Technical report, piloting cover structure (action B1)

UPACMIC LIFE12 ENV/FI/000592

TECHNICAL REPORT, PILOTING COVER STRUCTURE (ACTION B1) UPACMIC LIFE12 ENV/FI/000592

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Prepared by	Tarja Niemelin, Ramboll
	Tuomas Suikkanen, Ramboll
Checked by	Antti Virtanen, Fortum
	Harri Jyrävä, Ramboll

CONTENTS

1. INTRODUCTION

In this report, the piloting of cover structure in Hitura Mine made in the UPACMIC (LIFE12 ENV/FI/000592) project during 2017-2018, is presented.

1.1 Hitura Mine

Hitura Mine is located in Northern Ostrobothnia in Nivala, Finland (Figure 1) and it was owned by the company Belvedere Mining. Belvedere Mining was initially also an associated beneficiary of the UPACMIC project, but when the company went to bankrupt in December 2015, the company was withdrawn from the project. Mining activities stopped in the mine already in 2013 when the nickel price dropped dramatically below the break-even point.

Despite the company bankrupt the enrichment sand areas needs to be closed to block the seeping of rain water through metallic enrichment sand. These construction activities are made with the help of the deposit fund and the government money (project owner North Ostrobothnia Centre for Economic Development, Transport and the Environment).

Hitura mine ore has a nickel content of approximately 0,5 % and copper content of 0,10 %. Total quarrying in Hitura was 17,2 Mt. Ore was first quarried opencast mining and in 1991 the quarrying was gradually moved to underground mining. There are total of 15 Mt of enrichment sand and mining waste rock 7 Mt that are deposited as sulphur containing serpentinite rock pile and sulphide mineral content mica gneiss pile. In the final stages of the mining operations, the quarried rock was utilised in rockfill. The area of opencast mine is approximately 30 hectares (depth 170 m). (1)

Closing of the mine is on the responsibility of the state after company bankrupt. The supervising authority is the North Ostrobothnia Centre for Economic Development, Transport and the Environment who also made the competitive tendering for the closing activities for the I-stage of the closing. Closing will be done in II stages. The I stage was done in 2017-2019 and the II stage will be done during 2019-2022.

The winning tender of the I-stage was offered by Fortum Environmental Construction (currently Fortum Waste solution, abbr. Fortum). The contract consists ao. of replacing current water treatment process with new equipment and designing and construction of additional water treatment system. In addition, the closing of enrichment sand basins was part of the contract, for which the Fortum offered the UPACMIC solution utilising fibre clay in the structures.

Figure 1. Location of Hitura Mine in Nivala.

Initial situation in Hitura mine is that the enrichment sand deposited in the basins (Figure 2) has grain size distribution varying from silt to fine sand. The finest materials are in the middle of the basins and more coarser materials are in the sides. Enrichment sand contains sulphide minerals 1,4-5,9 % and sulphur 0,6-2,5 % but it is not characterized as acid producing waste. The nickel and copper contents exceed the threshold value of the national Decree 214/2007 (Government Decree on the Assessment of Soil Contamination and Remediation Needs) and zinc, cobalt and chromium contents are below of the Decree threshold values. In addition, the sand contains small amounts of benzene, carbon bisulphide, diethyl sulphate and terpenes.

Level of groundwater varies from the ground surface (the southern parts of the basin area) to approximately 1 m below ground surface. When making the plans, the level of seep water in basin 2 was above the filling surface in the middle of the basin. The bearing capacity of the foundation is related to the drainage of the area.

