Technical Report

TR-98-20

The biosphere at Aberg, Beberg and Ceberg

– a description based on literature concerning climate, physical geography, ecology, land use and environment

Tobias Lindborg, Regina Schüldt

NaturRådet

December 1998

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

The biosphere at Aberg, Beberg and Ceberg

– a description based on literature concerning climate, physical geography, ecology, land use and environment

Tobias Lindborg, Regina Schüldt

NaturRådet

December 1998

Keywords: biosphere, deep repository, nuclide disposal, climate, physical geography, ecology, land use, environment.

Information on SKB technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01), 1985 (TR 85-20), 1986 (TR 86-31), 1987 (TR 87-33), 1988 (TR 88-32), 1989 (TR 89-40), 1990 (TR 90-46), 1991 (TR 91-64), 1992 (TR 92-46), 1993 (TR 93-34), 1994 (TR 94-33), 1995 (TR 95-37) and 1996 (TR 96-25) is available through SKB.

Abstract

The current safety analysis, SR 97, compares three sites in Sweden. This report compares the biosphere for the three areas, Äspö, Finnsjön and Gideå, which have been studied to describe the conditions at three hypothetical sites, Aberg, Beberg and Ceberg. Data from these sites will be used in analysis and to make realistic models of the biosphere development. The report is based on a literature study considering climate, physical geography, vegetation, ecology, land use, environment and population. Data from each site is presented separately and is compared for present conditions and from a future perspective.

The locations of the sites along the south-north gradient influences the climate, temperature, vegetation period and precipitation. Aberg has a more humid climate with a longer vegetation period, a higher mean temperature, a higher diversity and a faster turn-over time than Beberg and Ceberg. There is also a difference in land use, where Beberg has the greatest potential for agriculture, because of the soil types and topography. Abergs location in the archipelago makes it very exposed to shore level displacement, compared to Beberg and Ceberg with a higher elevation. Highest population density is found in Aberg, but Beberg has the highest potential for increase.

Simplified models made from present and future biosphere conditions, show that the sites have different prerequisite concerning biosphere factors. The parameters that may affect the ecosystems and the biosphere over time are more likely to change in Aberg due to position above sea level, climate, sea level displacement and land use. Biosphere changes are however in a long time perspective hard to predict. The models used in this report are a suggestion on how to evaluate biological data in a more thorough study.

Sammanfattning

I nuvarande säkerhetsanalys, SR 97, jämförs tre olika platser i Sverige. Denna rapport presenterar data från de tre befintliga områdena, Äspö, Finnsjön och Gideå, för att beskriva biosfären i de tre hypotetiska områdena, Aberg, Beberg och Ceberg. Med hjälp av den sammanställda informationen kan nuvarande förutsättningar analyseras samt framtidsmodeller av biosfärsutvecklingen göras i samband med kommande säkerhetsanalyser. Rapporten är en litteraturstudie som behandlar klimat, landformer, vegetation, ekologi, markanvändning, miljö samt befolkning. Data från respektive område presenteras var för sig och jämförs utifrån nuvarande förhållanden samt ur ett framtida perspektiv.

Områdenas olika geografiska läge ger skilda förutsättningar vad gäller klimat, temperatur, vegetationsperioder och nederbörd. Aberg har ett mildare klimat med längre vegetationsperioder, högre diversitet och snabbare omloppstider i ekosystemen än Beberg och Ceberg. Det finns en påtaglig skillnad i markanvändning, där Beberg har störst potential för jordbruk på grund av jordmån och topografi. Abergs läge som en del av Smålands skärgård ger speciella förutsättningar för vattendrag, vattentransport och strandlinjeförskjutningar, medan Beberg och Ceberg är belägna högre över havet, vilket påverkar avrinningen. På grund av närheten till större tätorter är Beberg ett område med potential för befolkningsökning.

Genom att ställa upp enkla modeller av nuvarande och sannolika framtida förhållanden finner man att olika förutsättningar råder för områdena beroende på vilka miljöfaktorer som beaktas. De parametrar som kan påverka ekosystem och biosfär har större sannolikhet att förändras snabbt i Aberg på grund av position över havet, klimat, landhöjning och markanvändning. I ett längre tidsperspektiv är dock biosfärsförändringar svåra att förutsäga. Modellerna som framtagits för att bedöma områdena är ett första steg till tänkbara behandlingsmodeller för biologiska data vid säkerhetsanalyser.

Contents

Summary

The hypothetical study sites Aberg, Beberg and Ceberg are different in many ways. Beberg and Ceberg are the most similar, while Aberg has several parameters that separates it from the other two. The most obvious pattern is the gradual change from the south to the north, which is seen in climate zones, temperature, vegetation zones and vegetation periods. Models for evaluating biosphere changes in time have been made from presented data and are a suggestion on how to evaluate biological data.

Climate

Beberg and Ceberg are located in the same climate zone, 5-10 km from the coast and Aberg is situated in the archipelago and is a part of the coastline it self. An equalising effect on the climate made by the Baltic sea, gives Aberg a more humid climate. The climate also controls the vegetation period, which is about one month longer in Aberg than in Ceberg. The mean annual temperature follow the north-south gradient and differs a few degrees between the sites. The greatest difference in temperature is during winter, when the temperature in Ceberg drops several degrees below 0°C. Ceberg has the highest mean precipitation and the lowest evapotranspiration of the three sites. The annual run off is also highest in Ceberg region due to the low evapotranspiration, connected to the relatively cold climate. Aberg is located in the rain-shade of the south Swedish highlands, which has a major effect on the precipitation. The sites follow the same inter annual precipitation trend, with the highest values during late summer.

Physical geography

The landscape is an important factor for the site characteristics. An area with altering altitude has a high potential for many local habitats together with high diversity potential. Aberg and Ceberg are located in a landscape with great changes in altitude, but since Aberg is located just by the coast line the change in altitude is less obvious. Beberg is situated on the peneplain characterised by a low topographic relief. The soil-units varies, but Beberg has the most fertile soil comprising plenty of fine clay and organic matter. In Ceberg the soil is more acid with less growing potential. The soils in Ceberg and the thin soils in Aberg have a lower buffer capacity than Beberg.

The observed land uplift is greatest in Ceberg, but is of little importance because of the high position above sea level. On the contrary the land uplift in Aberg is low but is of major importance because of its position near the shore-level of the Baltic sea. A shore level displacement may change the conditions rapidly e.g. more land becomes available or present land becomes sea.

Flora & Fauna

A vegetation zone is a response to the past and present climate conditions. The vegetation zones and the climate zones at Aberg, Beberg and Ceberg do not coincide exactly, because of factors like soil, topography, water exchange and historical biogeography.

Aberg and Beberg are located in the same vegetation zone but not in the same climate zone. Aberg and Beberg belong the Boreonemoral zone, while Ceberg is more connected to the Taiga, north of Limes Norrlandicus. Even though Beberg and Ceberg are not directly situated at the coast, a coastal effect is seen on the vegetation.

Forest is the dominating land class at all three sites. Agriculture is also a major land class in Beberg, mostly due to the fine clay soils. Pine is the commonest tree and is most common in Aberg, while it is out-competed by spruce in the more boreal zone. None of the sites contain any nature reserves, but they all have classed areas of biological interest within the sites. Aberg is situated in an area of national importance for recreation and nature.

The environment in Aberg is more suitable for high diversity animal life than Beberg and Ceberg, because Aberg has a warmer climate and more local habitats e.g. marine environment, ancient cultural landscape and forest. Beberg has warmer climate and more habitats than Ceberg.

Running water and lakes

Only a few lakes are located within the study sites, but both Beberg and Ceberg have plenty of lakes in their regions. Since Aberg is located in an archipelago, a major part of the study site area is water. Beberg is surrounded by a wetland area, which drains the site towards the coast and Ceberg is influenced by two major rivers. The only site with eutrophic lakes is Beberg, mostly due to nutrient leakage from the cultivated areas.

Land use

The dominating land use at the sites is forestry. Beberg has the highest annual growth, the best site quality and the fastest rotation period. The low site quality in Aberg is probably due to the thin soil layers and high amount of impediment. The site with most arable land is Beberg. Aberg is an old agricultural area, but most of the land are now used in forestry. Some of the pasture land are still in use and Aberg has the highest amount of pasture land and meat production per km^2 of the sites.

Recreation

The amount of persons hunting in the study site areas is quite similar. Beberg has the highest numbers for shot moose. Sport-fishing is an important recreation in Ceberg and keep many local citizen and tourist occupied. The amount of fishing in Aberg is difficult to estimate, since the sport-fishing in the sea is not regulated. The best offers for recreation is found in Aberg. The archipelago is an unusually environment seen in a global perspective and has a high tourist potential.

Environmental pollution

There are no significant differences in the amount of environmental pollutions between the sites. The Ceberg region has lower deposits of sulphur and nitrogen and also a minor part of agriculture, which decreases the acidification in the area compared to Aberg and Beberg. On the other hand has Ceberg a considerable forest industry that causes acidification in lakes and running water. Acid pollutants from forestry also occur in Beberg, but is inhibited by the buffer effect from the calcareous soils. There are still high amounts of nuclides from the Chernobyl accident in Beberg and Ceberg, but the fallout in Aberg was negligible and show no detectable levels today.

Population

Ceberg has the highest number of inhabitants, but the number of citizen per km^2 is highest at Aberg. The region of Ceberg has a decreasing population trend, while the populations at Aberg and Beberg are slightly increasing. The location close to urban areas is favourable for Beberg, while Aberg has an increase in summer visitors.

Comparative biosphere table

Table 0-1. Comparative biosphere table of hypothetical ABC-berg. All data are representing the study site (see 1.2.1), if not marked differently. For further details see text.

Parameter	Aberg	Beberg	Ceberg
Climate	Warm Temperate	Snow climate	Snow climate
Climate Köppen System	Cfb	Dfb	Dfb
Vegetation period Days/year	170–190	160–180	160
Distance to coast (km) (from study site edge	0	10	5
Annual adjusted precipitation (mm)	675	670	765 (+/–25)
Monthly highest precipitation (mm)	60–70	77	80–90 (region)
Annual runoff (mm)	150–200	240	345
Annual evaporation (mm)	490	430	410
Mean annual temperature (°C) (region)	7.0	5.5	2.7
Average snow depth (cm)	10	20	30
Average snow cover (n) days	91	110	160
Proportion snow of annual precipitation (%)	18	35	33
Ground frost depth (cm)	30	50	>100
Landscape	Fissure valley	Peneplain	Peneplain/ Undulating Hilly land
Degree of exposed rock	high	medium-high	medium-high
Most common soil unit	Lithosols	Luvi-Cambisols	Podzols
Land uplift/year (mm)	2	6	8
Position above sea level (m)	0–15	20–44	80–130
Vegetation zone	Boreonemoral	Boreonemoral	Southern boreal
Most common land class (% in region)	forest (70)	forest (50)	forest (75)
Commonest tree (%)	pine (72)	pine (60)	pine (45)
Nature reserves (n in region)	1	1	0

Other areas of biological interest (n in region)	4	6	6
Nature reserves (n at study site)	0	0	0
Other areas of biological interest (n at study site)	1	2	1
Terrestrial vertebrates. reptile/bird/mammal (n/region)	19/191/47	13/190/47	10/181/40
Breeding birds species/region	159	185	163
Lakes within the region/ study site (n)	7/1	8/0	12/3
Most common lake type within the region	Oligotrophic	Eutrophic	Oligotrophic
Drilled wells (n)	3	5	2
Distance to closest public water catchment (km)	10	3	3
Forestry, annual growth (m^3 sk/ha)	3.9	6	4 (region)
Forestry, site quality (region) (m^3 sk/ha/year)	7–8	7–8	3–5
Forestry, growing stock/ha (m^3 sk)	100	85 (region)	110 (region)
Rotation period (years)	100	85	90
Forest distribution pine/spruce/deciduous	72/7/21	60/30/10	45/40/15
Farmers (n/km^2)	0.3	0.2	0.2
Milk production/year (l/km^2)	0	4800	4800
Meat prod./year (cattle) (kg/km^2)	312	255	161
Cultivated land municipality (%)	5.2	9.3	3.4
Hunters within the study site (n/km2)	0.8	0.7	0.2
Moose shot/year (n/km^2)	0.5	0.8	0.3
Moose meat/year (kg/km^2)	65	104	39
Fishing licences (n) (region) season/week/day	no data	90/0/205	750/50/50
Human population (n/km^2)	1.7	1.0	0.9

1 Background

Several study sites have been investigated in the Swedish programme for disposal of spent nuclear fuel. For all of these sites geological investigations have been carried out in more or less extensive programmes of surface geophysical surveys and geological mapping.

Before the siting process reaches the stage where two candidates are selected for site investigations, a comprehensive report on long term safety of deep repositories and on the performance assessment methods will be presented (SR 97). In the analysis three hypothetical sites, Aberg, Beberg and Ceberg, will be the objects for modelling. To achieve realistic models, the analysis will be made from three existing areas: Äspö (Oskarshamn municipality), Finnsjön (Tierp municipality) and Gideå (Örnsköldsvik municipality). The study sites have been selected because of the previous geological investigations that have been carried out and their differences in position and environment.

One part of the performance assessment is to provide site-specific data concerning the biosphere, which includes living organisms and their environment, e.g. soil, water flow, lakes, vegetation, flora and fauna, human activities. To make realistic models it is necessary that all types of information, that could improve the quality of the performance assessment, is presented. Since investigating biosphere conditions also map out human behaviour in the past, biosphere information can turn out to be an important factor, when it comes to predicting the future. There are other studies (Bergström & Nordlinder, in press; Nordlinder & Bergström, in press) which handles the doses obtained in the three areas. The biosphere description in Nordlinder & Bergström (in press) is only based on maps. The quarternary geology is presented elsewhere.

1.1 Introduction

1.1.1 Biosphere

The biosphere is defined in slightly different ways, according to the source (e.g. The Biosphere, 1970; Campbell, 1993).

In this report and in the performance assessment (SR 97) the biosphere has been defined as the surface ecosystem above the bedrock. That means that it includes the quarternary deposits, surface waters, groundwaters in quarternary deposits, humans and other biota as well as the surface hydrologic cycle and climate.

1.1.2 Sweden

Over a long time period the environment of Sweden has changed continuously, mainly because of changes in the climate. Except for mankind's influence on the environment after the latest glacial, the Quaternary period is characterised by altering glacials and interglacials. After every deglaciation species from southern Europe had spread northwards again, in different combinations and quantities during various interglacials

(Gustafsson & Ahlén, 1996). The composition of the forest has changed noticeably in the past 2000 years, mainly because of human activities. There are still traces of changes due to natural processes such as succession.

Sweden is located within two climate groups, mid-latitude climates and high-latitude climates. Moist continental climate ranges from south of Sweden to Gävle and changes northwards into Boreal forest climate (Strahler & Strahler, 1976). In the north-west part of Sweden there is an Alpine zone with alpine vegetation.

Winds between south and west are dominant and bring warm air from the Gulf Stream. These winds give humid climate in many places, all along the coastline and also in western Jämtland and Lappland (Raab & Vedin, 1995).

Mean annual precipitation in Sweden is 500–1000 mm (Strahler & Strahler, 1976) and falls as snow during winter, less frequent in the southern parts. Sweden covers an area of about 450 000 km^2 and the landscape is dominated by forest (mostly coniferous), which covers more than half of its area. Wetlands are also common, comprising one fifth of the total area.

About 3% of the known species in the world can be found in Sweden (Gustafsson & Ahlén, 1996) and most of them are found in the southern part, i.e., south of "Limes Norrlandicus".

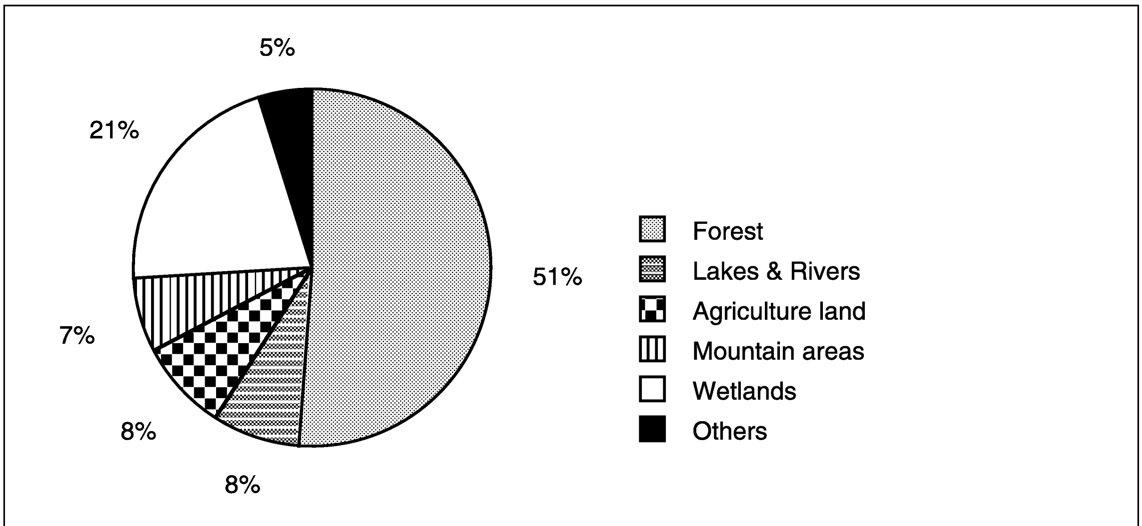

Figure 1-1. *Land class distribution in Sweden (data from Gustafsson & Ahlén, 1996).*

1.2 Material and methods

Data presented in this report is obtained from published literature. No field studies have been made except a one-day visit in each area.

1.2.1 The sites

The three hypothetical sites, Aberg, Beberg and Ceberg are demarcated in two zones, one inner area – the study site – and one outer area – the region (see map under each headline). The three study site areas are slightly different demarcated in this report than in previous studies (Gustafsson et al. 1987; Ahlbom et al. 1991; Stanfors et al. 1997). The Äspö/Aberg study site (inner area) is ca. 12 km^2, the Finnsjön/Beberg study site (inner area) is ca. 21 km^2 and the Gideå/Ceberg study site (inner area) ca. 32 km^2. The outer areas (regions) for Aberg, Beberg and Ceberg are around of 100 km^2. The sizes of the study site areas and the further description of the regions around the sites, are made regarding to the complex biosphere construction of food webs, dispersal abilities, the water discharge areas and other vectors that circulates biological material. If an object is situated for example downstream the study site and is of major importance it may be included in the outer area (region) even though it is located outside the 100 km^2. In order to describe the study sites in relation to each other and the rest of Sweden, a comparison with the region, the closest parish and the county, are made in the data from all the three sites.

1.2.2 Methods

All information, if possible, is stated in value/km^2 in order to facilitate the comparison between the hypothetical sites. Most of the information about the biosphere in the description of Aberg, Beberg and Ceberg, is presented in average values or in terms of vegetation zones, ecosystems and biotops.

Comments concerning estimation of ecological value and information reliability are made under each headline throughout the report. A glossary is available for specific biological terms and names. The Latin name of plant- and animal species are noted only the first time they appear in each chapter.

Calculations, elucidation and comments

Precipitation

An important error in point measurement of precipitation is due to the wind. In the summer days with showers, error due to evaporation from the gauge is large. The loss is estimated to be some 1.5 mm/month (Gottschalk, 1980). All types of error cause precipitation to be underestimated, why a correction of +18% has been made (Svensson, 1987).

Soils

Definition of soil units according to Nordiska Ministerrådet (1984):
Histosols – mostly peat dominating by organic matter. The O-horizon is more than 40 cm and contains of 20–30% organic matter.
Lithosols – common on solid ground and outcrops of bedrock. The soil profile is less than 10 cm deep.
Cambisols – brown soil, rich in mull. Contains a high degree of weathering material. Fe contents gives the soil a yellow/red colour.
Podzols – the B-horizon rich with organic matter and Fe/Al compounds, while the upper layers (A-horizon) are poor with Fe/Al. The podzols are formed during cold and moist conditions.
Luvisols – acid brown soils with high contents of clay in the soil layers (>35%).

Soil definition according to Ljungberg & Lönnbom (1993):
Soft soils – include sand, silty and sandy till and soft moraine – clay <15%,

Stiff soils – include all types of clay, clay mud and clay moraine – clay <15%,
Organic soils – include >20% organic matter, e.g. plain organic soils and organic soils with some content of minerals.

Areas of biological interest

Assessments of conservation values are based on biological and to some extent cultural criteria and the sites are often divided into three classes (SNV, 1975):

class I: highest value
class II: very high value
class III: high value

Forest

Site quality is an expression of the fertility of the forest land, which is influenced by the sites geographical location, climate, soil, humidity and species. This is then translated into a quality classification expressed as wood production (m^3) per hectare and year during the rotation period (100 years for pine and spruce, 50 years for birch) (Nilsson, 1990).

Domestic animals

Calculation for meat and milk production. Data for slaughtering-weight and milk production is from Per Andersson SLU, pers. com. The calculations have been made out of templates for cattle breeding in general and are not specific for the hypothetical regions.

One dairy cow produces 8000 l milk per year and 100 kg meat/year.
The meat production from the offspring (male) of the dairy cow is:
330 kg x 0.75 x 0.5 (M) = 124 kg/year

Cattle for meat production
The calculations are made from the offspring.
0.3 (F) x 0.5 (M) = 300 kg x 2 = 240 kg meat/cow/year
One sheep (ewe) produces 30 kg meat/year

One pig (sow) give birth to ca. 18 suckling-pigs.
65 kg (sow) x 18 x 80 kg = 1505 kg meat/sow/year
Slaughtering pig gives ca. 80 kg meat/year

Hunting

Produced meat from wild game hunting (moose & roe deer).
An average moose (adults and juveniles) produce 130 kg/individual
One roe deer produce ca. 10 kg
Data from H. von Essen, Svenska Jägareförbundet, pers.com.

2 Aberg

2.1 Study site

2.1.1 Location

The hypothetical Aberg site is located in the coastal area of Kalmar county, Oskarshamn municipality, Misterhult parish; position 57° 26' N, 16° 40' E. The major settlement in the region is Oskarshamn, 23 km south-west of the site. The study site is a part of Misterhult archipelago in the Baltic sea. Map, "ekonomisk karta över Sverige" 6H 3a Ävrö.

Kalmar county	11170 km^2
Oskarshamn municipality	1047 km^2
Misterhult parish	405 km^2
Aberg study site	11 km^2

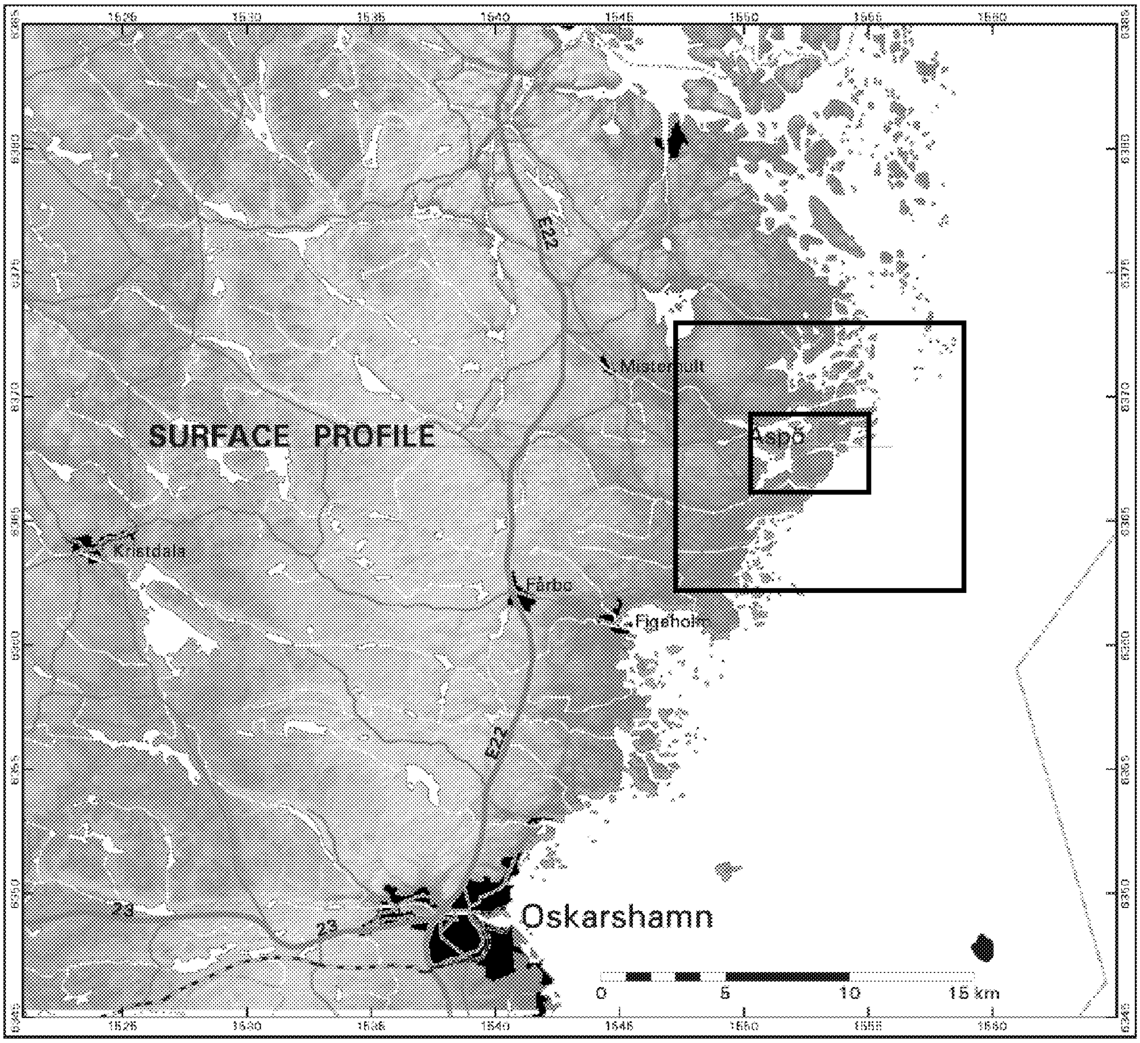

Figure 2-1. *Map of Aberg study site and region.*

2.1.2 General description

The Aberg region is situated in the archipelago, in a fissure valley landscape and is characterised by a relatively low topographical relief. The cover is composed of Quaternary sediments, mainly moraine, and the terrain is rocky. The regional bedrock is heterogeneous, dominated by Smålands granite, with high degree of exposed rock (Gustafson & Eriksson Nilsson, 1995; Ekman & Sidenvall, unpubl.; Hammarström & Olsson, 1996). The study site is situated in the north-east part of Oskarshamn municipality, which belongs to "ostkustens berg- och lerområde" (the mountain and clay area on the East coast), where exposed rock or rock with a thin soil cover is dominating (Översiktsplan, 1990).

