NUTRIENT LOADING OF LAKE KANKAISTENJÄRVI

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ABSTRACT

This thesis was made to estimate the nutrient loading of Lake Kankaistenjärvi and the impacts of forestry on the quality of the surface waters. Forestry was selected as the main focus of the thesis, because most of the drainage area of the lake is forest and the subject was topical at the time. The thesis was commissioned by the Protective Society of Lake Kankaistenjärvi, founded in June 2012, and the municipalities of Janakkala and Hämeenlinna. The quality of Lake Kankaistenjärvi has been noticed to deteriorate, based on sensory observations, which has led to a concern of the future of the lake and founding of the Protective Society. The aim of the thesis is to be used as a basis for other planned researches of the lake, and give information about the impacts of forestry and the possibilities to reduce the impacts.

As a theory basis was used existing information about the nutrient drifting and its impacts, and the impacts of forestry and possibilities to reduce the impacts. Out of the practical methods the most significant was the inquiry, based on which the experiences of the residents and other lake users were found out, and the impacts of the wastewater treatment on scattered settlement was estimated. Nutrient loading was also estimated by means of two different loading modeling systems, and water samples.

It was found out that of the human activities, Lake Kankaistenjärvi is under phosphorus loading from scattered settlement and forestry. More information is needed to estimate the impacts of agriculture and internal loading. Based on the modeling, the nitrogen loading is mostly of natural origin, but also scattered settlement, forestry, and agriculture have an impact. As a limiting nutrient the impact of phosphorus is a more significant contributor to the changes in the lake. In order to secure and improve the status of Lake Kankaistenjärvi, special attention must be paid to wastewater treatment in the drainage area. As head waters with a long retention time, and because of the wooded drainage area, the lake is also vulnerable to the impacts of forestry, which must be minimized.

Keywords nutrient loading, forestry, water protection, scattered settlement

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TIIVISTELMÄ

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Työn nimi Kankaistenjärven ravinnekuormitus

TIIVISTELMÄ

Tässä työssä arvioidaan Kankaistenjärven ravinnekuormitusta ja metsätalouden vaikutuksia pintavesien laatuun. Kankaistenjärven kuormitustekijöistä pääpaino valittiin metsätaloudelle, koska järven valuma-alueesta suurin osa on metsää ja koska aihe oli ajankohtainen. Työn toimeksiantaja on kesäkuussa 2012 perustettu Kankaistenjärven suojeluyhdistys, sekä Janakkalan kunnan ja Hämeenlinnan kaupungin ympäristötoimet. Kankaistenjärven kunnossa on havaittu aistinvaraisesti heikentymistä, joka on johtanut huoleen järven tulevaisuudesta ja suojeluyhdistyksen perustamiseen. Työn tarkoitus on toimia pohjana muille suunnitteilla oleville kuormitustutkimuksille, sekä antaa tietoa metsätalouden vaikutuksista ja mahdollisuuksista vaikutusten vähentämiseen.

Teoriapohjana hyödynnettiin olemassa olevaa tutkimustietoa ravinteiden kulkeutumisesta, vaikutuksista, sekä metsätalouden toimenpiteistä ja vaikutusmahdollisuuksista. Käytännön toimenpiteistä merkittävin oli asukaskysely, jolla kartoitettiin järven asukkaiden ja käyttäjien kokemuksia järven tilasta, sekä arvioitiin haja-asutuksen jätevesihuollon merkitystä kuormituksessa. Kuormitusta arvioitiin myös kahdella eri kuormitusmallilla, sekä otettujen näytteiden avulla.

Työssä havaittiin että Kankaistenjärveä kuormittaa ihmistoiminnan osalta haja-asutuksen, sekä metsätalouden fosforipäästöt. Maataloudesta ja sisäisestä kuormituksesta tarvitaan lisää tietoa vaikutusten arvioimiseksi. Typpikuormitus on mallinnuksen mukaan suurimmilta osin luonnollista, mutta myös haja-asutuksella, sekä metsä- ja maataloudella on vaikutusta. Rajoittavana ravinteena fosforin kuormitus on merkittävämpi järven tilan muutoksessa. Kankaistenjärven tilan turvaamiseksi ja parantamiseksi valuma-alueen jätevesienkäsittelyyn täytyy kiinnittää erityistä huomiota. Pitkäviipymäisenä latvavesistönä ja metsäisen valuma-alueen vuoksi Kankaistenjärvi on myös herkkä metsätalouden toimenpiteiden vaikutuksille, jotka pitää pyrkiä minimoimaan.

Avainsanat ravinnekuormitus, metsätalous, vesiensuojelu, haja-asutus

Sivut 38 s. + liitteet 20 s.

