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RESUME 99

Rapid Environmental Surveying Using Mobile Equipment

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Abstract

This report describes the exercise RESUME 99 that took place in the surroundings of Gävle in Sweden, September 6-9, 1999. The exercise was a part of the project BOK-1.2, Mobile measurements and measurement strategies, within the NKS research program for 1998-2001. RESUME 99 was primarily aimed at testing mobile gamma spectrometry with systems carried by cars, but also *in situ* measurements were carried out during the exercise. In the exercise, the activity levels of ^{137}Cs stemming from the Chernobyl accident in 1986 was measured and mapped. The objectives of the exercise were to train participating teams in measuring, to test co-operation for nuclear emergency preparedness, and to prepare for a larger European exercise in 2001. Another objective of the exercise was to integrate the carborne gamma-ray survey with recent airborne gamma-ray survey measurements of the area. The exercise generated a substantial database that can be used for further research in this field. Several interesting features were included in the RESUME 99 exercise, such as advanced on-site processing of data and direct presentation of results on an exercise web site. This report describes the planning, preparation and execution of the exercise, the participating teams, and results that was presented during the exercise.

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RESUME 99

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NKS
Nordic Nuclear Safety Research

Report from the NKS/BOK-1.2 project group
Mobile Measurements and Measurement Strategies

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CONTENTS **Page**

1. EXECUTIVE SUMMARY

The exercise RESUME 99 took place in the town Gävle and surrounding areas on September 6-9, 1999. Gävle is located in the middle of Sweden on the east coast, about 200 km north of Stockholm. The exercise was a part of the NKS research project BOK-1.2: Mobile measurements and measurement strategies, which main objectives are [NKS, 1999]:

> *To investigate the feasibility of integrating different field measurements, mainly mobile equipment (carborne and airborne), in the early phase of a nuclear emergency situation; to participate in a large European exercise on mobile γ - spectroscopy with the aim of achieving experience in applying the results for emergency response purposes.*

The objective for the RESUME 99 participants was to measure and map the fallout from the Chernobyl accident in 1986. The area around Gävle received the heaviest fallout in Sweden from the accident resulting in activity levels of ^{137}Cs of the order of 10 – 200 kBq/m^2 with smaller areas and "hot spots" of still higher activity. The area has been investigated since 1986 in different ways and is probably one of the best-documented areas in the world regarding the Chernobyl fallout. Recently, the Geological Survey of Sweden performed airborne measurements over the area [SGU, 1998]. These airborne measurement data will be one of the reference sets to the data produced during the exercise. The data will be used in the upcoming research projects within NKS/BOK-1.2.

Planning for the RESUME 99 exercise took place during several NKS project meetings, as well as in numerous exercise task group meetings. The last NKS project meeting in Stockholm on June 2, 1999, was attended by most of the participating organisations. The preparation for, and the execution of the exercise was to a large extent carried out by the Swedish Radiation Protection Institute (SSI).

The exercise was primarily intended to include only mobile measurement systems carried by cars. As the planning went on, the exercise was expanded, also to include several *in situ* teams that performed dose rate measurements and high-resolution gamma spectrometry in the area. A web site, www.nks.ssisweden.com, was created for the exercise, containing information on the planning of the exercise as well as exercise results, maps, etc.

The exercise had close to sixty participants from ten countries. Beside Nordic participation, there were measurement teams from Poland and the three Baltic countries as well as observers/consultants from Scotland and Canada. A total of ten mobile teams and seven *in situ* teams took part in the exercise.

The base of the exercise was placed at Älvkarleö Herrgård, some 20 km south-east of Gävle city centre. The exercise started with an information meeting on Monday, September 6 and ended with a dinner party on Thursday, September 9. Tuesday and Wednesday were dedicated to measurements with different tasks and Thursday was a day for discussion of results and planning of future research work.

In the conference building of Älvkarleö Herrgård the exercise headquarters were situated. Here, all information meetings were held and the administrative staff handled status reports from the teams and other logistic details. Maps and other results of the exercise could be studied here and computer facilities were made available to the participants.

The heart of the headquarters was the computer and communications centre (CCC) where data processing and presentation of results took place. To make the central processing work smoothly a special format for the data files, called the NKS-format, had been developed (Appendix III). Results from all mobile measurements were reported to the staff at CCC in this format.

The CCC assisted the teams with exercise specific maps and road descriptions for the measurements. Data processing were performed both on local computers and on computers located at the Geological Survey of Sweden (SGU) in Uppsala. Transfer of data was performed using ordinary e-mail and by the use of a satellite connection (300-400 kbit/s). In this way large files could be transferred from the ftp-site at SGU without too much time delay. Colour-graded point maps and interpolated grid maps with the fallout levels in the area were printed out at the headquarters using a large format plotter. Maps and other results were also transferred to a web server for presentation on the web site.

The first day of measurements, the mobile teams should measure along a specified calibration route, which was about 200 km long. All teams were to drive through the route in the same direction and in the same speed but with different starting times, to avoid crowding and to make the results comparable. Along the route there were four calibration points where the cars should stop to make stationary measurements. Three of these calibration points were situated on grass areas while one was an asphalt/forest site. This last point was included to compare the different systems measuring in a geometry similar to that of a road.

The second day, each mobile team was assigned an area of their own of about 15 x 15 km^2 for measurements. During a limited time, measurements were to be performed in the best possible way, with the aim of getting a good overview of the fallout within the team specific area. Thereafter, measurement data from all areas were combined to produce one map showing the fallout in the whole Gävle region.

For the *in situ* teams, 14 sites were selected where measurements should be made during the two days. In addition, the four calibration points along the route for the mobile teams should be measured to be able to compare *in situ*- and mobile results. The *in situ* sites were spread out over a large part of the Gävle region. They included sites with different type of soil and vegetation and activity levels of ^{137}Cs ranging from about 5 to 60 kBq/m^2 (equivalent surface activity, cf. p. 8). Beside high resolution gamma spectrometry, dose rate measurements were performed and soil samples were taken. Soil samples were analysed in the field or in the hotel rooms, but were also sent to laboratories for analysis.

The reported results displayed large differences between the teams. At the calibration points, differences up to a factor of three in the equivalent surface activity of ^{137}Cs was observed. Excluding the Baltic and Polish results, that were a factor of two too high due to a calibration error, there was still more than a factor of two in difference between the highest and lowest values reported. Even though the absolute levels displayed large differences, the ratio between levels recorded by the different teams stayed more or less constant at the four calibration points. This indicates a large uncertainty in the calibration of the different systems.

The mosaic task of combining measurements in different areas into one big fallout map went well, though there were problems reaching many of the smaller roads due to locked road gates. To account for the differences in the calibration of the systems, all values reported during this part of the exercise were scaled to give the same value at one of the calibration points that was measured the first day.

The map production and the presentation of results on the web page were successful parts of the exercise as they were characterised by swiftness. Only a couple of hours after the delivery of the NKS-files high quality results were presented to the public.

The performance of the teams and the co-operation between them showed that exercises like this is necessary to keep the competence within the area and to reveal problems and weaknesses of the systems. Many teams were affected by problems during the first day of measurements, but as the exercise moved forward most problems were solved.

In the diagram below results from the four calibration points from both mobile and *in situ* teams are shown.

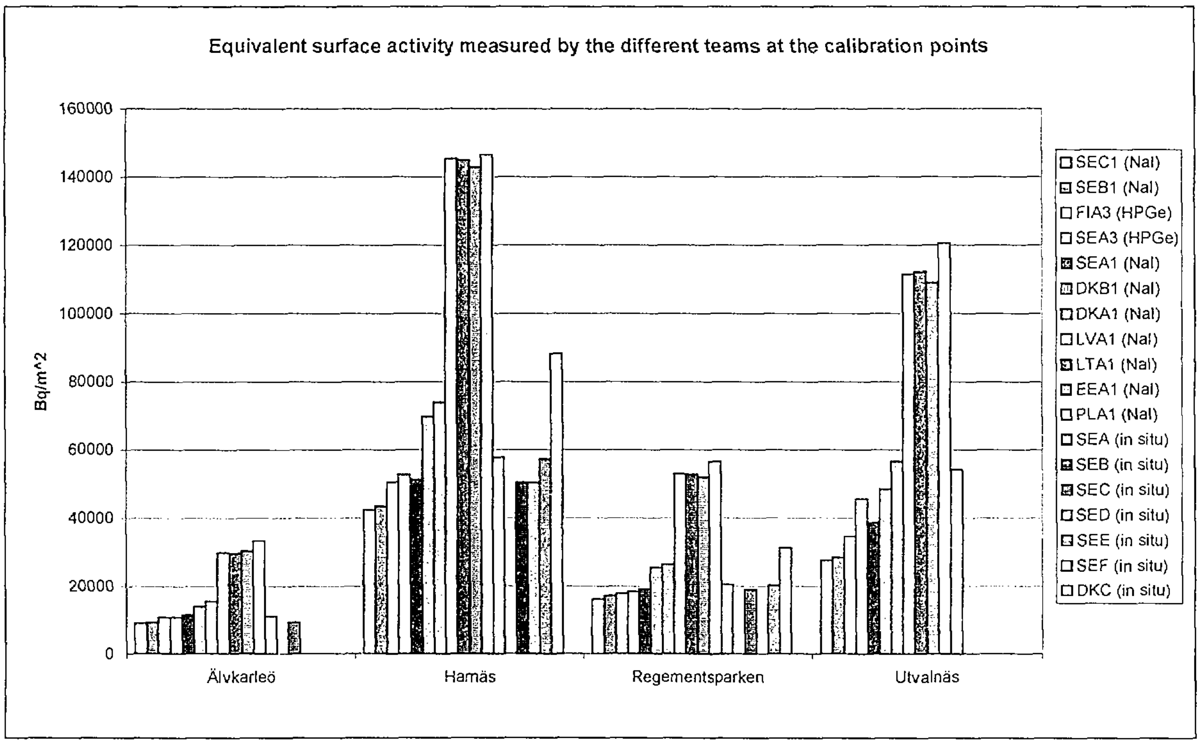


Figure 30. The equivalent surface activity (Bq/m^2) at the four calibration points visualised in a diagram.

2. INTRODUCTION

The exercise RESUME 99 (Rapid Environmental Surveying Using Mobile Equipment) took place in the Gävle area in Sweden, September 6-9, 1999. The exercise was a part of the NKS research project BOK-1.2: Mobile measurements and measurement strategies, which main objectives are [NKS, 1999]:

> *To investigate the feasibility of integrating different field measurements, mainly mobile equipment (carborne and airborne), in the early phase of a nuclear emergency situation; to participate in a large European exercise on mobile γ - spectroscopy with the aim of achieving experience in applying the results for emergency response purposes.*

The exercise was at first called the Gävle mini exercise, but as it grew bigger it was given the name RESUME 99 after a previous exercise in Finland 1995, called RESUME 95 [NKS, 1997]. The exercise had close to 60 participants from 10 different countries. Beside the Nordic participation there were measurement teams from Poland and the three Baltic countries and also observers/consultants from Scotland and Canada. A total of 10 mobile teams and 7 *in situ* teams took part in the exercise. The exercise also involved the Swedish nuclear emergency preparedness organisation.

The objectives of the exercise were to prepare for a larger European exercise in 2001, to test and train field teams in rapid measurements of ionising radiation in a fallout area of a nuclear reactor accident and also to test the co-operation between teams, simulating international assistance to a country after an accident.

The exercise was also performed to get a better understanding of the differences and similarities between airborne and carborne gamma spectrometry. For this purpose Gävle is an ideal place. The area around the town Gävle received the largest fallout in Sweden from the Chernobyl accident in 1986. The activity of ^{137}Cs was of the order of 10 – 200 kBq/m^2 with smaller areas and "hot spots" of still higher activity. The area has been investigated since 1986 in different ways and is probably one of the best-documented areas in the world regarding the Chernobyl fallout. Recently, the Geological Survey of Sweden performed airborne gamma spectrometric measurements over the whole area [SGU, 1998]. The line spacing used was 200 meters, the flying height was 60 meters, and the integration frequency was 4 Hz, resulting in one measurement point every 16 meters. The airborne measurements were one of the reference data sets to the data produced during the exercise.

The exercise was focused on mobile gamma spectrometry from cars. Other measurements like *in situ* high-resolution gamma spectrometry using portable equipment and soil sampling and preparation with subsequent measurements on portable or laboratory based gamma spectrometers were also performed. Reporting and processing of measurement data were to be as realistic as possible, simulating the time constraints of a real accident. All measurement data were to be reported as soon as possible, i.e., within 1-2 hours after completion of each task. A computer and communications centre (CCC) at the exercise headquarters received and stored the data after a completed measurement. The CCC also produced high quality fallout maps that could be viewed only hours after the data delivery. Maps and other interesting results and information was continuously put on display to all participating teams at the CCC, and also to the public on a web site dedicated for the exercise.

3. EXERCISE DETAILS

3.1 Pre-exercise work

The planning of the exercise started with meetings at Risø in Denmark in May 1998 and in Stockholm in November 1998, and two more meetings were held during the first half of 1999. In between these meetings, the preparation for the exercise was to a large extend carried out by the Swedish Radiation Protection Institute (SSI). Several trips to the exercise area were made during the spring and summer 1999 to arrange the details of the exercise and to find suitable accommodation for the headquarters and the participants.

During June 1999, the Swedish Defence Research Establishment (FOA) measured the activity of ^{137}Cs in the soil at three of the calibration sites of the exercise and determined the depth distributions. The results were presented in a report that was made available during the exercise [FOA, 1999], and some of the results are also presented here (Appendix II). During late spring and summer 1999, the planning involved many people at SSI. A computer network was set up and tested and a substantial amount of work went into the creation of the web site for the exercise. Exercise specific maps were developed for distribution to the participants. A common data format was developed to facilitate data processing and map production.

3.2 The exercise area and Älvkarleö Herrgård

The exercise was held in Gävle and surrounding areas. Gävle is located about 200 km to the north of Stockholm on the Baltic Sea coast. The total area where measurements were made is about 50 x 50 km, with Gävle in the centre of this region. Forest and rural areas are dominating the landscape. The road type ranges from small gravel roads to four-lane asphalt covered highways. The asphalt roads in the area have only a negligible covering of ^{137}Cs and therefore it was recommended to travel only on the smaller roads to avoid differences in the measurements due to such geometry effects.

The exercise area was selected to contain both high and low activity levels of ^{137}Cs. The ^{137}Cs activity in the region range from very low levels up to over 200 kBq/m^2. It was decided to report results in *equivalent surface activity*, defined as the homogeneous activity per unit area on an infinite, plane surface that will produce the same primary fluence rate at a certain energy one meter above the surface as the actual depth distributed source.

The headquarters were situated at the mansion "Älvkarleö Herrgård" about 20 km south-east of the city centre (Figure 1). Most of the participants were accommodated at the mansion while some stayed at the tourist hotel in Älvkarleby, located 4 km away. The mansion is beautifully situated in the countryside at the river Dalälven.

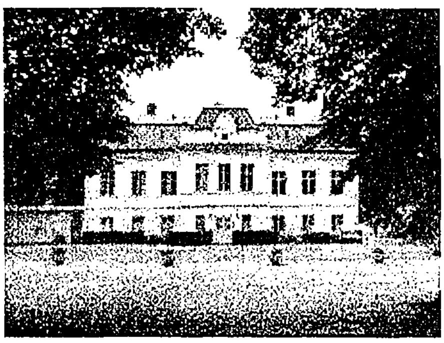


Figure 1. The main building at Älvkarleö Herrgård.

The mansion has good conference facilities, with several group rooms of different sizes. A separate building was used as headquarters for the exercise staff. The computer and communication centre (CCC) with its network of computers was stationed here and a big conference room in the same building was used for the daily meetings. As a service to the observers and participants, maps produced during the exercise were put on the walls in the conference building. A "public" computer was installed here so that those interested could study exercise news and results presented on the web site. Outside the conference building a big tank of liquid nitrogen was placed, so that everyone had access to nitrogen for the HPGe detectors.

All meals during the exercise were served in the dining room in the main building. Most of the hotel rooms were located in a separate building which also contained kitchen and sauna facilities.

Prior to the exercise, the participants had the opportunity to calibrate their spectrometric equipment at the calibration facilities at Dala Airport outside Borlänge, situated about 100 km west of Gävle. The facilities consist of four calibration pads of diameter 10-11 metres. Three of the pads contain high amounts of one of the natural radioactive nuclides, potassium, uranium, and thorium, while the last pad is a "zero pad" that contains low amounts of all three of these nuclides.

On Monday, September 6, 1999, before the actual start of the exercise, the *in situ* teams participating in the exercise had an opportunity to perform gamma spectrometry and take soil and grass samples at Uppsala Näs outside the city of Uppsala, about 100 km south of Gävle (cf. Section 3.6). The road descriptions to Dala Airport and to Uppsala Näs were put on the web page before the exercise.

In the map below, the placement of the exercise headquarters, the calibration pads at Dala Airport and the experimental area at Uppsala Näs are shown. Stockholm is located about 70 km south of Uppsala.

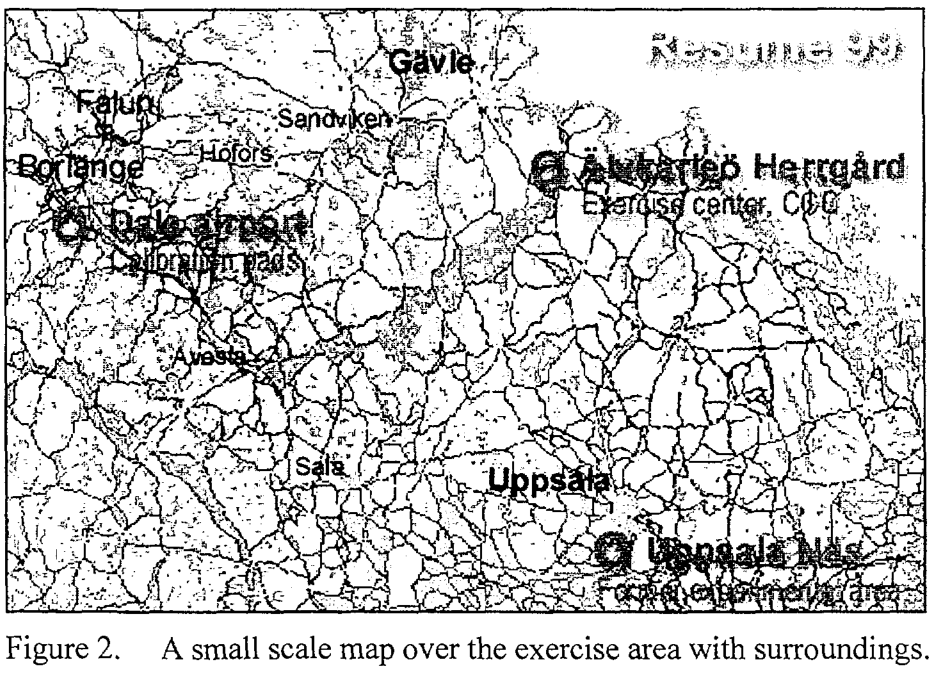


Figure 2. A small scale map over the exercise area with surroundings.
(Permission by the National Land Survey of Sweden 1996. From GSD-Bas 250 Registration number: MSG 96269)

3.3 The time schedule

As the exercise draw closer, the time schedule became full, including early morning and late evening events. There were only two days for measurements, and especially those days tended to be very intensive because of time-consuming exercise tasks that had to be completed.

The actual exercise started with a dinner at 18.00 on Monday 6/9 and ended after the discussion and summary at 14.00 on Thursday 9/9. Many of the participants stayed on to join the following discussion of the post exercise work, and, of course, everyone who wanted could take part in the Thursday night dinner party.

After the common dinner on Monday night, a meeting was held where the time schedule and some last minute information was given. The procedures for the two exercise days were discussed and maps were distributed. All teams were given names, which were used to identify team positions during the measurements and to identify the data reported to the CCC. After the meeting, some time was left for the teams to make further preparations for the upcoming measurement tasks.

In the table below, an overview of the activities during the exercise is presented.

	Time	**Event**	**Comment / Place**
Monday 6/9 – 99	09.00 – 16.00	Voluntary *in situ* measurements and soil sampling.	Uppsala Näs, former experimental area at the University of Agricultural Sciences.
	15.30	Press information	Älvkarleö Herrgård
	18.00	Dinner	Dining room
	19.00 - 19.30	Fill in participation form. Booking of dinner.	CCC
	20.00 - 21.00	Information meeting.	Conference room.
Tuesday 7/9 – 99	Morning	Breakfast	At your place
	08.00	*In situ* teams depart from Älvkarleö.	Measurements at fixed points according to instructions.
	08.00	Measurements along the compulsory route.	Mobile teams depart one by one with about 15 minutes time spacing.
	Dusk	Return to Älvkarleö	All teams shall have returned before dusk
	20.00	Dinner	Dining room, Älvkarleö
	21.00	Discussion meeting	Conference room
	22.00	Latest time to deliver data	CCC
Wednesday 8/9 – 99	Morning	Breakfast	At your place
	08.00	Departure from Älvkarleö	Each team will head for their respective areas and start measurements
	13.00 - 14.00	Mobile teams: Delivery of overview data.	On 3,5" diskette to DC or CCC or by e-mail.
	Dusk	Return to Älvkarleö	All teams shall have returned before dusk
	20.00	Dinner	Dining room, Älvkarleö
	21.00	Discussion meeting	Conference room
	22.00	Latest time to deliver data	CCC

Thursday 9/9 – 99	Morning	Breakfast	At your place
	09.00 - 10.00	Analysis of day 1 data	Conference room
	10.00	Coffee	-
	10.30 – 12.00	Analysis of day 2 data	Conference room
	12.00	Lunch	Dining room
	13.00 – 14.00	Discussion and summary. Exercise ends.	Conference room
	14.00 - 15.00	Discussion regarding the post-exercise work.	Conference room
	15.00	Coffee	-
	19:00	Dinner party	Dining room
Friday 10/9-99	12.00	Latest time to leave Älvkarleö	-

Table 1. Time schedule with all events during the exercise.

3.4 Tuesday exercise for mobile teams

During the first day of measurements, all mobile teams measured on the same route. This was decided to be able to compare the response of the different systems depending on road type, radiation level and system set up in the cars. It was also done to obtain an intercalibration between the systems.

The route was approximately 200 kilometres long and covered areas with both high and low activity levels of ^{137}Cs from the Chernobyl accident. It passed through both rural and urban areas and followed many different road types, ranging from narrow gravel roads to broad asphalt roads. A speed limit of 50 km/h was recommended while measuring. The time to drive the route, including breaks for lunch and for measurements on all calibration points was estimated to be 7 – 8 hours.

There were four calibration points along the route that should be measured by each team as they passed by. These were introduced to get a more exact comparison between the different systems. Three of the points were situated on grass areas with different levels of contamination and one point was placed on an asphalt road in a forest. This last point was used to get the system response in a geometry similar to that of normal car measurements. The asphalt road was constructed after the Chernobyl accident, so there was no, or at least negligible amount of ^{137}Cs on it. At each reference point, there were people from the exercise staff to guide the participants to the exact spot for the measurement.

Without letting the participants know, two point sources were placed on the route. The sources were a 15 GBq ^{99m}Tc source and a 3 GBq ^{137}Cs source. The technetium source was placed in the forest about 10 meters from the road and gave a dose rate on the road of 1 - 2 μGy/h. The caesium source was placed in a car wreck next to the road and gave a dose rate of about 30 - 50 μGy/h. People from the exercise staff were controlling the two sources during the measurements.

