Diploma Thesis for the degree Diplom – Ingenieur in

BERGWESEN

Implementation of the new Mining Strategy at the Open Pit Mine „Mormont“ of Holcim (Switzerland) AG regarding the augmented kiln capacity.

submitted to the department of mining engineering,
University of Leoben

cand.ing. Alfred Schreilechner

Holcim

Declaration on Oath

I declare in lieu of oath that I did this diploma thesis in hand and by myself using only literature cited at the end of this volume.

Eclépens, February 2007

Alfred Schreilechner

Acknowledgements

In this place I want to express my sincere gratitude to all those who helped me with the realization of this thesis.

First of all I want to thank Dipl. Ing. Dr. mont. Gerhard Reichholf from Holcim (Suisse), who put me on this job, for his confidence and guidance, his technical and mental support and for his friendship.

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Thank you to Mr. Matthieu Honorat, Mr. Claude Brocard and many others at the Eclépens Plant for the technical help, the pleasant accommodation and the excellent working atmosphere.

Many others who helped me with their technical support, especially Dipl. Ing Harald Hacker, Miroslav Nagy, Brigitte Hangebrock and my computer gurus Klaus-Peter Tucan and Bernhard Jasny, thanks a lot.

Last but not least many thanks to my loving parents for enabling me to do what I do, be what I am and for their full support of whatever I do and all the possibilities they opened up for me.

Content

1 Preamble

The Eclépens Cement plant is part of the internationally active Holcim Group. It was designed and constructed in the years 1948 to 1953, where it went operational. Nowadays it employs 104 people from the region and has an annual production capacity of 510.000 t of clinker and 560.000 t of cement.

To meet its raw material consumption the plant is currently running the Marl Quarry "Les Côtes de Vaux" with a production of approximately 200.000 t/year and the Limestone Quarry "Mormont" with a production close to 700.000 t/year. The two quarries are in the vicinity of the plant. 14 workers are in charge of running them and supplying the plant with raw material.

In the Marl Quarry "Les Côtes de Vaux", the soft rock is extracted by a backhoe excavator and loaded to 2 Volvo A40 trucks. It is then transported to a jaw crusher and a mixing bed.

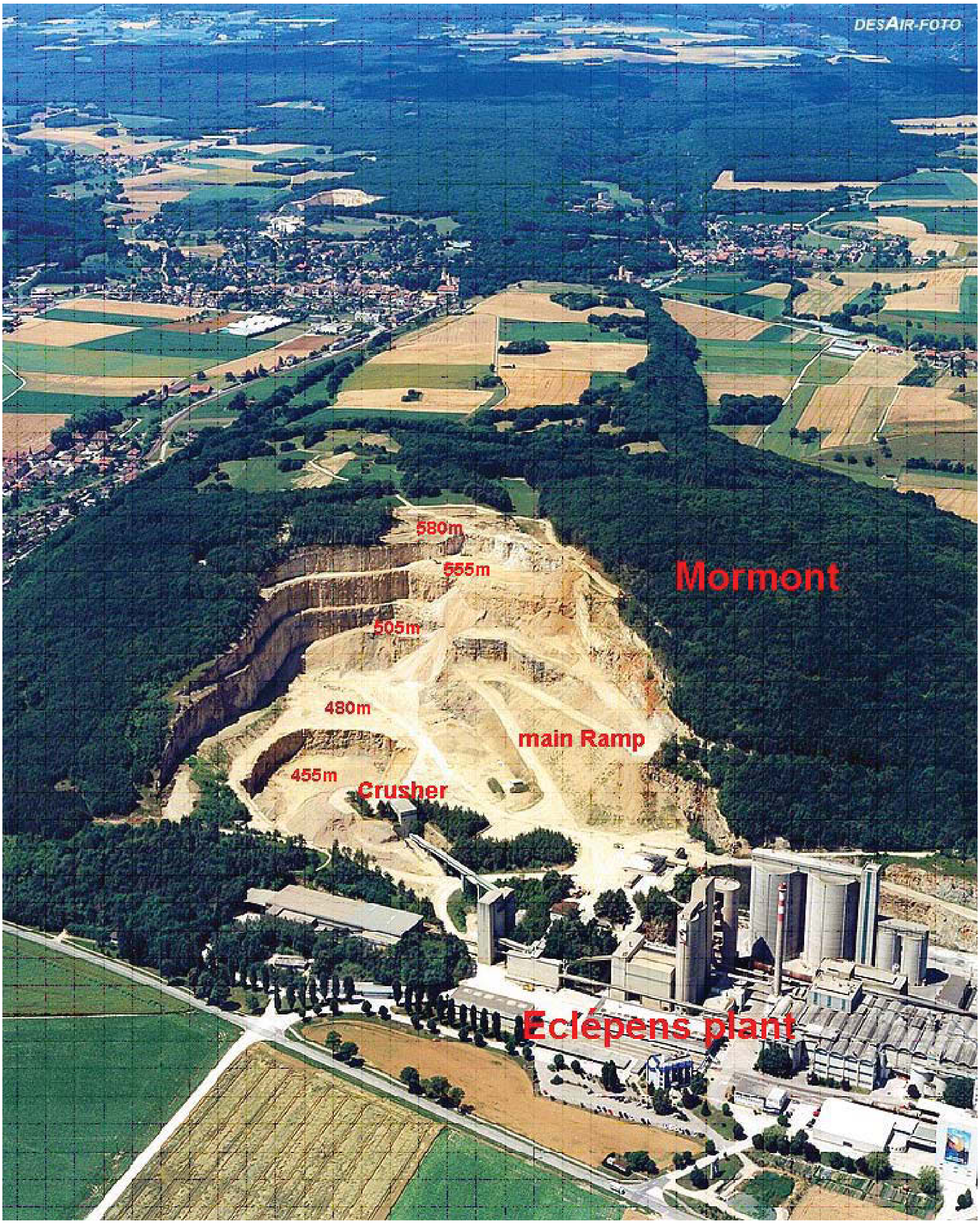
In the Limestone Quarry "Mormont", which is subject of this thesis, the material is extracted by drilling and blasting. The loosened hard rock is loaded to trucks and transported to a double axle hammer crusher, from where it goes to two silos by a belt conveyor.

Originally, the Quarry is planned and operated with bench heights of 40m. The material is blasted and then dumped bench by bench until it reaches the level at which the crusher is installed. This does not allow any control of the raw material quality.

The high benches also pose a security risk and a problem with blast vibration control evolves. In 1999, the continuous expansion of the quarry makes the development of a haul ramp necessary. Now the material is loaded to heavy trucks on the blasting site and directly transported to the crusher.

In 1999, an Extension of the Quarry, the so called "Mormont VI" is planned and permitted by the state of Vaud. This planning still supposes a bench height of 25m. However, after the permission is obtained, it is decided to again reduce bench heights to a maximum of 12.5m. The aim is to increase safety and reduce the blast vibrations which become an ever increasing problem.

This reduction of the bench heights and increasing quality demands make a detailed planning of the future mining layout necessary.



Picture 1-1: The Mormont Limestone Quarry
Source: DesAir Foto

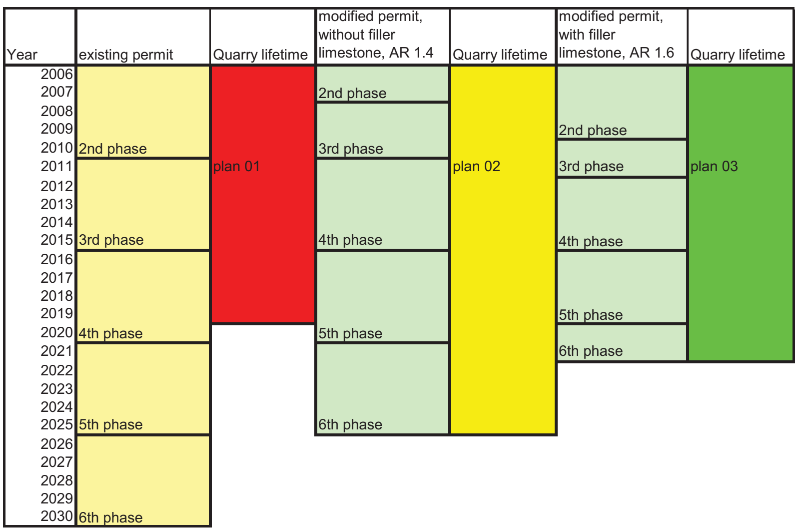
2 Abstract

The planning of the new mining strategy at the “Mormont” limestone Quarry comprises the following steps:

1.) Review of the existing exploitation permission “Mormont VI”
2.) Visualization of the existing exploitation permission “Mormont VI”
3.) Visualization of the results of QSO
4.) Detailed planning of the future mining operation
5.) Crusher examination
6.) Haulage prognosis
7.) Benchmarking the fleet

1.) The review of the existing exploitation permission “Mormont VI” shows that the volumes calculated by CSD are correct. Based on a yearly production of 300’000 m^3 the raw material will last until 2031. As the CSD plans are based solely on legal and environmental aspects, the implementation would hardly be possible. Finally, the visualization shows that the plans are geometrically not correct.

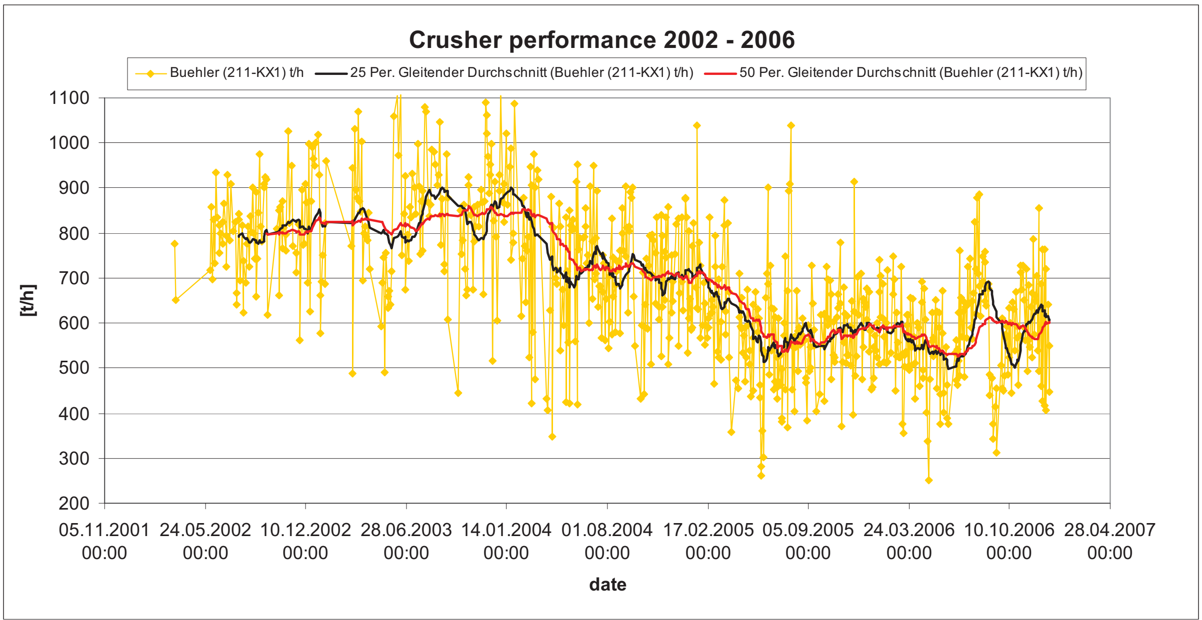
2.) The long term Quarry optimization is performed by applying QSO. The planning shows that the chemistry of the Raw Material in the Quarry, especially in the lower layers, is not as suitable as expected. This and the augmented kiln capacity shortens Quarry lifetime by 10 years. In comparison with the geometrical planning of CSD, QSO shows that 3’100’000 m^3 or one third of the available material does not meet the chemical requirements of the daily clinker production without further blending.



3.) The Visualization of the QSO results gives the basis for a detailed planning. This mainly comprises the design of the haul roads. They have to be as short as possible to ensure that the Dumpers are able to carry enough material to the Crusher. The production focus is already given by the QSO planning. As the shape of the perimeter has to be respected, the possibility for future ramp design is very restricted. Nevertheless a few options are taken into consideration. One result of this planning is that the main haul ramp on the north-eastern side of the pit will remain the only access to the benches. Whenever possible it should be avoided to climb the two hairpin bends of the main ramp. With the progression of the mining front, the lower benches should become accessible by the construction of shorter ramps.

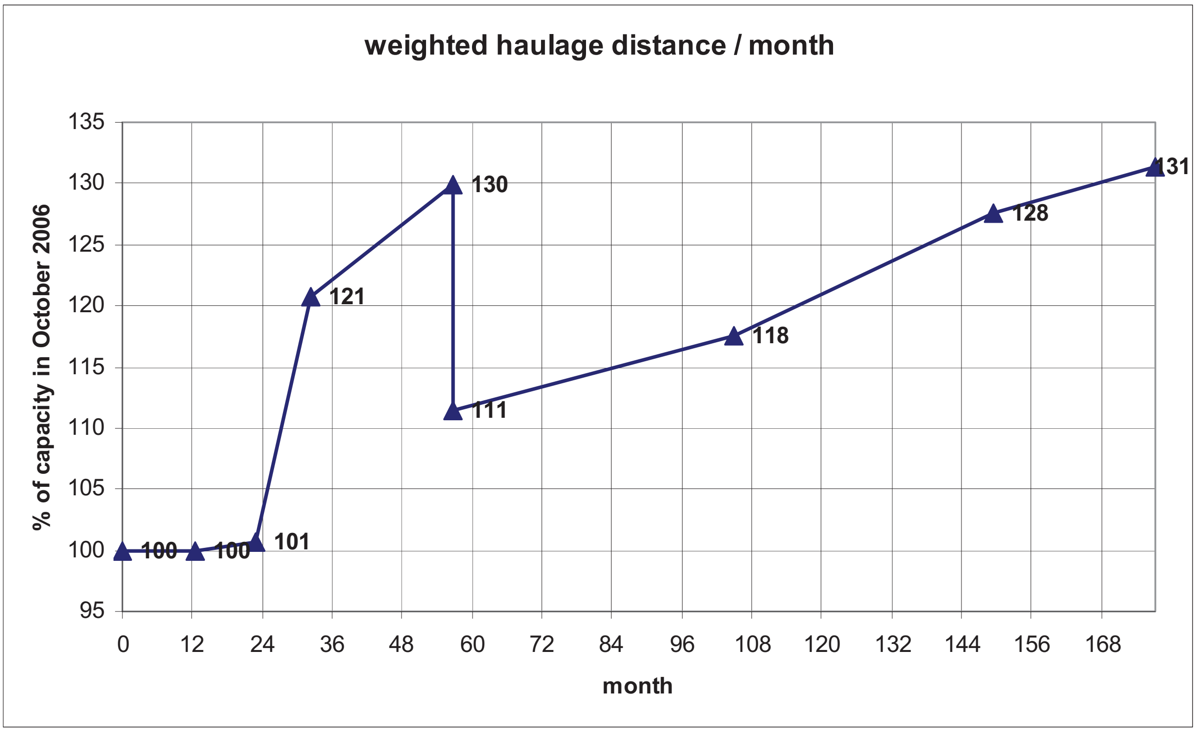
4.) The detailed planning enables to determine the future haul road length and the production by bench. This gives the possibility to calculate a haulage prognosis and to benchmark the fleet.

5.) The analysis of the crusher performance of the last 3 years gives worrisome results. Although the nominal crusher capacity is 750 t/h, the actual crusher capacity of 2006 is only 600 t/h.



A graphical examination of all data available in TIS shows that the crushing capacity diminished in two steps from about 800 t/h until January 2004 to 700 t/h until January 2005 and finally to not even 600 t/h after June 2005.

6.) To calculate a haulage prognosis and to benchmark the fleet, the average haul distances and the productions by phases and benches are derived from the plans designed in Surpac. Taking this data, a weighted haulage distance is calculated in tons*kilometres.



This shows that there will be little change in capacity needs until October 2008. From this date on the demand rises to a peak in summer 2011. After the completion of shortcut ramps to the high productive benches, the capacity demand drops significantly. Until 2021, it smoothly rises to about the same level than in summer 2011, representing the growing distances from the crusher to the benches.

7.) With the data collected, it is possible to calculate production needs. This is done in three different ways.

Way 1:

A calculation by yearly tonnage (1’000’000 t/a) gives the necessary yearly crushing hours, which amount up to 1’666 hours for a crushing capacity of 600 t/h and 1’333 hours for 750 t/h.

Way 2:

A similar calculation by the available working time gives the necessity to crush 873 t/h for a crushing time of 28 hours per week and 686 t/h for 41,5 h.

Way 3:
Taking the machine performance data into consideration, a benchmarking of the fleet is possible by calculating the expectable haul capacities.
As it is mathematically not possible to determine the optimum, all theoretically possible machine combinations are examined by some examples.
The calculation for a very unfavourable situation in 2010 with rather long haul distances gives an expected maximum haul capacity of 669 t/h. This is only 2.5% short of the minimum demand of 686 t/h for the 41,5 working hours weekly. The calculation for the same benches in 2012, after the completion of some shortcut ramps, shows, that with 905 t/h the haul capacity needs can easily be exceeded.

Two conclusions can be drawn:
First, the calculations show that the fleet generally meets the needs of the production. Only in the years 2010, 2011, 2020 and 2021 the situation regarding the haul capacity could be tight. However it should be possible to cope with that keeping the actual fleet.
Second, it is very important to augment the capacity of the crusher to its nominal.

Generally there are a three important distances distinguished.
1.) At 2300m round trip or less, the 750 t/h of the crusher is the limiting element.
2.) Until a distance of 2500m round trip the normal working time of 41,5 hours per week is expected to be sufficient to ensure the production.
3.) At a distance of 3000m, the haul capacity has dropped to 600 t/h which represents the crushing capacity indicated by TIS at the time this thesis is prepared.

Finally, QSO has shown that the Mormont Quarry will be able to supply Raw Material in sufficient Quantity and Quality only until 2021. Possible alternatives have to be searched for the time after 2021.

3 Concept

3.1 Strategy

3.1.1 Inquiry of the basics

The first step of the conceptual formulation is to inquire the basics. Therefore the existing planning and other available information are reviewed and maps are being digitized. There is an existing 3D map of the area in form of a .str and .dtm file. This existing 3D map, which is derived from an aerial stereo photography, is put up to date by re-measuring the existing benches In the Mormont Quarry with the plants Garmin GPS.

3.1.2 Visualization of the existing plans

Starting from the up to date topography and the digital maps from the extraction permission, the latter are visualized in 3D by using mine Planning Software. The original planning has been done by “CSD Ingénieurs Conseils SA”.

3.1.3 QSO / Rough planning

QSO – Quarry Schedule Optimization is a mine planning software from Holcim Group Support and will be described in detail in chapter 8.3. It uses a block model to determine the optimal mining sequence in order to guarantee a steady raw material quality for the kiln. The optimisation sequence is defined by Holcim standards. The results are given as centre points of the blocks, which describe a rough basis for the geometrical planning of the Mormont quarry.

3.1.4 Detailed planning

After the QSO results are visualized, the detailed planning is done. Using the block model as a guideline, 7 exploitation phases are constructed. These phases take different other constraints into account, such as bench heights, ramp inclinations and slope angles.

3.1.5 Examination of different variants

During the detailed planning process, a number of different possibilities for the design of the haul roads and other details open up. Some of them are visualized in independent plans; others will be discussed in chapter 9.4 “Examination of variants”.

3.1.6 Haulage prognosis

After the detailed planning is finished, the average length and geometry of the future haul roads can be determined. Using speed measurements of the mining trucks and machine performance data given by the manufacturers, the average future production capacity of the quarry fleet is calculated.

4 The Mormont Quarry

4.1 History

The main raw materials at Eclépens to produce clinker are limestone and marl. Both materials are extracted in the vicinity of the plant. While the limestone quarry “Mormont” lies directly behind the plant, the marl quarry “Marnière” is situated in approximately 1 km distance. The total material consumed by the plant in 2005 added up to 865,000 tonnes. About 676,000 tonnes was limestone and the remainder mainly marl and minute quantities of iron ore and sand.

