New Projects: Review of Lone Star Leach Pad Design, Construction, and Operation

Philippa Killian, Freeport-McMoRan Inc., Safford Operations, USA

Abstract

The Freeport-McMoRan Safford mine in Southeastern Arizona has become one of the company's highest producing copper mines in North America. The Lone Star (LS) resource was identified in 1886 and drilled and developed from the 1940s onwards. Feasibility studies were completed in the late 1980s, with mining permitted and operations initiated in late 2017. The mining of the deposit takes place more than four miles from the crushing facility, and required construction of new infrastructure, including extending ore conveyors, and building a new leach pad. The ore has low calcite and approximately 70% chrysocolla, making it a highly desirable expansion opportunity. The first Lone Star ore was delivered to a new leach pad on February 14, 2020.

The Lone Star pad is the newest leach stockpile constructed within Freeport's operations. The pad was designed with considerations and learnings from all previous leach pad projects within Freeport, using the best technologies available. The pad is 1.75 miles (2.8 km) long and a half mile (0.8 km) wide.

This paper summarizes the project development and operation, including lessons learned during construction, start-up, and operation. Also, specific examples of good practice that have been applied to the new pad will be discussed. This includes important Key Performance Indicators (KPIs) that are tracked and reviewed regularly to optimize pad performance. KPIs are discussed in the context of their impact to upstream and downstream performance of Safford copper production processes.

Safford uses remote monitoring of each module on the leach pad, including measurements of flow and pressure. Flushing is automated and monitored remotely to help ensure effectiveness.

Pad design, lift height, module layout, and piping are reviewed, along with over-liner neutralization, instrumentation, and monitoring. Also reviewed are flow transition between pads and predicting the solution balance and its associated challenges, and production predictions.

Figure 1: Aerial view of the Lone Star pit and leach pad

Introduction

The Lone Star resource was identified over 140 years ago. An aerial view of the site is shown in Figure 1. The deposit was drilled and developed beginning in the 1940s. The deposit is predominantly oxide, with some mill grade sulfide at deeper levels. Feasibility and design of the pit, roads, and leach pad facility were ongoing from the late 1980s through 2016, with mining commencing in the pit in late 2017. The leach pad construction began in June 2018, and was completed in June 2020. The first ore was delivered to the new leach pad in February 2020.

Design and construction

The Lone Star pad was designed using input from learnings derived from crushed leach pad operations throughout FMI in conjunction with technical analysis from experienced FMI engineers and the engineer of record (EOR).

The design needed to safely optimize copper recovery, while maintaining a geotechnically stable stockpile. This involved testing of construction materials for inclusion in the pad.

A considerable amount of learnings came from the construction and operation of the original Safford Phase 1 pad. This includes initial construction, stacking practices, operating practices, and compaction reduction strategies.

The Lone Star pad has a proposed height of 350 feet constructed in three phases, with potential capacity of up to 1.6 billion tons of crushed leach ore. The liner is comprised of low permeability fill material overlaid with an LDPE geomembrane. The LDPE was protected by 2 feet of fine over-liner fill and 2 feet of run of mine (ROM) material to complete the base of the heap leach pad. Crushed ore is fed to the prepared leach pad using a conveyor/stacker system, which includes overland conveyors, portable grass-hoppers, and automatic stackers. Most of the pre-existing portable equipment used for the original Safford pad was re-used. Phase 1 of the Lone Star leach facility is designed to have 10 lifts. Each lift is intended to be 18 to 20 feet.

The first lift was designed to include the 4 feet of over-liner material, so the crush ore stacked was 16 feet. The ROM/crushed leach over-liner was neutralized during stacking and leaching the first lift of new ore. Column testing had shown this was feasible without extreme acid consumption.

Solution is applied to the ore and carried through a solution collection system to the LS PLS tank. The solution collection system was installed within the over-liner and immediately above the geomembrane liner. Lateral collection pipes of 4" and 6" diameter, perforated, corrugated, polyethylene were laid across the pad at 20 feet spacing with a slope of approximately 2%. These route flow to larger perforated HDPE header pipes up to 24" in diameter. These pipes were laid in collection trenches running lengthwise in the pad (see Figure 2). Solution flows by gravity to a collection sump (LS sump) and then on to the LS tank. Solution can then be pumped to the solvent extraction/electrowinning(SX/EW) plant for processing. The solution can also be returned to the pad for additional cycles of leaching or, in stormwater runoff conditions, it may overflow into a process solution pond.

