VESIENTUTKIMUSLAITOKSEN JULKAISUJA
PUBLICATIONS OF THE WATER RESEARCH INSTITUTE 39

VESIHALLITUS — NATIONAL BOARD OF WATERS, FINLAND
Helsinki 1980

ISBN 951-46-5307-6
ISSN 0355-0982

Helsinki 1981. Valtion painatuskeskus

THE EFFECTS OF DREDGING ON WATER QUALITY IN LAKE KALLAVESI

Irmeli Taipalinen

TAIPALINEN, I. 1980. The effects of dredging on water quality in Lake Kallavesi. Publications of the Water Research Institute, National Board of Waters, Finland, No. 39.

The effects of dredging work on water quality in the Varkaus – Kuopio deep-water channel were studied by taking samples twice in 1969, while dredging was in progress, and three times in 1972, during the final stages of the work. It was shown that dredging caused turbidity and an increase in the concentration of suspended solids. The area of turbidity spread through the water rather rapidly, but the suspended solids were found to be confined to a narrow area close to the dredging site. A slight increase in phosphorus concentration was observed. No other changes in water quality were detected as a result of the dregging work. The measured indicators of water quality were found to have reached almost their original values within six months of the final suction-cutter dredging.

Index words: Dredging, water quality, turbidity, suspended solids.

1. INTRODUCTION

During dredging, i.e. removal of bottom deposits, the accumulating sludge is transferred to a new site either on dry land or on the bottom of the water body away from the dredged channel. Dredging has a direct influence on conditions at the water bottom and also has an effect on water quality due to the mixing of sedimented material into the water body. Changes in the bottom layers affect the environmental conditions of benthic organisms and hence also the fish populations which feed on these organisms or use the areas for breeding. Turbidity and changes in water quality may thus be detrimental to both aquatic organisms and water utilization.

The aim of this investigation was to determine the effect of dredging work on water quality in the Varkaus – Kuopio deep-water channel.

2. MATERIALS AND METHODS

The area covered by this investigation was the lake chain consisting of Sotkanselkä to the south of Kallavesi, Koirusvesi and Unnukka (Fig. 1). Water from Kallavesi flows through the Puutossalmi sound to Sotkanselkä. The waters pass mainly by the west side of the island of Jouhisaari and flow into Humalaselkä, from where the stream continues into Koirusvesi through the straits of Patasalmi and Hanhivirta. From here, the waters drain into the Konnusvesi basin and onwards into Voipaanselkä by way of the rapids at Konnus and Naapuskoski, before entering Unnukka by way of Leppävirta and Pikonvirta.

Dredging work was carried out at several places along this route between May 1969 and November 1971. The observations carried out were mainly intended to monitor the effects of