Maps with the route marked were distributed to all teams together with a detailed road description (Appendix V). In addition, signs were placed in the terrain along the route at all places where the choice of road could be in doubt. To avoid crowding during the measurements, all mobile teams started with 15 minutes intervals from Älvkarleö Herrgård and were instructed not to stay more than 15 minutes on any of the four calibration points.

At dusk, all teams were expected to be back at the headquarters at Älvkarleö Herrgård for delivery of data to the CCC. Data from the route and from the four calibration points was delivered as separate data files. The CCC then started the production of maps for all teams. Later in the evening a meeting was held to discuss the results of the first day of measurements.

Below is a map with the calibration route together with a table showing the co-ordinates of the four calibration points.

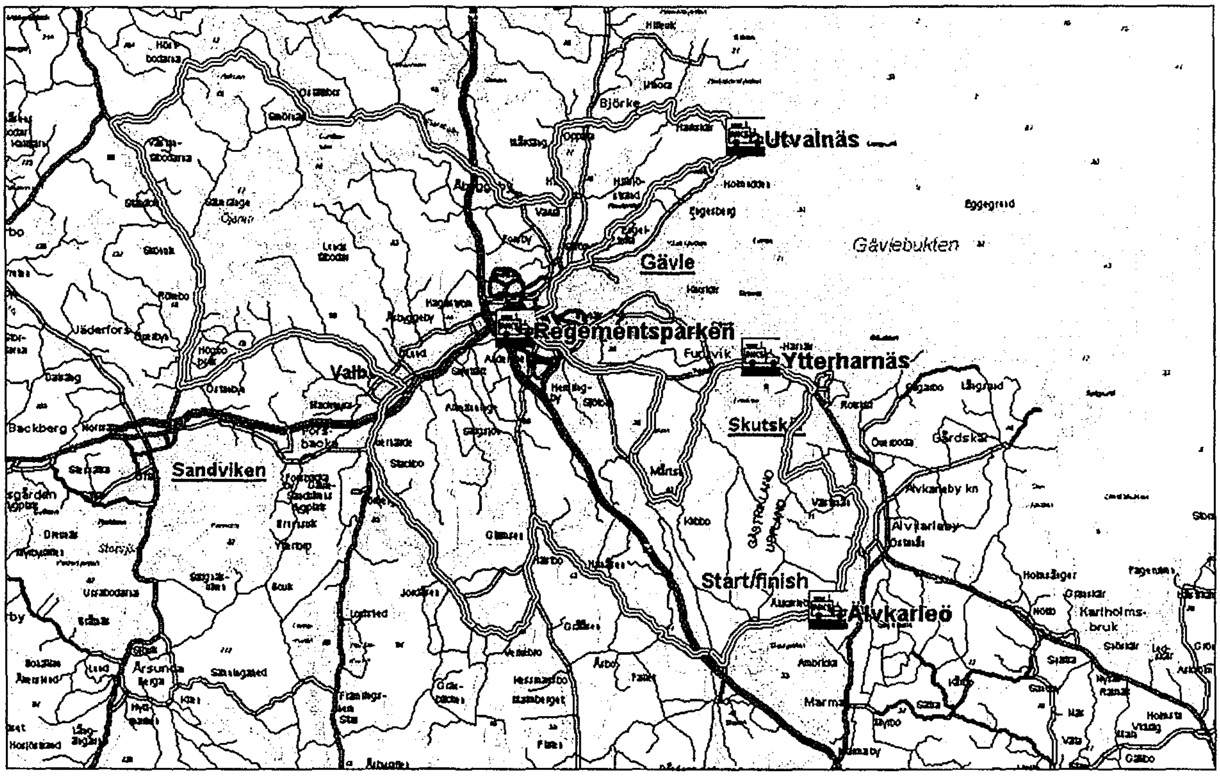


Figure 3. Map with the compulsory calibration route and the four calibration points.
(Permission by the National Land Survey of Sweden 1996. From GSD-Bas 250 Registration number: MSG 96269)

Site	X_RT90	Y_RT90	X_WGS84	Y_WGS84
Älvkarleö	1588005	6714120	17° 24.50	60° 32.09
Ytterharnäs	1584602	6727254	17° 21.10	60° 39.22
Regementsparken	1571761	6728772	17° 07.07	60° 40.18
Utvalnäs	1583796	6738703	17° 20.53	60° 45.38

Table 2. Names and co-ordinates for the four calibration sites on the calibration route. The co-ordinate names are written according to the NKS file format, where X is the east- and Y is the north co-ordinate.

3.5 Wednesday exercise for mobile teams

On the second measurement day, each mobile team was assigned an area of their own somewhere in the Gävle region. The main purpose of this exercise was to see how the teams could co-operate to produce a common fallout map over a large area. The equivalent surface activity of ^{137}Cs was to be measured along as many roads as possible in the area, with the aim of getting a good estimate of the fallout. The areas were placed edge to edge, without any overlap. An overlap would be desirable to be able to compare the results from different teams directly, but it was assumed that an overlap would be created anyway as the teams were reaching roads that crossed the area borders. Most of the areas had the size of 15 x 15 km^2, but the area containing the city centre was made smaller because of the high density of roads here, while a few other areas with large lakes and forests were made a little bigger.

During the first five hours or so, an overview of the fallout in each area was obtained. Between 13.00 and 14.00 in the afternoon the data from the teams were delivered to the CCC at Älvkarleö Herrgård. Data could be delivered on a diskette, but to facilitate data reporting for teams that performed measurements far away from the headquarters there were also several other ways of delivering data: A delivery central with personnel from the headquarters was set up at the Scandic Hotel outside the centre of Gävle; the teams could phone the headquarters to make an oral description of the fallout according to predefined rules; and finally, there was a possibility of sending data by e-mail to the CCC.

After this delivery of data, personnel at the CCC started to create preliminary fallout maps. The participants now continued to measure in the area in more detail, especially in the parts with the highest contamination. At dusk all teams were expected to be back at the headquarters. The preliminary maps were studied and discussed at the evening meeting and all remaining data from the afternoon measurements was delivered. During the night map production continued and the following morning final maps were presented.

Maps were produced for all different teams separately, as was the case for the measurements on the calibration route the day before, and a combined map was created out of all the measurements that had been made during the day. The results from the measurements on the calibration points the day before were used to re-calibrate the data from the individual teams before making the combined map.

On the next page is an overview map of the exercise area with the individual areas that were measured by the mobile teams marked as squares.

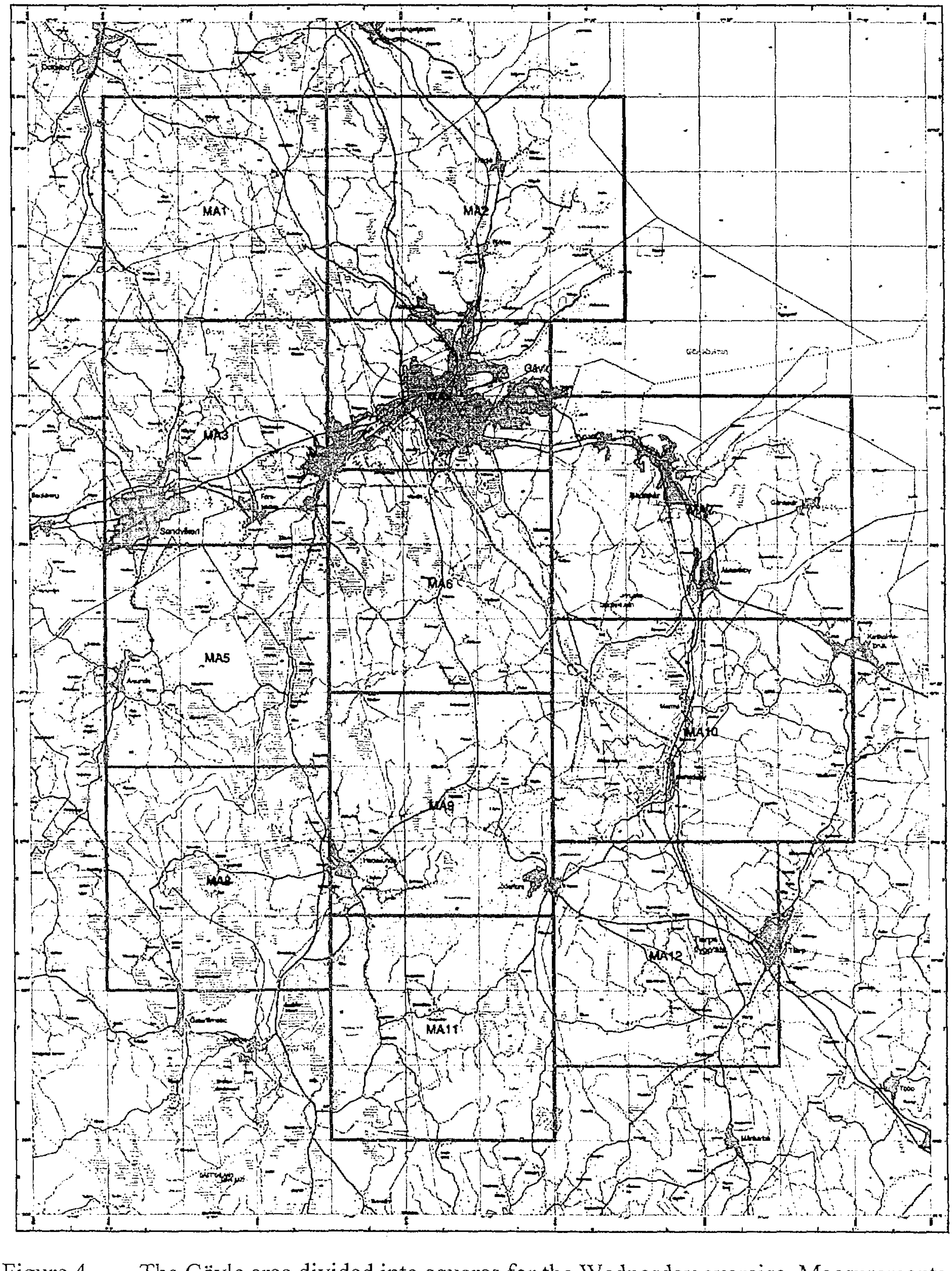


Figure 4. The Gävle area divided into squares for the Wednesday exercise. Measurements from all teams were put together for production of a combined fallout map.

(Permission by the National Land Survey of Sweden 1996. From GSD-Bas 250 Registration number: MSG 96269)

3.6 The exercise for the *in situ* teams

Parallel to the measurements made by the mobile teams seven *in situ* teams performed measurements on selected sites. A total of fourteen *in situ* points were set up, and, in addition, the four reference points on the calibration route for the mobile teams were to be measured. There was also a possibility of making use of new *in situ* points during the exercise. The co-ordinates and a description of new points had to be reported to the CCC as soon as possible so that other teams could be directed to those points.

Detailed instructions and maps for the measurements were distributed at the Monday evening meeting. The teams were also provided with a special reporting form made for the exercise. All teams were encouraged to deliver as many results as possible during the exercise. Soil samples were to be analysed in the field or in the hotel rooms, but there was also a possibility to send them to home laboratories or laboratories not participating in the exercise, for analysis there.

Data from the measurements were delivered to the CCC on the distributed form. In addition, the Swedish *in situ* teams should deliver data in a system called RadGIS according to the procedures prescribed by the Swedish Radiation Protection Institute. The *in situ* data did not have to be delivered in the NKS format used by the mobile teams.

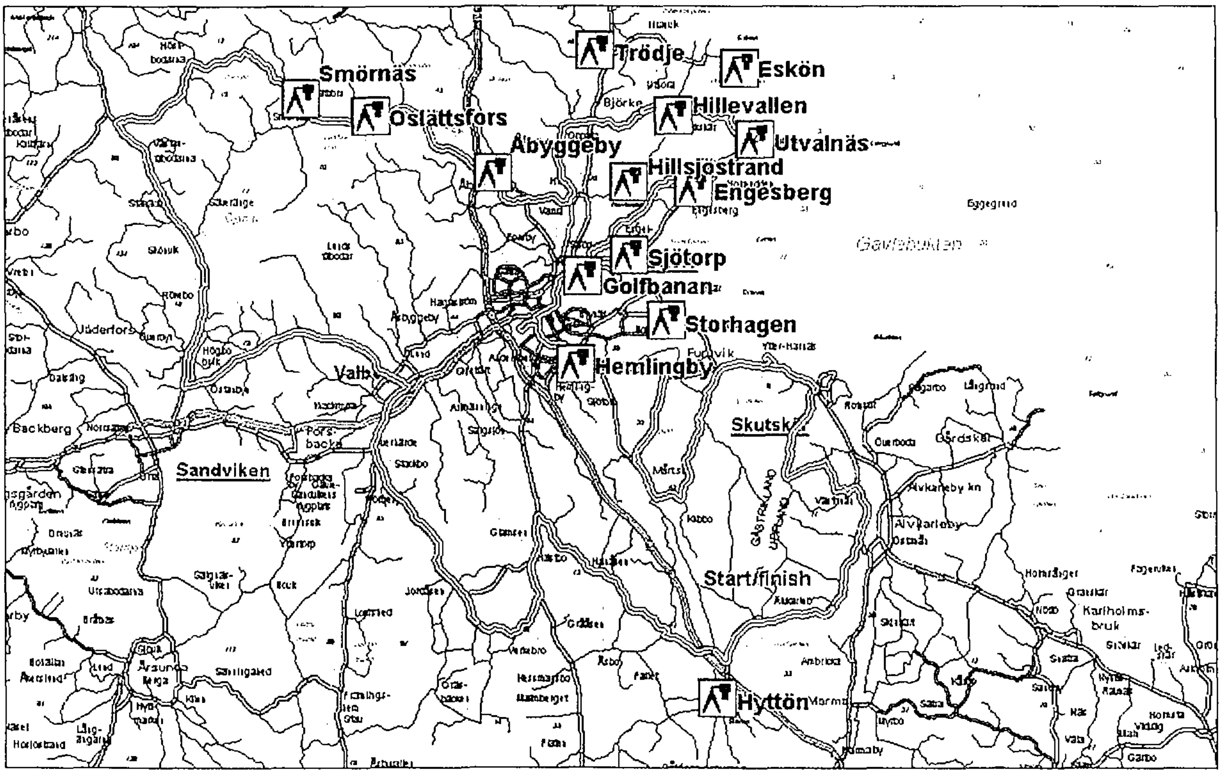


Figure 5. The map shows the calibration points where measurements were carried out by the *in situ* teams. The calibration route for the carborne teams is also included.

(Permission by the National Land Survey of Sweden 1996. From GSD-Bas 250 Registration number: MSG 96269)

In the following are short descriptions of how to get to the 14 *in situ* points, together with pictures of each site and co-ordinates of the sites using the Swedish co-ordinate grid RT90. The main *in situ* point (Point A) was marked in the terrain, while a second (Point B) could be chosen at will in the vicinity of the first point.

Hyttön, HY (X_RT90 = 1582070, Y_RT90 = 6709390)
Take the road from Älvkarleö to the west. The road is turning to the south and crossing the highway E4. After the crossing, about 1.2 km further on to the south, there is a sharp right turn. After a few hundred metres there is a sign "Här slutar allmän väg". Follow the road to the right of the sign about 100 m. To the left there is a grass area. (Point A).

Figure 6. Hyttön

Storhagen, ST (X_RT90 = 1579450, Y_RT90 = 6729150)
From the large road in Bomhus, enter the road Doppingvägen. At the end of the road there is a park with a grass area. (Point A).

Figure 7. Storhagen

Hemlingby, HE (X_RT90 = 1574690, Y_RT90 = 6726870)
From road 76, enter the road Fridalsvägen. Straight ahead is a grass area (Point A). It is located just below a slalom slope.

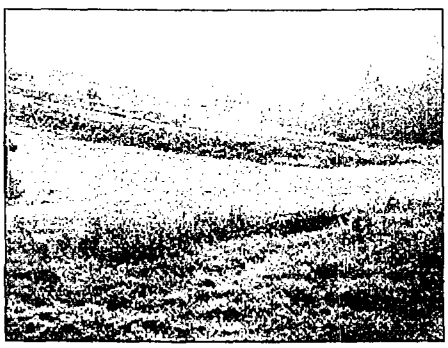


Figure 8. Hemlingby

Sjötorp, SJ (X_RT90 = 1577510, Y_RT90 = 6732590)
On the road from Gävle to Bönan there is a place called Sjötorp. On the right side of the road there is an open field covered with high grass (Point A).

Figure 9. Sjötorp

Golfbanan, GO (X_RT90 = 1575090, Y_RT90 = 6731470)
On the road from Gävle to Björke, just after leaving the densely built-up area there is a gravel road to the right crossing an open field. There is also a sign "Vattentäkt" and "MC-klubb". Follow this road some 500 m until you reach the blocking gates. On the left there is a golf course. Park your car and carry your measuring equipment. Be sure to turn on your survey instrument and start walking along the narrow gravel road to the left. The road slowly bends to the right and slopes slightly upwards. After a few hundred metres the road starts downhill. At the bottom, on the left there is rough. (Point A). This site is a very interesting place were you can spend some time with your survey instrument figuring out what happened here.


Figure 10 and 11. Golfbanan

Engesberg, EB (X_RT90 = 1580940, Y_RT90 = 6736000)
On the road from Gävle to Bönan, when entering Engesberg, there is a road to the left. Follow this road for 50 m. There is a large open area covered with high grass on the right hand side (Point A).

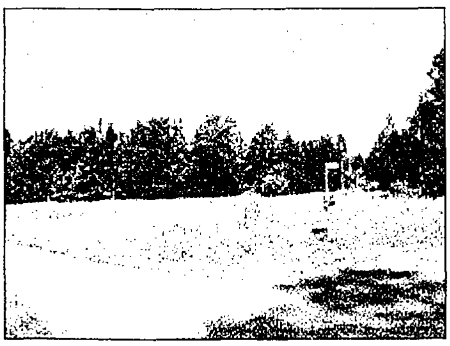


Figure 12. Engesberg

Utvalnäs, UT (X_RT90 = 1584120, Y_RT90 = 6738560)
On the road from Bönan to Harkskär in the village Utvalnäs there is a small road to the right. Just before the crossing there is an open area on the right side covered with heather (Point A).

Figure 13. Utvalnäs

Hillevallen, HV (X_RT90 = 1579860, Y_RT90 = 6739830)
The road from Harkskär to Utnora. About 2,5 km from Harkskär the road passes over a small stream. There is an area covered with high grass on the left side just before the stream (Point A). A second point (B) can be chosen on the open lay-pasture field about 50 m south east of point A. The areas around the stream were flooded during the Chernobyl accident and quite high dose rates were measured here. It is recommended that you investigate the area with a survey instrument.

Figure 14 and 15. Hillevallen

Eskön, ES (X_RT90 = 1583300, Y_RT90 = 6742330)
After crossing the narrow waters to Eskön the road turns to the left. After 500 m there is a crossing with a small road to the right and a sign "Här slutar allmän väg". Continue about 2,5 km. On the left side there is an open grass field (Point A) and a barn about 100 m from the road.

Figure 16. Eskön

Trödje, TJ (X_RT90 = 1575770, Y_RT90 = 6743240)
1 km south of Trödje there is a small road leading to the west. A large gravel pit is on the south side of the road. The road crosses a railway. Take the road to the left along the railway, heading south. After some 500 m there is a passing point on the right and an open area to the left between the road and the railway (Point A). The open area was created by a forest fire some years ago. It is now covered with lingonberries. Small trees have started to grow. Measurement data from this area can be compared to the untouched areas a few hundred metres further to the south (Recommended point B).

Figure 17. Trödje

Hillsjöstrand, HS (X_RT90 = 1577520, Y_RT90 = 6736350)
From the main road between Gävle and Björke, take the small road east towards Hillsjöstrand. About 2,5 km from the beginning of the road there is an open area covered with high grass on the right side (Point A).

Figure 18. Hillsjöstrand

Åbyggeby, AB (X_RT90 = 1570370, Y_RT90 = 6736820)
The road from Åbyggeby to Smörnäs. About 1 km north west of Åbyggeby there is a small road to the right with a sign "Till Oslättsforsvägen. 64 - 73". Follow the road 400 m. On the right side there is an area covered with high grass close to the small river Testeboån (Point A).

Figure 19. Åbyggeby

Oslättsfors, OS (X_RT90 = 1564030, Y_RT90 = 6739800)
Take the road from Åbyggeby to Smörnäs. After about 8 km, the road crosses a railroad. Immediately to the left after the crossing there is an area covered with high grass (Point A). This has probably once been a garden with a house.

Figure 20. Oslättsfors

Smörnäs, SM (X_RT90 = 1560350, Y_RT90 = 6740740)
The road from Smörnäs to Höstbodarna passes under large power transmission lines about 1 km north west of Smörnäs. After passing the last power line, drive 500 m. There is a very small grass area to the left (point A), probably an old timber transport path.

Figure 21. Smörnäs

As mentioned earlier, there was a special opportunity for the *in situ* teams to perform measurements on the day before the exercise started. There is a former experimental research area at Uppsala Näs outside Uppsala belonging to the Swedish Agriculture University. This area has been contaminated with ^{137}Cs, ^{90}Sr and ^{239}Pu to a level of about 8 MBq/m^2. The area is not used for experiments anymore and soon it will be decontaminated and restored. Here, all *in situ* teams could make spectrometric measurements and take grass and soil samples. The content of radionuclides in the soil is well documented. The area is fenced off, but a guide was there to let the teams in and show them where to make measurements and take samples.

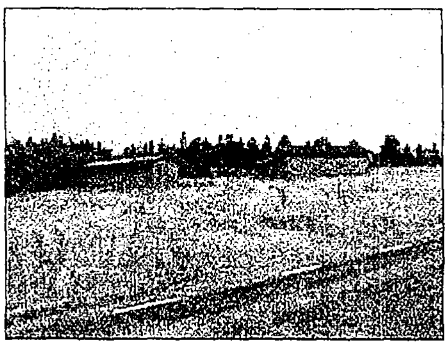


Figure 22. The SLU Experimental area

3.7 The computer and communication centre

The exercise was co-ordinated from the headquarters, located in the conference building at Älvkarleö Herrgård. The staff here arranged all practical details, such as meals and accommodations and they supplied the exercise participants with relevant information. The staff had a co-ordinating role during the measurements and were available for the teams if problems or questions turned up. The mobile teams reported their positions at different times during the exercise to the headquarter and could be redirected if the risk of crowding at the calibration points was large. If the *in situ* teams used new measurement points, that should also be reported so that other teams could be sent to the same sites.

The heart of the headquarters was the computer and communications centre (CCC). The staff here provided service to the teams in terms of map material, data processing, and visualisation of results. They also continuously updated the web page with results and other interesting information. Special maps for the exercise, showing the calibration route, the *in situ* measurement points, etc., were produced prior to the exercise, but printed out at the CCC on the large format plotter that was connected to the computer network.

All data files produced by the mobile teams during measurements were delivered to the CCC in the NKS-format developed for the exercise (Appendix III). The staff at CCC processed the data and the results were visualised on maps and in graphs in an exercise specific layout. It was pointed out that these services were to be considered as complementary only, and the teams were strongly encouraged to use their own software to present the results in their normal way. Space was reserved on the walls to expose both team specific results and results from common efforts.