Until recently conducted detailed investigations, the limestone from the quarry was subdivided into two primary qualities according to the lithological layers:

'blue' stone Relatively low CaO content of 44 - 49 %

Relatively high SO3 content of 0.8 - 1.4 %

'yellow' stone Forms the dominant material in the quarry

Relatively high CaO content of 49 - 53 %

Relatively low SO3 content of 0.1 - 0.2 %

The two different layers in the quarry are shown in Picture 4-1.

Picture 4-1: Eclépens pit

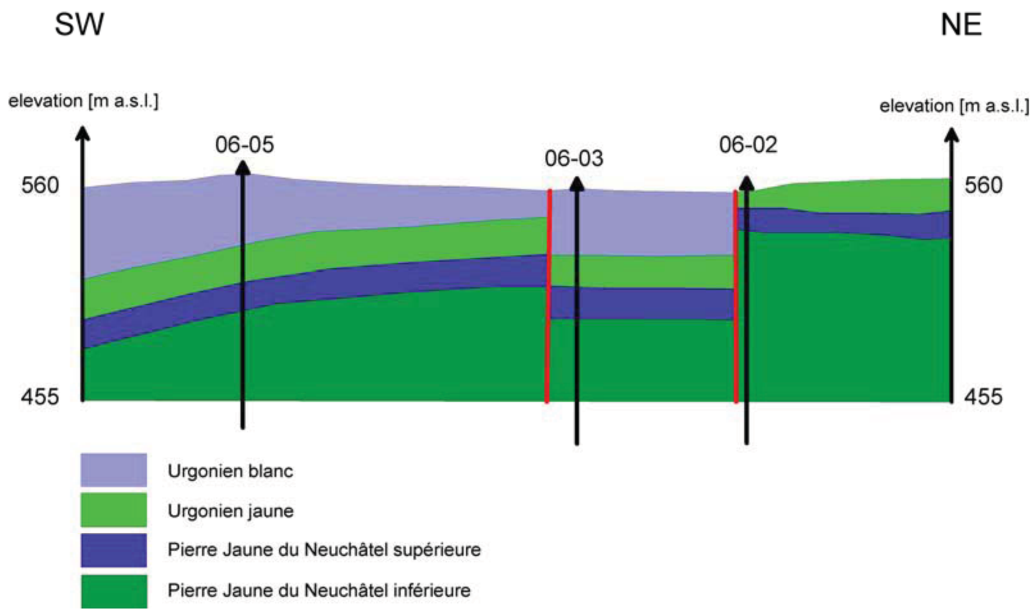
Mining is conducted on 7 separate benches with an individual height of 12,5 to 25 meters. On the basis of the thesis of Mr. Schachinger, all bench heights will be diminished to 12,5 m in the future. The benches are accessed over a ramp system.

The present manoeuvrability at Eclépens is limited due to a relatively steep mining face, because of (1) a lack of overburden stripping over time and (2) the outer pit walls had to be left behind due to a fault zone and sensibility to ground vibrations during blasting. The material is drilled with an Atlas Copco ROC F6 and blasted using conventional methods. Thereafter, the limestone is loaded by CAT wheel loaders onto CAT dump trucks and transported to the primary limestone crusher with a nominal capacity of 750 tonnes/hour. The material is then fed into two intermediate silos of 6,000 tonnes capacity each, which in turn fill a bin of 160 tonnes capacity in front of the VRM. (Report MT 02/13548/E, Peter Gabrielli: Investigation into Potential Benefits of a QuarryMaster Installation at Eclépens)

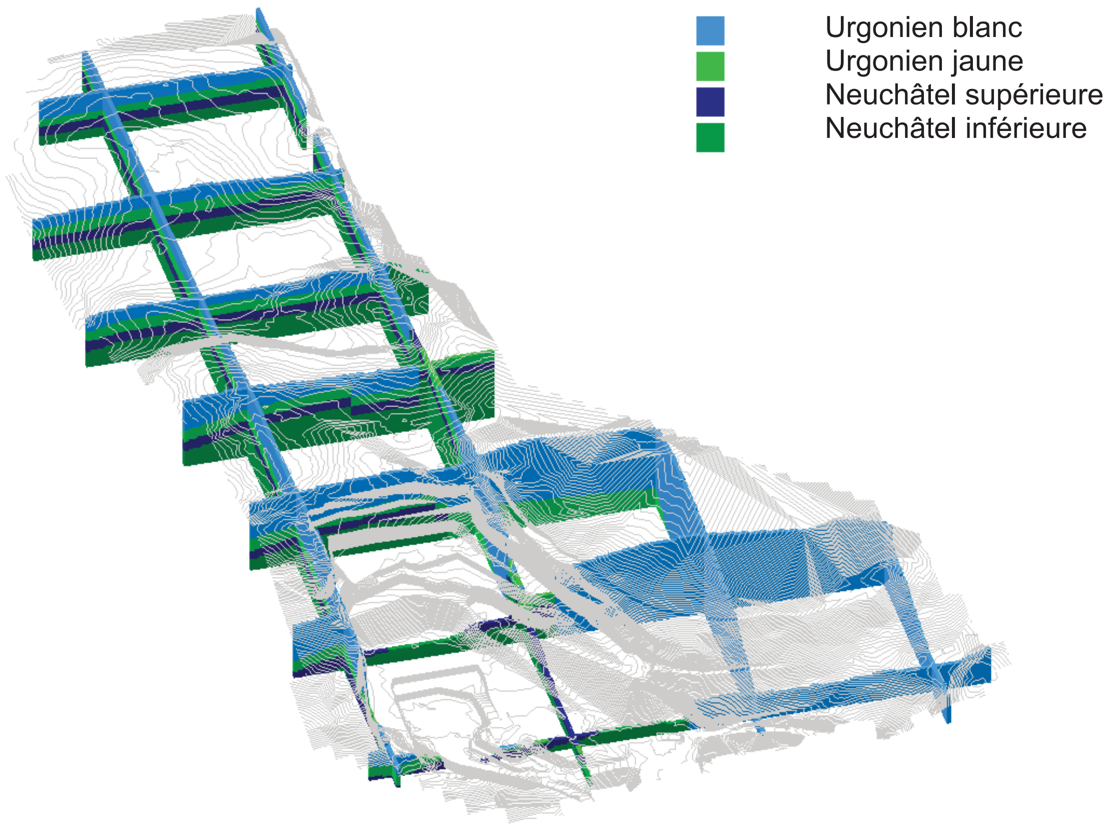
4.2 Geology

The Mormont hill geologically is a Horst structure consisting of Cretaceous Limestone. From a structural point of view, the quarry is located in the core and south flank of the Mormont anticline. This anticline is strongly affected by strike-slip faults and associated secondary faults. In the main fault zone in the northern side of the quarry, a large area shows sulphur mineralization with large crystals of pyrite.
Siderolithic pockets and karst systems, often filled up with red clay, are also recognized throughout the limestone deposit. Locally, this clay sand contaminates the quality of the limestone.

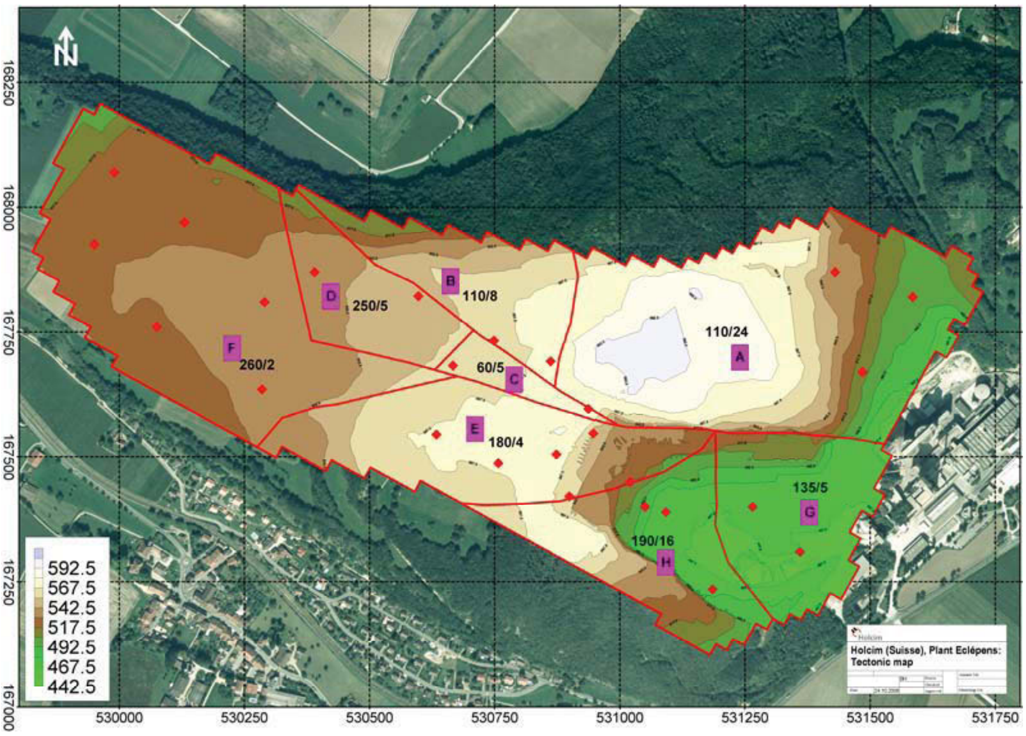
The uppermost limestone layer found is Urgonien blanc, followed by Urgonien jaune, Pierre jaune du Neuchâtel superieure and Pierre jaune du Neuchâtel inferieure. The pictures Picture **4-2** to Picture **4-4** show geological cross sections and the main failures of the Mormont hill.



Picture 4-2: Typical geological cross section of the Mormont hill



Picture 4-3: 3D View of the Geology of the Mormont hill



Picture 4-4: Map of the main geological failures on the Mormont hill

4.3 *Quarry Equipment*

4.3.1 Drilling Machines

4.3.1.1 Atlas Copco ROC F6

The Atlas Copco ROC F6 is the standard drilling machine in the Quarry. It is equipped with a Down the Hole Hammer. As soon as the new Tamrock Ranger 800 arrives, it will be used as reserve machine.

Picture 4-5: AC ROC F6

Year of construction	not available
Operating Weight	17,2 t
Power of Engine	170 kW
Planned replacement	2011
Borehole diameter	89 mm
Rod length	4 m
Scavenging Air Volume	not available
Dust Collector	not available
Driving Speed	not available
Average Fuel Consumption (l/h)	34,1
Hours by End 2005	5024

4.3.1.2 Böhler DTC 122

Until the arrival of the new Tamrock Ranger 800 the Böhler DTC 122 is the second standard Down the Hole Hammer (DTH) drilling machine of the Quarry.

Picture 4-6: Böhler DTC 122

Year of construction	1987
Operating Weight	14 t
Power of Engine	78 kW
Planned replacement	2007
Borehole diameter	89 mm
Rod length	4 m
Scavenging Air Volume	9 m^3
Dust Collector	not available
Driving Speed	not available
Average Fuel Consumption (l/h)	19,3
Hours by End 2005	5321

4.3.1.3 Böhler DTC 111

The Böhler DTC 111 is a small Down the Hole Hammer (DTH) drilling machine used to drill in difficult terrain where the bigger machines can not operate.

Picture 4-7: Böhler DTC 111

Year of construction	1991
Operating Weight	6,2 t

Power of Engine	72 kW
Planned replacement	2015
Borehole diameter	89 mm
Rod length	4 m
Scavenging Air Volume	6 m^3
Dust Collector	not available
Driving Speed	not available
Average Fuel Consumption (l/h)	16,2
Hours by End 2005	5309

4.3.1.4 Tamrock Ranger 800

The Tamrock Ranger 800 will arrive in April 2007 and is due to replace the DTC 122. It is equipped with a Top Hammer and an automatic sampling system.

Picture 4-8: Ranger 800
Source: Tamrock

Year of construction	2007
Operating Weight	14,7 t
Power of Hammer (Top Hammer)	21 kW
Power of Engine	168 kW
Planned replacement	not available
Borehole diameter	89 mm
Rod length	3660 mm
Scavenging Air Volume	9,5 m^3/min
Dust Collector	23 m^3/min
Driving Speed	3,5 km/h
Average Fuel Consumption (l/h)	not available
Hours	0

4.3.2 Loading Machines

4.3.2.1 CAT 990 II HighLift

The CAT 990 II Wheel loader is the standard loading machine. It is the only machine able to load the CAT 777 D Dumper until the arrival of the Komatsu PC1250 Excavator. However, it is not constructed to fit with the CAT 777 D, and thus does not fully load it with 91 tons but with only 80 tons.

Picture 4-9: CAT 990 II HighLift

Year of construction	2002
Operating Weight	80 t
Power	548 kW
Planned replacement	2010
Volume heaped	8,6 m^3
Average Fuel Consumption (l/h)	62,6 l/h
Hours by End 2005	5257 h

4.3.2.2 Komatsu WA 600

The Komatsu WA 600 Wheel loader is kept as reserve machine.

Picture 4-10: WA 600

Year of construction	1997
Operating Weight	45,6 t
Power	310 kW
Planned replacement	Reserve

Volume heaped	6,5 m^3
Average Fuel Consumption (l/h)	43,5 l/h
Hours by End 2005	11279

4.3.2.3 CAT 988 FII

The CAT 988 FII Wheel loader is currently used as one of the two standard loaders. It will be replaced in 2008.

Picture 4-11: CAT 988 FII

Year of construction	1999
Operating Weight	57,6 t
Power	327 kW
Planned replacement	2008
Volume heaped	6,3 m^3
Average Fuel Consumption (l/h)	46,0 l/h
Hours by End 2005	8798 h

4.3.2.4 Komatsu PC1250-SP8

The Komatsu PC1250 excavator is put into service in February 2007. It is the new standard loading machine and is able to load all trucks applied in the Quarry.

Picture 4-12: PC1250-SP8
Source: Komatsu

Year of construction	2006

Operating Weight	110,7 t
Power	502 kW
Planned replacement	not available
Volume heaped	6,7 m^3
Average Fuel Consumption (l/h)	not available
Hours by End 2005	0

4.3.3 Dumpers

4.3.3.1 CAT 777 D

The CAT 777 D is the biggest dumper used in the quarry. Until the arrival of the Komatsu PC1250 Excavator, there is no appropriate machine for loading it. Thus it is generally only loaded with 80 tons of cargo and not with the 91 tons possible.

Picture 4-13: CAT 777 D

Year of construction	2002
Total Weight	161t
Payload	96t
Machine Weight	65t
Power	746 kW
Planned replacement	2017
Volume struck	42,1 m^3
Volume heaped 3:1	54,4 m^3
Volume heaped 2:1	60,1 m^3
Average Fuel Consumption (l/h)	39,42 l/h
Hours by End 2005	3009 h

4.3.3.2 CAT 771 D

The CAT 771 D Dumper is used as standard Equipment until the arrival of the new Komatsu HD 605-7 in the beginning of 2007.


Picture 4-14: CAT 771 D

Year of construction	1996
Total Weight	74 t
Payload	40,6 t
Machine Weight	33,4 t
Power	362 kW
Planned replacement	2007
Volume struck	20,2 m^3
Volume heaped 3:1	25,1 m^3
Volume heaped 2:1	27,5 m^3
Average Fuel Consumption (l/h)	22,7
Hours by End 2005	10551

4.3.3.3 CAT 769 C

The CAT 769 C Dumper is used as standard Equipment until the arrival of the new Komatsu HD 605-7 in the beginning of 2007.


Picture 4-15: CAT 769 C

Year of construction	1990
Total Weight	62,4 t
Payload	31,8 t
Machine Weight	30,6 t
Power	362 kW
Planned replacement	2007
Volume struck	not available
Volume heaped 3:1	not available
Volume heaped 2:1	23,5 m^3

Average Fuel Consumption (l/h)	23,4 l/h
Hours by End 2005	13925 h

4.3.3.4 Komatsu HD 605-7

Two new Komatsu HD 605-7 are put into service by the beginning of 2007 as new standard equipment. They replace the old CAT 771 D and CAT 769 C Dumpers.

Picture 4-16: HD 605-7
Source: Komatsu

Year of construction	2006
Total Weight	110 t
Payload	63 t
Machine Weight	47 t
Power	533 kW
Planned replacement	not available
Volume struck	29 m^3
Volume heaped 3:1	36 m^3
Volume heaped 2:1	40 m^3
Average Fuel Consumption (l/h)	not available
Hours	0

4.3.4 Auxiliary Machines

4.3.4.1 CAT 320 Hydraulic Excavator

The CAT 320 Excavator is used as auxiliary machine for a number of different purposes, for example crushing blocks.

Picture 4-17: CAT 320

Year of construction	1999
Operating Weight	22 t
Power	100,5 kW
Planned replacement	2008
Average Fuel Consumption (l/h)	16,9
Hours by End 2005	6874

4.3.4.2 CAT D5H Series II Bulldozer

The CAT D5H Dozer is used for the upkeep of the haul roads.

Picture 4-18: CAT D5H Series II

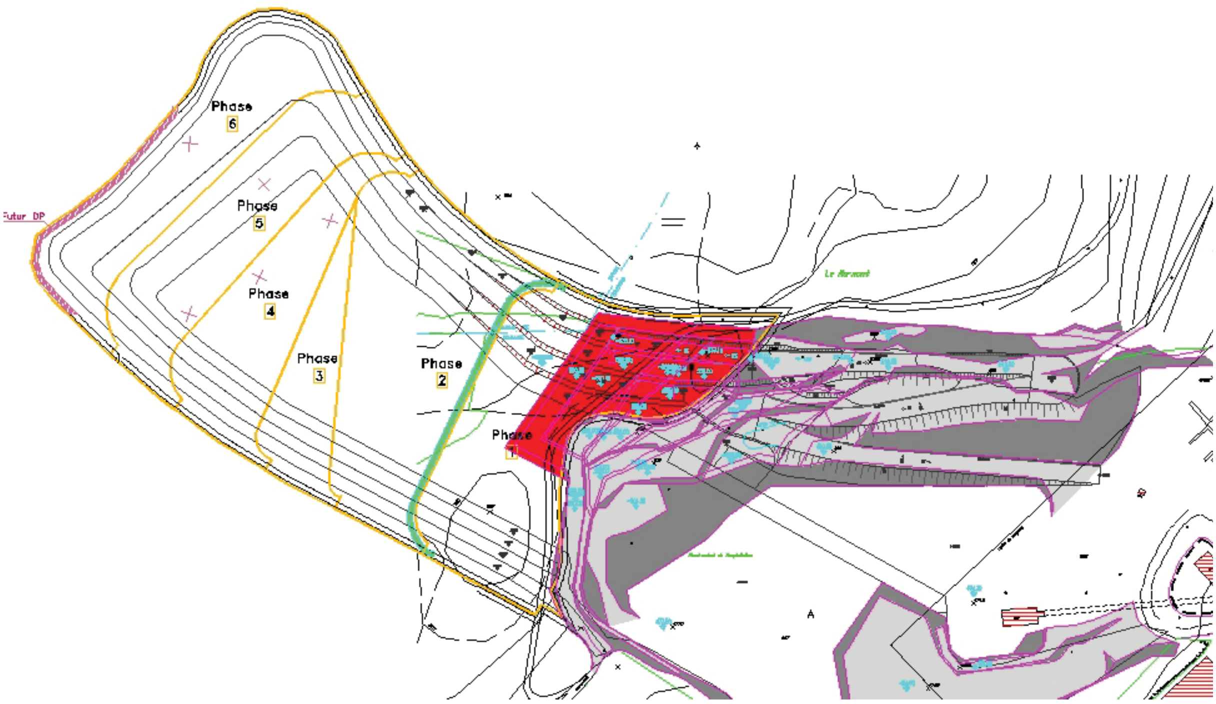
Year of construction	1988
Operating Weight	13,8 t
Power	89 kW
Planned replacement	not available
Average Fuel Consumption (l/h)	not available
Hours by End 2005	not available

5 The existing exploitation permission "Mormont VI"

The existing exploitation permission, called "Mormont VI", dates from 1999. It is planned by the company "CSD Ingénieurs Conseils SA".

The planning is intended to cover a period of 30 years from 2002 onwards. Due to the agro forestry legislation of the state of Vaud, the exploitation permission is subdivided into 6 phases of a foreseen production time of 5 years each, respectively 1.500.000 m^3 of exploitable volume. The 30 years duration for the permission is not seen as the end of the mining activities on the Mormont hill, but is the longest possible period for which deforestation permission is obtainable.

It is important to note that the planning of the future Quarry geometry and the phases of permission do not take into account geological and technical constraints but are based solely on environmental and legal considerations.



