Unique Push Back Exercises, Practiced at Iron Ore Company of Canada to Optimize Humphrey Pit Designs

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Every day, more than 190K tonne of materials are mined in two main mining zones, Humphrey and Luce, at Iron Ore Company of Canada, the largest iron pellet producer in Canada. The large operating site, unique ore body shape and the severe weather conditions create a challenging environment for mine planning engineers.

This paper provides general information about the current operating pits, the ore properties, and the mine planning software packages used on the site, and then it introduces the sequence of a series of push back exercises that have been, and planned to be practiced at IOCC to optimize the existing mine designs for Humphrey pit in order to both increase the reserve, and facilitate the orderly scheduling of production over time, by taking advantage of having more than one access ramp to the pit and consequently retrieving the remaining ramps. Finally, a numerical comparison between the reserves before and after the betterment in designs is presented.

**Keywords:** Open Pit, Push Back, Iron Ore Company of Canada, Humphrey Pit

1. Introduction (Iron Ore Company of Canada)

Iron Ore Company of Canada (IOC) was officially incorporated in 1949. After constructing the mine infrastructure and a 573 km railway from Schefferville mining area to Sept_Iles terminal, IOC shipped its first freight in 1954.

In 1962, IOC left Schefferville mining area and established Carol Lake project in Labrador west. And eventually, Rio Tinto became the main shareholder of IOC in 2000.

IOC mined in excess of 60 MT in 2008 in Humphrey and Luce mining areas. 39 MT ore was sent to the concentrator and pallet plant at average of 37-39% Fe and 37-43% weight yield. Weight Yield is a formula developed at IOC to better indicate the ore quality since Fe percentage is not a good indicator of the ore quality. For instance, in some ore type the high percentage of Fe does not necessary mean that the recoverable ore is high too. The basic breakdown of Formula Weight Yield recovery is as below:

\[
FWR = (\text{Recovery of Specularite}) + (\text{magnetite recovery}) + (\text{Gangue recovery})
\]

Magnetite and Hematite/Specularite are two type of iron ore mined at IOC. However, since the magnetite plant capacity is limited, the mine is always scheduled accordingly to provide the concentrator with a certain percentage of Magnetite through a careful blending plan.

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2. Mining Operation and Mine Planning

IOC has employed more than 25, 240t Komatsu 830E and few recently purchased 930 haul trucks, as well as two Bucyrus Ire 295 and three P&H PX 4200 shovels with one more coming on site to meet their more than 170Kt per day mining production.

The followings are a list of the production equipments.

- Bucyrus Erie Rotary Drills (4) – 49 RH_100000-115000 lb-F pull down
- P&H Drills 120A and 320XPC_140000-150000 lb-F Pull down
- Production L1800 and L1850 Loaders with 20 cubic yard bucker
- BE 295-BII Shovel with 18 Cubic yard bucket
- P&H 2800XPB Shovel with 30-36 Cubic yard bucker

At IOC, the main mine design software is Vulcan and for scheduling purposes XPAC is used. Whittle is also the mine optimization software to produce the final pit shells. A XACT model has also being developed recently for short term planning.

The technical team, produce a strategic mine plan (life of mine plan), five year plan and also a 1 year plan. The short term, three months and 6 weeks plans are also updated on weekly basis.

3. Humphrey pit

IOC is currently mining in two active mining areas, Luce and Humphrey. Humphrey West and Main are two small pits that have been joined together to form a bigger pit. Humphrey pit was abandoned for a short period and the all mining capacity was concentrated in Luce area however for some reasons a decision was made to reopen the Humphrey pit.

First of all, after a rapid jump in Iron ore price, the current final pit was reevaluated and new pit shell was generated in Whittle.

Second, Humphrey has a good ore quality which compensates the poor ore quality in Luce.

Third, since Humphrey and Luce are relatively far from each other, during the blasts in either pit, the other pit can still stay operational.

And finally, number 4 loading pocket which is the largest among the three loading pockets which feed the ATO, the automated ore delivery system from the mine to the concentrator, is located in north of Humphrey pit. By having operation in the Humphrey area, number 4 pocket can be fully utilized.

4. Ore body in Humphrey area

Humphrey has a relatively good ore quality with high magnetite content. Humphrey Main/West pit is located in a syncline where the ore body is plunging from west to east into depth. As a result, the steeper Highwall is designed on the east wall; the higher ore recovery is achieved.
5. **Humphrey pit optimization**

The mine designs and the final pit boundaries are evaluated periodically by previously the Rio Tinto technical team off site in Australia and recently after recruiting the necessary expertise at IOC, it is done onsite.