When the files from the measurements started to drop in, the CCC began their work with data processing and map production. Maps were produced in two ways:

At the CCC, small A4 maps were produced by converting the data from the teams to a MapInfo point coverage which was visualised in the form of colour-graded points, using geographical background information from the Swedish Land Survey ("Röda kartan", scale 1:250,000). A specially designed MapInfo-application was available for this task. The teams had the opportunity to visually inspect their data, request graphs over areas of special interest, and to print the resulting maps and graphs on an A4 colour printer using an exercise-specific layout.

Larger and more detailed maps over each team measurement area in the scale 1:50,000 were compiled at the Geological Survey (SGU) in Uppsala with the help of Arc/Info software. The data was transferred from Älvkarleö to Uppsala through the telephone line (56k modem); and mail was sent to Uppsala to automatically trigger the map compilation. The resulting digital maps ended up at an ftp-site at SGU, from where they were sent back to Älvkarleö through a satellite link (250-400 kbps) and subsequently plotted on-site. The map production included point maps as well as interpolated grid maps for a given key parameter such as dose rate or ^{137}Cs surface activity. The results from the individual teams were compiled to yield mosaic maps showing the results of the joint effort.

Both the maps compiled at the CCC in Älvkarleö and the maps produced at SGU were also produced as PDF-files and made available to the editor of the exercise web site.

3.8 The mobile teams and their equipment

Data were delivered from eleven mobile systems carried by nine different cars. The teams originated from Sweden, Denmark, Finland, Poland, Estonia, Latvia and Lithuania. All measurement systems and all cars that were used in the exercise got a name for identification according to the list shown below. Nine of the eleven systems were of NaI(Tl)-type, while two were HPGe systems. All systems used GPS or DGPS for automatic positioning of the measurements. The integration time for each measurement varied between two and ten seconds. For a detailed description of each system, see Appendix VI.

System	Car	Detector type	Detector size	Detector height over ground	Integration Time
DKA1	Golf	NaI(Tl)	4 litres	220 cm	2 s
DKB1	Golf	NaI(Tl)	3"x 3"	80 cm	10 s
EEA1	Charlie	NaI(Tl)	4 litres	220 cm	2 s
LVA1	Echo	NaI(Tl)	4 litres	220 cm	2 s
LTA1	Delta	NaI(Tl)	4 litres	220 cm	2 s
PLA1	Foxtrot	NaI(Tl)	4 litres	220 cm	10 s
FIA3	Hotel	HPGe	35 %	170 cm	10 s
SEA1	Alpha	NaI(Tl)	3"x 3"	175 cm	5 s
SEA3	Alpha	HPGe	72,1 %	180 cm	10 s
SEB1	Bravo	NaI(Tl)	3"x 3"	135 cm	10 s
SEC1	India	NaI(Tl)	3"x 3"	210 cm	10 s

Table 3. A brief description of the different systems that were used in the exercise.

Figure 23. The vehicles used by the mobile teams in RESUME 99.

3.9 The *in situ* teams and their equipment

Seven *in situ* teams took part in the exercise, out of which six came from Sweden and one from Denmark. The "main" equipment for the *in situ* teams was the HPGe detector, which all teams used for measurements, but many teams also used dose rate meters and soil sampling equipment, etc. Below is a list of the teams together with most of the equipment that they used during the exercise.

Team	Car	HPGe detector/analyser	Other
SEA	Lima	EG&G Ortec 50 % Nomad plus	Scintrex, Dose rate meter Soil sampling equipment
SEB	Mike	EG&G Ortec 55 %	SRV 2000 Rados , 2 pcs RNI 10/R , 2 pcs Soil sampling equipment ∅ = 9,8 cm and 3,6 cm
SEC	November	Tennelec 22,4 % Canberra Inspector	Bicron R-meter Soil sampling equipment
SED	Oscar	EG&G Ortec 36 % Dart	Alnor RDS-100 Survey meter Soil sampling equipment
SEE	Papa	HPGe 10 %	RNI 10/D RNI 10/SR Soil sampling equipment ∅ = 8,0 cm
SEF	Quebec	Canberra 35 %	Canberra EasySpec 1"x 1" NaI Gammameter 2414A Plastic spec. Automess 6150 AD 3R Soil sample equipment
DKC	Kilo	Tennelec 25 %	Gammameter 2414

Table 4. An overview of the equipment used by the *in situ* teams during the exercise.

In addition, three Swedish teams, SEG, SHE, and SEI, made soil sample spectrometry at their home laboratories. The soil samples were sent to the laboratories by train or by car and the results were sent back to the headquarters by fax.

Figure 24. The *in situ* team SEA in action.

4. RESULTS

In this chapter, results are shown as they were presented at the exercise. Further analyses of the data will be made in the year 2000 when the research and development projects within NKS/BOK-1.2 will start. Some of the projects that are planned for are:

- Integration of AGS, CGS and results from other detector systems.
- CGS dose rates from NaI(Tl) gamma spectra by a SDI technique.
- Handbook on good/best data acquisition and processing for CGS.
- Methods for search of point sources, description and development.

Possibly most of these projects, and maybe a few more, will start up during spring 2000. Using data from the Gävle area to study the integration of airborne and carborne gamma spectrometry will be interesting, since the Gävle area has been very well documented from the air, and, as a result of the exercise, also from the ground. If this project shows positive results, AGS and CGS teams will be able better to complement each other in future mappings of fallout areas.

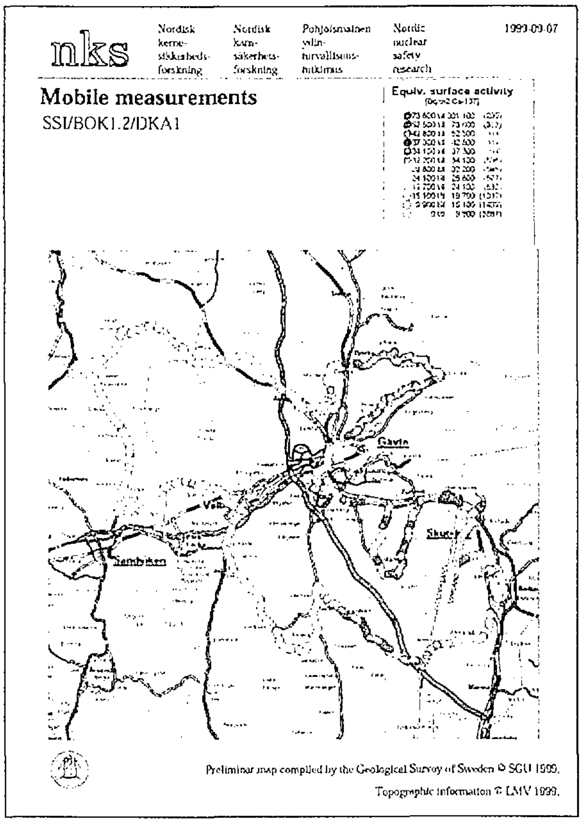
4.1 The calibration route for the mobile teams

The first day of measurements by the mobile gamma spectrometry teams was carried out as an intercomparison exercise, during which all teams measured along the same route. The results will be used in future research and development projects to analyse how differences between the systems depend on road type, detector type, system set up, etc. This will hopefully provide a better understanding of the problems and difficulties that occur when carborne gamma spectrometry is performed.

The data was delivered for the whole route in one file and for the four calibration points in separate files. The results from the calibration route was presented on maps and in diagrams by the CCC as shown in the figures on the next page. On site in Älvkarleö small A4-plots of the route was produced with the use of MapInfo software. The equivalent surface activity of ^{137}Cs was visualised as colour graded spots in these maps.

The two radioactive sources that were hidden along the calibration route proved to be quite difficult to find. On purpose, they were placed on the final part of the route, so that the participants would have lost some of their attention while passing them. No team found both sources (except for SEA that had prior knowledge of the sources), but some teams found the ^{137}Cs source. From the delivered data, the part where the cars passed the ^{137}Cs source was extracted. This was plotted in a diagram in which one could infer whether the cars had stopped to inspect the source or not. The ^{99m}Tc source could of course not be seen by looking at the ^{137}Cs activity in the data file.

In addition to the maps and diagrams produced in Älvkarleö, maps were also produced at the Geological Survey of Sweden in Uppsala. These were larger (60 x 90 cm), more detailed maps that were produced with the software Arc/Info. The equivalent surface activity of ^{137}Cs was plotted both as colour graded points and as an interpolated grid. Additional information was added in form of smaller maps showing the contents of the natural radionuclides. A summary statistics showing mean and max values and the number of measurement points in different parts of the area were also shown.



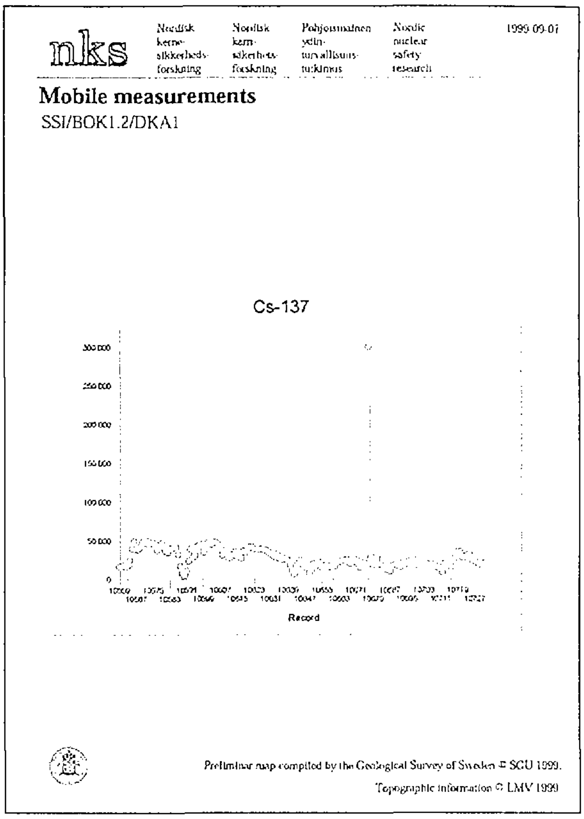


Figure 25 and 26. A map and a diagram produced locally by the CCC (System DKA1).

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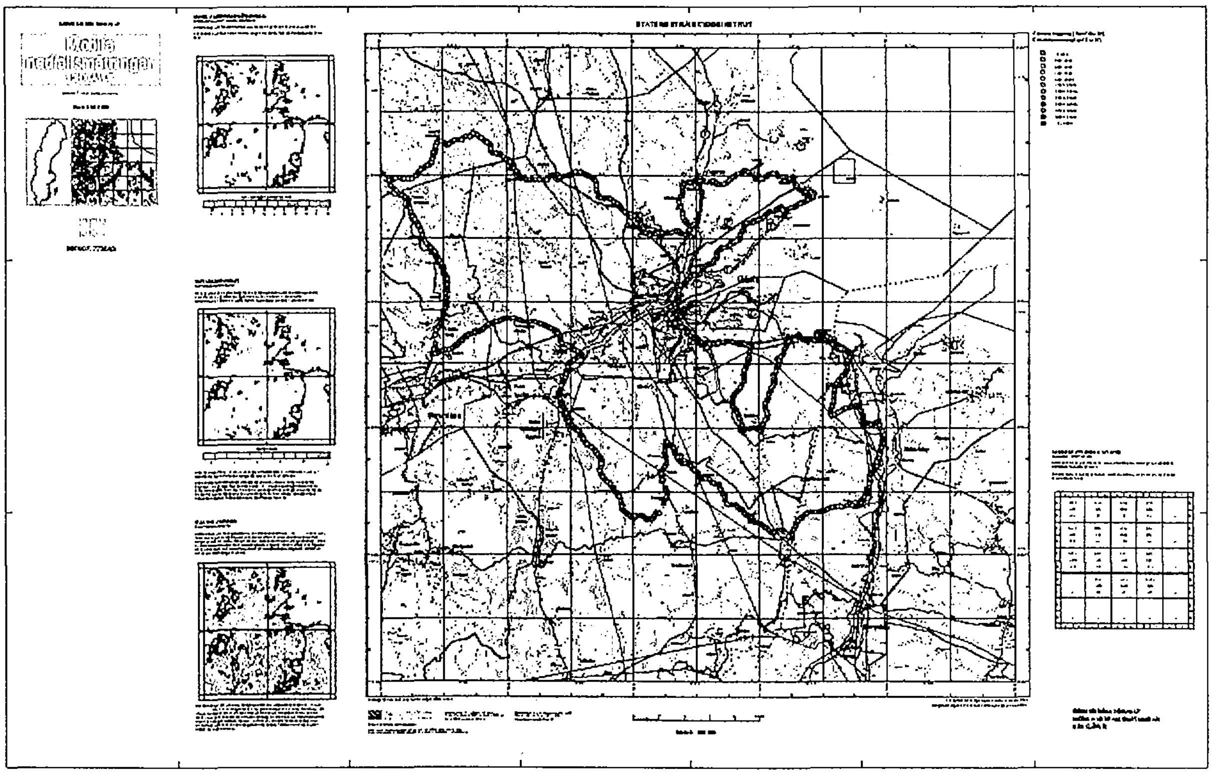

Figure 27. An example of the more detailed maps that were produced at the Geological Survey in Uppsala and plotted at the CCC. Original size was about 60 x 90 cm.

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Below are the spectra obtained with the system SEA1 while passing the two point sources along the calibration route. The ^{99m}Tc spectrum has a much higher count rate per second than the ^{137}Cs spectrum. This is because the measurement was made with the car standing still during one minute when the source was discovered. The ^{137}Cs spectrum was measured "in flight" because the system had an overflow when the car stopped in front of the source. The dose rate in front of the ^{99m}Tc source was estimated to 2 **μGy/h and the dead time while** measuring here was 27 %. The dose rate in front of the ^{137}Cs source was 30 – 50 **μGy/h and** the dead time when passing the source was about 16 %. For normal background the system has a dead time of 1-2 %. The spectra consist of 256 channels, while only 100 channels are shown in the figures. In both spectra the ^{137}Cs peak is positioned in channel 58.

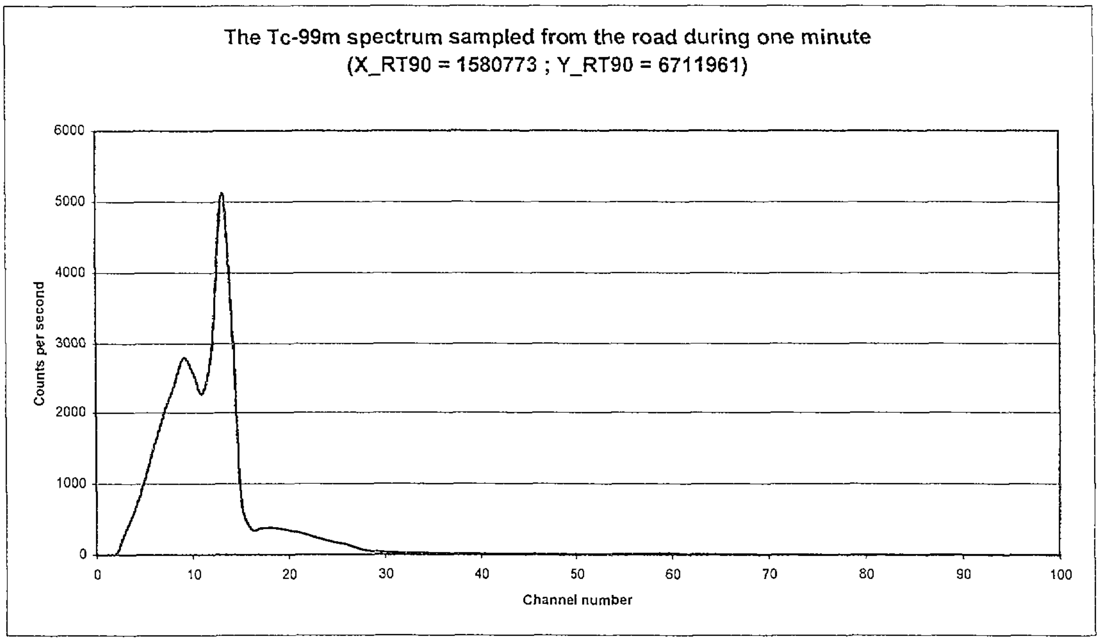

Figure 28. The spectrum measured while stopping in front of the hidden ^{99m}Tc source.

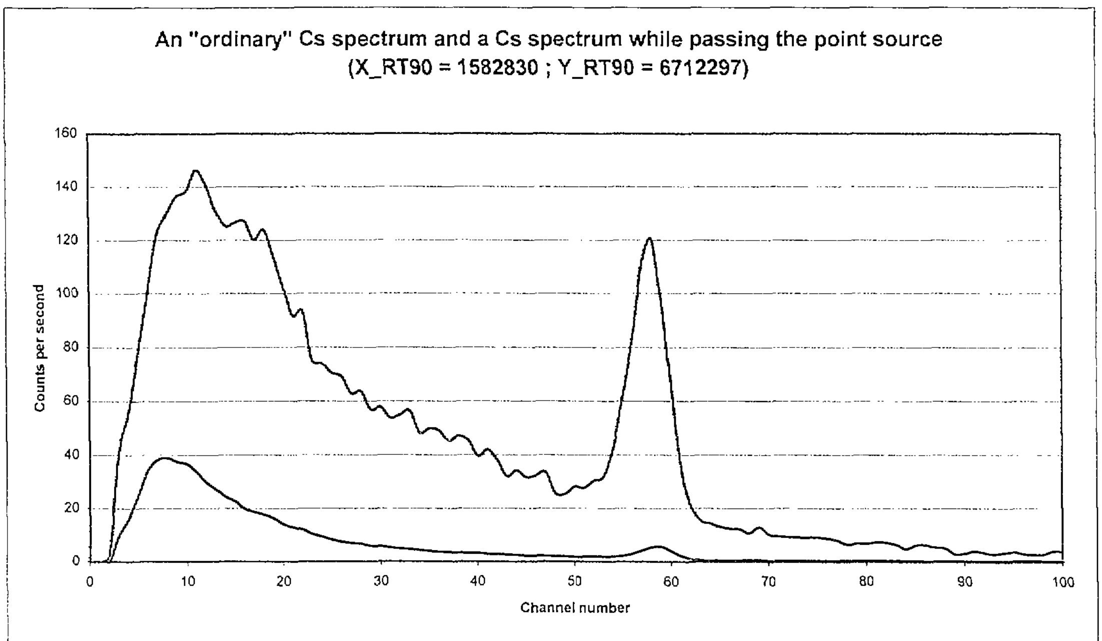

Figure 29. The ^{137}Cs spectrum measured while passing the hidden source compared to a spectrum measured along another part of the same road.

The calibration points on the route were measured by all mobile teams, and also by some of the *in situ* teams. The table and the diagram below show the results. As can be seen, there are large differences in the reported values. In particular, the three Baltic systems and the Polish system show values around a factor of 2.5 higher than the mean of the other values. This was discussed at the exercise and was identified as a calibration error. The four systems were identical and calibrated in the same way.

System	Älvkarleö	Ytterharnäs	Regementsparken	Utvalnäs
SEC1 (NaI)	8980	42400	16000	27600
SEB1 (NaI)	9472	43500	17190	28500
FIA3 (HPGe)	10633	50600	17817	34659
SEA3 (HPGe)	10707	52735	18383	45580
SEA1 (NaI)	11478	51207	19179	38794
DKB1 (NaI)	13851	69827	25583	48497
DKA1 (NaI)	15500	74026	26466	56617
LVA1 (NaI)	29930	145384	52935	111427
LTA1 (NaI)	29662	145054	52803	112307
EEA1 (NaI)	30411	142926	52119	109118
PLA1 (NaI)	33290	146542	56486	120564
SEA (*in situ*)	11050	57800	20600	54200
SEB (*in situ*)	-	-	-	-
SEC (*in situ*)	9300	50400	19000	-
SED (*in situ*)	-	50400	-	-
SEE (*in situ*)	-	57300	20300	-
SEF (*in situ*)	-	88200	31300	-
DKC (*in situ*)	13400	75000	26600	-

Table 5. The equivalent surface activity of ^{137}Cs (Bq/m^2) measured at the four calibration points.

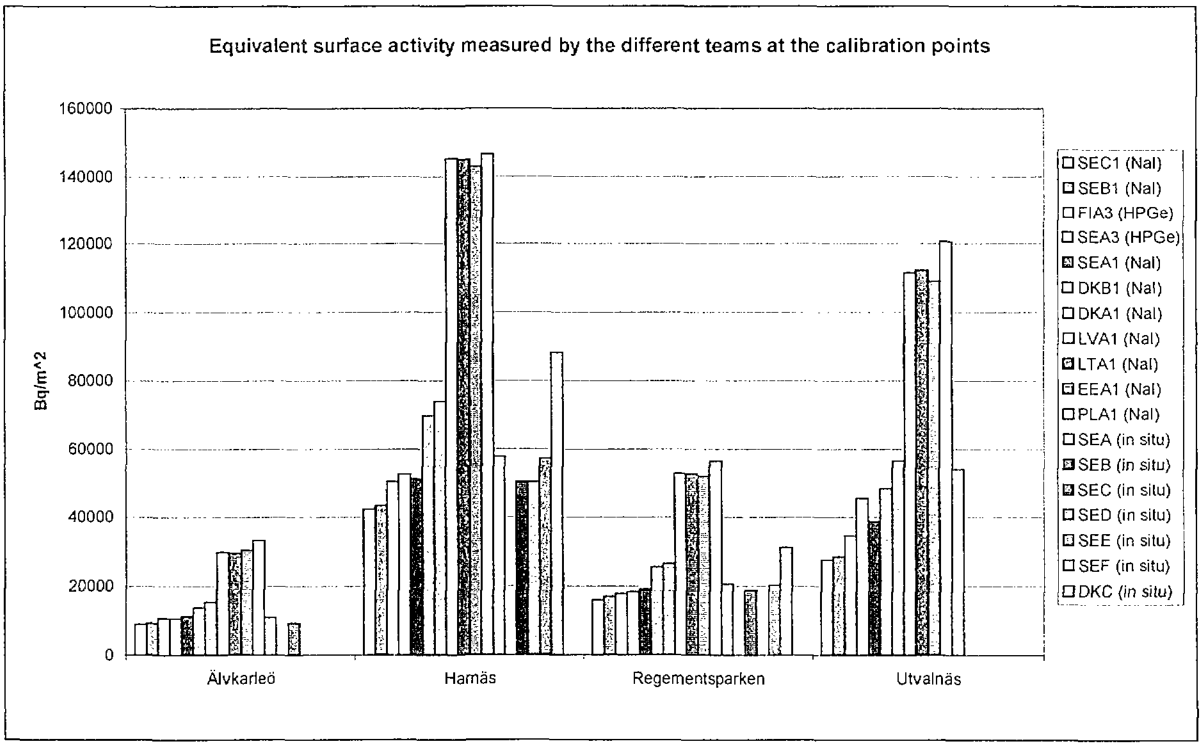

Figure 30. The equivalent surface activity of ^{137}Cs (Bq/m^2) at the four calibration points visualised in a diagram.