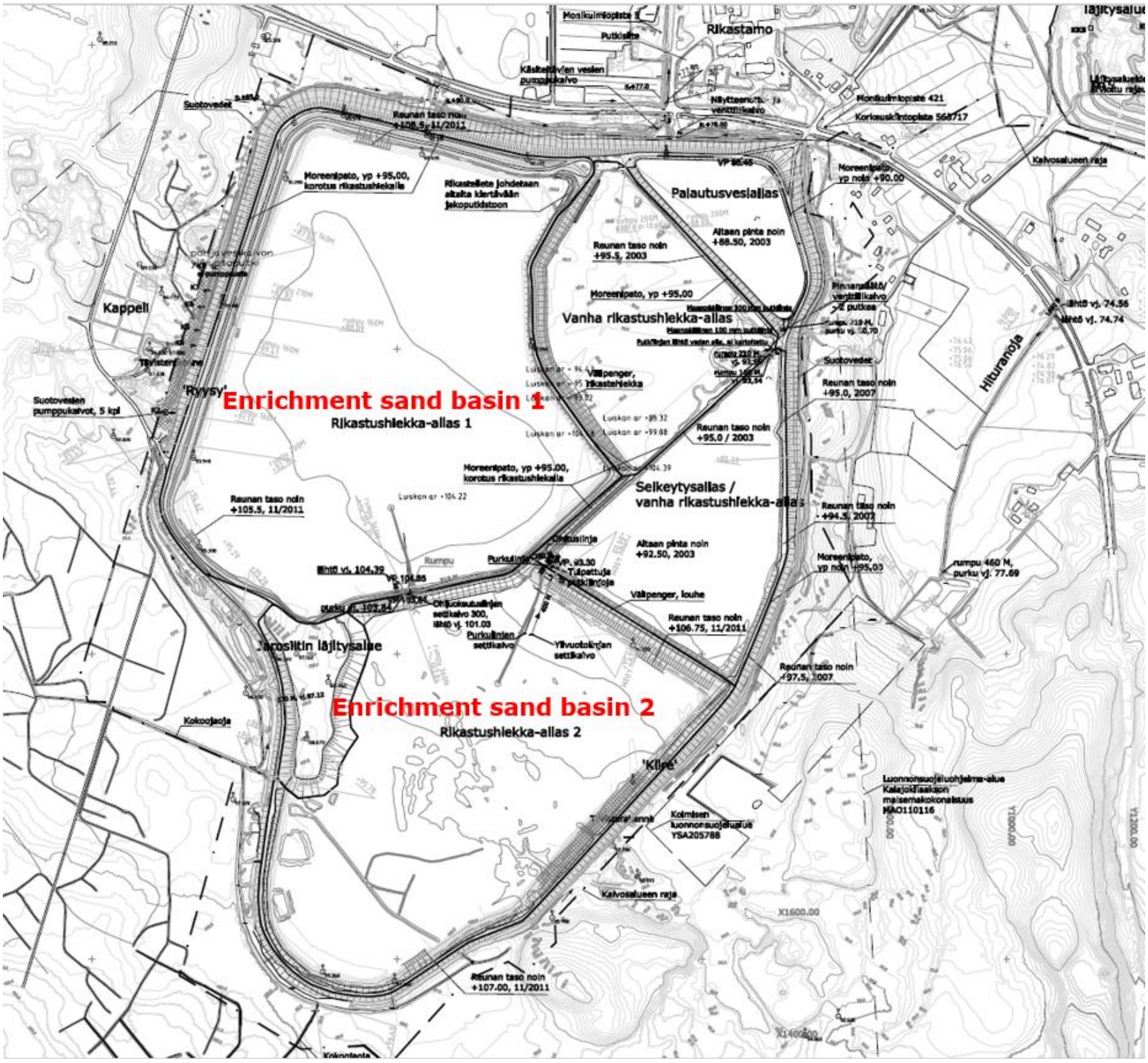

Figure 2. Hitura enrichment basins.

1.2 Project proposal

Piloting of the cover structure is part of the UPACMIC project action B1 Piloting. According to the project proposal, the objective of the action is to demonstrate the practical implementation of the sustainable and eco-efficient mine closure process based on materials (action A3) and applications (action A4). The objective is to promote the utilization of industrial by-products with the possibilities existing in European countries in relation to mine construction with common alternative construction materials.

In the proposal the cover structure piloting was described as following:

Demonstration site will be the cover structure for an old tailings heap in Hitura mine. The area of the site is 117 ha. An impermeable sealing layer, with oxygen diffusion barrier properties (goes hand in hand with low hydraulic conductivity), is constructed to create a shield over the underlying sulfate mineral rich tailings heap. The high alkalinity and rich Ca-content of the material are beneficial for achieving a functional impermeable buffering layer. The construction method of layer stabilization is demonstrated, tested and further developed. In addition, the cover structure includes, a vegetation cover constructed out of composted sludge or sludge from water treatment plant.

In the proposal the following constraints and assumptions were recognized related to piloting construction:

1) Local contractor partners need to respect the construction specifications and applied methods, in order for proper implementation of piloting. Contractors are guided and instructed properly.

2) For smooth construction on top of the tailings heap, materials and heavy machines need to find proper storage and construction area. Preliminary, different kinds of artificial storage areas, or supporting work roads could be constructed on top of the tailings heap.

3) Earth construction with industrial by-products, contains similar risks to constructing with clay materials. Heavy rains can cause increased risk for proper compaction, material blending and storage. The total halt of 1 month in 5 years is assumed during the project duration. In order to protect materials, they can be clamped or even covered against the rain. The open-air storage is focused in depth in action B4 (logistical model). Also, the possibility of halting material transportations, should be taken into consideration. Also heavy rains may create problems, when moving on top of the tailings heap. Extra water may create a problem, since the extra water need to be runned of the surface.

Expected results according to the project proposal are (for all planned three applications; bottom and cover structures and reactive dam):

It is expected that 3 engineering applications determined and planned in the previous actions will be constructed during the duration of this project. This will allow for the 75 % savings in the overall use of the virgin materials required for the construction purposes and allow for their substitution with innovative waste mixtures as secondary materials. This will also result in the diminished amount of the landfilled waste in Finland as otherwise most of the waste streams planned to be used in this project would be landfilled.

It is expected that the demonstrative piloting will create plenty of valuable information to disseminate around the mining industry, contractors, scientific community and legislators. However, the following key results are expected.

1) The superb qualities of intelligent by-product mixtures, and their applicability to mining remediation targets.

2) A direct result of how to use deep mixing technology to insert reactive waste materials to reactive dam structure.

3) A direct result of how to use layer stabilization technology to construct functional sealing layers.

4) Huge masses of materials are transported into mining area. Best practices of handling capacity and open space issues for materials and machines, transportation inside the site and open-air handling of materials, are verified.

5) State of the art information of applicability of single-unit/multi-feeder system prototype to alternative material blending, and alternative construction material development.

Four technical reports will be written about each of the pilots and a summarizing final report of all the experiences of the mine remediation with alternative construction products

2. MATERIALS AND STRUCTURES

2.1 Original structure of moraine

Initially the seal course (cover structure) was designed to be made of approved mineral material such as dry crust clay, silt or silt moraine. The requirement was that the layer is homogenic and the water permeability value is k ≤ 1,0 x 10^{-8} m/s. The total thickness of the compaction layer is ≥ 200 mm (see Figure 3).