Picture 5-1: The Quarry expansion "Mormont VI"
Source: CSD

The expansion of the Quarry in north-west direction will have the form of a gully with a width of about 200m and a final length of 450m. From a geological point of view the material is composed of white Urgonien, yellow Urgonien, upper Neuchâtel and lower Neuchâtel series. The chemical quality makes it suitable for the production of clinker.

However, as there are large variations in chemistry, exploitation of different spots will be necessary.

The highest point affected by the extraction is situated at 580m, the lowest point at 458m. This gives a maximum mining height of 122m. The lowest point of the whole Quarry is the decantation basin at an altitude of 455m, at least 7 m above the plane that limits the Mormont hill.

The technical planning foresees bench heights of 25m. The different benches will be accessed by a haulage ramp. The ramp is planned with a width of 8m and a slope angle of 8%. It is constructed at the north-north-eastern side of the Quarry by heaping mainly overburden material and covers a major fault which is running close to the limit of exploitation.

The rock is loosened by drilling and blasting. At the blasting site the material is loaded to trucks and transported to the crusher.
The angle of the final slope is generally at 63°, which is expected to form a stable slope in this carbonate material. At the north side of the Quarry the final slope angle is reduced to 55° taking into account the system of big geological failures situated here. To cope with small falling rocks, especially at times of freezing and defrosting, special security zones are installed at the foot of the walls where human activities are reduced to a minimum.

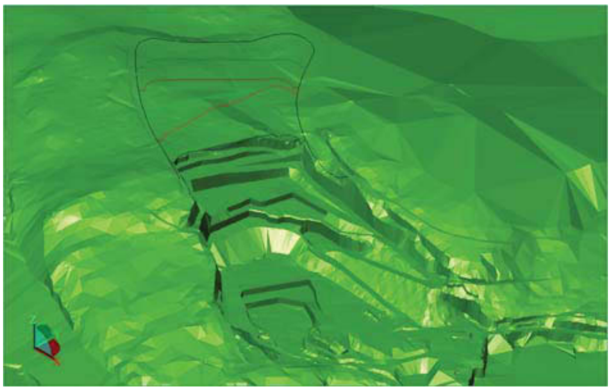
By the end of 2006, phase one of the permission is finished and phase two is prepared for production by clearing the forest and removing the soil that covers the carbonate rock.

6 Surpac Visualization of the existing exploitation permission "Mormont VI"

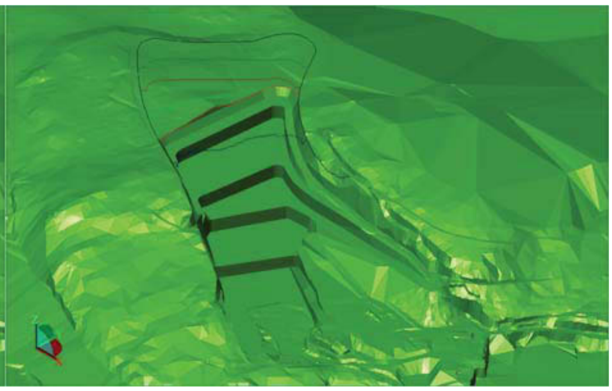
6.1 Visualization

The first task after inquiring the basics is to visualize the plans drawn by CSD and authorized by the State of Vaud. Therefore the plans, which are drawn on AutoCAD are converted and imported into the Surpac mine planning software. There they are reworked, given height coordinates and integrated into the existing topography. The result is a 3D surface which gives a good impression of the future appearance of the Quarry as planned by CSD. To describe the focus of the mining activities, pictures Picture 6-1 to Picture 6-11 show the development of the quarry with respect to the material extracted. The material to be extracted is marked in pink colour in the left pictures, the right pictures show the phases after extraction.

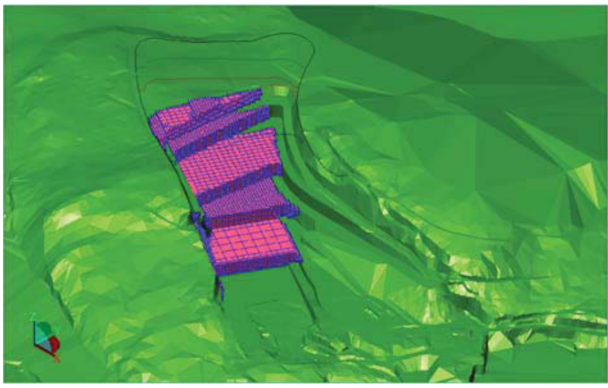
Phase one of the extraction plans is not visualized as it is finished by the time this thesis is written.



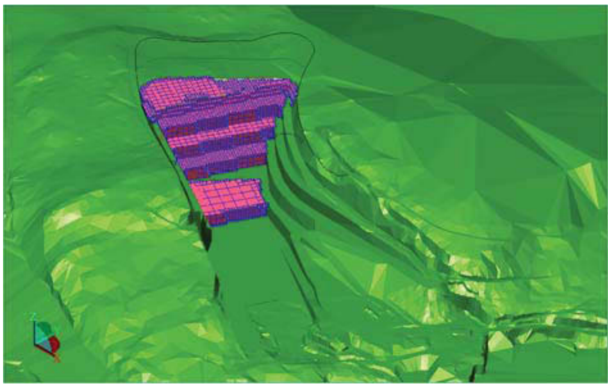
Picture 6-1: The shape of the Quarry in October 2006



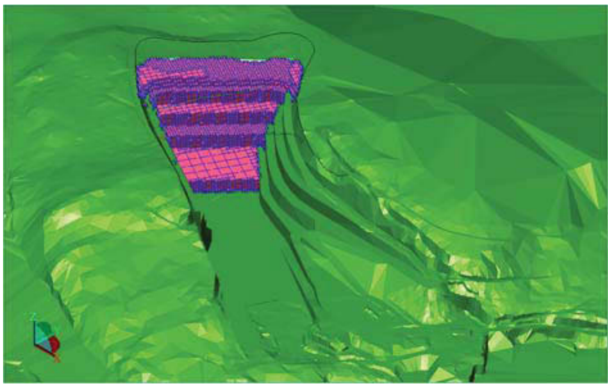
Picture 6-2: Extraction of Phase 2 of "Mormont VI"
Picture 6-3: Extraction of Phase 2 of "Mormont VI"



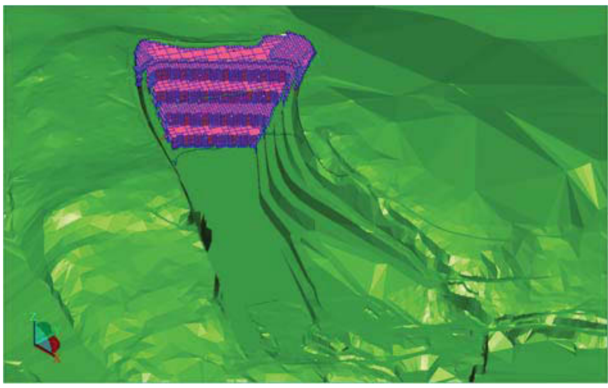

Picture 6-4: Extraction of Phase 3 of "Mormont VI"
Picture 6-5: Extraction of Phase 3 of "Mormont VI"



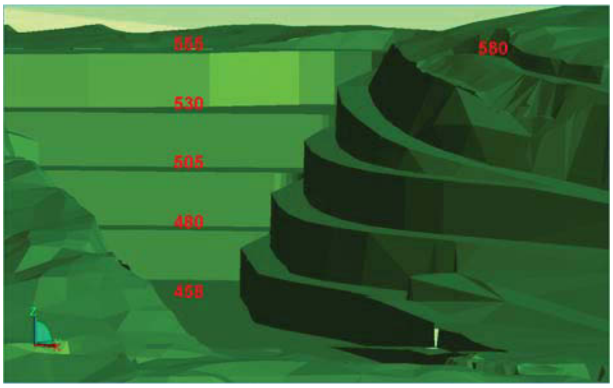

Picture 6-6: Extraction of Phase 4 of "Mormont VI"
Picture 6-7: Extraction of Phase 4 of "Mormont VI"




Picture 6-8: Extraction of Phase 5 of "Mormont VI"
Picture 6-9: Extraction of Phase 5 of "Mormont VI"




Picture 6-10: Extraction of Phase 6 of "Mormont VI"
Picture 6-11: Extraction of Phase 6 of "Mormont VI"



Picture 6-12: The Mormont Gully

At this point it has to be stated that the plans delivered by CSD are geometrically not correct. The bench geometry given by height marks and the technical handbook does not correspond with the geometry found on the drawn plans.

Due to the technical handbook the final slope angle should be 63° whereas the plans arrive at angles of 66°. The visualisation has been done by making the drawn plans three-dimensional and disregarding geometrical mistakes.

6.2 Discussion

6.2.1 Volumes

It can easily been derived from the pictures that the mining is performed in 5 benches of equal height of 25m. Although the volume of each phase is projected to be 1.500.000 m^3, the results of the 3D visualization give slightly different numbers.

	volume [m^3]	planned consumption [m^3]	years	years total
Phase 2	2'677'023	300'000	8.9	8.9
Phase 3	1'870'850	300'000	6.2	15.2
Phase 4	1'525'745	300'000	5.1	20.2
Phase 5	1'650'068	300'000	5.5	25.7
Phase 6	1'523'300	300'000	5.1	30.8

Table 6-1: Calculated volumes of the Phases of extraction as planned by CSD

As it can be seen in Table 6-1, phase 2 has a volume of 2.677.000 m^3 and thus is 1.170.000 m^3 bigger than expected; phase 3 contains still 320.000 m^3 more than projected.

Generally this could be seen as good news from the side of the Plant, as it should extend the lifetime of the Quarry. The much higher volume of Phase 2 is largely explainable by the final slope angle. Each phase as planned by CSD finishes with an angle of 63°, which in reality is not practicable for an ongoing mining operation.

6.2.2 Practicability

6.2.2.1 Bench Height

The planning by “CSD Ingénieurs Conseils SA” intends bench heights of 25m. Due to considerations of safety, quality and blast vibration control the bench heights in the actual mining operation are reduced to a maximum of 12,5m. This has a wide range of positive and negative effects:

Positive effects:

1.) The security is increased as the possibility for falling rocks to cause damage is diminished. A rock falling from 12,5m has only half of the energy available to do damage than a rock falling from 25m.
2.) The frequency of rocks falling will decrease because at a 12,5m bench it is possible to clean the face from loose rocks while loading the blast rock.
3.) The possibility to control the quality of the rock going to the cement plant is increased as there is less uncontrolled blending.
4.) Blast Vibrations diminish with lower borehole depths.

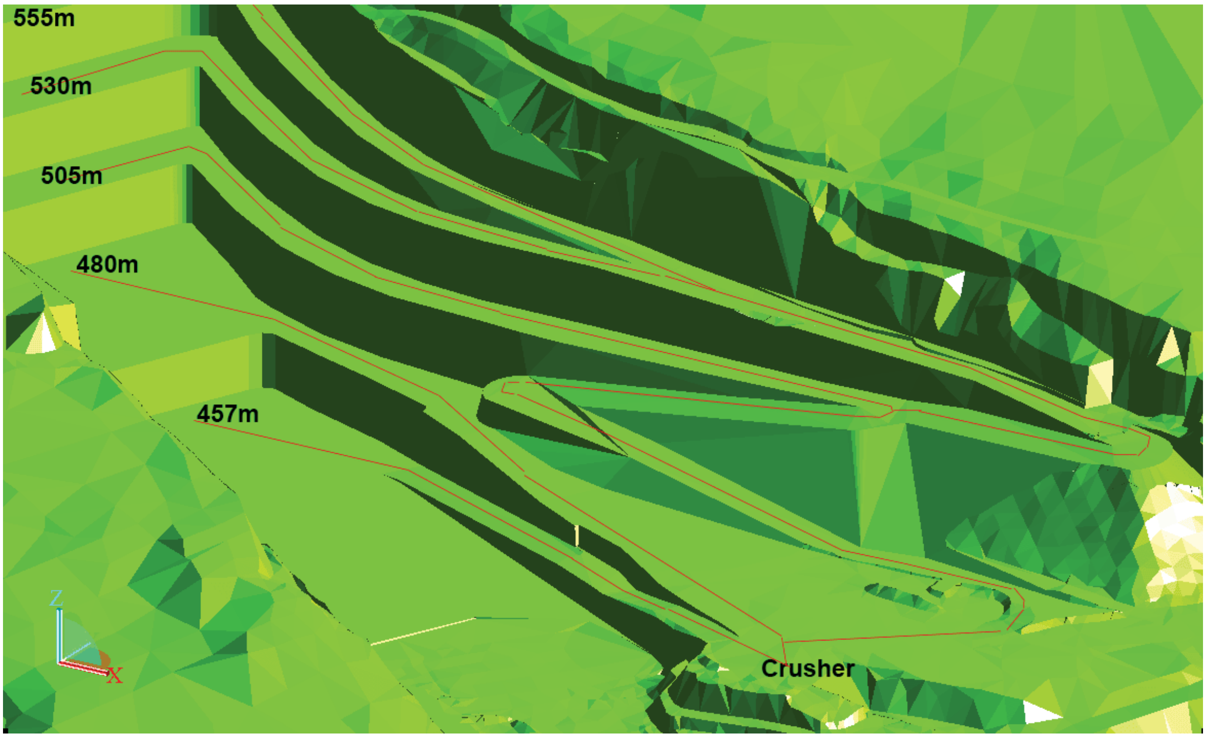
Negative effects:

1.) The number of benches will increase, which results in more and longer haul roads.
2.) The space available for loading on each bench diminishes. This makes it more difficult for the operators to manoeuvre.
3.) The costs for drilling and blasting increase as more boreholes have to be drilled.

Generally it is agreed that the positive effects prevail.

6.2.2.2 Haul Roads

In the planning of CSD, no attention has been paid to the optimization of the haul roads. The levels 505m, 530m and 555m are accessed over the heaped up ramp with 2 hairpin bends. At the level 555m there is no alternative, but at the levels 505m and 530m it would be easy to economize up to 600m of route at each haul cycle. To achieve this, more direct access can be gained as early as stage 3 is started by constructing ramps continuing straight from the first hairpin bend to the benches. This will not only mean an augmentation of the productivity but also an economisation of fuel, which benefits the CO_2 statistics and is highly positive for the environment. A re-shaping of the haul roads has to be taken into account in the detailed design of phase 2 in order not to mine the volume necessary for ramp construction.



Picture 6-13: Haul roads during phase 3

The reduction of the bench heights also has a great influence on the haul roads, as there are twice as much access points to the benches necessary.

6.2.2.3 Main mining direction

Determined by the shape of the perimeter that is visible as thin coloured lines in Picture 6-1 to Picture 6-11, the main mining direction is subjected to changes during the progress of the mining phases. While the main blasting face shows into the direction west-north-west during phase 1, it will be turned almost directly to the west by the end of phase 2, only to be turned back to west-north-west during phase 3 and even further to north-west until the end of the permitted mining perimeter.

Picture 6-14: The shape of the perimeter (facing north)

The change of the main mining direction generally is a logistical problem and should never be done in a regular planning. Even if it is necessary for reasons of slope stability it takes a long time with irregular working conditions to turn a mining face.

In this special case there is not only the problem not to have steady working conditions, but there is also a problem with blast vibrations.

In the past years the Mormont Quarry repeatedly had problems with blast vibrations. The citizens of the village of Eclépens, which is situated 300m to the south-west and west of the perimeter complained about high vibrations, which even lead to the introduction of a "Blast vibration Control" study in 2005. One result of this study was to try not to have working faces which are turned towards the village, as planned to have at phase 2 of the extraction plan.

The unusual shape of the different mining phases and of the whole perimeter – generally in mining it is tried to avoid rounded edges and changes of the general direction – is a result of the total neglecting of the technical needs of an open pit mining operation compared to the ecological perceptions by CSD.

The especially unusual form of phase 2 is a result of the planning of the main haulage ramp which should reach the top bench at the north western end of the Quarry as soon as practicable.

7 Rough planning / Visualization of the results of QSO

The planning of the quarry design until the limits of the actually permitted perimeter is conducted by HGRS by using the self developed block model program QSO. 3 plans with different restrictions are developed. (see: Table 8-1).

Year	existing permit	Quarry lifetime	modified permit, without filler limestone, AR 1.4	Quarry lifetime	modified permit, with filler limestone, AR 1.6	Quarry lifetime
2006						
2007			2nd phase			
2008						
2009					2nd phase	
2010	2nd phase		3rd phase			
2011		plan 01		plan 02	3rd phase	plan 03
2012						
2013						
2014						
2015	3rd phase		4th phase		4th phase	
2016						
2017						
2018						
2019					5th phase	
2020	4th phase		5th phase			
2021					6th phase	
2022						
2023						
2024						
2025	5th phase		6th phase			
2026						
2027						
2028						
2029						
2030	6th phase					

Table 7-1: Comparison of Quarry plans

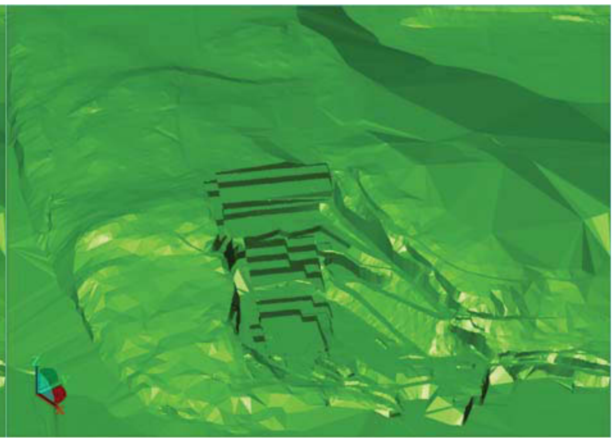
Table 7-1 shows a comparison of these plans. The two columns on the left side show the longest possible quarry lifetime without a modification of the permission (in red colour). In this case the longest achievable lifetime is until 2019. The centre columns give the possible lifetime if no limestone is used as filler and the Alumina Ratio is set 1,4 (in yellow). The columns on the right side represent the lifetime of the quarry with filler limestone and an Alumina Ratio of 1,6.

The outcome of plan 03 is considered as optimum obtainable and thus given to the Author for further processing.

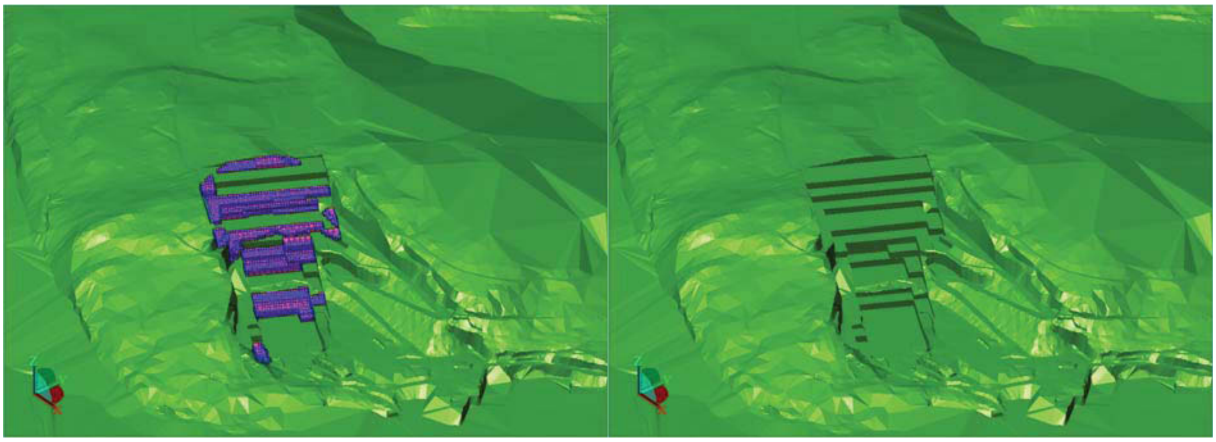
The result of QSO is an expected quarry lifetime until 2021, by sticking to the permitted phases as long as possible but disregarding them if necessary. For the input parameters see chapter 8.3.1.

