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Oskarshamn site investigation

Complementary slug tests in groundwater monitoring wells February 2006

Subareas Laxemar and Simpevarp

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November 2006

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

A pdf version of this document can be downloaded from www.skb.se

Abstract

The Swedish Nuclear and Waste Management Company (SKB) carries out site investigations in the Simpevarp area. An important aspect in these investigations is to characterise the hydraulic properties of the soil. One way of doing this is by performing slug tests. The principle behind the test is to create a rapid change in the water level, and then measure the recovery back to initial conditions. When the slug is performed by causing a sudden rise of water, and the recovery of water level sinking back to initial conditions is studied, it is referred to as a falling-head test; when a sudden fall of water level is created, it is referred to as a rising-head test. In this activity, the displacement of water level, performed as instantaneous as possible, was generated either by lowering and raising a solid object (a slug), or by adding a known volume of water.

This activity was performed in order to test all groundwater monitoring wells in soil within the investigation area, that have not been tested before October 2005. The reason that the wells have not prior been tested varies. Some have been installed as environmental surveillance of the core drilling program, and the hydraulic properties has then not been the main interest for the well design, others have been dry at the occasion for testing, or have a too narrow diameter for the slug. Accordingly, a considerable proportion of the tests (7 out of 24) has not been possible to evaluate.

For the analysis, data has been matched to type curves both in a computer program, and by hand. In the computer program, no results derives from automatic matching, but from visual matching of type curves. The Cooper-Bredehoeft-Papadopulos method /1/ has been the main evaluation method. Wells with character of unconfined aquifer have also been evaluated with the Bouwer and Rice method /2/. Though the fitting of a straight line in this method often involves a large uncertainty, restrictiveness has been used to choose this method as best choice in the results.

The evaluated transmissivities lie within the range of $3.4 \cdot 10^{-9}$ to $1.3 \cdot 10^{-3}$ m^2/s. The results follow what could be expected according to the geology rather well. The results from slug tests are only describing the characteristics of a small volume around the tested well; hence the values of the storativity are associated with large uncertainties and will not be presented in this report.

Sammanfattning

Svensk Kärnbränslehantering AB (SKB) genomför platsundersökningar i Simpevarpsområdet. En viktig del i dessa undersökningar är att karaktärisera jordlagrens hydrauliska egenskaper. Ett sätt att göra detta är genom slugtest. Principen för slugtest är att skapa en hastig vattennivåförändring i brunnen och sedan studera återhämtningen tillbaka till det statiska förhållandet. En slug skapad genom en plötslig vattennivå höjning, där man studerar hur vattenytan sjunker åter till ursprungliga förhållanden, benämns i denna rapport som ”falling-head test”. Vice versa benämns då fallet en plötslig vattennivåsänkning genereras ”rising-head test”. Vattennivåförändringen, vilken gjordes så momentant som möjligt, skapades antingen genom att en solid kropp (en ”slug”) sänktes ner och drogs upp, eller genom att en känd volym vatten tillsattes.

Denna aktivitet genomfördes i syfte att testa de jordrör i undersökningsområdet som inte testats innan oktober 2005. Vissa jordrör har installerats som miljörör i syfte att övervaka miljöpåverkan från kärnborrplatser. För dessa har inte markens hydrauliska egenskaper varit i fokus och de har därmed inte blivit testade. Andra rör har antingen haft en för liten diameter för att kunna få ner en slug, eller har de varit torra vid det tänkta testtillfället. Följaktligen har en stor andel av testerna (7 av 24) inte gått att utvärdera.

Utvärderingen har gjorts både med datorprogram, men då med manuell passning av kurvor och för hand genom passning av typkurvor till plottad normaliserad data. Cooper-Bredehoeft-Papadopulos metod /1/ har utgjort den huvudsakliga utvärderingsmetoden men brunnar som har haft karaktären av öppet magasin har även utvärderats enligt Bouwer och Rice /2/. Då det ofta finns en stor osäkerhet i passningen av en rät linje i den senare metoden har en viss restriktivitet använts till valet av Bouwer och Rice som ”Best Choice” i resultaten.

De utvärderade transmissiviteterna ligger inom intervallet $3{,}4\cdot10^{-9}$ till $1{,}3\cdot10^{-3}$ m^2/s. Resultaten återspeglar till stor del vad som kunde förväntas med avseende på geologin. Då resultaten från slugtester endast beskriver en liten volym omkring den testade brunnen är värden på magasinskoefficienten förknippade med stora osäkerheter och presenteras därför inte i denna rapport.

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1 Introduction

This document reports the methodology, analysis, and results of slug tests performed in groundwater monitoring wells. The activity was performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-05-097. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The main objective of slug tests is to characterize the hydraulic properties, such as transmissivity, of an aquifer. The principle behind the test is to create a rapid change in the water level and then measure the recovery to initial conditions.

Slug tests were performed at 24 groundwater monitoring wells; the majority were performed as falling-head tests, i.e. a slug causing a sudden rise in water level was introduced to the well, in some wells though, where the initial water level was very low, or where the diameter of the standpipe was to narrow, a known volume of water was added. The locations of the tested groundwater monitoring wells are given in Figure 1-1.

The slug tests were performed as an internal SKB activity, and the field campaign was carried out between November 2005 – February 2006. The original data and results were delivered to SKB primary data base, SICADA, and are traceable by the activity plan number, AP PS 400-05-097.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Slugtester i jordrör	AP PS 400-05-097	1.0
Method description	**Number**	**Version**
Metodbeskrivning för slugtester i öppna grundvattenrör	SKB MD 325.001	1.0

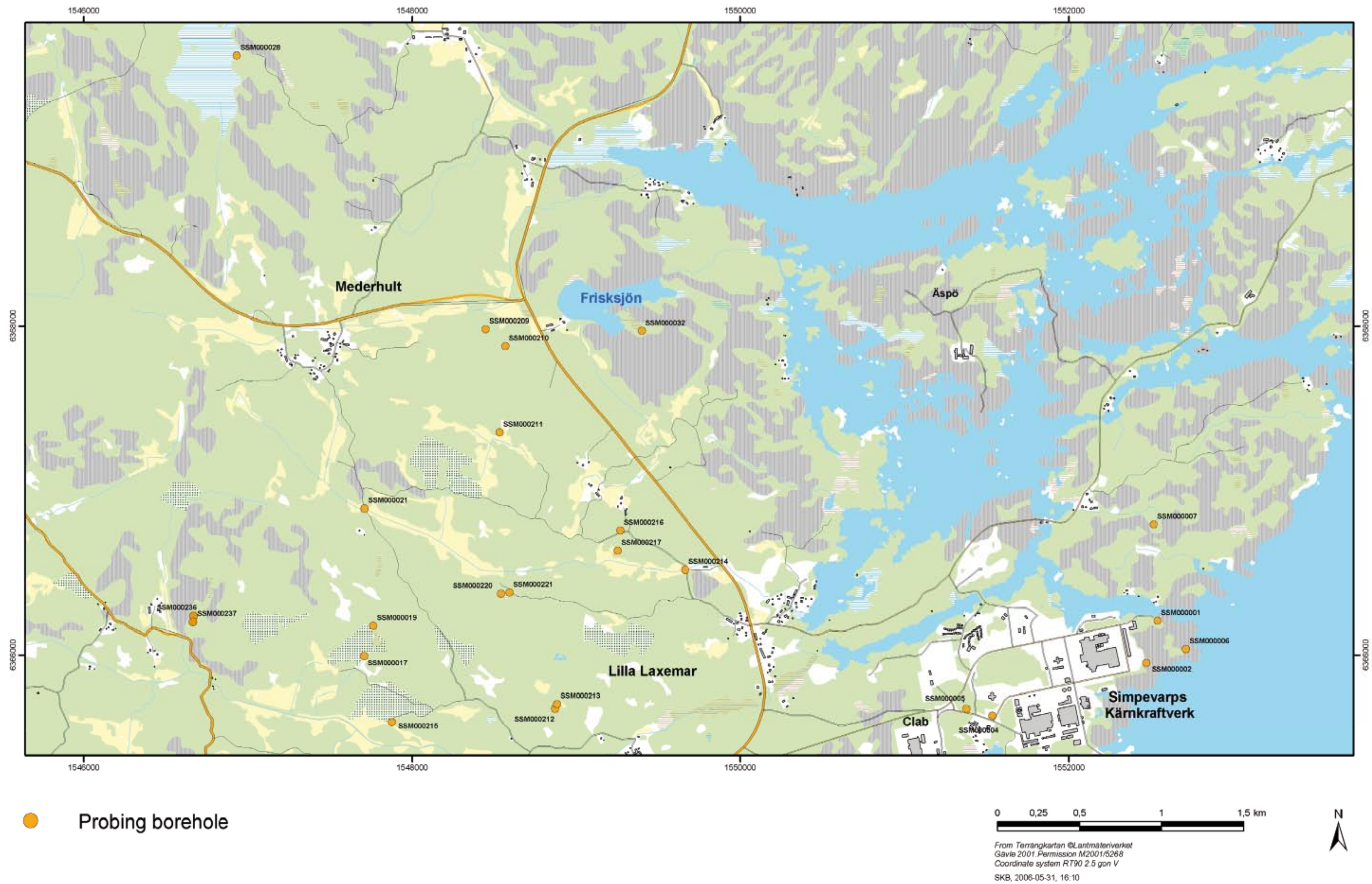


Figure 1-1. *Overview over the tested groundwater monitoring wells.*

2 Objective and scope

The specific objectives of the performed slug tests are to determine the hydrogeological properties, mainly transmissivity and hydraulic conductivity, and relate these to the characteristics of the surrounding soil.

3 Equipment

In this chapter, the equipment, instruments, and tools that were used for the tests are described.

3.1 Description of equipment

The following equipment was used at the execution of the tests:

- Pressure transducer Diver® from Van Essen Instrument, range 10 m, accuracy +/– 1 cm, resolution 0.2 cm.
- Slug and wire.
- Water level meter.
- Portable PC.
- Stopwatch.

3.2 Description of interpretation tools

For transferring data from the Diver to PC and a first check of raw data the software EnviroMon Version 1.507 was used. For the analysis the computer program AqteSolv® from HydroSOLVE, Inc. was used.

Figure 3-1. *Slug and water level meter.*

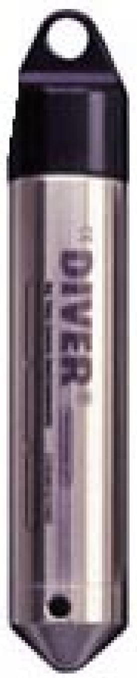


Figure 3-2. *Pressure transducer.*

4 Execution

The work was performed according to SKB's method description for slug tests, "Slugtester i öppna grundvattenrör" SKB MD 325.001, and the activity plan "Slugtester i jordrör" AP PS 400-05-097 (SKB internal documents).

4.1 Preparations

Before the tests, all clocks were synchronized to Swedish local time, GMT +1.

The water level meter had previously been calibrated according to SKB standard.

All equipment that was lowered in the borehole was cleaned before start of fieldwork.

The possibilities to fill water in the wells were controlled with the SKB activity leader for geochemistry, that no water sampling is planed for the monitoring wells in point. Tap water from SKB site investigation office was used.

The Divers were programmed with a logging interval of 1 second, except for the second attempt of SSM002 where a logging interval of 10 seconds was used.

4.2 Execution of field work

The principle of slug test is to measure the recovery of water level after a near instantaneous change of water level in the well, as described in the method description SKB MD 325.001. The water level change was caused either by lowering and lifting of a slug, or by adding a known amount of water to the monitoring well. Both techniques were used; preferably using the slug, but at the wells where the groundwater level was within or close to the screen, water was added. Water was also added in three wells where the casing diameter was too narrow for the slug.

4.2.1 Test procedure

The test procedure was following the method description SKB MD 325.00, and can be resumed as following:

1. Measurement of groundwater level from top of standpipe.
2. Measurement of depth from top of standpipe to bottom of well.
3. Determining of test method.
4. Determining the placing depth of the Diver and slug.
5. Lowering the Diver. The Diver was constantly measuring, so the air pressure before the test was logged, thereby the depth from the undisturbed water level in the well was measured.
6. Waiting for recovery from the slug that was created by lowering the Diver in to the well. The recovery was controlled with water level meter.
7. Performing of slug tests. In the test where a slug was used both raising- and falling head test was performed, and at the test using water just falling head. For the tests where the full recovery took less than 10 minutes the test procedure was repeated. The recovery was followed with more or less continual checks with water level meter.

4.3 Data handling/post processing

The Diver that was used for the test is a combined pressure transducer and logger. Level data was measured and stored on the Diver every second. Data was transferred optically to a portable PC using the program EnviroMon Version 1.507. Raw data was saved both in EnviroMon's own filetype, *.mon, as an extra backup, and exported as comma separated format, *.csv.

The raw data was processed in MS Excel and saved in *.xls format. The processing included:

1) Compensation for possible changes in barometric pressure during the tests.
2) Identification of the exact start time and cutting of the file to just include the test.
3) If necessary compensation for initial pressure effects, obtained as a pulse from lowering and hoisting the slug. The requirement of this compensation was identified after plotting the data.
4) Normalising of the data, creating a column where the water level set off is normalised between 1 and 0, with 1 as the full set off and 0 as total recovered.

The data files have been delivered to SKB database/file archive according to the method description.

4.4 Analyses and interpretations

The Cooper-Bredehoeft-Papadopulos method /1/ has been the main evaluation method for the tests. Wells with character of unconfined aquifer have also been evaluated with the Bouwer and Rice method /2/. As the fitting of a straight line in this method often involves a large uncertainty, restrictiveness has been used to choose this method as best choice in the results (see Table 5-1). Both Cooper-Bredehoeft-Papadopulos and Bouwer and Rice assume radial flow in a homogenous media. If radial flow conditions are not fulfilled, Karasaki et al. /4/ have developed solutions to various models of slug tests that may be applicable in analyzing the results of tests where existing solutions are inadequate. All tests in this report have been qualitative evaluated with respect to flow regime.

For the analysis, data has been matched to type curves both in a computer program, and by hand. In the computer program, no results derives from automatic matching, but from visual matching of type curves. Some of the tests have been evaluated with both procedures to ensure the accuracy of the other line of action.

In some cases, the initial displacement is larger than the theoretical maximum displacement, calculated from the volume of the slug. This phenomenon is assumed to be an effect of a pressure pulse caused as the slug penetrates the water surface. By designating the theoretical value of the initial displacement as the volume of the slug, it is possible to compensate for the pressure pulse. The well and screen characteristic are not always idealistic, so to ensure the reasonableness of the designated value, the compensated data is plotted and compared to the type curve, and if possible other tests in the same well.

4.4.1 Analysis according to Cooper-Bredehoeft-Papadopulos

Cooper et al. have developed a solution for estimation of transmissivity and storativity in fully penetrating wells in confined aquifers. The method may be applicable to partly penetrating wells if the formation thickness is replaced by the effective screen length.

The method is based on fitting family curves to a plot of the ratio of h_t/h_0 plotted against the corresponding time in a lin-log diagram. The method and its conceptual model are described in detail in Butler /3/ and Kruseman and de Ridder /5/.

4.4.2 Analysis according to Bouwer-Rice

The method of Bouwer and Rice, designed for wells in unconfined aquifers, estimates the hydraulic conductivity of the aquifer.

The logarithm of the response data is plotted against the time, and a straight line is fit to the data plot. The method and its conceptual model are described in detail in Butler /3/ and Kruseman and de Ridder /5/.

There are some uncertainties in relation to analysis according to Bouwer and Rice. One of these is the interval of which the line is fitted; the curves often show a concave-upward curvature and depending of which slope is chosen, the results may vary considerably.

The method is also sensitive for short series of data, i.e. the uncertainty of the curve fitting procedure increases significantly when the measured data does not fully reach steady state conditions.

4.4.3 Creating a slug by adding water

The hydraulic principles are the same regardless of the pulse is created by adding a known volume of water, or by lowering of a slug. The difference is that it is more difficult to make a pulse with water instantaneously. On the test that is performed with water, the starting time of the test is counted from the time when the highest value is registered on the Diver. This value is then used as the maximum displacement.

The method to fill water was chosen in the cases where the inner diameter was too small for the slug, or when the water depth was too small to completely cover the Diver and the slug. The analysis of these tests is based on the assumption of radial flow, and that the position of the water table, and thus the saturated thickness of the formation, does not change during the course of the test /1/. The well was, when possible regarding the total well length, filled with water to a displacement of 2–3 m, according to the method description SKB MD 325.001. When the initial water table is within the screen, the above stated assumptions are not valid. In these cases, raw data was plotted, and from the plot it was possible to detect a time when the well was nearly recovered, where the flow regime becomes nearly radial. The data was cut and normalised for this displacement, approximately 10 cm, and with a new t = 0. This was done for SSM004, SSM006, SSM007, and SSM211. The assumptions were regarded as valid with a local change within the well in cm-scale compared to the aquifer thickness in m-scale, and an extra time to create the pulse which constitutes a few percent of the recovery time. Compared to other uncertainties in this type of test it is regarded as acceptable.

In the wells SSM212, SSM214, SSM216, and SSM217 the groundwater level was below or just some cm over the lover end of the screen prior to the test, thus the above mentioned assumption could not be done, and the tests were consequently regarded as non evaluateable.

4.5 Execution well by well

4.5.1 SSM001

SSM001 is 3 m deep with screen between 2 and 3 m counted from top of stand pipe (ToSP), located 0.8 m above ground level. Manual measurement gave a groundwater level 0.90 m below ToSP prior to the test. During the slug test the recovery was followed with manual measurements, and after a few minutes it was realised that the Diver would run out of memory before the well was fully recovered. Therefore, the preinstalled logger, a Minitroll normally measuring for the Hydro Monitoring System (HMS), was used. The two loggers were altered as instantaneous as possible, and to enable to put the different measurements into same height system (metres above sea level), the groundwater level was measured manually before and after the change of loggers. There is a small difference in volume between the two loggers, mainly since the Minitroll is connected to a cable while the Diver hangs in a thin cord; the volume difference was however neglected. On the rising-head test only the Minitroll logger was used. In the analysis of the tests the two recovery curves were quite similar, but the rising-head curve was used as best choice since it contains least uncertainties.

4.5.2 SSM002

SSM002 is 3 m deep with screen between 2 and 3 m counted from top of stand pipe (ToSP) which is 0.9 m above ground level. In SSM002 two falling-head tests were conducted. At the first test the ordinary 1 second scan time was used on the Diver, the memory capacity was however not enough to measure the complete recovery. Thus, the test was redone the next day with a scan time of 10 seconds. The first test has not been evaluated; all information for the analysis refers to the second test. The water level prior to the test was 1.39 m below ToSP. The falling head test indicates more of a linear flow than a radial flow according to the principles described in /4/. This could be the effect of a thin, more high-conductive layer above the initial groundwater level. A theory that appears likely when the sandy and gravely layer at this level in the geological log is taken into account. No attempt has however been made to evaluate the falling head test, the analysis has been focused on the rising head which shows the pattern of a more normal radial flow. The resulting transmissivity is however on the measuring limit of this method.

