Chapter 3 DEVELOPMENT OF A MINE PLANNING SYSTEM

3.1 Background

The HLP model works on the basis of establishing the relationship between mine development and all other activities following that. To optimise this, the smallest independent repetitive development suite has to be utilised. The mine can be divided into the following basic development suites:

- Initial capital development
- Ongoing capital development
- Level development (two half levels)
- Secondary development.

Two suites were selected as the main drivers of production capacity planning for the following reasons:

- The half level is the smallest self-sustainable production unit containing all mining activities.
- The ongoing capital development is for the excavations required to replace levels.

The HLP model was developed in Microsoft Excel and consists of interlinked worksheets where each addresses specific components of the planning process. The rest of the chapter details each of the worksheets.

3.2 Ongoing capital description

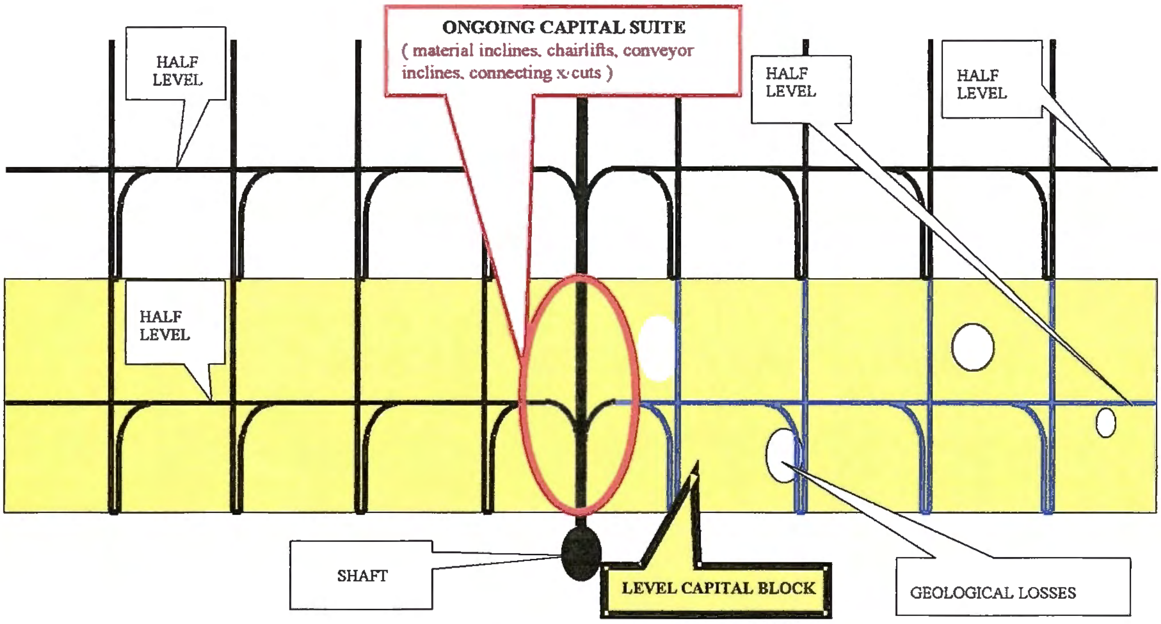

Figure 3.1: Plan view of the "Ongoing capital suite"[27]

Figure 3.1 explains the ongoing capital concept – the yellow rectangle stretches over two half levels (an entire level) and the red ellipse represents the area where main development has to be completed before the yellow rectangle can be extracted (mined). There are many configurations but in Anglo Platinum incline clusters are commonly used to access new or replacement levels.

The typical excavations found in an incline cluster configuration may contain some of the following:

Material incline:
Inclined excavation normally parallel below the reef plane, equipped with a winding or hoisting device and tracks. Material, rock, men and equipment may be conveyed through this excavation.

Conveyor belt incline:
Inclined excavation normally parallel to the reef plane, equipped with conveyor belts for rock handling. Some mines have man-riding conveyor belts that convey men and rock.

Chairlift incline:

An excavation parallel to the reef plane, equipped with a chairlift for conveying people (endless rope with chairs attached).

Return airway:

Used ventilation gets exhausted through this excavation.

Other development includes ends connecting all the inclined excavations to the particular level and may contain some of the following: Stations or landings, reef passes, waste passes, connecting cross-cuts and haulages as well as workshops and refuge chambers.

3.3 Half-level description

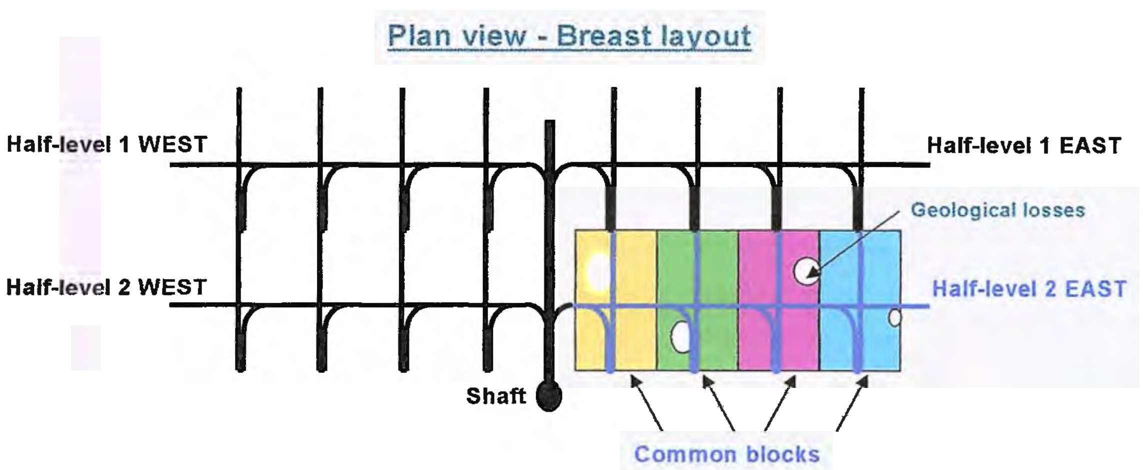

Figure 3.2: Plan view of the "Half-level suite"[28]

