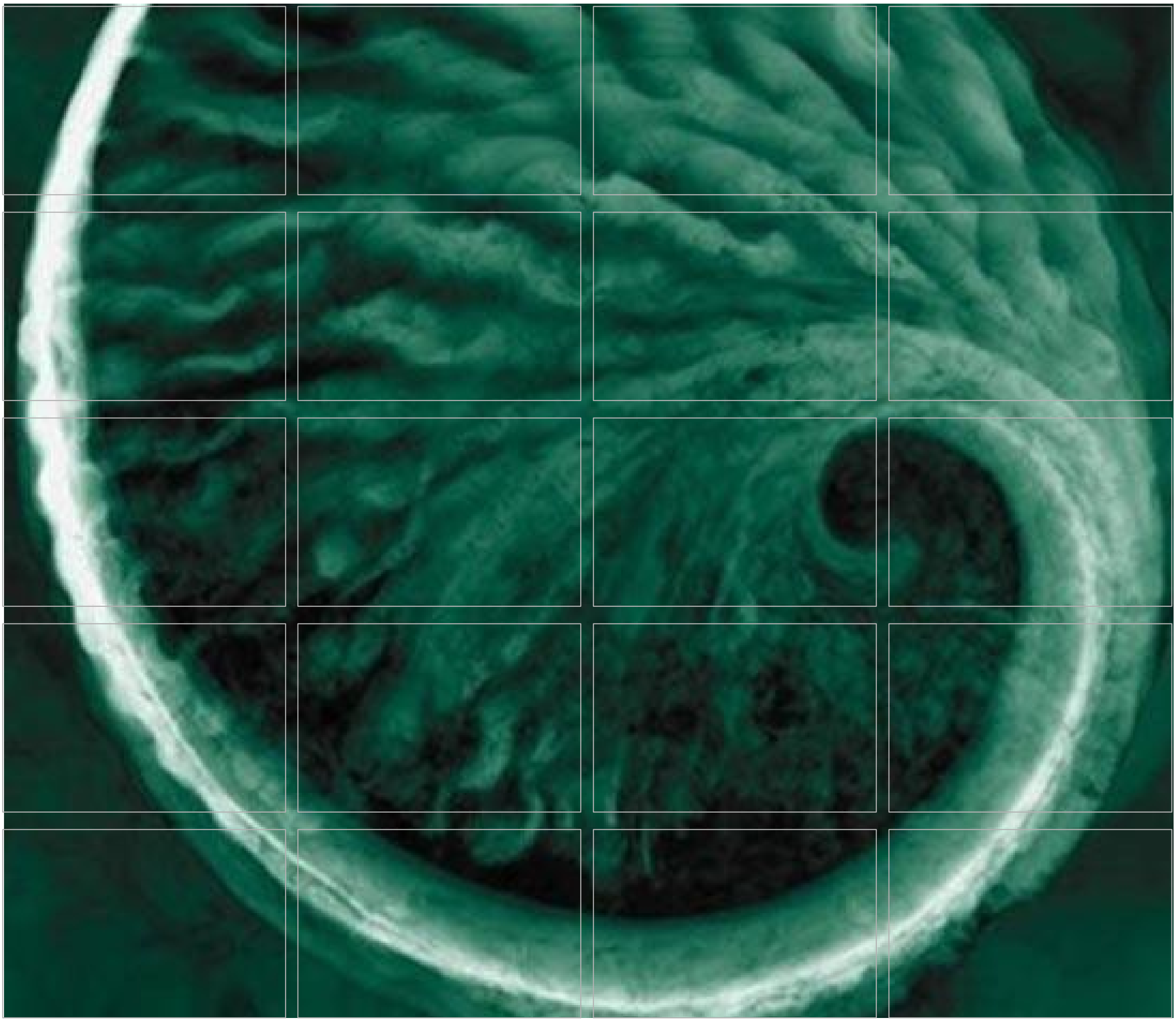

Solvay

Rattlechain Lagoon – North Slope Improvement Works.

Information for the Environment Agency

April 2013

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Rattlechain Lagoon –
North Slope Improvement

Information for the Environment Agency

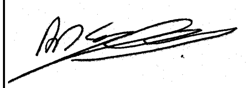
April 2013

Prepared by: Jack Buyse DCI / Paul Hesketh ERM

For and on behalf of
Environmental Resources Management

Approved by: Andrew Sykes

Signed:



Position: Partner

Date: 10th April 2013

CONTENTS

1 BACKGROUND - CONTRACT REQUIREMENTS

This document has been prepared by Environmental Resources Management (ERM) and Group DC and outlining the stability of the North slope on Rattlechain Lagoon.

1.1 PRE-CONSTRUCTION WORK SLOPE INFORMATION

The stability risk assessment of 2004 and the yearly Rattlechain lagoon slope monitoring reports show that there is evidence of ground movements and some local instability. Some slope angles are steeper than the angle of repose of the waste and these areas of slope are likely to have unsatisfactory factors of safety (i.e. are marginally stable). Progressive failure is still a possibility, and therefore URS recommended that the inspection of the slope was continued annually to ensure that the localised failures do not propagate (Ref. Rattlechain lagoon slope monitoring report of 2011).

1.2 CURRENT SLOPE INFORMATION

Topographic inspections of the Northern and Eastern slopes have been undertaken and it is evident that two issues exist with regard to the slopes:

- a structural slope problem that presents a risk of deep slope gliding (collapse) into the lagoon itself with an estimated impact of about 10 m maximum; this is mainly situated at the Northern and Northeast slope.
- natural slope erosion due to the steep incline of the slopes.

In addition it is apparent that the current excavated areas, made by the bottle diggers, will allow extra water infiltration and ultimately increase the potential for sliding of the slope; this coupled with the steep slopes is likely to make the North bank locally unstable. However, there have been no structural signs of compromised integrity identified such as tension cracks that could indicate an imminent danger of breaches to the canal or railway, and there is only a small local risk for the fence at the top of the Northern slope in one area. With regards to the Eastern bank, the slope is very steep but, in contrast to the Northern slope, there are currently no clear signs of the slope sliding, and only some surface relicts in the topography in the northern part could be found on the Eastern slope.

A series of investigations have been undertaken from a pontoon in the lagoon to determine the make-up of the bed (See Annex A). We know that the slope in the North – Northeast is very steep and, during our works with the pontoon to construct the access/anchor way, we found out that the base of the slope is made up of very soft material along the Northern slope. At the East side the underwater slope is however made of more structurally sound material and this could explain why this slope remains relatively more intact compared to the Northern slope.

1.3 *IMPACT ON THE CONTRACTUAL WORKS*

Due to the fact that the base of the Northern slope at the edge of the lagoon was not seen as sufficiently stable to create the access/anchor path at its base (lagoon level) it was decided to create a work path higher up on the Northern slope in order to construct in a safe way the access/anchoring path and allowing the anchoring of the geotextile. As part of the access works the slope would be slightly modified which would improve stability a little (however the slope would still only be considered to be marginally stable).

Using SLOPE/W, relevant factors of safety (FOS) have been calculated to demonstrate that the reworked slope profile (including the safety path) has not materially affected the pre-existing condition of the slope i.e. the works undertaken fall within the requirements of the contract. The calculated FOS for the Northern slope fall between 1.068 and 1.252, with these being comparable with the pre-existing FOS calculated by URS for this slope (see Annex B).

It is also evident from undertaking the work that the overall global stability at the Northern Slope does not affect either the canal or railway.

2 GLOBAL SLOPE ANALYSIS AND POTENTIAL SOLUTIONS

All previous information concerning the slope together with the recent investigation results have been discussed with a structural engineer and an assessment has been made which details that there are two aspects that affect the slope (a structural aspect and an erosion aspect).

2.1 OPTIONS FOR IMPROVEMENT

The fact that base of the Northern slope is not made up of a competent material, coupled together with the steepness of the slope, means that there is too much weight on the base of the underwater slope. This creates a permanent risk of gliding of the superficial slope mass into the lagoon. Ultimately this means the slope can only be considered to be marginally stable. A solution therefore is to reduce the weight of the slope at the edge of the lagoon by re-profiling the slope to the North i.e. displacing the general gravity point of the slope mass to the North resulting in less pressure on the steep soft underwater material and the base of the slope would be displaced towards better structured material further away from the lagoon edge.

Site and design specific restrictions (e.g. space to the fence line, and the need for an access track) place some limitations on what form the final design of the slope profile on the Northern slope can take. Taking into account the general horizontal distance between the edge of the lagoon and the fence and the difference in topographic height, the most optimum slope that can be constructed is 1/1.5 (33.7°). This allows parts of the material excavated during re-profiling of the Northern slope to be used to fill back the depression on the top of the slope and to correct some parts of slope. Surplus material will be used to increase the slope structure stability of the Eastern slope.

In addition to the structural slope problem, erosion of material from the Northern slope presents a problem, but this will be reduced by remodelling the slope to a shallower angle, so that it is re-profiled to a maximum inclination of 33.7°. Once re-profiled erosion can still take place but this is to a lesser degree than the slopes existing condition. To avoid slope erosion supplementary actions must be made by compacting the superficial materials and planting new vegetation on the slope which can be supplemented with the use of artificial anti-erosion structures. To tackle the erosion problem three potential solutions are detailed:

- Option A: Compaction and vegetation,
- Option B: Reinforced with MacMat-R; and
- Option C: Reinforced with Geocells.

Once the correct slope angle is achieved the new slope would be compacted using an excavator arm mounted rotating compacting wheel, resulting in the newly constructed slope being less vulnerable to erosion due to the slope compaction. On top of the newly compacted slope it is necessary to place a layer of good topsoil to promote good vegetation growth (seeded grass and new planted bushes). The current material coming out of the slope is not a fertile soil but a mix of materials including ash, bricks, rubble and loamy materials that does not serve as a fertile substrate and will limit vegetation growth.