4.5.3 SSM004

Prior the test the water level in the well was 0.26 m above the bottom. The borehole depth is 3 m, and the filter length is 1 m. Since the water depth was too small to cover the whole slug, water was added into the hole. Water was added twice, 2 and 6.5 L respectively, and both additions took approximately 7 seconds each. The start time for the new normalisation, which was made for the last 10 cm recovery of the second test, was recorded 6 seconds after the peak value.

4.5.4 SSM005

The borehole depth is 2 m and the filter length is 1 m, the groundwater level prior the test was approximately 0.64 m above the borehole bottom. This means that the initial groundwater level was within the filter, and that the water column was too small to cover the whole slug, and for that reason water was added into the hole. Unfortunately the casing, which is installed around the monitoring well to protection, is dug down too deep and is not filled with bentonite. Consequently, there was a leakage, which resulted in that the water that was filled in the monitoring well just filled up the casing. The test is therefore not possible to evaluate.

4.5.5 SSM006

SSM006 is a very shallow monitoring well, only 0.70 m deep, and the upper part of the screen is just below ground level. Prior the test, the water level in the well was 0.37 m above borehole bottom. Since the water depth was too small to cover the whole slug, water was added into the hole. Water was added twice, 1.7 and 2 L respectively, and both additions took approximately 7 seconds each. There was an obvious risk that water should leak up to ground level after addition, but no such phenomenon was observed. The upper edge of the screen was over the ground water level; the complete test could therefore not be used for evaluation. Instead last part of the test, starting from a displacement of 9 cm was used for a new normalisation. The first value was recorded 6 seconds after the peak value.

4.5.6 SSM007

Prior to the test the water level in the well was 0.38 m above the bottom. The borehole depth is 2 m and the filter length is 1 m. Since the water depth was too small to cover the whole slug water was added into the hole, the filling took approximately 7 seconds. The start time for the new normalisation, which was made for the last 9 cm recovery of the second test, was recorded 6 seconds after the peak value.

4.5.7 SSM017

SSM017 is 2.1 m deep with screen between 1 and 2 m counted from top of stand pipe (ToSP) which is 0.65 m above ground level. Manual measurement gave a groundwater level 0.81 m below ToSP prior to the test. The well was tested with slug, and after compensation for a pressure pulse on the falling head test, created by a little to fast lowering of the slug, two good looking curves were accomplished.

4.5.8 SSM019

Since a broken pressure transducer made the Diver measurements unusable, the evaluation of SSM019 has been done entirely from manual water level measurements with water level meter. During the falling-head test approximately 20 measurements were made, which gave a satisfactory recovery curve, while the number of measurements during the rising-head test was insufficient, and it has therefore not been evaluated. The screen in SSM019 is placed between 2–3 m below ToSP in a sandy-till.

4.5.9 SSM021

Prior to the test, the groundwater level was approximately 2.18 m above the bottom of the 3.7 m deep well (counted from ground level). The normalisation of the falling head test was adjusted to the theoretical displacement of the slug to compensate for the pressure pulse from the lowering of the slug. This gave a curve that attuned well to the rising head.

4.5.10 SSM028

As the monitoring well SSM028 is located some kilometres away from the other, and a newly installed well, SSM243, is located only approximately 50 m west of SSM028, it was decided that the wells will be tested together later on.

4.5.11 SSM032

SSM032 is located in a marsh south of Frisksjön. The geological log counted from ground level is: peat 0–0.4 m, gyttja 0.4–2.5 m, and gyttja-bearing clay with sand layer 2.5–2.8 m. The screen covers the depth 1.8–2.8 m, and the top of stand pipe (ToSP) is 1.2 m above ground level. Prior to the test the groundwater level was measured manually to 1.36 m below ToSP. A slug was lowered and 90% recovery was measured during the 1.5 hour the test was carried out. The slug was raised from the well and the recovery was measured for over 2.5 hours. After that time the recovery was less than 10%, which means that in that pace it would take weeks before the hole was fully recovered, and the test was therefore terminated.

The best explanation for this behaviour is that the gyttja is more or less impermeable, but there is a leakage through the borehole sealing. When the slug is lowered, water goes up into the peat and flows away from the well. When the slug is raised there is no water available for the rising-head. The test was regarded as nonevaluateable.

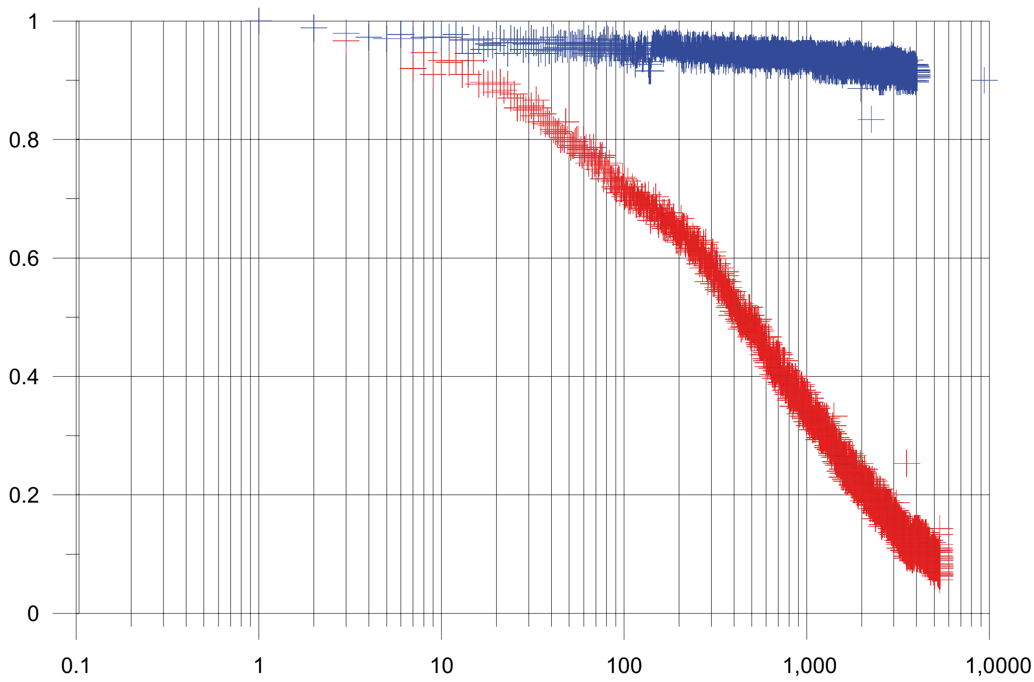


Figure 4-1. *Recovery curves for SSM32 red is the falling head test, blue rising head.*

4.5.12 SSM209

SSM209 was not found despite industrious searching. The standpipe has been damaged during the storm "Gudrun" in January 8, 2005, and the well it is therefore not possible to find.

4.5.13 SSM210

In the 4 m deep SSM210, the groundwater level prior to the test was 1.74 meter below ToSP. The screen covers the depth between 2 and 4 m. After a minor compensation for a pressure pulse on the falling head test, created by a little too fast lowering of the slug, the two tests give very similar recovery curves with initial head displacements just under the theoretical value for the slug.

4.5.14 SSM211

Prior to the test the water level in the well was 0.54 m above the bottom. The borehole depth is 3 m and the filter length is 1 m. Since the water depth was too small to cover the whole slug water was added into the hole. The filling of water took approximately 7 seconds. The start time for the new normalisation, which was made for the last 42 cm recovery of the second test, was recorded 17 seconds after the peak value.

4.5.15 SSM212

Manual measurement of the groundwater level showed that the well was dry prior to the test. Water was added twice into the 2 m deep well, 5 and 7 L respectively. When the second test was terminated there were still some water in the well. Regarding the recovery curve, and the manual measurement, the overall picture of the groundwater level during the test is that water was added in the unsaturated zone, raising the level into the screen. The test could therefore not be evaluated.

4.5.16 SSM213

SSM213 is 2.1 m deep with screen between 1 and 2 m counted from ToSP. The static groundwater level was close to the upper screen limit before the test. Water was added twice in this well, 0.5 L both was used both attempts. This resulted in approximately 0.23 m displacement created in 3 seconds. This hole was the only one where the complete pulse created by water could be used and normalised. The two tests gave very similar recovery curves and transmissivity, which however showed some character of an unconfined aquifer.

The tests show effects that could be explained by the presence of a more permeable material in the surrounding which could explain the steep slope when the measured data is plotted in lin-log scale. The steep slope gives a very low value of S and an overestimation of the hydraulic conductivity of the till.

4.5.17 SSM214

Manual measurement of the groundwater level showed that the well was dry prior to the test. Water was added twice into the 6 m deep well. Both the manual measurements and the recovery curve confirm a groundwater level below the screen, thereby the water is added in the unsaturated zone and the test could thereby not be evaluated.

4.5.18 SSM215

The screen of SSM215 is positioned 1.7–3.7 m below ground level partly in a layer of gravel, and accordingly the well responds fast. In all four tests that were performed, approximately 10% of the displacement remained 10 seconds after the slug lowering/raising. This gives a transmissivity close to the upper measurement limit of this method, even though the aquifer is well confined with clay in the uppermost meters of the geological log.

4.5.19 SSM216

The manual measurement of the groundwater level prior to the test show that there were a few centimetres of water at the bottom of the well, but it was uncertain if it was just the cone that was filled with water or it was the actual groundwater level. Water was added twice, and both new manual measurements and the recovery curve confirm a groundwater level below the screen. Thereby the water is added in the unsaturated zone and the test could thereby not be evaluated.

4.5.20 SSM217

Manual measurement of the groundwater level prior to the test show that there was some water at the bottom of the well, but it is uncertain if it is just the cone that was filled with water, or it was the actual groundwater level. 7 L of water was added to the 4 m deep well two times. The recovery curve indicates a groundwater level below the screen, thereby the water is added in the unsaturated zone and the test could not be evaluated.

4.5.21 SSM220

The screen of SSM220 is positioned on the depth of 1.8–2.8 m in boulder-bearing gravely sandy till. This very high conductive material is on the upper measurement limit of this method, even though this is a well confined aquifer with initial groundwater level within the clay which overlays the till, for detailed well design see Appendix 1. The test procedure with slug up and down was repeated twice, and in all tests less than one percent of the displacement remained after ten seconds.

4.5.22 SSM221

SSM221 is another well situated in a course till with a groundwater table a few decimetres below ground level prior to the test. The well is not as fast as SSM220, but after 30 seconds only around 5% of the displacement remains. The testing result of this well contained a pressure pulse in both the falling- and rising-head test, an due to that the data from the test was normalised to the theoretical displacement of the slug.

4.5.23 SSM236

At first test of SSM236 with slug lowering the whole slug was probably not covered by water therefore the test was redone. It was noticed that the recovery level differed between the rising- and falling-head tests, so the tests were complemented with an adding water test.

A difficulty at the evaluation was to choose the static level from which the displacement was counted, since it varies after and before the tests. The test gave very confusing results. Raw data is shown in Figure 4-2. The screen is placed 2–3 m bellow ToSP which means a bit over the static groundwater level which was measured to 2.15 with a water level meter prior to the test. Attempts to evaluate the data resulted in transmissivities that seemed unlikely for the clayey-silt and sandy-silty-till where the screen is placed.

The explanation for this strange behaviour is probably that it is just the screen-sand and not the aquifer that has been tested. The monitoring well is installed with Ø120 mm NOEK-drilling. Around the standpipe-screen the hole is filled with sand covered with bentonite. The ambient silt has a much lower conductivity than the sand; the uppermost meter of sand is unsaturated. When water is added, either by lowering a slug or adding water, the water level is raised in the Ø120 mm hole to a new level. When the slug is raised the water level goes back to the initial one. Consequently the well was regarded as nonevaluateable.

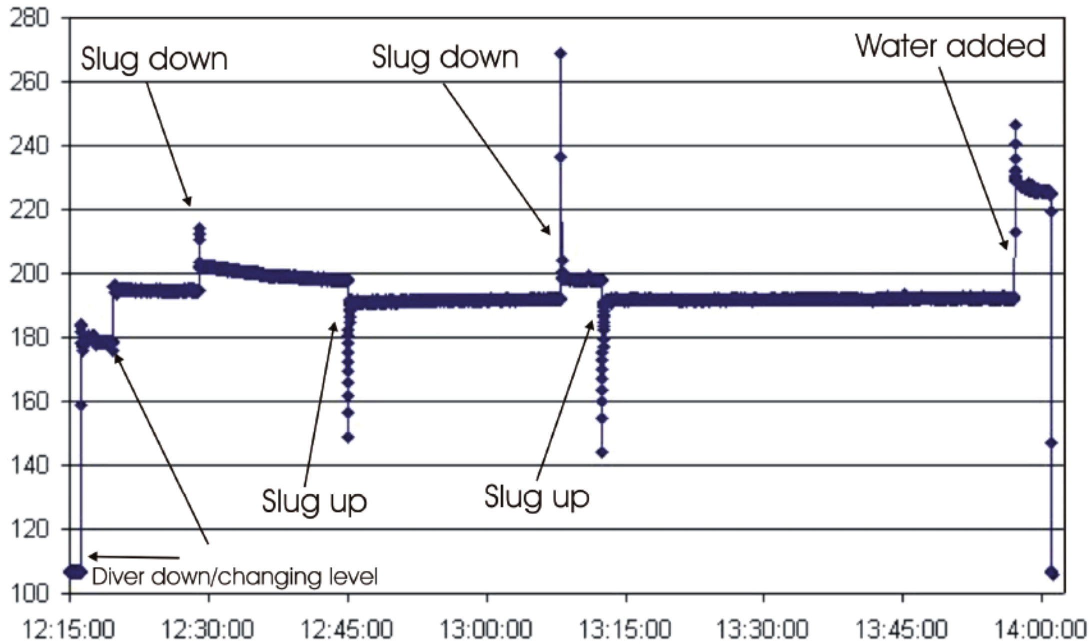


Figure 4-2. *Raw data for SSM236, notice the different recovery levels and the extremely fast recovery of the falling head test.(The scale is in cm but not adjusted.)*

4.5.24 SSM237

SSM237 is 3.1 m deep with screen between 2 and 3 m counted from top of stand pipe (ToSP) which is 0.3 m above ground level. Manual measurement gave a groundwater level 1.6 m below ToSP prior to the test. The well was tested with slug, one falling- and one rising-head test, the two tests gives very similar recovery curves with initial head displacements not remarkably under the theoretical value for the slug.

4.6 Nonconformities

During the tests, pressure transducers were installed in all wells. The groundwater level was also measured manually with a water level meter. In some wells, stated in Table 4-1, the measurements only gave an approximate value due to technical problems with the water level meter.

In one well, SSM219, the pressure transducer did not save data correctly, consequently manual data has been used in the analysis.

ID	Comment
SSM021	Uncertain manual waterlevel measurements
SSM032	Uncertain manual waterlevel measurements
SSM210	Uncertain manual waterlevel measurements
SSM211	Uncertain manual waterlevel measurements
SSM212	Uncertain manual waterlevel measurements
SSM214	Uncertain manual waterlevel measurements
SSM216	Uncertain manual waterlevel measurements
SSM217	Uncertain manual waterlevel measurements
SSM219	Manual measurements used in analysis
SSM220	Uncertain manual waterlevel measurements
SSM221	Uncertain manual waterlevel measurements
SSM236	Uncertain manual waterlevel measurements
SSM237	Uncertain manual waterlevel measurements

5 Results

The evaluated parameters are presented in Table 5-1. In cases where more than one series of tests have been done in a well, results have been selected from the best fitting curves for one falling- and one rising-head tests respectively, and these results are presented in the table. The Bouwer and Rice evaluation is done from the dataset with the best matching curve in Cooper et al. The Best Choice is the author's selection of the most reliable result for each test. This column is stored in the SKB database SICADA, and it is this data that the authors recommend for further hydrogeological modelling. The data is traceable in SICADA by the Activity Plan number AP PS 400-05-097.

The results from slug tests are only describing the characteristics of a small volume around the tested well; hence the values of the storativity are to be considered as uncertain. The storativity values have been calculated, but due to the uncertainties, they will neither be presented in this report nor stored in the SICADA database. They do appear, however, in the plots of Appendix 2.

The assumption of radial flow was questioned in all tests. However, in the cases where the characteristic of another flow regime was identified, some other necessary assumption could not be made, for instance, constant aquifer height or adding of water in the unsaturated zone. Therefore, all presented and delivered data are evaluated as radial flow in a homogenous aquifer.

Table 5-2 gives a rough comparison between the evaluated result and the geology surrounding the well screens. The results are divided into groups with transmissivities of the same order of magnitude. The results seem trustworthy with boulder and gravel in the high conductivity column, and clayey till in the lowest.

5.1 Suggestion for further investigations

Some wells, i.e. SSM213, SSM215, SSM220, and SSM221, have hydraulic conductivities close to the upper measurement limit of this method, and the evaluation of these tests also gave extremely low values of the storativity ($S \approx 1 \cdot 10^{-11}$). More precise results will be provided with pumping tests. If possible, the supplementary tests should be preformed as interference tests, in order to achieve reliable values of the storativity of the aquifers, and not only an approximate value of the area close to the wells.

In the wells that were found dry at the time for testing, SSM212, SSM214, SSM216, and SSM217, it may be possible to perform pumping tests during wetter conditions with an elevated groundwater table.

In SSM236, were the upper part of the screen sand seems to be unsaturated, the ambient till most probably have a too low conductivity to be tested with a pump test. This well could possibly be tested with a constant head injection test. This however assumes that larger amounts of water could be added into the well, which must be confirmed with the SKB Activity leader for Geochemistry as SSM236 is a well for environmental surveillance.

SSM028 is yet to be tested, tentatively this is done together with the recently installed SSM243.

Table 5-1. Evaluated results.