The first task is to visualize the QSO planning in 3D. This allows a verification of the exploitable volumes calculated by QSO, a comparison with the exploitable volume calculated for the existing exploitation permission and it is basis for the detailed planning. Picture 7-1 to Picture 7-15 show this visualization of the results of the block model. In the pictures on the left side the volume to be extracted is marked in pink colour, the pictures on the right side show the shape after extraction. Picture 7-1 represents the shape of the quarry in October 2006.

Picture 7-1: The shape of the Quarry in October 2006

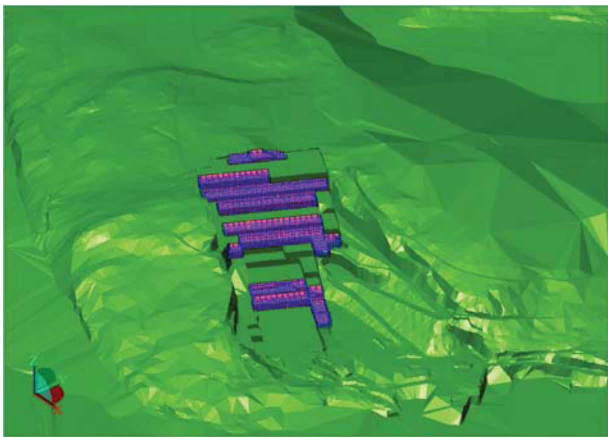


Picture 7-2: The QSO Extraction plan 2006 - 2007
Picture 7-3: The QSO Extraction plan 2006 - 2007



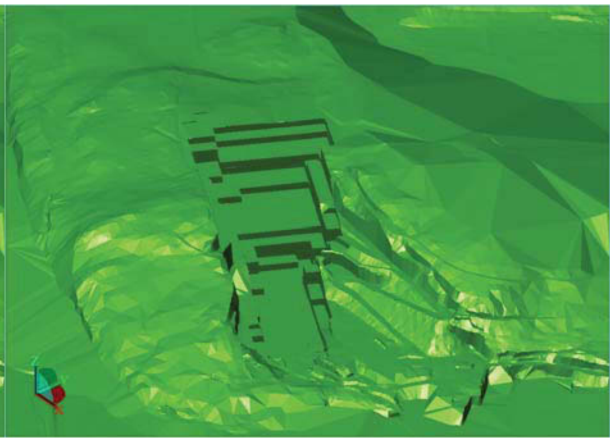
Picture 7-4: The QSO Extraction plan 2007 - 2008

Picture 7-5: The QSO Extraction plan 2007 - 2008



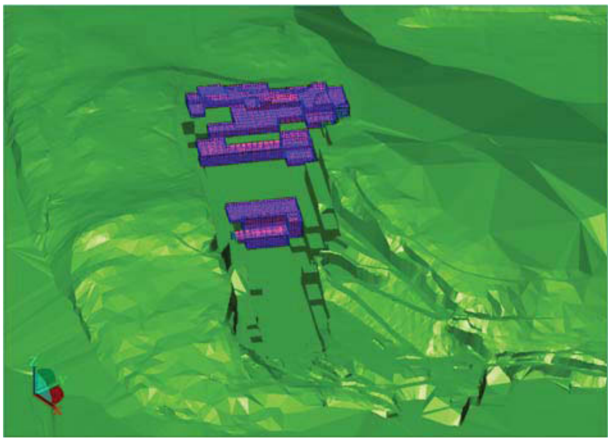

Picture 7-6: The QSO Extraction plan 2008 - 2009
Picture 7-7: The QSO Extraction plan 2008 - 2009


Picture 7-8: The QSO Extraction plan 2009 - 2011
Picture 7-9: The QSO Extraction plan 2009 - 2011

Picture 7-10: The QSO Extraction plan 2011 - 2015
Picture 7-11: The QSO Extraction plan 2011 - 2015

Picture 7-12: The QSO Extraction plan 2015 - 2019
Picture 7-13: The QSO Extraction plan 2015 - 2019



Picture 7-14: The QSO Extraction plan 2019 - 2021
Picture 7-15: The QSO Extraction plan 2019 - 2021

7.1 Comparison of the volumes CSD – QSO

As a basis for the planning from CSD, a chemical estimation in form of a block model was calculated. As it is known now, the input parameters for this calculation were not sufficient. By that time it was thought that all the material within the permitted perimeter meets the chemical needs for clinker production. A recently conducted drilling campaign that gave the chemical basis for the QSO planning showed that this is not the case and that the material is far more heterogeneous than thought before.

Table 7-2 shows a comparison of the exploitable volumes calculated by CSD and by QSO. The huge difference of more then 3’100’000 m^3 or 1/3 of the material planned for exploitation is largely due to chemical constraints.

Volume Quarry						
QSO		**CSD**				
Years	Volume [m3]		volume [m3]	planned consumption [m3/a]	years	years total

2006-2007	396’444	Phase 2	2’677’023	300’000	8.9	8.9
2007-2008	404’591	Phase 3	1’870’850	300’000	6.2	15.2
2008-2009	409’390	Phase 4	1’525’745	300’000	5.1	20.2
2009-2011	801’473	Phase 5	1’650’068	300’000	5.5	25.7
2011-2015	1’638’838	Phase 6	1’523’300	300’000	5.1	**30.8**
2015-2019	1’642’037	total	9’246’986			
2019-2021	824’685					
total	6’117’458					
years total	**15**					

Table 7-2: Comparison of calculated volumes CSD – QSO planning

Because of the 3’100’000 m^3 that can not be used due to unsuitable chemistry, and because of the higher raw material consumption of ECCE+, there is a big difference in the timeline. The CSD planning gives a Quarry lifetime of 30 years, whereas the QSO planning reduces that lifetime to 15 years. CSD regards the actual consumption as roughly 700’000 t per year and 9’250’000 m^3 of reserves, whereas the QSO planning is based on the expected consumption of 1’000’000 t per year after the completion of ECCE+ and reserves of only 6’100’000 m^3.

8 Parameters for the detailed planning

8.1 ECCE+

Until 2006, the Eclépens cement plant had an annual production capacity of 510.000 t of clinker and 560.000 t of cement. In 2006, Holcim Eclépens started to upgrade the plant. The upgrade results in an increase of the production capacity by 35%, resulting in a new annual production capacity of 690.000 t of clinker by April 2007. On account of this, the raw material production in the Mormont Quarry has to be augmented as well, resulting in a new annual production rate of 1.000.000.t.

8.2 Perimeter

The perimeter of the Quarry permission and the different phases of the quarry permission are determined solely by considerations of landscape design and ecological and agro forestry perceptions. There have no considerations been made to assure a smooth conduct of the mining operations. Even the duration of the permission is determined by the maximum period for which deforestation permission is obtainable in the state of Vaud.

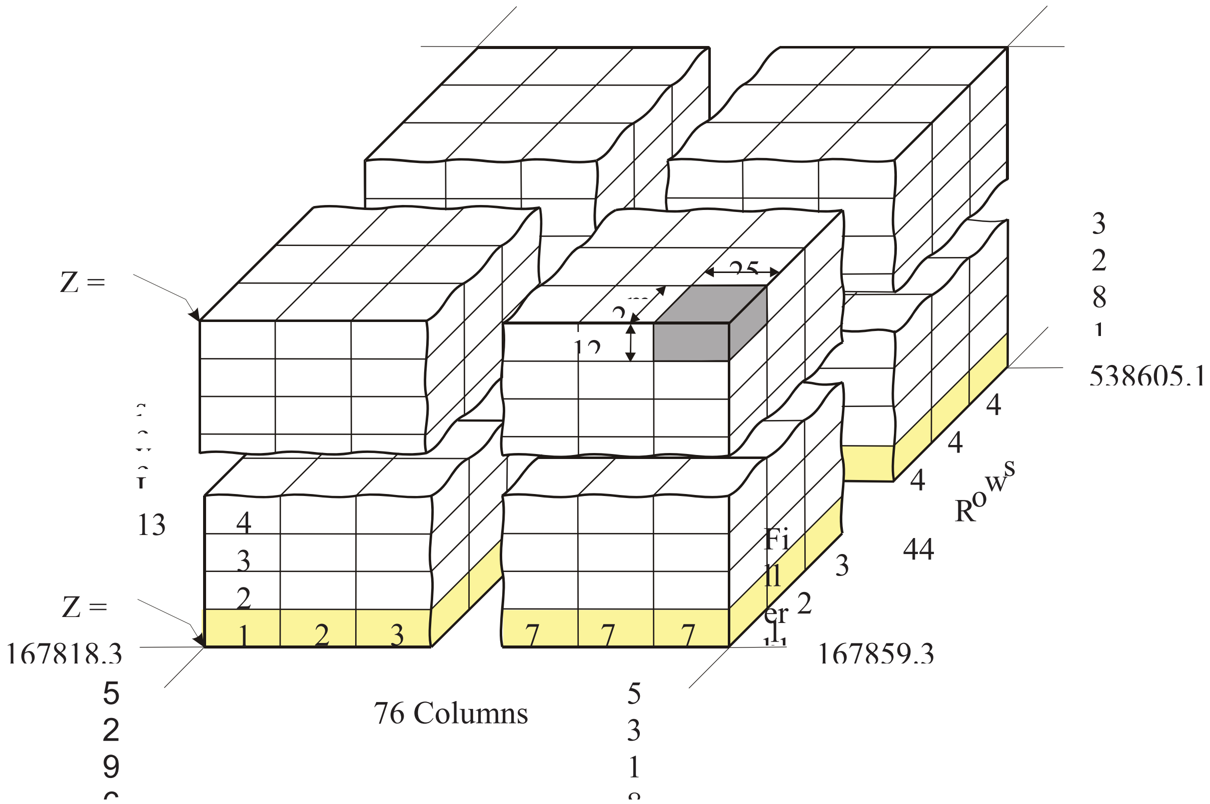
8.3 QSO Quarry Schedule Optimization

QSO Expert is software developed by HGRS that processes the data of a deposit (block) model for medium to long-term quarry planning and strategic evaluations. Other raw mix components and correctives, including the utilization of AFR, can be considered.

QSO Expert has three main fields of applications:

1. Visualization and verification of a block model:

QSO Expert permits the display of all block model parameters in level views, cross sections and 3D-perspective.



Picture 8-1: Geometry of the block model for the Mormont Limestone deposit

2. Strategic Evaluation of Resources:

A profound knowledge of the reserves in a deposit is crucial to make the right strategic decision. With the integrated Optimizer and Expert Planner, the reserves of a deposit can easily be determined.

A raw material investigation starts with quite a vast tonnage of say, measured resources. These resources typically consist of limestone, marl and some unsuitable (overburden) material. The application of restrictions reduces the available tonnage, e.g. not all the marl is necessary for the existing limestone. Additionally, some correctives are needed. Finally, when also considering the accessibility of the material, only a part of the limestone can be consumed, which further reduces the available tonnage, which is now called ‘proved reserves’.

3. Long-term planning with QSO Expert:

QSO Expert is the tool for developing long-term mining plans. Different scenarios (different clinker qualities, mining restrictions) can easily be calculated and visualized. These mining plans then are transformed into 2-dimensional mining plans to develop the mining concept.

8.3.1 Input parameters in the Mormont VI planning:

The input parameters of the QSO planning can be divided into three parts:

1.) Chemical restrictions are defined by the laboratory of the Eclépens plant. These are:

- lime saturation 103-105
- silica ratio 2.45-2.55
- alumina ratio 1.6-2
- 7 % Filler (CaO > 50%)

2.) Restrictions from the production side. This is the planned consumption of Limestone in the plant:

- 1.116 mio. t raw mix/year

3.) Restrictions which include mining and legal compliance:

- Free faces 1; wall slope 56° (cone 3)
- Keep to the permitted perimeter as long as possible

	Pierre jaune du Neuchâtel inférieure		Pierre jaune du Neuchâtel supérieure		Urgonien jaune		Urgonien blanc	
	Variance	Median	Variance	Median	Variance	Median	Variance	Median
SiO_2 [%]	19.684	13.2890	2.339	1.7460	15.691	7.8980	10.814	2.4890
Al_2O_3 [%]	0.979	2.3150	0.045	0.5300	0.412	1.6010	0.508	0.8050
Fe_2O_3 [%]	0.160	1.6400	0.166	1.2650	0.192	1.5700	0.140	0.8600
CaO [%]	10.100	44.1770	1.673	53.0600	10.454	48.1740	6.950	53.2450
MgO [%]	0.368	1.1660	0.017	0.4530	0.284	0.9600	0.022	0.3650
SO_3 [%]	1.175	0.9650	0.574	0.3650	0.238	0.5805	0.100	0.0720
K_2O [%]	0.063	0.5730	0.005	0.0790	0.025	0.3595	0.017	0.0980
Na_2O [%]	0.080	0.0670	0.094	0.1270	0.082	0.1380	0.083	0.0310
TiO_2 [%]	0.004	0.1040	0.000	0.0210	0.003	0.0830	0.008	0.0450
Mn_2O_3 [%]	0.000	0.0190	0.000	0.0430	0.004	0.0260	0.000	0.0180
P_2O_5 [%]	0.004	0.0840	0.000	0.0410	0.001	0.0450	0.000	0.0225
Cl^- [%]	0.000	0.0020	0.000	0.0030	0.000	0.0020	0.000	0.0020

Table 8-1: Medians of the chemical variables of the Mormont Limestone deposit

Table 8-1 shows the medians of the chemical variables of the Mormont limestone deposit. This is the data feed for QSO, which processes them according to the restrictions given above.

8.4 Bench height

The planning of CSD intends bench heights of 25m. Due to safety and quality reasons and to control blast vibrations, the bench heights in the actual mining operation are reduced to a maximum of 12,5m.

Apart from the effects the reduction of the bench height has to the security and quality, it has a huge effect on the geometrical design inside the quarry. By halving the height of the benches, the number of working points doubles from 5 to 10. This also means that the number of ramps accessing the berms doubles. As each ramp at least needs to be wide enough for the biggest machine to drive and the dip must not exceed certain steepness, the grade of geometrical freedom is drastically reduced.

8.5 Slope angle

The existing quarry permission allows a general slope angle of 63°, which is expected to form a stable slope. This angle is reduced to 55° at the north side of the Quarry, taking into account the geological failures here.

The variability of the slope angles in a block model is limited by the shape and the size chosen for the blocks. In QSO, the angle of the slope has been predetermined to be 56°. As the detailed planning has to follow the geometry given by QSO, the slope angle in the final geometrical planning is 56° or flatter.

Theoretically, this results in a loss of material compared to the permitted quarry plan. Practically this has little influence on the volume of the raw material that can be mined, because this is determined by the chemical constraints.

8.6 Ramp inclination

Due to the quarry permission, the inclination of the main ramp must not exceed 8%. However, the secondary ramps may be steeper. The trucks used for hauling have a climbing and descent capability of up to 20%. For security reasons the maximum inclination of the ramps has been limited to 13% in the planning. This represents the steepest possible descent with the 2nd gear for the loaded CAT777D and the 3rd gear for the loaded HD605-7.

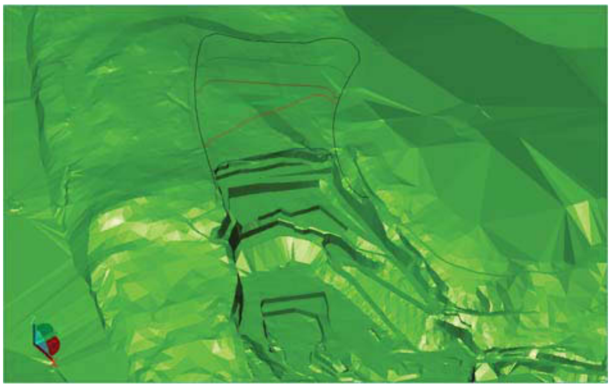
9 Detailed planning

9.1 Geometry

QSO has to meet chemical as well as mining requirements. QSO neither takes into account the practicability of the conduct of mining operations nor the design of haul roads. Therefore, the first step is to design a mine shape which can be implemented in practice. Picture 9-1 to Picture 9-17 describe the development of the mormont quarry in 7 phases. It is important to keep in mind that these phases only represent moments in the ongoing change of the mine shape and will not necessarily be exactly implemented in practice. They merely show the general geometrical development of the pit and are used as guidelines for the quarry manager and to gain data for prognosis calculations.

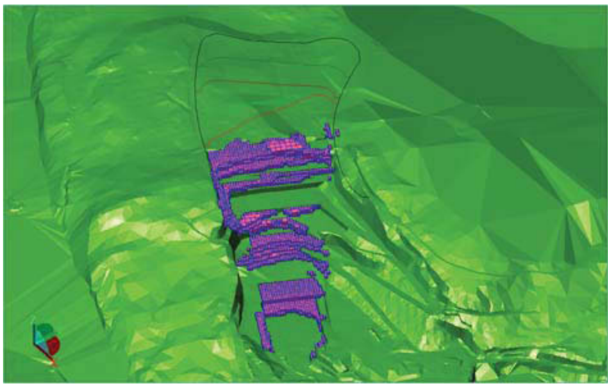
Where the pictures are represented two by two, the picture on the left side shows the volume planned for extraction in pink colour. The picture on the right side represents the remaining geometry.

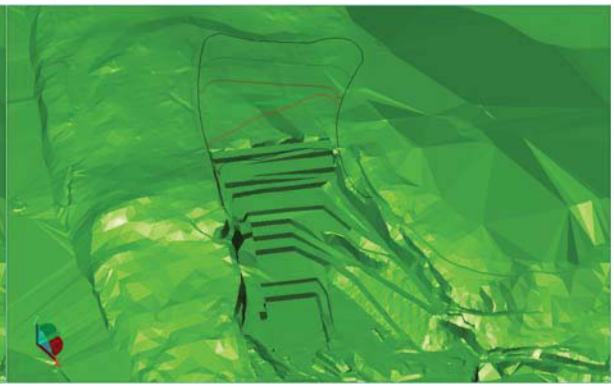
The permitted phases and the perimeter of the pit are made visible as thin coloured lines. Major changes in haul geometry are described separately with detailed views.



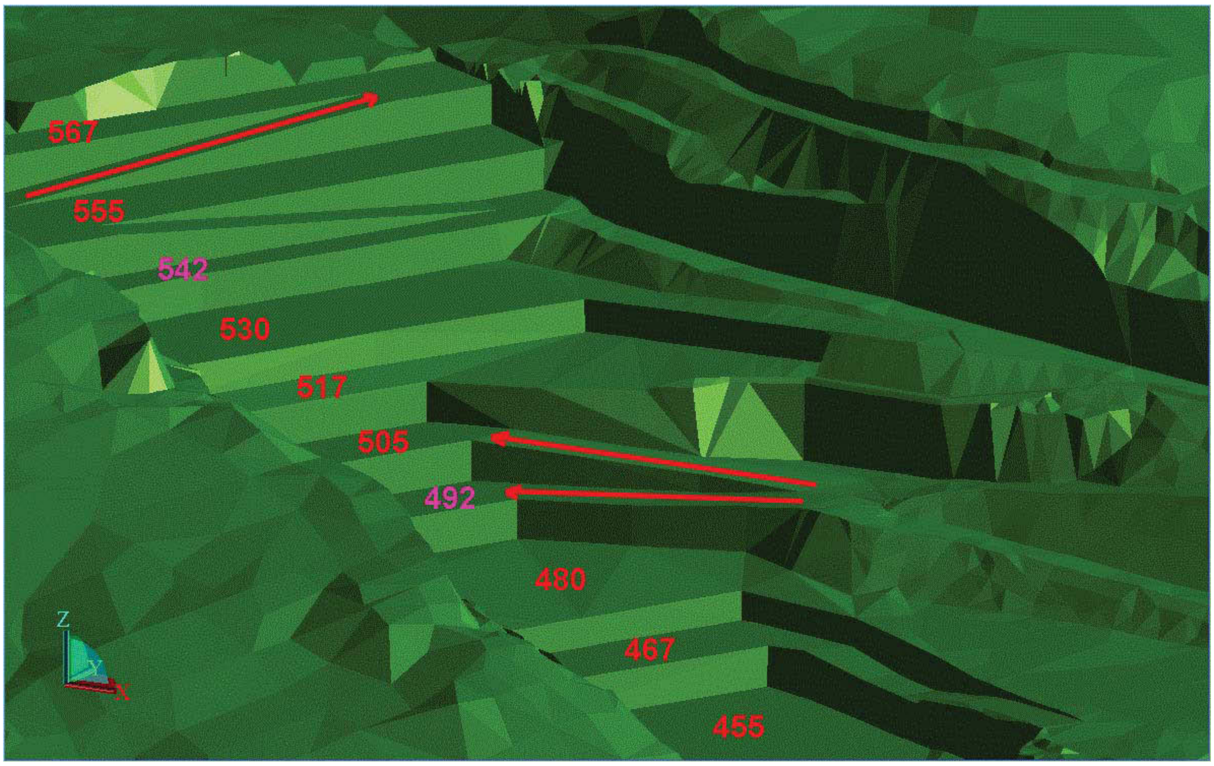
Picture 9-1: The shape of the Quarry in October 2006

Picture 9-1 shows the Shape of the Quarry in October 2006. This is the base of the QSO planning as well as the detailed planning.





