

# Environmental Monitoring

- Lillgrund Offshore Wind Farm

Lillgrund Pilot Project

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## PREFACE

Vattenfall's Lillgrund project has been granted financial support from the Swedish Energy Agency and Vattenfall will therefore report and publish experiences and lessons learned from the project. This report is compiled in a series of open reports describing the experiences gained from the different aspects of the Lillgrund Wind Farm project, for example construction, installation, operation as well as environmental, public acceptance and legal issues.

The majority of the report authors have been directly involved in the Lillgrund project implementation. The reports have been reviewed and commented by a reference group consisting of the Vattenfall representatives Sven-Erik Thor (chairman), Ingegerd Bills, Jan Norling, Göran Loman, Jimmy Hansson and Thomas Davy.

The experiences from the Lillgrund project have been presented at two seminars held in Malmö (4<sup>th</sup> of June 2008 and 3<sup>rd</sup> of June 2009). In addition to those, Vattenfall has presented various topics from the Lillgrund project at different wind energy conferences in Sweden and throughout Europe.

All reports are available on [www.vattenfall.se/lillgrund](http://www.vattenfall.se/lillgrund). In addition to these background reports, a summary book has been published in Swedish in June 2009. An English version of the book is foreseen and is due late 2009. The Lillgrund book can be obtained by contacting Sven-Erik Thor at [sven-erik.thor@vattenfall.com](mailto:sven-erik.thor@vattenfall.com).

Although the Lillgrund reports may tend to focus on problems and challenges, one should bear in mind that, as a whole, the planning and execution of the Lillgrund project has been a great success. The project was delivered on time and within budget and has, since December 2007, been providing 60 000 households with their yearly electricity demand.

Sven-Erik Thor,  
Project Sponsor, Vattenfall Vindkraft AB

September 2009

## DISCLAIMER

Information in this report may be used under the conditions that the following reference is used: "This information was obtained from the Lillgrund Wind Farm, owned and operated by Vattenfall." The views and judgment expressed in this report are those of the author(s) and do not necessarily reflect those of the Swedish Energy Agency or of Vattenfall.

# Environmental Monitoring - Lillgrund Offshore Wind Farm

## SUMMARY

The purpose of this report is to describe the environmental monitoring measures performed for the Lillgrund Offshore Wind Farm and to summarize the results and conclusions.

The Lillgrund project was developed by Örestads Vindkraftpark AB (ÖVP) and purchased by Vattenfall AB in 2004. Vattenfall has been responsible for the purchasing and contracting phases of the project. Construction work started in 2006 and the plant was energized in December 2007. At the time of construction Lillgrund was the third largest wind farm offshore in the world and the first large offshore wind farm in Sweden.

The purpose of the environmental monitoring is to ensure that there are no negative impacts on the environment stemming from construction of the Lillgrund wind farm as well as to ensure that the conditions stated by the authorities and the Company's commitments are met. Also the aim is to collect more information and knowledge on the possible environmental impact for future offshore wind farm projects.

For the Lillgrund project, all monitoring programs were included in one document, Monitoring Program – Lillgrund. It was included as part of the procedures to ensure that the Swedish legal requirements on operators control were followed. The authorities approved the document before construction started.

The monitoring measures performed during the construction phase included:

- A feedback and monitoring program on dredging and spillage
- A feedback and monitoring program on flora and fauna
- Studies and inspections of the refilling and re-establishment of the sea bottom
- Procedure for operators control ("egenkontroll")

The purpose of having a feedback control is to supervise the work performed from an environmental view and to be able to take quick corrective actions if any environmental risks are identified.

The mean measured sediment spillage, as part of the monitoring program on dredging and spillage, varied between 4.6 - 4.8% depending on dredger used. The maximum value allowed by the conditions is 5%.

In general, the calculated values for suspended material were limited and the critical value of 0.01 kg/m<sup>3</sup> was exceeded only in minor areas for a very limited time. No corrective actions were required. The deposition of sediment was very low and even at the most effected sites it was only just over 1 mm.

The largest dredging volumes were for the foundation work, in total 82 225 m<sup>3</sup> which is significantly lower than the max stipulated 200 000 m<sup>3</sup>, due to the fact that vessels able to operate in shallow waters were used. The method used for the dredging was also adjusted to reduce the amount of spillage.

The total dredged volume was 68 598 m<sup>3</sup> for cable work, which is well below the stipulated max of 100 000 m<sup>3</sup>.

For the feedback control on flora and fauna, the key environmental parameters were eelgrass and common sea mussels. No negative impacts were observed during construction.

The results from the monitoring programs performed during the construction phase show that the chosen methods for dredging, refilling of trenches and the restoration of the sea-bottom did meet the environmental protection conditions and regulations stated in the permits.

For possible effects on the nearby coastline, a monitoring program has been performed, including a baseline<sup>1</sup> study and follow-up studies. The follow-up study was performed during autumn 2008 and results show no negative effects on the nearby coastline from the construction of the wind farm.

The Swedish legal requirement on operators control implies that the contractors' environmental work is supervised and checked in a systematic way. One way to do this is to have a checklist covering all relevant items and provide consistent reporting to the responsible party. Such a checklist was prepared for the Lillgrund project and provided to the contractors before contract signing. It was also included in the approved document "Monitoring Program – Lillgrund".

To ensure that the contractors worked in accordance with the Swedish requirements for "operators control", audits of their management systems were performed checking their procedures for fulfilling legal requirements and other environmental requirements. Audits were also performed on site, based on the above-mentioned checklist. The procedure worked well and no major deviations were found at the audits performed. For all minor deviations corrective actions were taken accordingly.

A number of further environmental monitoring programs are performed including studies on:

- Birds
- Fish and Fishing
- Infauna<sup>2</sup> above cables (part of the Flora and Fauna program)
- Noise

Baseline studies on noise have been performed and show that the equivalent noise level measured varied between 31-46 dB(A) at wind speeds between 2-8 m/s. This means that the background noise level for longer periods is above the max noise level stated by the authorities. However, the consultants conclusion from the baseline studies is that it will be

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<sup>1</sup> Baseline studies are performed before the plant is built and results are compared with results from follow-up studies in order to identify a possible environmental impact.

<sup>2</sup> Animals living in the sea bottom sediment

possible to perform immission measurements as planned, given the correct weather conditions and times are chosen. Follow-up studies have not been concluded and results are expected for spring 2009.

Baseline studies on fish, fishing and birds have been performed and monitoring programs have been modified accordingly. Follow-up studies are planned for three years. Results from first year (2008) are expected to be available in spring 2009 and therefore no final conclusions can be drawn at this stage.

Additionally, a monitoring program for infauna on the seabed above the buried cables is carried out. The purpose of the study is to survey if the electromagnetic fields from the sea cables interrupt organisms in the water and the infauna is used as an indicator of this. The baseline study has been performed and a follow-up study on the infauna is planned for 2009.

The work with the monitoring programs has also been co-ordinated with studies performed within the Swedish research program Vindval. For example, a study [17] has been performed on the possible impact on fish during the dredging and installation works of the gravity foundations at Lillgrund. The final conclusion is the following: "As a summary the studies indicate that the different installations steps (dredging and stone bed preparation) will have minor or no effect at all on small fish at distances 100 m and more from the point of installation."

Also the studies performed by Fiskeriverket within Vindval are co-ordinated with the monitoring program on fish and fishing.

## **SAMMANFATTNING**

Avsikten med denna rapport är att beskriva de miljö- och kontrollprogram som är gjorda och pågår för Lillgrund vindkraftpark samt att summera resultaten och slutsatserna.

Lillgrundprojektet utvecklades av Örestad Vindkraftpark AB och köptes av Vattenfall år 2004. Vattenfall har haft ansvaret för upphandling och byggnation av vindkraftparken. Byggnationen påbörjades 2006 och anläggningen spänningssattes i december 2007. När Lillgrund byggdes var det världens tredje största havsbaserade vindkraftpark och den första större havsbaserade parken Sverige.

Avsikten med miljö- och kontrollprogrammen är att säkerställa att det inte sker någon negativ påverkan av miljön från byggnationen av Lillgrund samt att säkerställa att de villkor som myndigheterna bestämt för parken och bolagets egna åtaganden uppfylls. Ambitionen är också att få mer information om möjlig miljöpåverkan som kan användas för framtida havsbaserade vindkraftprojekt.

För Lillgrundprojektet sammanställdes alla kontrollprogram i ett dokument "Kontrollprogram Lillgrund" som en del av arbetet med att säkerställa att det svenska lagkravet på egenkontroll uppfylldes. Dokumentet godkändes av myndigheterna innan anläggningsarbetena påbörjades.

Kontrollprogram och rutiner som genomfördes under byggnationen omfattade bl.a.:

- Feedback och kontrollprogram avseende grävning och sedimentspill
- Feedback och kontrollprogram avseende flora och fauna
- Inspektioner och kontroll av genomförd återställning av havsbotten
- Rutiner för säkerställande av efterlevnad av kravet på egenkontroll enligt miljöbalken

Avsikten med ett feedbackprogram är att ur ett miljöperspektiv övervaka genomförda arbeten och att snabbt kunna utföra korrigerande åtgärder om en miljörisk upptäcks.

Det under grävningsarbetena uppmätta genomsnittliga sedimentspillet varierade mellan 4.6 och 4.8% beroende på vilket grävningfartyg som användes. Maxnivå enligt villkor var 5%.

De beräknade och simulerade värdena för sedimentpill var begränsade och det kritiska värdet på 0.01 kg/m<sup>3</sup> överskreds bara på ett fåtal ställen och under begränsad tid. Inga korrigerande åtgärder behövde genomföras. Deponeringen av sediment på havsbotten var mycket begränsad och på de mest utsatta ställena var den bara ca 1 mm.

De största volymerna av grävda massor erhöles vid grävarbeten för fundamenten, totalt 82 225 m<sup>3</sup>, vilket är betydligt lägre än den maximala mängd på 200 000 m<sup>3</sup> som angavs i villkoren. Detta berodde i första hand på att fartyg användes som kunde arbeta i grunt vatten, dvs. inga arbetskanaler behövde grävas.

För kabelarbetena blev den totala volymen för grävda massor 68 598 m<sup>3</sup>, vilket också är betydligt under det angivna värdet på max 100 000 m<sup>3</sup>.

För feedbackprogrammet avseende flora och fauna valdes de kritiska biologiska parametrarna ålgräs och blåmussla. Vid inget tillfälle kunde en negativ påverkan på dessa parametrar identifieras.