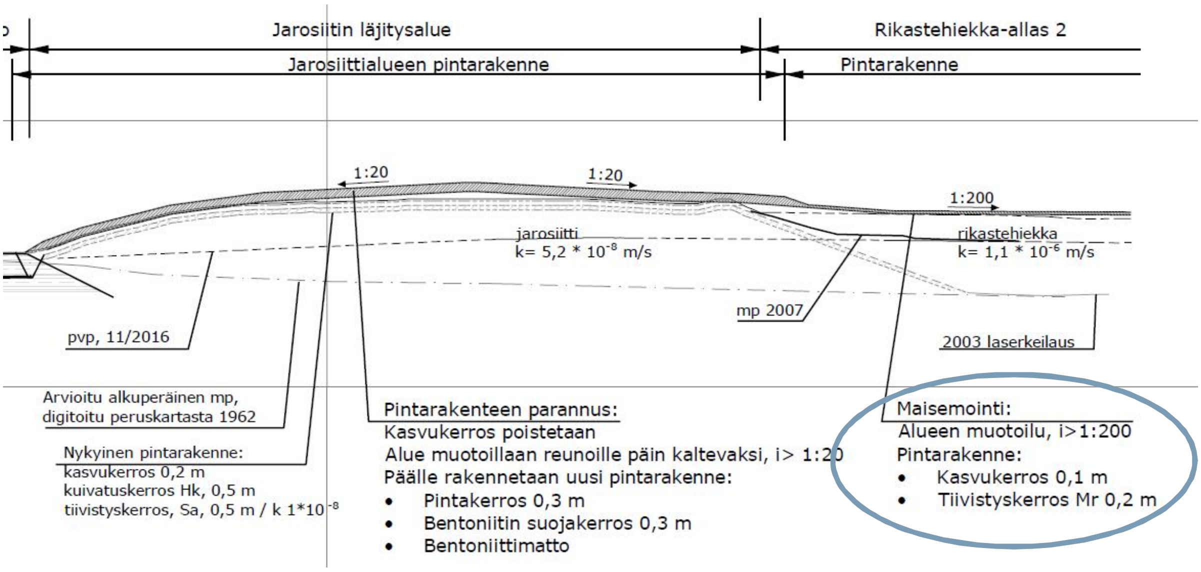

Figure 3. Initial structure made of 0,2 m moraine layer.

The requirements for the finalized structure are presented in Table 1.

Table 1. Requirements for the finalized structure.

Qualification	Method	Quality requirement	Frequency
Layer thickness, location and level	Tachymeter, precision GPS, 3d equipment	≥ 200 mm +50 mm/-0 mm	ready cover to 20 x 20 m square and breaklines (top and bottom sides of the slopes, ditches, etc) 5 m gaps
Levelness	4 m straight edge and visual estimate	± 50 mm, no water collecting depressions	1 per 400 m^2

Water permeabilities are determined in the laboratory according to the standard ASTM D5084 with soft wall permeability test. Only the essential results of the fibre clay preliminary tests are reported in this report.

Preliminary tests and quality requirements for the mineral material are presented in Table 2.

Table 2. Requirements for the mineral material.

Characteristics	Method	Quality requirement	Frequency
Grain size distribution, maximum grain size, homogeneity	SFS-EN 933-1 CEN ISO/TS 17892-4:fi	Dmax ≤ 32 mm, normative below the film ≤ 8 mm	≥ 2 samples
Fine particles (< 0,063 fraction)		≥ 20 %	
Clay content (< 0,002 fraction)	hydrometer/sedigraph CEN ISO/TS 17892-4:fi	≥ 14 %	
Water content	Oven drying CEN ISO/TS 17892-1:1, SFS-EN 1097-5	≥ plastic limit	
Organic content	Combustion method GLO-85 of < 2 mm fraction in 550 °C	< 2 %	≥ 1 sample
Natural state unit weight	CEN ISO/TS 17892-2:fi		≥ 1 sample
Optimum water content and maximum dry density	Improved Proctor test		≥ 1 sample (5 water contents)
Water permeability (k-value)	Constant pressure test CEN ISO/TS 17892-11:fi	$k < 10^{-8}$ m/s	≥ 1 sample
Dry shrinkage	Volume shrinkage, ASTM D4943		

Compactivity requirement (dry density) is determined on the basis of preliminary tests and test field. Compactivity results are followed with quality control tests.

The surface of seal course is levelled even for example with vibrating roller. It is forbidden to drive over the finished surface with such equipment that can cause deformations to the surface or loosening of the material.

When constructing the mineral seal course, the temperature has to be over +5°C and mineral seal course must not be constructed when it is raining. The material to be compacted must not be frozen and it must not contain any ice or snow. When the mineral seal course is finalized, it must be protected from drying. The sludged/disturbed material during the construction must be removed.

2.2 Fibre clay characteristics

Fibre clay is produced as a residual material in paper recycling process in Paper industry. Fibre clay is easy to modify and it is a light material with good resistance for deformations. It is a weather proof material, so it can be transported and stored already in winter at its construction site.

Fibre clay (Mänttä, Finncao) has water permeability between $k= 1 \times 10^{-9}$ m/s - $k=1 \times 10^{-8}$ m/s. The environmental eligibility has been analysed and despite of the process materials, all the generated fibre clay fills earth construction and land fill requirements.

Fibre clay has been used several decades in landfill liners as cover and bottom structures. In addition, references can be found in shaping of ski slopes, bicycle and pedestrian lane structures, exercise path structures and encapsulating contaminated soils. Most recent applications are golf course structures and field structures and different types of embankments and barriers.

NOTE: This material information concerns only fibre clay from Metsä Tissue Mänttä pulp. Other fibre clays have not been productized.

Fibre clays from Äänekoski, Mänttä and from Oulu (called OPA-sakka) were tested for compactibility, water permeability and environmental properties and the conclusion was that all of those are suitable to use for sealing the enrichment sand basins (see the following chapters for test results). Figure 4 shows fibre clay at the construction site.

Figure 4. Fibre clay in Hitura construction site before used in the piloting structure.

2.3 Fibre clay utilisation in Hitura Mine

Fortum offered the UPACMIC solution where moraine (requirements described in previous chapter), that would normally be used for sealing the enrichment sand basins, would be substituted with fibre clay.

Two different statements were given for the fibre clay suitability for the intended use in the mining environment. Both statements showed that fibre clay can be used for sealing the enrichment basins and it is even better than the conventional mineral material. Mineral material has water permeability value $k = 1x10^{-8}$ m/s and fibre clay has lower, $k < 1,0x10^{-8}$ m/s and thus the water movement through the structure is more restrained/not much water if all, seeps through the fibre clay structure. The statements were given by the companies Ramboll and Envineer.

In table 3 the characteristics of three different fibre clay materials are presented and compared to the values given in the national Decree 214/2007 Government Decree on the Assessment of Soil Contamination and Remediation Needs. None of the values exceed the presented limits.

Table 3. Properties of tested fibre clays compared to threshold values of the Decree 214/2007.