2.1.1 MacMat R

MacMat® R is a geomat with a high voids content made from a 3-dimensional PP mono-filament matrix, heat-bonded at the contact points with a variable profile and thickness, reinforced by a polymer reinforcement grid, for erosion control and soil veneer applications

2.1.2 Geocell

Terram geocell is a relatively shallow cellular confinement system which is used to combat erosion on slopes up to 1:1. The geocell is fabricated using a geotextile so it is permeable and allows water to flow between cells encouraging drainage and vegetation. Once placed and secured on the slope, the geocell can be filled with soil or a mineral fill. The result is that the confined fill is able to better resist the erosive effects of wind and run-off. The expanded panels should be fixed at every perimeter cell and at 1m centres throughout using steel fixing pins.

2.2 IMPROVEMENTS GAINED

The stability improvements gained through each of these options are detailed in *Table 2.1*, below.

Table 2.1 North Slope Stability Improvements

North slope stability improvements						
	Profile A	Increase in FOS	Profile B	Increase in FOS	Profile C	Increase in FOS
Existing Slope Profile	1.102		1.252		1.068	
Option A: Compaction						14.98%
& vegetation	1.314	19.24%	1.258	0.48%	1.228	
Option B: Reinforced						20.79%
with Macmat	1.34	21.60%	1.28	2.24%	1.29	
Option C: Reinforced						28.84%
with Geocells	1.382	25.41%	1.334	6.55%	1.376	

Detailed specifications for each of these options are provided in Annex D.

The Eastern slope is very steep and the slope angle is the maximum that can be reached but it seems relatively stable due to the more structurally sound materials at the base of the slope. Therefore no slope modification is proposed here.Another way of increasing the structural slope stability is to put additional material at the underwater base of the slope. By doing this, the risk is further reduced of having structural collapse / gliding of the slope material into the lagoon. Then only surface erosion would likely impact the capping system but this is far less likely when compared to the Northern slope.

2.3 *NEXT STEPS*

The outlined works provide an improvement in the stability of the northen slope and as a result will also provide continued assurance that the installed capping will not be damaged by future failure of the slope.

Solvay has instructed ERM to undertake the basic re-profiling of the slope with a view to further identify at a later date the slope dressing/reinforcing.

Annex A

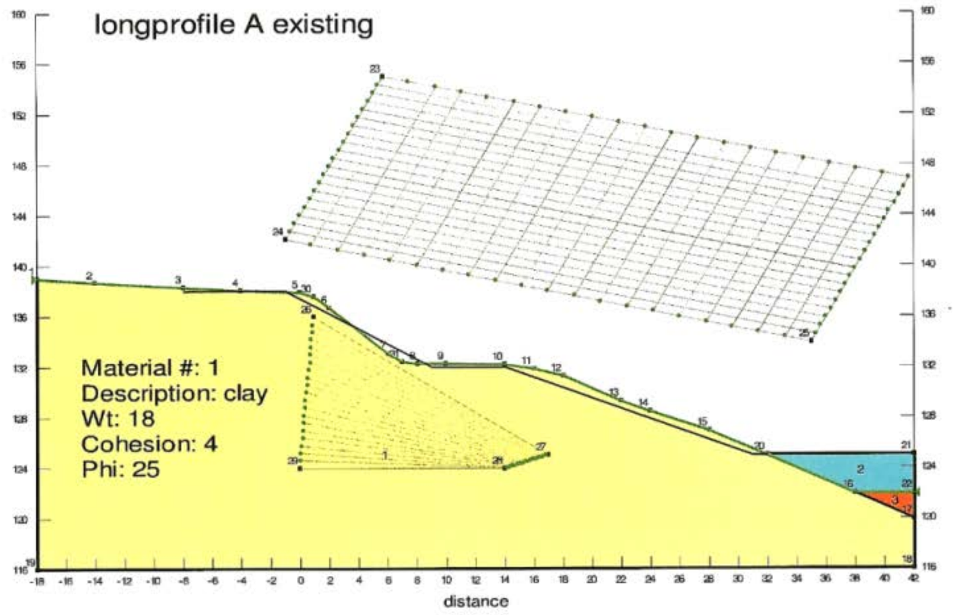
Details of Lagoon Base Investigation works

Information to Follow

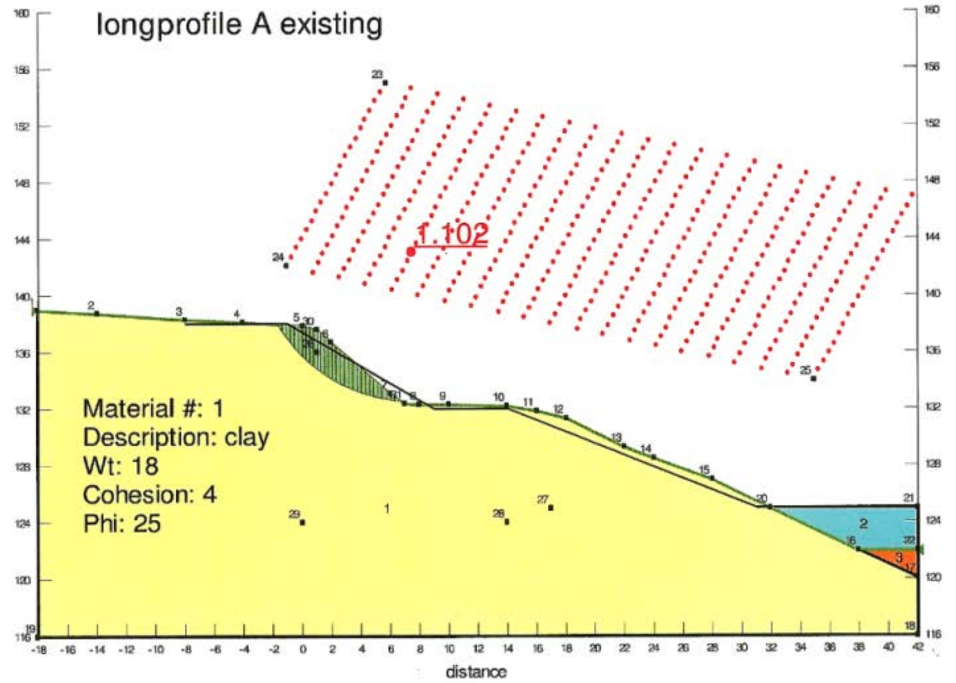
Annex B

Slope Stability Calculations – Existing Slope Profile

Slope Profile A

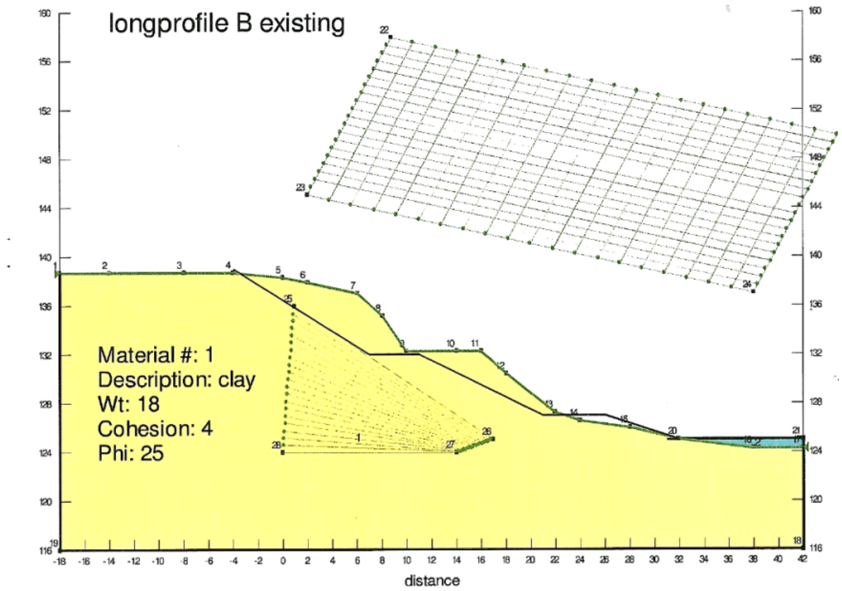


result : F =1,1 (estimated)

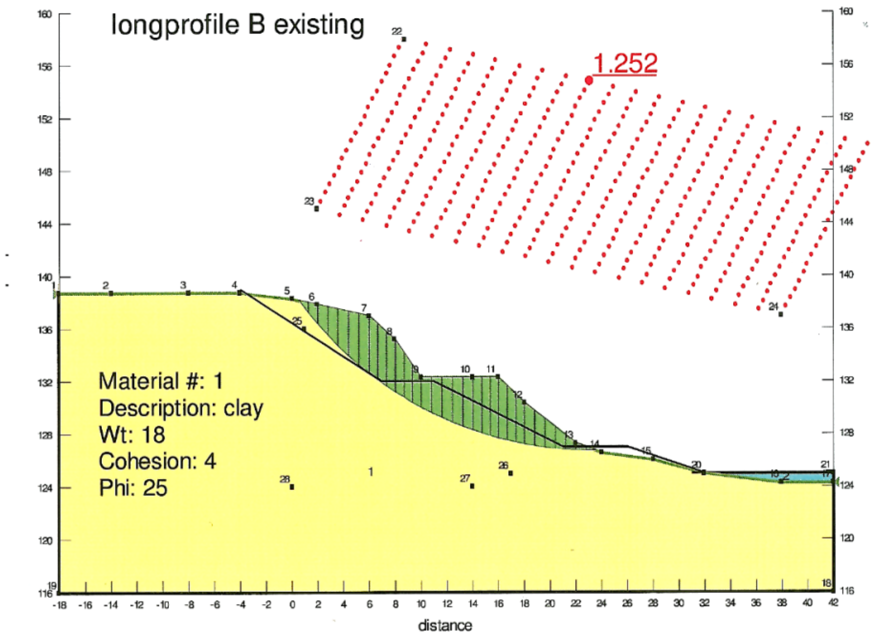


Slope Profile B

longprofile B existing :