Forest is the major land class in Oskarshamn municipality followed by meadows, impediment and settlements. Coniferous forest with some contribution of deciduous is most common and arable land occur to some extension (Översiktsplan, 1990). The dominating vegetation type is pine forest on outcrops of bedrock and the plants and animals occurring are typical for the coastal area (Gustafson & Eriksson Nilsson, 1995). The region contains few lakes.

2.1.3 Previous investigations

The Äspö project began 10 years ago with geoscientific investigations on Äspö and nearby islands. Since then, bedrock conditions have been investigated by several boreholes, the Äspö Research Village has been built and extensive underground construction work has been undertaken in parallel with comprehensive research. This has resulted in a thorough test of methods for investigation and evaluation of bedrock conditions for construction of a deep repository (Äspö Annual Report, 1997).

The construction of the Äspö Hard Rock Laboratory was finished in 1995. The project in progress is international with several nations participating (Hammarström & Olsson, 1996). The laboratory has been designed to meet the needs of research, development and demonstration projects that are planned for the Operation Phase. The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö, where the tunnel continues in a spiral down to a depth of 450 m. Many experiments will be performed in the Operation Phase and be described in a series of Test Plans, where the experiment are planned to extend over long time periods.

There has been a governmental approval of the Äspö Hard Rock Laboratory, NRL 4 § 2, and the area around the Äspö Hard Rock Laboratory and the Simpevarp nuclear plant is particularly suitable for industrial and energy production, NRL 2 § 8 (Översiktsplan, 1990).

2.2 Climate

2.2.1 Climatic region

The Aberg study site is located in the warm temperate climates, referring to the Köppen climate classification, key letters Cfb. Mean temperature of coldest month is between 18°C and –3°C, sufficient precipitation in all month and at least 4 month have means over 10°C (Strahler & Strahler, 1989).

According to Kaj Petersen (1984), this part of Sweden is included in the climate zone with the key letters BC, which is a further differentiation made from the Köppen system. The mean value for the warmest month is 15°C–18°C and the mean value for the coldest month is =/> –3°C, negative evapotranspiration (NMR, 1984).

The vegetation period in Sweden (mean temperature above 6°C), alters between 250 days in the southern region and 130 days up north. The vegetation period in the Aberg region is about 170–190 days (NMR, 1984). The highest precipitation is during summertime.

The study site has a typical coastal climate, since the Baltic sea has an equalising effect on the climate in the coastal region (Översiktsplan, 1990).

2.2.2 Precipitation and runoff

In the Aberg region there are two major catchment areas, Virån and Marströmmen. Two streams, Laxemarån and Gerseboån, between the major streams, were chosen to represent the coastal area (Svensson, 1987).

Region

The precipitation in the area is affected by the location in the rain-shade of the south-Swedish highland. Annual adjusted precipitation for the region is 675 mm/year (Svensson, 1987; Översiktsplan, 1990). The highest measured precipitation occurs in the period July–September, with a mean value of 60–70 mm/month and lowest values is during springtime from February until May, with mean precipitation value of 30 mm/month (estimated mean values 1961–1990) (Raab & Vedin, 1995). During the vegetation period, April–September, the Aberg area receives about 300 mm (statistics from SMHI) (Länsstyrelsen Kalmar, 1985).

The estimated runoff per square kilometre for the two catchment areas, Virån and Marströmmen, is approximately 0.006 m^3/s (km^2) (Svensson, 1987). The mean annual runoff in the catchment area is ca. 150 mm and 500–550 mm/year evaporates (Översiktsplan, 1990).The calculated actual evapotranspiration is 490 mm/year (Svensson, 1987).

Table 2-1. Data for major catchment areas in the region around Simpevarp and Aberg. Lake area as percentage of the catchment areas (data from Svensson, 1987).

Watercourse	Annual mean runoff (m^3/s)	Catchment area (km^2)	Lake area (%)
Virån	3.6	601	8.0
Marströmmen	2.9	486	7.0
Laxemarån	–	41	1.2
Gerseboån	–	25	12.0

Study site

The meteorological station used for precipitation measurements for the Aberg study site is Oskarshamn, ca. 15 km south of the site (statistical information obtained from SMHI). Annual mean precipitation for the meteorological station in Oskarshamn (1961–1995) was 675 mm (adjusted) (Rhén et al. 1997).

Table 2-2. Calculated water balance of Aberg catchment area (mm/year) (data from Rhén et al. 1997).

Adjusted precipitation	675
Calculated evaporation	490
Potential evapotranspiration	616
Runoff	150–200

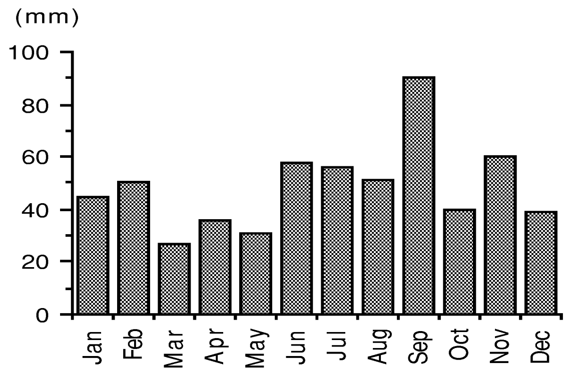

Figure 2-2. *Monthly mean precipitation in Aberg study site (1987–1996) (data from SMHI, mean value from the meteorological stations: Målilla, Oskarshamn, Ölands Norra udde, Gladhammar & Oceanografisk station "Osk").*

2.2.3 Temperature

Region

The coldest month in the coastal area of Aberg region is February with a mean temperature of –2°C and the warmest months, July–August, have a mean temperature of +16°C (mean values, 1961–1990). The temperature is below 0°C for almost three months of the year (Raab & Vedin, 1995).

Study site

The mean annual temperature for the site is between 7.1 °C at the meteorological station in Oskarshamn (1961–1995) (Rhén et al. 1997) and ca. 6.9 °C (1931–1960, SMHI) (Länsstyrelsen Kalmar, 1985).

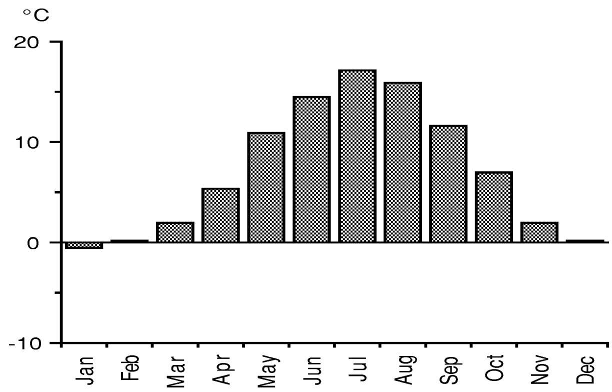

Figure 2-3. *Monthly mean temperature for Aberg (1987–1996) (data from SMHI, mean value from the meteorological stations: Målilla, Oskarshamn, Ölands Norra udde, Gladhammar & Oceanografisk station "Osk").*

2.2.4 Wind and air pressure

Sweden is located in the belt of west winds. Wind forces varies over the year (table 2-3). Land and sea breezes form a circulation system that occurs in coastal districts. Since study site is located close to the coast of the Baltic sea this has an effect on the local climate. The wind circulation sometimes pushes inland, up to 20 km, with a speed of 5–10 m/s (Raab & Vedin, 1995). The mean air pressure in this part of Sweden varies very little over the year. The dominating value is 1013 hPa (Raab & Vedin, 1995).

Table 2-3. Monthly resolved wind average (m/s) from 1985 through 1994, based on data from SMHI (Ölands norra udde, temporal resolution of 8 h) (Engquist, 1997).

	J	F	M	A	M	J	J	A	S	O	N	D
East/West	6.2	5.5	4.7	4.2	3.8	3.9	4.0	4.3	4.8	4.8	5.0	5.4
SE/NW	5.9	5.5	4.7	4.4	3.7	3.7	3.9	4.0	4.8	5.3	5.7	5.8

2.2.5 Snow cover and ice

The first snow cover in Aberg region can occur as early as in the beginning of December, but the most common is that the lasting blanket of snow comes in January and disappears in March. The probability of a white Christmas is 40%. The average snow depth for the period is 10 cm except February with 30 cm snow depth, which also is the maximum snow depth during winter (mean values 1961–1990) (Raab & Vedin, 1995).

The durability of the snow cover varies considerably between years, but in general the durability of the snow cover in the Aberg region is about 91 days. About 18% of the mean precipitation in Kalmar county area falls as snow (Rhén et al. 1997).

Ground frost depth in this part of Sweden is c. 30 cm, without snow even deeper. Lakes and streams in the Aberg site are generally frozen from the middle of December until the beginning of April, c. 120 days. The number of days with ice cover in the Baltic sea outside Aberg region is c. 80 days (Ångström, 1974).

Comments – Climate

Data for mean annual precipitation varies slightly in different reports (Grundfelt et al. 1990; Nyberg et al. 1992; Rhen et al. 1997). The climate figures for Aberg study site correspond with the Köppen and the Petersen climate classification (see temperature, precipitation and run off).

2.3 Physical geography

2.3.1 Land forms

The Aberg region is situated in a fissure valley landscape, which changes into archipelago closer to the Baltic sea. The area rests on archean rock, dominated by Smålands granite, with a high degree of exposed rock (Gustafson & Eriksson Nilsson, 1995; Ekman & Sidenvall, unpubl.; Hammarström & Olsson, 1996).

The Ice of the latest glaciation melted in the area about 11 900 years ago and left deposits, mainly till but also silt, sand and clay (Rhén et al. 1997). Two major eskers are situated in the municipality, Tuna-Fårboåsen and Kristdala-Påskallaviksåsen (Ekman & Sidenvall, unpubl.).

2.3.2 Soil

Soil is an integral part of the biosphere. Differences in soil properties produced by the interaction of parent materials, topography and vegetation over time have a profound effect on the biological systems that they support.

Region & study site

The most common soil units in the Aberg region are Lithosols, with some occurrence of Luvi-cambisols, table 2.4 (NMR, 1984). About 30–50% of the area in Oskarshamn municipality contain brown soil units, rich with mull (Rühling, 1997). Moraine is the most common sediment and occurs beneath most of the soil units. The degree of exposed rock is high in the northern and eastern part of the municipality (Ekman & Sidenvall, unpubl.). The study site has also a major degree of exposed rock, with thin soil layer in the depressions, sometimes covered with a thin peat layer. The bays are often covered with mud with underlying ground moraine (Gustafson & Eriksson Nilsson, 1995).

Table 2-4. Soil composition and soil units in Aberg region. Data from NMR (1984) (for definition of soil units, see Methods).

	Soil composition	Soil unit
Most common (>50%)	Exposed bedrock	Lithosols
Other soils (<50%)	Sand & fine sand	Luvi-cambisols
	Moraine	

Table 2-5. Distribution (km^2) of soil in Aberg catchment area, represented by river Marströmmen and river Virån and their coastal recipients (data from Ljungberg & Lönnbom, 1993). Soil definition, see Methods.

	soft soils	stiff soils	organic soils	total area
Marströmmen	22.2	–	2.4	24.7
Coast	8.3	1.4	–	9.8
Virån	34.5	–	4.8	39.3
Coast	8.3	–	–	8.3

Further information about soils and sediment is treated elsewhere (in press).

2.3.3 Shore level displacement

A large part of the Swedish land still has an uplift caused by the latest glacial. The isostatic movements started when the Ice begun to melt and the uplift today is a result of isostatic and tectonic movements in the earth crust. The uplift was fast at the beginning and slows down towards the old equilibrium state (Påsse, 1996, 1997). The sea level is also determined by eustatic and isostatic changes. The co-operation of these factors alters the position of the shoreline.

Region

The region is situated below the highest coast line (HK) (Gustafson & Eriksson Nilsson, 1995), which in Kalmar county is 120–130 metre above sea level (Rühling, 1997). About 40% of the total area of the municipality (north-east part) is situated more than 50 m above sea level (Ekman & Sidenvall, unpubl.).

The present uplift in Sweden is from 1 mm/year in the southern part to 9 mm/year up north (Lunds universitet, 1991). The relative uplift at the Aberg region is 2 mm/year (Länsstyrelsen Kalmar, 1985) and according to Påsse (1996) ca. 1.5 mm/year.

Short time level fluctuations due to earth tides, caused by the tidal forces of the sun and the moon, occurs. The calculated earth tides indicate that the maximum changes of the level of the ground surface relative to mean level of the ground surface is about +/– 0.25 m (Rhén et al. 1997).

Comments – Physical geography

Even though the land uplift in Aberg is slow compared to Beberg and Ceberg, it may be of importance because of the location close to the water surface, when calculating future and events, see Discussion.

2.4 Vegetation

2.4.1 Vegetation zone

The Aberg study site is a part of the Boreonemoral zone, which contains the woodlands south of "Limes Norrlandicus", the biological Norrland boundary (Sjörs, 1967). The northern limit of the boreonemoral zone coincides with the limit of oak and contains of 750–900 different species of vascular plants (NMR, 1984).

Aberg region is a part of "Sörmlands and northern Götalands archipelagos", a sub region to "Coast and archipelagos of the Baltic sea" (NMR, 1984). In this part of the archipelago there is no occurrence of birch (*Betula pendula*) and the mean annual temperature and the water deficit during the vegetation period is higher than in the main region (Gustafson & Eriksson Nilsson, 1995).

2.4.2 Land class distribution and landscape

Region

The landscape is a mosaic of heterogeneous land forms, vegetation types and land uses. The agents of pattern formation on natural landscapes can be categorised as disturbances, biotic processes and environmental constraints (Levin, 1978).

The landscape is dominated by forests, i.e. 70% of the area of Oskarshamn municipality (Gustafson & Eriksson Nilsson, 1995). The most common forest is pine forest on outcrops of bedrock, which by the coast also contains young oak trees.

The categories of coniferous forests compose 80% of the total forest area and is divided into: pine forest (c.40%), spruce forest (c.25%) and mixed forest (c.15%) (Gustafsson & Ahlén, 1996). The most common undergrowth is the grass type, which is considerably more common in southern than in northern Sweden. The beech (*Fagus sylvatica*), which is sensitive to frost in spring, has its northern limit in the Kalmar county (Gustafsson & Ahlén, 1996).

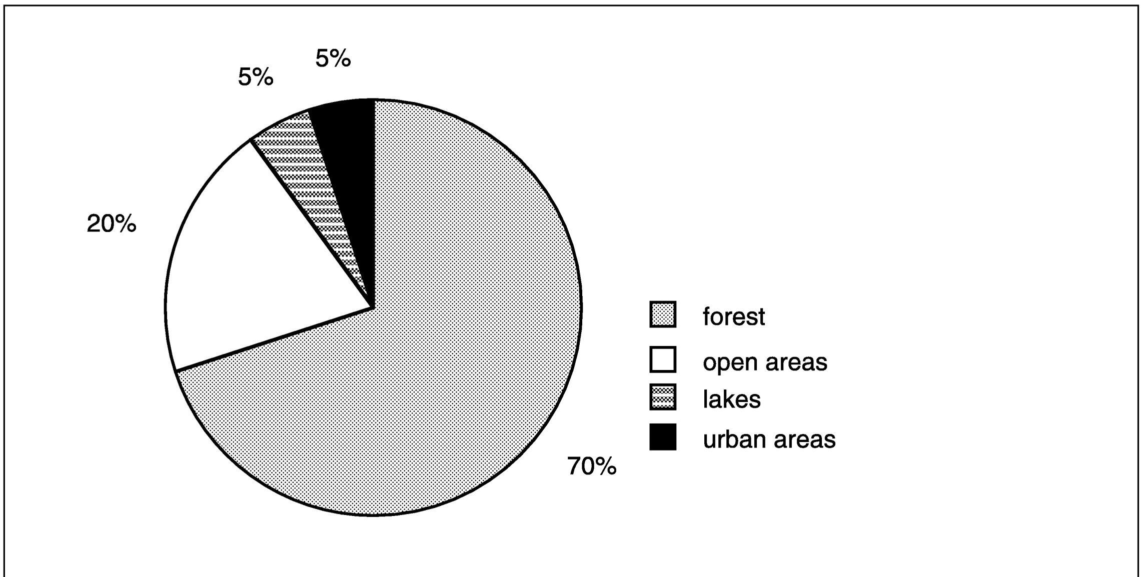

Figure 2-4. *Land class distribution in Kalmar county (data from Nilsson, 1990).*

The amount of arable land in Oskarshamn municipality is about 4% of the total area (1993). Half of the arable land is pasture, ca. 1.2% (Gustafson & Eriksson Nilsson, 1995). This is a lower figure than for the rest of the county (Carlsson et al., 1989).

The three dominating types of wetland in the Kalmar province are inundated wetlands, bogs and fens; swamps do occur at some extent (Gustafsson & Ahlén, 1996).

2.4.3 Description of vegetation

Region

The landscape is complex comprising a fissure valley landscape with marsh meadows and an old cultural landscape, preserved to some extent. A diversity of nature types of ecological interesting zones and typical herb communities are found from the inner to the outer archipelago (Naturvårdens riksintressen, 1989).

The flora is rich and varied, dominated by pine forest. Mixed deciduous forests occur and also forests with one dominating species, for example oak (*Quercus robur*). The dominating vegetation type in the coastal area is pine forest on outcrops of bedrock (Gustafson & Eriksson Nilsson, 1995).

Only a small part of the former agriculture land is now in use and most of the arable land is used for extensive grazing (Naturvårdens riksintressen, 1989). One example of ancient arable land is the road to Upplångö, just north of the study site, that is bordered by an old cultural landscape, still in use.

The most common land class in the municipality is forest, 75%, pasture and meadow represent 7%, impediment 13%, urban areas 4% and 1% is power line areas (Översiktsplan, 1990). In Oskarshamns municipality there are about 1330 different herb species and the mean value for Aberg region is 390 species/25 km^2 (Rühling, 1997).

Study site

The study site contains both inner- and outer archipelago. The shoreline is compound with water, land and bays with different shape and size.

The vegetation in the study site is very similar with the region. The old cultivated, mostly abandoned, landscape, is dominating together with old pastures and pine forests with contribution of oak, rowan (*Sorbus aucuparia*), birch, ash (*Fraxinus excelsior*) and pine (*Pinus sylvestris*). A minor part of the area has pine forest on outcrops of bedrock. Utlångö, in the north-east corner of the study site, mostly consists of a 10–15 year old pine forest and Äspö island comprising both pastures, clear-cut woodland and planted young forest (pine and spruce (*Picea abies abies*)). Former arable land is now used as pasture, meadow or lie fallow. At some places brackish water eventually floods and creates marsh meadows, often used as pasture. In the central part of the Äspö island there are small wetland areas, comprising species like “skvattram” (*Ledum palustre*) and Common cotton-grass (*Eriophorum angustifolium*).

Comments – Vegetation

The vegetation in Aberg is in progress, because of change in land use from agriculture to forestry and the shore level displacement. Therefore the herb communities and their ecosystems are expected to change quite rapidly in the years to come.

2.5 Areas with biological interest

Aberg study site/region is situated within an area of national importance for recreation and environmental protection, "riksintresse för friluftsliv och naturvård" (Översiktsplan, 1990). There are four areas, except the area of national importance, within the region that are of biological interest; one is a nature reserve (area protected by law) and the others are classified because of their conservation values (see Methods). According to Gustafson & Eriksson Nilsson (1995) there are 34 areas in Oskarshamn municipality that have conservation values.

Region

Misterhults Nature Reserve

The nature reserve within the region, Misterhults Northern Archipelago Nature reserve, is situated ca. 2 km north-east of the study site. The reserve has an area of 8400 hectare, including a land area of 1470 hectare, and comprises three types of archipelago: outer, middle bay and inner archipelago. The aim of the nature reserve is to preserve the environment and the old cultivated landscape. Some of the islands have a "vatten-skyddsområde", a water sanctuary zone, and the nature is unexploited (Länsstyrelsen, sign-post).

Bussvik (Kärrsvik)

A cultivated sea-shore meadow situated 2 km outside the north-west corner of the study site. The area is characterised by nutrient rich water that run out in the bay (Rühling, 1997). The area is grazed by cattle. Typical herb communities are represented on the sea-shore meadow, containing species like Seaside Centaury (*Centurium littorale*), Sea milkwort (*Glaux maritima*), Mud rush (*Juncus gerardii*) and Sea Plantain (*Plantago maritima*). The trekking route "Ostkustleden" passes through the area (Gustafson & Eriksson Nilsson, 1995).
class: II

Ström/Stora Laxemar

An area with a hilly landscape in an old cultivated environment. The settlement is well preserved and old stone fences and cairus occur. Some pasture/meadow species are left e. g. Common quaking-grass (*Briza media*), Heathgrass (*Danthonia decumbens*) and Common Rockrose (*Helianthemum nummularium*) (Gustafson & Eriksson Nilsson, 1995).
class: III

Götemaren

Lake Götemaren, see Lakes.

Study site

The Aberg study site is situated within an area of national importance for recreation and environmental protection. Both the study site and the outer area of Aberg region is included in this protection plan. According to the Översiktsplan, Oskarshamns kommun (1990) some areas on Äspö island are built up as a part of the Äspö Hardrock Laboratory.

2.6 Fauna

2.6.1 Animal population

The number of species of mammals in Sweden is geographically relatively equally distributed. Of Sweden's 66 species almost half are spread through-out the country, 22 are limited to the south part and 14 to the north part (Gustafsson & Ahlén, 1996).

Region & Study site

Hare (*Lepus sp.*) and roe deer (*Capreolus capreolus*) are frequently visitors in the Aberg region, even though the number of roe deer has decreased during the last decade (G. A. Petersson "Lilla Laxemar jaktområde" unpubl.). Mammals that are seen more seldom are moose (*Alces alces*), badger (*Meles meles)*, and fox (*Vulpes vulpes*) (Äspö stigen, sign-post). The estimated population size for moose in Aberg region is 0.85 animals/km^2 (winter population). In the outer area of Aberg region grey seal (*Halicoerus grypus*) occur frequently and otter (*Lutra lutra*) is seen temporarily in the study site area (Naturvårdens riksintressen, 1989). The otter is on the boarder of extinction and there are only 500–1000 animals left in Sweden, ca. 50 in Götaland (Rädda Uttern i småland, 1995).

According to Gustafsson & Ahlén (1996) has none of the four species of large carnivores their present distribution in this part of Sweden. Although observations of lynx (*Lynx lynx*) have been made by hunters in the study site area during winter (G.A. Petersson, Lilla Laxemar jaktområde, unpubl.). The number of breeding bird species (Kalmar county is included in the region "southern part of Sweden") is fairly high in this part of Sweden ca. 159 species/region (Gustafsson & Ahlén, 1996).

Since bird species often are bound to one particular habitat, the breeding bird species in the Aberg region are bound to the coastal environment. The bird fauna is typical for example: goosander (*Mergus merganser*), red-breasted merganser (*Mergus serrator*), eider (*Somateria mollissima*), tufted duck (*Aythya fuligula*), great crested grebe (*Podiceps cristatus*), and common sandpiper (*Tringa hypoleucos*). Exclusive species like Arctic skua (*Stercorarius pomarinus*), razorbill (*Alca torda*), white-tailed eagle (*Haliaeetus albicilla*) and eagle owl (*Bubo bubo*) occur, but do not breed (Naturvårdens riksintressen, 1989)

About 50 bird species are breeding on Äspö island (study site), e.g. willow warbler (*Phylloscopus trochilus*), chaffinch (*Fringilla coelebs*), robin (*Luscinia svecica*), great crested grebe and tufted duck are breeding within the study site; osprey (*Pandion haliaetus*) and grey heron (*Ardea cinerea*) occur.

For this part of Sweden the number of species/region of terrestrial vertebrates subdivided into reptiles /amphibians, birds and mammals is:

Reptiles and amphibians	19
Birds	191
Mammals	47

To be counted as belonging to one of the regions a species has to have at least 5% of its total Swedish occurrence in that region (Gustafsson & Ahlén, 1996).

2.6.2 Sanctuaries for birds and seals

To protect the fauna, the County Administration has established sanctuaries for birds and seals along the coast. Public access is restricted during certain periods of the year.

There are 35 sanctuaries for birds and three sanctuaries for seals in Oskarshamn municipality (coastal area). There are no sanctuaries within the study site, but there are three sanctuaries for birds in the region about 2 km from the study site (Fågel- och sälskydd längs Kalmar kust, 1990).

Comments – Fauna

Because of deficiency in data for animal population sizes and distribution, the figures for the study sites often are based on information from larger areas and regions.

2.7 Hydrology

2.7.1 Drainage basin and streams

In the Aberg region there are two major catchment areas, Virån and Marströmmen. Two streams, Laxemarån and Gerseboån, represent a minor drainage basin between the major streams, representing the coastal area (Svensson, 1987). The river Laxemarån is of great importance because of its permanent water flow (Rühling, 1997). In the archipelago fresh water wetlands and fens, with their typical vegetation, are unusual (Rühling, 1997). There are no wetlands within the catchment area that can affect the hydrology in Aberg (Våtmarksinventeringen inom fastlandsdelen av Kalmar län, 1984.)

The natural fluctuations on the ground water level is generally less than 1 m/year. The highest ground water level in Aberg study site is approximately +4 m above sea level (Ekman & Sidenvall, unpubl.). The water has low alkalinity within Aberg catchment area (5.3–6.1 pH) (Miljöskyddsprogram Oskarshamns kommun, 1986).

2.7.2 Lakes

Kalmar county is relativly rich with lakes and running water. The county contains ca. 2000 lakes that are bigger than one hectare and most of them are located in the northern part. The lakes in the northern part of the county are long and narrow, often fissure valleys filled with water. Most of the lakes in the area "Smålands and north Götalands archipelago" are oligothrophic and have a mean depth of 3,8 metre. In the southern part of the county the lakes are shallower and therefore more interesting for birdlife. The alkalinity is lower in the south part of the county. Flora and fauna of the lakes is poorly investigated throughout the county (Carlsson et al., 1989).

Region

There are seven lakes within the Aberg region. All of them are located upstream from the study site and only one of them (lake Götemaren) is classified (see Methods).

Lake Götemaren

The lake is situated upstream river Gerseboån, 6 km north of Aberg study site. The lake is deep and has a low alkalinity (pH 5.6) and a low level of humus (Miljöskyddsprogram, 1986). Because of the low pH in the granite rock the vegetation is sparse around the lake. Species like "flotagräs" (*Sparganium gramineum*) and "långnate", (*Potamogeton prarlongus*) are common here but rare within the county.