Figure 3.2 describes the half-level suite of a typical breast-mining layout. Note that each level is divided into two half levels by the "shaft" (east and west). Each half level contains all the mining activities mentioned before (development, ledging, equipping, stoping, vamping and reclamation) and is independent from any other half level. It is thus the smallest self-sufficient unit encompassing all mining activities.

Common blocks:

The smallest unit that can be used to define the layout and thus the basic development requirements is called a common block. A common block should be defined in such a way that it forms the half level, level and eventually the entire mine upon duplication. In the picture it is illustrated as coloured rectangles.

Note that each block is illustrated in a different colour starting with yellow, then green, followed by pink, and finally blue. This colour sequence is also used to distinguish between different common blocks in some of the worksheets.

Geological losses:

Geological losses are normally expressed as a percentage of the total ore reserve lost due to faults, dykes, potholes, slumps and certain reef replacements (iron replacement).

A fault is a "break" in the reef plane with displacement. A dyke is a plane-like intrusion also breaking the reef plane – it may result in displacement. Potholes are common to igneous reef planes – it can be explained as a load upon the reef plane (whilst in liquid state) thus displacing reef resulting in a narrower reef width in the area where the load occurred. Potholes vary in size and some may be kilometres in diameter. In some cases it is possible to mine the reef below the pothole. Slumps are formed through similar processes but reef widths may not be affected – undulations.

3.4 Life cycle of a half level's ore reserve

The term "ore reserve" has many definitions, but the only meaningful definition for the purpose of this study (and to truly manage a mine) is the minable ore reserve that implies that all the relevant development required to start ledging and/or stoping in a specific area is complete.

Anglo Platinum is also of the opinion that an 18-month ore reserve should be maintained. This should mean that if the primary (minimum upfront development to extract a block of reef effectively) is stopped, ore could be extracted at the steady-state rate for at least another 18 months.

This has huge financial implications and should thus initially be created during the capital phase of the mining project. It is also part of management's responsibility to maintain this reserve, but cost-cutting initiatives often cause development quantity cuts resulting in ore reserve shrinkage – normally irreversible without a reduction in ore production. Reducing the ore reserve size has short-term financial benefits due to development cost reductions but has resulted in total mine closure in the past – an extremely dangerous situation to be in.

The 18-month requirement mentioned before should also not be applied generically. Each layout has to be assessed on its own merit. The optimum steady-state ore reserve calculated by means of the planning model designed for this study varies from around 10 to 23 months (for different layouts) and the basis for this statement lies in the build-up to steady-state production[29]. This is referred to as the natural ore reserve and is automatically created when developing from the start of the half level to the point where steady-state mining activities are reached. It is also equal to the period that steady-state stoping can continue after all the primary development on the half level has been completed.

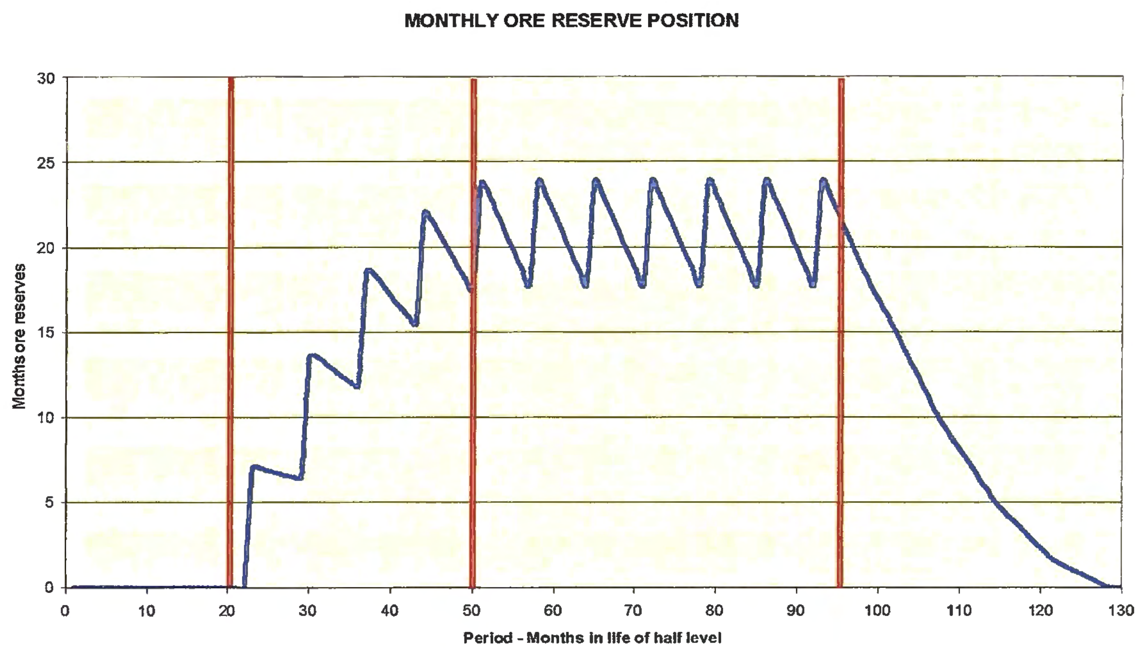

Figure 3.3: Monthly ore reserve position (as per the HLP model schedule)

Figure 3.3 shows what ideally happens in the life of a half level:

Build-up phase:

Initial development starts and the first ore reserves are created just after month 20 (first upward spike from x-axis). It then increases further to an average of 21 months in month 50.