Resultaten från kontrollprogrammen under byggnation visar att de valda metoderna för grävning och återfyllnad av kabelgravar samt återställande av havsbotten uppfyller ställda miljökrav och villkor.

För att säkerställa att leverantörerna uppfyllde de svenska lagkraven på egenkontroll, genomfördes regelbundna revisioner av deras rutiner och arbetssätt.

För att studera eventuell påverkan på närliggande kuststräcka har ett separat kontrollprogram avseende detta genomförts. Den avslutande studien som gjordes under hösten 2008 visade ingen bestående påverkan på kustlinjen från anläggningsarbetena.

Under anläggningsskedet innebär kravet på egenkontrollen att entreprenörernas arbete med miljökraven och med sina egna kontrollprogram och miljöplaner övervakas på ett systematiskt sätt. En checklista omfattande alla relevanta frågor och en regelbunden rapportering till ansvarig är ett sätt att genomföra detta på.

En sådan checklista togs fram för Lillgrundprojektet och överlämnades till leverantörerna för information innan avtal tecknades. Checklistan var också en del av det godkända dokumentet Kontrollprogram Lillgrund.

För att säkerställa leverantörernas arbete med egenkontrollen gjordes revisioner av deras ledningssystem där man kontrollerade hur man tog hand om lagkrav och andra miljökrav.

Revisioner gjordes också på anläggningen baserat på ovan nämnda checklista. Rutinerna för arbetet med egenkontrollen fungerade bra och vid genomförda revisioner identifierades inga större avvikelser. Alla mindre avvikelser blev åtgärdade.

Ytterligare ett antal kontrollprogram genomförs omfattande bl. a.:

- Fåglar
- Fisk
- Infauna<sup>3</sup> över kablarna (del av kontrollprogram för fisk)
- Ljud

Baslinjestudier avseende ljud har genomförts och dessa visar att den ekvivalenta ljudnivån är 31-46 dB(A) vid vindhastigheter mellan 2-8 m/s. Detta innebär att bakgrundsljudet under långa perioder överstiger den maximala ljudnivån på 35 dB(A) som angetts av myndigheterna. Slutsatserna från baslinjestudierna är dock att det kommer att vara möjligt att genomföra immissionsmätningar av ljudet från parken om korrekt väder och tidsperiod väljs.

Baslinjestudier avseende fisk och fågel har genomförts och programmen har modifierats utifrån de resultat som erhållits. Uppföljande studier under driftfas planeras för tre år. Resultat från genomförda studier under 2008 förekommer ännu inte och förväntas erhållas under våren 2009. Därför kan ännu inga slutsatser dras.

Från vindkraftparken till anslutning på land har en sjökabel lagts. Sjøkabeln kommer att generera ett elektromagnetiskt fält som potentiellt kan störa vattenorganismer. Infaunan kommer härvidlag att användas som instrument för att indikera eventuella störningar. Baslinjestudie är genomförd och uppföljande studie planeras under 2009.

Arbetet med miljöprogrammen har också skett i samverkan med de studier som gjorts för Lillgrund inom kunskapsprogrammet Vindval.

Ett exempel på detta är den studie som gjorts avseende möjlig påverkan på småfisk vid Lillgrunds vindkraftpark under konstruktionsarbeten och anläggning av gravitationsfundament [17]. Studien avslutas med slutsatsen "Sammanfattningsvis tyder studiens resultat på att konstruktionsarbetets enskilda arbetsmoment orsakat små eller inga negativa effekter på förekomst och antal arter av småfisk på avstånd större än storleksordningen 100 m från installationspunkten."

Vidare stäms kontrollprogrammet avseende fisk av med övriga studier som Fiskeriverket genomför inom Vindval.

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<sup>3</sup> Infauna innebär djur som lever i bottensediment.

## TABLE OF CONTENTS

1	INTRODUCTION.....	1
	1.1 Purpose of the report.....	1
	1.2 Background.....	1
2	DEFINITIONS .....	3
3	METHOD OF APPROACH .....	3
4	BIRDS.....	4
	4.1 Conditions in Permits.....	4
	4.2 The Company's Commitment .....	4
	4.3 Background.....	4
	4.4 Realisation .....	5
	4.5 Results.....	5
	4.5.1 Results from Baseline Studies [6].....	5
	4.5.2 Results from Follow-up Studies .....	6
	4.6 Conclusions .....	6
5	FISH AND FISHING.....	7
	5.1 Conditions in Permits.....	7
	5.2 The Company's Commitment .....	7
	5.3 Background.....	7
	5.4 Realisation .....	8
	5.5 Results.....	9
	5.5.1 Results from Baseline Studies [7].....	9
	5.6 Follow-up Studies .....	9
	5.7 Conclusions .....	9
6	BATS.....	11
	6.1 Conditions in Permits.....	11
	6.2 The Company's commitment .....	11
	6.3 Realisation .....	11
	6.4 Results.....	11
	6.5 Conclusions .....	11
7	MARINE FLORA AND FAUNA .....	12
	7.1 Conditions in Permits.....	12
	7.2 The Company's Commitments .....	12
	7.3 Background.....	12
	7.4 Realisation .....	12
	7.5 Results.....	14
	7.5.1 Results from Baseline Studies.....	14
	7.5.2 Results from Follow-up Studies .....	15
	7.6 Conclusions .....	16
8	DREDGING AND SEDIMENT SPILLAGE .....	17
	8.1 Conditions in permits .....	17
	8.2 The Company's Commitments .....	17
	8.3 Background.....	18
	8.4 Realisation .....	19
	8.4.1 General Procedures.....	19
	8.4.2 Feed Back Control (FBC).....	20
	8.4.3 Spill Monitoring Program for Suspended Material .....	20

8.4.4	Cable laying .....	23
8.4.5	Re-establishing of Sea Bottom .....	23
8.5	Results .....	24
8.5.1	Zero Solution - no blocking effect .....	24
8.5.2	Amount of Dredged Material .....	24
8.5.3	Spillage of Sediment .....	24
8.5.4	Affects on Fishing Industry and Biological Life .....	25
8.5.5	Disposal of Dredged Material .....	25
8.5.6	Effects on the "Rügen-herring" .....	25
8.5.7	Affects on the Water at Nearby Beaches .....	26
8.5.8	Cable laying .....	26
8.5.9	Re-establishment of Sea Bottom .....	26
8.6	Conclusions .....	27
9	NOISE .....	28
9.1	Conditions in Permits .....	28
9.2	The commitments by the Company .....	28
9.3	Background .....	28
9.4	Realisation .....	28
9.5	Results .....	29
9.5.1	Results from Baseline Studies .....	29
9.5.2	Results from Follow-up Studies .....	29
9.6	Conclusions .....	29
10	ARCHAEOLOGICAL INVESTIGATIONS .....	30
10.1	Condition in Permits .....	30
10.2	Background .....	30
10.3	Realisation .....	30
10.4	Results and Conclusions .....	30
11	INSPECTION OF NEARBY COASTLINE .....	31
11.1	Condition in Permits .....	31
11.2	Realisation .....	31
11.3	Results .....	31
11.3.1	Results from Baseline Studies .....	31
11.3.2	Results from Follow-up Studies .....	31
11.4	Conclusions .....	31
12	VISUALISATION OF THE WIND FARM .....	32
13	COORDINATION WITH VINDVAL .....	33
14	OPERATORS CONTROL IN ACCORDANCE WITH THE ENVIRONMENTAL CODE .....	34
15	CONCLUSIONS AND LESSONS LEARNED .....	35
16	REFERENCES .....	37

# 1 INTRODUCTION

## 1.1 Purpose of the report

The purpose of this report is to describe the environmental monitoring measures performed for the Lillgrund offshore wind farm and to summarize the results and conclusions.

## 1.2 Background

The Lillgrund project was developed by Örestads Vindkraftpark AB (ÖVP) and purchased by Vattenfall AB in 2005. Vattenfall has been responsible for the purchasing and contracting phases of the project. Construction started in 2005 and the plant was energized in December 2007.

Lillgrund is an area with shallow water located in the sound of Öresund between Denmark and Sweden. The area and the location of the wind farm are shown in Figure 1-1.

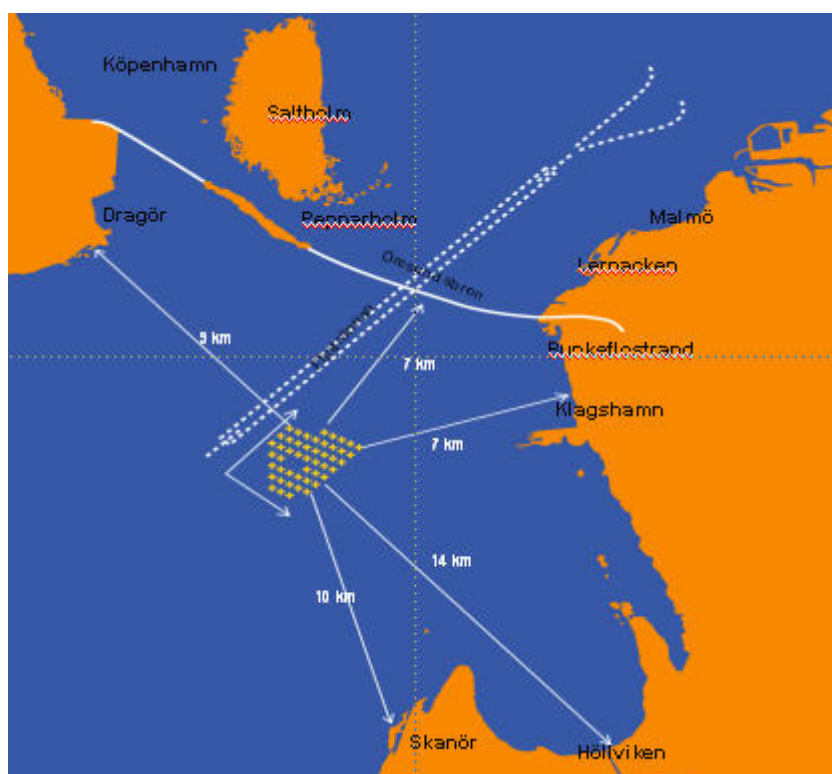


Figure 1-1 The Lillgrund Wind Power Farm located in the Öresund.

The permit under the Swedish NRL<sup>4</sup>, later replaced by the permit under the Swedish Environmental Code, including comprehensive environmental conditions valid for the Lillgrund wind farm, were established in a decision by the Swedish Government on the 22<sup>nd</sup> of March 2001 [1] and by verdict from the Environmental Court on 20<sup>th</sup> September 2002 [2]. The Government decided that the wind farm was legally permissible while the Environmental Court decided how the construction and operations were to be regulated.