If the upset condition is extensive the process solution pond may overflow into the non-stormwater impoundment. The collection ponds were designed to contain a 100-year rain event. Additional collection pipes were installed to the sump in preparation for the future Phase 2 and 3 expansions of the pad. The collection sump has 3 × 36" underdrain collection pipes that convey flow to the PLS tank. Both the PLS tank and the sump are designed to handle stormwater flow surges, and if necessary, overflow to the process solution pond (a diagram of the collection piping is shown in Figure 2).

The climate is generally arid in this area. Seismic activity is not a significant factor in the region. The only significant surface water control issue to consider was a means to accommodate surface water drainage during seasonal rainstorms. A stormwater collection channel was designed to route stormwater from the upstream areas around the leach pad.

The leach pad and piping corridors, conveyor corridors, etc., are all on liner. Sumps/ponds have leak detection systems. Safford is a zero-discharge facility, so all process solutions stay within the mine site.

The pad has a minimum slope of 1% north to south, with slopes west to east of up to 2%. The final side-slope angle for the pad is 3.33:1 west; all others are 2.6:1. Individual lift angles are 1.3:1 (1.4:1 after settlement).

Initially ore delivered to the leach pad was a combination of ore from the San Juan pit and the Lone Star pit, while mining was expanding in Lone Star.

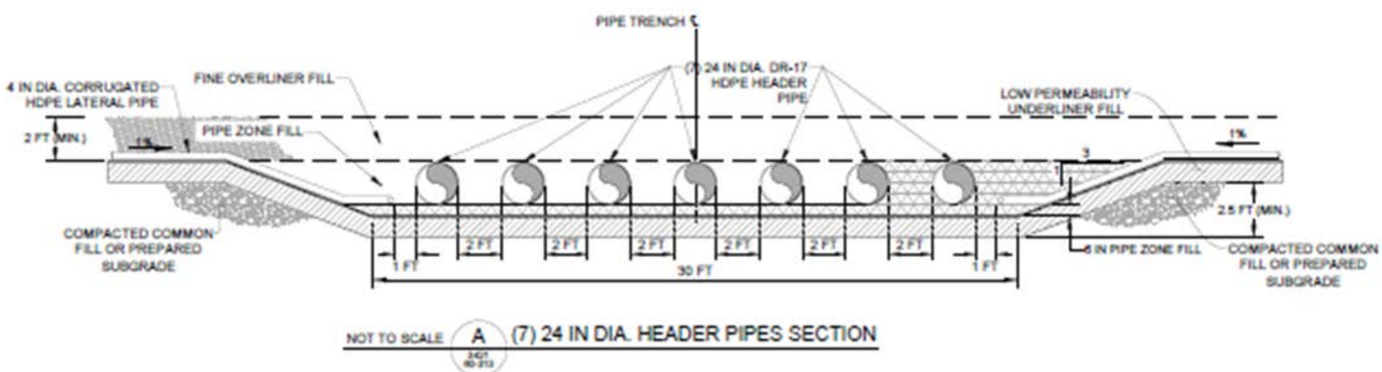

Figure 2: Solution collection diagram for the Lone Star leach pad

Operation – stacking

The ore is crushed to a P80 of 0.58" and then agglomerated with sulfuric acid and water as part of the acid cure process. Ore is then conveyed to the leach pad after agglomeration through a series of conveyors. The pad is stacked east to west by retreat stacking, so that the ore does not get compacted. Compacting the ore reduces permeability and leach recovery and can cause geotechnical concerns.

No equipment with a ground pressure of 5 psi or above is allowed on the pad, except the stacker. Compaction controls will be covered in more detail in a later section of this paper.