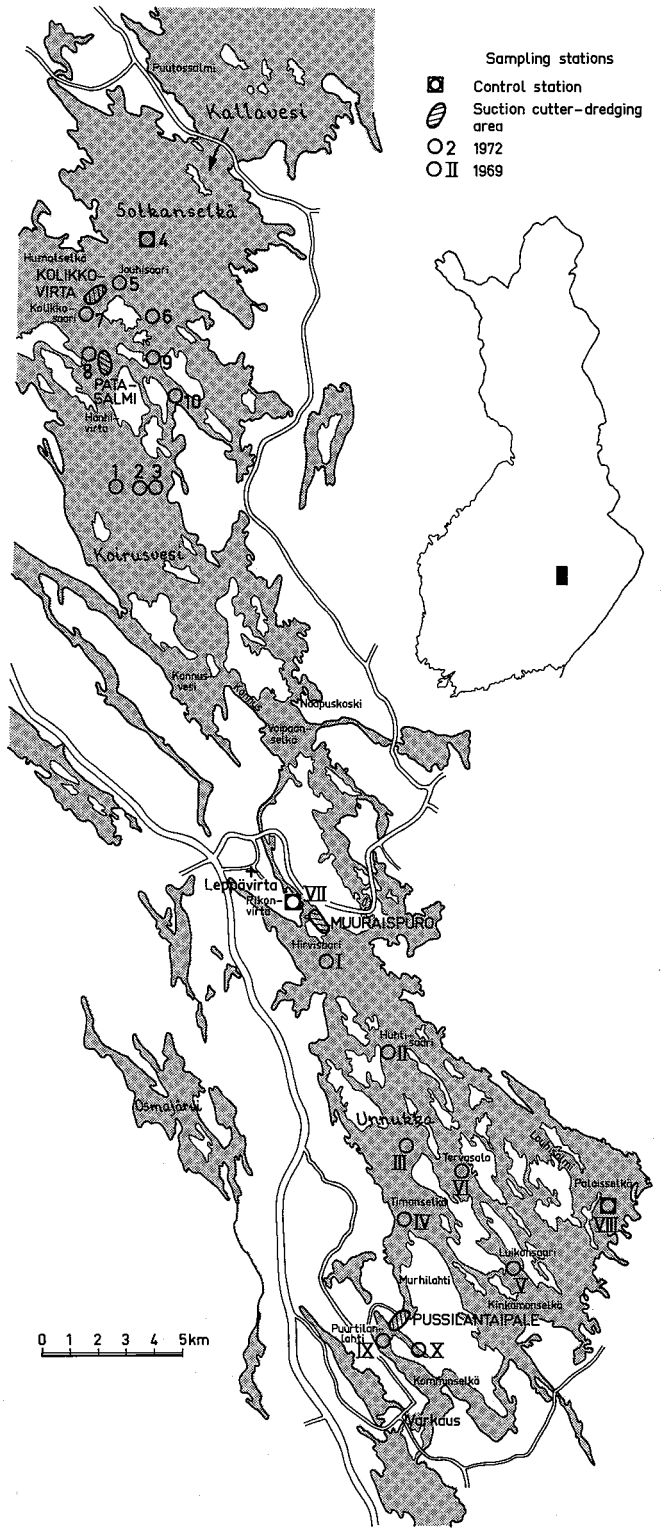

Fig. 1. Sampling stations and dredging sites.

the following dredgings:

- Deepening of the channel at Pussilantaipale 30.5.–17.10.1969 and in the summer of 1970. The volume of material removed was about 30 000 cubic meters.
- Muurainpuro 23.9.–21.11.1969: 58 000 m^3.
- Patasalmi (suction-cutter dredging) 9.10.–24.11.1971: 7 500 m^3.
- Kolikkovirta (suction-cutter dredging) 21.9.–21.10.1971: 32 000 m^3.

Observations relating to the effects of the dredging were made at 18 observation sites and at several temporary sites starting at the southern end of Unnukka and continuing as far as Sotkanselkä with the progression of the dredging work (Table 1).

In order to investigate sedimentation, sediment tubes (Ø 3 cm) were lowered to within 1 m of the bottom at eight observation sites in February 1972 and at seven sites in June 1972. The tubes were held in place for 2 weeks.

In the summer of 1969 a visual estimation of turbidity was carried out. Analyses of suspended solids, total residue and total fixed residue, total nitrogen and total phosphorus were performed from water samples taken in October and November of the same year.

Water samples taken in 1972 were analysed for oxygen concentration, turbidity, suspended solids, conductivity, pH, colour, chemical oxygen demand, total nitrogen and total phosphorus.

The material collected by the sediment tubes was analysed for suspended solids and total fixed residues.

Table 1. Dates of sampling, dredging sites and observation stations.