The economy evaluation and NPV assessment of the pit shell is run through Whittle and the new pit shell is generated. After that, using Vulcan the mining phases are designed. Figure 2 section a, is the first product developed off site.

This is a base for the preliminary development of the long term mine plan however this design has been carefully studied and reviewed by the mining experts on site. The following steps are taken by the mining engineers on site to optimize the design originally generated by the computer. At this stage, there very various parameters that computer is unable to comprehensive and only the mining engineers’ sharp mind is capable of processing all these data and opportunities to improve the mine plan. The steps that are taken to optimize the pit are listed below.

5.1. Studying the ore body

The first step is to study the ore body carefully and in details. The long term planning senior engineer at IOC, always say that “A good mining engineer should have a 3D picture of the ore body in his/her head before even initiating to work on the mine design.”

5.2. Looking for opportunities
The next is to look for any opportunities for pit betterment. It can be achieved by studying the current design and conducting numerous field trips to unveil the opportunities. There are very hidden opportunities created by the Mother Nature and the previous mining activities that we can take advantage of to improve our design.

In Humphrey case, these opportunities were discovered with a combination of people’s experience and two above steps. It can be identify in mining sequence and/or in the designs.

5.3. Identifying the operational deficiencies in the current design

There are many factors influencing the operational efficiency on site that cannot be easily discovered by the design engineers off site. Front line employees such as the team leaders and operators are dealing with all the operational issues therefore without their input a mine design is not complete or at least is not in its high efficiency stage. For instance, in a severe weather condition such what IOC is dealing with in Labrador, the road and ramp location is very important, in some places it is very hard to clear the ramps from snow in winter or maintain it in a good condition in rainy season. For another example, in very icy condition in winter, trucks have difficulty to accelerate on a slope after they come in a full stop at intersections, therefore by designing a flat platform before any intersections in the pit; the fleet productivity is increased as well as the safety. These are very detailed information that can be obtained on site from the experienced front line people.

6. Redesigning the final pit to increase safety, operational efficiency, and reserve and to reduce waste removal

In order to avoid any reworking, the Humphrey final pit was redesigned within the final pit boundaries generated by Whittle software on site. Therefore, a new NPV evaluation was not required as a result of the new design.

In Humphrey pit, since the ore body plunges from west to east, it was logical to try to avoid leaving any ramps on the east highwell because it would embed a significant amount of ore underneath itself in highwall.

On the other hand, it would reduce the pit width which would eventually limit the pit depth. The main goal is how to eliminate the spiral and east wall ramps which are indicated in the map a0 in figure 3.
Figure 2 Humphrey West/Main

Two opportunities were discovered which prepared the ground to retreat the final ramps. As it is shown in figure 2, there is a wide catch berm which would give the minimum width to connect the spiral ramp to the current ramp to number 4 pocket. Consequently, the spiral ramp can be back mined to number 4 pocket.

The second opportunity would be the current ramp to number 4 pocket. In order to push back the final east wall in Humphrey West, it is possible to connect the ramp on the last slice to the current ramp which allows the final ramp to be back mined for that push back slice. It can be achieved by resequencing the mining activities and rephasing the mine. It required to postpone the mining activities in the central area in order to connect two ramps, spiral and the east wall ramp to the current ramp to pocket number 4.

In order to do that, having a conceptual model and predicting the mining path in advance would help.
7. **Comparing the new design against the original design**

If the following three main requirements for the new design are met then that design can be easily sold to the managers and it can be put into implementation. Therefore, comparing new design against the original design, it has been proven that the following factors are improved.

7.1. **Truck cycle time**

In the new design and phasing, truck cycle time is reduced by connecting the push back ramps to the current ramps, as a result, after the connections are made trucks do not need to travel up the push back ramps and they can take the short cuts.

7.2. **Operational efficiency**

With a careful phase design, various operating faces are created which provides the operational team with more flexibility. Consequently, it will increase the production efficiency by reducing the down time during the blast and having better blending choices.

7.3. **Reserve comparison**

Last but not least, comparing two reserves calculated from the original and the new pit shell (Table 1), the new reserve is higher by approximately 16 million tonnes which drops the total stripping ratio by 0.01t/t.

The result showed a significant improvement in design which persuaded the managers to put the new plan into commission immediately.
8. New mining sequence and phase designs

Mining sequence and phasing is the most complex and important part of the mine planning process in any mines which requires more thinking and expertise. At IOC particularly for the Humphrey pit, the following steps were taken to design the new phases.