To examine the response of the systems at different radiation levels and in different geometries all measurements were normalised to the DKA1 value obtained at the Ytterharnäs calibration point. As can be seen in the diagram below, there is a good agreement between the measurements made on grass areas (Älvkarleö and Regementsparken) while the asphalt/forest calibration point in Utvalnäs shows bigger differences. This point is much more sensitive to changes in geometry because the asphalt itself is free from the ^{137}Cs fallout.

In the system description (Section 3.8) it can be seen that out of the four systems showing the lowest response on the site at Utvalnäs, SEB1 and DKB1 have a lower detector position in the car than the other systems while SEC1 and FIA3 was mounted with the detector in the centre of the car.

The system SEA3 shows a much higher response at Utvalnäs than at the other calibration points. SEA3 has a 70 % HPGe detector that probably has a different directional sensitivity than the NaI(Tl) systems. It is a new system and the directional sensitivity has not yet been examined in detail.

The reason that PLA1 shows a higher response at Utvalnäs is somewhat strange. The system is the same as the one used by the Baltic and Danish teams. The fact that the system also shows a little higher response at Regementsparken and Älvkarleö indicates that the reason for the difference may originate in the measurement at Ytterharnäs. The soil samples taken by FOA (see appendix II) indicate that the ^{137}Cs content in the soil is quite inhomogeneous here.

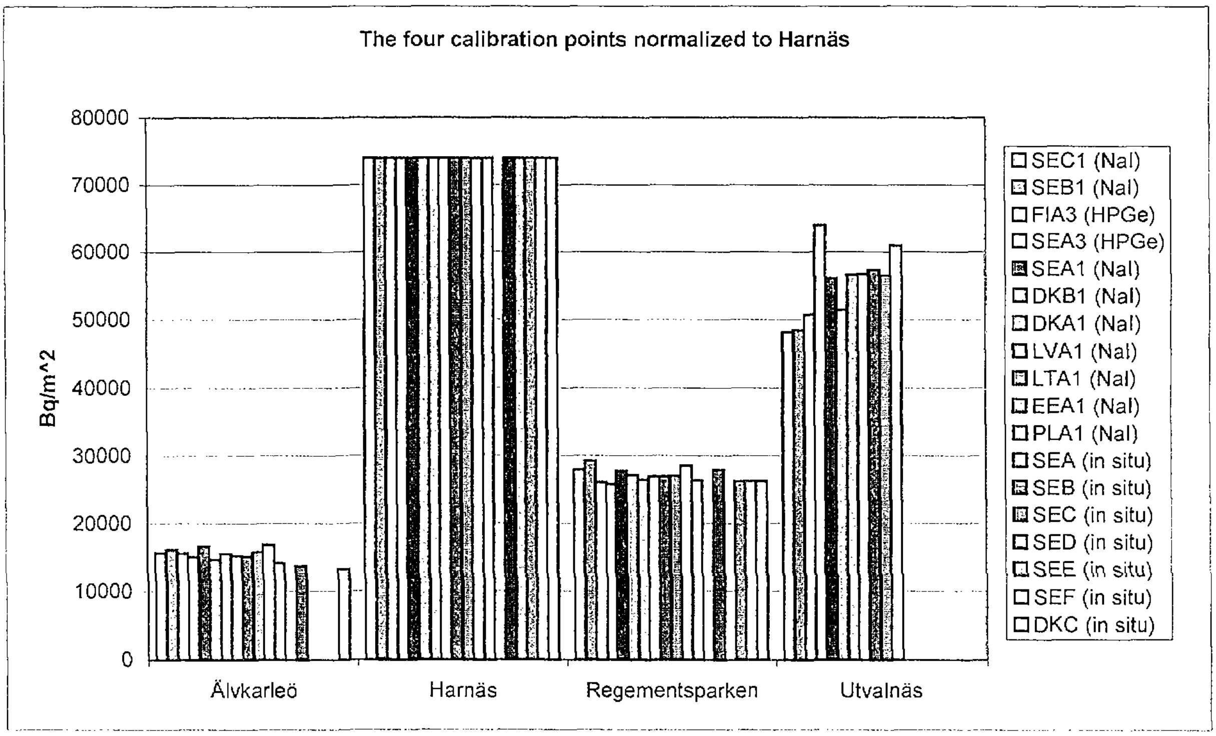

Figure 31. The equivalent surface activity at the four calibration points normalised to the DKA1 value at Harnäs.

The measurements from two different parts of the calibration route were extracted for further investigation of the response in different geometries. The values in the table below are the average equivalent surface activity of ^{137}Cs along these extracts. The first part was an asphalt section north of Sandviken of slightly more than five kilometres and the second was a gravel section in Hanåsen of about the same length. The results show almost the same trend as for the asphalt/forest calibration point in Utvalnäs. The system PLA1 has somewhat higher values than the average. The DKB1 system, with its low positioning in the car, has lower values. The higher response for the HPGe system SEA3 can however not be seen here. No values are shown for the systems SEB1 and LTA1 because of loss of GPS signal.

System	Ytterharnäs	Utvalnäs	Asphalt extract	Gravel extract
SEC1	42400	27600	3670	14000
SEB1	43500	28500	-	-
FIA3	50600	34659	5971	17092
SEA3	52735	45580	5928	18571
SEA1	51207	38794	6060	19200
DKB1	69827	48497	5287	16546
DKA1	74026	56617	9057	26932
LVA1	145384	111427	17591	53057
LTA1	145054	112307	-	-
EEA1	142926	109118	17183	53758
PLA1	146542	120564	24834	59880

Table 6. Measured equivalent surface activities of ^{137}Cs (Bq/m^2) along two extracts of the route compared with the two calibration points at Ytterharnäs and Utvalnäs.

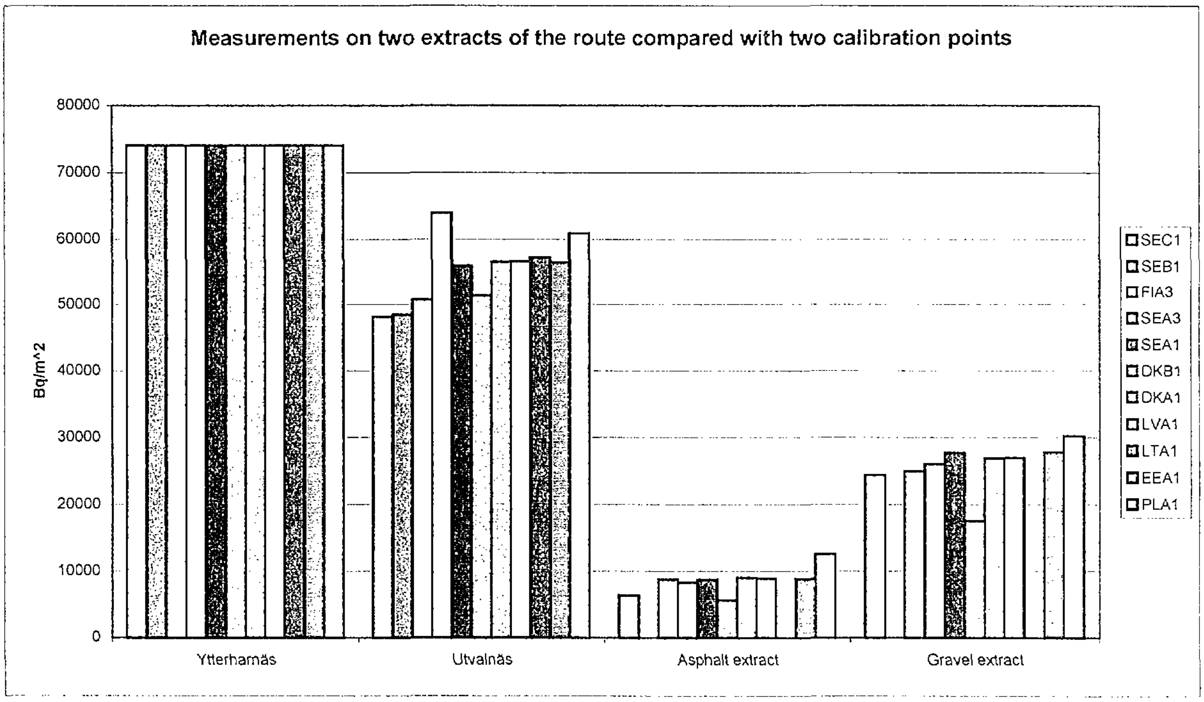

Figure 32. Measured equivalent surface activities of ^{137}Cs (Bq/m^2) along two extracts of the route compared with the two calibration points at Ytterharnäs and Utvalnäs. All values are relative to the DKA1 level at Ytterharnäs.

4.2 The mosaic measurement for the mobile teams

The result from the second measurement day was planned to be a common fallout map to which all teams should contribute with the measurements from their assigned area. In view of the differences in the ^{137}Cs values observed at the calibration sites, it was decided to make one of these a common calibration standard. The four calibration points on the route of the previous day were measured with the cars placed on the same spot and in the same direction, and for at least five minutes at each point. The measurements on these calibration points therefore show the differences between the systems and their calibrations. It was decided to calculate scaling factors by using the results from the calibration point at Ytterharnäs and the measurement made with the system DKA1 was again chosen to be the reference.

The table below shows the measured equivalent surface activity of ^{137}Cs at Ytterharnäs and the corresponding scaling factor for all systems.

System	Detector type	Reported equiv. surface activity at Ytterharnäs (Bq/m^2)	Relative level compared to DKA1	Applied factor for the mosaic map
SEC1	NaI	42400	0,573	1,75
SEB1	NaI	43500	0,588	1,7
FIA3	HPGe	50600	0,684	1,46
SEA3	HPGe	52735	0,712	1,4
SEA1	NaI	51207	0,692	1,45
DKB1	NaI	69827	0,943	1,06
DKA1	NaI	74026	1	1
LVA1	NaI	145384	1,964	0,51
LTA1	NaI	145054	1,960	0,51
EEA1	NaI	142926	1,931	0,52
PLA1	NaI	146542	1,980	0,51

Table 7. The scaling factors applied to the different data sets to create the common mosaic map.

With the scaling factors applied, all data sets were put together to form the mosaic map. Maps were made both in a point version and in an interpolated grid version. The maps were produced at the Geological Survey of Sweden with a geographical background in the scale 1:100 000. In the colour-graded point map on the next page it is difficult to see the radiation levels because of the small size of the map, but the amount of roads that were covered can be seen. Even though many roads were blocked by locked gates, which was a big problem for most teams, it can be seen that the covering of the area was very good.

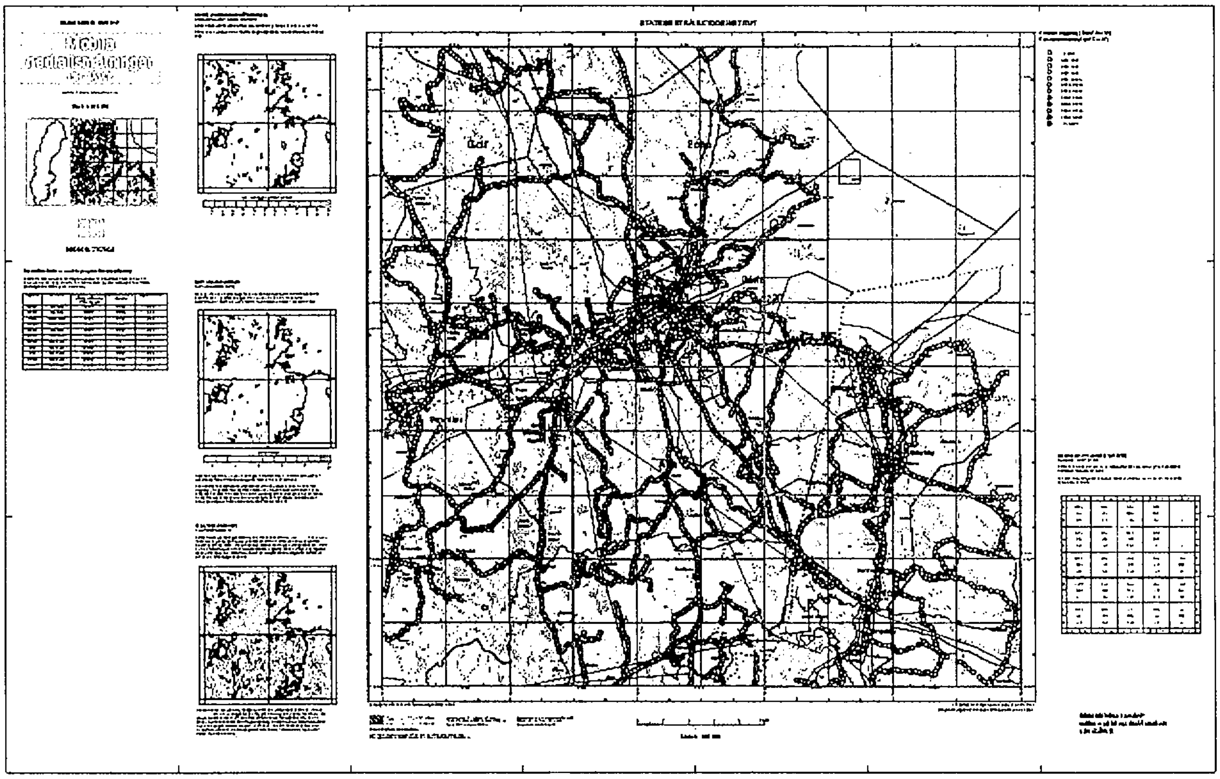

Figure 33. A point map of the measurements from all the gamma spectrometry teams during the second day.

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Because of large distances between some of the roads and some big areas without any roads at all, it is difficult to do a good interpolated grid of the data set produced. The map will not show the true values in the many places where the radiation has not been measured and artefacts may occur in the interpolation. This was done anyway and on the next page this map is shown. As a comparison an interpolated grid map of the airborne ^{137}Cs measurements made in 1997 by the Geological Survey of Sweden is inserted [SGU, 1998]

Although the contrasts between the high and low contaminated areas are not that distinct in the carborne map, the two maps clearly show similarities in the larger scale. This CGS map was made in a hurry during the exercise and the colour scale of the different ^{137}Cs levels is not optimised.

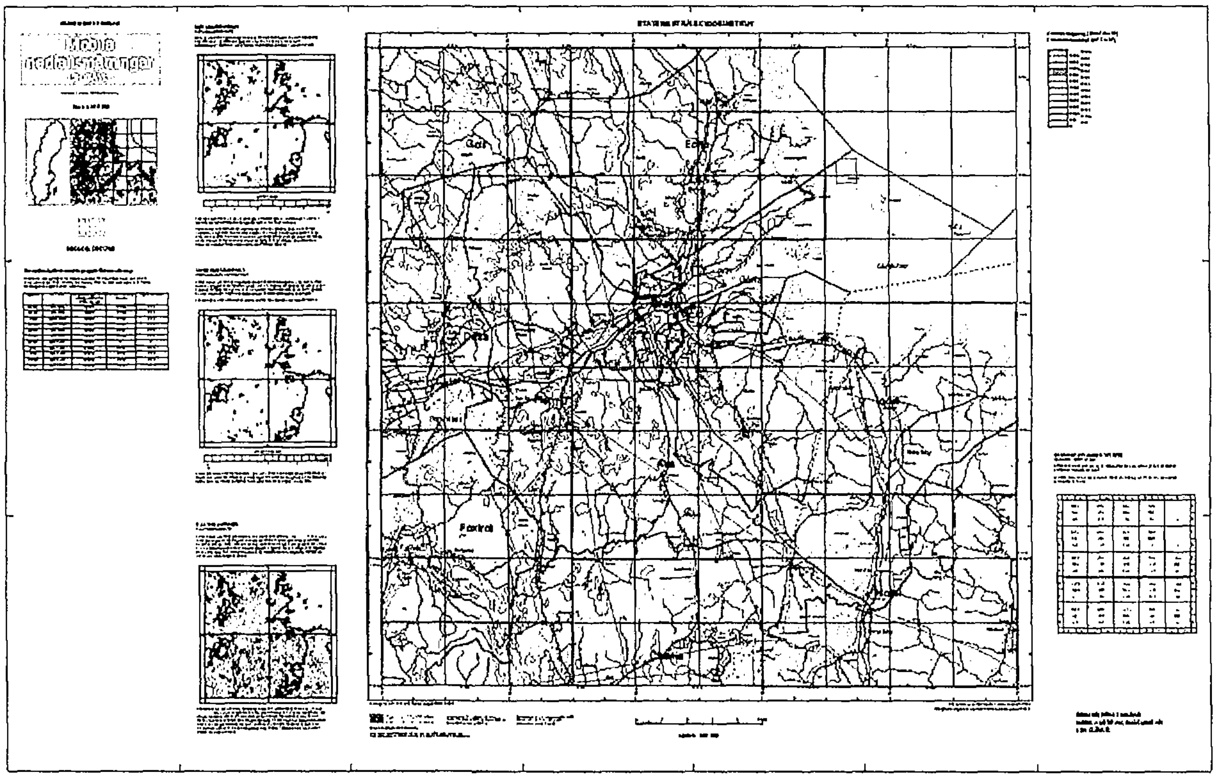

Figure 34. A map with an interpolated grid of the measurements from all the gamma spectrometry teams during the second day.

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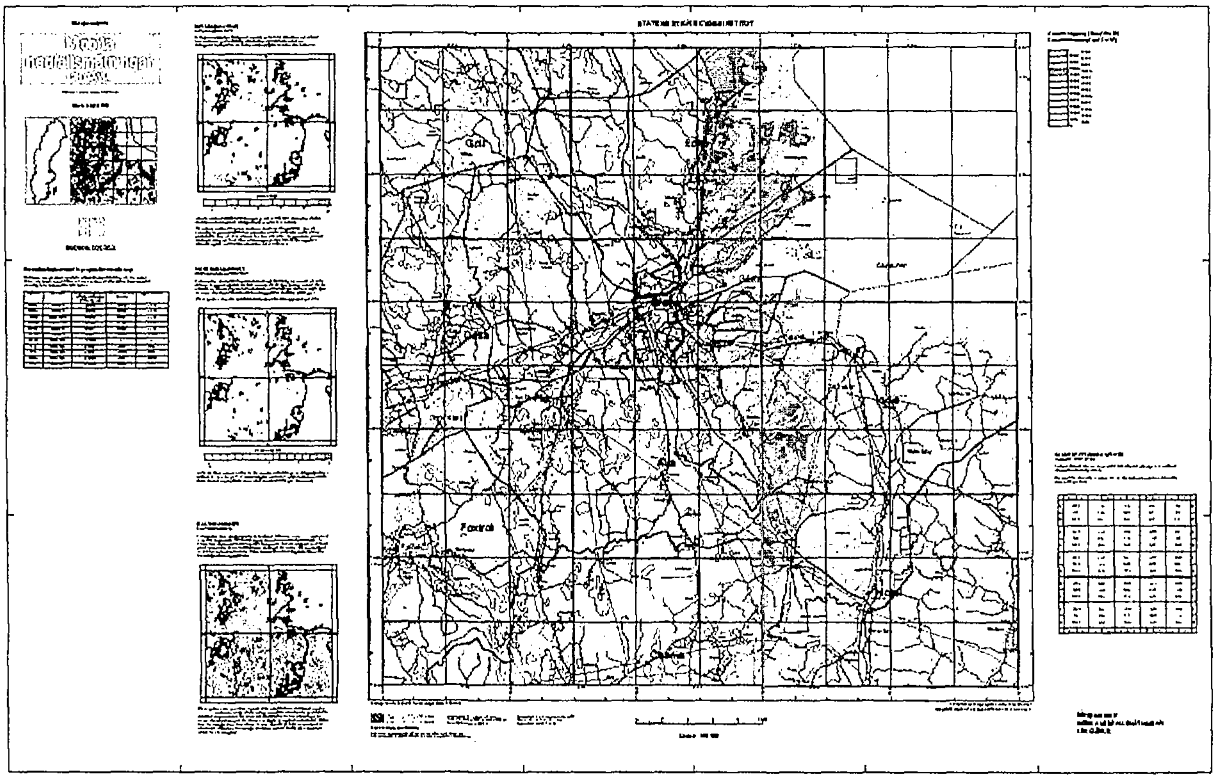

Figure 35. A map with an interpolated grid of the airborne measurements made by the Geological Survey of Sweden in 1997.

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4.3 *In situ* results

The *in situ* measurements were performed at fourteen different *in situ* points as well as at the four calibration points for the mobile teams. The equivalent surface activity of ^{137}Cs measured at the four calibration points was presented above together with the results of the mobile teams (Section 4.1). Beside measurements of equivalent surface activity of ^{137}Cs, the *in situ* teams were encouraged to take soil and grass samples, which most of them did. Many of the teams used equipment for estimations of the dose rate, and also calculated activities of other nuclides than ^{137}Cs.

In this section, the measurements of ^{137}Cs activities and of total dose rate are presented. The table and figure below show the equivalent surface activities of ^{137}Cs at the *in situ* points.

(Bq/m^2)	SEA	SEB	SEC	SED	SEE	SEF	DKC
Hyttön	28900	25000	25500	25165	29000	-	37800
Storhagen	51200	42360	43900	43900	-	-	66500
Hemlingby	24600	18916	21800	22400	-	35800	31000
Sjötorp	34600	28276	-	-	-	49600	-
Golfbanan	3300	4064	-	-	-	7780	-
Engesberg	27200	23117	24200	-	27100	39700	-
Utvalnäs	63200	52580	-	41900	44000	-	81900
Hillevallen	68900	53672	-	57000	66000	110000	-
Eskön	-	54275	-	54800	62380	-	83300
Trödje	-	60467	-	58900	-	-	-
Hillsjöstrand	7850	6489	-	-	-	11500	9500
Åbyggeby	-	12474	14000	13200	-	23500	-
Oslättsfors	-	10968	11900	-	-	-	16100
Smörnäs	-	17737	17500	17500	-	-	-

Table 8. The equivalent surface activities of ^{137}Cs measured at the fourteen *in situ* points.

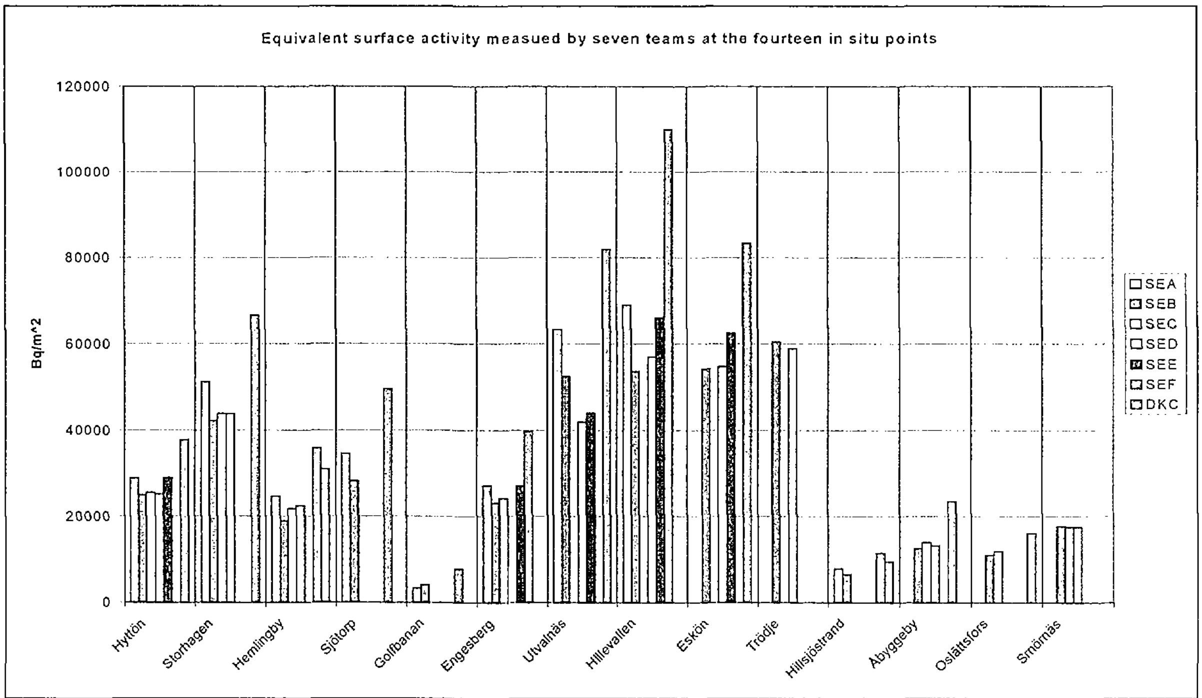

Figure 36. The equivalent surface activities of ^{137}Cs measured by the seven teams at the fourteen *in situ* points.