Date of sampling	No. of observation stations	Observation area	Dredging stage being investigated
27.6.1969	3	Komminselkä	Pussilantaipale
24.7.1969	3		Pussilantaipale
18.8.1969	3		Pussilantaipale
13.–15.10.1969	6	Unnukka	Pussilantaipale and Muuraispuro
11.–13.11.1969	9	Unnukka	Muuraispuro
23.–29.2.1972	10	Koirusvesi,	Patasalmi,
13.6.1972	8	Sotkanselkä	Kolikkovirta
18.10.1972	2	Sotkanselkä	Kolikkovirta

3. RESULTS

Concentrations of suspended solids below the Muuraispuro dredging area during the sampling perios 13.–15.10.1969 were considerably higher than the corresponding concentrations in the control sampling station (VII in Fig. 1) above this area (Table 2). The concentration at the observation station to the east of Hirvisaari (I), about 1.5 km from the dredging site, was double that measured at the station to the southwest of Huhtisaari (II), at a distance of 5.5 km. At stations IV (Timonselkä) and V (Kinkamonselkä),

Table 2. Suspended solids in Unnukka 13.–15.10.1969.

Depth	Suspended solids (mg/l) at observation station No.						control station No.
m	I	II	III	IV	V	VI	VII
1	65	30	7	4	5	11	3
5	60	25				8	
7			6				
8					9		
10	60	28		5		12	
15		30			8	10	
17			7				
20	65	30		7		13	
22					12		
25	790					12	
30	770	38					
32						12	
35				7			
39		38					

situated over 10 km from Muuraispuro, the concentrations observed were only 1–2 mg/l higher than those at the control station. At the nearest station (I) to the dredging the solids concentration in the bottom 6–7 m of water was very high. At the other stations the concentration was fairly evenly distributed in the vertical plane.

The control sampling carried out during the period 11.–13.11.1969 at station VIII (Table 3) at Paloisselkä, where the effect of the dredging at Muuraispuro can be assumed to have been very small. The solids concentration at Huhtisaari (II) was nine times greater than that at the control station, while at station III, 9 km from the dredging area, the concentration was seven times higher than at the control station. It is evident that the suspended solids had become evenly distributed throughout the area investigated, i.e. that the material had been carried further away from the dredging area. Sedimentation and the distribution of the solid particles were presumably the main causes of the reduction in concentration. Comparing stations IX and X, below the dredging area at Pussilantaipale, the solids concentrations at Puurtilanlahti (X) were clearly higher, indicating that the amount of suspended material carried to Komminselkä was comparatively small.

In February 1972 at stations 5 and 7, about 1 km from the Kolikkosaari dredging area, the suspended materials concentrations were at a depth of 1 m almost the same as that at the control station (Sotkanselkä, 4), whereas in the deeper layers of water the concentrations in stations 5 and 7 were very much higher than at the control station (Table 4). At a distance on 2 km, the differences between the observed concentrations at station 8 and at the control station (4) were relatively small. Concentrations at the other observation stations were almost the

Table 3. Suspended solids in Unnukka 11.–13.11.1969.

Depth	Suspended solids (mg/l) at observation station No.							control station No.
m	II	III	IV	V	VI	IX	X	VIII
1	30	26	16	18	23	4	45	3
2							40	
5	20	28	12	16	23	4		2
7								2
8								5
10		28	8	18				
15	20		8	16	28			
17		46						
20			8					
22				18				
25	28		8		45			
30			8					
32					5			
34			8					
35	42							

Table 4. Suspended solids at Koirusvesi and Sotkanselkä 23.–29.2.1972.

Depth	Solids concentration (mg/l) at observation station No.									control station No.
m	1	2	3	5	6	7	8	9	10	4
1	2	3	4	2	1	1	2	1	1	1
5	5	5	2	2	1	36	4	2	2	1
7							5			1
10	3	4	4	90	75	740		1	1	
11			3	295	110	1 180			10	
15	3	4						2		
20	10	8								

same as those at the control station.

In June 1972, six months after the final dredgings, the solids concentrations at the different observation sites were almost equal (differences 1 mg/l). The highest concentration (7 mg/l) was measured at station 9 at a depth of 5 m. The degree of turbidity was also very similar at all the observation stations.

In the sampling in October 1972, when samples were taken only from two stations (2 and 7), no appreciable differences were observed in either solids concentration or turbidity between the sampling stations.