Steady-state phase:

The reserve remains at the average 21 months from month 50 to month 95.

Level reserve depletion:

From month 95 the ore reserve is depleted to zero in month 128. This phase starts when all the primary development on the half level has been completed – at this point this development should be blasted on a replacement level. The capital development to create a new half level should thus be completed.

3.5 Detailed model operation

Table 3.1: Detailed HLP model operating procedure

Primary Procedure	Secondary Procedure
Layout and activity definition	1 Identify specific reef block on a half level (Common block)
	2 Define all development excavations in the common block
	3 Define all stoping excavations in the common block
Steady state calculation	1 Schedule development activities
	2 Schedule ledging activities
	3 Schedule stoping activities
	4 Schedule sweeping and vamping activities
	5 Schedule reclamation activities
	6 Define winch requirements
Best fit	1 Define half level remaining strike life
	2 Define active blocks
	3 Define development outside active blocks
	4 Match main end (normally haulage)
	5 Match main end and reef extraction
Long term planning	1 Set flexibility
	2 Set starting year
	3 Set starting month
	4 Activate auto plan function

The model is based on the determination of optimum relationships between primary or block-opening development and all other mining activities (ledging, equipping, stoping, sweeping and vamping, reclamation and also the supporting logistics and services).

The tables that follow illustrate elements of the HLP model in terms of data inputs or results outputs.

3.6 Layout and activity definition

3.6.1 The Common Block

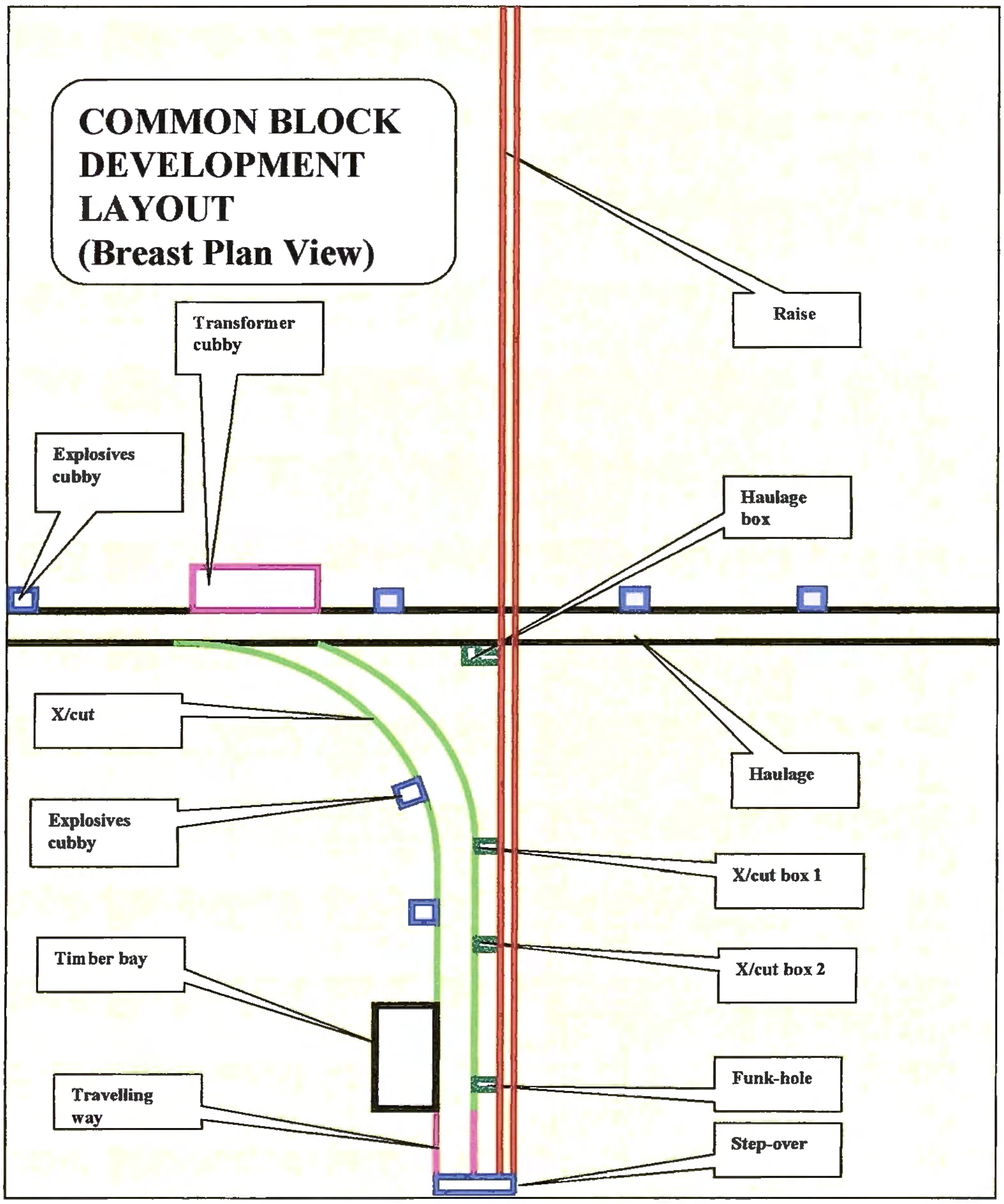

Figure 3.4: Plan view of a common block (Breast layout)

Defining the common block is the most important part for modelling the relationship between the activities on the half level. Every development end supporting the extraction of a specific reef area has to be listed and defined in terms of its dimensions (length, width, height) as well as its position relative to the reef plane (made in reef or waste).