CONTENTS

1 INTRODUCTION

Lake Kankaistenjärvi is a small, oligotrophic lake located in the Kanta-Häme region, belonging to the municipalities of Hämeenlinna and Janakkala. The lake is head waters, and gets its water from the drainage area by run-off water and groundwater springs. The lake water runs to Lake Katumajärvi, and from there to the river Kokemäenjoki. The need to study the nutrient loading of Lake Kankaistenjärvi is based on sensory observations by the lakeside residents that the water quality of the lake has deteriorated, which has been noticeable due to eutrophication and decrease in the visual depth of the water. The concern of the future of the lake led to the founding of the Protective Society of the lake Kankaistenjärvi, which cooperates with the municipalities of Hämeenlinna and Janakkala to maintain the excellent status of the lake. Part of this cooperation was commissioning a thesis about the nutrient loading of the lake from HAMK University of Applied Sciences.

The Protective Society of Lake Kankaistenjärvi was founded on 15 June 2012 and currently it has about 100 members. The goal of the Protective Society is to maintain the excellent status of the lake by researching the condition of and threats to the lake, planning and implementing remediation and treatment activities, giving recommendations for water protection in the area, and taking a stand on the projects carried out on the lakeside.

The goal of this thesis is to provide information on the nutrient loading of the lake and of the effects of forestry on the quality of surface waters and give recommendations on how to maintain the high quality of the lake. The main focuses of the thesis are the impact of forestry on the lake, and the inquiry, which is used to estimate the wastewater treatment in the area, the changes in the lake, and the reasons for the changes. Internal loading and the main drainage area to the north of the lake will be covered by other researches planned for the year 2013, and therefore, these parts are only covered briefly.

The results of the thesis include estimations of the nutrient loading by two modeling systems, and the estimations of the impact of water protection measures used in forestry area on the eastern side of the lake. Recommendations presented in Chapter 7 include recommendations for monitoring of the lake status and activities in the drainage area, how to reduce loading caused by scattered settlement, how to protect surface waters in the forestry processes, and other recommendations based on the inquiry.

2 BACKGROUND INFORMATION

2.1 Definition and description of the study area

Lake Kankaistenjärvi (35.236.1.003) is located in the Kanta-Häme region, belonging to the municipalities of Hämeenlinna, and Janakkala. The lake belongs to the third river basin district (Kokemäenjoki-Archipelago Sea Bothnian Sea River Basin District), and is part of the drainage basin of Lake Katumajärvi (35.236). The surface area of the lake is 272.6 hectares, and the area of the drainage is approximately 1300 hectares (Figure 1). (Jutila 2012)

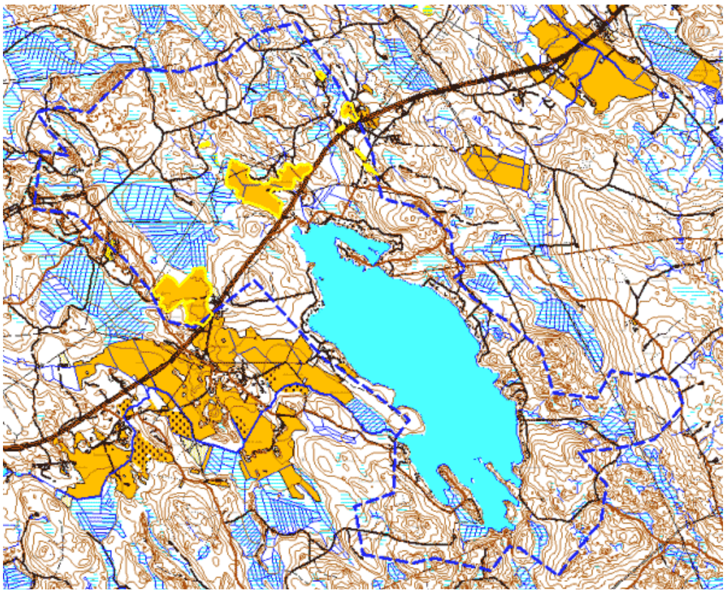


Figure 1 Drainage area of the lake Kankaistenjärvi (Jutila 2012). Scale 1:50000.

Lake Kankaistenjärvi is an oligotrophic, and clear water lake. The status of the lake has been classified to be excellent, and the visibility is from 2.8 up to 6.8 meters. The volume of the lake is approximately 15.9 million m³, and the maximum depth is 17.6 meters. The length of the shoreline is 14.97 km. The outlet ditch Myllyoja on the west of the lake leads to Lake Katumajärvi through the Matkolampi pond. Due to a small drainage area, the retention time of water is very long (Jutila 2012)

Drainage area of Lake Kankaistenjärvi is relatively small, and the lake covers 21 % of the drainage area. About 3 % of the drainage area is cultivated land, and most of the drainage area consists of forestry and swamps. Most of the drainage area is located in the northern part of the lake, including the only cultivated areas in the drainage area. (Jutila 2012)

The main focus of this thesis was set on the forestry area on the eastern side of the lake, as it was the most acute case at the time of this work, and Metsäkeskus is planning to take samples from the ditch in the largest drainage area in the north, and possibly take some water protection measures. (Lukanniemi, interview 5.3.2013.)