ID	Cooper et al. falling-head test T [m²/s]	rising-head test T [m²/s]	Bouwer-Rice K [m/s]	Best Choice T [m²/s]	K [m/s]	Comment
SSM001	$7.8\cdot10^{-07}$	$7.8\cdot10^{-07}$	$1.8\cdot10^{-07}$	$7.8\cdot10^{-07}$		
SSM002		$3.4\cdot10^{-09}$		$3.4\cdot10^{-09}$		
SSM004	$7.0\cdot10^{-06}$		$4.6\cdot10^{-06}$		$4.6\cdot10^{-06}$	Effective screen length 0.26 m.
SSM005						Not possible to evaluate, see Section 4.5.4
SSM006			$2.3\cdot10^{-05}$		$2.3\cdot10^{-05}$	Effective screen length 0.37 m.
SSM007	$1.9\cdot10^{-05}$		$1.0\cdot10^{-05}$	$1.9\cdot10^{-05}$		
SSM017	$4.4\cdot10^{-06}$	$4.6\cdot10^{-07}$		$4.4\cdot10^{-06}$		
SSM019	$1.0\cdot10^{-05}$		$1.9\cdot10^{-06}$	$1.0\cdot10^{-05}$		
SSM021	$6.3\cdot10^{-05}$	$6.6\cdot10^{-05}$		$6.6\cdot10^{-05}$		
SSM028						Not tested
SSM032						Not possible to evaluate, see Section 4.5.11
SSM209						Not tested
SSM210	$2.4\cdot10^{-05}$	$3.9\cdot10^{-05}$	$1.1\cdot10^{-05}$	$2.4\cdot10^{-05}$		
SSM211	$5.5\cdot10^{-06}$			$5.5\cdot10^{-06}$		
SSM212						Not possible to evaluate, see Section 4.5.15
SSM213	$7.6\cdot10^{-05}$			$7.6\cdot10^{-05}$		
SSM214						Not possible to evaluate, see Section 4.5.17
SSM215	$4.9\cdot10^{-04}$	$8.7\cdot10^{-04}$		$8.7\cdot10^{-04}$		
SSM216						Not possible to evaluate, see Section 4.5.19
SSM217						Not possible to evaluate, see Section 4.5.20
SSM220		$1.3\cdot10^{-03}$		$1.3\cdot10^{-03}$		
SSM221		$2.1\cdot10^{-04}$	$5.4\cdot10^{-05}$	$2.1\cdot10^{-04}$		
SSM236						Not possible to evaluate, see Section 4.5.23
SSM237	$2.4\cdot10^{-06}$	$1.4\cdot10^{-06}$		$2.4\cdot10^{-06}$		

Table 5-2. Comparison of results and geology.

$T = 1\cdot10^{-9}$ [m²/s]	SSM002	Till – clayey silty
$T = 1\cdot10^{-7}$ [m²/s]	SSM001	Till – clayey silty
$T = 1\cdot10^{-6}$ [m²/s]	SSM004	Till – cobbly blocky and bedrock
	SSM006	Organic topsoil and coarse grained soil
	SSM211	Silty sandy till
	SSM237	Silty clay with sandlayer and sandy silty till
	SSM017	Till – sandy silty and Till – sandy
$T = 1\cdot10^{-5}$ [m²/s]	SSM007	Silty pebbly sand
	SSM019	Sandy till
	SSM021	Clayey gyttja/sand
	SSM210	Sandy till
	SSM213	Sandy clay and clayey sandy silty till
$T = 1\cdot10^{-4}$ [m²/s]	SSM215	Sandy gravelly clay and pebbly sandy gravel
	SSM221	Boulder bearing pebbly clayey gravelly sand and boulder bearing silty sand till
$T = 1\cdot10^{-3}$ [m²/s]	SSM220	Boulder bearing gravelly sandy till

References

/1/ **Cooper, H H, Bredehoeft, J D, Papadopulos S S, 1967.** Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263–269.

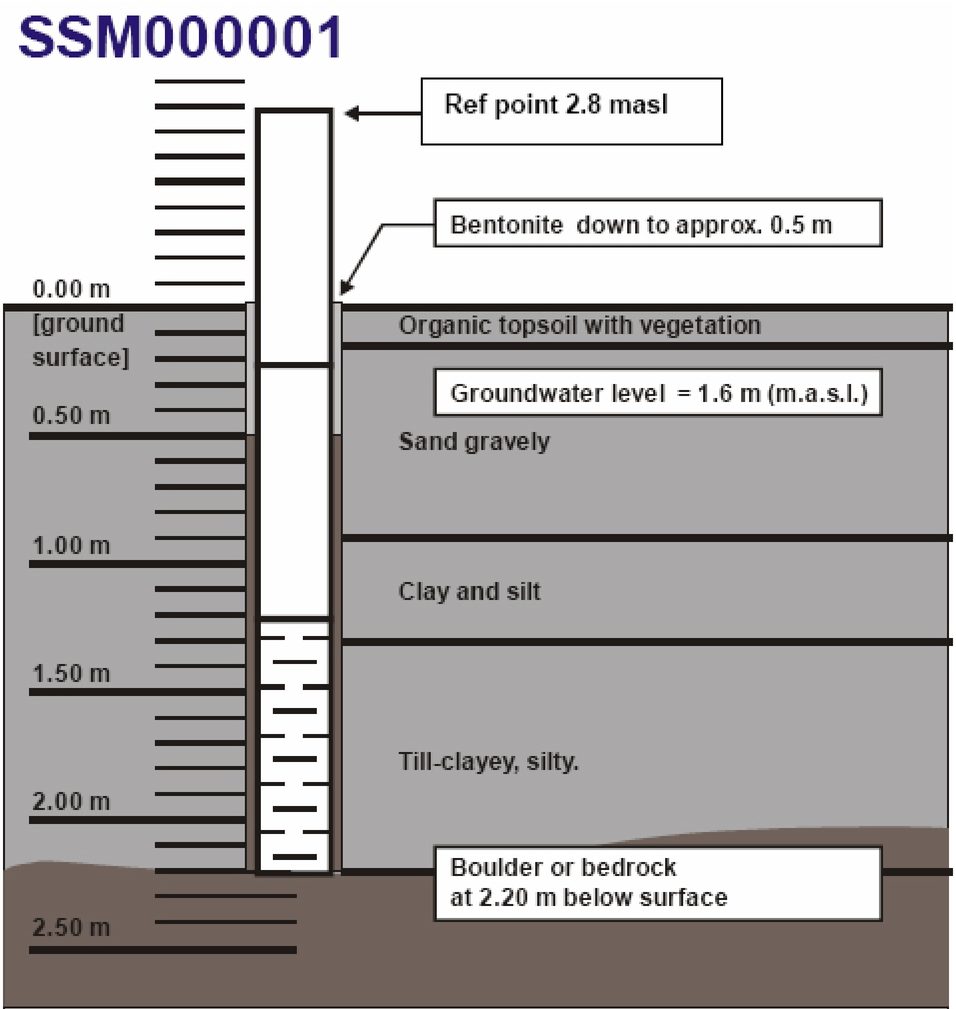
/2/ **Bouwer H, Rice R C, 1976.** A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research, vol. 12, no. 3, pp. 423–428.

/3/ **Butler J J Jr, 1998.** The design, performance and analysis of slug tests. Lewis Publisher.

/4/ **Karasaki K, Long J C S, Witherspoon P A, 1988.** Analytical Models of Slug Tests, Water Resources Research, vol. 24, no. 1, pp 115–126.

/5/ **Kruseman G P, de Ridder N A, 1990.** Analysis and Evaluation of Pumping Test Data. ILRI publication 47, 2nd ed, International Institute for Land Reclamation and Improvement, The Netherlands.

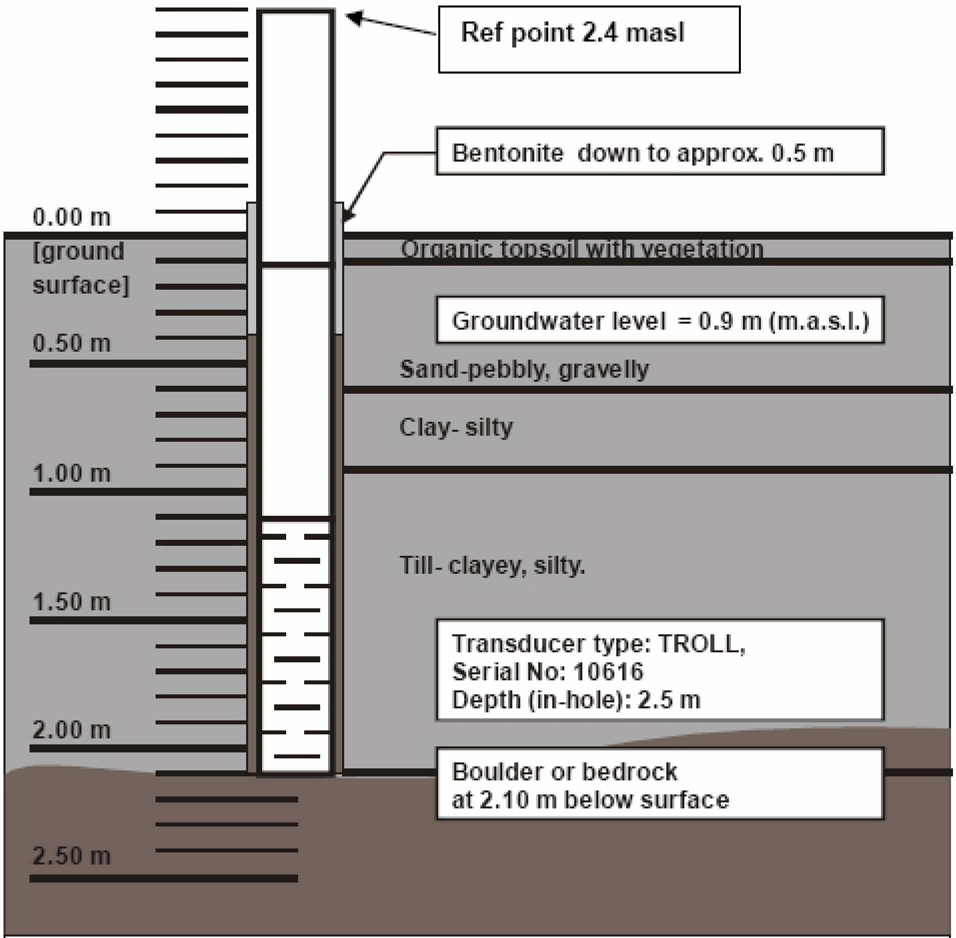
Borehole description including geological log



Date:
2002-10-08
Method:
Auger drilled
Diameter = 72 mm
Inner tube:
Ø$_o$ = 63 mm
Ø$_i$ = 50 mm

Reference point
Northing: 6366208 (m), RT90 2.5 gon V 0:-15
Easting: 1552540 (m), RT90 2.5 gon V 0:-15
Elevation: 2.788 (m), RHB 70
Orientation
Azimuth: 120 (0-360 degrees, ref. north)
Dip: -87 (0 = horizontal, -90 = vertical)

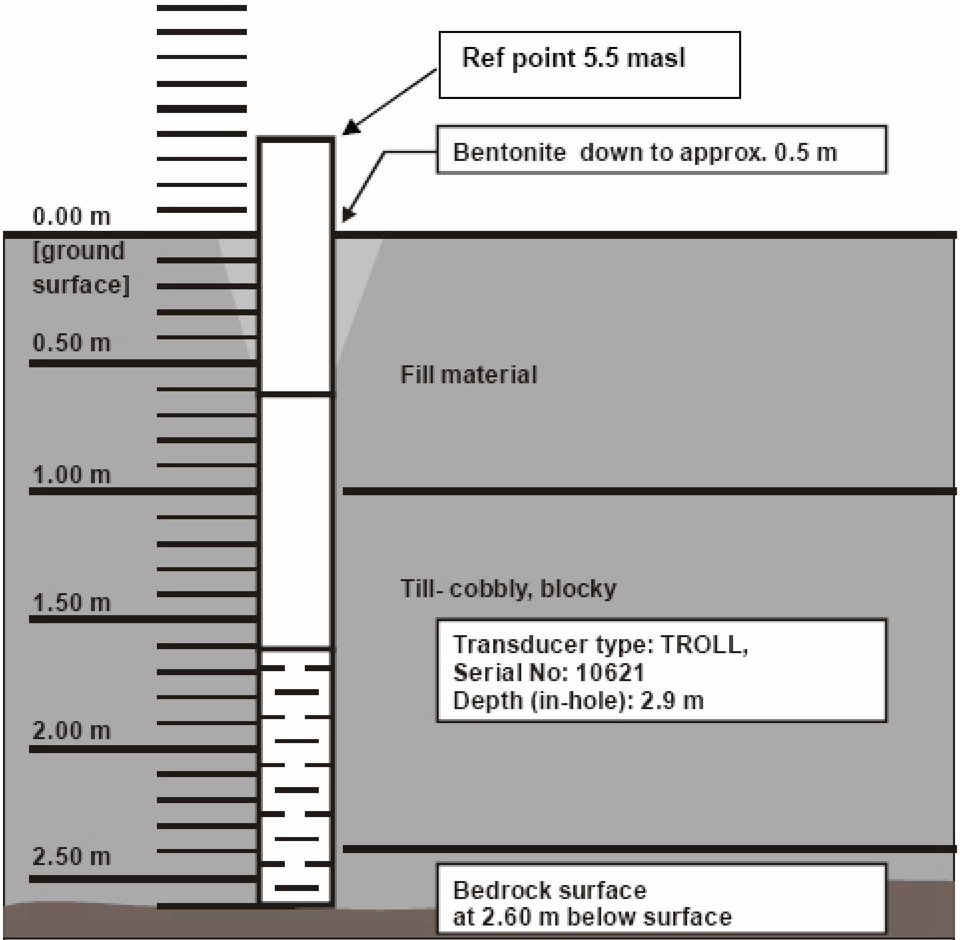
SSM000002



Date:
2002-10-08
Method:
Auger drilled
Diameter = 72 mm
Inner tube:
Ø$_o$ = 63 mm
Ø$_i$ = 50 mm

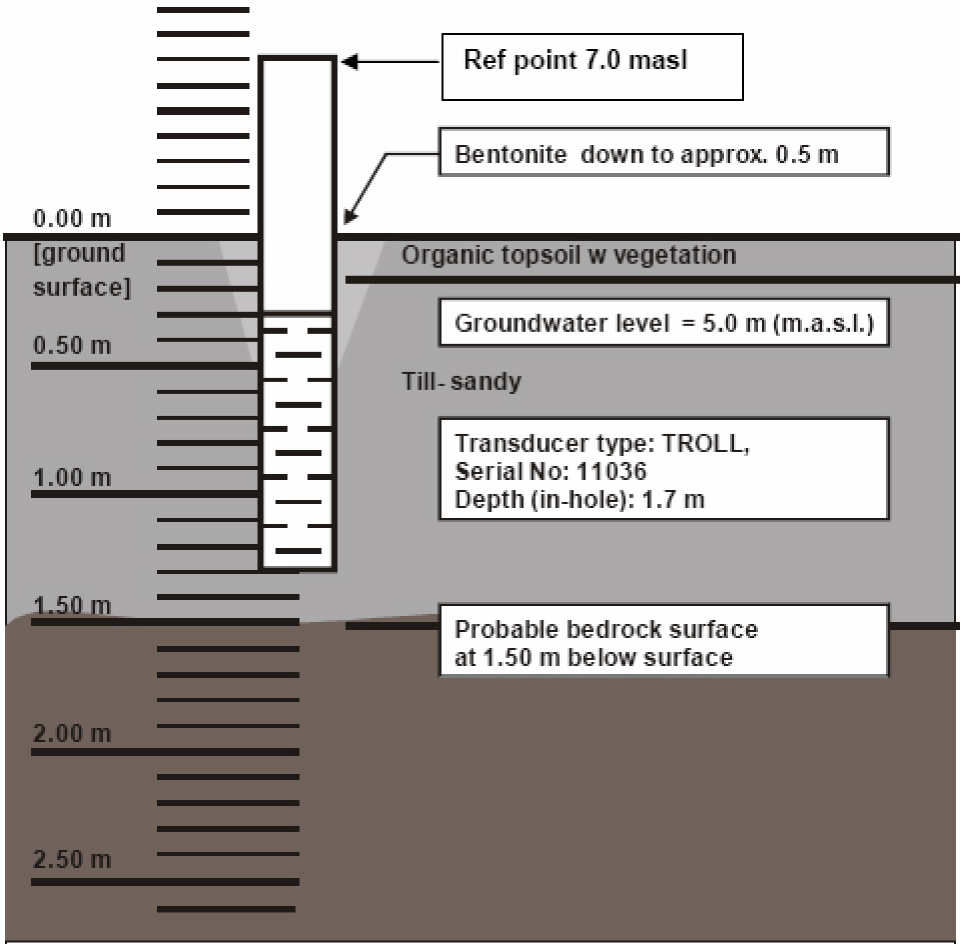
Reference point
Northing: 6365952 (m), RT90 2.5 gon V 0:-15
Easting: 1552471 (m), RT90 2.5 gon V 0:-15
Elevation: 2.399 (m), RHB 70
Orientation
Azimuth: 266 (0-360 degrees, ref. north)
Dip: -87 (0 = horizontal, -90 = vertical)

SSM000004



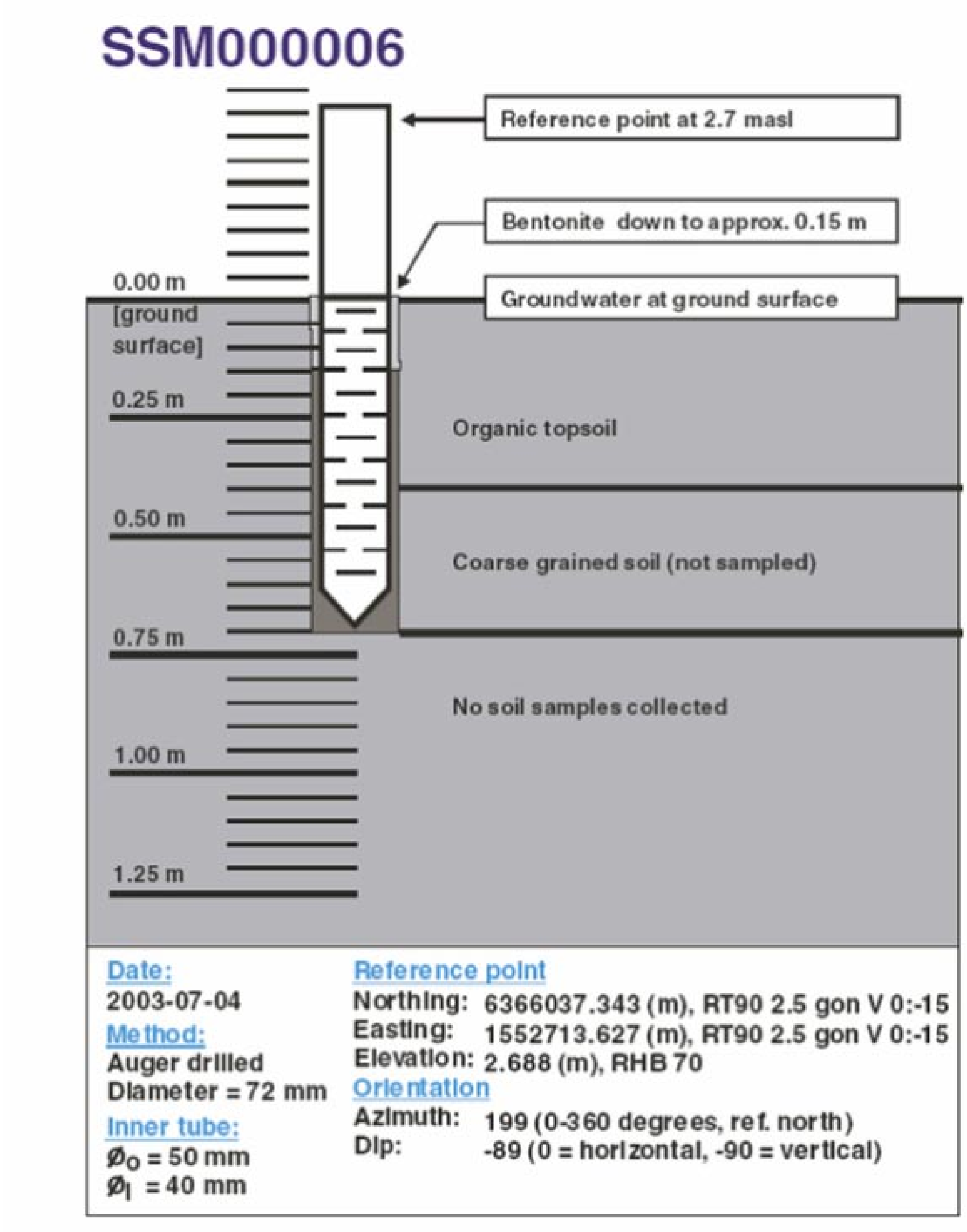
Date:	**Reference point**
2002-12-12	Northing: 6365631 (m), RT90 2.5 gon V 0:-15
Method:	Easting: 1551534 (m), RT90 2.5 gon V 0:-15
Dug	Elevation: 5.490 (m), RHB 70
Inner tube:	**Orientation**
$\varnothing_o$ = 63 mm	Azimuth: 122 (0-360 degrees, ref. north)
$\varnothing_i$ = 50 mm	Dip: -74 (0 = horizontal, -90 = vertical)