The total and total fixed residues in one sample taken from just above the bottom at the station nearest to the Muuraispuro dredging area in October 1969 were 10 times greater than the control values. Apart from this, very little variation was observed between the different stations.

In a visual inspection carried out on 27.6.1969 the turbidity caused by dredging at Pussilantaipale was found to extend half-way through Komminselkä to the south and to the mouth of Murhilahti to the north. On 24.7.1969 only slight turbidity was recorded in Komminselkä and Murhilahti. By 18.8.1969 slight turbidity was observed in Murhilahti only in a small region above the dredged area. To the south of the channel, however, the whole of Puurtilanlahti was found to be very turbid. Moderate turbidity was observed in the north-western end of Komminselkä and area of slight turbidity extended half-way into Komminselkä (Fig. 2).

The area of turbidity due to dredging work being carried out at Muuraispuro was observed on 14.10.1969 to extend to between Sinikonniemi and Timonsaari in Timonselkä, to the northern tip of Luikonsaari in Tervaselkä and to a point between Tervasalo and the south point of Riihiniemi in Louhisalmi (Fig. 3). Secchi disc depths measured in the turbid area varied between 5 and 100 cm, compared to corresponding depths of 150–170 cm in the southern part of Unnukka. By 15.10.1969 the turbid area had extended from Timonselkä about 2.7 km into Yölinnunsalmi and from the tip of Liukonsaari about 3.7 km to the west and 3.1 km to the east. From Louhisalmi the turbidity had extended about 4 km into Paloisselkä. These observations on consecutive days demonstrate that the area of increased turbidity increased very rapidly (Fig. 3).

In observations carried out during the period 11.–13.11.1969 the turbid area was found to include the whole of Unnukka except the southern part of Paloisselkä. Secchi disc depths were in the turbid area 50–70 cm and in the southern part of Paloisselkä 250 cm.

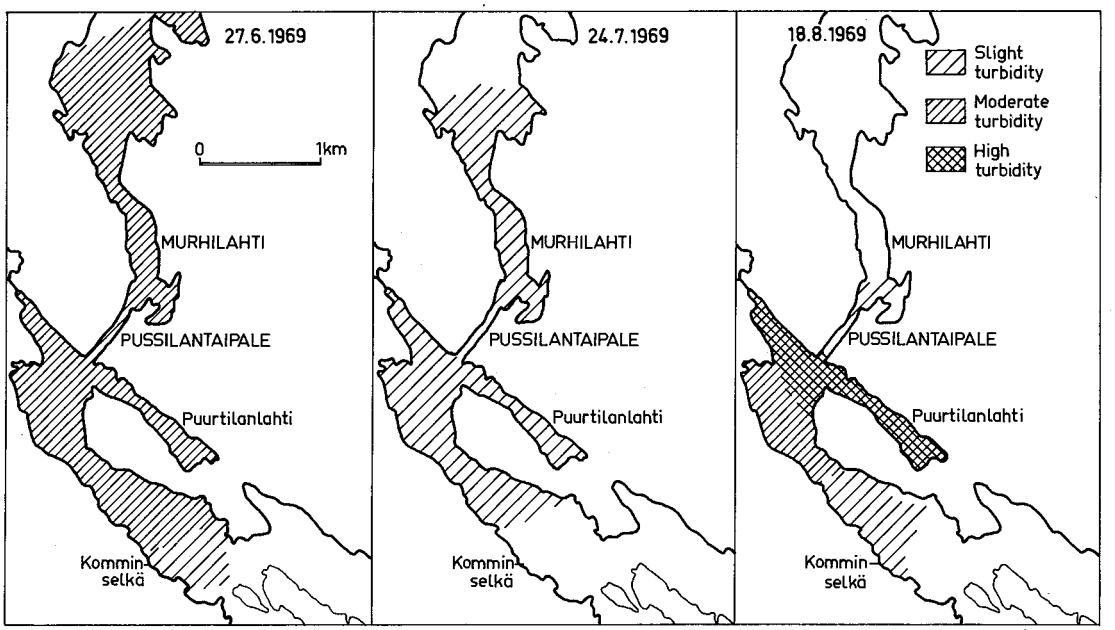

Fig. 2. Turbidity caused by dredging of the deep-water channel at Pussilantaipale.