2.2 Limiting nutrients

Nitrogen and especially phosphorus are the limiting nutrients for the growth of phytoplankton in a lake, because they are the only nutrients for which there is more demand than supply. Lakes which have a higher concentration of limiting nutrients are called eutrophic lakes. The opposite is oligotrophic lake. The term eutrophication is used to describe disturbance in the water ecosystem, which leads to a rapid growth of biomass. (Helminen, Mäkinen & Horppila 1995, 25; Salonen, Frisk, Kärmeniemi, Niemi, Pitkänen, Silvo & Vuoristo 1992, 10.)

As a lake becomes eutrophic, the amounts of phytoplankton and vegetation on shores and water will increase, the water quality will deteriorate and the fish stock will be dominated by black clams. The valuable fish species, such as powan and trout, will disappear from eutrophic lakes. Out of valuable fish species, only pikeperch also thrives in eutrophic conditions. Eutrophication weakens the ecological status of the lake and reduces the possibilities of recreational use of the lake (Sarvilinna & Sammalkorpi 2010, 10–11.)

External nutrient loading alters the food chain and increases the amount of blue-green algae. Though the amount of aquatic vegetation increases, the diversity will decrease. Species thriving in oligotrophic conditions will disappear and common reed and similar plants start to form dense plant stands in large areas. The decaying of increased biomass will consume the oxygen in the water, and especially in winter time oxygen content can be very low in eutrophic lakes. This can lead to mass deaths of fish and crab populations. The accumulation of the nutrients in the lake sediment will together with the lack of oxygen lead to internal loading, which can continue the eutrophication process in the lake for many years, even if external loading is reduced. (Sarvilinna & Sammalkorpi 2010, 10–11.)

2.2.1 Phosphorus

Phosphorus is an essential element for all plant cells, because it is needed as a component for the production of nucleic acids and adenosine triphosphate. Out of the dry weight of a plant, usually 0.5-2 % is phosphorus. Algae usually use dissolved orthophosphate, until the concentration of it in the water is very low (less than 1 mg/m^3). Some alga species can also use dissolved organic phosphorus with the help of their alkaline phosphatase enzymes. A low phosphatase activity indicates that the plant cells have enough phosphorus in the cells. Measuring the total or phosphate phosphorus doesn´t give accurate results of the amount of phosphorus available for the plants (Salonen et al. 1992, 21.)

The amount of phosphorus in the water is usually low and therefore, it is often a so-called minimal nutrient in an aquatic environment. The increase in phosphorus content in an oligotrophic lake leads most commonly to a rapid growth of algae production. Phosphorus enters the lake by deposition, surface run-off, and from the drainage area via ditches and brooks. The phosphorus loading of the lake depends on the form of land use (especially agriculture) and the rock types on the soil of the drainage area. Annual phosphorus loading can be estimated by taking samples and measuring the discharge in the ditches and brooks leading to the lake. (Helminen et al. 1995, 28–29.)

Phosphorus is present in the water as dissolved inorganic phosphates (PO_4^{3-}) dissolved or colloid organic phosphorus compounds or organic or inorganic compounds bound to solid matter. A noticeable part of phosphorus, over 90 %, is bound to algal biomass or soil particles and therefore, can´t be used by producers. The only usable form of phosphorus for plants is orthophosphate (PO_4^{2-}). Phosphate, however, can form compounds with cations quickly, such as iron and calcium, which in the presence of oxygen are almost insoluble. Phosphorus can also be stored in the surface of clay particles and different kinds of carbonates and hydroxides. (Salonen et al. 1992, 12; Helminen et al. 1995, 28–29.)

Phosphorus exits the water body either by outflow water or sedimentation. The stability of the phosphorus in the sediment is controlled by the reduction potential of the sediment surface, pH-level, temperature, and the water current. Also, the metabolic activity of bacteria and fungi, and especially the black clam populations can have an impact on the release of phosphorus from the sediment to the water. Phosphorus released from the sediment accumulates in the hypolimnion during the time of temperature stratification, and is released to the productive layer in the overturn on spring and autumn. (Salonen et al. 1992, 12; Helminen et al. 1995, 30.)

Classification of surface waters based on the amount of total phosphorus is presented in Table 1.

Table 1 General quality classification of water systems, values for total phosphorus. (Vesistöjen laadullisen käyttökelpoisuuden luokittaminen 1988, 34–35.)