SSM000005

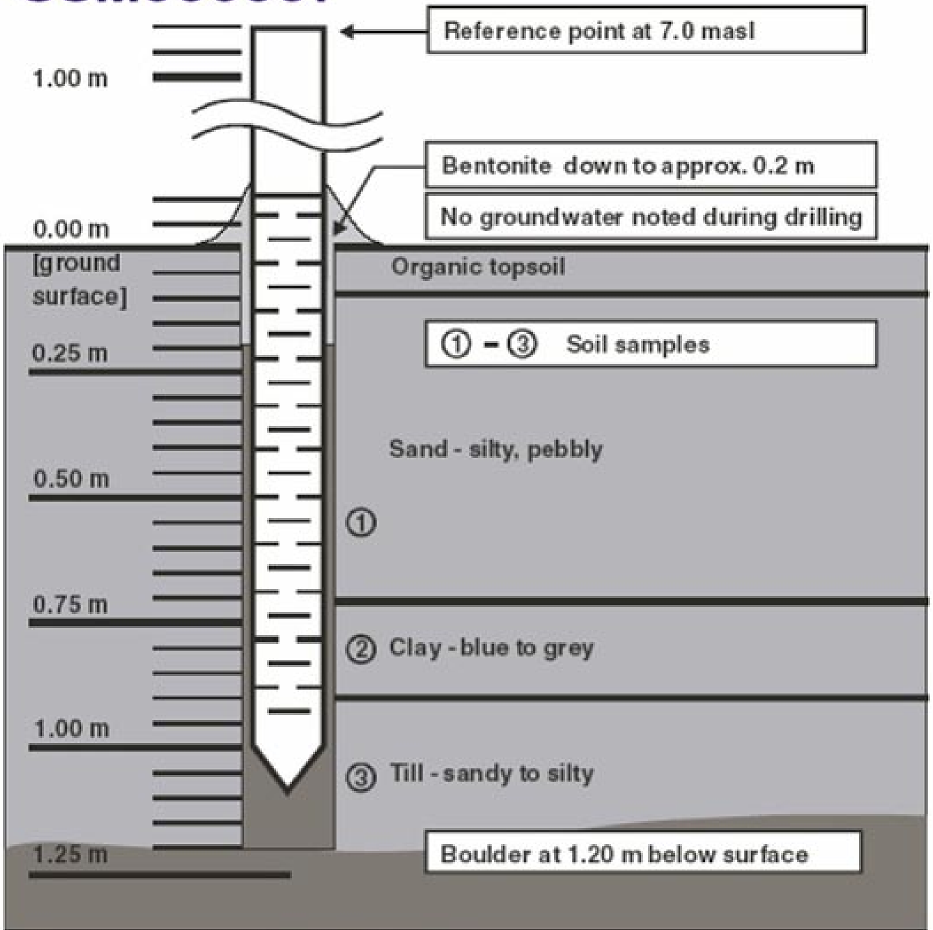


Date:
2002-12-12
Method:
Dug
Inner tube:
$Ø_o$ = 63 mm
$Ø_i$ = 50 mm

Reference point
Northing: 6365675 (m), RT90 2.5 gon V 0:-15
Easting: 1551376 (m), RT90 2.5 gon V 0:-15
Elevation: 6.980 (m), RHB 70
Orientation
Azimuth: 35 (0-360 degrees, ref. north)
Dip: -68 (0 = horizontal, -90 = vertical)


SSM000006
Reference point at 2.7 masl
Bentonite down to approx. 0.15 m
Groundwater at ground surface
0.00 m
[ground
surface]
0.25 m
0.50 m
0.75 m
1.00 m
1.25 m
Organic topsoil
Coarse grained soil (not sampled)
No soil samples collected
Date:
2003-07-04
Method:
Auger drilled
Diameter = 72 mm
Inner tube:
Ø$_O$ = 50 mm
Ø$_I$ = 40 mm
Reference point
Northing: 6366037.343 (m), RT90 2.5 gon V 0:-15
Easting: 1552713.627 (m), RT90 2.5 gon V 0:-15
Elevation: 2.688 (m), RHB 70
Orientation
Azimuth: 199 (0-360 degrees, ref. north)
Dip: -89 (0 = horizontal, -90 = vertical)

SSM000007

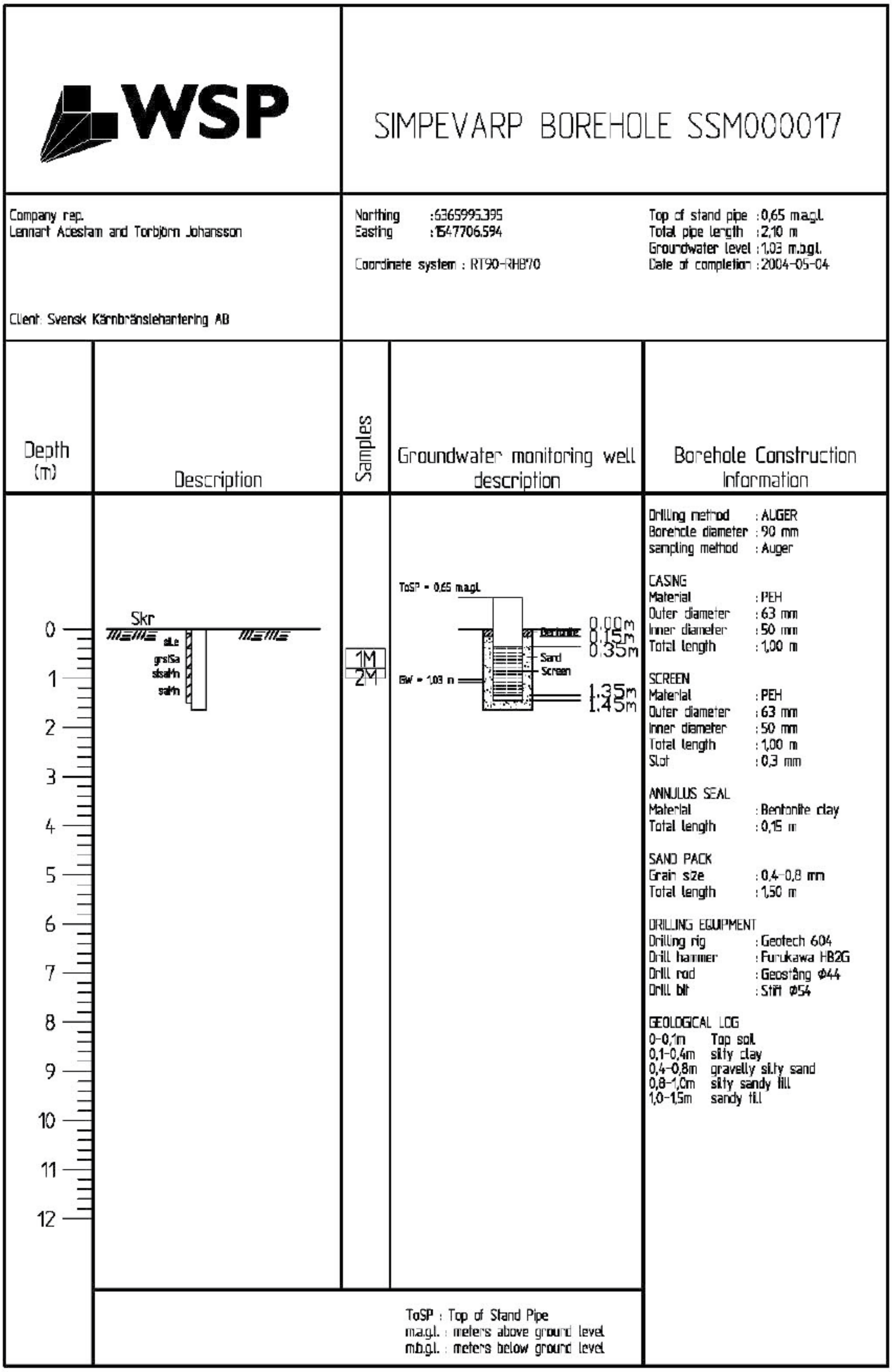


Date:
2003-10-07
Method:
Auger drilled
Diameter = 72 mm
Inner tube:
$Ø_O$ = 63 mm
$Ø_I$ = 50 mm

Reference point
Northing: 6366794.814 (m), RT90 2.5 gon V 0:-15
Easting: 1552516.791 (m), RT90 2.5 gon V 0:-15
Elevation: 7.005 (m), RHB 70
Orientation
Azimuth: 309 (0-360 degrees, ref. north)
Dip: -87 (0 = horizontal, -90 = vertical)

Appendix 2

Plots of best choice evaluation



SIMPEVARP BOREHOLE SSM000019

Company rep.
Lennart Adestam and Torbjörn Johansson

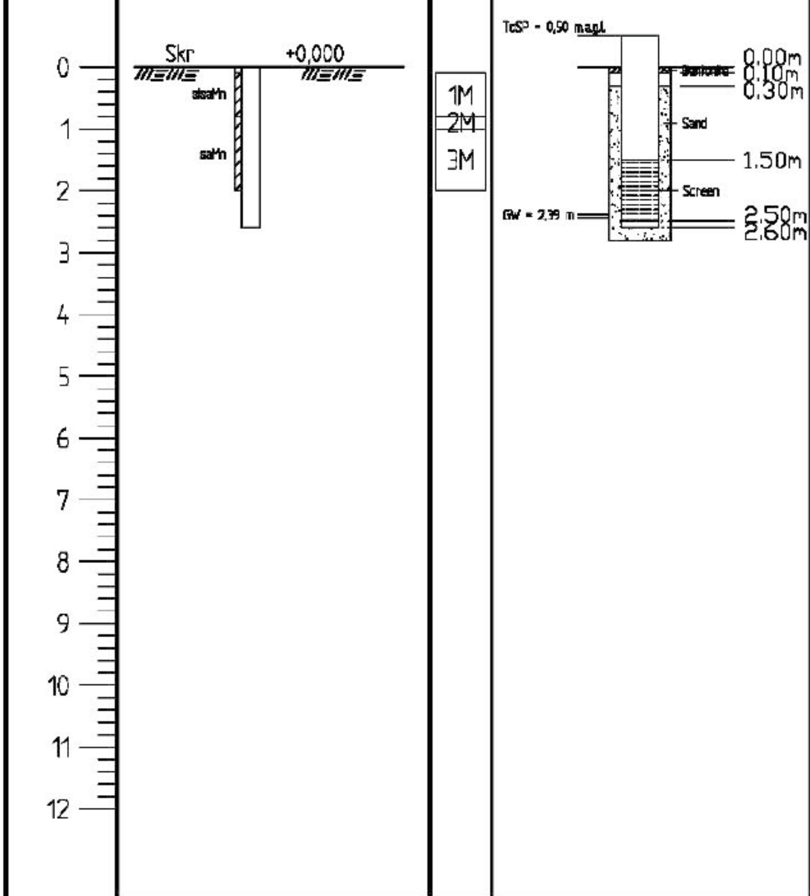
Client: Svensk Kärnbränslehantering AB

Northing : 6366177.502
Easting : 1547762.047

Coordinate system : RT90-RHB70

Top of stand pipe : 0,50 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 2,39 m.b.g.l.
Date of completion : 2004-05-04

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : AUGER
Borehole diameter : 90 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,10 m

SAND PACK
Grain size : 0,4–0,8 mm
Total length : 2,50 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0–0,1m Top soil
0,1–0,8m silty sandy till
0,8–2,0m sandy till

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

WSP

SIMPEVARP BOREHOLE SSM000021

Company rep.
Lennart Adestam and Torbjörn Johansson

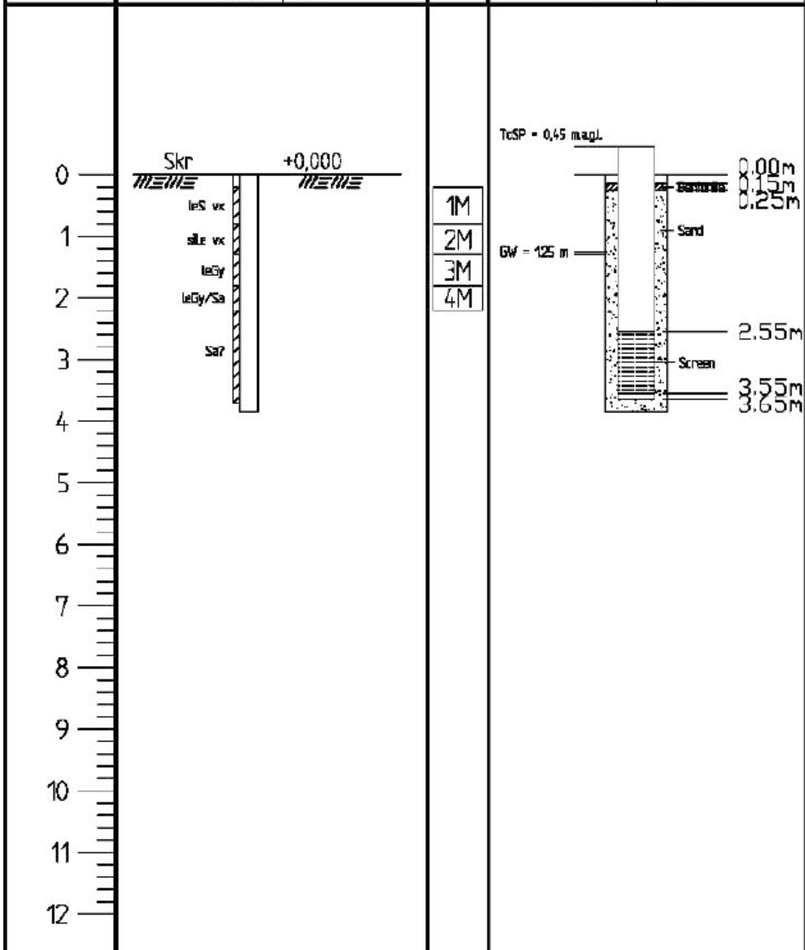
Client: Svensk Kärnbränslehantering AB

Northing :6366889.706
Easting :1547709.616

Coordinate system : RT90-RHB70

Top of stand pipe : 0,45 m.a.g.l.
Total pipe length : 4,10 m
Groundwater level : 1,25 m.b.g.l.
Date of completion : 2004-05-04

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : AUGER
Borehole diameter : 90 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 3,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,10 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 3,60 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,2m Top soil
0,2-0,8m clayey silt containing plant remains
0,8-1,3m silty clay containing plant remains
1,3-1,8m clayey gyttja
1,8-2,2m clayey gyttja/sand
2,2-3,7m frictional material (Sand?)

