

**Model: Long-Hole Productivity**  
**Level: Micro**

## **Operating procedures**

### **Introduction**

The goal of the model is to calculate realistic productivity from data collected on site and to estimate the effect when changing certain parameters. The physical factors (number of sub-levels, drilling pattern, anchor cables, etc.) and the time factors (length of work shift, number of miners, time inside the stope, etc.) constitute the basic parameters of the model. Many cells in the spreadsheet were left empty to allow users to personalize the model according to their needs.

This document will help users by:

- describing the approach used to effect the productivity calculations;
- giving a description of the worksheets in the “Excel” file and their functions;
- identifying the types of required data and indicating where to insert them; and
- describing the different sections of the model.

### **1. Approach of the model**

The global approach of the model is based on the normal working cycle inside the stopes. Each mining step is separated into activities or tasks which miners must carry out daily. This method of proceeding allows users to be rapidly situated in the mining cycle in order to ensure that all elements are included.

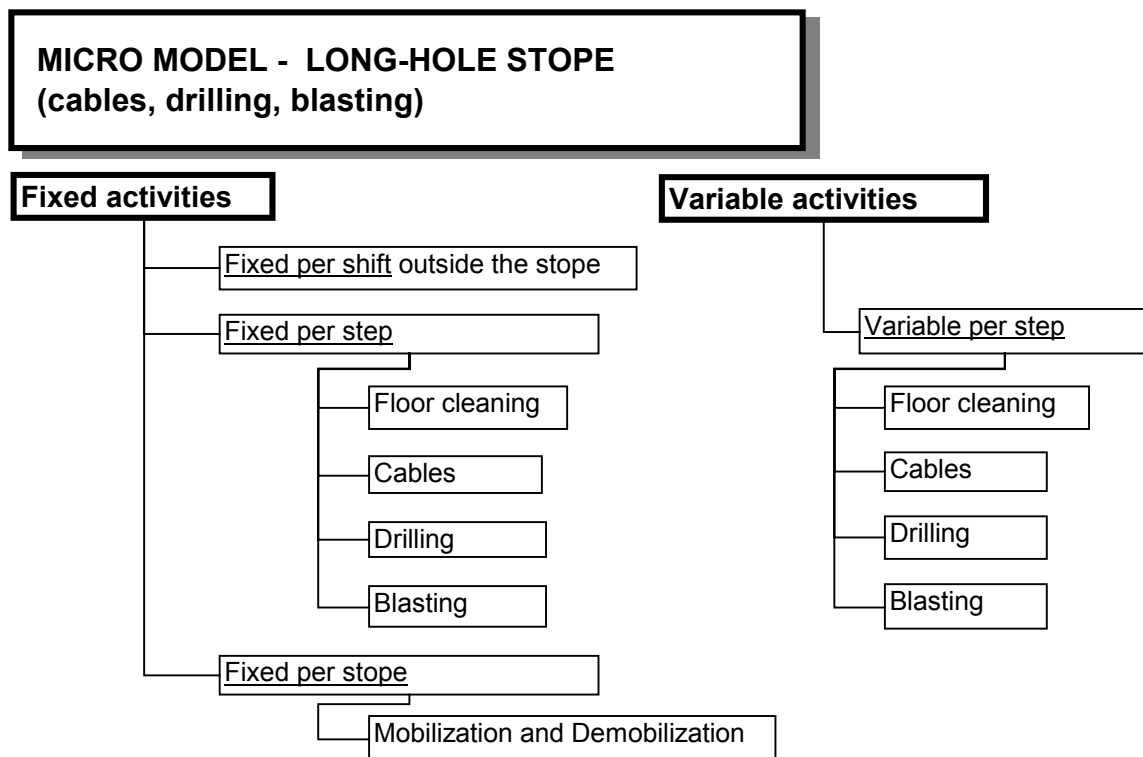
In addition, because most mining activities are comprised of both variable and fixed aspects, the model deals with these separately. In order to clearly appreciate the difference between the two types, an example is given for each aspect.

The variable aspect of each task in the model is considered as being directly proportional to the number of miners; this means that the time required to perform a task will be twice as short if there are two miners as opposed to one. For example, the time required to drill the holes for the anchor cables will be twice as fast with two miners instead of one, in the case where each miner operates a drill.