Classification	Description	Limit value of Tot.P
Excellent	On natural state, clear or small amounts of humus	< 12 µg/l
Good	Slightly eutrophic	< 30 µg/l
Satisfactory	Either naturally eutrophic, or under a slight loading	< 50 µg/l
Unsatisfactory	Heavily loaded water system	50-100 µg/l
Poor	Spoiled water system, unusable by other activities than transport	> 100 µg/l

2.2.2 Nitrogen

Nitrogen can be present in water as a molecular nitrogen (N_2), ammonium nitrogen (NH_4), nitrate nitrogen (NO_3-N), or nitrite nitrogen (NO_2-N), or as different organic compounds such as amino acids and proteins. Nitrogen is one of the two nutrients affecting the production of the inland water ecosystems, but it isn´t usually the limiting nutrient in Finnish lakes. Nitrogen compounds can enter the water system from the air with precipitation or dry deposit, processes in the water and sediment which bind gaseous nitrogen can release nitrogen to the water, and nitrogen can enter the water as a leaching from the drainage area. Nitrogen exits the water system by outflow and denitrification. The balance between entering and exiting nitrogen dictates the nitrogen level in the water body. (Helminen et al. 1995, 30–31.)

The most useful of the nitrogen compounds to plants is the ammonium nitrogen, followed by nitrate nitrogen, and as last the molecular nitrogen. The main source of nitrogen in the water is the molecular nitrogen which can be bound by some soil and water bacteria and blue-green algae. Even the blue-green algae capable to bind molecular nitrogen, starts using it after the other nitrogen compounds have been used. (Helminen et al. 1995, 30–31.)

Heterotrophic bacteria break down proteins and other organic compounds containing nitrogen and form ammonium. The ammonium content in the productive layer is usually low, because photosynthesising algae and vascular plants bind ammonium. In oxygen rich conditions *Nitrosomonas* and *Nitro bacteria* oxidize ammonium to nitrite and nitrate, in a process called nitrification. In oxygen-free conditions nitrification ceases and the sediment of the lake starts to release ammonium back to the circulation. In anaerobic conditions nitrate is reduced to molecular nitrogen, which is either bound by plants, or returning to atmosphere. In eutrophic lakes the amounts of ammonium and nitrate are low in the productive layer, due to increased production. (Helminen et al. 1995, 30–31.)

3 INQUIRY

To evaluate the changes in the lake and the impact of scattered settlement, an inquiry was made using Webropol online survey and analysis software. The inquiry was sent to the members of the Protective Society of Lake Kankaistenjärvi and other property owners on the lakeside. The addresses were received from the Protective Society of Lake Kankaistenjärvi. For the recipients, whose email address was known, the inquiry was sent via Webropol -software, which enables sending a direct link to the recipients´ email. To others inquiry was sent by mail. The inquiry was sent at the end of February 2013 successfully to 130 recipients, by mail to 61 recipients and by email to 69 recipients. The inquiry is presented in Appendix 2 and the summary of the results in Appendix 3.

Out of the recipients, 20 answered by mail and 28 by email. The response rate by mail was 32.8 %, and by email 40.6 % The total response rate was 36.9 %.

3.1 Scattered settlement

Questions 4 and 6-14 in the inquiry were for estimating the impact of scattered settlement, and especially the level of wastewater treatment. A summary of the results is presented in the appendices. Wastewater treatment and sanitation systems used in the area are presented in Table 2.

Table 2 Wastewater treatment and sanitation systems in the drainage area of Lake Kankaistenjärvi according to the respondents.

	Black wastewater	Grey wastewater	Separate sauna
Sewer network	5	5	2
Soil filtration	2	16	11
Holding tank	17	7	3
Package treatment plant	0	0	0
Infiltration system	2	8	10
Dry toilet	19	x	x
No treatment	x	3	3
Other, what?	2	5	2
Total	46 (47)*	44	31

* One of the respondents answered having both dry toilet and soil filtration.

Out of the dry toilets, most commonly used was a composting dry toilet which was used by 71 % of the respondents. The majority of the respondents, 83 %, answered that they aren´t planning any changes in their real estate or water supply and sewage systems. The remaining 17 % of the respondents were planning improvements in the treatment of grey wastewaters, building of a well, or connecting their real estate to the public sewer. To question 10, about the final disposal of the waste in holding and depositing tanks, all 19 respondents answered that sewage suction truck transports the waste away.

About 62 % of the respondents answered that their wastewater treatment currently fulfils the demands by the Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (209/2011). About 36 % of the respondents didn´t know, and only one respondent answered 'No' to the question. About 40 % of the respondents answered that they wash carpets or cars within about 200 metre radius from the lake. Most commonly the washing was made without detergents, or with tall oil soap, and two respondents mentioned using the washing-up liquid Fairy.