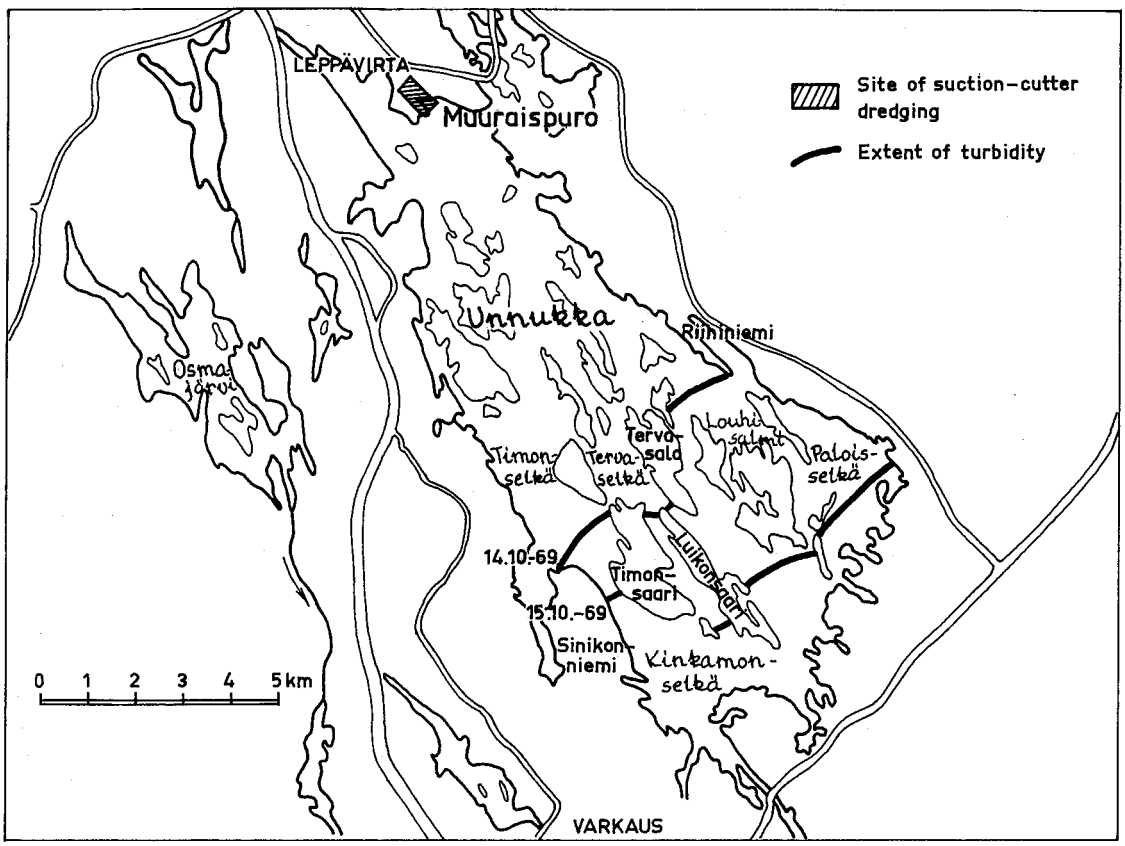

Fig. 3. Progression of the area of increased turbicity 14.–15.10.1969.

In February 1972, high values of turbidity, between 300 and 1 200 (Klett), were measured in samples from near the bottom at stations 5 and 7 nearest to the dredging area at Kolikkovirta. Corresponding readings in samples taken further away were between 0 and 10. During the three months after the cessation of dredging in Kolikkovirta, the area of high turbidity had thus become confined to the bottom layers of water at a distance of 1–2 km from the site of dredging. In June 1972 the turbidity was low and almost constant throughout this area, with readings of 3–12 on the same scale.