In preparation for stacking after each leach cycle is completed, the area is stripped of piping and dripline. The surface is slightly graded and then ripped with a low ground pressure (LGP) track dozer. Residual drilling, stability assurance, and any other necessary activities take place during the stripped period before the next lift is stacked. See Figure 3, which shows the Lone Star pad with stacking in progress.

Figure 3: Active stacking of the Lone Star leach pad

Operation – leaching

Phase 1 of the Lone Star pad operates a nominal flow of 36,000 gallons per minute (gpm) of raffinate to the pad.

Recipe

- The days under leach (DUL) target is 150 days.
- The application rate is 0.0022 gpm/ft^2.
- The P80 target is 0.58".
- Lift heights are 20 feet. The optimum lift height was determined by column testing.

The sulfuric acid concentration is targeted at 13.5 gpl. This enables operations to apply enough acid in the first cycle to recover the optimum amount of copper and align with estimated recovery curves. Lone Star ore has lower acid needs from gangue minerals than the prior pits mined at Safford, but has a much higher-grade ore, so the material is still a high acid consumer.

Our leachable area is separated into cells going south to north, which are in turn broken out into modules (see Figure 4). Lift 1 had 18 cells and 11 modules, but as the pad area decreases with additional lifts, the number of cells/modules shrinks.

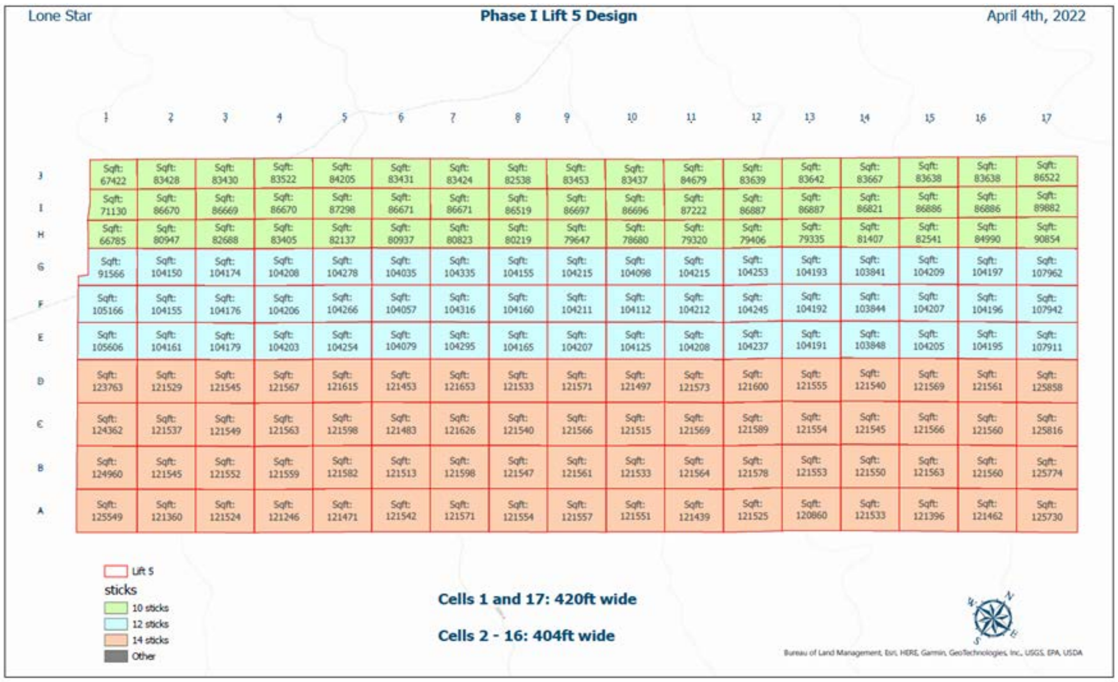

Figure 4: Lone Star leach pad layout

Raffinate piping is installed with 12" HDPE main feed lines to each cell. Then, 4" PVC pipe is used to connect to the modules. Dripline is installed to apply the raffinate solution. Module and cell widths are optimized based on previous flow testing and operation to ensure even flow across the area. Modules are typically 420 feet by 300 feet. Dripline feeds from north to south. Module flow feeds from the center in both directions. Solution is also applied to the side slopes.