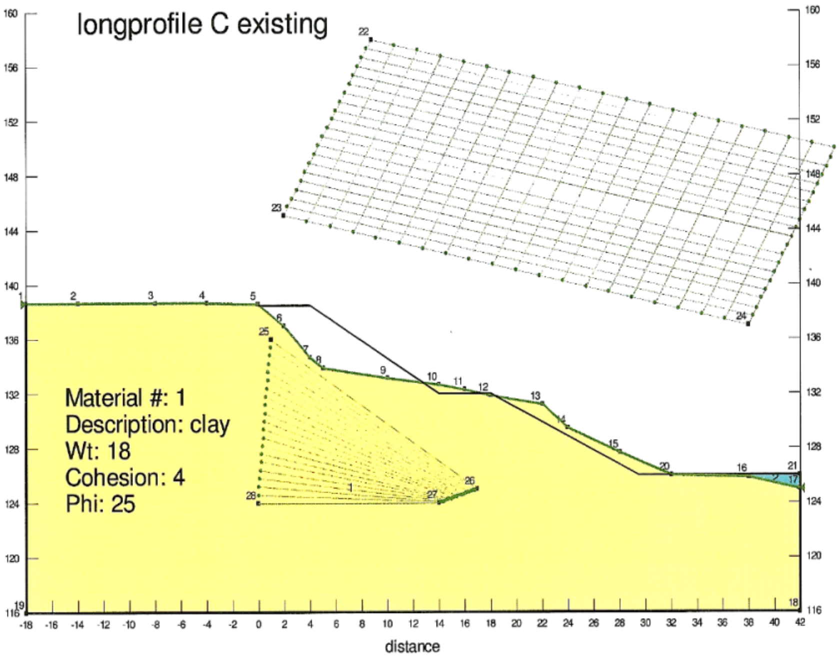


result : 1,25

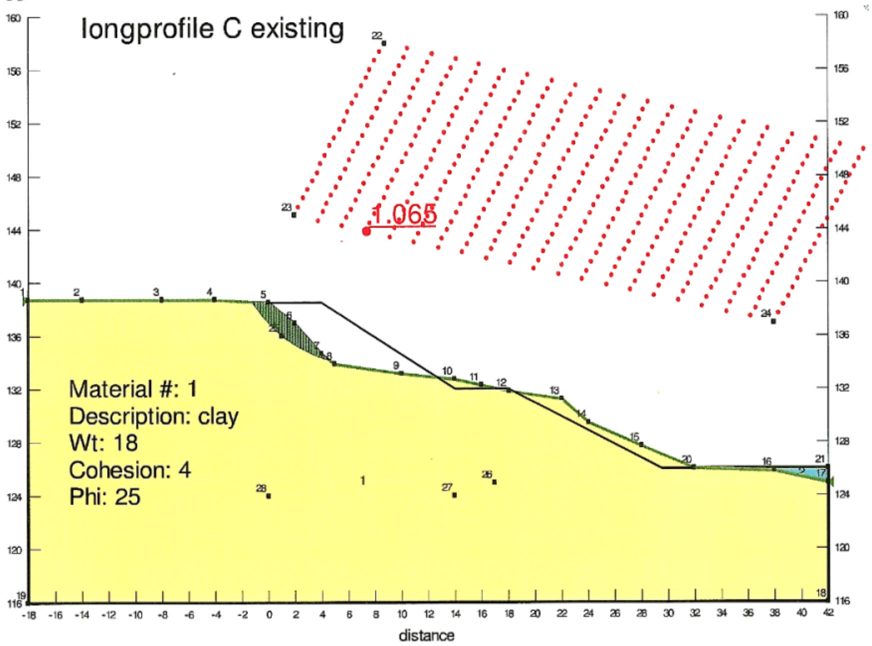


Slope Profile C

longprofile C existing :



result : 1,065



Annex C

Slope Stability Calculations –Proposals for re-profiling northern slope

C1 SLOPE RISK CALCULATION AND FACTOR OF SAFETY.

C1.1 INTRODUCTION:

Once the global slope analyses and potential solution has been elaborated then a mathematical slope risk calculation is done on the current slope profiles and the new proposed slope profiles, including the effect of the artificial anti-erosion structure. From those calculations we can derive a factor of safety for the slope what gives us a scientific tool to judge about the proposed potential slope measures.

The existing long profiles are verified using slope stability software (Slope/W from Geoslope). This verification is used to compare the slope stability before and after the change in profile. The exact safety of the slope is difficult to compute and to compare, since the soil friction and cohesion are estimated. However, we can assume that the existing slopes are just stable (thus $F > 1$). If the modified slope has a higher safety factor then the existing slope, the safety increases, and thus $F > 1 +$ extra %, this gives us an estimation of the safety increase.

The proposed anti-erosion structures are also introduced in the calculation. The extra safety factor that this structure/layer provides is also analysed.

C1.2 CALCULATIONS :

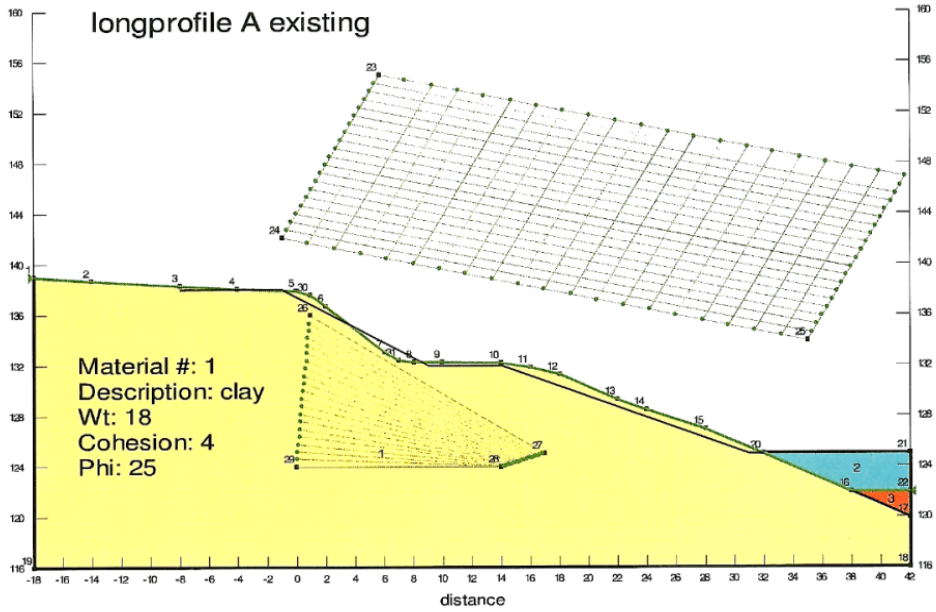
On the next pages the calculation model is given for different situations. Reference to the stability factors of safety for the existing profile is given in Annex B. The input and output of the model are given on a graphic print of the situation.

In a second model, the critical slope surface is covered with the anti-erosion structure with Geocells. The cover with MacMat-R is not computed separately, this thin layer will give also an increase, but less than the Geocells solution. The result is estimated as a 50 % effect of the Geocells solution.

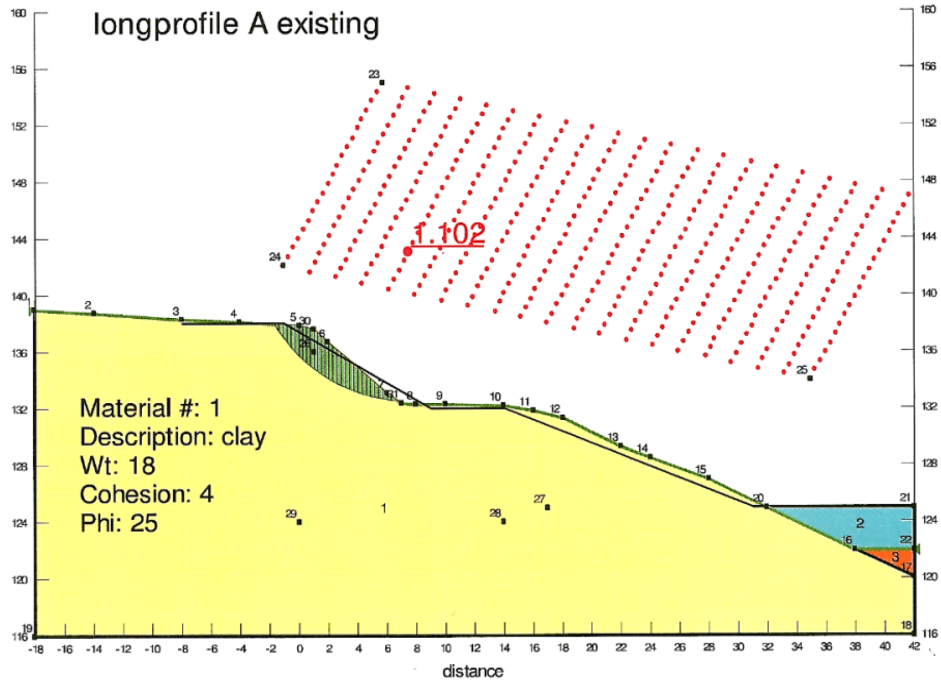
SLOPE/W calculates the weakest slip surface. That surface is always automatically generated on the output print of the model. The bigger the shaded dark green the bigger the earth volumes that could slip down the slope. In fact two slopes or parts of slopes with the same factor of safety do not tell anything about the impact of the slope collapse. This means that if a slip surface is not profound only a small part can collapse, while a profound slip surface will have a devastating effect on the slope although potentially having the same slope factor of safety. In fact then we have to simulate/compute the same profound slip surface on the new profiled slope to see what the new slope factor of safety is that would generate the same devastating collapse.