Permits under the Swedish Environmental Code normally include a general condition stating that the activity in question has to be designed and operated principally in accordance with the permit application and other documents in the procedure, including the Environmental Impact Assessment. This means that the operator has to fulfil all commitments made during the procedure. ÖVP made generous commitments concerning the monitoring of the Lillgrund Wind farm and its consequences. Those commitments are binding under Swedish law.

A couple of years prior to the start of the Lillgrund project, the Öresund Bridge project were subjected to an environmental trial according to Swedish law. This resulted in several permit conditions for Lillgrund Wind farm identical to or inspired by the conditions handed out for the Öresund Bridge project.

To meet the conditions set by authorities and by legal decision, as well as to achieve the targets set by Vattenfall, a series of monitoring programs have been initiated and carried out. The programs cover monitoring both during the pre-construction phase and construction, as well as during operation. The design of the monitoring programs has been based on the guidelines set by authorities, trials, and baseline studies.

In 2001 the monitoring programs for marine flora and fauna, fish and birds began with the base studies and have been continuing since.

Before start of the construction work, all monitoring programs for Lillgrund were described in one common document (“Kontrollprogram Lillgrund”), which was approved by the County Administrative Board of Skåne, supervisory authority under the Environmental Code. The overall environmental surveillance for the construction of the wind farm at Lillgrund started up in late 2005.

The Environmental Code required operators control (“egenkontroll”) in addition to the set conditions and Vattenfall’s voluntary undertakings. A separate procedure for ensuring that the contractors meet the requirements for operators control was included in the approved monitoring document and the work was co-ordinated by Vattenfall.

Vattenfall developed a QHSE (Quality, Health, Security, Environment) manual for the activities in the project, which addressed the handling of permits, conditions and environmental issues. Vattenfall also demanded contractors to adhere to the QHSE manual in a satisfactory way.

The Contractors, Vattenfall and Swedish authorities carried out the environmental surveillance work during construction. Regular surveillance meetings were held with the County Administrative Board of Skåne, as well as representatives for the City of Malmö, and the Contractors.

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<sup>4</sup> Naturresurslagen (Natural Resources Code)

The work with environment and accident prevention procedures were coordinated with the construction procedures used. This to meet the demands and conditions set in the Environmental Code.

For the construction phase for the Lillgrund project, two main contractors were appointed, Pihl Hochtief Joint Venture (PHJV), responsible for foundations works, and Siemens Windpower A/S (Siemens), responsible for wind turbines and electrical installations including cable works.

Construction of foundations, cable works and wind turbines were finalised in 2007. The wind farm was fully operational by December 2007.

## **2 DEFINITIONS**

In this document no distinction has been made between Vattenfall Vindkraft Lillgrund AB, Vattenfall Vindkraft AB and Vattenfall AB, "Vattenfall" will be the common term used, alternatively the "Company". The main contractors Siemens and PHJV are referred to as the "Contractors". Legal commitments, before the project was purchased by Vattenfall AB in 2005, where done by Örestads Vindkraftpark AB (today Vattenfall Windpower Lillgrund AB) referred to as "ÖVP". In the document references are made to procedures for "operators control" in Swedish "egenkontroll" as regulated by the Swedish Environmental Code and the specific regulation for operators control (SFS 1998:901).

## **3 METHOD OF APPROACH**

The author is from Vattenfall and was responsible for supervising the environmental work performed during the construction phase as well as for the performed baseline studies.

This report is based on the author's experiences from the project and on the reports published as well as from minutes of meetings from the construction period.

During the construction works, regular meetings were held with contractors and supervising authorities, County Administrative Board of Skåne and the municipality of Skåne, in order to check and follow up legal and environmental aspects and requirements.

## **4 BIRDS**

### **4.1 Conditions in permits**

- The Government's decision of 2002 includes the following condition: The company shall, with a maximum amount of 1,5 MSEK, based on the price level of 2001, pay for surveys to study and follow-up the wind farm's impacts on bird life. The company shall, in cooperation with ornithologist expertise and after consultation with the Swedish Environmental Protection Agency and the County Administrative Board of Skåne, prepare a program for such surveys. The program shall be presented for and approved by the County Administrative Board in due time before start of construction works. [1].

### **4.2 The Company's commitment**

- During the procedure in the Environmental Court, ÖVP made a commitment to increase the monitoring program for birds by 1,2 MSEK, of which 400 000 SEK was budgeted for more in-depth baseline studies and 800 000 SEK budgeted for another two years of study after the farm is taken into operation. This means that the follow-up studies on the effects on bird life, due to the project, will be in progress for at least three years after the wind farm is completed. [2]
- A follow up on the effects on the bird life are to be monitored for three years after the wind farm is completed. The Company proposed a continuous evaluation of bird life to be implemented in order to determine if the monitoring program should be terminated early. [2]
- Due to the delay of start of the construction work, Vattenfall decided to prolong the baseline studies to three years after consulting with the County Administrative Board.

### **4.3 Background**

In accordance with the government conditions and court decisions, a monitoring program overseeing the farm's impacts on birds, shall be carried out. Ekologiska Institutionen at the University of Lund has presented recommendations for such a program. The suggestion has also been discussed with and approved by the Swedish Environmental Protection Agency and the County Administrative Board of Skåne.

Main issues in the context are:

- To which extent will the wind farm affect the bird migration during autumn and spring?
- To which extent is the wind farm affecting the bird's local pattern of motion?

- How will the birds react when they meet the wind farm and how can this affect their behaviour and living conditions?
- What is the mortality risk for birds associated with the wind farm?
- To which extent is the environment, where the birds seek food, reduced and which are the consequences regarding the bird's usage of the area of Öresund?

The surveys of possible wind farm effects on the bird population in the area, are based on identified aspects and recommendations by ornithological experts, and are designed to meet requirements made by the Environmental Court.

For the radar studies, two surveillance radar stations from the army are used. Certain periods are selected for further analysis based on field observation results.

The methods used for the aviation and boat inventories were based on similar studies performed in Denmark before the planned wind power expansion.

#### **4.4 Realisation**

From all the feasibility studies conducted, it was shown that using the boat inventories is the best suitable method for conducting the planned studies. These studies are based on a modified ESAS-standard (ESAS=European Seabird at Sea), adjusted to apply to the smaller ships used for in the shallow waters of Öresund. Supplementary aviation inventories have also been carried out.

The baseline studies were initiated in year 2001 and were in process until the start of construction in 2005. The baseline studies were initially planned for one year but because of concerns from authorities and the delay of construction start, they were prolonged. A final report from the baseline studies has been submitted and approved by the County Administrative Board.

No studies were carried out during the construction phase.

After the completion of the construction phase, a three-year follow-up will be carried out. Progress reports will be conducted on a yearly basis. A final report of the monitoring program will be presented after the completion of this series of surveys. The first year's studies have been carried out but results are not yet available.

#### **4.5 Results**

##### **4.5.1 Results from Baseline Studies [6]**

Wintering and staging water birds were censused by boat or aeroplane. The boat surveys covered an area from the Öresund Bridge in the north, over Lillgrund, down to Bredgrund in the south. The aerial surveys covered a larger area from the bridge in the north down to shallow areas south of the Falsterbo peninsula. Nineteen boat surveys were conducted between 2001 and 2005, two and five flight surveys were made in 2004 and 2006, respectively. All the boat surveys were made between autumn and early spring (i.e. over winter). The flight surveys were made between January and May.

Migrating birds were monitored by analysing the radar data collected from military surveillance radar (autumn 2001, spring 2002 and 2005) and by conducting land-based field observations (autumn 2001 and spring 2002). Radar data from 11 days in autumn and 41 days in spring was analysed for migration intensities and detailed flight tracks. Field observations were made for 39 days in the autumn and 20 days in the spring.

Relatively few species of water birds were found in the Lillgrund area, but the quantities were high. During the winter, up to 6500 red-breasted mergansers, 5000 cormorants, 2000 common eiders and 400 long-tailed ducks were registered. In situations when ice covered the more shallow parts of Öresund, larger numbers of Goldeneyes (up to 2500) also occurred in the area. The most common water bird using the general area was the tufted duck, with numbers of up to 10 000 birds. Most of these did not, however, use Lillgrund as a foraging area, but kept to Bredgrund and the shallow areas just north of the Falsterbo peninsula instead. The Lillgrund-Bredgrund area is of international importance to wintering red-breasted mergansers as more than 1% of the total north- and central European population (1% in this case = 1700 birds) occurred on a regular basis.

The common eider was the dominating water bird at Lillgrund during spring with up to about 8000 birds. Most of these do probably belong to the large breeding colony on nearby Saltholm. This implies that Lillgrund is of importance for the local population. Lillgrund may also be of importance for the total Baltic population. Peak numbers at Lillgrund were just below the 1% limit for this population (1% in this case = 10 300 birds).

Large numbers of migrating birds were passing the area during autumn. Öresund has one of the largest concentrations of migrating birds in all of Scandinavia. About 15% of this large migration volume passes over the central parts that include Lillgrund. It is estimated that somewhere in the order of five million birds are passing over Lillgrund during autumn. The autumn migration was dominated by passerines, as well as high numbers of water birds, raptors and pigeons. The spring passage was also of large importance, although total numbers of passing birds were lower than during the autumn migration. A more concentrated passage of low altitude migrating water birds occurred in spring. Compared to the autumn a higher proportion of the overall migration volume was passing the central parts of Öresund that include Lillgrund (22-26%). The proportion of night migrants may have been higher during spring compared to the autumn.

#### 4.5.2 Results from Follow-up Studies

First results from follow-up studies are expected to be available spring 2009.

### 4.6 Conclusions

At this stage it is too early to draw any conclusions from the performed studies, as the studies from the operation phase are not concluded.