Dose rates measured at the *in situ* points and calibration points are shown in Table 9 and in Figure 37. Most values are measured with the use of calibrated dose rate meters while some are calculated from spectra. All results are expressed in **µSv/h except for the DKC and PLA** values that are expressed in **µGy/h. PLA was a mobile team but performed dose rate** calculations at the calibration points and is therefore included here as well.

Site	SEA	SEB	SEC	SED	SEE	SEF	DKC	PLA
Hyttön	0.21	0.2	0.25	0.17	0.21	-	0.12	-
Storhagen	0.24	0.29	0.35	0.29	-	-	0.17	-
Hemlingby	0.15	0.22	0.25	0.18	-	0.16	0.12	-
Sjötorp	0.19	0.23	-	-	-	0.2	-	-
Golfbanan	0.1	0.18	-	-	-	0.1	0.09	-
Engesberg	0.16	0.22	0.25	-	0.26	0.2	-	-
Utvalnäs	0.25	0.4	-	0.3	0.42	-	0.24	-
Hillevallen	0.35	0.35	-	0.38	0.43	0.3	-	-
Eskön	-	0.37	-	0.3	0.36	-	0.21	-
Trödje	-	0.39	-	0.31	-	-	-	-
Hillsjöstrand	0.1	0.14	-	-	-	0.08	0.075	-
Åbyggeby	-	0.15	0.2	0.19	-	0.1	-	-
Oslättsfors	-	0.13	0.2	-	-	-	0.1	-
Smörnäs	-	0.17	0.25	0.21	-	-	-	-
Ytterharnäs	0.24	-	0.35	0.25	-	0.2	0.17	0.243
Regementsparken	0.12	-	0.2	-	-	0.11	0.092	0.133
Utvalnäs	0.27	-	-	-	-	-	-	0.266
Älvkarleö	0.16	-	0.17	-	-	-	0.064	0.101

Table 9. Dose rates measured at the in-situ- and calibration points. All values are expressed in **µSv/h except for the values of DKC and PLA that are in µGy/h.**

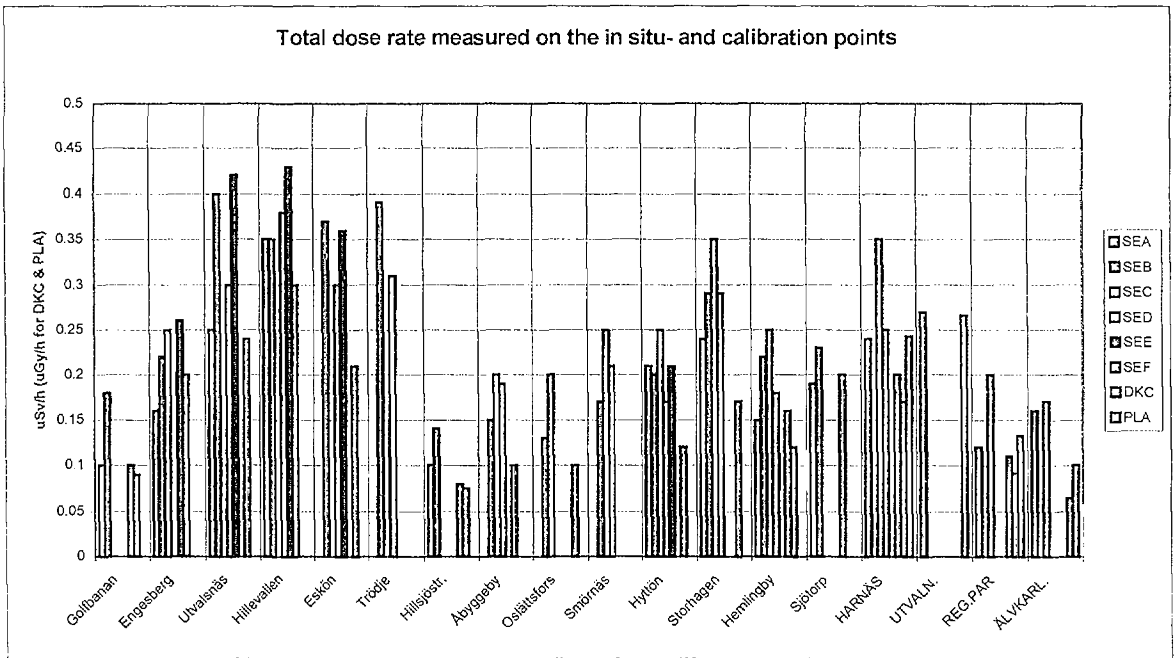

Figure 37. Dose rates measured at the in-situ- and calibration points. All values are expressed in **µSv/h except for the values of DKC and PLA that are in µGy/h.**

5. DISCUSSION

In this chapter the different elements of the exercise are discussed. The discussion is limited to observations made during the preparation phase of the exercise and during the exercise itself. The discussion is in part based on comments from the participants, received before, during and after the exercise.

5.1 Planning and preparations

Planning for the RESUME 99 exercise took place during several NKS project meetings, as well as in numerous exercise task group meetings. The last NKS project meeting in Stockholm on June 2, 1999, was attended by most of the participating organisations. The preparation for, and the execution of the exercise was to a large extent carried out by the Swedish Radiation Protection Institute (SSI).

It can be concluded that preparations worked smoothly in general. Many small details were worked out by the task group. The exercise was extended to include elements not of primary interest to NKS. This part of the exercise was run as a Swedish subproject lead by the emergency response group at SSI and included in-situ and dose-rate measurements according to Swedish protocols, reporting of results into the RADGIS system, etc. An experience drawn was that co-ordination between the two exercise branches sometimes was difficult. Some tasks were in a grey-zone in between the two branches.

There was a lot of work to be done during the final weeks before the exercise and the preparations engaged a lot of personnel at SSI. The computer network was put together and tested and the Resume 99 web site had to be updated with news and finalised. There were also a lot of practical details to be solved. Because Älvkarleö Herrgård is more of a conference centre than a hotel, there were some problems arranging all logistics in the best way for a group this large, demanding a great effort from SSI. The personnel at Älvkarleö were, however, very helpful during the planning and execution of the exercise.

5.2 Exercise logistics

The quality of the lodging at Älvkarleö Herrgård was appreciated. The mansion is positioned in a place of great natural beauty and during the exercise days the weather was very nice. In the spare time one could go for a walk in the surrounding areas or go on a canoe ride in the river Dalälven. The rooms at Älvkarleö Herrgård were of varying standard, but most participants were satisfied. Easy access between the cars and the rooms and a lot of space in general made the preparation of the measuring systems and processing of data easy for all teams. The tourist hotel in Älvkarleby had to be used for lodging as well. It would of course have been better to accommodate everyone at the same place but the short distance (4 km) made the inconvenience acceptable.

The food served at Älvkarleö was good and the portions were sufficient for starving field workers. The lack of a "real" restaurant forced everyone to eat at the same specified time. This was a little problematic due to the irregular working times, but it was also good for the fellowship and socialising between the groups. For some of the teams working in the field there were problems finding restaurants for lunch. The dinner party on the final day was a nice conclusion of the exercise with good food and wine and a lot of fun.

Most time of the day and night there were personnel at the exercise headquarters that could answer questions and support the teams. The conference building served well as the centre of the exercise, with exercise staff, administrative personnel, computer and communication staff and rooms for meetings and discussions under the same roof. Several information meetings were held during the exercise to inform about the different tasks and the procedures during the measurements and the stay at Älvkarleö Herrgård.

The Resume 99 web site was a useful and successful part of the exercise. On the "public" computer that was put in the headquarters, the teams could check for information and look at results. It was, however, very time consuming to prepare the web site for the exercise and to update it with new results during the exercise days.

5.3 Exercise tasks

Task 1, calibration route:

All mobile teams completed the calibration route without severe problems. Being the first measurement day, some teams had problems getting their systems to work at first, but most technical problems were solved after a while. The teams took off with 15 minutes intervals to avoid queuing at the calibration points and this proved to work well. The road description for the route was very detailed and almost all cars followed the track without problems. The route was about 200 km long. It was feared that it would take to long to drive, including breaks for food and measurements at the calibration points, but all teams managed to get back to the mansion in Älvkarleö in good time before dinner. The calibration measurements performed in this task gave valuable and interesting information about differences in calibration and in system characteristics and geometries.

Task 2, mosaic mapping:

The mosaic measurements during day two also proceeded without major problems. Most teams were delayed by the many locked gates in the Gävle area. Because of these gates several areas with smaller roads had to be left unmeasured. Despite this fact, the covering of the area was surprisingly good. The problem with the gates was well known before the exercise but no good solution was found. The midday delivery of data went well. Some teams delivered the data on diskette and others delivered them by phone according to the instructions given. Team DKA and SEC used the possibility to send the data by e-mail. Probably more teams will develop their systems for transferring data in a similar way. It is less time consuming and in many real cases the only possible way.

Task 3, in-situ mapping:

The *in situ* measurements went well most of the time. The variety of the *in situ* sites was good for testing of the equipment and the road description to the sites was well written. Many of the systems used were designed more for laboratory use than for field use, but because of the good weather this was not a problem. The Swedish laboratories that are under contract with the emergency preparedness organisation at SSI used many different types of tools and equipment for the measurements, and it could be useful to standardise some of these, like soil sampling equipment and analysis programs, etc.

Some teams made soil sample measurements on site at the *in situ* points or in the hotel rooms when they had returned. Different types of shielding material were used, such as water or lead. That seemed to work well with fully acceptable measurement results. Soil samples were also sent to the home laboratory or to laboratories not participating in the exercise. Results were sent back to Älvkarleö by fax. Both methods could probably be used in real situations although the use of laboratories is preferable to reduce the work-load for the teams working in field. The exercise was a good way to train the Swedish *in situ* teams to report results in the RadGIS system. Some problems and bugs in the program were brought to light through this test.

5.4 Computer & communications centre

Prior to the exercise, a workflow ranging from NKS files, delivered in various ways from the measurement teams, to decision-making support products in the form of compilations of statistics and maps, had to be established. This had to be done bearing in mind the limitations imposed by the fact that the CCC was located on-site, rather than in a traditional emergency central. The exercise, however, proved the feasibility of the chosen approach.

At the start of the exercise, each team was provided with map material compiled specifically for the exercise and individually for each team. The fact that road descriptions, location of reference and in-situ points, etc., were already printed on the maps may have saved some time for the teams in the preparation of the field campaign, time which probably was spent in getting the equipment in order. The maps proved to be adequate for navigational purposes, since all teams managed to return in the evening.

The reporting of data during the exercise worked surprisingly well, with real-time field reports ranging from oral description of the fallout situation over the phone to e-mail transfer of processed data using cellular phones and modems. Deadlines were generally respected, as was the NKS file format description, although some teams had to iterate a few times.

The problems encountered during the data processing provided by the CCC were minor. Some instabilities in the ESRI Arc/Info license manager required rebooting of the system, and the limit for what Microsoft Excel could handle (some 65,000 records) was exceeded for some data sets. The unforeseen introduction of a strong point source along the road led to a slight redefinition of the classification of the data prior to plotting in order to prevent the anomaly from suppressing all other events.

The concept of mail-triggered off-line processing at the Geological Survey in Uppsala, a batch-oriented process not requiring any human interaction at the Survey, proved to be efficient and robust, with no recorded communication breakdowns. The transfer rates with which ready-made plots could be retrieved through satellite-based communication were sufficient to keep the plotters busy. Even though it was decided at a late stage prior to the exercise to provide advanced on-site capabilities for GIS analysis and map making, the use of the SGU for the processing of large data sets lead to a reduced load on the on-site resources as well as to the access to vast resources of geographical information in a more detailed scale than what was available in Älvkarleö.

The single most serious degradation of the processing results was the loss of GPS information over considerable parts of some data sets, something which eventually should have been dealt with in-field.

Maps and results were continuously submitted to the exercise-specific web site, physically located in Lund in the south of Sweden. As most pre-exercise efforts had been put into the enabling of map production intended for on-site display, the resulting products were not optimised for web purposes. Plots were uploaded to the web server in GIF as well as PDF formats, thus enabling rapid download (GIF) as well as high resolution (PDF). Future exercises should possibly address the possibility of providing more interactive means of accessing results through the web using an internet map server with the capability of dynamically creating maps from user requests.

During the exercise, few teams presented results from internal processing, despite the fact that geographical information for map-making purposes was provided in digital form prior to the exercise. The providing of centralised processing facilities might have hampered the motivation for more elaborate work on the visualisation part of the measurement campaign. This might require special focus in future exercises, since the optimal processing, interpolation and visualisation of these kinds of data is far from trivial.

5.5 Reporting

All results reported from the mobile teams were to be in the NKS file format that was developed for the exercise (see appendix III). Prior to the exercise, the task group at SSI asked for data files in this format to check for errors that could create problems for the teams or the CCC during the exercise days. During the exercise there were still some teams that had problems with transformation into correct NKS files, but this was corrected and no files were delivered later than midnight during any of the two days. There are many advantages of having a common file format like this when data files shall be exchanged between different organisations. The NKS file format, although space consuming, worked well and should be considered as an alternative in future data exchange. Co-ordinates were given in either the Swedish grid (RT90) or in WGS84. No problems were observed.

A big and important part of the exercise was the use of telecommunication. The exercise staff kept control of positions and status for all the different teams by stating times that each team should leave a report. A lot of data was transferred both in and out of the headquarters by the use of telephones, fax machines, e-mail and satellite links. Most of this worked very well and contributed to the success of the exercise.

5.6 Results

The only results that have been analysed for this report are the ones presented during the exercise. The most notable observation so far is the big differences between the values measured at each calibration point by the different teams. These differences are mainly due to differences in the calibration of the systems but can also be due to other things such as differences in geometry, shielding or displacement of the system. The biggest differences from the median value were measured with the Polish and Baltic systems. These differences were due to an error in the calibration. The values are a factor of two larger than the Danish system DKA1 which was calibrated in the same way. The differences in the results on the calibration points will be analysed more thoroughly in the upcoming research projects within NKS/BOK-1.2. The route and the mosaic measurements will also be analysed in detail.

From the mosaic measurement it was seen that in large areas the fallout can be measured from cars, without spending too much time or manpower. Measuring with carborne systems is cheaper than using airborne systems and demands less planning. Whether the results are immediately comparable to results from airborne measurements remains to be investigated.

One of the objectives of the RESUME 99 exercise was to test and train field teams in rapid measurements of ionising radiation in a fallout area of a nuclear reactor accident and to test the co-operation between teams simulating international assistance to a country after an accident. The testing and training of teams is important within this field. To train in a "close to real" situation gives a lot of experience and brings out weaknesses and problems that can be mitigated. The preparation for an exercise like this also provokes the development of measurement techniques and systems.

Another important objective was to create a big data set for research purposes and especially for investigation of the feasibility of integration of airborne and carborne measurements. The data collected should provide good opportunities for research within the area. The data set consists of data from eleven different mobile systems (two equipped with HPGe detectors). Most systems contributed with both NKS files and full spectral files. In the NKS files it can be seen that several teams suffered from loss of GPS signals at some parts of the calibration route. In some cases this was due to shielding caused by the car roof or by surrounding elements and in other cases it was due to technical problems.

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APPENDIX II. THE REFERENCE MEASUREMENTS MADE BY FOA

On two occasions during May and June 1999, a group from the Swedish Defence Research Establishment (FOA) collected reference data from three of the four calibration sites on the route for the mobile measurement teams. They performed *in situ* measurements and took a large number of soil samples from the three grass area sites. The asphalt/forest site was not investigated at that time. The soil samples were taken according to the pattern shown below. At each site, three times ten bulk samples were taken with diameters of 3,6 cm. They were put together three and three as they were taken. In a triangular shape around the centre of the site, three more samples were taken, that were sectioned in 1-2 cm slices. The diameter of these samples was 9.8 cm. All samples were taken to a dept of around 20 centimetres.

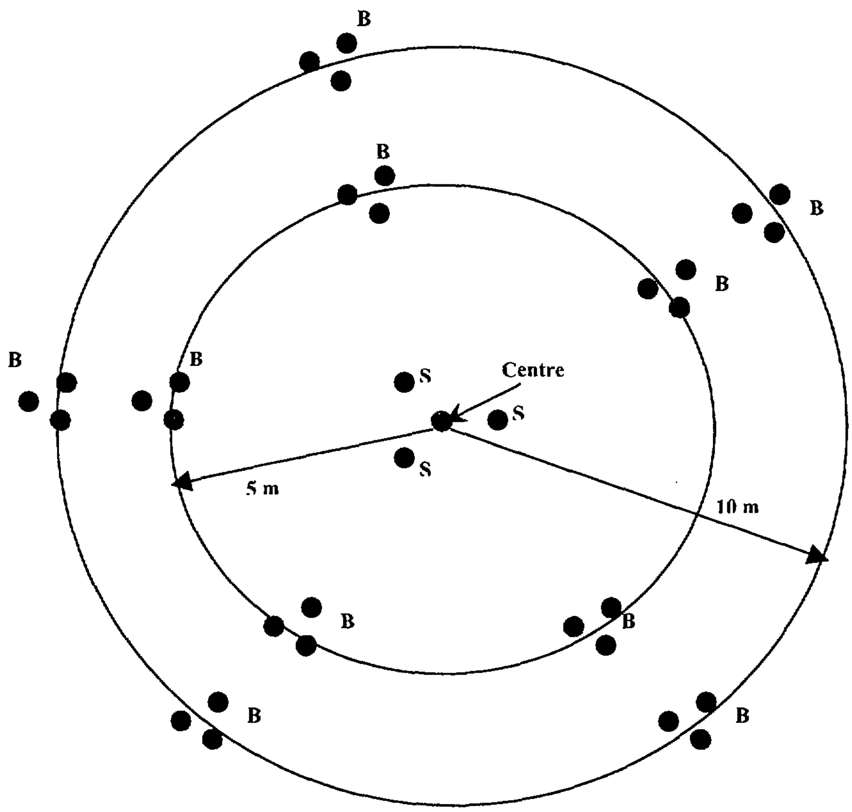


Figure AII-1. The sampling grid used at the three sites. The two circles have 5 m and 10 m radii. B stands for bulk samples and S for sectioned samples.

From the bulk samples, the highest ^{137}Cs activity was found at the Ytterharnäs site (195 kBq/m^2) followed by Regementsparken (82 kBq/m^2) and Älvkarleö (45 kBq/m^2). In the table below, data from the three sites are shown. Notable is the smaller standard deviation for the natural nuclides ^{204}Bi, ^{208}Tl and ^{40}K, compared to the anthropogenic nuclides ^{137}Cs and ^{134}Cs.

Site	Regementsparken	Ytterharnäs	Älvkarleö
Thickness (cm)	22 (± 0)	19.1 (±2.0)	20 (± 0)
Density wet (kg/m^3)	1360 (±57)	1480 (±324)	1390 (±68)
Density dry (kg/m^3)	1143 (±73)	1408 (±317)	1226 (±70)
Water content (%)	16.4 (±3.8)	4.7 (±1.4)	11.6 (±2.7)
Cs-137 (Bq/m^2)	82200 (±24700)	195200 (±59300)	45000 (±24700)
Cs-137 (Bq/kg)	320 (±100)	1100 (±530)	190 (±110)
Cs-134 (Bq/kg)	3.3 (±1.16)	10.5 (±5.0)	1.6 (±1.12)
K-40 (Bq/kg)	791 (±43)	850 (±80)	785 (±20)
Tl-208 (Bq/kg)	8.4 (±0.8)	7.1 (±1.1)	8.8 (±0.5)
Bi-214 (Bq/kg)	23.1 (±1.2)	25.1 (±3.5)	21.3 (±0.8)

Table AII-1. Results of measurements of bulk samples taken at the three sites. For estimations of the ^{137}Cs activity, the results of the sliced samples were also included. For calculations of the ^{232}Th equilibrium activity concentration the actual ^{208}Tl activity concentration should be divided by the branching factor of ^{208}Tl (0.36). The value within brackets is one standard deviation.

From the *in situ* measurements, the equivalent surface activity of ^{137}Cs was calculated for the three sites. The results are shown in the table below.

Site	Regementsparken	Ytterharnäs	Älvkarleby
Equivalent surface activity (Bq/m^2)	15800	49000	9300
Error (1 sigma count stat.)	100	200	100

Table AII-2. The equivalent surface activity at the three calibration points.

At each site, three samples were sliced to measure the depth distribution of ^{137}Cs in the soil. The slices were made 1-2 cm thick in the top layers and a bit thicker in the deeper layers. Diagrams of the depth distribution at the three sites are shown on the following pages. As can be seen, the maximum activity of ^{137}Cs is at a depth of around 2-3 cm at all three sites.

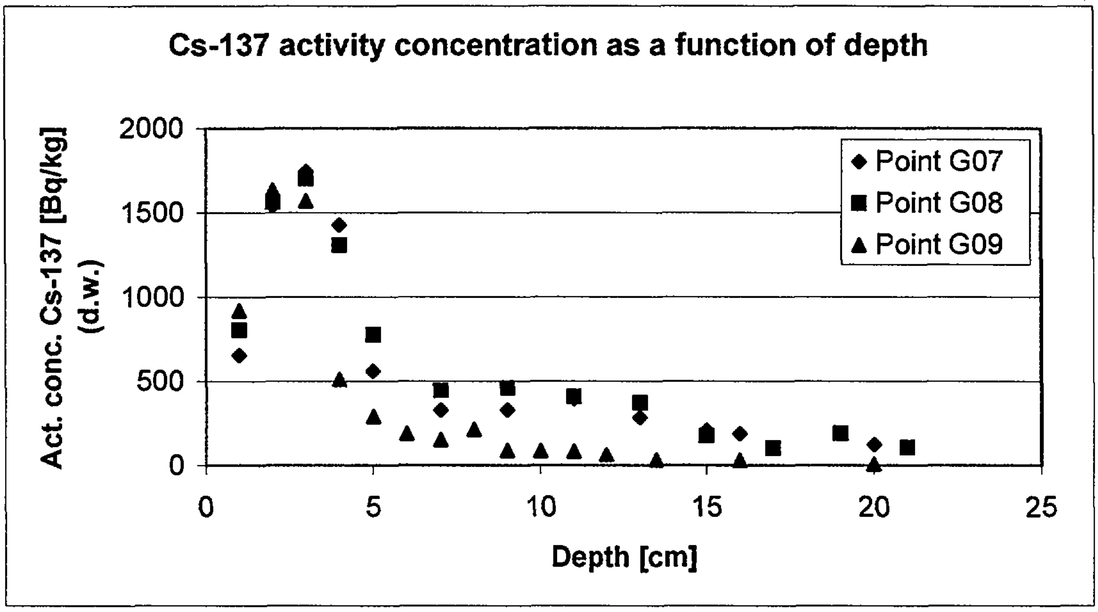


Figure AII-2. The activity of ^{137}Cs per unit mass dry weight plotted as a function of depth in the sectioned samples taken at the Regementsparken site.