Element	Unit	Fiber clay Mänttä, sample I	Fiber clay Mänttä, sample II	Fiber clay Mänttä, sample III	OPA sludge, sample I	OPA sludge, sample II	Fiber clay Äänekoski, sample I	Fiber clay Äänekoski, sample II	Natural content*	Threshold value*
Mercury, Hg	mg/kg	<0,10	<0,10	<0,10	<0,10	<0,10	<0,17	<0,15	0,005	0,5
Arsenic, As	mg/kg	<2,3	<1,7	<1,4	<0,86	<1,3	<4,2	<3,7	1,0	5,0
Cadmium, Cd	mg/kg	<0,23	<0,17	0,14	<0,086	<0,13	<0,42	<0,37	0,3	1,0
Cobolt, Co	mg/kg	2,3	2,3	1,8	0,51	0,25	0,53	0,4	8,0	20
Chrome, Cr	mg/kg	18	19	15	5	<6,3	<21	<19	31	100
Copper, Cu	mg/kg	99	90	89	4,7	<6,3	<21	<19	22	100
Nickel, Ni	mg/kg	6,1	6,8	5,8	2,5	2,1	4,4	<3,7	17	50
Lead, Pb	mg/kg	<12	<8,5	<6,9	4,4	<6,3	<21	<19	5,00	60
Antimony, Sb	mg/kg	<2,3	<1,7	<1,4	<4,3	<6,3	<21	<19	0,02	2,0
Vanadinium, V	mg/kg	10	9,5	8	2,2	1,7	<4,2	<3,7	38	100
Zinc, Zn	mg/kg	29	24	22	9,8	11	<21	<19	31	200
Chlorine, total content	% average	<0,18	<0,12	0,11	<0,070	<0,070	<0,070	<0,070		
TOC	% average	23	25	21	11	11	21	21		

The design was changed so that the initial 0,2 m moraine layer (Figure 3) was substituted with 0,25 m fibre clay layer (Figure 4) (Annex 1).

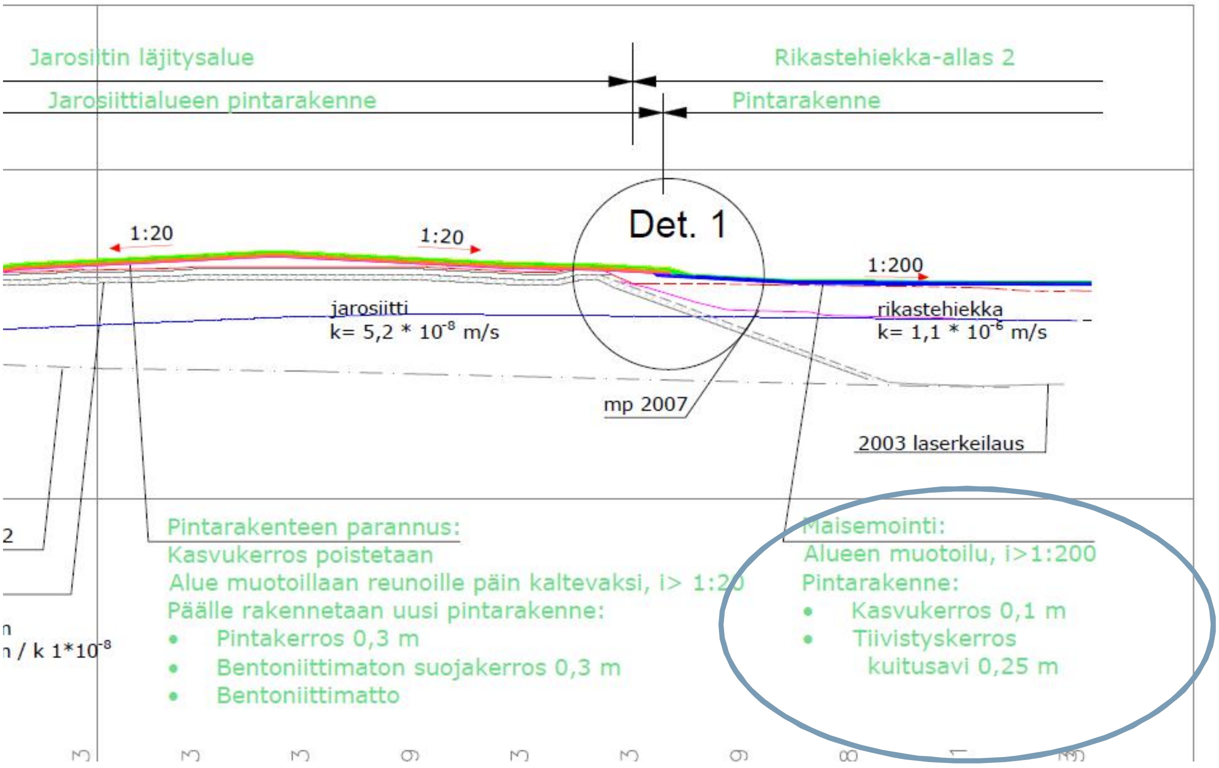

Figure 5. Modified structure where 0,2 m moraine layer is substituted with 0,25 m fibre clay layer

2.4 Test structure for Mänttä fibre clay

In order to ensure the usability of fibre clay, a test field was constructed on 14th September 2017 by utilizing fibre clay from Metsä Tissue Mänttä. The size of the test field was approximately 10 m x 20 m and the bottom of the field was equivalent for the actual structure. The seal course was constructed as one layer, and the compacted thickness was 250 mm. The fibre clay was spread by using 20-30 t crawler excavator. When driving over the seal course (fibre clay) the amount of overdriving was varied in order to determine the needed compaction work for the target dry unit weight (445 kg/m^3). The compaction of the structure was followed with Troxler measurement and the achieved water permeability value is $k < 1{,}0 \times 10^{-8}$ m/s. The results are showed in Table 4.

Table 4. Measurement of test structure characteristics, Mänttä fibre clay.

Troxler points	Over driving times (back and forth)	Layer thickness (mm)	Dry density (kg/m³)	Wet density (kg/m³)	Water content (%)
1-5	1	320	441	1200	173
6-10	2	290	475	1222	162
11-14	3	280	542	1248	131

Five water permeability samples were taken from the test fields. The test samples were prepared in the laboratory by ICT compactor, target compactivity was wet density 1200 kg/m³ and it was exceeded as the dry density after three over driving times was 1248 kg/m³. Water permeability was measured with two unequal gradients, 31 and 5. There were no significant difference between the two used gradients. Sample point TRX6 was tested parallel determination by using gradient 5. There was no difference between gradients.