Controls and monitoring

Each module has a feed side instrumentation skid, which controls the flow to the area and measures flow and pressure. These are battery-operated with radio communication.

Flushing the system occurs on a regular frequency and is essential to prevent drip line plugging from upstream solids or organic from the SXEW plant. On the non-feed side of the module there are two automatic flush valves on each end of the line, mounted on skids. These are also battery-operated with solar panels, and controlled by radio remotely to maintain an optimum flushing cycle. See the typical module layout in Figure 5.

The company has a team of water balancers who adjust skid flows as needed to stay within the intended design parameters. A team of maintenance personnel address and repair issues with both types of skids, as needed.

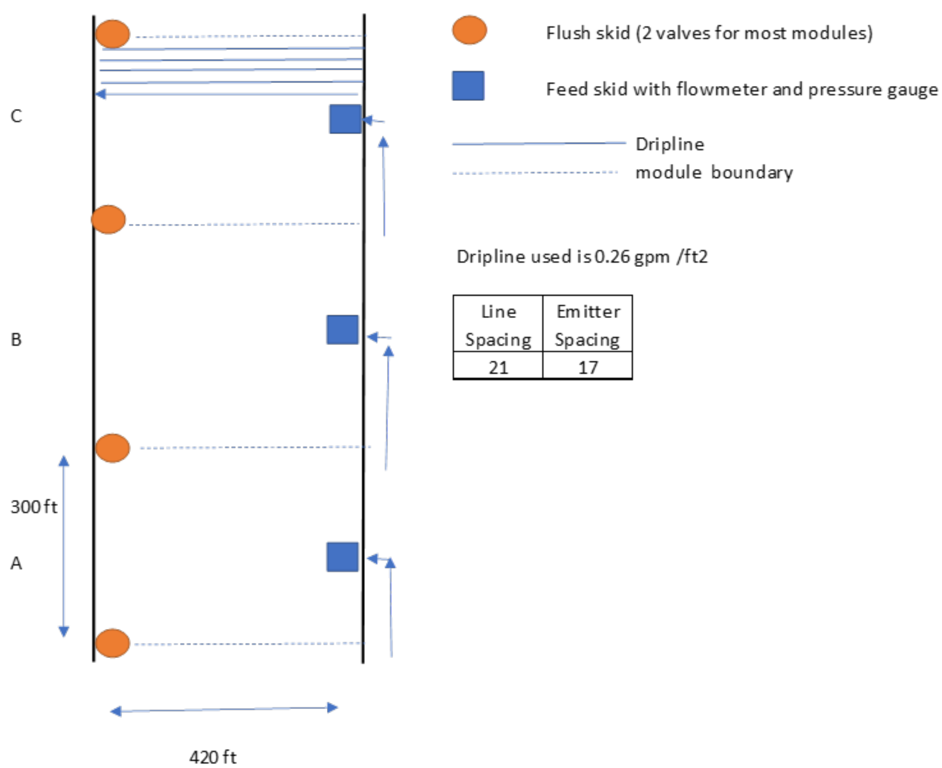

Figure 5: Flow and pressure skid layout

The solution application rate and flushing quality is monitored daily and during each shift, using many tools. A flow target is generated each day for each module. This is application rate in gpm/ft^2 multiplied by its surface area. The water balancers target this flow and adjust the skids in the field. Tablets are used with applications that are customized so that the real time flows coming from data in the PI database can be seen. Daily reports are generated to show the previous day's performance, and given a score as a percentage. At the same time, a geotechnical report is generated showing anything that is unacceptable. Geotechnical KPIs will not be reviewed in this paper for reasons of brevity.

To prevent preferential pathways or channelling in the stockpile, flow is stepped up in stages as new ore is placed under leach.

An example of a typical report is shown in Figure 6.