## **5 FISH AND FISHING**

### **5.1 Conditions in permits**

- The Environmental Court issued a permit condition stating that works causing turbidity must not be conducted in a way that can affect the migration of the “Rügen-herring” in Öresund. [2]
- The Government issued the following permit condition: The Company shall, with a maximum amount of 2.5 MSEK based on 2001´s price level, pay for surveys regarding the effects on fish population and fishing, required before and after the installation of the wind farm. The Company shall, after consultation with the Swedish Board of Fisheries (Fiskeriverket) and the County Administrative Board of Skåne, prepare a program for such surveys. The program shall be presented for approval to the County Administrative Board in due time before start of construction works. [1]
- Based on the extensive studies on fish and fishery promised by ÖVP during the trial process, the Environmental Court decided that a special condition for fishery and fish was not required. [2]

### **5.2 The Company’s commitment**

- During the trial in the Environmental Court, ÖVP made a commitment to increase the monitoring program for fish and fishery by 1.4 MSEK, of which 400,000 SEK were budgeted for additional baseline studies and 1 MSEK were budgeted for two additional years of studies after the plant was taken into operation. The studies were suggested to use telemetric tracking methods in order to study how electromagnetic fields from the transmission cable affect migrating fish [2].
- Vattenfall has decided to prolong the baseline studies due to delay of start of construction work.
- Based on results from the baseline studies, methods used, have been revised as agreed upon with the Swedish Board of Fisheries (Fiskeriverket)

### **5.3 Background**

In accordance with the Government conditions and the court decisions, a monitoring program overseeing the farms impact on fish and fishery shall be carried out. Recommendations on such a program have been prepared by the Swedish Board of Fisheries, Håkan Westerberg, at the request of the Company. The County Administrative Board of Skåne and the Swedish Board of Fisheries have approved the program.

The Swedish Board of Fisheries is responsible for carrying out the monitoring program.

Studies on the impact of the migration of the herring of Rügen have been carried out in previous monitoring programs, designed for the Öresund bridge project, located close to the

wind farm. The results from this study did not indicate on any negative effects. Based on these findings, and the fact that the spillage of sediment is significant lower in the construction of Lillgrund, it has been concluded that there will be no effects on the Rügen herring.

#### 5.4 Realisation

The objective with the studies is to observe the possible impact from the wind farm on:

- Bentic fish i.e. fish living on sea-bed
- Pelagic fish i.e. moving fish like herring
- Fish migration

Results from studies performed during the baseline period are to be compared with the results from the studies performed when the wind farm is taken into operation.

To provide experience about composition of species, abundance, size-distribution and fish spawning of bentic fish, test fishing was planned using hoop-net and net at Lillgrund and at two separate reference areas, one placed south and another placed north of Lillgrund.

The wind farm's influence on pelagic fish was to be measured with hydro-acoustic methods. The main aim is to quantify the number of pelagic fish in water. An area north of Öresund was chosen as a reference.

Studies of fish migration following the herring and eel were originally planned. The study on herring was excluded as described in chapter Background. The study on eels was to be carried out by acoustic surveys.

Following activities were planned:

- Test fishing with net
- Test fishing with hoop-net
- Test fishing spawning
- Eco-detection in order to study fish migration and behaviour of fish around the wind turbines
- Active and passive<sup>5</sup> telemetric measurements of the migration of eel
- Hydro-acoustic measurements in order to study the impact from noise on fish

The baseline studies were initiated in 2001 and were in progress until the start of construction in 2005. The baseline studies were initially supposed to be carried out for only one year but was prolonged until 2005 because of a delayed construction start. Reports

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<sup>5</sup> With active telemetri the transmitter is located on the eel and the receiver on a ship following the eel. With passive telemetri the receivers are located at a fixed location and another type of transmitteras are used.

from the baseline studies were done for 2002, 2003 and 2004. [2] The reports were approved by the County Administrative Board. A follow up study is planned three years after operation start.

The studies during the operation phase have started up but no results are yet available.

## **5.5 Results**

### **5.5.1 Results from Baseline Studies [7]**

The Swedish Board of Fisheries has carried out the test fishing, eco-detection and telemetric surveys between 2002 and 2005.

The test fishing, except from the aimed spawning test fishing, succeeded well. The spawning test fishing was disturbed by drifting algae and was therefore concluded in 2004. The analysis of the statistic significance showed that test fishing with nets and hoop-nets enable large changes in catch to be detected after the wind farm is constructed.

The wind farm's influence on pelagic fish, and especially the migration of herring, was investigated with the use of hydro-acoustic methods (eco-detection). The analysis of the statistic significance showed that, under the present conditions and procedures, the probability to reveal large changes in numbers of pelagic fish after the construction is low. This could be improved by increasing the number of transects in the reference area, and by decreasing the variability through improvement of the design of the transects and by using section transects for the evaluation.

Eel and herring migration patterns were chosen to study the wind farm's effect on fish migration. To survey the eels' natural choice of migration, active and passive telemetric measures were used. The evaluation has shown that the passive telemetric method was preferable for the operation surveys because of its ability to follow a larger number of eels, giving a better picture of migration patterns. It is concluded that changes in the eels' migration patterns will be more detectable with the passive telemetric methods.

Eco-detection and measurements and data have been analysed but no results can be drawn from this until follow-up studies have been performed.

Hydro-acoustic measurements have not been performed but are planned for the operation phase.

## **5.6 Follow-up studies**

First results will be available in spring 2009.

## **5.7 Conclusions**

Based on the results from studies performed during construction of the nearby Öresund Bridge, it was concluded that there would most likely be no effect on the migration of herring. To further minimize the risks for possible negative impacts, the construction works for the foundations was not started until the expected migration of herring had passed.

Test fishing of spawning fish was not possible due to large amounts of drifting algae. The methods for identifying pelagic fish can be approved by increasing and improving the design of transects.

The method using eco-detection to measure the effects on pelagic fish, especially on the migration of herring, showed no statistic relevance and must be improved.

Passive telemetry was more successful than active telemetry for the study of eel migration. Otherwise, proposed investigation methods worked well.

As studies during the operation phase have just started, no results showing possible effects of the wind farm on fish and fishing are yet available, and it is too early to draw any further conclusions.

## **6 BATS**

### **6.1 Conditions in permits**

- There were no conditions in the permit from the Government concerning bats.
- The Environmental Court considered that a control should be carried out according to the applicant's undertakings. A specific condition for this was not considered necessary to prescribe. [2]

### **6.2 The Company's commitment**

- ÖVP made a commitment to the Environmental court to perform studies on the bat's autumn migration, to see if bats occur in the area and whether the wind farm affects them. Costs for studies were estimated to 200,000 SEK. The studies would include observations from before the construction of the wind farm and then after the farm is put into operation. [2]

### **6.3 Realisation**

A study of bat migration patterns in the south of Öresund, as a consequence of the placement of a wind farm in south Lillgrund, was carried out by the environmental consultant and by the Swedish expert on bats, Rune Gerell.

### **6.4 Results**

The report on the analysis and study performed was published October 1, 2003 [5]. The conclusion from the report is that the risk for bats to be killed as a result of a collision with a wind turbine in Lillgrund is estimated to be very small and possible losses are neglectable in respect to the size of the bat population.

Because of this conclusion, the County Administrative Board decided that additional monitoring programs with respect to bats are not necessary as long as no new facts are discovered.

### **6.5 Conclusions**

The performed studies showed that there is a low risk for bats to collide with the wind farm and that possible losses are negligible compared to the size of population for the species studied.

## **7 MARINE FLORA AND FAUNA**

### **7.1 Conditions in permits**

- Areas where temporary filling and dredging have been taking place, shall be restored after completed work as to allow re-establishment of flora and fauna. [2]

There are no other conditions regarding flora and fauna.

### **7.2 The Company's commitments**

- The applicant has satisfied the County Administrative Boards motion regarding the performance of a monitoring program regarding the spillage of sediment. The program is carried out in accordance with the proposal from the County Administrative Board and includes a study of marine flora and fauna. The program includes follow-up controls at three locations, partly in connection to the construction works and partly right after. Toxicon AB, which did similar studies for the Öresund Bridge, estimated the costs for such a program to be 1 MSEK. [2]
- The Company recommended a follow-up on the effects on the bottom fauna from the electromagnetic field from the sea cable. The study was suggested to be carried out by a survey of the seabed communities through a transect over the cable before the construction phase and at two additional occasions, two and four years after operation start. The costs for the study were estimated to 200 000 SEK. [2]
- The baseline studies have been prolonged due to delay of start of construction works.

### **7.3 Background**

The Government has not demanded any monitoring program for flora and fauna. The Company has yet complemented with such a program in accordance with a suggestion from the County Administrative Board. The Company offered to follow up the effects through suggested monitoring program as a beginning with the possibility to terminate the programme if the impacts turned out to be insignificant. The experiences from the construction of the Öresund Bridge had indicated that the largest environmental impacts are caused by sediment spillage from dredging work. Therefore the focus on organizing an environmental surveillance was to secure that the effects from the emissions were minimized.

### **7.4 Realisation**

The monitoring program regarding flora and fauna consists of two separated parts:

- Part 1 studies the impacts on the biological key variables under construction and constitutes part of the Feedback Control (FBC) program.

- Part 2 studies the impact on flora and fauna around the buried cables.

The purpose of the FBC was to ensure that the sediment spillage stayed within given threshold values and that the fauna and flora were not negatively affected by it. It also provided fast action on corrective measures if any negative effects were identified.

Two major tools for ensuring the objectives stated above are met:

- During the construction work the spillage amount in relation to total amount of dredged material and the expansion of the sedimentation plume were checked. These observations underlie the biological variables in the FBC.
- A monitoring program, which covers the biological key variables and reflects the impact of the eco system, is being implemented.

The company Toxicon was responsible for performing the monitoring program and FBC on flora and fauna. The biological indicators chosen are the eelgrass and the common sea mussel. The eelgrass parameters indicated a possible shadow effect caused by sediment spreading, while the analysis of the common sea mussel parameters indicated a possible disturbance from resedimented material. The parameters studied on eelgrass were sprout number, sprout length, biomass and carbohydrate level of which sprout number is the most critical biological parameter.

During the construction phase, a part of the FBC program called for modelling of the potential consequences of the dredging on the sedimentation in Öresund. This work was conducted by DHI and is described in the section about dredging and sediment spillage.

The studied areas are divided into the following parts:

- Impacts on the inner area (the wind farm with an area 500 meters outside the farm).
- Impacts on the outer area (6 km north and south and 4 km east and west of the inner impact area)
- Reference areas (areas outside the outer impacts area)

The program was to be carried out in three separated phases:

- Baseline
- Construction phase
- Operation phase

The coordinator responsible for the FBC program was also responsible for the environmental issues for the Lillgrund project group.

If the FBC program should indicate a negative impact on key variables, the goal was to take corrective measures quickly to minimize the spill.

In order to be able to carry out the FBC baseline study, key variables studies were required. The baseline study was initiated in 2001 and had to be prolonged until 2005 because of delayed start of construction. The updates were regarded as essential in order to secure base data as close as construction start as possible.

Further a monitoring program for infauna on the seabed above the buried cables was carried out. The purpose of the study was to survey if the electromagnetic field emitted from the sea cables, interrupt organisms in the water.