All tested five water permeability samples fills the requirement $k \leq 1 \times 10^{-8}$ m/s. See table 5 for the tested results.

Table 5. Water permeability results.

Sample	Wet density (kg/m³) before test	Wet density (kg/m³) after test	Dry density (kg/m³) before test	Dry density (kg/m³) after test	Gradient	k (x 10^{-9} m/s)
TRX 1	1201	1067	447	442	31	7,3
TRX 8	1199	1057	445	454	31	5,5
TRX 14	1203	1072	447	452	31	5,8
TRX 1	1208	1075	449	457	5	9,0
TRX 6	1207	1065	453	448	5	7,5
TRX 6 (parallel)	1210	1061	454	495	5	7,6
TRX 8	1201	1037	446	437	5	4,5
TRX 11	1213	1030	467	460	5	7,6
TRX 14	1204	1059	447	450	5	5,6

2.5 Test structure for OPA fibre clay

Test field for OPA fibre clay was constructed on 22nd May 2018. Layer thickness of the compacted sealing course according to the plans was 250 mm. Test field was constructed as one layer which was compacted with 1-3 back and forth driving with excavator. Water permeability requirement was the same $k<1,0 \times 10^{-8}$ m/s.

The average dry density with minimun three back and forth driving was 960 kg/m³. Two test specimens were made from the test field structure, dry densities 860 kg/m3 and 989 kg/m³. Both specimens filled the water permeability requirement $k<1 \times 10^{-8}$ m/s. Results are presented in Table 6.

Table 6. Measurement of test structure characteristics, OPA fibre clay.

Sample	Over driving times (back and forth)	Dry density (kg/m^3)	Wet density (kg/m^3)	Water content (%)
TRX1	3	860	1287	49,6
TRX2	3	970	1463	50,8
TRX3	3	985	1441	46,3
TRX4	3	999	1445	44,6
TRX5	3	1004	1404	39,9

2.6 Test structure for Äänekoski fibre clay

Test field for Äänekoski fibre clay was constructed on 27th March 2018. The structure compaction was started from 350 mm layer thickness. After three back and forth over driving, the layer thickness was approximately 290 mm. After three over drives, the average wet density was 1267 kg/m3, average dry density 492 kg/m^3 and water content 157,9 %. The measurements were made from 150 mm depth.

Table 7. Measurement of test structure characteristics, Äänekoski fibre clay.

Sample	Over driving times (back and forth)	Layer thickness (mm)	Dry density (kg/m^3)	Wet density (kg/m^3)	Water content (%)
TRX1	3	290	489	1257	156,8
TRX2	3	280	493	1272	158,2
TRX3	3	300	493	1272	158,7

The target dry density was 485 kg/m^3 which was achieved after three over drives. Water permeability test specimen was made from TRX3 sample and the result filled the requirement $k<1x10^{-8}$ m/s.

2.7 Pilot structure

During the construction, the densities of the used fibre clays were tested. Density targets were achieved with all used fibre clays (and moraine) (table 8).

Table 8. Realized densities compared to target densities.

Material	Dry density target (kg/m^3)	Realized (average kg/m^3)
OPA-sakka fibre clay	860	976
Äänekoski fibre clay	485	544
Mänttä fibre clay	445	497
Moraine	1985	2181

3. CONSTRUCTION AND FOLLOW-UP

3.1 Fibre clay utilisation

Altogether, fibre clay materials were utilized in 148 850m^2 Hitura I stage construction. The whole compaction layer area in enrichment sand bond 2 was 265 092 m^2 -> 56 % of the compaction layer area in enrichment sand basin 2 was constructed with fibre clay. Map of different fibre clay and moraine areas in enrichment sand bond 2 during Hitura I construction is showed in annex 2.

Moraine structure, as described in chapter 2.1 and moraine areas showed in annex 2, will be used as comparative structure when the follow-up will be done.

Construction with fibre clay did not need any special equipment. The material was levelled and compacted with crawler excavators (figure 6).

Figure 6. Fibre clay utilisation in Hitura did not require any special vehicle or equipment.

3.2 Quality control of the cover structures

Following requirements must be fulfilled:

<u>Fibre clay, compaction layer</u>

Compaction layer is made of fibre clay that is approved for the intended use on the basis of pre-tests. The condition for the use of fibre clay in compaction layer:

- The water permeability $k \leq 1{,}0 \times 10^{-8}$ m/s.
- The basis where fibre clay is used must be bearing and dry
- Layer thickness ≥ 250 mm (+50/-0 mm)
- The levelness/evenness of the compaction layer is constantly visually estimated. The requirement ±50 mm and no depression for collecting water.
- The compaction requirement (dry density requirement) is determined according to the preliminary tests and test field results

- The compaction layer is compacted with the suitable equipment. Surface of the layer is levelled even. On top of the finished layer/coating must not be driven with machines that can cause deformations on the top or loosing material from the coating.

3.3 Follow-up

The cover- structures will be monitored with lysimeters which will be installed during autumn 2019-spring 2020. One lysimeter is installed per structure and the lysimeter locations are showed in the annex 2. The purpose of the lysimeter monitoring is to verify the structural functionality (low permeability) of the structure. This is carried out by measuring the amount of permeable water. This is a plan and it is possible to use other possible monitoring methods.

4. IMPACTS

4.1 Environmental benefits

Approximately 80 000 tons of natural moraine has been saved during the cover structure construction in Hitura mine. Moraine is coarse soil type through which the rainwater and melt water filtrates, generating ground water (see Figure 7). The cover structure piloting was part of a bigger construction work in order to have comparative information on the work methods and structures. In addition, above the cover structure in the soil layer, industrial secondary materials such as branch chips and decomposition residue are used, and this also has saved natural soil materials ~5000 m^3.