C1.3 *SLOPE PROFILE A :*

Original Slope A

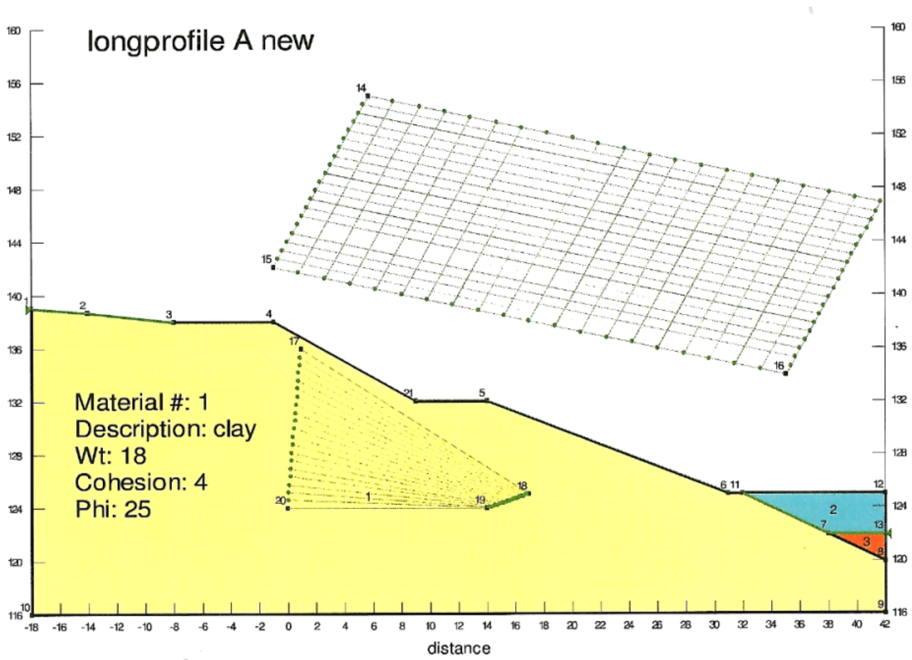


result : F =1,1 (estimated)

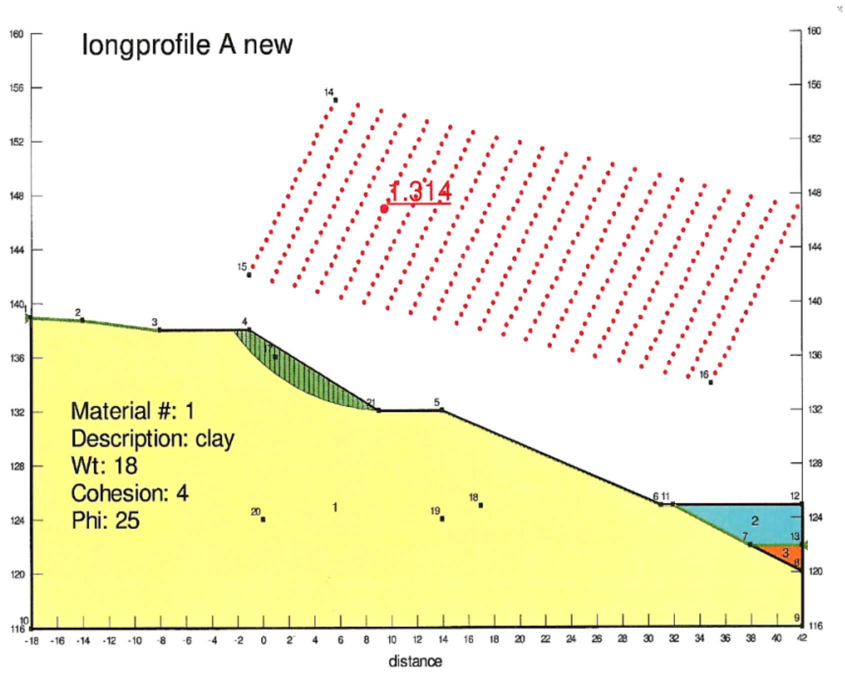


For the existing slope we have we have an estimated slope safety factor of 1.1

Option A: New designed A slope without artificial anti-erosion structure :



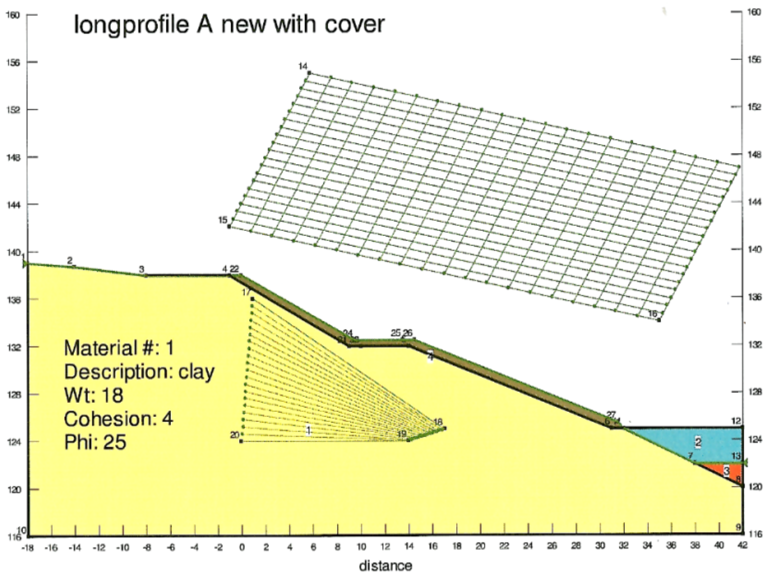
result : F = 1,3 instead of 1,1 = + 20 %



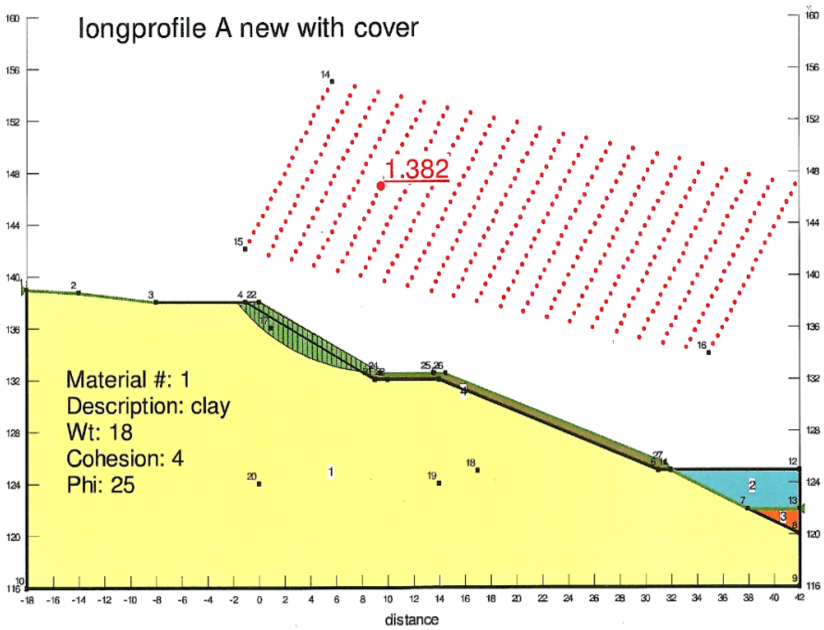
The re-profiled slope has now a slope safety factor of 1.3 instead of 1.1 this means an increase of 20 % in the slope stability.

Option C: New designed A slope combined with an anti-erosion structure (Geocells)

longprofile A with geocell : geometry



result : 1,38 , so another 10 % increase
(about 1,34 or 5 % with macmat)



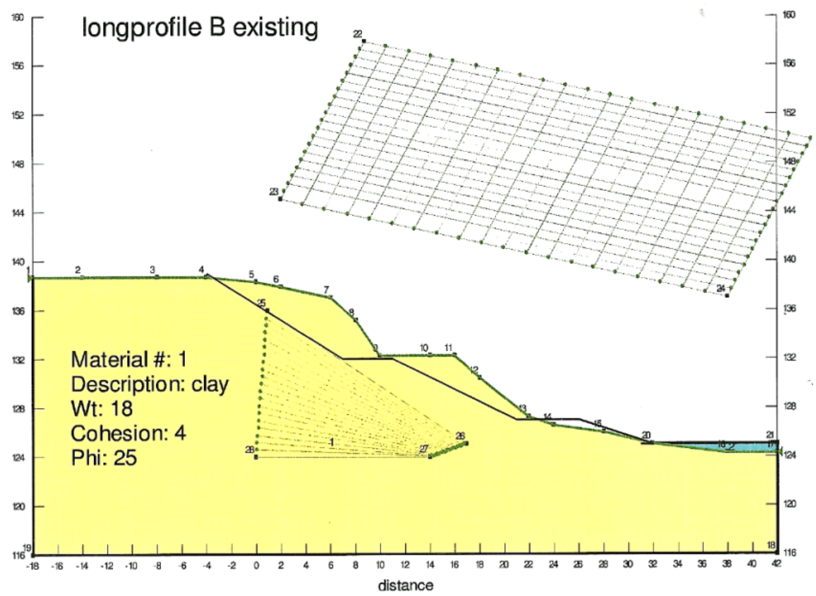
The anti-erosion structure (Geocells) has a computed slope factor of safety of 1.38 or another increase of 10 % on the re-profiled slope. The factor of safety generated by utilising MacMat-R is about 1.34 or a 5% increase on the Option A.