On the other hand, the fixed aspect of a task in the model is the part which is not directly proportional. For example, the time required for the mobilization of equipment in a sub-level by three or four miners is not directly proportional to their number. With three miners, the length of

this task can be estimated to take six hours whereas, with four miners, approximately four hours can be required. The time ratio of 6/4 hours is 1.5, while the ratio of 4/3 miners is 1.33. It is possible to notice a relationship between the number of miners and the time required to perform a task, but it is often very difficult to determine. It is for this reason that all tasks having this characteristic are classified as being fixed in the model.

In order to better understand the relationship between the information dealt with in the model and the work cycle, the following flow chart summarizes the different aspects in schematic form.



## 2. Notice

The present model does not perform any automatic verification to notify users when they enter incorrect data. Consequently, it is very important to take the time to verify the entered data.

The results obtained from this model cannot replace a detailed study required for a feasibility study. Natural Resources Canada does not assume any liability for any direct or indirect consequence deemed to have occurred due to the use of the results obtained from this model.

### 3. Worksheets

The file contains seven worksheets: Compilation, Costs, Long-Hole, Prod\_Drilling, Drop Raise\_Drilling, Cable\_Drilling, Drawing. Here are their main functions and a brief description of each worksheet:

Compilation: A summary of the tasks related to support, drilling and blasting showing the productivity for each of them.

Costs: Cost calculation per tonne in accordance with the mining steps inside the stope, the manpower hourly rate and supplies.

Long-Hole: In-stope productivity calculation in accordance with the drilling preparation, displacements of equipment, drilling and anchor cable installation, as well as the drilling and blasting of production holes and drop raises.

Prod\_Drilling: Calculation of drilling productivity for the production holes in accordance with the displacements of the drill in relation to the drilling pattern.

Drop Raise\_Drilling: Calculation of drilling productivity for drop raises in accordance with the displacements of the drill in relation to the drilling pattern.

Cable\_Drilling: Calculation of drilling productivity for anchor cables in accordance with the displacements of the drill in relation to the drilling pattern.

Drawing: Illustration of a typical long-hole stope.

Please note that all worksheets are independent, except for “Compilation” and “Costs” which are linked to the “Long-Hole” worksheet.

### 4. Sections of the model

The “Long-Hole” model is different from other mining methods. Each mining step is performed by a different number of workers, usually specialized staff. The model must allow users to control each mining step separately before adding them for the calculation of the global productivity. Here is the list of steps and the way in which they are grouped together:

## **Long-Hole**

- Direct fixed activities per shift (outside the stope)
- Direct fixed activities per step (inside the stope)
  - Floor cleaning
  - Anchor cable installation
  - Blasting
- Direct fixed activities per stope
  - Mobilization and Demobilization
  - Other activities per stope
- Direct variable activities per step (inside the stope)
  - Floor cleaning
  - Stope parameters
    - Drop raises
    - Production rows
  - Drilling
  - Support by anchor cables
  - Blasting
    - Loading parameters
    - Loading time
- Stope compilation
  - Table of required hours per activity
  - Stope productivity calculation
- Stope statistics
  - Stope planning factors.

### **4.1 Description of the sections of the model**

#### **4.1.1 Direct fixed activities per shift (outside the stope)**

This section takes into consideration all the time required for activities outside the stope which is attributed to each miner towards the calculation of productivity. This total time has an important effect on each of the steps.

#### **4.1.2 Direct fixed activities per step (inside the stope)**

Direct fixed activities per step allow users to verify the required work according to the mining cycle.

- Floor cleaning:

Fixed floor cleaning activities are related to material handling from one sub-level to another and to preparations or the required work before and after cleaning. The productivity is dealt with separately in the “Direct variable activities – Floor cleaning” section.

- Anchor cable installation:

Fixed activities related to anchor cable installation consist in the preparation work, cleaning the pump and accessories for grouting, as well as storing the required material. All other aspects are dealt with in the “Direct variable activities - Support by anchor cables” section.