## 7.5 Results

### 7.5.1 Results from Baseline Studies

#### Eelgrass

In July and September in 2001 baseline studies of eelgrass were carried out on five stations (3 reference stations and 2 effect stations). Each of them consisted of two deep intervals. A third effect station was excluded since no significant eelgrass meadows were observed in the area. The studied parameters, sprout number, sprout length, biomass and carbohydrate level, hovered around the same level as they did compared to previous surveys done for the Öresunds bridge project.

A statistical analysis of data indicated that the program needed to be adjusted to fulfill the demands of detecting 25% of change between two consecutive surveys. This could be achieved by doubling the replica number on both of the effect stations. This allowed the eelgrass program to be used to track the possible impacts from the construction of the Lillgrund wind farm with respect to the above-mentioned parameters.

In September 2003, and under two periods in 2005, supplementing baseline studies of eelgrass were carried out on five stations (three reference and two effect stations), each one consisting of two deep intervals [8]. The station locations and the amount of time to carry out the tests were similar to the baseline study carried out in 2001. The studies performed were adjusted slightly to results from previous analysis of statistic data by doubling the number of samples (replicates) studied on the two effect stations.

The parameters sprout number, sprout length, biomass and carbohydrate level and sprout remained at about the same level as they did for previous surveys.

The variation between samples (replicates) for different parameters indicated successful testing with relatively low variations. If the same variation can be maintained in planned investigations, it indicates that undesired changes and exceeding of the limits stated by the monitoring program would be able to be detected at future investigations.

The results from the updated baseline studies in 2005 were the basis for the FBC program.

#### Common Sea Mussel

A baseline study of the Common Sea Mussel was carried out in July and September 2001 on five locations (2 reference and 3 effect stations) each composed by three substations.

The following parameters were studied:

- Degree of coverage,
- Area specified density,
- Biomass

The results were approximately on the same level as measured for the Öresunds bridge project. The difference between different years and stations was relatively large and the coefficient of variation was high for all parameters.

The statistical analyses showed that the diffusion in the material was too high to be able to be used for detection of a 25% change in analysed parameters. This, in combination with the risk for the displacement of the population in the areas as a consequence of physical reasons, unrelated to wind farm construction, required a revision of the monitoring program for sea mussels.

A method with video screening of selected areas was suggested to detect if the sea mussel banks were being covered by sediment due to sediment spillage. The study was to determine whether the maximal 25 % degree of coverage reduction had occurred or not. This revised method and procedure was accepted by Vattenfall and the authorities.

The baseline study of the common sea mussels was updated on the 3rd of April in 2006 to achieve updated information data. This study was the basis for the FBC performed on Sea Mussels

### Infauna

A baseline investigation of the fauna on the sea bottom was performed on the 16<sup>th</sup> of September 2005 on eight stations located on two depths; 0.5 meters and 2 meters respectively, divided on four effect stations and 4 reference stations.

The study showed that the fauna in these stations was normal for this type of environment. The total parameters were on significant more even level compared to the results from the taxonomic main groups separated. The stations in areas of shallow water generally showed a higher numbers of species, individuals and biomass compared to stations in deeper areas. In general the fauna was in good condition.

The monitoring program of the infauna was planned for the first year of operation. However after further discussion it was suggested by Toxicon that the studies should be postponed to 2009 because it would take some time for the infauna to settle on the seabed after dredging for the cable laying. The one year delay would be beneficial to be able to study possible effects from the magnetic fields around the cable.

## 7.5.2 Results from Follow-up Studies

### Eelgrass

As part of the FBC program implemented during the construction phase, three investigations on the effect on eelgrass were performed in May-June 2006, September 2006 and June 2007 [12][13][14].

In general these investigations showed a significant decrease in the parameters sprout number, sprout length, biomass and carbohydrate level compared to the baseline studies in 2005. The only parameter that increased for all stations at the investigation in June 2007 is sprout length. It is assumed that sun radiation increased during that time.

The decreases in the parameters were more significant at the reference stations but the differences between Lillgrund and the reference stations never exceeded 25%.

The clear conclusion of all the investigations was that the dredging work at Lillgrund did not have a negative effect on the eelgrass population.

During the construction phase, one further investigation on the eelgrass population was performed in September 2008 [15]. The results show a decrease in both sprout numbers and carbohydrate levels compared to the investigations performed in 2007 for the stations in shallow water. For the deep stations, the sprout number and biomass had increased. As the case has been with the studies performed from 2001 to 2007 the changes in the reference stations were similar to the changes on the effect stations at Lillgrund. The conclusion is that the construction work at Lillgrund did not negatively effect the eel-grass population.

Based on the above results, Toxicon requested to stop any further investigations on the eelgrass population.

### Common Sea Mussel

As part of the FBC program three video screenings were performed during construction works on May 10<sup>th</sup>, July the 13<sup>th</sup> and October 10<sup>th</sup> 2006 [9][10][11]. With this feature, any sediment covering the mussels could be visibly detected by these screenings.

### Infauna

This study is proposed for 2010.

## **7.6 Conclusions**

For the impact on flora and fauna, the biological key variables eelgrass and common sea mussels were chosen. For eelgrass the parameters of sprout number, sprout length, biomass and carbohydrate level were investigated. Statistic analysis performed showed that the method chosen was successful.

The statistical analyses of the results from the first baseline study of the sea mussels showed that the diffusion in the material was too high to be able to be used for detection of a 25% change in analysed parameters, as required. Therefore the original method was revised and the method with video screening was applied.

The results from the studies performed during the construction period for eelgrass and sea mussels and first year of operation for eelgrass, showed no negative effects on flora and fauna from the construction work performed for erection of the Lillgrund wind farm.

No conclusions on possible effects on the infauna from the magnetic fields of the cables can be drawn until this study is concluded. Conclusion of the study is currently planned for 2010.

## 8 DREDGING AND SEDIMENT SPILLAGE

### 8.1 Conditions in permits

- According to the permit from the Government the spillage of sedimentation connected to handling of dredged material shall be limited to an average of 5% of dredged material. [1]
- The permit also includes the condition that works causing turbidity should be limited in matters of intensity, time and place with respect to the fishing industry and biological life in Öresund. [1]
- The verdict by the Environmental Court includes a general condition that is a standard for all permits given under the Swedish Environmental Code. The condition had an additional paragraph aiming to limit the blocking effect in Öresund: The wind farm shall be designed and operated principally in accordance with the application with the documentation enclosed therein. The County Administrative Board of Skåne can allow minor discrepancies that do not increase the blocking effect of the project or the average sediment spillage, and obviously has no effect on public or private interests. [2]

The verdict also includes the following conditions:

- The volume of dredged material must not exceed 200 000 m<sup>3</sup> for foundations and 100 000 m<sup>3</sup> for cable- and installation trenches. [2]
- Excavated and dredged material may not be dumped on the seabed outside of the areas required for wind turbine foundations and cable trenches. [2]
- Works causing turbidity must not be conducted in a way that affects the migration of the “Rügen-herring” in Öresund. [2]
- During the period of 1<sup>st</sup> June to 31<sup>st</sup> August dredging shall be performed in such a way that turbidity does not cause seawater transparency of less than 1 meter measured at nearby beaches. [2]
- Areas where temporary filling and dredging have been taking place shall be restored after completed work as to allow re-establishment of flora and fauna. [2]

### 8.2 The Company's commitments

No commitments were stated by the Company. Tolerances for refilling trenches and re-establishing sea bottom were stated in the method descriptions and approved by authorities.

### 8.3 Background

Most of the conditions above are based on the conditions, which were given for the construction of the bridge at Öresund, but it should be noted that the dredging work was significantly more extensive for the Öresund Bridge than for the Lillgrund wind farm.

One of the conditions from the court states that: “The spillage of sedimentation connected to handling of dredged material shall be limited to an average of 5% of dredged material. The Öresund Bridge had the same condition for spillage. The definition of spillage for the Öresund Bridge Project was “material which sediments more than 200 meters away from the working area”. The same definition has been used for the Lillgrund project.

Extensive modelling work performed by the DHI during the permit process, indicated that the project would not have a negative blocking effect on Öresund. Construction work is performed in accordance with the description in the Environmental Assessment performed [4].

Figure 8-1 shows dredging works performed at Lillgrund by the dredger Grete Fighter.



Figure 8-1 Dredger in operation at Lillgrund

## 8.4 Realisation

### 8.4.1 General Procedures

In the contract documentation, contractors were required to follow stated conditions.

The contractors QHSE (Quality, Health, Security, Environment) plans and time schedules were adjusted to these conditions and procedures for their surveillance were prepared and agreed upon. This includes:

- Time plans were adjusted to stated conditions and approved by authorities concerned.
- Method descriptions prepared by the Contractors were reviewed and compared to given conditions.
- The contractor reported the amount and location of dredged material to Vattenfall on a weekly basis.
- Model measurements of sediment spillage were carried out.
- Regular meetings with the reviewing authority under the Environmental Code (County Administrative Board of Skåne), representatives for the city of Malmö and the main contractors were held on a monthly basis.
- A feedback control program regarding effects on flora and fauna from dredging works has been carried out, see separate chapter for more information.
- A feedback and monitoring program regarding spillage of sediment was carried out.
- Regular visual inspections of the spreading of sedimentation plume have been carried out by the contractor responsible for the foundation works, during the period 1<sup>st</sup> June-31<sup>st</sup> August 2006 to ensure that nearby beaches would not be affected. Reports were submitted to Vattenfall on a weekly basis.
- Measurements and photo documentation of the seabed was carried out before start of the works and after re-establishing the seabed.
- Special photo documentation of critical parts of the seabed was performed.

For the dredging of the trenches, the method description was adjusted in order to minimize the sedimentation spillage.

#### 8.4.2 Feed Back Control (FBC)

Two main tools have been used to ensure that the sediment spillage from dredging works will fulfill given conditions and will not affect the environment (see also the monitoring program for Marine flora and fauna):

- A monitoring program for the suspended sediment caused during construction work of the Lillgrund wind power plant, including during the laying of sea cables, is carried out by a numerical modelling method of the sediment spill. This means that calculations based on the amount of dredged material and supplemented with spot checks surveys of the spill rates were used. This section of the program was performed by DHI.
- A monitoring program on flora and fauna, which covers the biological key variables and reflects on the impacts on the eco system, was implemented. As basis for these studies were results from runs with the model, done according to the first item. The company Toxicon carried out this program.

The above programs were the basis for the Feedback Control (FBC) on dredging works performed. The principle of the FBC aims to quickly alarm the supervisors if the construction workers cause an unacceptable change of chosen parameters and to perform corrective actions. The monitoring and FBC on marine flora and fauna is described in detail in chapter Marine Flora and Fauna. Vattenfall was responsible for the coordination of the monitoring programs and reporting to authorities and other stakeholders.

