Embankments around Lake Roxen

basic data, current status and future outlook

LÄNSSTYRELSEN
ÖSTERGÖTLAND

Bird
Wetlands, nature reserves and cultural landscapes for rural development

Baltic Sea Region
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Cover picture: Pump house at Skrukeby embankment scheme. The raised concrete base shows how much the embankment has sunk. Grazing and trampling by cattle reduces the risk of damage to the embankment by voles and tree roots.
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The BIRD Project

The County Administrative Board of Östergötland is a participant together with five other Baltic states (Finland, Estonia, Latvia, Lithuania and Germany) in an international Baltic Sea project named BIRD. This project, which is partly financed by the EU, focuses on countryside development matters concerning wetlands, nature reserves and cultural landscapes. Because of the vast areas that are embanked at Lake Roxen the County Administrative Board has considered it important to get knowledge about the total extent of embankments around Lake Roxen as well as the condition in which they are today and how the owners of embanked land look upon the future of the embankments and their utilisation.

Background

The southern and western shores of Lake Roxen are very flat. Combined with the fact that the water level in a normal year fluctuates by about 1.0 meter, this has meant and still means today that large parts of the shores of Roxen flood at high water level. Over the centuries this was something that had to be accepted and the flooded areas could at best be used for grazing and as mown water meadows. At the end of the 19th century at least one farmer tried to embank an extensive flooded area to protect it from the high water levels of Lake Roxen. His idea was to pump water out of the embanked area with aid of a steam pump and a wind pump. But this project did not work very well and in 1896 a statutory embankment scheme was entered into with the intention of making the dikes more robust with a wind pump undertaking the pumping function. As far as is known this project was implemented. Several decades then went by before further statutory schemes were entered into aimed at converting flooded water meadows to arable land through embankments and pumped drainage.

The electrification of the countryside opened up new technical opportunities for pumping water from an embanked area in a relatively easy and safe way. Against this background, during the thirties and increasingly during the forties no less than around twenty statutory schemes were entered into aimed at establishing embankments around the shores of Lake Roxen. The area involved in these statutory schemes covered ca 1500 hectares and the total extent of embankment dikes was more than 45 km (30 miles)! The vast majority of the land affected by these embankments was originally uncultivated peat marsh.

The embanked areas that were created along the shores of Lake Roxen became important arable land and in many cases made a very valuable contribution of cultivated land to a number of agricultural holdings involved. At the same time these embanked arable areas incur much greater costs in terms of management and husbandry than fields that are not embanked.

Embankments studied at Lake Roxen

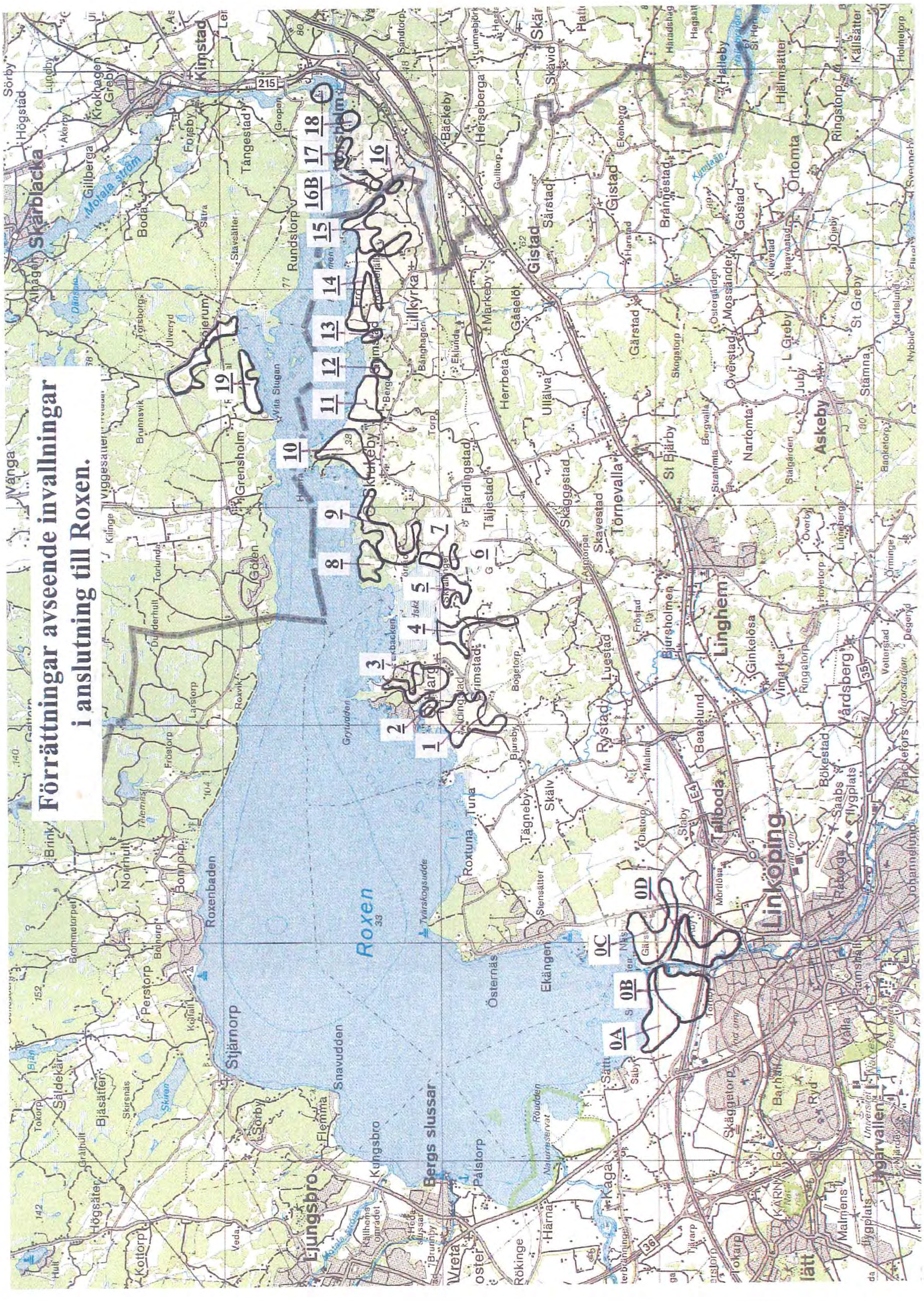
The study now completed comprises embankments for agricultural purpose that have been established by statutory procedures in accordance with the Water Act. There are as far as is known no embankments established without such a procedure.

The map of Lake Roxen reproduced on page six shows all embankment schemes with their approximate situation and size. Every embankment has been given an individual number in the sequence 0A - 0D and 1-19. The reason why the embankments directly associated with the city of Linköping have been given their own number sequence is that because of their close association with the city they cannot be regarded as a part of rural development within the scope of the BIRD project. Against this background, basic data for embankments 0A – 0D have been reported to give a full picture of all embankment schemes around Lake Roxen. However, the landowners associated with these embankments have not been interviewed with regard to the present situation and future outlook. Of the embankments 1-19 all have been established by statutory authorisation with the exception of number 18.

***Photo 1**. Pump house at the Skrukeby embankment.*

All statutory embankment schemes situated around Lake Roxen

Black line border indicates the approximate coverage of the embankment scheme.