Data Lake Götemaren (Johansson, 1991):

Depth (max)	17.8 m
Size	2.84 km^2
Catchment area	17.2 km^2
Water flow discharge	0.09 m^3/s
Altitude	1 m. a. s. l.

The water level in the lake was lowered during the 19th century to get more arable land. Since 1982 OKG is allowed to dam the lake in order to use the water at Oskarshamnsverken as fresh water, drinking water and cooling water (Johansson, 1991). Fish species like pike (*Esox lucius*), perch (*Perca fluviatillis*), burbot (*Lota lota*), eel (*Anguilla anguilla*), bream (*Abramis brama)* and bleak (*Alburnus alburnus*) are common. Since 1979 the lake is a part of a research programme for eel performed by Drottningholms freshwater laboratory. The noble crayfish (*Astacus astacus*) was found earlier in the lake. The lake has high ornithological values. Bird species that breed around the lake are e.g. mute swan (*Cygnus olor*), tufted duck, crane (*Grus grus*), black-throated diver (*Gavia arctica)* and osprey.
class II (national interest)
value: birds and geology

Study site

There are one small lake within the study site, lake Pistlan. No data available.

Coastal area

Since the Aberg study site is situated by the coast, several coastal factors effects the biosphere, e.g. salinity, water temperature, sea level rate of change etc. In the coastal area of Aberg region the "strandskydd", the shore line sanctuary zone, is extended to maximum 300 m. The normal sanctuary zon for lakes, wetlands and coastal areas is 100 m.; some areas have the zone extended to 200 m. (Översiktsplan, 1990). Water exchanges estimates for the basins surrounding Aberg and adjacent coastal water is presented by Engqvist (1997).

2.7.3 Wells and water use

According to Brunnsregistret (SGU) there are three drilled wells within the study site, situated at three different real estates.

Table 2-6. Data for drilled wells in Aberg study site (Brunnsregistret SGU).

Real estate	Depth (m)	Water flow (l/h)
Lilla Laxemar 1	31	200
Lilla Laxemar 2:9	56	300
Långö 2:16	28	400

The capacity for ground-water outlet (drilled wells) in the municipality is fairly good. The mean outlet capacity alters between 600–2000 l/h. Drilled wells with high level of fluoride and chloride occur in the coastal area (Ekman & Sidenvall, unpubl.).

The closest public water source is at Fårbo, Oskarshamn municipality, ca. 10 km westerly upstream the study site (Nilsson, 1989).

OKG uses lake Götemaren and river Laxemarån (situated just outside the Aberg region) as water catchment for drinking water and the manufacturing processes (Översiktsplan vatten, 1989).

Comments – Hydrology

Since Aberg is located in the archipelago, the influences from/of the Baltic sea is an important factor when discussing hydrology conditions. The number of wells in the region/study site may be higher, while only drilled wells are registered in Brunnsregistret.

2.8 Land use

2.8.1 Forestry

Region

The landscape of Kalmar county is dominated by forest and the region has an average annual growth of 4–5 m^3 sk/ha (Nilsson, 1990). In the Aberg region the site quality (potential productivity) is 7–8 m^3 sk/ha/year, see Methods (Nilsson, 1990). The distribution of forest in Aberg region referring to age: 7.5–10% of the forest lie fallow or is clear-cut, 20–30% are mature for final felling and the rest is growing, compare table 2-7 (Nilsson, 1990).

Study site

The major land owner in Aberg study site is OKG, which owns about 85% of the area. The other 15% is private owned land (7 owners). Most of the forest is productive (69%) but a significant part is impediment, consisting of rock (29%) and marsh land (2%).

The type of forests at the study site are pine 72%, spruce 7%, oak 14% and other deciduous trees 7%, with a average annual growth of 3.5 m^3 sk/ha, which is lower than the average value for the county. In average, the rotation period for the forest in the Aberg region is 85 years (I. Lennartsson, Skogsvårdsstyrelsen Oskarshamn, unpubl.). The volume of total growing stock/ha of all species is 100 m^3 sk, the rotation period is ca. 100 years and the site quality (potential productivity) is 3.9 m^3 sk/ha/year. The low site quality value, compered with the region, is due to the large amounts of impediment in Aberg.

Table 2-7. Age distribution for trees in forestry, Aberg study site (I. Lennartsson, Skogsvårdsstyrelsen Oskarshamn, unpubl.).

Age	Distribution (%)
0–20	14
20–40	4
40–60	14
60–80	36
80–100	28
100–	4

2.8.2 Agriculture

Region

The amount of arable land has decreased, ca. 50%, during the last decades (1951–1989). In the Kalmar county the pasture land increased with ca. 10% during the same period (Clason & Granström, 1992). The amount of arable land in the municipality is ca. 42.24 km^2 and pasture land is ca. 12.60 km^2 (Gustafson & Eriksson Nilsson, 1995). A comparison of arable land productivity in Sweden have been presented by Clason & Granström (1992). The productivity is affected by many factors e.g. soil units, climate and organisms and is divided on a scale from 1–10 where 10 has highest productivity. In Aberg region the productivity is ca. 2 (Clason & Granström, 1992).

According to Lantbruksregistret (1995) the farmers/agriculture companies own totally 76.13 km^2 in the Misterhult parish, where the Aberg study site is located (counting only farms with more than 2.0 hectare of arable land). The area of arable land is 15.18 km^2, pasture 2.89 km^2, forest 48.84 km^2 and land for other use 9.22 km^2. A major part of the arable land (8.34 km^2) is used as hay-meadow and 2.44 km^2 is used as ley. The fields are cultivated with spring-barley (1.79 km^2), oats (0.30 km^2), other grain ca. 1.50 km^2 and 0.74 km^2 is fallow land.

Study site

There are three farmers that cultivate land within the study site, but none of them have their farms in the study site area. The total area of arable land is 28.5 ha., of which 5.7 ha is field, comprising 3.9 ha grain and 1.8 ha ley, and 22.8 ha is pasture (B. Pagels, Länsstyrelsen Kalmar län, unpubl.)

Table 2-8. Contribution of arable land in Aberg study site and Misterhults parish presented in km² and % of total area (data from Lantbruksregistret 1995; B. Pagels, Länsstyrelsen Kalmar län, unpubl).

	study site (km²)	%	parish (km²)	%
Arable land	0.285	2.4	15.18	3.7
Pasture land	0.228	1.9	2.89	0.7
Spring-barley			1.79	0.4
Oats			0.30	0.1
Other grain	0.039	0.3	1.50	0.3
Ley	0.018	0.1	2.44	0.6
Hey-meadow			8.34	2.0

2.8.3 Domestic animals

Region

In Oskarshamn municipality (1995) there was 4780 cattle of which 1195 were dairy cows. Sheep farming was altogether 1621 animals (Gustafson & Eriksson Nilsson, 1995). In Misterhult parish there was a total number of 816 adult cattle, of which 283 were dairy cows and 148 were cows used for breeding. Sheep farming had altogether 175 adult animals and 239 lambs. The amount of pigs were 9 sows and 327 pigs for slaughter and the number of hens for egg production was 290 (Lantbruksregistret, 1995).

Study site

The three farmers within the site practice extensive animal farming. According to Pagels, Länsstyrelsen Kalmar län (1997, unpubl.) there were 14 cattle (cows for breeding), 320 pigs, 3 horses and 35 hens within the study site. The pastures were only used during the vegetation period and only grazed by cattle. All other time cattle was indoor on the farms, outside the study site.

Table 2-9. The number of domestic animals per km² in Aberg region and study site. Meat production presented as kg/km²/year (for calculation, see methods) (data from Lantbruksregistret 1995; B. Pagels, Länsstyrelsen Kalmar län, unpubl).

Animals (n)	n/km² (region)	n/km² (study site)	kg/km²/yr (study site)
Cattle	2.0	1.2	288
Pig	0.8	27	2160
Pig (sow)	0.02	–	–
Hen	0.7	24	–
Horse	–	0.3	–

Comments – Land use

Since Aberg has minor qualifications for cultivation, pasture land is the most common form of agriculture. Because of the thin soils, forestry is the most profitable form of land use. According to table 2-7, a clear-cutting of about 30% can be assumed in the near future. If shore level displacement make it possible to cultivate the present bottom of the sea, the conditions for agriculture may change. The pigs in Aberg site (table 2-9) are only fed from none local produced food.

2.9 Recreation

2.9.1 General

The northern part of the archipelago in Kalmar county is of great importance for outdoor life concerning open air baths, canoeing, sport fishing and skating (Friluftslivets riksintressen, 1989). A trekking route (Ostkustleden) passes through Oskarshamn municipality, just west of the study site. The route is organised with small cottages along the way and has many visitors every year. Canoeing is common in the calm waters of the inner archipelago along the coast line. This part of the archipelago is also frequently used by boats, since Misterhult archipelago have conveniences like camping grounds, harbours and god open air bath arrangements (Carlsson et al., 1989). Two small harbours, like Kråkelund and Bussvik, are within the Aberg region.

2.9.2 Hunting

Today Sweden has well-organised hunting seasons and probably has there never been so much wild game available for hunting as there is today. In the mid 19th century, there were for example moose found only in a few districts in central Sweden and there were no more than a couple of hundreds roe deer left in Skåne (Gustafsson & Ahlén, 1996). Today about 5–7.5% of the population in the region is hunting sometime during the year (SNA, 1993).

Region & Study site

A major part of Aberg study site is located within "Lilla Laxemar hunting-ground" with an area of ca 10 km^2. The hunting ground support 14 licensed hunters (moose hunting) and all of them are local citizens. The ration for shooting moose in Aberg is 0.7 moose per km^2 and about 70–75% of the ration are shot, i.e. 0.5 moose/km^2. The number of roe deer has decreased from 6.5 to 1.5 per km^2, during the last decade according to number of roe deer shot. During 1997, 13 foxes were shot and some martens, minks and badgers were caught with traps. Fallow-deer and game bird hunting occurred to some extent (G. A. Petersson, "Lilla Laxemar jaktområde" unpubl.).

2.9.3 Wild berries and mushrooms

Picking wild berries and mushrooms plays an invaluable role for recreation and gastronomic satisfaction. More than 80% of the Swedish population spend some time every year picking wild berries or mushrooms. Up until the end of the 19th century forest berries were rarely used as food. In the beginning of the 20th century picking wild berries had become a large market, especially lingonberry, (*Vaccinium vitis-idaea*). Today we pick at most 7% of all available berries, about 80 million litres and 3% of available edible fungi, about 22 million kilos in entire Sweden (Gustafsson & Ahlén, 1996).

Region and Study site

In the southern part of Sweden about 40 litres of berries are picked per person and year. Even though the Aberg site is dominated by forest, the figures for the study site ought to be lower because of the unfavourable forest ecology e.g. grass type undergrowth and impediment. The site is estimated to produce ca. 2.5 tons of wild berries/year (calculated from Gustafsson & Ahlén (1996)).

2.9.4 Open air baths

This part of the archipelago have no arranged baths, but most of the coast line offers god opportunities for open air bath and is also frequently used by boats, since Misterhult archipelago have conveniences like camping grounds and harbours (Carlsson et al., 1989).

2.9.5 Sport-fishing

Sport-fishing is a common recreation. Today about 37% of the Swedish population go fishing at some time during the year (Gustafsson & Ahlén, 1996).

Region

In the Kalmar county the lakes are seldom used for fishing. The most common is fishing in the coastal area. The coastal area outside Aberg is also a reproduction area for several fish species: perch (*Perca fluviatillis*) whitefish (*Coregonus maxillaris*), Baltic herring (*Clupea harengus*) and pike (*Esox lucius*) (Naturvårdens riksintressen Kalmar läns fastland, 1989). The northern archipelago of Kalmar county is a commercial fishing area of national interest. The number of several fishspecies e.g. brown trout (*Salmo trutta*) and cod (*Gadus morhua*), has decreased in the archipelago during the last decades and there are only a few fishermen left in the region (Kulturmiljövårdens riksintressen, 1988). About 1.25% of the population in the region are sport-fishing (SNA, 1993).

There are four fish-farms in Oskarshamn municipality; two in the north part at the boarder of Västervik municipality and two south of the study site at Påskallavik (Blücher, 1992). The fish farms produce about 200 tons fresh weight/year (Översiktsplan, 1990). No fish-farms are situated within the Aberg site.

Comments – Recreation

Recreation quality is difficult to evaluate, since it often is a personal subjective opinion. The spontaneous out-door life is also difficult to evaluate because it is not registered in any way. Coastal areas have generally high recreational values, especially if they are accessible by car.

The only captures that are continuously reported is moose shot per year, which leads to uncertainties of the values for hunting and sport-fishing. The figures for picked wild berries are uncertain on a local level, because of transformation of values from larger regions.

2.10 Human population and occupation

2.10.1 Human population

Region

The number of citizen in Kalmar county is 5–10 per km^2 (SNA, 1991). In 1990 there were c. 27 300 people living in the municipality, of which 18 500 lived in settlement areas. The people in the northern part of the municipality are generally older than the average (Översiktsplan, 1990). According to Rühling (1997) are 85% of the citizens in the municipality living in urban areas.

The population of Oskarshamn municipality has decreased during the last decade (Ekman & Sidenvall, unpubl.). Kalmar county is following the same trend and according to SNA (1991) the prediction is a decrease of population with 25% to year 2015.

Number of citizen/km^2 (region)	2.1	(SCB, 1997)
Number of citizen, municipality	27 300	(Översiktsplan, 1990)
Number of citizen,urban areas	18 500	(Översiktsplan, 1990)

The number of holiday cottages in the coastal area of Oskarshamn municipality is 10–20/ km^2 (SNA, 1991).

Study site

There were 20 citizen permanently living in the study site area in 1996 (1.7/km^2) (SCB, unpubl.).

2.10.2 Occupation

People working with agriculture or forestry in this part of Sweden is 0–5% of the population (Clason & Granström, 1992). It is uncommon to work in another municipality than the home municipality, < 9% (SNA, 1991).

Table 2-10. Occupation by industry sector in Oskarshamn municipality compared to Sweden. People who work in the municipality (16–64 yrs.), irrespective of where they live (data from www.isa.se, 1997-10-10).

Branch of industry	Municipality (%)	Country (%)
Agriculture, forestry and fishing	1	2
Manufacturing, mining and quarrying	29	20
Electricity, water supply and waste disposal	8	1
Construction	7	6
Trade, transport and communication	13	19
Financial and business activities	7	10
Education and research	6	8
Social and personal service activities	21	20
Public administration etc.	4	6
Health and social work	1	2
No specified activities	3	6

Comments – Human population

Aberg has a potential for an increase of summer visitors, because of its attractive location close to the coast. The number of persons living in holiday cottages is not included in the figure for persons living in the site. When comparing the number of citizen per km^2 in the municipality and in the region/site, a major difference is noticed. The low number for the region and the study site may be due to the location close to the nuclear plant and the "strandskydd", the protection of shores.

2.11 The environment

2.11.1 Air pollution and deposition

The south-east part of Sweden has a high amount of air pollution compared to the rest of the country. A major part of the acid air pollutants NO_3, NH_4 and SO_4 comes from sources outside Sweden and only a small part of the air pollution in the region has a local source, e.g. sulphur ca. 15% (Bernes & Grundsten, 1992).

The deposition in Kalmar county is lowest in the northern part, where Aberg is located, but is high compared to other parts of Sweden (Carlsson et al., 1989). In the precipitation the pH value is almost as low in southern Sweden as in Central Europe, about 4.2–4.3 (Bernes & Grundsten, 1992).

The mean value of wet deposition of both sulphur and nitrogen in Kalmar county during 1983–1987, were 600–800 kg/km^2 (Bernes & Grundsten, 1992). According to Ljungberg & Lönnbom (1993), the total amount of nitrogen deposits in Oskarshamn municipality during 1990/91 was 565 $kg/km^2/year$. In table 2.13. the application to sulphur and nitrogen deposits in both ABC-berg are presented.

Table 2-11. The amount of SO_2 from combustion, NO_2 from the traffic and local pollution from paper mills and forest industry (Carlsson et al., 1989).

Pollution (year)	Oskarshamn (municipality)	Kalmar county
SO_2 ton/year (1980)	700	6900
SO_2 ton/year (1985)	800	4900
SO_2 ton/year (2000)	140	1380
NO_2 ton/year (1980)	950	9150
NO_2 ton/year (1985)	1000	9200
NO_2 ton/year (2000)	665	6405

A major part of the disposed matter in Aberg region during the 80'ies is estimated and presented by Carlsson et al. (1989) (table 2-13.). The matter disposed from local human activity, e.g. NH_4, NO_3, H+, decrease from south to north in the county. Matter like Na, Cl, Mg, have the highest concentrations in the coastal area, because of the marine environment.

Table 2-12. Estimated values of disposal for Aberg region (data from Carlsson et al., 1989).

matter	observed value (mevk./l)	metals	observed value (µg/l)
pH	4.3	Cd	0.1
H+	40–50	Cu	1–2
NH_4	30–50	Pb	3–6
NO_3	30–45	Zn	5–10
SO_4	60–85	Cr	0.15–0.25
Ca	10	Ni	0.25–0.5
Mg	5	V	0.75–1.25
Na	10–15	Hg	0.01–0.015
K	3		
Cl	10–25		

The fallout of lead (Pb) has been halved in Sweden since 1975, however it is still several times greater in south Sweden than in inner Norrland. The chromium (Cr) fallout in Sweden comes mainly from domestic sources. The amount of lead (Pb) and chromium (Cr) deposition in Aberg region is 1000–1500 g/km^2/year and 100–200 g/km^2/year respectively (Bernes & Grundsten, 1992).

Table 2-13. Sulphur and nitrogen compounds in ABC-berg (yearly average) (data SNV 1995).

Matter (mg/m^2/year) (dry & wet dep.)	Aberg	Beberg	Ceberg
S	500–750	500–750	500–750
NO_x – N	300–500	300–500	100–300
NH_x – N	300–500	300–500	100–300
(µg/m^3 air conc.)			
SO_2	1–2.5	0.6–1	1–0.6
NO_2	1–2.5	0.6–1	0.3–0.6
$NH_4^+ + NH_3$	1–2.5	0.6–1	0.3–0.6
SO_4^{2-}	0.6–1	0.6–1	0.3–0.6
$HNO_3 + NO_3^-$	0.3–0.6	0.1–0.3	0.1–0.3

A mean value for ozone concentration for Aberg region is 50–60 µg O_3/m^3, but during pollution episodes the value is much higher, 120–140 µg/m^3 (Bernes & Grundsten, 1992).

2.11.2 Ground chemistry

The acid rain causes great damage in Kalmar county. About 20% of the coniferous forest has needle loses and the natural acid ground, caused by the spruce forest and the acid bedrock, make the ground pH value even lower.

The pH of the soils in Kalmar county are:

Humus layer	4.3–4.4
Illuvial layer (B-horizons)	4.9–5.0

The nutrient leakage from the agricultural land is the major source of the nitrogen transported with the running water. The estimated ammonia emissions from farms and artificial fertilisers in relation to the total area of land in Aberg region is ca. 100 kg NH_3/km^2/year (Bernes & Grundsten, 1992).

The amount of pesticides used in the south of Sweden is often high, because of a higher amount of cultivated land. In table 2.14. the use of pesticides in ABC-berg is presented.

Table 2-14. Use of pesticides in agriculture in kg/km²/year in the counties of ABC-berg (Bernes & Grundsten, 1993)

Pesticides	Aberg	Beberg	Ceberg
Herbicides	40–69	40–69	<10
Fungicides	6–14	2.5–6	<1
Insecticides	0.3–0.5	0.3–0.5	<0.3

The amount of metals in forest soils has decreased in Kalmar county during the last 30 years. The amount of mercury in the humus layer for Aberg region is 0.25–0.30 mg/kg organic matter (Bernes & Grundsten, 1992) and the content of Pb and Cd in lichen and moss has decreased with more than 50% since the 1960'ies (Carlsson et al., 1989). In spite of the decrease there are still traces of metals found in animals, e.g. cadmium found in moose kidneys is 1.5–1.9 mg/kg/year (wet weight) (Bernes & Grundsten, 1992).

More data of ground chemistry is treated elsewhere (in press).

2.11.3 Running water, coast and lakes

The influence of toxic pollution in the coastal area of Aberg is low. Because of the low rate of water exchange in the long and narrow bays, the risk of eutrophication and oxygen deficiency in the coastal water is impending. Local signs of eutrophication are visible along the coast line, e.g. the Bussviken bay. The area outside Oskarshamn is often subjected to algae blooming of cyanobacteria (Ljungberg & Lönnbom, 1993).

Most of the lakes in Aberg region are oligotrophic, see 2.7.2. The few eutrophic lakes in the region are affected by artificial nutrients. Toxic pollutants in the lakes are often bound to the humus. High amounts of Hg, Pb, Zn and Cd have been noticed in Aberg region, but not in the study site area. For specific values of metals in lakes, see Carlsson et al. (1989).

Local nutrient sources, like sewage plants, industry and fish farming, may have a major affect on the local environment. The sewage plants closest to Aberg are "Sewage plant Oskarshamn", which release ca. 152 ton N/year and ca. 10.8 ton P/year and "Sewage plant Västervik", which release ca. 182 ton N/year and ca. 2.5 ton P/year.

The sensitivity of ground water to acidification is moderate in Aberg region (Bernes & Grundsten, 1992) and the transport of human induced nitrogen and phosphorus have decreased in river Marströmmen and river Virån the last 20 years. Phosphorus has almost disappeared and the nitrogen has decreased with 50%, due to more effective sewage plants (Enefalk, 1997).

The total amount of nitrogen and phosphorous transported with the river Marströmmen and the river Virån in Aberg catchment area during 1989 was, according to Carlsson et al.:

Marströmmen	78.7 N/ton/yr	2.0 P/ton/yr
Virån	98.1 N/ton/yr	2.5 P/ton/yr

Table 2-15. Discharge of nitrogen and phosphorous to the Aberg catchment area (1991) (Ljungberg & Lönnbom, 1993).

Tot-P (ton/year)	Sewage plant	Private outlet	Agri-culture	Forestry	Other source
Marströmmen	0.10	–	0.93	1.37	0.80
Coastal area	0.08	–	0.54	0.72	0.66
Virån	0.15	0.40	1.45	2.14	0.64
Coastal area	2.32	0.37	0.63	0.68	0.41
Tot-N (ton/year)					
Marströmmen	0.3	–	50.5	42.4	47.7
Coastal area	>1.0	–	23.0	21.6	40.0
Virån	1.7	3.7	80.8	64.4	38.3
Coastal area	56.0	3.6	28.3	20.6	24.6

The environmental protection regulations classify about 25 types of industries as so hazardous for the environment that they must have a licence from the Franchise Board of Environmental Protection. Five of these industries are in operation in the area around Aberg region, but none of them are within or upstream the region. Several of the installations closest to the Aberg site is connected to the iron or forest industry.

Oskarshamn – engineering works
Gunnebo – engineering works
Västervik – refinery
Figeholm – forest production mill
Simpevarp – nuclear power plant

The major sources of local toxic pollutants in the region are the areas of Oskarshamn/Verkebäcksviken. The metals Cd, Cu, Zn, Ni have been found in Bladder wrack (*Fucus vesiculosus*) and Blue mussel (*Mytilus edulis*) in the coastal area. Organic Cl has been found in the recipient of the paper mill Mönsterås Bruk (Carlsson et al. 1989).

The fibre-banks with high amount of PCB and Hg outside the coast of Västervik have been partly cleaned, but Cu and Sn from boat paint, have been able to spread in the area and accumulate in the sediment, because of the boat traffic in Aberg archipelago (Carlsson et al. 1989).

2.11.4 Radio nuclides

Samples taken from the marine ecosystem in the area surrounding nuclear plants show, that nuclear power plants discharge increase the amount of radio nuclides in the environment, however well below hazadous levels. The dominating nuclide appearing in the samples is cesium 137, which has its origin from the Chernobyl accident (Bengtsson et al. 1996).

Local differences in precipitation amounts after the Chernobyl accident 1986 led to great variations in the cesium fallout. The amount of cesium 137 in the soil after Chernobyl was <3 kBq/m^2 in Aberg, which is the same as the natural level (Bernes & Grundsten, 1992). Around the nuclear plant of Simpevarp a higher amount than the natural level of cobalt 60, manganese 54 and cesium 137 is detectable (Bengtsson et al. 1996).

During the 90'ies several samples were taken to detect the amount of cesium 137 in fish. The species with the highest value in Aberg region was perch ca. 200 Bq/kg d w (Bengtsson et al. 1996).

Comments – The environment

The data for pollution is often unspecified because measurement problems together with local and temporal differences in values. In most cases the values for Aberg site are the same as for the municipality or the county.

2.12 Historical overview

The early prehistoric settlements in Kalmar county are interesting (Carlsson et al., 1989). The first attempts to cultivate the area were made 5000–4000 B C and the settlements were situated at rivers or in the coastal area. During the Bronze Age the forest was cleared, because of the need of arable land, for pasture and crops (Gustafson & Eriksson Nilsson, 1995). Since the soil was more favourable in the depressions of the fissure valley landscape, most of the grain was grown inland and the coastal area was used for pasture. The most common crops during the beginning of the Middle Age were rye and hops; during the 16th century bread-stuffs and barley were more common (Gustafson & Eriksson Nilsson, 1995). During the 19th century the reorganisation of farm boundaries was carried through in order to increase the production. Meadows became fields and the forest-pasture decreased because of the importance of forestry. In the Aberg study site the forest was grazed until 1950's and the first clear-cut took place in the 70's (I. Lennartsson, Skogsvårdsstyrelsen Oskarshamn, unpubl.). The amount of arable land was highest in the 30's and has decreased ever since (Gustafson & Eriksson Nilsson, 1995).

Fishing was important for the early settlers, who were both farmers and fishermen. Later the fishing was also carried out by the townsmen and the fishing-permissions were limited to landowners only. From the beginning of the 20th century the fishing was carried out more often at the open sea. The amount of fisherman decreased with 30% from 1900–1960 and decreases still (Översiktsplan, 1990). Today there are only a few fishermen left in the region (see 2.9.5).

Hunting was intensive during the 19th century and many species were locally extinct, for example bear, beaver and wolf. For the last 100 years the hunting has been of little importance and is today carried out in a form of gamemanagement and for recreation (Länsstyrelsen Kalmar, 1985).