Picture 9-2: The detailed extraction plan 2006 - 2007
Picture 9-3: The detailed extraction plan 2006 – 2007



Picture 9-4: Major changes 2006-2007

Picture 9-4 shows the major changes of the Quarry shape which will take place during the year 2007. The numbering of the benches is derived from their altitude above sea level. Each number effects the upper limit and simultaneously the name of the bench. For Example, the plain marked 455 actually has an altitude of 455m above Sea level. This numbering will be kept throughout the whole thesis.

Changes from top to bottom:

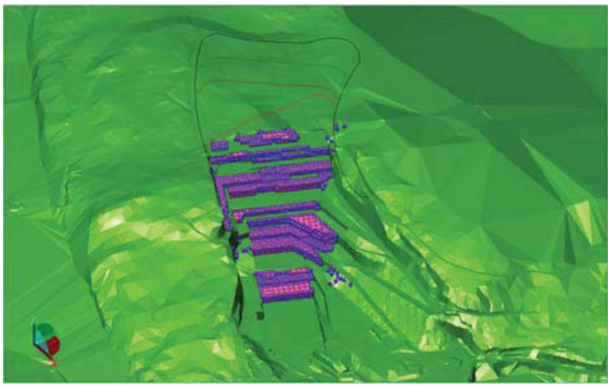
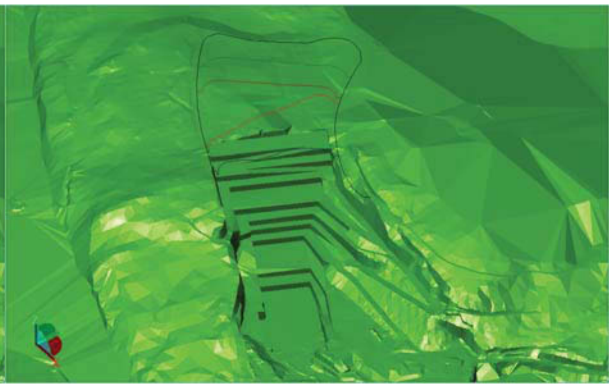
-The access ramp to bench 567 changed its direction from SW to NE, economizing about 270m of haul distance per cycle. This ramp, as well as the ramp accessing bench 555 is crossing the blasting face and will be a "moving ramp" with the necessity to move it with the face.

-Bench 542 is established by splitting the 25m high bench 555 into two 12,5m benches.

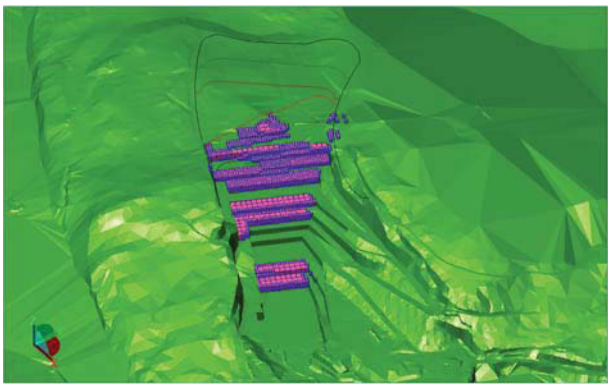
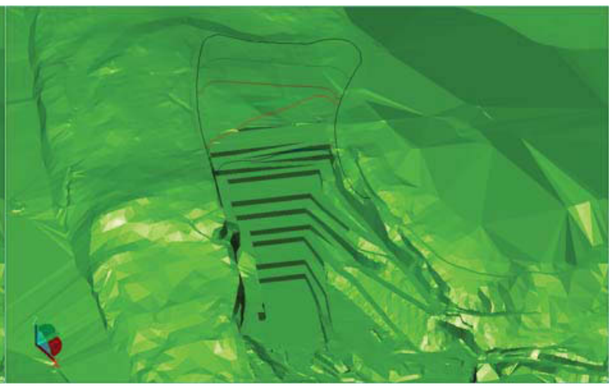
-Bench 492 is established by splitting the 25m high bench 505 into two 12,5m benches.

-The accessibility of Bench 515 is improved by limiting the inclination of this secondary ramp to 10%. The newly established Bench 492 is reached from the first hairpin bend of the main ramp.

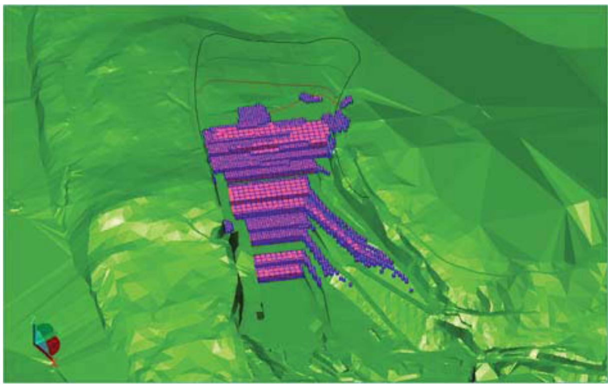
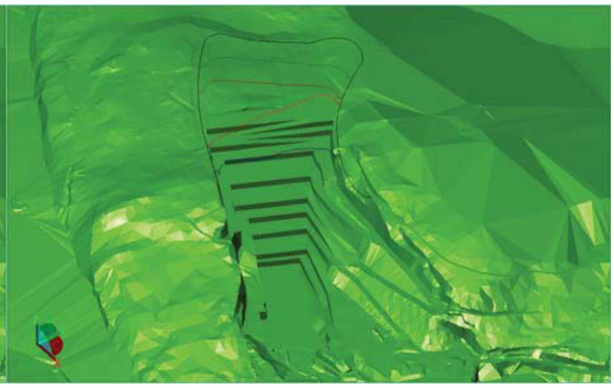
Both the ramps to 505 and 492 have to be reshaped from time to time, turning them further northwards as the benches progress.

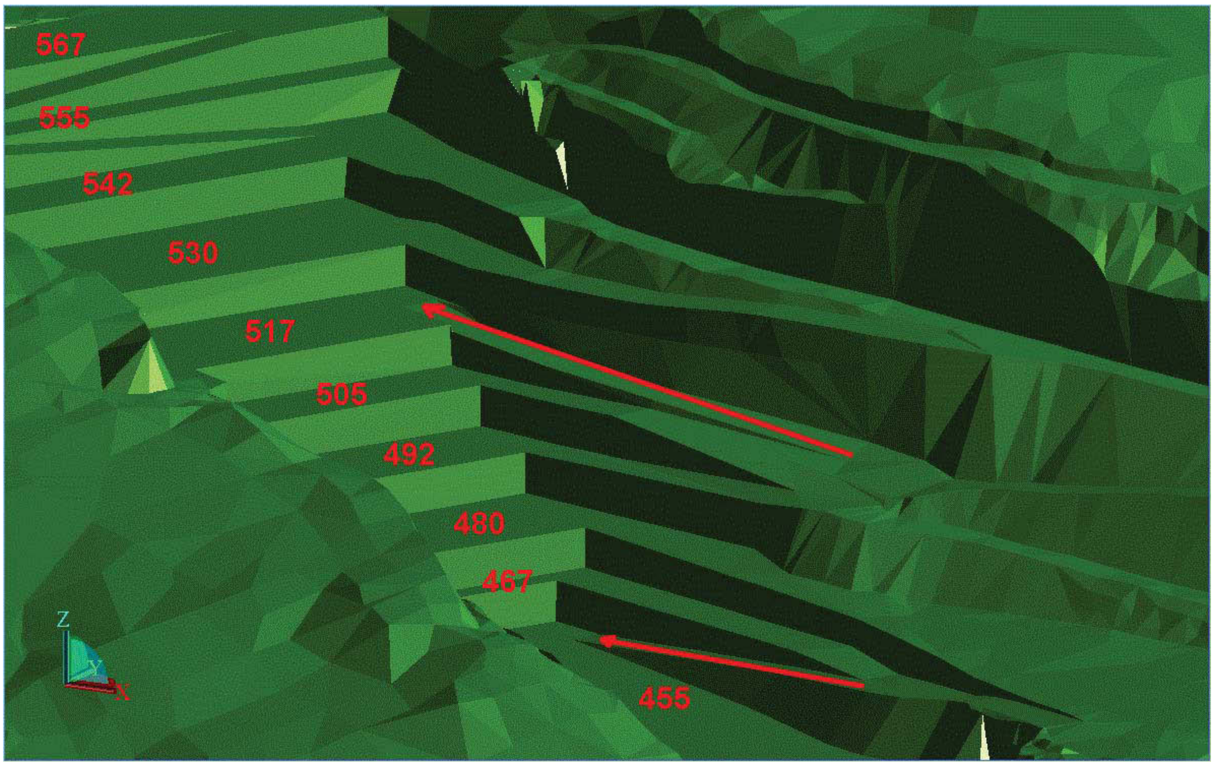
Picture 9-5: The detailed extraction plan 2007 - 2008
Picture 9-6: The detailed extraction plan 2007 - 2008

Picture 9-7: The detailed extraction plan 2008 - 2009
Picture 9-8: The detailed extraction plan 2008 - 2009

Picture 9-9: The detailed extraction plan 2009 - 2011
Picture 9-10: The detailed extraction plan 2009 - 2011



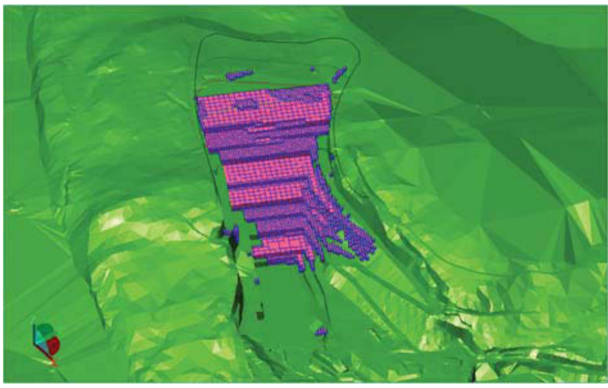
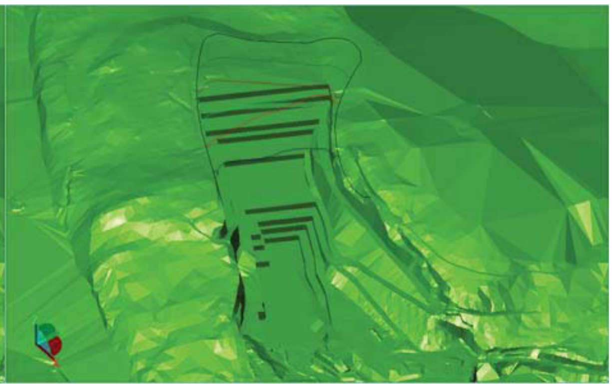
Picture 9-11: Major changes 2011 - 2015

From 2007 to 2011, no significant changes are possible in the pit. By the end of 2011 the progress of the Quarry is far enough to allow some important changes in the haul road geometry.

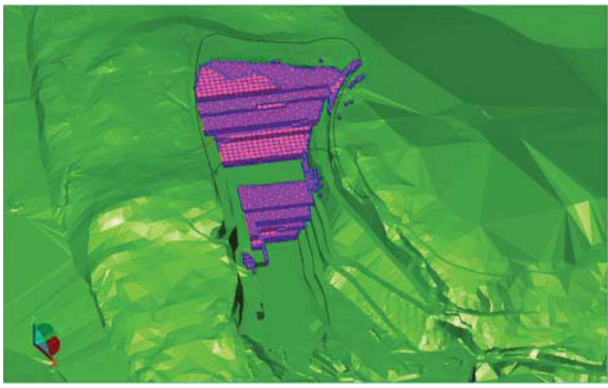
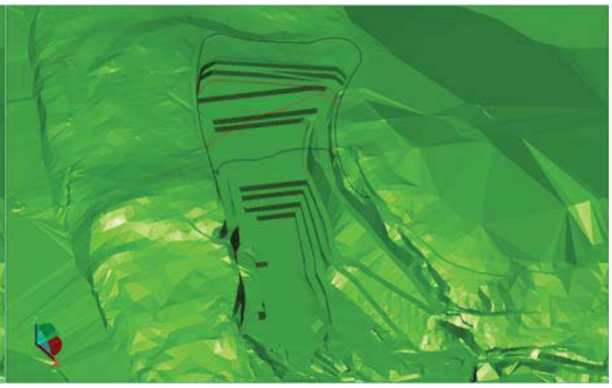
-Bench 517 can be accessed directly by a ramp with an inclination of 12%. The inclination should be reduced to at least 9% as soon as the geometry of the pit allows it. To build this ramp it is imperative to construct it by blasting it out of the rock. A ramp constructed of depositing broken rock would need too much space. In addition, the parallel access to the benches 505 and 492 would be difficult.

This new secondary ramp starts at the first hairpin bend of the main haul ramp and economizes around 1140m of distance at each hauling cycle.

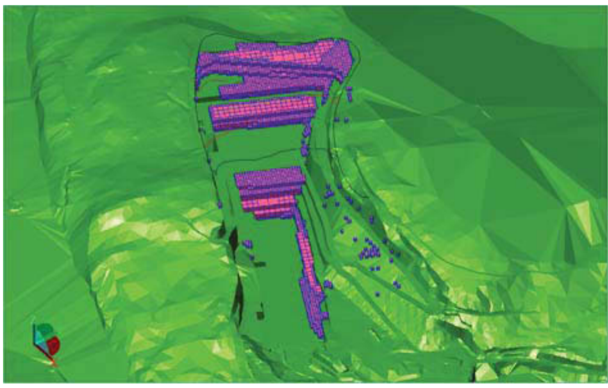
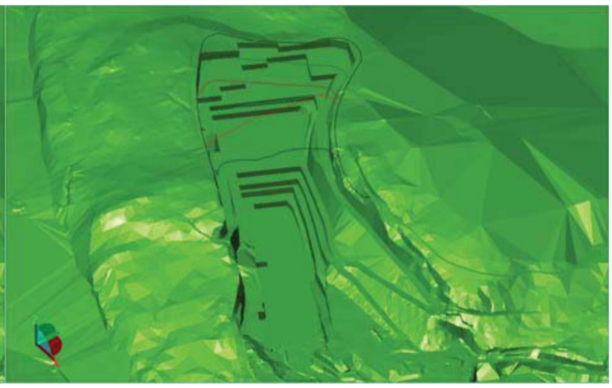
-Bench 455 can be accessed by building a ramp starting directly at the crusher with an inclination of 9%. This will shorten the hauling distance by 820m per cycle.

Picture 9-12: The detailed extraction plan 2011 - 2015
Picture 9-13: The detailed extraction plan 2011 - 2015

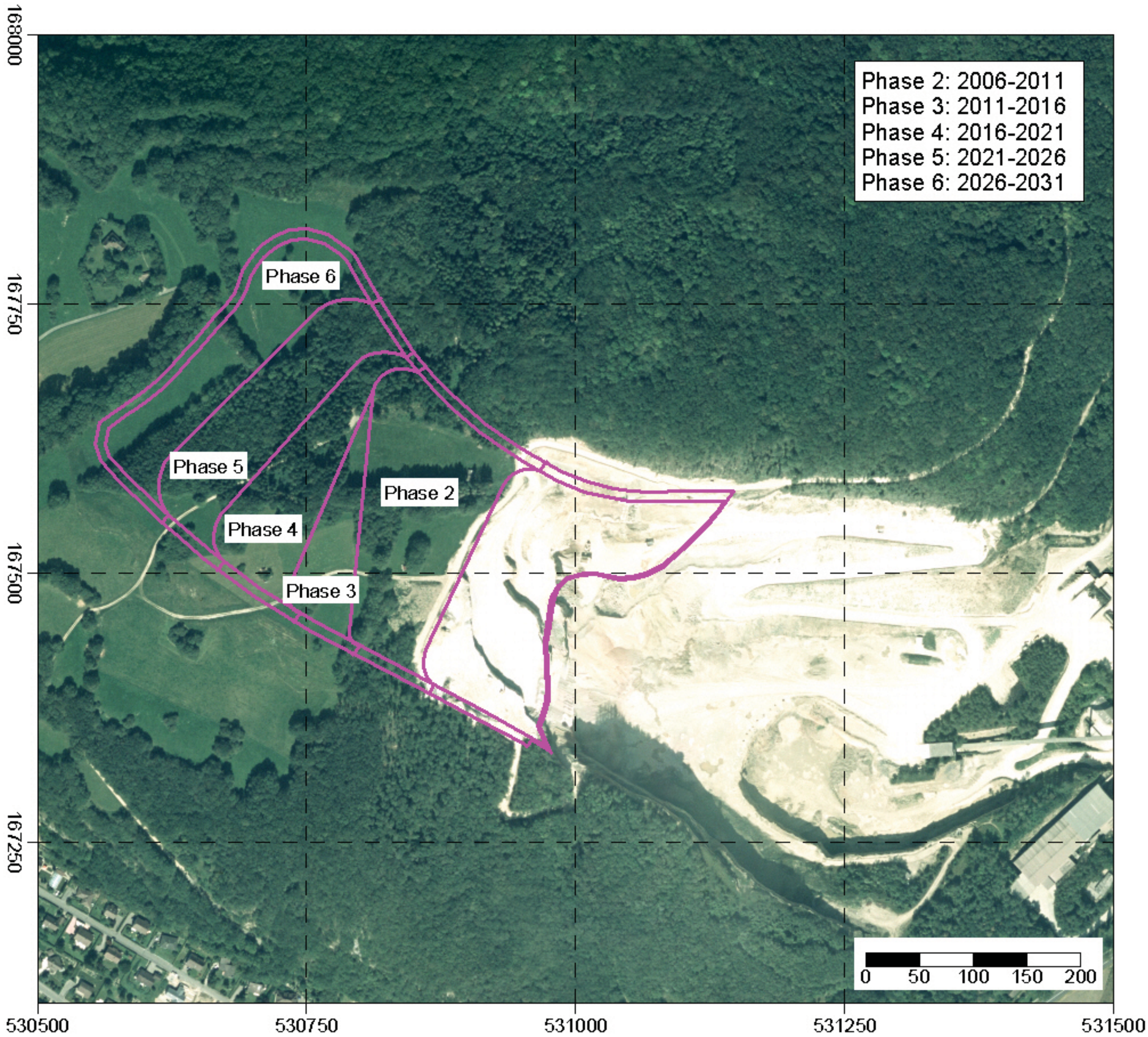
Picture 9-14: The detailed extraction plan 2015 - 2019
Picture 9-15: The detailed extraction plan 2015 - 2019

Picture 9-16: The detailed extraction plan 2019 - 2021
Picture 9-17: The detailed extraction plan 2019 - 2021

9.2 Phases

As referred to in Chapter 5, the Exploitation permission is subdivided into 6 phases of 5 years. Today phase 1 is already completed and by the end of 2006 phase 2 is entered. Due to the production augmentation by ECCE+ and the chemical constraints, the expected lifetime of the phases of 5 years is drastically shortened. To ensure the Raw Material supply of the Plant with sufficient quality and quantity, the phases will have to be opened up earlier. A comparison of the volumes of the CSD and QSO planning can be found in Table 7-2.



Picture 9-18: Permitted perimeter and clearing phases according to CSD

Table 9-1 gives a comparison of the planning of CSD and QSO by the year the phases are entered. A detailed description is found below.

	CSD		QSO	
phase	start of production	end of production	start of production	end of production
2	2006	2011	2006	2009
3	2011	2016	2009	2011
4	2016	2021	2011	2015
5	2021	2026	2015	2019
6	2026	2031	2019	2021

Table 9-1: Comparison of the years of clearing: CSD vs. QSO

-Phase 3 has to start production by the end of 2009. This means the clearing has to start in the beginning of that year at the latest, dependent upon the possible archaeological findings probably even earlier.

-Phase 4 has to start production by the end of 2011. For the timing of the clearing the same timeline as for phase 3 is applicable.