3.2 Changes in the water quality

Questions 16-27 and 30-31 were made to estimate the changes in the water quality.

One of the factors used to estimate the changes in the lake were the changes in fish catches and the slime build-up in fishing nets. Out of the 28 respondents 29 % estimated that the fish catches had decreased, and 11 % that the fish catches have remained unchanged, the rest didn´t know. Out of the 29 respondents, only two had noticed the relative amount of black clams to increase, compared to valuable fish. Out of the 29 respondents 59 % had noticed slime build-up in their fishing nets, and all of them also responded that the slime build-up has increased. The slime build-up is most common in summer, according to the majority (33 %) of the respondents.

About 56 % of the respondents had noticed blue-green algae in the lake and out of them over 81 % answered that it has occurred more often within the last five years. Over 50 % of the respondents answered that the visibility depth has decreased, no-one answered that the visibility had increased. The timing of the decrease in the visibility varied in the responses from 1970 to 2012, but most commonly it was estimated to have happened within the last 5-10 years. Out of the respondents to the question 24, 44 % had noticed slime build-up on the rocks on the shore and out of them 81 % answered that the slime build-up has increased within the last five years.

Out of the respondents 65 % estimated that the amount of aquatic vegetation has increased, and about a third of the respondents had noticed changes in the species. According to the answers to question 27 almost all types of aquatic vegetation had increased, but pond water-crowfoot, and perfoliate pondweed were mentioned most commonly.

Question number 30 about the changes in the lake was answered by 33 respondents. Most commonly mentioned changes were the decrease in the water level, increase in aquatic vegetation, the decrease in the visibility depth, and the increase in the amounts of blue-green algae. Changes in the fish catches, increased amounts of humus, and slime build-up were also mentioned in a few answers. In a few responses the changes in the lake were mentioned to be minor.

Most of the 21 respondents to the question 31 estimated the changes in the lake to be caused by the waters running from the forestry area. The secondly most common answer was the increased settlement near the lake, and other answers included ditching of the marsh areas in the northern drainage area, cultivated areas and the soil landfill in the northern drainage area, climate change, and deposition of polluted air.

4 NUTRIENT LOADING OF LAKE KANKAISTENJÄRVI

Nutrient loading can be divided to internal loading and external loading.

4.1 Internal nutrient loading

Internal nutrient loading means the release of phosphorus back into the circulation from the sediment of the water body. The release of phosphorus usually begins when the oxygen content on the bottom is low, for example, during winter time. Internal loading can also occur without oxygen depletion, due to high pH. Black clam-intensive fish population, which is common for eutrophic lakes, can also increase the internal loading, by collecting nutrition from the sediment and spreading the nutrients by faeces and secretion. Black clams also use large amounts of animal plankton as nutrition, which assists the growth of algal biomass. Lakes in Finland are mainly so shallow that the tolerance for wastewater is weak, but on the other hand, lakes are deep enough for the stratification of water, which weakens the oxygen supply to the lower water layers during the stratification periods. (Helminen et al. 1995, 74–77.)

Determining the internal nutrient loading of a lake is more challenging than external nutrient loading, because of the bidirectional movement of matter between sediment and the lake. One clear sign of internal loading is if external loading has decreased significantly, but still the nutrient content in the water is higher than it should be based on external loading. Another sign of internal loading is if the phosphorus content in the water increases during the growing season and low inflow. Internal loading can occur by various mechanisms, including phosphorus diffusion from the sediment to the water, wind-induced resuspension, gas convection, and bioturbation. In order to have the most effective rehabilitation methods for an eutrophic lake, it is important to find out with at least a moderate accuracy what the internal loading mechanism in the lake is. (Martinmäki, Marttunen, Ulvi, Visuri, Dufva, Sammalkorpi, Ahtiainen, Lemmelä, Auvinen, Partanen-Hertell, Lehto, Väisänen, Mustajoki & Ihme 2010, 25.)

The internal loading of Lake Kankaistenjärvi couldn´t be thoroughly estimated in this thesis, due to the lack of research results. Considering the oligotrophic state of the lake, and the relatively good oxygen situation in the bottom of the lake in the taken samples (Jutila 2012), it can be anticipated that internal loading doesn´t necessarily have a significant effect on the loading of the lake, but to be sure the situation should be estimated by researching the lake sediment. Some estimations can also be made by monitoring the oxygen level in the basins of the lake, and by estimating the nutrient balance of the lake, which requires sampling also from the drain ditch.