It is also important to determine the maximum advance per single blast obtainable per end. This advance should be equal to the effective length of the blast holes. Table 3.2 explains the process.

Table 3.2: Common block definition

COMMON BLOCK DEFINITION				
Development end name	Length (m)	Width (m)	Height (m)	Max possible adv/blast (m)
Haulage	200	3	3.2	2.0
X/cut	120	2.7	3.2	2.0
Timber bay	10	3	3.2	2.0
Travelling way	10	2.4	2	2.0
Box 1	24	1.5	1.5	1.0
Box 2	30	1.5	1.5	1.0
Box 3	36	1.5	1.5	1.0
Haulage box	42	1.5	1.5	1.0
Funkhole	12	1.5	1.5	1.0
Step over	5	2	2.4	2.0
Raise	200	1.6	2.4	2.0
Transformer cubby	10	3	3.2	2.0
Explosives cubbies	5	1.5	2	1.5

All the development ends are included in Table 3.2 but the cubbies and the timber bay are not primary development ends – they are not required to make the reef block minable, but serve as storage area for equipment and material required during the mining process.

The reef block that can be extracted once the above-mentioned development is in place and is defined in terms of its width or strike length, dip or back length, and the reef thickness (height).

3.6.1.1 Ore losses

The ore losses refer to the portion of the reef that is not extractable at the time the production plan is compiled. The situation may vary as technology, markets and the life of the mine change – some mines currently survive by removing pillars previously left behind as a loss. Ore losses mainly occur due to geological features and stability pillars that have to be left behind. Some areas are not being mined due to current extraction costs or economic content of the reef. This is normally put into the "unpay" blocks, but this may, however, change over time. Table 3.3 explains the process to determine the extractable reef area per common block.

Table 3.3: Common block (reef area) dimensions and ore losses

REEF BLOCK DIMENSIONS			ORE LOSSES		
Width (m)	Back Length (m)	Height (m)	Geological losses(%)	Other losses(%)	Total losses(%)
200	200	1.0	10%	5%	15%

REEF BLOCK AREA (m^2) pre-losses	REEF BLOCK AREA (m^2) available
40000	34200

The ore losses are defined as a percentage of the total block area and is split into geological losses and other losses. The other losses refer to a reef not being minable due to stability pillars that have to be left behind and to falls of ground. There are thus two reef areas, pre-losses and post-losses. The area available for extraction is the area remaining after all losses have been subtracted. Note that 15% of 40 000 x (100%-15%) = 34 000 and not 34 200. This is due to the fact that some other losses, for instance pillar losses, may be situated inside geological losses.

The amount of primary development meters per common block is not affected by the loss factors; however, less reef square meters per development meter are extractable after applying the loss factor. Losses do however influence the amount of secondary development meters required per common block.

3.6.1.2 Replacement factors

Mines normally apply a single replacement factor that means every meter of development replaces a fixed amount of square meters. This however does not specify the development requirements per specific development end and in most cases the more accessible development ends are overdeveloped, for instance haulages and cross-cuts. Common blocks, with all development being complete except all the ore passes, are often encountered and no effective stoping can take place in these blocks. The HLP model allows each end to be managed according to its own specific replacement factor. By using this system, different ends can be prioritised and planned according to specific needs. These replacement factors take the applied losses into account, for example a haulage of 200 meters only replaces 34 200 square meters – not 40 000 square meters. To replace 40 000 square meters, a longer haulage is required:
(40 000)/(34 200/200) = 234 meters of haulage.

The HLP model automatically increases the development meters as the foreseen losses increase. The same block with 35% losses leaves (40 000)*(100%-35%) = 26 000 square meters and (40 000)/(26 000/200) = 308 meters of haulage will now replace 40 000 square meters.

Note that some ends require low amounts of development meters per month – in this case it may be more practical to leave it over for, say, two or three months and to then blast the combined requirement at an increased monthly advance rate without moving equipment or people. Table 3.4 shows the specific replacement factors per development end required in the defined common block. The position of the development end relative to the reef plane is also included (end either in waste or reef).

Table 3.4: Development replacement factors and position of excavations relative to the reef horizon

DEVELOPMENT END REPLACEMENT RATES + POSITION				
Development end name	(m^2 reef) per (m developed)	(m developed) per (m^2 reef)	Minimum monthly development replacement (m)	End in Reef or Waste
Haulage	171	0.0058	29.2	Waste
X/cut	285	0.0035	17.5	Waste
Timber bay	3420	0.0003	1.5	Waste
Travelling way	3420	0.0003	1.5	Waste
Box 1	1425	0.0007	3.5	Waste
Box 2	1140	0.0009	4.4	Waste
Box 3	950	0.0011	5.3	Waste
Haulage box	814	0.0012	6.1	Waste
Funkhole	2850	0.0004	1.8	Waste
Step over	6840	0.0001	0.7	Reef
Raise	171	0.0058	29.2	Reef
Transformer cubby	3420	0.0003	1.5	Waste
Explosives cubbies	6840	0.0001	0.7	Waste

The replacement rates are specified in terms of square meters reef extractable per meter developed, or meters developed per square meter extractable. The only two ends developed in the reef plane are the raise and step-over, and this is selected in the last column as illustrated in Table 3.4. The column containing the minimum required development per month is also included. This refers to a breast layout as defined and a half level producing 5 000 square meters reef per month. Note the low advance rates in all the development ends except the haulage, cross-cut and raise. As mentioned previously, advancing some of these ends may be held back for equipment and labour optimisation, but this should only be done on independent ends. "Box 1, 2 and 3" in this case are to some extent independent and can be blasted without influencing the advance rates in other ends, but, if they do not reach the raise's elevation in time, the raise may be affected negatively.