-Phase 5 has to be opened up by the end 2015, making the clearing of it by the beginning of 2015 necessary.

-Phase 6 will be started by the end of 2019. By the end of 2021 a new perimeter has to go into production in order to get the Raw Material quality needed for the Clinker production.

Before opening a new phase, the phase has to be cleared and the soil has to be removed. The areas of clearing for each phase are shown in Table 9-2. Phase 2 is already cleared by the end of 2006 and production starts in the beginning of 2007.

clearing areas	
Phase 2	28522 m^2
Phase 3	8219 m^2
Phase 4	14938 m^2
Phase 5	18816 m^2
Phase 6	21028 m^2

Table 9-2: cleaing areas

9.3 Volumes

Table 9-3 shows a comparison between the extracted volumes calculated by QSO and by Surpac. The detailed planning gives slightly different figures for the volumes than the QSO planning. The total difference of shape is 65’500 m^3, which is negligible, compared to the total production volume of 6’000’000 m^3. This difference represents some small areas which can not be mined because they are needed to construct haul roads.

During the phases the difference can come up to 118’900 m^3, which still shows a high accuracy. This just says that the step visualized in Surpac will be reached a little earlier or later than the step planned in QSO.

Volume Quarry			
QSO		**detailed planning**	
Years	Volume [m3]	Volume [m3]	difference [m3]
2006-2007	396’444	429’700	-33’256
2007-2008	404’591	349’300	55’291
2008-2009	409’390	322’400	86’990
2009-2011	801’473	831’000	-29’527
2011-2015	1’638’838	1’646’500	-7’662
2015-2019	1’642’037	1’529’300	112’737
2019-2021	824’685	943’600	-118’915
total	6’117’458	6’051’800	65’658
years total	15	15	

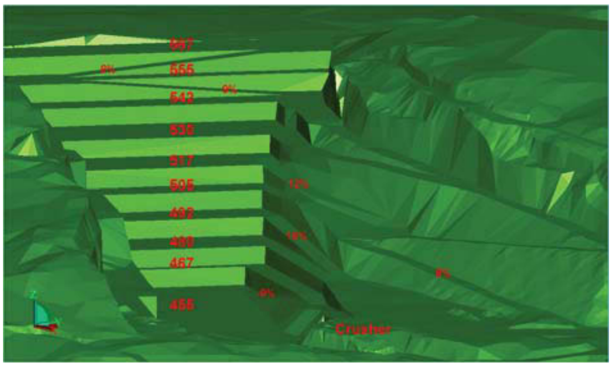
Table 9-3: Comparison of calculated volumes QSO - detailed planning

9.4 Examination of different variants

In this chapter some other possibilities will be highlighted. The first three variants base on the actual planning, while the fourth describes a different concept.

9.4.1 A Shortcut to 492

In 2011, there is the possibility to construct a shortcut ramp to access bench 492, starting at bench 480 and thus bypassing the main ramp. This would economize about 200m of distance per haul cycle. As the total production volume of bench 492 is not exceeding 150’000t after 2011, such a ramp will not be a significant facilitation for the production, especially as it makes the remaining room on bench 480 smaller.

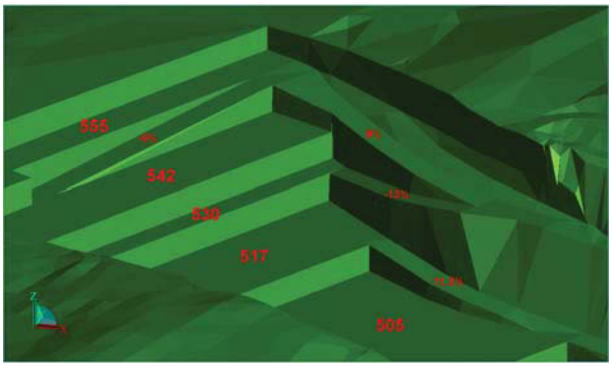


Picture 9-19: Sketch of the shortcut ramp to bench 492

9.4.2 Raising the main ramp

Due to the original Quarry planning, the main haul ramp should be constructed up to the highest point as fast as possible. This is not the case in the detailed planning discussed earlier, in chapter 9.1.

Constructing the main ramp with a continuous inclination of 8% shows that this will lead to the necessity of constructing a separate access to bench 542. This access is shown in Picture 9-20 as a ramp descending from 555 to 542. In reality this bench will never be constructed in this way but should only be seen as an illustration of the need for a separate access. However, constructing this access directly from the main ramp straight to the bench will lead to significant geometry changes and results in a further loss of reserves.



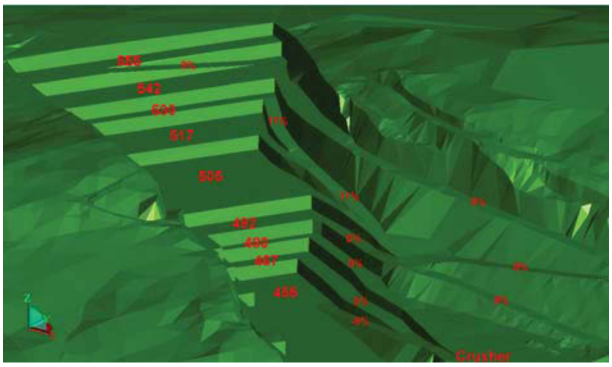
Picture 9-20: Sketch of the effect of raising the main ramp

9.4.3 Direct access to 530

A very significant change in terms of haulage distance is the construction of a shortcut ramp to bench 530. This ramp can be constructed in 2015, having an inclination of 11% to 12% on a total length of 300m. Accompanying the ongoing mining operations this inclination can be reduced to 8%.

If necessary, this access can even be realized some years earlier by constructing a ramp that crosses the main blasting front, as applied in the top benches of the Quarry.

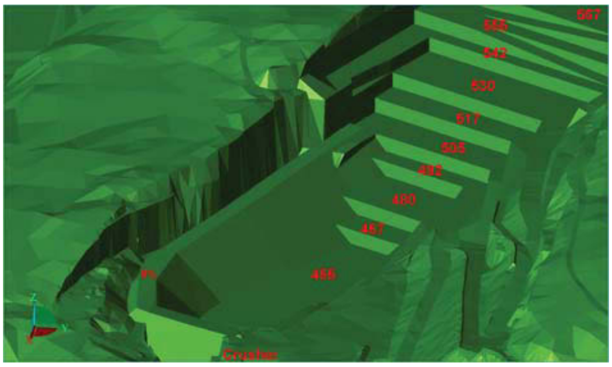
The haul distance economized is at least 940m by full cycle. The total production coming from bench 530 between 2015 and 2021 will cumulate to more than 350'000t. If the ramp is blasted out of the rock, the total structure can be constructed very small, so no loss in reserves is to be expected.



Picture 9-21: Sketch of the shortcut ramp to bench 530

9.4.4 Main Ramp on the Eclépens side

The last variant discussed in this thesis is a main ramp on the Eclépens side of the Quarry. Picture 9-22 graphically shows why such a ramp would not have any advantages if constructed at the present state of the pit or later.



Picture 9-22: Sketch of the consequences of putting the main ramp to the Eclépens side of the Quarry

Due to the authorization of the State of Vaud, the inclination of the main ramp has to be 8% or less. Constructing the ramp on the Eclépens side with an inclination of 8%, it could reach bench 505 with the present shape of the pit. By 2010 or 2011, it will reach bench 517. Until the end of the period considered in this planning, by the year

2021, it will not have reached bench 555. Thus, if constructed, it will never be able to replace the main haul ramp already existing on the other side of the Quarry, and it will result in major losses of deposit volume.

10 The Crusher

10.1 Examination of the crushing performance

As a first step to gain data for a haulage prognosis, the crushing performance of the Bühler 211-KX1 Double Axle Hammer Crusher, given by the manufacturer with 750t/h, is verified by the data derived from TIS (Technical Information System). The detailed statistical examination of the data of the period 12.12.05 - 08.12.06 is shown in Table 10-1: Detailed statistical examination of the Crusher performance in 2006.

		[t/h]	[t/h]	[t/h]
considered period	time frame	arithmetic average	median	upper quartile
12.12.05 - 08.12.06	hourly all	580	603	737
	hourly > 0,89 h	601	638	753
	hourly full hours only	582	607	744
	hourly > 0,79 h	593	624	744
	hourly > 0,59 h	585	609	738
	hourly 0.9 only	652	675	774
	daily all	573	571	652
	daily > 6.9h	598	608	662
	daily > 5.9h	597	593	653
	daily > 4.9h	594	593	653
12.12.05 - 31.07.06	hourly all	562	593	716
	hourly > 0,89 h	588	632	737
	hourly full hours only	570	607	728
	hourly 0.9 only	643	672	762
	hourly > 0,79 h	582	619	727
	hourly > 0,59 h	570	599	720
	daily all	558	562	636
	daily > 6.9h	586	601	645
	daily > 5.9h	582	586	644
	daily > 4.9h	578	580	644

Table 10-1: Detailed statistical examination of the Crusher performance in 2006

The data is examined for daily values as well as for hourly values. The result is that the actual crushing capacity found is close to 600t/h. To get an impression whether this has been the performance over a longer period, and to search for reasons for this big difference between the nominal and actual capacities, all data available in TIS is put into Chart 10-1.

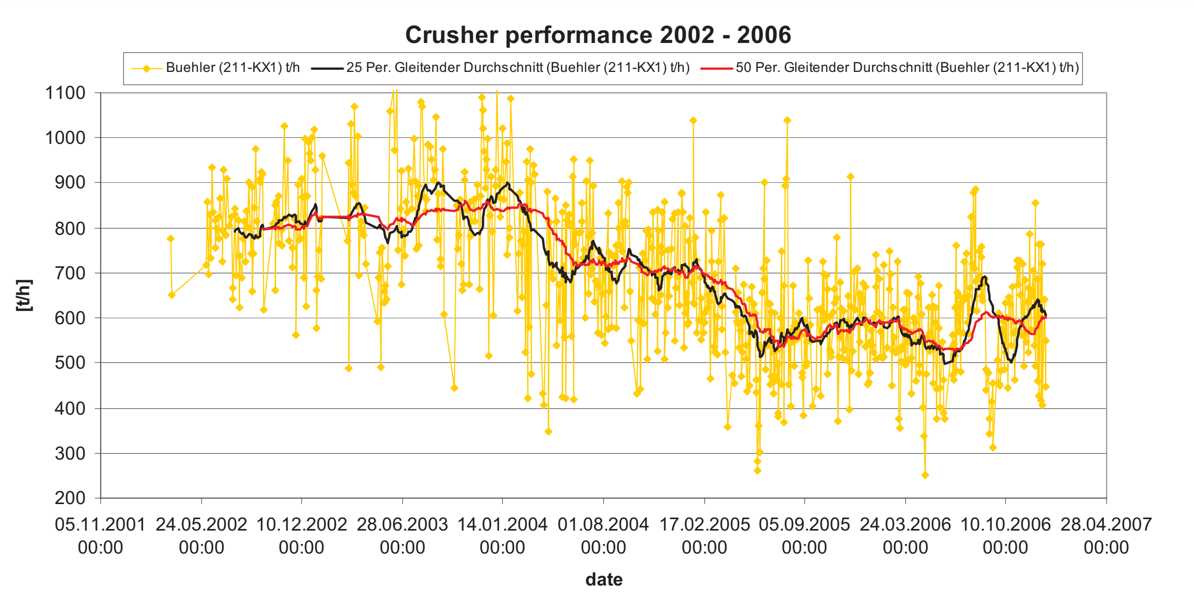


Chart 10-1: The Crusher performance 2002 to 2006

The Chart shows that the crushing performance exceeded the nominal capacity until the beginning of 2004. After that it dropped significantly in two steps. The yellow line drawn is following the actually measured values cleared by data which is obviously incorrect. The black and the red lines are 25 and 50 periods running averages.

There is no explanation found for these two drops. Investigating this, the following points have to be taken into consideration:

-The accuracy of the scale should be investigated.

-In June 2004 the mining method was changed from dropping the rock bench by bench to directly transporting it from the blasting site to the crusher. This definitely resulted in an increase of the grain size put into the crusher.

-In June 2005, the old rotors were replaced by new ones.

-By the end of 2005 problems with overloading arose which finally lead to a limitation of the feeder speed.

10.2 The position of the crusher

The position of the crusher is a very critical element of every open pit planning and has a great influence on haul road design. Changing the position of the crusher can often greatly increase the productivity of a mine.

In the Mormont mine, the crusher is situated at an altitude of 473m, which is the level of Bench 480 in the nomenclature used in this thesis. The altitude difference to the highest level accessed by the Dumpers is 92m, the altitude difference to the lowest level is 18m, giving a total height difference of 110m for the bermes. As the inclination of the main ramp is limited to 8% by the authorities, the minimum distance to gain the 92m of height is 1150m one way, or 2300m for the full hauling cycle. The actual length of the haul road to the highest bench is 2800m. Considering that 8% is the upper limitation of the inclination, this is close to the shortest way possible.

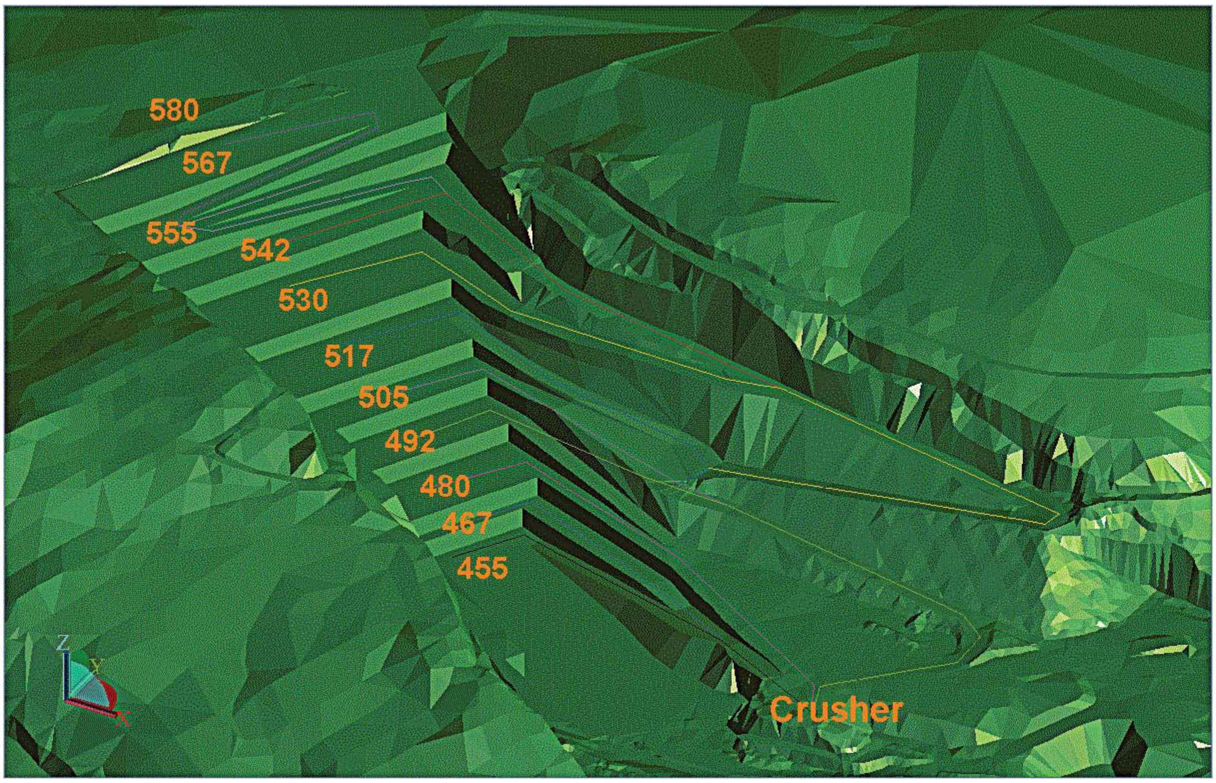
In general, the more material is hauled downwards the better is the positions economic impact (low fuel consumption, speed, wear, etc.). Thus the 18m of height difference to the lowest bench should not be increased.

All these constraints lead to the ultimate conclusion that shifting the crusher during the production period 2006 to 2021 would be a huge technical and financial effort without any improvement for production conduct or productivity.

11 Haulage prognosis

11.1 Development of haul distances

Following the phases constructed in the detailed planning (chapter 9.1), the haul distances and their development over time can be estimated. Therefore the average haul roads for each phase are drawn determined with Surpac. Picture 11-1 shows the haul roads as thin coloured lines in the 3D Visualization of the state of the Quarry in 2011.



Picture 11-1: Sketch of the haul roads

To ensure a maximum accuracy of the haulage prognosis based on these figures, the distances are subdivided into three categories of inclination: less than 4%, 4% to 10% and steeper than 10%. Table 11-1 gives an example for the average distances to the benches 455, 467 and 480 between October 2006 and October 2007.

2006 - 2007	[Nr]	455	467	480
single distance < 4%	[m]	386	104	276
single distance 4% to 10%	[m]	176	47	1
single distance > 10%	[m]	1	36	1

Table 11-1: Haul distances as measured by Surpac

Chart 11-1 shows the development of haul distances over time. The figures shown are the total distance of a haul cycle, which comprises the way from the crusher to the loader and back to the crusher. As there is only one possibility of access to each bench, with oncoming traffic, this is always two times the single way.

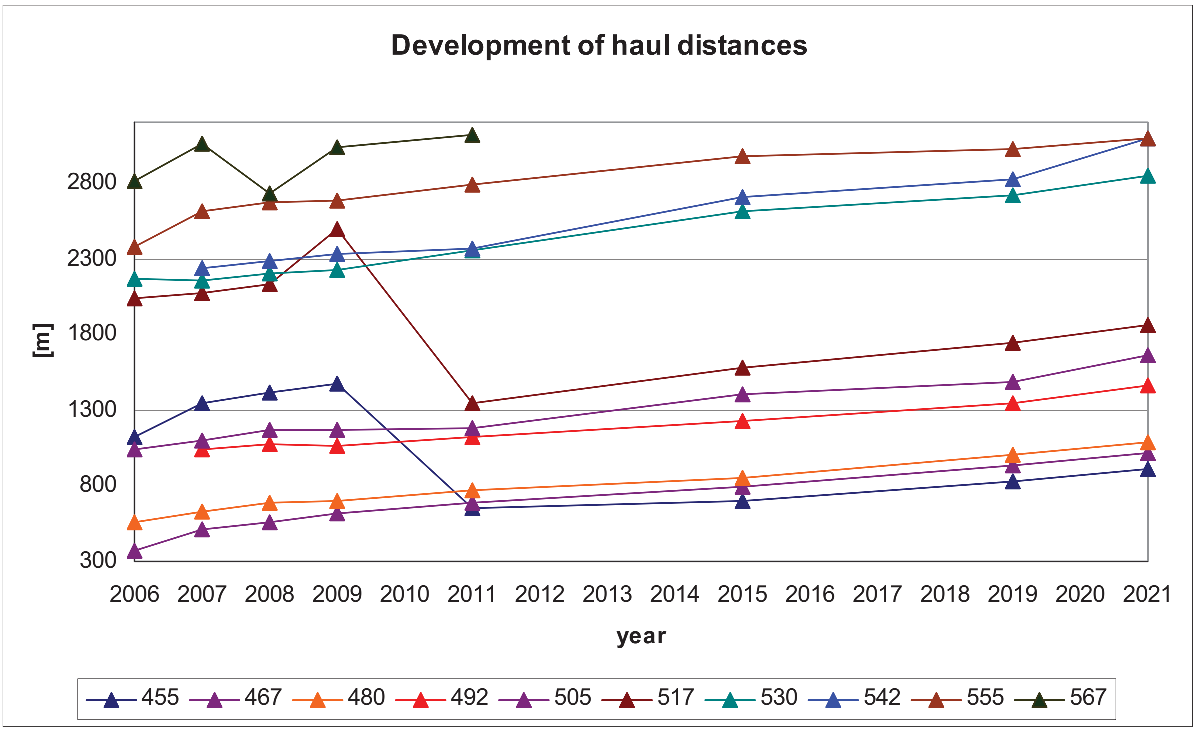


Chart 11-1: The development of haul distances over time

Due to the mining strategy, the hauling distances increase over time. However, between 2009 and 2011 the graph shows a huge drop in haul distance for the benches 479 and 517. This drop marks the opening of the direct access to these benches discussed in chapter 9.1 and illustrated in Picture 9-11. If the direct access to bench 530 is implemented as referred to in chapter 9.4.3, there could be a similar drop in the haul distance for this bench in 2015.