- Blasting:

This section deals with fixed activities related to blasting, such as the effects of the blasts on the access, the condition of the floors in the sub-levels, the ventilation systems, as well as material handling and the preparation of the loading equipment.

#### 4.1.3 Direct fixed activities per stope

Direct fixed activities per stope are generally carried out a few times per stope. They have a major effect on average productivity. It is therefore important to estimate them properly.

- Mobilization and Demobilization:

In this section, users must estimate the time and frequency of all equipment mobilization and demobilization steps. Normally, the frequency corresponds to the number of sub-levels. The model was conceived to deal with six (6) sub-levels.

The number of sub-levels is higher than usual to allow for productivity calculation when a stope is very narrow at one extremity and much wider at the other end. It is therefore possible to separate each sub-level in many sectors.

- Other activities per stope:

In this section, users must include factors which may cause occasional delays in production. The most common delays occur due to visits from the technical and maintenance services, as well as repairs in the main access during the stope life.

#### 4.1.4 Direct variable activities per step (inside the stope)

The “Direct variable activities” section controls all the parameters related to dimensions and productivity (floor, drilling, anchor cables and loading of explosives). This section is typical to each mine and stope.

- Floor cleaning:

This section estimates the time required to prepare the sub-level floors before production drilling. It is necessary to enter a cleaning productivity in linear meters per hour for each sub-level and the number of men. This productivity must take into account all the floor preparation steps and is used to calculate the cleaning time for each sub-level. The length of each sub-level must be entered in the following section.

- Stope parameters:

The stope parameters are divided into two parts; one deals with drop raises and the other with production rows. These two parts constitute the basis of all calculations. It is therefore important to verify the entered data to ensure that it corresponds to the case at hand. The first data to be entered is the ore density.

- Drop raise parameters:

It is possible to rename each sub-level in this section. The new name will appear in all sections of the model. For each sub-level, users must enter all pertinent data in the yellow cells of the model. The width of a drop raise is the distance measured in the sub-level direction, whereas the height is measured perpendicularly to the sub-level direction. In the drilling columns, the diameter of the production holes and reamed holes must be entered. These diameters are used to calculate the quantity of explosives to be loaded. It is important to include the reamed holes in the production holes column in view of the fact that miners must drill twice. In the event that the ore width is greater than the drop raise width, it will be necessary to widen the opening; consequently, users will have to include additional holes in the production holes column. The entered blasting parameters are used to calculate the productivity in the “Blasting” section.

- Drilling and blasting parameters of production rows:

For each sub-level, all pertinent data must be entered in the yellow cells. The length of sub-levels entered in this section must include drop raises.

However, if a raise has already been excavated inside the stope, its width must be subtracted from the length of the sub-level. The average area per row and the spacing between rows provide a great flexibility in the tonnage calculation of each row, notwithstanding shape of the area and its drilling pattern. The drilling pattern is controlled by the “Number of drilled meters per row”. The “Number of rows per blast” column is used to calculate the loading time in the “Blasting” section.

It is very important to mention that the planned dilution in the “Average area per row” must be included. A comment has been inserted to that effect in the model in order to advise users.

- Drilling:

This section calculates the drilling time for drop raises and production holes. In order to perform this calculation, users must enter the drilling productivity for each type of drilling. The entered productivity corresponds to the one obtained when the operator is only drilling, including the displacement time of the drill and drill rig in and between the drilling rows. The average time for routine maintenance, which is normally carried out during each work shift, must be entered in the right-hand column.

In the event that users wish to verify the drilling productivity, the “Prod\_Drilling” and “Drop Raise\_Drilling” worksheets are used to calculate the drilling productivity per hour based on different parameters. Users will find the information on these parameters in the “Prod\_Drilling” and “Drop Raise\_Drilling” worksheet sections of this document.

The redrilling of damaged holes is common practice in several mining operations. In the “Redrilling time following blast damages” table, the redrilling percentage for drop raises and production holes must be entered for each sub-level.

- Support by anchor cables:

This section calculates the time required for drilling and the installation of anchor cables. The model provides the alternative of drilling and installing anchor cables by an access other than the production sub-levels normally used. The data to be entered is similar to the one in the “Stope parameters” section.