3.6.1.3 Blasting efficiency effect

The blasting efficiency is also taken into account when determining the maximum possible advance per end per month. A development end that has the capability to be advanced at a rate of 46 meters per month is downgraded to 33 meters per month due to a blast efficiency of 72%. This allows the generation of a model that is realistically more aligned with the specific mine's actual achievements.

Table 3.5: Blast efficiency calculation[30]

BLAST EFFICIENCY CALCULATION	Development	Stoping
BLAST SHIFTS IN MONTH	23	23
Blast frequency % (actual blasts / possible blasts)	80%	78%
Advance efficiency % (actual blast advance / possible blast advance)	90%	90%
Blast efficiency % (Blast efficiency x Advance efficiency)	72%	70%

Table 3.6: Monthly development end advance rates

MONTHLY DEVELOPMENT END ADVANCE RATES		
Development end name	Maximum advance/month (m)	Current advance/month (m)
Haulage	46	33
X/cut	46	33
Timber bay	46	33
Travelling way	46	33
Box 1	23	17
Box 2	23	17
Box 3	23	17
Haulage box	23	17
Funkhole	23	17
Step over	46	33
Raise	46	33
Transformer cubby	46	33
Explosives cubbies	35	25

3.6.1.4 Stoping panel definition

In the case of the stoping phase, the same process as per development is followed to define a stoping panel – the panel length, height and maximum advance per blast is defined. The average stoping panel has a monthly extraction rate of 436 square meters in the example used and this can be extracted anywhere in the common block. The amount of panels mined simultaneously in a single common block also varies depending on the mine or the layout. The blasting efficiency of a stope panel as per Table 3.5 is already supplied (70%) and a generic stope panel description can be viewed in the following extract:

Table 3.7: Average stope panel parameters and position relative to the reef horizon

AVERAGE STOPE PANEL PARAMETERS + POSITION				
Length (m)	Width (m)	Height (m)	Max possible advance per blast (m)	End in Reef or Waste
30	(N/A)	0.9	0.9	Reef
AVERAGE STOPE PANEL PARAMETERS + NUMBER REQUIRED				
Maximum advance per month (m)	Current advance per month (m)	m^2/panel per month	Working panels (minimum to produce steady state production at $435.9m^2$ per panel per month)	Equipped panels: minimum working panels x (100%+losses%)
20.7	15	435.9	11.5	13.20

In Table 3.7 "height" refers to the stoping or extraction width. In this case the model assumes that all extraction takes place in the reef plane and that all the broken rock is removed. This height is comparable to the block height and in this specific case it is lower than the 1-meter height of the block – reef is thus left behind. In most cases the prescribed mining height is in the region of 5% more than the reef thickness to allow total extraction. Here the HLP model will calculate the reef dilution and the value per ton will automatically be adjusted.

The working panels refer to the amount of active stoping panels required per half level to generate the previously mentioned 5 000 square meters of reef per month. It may be produced from more than one common block and it includes production from both ledging and stoping operations. Note that the equipped panels are more than the working panels. The geological losses also influence stoping and, due to the cost of labour, it is good practice to have additional equipped panels available for the re-allocation of stoping labour in the event of panel losses.

The destination of rock produced by all the different mining activities can also be defined separately. Some ends are blasted in reef but contain a certain waste component due to the height. A resue or a "double-cut" concept where the reef and the waste can be separated by blasting it at different times can be practised. This, however, requires focused management attention and may have a negative effect on the average advance rates – this detail can also be specified by the user of the HLP model.

Planned dilution of reef and waste may also be the case and this practice can be modelled by independently selecting reef and waste destinations in the model. Every time a selection is made, the effect on the unit grade can be observed (grams per ton to mill).

3.6.1.5 Grade dilution

The dilution refers to the lowering of the reef grade due to the addition of rock with a lower grade, or the loss of content through various possible mechanisms. The dilution effect of on-reef development that takes place with stoping, for instance blasting of equipment excavations (winch chambers) and broken ore handling trenches (advance strike gullies), can also be modelled by increasing the mining width of the stoping panel being mined.

This change in width must be equivalent to the true effect caused by waste generation from the above-mentioned excavations. Table 3.8 illustrates how the waste generated by the advance strike gully is incorporated – note the effect on the grade and reef tons at the 1,0 meter and 1,075 meter widths respectively.