#### 8.4.3 Spill Monitoring Program for Suspended Material

Full-time and on-line monitoring of spill during the entire construction period is laborious and expensive. Continuous monitoring may, in many cases, be replaced with numerical modelling of the sediment spill using the assumption that dredging is constant and thus spill sources are likewise. This means that calculations based on and supplemented with spot check surveys of the spill rates can be used instead. Applying this method will benefit the Lillgrund project and the distribution of the information on the spilled sediment will be an important tool. The results were used in the ecological models and for the work performed by Toxicon, see above. They were also used to inform the project on areas of increased turbidity and decrease of light penetration.

The spill monitoring program was performed by DHI.

The reporting from DHI to Vattenfall consisted of a technical report documenting the results of the surveys and the modelling, including maps of:

- Mean suspended sediment concentration exceeding 2 mg/l (visible limit)
- Mean suspended sediment concentration exceeding 10 mg/l (possible limit affecting fish migration and vegetation)
- Exceeding frequencies of the above limits in percentage.

Reporting was made each week during the start of the construction work for the foundations. However as the results indicated very low values for suspended material, reporting was reduced to a bi-weekly basis. All reports were forwarded to the authorities.

## Method for Spillage Measurements

In order to calibrate the model, spill measurements were performed. The measurements of the spill were carried out using the equipment listed below, see Table 8-1.

**Table 8-1 Instrumentation for the spill monitoring.**

<u>Instrument</u>	<u>Measures</u>
ADCP (Acoustic Doppler Current Profiler)	<ul style="list-style-type: none"><li>• Currents</li><li>• SSC (suspended sediment concentration)</li></ul>
CTD (Conductivity, Temperature, Depth)	<ul style="list-style-type: none"><li>• Salinity</li><li>• Water temperature</li><li>• Depth</li></ul>
OBS (Optical Backscatter)	<ul style="list-style-type: none"><li>• SSC</li></ul>
GPS (Global Positioning System)	<ul style="list-style-type: none"><li>• Locations</li></ul>
Echosounder	<ul style="list-style-type: none"><li>• Depth</li></ul>
Water pump	<ul style="list-style-type: none"><li>• For taking water samples on site</li></ul>

The sediment fluxes were monitored using an ADCP system mounted on a vessel, combined with other probes for calibration purposes. The spill percentage was computed based on the measured sediment fluxes and an average dredging rate of  $33.5 \text{ kg s}^{-1}$ . The spill percentages were computed in the interval 4.4% – 5.4% with an average range of 4.5-4.8% depending on the type of dredger used.

### Description of the Model

The present study was carried out using the hydrodynamic modelling tool MIKE 3. MIKE 3 is a generic system used for computation of hydrodynamics in oceans, estuaries, coastal areas, and lakes.

The modelling system was developed by DHI throughout the 1980's and has since been applied to a large number of studies including investigations prior to the establishment of the fixed link across Öresund, including the calculations for the zero solution.

The sediment transport model (MT-model) only includes the sediment from dredging spill. This means that the model is started up with no background concentration of suspended sediment and no sediment from natural sources is supplied from the boundaries. Likewise, the seabed is considered clean when the simulation starts. In this way, the only sediment included in the model is the spillage from the dredging and the change in turbidity and sediment deposition can readily be investigated.

### Method for Spillage Calculations

The dredging company delivered daily dredging reports. The reports include information on the timing and positions of dredging and the dredging amounts. This information was converted into a sediment concentration that was fed to the hydrodynamic model. The dredgers Grete Fighter and Grävlingen were used for the dredging works at Lillgrund. Grete Fighter is capable of carrying approximately 380 m<sup>3</sup> per loading. Grävlingen has an approximate capacity of 950 m<sup>3</sup> per loading using four external barrels.

Based on the above-mentioned field measurements the spill is in the interval 4.4–5.4% and a mean value was used in the calculations, depending also on type of dredger used.

Density of the bed sediment was taken as 1970 kg m<sup>-3</sup> meaning that if a dredging of e.g. 330 m<sup>3</sup> is reported, this is converted to 650 ton sediment.

### Analysis of Suspended Sediment Concentrations

The suspended sediment concentrations were investigated at two critical levels:

1. 0.002 kg/m<sup>3</sup>, at which level the suspended sediment can be recognised by the human eye. This concentration is close to the background concentration in the sound.
2. 0.01 kg/m<sup>3</sup>, at which level the rooted vegetation and the migration of fish might be affected.

This was investigated every week the monitoring program was in place and the mean concentrations were used to represent the week in an exceedance diagram, which shows the percent of time where the values are exceeded.

### Analysis of Bed Mass Changes

The bed mass change was reported as a map after conclusion of each four-week period's simulation. The map includes sediment for all weeks since the dredging was started. This makes it possible to investigate the accumulated effect of the dredging works.

The modelling was carried out on a weekly basis. The first week of the dredging period started up without any sediment movement. For the remainder of the weeks, the model was started up using the final maps from the preceding week(s). Thus, any suspended sediment originating from previous weeks and sediment deposited at the bed were taken into account for the week in question.

### Spill Monitoring of Cable Trench work

The cables were laid in pre-dug trenches. A proven method, where most dredging work of the cable trenches was done below the seawater surface, was used in order to minimize the spillage. Before start of the construction works, DHI performed a modelling of the expected sediment spillage showing only limited values of spillage. Based on these results and that only a limited amount of material was dredged, it was agreed upon that no substantial monitoring would be required. The supervising authorities approved this procedure as well as the method description for dredging. Visual inspections and checks during construction work confirmed the method worked as expected.

#### 8.4.4 Cable laying

The authorities required that the export cable from the transformer platform to the shore and the cables in the wind farm should be buried to a depth of 1.0 meter. The sea bottom was classified as medium hard with a topmost sediment layer consisting of sand at the sea floor resting on clay till and below that limestone. The sand layer has an approximate thickness ranging from 0-1 meters.

The contractors decided on a method for cable laying where the cables were laid in pre-dug trenches, followed by the back-filling of those trenches. The vessel for digging trenches is shown in

Figure 8-1.

#### 8.4.5 Re-establishing of Sea Bottom

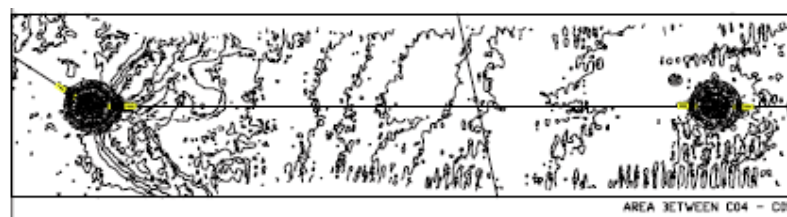
##### Foundations

After the foundation work was finalized, the sea bottom around the foundations and working area was filmed in order to confirm that the sea bottom had been re-established in accordance with requirements and that no objects were left behind.

##### Trenching and cable works

Before the trenching work started, an in-survey of the cable routes between the wind turbines and the transformer platform, as well as the export cable-landing location was carried out. The purpose of the survey was to document any excessive amounts of boulders or other obstacles e.g. wrecks, cables, pipes etc. existing along the seabed of the cable route which might interfere with the trenching or the cable laying. The survey also constitutes a reference for the backfill work.

The marine survey vessel M/V SOUND SEEKER, equipped with Multibeam echo sounding equipment, performed the survey. The vessel is positioned by the use of DGPS working in RTK mode. The area covered by the survey was approximately 30 meters. A typical result from the in-survey is shown in Figure 8-2.



**Figure 8-2 Results from in-survey between foundation C04 and C05.**

On completion of the backfilling, a final inspection and out-survey was carried out using the same vessel and Multibeam equipment as in the in-survey taken prior to trenching. The results from the out-survey were compared to the in-survey in order to ensure that the seabed was re-established in accordance with requirements.

The supervising authority interpreted the condition regarding re-establishment stated in the permits so that a max tolerance between in and out survey of 0.3 meters was acceptable.

## 8.5 Results

No baseline studies were required.

### 8.5.1 Zero Solution - no blocking effect

The construction was designed and the works were performed in accordance with the application to the Environmental Court and as described in the Environmental Impact Assessment. For this design, detailed modelling work had been performed by DHI showing there will be no blocking effect in Öresund. The material was presented to and accepted by the Environmental Court.

### 8.5.2 Amount of Dredged Material

The largest dredging volumes were the foundation works, in total 82 225 m<sup>3</sup> which is significantly lower than the max stipulated 200 000 m<sup>3</sup>. This was the result of using vessels accustomed to operating in shallow waters therefore not requiring any working channels and that the method for the dredging works was adjusted to reduce the amount of spillage.

For the Export Cable, from transformer platform to landing location at sea shore, a total of 9507 m<sup>3</sup> (total length of trench about 7 km) dredged material was handled. For the Inter-Array Cables, between the wind power turbines and to the platform, 59 091 m<sup>3</sup> (total length of trenches 22 km) dredged material was handled. This gives a total of 68 598 m<sup>3</sup> which is well below the stipulated max of 100 000 m<sup>3</sup>.

### 8.5.3 Spillage of Sediment

#### Measurements

The spillage from the foundation works was measured at three different occasions by DHI as part of the spill monitoring program, on May 17<sup>th</sup>, June 1<sup>st</sup> and June 13<sup>th</sup> 2006. The results were in the range between 4.4%-5.4% with an average of 4.8% [16].

Further spill measurements were performed by PHJV, responsible for the foundation works, on April 12<sup>th</sup>, April 18<sup>th</sup>, June 7<sup>th</sup>, June 8<sup>th</sup> and June 9<sup>th</sup>. The mean value for spillage from these measurements was 4.1%.

These average figures could be compared by the max-allowed value of 5%. However it should be noted that the total amount of dredged material was far below the allowed max value stated thus also giving a considerably lower value for the total spillage produced.

#### Results from Modelling

The spillage from the foundation works was modelled by DHI as part of the FBC program and as described above. The modelling was performed from week 18 to week 50, 2006. Up to week 30, weekly reports were issued, but after that only reporting each fourth week were considered necessary due to the low values observed and due to the decrease of dredging operations.

At no time it was necessary to stop the dredging operations due to high values of sediment spillage.

The results from the modelling showed that peak values due to increased dredging were received for week 27, 2006. The results for this week showed that a suspended sediment concentration of  $0.0002\text{kg/m}^3$  exceeded over an area of 11.7 km for more than 5% of the time. The concentration of  $0.01\text{ kg/m}^3$  was exceeded at minor individual areas for about 5% of the time.