From the 2 computed situations is clear that the most critical sliding zone (shaded green) remains within the Rattlechain boundary and does not affect the canal and railway.

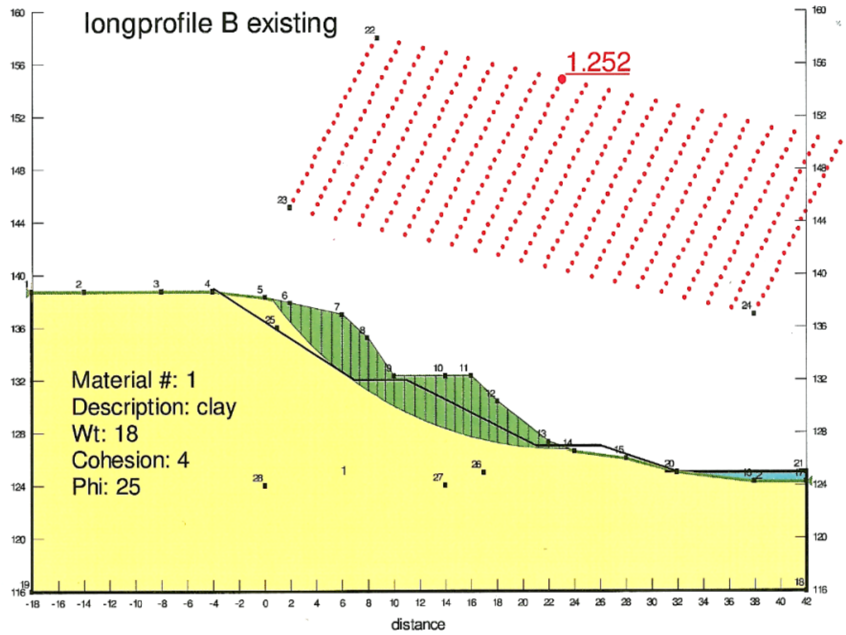
C1.4 *SLOPE PROFILE B :*

Original Slope B

longprofile B existing :



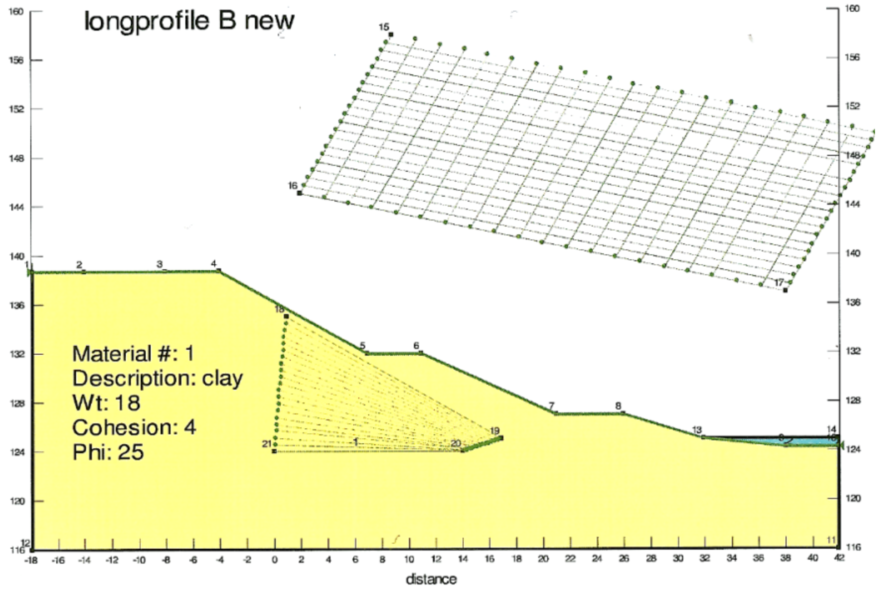
result : 1,25



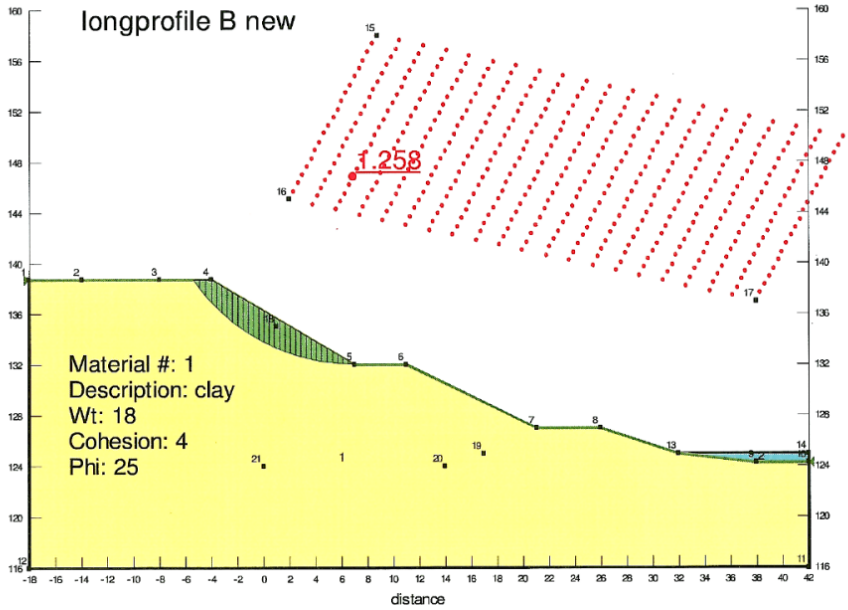
The slope stability factor on the existing slope profile is 1.25 but when the slope is slipping the total soil movable mass is large due to the quite deep slip surface. The bigger the shaded green area the bigger the impact of the slope collapse can be. Here it is very clear, if such a great volume of earth goes down it will have a devastating effect on the installed capping, if it occurs.

Option A: New designed B slope without artificial anti-erosion structure :

longprofile B new :

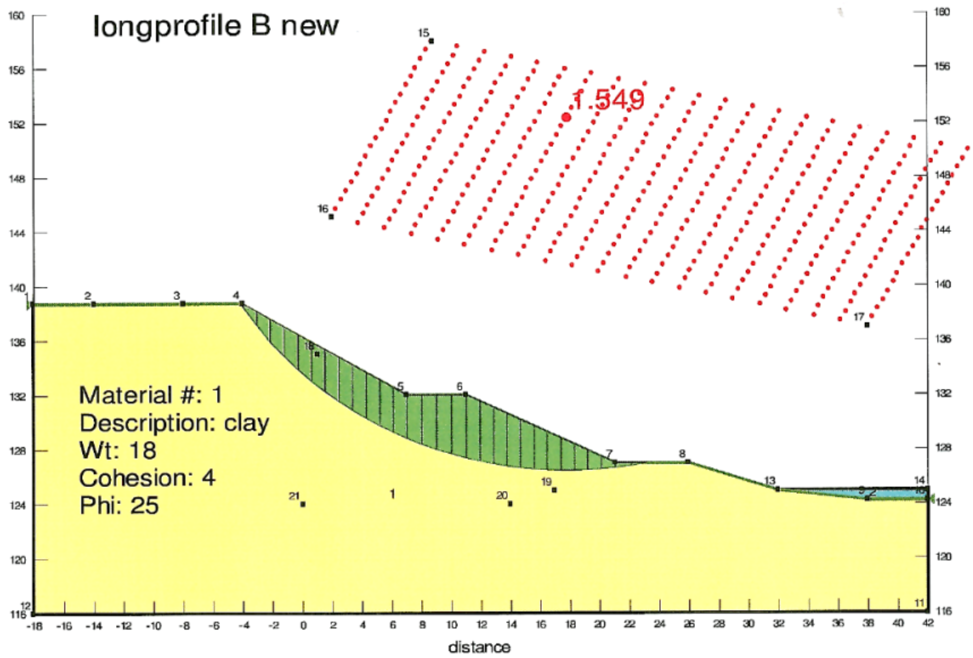


result : 1,26 (unchanged, but smaller and higher position)
global stability of the same slipzone as existing : 1,55 (see next page)
thus here also an important gain in stability.



The new slope safety factor of 1.26 is almost unchanged but the volume of the slip area is far reduced and is only situated at the top part of the slope. If a collapse would happen only a small un-deep part of the upper slope would be impacted and the damage to the capping would be limited. To have an objective slope safety factor comparison we have to simulate the same slip surface on the new profile.