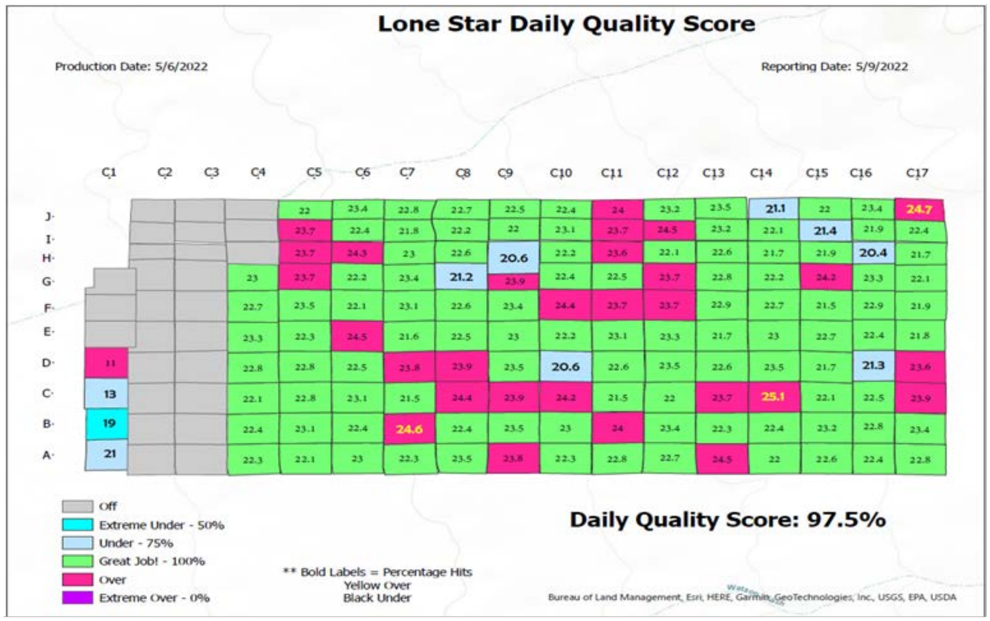

Figure 6: Typical daily quality score

In addition to application rate monitoring, flushing per module is tracked and reported daily.

An extensive drone program is utilized to observe issues on the pad, including slopes.

On the original Safford pad extra steps were learned to prevent any geotechnical issues. Equipment access to the leach pad is controlled to prevent compaction. Compaction of the new or pre-leached ore affects permeability, which affects pad porosity, flow distribution, and copper recovery.

Porosity can result in solution build-up within the pad, which can be a slope-stability concern.

Generally, no equipment is allowed on the pad with a ground pressure over 5 psi. A permit system has been established for unusual situations where no alternatives are possible. Previously leached areas are dried for three days before allowing any equipment on the area. No equipment is allowed on freshly stacked ore. Drain lines are installed around the perimeter during stacking to drain solution, to prevent solution build up. Vertical wick drains are installed throughout the pad to assist in solution percolation. The application rate is monitored closely to identify modules that exceed geotechnical KPIs, so that they can be corrected in a timely manner.

Performance

Copper recovery is monitored using mass balance accounting and recovery drilling. Copper grades, mineralogy, acid consumption/addition, P80, and many other parameters are tracked to the shift level and exact pad location using GIS, and by sampling the ore using a belt-cut sampler. The belt-cut sampler is located between fine crushing and the agglomerator. The unit automatically takes a sample every two hours from the crushed material as it passes to the agglomerator. After the leaching cycle, copper recovery is calculated by drilling some locations and comparing that to the original stacked data. Typically, three holes are drilled in each location to get an average recovery. To date, performance has been in alignment with expectations.

Geotechnical monitoring

The stability of the heap is monitored using piezometers, which monitor pore pressure (which indicates solution level), survey monuments, and GPS units to detect displacement, shape arrays monitor subsurface movement and also InSAR, which compares satellite images to monitor displacement. These controls are monitored daily and reports generated.

Challenges/learnings

The first issue encountered was while establishing the first lift of crushed material, as the stacker began having lateral stability issues. This was due to the ROM being too coarse in some areas, resulting in the stacker tracks becoming misaligned and tripping out on safety factors. This was remedied by removing the larger rocks with skid steers and having 24-hour ground observers to assist in identifying potential issues.