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000028

Company rep.
Lennart Adestam and Torbjörn Johansson

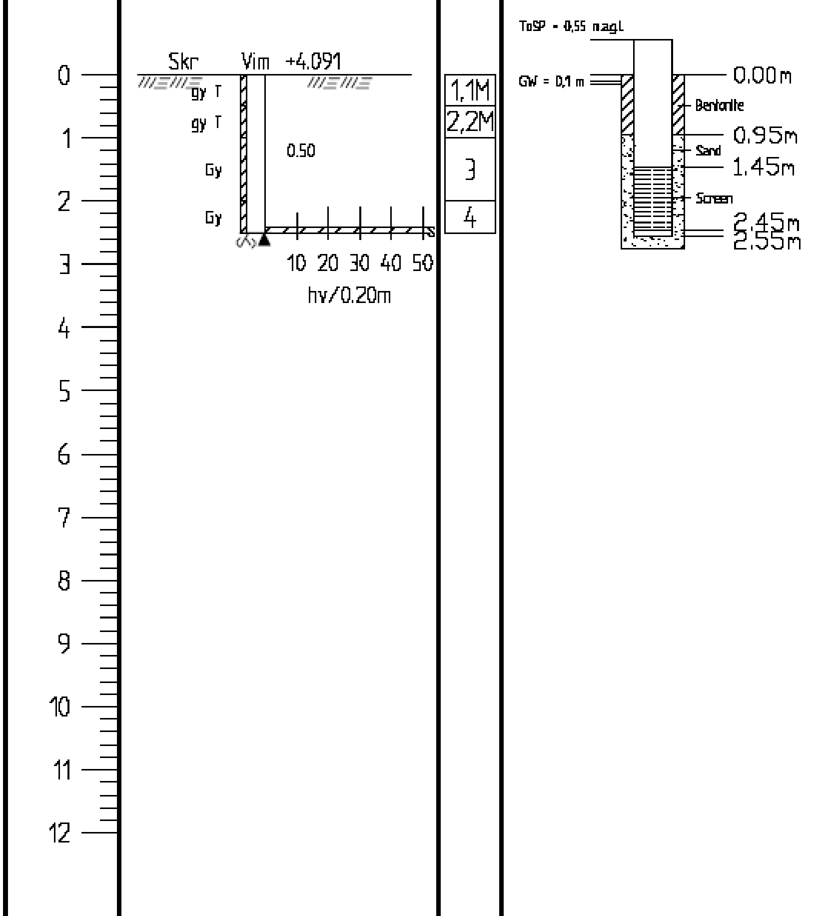
Client: Svensk Kärnbränslehantering AB

Northing :6369642.670
Easting :1546933.108

Coordinate system : RT90-RHB70

Top of stand pipe : 0,55 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 0,1 m.b.g.l.
Date of completion : 2004-06-09

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : Auger
Borehole diameter : 82 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,95 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,80 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-1,0m Gyttja-bearing Peat
1,0-2,5m Gyttja

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

WSP

LAXEMAR BOREHOLE SSM000032

Company rep.
Lennart Adestam and Torbjörn Johansson

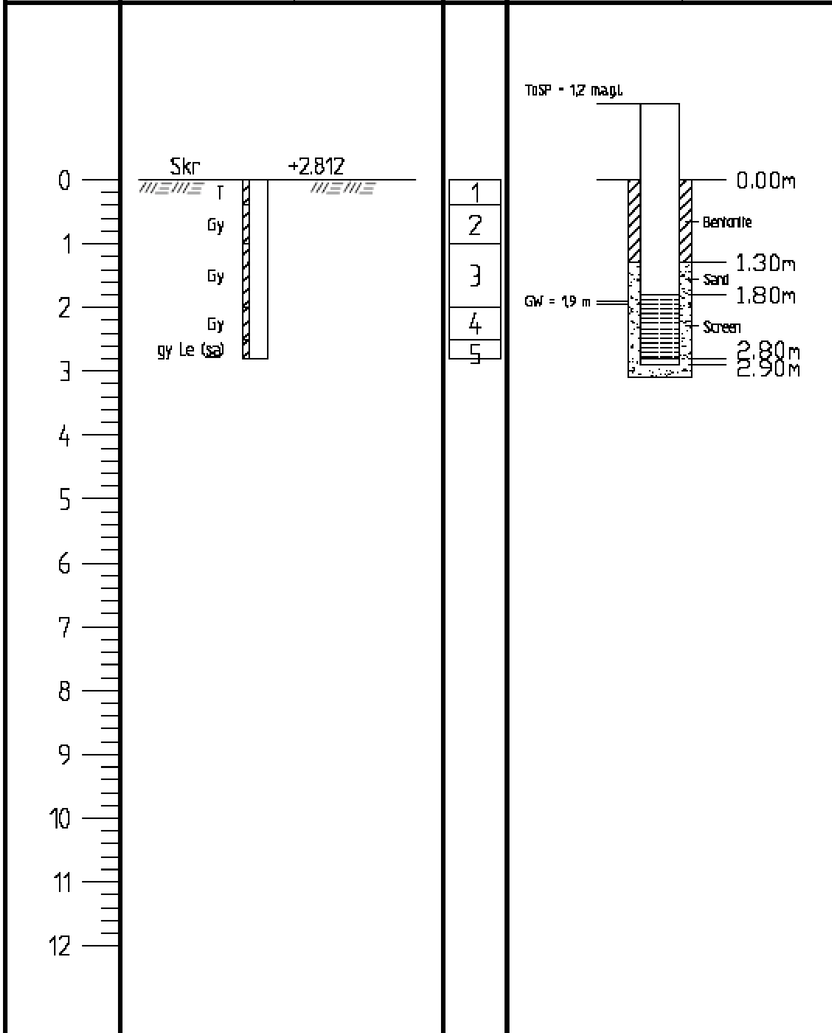
Client: Svensk Kärnbränslehantering AB

Northing : 6367970.561
Easting : 1549397.481

Coordinate system : RT90-RHB70

Top of stand pipe : 1,2 m.a.g.l.
Total pipe length : 4,10 m
Groundwater level : 1,9 m.b.g.l.
Date of completion : 2004-06-15

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : Auger
Borehole diameter : 82 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 3,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,30 m

SAND PACK
Grain size : 0,4–0,8 mm
Total length : 1,80 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Shift Φ54

GEOLOGICAL LOG
0–0,4m Peat
0,4–2,5m gyttja
2,5–2,8m gyttja-bearing clay with sand layer

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000209

Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

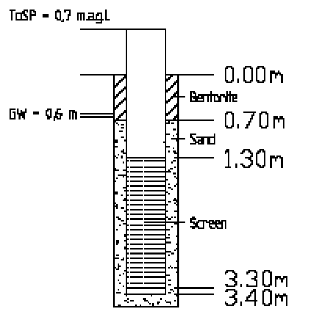
Northing :6367980.830
Easting :1548118.377

Coordinate system : RT90-RHB70

Top of stand pipe :0,7 m.a.g.l.
Total pipe length :4,10 m
Groundwater level :0,6 m.b.g.l.
Date of completion :2004-06-29

Depth (m)	Description	Samples
0	Skr +10.850	
	sa Mu	1,1M
	Sa	2
1	saf Si	3, 2M
2	Sa	4
3	gr sa Mn	5
4		
5		
6		
7		
8		
9		
10		
11		
12		

Groundwater monitoring well description



Borehole Construction Information

Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,70 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,90 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,2m Sandy topsoil
0,2-0,8m sand
0,8-1,2m fine sandy silt
1,2-2,8m sand
2,8-3,8m gravelly sandy till

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000210

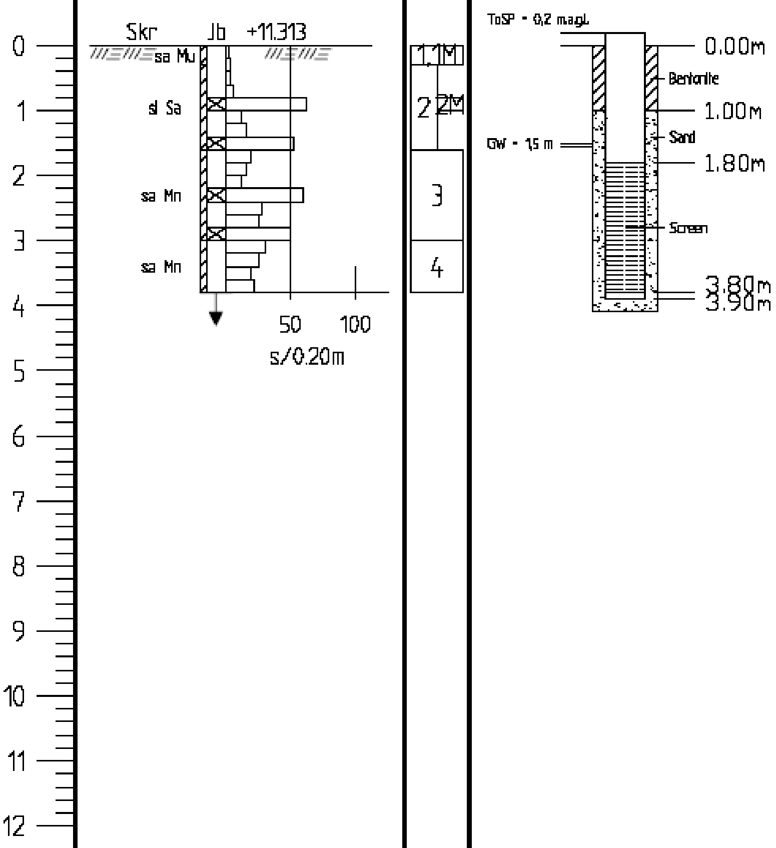
Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

Northing	:6367877.080
Easting	:1548567.865
Coordinate system : RT90-RHB70	

Top of stand pipe	:0,2 m.a.g.l.
Total pipe length	:4,10 m
Groundwater level	:1,5 m.b.g.l.
Date of completion	:2004-06-29

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,00 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 3,10 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,3m Sandy topsoil
0,3-1,6m silty sand
1,6-3,8m sandy till

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000211

Company rep.
Lennart Adestam and Torbjörn Johansson

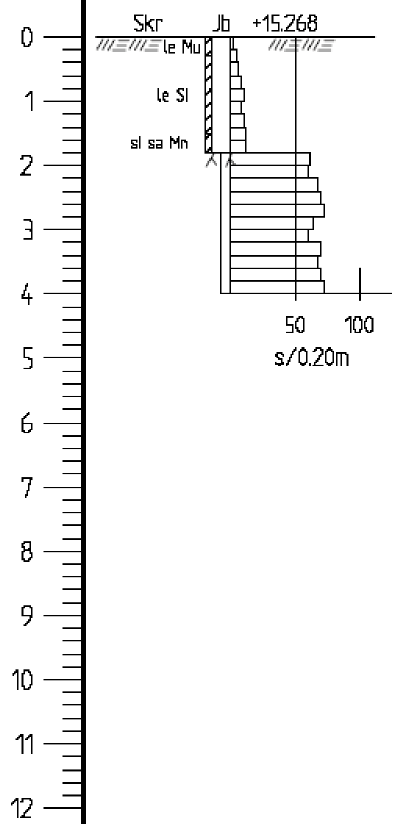
Client: Svensk Kärnbränslehantering AB

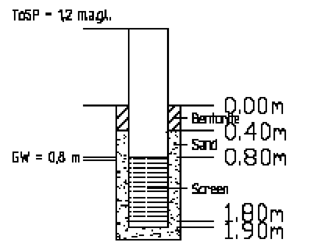
Northing :6367353.169
Easting :1548533.850

Coordinate system : RT90-RHB70

Top of stand pipe :1,2 m.a.g.l.
Total pipe length :3,10 m
Groundwater level :0,8 m.b.g.l.
Date of completion :2004-06-30

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information





Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,40 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,70 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång ø44
Drill bit : Stift ø54

GEOLOGICAL LOG
0-0,3m Clayey topsoil
0,3-1,5m clayey silt
1,5-1,8m silty sandy till
1.8m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

WSP	LAXEMAR BOREHOLE SSM000212

Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

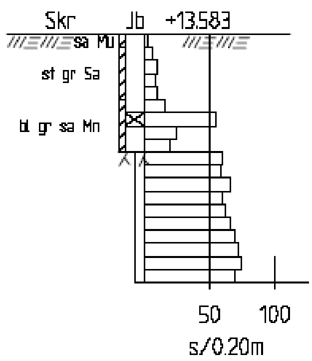
Northing : 6365673.710
Easting : 1548869.822

Coordinate system : RT90-RHB70

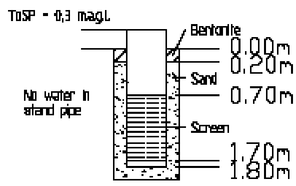
Top of stand pipe : 0,3 m.a.g.l.
Total pipe length : 2,10 m
Groundwater level : -
Date of completion : 2004-07-05

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12



Samples: 1 1M, 2 2M, 3



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,20 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,80 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,2m Sandy topsoil
0,2-1,0m cobble-bearing gravelly sand
1,0-1,8m boulder-bearing gravelly sandy till
1,8m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000213

Company rep.
Lennart Adestam and Torbjörn Johansson

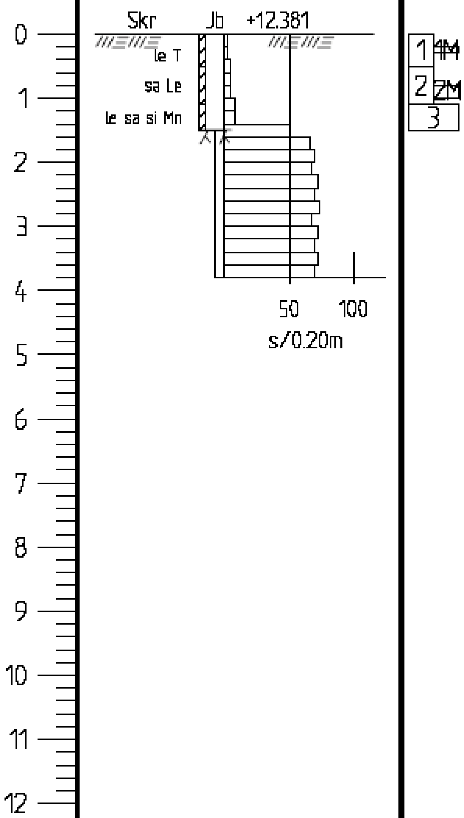
Client: Svensk Kärnbränslehantering AB

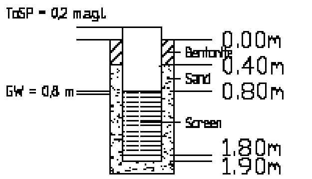
Northing :6365702.618
Easting :1548881451

Coordinate system : RT90-RHB70

Top of stand pipe :0,2 m.a.g.l.
Total pipe length :2,10 m
Groundwater level :0,8 m.b.g.l.
Date of completion :2004-07-06

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information





Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,40 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,70 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,5m Clayey peat
0,5-1,1m sandy clay
1,1-1,5m clayey sandy silty till
1,5m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

WSP

LAXEMAR BOREHOLE SSM000214

Company rep.
Lennart Adestam and Torbjörn Johansson

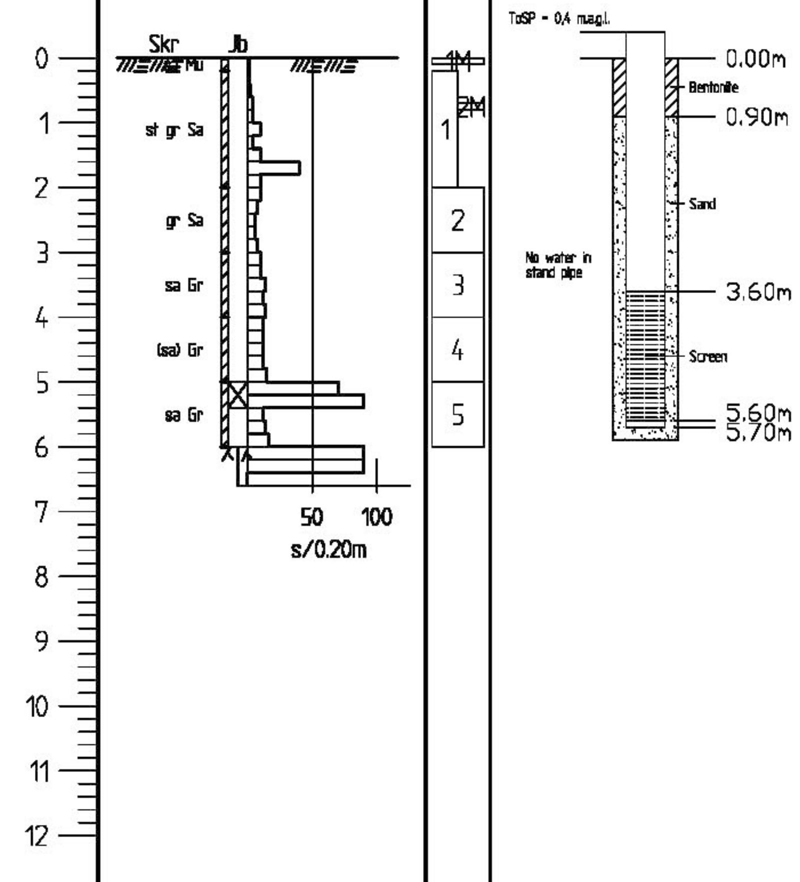
Client: Svensk Kärnbränslehantering AB

Northing :6366513
Easting :1549650

Coordinate system : RT90-RHB70

Top of stand pipe : 0,4 m.a.g.l.
Total pipe length : 6,10 m
Groundwater level : -
Date of completion : 2004-11-30

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 4,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,90 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 5,00 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,2m Sandy topsoil
0,2-2,0m cobble-bearing gravelly sand
2,0-3,0m gravelly sand
3,0-4,0m sandy gravel
4,0-5,0m somewhat sandy gravel
5,0-6,0m sandy gravel
6,0m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000215

Company rep.
Lennart Adestam and Torbjörn Johansson

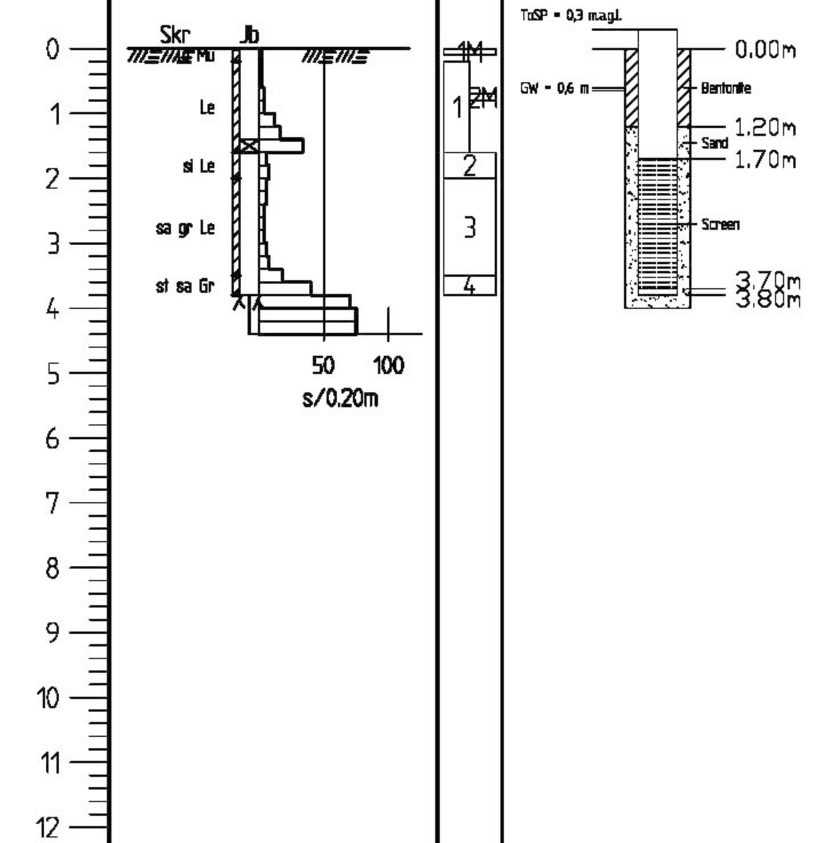
Client: Svensk Kärnbränslehantering AB

Northing :6365593
Easting :1547861

Coordinate system : RT90-RHB70

Top of stand pipe : 0,3 m.a.g.l.
Total pipe length : 4,10 m
Groundwater level : 0,6 m.b.g.l.
Date of completion : 2004-12-06

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,20 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,80 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,2m Clayey topsoil
0,2-1,6m clay
1,6-2,0m silty clay
2,0-3,5m sandy gravelly clay
3,5-3,8m cobble-bearing sandy gravel
3,8m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000217