2.13 Predictions of the future

During the last 50 years the arable land in the region has changed from small-scale agriculture to a large-scale forestry. The amount of forest is continuously increasing at expense of arable land, meadow and pasture (Översiktsplan, 1990). With this development the environment becomes more homogeneous and the number of species connected with the open land is reduced. This development and the land usage will most certainly continue in the nearest future, about one rotation period (see 2.8.1), and probably longer. This means that the forest habitat will be the dominating land class and ecological system for a long period of time. Abergs location by the coast, regarding to the mosaic archipelago, is decreasing the opportunities for urbanising the area according to present society structure. On the other hand the archipelago is a very attractive recreation area and may therefore quickly become urbanised if the society system or the laws for settlers changes in the future.

The calculated future shore level displacement at Oskarshamn (Äspö) area will be ca. 5 m. in about 4500 years and 10 m. in 10.000 years from today (Påsse, 1997). The future for Aberg, Beberg and Ceberg is further discussed later (see Discussion).

3 Beberg

3.1 Study site

3.1.1 Location

The hypothetical Beberg site is located in northern part of Uppsala county, in the municipality of Tierp, Österlövsta parish; position 60° 22' N, 17° 54' E. The major settlement in the region is Tierp, ca. 22 km west of the study site. Map, "ekonomisk karta över Sverige" 12I 9d Giboda, 12I 8d Finnsjön.

Uppsala county	6989 km^2
Tierp municipality	1543 km^2
Österlövsta parish	280 km^2
Beberg study site	21 km^2

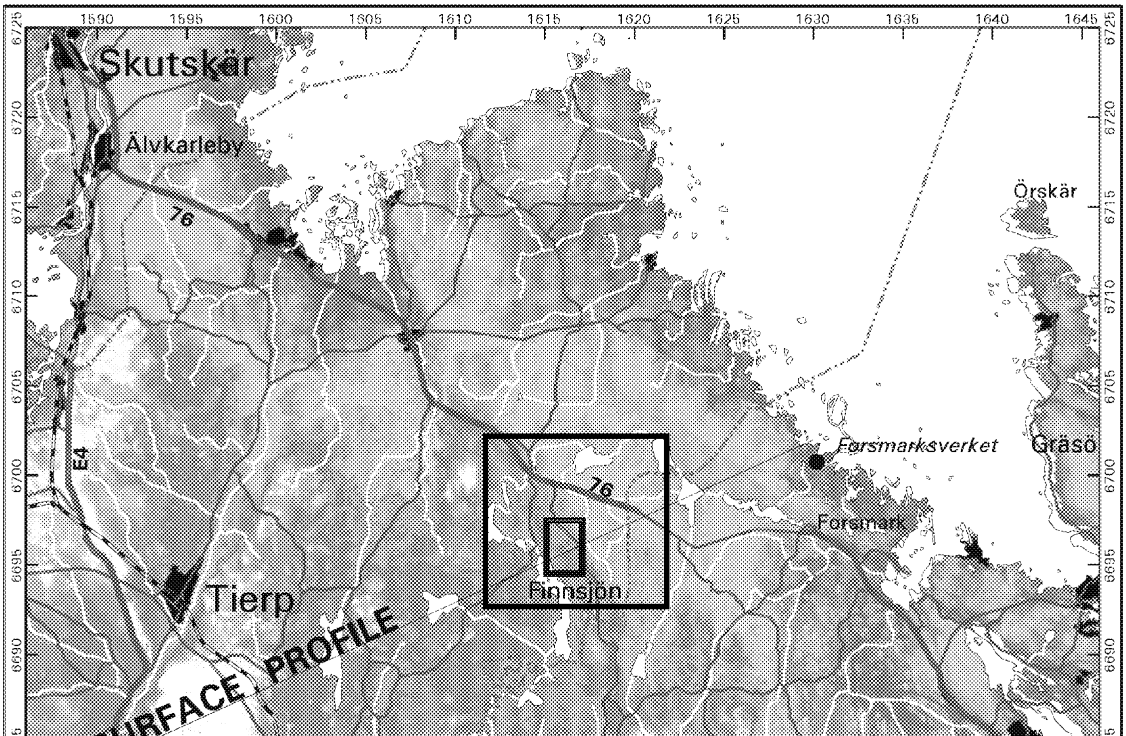

Figure 3-1. *Map of Beberg study site and region.*

3.1.2 General description

The area is characterised by a relatively low topographical relief. The cover is composed of Quaternary sediments, mainly moraine and peat (Ahlbom et al. 1992). The bedrock of northern Uppland is between 2,200 to 1,600 million years old. The bedrock consist mainly of four rock types: leptite, metabasite, granoderitic gneiss and late orogenic granite (Gustafsson et al. 1987), with a high degree of exposed rock (foliated granodiorite) (Ahlbom et al. 1992). Pine forest with some contribution of deciduous is the most common, but forest with spruce (*Picea abies abies*) occurs. Active forestry with both pine (*Pinus sylvestris*) and spruce is common and arable land occur to some extension. The northern part of Uppsala county is close to the northern limit for some plant- and animal species extension. The big wetland area upstream Lövstabruk is surrounding the study site in the west, the north and the east. The closest lake is Finnsjön, ca. 500 m. west of the study site.

3.1.3 Previous investigations

The Finnsjön region was selected as study site 1977 (KBS, 1977 & 1978) because of its geological characteristics, large homogeneous and well exposed rock block, together with its favourable location close to the nuclear power plant. All together, the Finnsjön studies have involved 11 cored boreholes, down to max. 700 m depth. The Finnsjön site has been studied more or less frequently from 1977 until today. The studies have included site characterising activities as well as testing new instruments and characterisation methods. All studies in the Finnsjön area before 1989 are presented by Ekman (1989).

3.2 Climate

3.2.1 Climatic region

The Beberg site is located in the snow climates, referring to the Köppen climate classification, key letters Dfb. Warmest month mean is over 10°C and the coldest month mean is under –3°C, sufficient precipitation in all month and at least four months are on average over 10°C (Strahler & Strahler, 1989).

According to Kaj Petersen (1984), this part of Sweden is included in the climate zone with the key letters DS1, which is a further differentiation made from the Köppen system. The mean value for the warmest month is 10°C–18°C and the mean value for the coldest month is –3°C, positive evapotranspiration.

The vegetation period in Sweden, with a mean temperature above 6°C, alters between 250 days in the southern region and 130 days in the northern region. The vegetation period in the Beberg region is about 160–180 days (NMR, 1984). The highest period for precipitation is during summertime.

It is also important to notice, that since the Beberg region is located close to the Baltic sea (c. 10 km), there is a coastal effect on the climate.

3.2.2 Precipitation and runoff

The study site is located within the drainage basin of river Forsmarksån, in the northern part of Uppland. The slope, on which the site is situated, is dipping slightly towards the north-east (Gustafsson et al. 1987).

Region

Annual precipitation for the Beberg region is ca. 700 mm/year. The highest measured precipitation occurs in July and August, with mean value of 80 mm/month and lowest values is during springtime from February until May, with mean precipitation value of 30 mm/month (estimated mean values 1961–1990) (Raab & Vedin, 1995).

The runoff in an area is direct related to the precipitation and the evapotranspiration. The mean value for Uppland county is between 200–300 mm annual runoff (1961–1990). The season with the highest mean value is the spring runoff, March–May, about 100–200 mm (Raab & Vedin, 1995).

Study site

The meteorological station closest to the Beberg study site is Lövsta Bruk, 1 km north-west of the site (statistics from SMHI). An important error in point measurement of precipitation is due to the wind (see Methods). In the summer days with showers, error due to evaporation from the gauge is large (Gottschalk, 1980). The months with the highest mean precipitation, during 1931–1960, were July and August with 63 and 77 mm/month, and lowest mean precipitation was in February with 30 mm. Totally mean precipitation for the same period was 582 mm/year (adjusted, 690 mm/year) (Gustafsson et al. 1987).

Water discharge measurements have been carried out during 1973–1979 in river Forsmarksån and since 1925 in river Tämnarån, north of the Beberg study site.

The water balance of the Beberg study site has, according to Carlsson & Gidlund (1983) been calculated to:

Adjusted precipitation	670 mm/year
Actual evaporation	430 mm/year
Runoff	240 mm/year

With calculations and field mapping Carlsson & Gidlund (1983) showed that about 30% of the central part of the study site consist of areas for ground water discharge.

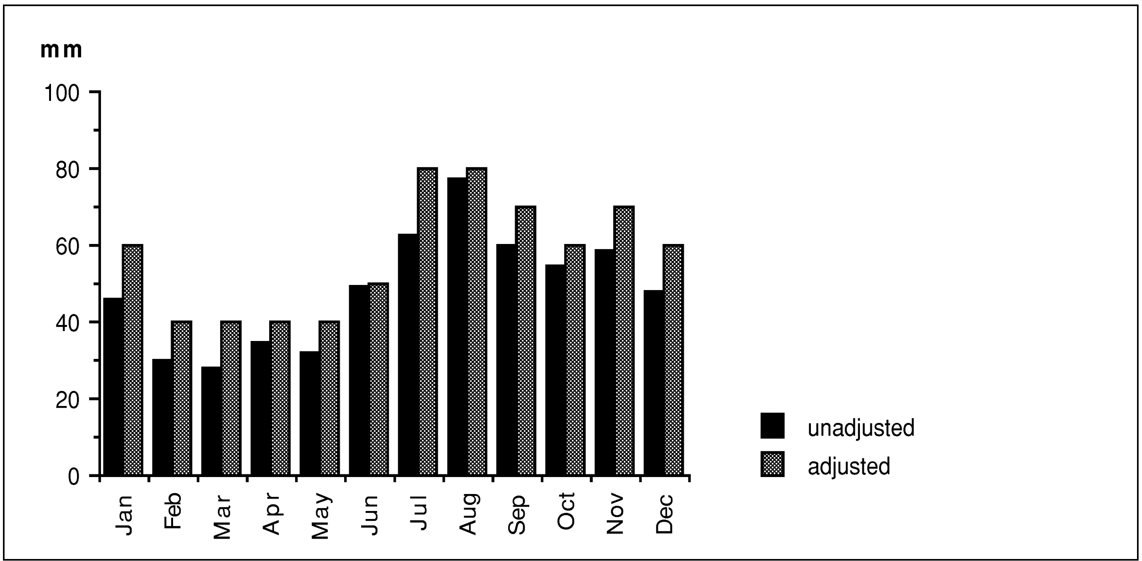

Figure 3-2. *Monthly mean precipitation (mm) at Lövstabruk (1931–1960) (data from Gustafson et al., 1987).*

3.2.3 Temperature

Region

The coldest month in Uppland county is February with a mean temperature of –4°C and the warmest months, July–August, have a mean temperature of +15°C (mean values, 1961–1990) (Raab & Vedin, 1995).

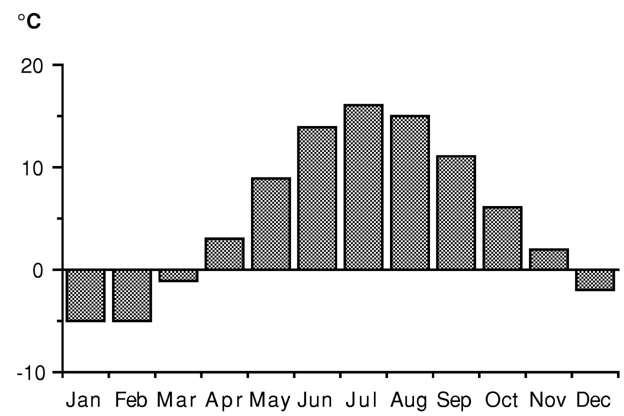

***Figure 3-3.** Monthly mean temperature (°C) in Beberg (1961–1990) (data from Raab & Vedin, 1995).*

Study site

Two meteorological stations have been regarded as representative for the study site, Lövsta Bruk – 1 km north of the site and Films kyrkby 11 km south of the Beberg study site. The annual mean temperature in northern Uppland is about 5.5 °C. The temperature is below 0°C for almost five month of the year (Gustafsson et al. 1987).

3.2.4 Wind and air pressure

Sweden is located in the belt of west winds. Wind forces varies over the year. Land and sea breezes form a circulation system that occurs in coastal districts. Since Beberg study site is located close to the coast of the Baltic sea this may have an effect on the local climate. The wind circulation sometimes pushes inland, up to 20 km, with a speed of 5–10 m/s (Raab & Vedin, 1995).

Region

Since the northern coast of Uppland is a windy part of Sweden, there have been discussions about establishing wind-power stations along the coast line (Länsstyrelsen & landstinget Uppsala, 1982).

The mean air pressure in this part of Sweden varies very little over the year. The dominating mean value during the year is 1011 hPa (Raab & Vedin, 1995).

3.2.5 Snow cover and ice

Region

The first lasting cover of snow in Beberg region can fall as early as in the middle of November, but the most common is that the lasting blanket of snow comes in December and disappears in March. The probability of a white Christmas in this area is 70%. The average snow depth for the period is 20 cm and the maximum is 100 cm (mean values 1961–1990) (Raab & Vedin, 1995).

The proportion of snow is about 35% of the annual mean precipitation. The durability of the snow cover varies considerably between years, but the mean durability of the snow cover in the Beberg area is about 110 days (Gustafsson et al. 1987). Ground frost depth, without snow, in this part of Sweden is c. 50 cm for about 3 month a year. Lakes and streams in the Beberg site are generally frozen from the middle of November until the middle of April, c.150 days (Ångström, 1974).

Comments – Climate

The climate data for Beberg study site correspond with the Köppen and the Petersen climate classification (see Temperature, Precipitation and run off). Air pressure varies little for hypothetical ABC-berg, both over the year and between the sites.

3.3 Physical geography

3.3.1 Land forms

Region

The Beberg region is a part of the sub-Cambrian peneplain (NMR, 1984), characterised by a relatively low topographic relief, with an altitude that varies less than 15 m within the site (Gustafsson et al. 1987).

3.3.2 Soil

Region & study site

The most common soil unit in the Beberg region is Luvi-cambisols with some occurrence of podzols. Calcareous soils also occur at some extension (NMR, 1984). The most common sediment is a sandy silty clay with 10–20% $CaCO_3$. As the area is situated below the highest coastline the till was washed out and sand deposits are found in the depressions e.g. at Gåvastbo. Peat deposits are widespread in the central part of the site (Gustafsson et al. 1987). The degree of exposed rock (foliated granodiorite) is c. 15% and is most common in the west part of the region (Ahlbom et al. 1992).

Table 3-1. Soil composition and soil units in Beberg region. Data from NMR (1984) (for definition of soil units, see Methods).

	Soil composition	Soil unit
Most common (>50%)	Moraine	Luvi-cambisols
Other soils (<50%)	Sand & fine sand	Histosols
	Clay & silt	Podzols

An estimate of a real distribution of different Quaternary deposits within the study site area is made by Carlsson & Gidlund (1983).

3.3.3 Shore level displacement

There is still a land uplift in most part of Sweden, because of the latest glacial.
The uplift begun for about 10.000 years ago when the Ice melted (Länsstyrelsen & landstinget Uppsala, 1982; Björck et al. 1988). Recent uplift is a result of isostatic and tectonic movement in the earth crust. By studying the shore level displacement, it is possible to calculate were the Ice was most thick. The sea level is determined by eustatic and isostatic changes. The interaction of these factors alters the position of the shoreline (Påsse, 1996).

Region

The region and study site is situated below the highest coastline. The topography is relatively flat, 20–44 metres above sea level (Gustafsson et al. 1987).

The observed uplift at the Beberg region is 6.5 mm/year according to Länsstyrelsen Uppsala (1986) and 6.0 mm/year according to Påsse (1996). In this area the shore level displacement has had the same rate the last 1000 years (Länsstyrelsen Uppsala, 1986; Lundqvist, 1986). The emerged shoreline outside Beberg site is of scientific interest because of the special wetlands "havsstrandspåverkat topogent kärr" (a fen effected by the topography and the sea shore). The area is of scientific interest for studying succession and sedimentation rates (Länsstyrelsen Uppsala, 1986).

3.4 Vegetation

3.4.1 Vegetation zone

The Beberg study site is located in "the woodlands south of Limes Norrlandicus", the biological Norrland boundary, which is a part of the Boreonemoral zone (Sjörs, 1967). The Boreonemoral zone has its northern limit coincides with the limit of oak (*Quercus robur*) and contains of 750–900 different species of vascular plants (NMR, 1984).

Because of the humid climate along the coast line, many species of plants and animals have their extension further north in this part of Sweden.

3.4.2 Land class distribution and landscape

The landscape of Uppsala county is dominated by forests, that covers more than 50% of the area (Länsstyrelsen & landstinget Uppsala, 1982). The categories of coniferous forests compose 75% of the total forest area and is divided into: spruce forest (25%), pine forest (25%) and mixed forest (25%) (Gustafsson & Ahlén, 1996). The most common undergrowth is the "nutrient rich herb type", which is found in calcareous areas, where the" dwarf shrub type" is not so common (Gustafsson & Ahlén, 1996).

The most common pasture type is old type of grazed forests (50%), Ancient open pasture (30%), Ancient shore pasture (15%) and Ancient pasture with birch (5%). The most common type of meadow land is Damp and wet ancient meadow (55%), Ancient open meadow (35%) and Ancient freshwater-shore meadow (10%) (Gustafsson & Ahlén, 1996).

There are three dominating types of wetland in the province of Uppland: fen, bog and inundated wetlands; some swamps do also occur in the area (Gustafsson & Ahlén, 1996).

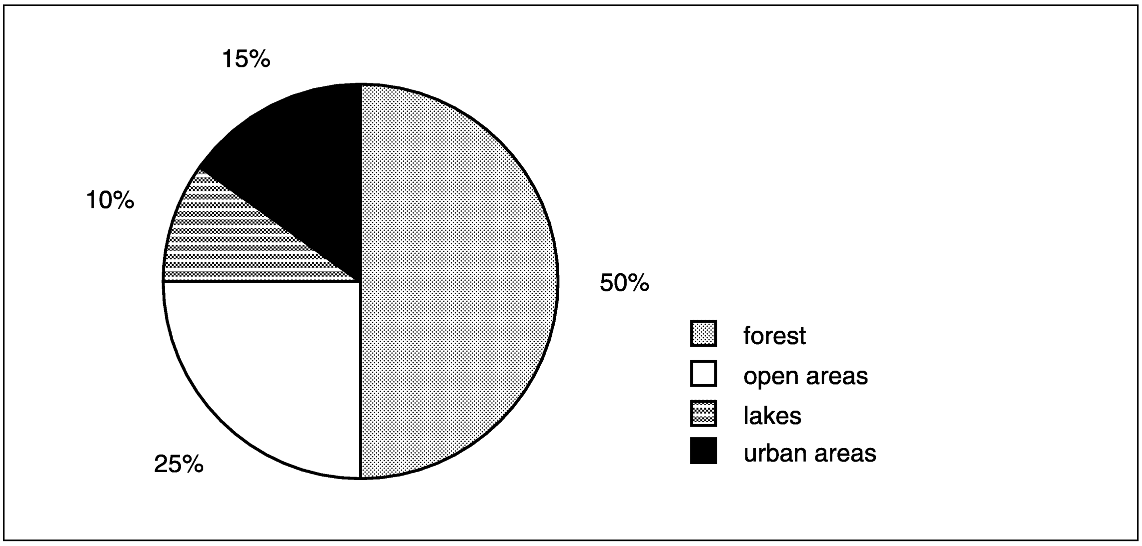

Figure 3-4. *Land class distribution in Uppsala county (data from Nilsson, 1990).*

3.4.3 Description of vegetation

Region

A major part of the forest in the region is planted or grows on abandoned arable land. Three types of forest are common: pine forest on outcrops of bedrock, pine forest (lichen type) and coniferous forests rich with moss. Deciduous forests are often connected to old cultivated areas. During the 19th and 20th century a major part of the wetlands were ditched to gain arable land.

Small lakes on the plains are common. Most of them are nutrient rich and shallow, but the calcareous soil give the lakes high alkalinity.

Study site

The vegetation in the Beberg study site is characterised by the forestry, with large areas of clear-cut woodland and young forest. The coppiced woodland contains plants of spruce (*Picea abies abies*) and pine (*Pinus sylvestris*), mixed with deciduous trees.

Species rich calcareous habitats are also found within the study site. At some places there are traces of old cultural landscape like abandoned fields and pastures; at some extension the agriculture tradition still carries on.

Wetlands occur at the site, but fewer than in the other parts of the region.

3.5 Areas with biological interest

There are six areas in the region that are of ecological interest; two of them are within the Beberg study site. One nature reserve is located in the region.

Areas of biological interest in the coastal region of Östhammar municipality, downstream Beberg catchment area, is presented by Birgersson & Sidenvall (1996). Criteria for biological classification, see Methods.

Region

Florarna

The only nature reserve in the region is Florarna, about 7 km south-west of the study site. Florarna is a part of the big wetland area upstream Lövsta Bruk that surrounds the study site in the west, the north and the east. Together with the fens within the drainage basin of river Forsmarksån, Florarna constitute one of the largest connected wetlands in the southern and the middle part of Sweden. Only a small part of the area is ditched. The area is a mosaic comprising fen, fen woodland and sedge fen. The vegetation in the lakes are sparse.

The wetland is famous for the good nesting sites and several rare owl and woodpecker species occur.

The Florarna has high environmental value both from a scientifically and a recreational point of view. It is also an important habitat for wildlife like moose (*Alces alces*), roe deer (*Capreolus capreolus*) and waders. (Länsstyrelsen Uppsala, 1987).
classification: I (national interest)
values: flora, fauna, geology, hydrology and recreation.

Fälaren

Also a part of the big wetland area upstream Lövstabruk. The lake is less then 2 metres in depth and the water is humus rich. Because of the lowered water level, the lake shore is like a soft fen with less plant species than rest of the area. No old coniferous forest occurs (Länsstyrelsen Uppsala, 1986).
classification: I
values: flora, fauna, geology, hydrology and recreation.

Myrmark sydost om Fälandbo

"Myrmark sydost om Fälandbo" is a slightly dome-shaped bog, completely surrounded by coniferous forest. The area is ca. 15 hectare and is located ca. 5 km south-west of study site (Länsstyrelsen Uppsala, 1994).
classification: II
values: flora and hydrology.

Storgubben

One more area with ecological interest is Storgubben, situated a few kilometres east of the study site. This is an old pasture land, calcareous soil, with several for the region rare species like Maiden pink (*Dianthus deltoides*), Mountain Everlasting (*Antennaria dioica*) , "låsbräken" (*Botrychium lunaria*). (Länsstyrelsen Uppsala, 1994).
classification: –
values: –

Study site

There are no nature reserves (area protected by law) within the Beberg study site. Wetland areas are not as well represented in the study site as in the region. According to nature preserving program for the county of Uppsala (1987) there are only two small areas, classification II, within the study site.

Bredmossen

Situated a few kilometres north of Finnsjön. Bredmossen is a 40 hectare big bog with about 10% swale-forest.
classification: II
values: botanical and hydrological.

Träsket

A swamp situated east of Giboda. Most of the area is covered with swale-forest, to some extent extremely rich with typical species like orchids, Common butterwort (*Pinguicula vulgaris*), several carex-species. Deciduous forest appear in great abundance. The area is also important for birdlife and molluscs.
classification: II
values: botanical and zoological.

Comments – Areas of biological interest

Since this part of Sweden is rich with wetlands, a major part of the classified areas in the region and the study site are wetland type e.g. swamps, bogs, fens.

3.6 Fauna

3.6.1 Animal population

The number of mammal species in Sweden is geographically relatively equally distributed. Of Sweden's 66 species almost half are spread through-out the country, 22 are limited to the south part and 14 to the north part (Gustafsson & Ahlén, 1996).

Region & study site

The estimated population size for roe deer and moose in Uppsala county is 4 roe deer/km^2 and 0.7–1 moose/km^2 (winter population). Other species that occur are: hare (*Lepus sp.*), fox (*Vulpes vulpes*), badger (*Meles meles*), mink (*Mustela vison*), marten (*Martes martes*), beaver (*Castor fiber)* (S. Holm, Uppsala län jaktvårdsförening, unpubl.). Otter (*Lutra lutra*) occur in the big wetland area upstream Lövsta Bruk.

None of the four species of large carnivores have their present distribution in this part of Sweden. Three of them, except wolverine (*Gulo gulo*), are occasionally found further south trying to colonise lost areas.

The number of breeding bird species per region (Uppsala county is a part of the "Uppland/Sörmland region") is highest in this part of Sweden ca. 185 species/region (Gustafsson & Ahlén, 1996). The northern part of Uppland has also one of the highest number of breeding bird species per 25 km^2 compared to the rest of Sweden; mean value more than 100 species/25 km^2. Since the number of red-listed birds often reflects the total number of species in different parts of Sweden, also a large number of threatened species are to be found in the northern part of Uppland (Gustafsson & Ahlén, 1996).

For this part of Sweden the number of species/region of terrestrial vertebrates subdivided into reptiles/amphibians, birds and mammals is:

Reptiles and amphibians	13
Birds	190
Mammals	47

To be counted as belonging to one of the regions a species has to have at lest 5% of its total occurrence in that region (Gustafsson & Ahlén, 1996).

3.6.2 Sanctuaries for birds and seals

To protect the fauna, the County Administration has established sanctuaries for birds and seals along the coast. Public access is restricted during certain periods of the year. There are five sanctuaries in Tierps municipality: Stenarna-Klubbarna, Västerskian, Bleckan-Söderören, Svartören and Ledskärsängarna. None of them are within the Beberg region.

The running waters in the Beberg area are connected with the coast of Östhammar municipality. Only a few of the 15 sanctuaries in Östhammar municipality are directly affected by river Forsmarksån fresh water discharge (Djurskyddsområden, 1994).

Comments – Fauna

Because of deficiency in data for animal population sizes and distribution, the figures for the study sites often are based on information about larger areas and regions. It is not possible to transform biodiversity figures from 25 km^2 to the size of the study site without a large source of error.

3.7 Hydrology

3.7.1 Drainage basin and streams

The drainage basin in the Beberg area is connected with the coast through river Forsmarksån and river Olandsån. The water streams have high water flow and support the coastal area with plenty of fresh water (Länsstyrelsen Uppsala, 1987). The hydrology in the drainage basin of river Forsmarksån has been more or less frequently studied since 1960 (Haglund, 1972). The ground water level is between 22–33 m above sea level. Because of the flat topography, the water flows very slowly towards the north (Ekman & Sidenvall, unpubl.). A conceptual model to estimate the ground water flow in Beberg is treated elsewhere (in press).

Water flow in river Forsmarksån according to Länsstyrelsen Uppsala (1982).

Highest water flow	25.0 m^3/s
Normal water flow	2.2 m^3/s
Low water flow	0.4 m^3/s

There are several dams in river Forsmarksån. Most of them, for example Kvarndammen, are connected to Lövsta Bruk, where the ore-mining took place (Länsstyrelsen Uppsala, 1982).