The average installation time of anchor cables per hole and the number of men normally assigned to this task must be entered in the right-hand column. In the left-hand column, the drilling productivity per hour and the number of men must also be entered. An average productivity per shift, for planning purposes, is calculated from the data in this section. It is also possible to verify the productivity per hour by referring to the explanations in the “Cable\_Drilling” worksheet.

- Blasting:

This section is also divided into two parts. The first one deals with the loading parameters and the second with the loading time.

- Loading parameters:

This section is used to calculate the required quantity of explosives per blast for both drop raises and production holes. The total length not loaded per row and the loading parameters must be entered in the lower right-hand side. The number of primers per hole is important because it influences the loading time.

- Loading time:

The loading time is very important towards the calculation of productivity. The time estimates must correspond to the actual time. The calculation of the total loading time takes into account the number of men, the transportation productivity, loading productivities (drop raises and production holes), as well as the average fixed time for the loading of explosives.

#### 4.1.5 Stope compilation

This section is divided into two parts. The first one deals with the time required for each activity and the second one compiles data towards the calculation of the global productivity.

- Table of required hours per activity:

This section collects all the data in the model and classifies it in fixed and variable data. The variable data is proportional to the manpower. It is possible to change the planned number of men for each activity. It should be pointed out that the accuracy of the required hours per activity decreases when the number of men is increased or decreased by more than 50%. In that case, the original estimate in the section corresponding to that activity should be revised.



- Stope productivity calculation:

This section calculates the productivity based on the changes made to the previous section and the hours resulting from direct fixed activities. In order to complete the productivity calculation, the length of the work shift and the contingency rate must be entered.

The “contingency” cell represents the uncertainty level and data variation. The smaller the data variation, the more the percentage will decrease. However, if the variation is high, it is suggested that a contingency percentage superior to 15% be preserved.

It is important to mention that the calculated tonnage must include the planned dilution when entering the “average area per row” data of section “4.2.2 – Drilling and blasting parameters of production rows”.

#### 4.1.6 Stope statistics

This section summarizes the drilled meters per diameter, the planned tonnage, the ratio of tonnes per drilled meter, the total quantity of explosives and the powder factor. This summary will be used to calculate mining costs in accordance with productivity estimates.

In order to assist users, the model calculates the time required for the mining steps and the final average productivities. These factors are very useful when comparing different mining approaches.

It should be noted that the data from this section is used in the “Compilation” and “Costs” worksheets.

## 4.2 “Compilation” worksheet

This worksheet summarizes the productivity graphically in accordance with the work shift schedule for each long-hole mining activity. It shows the allocation of time per shift (eight hours in this case). In this table, users can observe that, during each work shift, a portion of time is allocated to activities outside the stope and a portion inside the stope. The portion inside the stope is divided into fixed and variable activities. The variable activities, highlighted in pink, are normally productive. In this table, users can also verify the productivity calculations by referring to the sections of the model which are indicated therein.

### 4.3 “Costs” worksheet

This worksheet calculates the global unit cost for the long-hole mining method. Users simply have to enter the basic salary and bonus hourly rates, as well as the proportion of the manpower fringe benefits to calculate the cost per tonne for each activity.

The cost of supplies must be entered to calculate the total cost per tonne. In view of the fact that the cost of supplies varies considerably from one site to another, no section was created to estimate them.

### 4.4 “Prod\_Drilling” worksheet

This worksheet calculates the effects of the drilling pattern (parallel or fan holes), of the type of drill, of the length of drilling rods and of the spacing between sub-levels on the drilling hourly rate.

The basic approach consists in calculating the total drilling time, rod handling and the displacements of the drill and drill rig for the drilling of one row. This time is then converted into an average hourly rate. This result must be entered in section “4.3 - Drilling” of the “Long-Hole” worksheet. It is important to point out that the data used in the model must correspond to the mean, and not to optimal or pessimistic values.

In addition to the length of the rods, six (6) factors were identified: the average drilling time per rod, the use of casing, hole breakthrough, pivoting the drill on the same rotation point, moving the drill on the same row without changing the position of the drill rig and, finally, moving the drill rig from one row to another or on the same row. These factors allow users to simulate the conditions and displacements of all available long-hole drills on the market since each influential factor is dealt with separately. Please note that these factors are specific to each drill and each type of ore.