Table 3.8: Grade dilution effect of advance strike gully

ADVANCE STRIKE GULLY - EQUIVALENT STOPE WIDTH INCREASE			
STOPE FACE ADVANCE PER UNIT (ASG)	1	TONS TO REEF	4e GRADE
UNIT TOTAL HEIGHT (m)	2.5		
UNIT TOTAL WIDTH (m)	1.5		
UNIT TOTAL LENGTH (m)	1		
UNIT ADDITIONAL VOLUME (EXCLUDES STOPE WIDTH)	2.25		
AVERAGE HEIGHT OF STOPING PANEL (m) (NO CORRECTION)	1.0	19,696	@ 6.23 g/t 4e
AVERAGE LENGTH OF STOPING PANEL (m)	30		
NORMAL VOLUME PER PANEL PER SPECIFIED ADVANCE	30		
NEW VOLUME PER PANEL PER SPECIFIED ADVANCE	32.25		
VOLUME INCREASE FROM NORMAL (%)	7.50%		
EQUIVALENT STOPE PANEL WIDTH INCREASE (m)	0.075		
EQUIVALENT STOPE PANEL WIDTH (m) AFTER CORRECTION	1.075	21,034	@ 5.84 g/t 4e

Note that the tonnage or grade variance is less than 7,5% – this is caused by the variance in density between the reef and waste in the case of this example. The grade decreased from 6,23 g/t to 5,84 g/t due to adding the waste rock from this excavation to the reef produced from the stoping operation.

The face winch chamber is incorporated in the same way, but the effect is less significant because it only occurs once every 30 meters of face advance.

This leads to a less than 2% equivalent increase in the stope panel width but still has a noticeable influence on the produced shaft head grade diluting it from 6,23 g/t to 6,13 g/t.

Table 3.9: Grade dilution effect of winch chambers

WINCH CHAMBER - EQUIVALENT STOPE WIDTH INCREASE			
STOPE FACE ADVANCE PER UNIT (WINCH CHAMBER)	30	TONS TO REEF	4e GRADE
UNIT TOTAL HEIGHT (m)	2		
UNIT TOTAL WIDTH (m)	4		
UNIT TOTAL LENGTH (m)	4		
UNIT ADDITIONAL VOLUME (EXCLUDES STOPE WIDTH)	16		
AVERAGE HEIGHT OF STOPING PANEL (m) (NO CORRECTION)	1.0	19,696	@ 6.23 g/t 4e
AVERAGE LENGTH OF STOPING PANEL (m)	30		
NORMAL VOLUME PER PANEL PER SPECIFIED ADVANCE	900		
NEW VOLUME PER PANEL PER SPECIFIED ADVANCE	916		
VOLUME INCREASE FROM NORMAL (%)	1.78%		
EQUIVALENT STOPE PANEL WIDTH INCREASE (m)	0.018		
EQUIVALENT STOPE PANEL WIDTH (m) AFTER CORRECTION	1.018	20,013	@ 6.13 g/t 4e

3.7 Steady-state calculation

3.7.1 Scheduling of mining activities

Once the layout is defined, the scheduling of events can commence. This is done by selecting the start month of each activity, as it would logically follow after another in the first common block. The "haulage" is normally the first development end for all normal conventional layouts and will thus serve as the primary activator for every block to follow after the first block – nothing can take place in any block unless the haulage is completed. The model however allows for any other end to be entered as a primary activating end.

Table 3.10: Development monthly scheduling

DEVELOPMENT SCHEDULING (METERS PER MONTH)																	
START MONTH	END IN COMMON BLOCK			1	2	3	4	5	6	7	8	9	10	11	12	13
1	Haulage			33	33	33	33	33	33	1						
8	X/cut										33	33	33	21		
11	Timber bay													10		
12	Travelling way														10	
10	Box 1												17	7		
9	Box 2											17	13			
9	Box 3											17	17	3		
10	Haulage box												17	17	9	
12	Funkhole														12	
13	Step over															5

Table 3.10 refers to development scheduling that has to be completed by the user. The main colour is bright yellow indicating that scheduling is done in the first common block according to Figure 3.2. The light yellow cells with the red text in Table 3.10 are the user-defined values.

The haulage starts in month 1 and advances at an average rate of 33 meters per month until completion in month 7 where only 1 meter has to be blasted. All the other ends are then also scheduled in a logical sequence taking interrelationships into account. Note that Boxes 1 to 3 are started before the X/cut is completed – they are blasted from a position inside the X/cut and not afterwards, like the "Travelling way".

In Table 3.11 the user also initially schedules the activities following development, but instead of meters per month, square meters are used. The overall activity coverage (total area) and the extraction rate also have to be manually defined after considering the stoping blasting efficiencies and the specific mine standards.

Table 3.11: Post-development monthly progress and total requirements

POST DEVELOPMENT ACTIVITY SCHEDULING (m^2 PER MONTH)									
START MONTH	ACTIVITY	21	22	23	24	25	26	27	28
21	LEDGING 1	1000	1000	400					
23	EQUIPPING 1			1000	1000	400			
27	STOPING 1							1744	1744
34	SWEEP and VAMP 1								
35	RECLAMATION 1								

In Table 3.11 LEDGING 1 takes place at a rate of 1 000 square meters per month and the total area to be ledged is 2 400 square meters – 12 meters over the full length of a 200-meter-long raise. Once the ledging is completed, the remaining extractable area for stoping is 31 800 square meters (34 200 – 2 400). The EQUIPPING 1, SWEEP and VAMP 1, and RECLAMATION 1 activities are given areas and rates aligned with the actual capabilities of the mine as a means to determine the resource requirements in terms of labour and equipment.

At this point all the main mining activities are defined – from initial development to the reclamation of the equipment utilised. All the normal mining activities as mentioned before, including vamping and reclamation, have been scheduled. All activities after the development have been given a numeric monthly progress rate and a total objective.