11.2 Development of Production volumes per bench

It is possible to determine the production volumes for the different phases and benches. This is done for all seven phases of the detailed planning and plotted in two different charts.

Chart 11-2 shows the total production of a certain bench between 2006 and 2021. It is clearly visible that there are some benches with a high and some with a lesser production. The benches with the higher production rates are the upper benches, whereas there is less material taken from the lower benches.

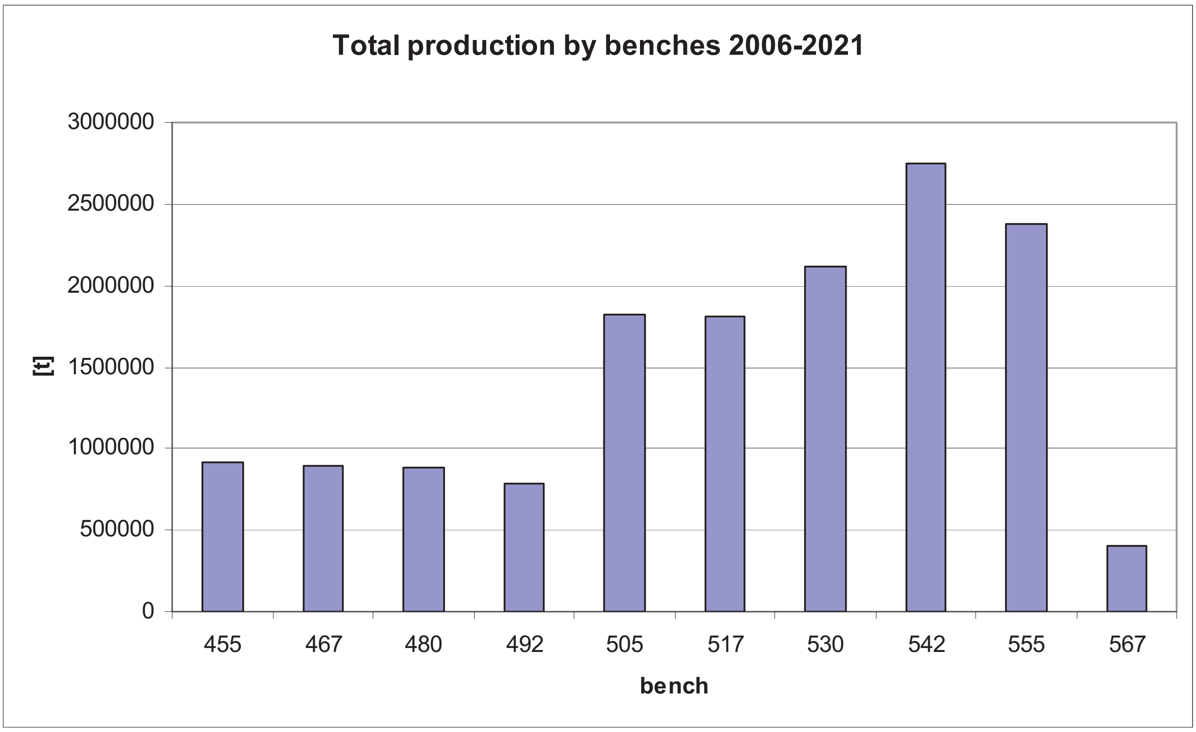


Chart 11-2: Total production of the benches 2006 to 2021

Generally there are two reasons for that. First it is a question of size. As the pit gets smaller the deeper it gets, more material has to be taken from upper than from lower parts. From that point of view it could be expected that the diminution of production by bench is a linear function with exception of the highest benches which simply disappear when the terrain drops. The huge drop from 505 to 492 is due to chemical constraints. The rock on bench 492 does not meet the chemical needs for Clinker production without being blended with high quality limestone. QSO showed that there is not sufficient high grade limestone within the perimeter, so almost 3’000’000 m^3 of material have to remain untouched until a new source of high grade limestone is permitted.

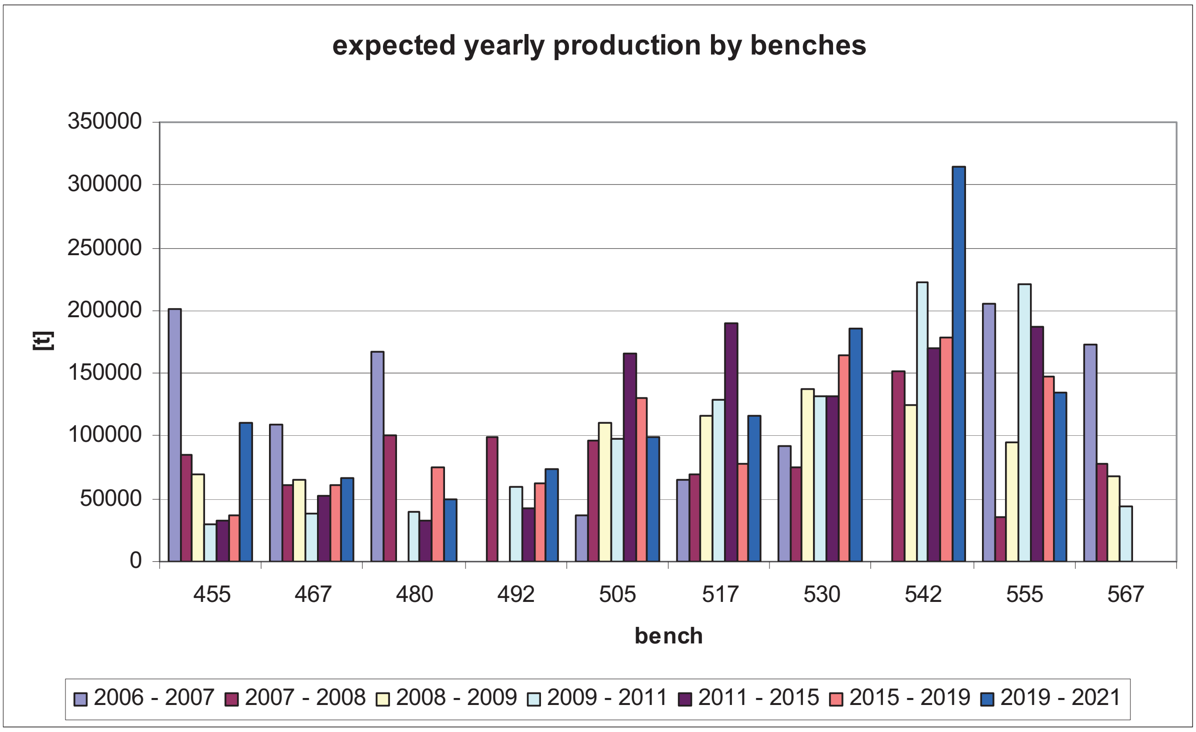


Chart 11-3: Yearly production by bench 2006 to 2021

Chart 11-3 gives the same figures as Chart 11-2, but on a yearly basis. This shows the development of the main focus of production. During the period 2006 to 2007, the focus is on the extremities of the Quarry, with high production on the lowest and highest benches. After that it is steadily moving towards the benches 505 to 542.

11.3 Weighted haulage distance

Taking the findings described in Chapter 11.1 and Chapter 11.2, it is possible to calculate a weighted haulage distance. This weighted haulage distance is calculated as t*km. It gives a very accurate indication of the haul capacity needed. The result is plotted in t*km/month in Chart 11-4, and normalized in % of October 2006 in Chart 11-5. Calculating the capacity on a monthly basis is necessary to avoid big mistakes from the yearly examination, which is not exactly 12 months, dependent on the geometry of the phases. Standstills of the plant are not taken into consideration, so the numbers in Chart 11-4 could be 8% to 10% higher than the actually given weighted haulage distance.

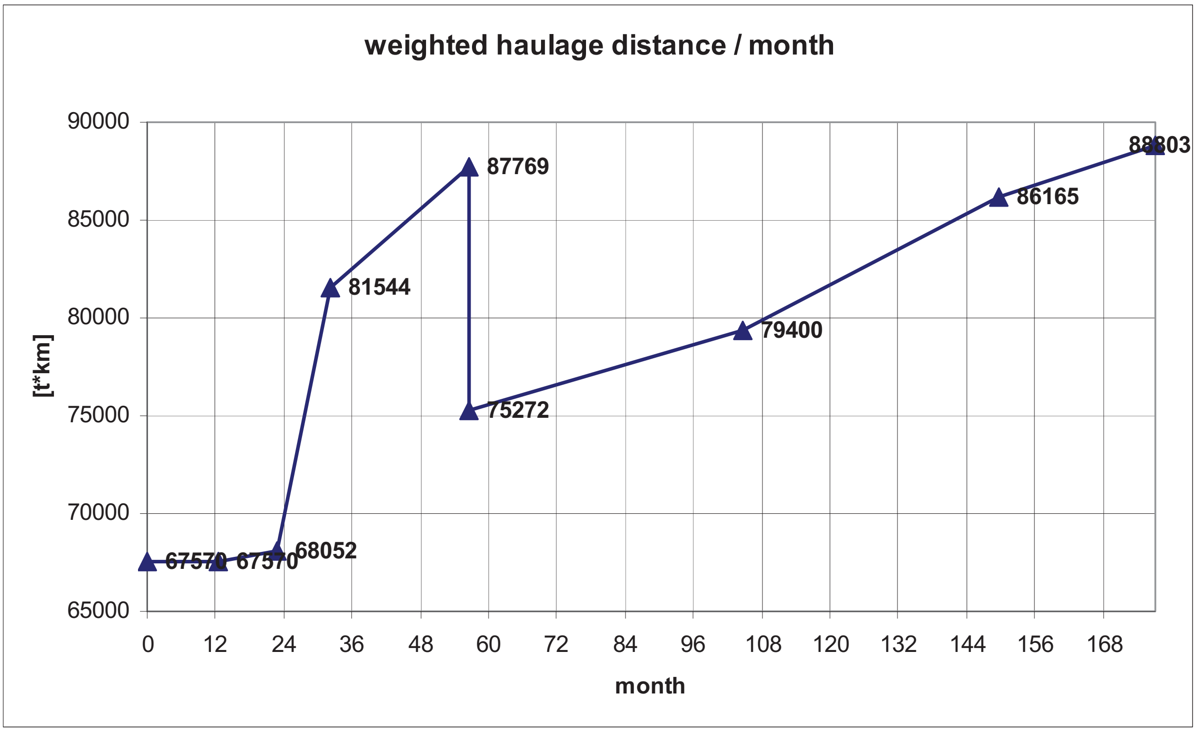


Chart 11-4: weighted haulage distance per month [t*km]

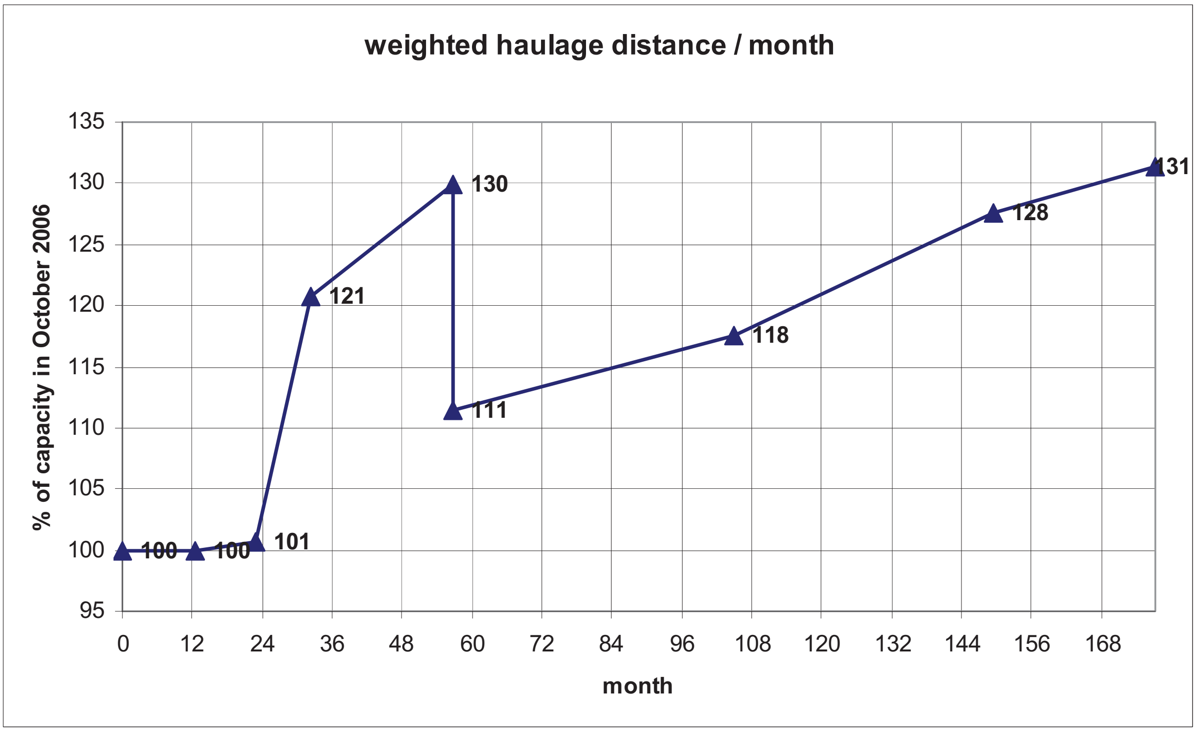


Chart 11-5: weighted haulage distance per month normalized

Two points are remarkable in the charts. The first is that there is almost no augmentation of the needed capacity during the first 23 months (until September 2008), and then it suddenly rises to a peak in month 58 (August 2011). The second is the huge drop in month 59. After that point the capacity demand continuously rises for the rest of the production period which clearly represents the benches slowly moving away from the crusher.

The small haulage capacity needed in the first 23 months is a result of the very short hauling distances during that period. The main focus of the production at that time is on the lower benches. By opening of phase 2 of “Mormont VI”, a point comes where suddenly a huge part of the material has to be hauled at long distances. This is represented by the huge and fast augmentation between month 23 and month 58. The production in this period not only comes from the highest benches but also the central ones, 505 to 542. The augmentation thus is clearly caused by unfavourable haul road design, which also leads to the explanation of the huge drop in month 59. This point represents the time when the shortcut ramps to bench 455 and 517 are opened as shown in Picture 9-11.

An important finding derived from these graphs is that if the transport capacity of the fleet deployed is sufficient for summer 2011 (months 56 to 58 in the graph), it will be sufficient for the whole planning period. This is investigated in chapter 11.4 and 11.5.

11.4 Rating of Load and Haul combinations

To analyze whether the existing fleet meets the transport requirements of the plant until 2021, an assessment of the possible loading/hauling combinations is done. The input parameters for this calculation are given in Table 11-2.

Input of Calculation Parameters

			HD605	777
load parameters PC 1250	Number of Charging cycles	[1]	5	8
	time for Charging cycle (fast)	[s]	22	22
	time for Charging cycle (slow)	[s]	26	26
load parameters CAT 990	Number of Charging cycles	[1]	4	5
	time for Charging cycle (fast)	[s]	44	44
	time for Charging cycle (slow)	[s]	52	52

			up	down
haul parameters (all Trucks)	Timeloss Curve (fast)	[s]	1	2
	Timeloss Curve (slow)	[s]	2	3
	Timeloss Bend (fast)	[s]	2	4
	Timeloss Bend (slow)	[s]	3	6

driving speed	**empty**	average driving speed empty 4% (slow)	[km/h]	11	11
		average driving speed empty 10% (slow)	[km/h]	13	15
		average driving speed empty >10% (slow)	[km/h]	10	16
		average driving speed empty 4% (fast)	[km/h]	15	15
		average driving speed empty 10% (fast)	[km/h]	17	22
		average driving speed empty >10% (fast)	[km/h]	14	26
	loaded	average driving speed loaded 4% (slow)	[km/h]	10	10
		average driving speed loaded 10% (slow)	[km/h]	12	16
		average driving speed loaded >10% (slow)	[km/h]	9	14
		average driving speed loaded 4% (fast)	[km/h]	18	20
		average driving speed loaded 10% (fast)	[km/h]	16	24
		average driving speed loaded >10% (fast)	[km/h]	12	20

dump parameters (all Trucks)	time for dumping (fast)	[s]	50	(including time for approaching Crusher)
	time for dumping (slow)	[s]	70	(including time for approaching Crusher)

other parameters	density of rock	[t/m3]	2.44
	net working time per day	[h]	6

			CAT 990	PC 1250
Payload	Komatsu HD605	[t]	63	63
	CAT 777	[t]	80	90

Table 11-2: Input parameters for the calculation of the rating of load and haul combinations

As there are two different loading machines and two different types and sizes of dumpers in use, there are 4 different machine combinations possible. For a detailed description of the machines see chapter 4.3.

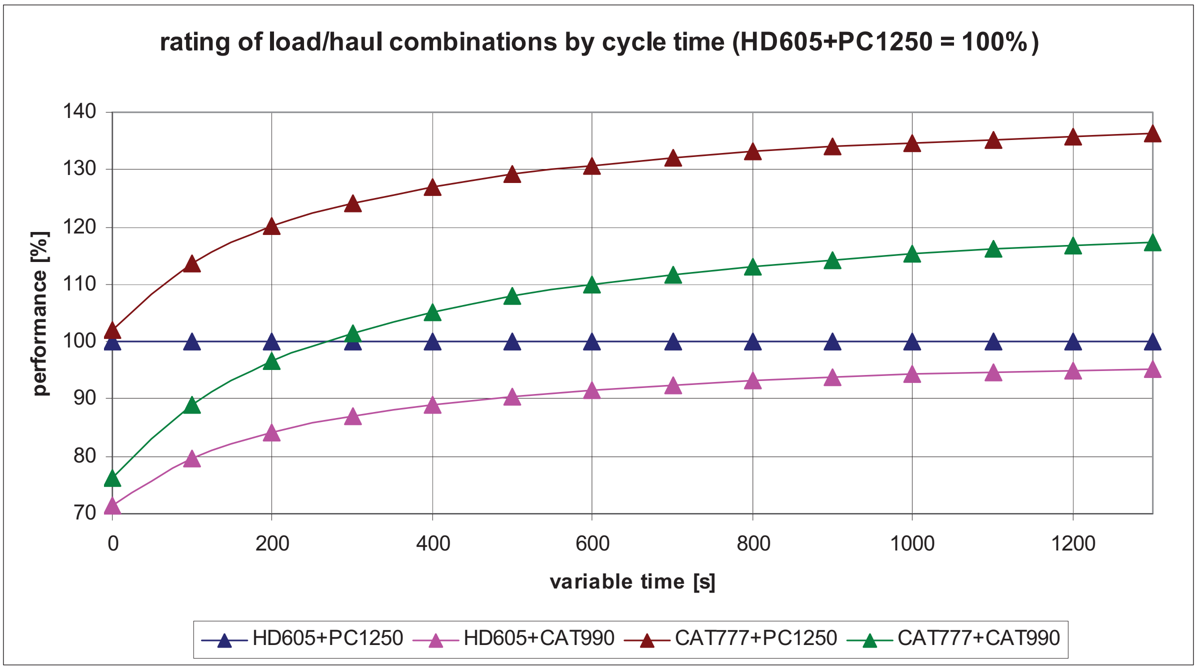


Chart 11-6: rating of load and haul combinations, normalized

Chart 11-6 shows the normalized rating of the load/haul combinations with respect to the variable time. It is calculated as Payload/(fix times+variable time), plotted by variable time and normalized to a reference. The combination of the PC1250 Excavator and the HD605 Dumper is used as this reference and set as 100%. The chart gives an impression of the relative outperformance of the combinations towards each other. The point “zero variable time” means that the dumpers are theoretically only loaded, and then dump the payload without transporting it. The variable time, plotted as X-Axis, covers mainly the driving time, but can as well comprise time waiting for the oncoming traffic or the crusher to be emptied.