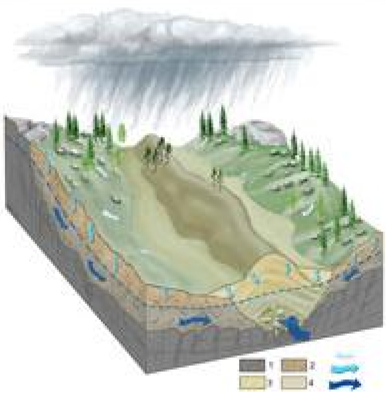

Figure 7. Groundwater formation 1) solid rock, 2) moraine, 3) esker formation, 4) sediments of fine sand and silt. (Reference: Geological Survey of Finland).

These natural esker formations are important ground water formation areas and if the aggregate material from the eskers are utilized, nothing can bring back these formations. This kind of use of alternative use materials is very important especially in Finland, as we use approximately 15,5 tons aggregates per capita according to the Finnish Environmental Institute. This rate is one of the highest in Europe due to abundant reserves of aggregate materials in Finland. We find this one of the key aspects and of the UPACMIC project objectives.

Fibre clay structure is technically better structure than moraine structure, as fibre clay has lower water permeability which is important in this kind of use. If fibre clay would not be used for construction purposes, the material would be combusted as it is expensive to storage large amounts of material. As fibre clay does not have actual proper heat value due to high water content, it is important to find utilization for fibre clay from the resource efficiency point of view.

Expected results of the UPACMIC project is to save in CO_2 emissions, but at this stage of the project the savings are not calculated yet. This information will be produced later in the Verification stage when the streamlined LCA/LCC calculations are done.

The use of recovered/recycled/alternative materials is 'reuse' according to the Waste Framework waste hierarchy (Directive 2008/98/EC). In case fibre clay would not be used in this kind of application, the material would be utilised in landfill structures but as the number of landfills is to be decreased, old ones are shut down and no more new landfills are based, new innovations for the material is needed.

4.2 Long-term benefits and sustainability

Cover structure has been constructed by utilising partly dried fibre clay (fibre suspension), which is a paper industry by-product. Fibre clay has been used in landfill sealing layers for a long-time, but now it has been used for the first time in the mining environment.

Fibre clay is easily workable and light material and has a good resistance against deformations. The material does not crack when drying, as does some natural soils. This will help fibre clay to maintain the low water permeability, which is essential to keep the structure functional. The material can be transported and stored to the construction site already in the winter time, so the material ready for construction purposes as soon as the soil frost has melted in spring.

In Hitura Mine, three different fibre clays (from different plants) has been used. The UPACMIC method has brought good reputation for the Hitura Mine. In the surroundings of Nivala, where Hitura mine locates, many people lost their jobs when the mining company went to bankrupt. Now the construction activities to shut down the mine has brought vitality to the area as the construction workers have work and the local hotel & restaurant has customers on a daily basis.
Experiences from the cover structure piloting has brought especially for Fortum new know-how and the company can refer to the project when negotiating with new opportunities.

Long-term benefits and sustainability will be complemented as the project progresses with the bottom and reactive dam structures. The follow up results will be reported in "Final report – Quality control"

4.3 Financial notes

For confidential reasons, actual prices are not given in this report but according to Fortum, fibre clay structures were approximately 55 % more expensive than used moraine structure. The costs used in the comparison included only the transportation of materials in working site with loader, spreading of materials with bulldozer and excavator and compaction with vibratory roller. The timing was also one challenge with fibre clay as it needs to be spread and compacted as soon as possible after it was delivered to the construction site. The fibre clay was transported close to the site with trailer lorries and unloaded. The material was transported from the unloading area to the site with loaders. The transportation was carried out mostly during winter time which increased the road maintenance costs in the site.

The transportation distances for fibre clay from over 100 km raised the costs of fibre clay construction compared to moraine. Moraine was purchased from the nearby locations, but even moraine availability was poor due to high quality requirements. The cost evaluation does not include the landfilling fee or waste tax that material producer would have need to pay, if the material would have been landfilled instead of utilization. The waste tax alone is 70€/ton in Finland.

The transportation distance is important factor to be considered with industrial by-products when evaluating financial and environmental effect of structure. The long transportation of large volume of materials increases both costs and emissions and therefore decreases the positive effects compared to use of virgin raw materials. In this project, the fibre clay was transported on purpose longer distances so that the piloting was possible to carry out. The utilization of industrial by-products can bring cost savings via reduced waste taxing when waste material is utilized and is not considered as waste and it is not under waste tax regulations. In addition, in some cases the material needs for industrial by-product-based structures can be lower compared to virgin raw material structures (thinner structural layers).

Although working with fibre clay was somewhat challenging compared to moraine, there were no crushing needs as with moraine.

5. DISCUSSION

Points that came up during the construction work:

- Actual construction with the compaction materials (fibre clays) worked out well.
- Covering the levelled and compacted fibre clay must be done immediately with soil, otherwise the fibre clay will dry out
- It is important that the measurer follows the material amount during the construction works
- Greatest challenge on the use of fibre clay are long transportation distances and routing of the transportation vehicles in the construction area
- Constructing fibre clay structure is optimal in dry circumstances. Raining can disturb and interrupt the construction works.
- When the weather circumstances, foundations and vehicle functionality are at their best, the work performance can be approximately 1 hectare per working day (12 hours) of 250 mm fibre clay and 200 mm moraine

When writing the proposal, it was foreseen to construct an impermeable sealing layer with low hydraulic conductivity (k-value) to be constructed over underlying sulfate mineral rich tailings heap. According to the proposal, layer stabilization method would have been demonstrated with this pilot structure but as the constructing took place with fibre clay, there were no place/reason to use layer stabilization method. In the proposal it was written that the cover structure includes also a vegetation cover constructed out of composted sludge or sludge from water treatment plant. Now in Hitura, the soil layer was made of branch chips and decomposition residue. This soil layer from industrial secondary materials (forest industry) has save natural soil materials approximately 5000 m^3.

Issues that came up during the construction concerning the utilization of fibre clay, do not differ much from the recognized constraints and assumptions written in the proposal. It is important to respect the given instructions and the circumstances, logistic and storage play an important role to succeed in the fibre clay utilization. Especially the transportation distances for industrial by-products has major influence on the cost-effectiveness of the construction and it should be evaluated on case by case.