3.7.2 Lakes

Most of the lakes in Uppsala county are eutrophic and contains more nutrients than the plant life can absorb. The great increase of nutrients are due to sewage water, which is rich in phosphorus and nitrogen and losses of nutrients from agriculture and forestry. The lakes in north-eastern part of Uppland are located in a an area with calcareous clay layers and are often inhabited by *Chara* algae. Most of the lakes are shallow, often because they are drained to gain or improve arable land (Länsstyrelsen & Landstinget Uppsala, 1982).

Further data on the lakes in Uppsala county is presented in Brunberg & Blomqvist (1998).

Region & Study site

There are no lakes within the Beberg study site, but the study site is surrounded by a chain of eight lakes, that are a part of the big wetland area upstream Lövsta Bruk (ca. 27 m.a.s.l.). All the lakes are connected with small streams. The wetland has a total area of 135 km^2 of which 8% are lakes and water flows, ca. 40% are peat bog, where the ditched area is about 10%, ca. 53% is forest and 1% is arable land (Haglund, 1972). All the lakes in the chain have a shore line sanctuary zone of 100 m.

The pH level in the lakes is between 7.1–7.7 and the mean depth about 2 metres (Haglund, 1972). Compared to other lakes in Uppsala county they contain less nutrients (Länsstyrelsen Uppsala 1982). Around the lake shore peat bog is most common, laying on 1–3 metre mud. The morass is mostly sedge fens together with fen woodlands (Haglund, 1972).

The chain of lakes

Finnsjön

Lake Finnsjön is the biggest lake in the sea chain, 6 km in length, 1/2–1 km wide and 4 metre deep at the most (Haglund, 1972). Some 60% of the shores around lake Finnsjön are rocky, but along the southern part of the lake the shore is sandy, with reed (*Phragmites australis*) and rush (*Schoenoplectus lacustris*).

Lake Lissvass & Ensjön area

Both lakes are 1–2 metre deep and are surrounded by wet fens and hard ground shores. The mixed forests consist of lime-tree (*Tilia cordata*), hazel (*Corylus avellana*) and grove-vegetation. The area has a biological value comparable to Florarna nature reserve (Haglund, 1972).

Lövsta Bruk Skälsjön & Norra Åsjön

An old cultivated landscape with several old deciduous trees. A major part of the agriculture is no longer in use and in some areas the vegetation is growing heavy. Skälsjön is an eutrophic lake with a maximum depth of 1.5 metres. The lake is very important for birdlife and nesting. Common birds are e.g., crane (*Grus grus*), black-throated diver (*Gavia arctica*), Osprey (*Pandion haliaetus*) and different waders, woodpeckers and falcons. Norra Åsjön is shallow and has a rich flora. The lake is surrounded by morass and is very important for birdlife and nesting (Haglund, 1972).

Södra Åsjön

Södra Åsjön is a shallow lake with a lot of rush. The water is regulated through a barrage in river Forsmarksån. By the eastern side of the lake there is a sedge fen with occurrence of quagmire. Some parts of the fen have been grazed earlier and are now wildwood with spruce, pine and several orchids. The area is of great importance for birds and wildlife (Haglund, 1972).

3.7.3 Wells and water use

According to Brunnsregistret (SGU) there are five drilled wells within the study site, situated in four different real estates.

Table 3-2. Drilled wells in Beberg study site (Brunnsregistret SGU).

Real estate	Depth (m)	Water flow (l/h)
Gåvastbo 1:1	30	900
(Imundbo)	16	400
Imundbo 1:18	23	400
Imundbo 1:9	40	700
Imundbo 1:22	61	700

The public water catchment closest to the study site is located in Lövsta Bruk (3 km). It is a drilled well that supply Lövsta Bruk village.

The drainage basin of river Forsmarksån is used as a recipient after treatment of the sewage water; Lövsta Bruk 130 persons and Forsmark 80 persons (Länsstyrelsen Uppsala, 1982).

Comments – Hydrology

The number of wells in the region/study site may be higher, because only drilled wells are registered in Brunnsregistret.

3.8 Land use

3.8.1 Forestry

Region

The landscape of Uppsala county is dominated by forest (see 3.4.2). The volume of total growing stock/ha of all species is 130 m^3 sk in the region and average annual growth is 4–5 m3 sk/ha. In the Beberg region the site quality (potential productivity, see Methods) is 7–8 m^3 sk/ha/year. The distribution of forests referring to age: 7.5–10% of the forest is fallow or clear-cut land, 20–30% are mature for final felling and the rest is growing (Nilsson, 1990).

Study site

The study site includes eight separate landowners, of which six are owned by private persons. The two major owners are the corporations Korsnäs AB and Lövsta Bruk, of which Korsnäs AB owns ca. 65% of the area. Most of the forest is productive (95%) and the rest (5%) is impediment.

The type of forests in the study site are distributed in pine 60%, spruce 30% and deciduous trees 10%, with a average annual growth of 6m^3 sk/ha. In average, the rotation period for the forest in the Beberg region is 85 years (R. Persson, Skogsvårdsstyrelsen Uppsala län, unpubl.).

3.8.2 Agriculture

Region & Study site

The arable and pasture land has changed over the years. Between 1951–1988 the arable land decreased with c. 30% and the pasture increased with 30% in this part of Sweden (Clason & Granström, 1992).

The productivity is affected by many factors e.g. sediments, climates and organisms and is divided on a scale from 1–10 where 10 has the highest productivity. The productivity of the arable land in the region is ca. 2 (on a scale 1–10) (Clason & Granström, 1992).

According to Lantbruksregistret (1995) there are 65 farmers/agriculture companies that own land in Österlövsta parish, where the Beberg study site is located (counting only companies with more than 2.0 hectare of arable land). Together they own an area of 68.56 km^2, of which 26.12 km^2 is arable land (25.92 km^2 in use).

Most of the arable land (9.46 km^2) is used as hay-meadow or pasture, 7.77 km^2 is used for spring barley, 4.67 km^2 is used for oats and 2.13 km^2 lie fallow. Most of the land is used for forestry (35.03 km^2) and a small part is pasture land (3.01 km^2).

Table 3-3. Contribution of arable land in Österlövsta parish and transformed figures to correspond with Beberg study site presented in km^2 and % (data from Lantbruksregistret 1995).

	Parish (km^2)	Study site (km^2)	Study site (%)
Arable land (total)	26.12	1.95	9.3
Hay-meadow	9.46	0.69	3.3
Spring barley	7.77	0.61	2.9
Oats	4.67	0.36	1.7
Fallow	2.13	0.15	0.7
(Pasture land	3.01	0.20	1.0)

3.8.3 Domestic animals

Region & Study site

In Österlövsta parish there were 990 cattle in 1993 of which 430 were dairy cows and 152 were for breeding. Sheep farming was not so common, altogether 284 animals of which 167 were lambs; the eastern part of the district had no sheep farming at all. Pig farming had 14 sows and 35 pigs for slaughter (Lantbruksregistret, 1994).

Table 3-4. The number of domestic animals per km² in Beberg study site transformed from Lantbruksregistret (1995). Meat production (kg/km²/year) and milk production (l/km²/year) presented as production (for calculation, see Methods).

Animals	study site (n)	n/km²	production (meat)	(milk)
Cattle	73	3.5	–	
Cow (breeding)	10	0.5	120	
Dairy cow	13	0.6	135	4800
Sheep (ewe)	8	0.4	12	
Pig (sow) n	1	0.05	73	
Pig (slaughter)	2	0.12	10	

Comments – Land use

One of the two major land owners in Beberg (Korsnäs AB), is a major company which owns forest land all over Sweden. Lövsta Bruk is a local owner only. The study site figures for domestic animals in Beberg are calculated from municipality data and are not exact figures like for Aberg site.

3.9 Recreation

3.9.1 General

The recreation possibilities in the Beberg region is concentrated to the big wetland area upstream Lövstabruk. It is famous for its nature of wilderness and the good conditions for canoeing and fishing (Haglund, 1972). Upplandsleden, a trekking route through Uppland, passes through the region. The last part of stage 8 of the route passes just outside the north-west corner of the Beberg study site. A youth hostel is located in Bovreten, in the centre of the study site.

3.9.2 Hunting

Region & Study site

Sweden has well-organised hunting (see 2.9.2). Today about 7.5–10% of the population in the region is hunting sometime during the year (SNA, 1993). The hunting-ground for Österlövsta parish is ca. 280 km² and support about 400 licensed hunters; only people from the region hunt in the study site. The ration for shooting moose in Österlövsta parish is one moose per 2 km². The average number of hunters in this region is 0.7–1/km² (S. Holm, Uppsala län jaktvårdsförening, unpubl.). 8000 persons hold temporarily hunting licence in Uppsala county every year and 5000 persons are members in the Uppsala game preservation society (S. Holm, Uppsala län jaktvårdsförening, unpubl.).

Table 3-5. Animals reported shot in "Österlövsta jaktvårdskrets" (hunting area 104.35 km²) from July 1996 to June 1997 (S. Holm, Uppsala län jaktvårdsförening, unpubl.). Calculations for meat production is presented in Methods.

Species	Parish (n)	Study site (n)	Meat kg/km²/yr
Moose	47	9	62
Roe deer	308	58	30
Hare	43	8	–
Fox	28	5	–
Badger	27	5	–
Mink	15	3	–
Marten	1	–	–
Geese	10	2	–
Duck	90	17	–
Dove	6	1	–
Woodcock	1	–	–
Capercaillie	5	1	–
Jay	5	1	–
Fieldfare	4	1	–
Crow	37	7	–
Magpie	11	2	–

3.9.3 Wild berries and mushrooms

Region & Study site

In the Southern part of Sweden citizens pick about 40 litres of berries per person and year. Since the Beberg site is largely forested, the figures for the study site will be about the same. If the values are transformed to the size of the study site and population, the amount of picked wild berries will be about 80 kg/year per km².

3.9.4 Open air baths

Region

About 60 holiday cottages are situated in Källviken, at the shore of lake Finnsjön. Most of the houses were built in the 1960's (Haglund, 1972). Because of the open air bath close to the holiday cottages and the beautiful environment is lake Finnsjön a valuable recreation area. No open air baths are situated in Beberg study site.

3.9.5 Sport-fishing

Sport-fishing for personal use is generally spread. Today about 37% of the Swedish population go fishing at some time during the year (Gustafsson & Ahlén, 1996) and 1–1.25% of the population in the region is sport-fishing more frequently (SNA, 1993).

Region

Angling is quite common in the lakes that are a part of the big wetland area upstream Lövstabruk. The most popular fishing-grounds are lake Finnsjön and lake Ensjön; both a part of the angling society "Finnsjön-Ensjön fiskevårdsförening", which is the only sport-fishing society in the lake system. During 1996, 205 (one-day) fishing licences and 90 (season) fishing licenses were sold (including 15 b-licenses for land owners). The fish species that are usually caught by anglers are pike (*Esox lucius*), perch (*Perca fluviatillis*) and the introduced pike-perch (*Stizostedion lucioperca*) (S. Andersson, fiskevärd, pers.com.). No data of the amount of fish caught in the lake system is available.

Comments – Recreation

Recreation quality is difficult to evaluate, since it often is a personal subjective opinion. The spontaneous out-door life is also difficult to evaluate because it is not registered in any way. The only captures that are continuously reported is moose shot per year, which leads to uncertainties of the values for hunting and sport-fishing. The values for picked wild berries are uncertain on a local level, because of transformation of values from larger regions.

3.10 Human population and occupation

3.10.1 Human population

Region

The number of citizen in Uppsala county is 10–40/ km^2 (SNA, 1991) and the number of citizen in Tierp municipality is ca. 20 275 (Ekman & Sidenvall, unpubl.). The number of resident people living in Tierps municipality was 13.4 per km^2 (1980) and 13.1 per km^2 (1994) (Strömquist & Pleiborn, 1996). If the settlements are excluded, it correspondence well with the average number for Uppsala county.

In prognosis for Östhammar municipality, a municipality next to Tierp, (Strömquist & Pleiborn, 1996), there are calculations made for the number of citizen in the area for the next 40 years. Because of the position close to the Uppsala-Stockholm region there will probably be an increase with 15%. The goal of the municipality is that the number of citizen will increase to about 30.000 individuals in the year 2010 (Ekman & Sidenvall, unpubl.).

Number of citizen, region/km^2	3.2	(data from SCB)
Number of citizen, municipality/km^2	13.1	(Strömquist & Pleiborn,1996)

The number of holiday cottages in the region 5–10/ km^2 (SNA, 1991).

Study site

In Österlövsta parish there were 1799 resident citizens in 1996. If the settlements are excluded, there were 850 resident people in the sparsely built-up area (Tierps kommun, 1996).

There were 20 citizen permanently living in the study site area in 1996 (1.0/km^2) (data from SCB, Statistiska centralbyrån).

3.10.2 Occupation

The number of jobs in Tierps municipality was 5,3/km^2 in 1980 and 4,7/km^2 in 1994 (Strömquist & Pleiborn, 1996). The number of people who are working in another municipality then where they live is 15–19% (SNA, 1991).

The annual gross production in Tierp municipality (1993) was 2500 millions kr/yr or 6,7% of the total gross production in Uppsala county (Strömquist & Pleiborn, 1996).

Table 3-6. Occupation by branch of industry in Tierp municipality compared to Sweden. People who works in the municipality (16–64 yrs.) irrespective of where they live (www.isa.se, 1997-10-10).

Branch of industry	Municipality (%)	Country (%)
Agriculture, forestry and fishing	8	2
Manufacturing, mining and quarrying	29	20
Electricity, water supply and waste disposal	1	1
Construction	7	6
Trade, transport and communication	12	19
Financial and business	5	10
Education and research	7	8
Social and personal service activities	21	20
Public administration etc.	3	6
Health and social work	2	2
Non specific activities	5	6

Comments – Human population

The number of persons living in holiday cottages is not included in the figure for permanent citizens living in the area. When comparing the number of citizen per km^2 in the municipality and in the region/site, a major difference is noticed. The low figure for the region and the study site is probably because the figure for the municipality includes urban areas.

3.11 The environment

3.11.1 Air pollution and deposition

A major part of the acid air pollutants NO_3, NH_4 and SO_4 comes from sources outside Sweden and only a small part of the air pollution in the region has a local source, e.g. sulphur ca. 15% (Bernes & Grundsten, 1992). The sulphur and nitrogen deposition per km^2/year in Beberg region is comparable to the mean values for Sweden. The mean value of wet deposition of both sulphur and nitrogen in Beberg region is, according to Bernes & Grundsten (1992), 400–600 kg/km^2/year (average 1983–87). According to Länsstyrelsen Uppsala (1996) the average amount of nitrogen deposition in Uppsala county is 500–900 kg/km^2/year and the deposition should decrease with 40% to avoid damage on the ecosystems. Most of all sulphur deposits (50–70%) in Uppsala county are wet deposition.

The pH level in precipitation is almost as low in Sweden as in Central Europe, pH 4.2–4.3 (Bernes & Grundsten, 1992). Values presented by Länsstyrelsen Uppsala (1996) show a bit higher pH level, 4.3–4.6.

The yearly average of sulphur and nitrogen deposition in ABC-berg is presented in table 2-13.

The fallout of lead (Pb) has been halved in Sweden since 1975, however it is still several times greater in south Sweden than in inner Norrland. The chromium (Cr) fallout in Sweden comes mainly from domestic sources. The amount of lead (Pb) and chromium Cr) disposal in Beberg region is 1500–2500 g/km^2/year and 200–400 g/km^2/year respectively (Bernes & Grundsten, 1992).

The fallout of cadmium (Cd) in Uppsala county was during the 80'ies ca. 0.5 ton/year. If these figures are transformed for the study site area it will be about 1.5 kg cadmium per year or ca. 70g/km^2 (Länsstyrelsen Uppsala, 1996).

Typical ozone concentration in Uppsala county during pollution episodes is < 120 µg/m^3 (Bernes & Grundsten, 1992).

3.11.2 Ground chemistry

The soil condition of Uppsala county is better than the average for Sweden. An alkalinity in the humus with a pH level of 4.3 is the most common, but were calcareous soils occur the pH level rise to above 6.0 (Länsstyrelsen Uppsala, 1996). Even though the pH level is fairly high, some 6% of the coniferous forest has 20% needle loses or more. The pH of the soil in Uppsala county (1992) was:

humus layer	>5.5
illuvial layer (B-horizons)	5.3–5.4

The nutrient leakage from the agricultural land is the major source of the nitrogen transported with running water. The estimated emissions of ammonia from farms and artificial fertilisers, is 100–200 kg NH^3/km^2/year (Länsstyrelsen Uppsala, 1996), which is a relatively high figure compared to the rest of Sweden. The amount of pesticides used in the south of Sweden is often high, because of a higher amount of cultivated land. Use of pesticides in agriculture (kg/km^2/year) is presented for Aberg, Beberg and Ceberg, table 2-14.

The amount of metals in forest soils has decreased in Uppsala county during the last 30 years. The amount of mercury in the humus layer for Beberg region is > 0.35 mg/kg organic matter and the amount of cadmium found in moose kidneys are 1.0–1.4 mg/kg/year (wet weight) (Bernes & Grundsten, 1992). More data of ground chemistry for ABC-berg is treated elsewhere (in press).

3.11.3 Running water and lakes

A major part of the lakes and the running waters in Uppsala county are shallow and eutrophic, see 3.7.2. Most of the running water have a relatively high buffer capacity, because of the calcareous soils. Therefore sensitivity for ground water acidification is low (Bernes & Grundsten, 1992). The total amount of phosphorous in the lakes is normally higher than 25–50 µg/l. The natural level for the running waters in Mälardalen have been approximated to 27.5 µg/l phosphorous and 0.8 mg/l nitrogen, but many streams and rivers have doubbled that value (Länsstyrelsen Uppsala, 1996). The pH level in lakes and running waters varies between 6.3–6.8. The river Forsmarksån has nutrients values close to the natural level and no obvious signs of decreasing alkalinity can be detected in the Forsmarksån catchment area either. According to Länsstyrelsen Uppsala (1996), the amount of nutrients ought to be reduced with 25–50% to avoid eutrophication.

Toxic pollutants in the lakes are often bound to the humus. In the running waters of Beberg region the amount of mercury in pike has a mean value of 0.42 mg/kg (wet weight) (Länsstyrelsen Uppsala, 1996). The background level for mercury in pike is calculated to 0.22 mg/kg muscle/1 kg pike (Wallsten, 1992) and a high value is more than 0.5 mg/kg (Länsstyrelsen Uppsala, 1996).

The environmental protection regulations classify about 25 types of industries as so hazardous for the environment that they must have a licence from the Franchise Board of Environmental Protection. Seven industries are in operation in the area around Beberg region, but none of them are within or upsteam the region. Several of the installations closest to the Beberg site are connected to the iron or forest industry.

Söderfors – steel industry
Karlholm – paper mill
Hallstavik – paper mill, combustion plant
Skutskär – forest production mill
Gimo – engineering works
Dannemora – mine
Forsmark – nuclear power plant

The discharges from Formarks sewage plant and Tierp sewage plant is far below the highest allowed level of toxic organic matter e.g. PCB, PAH, Toluen (Länsstyrelsen Uppsala, 1996).

3.11.4 Radio nuclides

Samples taken from the marine ecosystem in the area surrounding nuclear plants shows, that nuclear power plants discharge increase the amount of radio nuclides in the environment, however well below harzadous levels. The dominating nuclide appearing in the samples is cesium 137, which has its origin from the Chernobyl accident (Bengtsson et al. 1996).

The level of cesium 137 on the ground after Chernobyl 1986 was 10–30 kBq/m^2. The mean surface activity of cesium 137 in June 1986 was 2100 Bq/kg dw and lichen had about 30 000 Bq/kg d w (Gustafsson et al. 1987). At Beberg study site an essential part of the activity was deposited as hot-spots (active particles). Information about distribution and migration of radio nuclides after the Chernobyl accident in Beberg area is presented in Gustafsson et al. (1987). The activity of radio nuclides in Beberg region is still high in fresh water fish, wild game and mushrooms (Länsstyrelsen Uppsala, 1996).

Around the Forsmark nuclear plant a higher amount than the background level of cobalt 60, manganese 54 and cesium 137 is detectable (Bengtsson et al. 1996).

Comments – The environment

The data for toxic pollution is often unspecified because of measurement problems and local and temporal differences in values. In most cases the values for Beberg are the same as for the municipality or the county.

3.12 Historical overview

The first documented settlements are from 2000 BC, when people began to cultivate the great peneplain of Uppsala. Probably has there never been so much agriculture and open land as during the Middle Ages. The meadows and pastures became the most important land use, because of substantially cattle breeding (Gustafsson & Ahlén, 1996). During the 19th century the old mosaic landscape disappeared and the rich soil in the peneplain became large-scale agriculture. Only a small part of the ancient landscape is left today.

Between the 11th to the 19th century the forestry was a big industry in the region. From the 17th century to the beginning of the 20th century, charcoal was used to run the mining industry in Lövsta Bruk and Österby Bruk. The water from river Forsmarksån was later regulated for the ore-mining. These places are today of national importance for the culture history, NRL 2:6 (Hogdal, 1993). Uppland has never been so forested as it is today. In several areas you find the first generation of woodland since the first settlements, as a result of agriculture (Länsstyrelsen & landstingen Uppsala, 1982).

The lakes in the Beberg region became separate from the Baltic sea about 2500–2000 years BC. Today only some 10% of the original lakes are left, because of the shore level displacement and sedimentation (Haglund, 1972). Fishing was important for the early settlers, for both farmers and fishermen. From the beginning of the 20th century the fishing was carried out more often at the open sea, by inhabitants of the archipelago.

Hunting was intensive during the 19th century and many species were locally extinct, e.g. bear, beaver, wolf. For the last 100 years the hunting has been of little importance and is today carried out in a form of game management and recreation.

3.13 Predictions of the future

Nature is dynamic. In prehistoric times changes took place slowly, in step with changes in the climate, but today human activity cause the greatest changes. Nearly all of the nature that we see today is transformed through human activity. The changes that will be in the future is therefore reflecting our decisions how to take care of the environment. Land use changes continuously towards large-scale forestry. With an increase of forest land, the amount of open landscape like arable land, meadow and pasture will decrease even more than today. Like in Aberg site, the environment may become more homogeneous and the number of species connected with the open land is reduced. New computer technics (IT) makes it possible for people to live and work in different areas with retained real wages. This trend decreases the amount of small-scale, often unprofitable agriculture's, and the forest habitat increases even more. Some of the land will be kept open as long as the government subsidise the landowners.

Because of Bebergs position close to the urban areas Uppsala and Stockholm, there is a possible increase of the population size with ca. 15% in the next 40 years (Strömquist & Pleiborn, 1996). The goal of the municipality is that the number of citizen will increase to about 30.000 individuals in the year 2010 (Ekman & Sidenvall, unpubl.). If the increase will appear in Beberg study site is uncertain, while areas closer to the coast and the archipelago, Östhammar municipality, probably are more attractive.

In a longer perspective, climate changes and shoreline displacement are of importance for the development of Beberg region. New lakes will be formed due to the land uplift and the cut off bays, while other will disappear due to increased growth and increased sedimentation (some 0.2 mm per year) (Haglund, 1972). The future for Aberg, Beberg and Ceberg is further discussed later (see Discussion).

4 Ceberg

4.1 Study site

4.1.1 Location

The hypothetical Ceberg study site is located in the northern part of Västernorrland county, in Örnsköldsvik municipality, Gideå parish; position 63° 28' N, 19° 03' E. The major settlement in the region is Örnsköldsvik situated ca. 30 km south-west of the study site. Map, "ekonomisk karta över Sverige" 19J 9c Flisbäcken, 19J 8c Gideå bruk, 19J 9d Skademark.

Västernorrland county	21678 km^2
Örnsköldsvik municipality	6700 km^2
Gideå parish	473 km^2
Ceberg study site	32 km^2

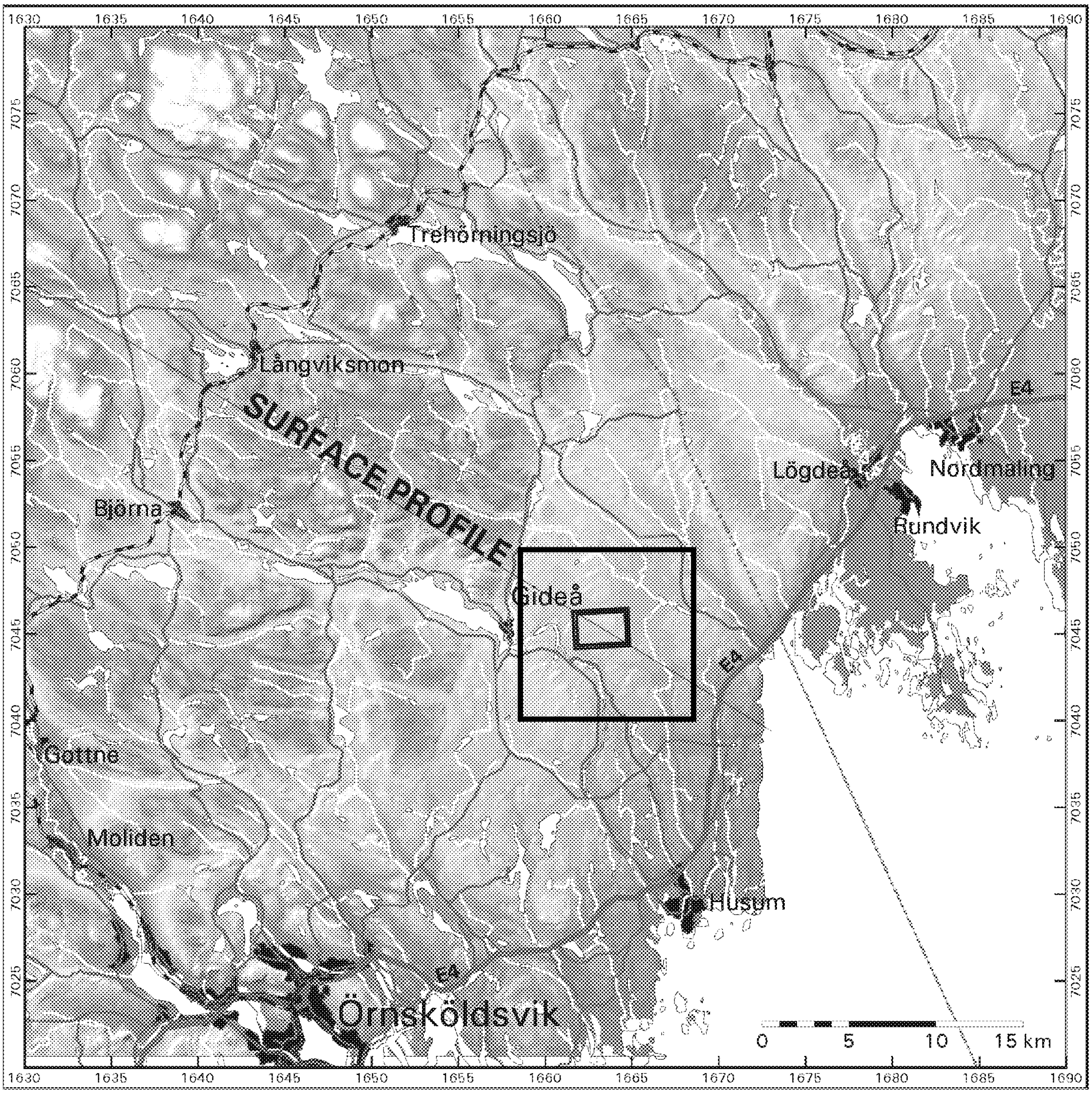

Figure 4-1. Map of Ceberg study site and region.