4.2 External nutrient loading

External nutrient loading can be divided to point source loading and non-point source loading. Point source loading originates from a specific source, such as a factory, fish farm or urban community, which can be easily measured and controlled. Non-point source loading originates from wide, unspecific areas, making the controlling of it more difficult than point source loading. Non-point source loading means, for example, the loading from cultivated areas and forests. Some estimations of non-point source loading can be made, for example, on the basis of the distribution of the land use of the drainage area. Results can, however, be regarded only as suggestive, because the non-point source loading varies greatly by year, depending on, for example, the amount of rainfall. Non-point source loading from the cultivated areas is the most significant source of nutrient loading to the surface waters, especially when considering the amount of phosphorus. (Helminen et al. 1995, 77–78.)

4.2.1 Drainage area to the north of the lake

Drainage area to the north from the lake is approximately 620 hectares, including the only cultivated areas, approximately 40 hectares, in the drainage area of the lake. Approximately 90 hectares of the area is marsh area, and the rest are forest and roads (Jutila 2012; Maanmittauslaitos n.d.)

Kokemäenjoen vesistön vesiensuojuyhdistys ry (later KVVY) (unofficial translation: Water Protection Society of the river Kokemäenjoki water system), which operates to improve water quality in the drainage area of the river Kokemäenjoki, took three water samples from the Komulahti ditch transporting water to the lake on October 31st 2012. The samples were analyzed in the KVVY laboratory, and the results and map are presented in Appendix 1.

During the time of the sampling, the discharge in point 1 in the mouth of the ditch was 100 l/s. Above the cultivated areas in point 3 the discharge was only 18 l/s, so it rose fivefold before point 1. In point 3 water was clear, low in nutrients, acidic, and low salt humus water. The hygiene level of the water was good. (Oravainen 2012.)

In point 2 water was more murky, and pH was low 4.8. The nitrogen content was slightly increased, but despite the high humus content the amount of ammonium nitrate was low. Phosphorus content increased threefold between the sampling points 2 and 3, and about 40 % of it was in dissolved form, and therefore, originating from erosion. Bacterium coli was also present in the sample, so there are deficiencies in the treatment of wastewater in the area. (Oravainen 2012.)

In point 1. water quality was slightly better than in point 2 and water was clearer, so waters on the downstream have had a good quality. (Oravainen 2012.)

4.2.2 Forestry area in the drainage area of the lake

On the eastern side of the lake is located a forestry area of UPM (United Paper Mills), which is in the drainage area of the lake. A notice of proposed cutting in the area was made in autumn 2010, and the clear cutting was carried out during the winter time 2010-2011. Stumps were extracted from the Heinämäki hill area in July 2012, and the area below the hill was mounded in spring 2012 (Figure 2). The distance from the cutting area to the lake is about 300 meters, and in-between there is a direct connection by a ditch. (Honkala 2012, memorandum.)

Figure 2 Clear cutting area of Heinämäki hill and the ditch leading to Lake Kankaistenjärvi.

KVVY took two samples from the ditch on October 31st. 2012, and they were analyzed in the KVVYs laboratory. The results and map are presented in Appendix 1.

According to the results, the water was relatively clear, and the content of solids was on a normal level. Electrical conductivity was low, and water was acidic humus water. The discharge at the time of sampling was approximately 30 l/s. The phosphorus content was a bit higher than normal, and over a half of it was in a dissolved form. Water has an eutrophicating effect on the lake because phosphorus is the minimum nutrient for production. The hygiene level of water was good. During the time of sampling, water quality was better in the sampling point below the forestry area than in the point above the area, so at the moment forestry area didn´t cause extra loading. (Oravainen 2012.)

4.2.3 Scattered settlement

Scattered settlement accounted for 3 % of the nitrogen, and 8 % of the phosphorus, of the total nutrient loading caused by human activities in the year 2004. The goal to reduce nutrient loading, and BOD by 30 % before year 2005 was clearly unaccomplished, but the new Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (209/2011) which came into effect in 2003 has improved the protection of water systems. (Vesiensuojelun suuntaviivat vuoteen 2015 Valtioneuvoston periaatepäätös (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015) 2007, 15.)

The new Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks came into effect in 2011 replacing the one passed in 2003. The transition period of the new decree ends in the year 2016. The new decree demands that the purification level of the domestic wastewater has to be at least 80 % of organic matter, 70 % of total phosphorus, and 30 % of total nitrogen compared to untreated domestic wastewater based on so-called load factors. In areas vulnerable to contamination, corresponding figures can be as high as 90 % of organic matter, 85 % of total phosphorus, and 40 % of total nitrogen. (JätevesiA 209/2011.)

Other significant demands are the statement of the wastewater treatment system, required in the fifth article of the decree, based on which it is possible to estimate the load of the treated wastewater, and up-to-date use and maintenance instructions of wastewater treatment system, required in the seventh article. The statement is required also when it is possible within the confines of the environmental protection act to lead untreated wastewater to the soil. The statement and/or instructions have to be kept on the property, and displayed to the authorities when requested. (JätevesiA 209/2011.)