In general the values for suspended material were limited and the critical value of  $0.01\text{ kg/m}^3$  was exceeded only on minor areas for a very limited time.

The deposition of sediment was very low and even at the most affected sites it was only just over 1 mm.

For the dredging works performed for the cable trenches the spillage was modelled for one typical week by DHI as ordered by the main contractor responsible for wind turbines and electrical equipment including cable works. The results showed that the amount of suspended material was very limited.

#### 8.5.4 Effects on Fishing Industry and Biological Life

During construction works the working area at Lillgrund was a restricted zone and no fishing vessels or foreign vessels were allowed to enter the working zone. Vattenfall employed a vessel coordinator for keeping track and coordinating all movements of vessels etc.

Regular meetings were held with the professional fishermen for information.

The effects on biological life were studied in the monitoring program for Marine Flora and Fauna as part of the FBC.

No disturbances, non-conformances or complaints were reported at any time.

#### 8.5.5 Disposal of Dredged Material

Material from the dredging work, which was not used for refilling, was disposed in an area at the Malmö harbour in accordance with agreement with Malmö-Copenhagen Port authorities and Malmö City.

#### 8.5.6 Effects on the "Rügen-herring"

The time plan for the dredging work was adjusted to the migration of the Rügen herring. It is difficult to determine the exact time for the migration of the herring as it varies from year to year according to previous studies on the population. However, after consultation with the County Administrative Board of Skåne, a start time for the dredging work was agreed upon when it was most likely that the herring migration had ended.

It is believed that the limited amount of dredging occurring at Lillgrund covers only a limited area and raises little or no concern over the effect on the migration of the herring.

### 8.5.7 Effects on the Water at Nearby Beaches

The propagation of the sediment was regularly visually inspected and showed that there was no risk for impact on water at nearby beaches. The contractor reported the inspection results on a weekly basis for the period June 1<sup>st</sup> to August 31<sup>st</sup>.

This result was expected from the modelling performed in advance by DHI considering the strong currents at the Lillgrund site.

### 8.5.8 Cable laying

The method chosen for burying the cables was successful and the 1-meter depth requirement could not be met only for approximately 200 meters of the export cable. For these shorter distances, the cable was protected by a rock dumping method approved by the authorities. Experience showed that the time between digging and laying the cable was critical in order to avoid natural back filling of the trenches before the cable was laid.

### 8.5.9 Re-establishment of Sea Bottom

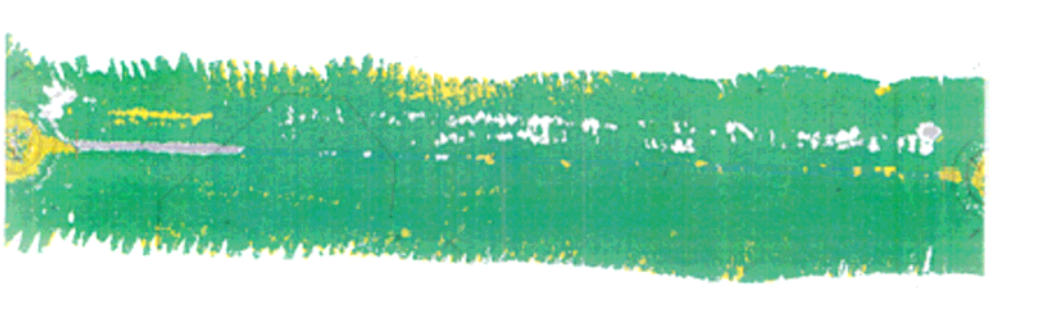
#### Foundation Works

After the foundation works were finalized, the area was videotaped. The films showed that the seabed was re-established in a satisfying way and no equipment or other material was forgotten on the seabed.

#### Cable Trenches

The results from the comparison between the in- and out-surveys were presented by the contractor in the form of diagrams showing the differences by curves and by colours. Figure 8-3 shows the differences between the in- and out-survey performed between foundations C04 and C05 in the colour version. The green fields indicate a seabed surface that has been refilled within the stipulated tolerance of  $\pm 0,3$  meters. Grey fields indicate that the seabed surface is within a tolerance of  $-0,6$  meters and yellow fields within a tolerance of  $+0,6$  meters.

On the left hand side of the figure (close to the foundation) it can be seen that the backfilling level is not sufficient.



**Figure 8-3 Results from comparison of out-survey with in-survey between foundations C04 and C05.**

The results showed that 94% of the area within the wind farm and 87% of the area along the export cable was refilled within the stated tolerances. Based on the results, some additional backfilling with existing material was done close to the foundations. The deviations between in- and out-survey was mainly dependent on the time between the measurements. During that lapsed time, some heavy storms and/or the heavy currents at Lillgrund could have caused the movement of material on sea bottom.

By recommendation of the authorities, areas not meeting the depth requirement were surveyed by video filming the sea bottom. This survey showed that the sea bottom was re-established as required even in most critical locations. Based on these results, the work with the re-establishment of the sea bottom was approved by the authorities.

## **8.6 Conclusions**

The Government and the Environmental Court required the dredging work at Lillgrund to meet certain conditions. The conditions were based on the conditions given for the construction works with the nearby Öresund Bridge Project.

A number of control and monitoring programs were executed during the construction work in order to ensure that the conditions stated in the permits were satisfied and limits not exceeded. The results show that the chosen methods for the dredging work, refilling the trenches and restoring the sea-bottom, could meet the requirements from the authorities and satisfy permit conditions. At no time during the construction work was there a risk that nearby beaches would be affected by the work performed.

The weekly modelling of the spillage distribution done during the construction phase showed that:

- The values for suspended material were limited and the critical value of  $0.01 \text{ kg/m}^3$  was exceeded only on minor areas for a very limited time.
- The deposition of sediment was very low and even at the most affected sites it was only slightly over 1 mm.

The method chosen for burying the cables to a depth of 1.0 meter by pre dug trenches was successful, and only for shorter distances of the export cable (approx 200 m), the requirements could not be met. The cable was protected by rock dumping as approved by authorities for these parts. Experience showed that the time between digging the trenches and laying the cable was critical in order to avoid natural back filling of the trenches before the cable was laid.

## **9 NOISE**

### **9.1 Conditions in permits**

- The Environmental Court has a condition stating that the equivalent noise level at the closest beach area shall not exceed 35 dB(A) [2].

### **9.2 The Company's commitments**

There are no legal requirements on the Company to monitor noise levels. However, Vattenfall has volunteered a monitoring program to measure noise levels.

### **9.3 Background**

The Environmental Court justified their condition of the permit by the following:

- The company has assured the courts that the noise level from the wind farm shall not exceed 35 dB(A) at the recreation area located between the wind farm and residential areas. The Environmental Courts paid a visit and inspected the recreation area (Strandhem), and noticed that the neighbours frequently used it. Therefore it is warranted to stipulate a special condition on noise levels, based on the applicant commitment.

### **9.4 Realisation**

To ensure that the condition was followed, Vattenfall decided to perform a monitoring program on noise levels. Noise level measurements were performed at Strandhem in Bunkeflo, before construction started (baseline) and after the wind farm was taken into operation. This was the location specified for the visit and inspection by the Environmental Court. The aim with the measurements was to estimate if the conditions are fulfilled and if the noise from the wind farm is audible in the area. The measurements include measurement of infra sound.

The measurements are carried out as immission measurements both manned (short term) and unmanned (long term), and are performed and reported by ÅF/Ingemansson AB. Measurements are performed in accordance with Swedish and European standards.

During the manned measurements, operation is stopped in order to be able to compare the noise levels when the wind farm is in operation to those of when it is not in operation.

## 9.5 Results

### 9.5.1 Results from Baseline Studies

#### Long term, unmanned

The noise levels were measured and registered during the periods 28<sup>th</sup> of February until the 4<sup>th</sup> of March and 11<sup>th</sup> until 14<sup>th</sup> of March 2006. The equivalent noise level was 30 dB(A) and varied between 23 to 53 dB(A) for intervals of 10 minutes. The equivalent noise level was lower during nighttime.

The conclusion was that the mean noise level varied between 35 dB(A) at low wind speed to nearly 45 dB(A) at 12 m/s. Highest levels could be observed when the wind direction was west to southwest. The equivalent noise level during nighttime, measured in intervals of 10 minutes, was often below 35 dB(A).

#### Short term, manned

The noise levels were measured on the 16<sup>th</sup> of August 2006, in the evening and during nighttime. Wind speed varied between 2-8 m/s. The equivalent noise level varied between 31 to 46 dB(A). The wind direction was from south, that is, from Lillgrund to the location at Strandhem.

One of the purposes of this investigation was to see if it is possible to measure the noise from the wind farm according to the Swedish recommendations. This requires that the background noise be below the noise level generated by the wind farm. The conclusion was that, with some adjustments in the measurement method, this could be possible.

#### Infra Noise

The measurements for infra noise were taken August 16, 2006. Wind direction was from south and wind speeds varied between 2-8 m/s. Noise levels were 50-57 dB(A) according to SS-ISO 7196. This noise level is far below the possible perception level for infra noise. The noise level readings did not differ with varying wind speeds.

#### Conclusions

The equivalent noise level measured varied between 31-46 dB(A) at wind speeds between 2-8 m/s. This means that the background noise level for longer periods is above the max noise level stated by the authorities. However the consultant's conclusion from the baseline studies is that it is possible to perform immission measurements as planned if the correct weather conditions and time chosen. No other conclusions can be drawn at this stage.

### 9.5.2 Results from Follow-up Studies

Measurements are in progress and will be concluded in spring 2009. Results are not yet available.

## 9.6 Conclusions

Follow up studies are not completed and results are expected for spring 2009.

## **10 ARCHAEOLOGICAL INVESTIGATIONS**

### **10.1 Condition in permits**

- The decision from the Government included the following condition: The Company shall, in consultation with the County Administrative Board of Skåne, decide if it is necessary to carry out marine archaeological investigations of possible occurrence of ancient remains within the construction area. The Company shall pay for the potential investigations. [1]

### **10.2 Background**

The Company had, in accordance with the conditions from the Government, performed marine archaeological investigations. During the investigation a shipwreck was identified on the site. The wreck remains did not have to be removed, as long as the construction works did not damage them. The locations of the cable trenches were adjusted in order to minimize the risks of damaging the wreck. If possible, scattered parts belonging to the ship were to be gathered and placed near the bulk of the shipwreck remains. The area around the shipwreck had to be marked with yellow bouys under the construction phase.