The greatest amount of material accumulating in the sediment tubes was observed at station 7, situated only 1 km downstream from the Kolikkovirta dredging site. High solids concentrations and total residues were also measured at stations 5 and 6. In the June samplings the corresponding values were higher throughout the area in questions, but exceptionally high values were observed only at station 7.

The transport of suspended solids can thus be seen to have continued for some considerable time after the conclusion of the dredging operations. It also appears that solid particles were slowly carried upstream from the dredging area, although the concentrations observed were considerably smaller than in the downstream stations.

Nitrogen concentrations in the surface layers of water below the Muuraispuro dredging area in October 1969 varied between 0.3 and 0.5 mg/l N. At station I, nearest to the dredging site, the concentration of nitrogen in the bottom layers was double that in the surface water. The concentrations at different depths at the other stations showed little variation.

In November 1969 the highest nitrogen concentrations were observed in the middle of Unnukka (stations III, IV and V, 0.4–0.6 mg/l N)

and below the Pussilantaipale dredging area (stations IX and X). No marked differences in concentrations were observed at different depths.

In February 1972, after the dredging at Kolikkovirta, the total nitrogen in surface water samples taken downstream from the dredging site was slightly higher than in samples from the control station. The highest nitrogen concentration (2 mg/l N) was observed near the bottom in a sample taken from the nearest station (7) to the dredging site. A similar situation was recorded in June 1972, although the concentrations in the bottom layers were somewhat lower.

During the dredging at Muuraispuro in October 1969 the total phosphorus concentration 1.5 km from the dredging (station I) was considerably higher (surface water 80 µg/l P, bottom water 800 µg/l P) than in the middle of Unnukka (20 µg/l P). The concentration at a distance of 5 km (station II) was double that in the middle of Unnukka. By November 1969 the concentrations had become more evenly distributed. However, the values for the nearest station (I) were not available, and the surface water concentrations had increased slightly above the October values.

In February 1972 the phosphorus concentration in surface waters downstream from the Kolikkovirta and Patasalmi dredging sites showed very little variation (10–20 µg/l P). The concentration in the bottom water at the nearest station (7) was, however, very high (1 390 µg/l P), and concentrations in excess of 100 µg/l P were observed at several other stations. In June 1972 the variations in phosphorus concentration in surface water samples were small (17–28 µg/l P) and the concentrations in the bottom layers had decreased considerably.

The concentration of dissolved oxygen was slightly lower in water below the dredging areas than at the control station (13.7 mg/l O_2) in February 1972. Concentrations in the surface water were 11.6–13.4 mg/l O_2 but in the bottom layers only 1.1–7.8 mg/l O_2. The latter values appeared to be related more to the depth of the water than to the vicinity of the dredging area. In June 1972 the oxygen concentrations in surface water were 9.8–11.2 mg/l O_2. The lowest value, 8.0 mg/l O_2, was recorded at the edge of the investigated area near the bottom (stations 1 and 2).

No great differences in electrical conductivity were observed between water samples taken in February and June 1972.

In February 1972 the pH of the water was slightly below 7.0, with differences of only 0.1–0.2 between different stations. In June 1972 the greatest differences observed were 0.3 pH units (variation 6.6–6.9).

Water colour in February 1972 below the Kolikkovirta dredging area (station 7) was very high (137–2 500 mg/l Pt) in samples from deep water. Rather high values (80–548 mg/l Pt) were also observed at station 5 above the dredging area. Corresponding values in the surface water were 42–58 mg/l Pt. In June 1972 water colour varied between different stations in the range 52–56 mg/l Pt.

In February 1972 the chemical oxygen demand (COD) at a depth of 1 m was slightly lower at all the test stations than at the control station. Values in excess of the control were observed near the bottom at stations 5 and 6 and, particularly, at station 7 (Table 7).