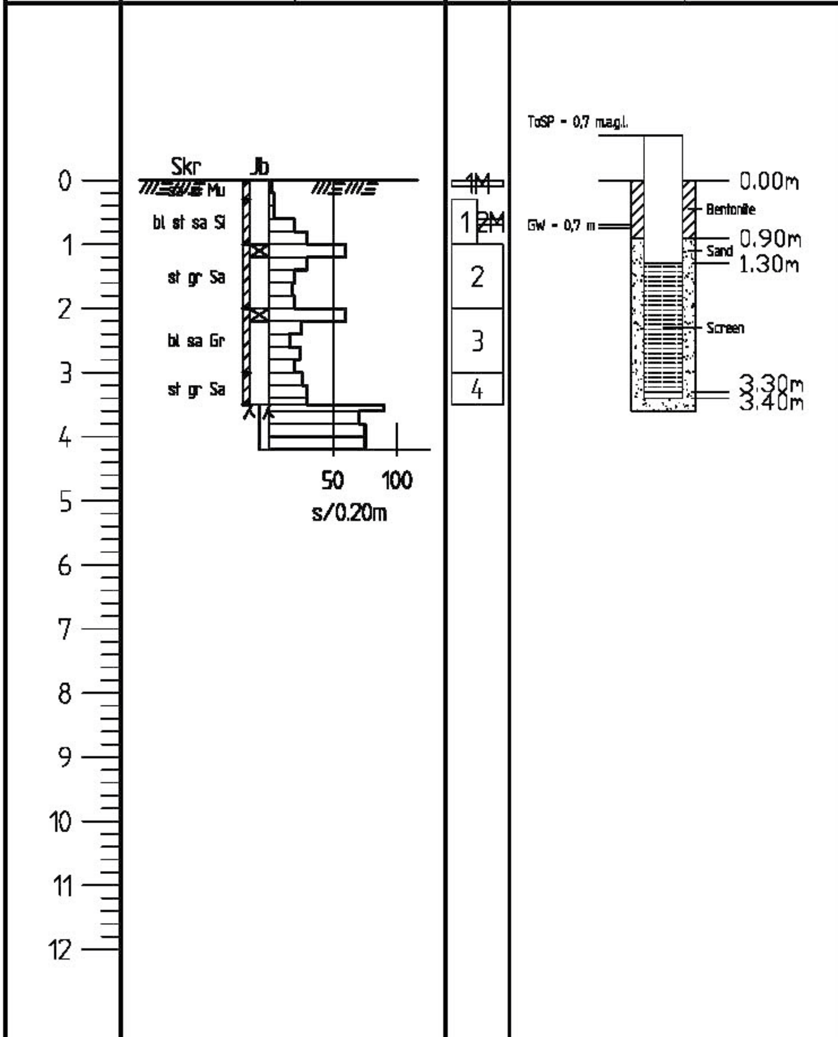
Company rep.
Lennart Adestam and Torbjörn Johansson

Client: Svensk Kärnbränslehantering AB

Northing	:6366636
Easting	:1549236
Coordinate system	: RT90-RHB70

Top of stand pipe	:0.7 m.a.g.l.
Total pipe length	:4,10 m
Groundwater level	:0,7 m.b.g.l.
Date of completion	:2004-12-02

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,90 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 2,70 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

GEOLOGICAL LOG
0-0,3m Sandy silty topsoil
0,3-1,0m boulder- and cobble-bearing sandy silt
1,0-2,0m cobble-bearing gravelly sand
2,0-3,0m boulder-bearing sandy gravel
3,0-3,5m cobble-bearing gravelly sand
3,5m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000221

Company rep.
Lennart Adestam and Torbjörn Johansson

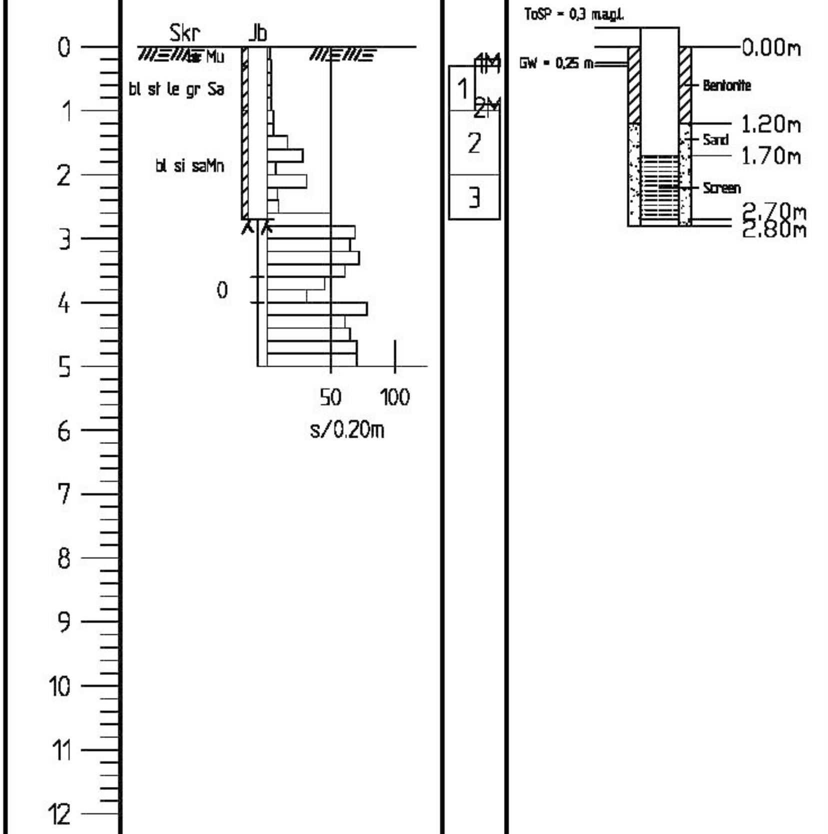
Client: Svensk Kärnbränslehantering AB

Northing :6366384
Easting :1548594

Coordinate system : RT90-RHB70

Top of stand pipe :0,3 m.a.g.l.
Total pipe length :3,10 m
Groundwater level :0,25 m.b.g.l.
Date of completion :2005-05-30

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information



Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,20 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,60 m

DRILLING EQUIPMENT
Drilling rig : Geotech 604
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Slift Ø54

GEOLOGICAL LOG
0-0,3m Clayey topsoil
0,3-1,0m boulder- and cobble-bearing clayey gravelly sand
1,0-2,7m boulder-bearing silty sand till
2,7m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000236

Company rep.
Torbjörn Johansson

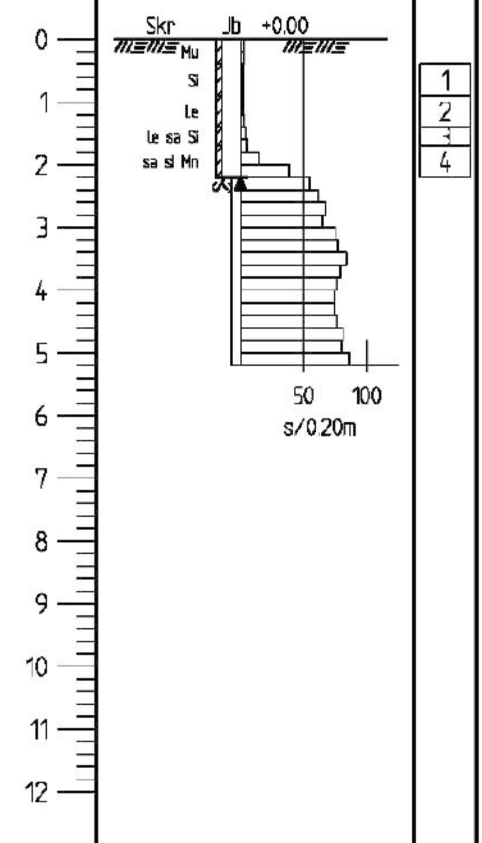
Client: Svensk Kärnbränslehantering AB

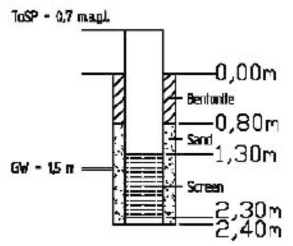
Northing :6366244
Easting :1546656

Coordinate system : RT90-RHB70

Top of stand pipe : 0,7 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 1,5 m.b.g.l.
Date of completion : 2005-11-02

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information





Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 0,80 m

SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,60 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Φ44
Drill bit : Stift Φ54

GEOLOGICAL LOG
0-0,4m Topsoil
0,4-0,9m silt
0,9-1,4m clay
1,4-1,7m clayey sandy silt
1,7-2,2m sandy silty fill
2,2m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

LAXEMAR BOREHOLE SSM000237

Company rep.
Torbjörn Johansson

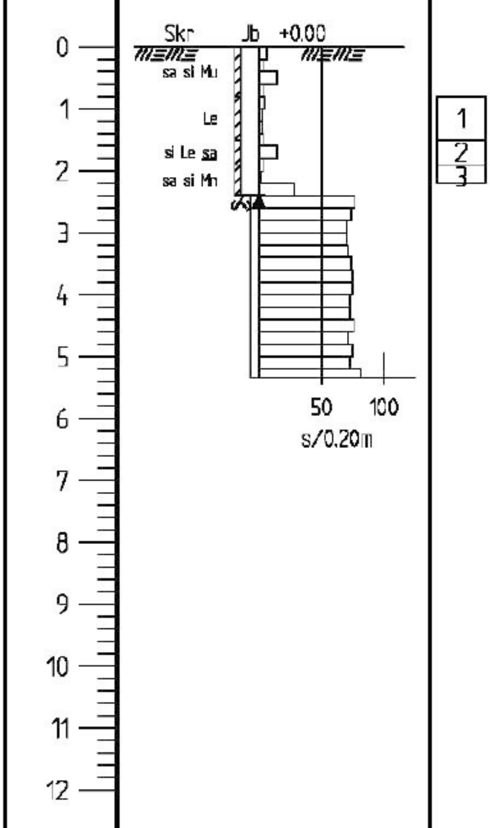
Client: Svensk Kärnbränslehantering AB

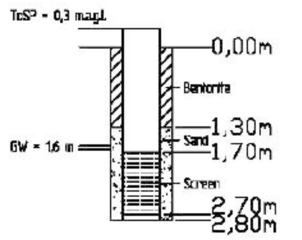
Northing :6366203
Easting :1546651

Coordinate system : RT90-RHB70

Top of stand pipe : 0,3 m.a.g.l.
Total pipe length : 3,10 m
Groundwater level : 1,6 m.b.g.l.
Date of completion : 2005-10-31

Depth (m)	Description	Samples	Groundwater monitoring well description	Borehole Construction Information





Drilling method : NOEK
Borehole diameter : 120 mm
sampling method : Auger

CASING
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 2,00 m

SCREEN
Material : PEH
Outer diameter : 63 mm
Inner diameter : 50 mm
Total length : 1,00 m
Slot : 0,3 mm

ANNULUS SEAL
Material : Bentonite clay
Total length : 1,30 m

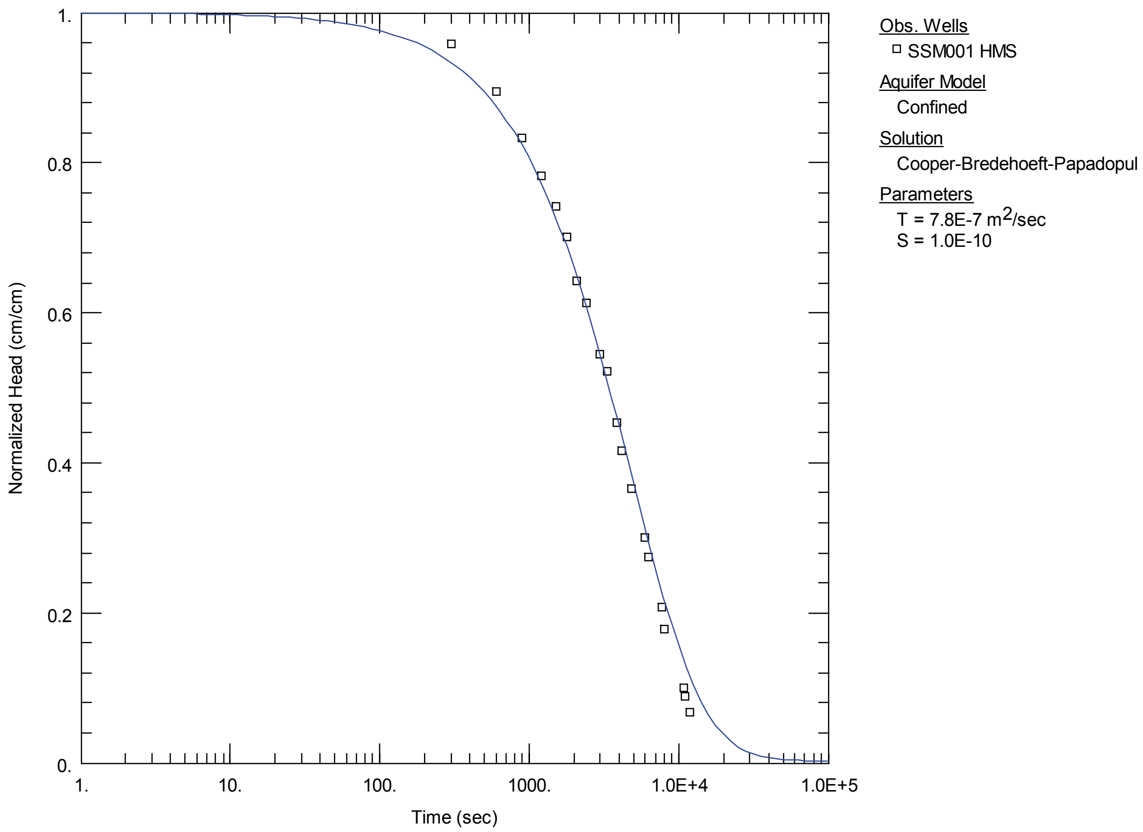
SAND PACK
Grain size : 0,4-0,8 mm
Total length : 1,50 m

DRILLING EQUIPMENT
Drilling rig : GM 65 GTT
Drill hammer : Furukawa HB2G
Drill rod : Geostång Ø44
Drill bit : Stift Ø54

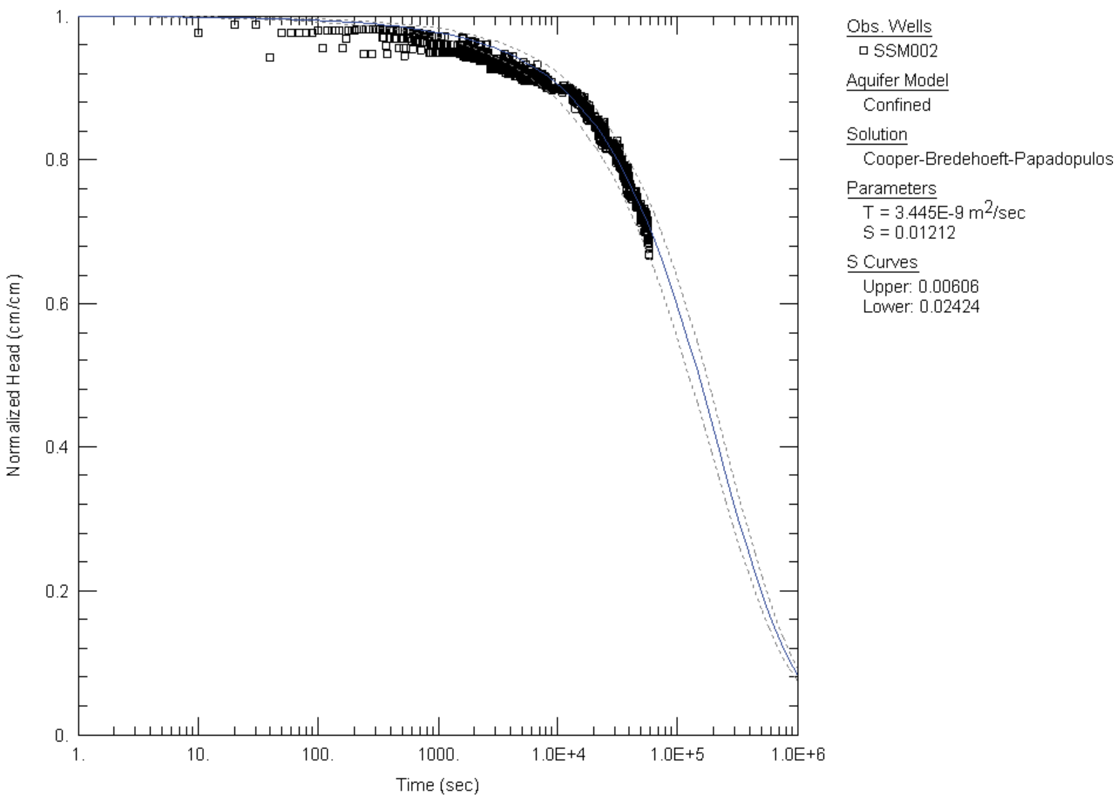
GEOLOGICAL LOG
0-0,8m Sandy silty topsoil
0,8-1,5m clay
1,5-1,9m silty clay with sand layers
1,9-2,4m sandy silty fill
2,4m rock surface

ToSP : Top of Stand Pipe
m.a.g.l. : meters above ground level
m.b.g.l. : meters below ground level