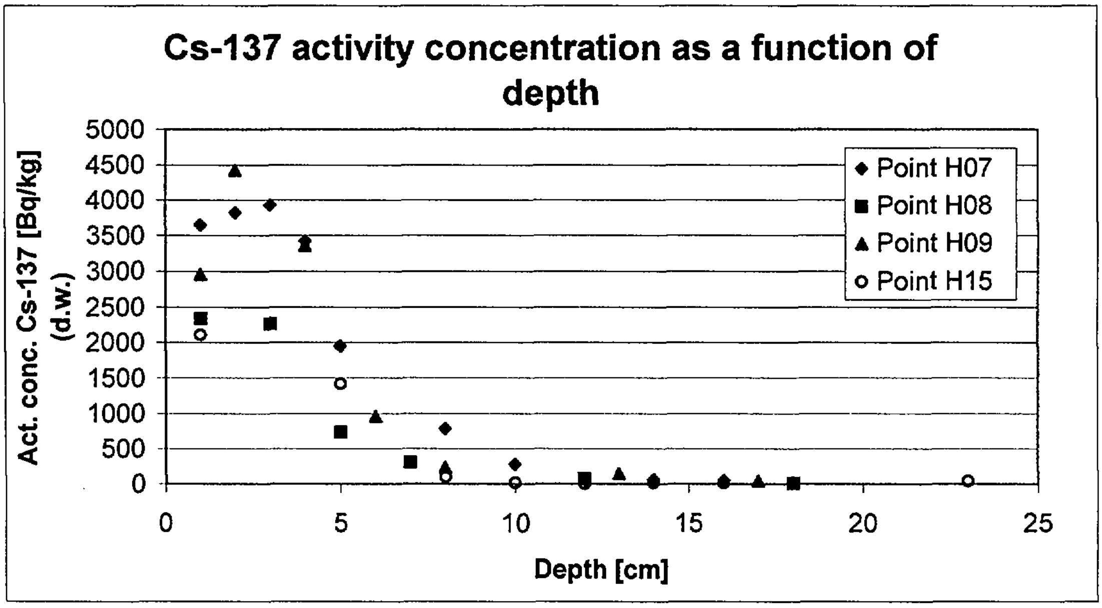


Figure AII-3. The activity of ^{137}Cs per unit mass dry weight plotted as a function of depth in the sectioned samples taken at the Ytterharnäs site.

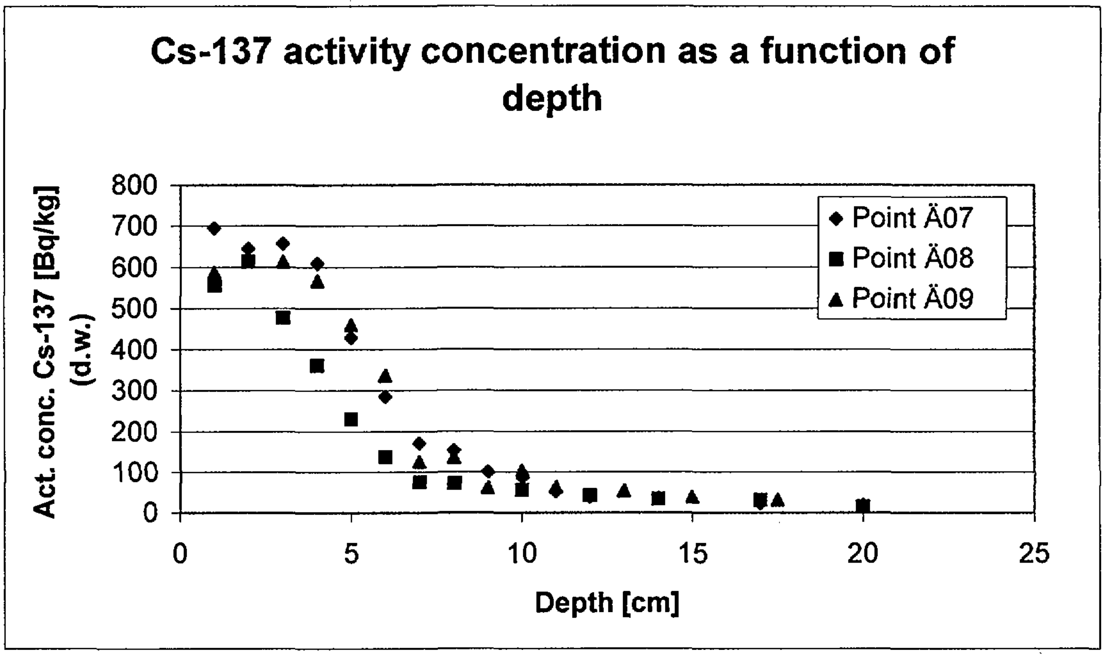


Figure AII-4. The activity of ^{137}Cs per unit mass dry weight plotted as a function of depth in the sectioned samples taken at the Regementsparken site.

APPENDIX III. THE NKS FILE FORMAT

Prior to the RESUME 99 exercise it was decided that data from mobile measurements should be delivered in a special format, the NKS-format. This format was developed to facilitate data processing at the computer and communications centre. A common format will also facilitate future co-operation when data files are being exchanged for research purposes, etc.

The NKS file format is an "open" format where additional identifiers can be added. The translator program, however, must be updated to recognise new identifiers. The program should discard identifiers that are not recognised.

General rules:

All data must be written in pairs as identifier(1) value(1) identifier(2) value(2) ... etc where identifier(x) is a specific identifier defined according to the *list of identifiers* (see below) and value(x) is the value for that identifier.

A record (line) can contain any number of paired identifiers and values, but each identifier written in the file must have a value belonging to it. The separator used is space, several spaces are OK. Points for decimals shall be used.

Examples of numerical formats are:
23
23.2
.0045792
56E+2
.3E+12

Records are allowed to have a comment. Comments must start with /*
Comments can follow after data but in this case /* must be preceded by a separator (space).
Data cannot follow after a comment.

Example of a data set:

```
/*
/* Measurements during Resume 99 exercise in Gävle, September 1999
/*
REC 1 SYS SEB2 DATE 19990907 TIME_UTC 172221 X_RT90 1800422 Y_RT90 6754001 CPS 122 /* no 1
REC 2 SYS SEB2 DATE 19990907 TIME_UTC 172231 X_RT90 1800544 Y_RT90 6754208 CPS 120 /* pt 2
REC 3 SYS SEB2 DATE 19990907 TIME_UTC 172241 X_RT90 1800657 Y_RT90 6754424 CPS 126 /* cc
```

This data set gives information on record number, system, date, time, position and count rate.

The NKS file format, list of identifiers:

Identifier	Description	Unit	Value example
AE_CS137	Equivalent surface activity of ^{137}Cs.	Bq/m^2	2345.6
AEM_CS137	Detection limit for equivalent surface activity of ^{137}Cs.	Bq/m^2	50
AEU_CS137	Uncertainty in surface activity of ^{137}Cs, standard deviation or standard error.	Bq/m^2	23.4
AR_CS137	Real activity of ^{137}Cs per unit area.	Bq/m^2	7845.6
ARM_CS137	Detection limit for real activity of ^{137}Cs per unit area.	Bq/m^2	70.
ARU_CS137	Uncertainty in real activity of ^{137}Cs per unit area, standard deviation or standard error	Bq/m^2	78.4
AR_K40	Activity of ^{40}K per unit mass.	Bq/kg	768
ARM_K40	Detection limit of the activity of ^{40}K per unit mass.	Bq/kg	12
ARU_K40	Uncertainty in the activity of ^{40}K per unit mass, standard deviation or standard error.	Bq/kg	7.6
AR_TH232	Activity of ^{232}Th series per unit mass.	Bq/kg	38.9
ARM_TH232	Detection limit of the activity of ^{232}Th series per unit mass.	Bq/kg	10
ARU_TH232	Uncertainty in the activity of ^{232}Th series per unit mass, standard deviation or standard error.	Bq/kg	8.9
AR_U238	Activity of ^{238}U series per unit mass.	Bq/kg	32.1
ARM_U238	Detection limit of the activity of ^{238}U series per unit mass.	Bq/kg	3.
ARU_U238	Uncertainty in the activity of ^{238}U series per unit mass, standard deviation or standard error.	Bq/kg	3.2
CPS	Counts per second full spectrum, live time.	Counts/s	1235.2
CPSU	Uncertainty in the counts per second full spectrum, live time, standard deviation or standard error.	Counts/s	123.
DATE	Measurement date.	Integer	19990907
D_CS137	Dose rate to air in free air from ^{137}Cs. Also used for air kerma rate.	µGy/h	0.022
DU_CS137	Uncertainty in the dose rate to air in free air from ^{137}Cs. Also used for uncertainty in the air kerma rate.	µGy/h	0.002
D_TOT	Total dose rate to air in free air from all sources. Also used for air kerma rate.	µGy/h	0.22
DU_TOT	Uncertainty in the total dose rate to air in free air. Also used for uncertainty in the air kerma rate.	µGy/h	0.02
H_TOT	Total ambient dose equivalent rate H*(10).	µSv/h	0.29

HU_TOT	Uncertainty in the total ambient dose equivalent rate H*(10).	µGy/h	0.03
REC	Record number.	Integer	23
SYS	System identification.	Alpha-numeric	DKA1
TAG	Identifier for surface type. Values are: ARW (asphalt road wide) ARN (asphalt road narrow) GR (Gravel road) CS (City street) GA (grass area)	Alpha-numeric	ARW
TIME_UTC	Time at measurement. UTC.	hhmmss	080511
TIME_LT	Time at measurement. Local time (in Sweden: UTC + 1h if not daylight saving time Summer time; UTC + 2h if daylight saving time).	hhmmss	100511
TIME_ST	Time at measurement. Standard time (in Sweden: UTC + 1h).	hhmmss	090511
X_RT90	X-co-ordinate, here defined as the East co-ordinate in the Swedish grid RT90 (seven integers).	m	1656211
Y_RT90	Y-co-ordinate, here defined as the North co-ordinate in the Swedish grid RT90 (seven integers).	m	6758321
X_WGS84	X-co-ordinate, here defined as the East co-ordinate in the World Geodetic System.	degrees	17.150868
Y_WGS84	Y-co-ordinate, here defined as the North co-ordinate in the World Geodetic System.	degrees	60.675144

Table AIII-1. The list of identifiers for the NKS file format.

APPENDIX IV. FILE NAME RULES FOR THE EXERCISE

The data files from the mobile measurements at RESUME 99 were assigned names of eight characters to facilitate recognition of the files from the different teams. The first four characters identify the system used, while the last four characters identify the measurement.

For the system identification, the first two characters identify the country, the third character identifies the team and the fourth character identifies the detector number. (The exercise staff assigned detector numbers to the teams after they had described their instrumentation). Detector numbers were selected according to the rule:

1, 2 - sodium iodide spectrometers
3, 4 - germanium spectrometers
5, 6 - dose rate instruments
7, 8 - soil sample spectrometry
9 - free use
0 - integrated systems

Example: DKA1 (Denmark, team A, detector number 1, a sodium iodide system).

The measurement is identified by characters five to eight. The fifth character is:

A for measurements in mosaic area,
L for measurements along specified roads or
P for measurements at reference points

Characters six to eight are used as a measurement number, ranging from 001 to 999.

Finally, the extension is NKS.

Example: DKA1A023.NKS

APPENDIX V. THE ROAD DESCRIPTION FOR THE CALIBRATION ROUTE

For future measurements along the RESUME 99 calibration route, the road description is enclosed here in the same manner as it was used during the exercise. It must be pointed out that the NKS signs were removed from the calibration route at the end of the exercise.

This route has been made to cover areas with both high and low contamination levels of ^{137}Cs. There are also some places with higher natural radiation. The route passes through both urban and rural environments, and goes on both asphalt roads of different sizes and small gravel roads. It can sometimes be hard to find the right way, so it is important that the map is carefully read and that the speed is kept low. A speed limit of 50 km/h is recommended. Where the choice of road can be unclear co-ordinates are given for those who can use that information. At some places signs are also placed to mark the correct road. Those places are marked in the text (**NKS sign**). There are a few places along the route where you can have lunch. In Gävle and Valbo there are restaurants in the vicinity of the route.

Please deliver the data from the route in two different files. One which only contains the calibration points (P), and one which contains the whole route (L). Observe the file name rules for the exercise.

From Älvkarleö Herrgård (X_RT90 1588008 Y_RT90 6714103) :

Turn left and go north towards Älvkarleby.
Turn left at the sign "Gävle 25" (reset trip meter), and continue in to Västanån.
A golf course is passed on the right side.
About 3,4 km after the sign "Gävle 25", turn left onto a small gravel road (**NKS sign**). This road is located just before a red house with a white fence (X_RT90 1589395 Y_RT90 6720449) (X_WGS84 17° 26.16 Y_WGS84 60° 35.50).
Turn right at the second cross about 700 meters from the road (**NKS sign**).
Take the first road left and pass over a railway crossing.
Turn right and follow the railway north until you come to some houses and an asphalt road where you turn left.
Continue 2,4 km and turn right at the crossroad after you passed under a power line (**NKS sign**).
Follow the road all the way up to road 76 and turn left.

Pass the sign "Gävle kommun and Gävleborgs län".
Turn right on Ytterharnäsvägen after a bus stop with a red bus-shelter (**NKS sign**) (X_RT90 1585317 Y_RT90 6726748) (X_WGS84 17° 21.85 Y_WGS84 60° 38.94).
Just before a small football course, turn right towards Ytterharnäs skola (**NKS sign**) and then left after 20 meters.
Cross a railroad and take the second road left on to Safarivägen.
Continue forward on a very small gravel road.
Here is a calibration point (X_RT90 1584598 Y_RT90 6727256) (X_WGS84 17° 21.10 Y_WGS84 60° 39.22).

Go back the same way to road 76 and turn right to continue towards Gävle (reset trip meter).
After 3,3 km, at the sign "Grinduga 2", turn left (X_RT90 1582169 Y_RT90 6726733) (X_WGS84 17° 18.43 Y_WGS84 60° 38.95).
In Grinduga turn left on Grindugastigen (reset trip meter).
Continue on this gravel road and turn right at the T-cross after 6,8 km.
In Mårtsbo, turn right at the sign "Gävle 10" (reset trip meter).
Turn right after 2,2 km, directly after a bridge where a sign says Långbro 5 km (X_RT90 1577823 Y_RT90 6721739) (X_WGS84 17° 13.59 Y_WGS84 60° 36.33).
Continue up to road 76 and turn left towards Gävle.

In Gävle, follow the road signs to the hospital ("Sjukhus").
Turn left towards Villastaden just before the bridge over the river Gavleån (X_RT90 1572668 Y_RT90 6728963) (X_WGS84 17° 08.03 Y_WGS84 60° 40.28). You see a big blue house where you shall turn.
Go straight and pass a clock tower.
At a big yellow house called Oden, turn right on a small gravel road in to the park "Regementsparken" **(NKS sign)**.
Here is the next calibration point (X_RT90 1571761 Y_RT90 6728772) (X_WGS84 17° 07.07 Y_WGS84 60° 40.18).

Go back and cross Gavleån.
Turn right on Staketgatan, with a sign "Lokal Slinga".
Drive straight ahead, pass under a bridge (reset trip meter) and go towards E4 and road 80.
Turn right towards Trödje about 1,5 km after the bridge.
Turn right towards Bönan.
Turn left towards Bönan (X_RT90 1575552 Y_RT90 6732309) (X_WGS84 17° 11.34 Y_WGS84 60° 42.06).
Turn left directly after about 5 meters **(NKS sign)**.
Turn right on "G:la Bönavägen" (reset trip meter).
Turn left after 1,1 km **(NKS sign)**.
Go straight ahead about 5 km after having entered "G:la Bönavägen" **(NKS sign)**.
Turn left 6,5 km after having entered "G:la Bönavägen" **(NKS sign)**.
Turn to the right, 9,3 km after having entered "G:la Bönavägen" **(NKS sign)** (X_RT90 1581667 Y_RT90 6737497) (X_WGS84 17° 18.18 Y_WGS84 60° 40.76).
Turn left when you reach the big road.

Pass the sign Utvalnäs.
Turn right on Utvalnäsvägen **(NKS sign)** (X_RT90 1583732 Y_RT90 6738082) (X_WGS84 17° 20.44 Y_WGS84 60° 45.05).
Keep to the left where the road splits in two.
In the middle of this newly built asphalt road there is a calibration point. (X_RT90 1583796 Y_RT90 6738703) (X_WGS84 17° 20.53 Y_WGS84 60° 45.38).
Stop the car with the wheels at the asphalt edge and the detector in line with the sign. Measure for at least 5 minutes.

Continue forward and turn right on the big road.
Turn left at the sign "Utnora 3".
Stay on Harkskärsvägen.
Continue to Utnora and turn left on "Utnorav." (X_RT90 1579914 Y_RT90 6740650) (X_WGS84 17° 16.30 Y_WGS84 60° 46.48).
Continue on this road and go straight through the village Björke without turning.

Cross the big road and go towards Oppala.
Turn left at the sign "Här slutar allmän väg"(X_RT90 1574002 Y_RT90 6739290) (X_WGS84 17° 09.77 Y_WGS84 60° 45.83).
Turn right towards Åbyggeby at the yield sign (A sign visible to the right when you stop says "Åbyggeby 3").
In Åbyggeby, cross the bridge and go directly to the right towards Oslättfors.
Keep going all the way up to Oslättfors.
Continue in on the road with the sign "Här slutar allmän väg"(X_RT90 1563823 Y_RT90 6739904) (X_WGS84 16° 58.58 Y_WGS84 60° 46.26).
Turn left towards Smörnäs in the first road cross. (A small sign says "Smörnäs 2,5").

In Smörnäs, turn right on to Sidbohällsvägen **(NKS sign)** (reset trip meter).
Continue for about 5,9 km until reaching a T-cross at a red house. Turn left here (reset trip meter).
Turn left again after another 3,6 km where there is a new T-cross (X_RT90 1554637 Y_RT90 6742679) (X_WGS84 16° 48.49 Y_WGS84 60° 47.83).
Turn left when reaching the large road (reset trip meter).
Keep going for 16,4 km.
Turn left towards Östanbyn, when having entered Sandviken (X_RT90 1554128 Y_RT90 6725774) (X_WGS84 16° 47.66 Y_WGS84 60° 38.72).

Go all the way to Valbo, and turn right on Valbovägen at the traffic light after passing the supermarket Vivo
(X_RT90 1565863 Y_RT90 6725758) (X_WGS84 17° 00.51 Y_WGS84 60° 38.60).
Pass IKEA and go under a bridge.
Continue in to Överhärde and turn left towards Västerås and Gysinge on road 67 (X_RT90 1564091 Y_RT90 6722646) (X_WGS84 16° 58.55 Y_WGS84 60° 36.98).
Turn left again after a couple of hundred meters where a sign says "Hästbo 12" (reset trip meter).

After about 9,5 km, in a sharp left curve, turn right on a gravel road called Ösarvägen **(NKS sign)**
(X_RT90 1568760 Y_RT90 6714868) (X_WGS84 17° 03.52 Y_WGS84 60° 32.72) (reset trip meter).
Continue 7,2 km until reaching Åsberga by following the "main" road and the **NKS-signs**.
Turn left on the big asphalt road in Åsberga (reset trip meter).
Continue about 4,5 km on this road and then turn right on to a gravel road with a sign "Hanåsen" (X_RT90 1572635 Y_RT90 6718930) (X_WGS84 17° 07.83 Y_WGS84 60° 34.89) (reset trip meter).
Turn right after 11 km, when reaching Dalenvägen.
Turn left when reaching the asphalt road Åsbovägen (X_RT90 1579289 Y_RT90 6712752) (X_WGS84 17° 14.97 Y_WGS84 60° 31.43).
Pass over the E4 and finally turn left towards Älvkarleö. /GOOD LUCK!!

APPENDIX VI. CGS SYSTEMS, CALIBRATIONS AND TEAM SPECIFIC WORK

In this appendix, the mobile gamma spectrometry systems used for RESUME 99 are described in detail. Short reports of team specific work within the area are also included in a few cases. The descriptions are made by the teams themselves, but have been put into the same format.

The systems included are:

System	Organisation	Measurements
DKA1	DEMA	Mobile
DKB1	Risø	Mobile
SEC1	Lund	Mobile
SEB1	FOA	Mobile
SEA1	SSI	Mobile
SEA3	SSI	Mobile
FIA3	STUK	Mobile
DKC3	DTU	*In situ*

The Baltic systems, EEA1, LVA1, LTA1, and the Polish system, PLA1, are similar to the Danish system, DKA1, and are not described separately.

<u>SYSTEM DKA1</u> **(Similar systems were also used by the Baltic and the Polish teams, EEA1, LVA1, LTA1, and PLA1)**

(ORGANISATION: DEMA)

1. Detector type

One 4L NaI-detector.
Dimensions of crystal 16"×4"×4"
Detector box made of Al - approximately 1.5 mm .
Insulation inside box - approximately 2 cm PU foam.
Detector encapsulation 0.25 mm stainless steel.

2. Position of detector

The detector is mounted on a roof-rack. The detector position is in the right side of the car placed as far to the back as possible. The detector box is placed as closed to the side of the car as possible. The detector is mounted on the roof rack on a frame i.e. there is no plate under the detector causing additional attenuation.

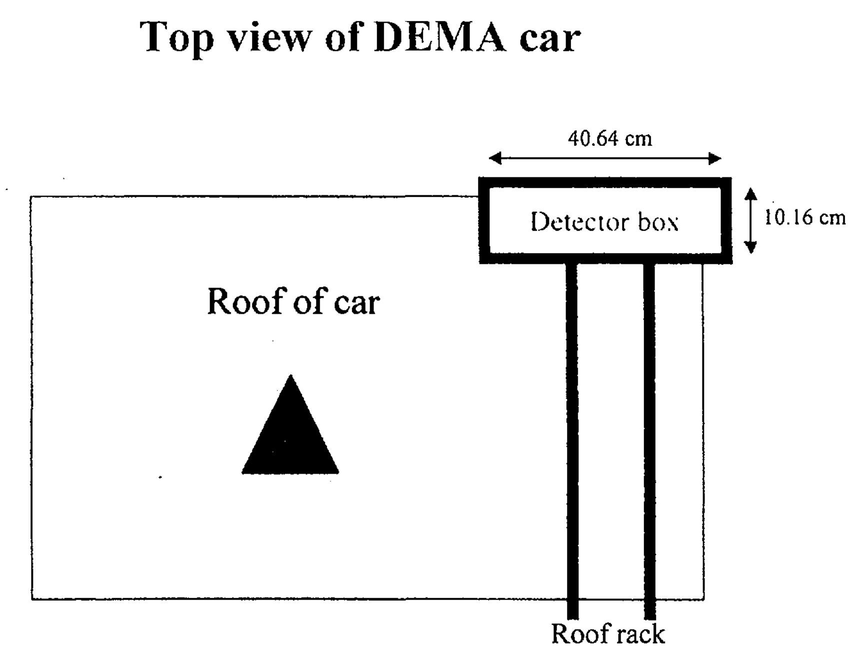


Figure AVI-1. Position of the detector in the DEMA vehicle.