In June 1972 the COD of surface water was greatest at the control station (9.3 mg/l O_2). The results were very similar throughout the investigated area.

4. DISCUSSION

Dredging resulted in increased water turbidity and solids concentration. The turbid area was found to expand rather quickly and the limit of the affected area was clearly discernible in visual inspection. Secchi disc depths of less than 1 m were recorded in the turbid area, normal values being 2–3 m.

In October 1969, when dredging was still in progress, rather high solids concentrations were recorded as far as 5 km from the Muuraispuro dredging area. At sampling station I, at a distance of only 1 km, the concentration near the bottom was almost 10 times that in the surface water, whereas at the more distant station II only slight vertical differences were observed indicating that the solid material had settled to the bottom in the area between these stations. The pattern of sedimentation, depending on particle size and water flow rate, would vary slightly in different areas.

During the research period in 1972 the dredging was largely completed. Work at Kolikkovirta and Patasalmi was in its final stages in January 1972.

In February 1972 rather high solids concentrations were measured at station 7 below the

Table 5. Accumulation of material in sediment tubes 7.–13.3.1972.

		Observation station No.							Control station No.
		1	2	3	5	6	7	8	4
Depth	m	20.5	20.6	11.2	13.4	12.5	12.9	6.0	7.0
Solids concentration	mg/l	133	117	50	6 967	1 533	60 700	67	13
Total residue	mg/l	400	325	375	7 075	1 625	65 375	200	63
Total fixed residue	mg/l	350	235	287	6 850	1 475	14 150	88	25

Table 6. Accumulation of material in sediment tubes 26.6.1972.

		Observation station No.						Control station No.
		1	2	3	5	6	7	4
Solids concentration	mg/l	874	790	653	1 080	823	2 863	400
Total residue	mg/l	1 088	938	1 000	1 150	1 025	3 175	670
Total fixed residue	mg/l	588	538	600	663	588	2 588	250

Table 7. Chemical oxygen demand (mg O_2/l) 23.–29.2.1972.

Depth m	Chemical oxygen demand (mg/l O_2) at observation station No.									control station No.
	1	2	3	5	6	7	8	9	10	4
1	9.9	9.9	9.6	9.4	9.6	8.3	9.9	10.1	9.9	10.4
6							9.9			
7										10.4
10	9.6	9.4	9.4	9.9	9.4	15.9		8.9	7.6	
11			9.4							
12.5					10.4	22.0			11.1	
13.5				11.9						
15										
19								10.1		
20.5	9.6	8.9								

Kolikkosaari dredging area, particularly in the bottom layers of water. No such elevated concentrations were however recorded at station 8 at a distance of 2.5 km. These observations indicate that the solid material was carried further during the icefree period than in winter. Because of the low number of samples and the unfavourable timing of sampling with respect to the dredging work, however, these results cannot be considered as very reliable.

By June 1972, solids concentrations and turbidity had again attained values corresponding to water in a natural state.

Large amounts of material were found in the sediment tubes only in the immediate vicinity (~ 1 km) of the dredging area. However, the results for June 1972 show that some of the solid material was carried to a greater distance in summer than in winter. The transport of material was very slow, because the solids concentrations in the most distant stations from the Kolikkosaari dredging area were lower in February than in June.

The phosphorus concentration was found to increase in water below the dredging areas. Although confined at first to a rather small area, the increase was considerable. The greatest increase was in the bottom layers. Later, phosphorus concentrations were elevated throughout the investigated area long with the expansion of the region of turbidity, again most noticably in the bottom layers. During the spring of 1972 this increased phosphorus concentration was either used for primary production or else had settled to the bottom adsorbed to solid particles, because by June 1972 the observed phosphorus concentrations were only very slightly greater in the test than in the control stations.

The concentrations of nitrogen in different sampling varied in a similar manner to those of

phosphorus, but the differences between different times and sites of sampling were smaller.