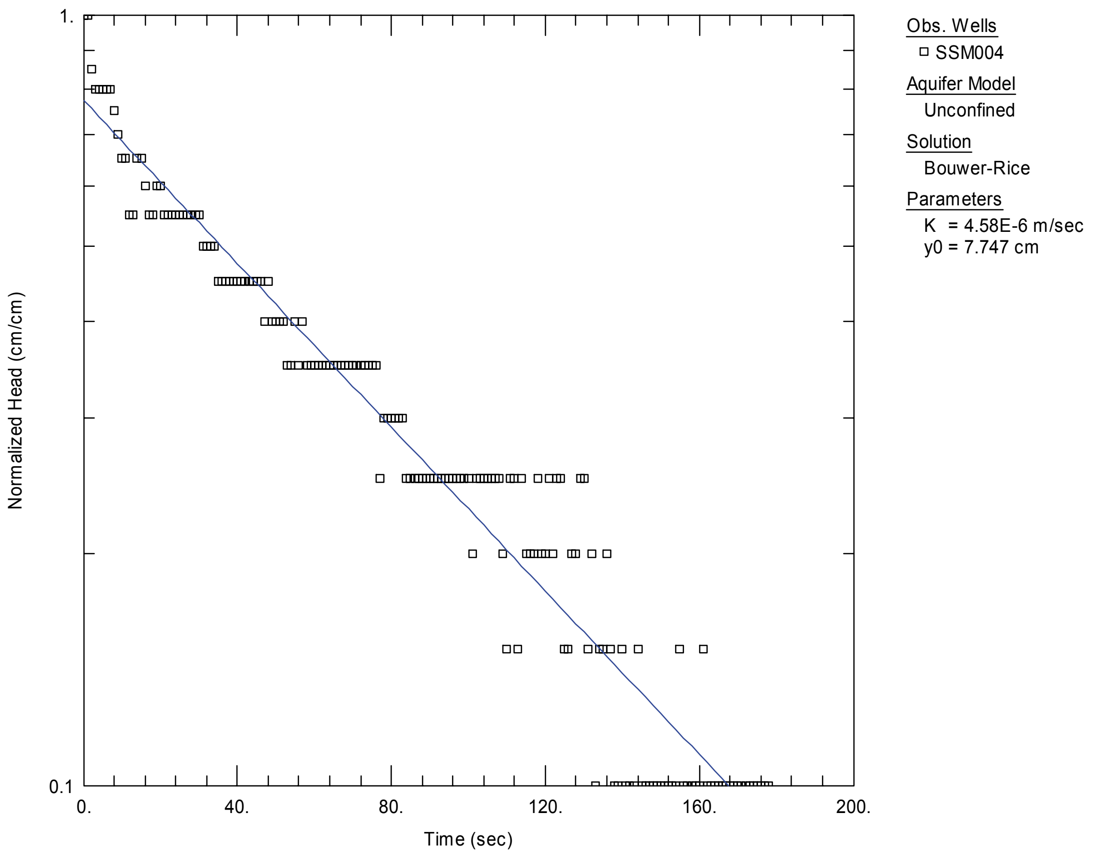
SSM001



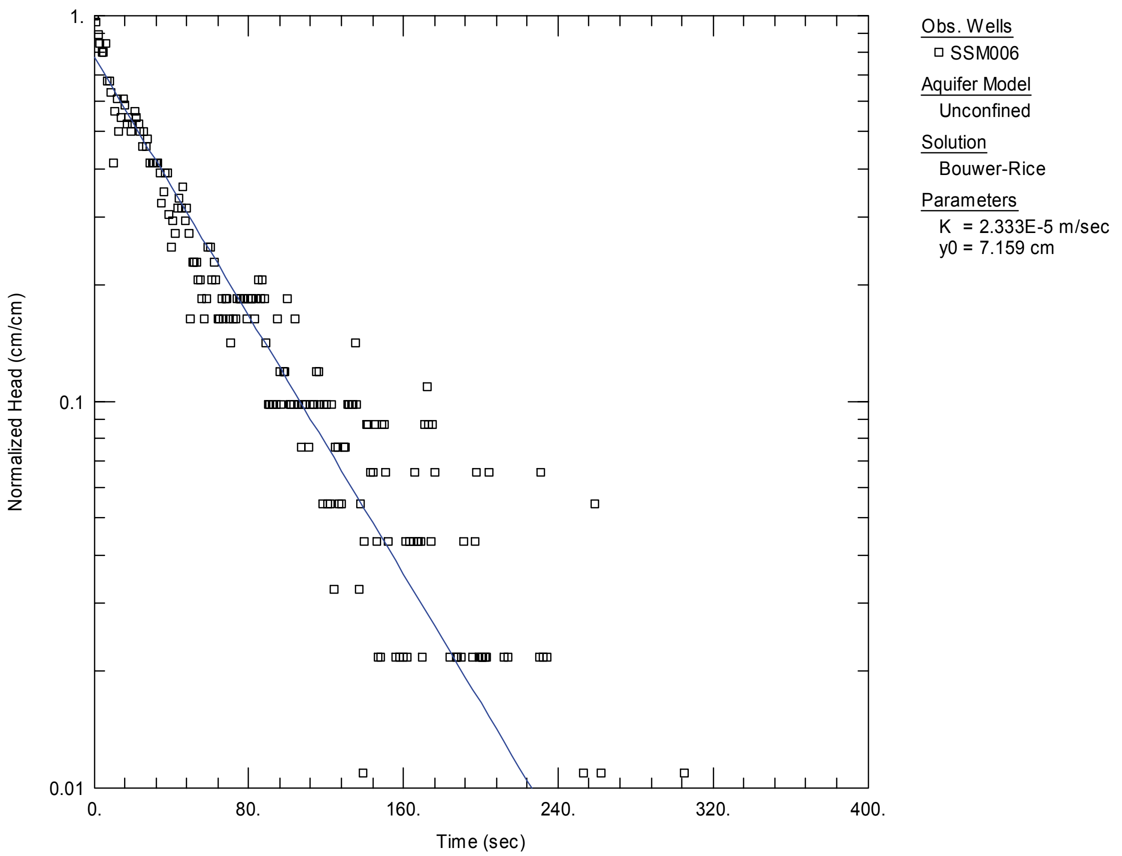
SSM002



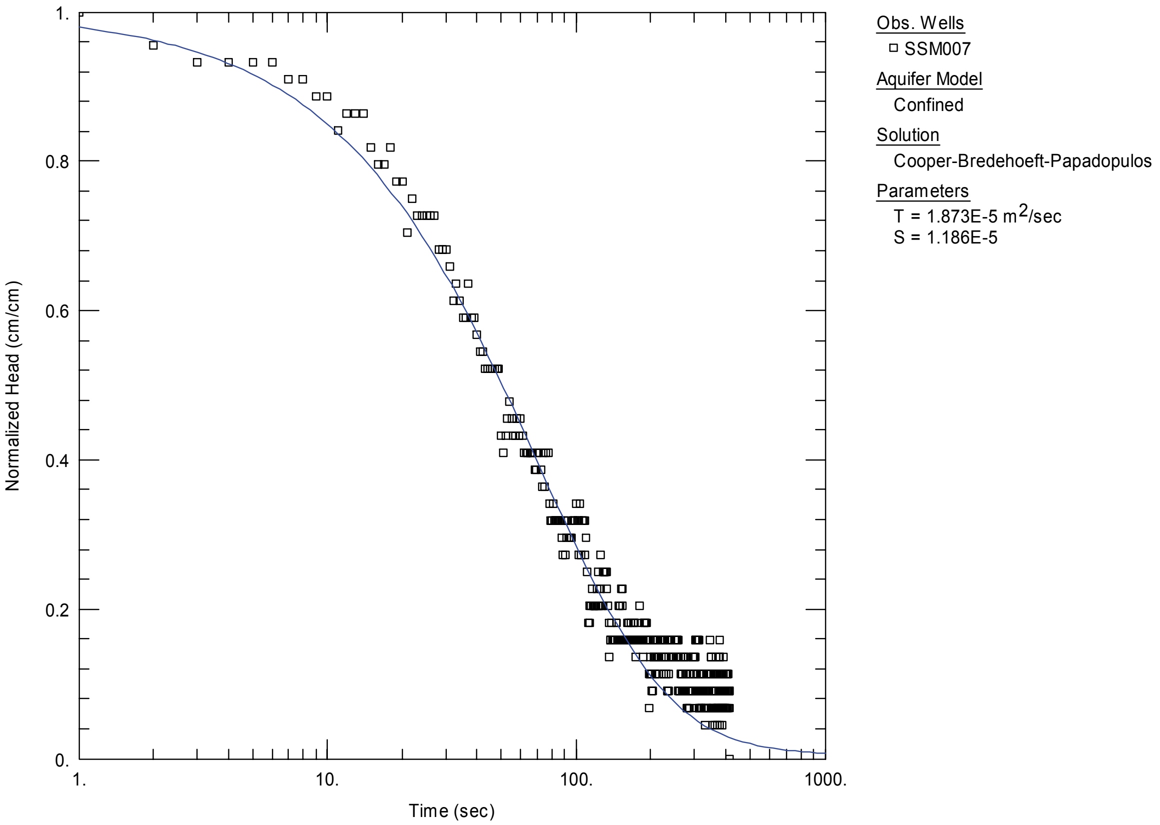
SSM004



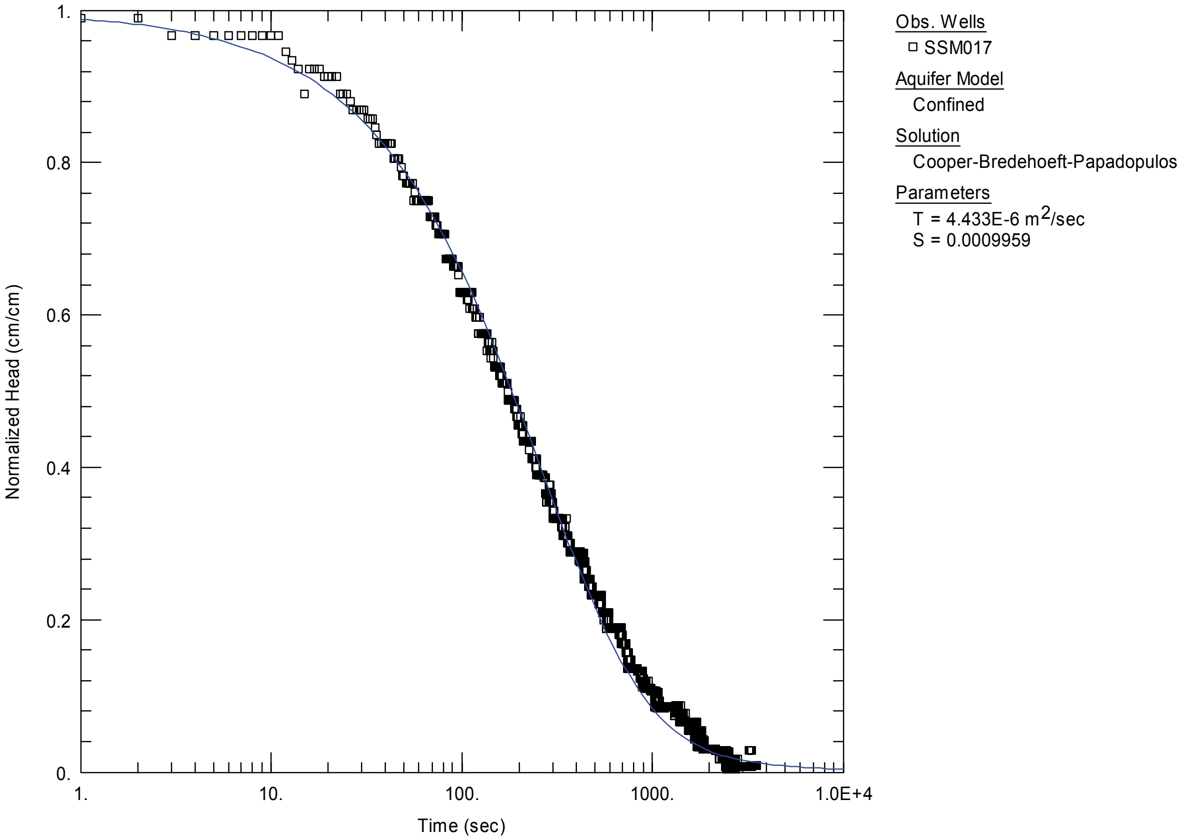
SSM006



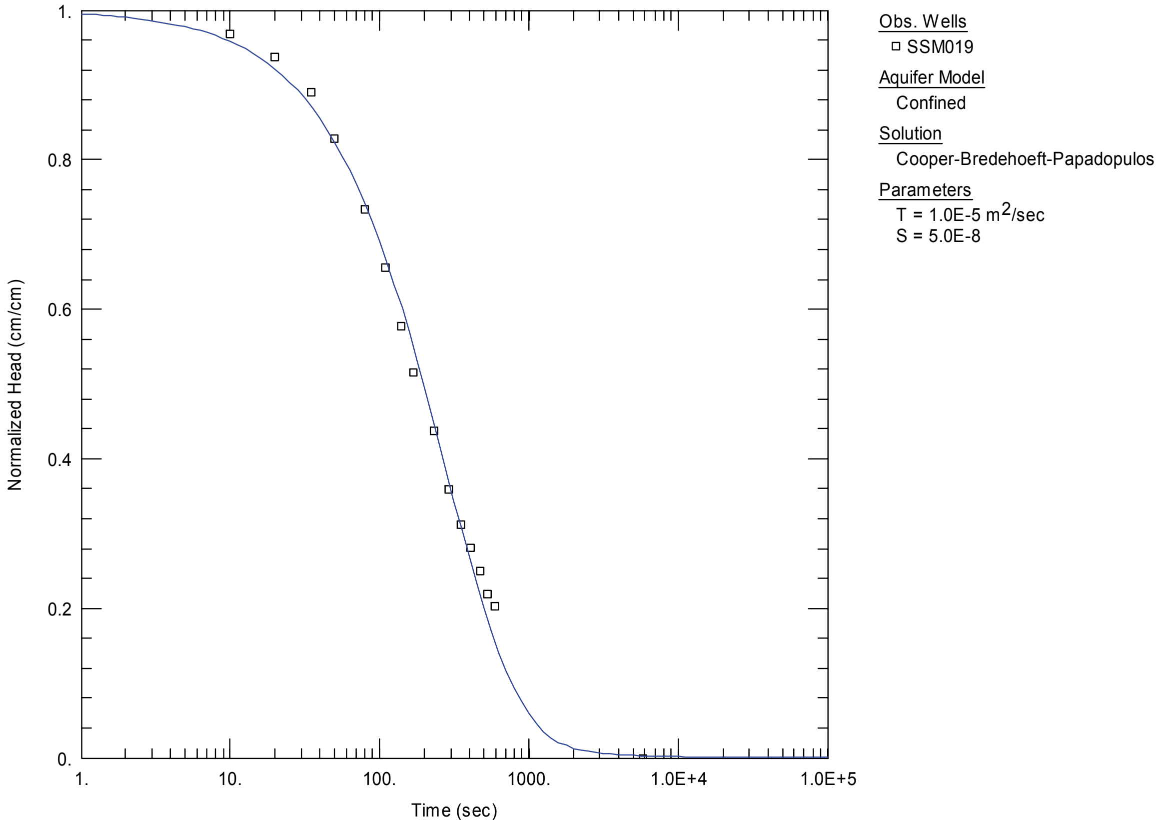
SSM007



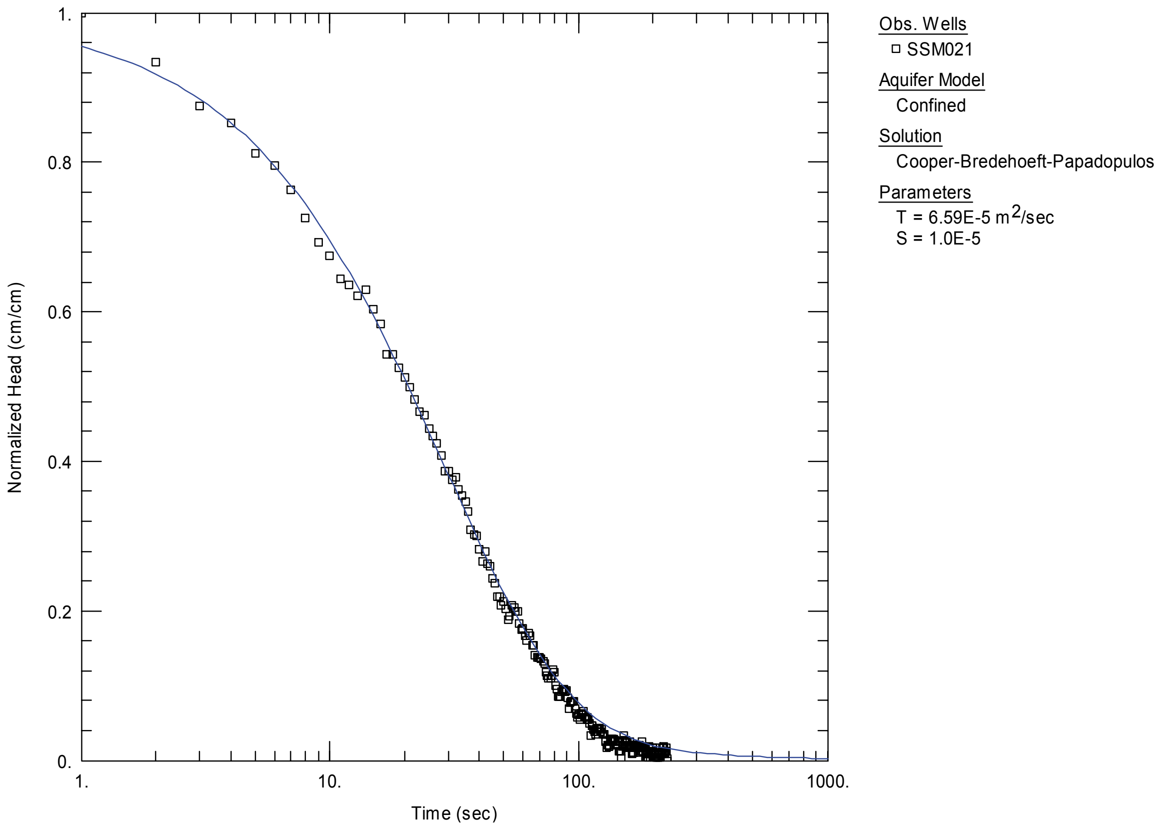
SSM017



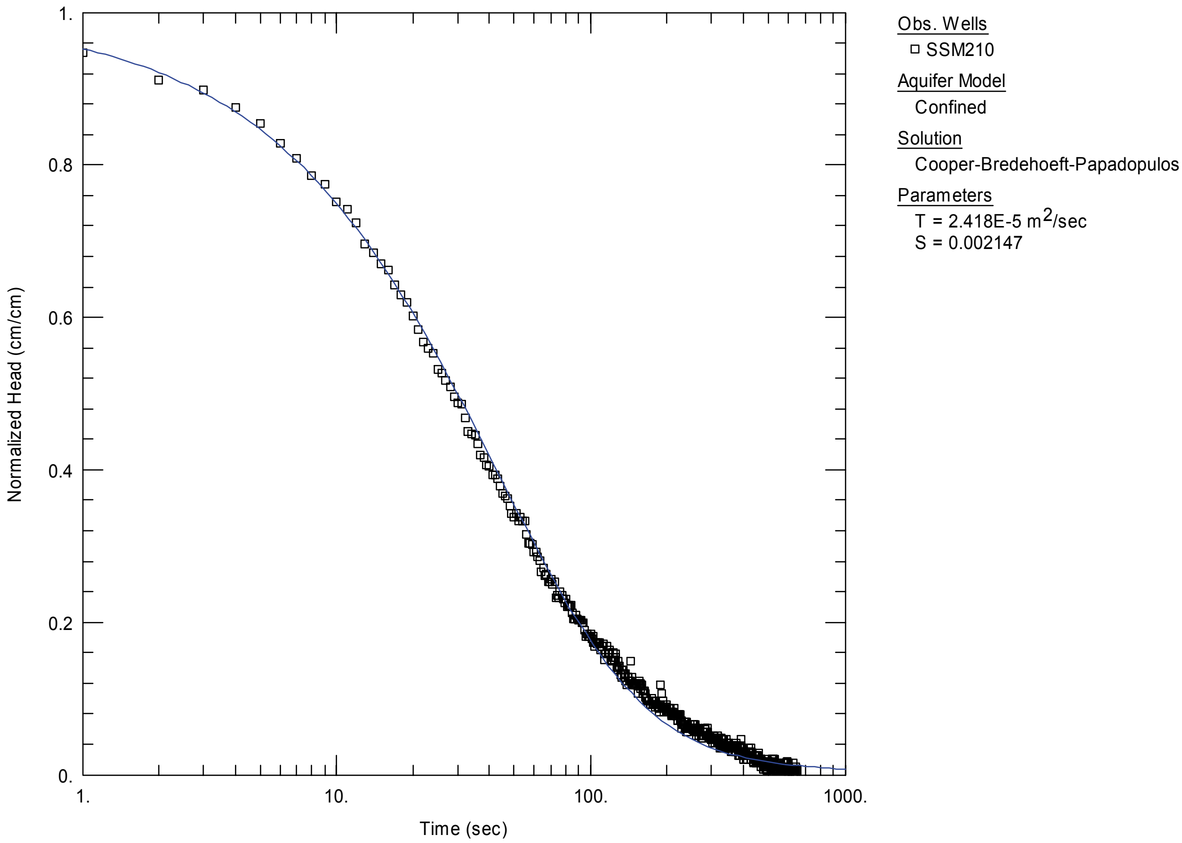
SSM019



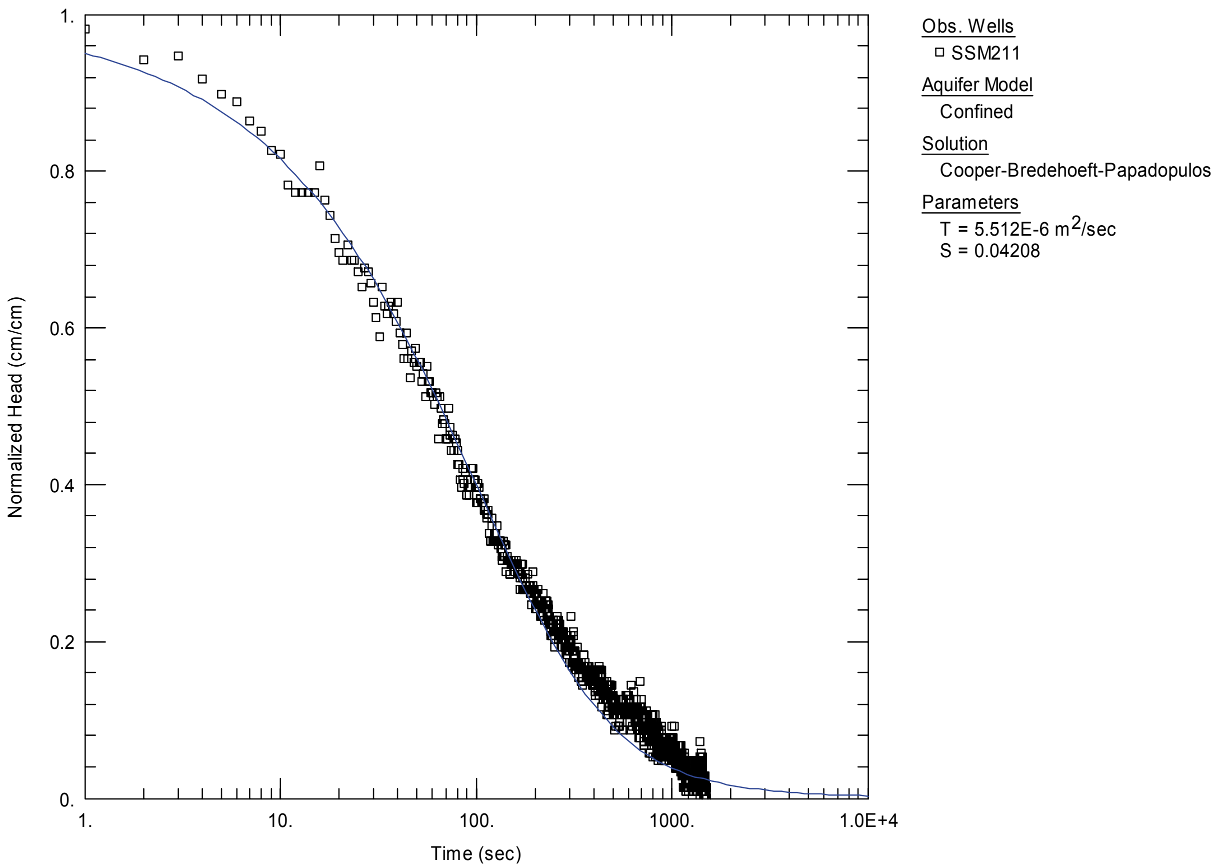
SSM021