3.7.2 Common block duplication

After scheduling, the HLP model uses the information supplied to complete the remaining common blocks up to the boundary of the half level automatically. In the example used, the haulage was viewed as the main end because it has to be completed (from cross-cut to cross-cut) to enable the start of the next block's development. It can be seen as the first end in both the common block definition phase and in the scheduling phase, and is highlighted in a light blue shade.

3.7.3 Stepping

The user of the HLP model will be allowed to alter the timing between blocks but the haulage advance rate will stay the determining factor, i.e. the next block may only be started later but not sooner than the haulage arrival rate. This is done by a process called "stepping" and it can be observed in Table 3.12. Note that the colour sequence as per Figure 3.2 applies to Table 3.12.

Table 3.12: Delays between common blocks

HAULAGE PROGRESSING THROUGH COMMON BLOCKS - OPTIMUM (m PER MONTH)																								
MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Haulage (IN BLOCK 1)	33	33	33	33	33	33																		
Haulage (IN BLOCK 2)							33	33	33	33	33	33												
Haulage (IN BLOCK 3)													33	33	33	33	33	33						
Haulage (IN BLOCK 4)																			33	33	33	33	33	33

HAULAGE PROGRESSING THROUGH COMMON BLOCKS - STEP (m PER MONTH)																								
MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Haulage (IN BLOCK 1)	33	33	33	33	33	33																		
Haulage (IN BLOCK 2)									33	33	33	33	33	33										
Haulage (IN BLOCK 3)																		33	33	33	33	33	33	

When the haulage or main end enters the next common block, activities in the previous block continue unaffected, resulting in a natural build-up of all activities. With all common blocks being the same and all also dependant on the same haulage advance rate and position, a steady-state condition starts to develop. This condition continues until one of the activities intersects the boundary of the half level whereafter development then decreases gradually. This phenomenon can be observed in the ore reserve graph, Figure 3.3. The flat "saw tooth" zone between months 45 and 95 represents steady state and peaks whenever a common block is ready for ledging.

This steady-state value is calculated by adding all the corresponding activities inside all the active blocks in a specific month. Averaging this sum over a cycle equal to the step size, supplies a smoothed line referred to as steady state.

Table 3.13: Calculation of steady-state square meter production rate

PRODUCTION BUILD-UP TO STEADY STATE											
STEADY STATE SQUARE METERS	4886	3581	3830	4080	4329	4578	4827	4886	4886	4886	4886
STEADY STATE DEVELOPMENT METERS	101	101	101	101	101	101	101	101	101	101	101
STEADY STATE PANELS MINED	11	8	9	9	10	11	11	11	11	11	11
MAXIMUM PANELS BLASTED	14	4	8	10	10	9	8	8	8	12	14
MONTH		33	34	35	36	37	38	39	40	41	42
TOTAL DEVELOPMENT	0	97	39	39	99	142	162	124	97	39	39
TOTAL LEDGING CENTARES		0	0	1000	1000	400	0	0	0	0	1000
TOTAL STOPING CENTARES		1744	3488	3488	3488	3488	3488	3488	3488	5231	5231
TOTAL SQUARE METERS	0	1744	3488	4488	4488	3888	3488	3488	3488	5231	6231

Table 3.13 indicates how the steady-state square meters (the first line in the above table) increase and then flatten out at 4 886 square meters from month 39. This steady-state value can be used to compare various mining methods because each layout has its own steady-state production rate. This however

cannot be viewed in isolation. Other factors, such as ventilation, tramming capacities and flexibility, must also be considered. This steady-state rate is mainly affected by the advance rate of the main end (haulage in this case) and it will increase if the haulage advance rate increases. Note that the common block colour coding does not apply to Table 3.13.

3.8 Application of the model on existing half levels

In most applications the planning of existing mines would have to be evaluated. The most important aspect of the exercise is to find a suitable "fit" between the actual current state of the area to be assessed and the ideal position in the life of the area as suggested by the HLP model. For example, in Table 3.14, a specific development end in the HLP model, i.e. the haulage, advanced 699 m. At this point, with the scheduling as specified by the user, no square meters could have been mined. By looking at the mine plans, the haulage advance at 700 m basically matches the ideal advance, but the rest of the development is behind schedule. The Stoping+Ledging square meters extracted are also 6 000 where the model suggests no extraction possible at this point. What may have happened in the actual case was that when the first block became available, the haulage was stopped and Stoping+Ledging continued – depleting reserves without replacing it. This can be simulated by the step function in the HLP model that allows the user to carry on in an accessible block whilst delaying the next block's start-up point.

Table 3.14 shows the condition where the haulage was matched and a natural step (no artificial delay) of 7 months was used – 7 months between common block start-ups.

By now increasing the step to 11 months – thus forcing an additional 4-month delay between common block start-ups on top of the natural 7-month delay – a reasonable haulage and Stoping+Ledging extracted square meter match was found (Table 3.15). The chances of getting a 100% match are rare due to the model working on a monthly basis – a fit is acceptable if the variance does not exceed 1 month's production in the main areas, i.e. the main development end (haulage) and the square meters extracted (Stoping+Ledging).