Compilation of basic data for all statutory embankment schemes

Here follows a compilation of basic data for all statutory embankment schemes around Lake Roxen. The information comes from official archive documents available at the County Administrative Board of Östergötland. Each statutory embankment scheme has an official name and for each scheme the relevant archive number is quoted as it appears in the archive series covering all water drainage schemes in the County of Östergötland. In order to make it easier to find each scheme on the map each has been given its own individual number (0a – 0D and 1 – 19) unique to this report. These numbers are shown on the map of embankment schemes around Lake Roxen.

The parameters reported for each particular statutory embankment scheme are as follows:

Time when the plan for the undertaking was finalised, in other words when the statutory scheme was entered into. This information is invariably found in the name of the undertaking. The name consists normally of the name of the largest properties that are involved in the undertaking followed by the year when the statutory scheme was entered into. This means for instance that in the case of the *Mylinge-Flodsta statutory embankment scheme of year 1941* the statutory scheme was entered into in 1941 and that the properties with the registered names Mylinge and Flodsta respectively have land benefitting from the scheme (area that becomes better for the intended purpose). Other properties with registered names other than Mylinge and Flodsta may be participants in the statutory scheme.

Number of participants is of importance for future management and maintenance of the undertaking. The greater the number of participants in a scheme the greater the diversity of opinions when it comes to proposals for taking maintenance actions or more radical changes like converting an embanked area back to wetland. The number of participants recorded refers to the number when the statutory scheme was implemented. Afterwards in most cases the number of participants has fallen as a result of the rationalisation in farm size that has occurred in agriculture.

Hectares of former arable land records how many hectares obtained improved drainage because of the embankment project. The establishment of a new embankment means not only that flood areas or areas that are too wet to cultivate are turned over to new arable land, it can often also mean that existing arable land with drainage problems gets full drainage.

Hectares of former non-arable land records how many hectares of wetland or grazed areas that could not be used as arable land now, thanks to the embankment, have become arable land.

Total hectares of benefit area records the total area of land that becomes better for its intended purpose following implementation of the embankment scheme.

Length of dikes is recorded because it gives an indication of what maintenance costs and risks are involved with an embankment. The longer the dike the greater the maintenance costs, the risks of water leakage and possible future breaching of the dike especially if the dikes are constructed using organogenic material, which is the case with most of the embankments around Lake Roxen.

The drainage area is an interesting parameter for an embankment especially put in relation to the extent of the drainage area from which water has to be pumped in order to drain the actual benefit area. The ideal would of course be to pump water only from the benefit area itself. Generally there is also water from areas at a higher level that drain into the benefit area and this also needs to be pumped. The larger the drainage area, the higher the costs for pumping and the greater the capital cost for pumps calculated per hectare of benefit area.

Energy demand (annual load factor) is a cost item not generally relevant to the drainage of "normal arable land". On "normal arable land" drainage occurs by natural self-drainage and there is no need for energy input to get rid of the surplus water that occurs on all land in our country as a result of the surplus annual precipitation we always have. The larger the area that has to be pumped in relation to the benefit area, the higher the energy cost per hectare benefit area. The energy demand recorded for each embankment is the theoretical demand that is given in the documents from the statutory scheme applications. In reality the demand can be considerably higher because of dike leakage and other reasons.

Basic data for each embankment

The following records the basic data relating to the embankments around Lake Roxen.

0A. Säby-Ullevi if 1941 (basic data)

1. No. 0A
2. Name, parish, archive number: Säby-Ullevi statutory embankment scheme of year 1941 in Sankt Lars parish, archive number 815
3. Area of benefit land ha: 97
4. Former arable land ha: 9
5. Former non-arable land ha: 88
6. Dike length: 2,100 m
7. Drainage area: ha: 494
8. Soil type: organogenic soil on clay
9. Number of participants: 7
10. Pump size in kW: three pumps totalling 25 kW
11. Annual load factor (kWh/year): 10,000
12. Other: Linkoping's urban expansion has meant that a part of the drainage area has been discharged in an open ditch to Stång stream.

0B. Tornby if 1931 (basic data)

1. No. 0B
2. Name, parish, archive number: Tornby statutory embankment scheme of year 1931 in Sankt Lars parish, archive number 1730
3. Area of benefit land ha: 126
4. Former arable land ha: 23
5. Former non-arable land ha: 103
6. Dike length: 300 m
7. Drainage area: ha: 162
8. Soil type: organogenic soil on clay

9. Number of participants: 1
10. Pump size in kW: 6
11. Annual load factor (kWh/year): 4,500
12. Other: Tornby statutory embankment scheme and Säby-Ullevi statutory embankment scheme are today linked together as one undertaking in the sense that there is no protective dike here between the two undertakings. This means that if a dike should be breached in one embankment flooding would occur also at the other embankment. Within Tornby embankment area today some building has taken place along with roadways and parking areas associated with a relatively large marina for leisure boats.

0C. Gärstad if 1940 (basic data)

1. No. 0C
2. Name, parish, archive number: Gärstad statutory embankment scheme year 1940 in Rystad parish, archive number 826
3. Area of benefit land ha: 99
4. Former arable land ha: 14
5. Former non-arable land ha: 85
6. Dike length: 3,800 m
7. Drainage area ha: 200
8. Soil type: organogenic soil on clay
9. Number of participants: 10
10. Pump size in kW: 4.7
11. Annual load factor (kWh/year): 5,500
12. Other: The embanked area is directly adjacent to urban Linköping and comprises ground where industry and other interests of built-up areas are present. In view of this background no landowners involved in this embankment scheme have been interviewed with regard to current situation and views on future utilisation.

0D. Kallerstad if 1931 (basic data)

1. No. 0D
2. Name, parish, archive number: Kallerstad statutory embankment scheme year 1946 Linköping township, archive number 973
3. Area of benefit land ha: 126
4. Former arable land ha: 50
5. Former non-arable land ha: 76
6. Dike length: 4,600 m
7. Drainage area ha: 200
8. Soil type: organogenic soil on clay
9. Number of participant: 4
10. Pump size in kW: Two pumps total power 16
11. Annual load factor (kWh/year): 7,200
12. Other: Kallerstad statutory embankment scheme is situated directly adjacent to urban Linköping and comprises ground where industry and other interests of built-up areas are present. In view of this background no landowners involved in this embankment scheme have been interviewed with regard to current situation and views on future utilisation.

1. Idingstad if 1934 (basic data)

1. No. 1
2. Name, parish, archive number: Idingstad statutory embankment scheme year 1934 in Östra Harg and Rystad parishes, archive number 1739.
3. Area of benefit land ha: 115
4. Former arable land ha: 50
5. Former non-arable land ha: 65
6. Dike length: 3,700 m
7. Drainage area ha: 140
8. Soil type: organogenic soil on clay
9. Number of participants: 3
10. Pump size: 7.6 kW
11. Annual load factor (kWh/year): 3,900
12. Other: Associated with the actual embankment scheme itself an area to the east and an area to the west were also ditched but without pumping. The embanked area itself is within these outer areas.