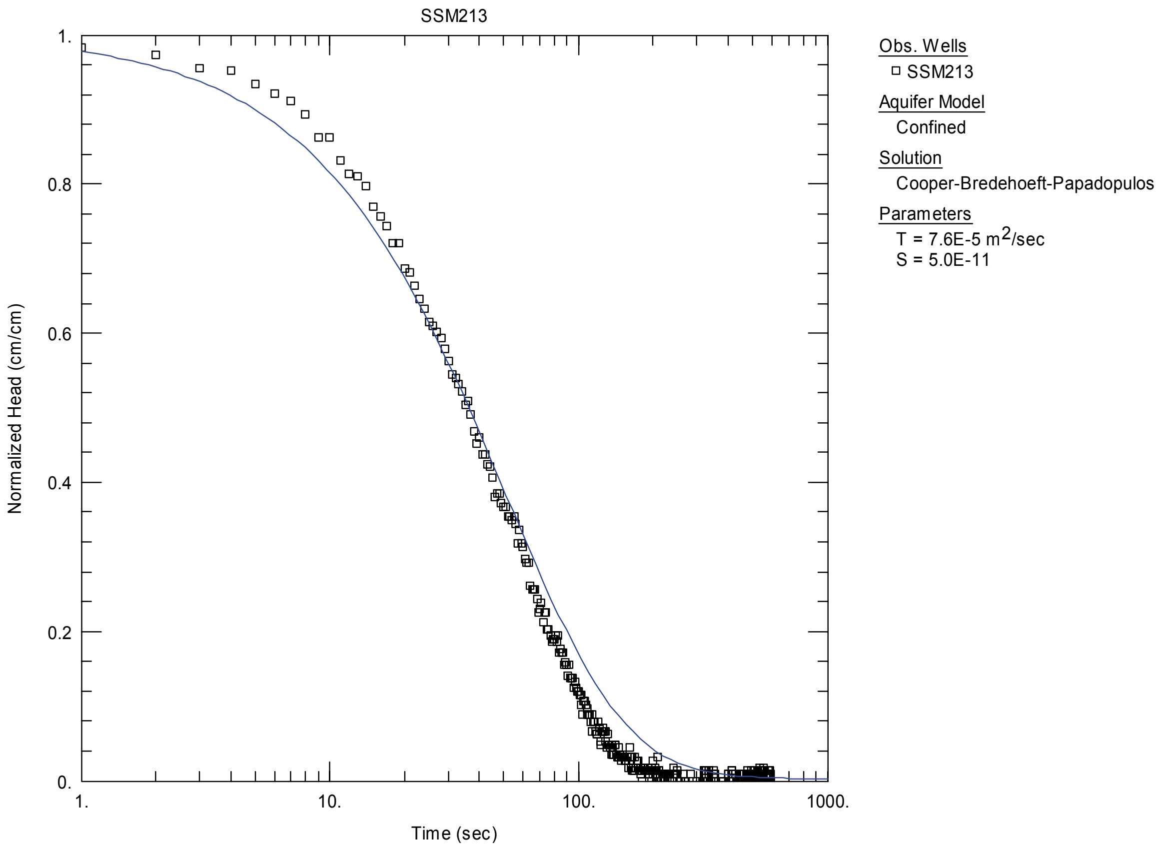
SSM210



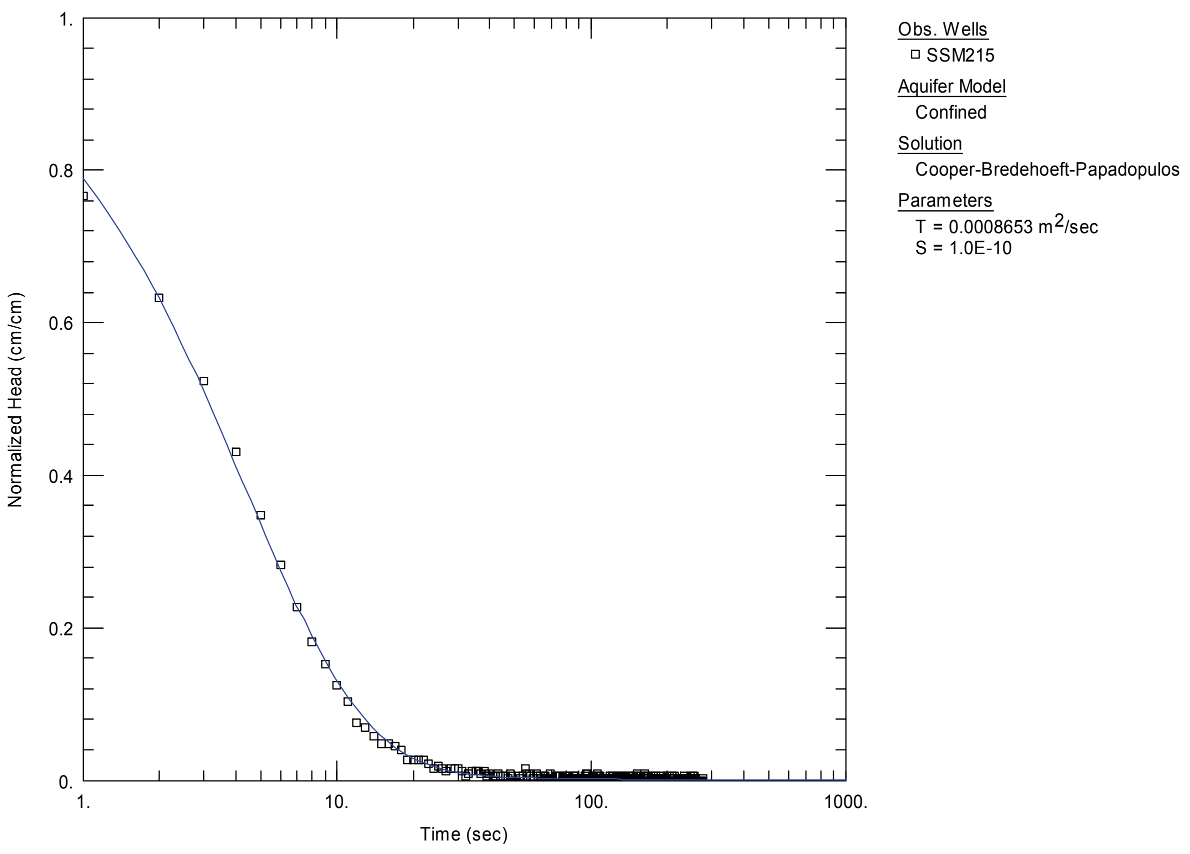
SSM211



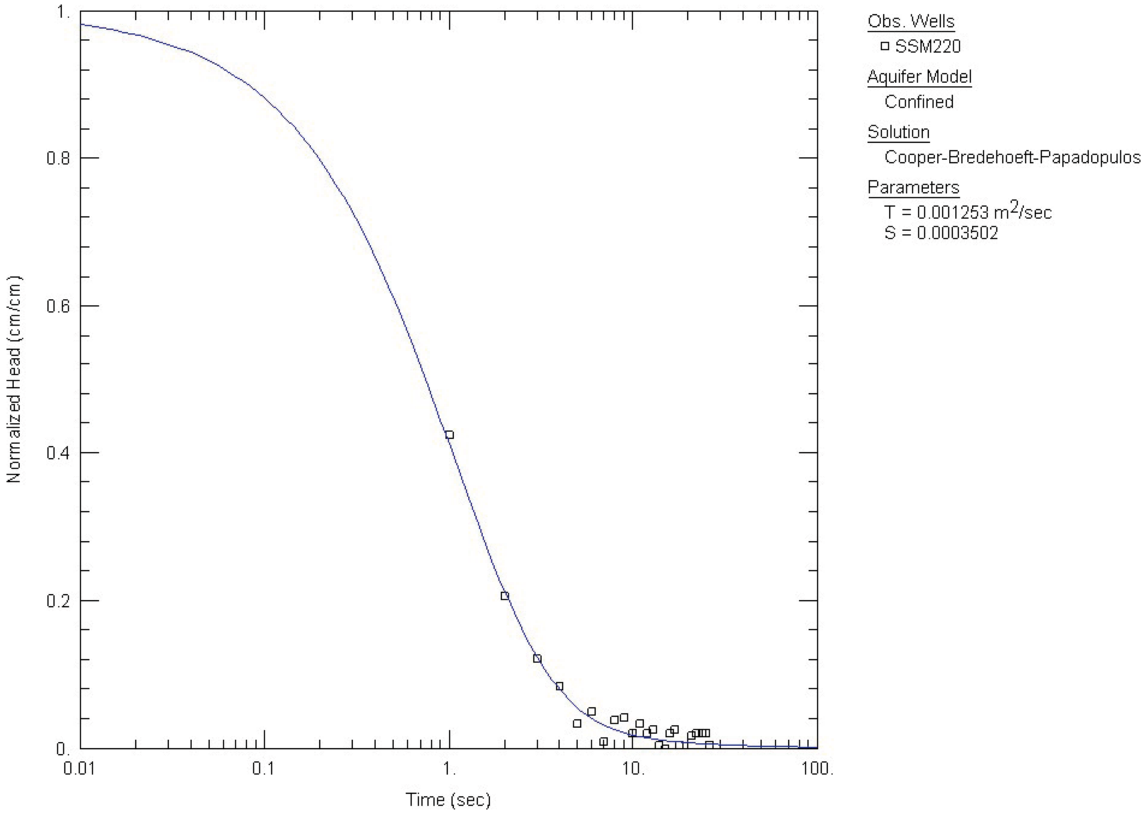
SSM213



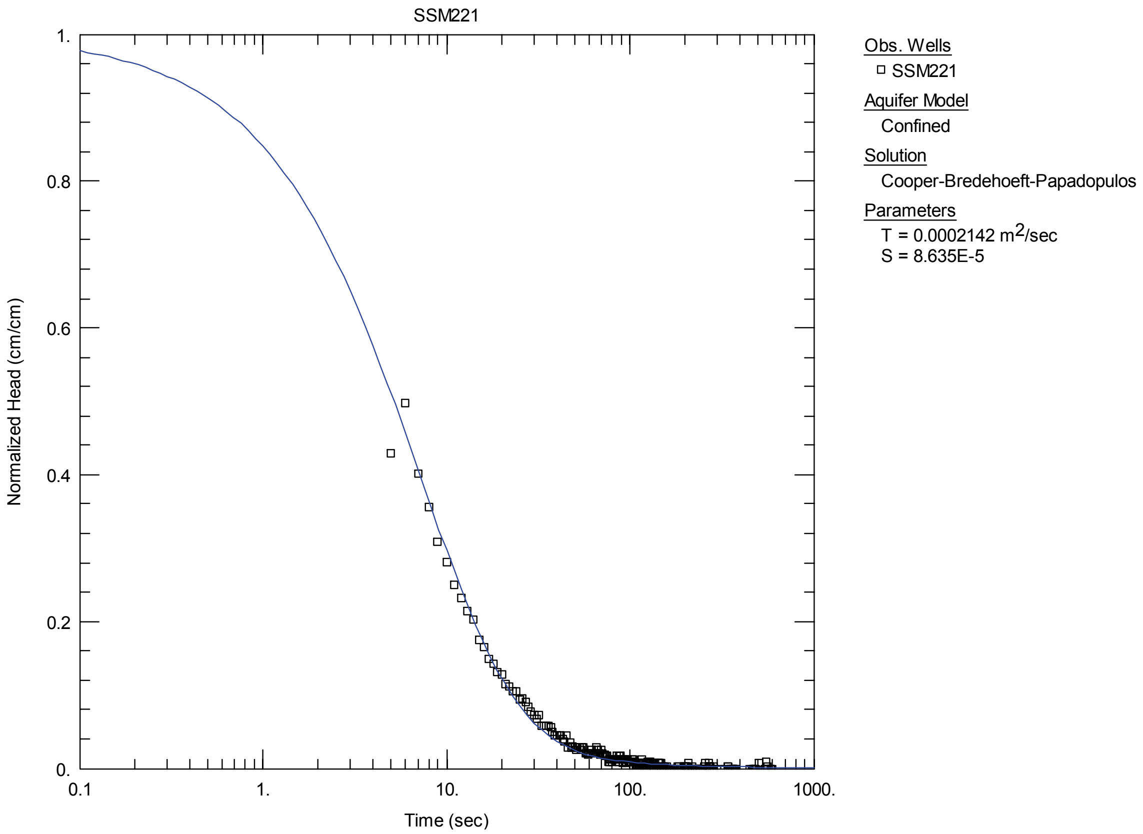
SSM215



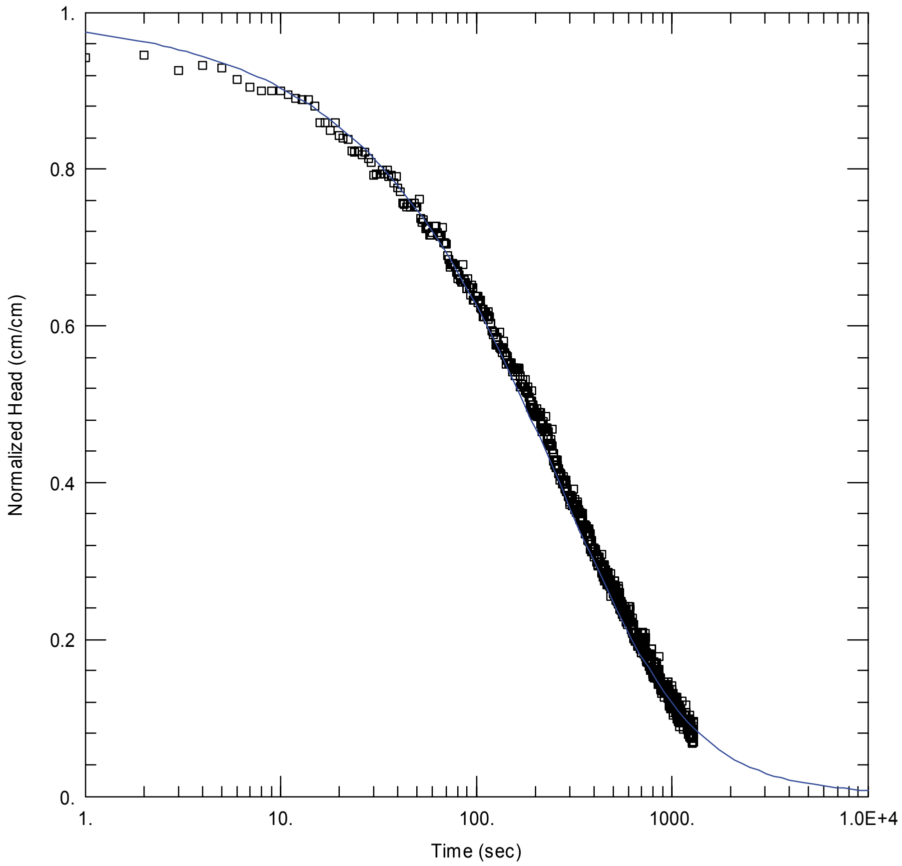
SSM220



SSM221



SSM237



Obs. Wells
SSM237

Aquifer Model
Confined

Solution
Cooper-Bredehoeft-Papadopulos

Parameters
T = 2.367E-6 m^2/sec
S = 0.026