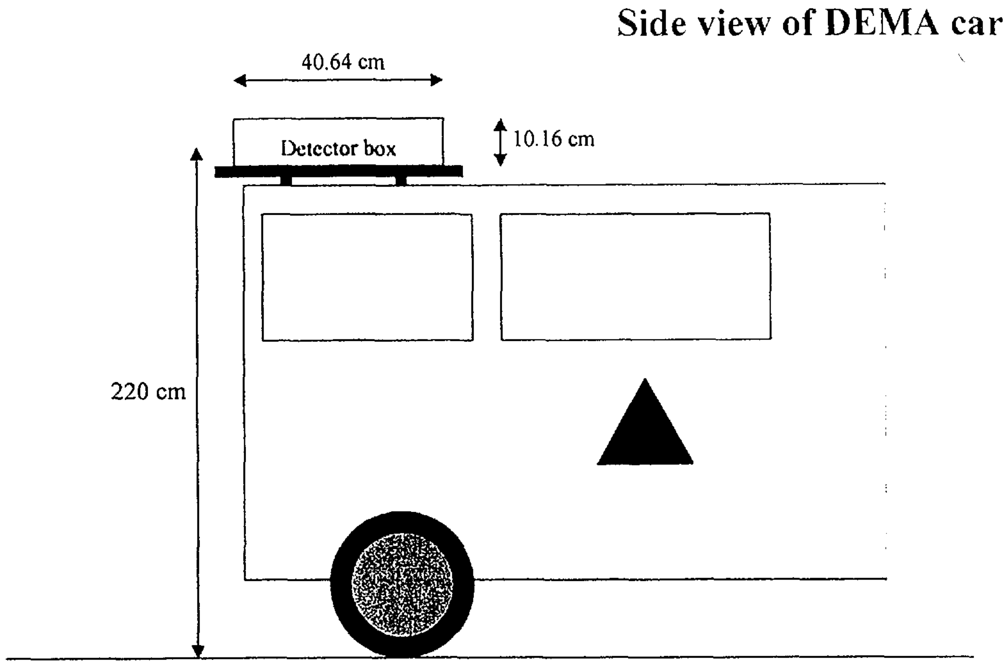


Figure AVI-2. Position of the detector in the DEMA vehicle.

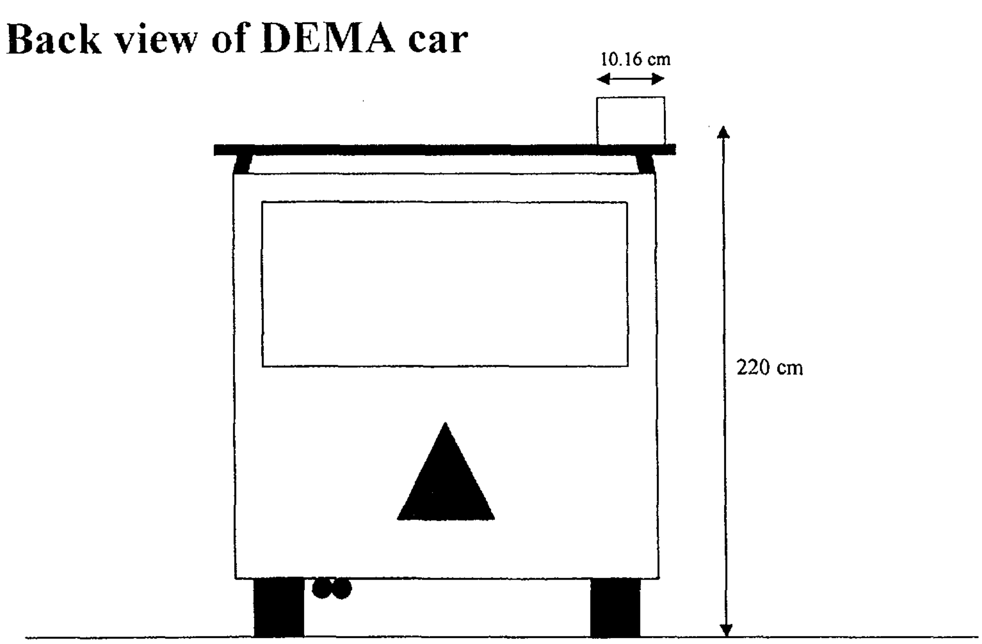


Figure AVI-3. Position of the detector in the DEMA vehicle.

3. Spectral measurements

Exploranium GR-320 spectrometer, 512 channels, on-line stabilisation using fixed Thorium peak position, real time 2 sec. per measurement. The Polish system, PLA1, uses 10 sec. integration time per measurement.

Energy calibration

Cs-137 peak in channel:	110
Tl-208 (Th) peak in channel:	418

Windows		**PLA1:**
Cs window channel:	100-120	100-120
K window channel:	222-253	224-252
U window channel:	267-299	268-298
Th window channel:	386-449	386-448

Strip coefficients

Alpha:	0.330
Beta:	0.439
Gamma:	0.814
a:	0.055
b:	0
g:	0
Delta (Th-Cs):	2.062
Epsilon (U-Cs):	2.777
Zeta (K-Cs):	0.337

Sensitivities

S_Cs:	19.74 cps/(kBq/m2)
S_K:	38.94 cps/%
S_U:	3.86 cps/ppm
S_Th:	1.80 cps/ppm

All measured and calculated by DEMA/DTU.

4. Description of attenuation materials in the car

Plastic roof, rear wheels etc.

5. Typical distance to the edge of the road, tagging of data

Approximately 1 m.
Tagging possible using 6 different tags. Tagging results stored in text files.
Manual tagging using record (spectrum) numbers.

6. Dose rate meters

No dose rate meter used by DEMA.

7. Other information

None.

SYSTEM DKB1

(ORGANISATION: Risø National Laboratory)

1. Detector type

Detector type
NaI(Tl)
Detector size (D x L)
3x3 inch
Detector box
2,5 mm aluminium box

2. Position of detector

Detector placed on the back seat of the DEMA vehicle (cf. system DKA1, above), close to the right hand side panel. The detector axis is horizontal, perpendicular to the driving direction, with the photo-multiplier to the left (towards the centre of the car), cf. Fig. AVI-4.
Detector height above surface: 80 cm

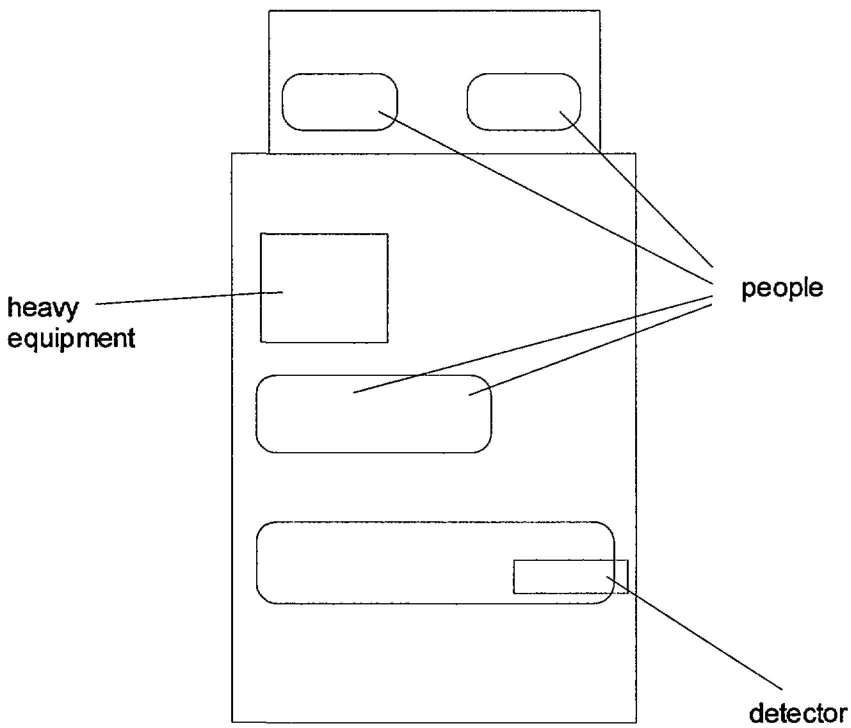


Figure AVI-4. Position of the detector in the Risø vehicle.

3. Spectral measurements

Portable measuring station designed and constructed by Risø National Laboratory
Multi-channel analyser: Nucleus PCAP board, operating in 256 channels mode.
No stabilisation employed.
Counting time = 10 sec.
Energy calibration: ^{40}K centroid at channel 146.
^{137}Cs window: Channels 58-64, incl.
Background subtraction: Channels 50 – 57, 65 – 82, incl.

4. Description of attenuation materials in the car

Shielding on the right hand side by car panel: 2 mm steel. Shielding to the left: 2 persons and equipment, covering approx. 90 degrees of the horizontal view, cf. Fig. AVI-4.

5. Typical distance to the edge of the road, tagging of data

Horizontal distance to edge of road: 1 m.
No tagging used.

6. Dose rate meters

None

7. Other information

In the following, the method of calibration of the Risø CGS instrument is described. The calibration factor from count rate to surface activity of ^{137}Cs is obtained by combining calibration measurements, using a known ^{137}Cs (662 keV) point source, with analytical methods.

For the RESUME 99 exercise, data were reported in units of *equivalent surface activity* of ^{137}Cs. This is defined as the constant activity of ^{137}Cs on an infinite plane surface that would give the same full-energy peak count rate as the actual amount of ^{137}Cs present in and on the ground. Because an infinite plane source may not be realised in experiments, the calibration factor is obtained only by combining calibration measurements with analytical or numerical estimates of how the photon fluence rate varies as the source extends to infinity.

The equivalent surface activity may be considerably smaller than the actual amount of deposited activity, since activity penetrated into the ground will be shielded from the detector. Even for fresh fallout, an irregular, non-plane surface (i.e., rough terrain) will give rise to partially shielding of the surface itself and the activity deposited on it, thereby reducing the equivalent surface activity. This shielding effect will be larger for ground based measurements (CGS) than for airborne measurements (AGS). For CGS, the shielding effect will be less for detectors mounted on top of a vehicle than for detectors mounted inside the vehicle.

The full-energy peak count rate may be written as

$$R_q(\vec{r}) = q\,p(E)\,\varepsilon(\theta,\phi)\frac{e^{-\mu r}}{4\pi r^2}, \tag{1}$$

where q is the activity of the source, $p(E)$ the emission probability of photons with energy E per disintegration, μ the linear attenuation coefficient in air excluding coherent scattering, and (r, θ, ϕ) the spherical co-ordinates of the point source, cf. Fig. AVI-5. Note, that with the definition of equivalent surface activity, not only primary photons but also coherently scattered photons should be included in estimating the photon fluence rate. The detector efficiency ε (the peak response) is that of the entire CGS system and includes the effects of attenuation in the vehicle. The detector efficiency may have a strong dependence on the direction of incidence of the photons, especially when the detector is mounted inside the vehicle.

For a uniform surface activity in the horizontal ground plane, σ (Bq/m^2), the count rate is obtained by integrating Eq. (1) over the surface elements,

$$R_\sigma = \int \rho\,d\rho\,d\phi\,\sigma\,p(E)\,\varepsilon(\theta,\phi)\frac{e^{-\mu r}}{4\pi r^2}, \tag{2}$$

where the variables have been defined in Fig. AVI-5. When the detector height z above the ground is small and the activity is located on the surface of the ground plane, contributions from large distances $r \gg z$, i.e., from large polar angles, $\theta \approx \pi/2$, will dominate the integral. Hence, we approximate the integral by

$$\begin{aligned} R_\sigma &\approx \int \rho\,d\rho\,d\phi\,\sigma\,p(E)\,\varepsilon(\frac{\pi}{2},\phi)\frac{e^{-\mu r}}{4\pi r^2} \\ &= \frac{\sigma}{4\pi}\,p(E)\int_z^\infty r\,dr\,\frac{e^{-\mu r}}{r^2}\int d\phi\,\varepsilon(\frac{\pi}{2},\phi) \\ &= \frac{\sigma}{4\pi}\,p(E)E_1(\mu z)\int d\phi\,\varepsilon(\frac{\pi}{2},\phi). \end{aligned} \tag{3}$$

In the second line, $r = \sqrt{\rho^2 + z^2}$ was substituted for ρ, and in the last expression, E_1 denotes the exponential integral of first order (Abramowitz and Stegun, 1970).

Combining Eqs. (1) and (3), the transformation from the full-energy peak count rate to equivalent surface activity is finally obtained,

$$\sigma \equiv k\,R_\sigma;$$

$$k = \frac{2}{<\varepsilon>\,E_1(\mu z)p(E)} = \frac{q}{<R_q>}\frac{e^{-\mu r}}{2\pi r^2 E_1(\mu z)}, \tag{4}$$

where the brackets denote average with respect to the azimutal angle, $<f> = \int \frac{d\phi}{2\pi} f$.

Calibration of the Risø CGS system was performed using a 1.9 MBq ^{137}Cs point source. With the equipment installed in a car, the point source was placed at a fixed distance of $r = 4$ m from the detector at positions to the left, right and back of the vehicle, and the average full-energy peak count rate was estimated at $<R_q> = 7.0\ s^{-1}$. With a detector height above the ground, $z = 0.8$ m, and a linear attenuation coefficient in air, $\mu = 9.1 \cdot 10^{-3}\ m^{-1}$, this gives a calibration factor of $k = 600$ Bq m^{-2} s.

During the exercise the system was mounted in a different vehicle. To account for the added shielding in the latter vehicle due to the presence of people and heavy equipment, cf. Fig. AVI-4, a reduction in the effective count rate by 15% was assumed, thereby increasing the calibration factor to $k = 700$ Bq m^{-2} s, the value employed for the exercise.

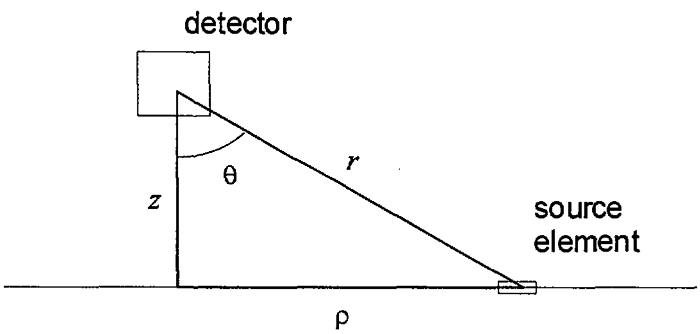


Figure AVI-5. Variables used in the text. The azimutal angle ϕ (the polar angle in the horizontal plane) is not shown in the figure.

8. References

M. Abramowitz and I.A. Stegun, eds., "Handbook of Mathematical Functions" (Dover, New York, 1970).

SYSTEM SEC1

(ORGANISATION: Radiation Physics institute, University of Lund)

1. Detector type

Detector type
NaI(Tl)
Detector size (D x L)
3x3 inch
Detector box
No encapsulation

2. Position of detector

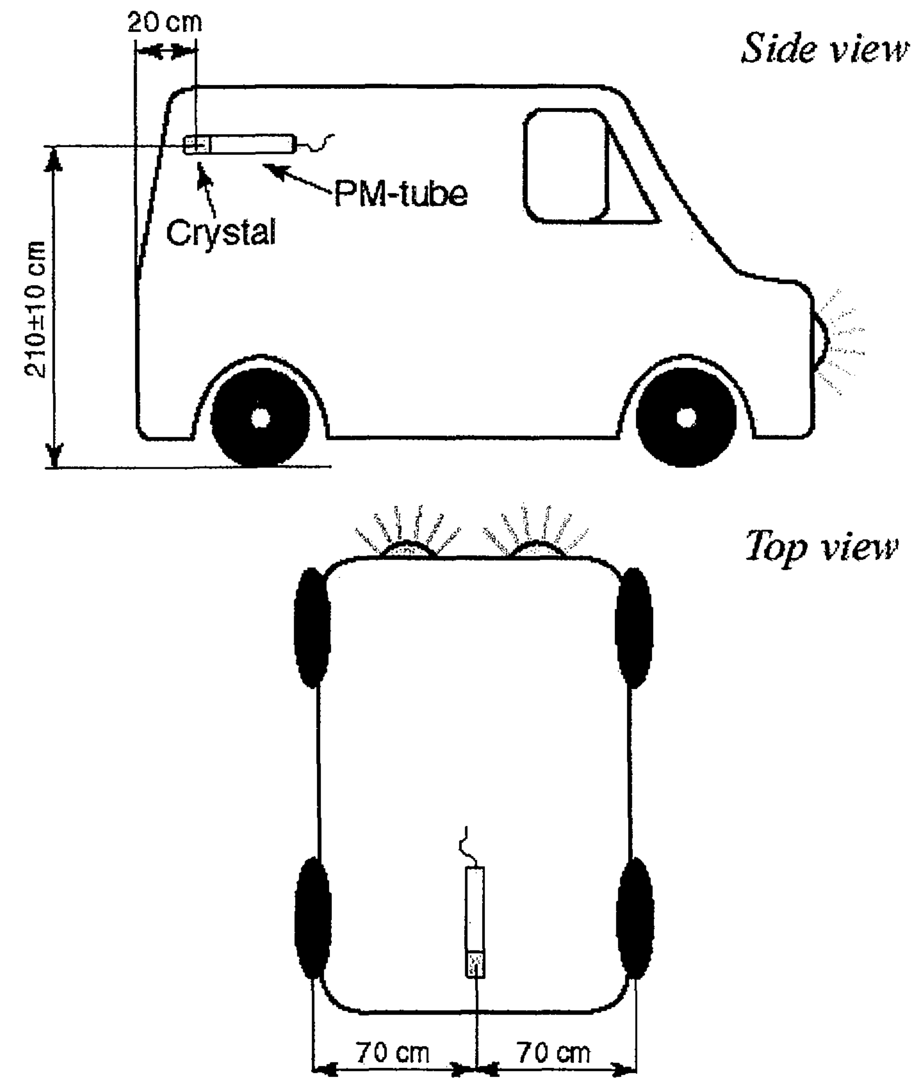


Figure AVI-6. Position of the detector in the Lund vehicle.

3. Spectral measurements

The system used was GammaDatas GDM40. Containing EG&G Ortec µACE™ MCA-card and EG&G Ortec ScintiPack™ photomultiplier base.

Number of channels

256

Counting time (s) per measurements

10

Centroid channels

^{137}Cs	58
^{40}K	131
^{208}Tl	223

Windows (From channel to channel)

^{137}Cs	45 - 67
K	110 - 137
U	140 - 168
Th	207 - 245

Means for getting net caesium counts

Following matrix we used to obtain the results

$$\begin{pmatrix} A_{Cs} & [Bq/m^2] \\ A_K & [Bq/kg] \\ A_{eU} & [eBq/kg] \\ A_{eTh} & [eBq/kg] \end{pmatrix} = \begin{pmatrix} 264.89 & -357.22 & -1166.9 & -183.12 \\ 3.8312 & 119.77 & -202.52 & 39.654 \\ 0.069231 & 0.082185 & 46.829 & -49.024 \\ -0.26242 & 0.54456 & -0.70912 & 45.052 \end{pmatrix} \begin{pmatrix} \dot{N}_{Cs} \\ \dot{N}_K \\ \dot{N}_{eU} \\ \dot{N}_{eTh} \end{pmatrix}$$

Origin of stripping factors

Measured by ourselves at SGU's calibration pads in Borlänge and the reference point in Regementsparken, Gävle for ^{137}Cs (see below for detailed description).

Principle of stabilisation

Not used

4. Description of attenuation materials in the car

The detector was mounted inside the car. The roof and part of the sides are made of plastic. No main shielding object is situated close to the detector.

5. Typical distance to the edge of the road, tagging of data

We tried to keep a distance of about 50 cm between the edge of the road and the right wheel pair. This results in a closest distance of 240 cm between the detector and the edge of the road.
No tagging was made.

6. Dose rate meters

None

7. Other information

Power supply

The car is equipped with a 220 V power supply, capable of producing 6kW. It takes fuel from the main petrol tank of the car and has it own fuel pump, *i.e.* the car engine does not have to be running for the power supply to work.

Communication

In field measurements data can be transferred by e-mail, using an ordinary laptop PC (Dell Latitude) and a mobile telephone (Ericsson 888) containing a GSM-modem. This where used successfully to e-mail the NKS-files from the mosaic measurements direct to the computer and communication centre.

More about the calibration

The calibration matrix above for U, Th, ^{40}K and ^{137}Cs were obtained as follows. Measurements for the three first nuclides were performed on SGU's (Geological Survey of Sweden) calibration pads in Borlänge, and for ^{137}Cs the Regementsparken in Gävle was used. The pads are circular with a radius of 5m. The car was placed so the detector was in the centre of the pads.

In the calibration of the matrix above it's assumed that the pads are of infinite lateral size (infinite slab source). Thus the data had to be corrected for the fact that the pads have a finite radius. Calculations were performed to estimate how much photon fluence was lost. Measurements were performed with the detector close to the pads, 0.1m, and on 1m height using a tripod (the best would have been to measure on the same height as the detector is placed in the car, *i.e.* 2m, but this was not practical). Instead MicroShield® was used to calculate the difference between 1m and 2m. The ratio of the fluence from the three nuclides on 2m and 0.1m height was taken as estimation of the loss of photons due to the finite size of the pads. Calculations were made for all three nuclides and the result was that the loss of fluence was similar. It was estimated that 45% was lost due to the finite size of the pads. This result entered the calibration calculations by scaling the actual nuclide contents of the pads with a factor 0.55. The approximation is then that a measurement 2m over a pad with activity concentration C gives the same result as a measurement on 2m height on an infinite slab source with activity concentration 0.55C.

In Regementsparken in Gävle the calibration point used in RESUME99 was used for the calibration. The assumption that the caesium was infinitely distributed in the lateral direction was made.

/ TH, CS

SYSTEM SEB1

(ORGANISATION: Swedish Defence Research Establishment, FOA)

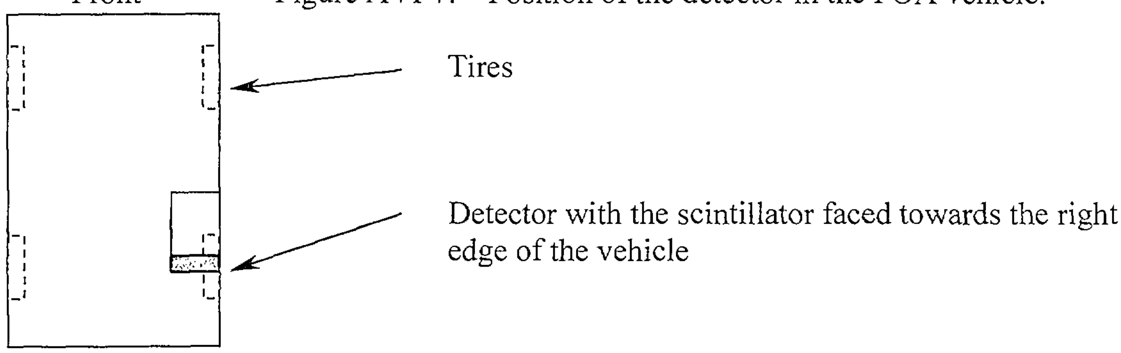
1. Detector type

3"x3" NaI(Tl) system, ***GDM40***, which includes a GPS system, electronics and a multichannel analyser (µAce, Ortec). The number of channels used was 256.