The appendices of the decree include the demands for the statement of the wastewater treatment system and the use and maintenance instructions. For example, for the commonly used holding tank in Lake Kankaistenjärvi, the demands are that the use and maintenance instructions must include instructions on how to test that the overflow alarm is functioning properly, which has to be done at least once a year, how to manage bookkeeping of the removed wastewater in order to make sure the tank isn´t leaking, and instructions for the inspecting of the waterproofness of the tank, which has to be at least once in five years. (JätevesiA 209/2011.)

The level of wastewater treatment in Lake Kankaistenjärvi is presented in Chapter 3.1.

Washing carpets on the shores of lakes is still a somewhat popular hobby in Finland, based on nostalgia, even though it´s tried to be limited by building drained washing places on land. The Centre for Economic Development, Transport and the Environment for Pirkanmaa researched the loading from the carpets of a single household in the summer 2003. The carpets were washed with a brush and tall oil soap in a drained carpet washing pit, and samples were taken from the water. The contents of solid matter were high, and sand, clay, organic matter and fibers of the carpet were released into the water. The amount of nutrients and bacteria were also high. In the rinsing water the amounts were smaller, but even in the third rinsing they were clearly higher than the amounts in the river water used for the washing. The impact of tall oil soap was determined to be so small that it is insignificant to the total loading. The loading originates from the dirt. (Wirola & Santala 2005.)

According to the results, washing carpets fouls the water even if it is done with tall oil soap or similar low phosphate detergents. Approximately 75 % of the phosphorus released when washing carpets is in a dissolved form, and therefore easily usable for plants and algae. Washing carpets in the water can cause deterioration in the hygiene level of the water, muddiness of the water, and increase the growth of vegetation. Washing the carpets further from the water system reduces the impacts. (Wirola & Santala 2005.)

4.3 Mathematical modelling of the nutrient loading

Nutrient loading was modelled in this thesis with two different loading models, VEPS and Bilaletdin. The models were selected based on their good usability and easily attainable information.

4.3.1 VEPS

The VEPS system maintained by the Finland´s environmental administration, was selected to be used in the work because of its multifunctional loading values, good usability, and being generally well-known.

The VEPS system includes loading values for point source pollution, agriculture, forestry, natural leaching, deposition, and scattered settlement. The new 2.0 version can also be used to estimate the loading of storm water, recreational settlement, and peat production. As a source to the system are the databases of environmental administration, such as VAHTI (monitoring and loading database), and for the calculation of land use SLICES database (Separated Land Use/Land Cover Information System). (Vesistökuormituksen arviointi- ja hallintajärjestelmä VEPS 2006.)

The system gives information about the nutrient loading of the water system area, the significance of the loading sources compared to each other, and also the long period changes for some sources. The estimation by the system has not, however, been compared to regional results, and therefore, the information from the system can be used as background information, and fulfilled by measurements, more accurate modeling, and know-how. (Vesistökuormituksen arviointi- ja hallintajärjestelmä VEPS 2006)

Table 3 The distribution of land use in the drainage areas of lakes Katumajärvi, and Kankaistenjärvi.

Form of use	Drainage area of Lake Katumajärvi	Drainage area of Lake Kankaistenjärvi
Catchment area (km²)	51.07	13
Agriculture (km²)	4.71	0.4
Forestry (km²)	33.76	9.87
Air deposition (km²)	6.82	2.73
Natural leaching (km²)	38.47	10.27
Scattered settlement (pcs)	1096	140
Lake percentage (%)	13.16	21

Specific loading factors, and the distribution of land use in the drainage area of Lake Katumajärvi, 35.236, including Lake Kankaistenjärvi, and its drainage area, were received from the Häme Centre for Economic Development, Transport and the Environment, from the Hämeenlinna unit. (Hulkko, e-mail 13.12.2012)

The distribution of land use in the drainage area of Lake Kankaistenjärvi, presented in the Table 3, was estimated based on the map of the drainage area (Jutila 2012), and information on Paikkatietoikkuna (unofficial translation: geographical information map window) (Maanmittauslaitos). The values for agriculture and scattered settlement are estimated based on the information on Paikkatietoikkuna, the figure of air deposition is based on the surface area of the lake, the area of natural leaching is calculated by combining the areas of forestry and agriculture. Since the drainage area of the lake is wooded, the amount of forestry was estimated to be the size of the drainage area, reduced by the areas of agriculture and the lake. The amount of scattered settlement units in the drainage area was estimated to be 140 pieces, based on the partition of real estate on Paikkatietoikkuna.