The operating procedures first consist in filling out the six sections in relation to the drill factors and the type of rock. Then, in the “Typical row” section, it is possible to control the drilling pattern parameters and the spacing between sub-levels.

### 4.5 “Drop Raise\_Drilling” worksheet

This worksheet calculates the effects of the drilling pattern, of the type of drill, of the length of drilling rods and of the spacing between sub-levels on the drilling hourly rate.

The same basic approach used for production drilling is applied to drop raises. However, it should be noted that the drilling of a drop raise is divided into rows. On each row, it is possible to have many rotation points (setups) and many positioning points of the drill rig. The average drilling hourly rate must be entered in section “4.3 – Drilling” of the “Long-Hole” worksheet. It is important to point out that the data used in the model must correspond to the mean, and not to optimal or pessimistic values.

#### 4.6 “Cable\_Drilling” worksheet

This worksheet calculates the effects of the drilling pattern, of the type of drill and of the length of drilling rods on the drilling hourly rate.

The basic approach is the same as production drilling. It is important to point out that the time allocated for the displacements of the drill rig should be different in view of the fact that, for most mines, the distance between rows of cables is greater than the spacing between production rows.

The average drilling hourly rate must be entered in section “4.4 - Support by anchor cables” of the “Long-Hole” worksheet.

### 5. Using the model

The productivity model of the long-hole mining method allows users to:

- simulate productivity according to the data collected on-site
  - for active stopes, and
  - when there is a change in the mining method
- validate new mining approaches; and
- validate the interest in importing a new concept and/or new technologies.

The main factors used in the model are:

- stope configuration;
- fixed time for each step;
- support pattern by anchor cables;
- drilling pattern and drill characteristics;
- number of workers for each mining step;
- length of work shifts;
- drilling productivity for production holes, drop raises and for anchor cables; and
- labour cost.

## 5.1 Changes in the mining method or stope configuration

In order to simulate the effect of a change in operation, it is important to first simulate the actual situation in order to calibrate the model. The required information in using the model is normally available for most mining operations. When the data is not recorded, a few measures can be taken underground.

It is also important to keep track of the changes made and their effect on productivity. The importance of certain factors on the productivity level can then be quantified. It will therefore be possible to target the critical factors to improve average productivity.

## 5.2 Validation of new mining approaches

The model allows for the simulation of new approaches or ideas. Users can quantify the effect of changing technologies on stope productivity and, in addition, changes in the type of drill, as well as drilling and support patterns give instant results.

However, it is important of not underestimating the effect of fixed time of a new technology. This fixed time, sometimes difficult to evaluate, may easily augment or diminish the interest in this new method.

In order to evaluate the effect on productivity when a new mining method is imported from one mine to another, it is important to gather as much information as possible on the other operation. The list of required data towards the use of the model (refer to the following section) identifies important data for users to collect during investigation visits.

## 6. Required data

For an easier comprehension of the model, a colour code helps users to find the cells where data must be entered.

- The yellow cells indicate where data, specific to the situation, must be entered. All the other cells are locked to prevent formula modifications which could produce false results.
- The green cells identify the results obtained from the entered data.

The following sections of this document list the required data towards the use of the model. As previously explained, the data is divided into two sections, fixed and variable.

## 6.1 Fixed data

Users are recommended to read over again section 1 “Approach of the model” for a clear definition of the term “fixed data”. That section explains the distinction between fixed and variable data. The variable items of the model are listed in the next section.

Here is a list of fixed activities most commonly carried out. If some activities are not included in this list, users can simply add them in the cells provided for that purpose in the model.