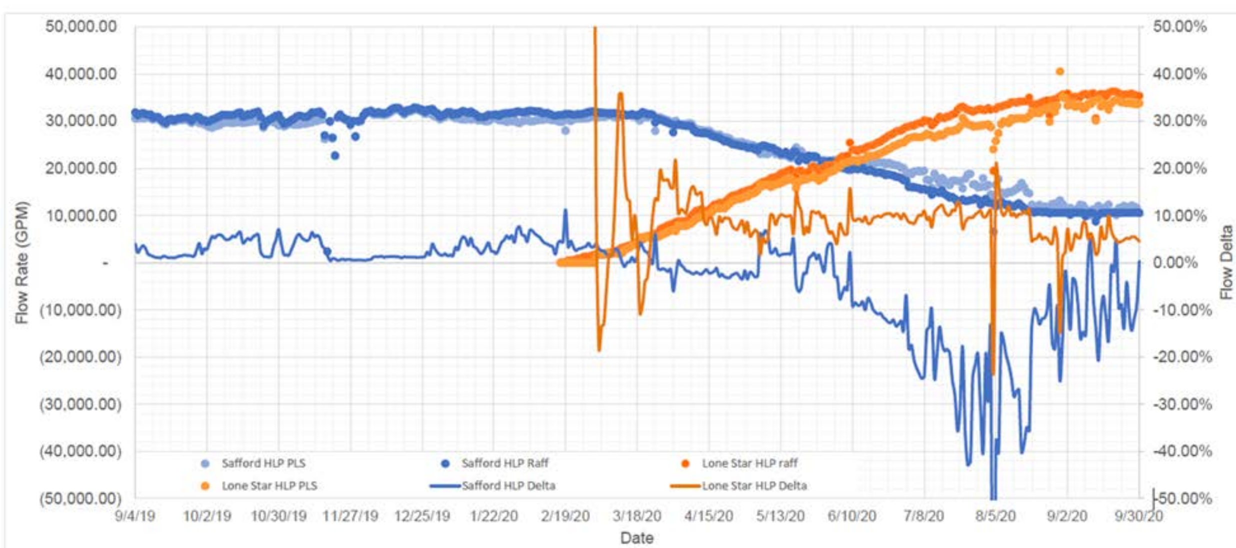

Figure 7: Flow transition between leach pads

See Figure 7 for charts showing flow transition. Transitioning flow from an existing pad can be a challenge. A deep stockpile will drain slowly, and there will be a period of time when the new pad is taking a small amount of solution but reporting quickly. Water management needs to be planned with sufficient storage for the existing flow to continue to drain, while adding increasing flow to the new area. Upfront planning was completed, and excess solution ponds were utilized during the transition and operations gradually decreased the old pad flow. Diesel pumps were also added in line to help with temporary pumping.

The leach pad was started in February, which was ahead of monsoon season in the southwest. Startup timing should be a consideration to adequately manage additional solution from storms. Fresh water make up should also be a consideration, and additional sources should be identified for the desired flows if needed.

The possibility of turbidity from the new area needs to be considered, and associated storage needs should be available. During initial operation, Lone Star did not generate any significant turbidity.

Acid consumption and down-stream effects should be considered. For an oxide copper deposit, the PLS was expected to have low acid initially. Column testing had given an indication of what to expect, and generally the results followed expectations. However, the PLS free acid increased more dramatically than anticipated, so low SX extraction efficiencies were seen for a short period.

Engineered raffinate piping designs did not quite meet the total flow needs when stacking the north end of the first lift. Engineering had divided the flow to feed an equal number of cells in the original design. Flow was preferentially flowing to the lower cells on the pad due to the effect of hydraulics, as the flow travels downhill for the first few lifts. This was remedied by moving the northern line tie-in point to feed cells further north on the pad, leaving the other two feed lines to feed more cells.

A significant flow discrepancy between the individual flowmeters on the modules (differential pressure meters) and the main line (magnetic) meters was also identified. Collaboration with the vendor was completed to help change the parameters in each DP meter to correct for the difference. Now the flow meters match closely.

Summary

By using collaborative resources for engineering and planning, resulting in controlled procedures for operation and construction, there are no production or geotechnical concerns. In conclusion, the Lone Star leach pad is operating as expected and producing the forecast copper, which is maximizing tank-house capacity.