2. Position of detector

The system is mounted horizontally inside the vehicle within a frame, 135 cm above the ground and near the right side of the car. The detector is mounted perpendicular to the length axis of the car with the scintillator faced towards the right side of the car.

Figure AVI-7. Position of the detector in the FOA vehicle.



Dimensions:
Vehicle L x W: 500 x 170 cm.
Distance between rear edge and the detector centre axis: 90 cm.
Distance between the right side of the vehicle and the centre of the scintillator: 20 cm.

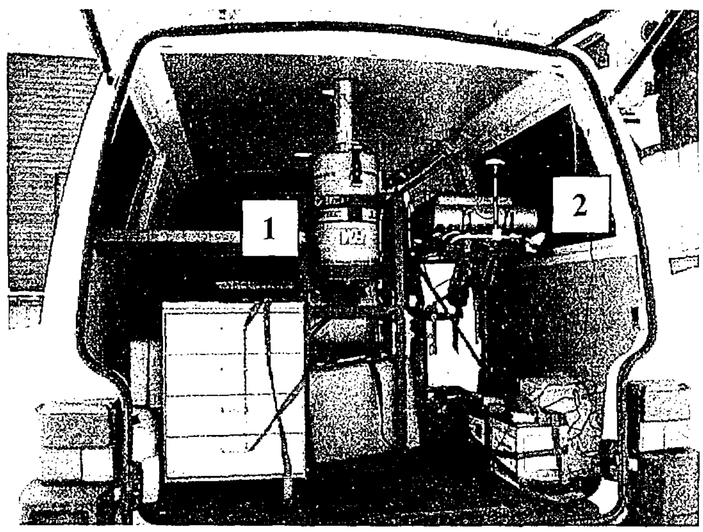


Figure AVI-8. The rear end of the measurement vehicle with the GDM 40 system [2] to the right and a HPGe (55 %) based system [1] to the left. The HPGe system has for the moment no possibilities to loop and store data automatically and was only used for stationary measurements during the exercise.

3. Spectral measurements

The detector system is calibrated using plates located at the airfield in Borlänge. These plates contains ^{232}Th, ^{238}U, ^{40}K separately. For ^{137}Cs, the known deposition at two sites, located near Gävle, were measured.
The counting time for each measurement was 10 seconds, and the centroid for the peaks were: channel 55 for ^{137}Cs, channel 125 for ^{40}K, channel 150 for ^{214}Bi and channel 225 for ^{208}Tl

The selected windows were:

^{137}Cs: from channel 50 to 60
^{40}K: from channel 115 to 135
^{214}Bi: from channel 140 to 160
^{208}Tl: from channel 210 to 240

Matrix for the activities:

$$\begin{pmatrix} A_K\,(Bq/kg) \\ A_{eU}\,(eBq/kg) \\ A_{eTh}\,(eBq/kg) \\ A_{Cs}\,(Bq/m^2) \end{pmatrix} = \begin{pmatrix} 20.131E+01 & -24.304E+01 & -29.333E+00 & 18.285E-01 \\ 31.256E-02 & 78.102E+00 & -59.106E+00 & 56.129E-03 \\ -56.874E-03 & -17.359E-01 & 68.744E+00 & -95.492E-03 \\ -20.504E-02 & -81.004E-02 & -60.768E-03 & 31.782E-02 \end{pmatrix} \begin{pmatrix} \dot{N}_K \\ \dot{N}_U \\ \dot{N}_{Th} \\ \dot{N}_{Cs} \end{pmatrix}$$

4. Description of attenuation materials in the car

The influence of the attenuation from the surrounded equipment is included in the calibration measurements.
The personnel were located in the front seats of the vehicle, approximately 3 metres from the detector system, during the measurements.

5. Typical distance to the edge of the road, tagging of data

Typical distance to the side edge of the road was 0.5 m. No tagging of data.

6. Dose rate meters

None

7. Other information

None

SYSTEM SEA1

(ORGANISATION: SSI)

1. Detector type

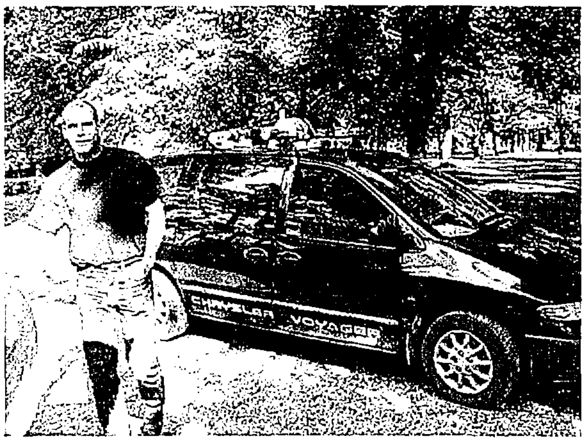
3"x 3" NaI(Tl) crystal.

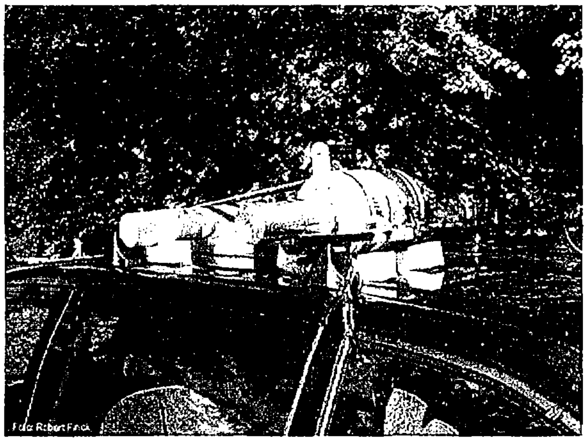
The crystal is encapsulated in a Al-tube with length 42 cm and a diameter of 10 cm. The thickness of the tube is 5 mm except for the front window, which is 1 mm.

2. Position of detector

The detector was placed on the roof of a Chrysler Voyager. On the same car was also mounted the HPGe system from SSI called SEA3.

The height of the crystal centre was 1,75 meters.
It was placed with the crystal pointing to the right side of the road and the PM-tube pointing towards the centre of the road.
The distance from the detector front to the side of the car was approximately 10 cm.
The distance from the detector to the back end of the car was approximately 1 meter.





Figures AVI-9 and AVI-10. Position of the detectors in the SSI vehicle.

3. Spectral measurements

Type of analyser:
SEA1 is a system called GDM 40 RPS. It consists of a 3"x 3" NaI(Tl) crystal, a EG&G Ortec µAce amplifier and MCA card, and a DGPS.

Number of channels:
256

Principle of stabilisation:
No stabilisation used. The gain was checked from time to time.

Counting time per measurement:
5 seconds

Centroid channels:

^{137}Cs	58
^{40}K	126
^{208}Tl	221

Windows from channel to channel:

Cs	53 - 63
K	116 - 138
U	135 - 162
Th	200 - 250

Matrix for the activities:

$$\begin{pmatrix} A_K\,(Bq/kg) \\ A_{eU}\,(eBq/kg) \\ A_{eTh}\,(eBq/kg) \\ A_{Cs}\,(kBq/m^2) \end{pmatrix} = \begin{pmatrix} 96.002 & -96.191 & -6.7104 & 0.0034594 \\ -0.029102 & 32.612 & -31.384 & 0.00048771 \\ 0.070182 & -0.89332 & 33.070 & 0.00046054 \\ -0.11538 & -0.62258 & 0.13258 & 0.2155 \end{pmatrix} \begin{pmatrix} \dot{N}_K \\ \dot{N}_U \\ \dot{N}_{Th} \\ \dot{N}_{Cs} \end{pmatrix}$$

To get the "correct" equivalent surface activity of ^{137}Cs the value obtained from the matrix has to be multiplied with the factor 1.8767. See under "Other information" for a detailed description of the calibration.

Origin of calibration:
Made by SSI at the calibration pads in Borlänge and at Regementsparken in Gävle.

4. Description of attenuation materials in the car

Steel roof. One person sitting under the crystal in the back seat of the car. Two people sitting in the front seat.

5. Typical distance to the edge of the road, tagging of data

1 meter.
Tagging of the road types was not made at the exercise, but we have the possibility.

6. Dose rate meters

None

7. Other information

The system is calibrated for natural radiation by measurements on the four calibration pads at Dala airport in Borlänge. For estimation of ^{137}Cs activities an additional measurement was made in Regementsparken in Gävle. An equivalent surface activity from ^{137}Cs of 19.33 kBq/m^2 was used for this measurement. This value was obtained by measurement with a 50 % EG&G Ortec HPGe detector. All calibration measurements with the NaI(Tl) detector were made in free air with the detector on a height of 20 cm above the ground. The activities are obtained from the matrix shown above. To calibrate the car system, measurements were made in Regementsparken with the detector placed in the car. A shielding factor was achieved through this measurement, and to get the "correct" equivalent surface activity the value obtained from the matrix is multiplied with 1.8767. Similar factors for the natural isotopes have not been developed which implements that the natural activities from system SEA is not correct.

Except for calculation of the equivalent surface activity of ^{137}Cs and the activities of the three natural radioactive isotopes, the system is calibrated for measurement of air Kerma rate. This calibration was made according to the SDI method. Because the crystal is small a function has been added that takes into account the amount of radiation passing through the crystal without interacting as well as the radiation that interacts in the crystal housing. For radiation fields of "normal" distribution this calibration tends to give results within 15 % of the true value.
As a complement to this calibration a function that separates natural and manmade dose rate has been implemented. The manmade dose rate is achieved by subtracting multiples of the three natural unit spectra from the total spectra. This method has to be further developed and tested in more extreme geometric environments such as large asphalt roads and in city centres.

As it is right now SSI doesn't have a car dedicated for measurements of this kind, which implies that a car has to be rented whenever field gamma spectrometry is being performed. There are both advantages and disadvantages with a system like this. In the case of contamination of the vehicle it is easier with a detachable system that quickly can be put in a new rental car (under assumption that the system is mounted inside the car and not contaminated itself). The problem with a rental car is that new calibrations have to be made for every different kind of car that is used. With a dedicated car the calibration can be made more precise which implies more exact measurements, the problems with power supply can be solved better and equipment can be installed in a better way. For RESUME 99 the same type of car (a Chrysler Voyager) was rented many times to be able to make calibrations and optimise installation of equipment prior to the exercise. Though, it was decided after the exercise that the type of car will be changed in the future because of the large shielding factor and other inadequate qualities of the Chrysler. How this is solved in the future remains to be seen.

SYSTEM SEA3

(ORGANISATION: SSI)

1. Detector type

72,1 % HPGe (EG&G Ortec mod. GEM-70200)

The diameter of the crystal is 74,9 mm and the length is 72,6 mm.

The detector encapsulation is 1 mm Aluminium and there is a 700 µm layer of inactive Germanium.

2. Position of detector

The detector was placed on the roof of a Chrysler Voyager. On the same car was also mounted the NaI system from SSI called SEA1, cf. Figs. AVI-9, AVI-10.

The height of the crystal centre was 1,8 meters.
It was placed with the crystal pointing to the right side of the road and the dewar pointing towards the centre of the road.
The distance from the detector front to the side of the car was approximately 10 cm.
The distance from the detector to the back end of the car was approximately 1.5 meter.

3. Spectral measurements

Type of analyser:
EG&G Ortec DART MCA. DGPS.

Number of channels:
2048

Principle of stabilisation:
No stabilisation used. The gain was checked from time to time and proved to be very stable.

Counting time per measurement:
10 seconds.

Centroid channels:
^{137}Cs 440

Windows from channel to channel:
Cs 435 – 445

Means for getting net Caesium counts:
See "Other information" below.

Origin of calibration:
Made by SSI at Regementsparken in Gävle.

4. Description of attenuation materials in the car

Steel roof. One person sitting under the crystal in the back seat of the car. Two persons sitting in the front seat.

5. Typical distance to the edge of the road, tagging of data

1 meter.

No tagging of data for different road types was made.

6. Dose rate meters

None

7. Other information

The development of a mobile HPGe system at SSI began during 1999 and the detector used for this purpose during the exercise was received only one month before the exercise. Therefore an exact calibration of the system couldn't be made, but will hopefully be made during the year 2000. The calibration for the exercise was made through a measurement in Regementsparken in Gävle. An equivalent surface activity from ^{137}Cs of 19.33 kBq/m^2 was assumed. That value origin from an earlier measurement with a calibrated HPGe detector. The background in the ROI (channel 435 – 445) was estimated to 1.7 counts per second. The "net" caesium counts was then multiplied with the calibration factor 664 to get the equivalent surface activity.

The experiences from RESUME 99 with this system were good. The ^{137}Cs peak was very stable and the DGPS and the Dart showed good qualities. Hopefully there will be time for further development and testing of the HPGe system during the year 2000.

During the exercise a temporary developed software was used with this system. SSI is slowly developing a new software for mobile measurements. The idea is to create an analysis module that can be common for many different systems and then there will be system specific modules for communication with the MCA. In this way one software can be used for many different detector systems. The analysis part will when finished contain methods for real time processing of results using GIS tools.

SYSTEM FIA3

(ORGANISATION: STUK)

1. Detector type

35 % HPGe detector with the dimensions
The diameter is 59,3 mm and the length is 59,7 mm.

The encapsulation is a Aluminium layer which is 1,27 mm.
There is a 0,7 mm thick layer of inactive Germanium.

2. Position of detector

Placement of equipment in the car:

2. Human beings, driver + 2 specialists
3. Computers
4. HPGe, hog 170 cm, detector facing up with devar below
13. PIC, hog 130 cm
14 GM-tube, hog 90 cm

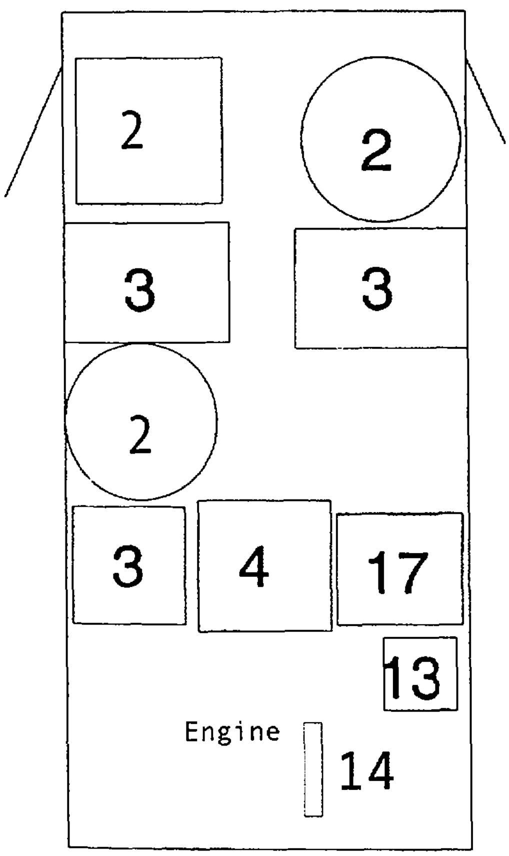


Figure AVI-11. Position of the detectors in the STUK vehicle.

3. Spectral measurements

Measurement equipment

1. HPGe Ortec 35% spectrometer, Nomad MCA. Measurement time 10 s.
2. PIC Reuter-Stokes RSS 112, reading every 30 s.
3. G-M RADOS RD-102L, reading every 30 s.
4. GPS (non-differential), serving all 3 measurement systems.

4. Description of attenuation materials in the car

The roof of the car is made of fibreglass.
Some additional equipment is situated in the rear of the car (Multichannel analyser, UPS etc.).
The car engine is in the rear and therefore immediately below the GM and partly below the PIC.

5. Typical distance to the edge of the road, tagging of data

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6. Dose rate meters

---

7. Other information

The calibration for ^{137}Cs is made by moving a point source around the car. In this way the shielding is taken into account.

SYSTEM DKC3 ***(in situ)***

(ORGANISATION: DTU)

Here is a description of the calibration of the system for equivalent surface activity and a method for determining the depth of the source in the soil that implies calculation of the total inventory of ^{137}Cs.

Calibration of the Danish HPGe detector for measuring Equivalent Surface Concentration (ESC) of caesium-137.

Before the RESUME 99 exercise the detector had not been calibrated for measuring ESC of caesium-137. It was decided to use the Ytterharnäs reference point for a co-calibration between the Danish CGS detector and the Danish HPGe detector. Further, by knowing the caesium-137 concentration depth profile at the Ytterharnäs site it was possible independently to determine the ESC at the reference point. The Danish CGS measurements gave an ESC of close to 75 kBq/m^2 at Ytterharnäs. A cursory examination of the depth profiles and the total activity in the samples from the Ytterharnäs site during the exercise gave an ESC very close to 75 kBq/m^2. A more detailed investigation after the exercise gave an ESC of 67 kBq/m^2, however, with a possible error of +/- 7 kBq/m^2. Therefore, an ESC of 75 kBq/m^2 at the Ytterharnäs site is used for co-calibrating the HPGe detector with the Danish CGS. The sensitivity is 0.756 cps/kBq/m^2 (net counts for the 662 keV peak with subtraction of spectral background). All measurements were performed with the detector axis horizontal.

Coarse calibration of the Danish HPGe detector for measuring depth of caesium-137 in the soil – and for a calculation of the inventory of caesium-137 (kBq/m^2).

The ratio between the (net) count rate of (a selected part of) the Compton continuum and the full energy peak (net) count rate for caesium-137 is dependent on the (mass) depth of the source in the soil. This ratio - the Compton to peak ratio - increases with increasing depth of burial.

The RESUME 99 *in-situ* sites included a range of the Compton to peak ratios - from 0.08 to 0.16. The lowermost ratio (0.08) was found at Utvalsnäs where the heather has kept the caesium-137 very close to the surface. Therefore, the measured Equivalent Surface Concentration (ESC) of 82 kBq/m^2 here is assumed to be equal to the total inventory. The highest Compton to peak ratio was observed at Hillsjöstrand where ploughing probably had mixed the caesium-137 within the uppermost 20-30 cm. The measured ESC was 9.5 kBq/m^2. Based on different assumptions on the (mass) thickness of the mixed layer one may calculate that the ratio between the inventory (actual amount in the ground) and the ESC is between 5.6 and 9.8 i.e. the inventory is between 53 kBq/m^2 and 93 kBq/m^2 . (The SGU AGS map for the area around the *in-situ* site at Hillsjöstrand shows an ESC of about 53 kBq/m^2.) This ratio is termed the Depth Factor.

Assuming a linear relation between the Compton to Peak ratio and the Depth Factor one calculates the total inventories listed in the table below.
Multiple measurements at some of the localities indicate a variation (standard error) of about 10 kBq/m^2 for the calculated inventories.

Locality	ESC (kBq/m^2)	Compton to peak*	Depth factor	Inventory (kBq/m^2)	Samples** (kBq/m^2)
Eskön	87.3	0.0836	1.159	101	
Ytterharnäs	75.0	0.1003	2.52	189	195
Hemlingby	31.3	0.1113	3.417	107	
Hillsjöstrand	9.5	0.1581	7.243	69	
Hyttön	37.8	0.1090	3.236	123	
Oslättfors	16.1	0.1156	3.772	61	
Regementsp.	26.6	0.1100	3.315	88	82
Storhagen	66.5	0.0986	2.381	158	
Utvalnäs	81.9	0.0816	1.00	82	
Älvkarleö	13.4	0.1170	3.884	52	45

Table AVI-1. Calculations of the depth factors and the total inventories for the measurements in RESUME 99.

*) For the Danish HPGe detector system the 662 keV peak is placed at channel No. 425. The (net) Compton count rate is based on the counts in the channels from No. 400 to No. 420 from which is subtracted the counts of the channels from No. 435 to No. 455.

**) Samples are average inventories based on 13 -14 samples at each locality measured by FOA.

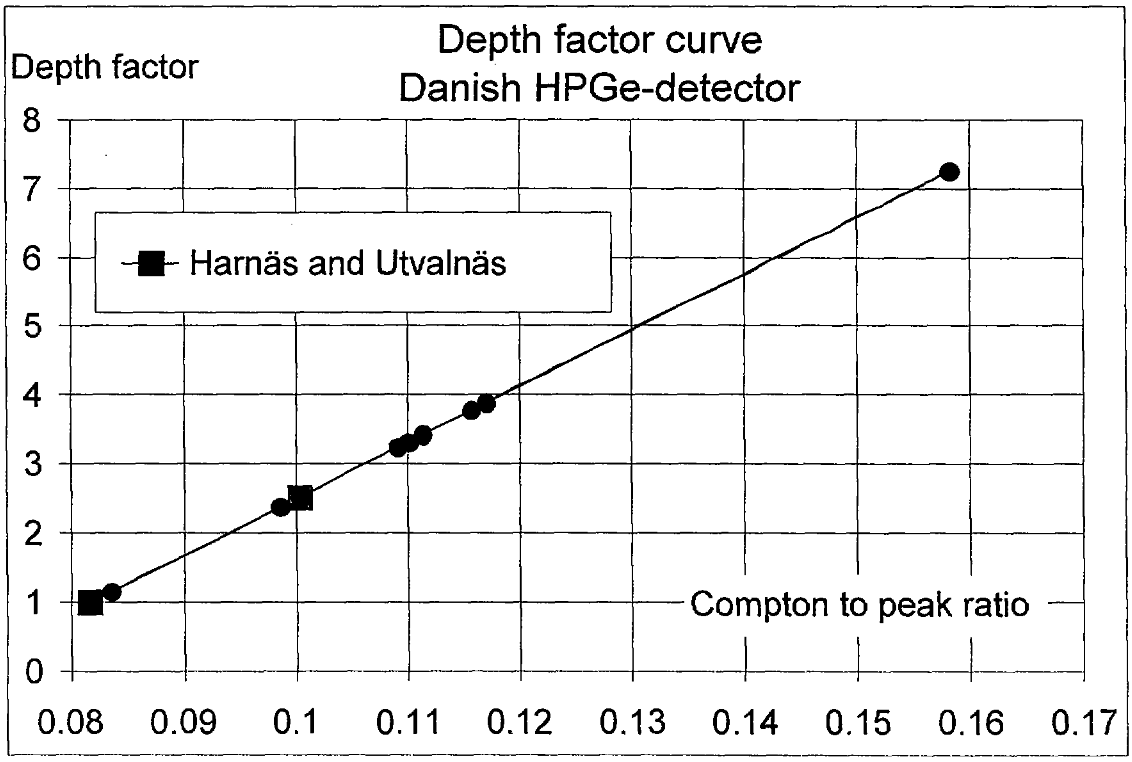

Figure AVI-12. The depth factor curve for the Danish HPGe detector.

/ HKA, KU