Schedule (section 5.2 of the model)

Number of hours per shift		hours
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Fixed time outside the stope (section 1.0 of the model)

Cage (at beginning and end of shift)		minutes
Travelling (shaft - refuge station - shaft)		minutes
Other travelling delays		minutes
Back and forth to stope		minutes
Supervision		minutes
Work planning		minutes
Complete daily reports		minutes
Lunch		minutes
		minutes
		minutes

Activities related to floor cleaning (section 2.0 of the model)

Bring and prepare material		minutes
Store material		minutes
		minutes

Activities related to anchor cable installation (section 2.0 of the model)

Bring and prepare material		minutes
Clean pump and accessories		minutes
Store material		minutes
		minutes

Activities related to blasting (section 2.0 of the model)

Bring and prepare material		minutes
Clean the floor following blast		minutes
Store equipment and explosives		minutes
Check blasting line		minutes
Connect the blast		minutes

Close access to the stope		minutes
Access verification following blast		minutes
Extra scaling		minutes
Repair and install ventilation		minutes
		minutes
		minutes

Activities related to mobilization and demobilization (section 3.0 of the model)

Prepare the slide and working areas		minutes
Bring and lower drill in the sub-level		minutes
Assemble the drill		minutes
Install electric services		minutes
Dismantle and bring out drill from sub-level		minutes
Remove electric services		minutes
		minutes
		minutes
Required number of men		men

Other activities per stope (section 3.0 of the model)

Geologists		minutes
Surveyors		minutes
Mechanics and electricians		minutes
Repairs main access		minutes
		minutes
		minutes

## 6.2 Variable data

Here is the variable data which users will have to estimate or measure in their operation:

Floor cleaning (section 4.1 of the model)

Cleaning productivity		meters/hour
Number of men		men

Stope parameters - Drop raises (section 4.2.1 of the model)

Ore density		tonnes/cubic meter
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Data	Sub-levels						Units
	1	2	3	4	5	6	
Drilled length							meters
Width (in the sub-level direction)							meters
Height (perpendicular to the sub-level direction)							meters
Number of production holes							holes

Diameter of production holes							mm
Number of reamed holes							holes
Diameter of reamed holes							mm
Number of blasts per drop raise							blasts/drop raise
Number of blasted holes per blast							blasted holes/blast

Stope parameters - Drilling and blasting parameters of production rows (section 4.2.2 of the model)

Data	Sub-levels						Units
	1	2	3	4	5	6	
Length of sub-levels							meters
Spacing between rows							meters
Average area per row							square meters
Number of drilled meters per row							meters/row
Average number of holes per row							holes/row
Number of rows per blast							rows /blast

Drilling (section 4.3 of the model)

Data	Sub-levels						Units
	1	2	3	4	5	6	
Redrilling percentage (drop raises)							%
Redrilling percentage (production)							%

Mechanical maintenance of drill (for each shift)		
Grease and lubricants		minutes
Check bolts of table, slide, etc.		minutes
Check hydraulic oil level		minutes
Drill cleaning		minutes
Other verifications		minutes
		minutes

Average drilling productivity (drop raises)		meters/hour
Average drilling productivity (production)		meters/hour

Support by anchor cables (section 4.4 of the model)

Data	Sub-levels						Units
	1	2	3	4	5	6	
Spacing between rows							meters
Number of holes per row							holes/row
Number of cables per hole							cables/hole
Number of drilled meters per row							meters/row

Data	Drift outside the mineralized zone				Units
	1	2	3	4	
Spacing between rows					meters
Number of holes per row					holes/row
Number of cables per hole					cables/hole
Number of drilled meters per row					meters/row

Drilling productivity		meters/hour
Number of men (drilling)		men

Average installation time of anchor cables		
Insert cables and hoses per hole		minutes
Cement the collar per hole		minutes
Grouting per hole		minutes
Install plate and tensioning per hole		minutes
Number of men (installation)		men

Blasting - Loading parameters (section 4.5.1 of the model)

Data	Sub-levels						Units
	1	2	3	4	5	6	
Total length not loaded/row							meters

Data	Drop raises	Long-Hole	Units
Explosive density			g/cc
Number of primers/hole			primers/hole

Blasting - Loading time (section 4.5.2 of the model)

Data	Drop raises	Long-Hole	Units
Cleaning/hole			minutes
Bottom hole blocking/hole			minutes
Single priming/hole			minutes
Collar verification/hole			minutes
Connecting time/row			minutes
Loading productivity			kg/hour
Number of men for loading			men
Explosive transportation productivity			kg/hour
Number of men for the transportation			men