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GM and GCL seal a dual-layer drainage system yielding an environmentally compatible "railway canal" foundation

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ABSTRACT: The aim of this study, is to publicise how the Railroad Authority of Sweden (Banverket) (RRA/BV) can "bridge the gap" between society's demand for new railways and the impact such structures have on the environment. Technically the issue is to define a reliable way to control water run-off at a pertinent part of the West Coast Route railway (VKB) intersection (2 km); a valuable groundwater resource in the city of Helsingborg.

1 INTRODUCTION

In the early 1990's, the RRA/BV commissioned KM, now J&W, to plan and design new double tracks for the VKB between Helsingborg and Kaevlinge.

Comprehensive studies of three alternatives for the route resulted in the choice of the one most convenient from a passenger point of view, as well as general traffic economy.

Unfortunately, the chosen route would pass over the "on line" groundwater resource constituting the production well for the waterworks in Helsingborg (Figure 1).

Consequently, completion of the chosen route would only be possible if the RRA/BV took full legal responsibility concerning all future risks of harming the above-mentioned resource.

2 CONCEPTUAL DESIGN

In the design phase of this project, the City Council of Helsingborg, operator of the waterworks, required an "extraordinary" factor of safety with respect to the function of the groundwater protector described herein. The city stipulated that the rubricated system be repairable, accessible for inspections, and functional for a minimum of 100 years.

After reviewing previous single and composite liner applications in similar cases throughout Sweden, a technically "simple" yet reliable monitoring system, including a state-of-the-art CQA with focus on installation construction, was incorporated.

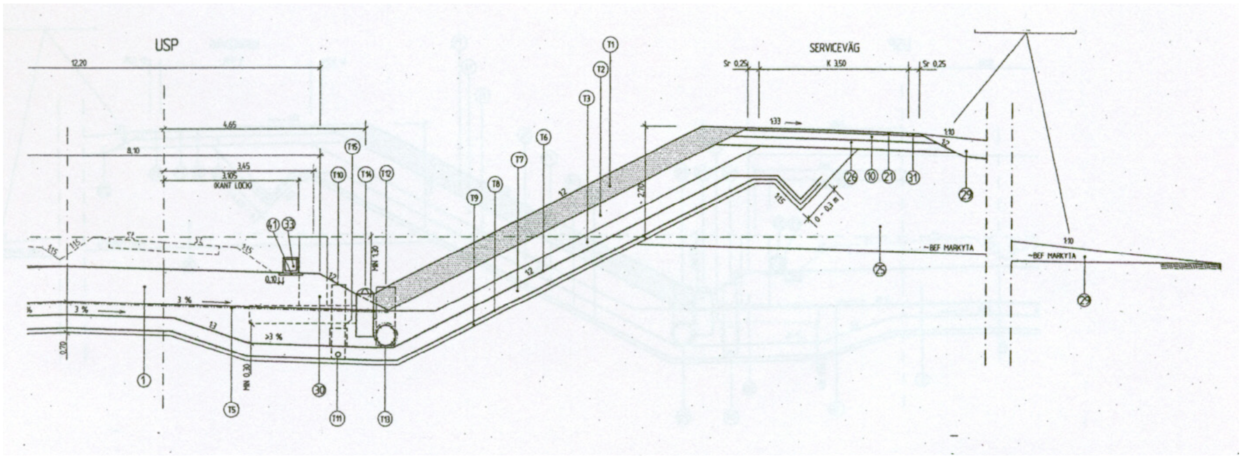
Figure 1. Plan of railway and reference legends (Morfeldt & Odemark, 2001).

3 DETAILED DESIGN

The layout and composition of the so-called "dual-layer" drainage system is illustrated (Figure 2). Included in the illustration and figure legend is a brief technical specification describing all project specific materials and quantities.

Combined, the machine and feeding device enable a complete "off subbase" placement of the heavy construction excavator (CAT). As well, it decreases the formation of folds resulting from the repositioning of the GCL panels; a common problem when using less "rigid" standard spreader bars.