4.1.2 General description

The site is situated on a flat plateau, surrounded by fracture zones, which can be observed as lineaments in the terrain. Geological the area belongs to the Sveco-Karelian mega unit (c. 1 800 million year). The dominating rock type is a migmatized veined gneiss of sedimentary origin. In a smaller scale the gneiss consist of fine-grained biotite rich paleosom and quartz-feldspar rich neosom (Gustafsson et al. 1987; Ahlbom et al. 1991). The migmatite granite is the subordinate rock type. The amount of exposed bedrock is fairly high (Ekman & Sidenvall, unpubl.).

A major part of Ceberg area is forested interchanging with mires (Gustafsson et al. 1987). Large-scale forestry is the major land use, where species like pine and spruce are cultivated. Marsh and peat land are also common in the area. The water divide is between two drainage basins; one is drained south-west towards river Gideälven and the other is drained east towards river Husån. The coastal region, south of the study site, is famous for the dramatic landscape, characterised by high mountains and faults.

A geological description of the Gideå area is given by Ahlbom et al. (1983).

4.1.3 Previous investigations

Geological investigations of study sites in the Swedish programme for disposal of spent nuclear fuel has involved several sites. One of the investigated sites is Gideå (Ahlbom et al. 1991). This site was investigated during the years 1981–1983, with the main objective to provide the site-specific data for the performance assessment for the KBS-3 report (Ahlbom et al. 1991). A 700 m deep borehole was drilled in 1981 in the central part of the study site. The result was regarded favourably and a decision to complete the investigations was taken. Up to date a total number of 13 cored boreholes have been drilled in the Ceberg study site (Ahlbom et al. 1991).

4.2 Climate

4.2.1 Climatic region

Ceberg is located in the snow climates, referring to the Köppen climate classification, key letters Dfb. Warmest month mean over 10°C and the coldest month mean under –3°C, sufficient precipitation in all month and at least 4 month have means over 10°C (Strahler & Strahler, 1989). According to Kaj Petersen (1984), this part of Sweden is included in the climate zone with the key letters DE_2, which is a further differentiation made from the Köppen system. The mean value for the warmest month is 10°C–16°C and the mean value for the coldest month is –3°C, positive evapotranspiration.

The vegetation period in Sweden (mean daily temperature above 6°C), alters between 250 days in the southern region and 130 days up north. The vegetation period in the Ceberg region is about 160 days (NMR, 1984). The period with highest precipitation is autumn.

Since the Ceberg area is located close to the Baltic sea (c. 5 km), there is a coastal effect on the climate.

4.2.2 Precipitation and runoff

The central part of Ceberg study site constitutes a recharge area for ground water, whereas a local discharge area is located in the lowland towards the east. The shallow ground water flow coinciding with the river Gideälven in the south-west and the river Husån in the east (Ahlbom et al. 1991).

Region

Annual precipitation for the Ceberg region is ca. 800 mm/year. The highest measured precipitation occurs in September with mean value of 80–90 mm and lowest values is during February–May with mean precipitation value of 30–40 mm/month (estimated mean values 1961–1990) (Raab & Vedin, 1995).

The runoff in an area is direct related to the precipitation and the evapotranspiration. The mean value for Ceberg region is 300–400 mm annual runoff (1961–1990). The season with the highest mean value is the spring runoff, March–May, about 200–300 mm (Raab & Vedin, 1995).

The water flow in Västernorrland county has increased since the 1960'ies, which causes an increase of nutrient transportation to the coastal area, see under the headline "The environment". The high water flow may be due to higher precipitation and more clear-cut woodland in the county (www.y.lst.se, 1997-10-20).

Study site

The meteorological station at Örnsköldsviks airport, ca. 10 km south of Ceberg, has been regarded as representative for the study site (data from SMHI). The station is situated at 103 m above sea level, which coincides with the mean altitude of Ceberg study site, 107 m above sea level. The annual mean precipitation is 660 mm (unadjusted) and 765 mm (adjusted) (Gustafsson et al. 1987).

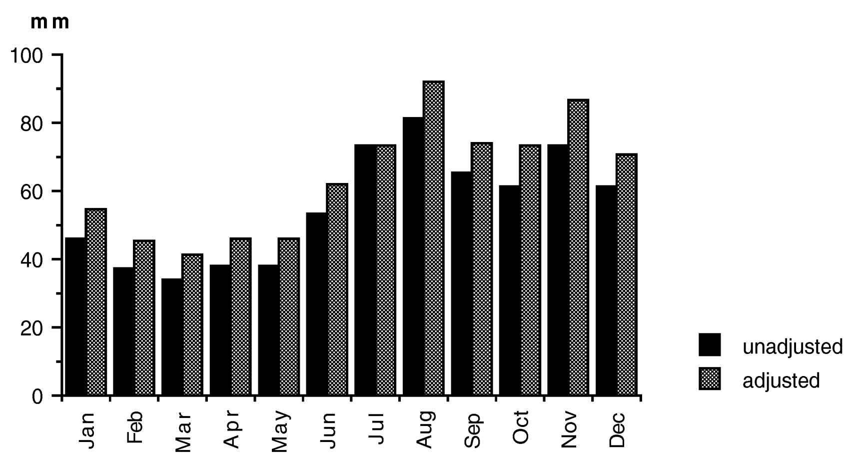

Figure 4-2. *Estimated monthly mean precipitation (mm) at Örnsköldsvik airport (Gustafsson et al. 1987).*

The water balance is determined by the precipitation, evaporation, runoff, change in storage and ground water flow through boundaries of the area. The water balance of Ceberg study site has been calculated by Ahlbom et al. (1983).

Adjusted precipitation	765 +/– 25 mm/yr
Actual evaporation	410 +/– 25 mm/yr
Runoff	345 +/– 10 mm/yr

4.2.3 Temperature

Region

The coldest month in the Västernorrland county is January with a mean temperature of –9°C and the warmest months, July–August, have a mean temperature of +15°C (mean values, 1961–1990) (Raab & Vedin, 1995).

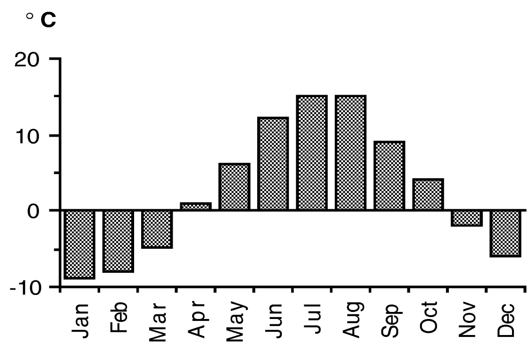

Figure 4-3. *Monthly mean temperature (°C) in Ceberg (1961–1990) (data from Raab & Vedin, 1995).*

Study site

The annual mean temperature for the Ceberg region is c. 2.7°C (Gustafsson et al. 1987).

4.2.4 Wind and air pressure

Since Ceberg study site is located close to the coast of the Baltic sea it may have an effect on the local climate. The wind circulation sometimes pushes inland, up to 20 km, with a speed of 5–10 m/s (Raab & Vedin, 1995).

The mean air pressure in this part of Sweden varies very little over the year. The dominating value during the year is 1011 hPa (Raab & Vedin, 1995).

4.2.5 Snow cover and ice

Region

The first lasting cover of snow in Västernorrland county can fall as early as in the end of October, but most common is that the lasting blanket of snow comes in November and disappear in April. The probability of a white Christmas in this area is 90%. The average snow depth for the period is 30 cm and the maximum is 130 cm (mean values 1961–1990) (Raab & Vedin, 1995).

The proportion of snow is about 33% of the annual mean precipitation. The durability of the snow cover varies considerably between years, but in general the durability of the snow cover in the Ceberg region is 160–167 days (snow cover duration data from the stations Mellansel and Nordmaling) (Gustafsson et al. 1987). Ground frost depth, without snow, in this part of Sweden is ca, 100 cm or more. Lakes and streams at the Ceberg site is generally frozen from the beginning of November until the middle of May, ca. 180 days (Ångström, 1974).

Comments – Climate

Air pressure varies little for hypothetical ABC-berg, both inter annual and between the sites. The climate figures for Aberg study site correspond with the Köppen and the Petersen climate classification (see Temperature, Precipitation and run off).

4.3 Physical geography

4.3.1 Land forms

The Ceberg region is a part of the peneplain area close to the coast line. The region boarders to the undulating hilly land region, which appears further into the land (NMR, 1984).

4.3.2 Soil

The most common soil unit in the Ceberg region is podzols. Luvi-cambisols and histosols occur to some extent (NMR, 1984). The soil cover consists primarily of till and sand, overlain in depressions by peat or moraine (Gustafsson et al. 1987). The eastern part has a high degree of exposed rock. Large areas are covered by peat, see 4.4

Table 4-1. Soil composition and soil units in Ceberg region. Data from Nordiska Ministerrådet (1984). (for definition of soil units, see Methods).

	Soil composition	Soil unit
Most common (>50%)	Moraine	Podzols
Other soils (<50%)	Sand & fine sand	Luvi-cambisols
	Clay & silt	Histosols

4.3.3 Shore level displacement

Most of the Swedish land still has a raised shoreline because of the latest glaciation. In this part of Sweden the raise begun for about 10.000 years ago BP (Björck et al. 1988). Today the uplift is a result of isostatic and tectonic movement in the earth crust, see 2.3.3.

Region & Study site

The region and study site is situated below the highest coastline; in this region 256 metre above sea level (Hammersland, 1997). The plateau, on which the site is situated, is relatively flat, 80–130 metres above sea level (Gustafsson et al. 1987). The observed shoreline uplift in the Ceberg region is highest in Sweden, c. 8 mm/year (Påsse, 1996). The highest coast line (HK) is also found in this area.

4.4 Vegetation

4.4.1 Vegetation zone

The Ceberg study site is a part of the Southern boreal zone, which contains the woodlands north of the biological Norrland boundary (Sjörs, 1967). North of "Limes Norrlandicus" there is a distinct change into the major Boreal zone, which in the east connects to the Taiga. There is some occurrence of nemoral trees in the Southern boreal zone. The Hilly lands of the South boreal region contains of 500–750 different species of vascular plants (NMR, 1984) and is the boarder for south Scandinavian species and Sub alpine flora (Översiktsplan, 1992).

4.4.2 Land class distribution and landscape

The landscape in the region is dominated by forests, that covers about 75% of the county area (Nilsson, 1990). The categories of coniferous forests compose 90% of the total forest area and is divided into: spruce forest (40%), pine forest (25%) and mixed forest (25%) (Gustafsson & Ahlén, 1996). The major type of undergrowth is the dwarf shrub type, which is the most common of the ground vegetation types in Sweden and is particularly dominant in the north of Sweden (Gustafsson & Ahlén, 1996).

The most common pasture type is Ancient open pasture (55%), Ancient shore pasture (35%) and Ancient pasture with mixed deciduous trees (10%). The most common type of meadow land is Ancient open meadow (70%), Ancient freshwater-shore meadow (10%) and other (20%) (Gustafsson & Ahlén, 1996).

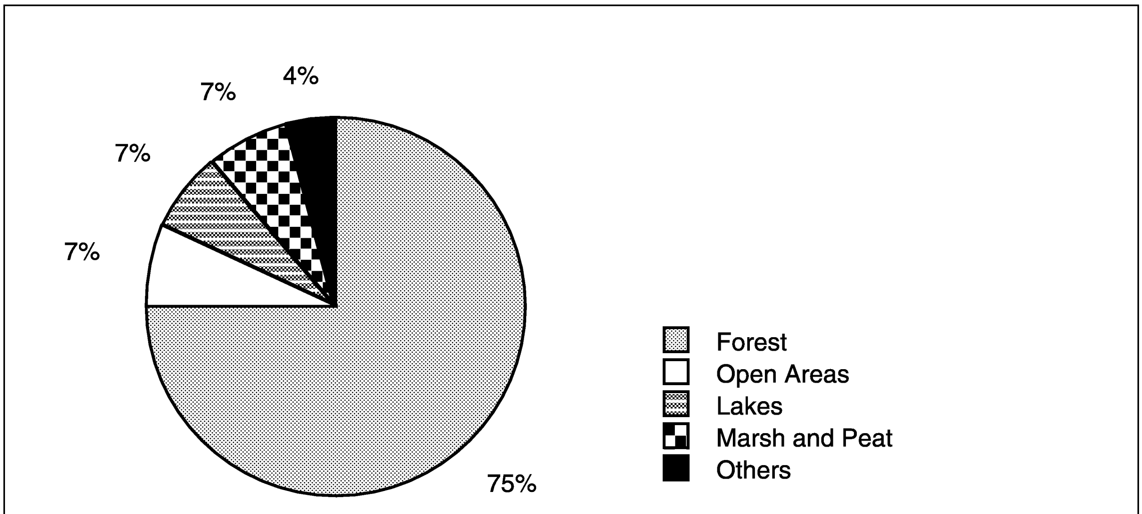

Figure 4-4. *Land class distribution in Västernorrland county (Nilsson, 1990).*

The northern part of the coastal area "Höga kusten" is located just south of the study site. The area ranges from Storfjärden by river Ångermanälven to Skagsudde. The dramatic landscape is characteristic with high mountains and faults. The sediment in the depressions are fertile, due to the silty sea sediment. The area is of great importance for recreation and tourism and has high nature and cultural values (Översiktsplan, 1992).

4.4.3 Description of vegetation

Region

Large-scale forestry is the major land use and an important industry in Örnsköldsvik municipality (Översiktsplan, 1992). The most common trees are pine (*Pinus sylvestris*) and spruce (*Picea abies abies*), with only a small occurrence of deciduous forest. Plant species from the southern part of Sweden may occur in areas close to the coast, but most of the region has a poorer flora, without contribution of herb species from the south. Only a small part is arable land, which is concentrated around lakes, rivers and the coastal area. Marsh and peat land are also common in the area. Many of the fens and marsh lands are ditched to gain forestry land or to make way for turbaries.

Study site

The inner area of the study site is like the region characterised by an effective forestry, mostly consisting of young pine forest. Together with the coniferous forest the major vegetation type is wetland, mostly fen and marsh land. Where the degree of exposed rock is high, pine forest on outcrops of bedrock is common.

Several big fens within the site, e. g. Stormyran (east part of the study site) are ditched. Some of the area has been taken into forestry and the land owner (MoDo skog AB) also have a concession for a turbary. Only a small part of both Ceberg study site and the region contains arable land, which is concentrated to water, i.e. the river Gideälven and the brook Flisbäcken.

4.5 Areas with biological interest

There are six areas of major biological importance (two of national interest) in the region. The only classified area in the study site is also of major cultural importance. About 15 km outside the region, another important area, "Nedre Gideälven" is located; connected with the study site through river Gideälven. Criteria for biological classification, see Methods.

Region

Gissjön

Gissjön is located ca. 5 km south-west (upstream) of the study site. The lake is situated below the highest coastline (HK) and contains Baltic ice sea relicts. The west part has a delta of great importance for birds. Lake Gissjön has high biological value because of a great number of fish species. The lake is regulated and contains water storage for the power plant. The lake is surrounded by pastures and fields (Vattenöversikt 2, 1986; Naturvårdsplanering DANI, 1997).
classification: I (national interest)
values: botanical, geological, zoological and recreational

Skallberget

The cave “Skallbergsgrottan” is a large cave in archean rock and is situated about 3 km west of the study site, outside Gideå village. Because of its complicated genesis it is one of the most interesting archean rock caves in Sweden. The west slope of “Skallberget” is of botanical interest.
classification: I
values: geological and botanical

Skademarksmyren

Located ca. 5 km south of the study site. It is not directly connected with the Ceberg catchment area. Skademarksmyren is a well shaped bog, a vegetation type unusual for Örnsköldsvik municipality. (Naturvårdsplanering DANI, 1997) (Översiktsplan, 1992).
classification: I
values: biotop, geological

Husån

River Husån passes through the eastern part of the study site and is a part of Ceberg catchment area. River Husån is a good example of an humus-rich oligothrophic stream. The water varies from slow water flow and deltas to waterfalls (up to 19 m). Species adapted to running water are common e.g. grayling (*Thymallus thymallus*), river pearl mussel (*Margaritana margaritifera*) and noble crayfish (*Astacus astacus*). Otter (*Lutra lutra*) and beaver (*Castor fiber)* are seen frequently in the river. Great effort are done to re-introduce brown trout (*Salmo trutta*) and river lamprey (*Lampetra fluviatilis*) in the water system. Several species have been able to reach the river since the fish-way was made in the river outlet (Naturvårdsplanering DANI, 1997) (Spens et al. 1991).
classification: I
values: zoological

Ön i Trångforsen

A small island downstream river Gideälven, south of the study site. This biotop is of importance for plants and animals (Översiktsplan, 1992).
classification: –
values: biological

Nedre Gideälven

Located outside the Ceberg region, but is connected with the site through river Gideälven. This part of the river is of national importance for sport-fishing and recreation and also an important reproduction area for several fish species like brown trout, salmon river lamprey, pike-perch (*Stizostedion lucioperca*) and grayling. Plenty of fish are reintroduced every year, mostly brow trout and salmon. (Vattenöversikt 2, 1986; Spens et al., 1991).
classification: I
values: hydrological, zoological

Study site

There is one area of biological interest within the study site.

Gideå bruk

An ancient iron industry environment, famous for its old cultural landscape and botanical value (protected by law) Kettles are common in the area (Naturvårdsplanering DANI, 1997). Old iron industries from the 19th century are rare from an industrial historical point of view and Gideå bruk is an example of a well preserved industry (Vattenöversikt 2, 1986).
classification: I (national interest)
values: botanical

4.6 Fauna

4.6.1 Animal population

The number of species of mammals in Sweden is geographically relatively equally distributed. Of Sweden's 66 species almost half are spread through-out the country, 22 are limited to the south part and 14 to the north part (Gustafsson & Ahlén, 1996).

Region & Study site

The animal species living in the Ceberg region are connected to forest or water habitats. Mammals like otter and beaver can be seen within the site and the region (Översiktsplan, 1992). The estimated population size for moose (*Alces alces*) in Västernorrland county is 0.6–0.7 moose/km^2 (winter population). The population of roe deer (*Capreolus capreolus*) in the area is very small and the hunting is negligible (H. Rönnbäck, Gideå bruk jaktvårdsområde, pers.com.).

Of the four species of large carnivores, one have its present distribution in this part of Sweden, Lynx (*Lynx lynx*). Brown bear (*Ursus arcto*) is frequently seen in the area (Hans Rönnbäck, pers.com.). Wolf (*Canis lupus*) is occasionally found, trying to colonise lost areas (Gustafsson & Ahlén, 1996).

The number of breeding bird species is quite high in this part of Sweden, ca. 163 species/region (Västernorrland county is a part of "mid-Sweden region") (Gustafsson & Ahlén, 1996).

For this part of Sweden ("mid-Sweden" region) the number of species/region of terrestrial vertebrates subdivided into reptiles/amphibians, birds and mammals is:

Reptiles and amphibians	10
Birds	181
Mammals	40

for definition, see 3.6.1.

4.6.2 Sanctuaries for birds and seals

To protect the fauna, the County Administration has established sanctuaries for birds and seals along the coast. Public access is restricted during certain periods of the year.

There are six sanctuaries in the coastal area of Örnsköldsvik municipality: Flasan-Gråbruten-Ratan, Värsingsklubbarna, Västerskär-Mellanskär, Själbådan, Kankgrund and Öfjärden. None of them are within the Ceberg region, but Kankgrund is located in the outlet area of river Husån and river Gideälven (Översiktsplan, 1992).

Comments – Fauna

Because of deficiency in data for animal population sizes and distribution, the figures for the study sites often are based on information about larger areas and regions.

4.7 Hydrology

4.7.1 Drainage basin and streams

The central part of Ceberg study site constitutes a recharge area for ground water, whereas a local discharge area is located in the lowland towards the east. The shallow ground water flow coinciding with the river Gideälven in the south-west and the river Husån in the east. The topography of the ground water table is rather flat, ranging from about 80 m to 125 m above sea level (Ahlbom et al. 1991). Several big fens within the site, for example Stormyran (east part of the study site) have been ditched, which may have an effect on the water flow in the drainage basin. River Gideälven has a runoff area of 3441 km^2 with a mean water flow of 32 m^3/s.

The regulation level has not been calculated, but the river has two dams (www.y.lst.se, 1997-10-20). The power plant capacity in river Gideälven is of national importance, NRL 2:8, but also the nature in the area is worth protecting, NRL 2:6. Sewage water is mainly produced in industries and settlement sewage plants (Ekman & Sidenvall, unpubl.).

4.7.2 Lakes

Lakes and running water cover ca. 5% of the total area of the municipality. About 80% of the lakes have low alkalinity and pH level and are artificially limed (Vattenöversikt 3, 1986; Hammersland, 1997). Sport-fishing is a very important part of the outdoor-life in Örnsköldsvik municipality. The running water contain plenty of common fish species e.g. pike (*Esox lucius*), perch (*Perca fluviatillis*) and pike-perch and some red listed species, for example: grayling and brown trout (Spens et al., 1991).

Region

There are 12 lakes within Ceberg region. Lake Gissjön is the largest lake in the region and has several biological values; for example has the lake the largest number of fish species of all lakes in the municipality (see 4.5).

Study site

There are three small lakes within the Ceberg study site: Stentjärnen, Hömyrtjärnen and Bladtjärnen. None of them are noted as particularly biological or economical important.

Coast

The coast outside Ceberg study site is a fishing area of national interest; most because of the trawling in the area south of Skagsudde and the area around Örnsköldsvik harbour (Översiktsplan, 1992).

4.7.3 Wells and water use

According to Brunnsregistret SGU there are two drilled wells within the study site, situated at different real estates.

Table 4-2. Drilled wells in Ceberg study site (Brunnsregistret SGU).

real estate	depth (m)	water flow (l/h)
Höjtjärn 1:4	100	600
Norrgissjö 2:2	48	400

The public water source closest to Ceberg is situated in Gideå, upstream the study site, and supplies the village with fresh water. The major water catchment in the region is "Gideå heden", situated downstream from the site, just north of Örnsköldsvik airport.

Comments – Hydrology

The number of wells in the region/study site may be higher, while only drilled wells are registered in Brunnsregistret.

4.8 Land use

4.8.1 Forestry

Region

Forestry is the most important industry in Örnsköldsvik municipality (Översiktsplan, 1992). The volume of total growing stock/ha of all species is 110 m^3 sk in the region (Nilsson, 1990). In the Ceberg region the site quality (potential productivity, see Methods) is 3–5 m^3 sk/ha/year. The distribution of forest referring to age: 5–7.5% of the forest lie fallow or is bare land and 30–40% are mature for final felling (Nilsson, 1990). The western part of the region is winter area for reindeer (*Rangifer tarandus*) (Clason & Granström, 1992).

Study site

The major land owner is MoDo skog, that owns ca. 80% of the area. The other 20% is owned by several owners. Most of the forest is productive (90–95%) and the rest (5–10%) is impediment (wetland).

The type of forests in the study site are distributed in pine 45%, spruce 40% and deciduous trees 15% (data from K.E. Södersten, MoDo skog Örnsköldsvik, unpubl.), with an average annual growth of ca. 4 m^3 sk/ha (Nilsson, 1990). In average, the rotation period for the forest in the Ceberg region is ca. 90 years (K.E. Södersten, MoDo skog Örnsköldsvik, pers.com.).

Several big fens within the site are ditched, for example Stormyran (east part of the study site). Some of the area has been taken into forestry and the land owner (MoDo skog) has a concession of ca. 360 ha for a turbary.

4.8.2 Agriculture

Region & Study site

The amount of arable and pasture land has changed over the years. Between 1951–1988 the arable land decreased with c. 30% and the pasture increased with ca. 90% in this part of Sweden (Clason & Granström, 1992).

Örnsköldsvik municipality has today about 180 km^2 arable land (Översiktsplan, 1992). A comparison of arable land productivity in Sweden have been presented by Clason & Granström (1992). The productivity is affected by many factors e.g. soil units, sediments, climates and organisms and is divided on a scale from 1–10 where 10 has highest productivity. In Ceberg region the productivity is ca. 2.

Table 4-3. Contribution of arable land in Gideå parish and transformed figures to correspond with Ceberg study site presented in km^2 and % (data from Lantbruksregistret 1995).

	parish (km^2)	Study site (km^2)	Study site (%)
Arable land	16.1	1.1	3.4
hay-meadow	10.6	0.7	2.2
Grazed ley	2.3	0.2	0.5
Spring barley	1.2	0.1	0.2
Other grain	0.2	0.01	–
Potatoes	0.1	0.01	–
(Pasture land	1.5	0.1	0.3)

According to Lantbruksregistret (1995) there were 100 farmers/agriculture companies that own land in Gideå parish and five in the study site (counting only companies with more than 2.0 ha of arable land). The farmers in Gideå parish owned an area of 94.86 km^2, of which 16.11 km^2 was arable land (ca. 0.2 km^2 were not in use).

Most of the arable land (10.55 km^2) was used as hay-meadow and 2.29 km^2 was grazed ley, 1.19 km^2 was used for spring barley, 0.11 km^2 was used for potatoes, 0.25 km^2 was used for other grain and 0.83 km^2 lie fallow. Most of the land was used for forestry (69.55 km^2) and a small part was pasture land (1.52 km^2).

4.8.3 Domestic animals

Region & Study site

In Gideå parish (1995) there were a total number of 660 cattle of which 296 were dairy cows and 54 were used for breeding. Sheep farming had altogether 165 adult animals and 194 juveniles. Pig farming had 3 sows and 15 animals for slaughter; the number of hens was 10 762 animals (Lantbruksregistret, Västernorrlandslän, 1995).