Table 3.14: Matching the model with the actual situation (natural step)

FINDING THE BEST FIT: IDEAL vs. ACTUAL (natural step)					
PERIOD	TOTAL LIFE	CURRENT POINT IN TIME			
DESCRIPTION	MAXIMUM	IDEAL	ACTUAL	VAR %	VAR
Haulage (m)	2600	699	700	0%	1
X/cut (m)	1560	339	240	-29%	-99
Timber bay (m)	130	20	20		
Travelling way (m)	130	20	20		
Box 1 (m)	312	48	48		
Box 2 (m)	390	60	60		
Box 3 (m)	468	105	72	-32%	-33
Haulage box (m)	546	101	84	-16%	-17
Funkhole (m)	156	24	24		
Step over (m)	65	10	10		
Raise (m)	2600	699	400	-43%	-299
Transformer cubby (m)	130	30	20	-33%	-10
Explosives cubbies (m)	65	15	10	-33%	-5
STOPING + LEDGING (m^2)	444600	-	6000		-6,000
Current EXTRACTION factor (m^2/m)	48.58	0.00	3.51		

Table 3.15: Matching the model with the actual situation (by using an additional delay)

FINDING THE BEST FIT: IDEAL vs. ACTUAL (additional delay)					
PERIOD	TOTAL LIFE	CURRENT POINT IN TIME			
DESCRIPTION	MAXIMUM	IDEAL	ACTUAL	VAR %	VAR
Haulage (m)	2600	699	700	0%	1
X/cut (m)	1560	360	240	-33%	-120
Timber bay (m)	130	30	20	-33%	-10
Travelling way (m)	130	30	20	-33%	-10
Box 1 (m)	312	65	48	-26%	-17
Box 2 (m)	390	60	60		
Box 3 (m)	468	108	72	-33%	-36
Haulage box (m)	546	126	84	-33%	-42
Funkhole (m)	156	36	24	-33%	-12
Step over (m)	65	15	10	-33%	-5
Raise (m)	2600	699	400	-43%	-299
Transformer cubby (m)	130	30	20	-33%	-10
Explosives cubbies (m)	65	15	10	-33%	-5
STOPING + LEDGING (m^2)	444600	6,759	6000	-11%	759
Current EXTRACTION factor (m^2/m)	48.58	2.97	3.51	18%	

Table 3.14, with the natural step (7 months), produced a main development match in month 24 meaning that the half level is in month 24 of its life cycle.

After adding an additional 4-month delay between blocks (11 months total step), the main development as well as square meter extraction matches in month 36 of the half level's life (results illustrated in Table 3.15).

Important though is the fact that some other development ends are behind schedule. Management should use this type of Table (3.14 and 3.15) to rectify adverse variances as soon as practically possible. This can be done by multi-blasting (more than one blast per day) all development ends where possible; slowing down the ore extraction rate should be a final resort.

3.9 Long-term planning

It is common for mines to make use of 5-year planning cycles. The HLP model has a built-in facility to calculate detailed plans for a period of 7 years from a selected point in time. These plans are supplied in a progressive annual as well as a monthly format and revenue streams are also included.

This procedure is simplified by the application of a button-activated macro. Before using this facility, one has to match the current state of the half level with the model. Management may prescribe a flexibility policy in terms of ensuring additional stope faces being available when required for certain mining layouts, for instance down-dip systems. This means mining less square meters per month than the maximum possible thus leaving certain panels idle (normally 1 panel per half level for down-dip mining). The reason why down-dip systems require an idle face is because every raise only opens one panel. If the panel cannot be accessed or mined for some reason, the labour has to be re-deployed in another panel. In optimum conditions the model assumes that a panel is mined as soon as a raise holes and all raises take the same time to hole. Adding all this production together results in a steady-state situation and the flexibility factor chosen simply depletes the reserve at a rate lower than steady state.

In breast layouts a single raise opens more than one face. In the chosen example, the raise is 200 m long and if the average panel consumes 33 m including the pillar, 6 panels can be established on either side giving a total of 12 panels. If mining a maximum of 4 panels per block at any point in time, each active panel has a maximum of 2 spare panels available. This means that no additional spare panels need to be defined for planning purposes.

Table 3.16 is an extract of the long-term planning output of the HLP model. This process has to be repeated for all the half levels and the sum of all the half levels would be the total shaft's planned output. Note that the annual plan is in a progressive format – to get annual numbers, the previous year has to be subtracted.

Table 3.16: Long-term planning output table (down-dip layout)

LONG TERM PLANNING FACILITY				
PARAMETER	ANNUAL PLAN (PROGRESSIVE)		MONTHLY PLAN	
Year	2003	2004	2003	2,004
Haulage (m)	932	1,166	19	19
X/cut (m)	480	600	10	10
Timber bay (m)	40	50	1	1
Travelling way (m)	40	50	1	1
Box 1 (m)	96	120	2	2
Box 2 (m)	120	150	3	3
Box 3 (m)	144	180	3	3
Box 4 (m)	168	210	4	4
SPD1 (m)	48	60	1	1
SPD2 (m)	20	25	0	0
Raise1 (m)	666	899	19	19
Raise2 (m)	40	50	1	1
Raise3 (m)	20	25	0	0
STOPING + LEDGING (INCL.FLEXIBILITY) (m^2)	58,181	95,869	2,995	3,141
EXTRACTION factor (m^2/m)	21	27	47	49
TONS TO REEF (t)	211,191	345,258	10,667	11,172
TONS TO WASTE (t)	47,787	59,733	996	996
4E GRAMS TO REEF (g)	1,300,266	2,134,417	66,332	69,513
4E GRAMS TO WASTE (g)	0	0	0	0
REVENUE (R)	R 130,026,613	R 213,441,668	R 6,633,217	R 6,951,255
TOTAL DEVELOPMENT (m)	2,815	3,585	64	64

This long-term planning facility is also useful for calculating the capital requirements for new mines. It gives you the point in time when every half level reaches steady state as well as all the production requirements to get to that point. Furthermore, the revenue build-up in real terms is supplied, which allows the user to calculate pay-backs, net present values or internal rates of return once costing information is available.