Utilisation of alternative materials will also bring positive impact for the mining industry which has been many times on a negative spotlight because of various environmental related problems. For the European competitiveness it is important that mines have environmentally and economically safe surroundings to operate.

UPACMIC project brings together different industries, such as paper and forest industry with mining and construction industries. Co-operation is essential to create solutions together and to efficiently as possible take steps towards resource efficiency.

New Government Decree (843/2017) on the recovery of certain waste in earth construction has come to effect in Finland starting from 1st January 2018 and the results of the UPACMIC project will also improve know-how and awareness of the alternative material (waste) utilisation in earth construction applications.

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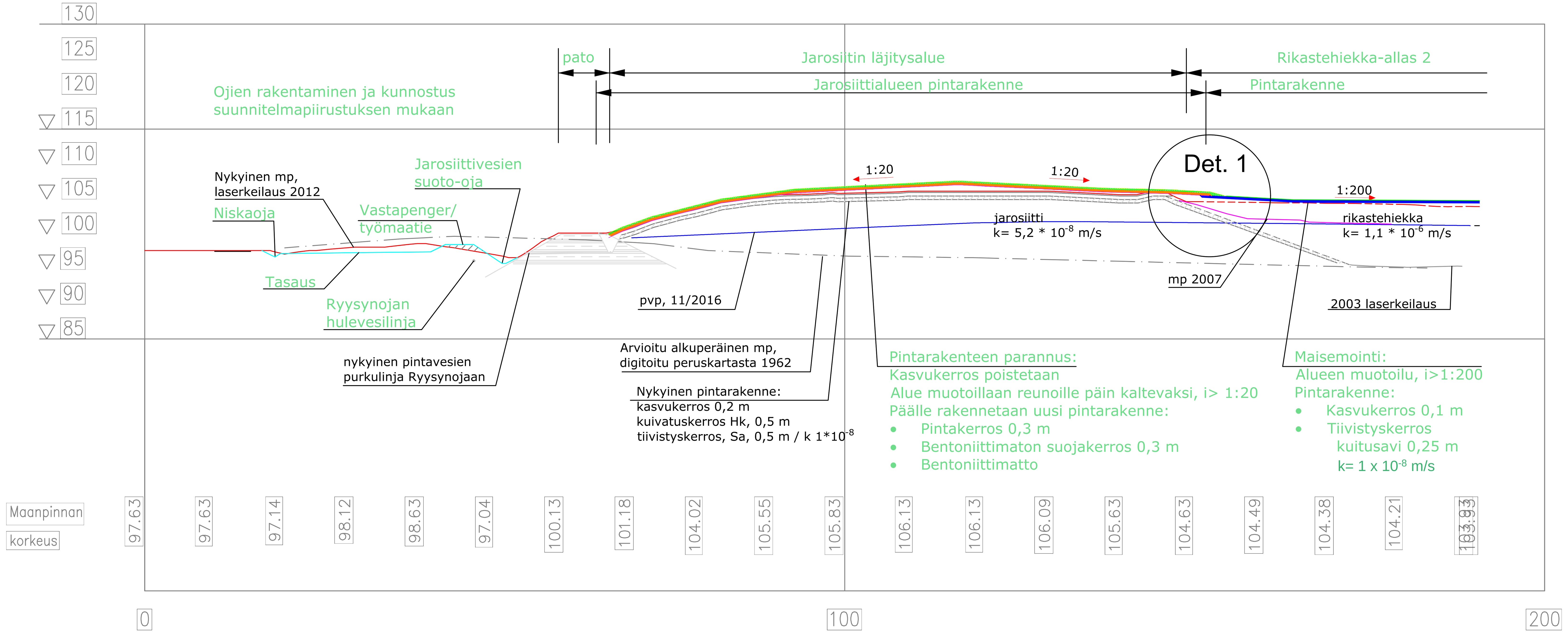
ANNEX 1. Cross section of fibre sludge cover structure