Table 4-4. The number of domestic animals in Gideå parish and Ceberg study site transformed from Lantbruksregistret (1995). Meat production (kg/km²/year) and milk production (l/km²/year) (for calculation, see Methods).

Animals	Parish	Study site	n/km²	production	
	(n)	(n)		(meat)	(milk)
Cattle	660	40	1.4	–	
Cow (breeding)	54	3	0.1	26	
Dairy cow	296	19	0.6	135	4800
Sheep (ewe)	165	10	0.3	9	
Lamb	194	12	0.4	–	
Pig	18	1	–	–	
Hen	10762	–	–	–	

4.8.4 Reindeer management

Reindeer occur in the north-west part of the municipality during wintertime. The study site is located at the boarder of these reindeer grazing areas.

Comments – Land use

The study site figures for domestic animals in Ceberg are calculated from municipality data and are not exact figures like in Aberg site.

4.9 Recreation

4.9.1 General

A major part of the recreation and out-door life in the region is concentrated to water, river Gideälven, river Husån and the coastal area. Several rivers upstream from the site are famous for their good canoeing conditions (Vattenöversikt 2, 1986). One example is river Gideälven, north lake Gissjön, which is uninfluenced by power plants and is suitable for canoeing (Kanotleder, 1979). The region also includes areas of wildlife suitable for out-door activities. In wintertime the region is frequently used for skiing.

4.9.2 Hunting

Sweden has well-organised hunting, see 2.9.2. Today about 2.5–5% of the population in the region is hunting sometime during the year (SNA, 1993).

Region & Study site

The major hunting-ground in the Ceberg area is "Gideå bruk jaktområde" (62.93 km^2), which support 12 licensed hunters. All of them are a part of the local hunting team, two hunters are local and the rest are from the municipality. Since most of the hunting-ground is owned by MoDo skog, some moose hunting by the company occur.

The ration for shouting moose in Gideå parish is ca. one moose per 300 hectare. During 1997 the ration for moose hunting in "Gideå bruk jaktområde" was 15–20 animals (Rönnbäck, Gideå bruk jaktvårdsområde, pers.com.).

Table 4-5. Animals reported shot during 1997 in "Gideå bruk jaktområde" and transformed figures for Ceberg study site. Calculations for meat production is presented in Methods.

	Gideå bruk Jaktområde	Study site	meat kg/km^2 year
Moose	20	10	39
Hazel-grouse	5	2	–
Capercaillie	3	1	–
Hare	5	2	–

The population of roe deer in the area is very small and the hunting is negligible (H. Rönnbäck, Gideå bruk jaktvårdsområde, pers.com.).

4.9.3 Wild berries and mushrooms

Picking wild berries and mushrooms plays an invaluable role for recreation, see 2.9.3.

Region & Study site

In the northern part of Sweden citizens pick about 350 litres of berries per person and year. Since the Ceberg site is largely forested, the figures for the study site will be the same. If the values are transformed in correspondence with the size of the population in the study site, the amount of picked wild berries will be 328 l/km^2/year.

4.9.4 Open air baths

There are no open air baths in the study site area. Some do occur in Ceberg region along the shore of river Gideälven and lake Gissjön (Vattenöversikt 3, 1986). Two are located by lake Gissjön.

4.9.5 Sport-fishing

Sport-fishing is generally spread. Today about 37% of the Swedish population go fishing at some time during the year (Gustafsson & Ahlén, 1996).

Region

There are ca. 50 fishery management areas and fishing societies in Örnsköldsvik municipality. The number of people sport-fishing has increased over the years, while the amount of commercial fishermen in the region has decreased significantly the last decades. Today only 11 persons are active fishermen in Örnsköldsvik municipality (Översiktsplan, 1992) and 0.5–0.75% of the population in the region is sport-fishing (SNA, 1993). Both river Gideälven and river Husån are popular recreation and fishing areas and a lot of money is spent every year to improve the environmental conditions, e.g. liming and reintroducing fish species (Översiktsplan, 1992).

Fish farming occur to some extension in the municipality. According to Översiktsplan för Örnsköldsviks kommun (1992) there are six permissions for fish farms; one is situated in a lake and the others are by the coast (two in the catchment area for Ceberg study site). Today only two of them are running, of which one of them (Köpmanholm) produce ca. 400 tons/year (J. Hammersland, Örnsköldsviks kommun, pers. com.).

Study site

Three fishery management areas are of importance for the study site: Nedre Gideälve, Nedre Husån and Gideå västra. These areas are covering the Ceberg catchment area, from lake Gissjön to the coast.

Nedre Husån

The annual number of fishing licence that are sold is 175 –200, where 50% are season licences, 25% week licences and 25% day licences. A major part of the fishermen are local habitants and members of the Nedre Husån fishing society (Nordlund, Nedre Husån fiskevårdsförening, pers.com.). During 1993/96 brown trout and river lamprey were reintroduced into the lake system (Spens et al., 1991)

Nedre Gideälven

A major part of the fishing licences are season licence and only a few one-day licences are sold. All the members of the Nedre Gideälven fishing society ca. 650 have season licence. About 12 000 salmon are introduced every year and 20% are recaptured. The mean weight for a salmon are 5 kg = 12 000 kg recaptured fish a year (Berglund, MoDo fritid och sportfiske klubb, pers.com.).

Gideå västra

The annual number of fishing licence that are sold is 250/year, mostly one-day licences. The Gideå västra fishing society have ca. 100 members and about 15 of them are fishing more frequently. The allowance for one-day licences is 4 fishes and each fish has a mean weight of 0.8 kg. During 1997 4000 salmon were introduced, most of them were brown trout (Spens et al., 1991; T. Edlund, Gideå västra fiskevårdsområde, pers.com.)

Coast

Fishing in the coastal area, south of Skagsudde, is of national importance. In Örnsköldsvik municipality the coastal fishing gives about 100 ton/year, where 50% is sport-fishing. The sport-fishing is most frequent during spring and autumn. The most common species are salmon, cod (*Gadus morhua*), brown trout, whitefish (*Coregonus maxillaris*) and Baltic herring (*Clupea harengus*). Burbot (*Lota lota*) is of economical importance for the fishermen (Fiske – Övik, 1991; Vattenöversikt 3, 1986)

Comments – Recreation

Recreation quality is difficult to evaluate, since it often is a personal opinion. The spontaneous out-door life is also difficult to evaluate because it is not registred in any way.

The only captures that are continiously reported is moose shot per year, which leads to uncertainties of the values for hunting and sport-fishing. The figures for picked wild berries are uncertain on a local level, because of transformation of values from larger regions. In Ceberg both sport-fishing and wild berry picking is a major part of out-door recreation.

4.10 Human population and occupation

4.10.1 Human population

Region

The number of citizen in Västernorrland county has declined with <25% during the last ten years (SNA, 1991). According to Översiktsplanen Örnsköldsviks kommun (1992) has the number of citizen in the municipality been stable for a long time, i.e. the population in sparsely built-up areas like Gideå parish, are decreasing and the number of citizen in urban areas are increasing. A prediction for the county is that the population will decreasing with 0–25% until 2015 (SNA, 1991). Gideå parish has 1300 citizen and the Gideå settlement has 370. Gideå and Husum are two of 16 settlements in Örnsköldsvik municipality that have a special build-up program, concerning service, dwelling and place of work (Översiktsplan, 1992).

Population/km^2 (region)	1.5	(SCB, 1997)
Total population, municipality	60 000	(Översiktsplan, 1992)
Municipality pop. living in urban areas	47 300	(Översiktsplan, 1992)

The number of holiday cottages in the region is ca. 0.8/km^2 (SNA, 1991). A major part of the cottages is in the coastal area (Vattenöversikt 3, 1986).

Study site

There were 30 citizen permanently living in the study site area in 1996 (0.9/km^2) (data from SCB Statistiska centralbyrån).

4.10.2 Occupation

The study site is a part of the region "Västergidsjö" and have 14 commuters that travel into the municipality and 224 commuters that are working outside Västergidsjö (Årsys, 1995). According to SNA (1991) the number of people who work in a another municipality than where they live are < 9% .

Table 4-6. Occupation by branch of industry in Örnsköldsvik municipality and Västergidsjö compared to Sweden. People who works in the municipality (16–64 yrs.), irrespective of where they live (www.isa.se, 1997-10-10; Årsys, 1995).

Branch of industry	Västergidsjö % (n)	Municipality %	Country %
Agriculture, forestry and fishing	41 (16)	2	2
Manufacturing, mining and quarrying	2.5 (1)	31	20
Electricity, water supply and waste disposal	–	1	1
Construction	26 (10)	7	6
Trade, transport and communication	20.5 (8)	16	19
Financial and business	–	6	10
Education and research	–	7	8
Social and personal service activities	2.5 (1)	19	20
Public administration etc.	–	5	6
Health and social work	–	3	2
Non specified activities	7.5 (3)	3	6

4.11 The environment

4.11.1 Air pollution and deposition

A major part of the acid air pollutants NO_3, NH_4 and SO_4 comes from sources outside Sweden and only a small part of the air pollution in the region has a local source, e.g. sulphur ca. 15% (Bernes & Grundsten, 1992). The amounts of sulphur and nitrogen deposits in Ceberg region differs depending on the source of information. According to the environment analysis made by Västernorrland County Administration (www.y.lst.se, 1997-10-20) the amount is:

SO_x–S	300–350	(mg/m^2)
NO_x–N	200–250	(mg/m^2)
NH_x–N	150	(mg/m^2)

Another estimate is presented by Bernes & Grundsten (1992), were the average value of wet deposition of both sulphur and nitrogen is 400–600 kg/km^2 (1983–87). The yearly average deposition of sulphur and nitrogen in ABC-berg according to Persson et al. (1995) is presented in table 2-13.

The pH level in precipitation is almost as low in Sweden as in Central Europe. The mean pH level for Ceberg is 4.4–4.6 (Bernes & Grundsten, 1992). The dispersion potential of nitrogen oxide in winter is low in Ceberg compared to Aberg and Beberg.

The fallout of lead (Pb) has been halved in Sweden since 1975, however it is still several times greater in southern Sweden than in inner Norrland. The chromium (Cr) fallout in Sweden comes mainly from domestic sources. The lead fallout in Ceberg region is 1000–1500 g/km^2/year and the chromium fallout is 200–400 g/km^2/year (Bernes & Grundsten, 1992).

The ozone concentration for Ceberg during pollution episodes is < 120 $\mu g/m^3$ (Bernes & Grundsten, 1992)

4.11.2 Ground chemistry

The acid rain causes some damage in Västernorrland county, but the pH level is not so low as in Aberg. Because of the acid bedrock, the thin soil and the acid spruce forest the alkalinity level may have difficulties to recover to former levels.

The pH of the soils in Västernorrland county are:

Humus layer	4.2–4.3
Illuvial layer (B-horizons)	5.0–5.1

The nutrient leakage from the agricultural land is the major source of the nitrogen transported with the running water. The estimated ammonia emissions from farms and artificial fertilisers in relation to the total area of land in Ceberg parish is ca. 100 kg NH_3/km^2/year (Bernes & Grundsten, 1992). Use of pesticides in agriculture (kg/km^2/year) is presented for ABC-berg, table 2-14.

The amount of mercury in the humus layer for Ceberg region is > 0.20–0.25 mg/kg organic matter and the amount of cadmium found in moose kidneys is 1.0–1.4 mg/kg/year (wet weight) (Bernes & Grundsten, 1992). The levels of toxic organic matter (PBC) found in mammals, e.g. otter, living in the region is still high (www.y.lst.se, 1997-10-20). More data of ground chemistry for ABC-berg is presented elsewhere (in press).

4.11.3 Running water and lakes

The major supplier of nutrients to running water is the agriculture. Some 15–20% of the fertilisers that are used on the fields are leaking to lakes and running water. The water flow in Västernorrland county has increased since the 1960'ies, which causes an increase of nutrient transportation to the coastal area. The clear-cutting increases the run off with ca. 25–40%, which leads to loss of nutrients e.g. nitrogen and phosphorus (www.y.lst.se, 1997-10-20). The ground water closer to the surface often has lower alkalinity and pH level than the deep ground water. The sensitivity of ground water to acidification is very high in Ceberg, mainly because of the acid bedrock and thin soil layers (Bernes & Grundsten, 1992). Data of ground water chemistry for ABC-berg is treated elsewhere (in press).

In the beginning of the 80'ies 32 of the 456 lakes in Västernorrland county had very low alkalinity, caused by the acid rain and leakage from the forestry. Efforts have been made to higher the levels of alkalinity, mainly by liming (www.y.lst.se, 1997-10-20). In Ceberg region the alkalinity levels have been the same since the 70'ies, 0.01–0.1 mekv/l, even though some liming has been made. In contrast to Ceberg region the eight referent lakes of the county had decreasing amounts of sulphur during 1983–93. The amount of phosphorus in the running water in Ceberg region is about 10–15 µg/l (www.y.lst.se, 1997-10-20).

Toxic pollutants in the lakes are often bound to the humus. In Västernorrland county about 42% of the lakes have an unacceptable high level of mercury, but the level has decreased during the last ten years. The high levels are mostly due to sources like clear-cut woodlands, air pollution and local sources (www.y.lst.se, 1997-10-20).

Table 4-7. Average mercury value per kg (w w) in Grayling and Pike from different running water in Gideå region between 1980–1993. Data from Örnsköldsviks kommun, Miljökontorets sjö- och vattendragsregister and Länsstyrelsens databas RMK.

	mg Hg/kg (w w)	year	sample (n)	watercourse
Pike	0.80	80	5	Stybbersmarkssjön
Pike	0.46	84	5	Bodumsjön
Pike	0.76	88	5	Bodumsjön
Grayling	0.24	91/92	20	Gideälven
Pike	0.68	92	5	Skademarkssjön
Pike	0.78	92/93	10	Gissjön
Pike	0.88	93	4	Landsjösjön
Pike	1.09	93	4	Dombäcksmarkssjön

The environmental protection regulations classify about 25 types of industries as so hazardous for the environment that they must have a licence from the Franchise Board of Environmental Protection. Four industries are in operation in the area around Ceberg region, but none of them are within or upstream the region.

Husum – forest production mill
Örnsköldsvik – airport
Köpmanholmen – chemical plant
Domsjö – chemical plant, engineering works, forest production mill

4.11.4 Radio nuclides

Sundblad & Bergström (1982) measured the activity level at Gideå site and found that the content of cesium 137 in the upper soil (0–25 cm) varied between 10–30 Bq/kg d w. After the Chernobyl accident (1986) the surface activity of cesium 137 was 5500 Bq/kg d w and lichen held about 60 000 Bq/kg d w (Gustavsson et al. 1987). In 1986 the amount of cesium 137 increased in fish in Ceberg region. The values were highest in the small fish species short after the accident, but the larger fish species soon had the same amount, ca. 15 000–20 000 Bq/kg. Since many of the lakes and running water in the Ceberg region have been limed, the production and turnover time have increased and the levels of cesium 137 are lowered in some running water (table 4-8.) (www.y.lst.se, 1997-10-20). The mean level of cesium 137 in moose (female, male and juvenile) is yearly calculated by Miljökontoret Örnsköldsviks kommun (unpubl.), and was in 1997 975 Bq/kg (n=80) in the municipality (ranging from 93 Bq/kg to maximum 3495). Information about distribution and migration of radio nuclides after the Chernobyl accident in Gideå area is presented in Gustafsson et al. (1987).

Table 4-8. Average Bq value per kg in Pike from different Watercourses in Gideå region between 1992–1994. Data from Länsstyrelsen Västernorrlands län, databas RMK.

	Bq/kg	year	sample (n)	watercourse
Pike	514	92	5	Skademarkssjön
Pike	1462	93	4	Dombäcksmarkssjön
Pike	225	93	4	Landsjösön
Pike	547	94	5	Getingasjön

Comments – The environment

The data for toxic pollution is often uncertain because measurement problems and local and temporal differences in values. In most cases the values for Ceberg are the same as the municipality or the county.

4.12 Historical overview

The earliest documented settlements in Örnsköldsvik municipality are from the Iron Age. In the 14th century the municipality was demarcated in three separate parishes, but Gideå was not a separate parish until the beginning of the 19th century. During the 16th century the king initiated a separation of crown estate and private land and the possibility to buy land increased. This had an important impact on the agriculture and forestry for the north part of Sweden (Pettersson, 1986). From the middle of the 18th century the saw-mill industry expanded and large-scale enterprises bought a major part of the forest area, in order to secure the supply of forest. Today they own about half of all the forest land in the county.

Large-scale exploration of the forest began during the 18th century, as Ceberg area supplied both the local iron industry, Gideå bruk, and other mining districts with fuel wood. The saw-mills were gradually closed in the early 20th century and paper-mills put on the role as major industry in the area. Ceberg and several parts of the north of Sweden concentrated their agriculture on stock-farming and not on cultivate grain. Together with farming they made a living out of hunting, fishing and handicraft sales (Pettersson, 1986).

4.13 Predictions of the future

Nature is dynamic. In prehistoric times changes took place slowly, in step with changes in the climate, but today human activity cause the greatest changes. Nearly all of the nature that we see today is transformed through human activity. The changes that will be in the future is therefore reflecting our decisions how to take care of the environment (Gustafsson & Ahlén, 1996). Forestry has been the dominating land use in Ceberg for a long time. The conditions for other types of land use in the future, for example agriculture, are unfavourable for this part of Sweden and forestry will probably be the dominating industry in the area even in the future. Peat mills in the region will probably increase, especially if the inquiry of alternative energy source grows. Some of the bogs will be drained to gain more forestry land. When wetlands are drained it may have substantial effects on the water flow in the catchment area and all the ecosystems that they supply.

The population in Ceberg is concentrated to Gideälven, where most of the arable land is located. According to Översiktsplan Örnsköldsviks kommun (1992) the population in the municipality has been stable for a long time, but the population in sparsely built-up areas like Gideå parish, is decreasing in favour of the urban areas. A forecast for the county is that the number of citizen will continue decreasing, see 4.10.1. The future for Aberg, Beberg and Ceberg is further discussed later (see Discussion).

5 Discussion

A criteria for locating spent nuclear fuel is that the environment is as suitable as possible. The definition of a suitable biosphere is an environment with a minimum risk of predictable negative events. A negative event imply an increased risk for migration of radio nuclides in the ecosystems in case of nuclide leakage. An accumulation of nuclides in the biosphere is unfavourable compared to a dilution. This means that an ecosystem with fast turn-over time is more favourable than a slow system.

In this report the judgement of suitability is made from present circumstances and from large-scale predictions of the future.

5.1 Conclusions from present conditions

When studying the data from Aberg, Beberg and Ceberg, differences are noted between the sites. Depending on where and when the differences occur, it is possible to compare the factors and estimate which of the hypothetical site that has the best realistic conditions for spent nuclear fuel, according to present biosphere conditions.

Colder climates have a slower turn-over time than warmer climates, leading to low environmental disposal but high accumulation, which ought to be seen as negative. If the release of pollution is constant, there will be an accumulation in the ecosystems if the speed of disposal is slower then the release. Aberg has a humid climate i.e. high turnover speed, which makes it the most suitable site from an accumulation point of view. The disposal/dilution of nuclides have a faster lapse here compared to Beberg and Ceberg. High precipitation and runoff increase the disposal/dilution of nuclides. The topography in the area has substantial influences on the runoff and the speed of percolation i.e. higher gradient the greater run off. The fissure valley landscape and the undulating hilly land in Aberg and Ceberg are therefore more suitable than Beberg in a dilution perspective.

Shore level displacement is an important factor. Aberg site has a position close to the sea level and is very exposed to water level changes. This means that the land uplift may has a major impact on Aberg site, even though the uplift per year is very small here compared to Beberg and Ceberg. A shore level displacement in Aberg may put the site under water or the most likely scenario, expose more land. The land uplift in Ceberg is high, but is of little importance because of its height above sea level. Ecosystems have different speed of turn-over and food chain systems, which is effected by climate factors and land use. An ecosystem with high productivity has a dilution effect on pollution's, which may spread faster in the food web. Since the vegetation period is longest in Aberg, the dilution of pollutants will be more effective here than in Beberg and Ceberg.

Land use is a factor affecting exposure to human. The major exposure factors for nuclides in the hypothetical areas today are agriculture, hunting, fishing, drilling wells and consuming of mushrooms and wild berries. The site with highest amount of agriculture is Beberg, which also has the best agricultural conditions. Aberg is still frequently used for grazing and has the highest meat production of the sites per year. The hunting frequency is similar for the sites, but the fishing conditions are much better in Aberg and Ceberg than in Beberg. Berry and mushroom picking is a major industry in some parts of north Sweden and the production of berries and mushrooms in Ceberg site has a great potential.

An area with human activity tend to increase the exposure to nuclides, i.e. a well that is drilled close to the deep repository. Human activity also increase the possible ways of distribution and migration of radio nuclides. The population in Aberg and Beberg has increased during the last decade or has a potential of increasing, while Ceberg has a decreasing population trend. Today Beberg has the highest potential of population increasing of the three sites.

One way of evaluate the three areas is to compare the parameters as they are today. Which or how many parameters that are included in the evaluation is completely determining for the result. In table 5-1 have certain parameters from the description of Aberg, Beberg and Ceberg been chosen to represent and clarify the relationship between the sites from their parameters. Radiological analysis has not been made and the models below are not based upon any radiological data. The factors have been awarded points (1–3) in order to evaluate their ability to distribute nuclides to the human population. The points 1–3 is a ranking system, where the minimum total score in table 5-1 is 7 and maximum is 21.

Table 5-1. Conditions of distribution and migration of radio nuclides in Aberg, Beberg and Ceberg made from present data in the biosphere. The values are ranked from 1–3, where 1 correspond to the lowest risk for human contamination. The values are relative and are used only to compare and classify the sites.

Parameters	Aberg	Beberg	Ceberg
Climate/temp.	1	2	3
Precipitation/runoff	3	2	1
Topography	3	2	1
Shore level displ.	3	2	1
Land use	2	3	1
Recreation for consumption	1	3	2
Human population	2	3	1
Σ points	15	17	10
Σ ranking	**2**	**3**	**1**

According to the result in table 5-1 would Ceberg be the most suitable place for spent nuclear fuel regarding to a possible risk of an impact based on the present biosphere conditions. For a complete judgement and a more proportional evaluation, other parameters must be weight and compared. This schematic evaluation may be used as a first step towards a more thorough study.

5.2 Predictions of the future

A prediction of the future can be made from the present state of the three sites. For predictions in longer time perspectives, time-scale of possible change for each parameter must be evaluated.

One important issue is that the factors that may change in the future not have the same influence on the biosphere. Some factors are greater than others and have a major impact on the minor factors changing ability. One example of a major factor is the climate. If the climate changes in any way, several other factors may change e.g. vegetation, ecosystems, animal- and plant population, land use.

When estimating the sensitivity of the parameters in ABC-berg, several processes have to be evaluated (table 5-2). In Aberg the sensitivity to the climate is high due to the location in the archipelago and the risk of climate caused shore level displacement, which may change the land use and the entire ecosystem. The shore level displacement due to climate changes has not the same effect in Beberg and Ceberg, because of their altitude. Beberg is on the other hand probably going to increase its population and are likely to change its agricultural land to forestry . There is probably no effect induced by the parameters in Ceberg during the next hundred years. Land use is limited by climate and the productivity of the soils. No growth of the population is predicted. A possible prediction of the sites is made in 2.13, 3.13 and 4.13, where the future for the next hundred years is described.

In table 5-2 the probability of change of a factor is plotted on a time-scale divided in four periods, ranging from present time to > 10 000 years. The factors are marked, according to when in the time-scale they appear. A site with possibilities for early changes like Aberg, will have a sharper logarithmic curve than the others, fig 5-1. Despite of the shape of the curve, all the sites approach each other after 10 000 years, i.e. the possibility of a change in the parameters is so difficult to predict that all factors must be evaluated as equal.

The table 5-2 is made from the probability in changes of the parameters that may have an effect on the ecosystem during different time intervals. If the change is "positive or negative" from a deep repository point of view has not been taken into consideration. The factors are not compared with each other regarding to their possible impact on the ecosystem. Since the parameters often are linked to each other, a change in one factor may lead to changes in other factors.

According to figure 5-1 Aberg has the fastest rate of change of the three sites. The probability of change in Ceberg is not likely to occur before the period 100–1000 years, while Aberg and Beberg may be effected by major changes as early as within the first hundred years, table 5-2.

If a comparison is made between table 5-1 and table 5-2, Ceberg appears to be the most suitable site in both tables. The site has the best prerequisites according to present conditions and has the lowest possibility for major changes in the future-scale (0–>10 000 years).

Table 5-2. The ABC-berg sites sensitivity for changes in the parameters made from biosphere conditions. A likely response to a change of a parameter is marked with (x).

Time (yr)	Parameters	Aberg	Beberg	Ceberg
0–100	Climate	x		
	Land use	x	x	
	Shore level displ.	x		
	Ecology	x		
	Society system			
	Population		x	
	Geology			
100– 1000	Climate	x	x	x
	Land use	x	x	x
	Shore level displ.	x		
	Ecology	x	x	x
	Society system	x	x	
	Population	x	x	
	Geology			
1000– 10.000	Climate	x	x	x
	Land use	x	x	x
	Shore level displ.	x	x	
	Ecology	x	x	x
	Society system	x	x	x
	Population	x	x	x
	Geology			
>10.000	Climate	x	x	x
	Land use	x	x	x
	Shore level displ.	x	x	x
	Society system	x	x	x
	Population	x	x	x
	Geology	x	x	x

If the two described models are to be used, it is necessary that they are used integrally. By using "the score-table" (table 5-1) in each time-period in "the table of probability of changes over time" (table 5-2), it is possible to detect which site that has and will have the most suitable biosphere conditions for deep repository of spent nuclear fuel.