2. Holmen if 1975 (basic data)

1. No. 2
2. Name, parish, archive number: Holmen statutory embankment scheme year 1975 in Östra Harg parish, archive number 304
3. Area of benefit land ha: 19
4. Former arable land ha: 0
5. Former non-arable land ha: 19
6. Dike length: 550 m
7. Drainage area ha: 22
8. Soil type: organogenic soil over clay
9. Number of participants: 1
10. Pump size: 3 kW
11. Annual load factor (kWh/year): 600
12. Other: A statutory embankment scheme was entered into in 1953. However, this was not carried out. In the first half of the 1970s the matter was brought up anew by a younger user generation wishing to utilise the cultivation potential of the farm and this is why a new undertaking was carried through.

3. Harg-Mörby if 1941 (basic data)

1. No. 3
2. Name, parish, archive number: Harg-Mörby statutory embankment scheme of year 1941 in Östra Harg parish, archive number 811
3. Area of benefit land ha: 75
4. Former arable land ha: 22
5. Former non-arable land ha: 53
6. Dike length: 1,700 m
7. Drainage area ha: 132
8. Soil type: organogenic soil over clay

9. Number of participants: 10
10. Pump size: 9 kW
11. Annual load factor (kWh/year): 3,300
12. Other: A number of summer cottages have sprung up on the actual embanked area which means that it is not solely affected arable land that is dependent upon the maintenance and future of the embankment.

4. Mylinge-Flodsta if 1941 (basic data)

1. No. 4
2. Name, parish, archive number: Mylinge-Flodsta statutory embankment scheme of year 1941 in Östra Harg parish, archive number 813
3. Area of benefit land ha: 90
4. Former arable land ha: 43
5. Former non-arable land ha: 47
6. Dike length: 1,500 m
7. Drainage area ha: 360
8. Soil type: organogenic soil over clay
9. Number of participants: 12
10. Pump size: one pump 8 kW and one pump 11 kW
11. Annual load factor (kWh/year): 7,900
12. Other:

5. Knylinge if 1942 (basic data)

1. No. 5
2. Name, parish, archive number: Knylinge statutory embankment scheme year 1942 in Östra Harg parish, archive number 812
3. Area of benefit land ha: 64
4. Former arable land ha: 30
5. Former non-arable land ha: 34
6. Dike length: 2,200 m
7. Drainage area ha: 100
8. Soil type: organogenic soil over clay
9. Number of participants: 11
10. Pump size: 1 pump 7 kW
11. Annual load factor (kWh/year): 2,100
12. Other: Almost half of the area of benefit land included in this statutory embankment scheme consisted of land already in arable use.

6. Skvällinge if 1942 (basic data)

1. No. 6
2. Name, parish, archive number: Skvällinge statutory embankment scheme year 1942 in Östra Skrukeby parish, archive number 832
3. Area of benefit land ha: 25
4. Former arable land ha: 9
5. Former non-arable land ha: 16

6. Dike length: 250 m
7. Drainage area ha: 50
8. Soil type: organogenic soil on clay
9. Number of participants: 2
10. Pump size: 3 kW
11. Annual load factor (kWh/year): 1,000
12. Other:

7. Skvällinge if 1970 (basic data)

1. No. 7
2. Name, parish, archive number: Skvällinge statutory embankment scheme year 1970 in Östra Skrukeby parish, archive number 287
3. Area of benefit land ha: 17
4. Former arable land ha: 0
5. Former non-arable land ha: 17
6. Dike length: 1,300 m
7. Drainage area ha: 20
8. Soil type: organogenic soil on clay
9. Number of participants 1
10. Pump size: 5.5 kW
11. Annual load factor (kWh/year): 550
12. Other:

8. Förråd if 1948 (basic data)

1. No. 8
2. Name, parish, archive number: Förråd statutory embankment scheme year 1948 in Östra Skrukeby parish, archive number 969
3. Area of benefit land ha: 20
4. Former arable land ha: 0
5. Former non-arable land ha: 20
6. Dike length: 320 m
7. Drainage area ha: 44
8. Soil type: organogenic soil on clay
9. Number of participants: 1
10. Pump size: 4 kW
11. Annual load factor (kWh/year): 1,400
12. Other: A partner implies that the landowner can decide quite independently how the embankment shall be maintained.

9. Förråd if 1939 (basic data)

1. No. 9
2. Name, parish, archive number: Förråd statutory embankment scheme year 1939 in Östra Skrukeby parish, archive number 1859
3. Area of benefit land ha: 78
4. Former arable land ha: 9

5. Former non-arable land ha: 69
6. Dike length: 1700 m
7. Drainage area ha: 180
8. Soil type: organogenic soil on clay
9. Number of participants: 3
10 Pump size: Two pumps, one 6 kW and the other 3.5 kW
11. Annual load factor (kWh/year): 4,200
12. Other: The pumping station has been rebuilt.

10. Skrukeby if 1940 (basic data)

1. No. 10
2. Name, parish, archive number: Skrukeby statutory embankment scheme year 1940 in Östra Skrukeby parish, archive number 805
3. Area of benefit land ha: 97
4. Former arable land ha: 8
5. Former non-arable land ha: 89
6. Dike length: 1,850 m
7. Drainage area ha: one 68 ha and one 116 ha
8. Soil type: organogenic soil on clay
9. Number of participants: 7
10. Pump size: Three pumps in total, namely 4, 4.5 and 3 kW
11. Annual load factor (kWh/year): 4,700
12. Other: The embanked area consists of two sub-areas, namely the Höringe area and the Skrukeby area. The embanked area is served by two different pumping stations, one with a single pump and the other with two.

11. Berga-Värla if 1939 (basic data)

1. No. 11
2. Name, parish, archive number: Berga-Värla statutory embankment scheme year 1939 in Östra Skrukeby parish, archive number 1860
3. Area of benefit land ha: 60
4. Former arable land ha: 15
5. Former non-arable land ha: 45
6. Dike length: 2.600 m
7. Drainage area ha: 86
8. Soil type: organogenic soil on clay
9. Number of participants: 5
10. Pump size: 4.2 kW
11. Annual load factor (kWh/year: 2,100
12. Other: Major dike breach in 1985 associated with high water level in Lake Roxen.

12. Grimstad if 1937 (basic data)

1. No. 12
2. Name, parish, archive number: Grimstad statutory embankment scheme year 1937 in Östra Skrukeby parish, archive number 1825

3. Area of benefit land ha: 19
4. Former arable land ha: 4
5. Former non-arable land ha: 15
6. Dike length: 1,200 m
7. Drainage area ha: 45
8. Soil type: organogenic soil on clay
9. Number of participants: 2
10. Pump size: 3.7 kW
11. Annual load factor (kWh/year): 930
12. Other:

13. Grimstad if 1939 (basic data)

1. No. 13
2. Name, parish, archive number: Grimstad statutory embankment scheme year 1939 in Östra Skrukeby parish, archive number 1861
3. Area of benefit land ha: 11
4. Former arable land ha: 3
5. Former non-arable land ha: 8
6. Dike length: 1,000 m
7. Drainage area ha: 27
8. Soil type: organogenic soil on clay
9. Number of participants: 1
10. Pump size: 2 kW
11. Annual load factor (kWh/year): 660
12. Other:

14. Fröö-Rännefjälla if 1937 (basic data)

1. No. 14
2. Name, parish, archive number: Fröö-Rännefjälla statutory embankment scheme year 1937 in Lillkyrka parish, archive number 1826
3. Area of benefit land ha: 102
4. Former arable land ha: 28
5. Former non-arable land ha: 74
6. Dike length: 2,400 m
7. Drainage area ha: Fröö 120 ha, Rännefjälla 85 ha
8. Soil type: organogenic soil on clay
9. Number of participants: 4
10. Pump size: Fröö 4.7 kW and Rännefjälla 6.7 kW
11. Annual load factor (kWh/year): Fröö 3,300 and Rännefjälla 2,300
12. Other: The embanked area is divided up into two sub-areas, Fröö embankment and Rännefjälla embankment. Flooding on one sub-area involves flooding on the other sub-area also.