8.1. Advanced Conceptual model of the mining path

As it was mentioned previously, in many cases more ore can be recovered that are not accessible simply by improving and changing the current mining path. Therefore, it is very important to think far ahead and lay down the mining sequence for the highest ore recovery as well as creating more options for the managers and the mine planners to deal with any fluctuations in the company goals and the market uncertainties.

For instance, if high stripping phases are designed without any low stripping phases simultaneously then in case if the company experience some financial difficulties during the mining of those phases, then it is hard to recover from this situation however, on the other hand; if low stripping ratio phases are design in conjunction with high stripping phases then the managers can easily weather the hard economy times without any difficulties. They have more options to make decisions and so do the planners to plan the mine with the highest rate of return.

8.2. Determining the size of push back

There are few factors which control the push back dimensions in the mine as listed below.

8.2.1. Blast Pattern and Final wall trim blast

Final wall trim blast is a technique applied to use large diameter rotary blast hole for both final row and production holes to create a clean undamaged final wall.(Crosby 1990)

At IOC, a modified version of the trim blasting is employed therefore it dominates the minimum width for the final push back. An also since the burden and spacing is about 7.5m it is preferred to have a round multiple of this length for the push back width and length.

8.2.2. Equipment size

Equipments size is another factor that dictates the size of the push backs. In order to create a safe and operationally efficient working bench, the minimum width of the push back is set to allow a safe two way traffic as well as enough space to back up and turn for the trucks and loading units. At IOC the minimum ramp width is approximately 40m therefore the width of the push back should not be lower than that.

8.2.3. Ore and waste contact

<table>
<thead>
<tr>
<th>Region</th>
<th>Ore (t)</th>
<th>Waste (t)</th>
<th>S/R (t/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humphrey Original Final Pit</td>
<td>141,070,000</td>
<td>21,135,000</td>
<td>0.51</td>
</tr>
<tr>
<td>Humphrey Optimized Final Pit</td>
<td>155,929,000</td>
<td>22,609,000</td>
<td>0.50</td>
</tr>
</tbody>
</table>
If it is possible, it is always a good practice to design the push back limits on ore and waste contact which creates an opportunity for the blast planner to separate the ore and waste by a careful blast design. It will reduce the dilution in the final product and increase the mining efficiency simultaneously.

8.2.4. Stripping ratio

One of the most important controlling factors in push backs size is the stripping ratio. By a careful planning, the engineers try to have a steady stripping ratio during the life of mine plan. Obviously the larger, the push backs are, the more waste is required to be removed up front. Consequently, as the push back moved to depth, the stripping ratio drops suddenly. This creates sharp fluctuations in stripping ratio curve which is not desirable to the managers.

As a result, in designing the push backs in Humphrey, a preliminary scheduling was conducted to identify the most efficient push back sizes in order to keep the stripping ratio steady.

8.2.5. Access

The main concern in designing the phases for Humphrey was the access to the benches. Having more than one access would reduce the equipment down time significantly. As well as it would reduce the haul truck cycle time.

Figure 2 a) Humphrey West Highwall first push back
b) Second Push back
Figure 4 shows the first and second push back on the Humphrey West east wall. As it is indicated on the map, that wall is pushed back in two steps. In each push back, the wall is moved about 60m back.

As the second push back is progressed in waste the first one has already reached ore. Ore is hauled to number 4 and 3 pocket and waste to the small wood dump.

And in the below pictures, the south side of Humphrey Central is pushed back in a spiral manner because of the unique ore shape in that area. As it was mentioned previously, one of the wide berm was used to connect the spiral ramp to the existing ramp to the pocket 4 in order to retreat the spiral ramp at a later time. The spiral ramp is in ore.

9. Conclusion

There are many optimization software available in the market that help the engineers to produce relatively optimized and efficient designs and plans however it should not be mistaken that the computers offer the most optimized designs. As per Humphrey case, it has been proven; that the computer would not replace the sharp engineers’ mind but it would assist the engineers in their planning tasks. Therefore, computers should not be relied 100 present and it should be believed that there are always room for improvement in designs and plans. The design betterment opportunities can be revealed by checking the designs periodically and reassessing the real time mining circumstances.
Figure 6 shows the final product of a combination of engineers and computer design for Humphrey West/Main pit.

10. Acknowledgment

The authors would like to thank the mine general manager, Mr. Mat Simpson, and the chief engineer, Mr. Andrew Knight, at Iron Ore Company of Canada for their kind supports.

11. References