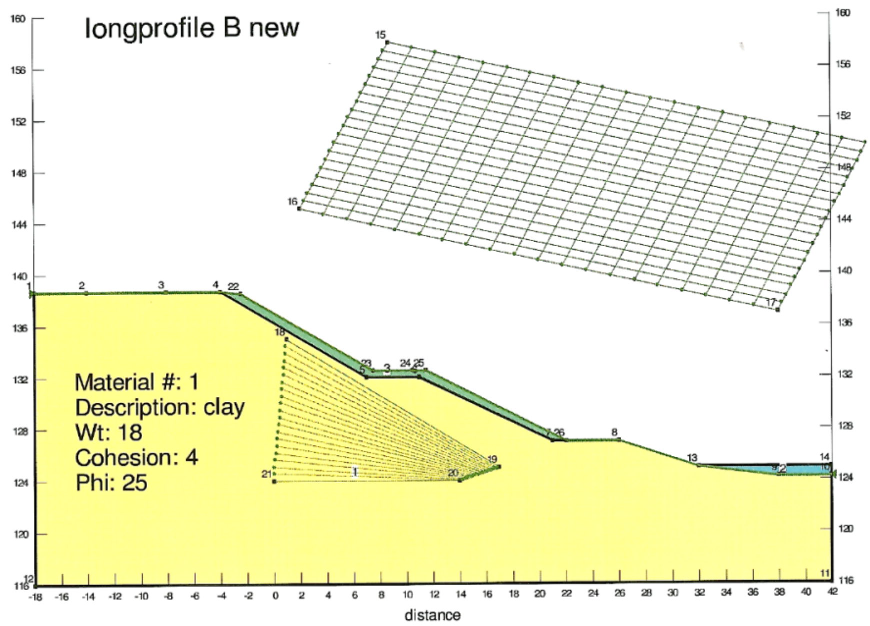
Longprofile B New



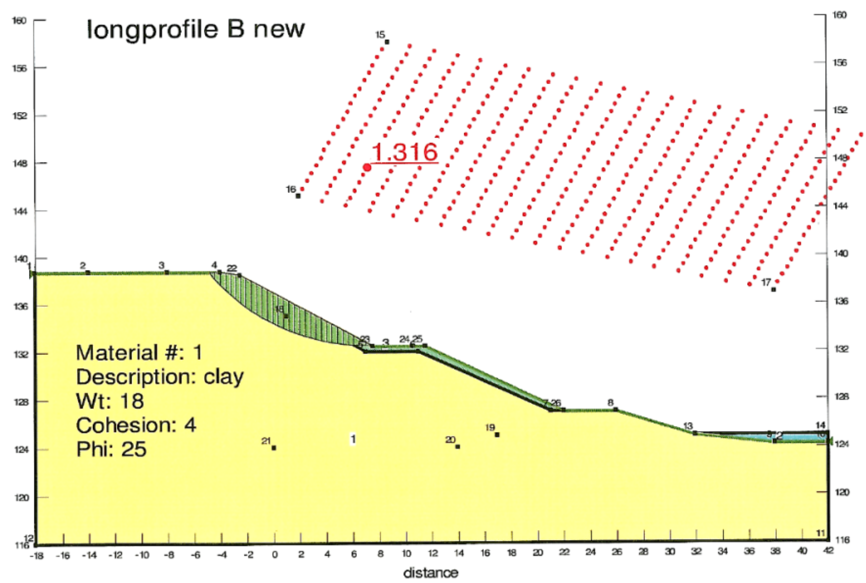
Finally the safety factor of the original same slip surface increase from 1.25 to 1.55 or an increase of 20%.

Option C: New designed B slope combined with an anti-erosion structure (Geocells)

Longprofile B with cover :



result : 1,32
about 5% extra safety
(about 2,5 with matmac estimated)



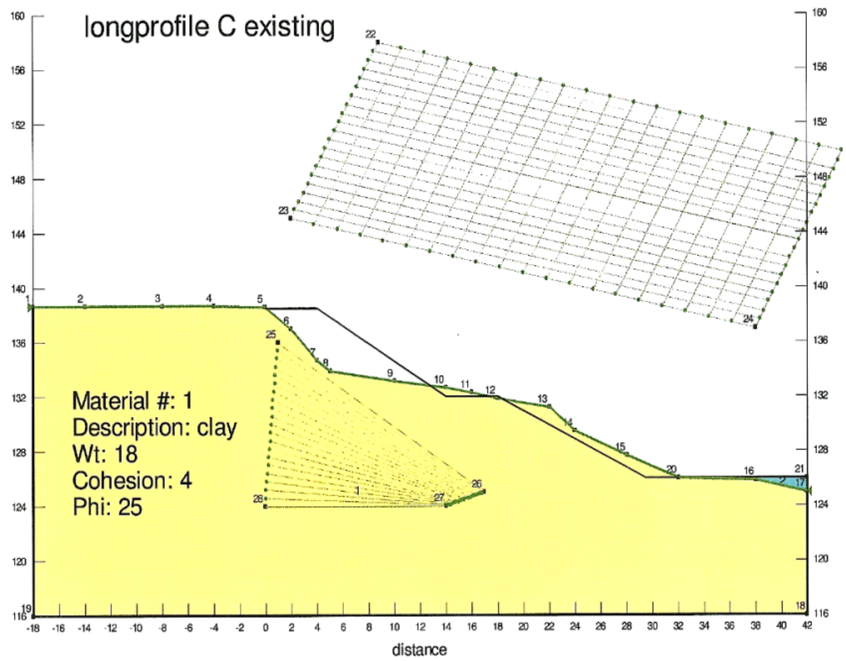
The anti-erosion structures (Geocells) have a computed slope factor of safety of 1.32 or another increase of 5% on the re-profiled slope. The factor of safety for utilising MacMat-R is about 1.29 or a 2.5 % increase on Option A.

From the two calculated simulations it is clear that the most critical sliding zone (shaded green) remains within the Rattlechain site and does not affect the canal or railway. If this slope profile is allowed to remain and if a collapse were to occur at this location the impact would be devastating compared to the re-profiled slope where the impact would be minimalized. By using an artificial anti-erosion structure the slope safety factor will increase between 2.5-5% depending on the type of artificial anti-erosion structure deployed.

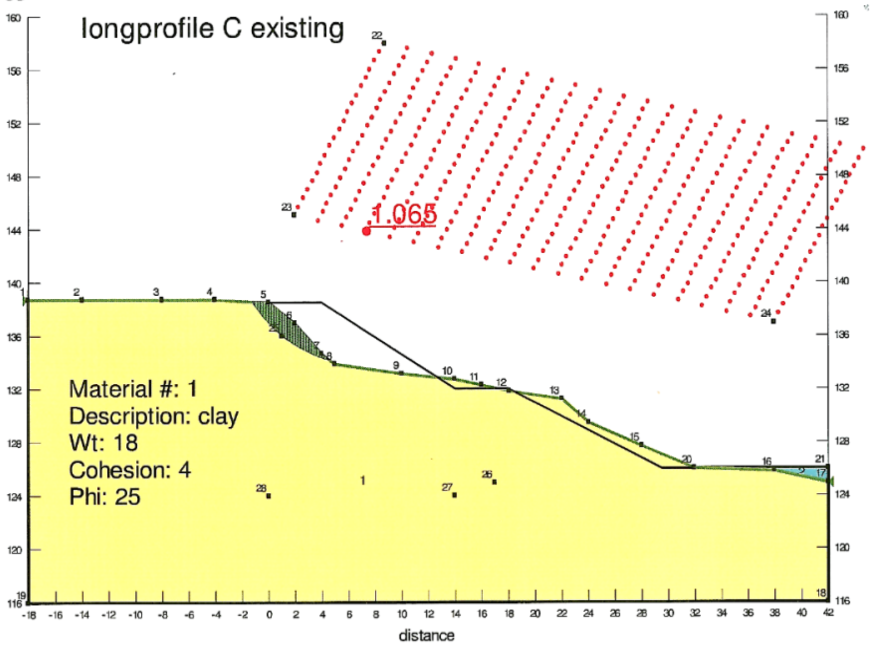
C1.5 SLOPE PROFILE C :

Original Slope C

longprofile C existing :



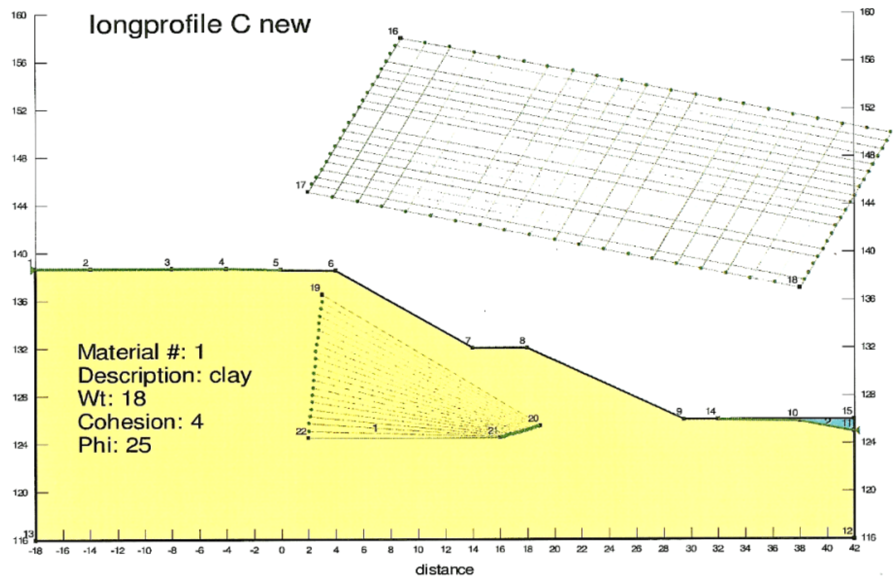
result : 1,065



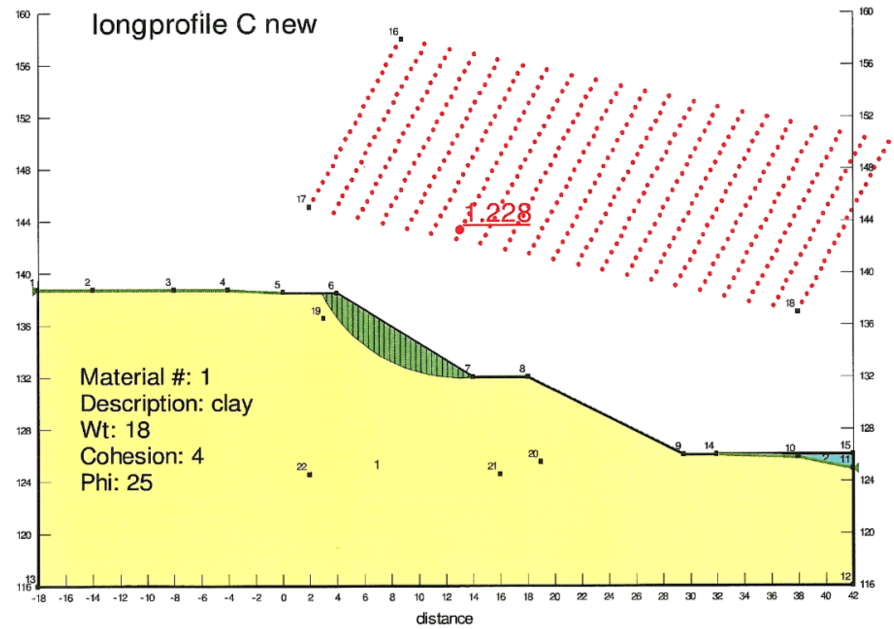
The slope safety factor of the existing slope is 1.06 very near to 1. The bad thing is that there is almost a permanent risk of a slope sliding in the upper part of the slope but the impact will be moderate due to the un-profound depth of the slip surface. Only the fence of the side would be probably impacted.