15. Rännefjälla-Lundby if 1943 (basic data)

1. No. 15

2. Name, parish, archive number: Rännefjälla-Lundby statutory embankment scheme year 1943 in Lillkyrka parish, archive number 865
3. Area of benefit land ha: 71
4. Former arable land ha: 12
5. Former non-arable land ha: 59
6. Dike length: 2,800 m
7. Drainage area ha: 100
8. Soil type: organogenic soil on clay
9. Number of participants: 8
10. Pump size: 8 kW
11. Annual load factor (kWh/year): 3,300
12. Other:

16. Lundby if 1951 (basic data)

1. No. 16
2. Name, parish, archive number: Lundby statutory embankment scheme year 1951 in Lillkyrka parish, archive number 1354
3. Area of benefit land ha: 15
4. Former arable land ha: 7
5. Former non-arable land ha: 8
6. Dike length: 450 m
7. Drainage area ha: 30
8. Soil type: organogenic soil on clay
9. Number of participants: 2
10. Pump size: 2.3 kW
11. Annual load factor (kWh/year): 650
12. Other: This embanked area has now been converted to wetland following agreement between landowners involved.

16B. Åby-Ulberstad if 1896 (basic data)

1. No. 16 B
2. Name, parish, archive number: "Åby-Ulberstad statutory embankment scheme year 1896" in Skärkind parish, archive number 10
3. Area of benefit land ha: 44
4. Former arable land ha: 2
5. Former non-arable land ha: 42
6. Dike length: 1,800 m
7. Drainage area ha: 153 ha
8. Soil type: organogenic soil on clay
9. Number of participants: 1
10. Pump size: Wind turbine which in a light breeze can raise ca 170 l/sec
11. Annual load factor (kWh/year): -
12. Other: In the early 1890s an embankment was constructed but this flooded in two consecutive years and consequently a statutory scheme was petitioned for as well as state financial support for a more robust embankment. This statutory scheme resulted in the Åby-Ulberstad statutory embankment scheme. The wind turbine was subse-

quently replaced by an electrically driven pump. This undertaking has been converted to wetland in the present decade.

17. Ulberstad if 1935 (basic data)

1. No. 17
2. Name, parish, archive number: Ulberstad statutory embankment scheme year 1935 in Skärkind parish, archive number 1788
3. Area of benefit land ha: 24
4. Former arable land ha: 2
5. Former non-arable land ha: 22
6. Dike length: 1,200 m
7. Drainage area ha: 83
8. Soil type: organogenic soil on clay
9. Number of participants: 1
10. Pump size: 4 kW
11. Annual load factor (kWh/year): 2.200
12. Other:

18. Norsholm if 1941 (basic data)

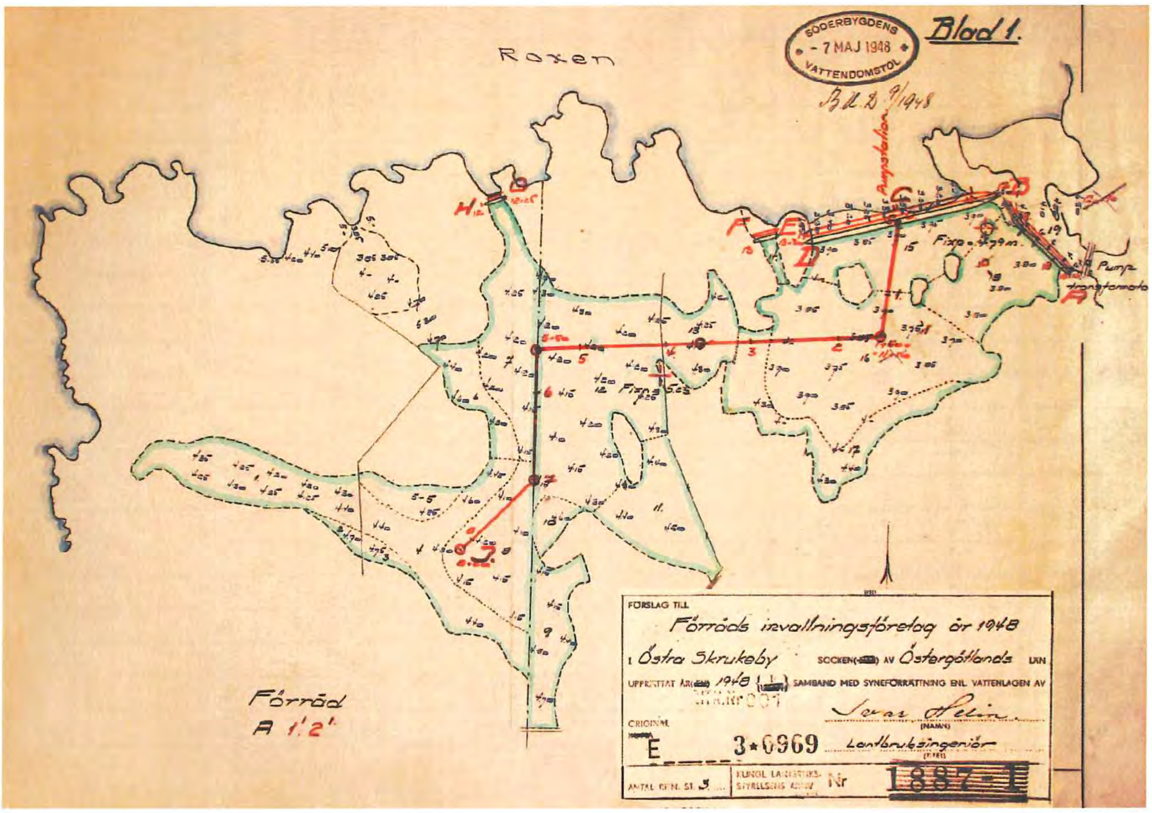
1. No. 18
2. Name, parish, archive number: Norsholm statutory embankment scheme nos. 1 and 2 of year 1941 in Kimstad parish, archive number 846
3. Area of benefit land ha: 2 areas - No. 1 with 17 ha and No. 2 with 16 ha
4. Former arable land ha: area No.1 = 0 ha and area No. 2 = 1 ha
5. Former non-arable land ha: 32 ha
6. Dike length: 1,500 m
7. Drainage area ha: area 1 = 100 ha area 2 = 25 ha
8. Soil type: organogenic soil on clay
9. Number of participants: 1
10. Pump size: area 1 = 4 kW, area 2 = 1.5 kW
11. Annual load factor (kWh/year): 2,700
12. Other: State support was granted for this embankment scheme but it was never executed and it was reported that it was not the intention to take up state aid. Today parts of the proposed embanked area are nature reserve.