### **10.3 Realisation**

The Company approved the Contractors' processes of identifying ancient remains.

The Contractors committed to immediately stopping the work and inform the Company and the County Administrative Board if they suspected ancient remains to be identified.

### **10.4 Results and Conclusions**

During the construction, another shipwreck was found on site. The wreck originally discovered had moved some distance probably due to heavy storms and water currents. None of these new discoveries affected the construction works.

The land cable trench work was planned and executed in co-operation with the archaeological experts of Malmö. No unforeseen remains were identified.

## **11 INSPECTION OF NEARBY COASTLINE**

### **11.1 Condition in permits**

- The Environmental Court included the following permit condition: The Company shall, both before the start of the work and at latest a year after the wind farm has been put into operation, inspect the beaches in connection to Klagshamn.

### **11.2 Realisation**

A program for the inspection of the nearby coastline has been performed by SGU (Geological Survey of Sweden) before and after the wind farm was built. The aim of the inspection was to investigate if the construction of the Lillgrund wind farm has caused changes of the coastline and on coast morphology.

### **11.3 Results**

#### **11.3.1 Results from Baseline Studies**

Field inspection reports and photographs of the coastline covering about 3 km north and 3 km south from the cape of Klagshamn were presented, and were carried out by SGU in November 2005 and January 2006.

The results were presented in a report dated January 26, 2006.

#### **11.3.2 Results from Follow-up Studies**

New inspections and investigations were performed by SGU in autumn 2008 and presented by SGU in a report dated December 4, 2008. The changes on the coastline and on the morphology were very small over the whole area studied. No changes at all could be identified for the protected beach meadows at Strandhem.

The conclusion of the report is that no changes on coast morphology, due to the construction of the wind farm, could be identified. Further more, the export cable from the wind farm to the connection point on land at the Bunkeflo substation, seems not to have caused any erosion damage. However, traces from the trench work can still be found, as new sea grass has yet not re-established at the landing point.

### **11.4 Conclusions**

The inspections performed by SGU of the coastline close to the wind farm before and after construction of the wind farm showed no effects from the construction work on the coastline or coast morphology.

## **12 VISUALISATION OF THE WIND FARM**

During the environmental permit process, the Company made a commitment to present a series of photographs taken from the same angles and locations as those used for the digital simulations of the wind farm for comparison purposes.

The digital visualisations created of the wind farm have been compared with the real photos taken after erection of the wind farm. The aim of the study is to show how well they correlated with real photos taken of the wind farm and how proficient the methods to do the digital visualisations are.

The complete study and results are presented in a separate report.

### 13 COORDINATION WITH VINDVAL

The Swedish Vindval research program started in 2005 and was planned to continue until 2008 but the program has been extended to 2012. Today, 20 projects within the program have been granted funds. The Swedish Energy Agency finances Vindval and has commissioned the Swedish Environmental Protection Agency to run the program.

Vindval's objective is to facilitate an increase in the expansion of wind power by compiling basic data for the environmental impact assessments (EIA) and for the permit application processes. Research within Vindval helps compile knowledge about how wind power affects plants and animals in the marine environment, how the landscape is affected and what effect it has on people.

Vindval's ambition is for their work to continue as planned and to launch wind farms, so-called pilot farms, supported by the Swedish Energy Agency. Their main focus has been on offshore farms.

The work with the monitoring programs has been co-ordinated with studies performed within Vindval. For example, a separate study [17] on the possible impact on fish, during the dredging and installation works of gravity foundations at Lillgrund, has been performed by Marine Monitoring, under Vindval's administration. The BACI model (Before/After/Control/Impact) was applied to the experimental design, where the impact areas at Lillgrund were compared to an undisturbed control area, before and after the different phases of construction work were carried out.

The study was divided into three separate case studies:

- 1) Long-term effects of dredging, with sampling conducted 1 month after impact, 60 and 200 meters from the construction site.
- 2) Short-term effects of dredging, with sampling conducted 24 hours after impact at a distance of 150 meters from the construction site.
- 3) Direct effects of stone bedding, with sampling conducted 60 and 200 meters from the construction site.

The final conclusion in the published report is: "As a summary, the studies indicate that the different installations steps (dredging and stonebed preparation) will have minor or no effect at all on small fish at distances 100 meters and more from the point of installation."

Studies on migration of eels, as part of the Fish and Fishing-monitoring program, are also coordinated with other studies performed by Fiskeriverket within Vindval.

## 14 OPERATORS CONTROL IN ACCORDANCE WITH THE ENVIRONMENTAL CODE

According to the Swedish Environmental Code, the operator of any activity that poses a threat for human health or affects the environment must have a procedure for controlling activities in order to prevent such consequences (operators control).

The operator shall, apart from fulfilling all specified conditions and undertakings which are consequences of the environment permits, also make sure that the operators control is being carried out adequately during the construction as well as during operation phases.

For activities and operations governed by environment management systems, there are usually procedures, which ensure the legal demands for operators control. One way to make the authorities surveillance work easier and facilitate the operator's work, can be to prepare a program for operators control in accordance to the regulation for operators control (SFS 1998:901) and general advice from the Swedish Environmental Protection Agency (Naturvårdsverket) (NFS 2001:2).

During the construction phase, operators control implies that the Contractor's work with the Environmental program and their own monitoring and control programs are supervised and checked in a systematic way. A checklist covering all relevant items and regular reporting to the responsible party can be used to fulfil this.

The Contractors received such a checklist for the Lillgrund project before contract signing. It was also included in the approved document Monitoring Program – Lillgrund.

The Contractor's handling of chemicals, mainly oil, was also an important environmental aspect reviewed for the Lillgrund project.

The operators control was coordinated with the environment management system, as well as with the routines for work environment and for protection from accidents.

To ensure the Contractors abide to the requirements for operators control, audits were performed to check how each specific requirement by the project and legal requirements were being obeyed. Audits were also performed on site, based on the abovementioned checklist.

Further, the contractor's work with these project and legal requirements were continuously supervised and any non-conformance was reported and documented at the regular meetings held with the authorities responsible for the surveillance and with the contractors concerned. For all non-conformities, corrective actions were agreed upon and carried out. No major non-conformances have been observed or reported during the construction phase of the project.

For the operation and maintenance phase, a separate program for the operators control is under preparation.

## 15 CONCLUSIONS AND LESSONS LEARNED

A number of different monitoring programs and procedures have been, and are, performed for the Lillgrund Offshore Wind Farm.

The purpose of the environmental monitoring is to ensure that there is no negative impact on the environment from construction of the Lillgrund wind farm, as well as to ensure that the conditions stated by the authorities and the Company's commitments are met. Also, more information and knowledge on the possible environmental impact for future offshore wind farm projects are gathered.

The results from the monitoring programs performed during the construction phase show that the chosen methods for dredging works, refilling the trenches and restoring sea-bottom do fulfil the environmental requirements and permit conditions.

Choosing ships that could work in shallow waters reduced the amount of dredged material, as no dredging for working channels was required.

The method chosen for burying the cables to a depth of 1.0 meter was successful and only for shorter distances of the export cable the requirement could not be met. For these parts, the cable was protected by "rock dumping", a method approved by the authorities.

The spill monitoring performed showed that the max limit of 5% spillage could be kept. The construction works did not have to be stopped at any time due to exceeded spillage rates.

The weekly modelling of the spillage distribution carried out during the construction work showed that:

- In general the values for suspended material were limited and the critical value of  $0.01 \text{ kg/m}^3$  was exceeded only on minor areas, for a very limited time.
- The deposition of sediment was very low and even at the most effected sites it was only just over 1 mm.

The results from visual inspections and spot check surveys performed confirmed the results from the spill modelling and this shows that modeling the spill distribution in Öresund, coupled with spot checks, is a reliable method for spill monitoring.

The regular visual inspections also showed that there were no risks for the nearby beaches to be negatively affected at any time during the construction period, which confirmed the results from the spill modelling.

No disturbances were found from resedimented material on the common sea mussel. The studies performed on eelgrass showed that the construction work at Lillgrund had no negative impact on eelgrass. The studies were performed during the construction work and after it, as a follow-up study in autumn 2008.

The study [17] performed within Vindval regarding impact from construction works on small fish at Lillgrund concluded that: "As a summary the studies indicate that the different installations steps (dredging and stonebed preparation) will have minor or no effect at all on small fish at distances 100 meters and more from the point of installation."

The Swedish legal requirement on operators control implies that the contractor's environmental work is supervised and checked in a systematic way. A checklist covering all relevant items and a regular reporting to the responsible party is often used to do this. Such a checklist was prepared for the Lillgrund project and handed over to the contractors as information before contract signing. It was also included in the approved document Monitoring Program – Lillgrund.

To ensure the Contractors' abide to the requirements for operators control, audits were performed on the contractors' management system and procedures. These were conducted to check how each requirement by the project and legal requirements were being obeyed. Audits were also performed on site, based on the above-mentioned checklist. The procedure worked well and no major deviations were found at the audits performed. For all minor deviations corrective actions were taken accordingly.

The monitoring program for inspection of the nearby coastline is concluded and the follow-up study showed that there was no impact from the construction works on the coastline or on coast morphology.

A follow-up study on eelgrass has been concluded and results show no disturbances from Lillgrund on the eelgrass. That is results from the studies performed during the construction phase were confirmed.

Baseline studies have been performed on fish and fishing. The results from these studies show that:

- Test fishing of spawning fish was not possible at Lillgrund due to large amounts of drifting algae.
- The method for identifying effects on pelagic fish with acoustic measures (eco-detection), especially migration of herring, can be improved.
- The results show that the passive telemetry method was more successful than active telemetry method for studying eel migration.

Results from follow-up studies on fish and fishing are not yet available. First results from follow-up studies are expected in spring 2009, and at this stage no further conclusions can be drawn.

Baseline studies on noise levels have been performed and show that the measured equivalent noise level varied between 31-46 dB(A) at wind speeds between 2-8 m/s. This means that the background noise level for longer periods is above the max noise level stated by the authorities. However, the consultants' conclusion from the baseline studies is that it will be possible to perform immission measurements as planned, if the correct weather conditions and times are chosen.

Baseline studies on birds have been successfully performed but results from follow-up studies are not yet available. First results are expected in spring 2009, and at this stage no conclusions can be drawn.

## 16 REFERENCES

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Reports [5]—[16] and other relevant information is available from the Swedish Lillgrund homepage: [www.Vattenfall.se/Lillgrund](http://www.Vattenfall.se/Lillgrund). Report [18] can be found on <http://www.naturvardsverket.se/>.