CROSS-SECT. IN CUT



<u>CONSOLIDATED QTY:S</u>
HDPE (TEXTURED – 1.5mm) 90.000m^2
GCL (BENTONITE)) 60.000m^2
CONTROL WELLS c/c 60 m 48 pcs

- T1&T2. Slope liner protection of gravel/macadam (0.8-0.9 m)
- T3. Protection layer of sand.
- T5. Separation layer of geotextile.
- T6. GM (upper layer) of textured HDPE (1.5 mm).
- T7. Control layer/drain-layer of well graded drainage sand (0-20 mm and 0.3 m thickness.
- T8. GCL (lower layer) with bentonite content equal to 4.8 kg/m^2 and hydrated during phase of construction.
- T9. Levelling layer of sand holding thickness of ≥0.1 m.
- T10. Inspection well for control drainage of PE and ∅350 mm. c/c approx. 60 m.
- T11. Control drainage of PE and dim. DR 110/99 mm.
- T12-T14. Run-off-drain water wells and pipe.
- T15. Control well penetration in form of prefabricated collar of HDPE (textured/1.5 mm), ∅~1.0 m, type MGAB Prefab

Figure 2. Typical detail of the drainage system, corresponding description to legends T1-T15.

3.1 *GM and GCL installation method*

The contractor, NCC, in co-operation with MGAB (lining consult), evaluated a number of project specific factors such as wind loads, required capacities (production per day), subbase (terrace) bearing ratio, and slope inclination, against choice of installation resources capable of mitigating forces destructive to GCL, HDPE, and foundation terrace during construction. Taking this into consideration, NCC developed and built the dual layer drainage system illustrated in a different size. However, identical design units were used, including a precision manoeuvrable hydraulic driven roll feeding device mounted on a CAT 330L by means of being hooked to the bucket on the extended twenty meter excavator arm.

The composition of these two units, and also their performance in the field, is illustrated in figure 3.

Referring to the cross section in figure 2, the relevant measures give a required reach length of approximately 17 meters for the suitable extension of the CAT arm.

When working with the goal of "off subbase" conditions, a slightly different approach was applied when selecting equipment for the placement of the 43 meter long panels.

In this case, the same CAT 330L carrying the large roll feeder (allowing 6.8 m roll width), stood on the west side of the "railway canal" feeding the membrane. In addition, a pulling wire connected to, and winched by, an agriculture tractor on the east side enabled a controlled installation of the HDPE panel across the breadth of the lined area.

Figure 4 illustrates the as-built condition regarding the GM part of the works.

Other topics with respect to installation, such as welding and testing, have been omitted as they are beyond the scope of this study. All aspects of installation and testing, however, were carried out respecting established technology and using state-of-the-art methods.

Figure 3. Shows the roll-feeding device.

Figure 4. Illustrates the as-built condition regarding the GM part of the works.

3.2 *The hydration and swelling of the GCL was accomplished solely by exposure to precipitation*

Due to the design of a "dual-layer" drainage system, the position of the GCL required pre-hydration before commencement of the HDPE installation.

The general work plan included a man-made process in the form of using various sprinkling systems to accomplish a "fully hydrated" GCL.

Possible reduction or in the best case full compensation of the above-mentioned process was to be assessed by measuring the pertinent total amount of precipitation during the "gap" of time in between the GCL and HDPE installation.

Consequently, a site and design specific experiment was performed in order to adapt a guideline yielding the impact of the weight of the GCL exposed to three different simulated precipitation loads evenly distributed over the length of June 1998.

Figure 5 illustrates the general relation between the amount of water absorption and the achievement of the GCL's ultimate hydrated weight.

Also included in figure 5 is the real amount of precipitation recorded at the site during the above-mentioned "gap" in time in June 1998.

Further, a destructive test was performed on a sample taken in the upper most part of the steepest and lined slope (1:2).