19. Sätra kärr-Visskärret if 1942 (basic data)

1. No. 19
2. Name, parish, archive number: Sätra kärr-Visskärret statutory embankment scheme year 1942 in Kimstad and Vånga parishes, archive number 835
3. Area of benefit land in ha: 101 that lies within two areas quite independent of each other, namely, Sätra marsh and Viss marsh.
4. Former arable land ha: Sätra marsh 39 och Viss marsh 1
5. Former non-arable land ha: Sätra marsh 30 och Viss marsh 31 ha
6. Dike length: 2,000 m
7. Drainage area ha: 820

8. Soil type: organogenic soil on clay
9. Number of participants: 3
10. Pump size in kW: three pumps for Sätra marsh and one pump for Viss marsh, total pump power 34 kW
11. Annual load factor (kWh/year): total load for the two areas 14,600
12. Other: The two independent areas have now been converted to wetland, the one area in 2004 and the other area in 2006.

Specimen map of an embankment scheme



Summary of data for embankments around Lake Roxen

The following summary has been made in order to obtain an overall picture of what areas have been embanked around Lake Roxen. One of the things that may be established is that ca 45 km of protective dike is constructed primarily to enable the reclamation of 1150 hectares of otherwise uncultivated ground, in other words flood plain (wetland). Additionally, the embankments have brought about the improved drainage of ca 380 hectares of arable land that now have proper drainage facilities. Purely theoretically, the annual power consumption needed to pump water from all these embankment schemes is calculated at ca 90,000 Kwh. In actual fact the energy consumption is appreciably greater because of leakage through the dikes together with the fact that the pumps have a lower efficiency than calculated as a result of wear. In some cases in recent years the option has been adopted to lift the pumped water over the dikes instead of taking it in outlet pipes that discharge below the water level of Lake Roxen, which also leads to greater pumping costs.

Collected information on embankments around Lake Roxen

no. of scheme	number of participants	ha former arable	ha former non-arable	total ha benefit land	dike length in m	drainage area in ha	annual load factor (kWh/year)
0A	7	9	88	97	2100	490	10000
0B	1	23	103	126	1300	162	4500
0C	10	14	85	99	3800	200	5500
0D	4	50	76	126	4600	200	7200
1	3	50	65	115	3700	140	3900
2	1	0	19	19	1100	22	600
3	10	22	53	75	1700	132	3300
4	7	43	47	90	1500	360	7900
5	11	30	34	64	2200	100	2100
6	2	9	16	25	250	50	1000
7	1	0	17	17	1300	20	550
8	1	0	20	20	1400	44	1400
9	3	8	69	78	1700	180	4200
10	7	8	89	97	1850	185	4700
11	5	15	45	60	2600	86	2100
12	2	4	15	19	1200	45	930
13	1	3	8	11	1000	27	660
14	4	28	74	102	2300	205	5600
15	8	12	59	74	2800	100	3300
16	2	7	8	15	450	30	650
16b	1	2	42	44	1800	153	
17	1	2	22	24	1200	83	2200
18	1	1	32	33	1500	125	2700
19	3	40	61	101	2000	820	14600
total	**96**	**380**	**1147**	**1531**	**45350**	**3959**	**89590**

The development of agriculture around southern Roxen

Going back in time, agriculture and forestry formed the basis for the rural economy. The countryside immediately south of Lake Roxen is part of the Östergötland plain where agriculture was the basis for the rural economy. The number of hectares of arable land combined with the fertility of the soil was the reason why so much could be produced. Looking at Östergötland as a whole, around 1930 was the peak in terms of cultivated area. Following this time there occurred a gradual abandonment of arable land of low productivity primarily in afforested and marginal rural areas. But as far as agriculture along the shores of Lake Roxen is concerned, cultivated areas were extended successively during the first half of the twentieth century with the peak being reached after the Second World War, in other words in the mid-1900s. This was thanks to the series of embankment schemes, the majority of which were undertaken during the 1930s and 40s with the aid of state support. By far the major part of the arable land present adjacent to southern Lake Roxen in the mid 1900s is still in use as arable land. In contrast, animal husbandry has fallen drastically and the number of working holdings has also successively reduced because of the amalgamation of agricultural holdings that occurred, a process still ongoing and in many cases an essential requirement for remunerative production. The embanked areas used to grow specialist crops, for example potatoes, but in more recent times these crops have been completely abandoned. In contrast, a large part of embanked land lies fallow. Under present circumstances fallow land ('setaside') is entitled to EU support in the form of area payment.

Strengths and weaknesses of the Roxen embankments

Strengths

The basic requirements for Roxon's embankments are very similar. The principle applicable to all embankment works is that where the topsoil does not already consist of clayey soil, it has an existing subsoil of organogenic material. This in turn means that when the organogenic soil is eroded through cultivation the clay comes to the surface and constitutes a good cultural substrate.

The amount of water that needs to be pumped out from the embanked areas is relatively limited because the catchment area (the area draining to the pumping station) is usually small in relation to the size of the benefit area (the area benefitting directly). This involves relatively low capital investment in pumps and energy costs.
The embanked areas are generally clearly defined and are linked to arable land that do not depend on pumping for their drainage. As a result extensive clearly defined areas of arable land are created. With today's demand for ever larger agricultural machines this is an important factor for achieving rational production, especially where the crops concerned involve bulk production of corn and oil-yielding crop.

Weaknesses

In the case of the majority of the embankments the area embanked had a significant depth (0.5-1.5 m) of organogenic soil (soil largely consisting of decayed plant material) that was overlying the clay substrate. As the dikes were usually built with local material excavated directly adjacent to the dike this often contained a significant amount of organogenic material. This material has relatively low strength in terms of its resistance "self-destructs" through oxidation when exposed to acid in the atmosphere. This means that over the decades the height and volume of the dikes have declined to a disturbing degree. Despite the fact that no levelling up of the dikes has taken place in this respect it is generally known that the majority of embankments today have dikes that are not up to prescribed heights. The lowest part of the dikes can be as much as 0.5-1.0 m below the specified height. This means that most of the dikes do not meet the maximum water level that may be expected to occur in Lake Roxen with extremely severe floods!

Large areas of the embanked ground consist of or have consisted of organogenic material. Erosion of the organogenic material combined with compression of the soil surface have resulted in ground subsidence of between 0.5-1.0 m over large areas. In some places this has meant that existing subsoil drainage is being ploughed up whilst the drains in other places are very shallow. The result of this is that in a few areas the ground has already had to have new subsoil drainage installed (at capital cost of 15,000-20,000 SEK per hectare) whilst significant areas will require new subsoil drains to be installed in the quite near future for the ground to be drained properly. Furthermore it may be that the subsidence has now got to such a stage that with the current low point at pumping stations it is impossible to lower the water level sufficiently to that needed for undertaking installation of subsoil drainage at full depth (0.9-1.3 m. The majority of all pumps in the embankments have today been replaced by new ones whilst existing pumping stations continue to be used. But many of them are in poor condition and may need some degree of renovation combined with a possible lowering.

Dikes and water levels in Lake Roxen

The water level in Lake Roxen varies in a normal year within the range ca +32.9-33.9 m (RH 00 height measurement system), in other words by one meter. But in a drought year the water level can fall to a height of ca +32.35 m whilst the maximum level for which the embankment schemes are designed is ca +34.85 m. This means that the interval between maximum high-water level and lowest low-water level is as much as 2.5 m! The dikes protecting arable land against flooding have a specified crown height of ca +35.4 m.