Option A: New designed B slope without artificial anti-erosion structure :

longprofile C new :



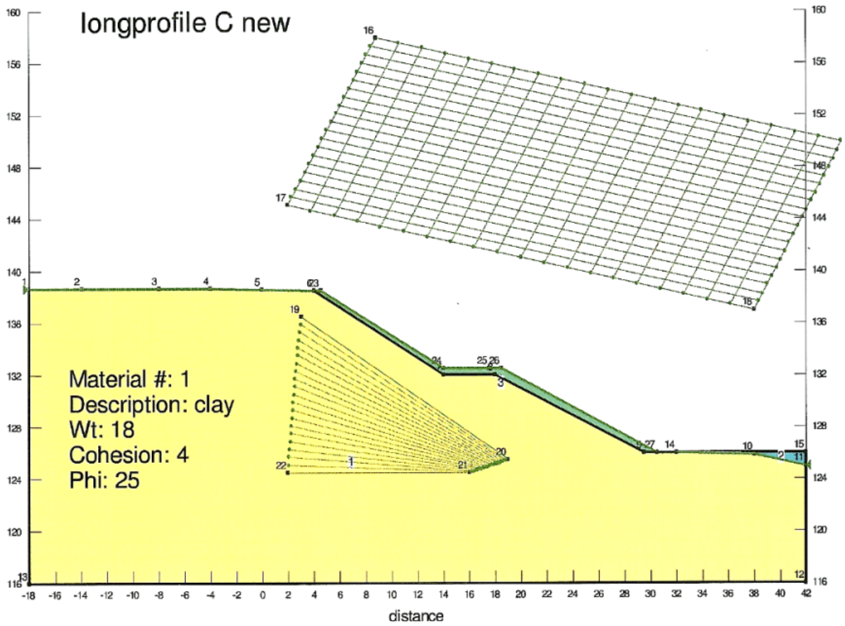
result : 1,22 = +20%



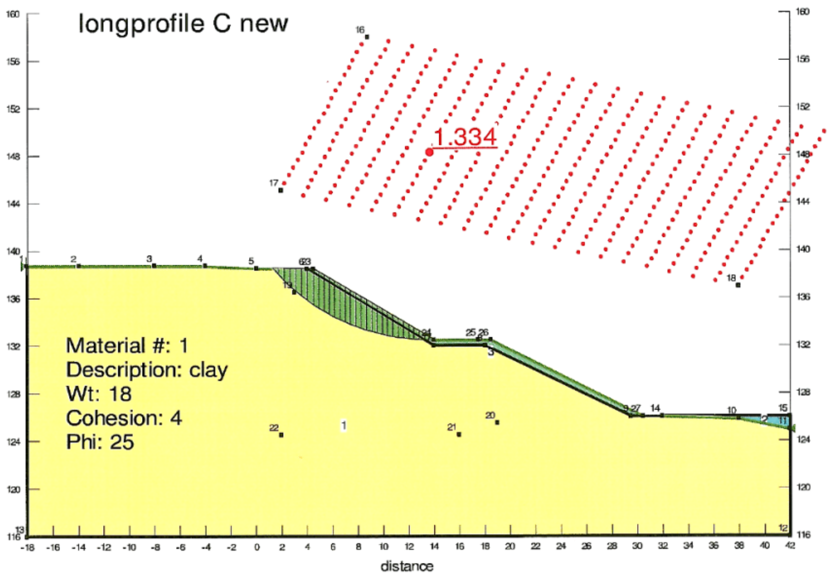
The re-profiled slope has now a slope safety factor of 1.22 instead of 1.06 this means an increase of 20 % in the slope stability.

Option C: New designed C slope combined with an anti-erosion structure (Geocells)

longprofile C with cover :



result : 1,33 , an additional 10 %
estimated 5 % with matmac



The anti-erosion structures (Geocells) have now a computed slope factor of safety of 1.33 or an additional increase of10 % on the re-profiled slope. The factor of safety for utilising MacMat-R is about 1.28 or a 5% increase on Option A.

From the two calculated situations is clear that the most critical sliding zone (shaded green) remains within the Rattlechain boundary and does not affect the canal and railway.

C2 SURFACE EROSION ON THE SLOPE AND POTENTIAL IMPACTS UPON THE CAPPING SYSTEM.

From the slope analysis undertaken we can conclude that there is no a significant risk of a profound slope collapse that could impact the canal and the railway.

By re-profiling the slope there is an average increase of slope stability factor to be expected of about +20 % for all slope profiles analysed and an additional increase in the slope stability factor of a further 10% by using artificial anti-erosion structures (Geocells) and about 5 % for the MacMat-R.

From the existing simulated profile B it is clear, that if a slope collapse occurs, the impact will be devastating on any installed capping. By re-profiling the slopes the physical impact of a collapse on the capping would be strongly reduced.

Annex D

Specifications for Slope Improvement Works

D1 POSSIBLE SLOPE IMPROVEMENT WORKS

D1.1 OPTION A - COMPACTION & VEGETATION:

D1.1.1 General description :

In fact the basic solution is implementing only vegetation and no artificial anti-erosion structure will be involved. In this case we are only just re-profiling the Northern slope so that the structure of the slope becomes right. Once the slopes have been compacted we are going to place a topsoil of 150 mm without artificial ant-erosion structure. Due to the fact that the angle of internal friction of loose topsoil is about 30° and at best 35° there is a permanent risk that the topsoil will erode due to heavy rainfall and especially during the period between the placement of the topsoil and the time that the vegetation has fully developed.

Product specification of the grass :

10% LOLIUM MULTIFLORUM AXCELLA
10% LOLIUM PERENNE PRANA
20% LOLIUM PERENNE MATHILDE
25% FESTUCA RUBRA MAXIMA
25% DACTYLIS GLOMERATA TREPOSNO
5% AGROSTIS H BENT
2,5% TRIFOLIUM REPENS MERWI (coated)
2,5% TRIFOLIUM PRATENSE LUCRUM

Note : The used specimens of grass and bushes will be the same in the 3 option.

Product specifications of the bush :

For the bush we propose to take CRATAEGUS because it is a good roots forming plant and it does not become higher than 2 meter. Once completely developed it forms a dense bush a together with it thorns it will be difficult for souvenir diggers to destroy the slope.

D1.1.2 What FOS does this provide:

The factor of safety (FOS) but also called the slope safety factor reveals that the new slopes would have an increase of about 20 % on the slope safety factor. This means that the risk a future deep and moderate deep sliding would be strongly reduced. Surface erosion could always take place due to the absence of artificial anti-erosion structure. If no re-profiling would be done, then if a slope collapse would occur then the impact would be devastating on the new installed capping.

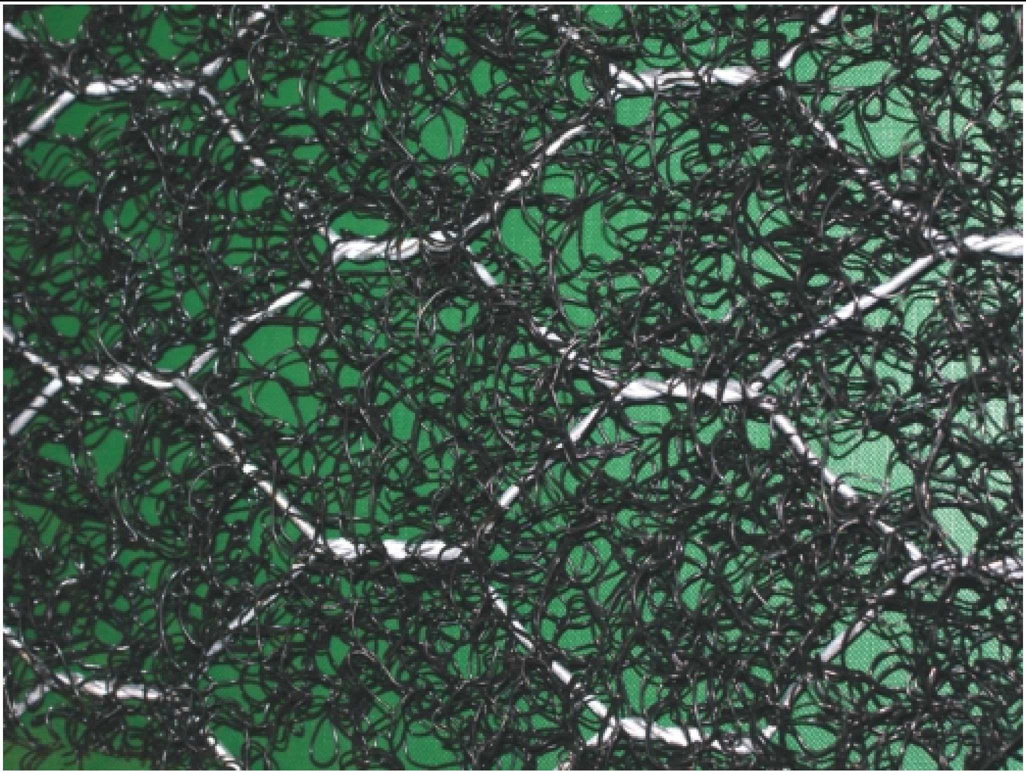
D1.1.3 *Inclusion*

- Re-profiling the slope
- Backfill of depressions on the top of the slope
- Excess soil of the Northern back will be transported by a chain dumper
- Excess soil will be placed against the underwater base of the Eastern slope
- Compacting the new formed slopes
- Delivery and placing the final topsoil layer of 150 mm on the new slopes
- Seeding grass on the upper topsoil
- Planting bushes every square meter on the slope.
- Creating a central path / terrace in the middle on the slope
- Constructing connection paths from the edge of the lagoon to the terrace and from the terrace to the top of the Northern slope
- Placing Geocells on the connection paths and the terrace to avoid erosion on the paths
- Filling the Geocells with broken asphalt so no erosion could occur and the North bank remains accessibly for repairs of the fence or maintenance works.

