likewise, it was necessary to review and modify the perimeter channels for intermediate situations, in this case maintaining the 100-year standard, so that any interior overflow can be duly intercepted by the temporary channels.

### Planning and integration between specialists and mine reviewers

For rapid design development there was a need to allocate a design engineer in the mine offices for an extended period, supported remotely by senior staff from the main office. The design engineer reported continuous and simultaneously to the director of the mine operator's planning and development office and worked in conjunction with the field data collection personnel; but with autonomous power to take design decisions. In this way, the rapid flow of information was achieved, feedback by direct observation of the performance of the work for design corrections, adjustments according to the most available construction alternatives, and in general a better alignment of the design with the restrictions of reality.

As a result of this and other experiences, for water management in a heap leach pad in general, it is recommended to consider the following:

- Request updated site information from the operator: topography, soil classification, geodynamic risks and as-built drawings, reflecting nearby structures and components, to identify restrictions for design and construction, coordinated with the design office to avoid overlaps or interference of plans such as the construction of new accesses not communicated.
- Develop annual water management plan for the work zone, which consists mainly of temporary channels on the edge of the area, in order to divert flows to authorized watercourses without affecting other mining components.
- Evaluate the runoff contribution area that was not considered in the original designs for the temporary channels. Consider the area that is altered, and how it will be in the near future, to evaluate the production of runoff and infiltration.
- As always there will be a gap between what is designed and what is later. It is recommended to use a factor on the runoff area, which can be statistically evaluated by comparing the design assumptions with subsequent as-built drawings; but while that statistical information is developed, based on experience, it is recommended to use 20% contingency.
- The design should focus on the greater capture and conduction of flows generated by surface runoff through temporary channels with a wide section. The optimum hydraulic section to capture and conduct the flows is the trapezoidal one. Also, consider the maintenance needs that require modifying the design and construction of wider sections than those required only by hydraulic conduction, so that

cleaning can be carried out with light machinery, since maintenance through the exclusive use of labor does not provide the speed necessary for timely cleaning.

- The design slopes for the temporary channel must achieve the behavior of flows with a subcritical regime (Fr<1) to avoid high velocities that require the construction of dissipation ponds, which is complicated by the limitations of the steep terrain.
- For the management and control of sediments, consider the construction of ponds located at changes in direction. The dead volume for sediments in the ponds must be at least 10% of their total capacity.
- It is recommended to use a temporary liner for channels and other drainage works, easy to install and dismantle, according to the availability of the mine; that guarantees the protection and liberation of the work area. Smooth HDPE geomembrane can be used to form drainage works; but its use should be avoided in areas susceptible to continuous rockfalls from the cut slopes that impact the liner.
- Temporary water management must have constant repair and cleaning to prevent leaks and clogging of structures. Periodic inspection or after each rain event is recommended.
- Pay more attention to the areas that, due to soil conditions, can generate, under the activating effect of infiltrations, mass movements, cracks and displacements; for which it is recommended, among other measures, to identify them, increase the size of the runoff collection channels and densify the drainage network in the area.

## Conclusions and recommendations

The construction of a heap leach pad in areas of intense rainfall entails updating the water management plan annually during the stages of execution and operation of the leach pad.

The impact of surface runoff on leach pads, according to experience, is manifested in flooding and instability of existing accesses due to the action of water flows, and instability induced in the cut slopes by infiltrations, especially during first years of operation.

The impact generated by surface runoff can be reduced through the coordinated participation of the design engineer on site with the planning, design, and construction areas of the mine operator to design and execute the water management plan in the site in the shortest time possible.

According to the case study, it is known that the cost of a temporary liner using a smooth 1.5 mm HDPE geomembrane for the water management system corresponds to 50% of the costs of a permanent liner, such as stone masonry.

The water management of a heap leach pad should be updated annually before wet season and designed for each construction phases for avoiding issues presented in this summary, however, most of the recommended actions described above is applied for an efficient water management control in a heap leach pad.