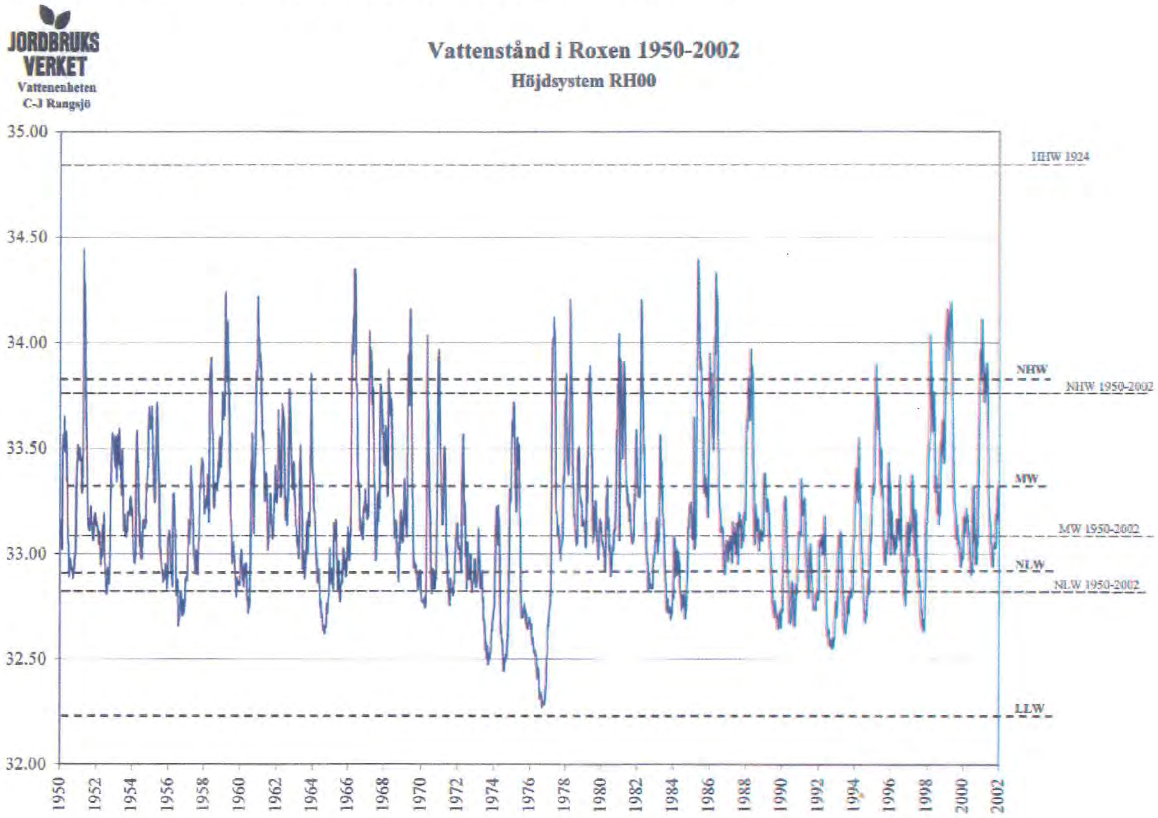
The following are the statistics for the water level in Lake Roxen:

Maximum known water level (1867)	+35.43
1924 water level	+34.84
1985 water level	+34.34
Mean high-water (MHW)	+33.93
Mean water (MW)	+33.30
Mean low-water (MLW)	+32.90
Lowest water level	+32.35

Taking into account the water level that may be expected under extreme flood conditions, the question that immediately arises is why the landowners do not make up their dikes to the specified dike height. The reason for this is that normally there is hardly any further material to get hold of adjacent to existing dikes. Often so much material as is possible to remove with a conventional mechanical digger has already been taken out both from outside and inside the dike. Any strengthening or raising of dikes therefore requires large amounts of bulk material further out on the lake side of the dike using an amphibious machine. This option for obtaining further bulk material therefore involves much greater cost than being able to take bulk material directly adjacent to the dike. A further option for restoring a dike of specified dimensions can be simply to shift the dike inwards onto embanked ground so that adjacent to the new dike there is sufficient bulk material to create one with specified dimensions.

Water storage capacity regulations apply to Lake Roxen. These have been applied in association with the hydroelectric generation plants downstream of Lake Roxen. The main principles for these regulations are such that the water level in Lake Roxen shall not differ from that occurring before Lake Roxen became the subject of control. To monitor that this decree is obeyed the regulating authority responsible for controlling Lake Roxen shall at regular intervals provide information on water extraction and water levels in Lake Roxen to SMHI (Swedish Meteorological and Hydrological Institute) which then has a control function for monitoring to be performed in a correct manner.

Discussions with a number of landowners raise the question of whether the water storage capacity regulations have not been changed over recent years in order to optimise power generation. The extent to which these apprehensions are or are not justified has not been analysed in this investigation. However, the Department of Agriculture has produced a diagram (see below) that shows how the water level in Lake Roxen has varied over the period 1950-2002 and this does not show any distinct indications of more water being stored in Lake Roxen in more recent decades compared with the 1950s and 1960s. Instead it may be considered that the variations in water level are governed by current precipitation.



Management guidelines and maintenance of embankments

All embankments have been executed before the 1983 Water Act came into being. This means that the statutory embankment schemes came within the jurisdiction of the 1918 Water Act. This specifies that if a land drainage undertaking has more than two participants, management of the undertaking and any matters associated with it shall be administered by a management committee with one or more members. It also contains detailed guidelines on calling notices for meetings, voting rights, the responsibility of the committee etc.

There is no formally elected committee for any one of the embankment undertakings for which the participants were interviewed. Instead a part-owner takes care of the management by old-established tradition. In one case the person who was the driving force associated with the creation of the embankment took over the father's role as the one responsible for the embankment undertaking. When the need arises the participants meet to discuss management of the embankment. This means that in reality only maintenance measures on which all partners

are agreed can be undertaken This is likely to mean that the participant having the lowest management targets is the one who determines how much maintenance is undertaken.
In practice it is possible to work in this manner and in fact this is how management has been carried out for many years. A disadvantage with this "simplified" form of management is that no management committee exists that is directly responsible for maintenance of the embankment in the event of a partner being dissatisfied. Nor do direct formal facilities exist for calling for change in management policy without first calling for a committee election then registering the committee election with the County Administrative Board. In the event of lack of maintenance resulting in the occurrence of significant damage to an embankment undertaking, for example through poor pump maintenance or poor maintenance of embankments or dikes, there is no committee to turn to and complain to, or in the extreme case to hold financially responsible. Equally there is a possibility of carrying out, against the wishes of the other participants, maintenance work that one regards as being within the scope for making one's own decision on embankment maintenance. In a recently published judgement of the Växjö District Court, an embankment undertaking had to pay considerable damages to a participant in an embankment undertaking because of poor maintenance of the ditch taking the water to the pumping station.
An embankment scheme that has been created in association with a statutory procedure is in principle a licence that is valid in perpetuity with the rights and obligations applicable to the undertaking. The sole means for formally changing this licence with its rights and obligations is either to "expunge" the installation or to review it if changes in circumstances have arisen. It is a requirement for a licensed installation that it shall be maintained for all time in such a way that no harm is caused to the general public or private interests as a result of poor maintenance. For a licensee to escape this responsibility he can petition the court that the installation be "expunged". If the court grants this request (which in principle it is always obliged to do) the establishment no longer has any legal power and nobody can in future make any demand for maintenance or compensation for harm incurred caused by poor maintenance.