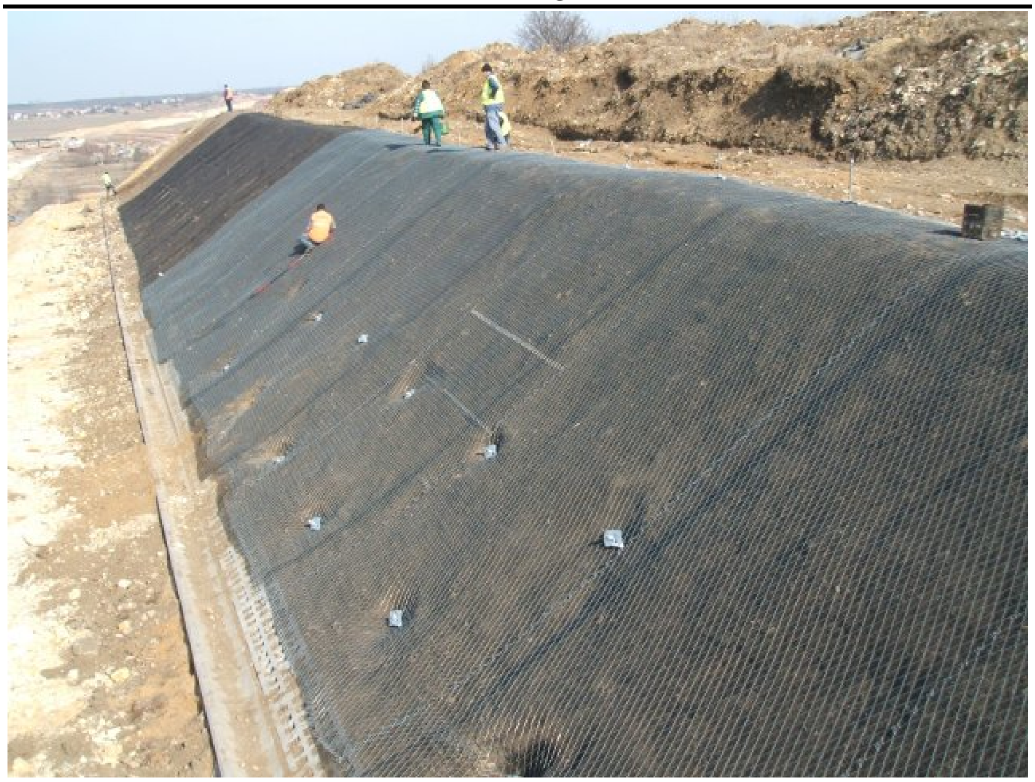
D1.2 *OPTION B – MACMAT-R*

D1.2.1 *General description :*

Another solution to reduce the surface erosion is to use reinforced 3 dimensional geocomposite which is reinforced with a hexagonal double steel wire mesh and entangled with monofilaments of polypropylene. The advantage is that the placement is less work intensive but the disadvantage is that it gives less superficial structural protection then the Geocells. Below a detail picture of the MacMat-R.



Once the slope has been shaped then a layer of topsoil of 10 cm is placed on the compacted slope. Then the MacMat-R is unrolled and nailed on the slope. Finally a thin layer of 5 cm topsoil will be placed on the anti-erosion structure. With the help of the rain topsoil will infiltrate and be captured in the monofilaments. Finally we will seed grass and for every square meter a bush will be planted. In annex you will find more general information concerning the MacMat-R anti-erosion artificial geostructure.



Product specification:

Code: 9301
Product: **MacMat® R 6x8 Galmac+PVC**
Specifications: 3-D geocomposite against erosion made from a core of monofilaments reinforced with a double twisted
steel woven mesh
• 3-D structure
Raw material : Polypropylene
Weight : 500 gr/m^2 (EN ISO 9864)
Stabilised against uv light
• Double twisted steel woven mesh
Raw material : steel with a Galmac (Zn-Al5%) and polymeric protective coating (EN 10244-2, Class A)
Dimensions of mesh : 6x8
Wire diameter : 2,2/3,2 mm
Thickness of polymeric protective coating : 0,5 mm
• Geocomposite
Tensile strength MD : 35 kN/m (EN ISO 10319)
Weight : 1970 gr/m^2 (EN ISO 9864)
Void index : minimum 90 %
Thickness under 2 kPa : 12 mm (EN 9863-1)
Standard rolls : 2 m x 50 m
TEXION

D1.2.2 What FOS does this provide

The slope safety factor reveals that the new slopes would have an increase of about 20 % on the slope safety factor. This means that the risk a future deep and moderate deep sliding would be strongly reduced. By implementing the artificial anti erosion-structure MacMat-R the impact of a moderate deep sliding would be farther reduced. On top of the increase in the slope stability factor we could approximately add 5 % due to the MacMat-R. Surface erosion would be strongly reduced.

D1.2.3 Inclusion

- Re-profiling the slope
- Backfill of depressions on the top of the slope
- Excess soil of the Northern back will be transported by a chain dumper
- Excess soil will be placed against the underwater base of the Eastern slope
- Compacting the new formed slopes
- Delivery and placing the basic topsoil layer of 100 mm on the new slopes
- Installing and nailing of the MactMat-R on top of the basic topsoil

- Delivery and placing of a 50 mm upper topsoil on top of the MacMat-R
- Seeding grass on the upper topsoil
- Planting bushes every square meter on the slope.
- Creating a central path / terrace in the middle of the slope
- Constructing connection paths from the edge of the lagoon to the terrace and from the terrace to the top of the Northern slope
- Placing Geocells on the connection paths and the terrace to avoid erosion
- Filling the Geocells with broken asphalt so no erosion could occur and the North bank remains accessibly for repairs to fence or maintenance works.

D1.3 OPTION C – GEOCELLS

D1.3.1 General description :

Taking in account that the angle of internal friction (φ) for loose topsoil is about 30° and that we would like the have topsoil layer of 10 cm over the complete cell then we have to take cells of 150 mm depth. Taking in account the height of the slope 11 m, the future slope angle would be about 34°, the angle of internal friction for loose topsoil is 30° and knowing the behaviour of the current slope we are coming to the conclusion to select a 20 Geocells structure per square meter with a depth of 150 mm.

The Geocells are perforated which gives the advantage that future grass and bushes roots will grow through resulting in the artificial anti-erosion structure being woven into the roots increasing slope stability. The Geocells will be placed and nailed/anchored on the slope and filled with good topsoil. Once the topsoil has been placed, grass will be seeded on the fertile soil and for every square meter a bush will be planted. In annex xx further information is provided in relation to Geocells.
The Geocells approach and the new vegetation provide a long term solution to the structural and erosion stability of the currently problematic Northern slope.

Product specification:

Code: 9513
Product: **TexiWeb® NEOLOY GWM 150 CATEGORY A**
Specifications: PRS NEOWEB 445-150 P S Category A
Material: Neoloy™ polymeric nano-composite alloy
Cell distance between weld weams: 445 mm (+/- 2,5 %)
Cell wall heights : 150 mm(□}5%)
No. of Cells/m^2 : 20
Seam Weld Strength – Weld Splitting > 12 kN/m (ISO 13426-1 Part 1 Method C(1))
Oxidative Induction Time (OIT) ≥ 125 minutes (ISO 11357-6) (OIT @ 200°C)
Durability to UV Degradation ≥ 1250 minutes (ASTM D5885)(HPOIT @ 200°)
Cell Dimension (Expanded) : 340 mm x 290 mm (+/- 3%)
Section Side (Expanded) : 2,8 m x 10,7 m (30 m^2) or 2,8 x 17,3 m (48,4 m^2)
Colour: sand
TEXION

D1.3.2 What FOS does this provide:

The slope safety factor reveals that the new slopes would have an increase of about 20 % on the slope safety factor. This means that the risk a future deep and moderate deep sliding would be strongly reduced. By implementing the artificial anti erosion-structure type Geocells the impact of a moderate deep sliding would also be strongly reduced. On top of the increase in the slope stability factor we could approximately add 10 % due to the Geocells. Surface erosion would be very strongly reduced due impact of the Geocells together with the new vegetation.

D1.3.3 Inclusion

- Re-profiling the slope

- Backfill of depressions on the top of the slope

- Excess soil of the Northern back will be transported by a chain dumper

- Excess soil will be placed against the underwater base of the Eastern slope
- Compacting the new formed slopes
- Installing and anchoring of the Geocells on top of the new compacted slopes
- Delivery and filling the Geocells with 150 mm topsoil
- Seeding grass on the topsoil
- Planting bushes every square meter on the slope.
- Creating a central path / terrace in the middle of the slope
- Constructing connection paths from the edge of the lagoon to the terrace and from the terrace to the top of the Northern slope
- Placing Geocells on the connection paths and the terrace to avoid erosion
- Filling the Geocells with broken asphalt so no erosion could occur and the North bank remains accessibly for repairs to fence or maintenance works.

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