It is visible that for short haul distances the performance is largely dependent upon the loading machine. There the influence of the fix time, which is mainly dependent upon this machine, is vast. For longer distances the influence of the Dumper is getting bigger, as the fixed time looses in importance relative to the variable time. Thus the performance of the combination HD605+CAT990 is asymptotically getting close to the performance of the combination HD605+PC1250. However, the performance of the combination CAT777+CAT990 is not getting close to the performance of the CAT777+PC1250, as it would be expected. This is due to the fact that the CAT990, in contrary to the PC1250, is not able to load the CAT777 with the full 91 tons of payload but only gets to about 80 tons.

For practical use, Chart 11-7 is of higher importance than Chart 11-6. It is based on the same calculation as above, Payload/(fix times+variable time) plotted by variable time, but it gives absolute numbers and is not normalized.

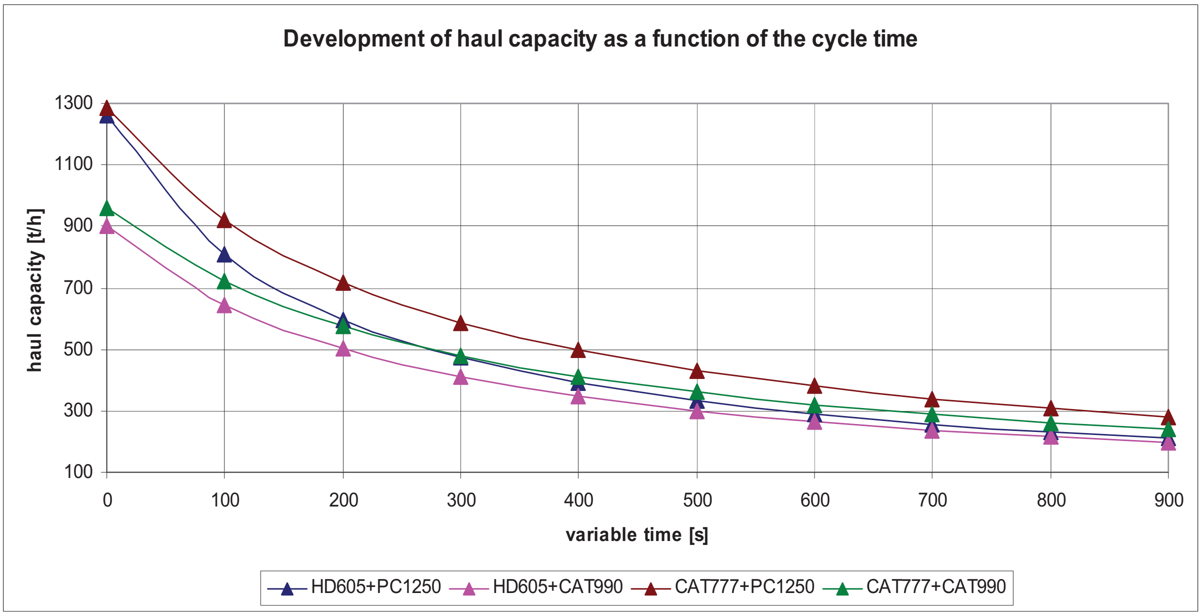


Chart 11-7: haul capacity by load and haul combination [t/h] as a function of the cycle time

Here it is important to note that this chart gives a theoretical value and is not diminished by factors of availability of man and machine. The input data for both charts is partly measured, partly given from the manufacturer.

There are some important findings regarding Chart 11-7.

The first is that the CAT777 + CAT990 combination has a relatively small capacity, taking into account that the payload of the CAT777 loaded with the CAT990 is 17 t higher than that of the HD605.

The second finding is that the capacity of the CAT777 + CAT990 combination exceeds the capacity of the HD605 + PC1250 combination after about 300 seconds of variable time, which is about 1000m of driving distance.

The combination of HD605 + CAT990 is the least productive, which is not surprising as the CAT990 wheel loader is slower than the PC1250 excavator and the HD605 Dumper has a payload of only 63 t, compared to 91 t of the CAT777.

11.5 Possible Load and Haul Combinations

11.5.1 Theoretical combinations

The Quarry fleet of Eclépens consists of 2 Komatsu HD605 Dumpers, a CAT777 Dumper, a CAT990 Wheel Loader and a Komatsu PC1250 Excavator. With that 6 combinations are theoretically possible, if we assume that all machines are working on the same bench at the same time. In Chart 11-8 the expectable capacity of these combinations is plotted against the variable time. Again, the variable time is mainly the driving time needed from the crusher to the loading machine and back to the crusher. It can as well comprise time awaiting the oncoming traffic and other waiting times. The 4 possible machine pairs (as used in the chart) are:

1: HD605+PC1250

2: HD605+CAT990

3: CAT777+PC1250

4: CAT777+CAT990

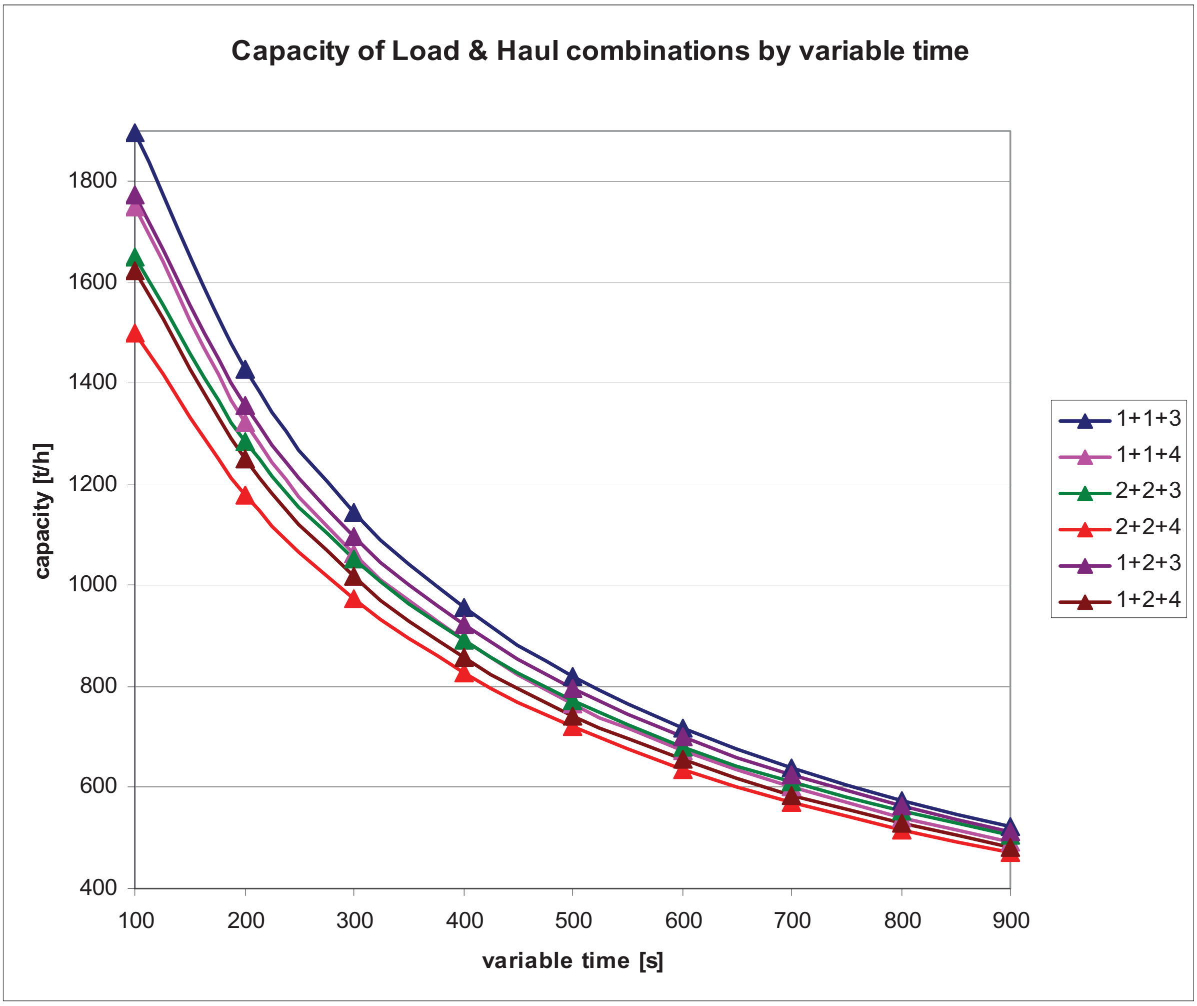


Chart 11-8: Summarized capacity of all possible machine combinations by distance

In contrary to Chart 11-7, Chart 11-8 is diminished by factors of availability and thus gives values that are close to reality. The diminishing factors are 0,83 for the availability of the operator and 0,9 for the availability of the machine. All diminishing factors multiplied, the two factors together give an availability of 0,747 or 74,7%.

Chart 11-8 clearly shows that generally the combinations where the PC1250 excavator is used for loading have a higher productivity. This is true if only one loading point is considered. As soon as there are more loading points the wheel loader is gaining advantage because it is more flexible than the excavator.

Far more important than the question which combination has a higher productivity is the total capacity that can be achieved by the existing fleet. In Chapter 10.1, it is described that the Crusher has a realistic crushing capacity of 600 t/h, and a nominal capacity of 750 t/h. Chart 11-8 shows that at a variable time of 545 seconds, all combinations drop beyond a performance of 750t/h, and after 740 seconds the capacity drops beyond 600t/h. This leads to the conclusion that at least on a daily average, these variable times per cycle should not be exceeded. Taking the input parameters given in table 11-7, 545s of variable time are a driving distance of up to 2300m and 740s represent a distance of 3000m.

11.5.2 Calculation of production needs

There are generally three ways of calculating the production needs. Calculations which base on the yearly tonnage or on the available time of are mathematically easy but do not give any indication whether the fleet is suitable for this production or not. The third and most accurate way, to calculate the production capacities of the machines, is mathematically not resolvable if there are different machine combinations. Thus this calculation has to be done using examples and search for good combinations by trial and error.

11.5.2.1 Way 1: Calculation by yearly tonnage

After the realization of ECCE+, the yearly need of Raw Material will amount up to 1’000’000 tons. As it is known from Chapter 10.1, the Crusher has a crushing capacity of 600 t/h, and should have a nominal capacity of 750 t/h.

If the capacity is considered as 600 t/h, the necessary crushing hours can be calculated as: $\frac{1'000'000[t/a]}{600[t/h]} = 1'666{,}6[h/a]$

Putting the crushing capacity to 750 t/h, the calculation results as:

$$\frac{1'000'000[t/a]}{750[t/h]} = 1'333{,}3[h/a]$$

TIS gives the yearly crushing time for the years 2005 and 2006 at 1150 h per year. If it is possible to get back to the nominal capacity of the crusher performance, 183 additional hours have to be planned for the future. If this is not possible, 516 additional hours per year will be necessary.

11.5.2.2 Way 2: Calculation by available working time

Similar to the calculation by yearly tonnage, the production needs can be calculated by the available working time. Here two different calculations have to be made. Up to now, the crusher is not in operation for all 41,5 hours per week but only for 28 hours per week. One day in total is maintenance day.

General assumptions:

1.) Necessary production: 1’000’000 t/a
2.) One year has 52 weeks.
3.) 5 weeks are needed for Maintenance of the Plant, thus there is no production during that time.
4.) One week has 5 working days.
5.) One week has 41,5 working hours.
6.) 41,5 hours per week are assumed to be gross working time, 28 hours per week are net working time.

Calculation for 28 hours per week:

$$47[weeks] * 28[h/week] = 1316[h/a]$$

It is known from TIS that the actual working hours of the crusher are 1150 hours per year. As they should theoretically be 1316 hours per year, it is possible to calculate the theoretical availability of the Crusher, or diminution factor η as:

$$\frac{1150[h/a]}{1316[h/a]} = \eta = 0,87$$

The necessary crushing capacity can be calculated as: $\frac{1'000'000[t/a]}{1316[h/a]*0,87} = 873[t/h]$

The same calculation without diminution factor results to: $\frac{1'000'000[t/a]}{1316[h/a]} = 760[t/h]$

The calculation shows that 28 hours per week will not be sufficient to ensure Raw Material production after implementing ECCE+. In general, attention has to be drawn to increase the crusher capacity to the nominal 750 t/h or more (see chapter 10.1). However, even with a capacity of 750 t/h, it is not possible to reach the needs of the plant. Taking into account the current availability and capacity of 600 t/h, the need is 270 t/h higher than achievable, considering the nominal crushing capacity of 750 t/h, it exceeds the possibilities by 120 t/h.

Calculation for 41,5 hours a week

$$47[weeks]*41,5[h/week] = 1950,5[h/a]$$

The diminution factor η is considered as follows:

-A worker is available 50 minutes out of 60 minutes to actually work. This is a figure generally assumed for quarry jobs. This gives η_{worker} as: $\frac{50}{60} = 0,833$

-The availability of the trucks is assumed as $\eta_{machine}$ = 0,9

η_{worker} and $\eta_{machine}$ multiply to $\eta = 0,833*0,9 = 0,747$

Taking these figures the necessary crushing capacity can be calculated as:

$$\frac{1'000'000[t/a]}{1950,5[h/a]*0,747} = 686[t/h]$$

By the time the thesis is written, this capacity can not be achieved. Still, 686 t/h are less than the nominal Crusher performance of 750 t/h, thus it will be possible to achieve production goals within the normal weekly working hours once the crusher has full performance again.

11.5.2.3 Way 3: Calculation by haul capacities

The calculation with respect to the haul capacities is based on the figures presented in chapter 11.4. The diminution factor η is again 0,747.

Theoretically possible machine combinations:

The fleet consists of 2 Komatsu HD605 Dumpers and one CAT777 Dumper, one Komatsu PC1250 Excavator and one CAT990 Wheel Loader. Reserve machines are not considered. Thus four different pairs of loading and hauling machines are possible:

1: HD605+PC1250
2: HD605+CAT990
3: CAT777+PC1250
4: CAT777+CAT990

Generally with these four combinations of loading and hauling machines there are ten combinations theoretically possible if all machines are working. These combinations are:

1+1+3: HD605+PC1250; HD605+PC1250; CAT777+PC1250
2+2+4: HD605+CAT990; HD605+CAT990; CAT777+CAT990
1+1+4: HD605+PC1250; HD605+PC1250; CAT777+CAT990
4+1+1: CAT777+CAT990; HD605+PC1250; HD605+PC1250
2+2+3: HD605+CAT990; HD605+CAT990; CAT777+PC1250
3+2+2: CAT777+PC1250; HD605+CAT990; HD605+CAT990
1+3+2: HD605+PC1250; CAT777+PC1250; HD605+CAT990
2+1+3: HD605+CAT990; HD605+PC1250; CAT777+PC1250
1+2+4: HD605+PC1250; HD605+CAT990; CAT777+CAT990
4+2+1: CAT777+CAT990; HD605+CAT990; HD605+PC1250

The first one or two machines always represent the machines applied on the lower bench, the third and third or second the machines applied on the higher bench. To aid the impression, the combinations operating on the lower benches are given grey background colour.

The Eclépens plant does not have a blending bed for blending the limestone from the Mormont quarry. The extracted material has to be stored in two silos with a capacity of about 5’500 t each. To diminish chemical fluctuation and to guarantee a homogenous raw material, the quarry is forced to blend the material at the crusher. Therefore raw material from the Mormont has to be extracted at several points in the quarry. The first two combinations comprise only one of the loading machines. Thus these combinations can not operate on two different benches at the same time and will not be considered for the following examples

It is mathematically not possible to determine the optimum combination or combinations. If this should be determined, there are a number of algorithms generally used for modelling such problems. They would have to be implemented as a computer simulation.

To calculate whether the fleet can come up to the production needs examples are calculated for very unfavourable haul scenarios. If the fleet is able to bring a capacity of 750 t/h or more to the crusher, it is taken as evidence that it will be able to ensure production for all haul scenarios. The examples are chosen regarding the average haul distance (chapter 11.1) and the production volume by bench (chapter 11.2). The capacity figures are calculated in the MS EXCEL file “Foerderleistung2.xls” and are already diminished by the availability factor η = 0,747.

Example 1: Year 2010, Production from Benches 517 and 555:

Haul Capacities for Bench 517; distance 2490m:

1: HD605+PC1250: 208 t/h
2: HD605+CAT990: 191 t/h
3: CAT777+PC1250: 273 t/h
4: CAT777+CAT990: 231 t/h

Haul Capacities for Bench 555; distance 2682m:

1: HD605+PC1250: 204 t/h

2: HD605+CAT990: 188 t/h

3: CAT777+PC1250: 269 t/h

4: CAT777+CAT990: 227 t/h

Thus the capacities of the possible machine combinations are:

1+1+4: 208+208+227=643 t/h

4+1+1: 231+204+204=639 t/h

2+2+3: 191+191+269=651 t/h

3+2+2: 273+188+188=649 t/h

1+3+2: 208+273+188=669 t/h

2+1+3: 191+204+269=664 t/h

1+2+4: 208+188+227=623 t/h

4+2+1: 231+191+204=626 t/h

In chapter 11.3 it can be seen that the case calculated above is one of the worst cases possible. The full capacity of 750 t/h will not be achieved with any of the combinations. However the best combinations are 1+3+2 and 2+1+3. They get relatively close to the minimum of 686 t/h required to be able to operate with 41,5 hours per week. One problem could be that both benches are accessed via the main haul ramp. Thus the capacity could be diminished even further because of problems with oncoming traffic.

In the years 2009 to 2011 the situation regarding the haul capacity will be tense. Relief will come by the end of 2011 with the construction of the shortcut ramps to bench 517 and maybe even 530. Then the situation will be as shown in

Example 2: 2012, Production from Benches 517 and 555:

Haul Capacities for Bench 517; distance 1348m:

1: HD605+PC1250: 321 t/h

2: HD605+CAT990: 282 t/h

3: CAT777+PC1250: 403 t/h

4: CAT777+CAT990: 332 t/h

Haul Capacities for Bench 555; distance 2792:

1: HD605+PC1250: 196 t/h

2: HD605+CAT990: 181 t/h

3: CAT777+PC1250: 258 t/h

4: CAT777+CAT990: 218 t/h

Thus the capacities of the possible machine combinations are:

1+1+4: 321+321+218=860 t/h

4+1+1: 332+196+196=724 t/h

2+2+3: 282+282+258=822 t/h

3+2+2: 403+181+181=765 t/h

1+3+2: 321+403+181=905 t/h

2+1+3: 282+196+258=736 t/h

1+2+4: 321+181+218=720 t/h

4+2+1: 332+282+196=810 t/h

The production capacity suddenly rises up to 905 t/h for the optimum combination, which is 155t/h more than the crusher can take. With this combination a bigger part of the production comes from the lower bench. Here it should be considered whether the HD605+CAT990 coming from Bench 555 can be temporarily put out of service. Then the production capacity will still amount up to 724 t/h, economizing not only machine hours but also liberating two workers for other purposes. If a higher production rate from bench 555 is needed, the combination 2+1+3 is able to ensure 736 t/h being transported to the crusher.

As it is impossible to determine the optimum combination, and as the optimum combination is likely to be different or every loading point, the necessary and possible capacities should be reviewed on a daily basis or at least on a weekly basis by the Quarry Manager.

As described earlier, the situation in Example 1 is close to the worst possible situation during the period considered in this thesis. The capacity needs are getting a lot lower after a peak in 2011, and then continuously rise until 2021. This is illustrated in Chart 11-4 and Chart 11-5. Thus it can be foreseen that it is not always possible to ensure the necessary production within the normal working hours. Especially in the years 2010, 2011, 2020 and 2021 the haul capacity will be a bottleneck. As the needed capacity does not exceed the available capacity too far, there is the possibility to bridge the times of high capacity demands by introducing flexible working time, working for a little mire than 41,5 hours a week when necessary.

Generally there are a three important distances distinguished. At a distance of 2300m round trip, the capacity of the highest productive machine combination is 750 t/h which should be the maximum capacity of the crusher. At a distance of 2500m round trip, the transport capacity of this combination is 685 t/h, which should just be sufficient to ensure production within the normal 41,5 working hours per week. At a distance of 3000m, the haul capacity is only 600 t/h, which represents the actual crushing capacity, but is too little to be able to fulfil Raw Material without additional working hours.

12 Annex

12.1 Register of Illustrations

12.2 Register of Tables

12.3 Register of Charts

12.4 Bibliography

Gabrielli, P. (2003): HGRS: Investigation into Potential Benefits of a QuarryMaster Installation at Eclépens; Report MT 02/13548/E

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