Changes in land use, conversion to wetland

As we know, all embankments around Lake Roxen have been created as a means of making use of wetland. By pumping water from this wetland and protecting the land from flooding it is thus converted to arable land. Most of the land has now been under cultivation for more than half a century, and in significant areas the ground has sunk by comparison with the level at the time of the creation of the embankments. At the same time it a known fact that most dikes have not been maintained to a sufficient extent and this is why today there is an obvious risk of water flooding over the dikes if extreme water levels are experienced in Lake Roxen. Furthermore there are demands from several sources for some degree of maintenance action in the form of subsoil drainage and renovation of existing pumping stations in order that the embankments shall be restored to the standard of drainage they originally had.

Maintenance of an embankment can be excessively onerous, for example because of subsidence being so severe that further drainage becomes impracticable without lowering the pumping station. Dikes can require an input of very great quantities of bulk soil to make the embankment secure against flooding including extreme high-water conditions. One alternative though may be simply to "shift" the actual embankment. This solution requires landowners involved to be in agreement on such an approach and preferably also that formal application is made for the embankment to be "expunged" so that in the future nobody comes up with a demand for the embankment to be restored to a good condition in the terms of the original statutory decree.

As the embankment schemes are all in low-lying ground, simply the cessation of pumping away the water from an embanked area will cause it to revert to wetland. The State has today created official guidelines making it easier for farmers to convert agricultural land to wetland if it is judged to be beneficial to nature conservation. By signing a 20-year agreement with the State a landowner can receive annual compensation over a 20-year period for this conversion of arable land to wetland. Almost any arable land other than embanked land can purely technically be converted to wetland by more simple means. In principle in the simplest scenario it only needs the pumps to be stopped and a hole made in the dike. This means that they will not hold back the water, thus causing flooding onto land lying higher than immediately adjacent to the actual embanked area.

It is considered that we do not have sufficient wetlands in our countryside and in view of the fact that embanked land can technically speaking be easily converted to wetland, it was thought interesting to learn the views of owners of embanked arable land on this land in the short and long term.

Embanked land that has been converted to wetland

As has already emerged from the section giving basic data for embankments, the two areas at Norsholm (Site 18) were never implemented. Parts of that area once intended for embankment are today nature reserve.

The large embankment scheme Sätra kärr – Visskärret (Site 19) has now been converted to wetland in two stages. The motivation for this was partly because the Visskärret sub-district had a very long dike along Lake Roxen where there were problems with leakage and ground subsidence. High capital investment was needed for both lowering of the pumping station and new subsoil drainage. In the case of the other district, Sätra kärr, that largely comprises deep organogenic soil, there was very severe subsidence and here too the pumping station needed to be lowered plus new subsoil drainage in extensive areas to enable the ground to continue in use as arable land. Another factor in this case was that the total catchment area compared unfavourably with the benefit area, in other words water that needed to be pumped away was present over an area much greater than the actual benefit area. Therefore at least three pumps were needed to cope with the pumping operation at the Sätra kärr embankment scheme. The capital investment that would have been needed to restore the embanked areas to well-drained arable land was therefore very significant. Furthermore, the extensive drainage area incurs continuing high running and maintenance costs associated with the pumping station. The ground within the area still comprises deep organogenic soil that would continue to subside severely if it should continue in arable use. Against this background the three landowners involved decided to convert the embanked land to wetland and have now obtained wetland compensation in conjunction with an obligation to maintain the ground as wetland over a period of at least 20 years.

The smallest embankment scheme also, namely Lundby (Site 16) has today been converted to wetland. This embankment scheme had run badly over a considerable period with flooding

and it was this situation that made the landowners decide to convert this area to wetland. Here too wetland compensation was obtained.
Finally, Åby-Ulberstad embankment scheme (Site 16B) was converted to wetland several years ago. This embankment scheme was the oldest of the schemes around Lake Roxen with a history going back more than 100 years. Here also the level of the embankment had gradually sunk over the years and extensive capital investment was needed for refurbishment to enable the ground to be drained properly. Against this background this embankment scheme also has been converted to wetland and as a result obtained wetland compensation.

Photo 2. Åby-Ulberstad statutory embankment scheme has been converted to wetland.

The view on agriculture and agricultural land

A fundamental attitude with the majority of farmers of arable land is that it constitutes a natural resource that shall be utilised and preserved. It shall be possible to hand over arable land to future generations in the same way as in the past. This basic view has governed and continues to govern the way a good number of farmers conduct their business. To hand over a holding to the next generation after ditches have been dug and further ground brought into cultivation is regarded not only as a long-term investment but also an ethically correct form of speculation. In the same way that it is the duty of a forestry owner to clear and plant his woods even though he himself will not be present to fell them, many landowners wish to keep custody of arable land for future generations.

Other farmers are able to regard arable land more objectively in the economic sense free from sentimentality.
During the second half of the twentieth century opinions on the future of agriculture have varied. Much cultivated land in afforested and marginal areas has had to be abandoned because

the economic conditions for continuing agricultural activity no longer existed. In other districts a number of smaller holdings have been bought up by neighbouring holdings or have been let out. This has enabled active farmers increase their farm size and thus be able to continue in farming. The economic situation in agriculture has fluctuated cyclically but following entry into the EU when we became subject to EU agricultural policy, the prices for arable land have risen very steeply.
The prices for cereals have risen very steeply at the end of 2006. Rocketing oil prices, quickly growing purchasing power in the world's two most highly populated countries (China and India) coupled with an increasing likelihood of future climatic change that can have a drastic effect on costs of both food and bioenergy, have influenced many farmers.

Attitudes of landowners to the embankment of arable land

At least one person in each embankment undertaking numbered 1-19 was personally interviewed. Most of the contacts were by extended telephone interview. With one exception, the persons contacted willingly agreed to extended interviews. A precondition in the interviews conducted which are directed at embankment schemes that are continuing to be run for agricultural production, was that answers and opinions given were not to be reported separately for each embankment scheme but that reported facts and opinions were reported in summary form.

Anxiety about dike height

There is a general feeling of unease primarily about the height of the dikes. There is an awareness that they are not maintaining specified heights. Some farmers also point out that with the virtual disappearance of cattle from the farmsteads, the opportunity for the dikes to be grazed has also now largely disappeared. Grazing of the dikes by cattle means that reeds and scrub vegetation on dikes and embankments are kept down very effectively, and in addition dikes are compacted by hoof traffic with vole holes and cracks also trampled out. A significant reason why the embankments have largely not been maintained is that it is not practicable to get access to supplementary bulk dike material directly adjacent to dikes and that the costs of otherwise obtaining bulk material to strengthen dikes incurs considerable cost. To prevent leakage through dikes, primarily at high water levels, some embankment undertakings have "buried" a synthetic film into the dike to seal it. But in the long term it has been demonstrated that even voles are capable of penetrating a barrier such as this.