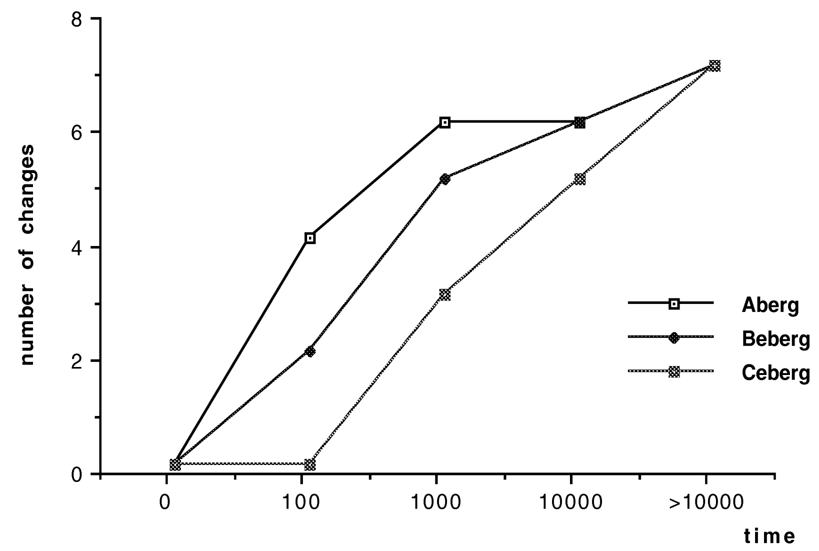

Figure 5-1. *Estimated rate of change in ABC-berg, visualised data from table 5-2.*

5.3 Suggestions for complementary studies

The result from table 5-1 and table 5-2 ought to be seen more as a suggestion on how to work with biosphere data and what conclusions one might be able to make, than a final evaluation. To make a full-scale model of the three sites, other factors like ground water flow, time of percolation and other hydrological data should be included. In order to chose the right parameters and be able to give them the right grade of importance, it is necessary to make a more thorough study of the factors influences on each other. The data from this report together with other data may be very useful for modelling biosphere conditions and predictions.

An assessment of and a comparison between the sites can be done from accessible literature concerning climate (Smagorinsky, 1974; IPCC, 1992; Raymo & Ruddiman, 1992; Bradley, 1992), ecology (Mattson, 1990; Schluter & Ricklefs, 1993), hydrology (Bergström, 1992) and shore level displacement (Påsse, 1996, 1997).

References

Ahlbom K, Andersson J-E, Andersson P, Ittner T, Ljunggren C & Tirén S, Finnsjön study site. Scope of activites and main results. SKB TR 92-33.

Ahlbom K, Andersson J-E, Nordquist R, Ljunggren C, Tirén S & Voss C, 1991. Gideå study site. Scope of activities and main results. SKB Technical report TR 91-51.

Annual Report 1996, 1996. Äspö Hardrock Laboratory. SKB technical report TR 97-08.

Bengtsson P, Larsson C-M & Lüning M, 1996. Omgivningskontroll vid kärnkraftsverken och Studsvik, 1994. SSI-rapport 96-06.

Bergström S, 1992. The HBV model – its structure and applications. SMHI. RH. No. 4.

Bergström U & Nordlinder S, 1998. Draft. Biosmod a modularized standard biosphere. SKB. (in press).

Bernes C & Grundsten C, 1992. The Environment. National Atlas of Sweden. First edition.

Birgersson L & Sidenvall J, 1996. Förstudie Östhammar, Markanvändning och miljöaspakter. SKB Projekt rapport PR D-96-011.

Björck et al, 1988. In Lunds universitet. 1991. P Möller (ed.) Geovetenskap för naturvetare, kompendium för geovetenskap. Naturgeografiska institutionen.

Blücher C, 1992. Fiskodlingar i Kalmar län. Länsstyrelsen i Kalmar län informerar. 1992:7.

Bradley R S, 1992. Global Changes of the Past. UCAR/Office fore Interdisciplinary Earth studies. Boulder, Colorado.

Brunberg A-K & Blomqvist P, 1998. Vatten i Uppsala län 1997 – Beskrivning, utvärdering, åtgärdsförslag. Uppsala: Upplandsstiftelsen Rapport nr 8/1998.

Brunnsregistret, SGU data files.

Campbell N A, 1992. Biology. Third edition. The Benjamin/Cummings Publishing Company, Inc. USA.

Carlsson L & Gidlund G, 1983. Evaluation of the hydrogeological conditions at Finnsjön. SKBF/KBS Technical Report 83-56.

Carlsson et al, 1989. Regional miljöanalys för Kalmar län. Länsstyrelsen i Kalmar län.

Clason Å & Granström B, 1992. Agriculture. National Atlas of Sweden. First edition.

Djurskyddsområden, 1994. En sammanställning av fågel- och sälskyddsområden i Uppsala län. Länsstyrelsen i Uppsala län.

Ekman L, 1989. Sammanställning av geovetenskapliga undersökningar utförda under tiden 1977–1988. SKB Arbetsrapport AR 89-09.

Enefalk Å, 1997. Närsalttransport till kusten via länets vattendrag. Avstämning av det regionala målet. Länsstyrelsen Kalmar län. Meddelande 1997:2.

Enquist A, 1997. Water exchange estimates derived from forcing for the hydraulically coupled basins surrounding Äspö island adjecent coastal water. A & I Engquist Konsult HB. SKB Technical Report TR 97-14.

Fastställda skyddsområden för grundvatten täkter, 1989. Länsstyrelsen i Kalmar län informerar. 89:12.

Friluftslivets riksintressen, 1989. Länsstyrelsen i Kalmar län informerar 1989:11.

Fågel- och sälskydd längs Kalmar kust, 1990. Länsstyrelsen i Kalmar län.

Gottsschalk L, 1982. Hydrologi kompendium. Lunds universitet.

Grundfeldt G, Lindbom B, Liedholm M & Rhén I, 1990. Predictive groundwater flow modelling of a long time period pumping test (LPT1) at Äspö. SKB Progress Report No PR 25-90-04.

Gustafsson L & Ahlén I, 1996. (Editors) Geography of Plants and Animals. National Atlas of Sweden.

Gustafsson E, Skålberg M, Sundblad B, Karlberg O, Tullborg E-L, Ittner T, Carbol P, Eriksson N & Lampe S, 1987. Radionuclide deposition and migration witjin The Gideå and Finnsjön study sites, Sweden: A study of the fallout after the Chernobyl accident. Phase I, initial survey. SKB Technical report TR 87-28.

Gustafson & Eriksson Nilsson, 1995. Odlingslandskapet i Kalmar län – Bevarandeprogram. Oskarshamns kommun. Länsstyrelsen i Kalmar län informerar. Medelande 95:16.

Hammarström & Olsson, 1996. Äspö Hardrock Laboratory. 10 years of research. SKB.

Hammersland J, 1997. Naturvärdesbedömningar Övre Gideälvens avrinningsområde. Rapport 1. Plan- och miljönämnden, Örnsköldsviks kommun.

Haglund E, 1972. Utdrag ur naturvårdsinventering, del 8. Tierps kommun, norra delen.

Hogdal J, 1993. Liv och landskap i Uppsala län. Uppsalastiftelsen. Svenska turistföreningen.

IPCC, 1992. Scientific assessment of climate change 1992. IPCC supplement. Intergouvernmental Panel on Climatic change. WMO. UNEP.

Johansson T, 1991. Naturvärdesbedömning av 20 värdefulla sjöar i Kalmar län. Länsstyrelsen i Kalmar län informerar 1991:6.

Kanotleder, 1979. Länsstyrelsen i Västerbottens län. KBS Technical Reports 1-120. Summaries. 1977-78. SKB TR 121.

Kulturmiljöprogram för Oskarshamns kommun, 1993. Oskarshamns kommun.

Kulturmiljövårdens riksintressen, 1988. Länsstyrelsen i Kalmar län informerar, 1988:9.

Lantbruksregistret, Kalmar län, 1995. Länsstatistik. Statistiska centralbyrån.

Lantbruksregistret, Uppsala län, 1995. Länsstatistik. Statistiska centralbyrån.

Lantbruksregistret, Västernorrlands län, 1995. Länsstatistik. Statistiska centralbyrån.

Levin S A, 1978. Pattern formation in ecological communities. in J S Steele ed. Spatial Pattern in Plankton Communities. Plenum press, New York.

Ljungberg M & Lönnbom H, 1993. Närsaltkällor i Kalmar län. Underlagsmaterial till regional miljöstrategi 1993. Länsstyrelsen i Kalmar län informarar 1993:9.

Lundqvist J, 1986. Late Weichselian glaciation and deglaciation in Scandinavia. Quaternary Science Reviews 5, s 269–292.

Lunds universitet, 1991. P Möller (ed.) Geovetenskap för naturvetare, kompendium för geovetenskap. Naturgeografiska institutionen.

Länsstyrelsen Kalmar, 1985. Kulturminnesvårdsprogram för Kalmar län. Ett läns utveckling. Etapp 1, översikt. Länsstyrelsen Kalmar län.

Länsstyrelsen och Landstinget Uppsala, 1982. Vägvisaren till naturen i Uppsala län. Länsstyrelsen i Uppsala län & Uppsala läns landsting.

Länsstyrelsen Uppsala, 1982. Stiftelsen för fritidsområden och naturvård i Uppsala län. Länsstyrelsen i Uppsala län.

Länsstyrelsen Uppsala, 1986. Inventering av våtmarker i Uppsala län. 1. Rapporter och bearbetning & 2. Katalog över samtliga objekt. Meddelande från planeringsavdelningen. Länsstyrelsen Uppsala län.

Länsstyrelsen Uppsala, 1987. Naturvårdsprogram för Uppsala län. 1. Värdefulla områden för naturvård och rörligt friluftsliv. Meddelande från planeringsavdelningen.

Länsstyrelsen Uppsala, 1994. Ekologiskt känsliga områden i Uppsala län. Länsstyrelsens meddelandeserie 1994:13.

Länsstyrelsen Uppsala, 1996. Regional miljöanalys för Uppsala län. Länsstyrelsen Uppsala län.

Mattson J O, 1990. Mikro och lokalkimatologi. Introduktion.

Miljöskyddsprogram, Oskarshamns kommun, 1986. MP 86-88. Oskarshamns kommun.

Naturvårdens riksintressen, Kalmar läns fastland, 1989. Länsstyrelsen i Kalmar län informerar. 1989:6.

Naturvårdsplanering, DANI, 1997. Data obtained from data files, Länsstyrelsen Västernorrlands län.

Nilsson B, 1989. Skyddat vatten. Länsstyrelsen i Kalmar län informerar. 1989:12.

Nilsson SNA, 1990. The Forest. National Atlas of Sweden. First edition.

NMR, 1984. Naturgeografisk regionindelning av Norden. Nordiska ministerrådet.

Nordlinder S & Bergström U, Ecosystem specific dose conversion factors for Aberg, Beberg and Ceberg. SKB.

Nyberg G, Jönsson S & Ekman L, 1992. Groundwater flow program. Report for 1990. SKB Progress report No PR 25-91-19.

Odlingslandskap i Uppsala län, 1993. Länsstyrelsens meddelandeserie 1993:4.

Petersen K, 1984. Klimatkarta över norden in Naturgeografisk regionindelning av norden. Nordiska ministerrådet.

Påsse T, 1996. A mathematical model of the shore level displacement in Fennoscandia. Sveriges geologiska undersökning. SKB TR 96-24.

Påsse T, 1997. A mathematical model of past, present and future shorelevel displacement in Fennoscandia. Sveriges geologiska undersökning. SKB TR 97-28.

Persson C, Lagner J & Robertson L, 1995. Regional spridningsmodell för Sverige. Redovisning från nationell miljöövervakning 1993/94. SMHI. Naturvårdsverket. Rapport 4386.

Pettersson, 1986. Program för Kulturminnesvård, Örnsköldsviks kommun. Örnsköldsviks kommun december 1986.

Raab B & Vedin H, 1995. (Editors) Climate, Lakes & Rivers. National Atlas of Sweden. First edition.

Raymo M E & Ruddiman W F, 1992. Tectonic forcing of the late Cenozoic climate. Nature. Vol. 359. Review article.

Rhén I, Gustafson G, Stanfors R & Wikberg P, 1997. Äspö HRL – Geoscientific evaluation 1997/5. Models based on charcterization 1986–1995. SKB Technical report TR 97-06.

Rühling Å, 1997. Floran i Oskarshamns kommun. AB C O Ekblad & Co. Västervik.

Rädda Uttern i Småland, 1995. Föreningen Rädda Uttern i Småland, faktasamling och åtgärder.

SCB – Statistiska Central Byrån, 1997. Jonny Selin, Befolkningsfrågor.

Schluter D & Ricklefs R E, 1993. Species Diversity in Ecological Communities – Historical and geographical perspectives. 1–12.

Sjörs H, 1967. Nordisk växt geografi. 2:a upplagan. Stockholm.

Smagorinsky J, 1974. Global atmospheric modeling and the numerical simulation of cilmate. Weather and Climate modification. Ed: W R Hess, J Wiley & Sons.

SNA, 1991. Befolkningen. Svensk National Atlas. First edition.

SNA, 1993. Arbete och Fritid. Svensk National Atlas. First edition.

SNV, 1975. Översiktlig naturinventering och naturvårdsplanering, Råd och anvisningar. Naturvårdsverket, 1975:1.

Spens et al, 1991. Fiske i Ö-vik. 1991. När, var, hur. Fiskevattengruppen i Örnsköldsviks kommun.

Stanfors R, Erlström M & Markström I, 1997. Äspö HRL – Geoscientific evaluation 1997/1. Overview of site charcterization 1986–1995. SKB Technical report TR 97-02.

Statistisk områdesindelning för Tierps kommun -96, 1996. Tierps kommun.

Strahler A N & Strahler A H, 1976. Elements of Physical Geography. Fourth edition. Wiley & Sons. USA.

Strömquist U & Pleiborn M, 1996. Förstudie Östhammar, Konsekvenser för bosättning och sysselsättning. SBK Projekt rapport PR D 96-021.

Sundblad B & Bergström U, 1983. Description of recipient areas related to final storage of unreprocessed spent nuclear fuel. SKB TR 83:11.

Svensson T, 1987. Hydrological conditions in the Simpevarp area. SKB Projekt rapport PR 25-87-09.

The Biosphere, 1970. A Scientific American Book. W H Freeman and Comp. San Fransisco. USA.

Tierps kommun, 1996. Statistisk områdesindelning för Tierps kommun.

Vattenöversikt 3, 1986. Riktlinjer och åtgärdsförslag. Örnsköldsviks kommun.

Vattenöversikt 2, 1986. Tabellbilaga. Örnsköldsviks kommun.

Våtmarksinventeringen inom fastlandsdelen av Kalmar län, 1984. Naturvårdsverket, rapport; snv pm 1787.

Wallsten M, 1992. Metaller och klorkolväteföreningar i gädda – Uppsala kommun, miljökontoret.

www.isa.se, 1997-10-10. Data obtained from Internet.

www.y.lst.se, 1997-10-20. STRAM – Länsstyrelsen i Västernorrlands län. Data obtained from Internet.

Ångström A, 1974. Sveriges klimat. GLA Stockholm 1974.

Årsys 95, 1995. Örnsköldsviks kommun.

Översiktsplan för Örnsköldsviks kommun, 1992. Örnsköldsviks kommun. Nytryck januari 1992.

Översiktsplan vatten, Oskarshamns kommun, 1989. K-Konsult. Arbetsmaterial Kalmar, 89-02-28.

Översiktsplan, Oskarshamns kommun, 1990. Oskarshamns kommun. Januari 1992. Reviderad juni och december 1992.

Appendix 1

Glossary

archean rock	urberg
Arctic skua	labb (*Stercorarius pomarinus*)
badger	grävling (*Meles meles*)
Baltic herring	strömming (*Glupea harengus*)
beech	bok (*Fagus sylvatica*)
black-throated diver	storlom (*Gavia arctica)*
Bladder wrack	blåstång (*Fucus vesiculosus*)
bleak	löja (*Alburnus alburnus*)
bog	mosse
Botrychium lunaria	låsbräken
bread-stuffs	brödsäd
bream	braxen (*Abramis brama*)
brown trout	öring (*Salmo trutta*)
bryophyte	mossa
burbot	lake (*Lota lota*)
cairus	odlingsröse
capercaillie	tjäder (*Tetrago urogallus*)
chaffinch	bofink (*Fringilla coelebs*)
clear-cut woodland	hygge
cod	torsk (*Gadus morhua*)
Common butterwort	tätört (*Pinguicula vulgaris*)
Common cotton-grass	ängsull (*Eriophorum angustifolium*)
Common quaking-grass	darrgräs (*Briza media*)
Common Rockrose	solvända (*Helianthemum nummularium*)
common sandpiper	drillsnäppa (*Tringa hypoleucos*)
coniferous forest	barr skog
coppiced woodland	skottskog
cowberry	lingon (*Vaccinium vitis-idaea*)
crane	trana (*Grus grus*)
crow	kråka (*Corvus corone cornix*)
deciduous tree	lövträd
eagle owl	berguv (*Bubo bubo*)
eider	ejder (*Somateria mollissima*)
esker	rullstensås
ewe	tacka
fallow	träda
fault	förkastning
fell	avverka
fen	kärr
fieldfare	björktrast (*Turdus pilaris*)
fish-way	fisktrappa
Fissure valley landscape	sprickdalsterräng
goosander	stor skrake (*Mergus merganser*)
grain	spannmål
grey heron	häger (*Ardea cinerea*)
grayling	harr (*Thymallus thymallus*)
grazed marsh meadow	betad strandäng

great chrested grebe	skäggdopping (*Podiceps cristatus*)
grove-vegetation	lundvegetation
hay-meadow	slåtteräng
hazel	hassel (*Corylus avellana*)
hazel-grouse	järpe (*Tetrastes bonasia*)
Heathgrass	knägräs (*Danthonia decumbens*)
hops	humle (*Humulus lupulus*)
inundated wetland	översilningsmarker
jay	nötskrika (*Garrulus glandarius*)
kettle	dödisgrop
Ledum palustre	skvattram
ley	vall
lime-tree	lind (*Tilia cordata*)
magpie	skata (*Pica pica*)
Maiden pink	backnejlika (*Dianthus deltoides*)
marten	mård (*Martes martes*)
meadow	äng
morass	träsk
Mountain Everlasting	kattfot (*Atennaria dioica*)
Mud rush	salttåg (*Juncus gerardii*)
mute swan	knölsvan (*Cygnus olor*)
noble crayfich	flodkräfta (*Capreolus capreolus*)
osprey	fiskgjuse (*Pandion haliaetus*)
pasture	betesmark
peat bog	torv mosse
peat mill	torvtäkt
peat	torv
perch	abborre (*Percha fluviatillis*)
pike	gädda (*Esox lucius*)
pike-perch	gös (*Stizostedion lucioperca*)
pine forest on - outcrops of bedrock	hällmarkstallskog
pine	tall (*Pinus sylvestris*)
Potamogeton prarlongus	långnate
quarring	stenbrytning
razorbill	tordmule (*Alca torda*)
red-breasted merganser	småskrake (*Mergus serrator*)
reed	vass (*Phragmites australis*)
river lampray	flodnejonöga (*Lampetra fluviatilis*)
robin	rödhake (*Luscinia svecica*)
rocky shores	fastmarksstränder
rotation period	omloppstid
rush	säv (*Schoenoplectus lacustris*)
rye	råg (*Secale cereale*)
Sea milkwort	strandkrypa (*Glaux maritima*)
Sea Plantain	gulkämpar (*Plantago maritima*)
sea-shore meadow	strandäng
Seaside Centaury	kustarun (*Centaurium littorale*)
sedge fen	starrkärr
soil composition	jordart
soil unit	jordmån
sow	sugga
Sparganium gramineum	flotagräs

spring-barley	vårkorn
spruce	gran (*Picea abies abies*)
swale-forest	sumpskog
tufted duck	vigg (*Aythya fuligula*)
turbary	torvtäkt
undulating hilly land	vågig bergkullterräng
waders	vadare
water catchment	vattentäkt
wetland	våtmark
white-tailed eagle	havsörn (*Haliaeetus albicilla*)
whitefish	sik (*Coregonus maxillaris*)
wildwood	naturskog
willow warbler	lövsångare (*Phylloscopus trochilus*)
wolverine	järv (*Gulo gulo*)
woodcock	morkulla (*Scolopax rusticola*)

List of SKB reports

Annual Reports

1977-78
TR 121
KBS Technical Reports 1 – 120
Summaries
Stockholm, May 1979

1979
TR 79-28
The KBS Annual Report 1979
KBS Technical Reports 79-01 – 79-27
Summaries
Stockholm, March 1980

1980
TR 80-26
The KBS Annual Report 1980
KBS Technical Reports 80-01 – 80-25
Summaries
Stockholm, March 1981

1981
TR 81-17
The KBS Annual Report 1981
KBS Technical Reports 81-01 – 81-16
Summaries
Stockholm, April 1982

1982
TR 82-28
The KBS Annual Report 1982
KBS Technical Reports 82-01 – 82-27
Summaries
Stockholm, July 1983

1983
TR 83-77
The KBS Annual Report 1983
KBS Technical Reports 83-01 – 83-76
Summaries
Stockholm, June 1984

1984
TR 85-01
Annual Research and Development Report 1984
Including Summaries of Technical Reports Issued during 1984. (Technical Reports 84-01 – 84-19)
Stockholm, June1985

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01 – 85-19)
Stockholm, May 1986

1986
TR 86-31
SKB Annual Report 1986
Including Summaries of Technical Reports Issued during 1986
Stockholm, May 1987

1987
TR 87-33
SKB Annual Report 1987
Including Summaries of Technical Reports Issued during 1987
Stockholm, May 1988

1988
TR 88-32
SKB Annual Report 1988
Including Summaries of Technical Reports Issued during 1988
Stockholm, May 1989

1989
TR 89-40
SKB Annual Report 1989
Including Summaries of Technical Reports Issued during 1989
Stockholm, May 1990

1990
TR 90-46
SKB Annual Report 1990
Including Summaries of Technical Reports Issued during 1990
Stockholm, May 1991

1991
TR 91-64
SKB Annual Report 1991
Including Summaries of Technical Reports Issued during 1991
Stockholm, April 1992

1992
TR 92-46
SKB Annual Report 1992
Including Summaries of Technical Reports Issued during 1992
Stockholm, May 1993

1993
TR 93-34
SKB Annual Report 1993
Including Summaries of Technical Reports Issued during 1993
Stockholm, May 1994

1994
TR 94-33
SKB Annual Report 1994
Including Summaries of Technical Reports Issued during 1994
Stockholm, May 1995

1995
TR 95-37
SKB Annual Report 1995
Including Summaries of Technical Reports Issued during 1995
Stockholm, May 1996

1996
TR 96-25
SKB Annual Report 1996
Including Summaries of Technical Reports Issued during 1996
Stockholm, May 1997

List of SKB Technical Reports 1998

TR 98-01
Global thermo-mechanical effects from a KBS-3 type repository. Summary report
Eva Hakami, Stig-Olof Olofsson, Hossein Hakami, Jan Israelsson
Itasca Geomekanik AB, Stockholm, Sweden
April 1998

TR 98-02
Parameters of importance to determine during geoscientific site investigation
Johan Andersson[1], Karl-Erik Almén[2], Lars O Ericsson[3], Anders Fredriksson[4], Fred Karlsson[3], Roy Stanfors[5], Anders Ström[3]
[1] QuantiSci AB
[2] KEA GEO-Konsult AB
[3] SKB
[4] ADG Grundteknik KB
[5] Roy Stanfors Consulting AB
June 1998

TR 98-03
Summary of hydrochemical conditions at Aberg, Beberg and Ceberg
Marcus Laaksoharju, Iona Gurban, Christina Skårman
Intera KB
May 1998

TR 98-04
Maqarin Natural Analogue Study: Phase III
J A T Smellie (ed.)
Conterra AB
September 1998

TR 98-05
The Very Deep Hole Concept – Geoscientific appraisal of conditions at great depth
C Juhlin[1], T Wallroth[2], J Smellie[3], T Eliasson[4], C Ljunggren[5], B Leijon[3], J Beswick[6]
[1] Christopher Juhlin Consulting
[2] Bergab Consulting Geologists
[3] Conterra AB
[4] Geological Survey of Sweden
[5] Vattenfall Hydropower AB
[6] EDECO Petroleum Services Ltd.
June 1998

TR 98-06
Indications of uranium transport around the reactor zone at Bagombe (Oklo)
I Gurban[1], M Laaksoharju[1], E Ledoux[2], B Made[2], A L Salignac[2],
[1] Intera KB, Stockholm, Sweden
[2] Ecole des Mines, Paris, France
August 1998

TR 98-07
PLAN 98 – Costs for management of the radioactive waste from nuclear power production
Swedish Nuclear Fuel and Waste Management Co
June 1998

TR 98-08
Design premises for canister for spent nuclear fuel
Lars Werme
Svensk Kärnbränslehantering AB
September 1998

TR 98-09
Test manufacturing of copper canisters with cast inserts
Assessment report
Claes-Göran Andersson
Svensk Kärnbränslehantering AB
Augusti 1998

TR 98-10
Characterization and Evaluation of Sites for Deep Geological Disposal of Radioactive Waste in Fractured Rocks
Proceedings from The 3rd Äspö International Seminar, Oskarshamn, June 10–12, 1998-11-10
Svensk Kärnbränslehantering AB
September 1998

TR 98-11
Leaching of 90-year old concrete mortar in contact with stagnant water
Jan Trägårdh, Björn Lagerblad
Swedish Cement and Concrete Research Institute
July 1998

TR 98-12
Geological-structural models used in SR 97
Uncertainty analysis
Pauli Saksa, Jorma Nummela
FINTACT Ltd
October 1998

TR 98-13
Late Quaternary changes in climate
Karin Holmgren and Wibjörn Karlén
Department of Physical Geography
Stockholm University
December 1998

TR 98-14
Partitioning and transmutation (P&T) 1997
Åsa Enarsson, Anders Landgren, Jan-Olov Liljenzin, Mats Skålberg, Lena Spjuth
Department of Nuclear Chemistry, Chalmers University of Technology, Gothenburg
and
Waclaw Gudowski, Jan Wallenius
Department of Nuclear and Reactor Physics, Royal Institute of Technology, Stockholm
May 1998

TR 98-15
Studies of surface complexation of H^+, NpO_2^+, Co^{2+}, Th^{4+} onto TiO_2 and H^+, UO_2^{2+} onto alumina
Anna-Maria Jakobsson, Yngve Albinsson
Department of Nuclear Chemistry, Chalmers University of Technology, Sweden
and
Robert S Rundberg
Los Alamos National Laboratory, USA
November 1998

TR 98-16
Backfilling with mixtures of bentonite/ ballast materials or natural smectitic clay?
Roland Pusch
Geodevelopment AB
October 1998

TR 98-17
Groundwater degassing in fractured rock:
Modelling and data comparison
Jerker Jarsjö and Georgia Destouni
Water Resources Engineering
Royal Institute of Technology, Stockholm
November 1998

TR 98-18
The interaction of sorbing and non-sorbing tracers with different Äspö rock types
Sorption and diffusion experiments in the laboratory scale
Johan Byegård, Henrik Johansson, Mats Skålberg
Department of Nuclear Chemistry, Chalmers University of Technology, Gothenburg, Sweden
and
Eva-Lena Tullborg
Terralogica AB, Gråbo, Sweden
November 1998

TR 98-19
Äspö Hard Rock Laboratory
Annual Report 1997
Svensk Kärnbränslehantering AB
May 1998