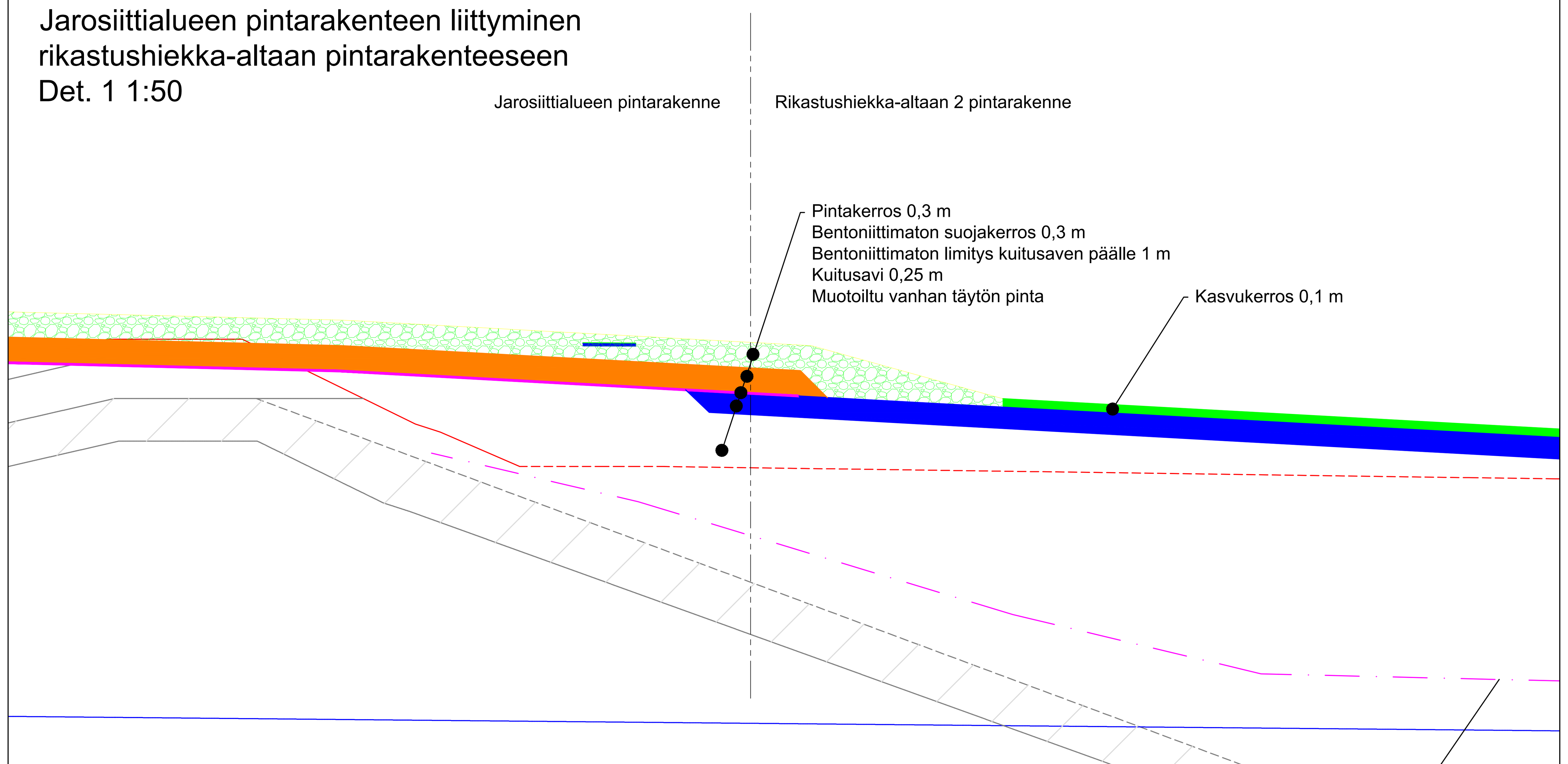
1:500

Leikkaus 1



Jarosiittialueen pintarakenteen liittyminen rikastushiekka-altaan pintarakenteeseen

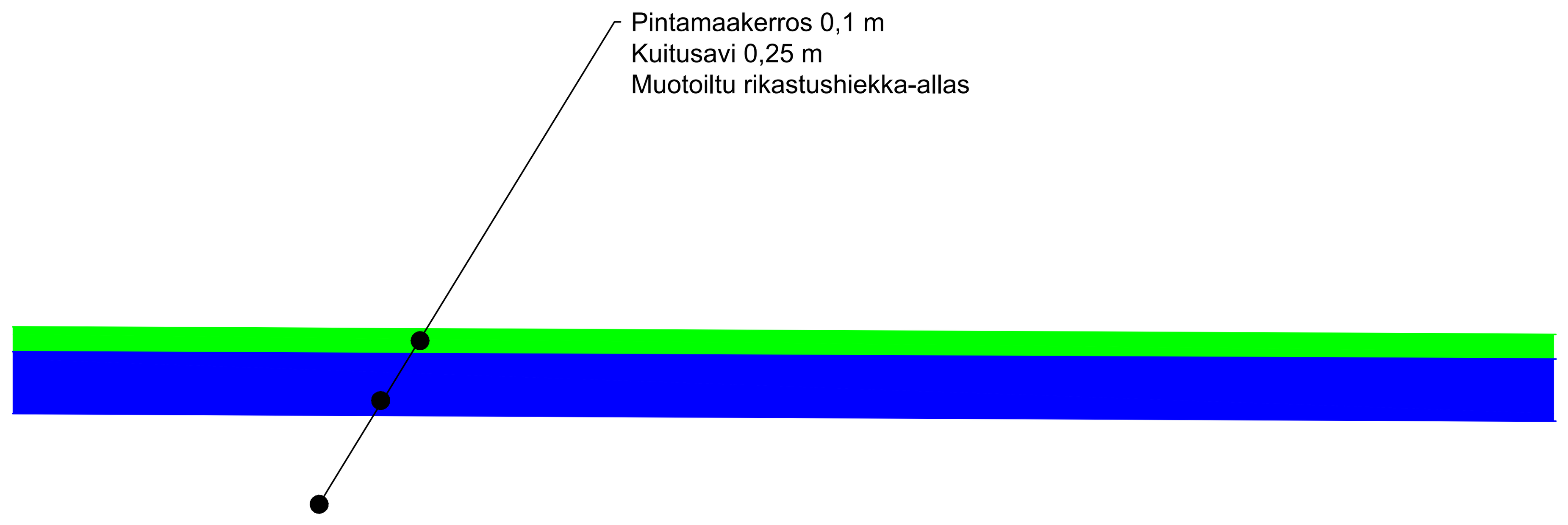
Det. 1 1:50



Bentoniittimaton peittosyvyys vähintään 0,6 m joka paikassa

Rikastushiekka-altaan peitto

Tyyppileikkaus 1:25



Kuitusavi
Metsä Tissuen Mäntän tehtaalta
$k < 1 -- 5 \times 10^{-9}$ m/s, vaatimus $k < 1 \times 10^{-8}$ m/s

Rev.	Muutos	Tekijä	Pvm

Fortum Environmental Construction Oy
Kuulojankatu 1
FI-11120 Riihimäki
+358 10 7551 000

K.osa/Kylä | Kortteli/Tila | Tontti/Rn:

Viranomaisen arkistomerkintöjä

Rakennustoimenpide

Piirustuslaji
POIKKILEIKKAUS

Rakennuskohteen nimi
POHJOIS-POHJANMAAN ELY-KESKUS
HITURAN KAIVOS
RIKASTUSHIEKKA-ALTAIDEN SULKEMINEN

Piirustuksen sisältö
RAMBOLLIN LEIKKAUS 1
PÄIVITETTY KUITUSAVIRAKENTEEKSI

Mittakaava
1:500
Paperikoko
3xA3

Suunnittelija ja pvm
Vesa Jokinen 17.7.2017
+358 400 973 849
vesa@voj-infraplanning.com

Piirustusnumero ja revisio
5371-101
5371 Hitura työsuunnitelma.dwg

Koordinaattijärjestelmä

Korkeusjärjestelmä

ANNEX 2. Piloting area map and lysimeter locations