The results from the above work confirm that this study represented a "fully hydrated" GCL.

3.3 *Water balance in control layer*

Long-term control of the water balance in the monitored layer is performed on a continuous basis by Hbg waterworks. The results from these observations are presented in a table-diagram form in figure 6. In order to control the function of upper liner, Hbg waterworks implemented a monitoring program of the water balance in well sump every two weeks. The results in this paper covers the time period from 2000-01-01 through 2001-09-30.

The overall run off area is symmetrically divided along the centre line of the railway into an east respectively west sub-area each holding 24 pieces of control wells (c/c)/60 meter and positioned according to cross section in figure 2.

The bottom of well number 1 represents the lowest level of the "railway canal" foundation.

Its position as a "dead end" of the flow path along the inclined foundation entitles well number 1 to become the prime control object in this study.

Knowledge of the drainage system behaviour during the monitored period were all achieved through an assessment of compiled data in figure 6 which yields the requirement of a permanent incorporated control and maintenance program for the system.

Since September 30, 2001, the RRA has included these tasks in their railway service program for VKB.

Estimated and Real Monthly Precipitation

	Simulated tests			Real value Precip. June 1998 Hbg
(mm) per 30 days	25	40	55	119.4*
x dry weight	2.2	2.1	2.2	2.0*

Source: Hbg waterworks.
Note that the GCL* sample was taken in the most unfavourable position concerning hydration of the liner.

Figure 5. Guideline of hydration and swelling.

4 CONCLUSIONS

Groundwater protection by means of a Geosynthetic Civil Engineering system yields a cost effective measurement in this case study.

The above statement is based on a comparative study with an initially proposed alternate conceptual design comprising a "concrete canal" in the form of an "open-top" cut and cover tunnel to secure the discussed part of the railway.

Finally, we include a typical view along the completed product in figure 7.

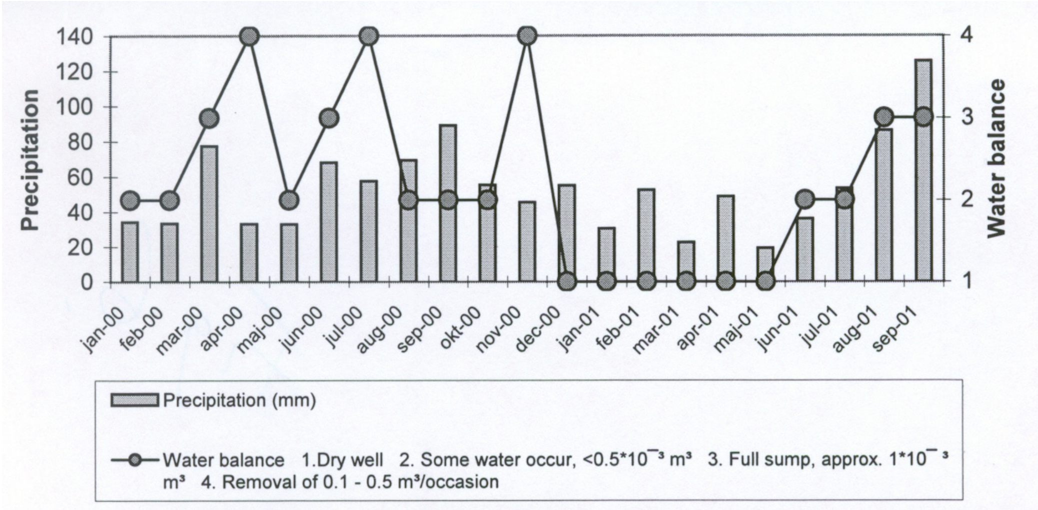


Figure 6. Chronological linking of precip. and water balance in control well (# 1 east). The west area represented dry well condition throughout the observation period 2000-2001.
Source: Hbg waterworks.

5 REFERENCES

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Figure 7. Shows the finished product.