The problem of subsidence

Because of its high content of organogenic material arable land at the embankment schemes has sunk to a significant degree over extensive areas. Existing subsoil drainage has been smashed or is ineffective. The question whether then to re-install subsoil drainage in the arable land is a decision that each participant has to make and which will not be dealt with by the embankment undertaking. Some farmers have re-installed subsoil drainage in their land whilst the majority have not and have perhaps planted trees. Those farmers who have chosen to invest in new subsoil drainage clearly have it in their interests to have the embankment undertaking well maintained and intend the embankment scheme to survive for the foreseeable future. Other farmers may be more cautious about high capital investment in embankment schemes and prefer to await developments before being prepared to speculate in a major way. Against this background different landowners sometimes have different target levels in undertaking major speculative investment and often the result is that only the most absolutely essential maintenance work is undertaken.

Old pumping stations

Most pumping stations are now sixty to seventy years old. It has always been an essential for the pumps to be maintained so that they operate more or less efficiently at all times. Immediately the pumps cease to operate drainage deteriorates very rapidly with the result that flooding soon occurs at the embankment undertaking. Several pumping stations are beginning to get into poor condition in terms of both inflow and outflow pipework. Additionally, subsidence has meant that to enable the land to be drained to full depth the inflow pipework needs to be sunk and the bottom of the pumping station lowered. A simple means of overcoming the problem of a poor outflow duct in which the flap valve is intended to prevent external reverse water pressure when pumping stops, is to have a new pipe to carry all the water over the crown of the dike and have the end of the outflow pipe above the normal level of high-water. This solution that has been the one adopted by several incurs higher energy consumption than the original technical solution.

Corn and oil-yielding crops dominant

The organogenic soils prevalent at most embankment schemes should permit specialist crops such as potatoes and carrots. There used to production of this nature but today it has ceased completely. On the one hand specialist crops present a risk with very great price fluctuations for products from year to year, on the other hand ongoing rationalisation calls for sophisticated specialist machinery that in turn incurs high capital cost. It is considered to be not possible in economic terms to bear such costs unless the grower has specialist bulk production or is able to cooperate with other farmers. Furthermore, specialist production on organogenic soil causes greater subsidence as a result of the more intensive cultivation of the soil and higher application of fertiliser.

Instead the traditional crops of corn and oil-yielding plants are dominant, complemented with some production of grass on some holdings. But many farmers have significant areas of fallow land which now qualifies for 'setaside' payment but does not produce anything. Extensive fallow land nationwide often means uncertainty about the future prospects for agriculture. But at the same time it does leave the door open for future cropping.

Doubtful status of energy crops

For many years energy crops have been promoted as an alternative to conventional crops. In actual fact no energy crops are grown on the embanked land apart from a few landowners entering into contracts for supply of corn for ethanol production. In reality this an energy crop but in terms of cultivation it hardly differs in any way from the production of corn for animal feed or human consumption. One landowner has signed a tenancy agreement with a condition that no energy crop is to be grown on embanked land in the form of willow or suchlike. The reason for this is that willow, with a cropping cycle of 3-5 years, incurs high risks of the willow roots penetrating drainpipes and blocking them with the result that the whole subsoil drainage system fails. If on the other hand the price situation for energy crops should subsequently improve, many landowners would regard energy crops as an interesting future alternative for utilising embanked land.

Other interests relevant to the embankments

On one embanked area some development of holiday cottages has occurred. This can create certain problems in the future. The holiday cottage owners are not participants in the embankment undertaking but it is perhaps in their greatest possible interest that the embankment is maintained in such a way that no flooding occurs. How can these additional interested parties influence how the future of the embankment scheme is handled? The questions are there but there is no answer. The same applies where roads cross embanked land, both to holiday cottages and to farm holdings with permanent residents. Here also interested parties are involved who are very dependent upon the maintenance of the embankment undertaking and its future utilisation.

Simple management a dilemma

A basic rule that applies to those embankment undertakings today having more than two participants (if a farm holding has more than one participant it is regarded as one participant) is that matters relating to the undertaking shall be dealt with by a committee that then has responsibility for administration. But all of the embankment undertakings studied here did not have a formally elected and registered committee. This could prove troublesome as such a situation would make it more difficult to analyse more systematically how an embankment scheme is to be maintained. This can in turn cause uncertainty as to how capital investment can be ventured, in subsoil drainage for example, or how the embankment undertakings can be utilised in the foreseeable future. Likewise it may be difficult to demand more thorough maintenance in the spirit of the aims of the original statutory embankment scheme.

Cautious optimism regarding the future

Most feel some degree of uncertainty regarding the future. Will the next generation be able to take over the farm and continue to run it or will it be bought out and amalgamated with a neighbouring holding? Will area payment disappear to some degree after 2012 without product prices experiencing any significant increase? Should this occur, it will become very difficult to operate an arable farm with any profitability. These are troublesome questions but at the same time developments globally during 2005 and 2006 have been such that they bring some hope from a producer's viewpoint. Higher prices and taxation of fossil fuels offer the opportunity for production of bioenergy at advantageous prices. Increased bioproduction on arable land, not least from a global viewpoint, means reduced agricultural production but increased world market prices for bulk products such as corn and oil-yielding crops as a consequence. A rise in world market prices is considered likely at national level. Overall most express cautious optimism on the requirements for future profitable agricultural production on embanked land.

Doubts about wetland ventures

It is technically very simple to convert an embanked area to wetland. Whether one would today convert one's embanked arable land to wetland was a matter that nobody wanted to directly recommend. On the other hand this option needs to be considered having in mind the fact that many embankment schemes do not possess protective dikes that are secure against extremes of high water and that large-scale capital investment is needed to restore the dikes to an effective state. For some years now state aid has been available for those opting to convert arable land to wetland. At the same time there is an annual area payment granted to all arable land whether or not it is under cultivation.

Another very obvious dilemma relating to the conversion of embanked arable land to wetland is that fundamentally acceptance by all landowners affected is required for such a change. Provided that there is only one landowner to an embankment scheme this complication does not exist but as soon as there are several it means that agreement must be reached on giving up the embankment for the foreseeable future. This means that in reality any part-owner with a very small shareholding in an embankment undertaking can in practice put a stop to an embanked area being converted to wetland. The fact that the embankment scheme has been created by statutory decree means that the embankment undertaking shall be maintained in perpetuity unless it is elected to review the whole statutory scheme or to "expunge" the embankment scheme. Both review and the expunging process require submission to the environmental court and if the landowners are not in agreement in such a procedure the court hearing can be both complex and costly apart from the fact that a case of this kind takes time.

It was generally considered that once embanked arable land had been converted to wetland and that wetland compensation had been obtained, it would then not be possible to restore the land to arable use. Taking the step of converting arable land to wetland for all time was felt to be too severe. There was a desire to retain one's options for the time being. But there was an awareness that much can change. The future may bring a rise in demand for agricultural land and product prices may rise sufficiently to successfully run an agricultural holding without area payment. On the other hand with today's product prices it is hardly possible to run a profitable farm without area payment. If area payment should disappear along with wetland compensation simultaneously with product prices remaining at today's levels, then certain embankment undertakings would be abandoned which would mean their reversion to wetland.

***Photo 3**. Sätra marsh, a statutory embankment scheme that today is wetland*

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