Oxygen concentrations were analysed on only a few occasions, so that little can be concluded from these results. Slightly lower oxygen concentrations were measured in samples from below the dredging areas than in control samples.

No other major changes in water properties were observed with the investigations performed. The value for COD was found to be slightly higher in surface water at the control station than elsewhere in the area investigated on both sampling occasions in 1972. Higher values of oxygen consumption than at the control station were however observed in the deeper water levels. One reason for this result could be that chemically oxidizing organic matter was adsorbed to the sedimenting particulate matter in the water affected by the dredging activities.

No clear model of the effect of dredging activities on a watercourse can be constructed on the basis of these results. However, the great increase in turbidity and solids concentration in water below the dredging area was clearly demonstrated. The areas of turbidity were rather extensive, but high solids concentrations were confined to considerably smaller areas.

SUMMARY

The aim of this investigation was to determine the effects on water quality of dredging in the Varkaus – Kuopio deep-water channel.

Dredging work was carried out between May 1969 and November 1971. Observations were made to assess the effects of dredging carried out at four sites.

Samples were taken from Unnukka twice in 1969 and three times from Koirusvesi and Sotkanselkä in 1972. Sedimentation was investigated using sediment tubes on two occasions in 1972. The area of turbidity was followed by visual inspection three times in 1969.

The dredging operations were found to have caused turbidity and increases in suspended solids concentrations. The area of turbidity spread at a rate of several kilometers per day.

The turbid areas were quite extensive, but high solids concentrations were observed only in small areas near to the sites of dredging. The highest concentrations were measured in the bottom water layers. Solid material appeared to be carried to a greater distance during the ice-free period than in winter.

Phosphorus concentrations were found to increase, initially only in the immediate vicinity of the dredging area but with the spreading of the turbid area also in the whole of the area investigated.

Other changes in water quality due to the dredging operations were not observed.

The watercourse had reverted almost to a natural state by June 1972, when six months had elapsed since the final suction-cutter dredging.

LOPPUTIIVISTELMÄ

Tutkimuksella pyrittiin selvittämään Varkaus – Kuopio syväväylätöiden vaikutusta veden laatuun.

Ruoppauksia tehtiin toukokuun 1969 ja marraskuun 1971 välisenä aikana. Havainnoin pyrittiin selvittämään neljän ruoppauskohteen vaikutuksia.

Näytteitä otettiin vuonna 1969 Unnukan alueelta kaksi kertaa ja vuonna 1972 Koirusveden ja Sotkanselän alueelta kolme kertaa. Sedimentoitumista tutkittiin sedimenttiputkien avulla kahdella tutkimusjaksolla 1972. Silmämääräisesti sameusalue kartoitettiin kolme kertaa vuonna 1969.

Ruoppausten havaittiin selvästi aiheuttaneen veden samentumista ja kiintoainepitoisuuden lisääntymistä. Sameusalue eteni melko nopeasti, tarkkaillussa tapauksessa useita kilometrejä vuorokaudessa.

Samentuneet alueet olivat varsin laajoja, mutta korkeat kiintoainepitoisuudet rajoittuivat suppeahkolle alueelle ruoppausalueen lähelle. Korkeimmat pitoisuudet analysoitiin pohjan lähelle. Kiinteä aines näyttää kulkeutuneen avovesiaikana kauemmaksi kuin talviaikaan.

Veden fosforipitoisuuden havaittiin nousseen, aluksi vain ruoppausalueen lähistöllä, mutta sameuden levitessä näyttää fosforipitoisuus nousseen koko tutkimusalueella jonkin verran.

Veden muiden ominaisuuksien ei havaittu muuttuneen ruoppausten vaikutuksesta.

Vesistöjen tilan voidaan katsoa palautuneen lähes luonnontilaan kesäkuuhun 1972 mennessä, jolloin viimeisistä imuruoppauksista oli kulunut noin puoli vuotta.