The latest information in the VEPS system for the river basin 35.236 is from the year 2007, except for forestry, for which the latest information is from the year 2005, and the latest information of the deposition is from the year 2002. The yearly variations of the values from 1990 to the latest information are large. The specific loading factors for agriculture, natural leaching, and scattered settlement have remained unchanged from the year 1990 to 2007, so they can be considered relatively reliable in describing the current situation. The specific loading factors are presented in Table 4.

Table 4 The specific loading factors for the drainage area of Lake Katumajärvi (35.236)

Specific load [kg/km²]/[kg/pcs]	Phosphorus	Nitrogen
Agriculture	62.00	1494.81
Forestry	0.91	14.02
Air deposition	12.90	563.52
Natural leaching	6.03	176.26
Scattered settlement	0.33	1.98

The values of forestry varied between the years 1990 and 2005 from 2.15 kg/km² to 0.91 kg/km² considering phosphorus and from 19.74 kg/km² to 14.02 kg/km² considering nitrogen, and they have been clearly decreasing over the known period. During the years from 2001 to 2005 the variation has been minor, and the decrease has slowed down. Therefore, the latest values of the year 2005 were considered to be the most reliable.

The values of air deposition varied between the years 1990 and 2002 from 21.05 kg/km² to 8.16 kg/km² considering phosphorus and from 708.80 kg/km² to 442.27 kg/km² considering nitrogen. The amount of air deposition depends strongly on the weather, so the averages of the values were considered to be the most reliable values for the estimation. The average value for phosphorus was 12.90 kg/km² and for nitrogen 563.52 kg/km².

4.3.2 Bilaletdin model

Bilaletdin model, developed by the Tampereen vesi- ja ympäristöpiiri (unofficial translation: Tampere district of waters and environment) was selected to be used in this project due to the limited amount of easily accessible loading factors.

Bilaletdin model was originally used in the water conservation study of Längelmävesi route. The model is based on two simple formulas for the yearly total loading of phosphorus and nitrogen. Formulas take into account the loading impacts of agriculture, point source loading, scattered settlement, forestry, and leaching. Air deposition is included in the leaching. The idea behind the selected formula type was to generate a method for the estimation of the loading, with as small amount of easily accessible contributors as possible, but so that the loading could be divided to different sources of loading. (Kaipainen, Bilaletdin, Perttula, Heino, Mäkelä, Viitaniemi 2002, 16.)

In the formulas, point source loading consists of industry, wastewater treatment units in urban areas, fish farming facilities, peat production, landfills, etc. Loading values of significant point source loaders can be found in the monitoring and loading database (VAHTI). The value for scattered settlement is based on an estimation about the distance to the water system and the water treatment efficiency of dwellings. The estimation of the impacts of forestry is based on specific loading factors, drawn from different sources. The leaching used in the formula includes the values of natural leaching, air deposition, and human impact, such as logging roads. (Kaipainen et al. 2002, 16.)

$$L_P = (p_1 + 1)^{-0.2}\,[0.9(2p_f + u_m)^{0.75} + L_w + L_s + (L_f + L_b)A^{-0.08}]$$

$$L_N = (p_1 + 1)^{-0.1}\,[4.5(4p_f + u_m)^{0.90} + L_w + L_s + (L_f + L_b)A^{-0.08}]$$

(Bilaletdin, Frisk, Koskinen, Wirola 1992, 61.)

Abbreviations, units, and factors used in the Bilaletdin model are shown in Table 5.

Table 5 Abbreviations, units, and factors used in the Bilaletdin model.

Abbreviation	Description	Unit	P	N
L_P	total phosphorus load	(kg/km²/a)	x	-
L_N	total nitrogen load	(kg/km²/a)	-	x
p_1	lake percentage	(%)	21	21
p_f	percentage of arable land	(%)	3	3
u_m	the amount of cattle units	(pcs/km²)	0	0
L_w	point source loading	(kg/km²/a)	0	0
L_s	loading from scattered settlement	(kg/km²/a)	4.49	26.96
L_f	loading from forestry	(kg/km²/a)	0.91	14.02
L_b	leaching	(kg/km²/a)	7.47	257.53
A	the size of the drainage area	(km²)	13	13

The calculations were made using the same specific loading factors and information on the distribution of land use as in VEPS section. Lake Kankaistenjärvi drainage area doesn´t include any point source polluters, or cattle. Loading from scattered settlement (L_s) was calculated using the results of the VEPS section in Chapter 6.1, where the values for the scattered settlement are 46.20 kg/a for phosphorus and 277.20 kg/a for nitrogen. To get the values to the right unit, they were divided by the size of the drainage area reduced by the size of the lake, 10.28 km², as the lake% is already taken into account in the formula. The used loading factor was then 4.49 kg/km²/a for phosphorus and 26.96 kg/km²/a for nitrogen.

In VEPS system the values of air deposition and natural leaching are presented separately, but in the Bilaletdin model they are considered as leaching. The figures of leaching in the Bilaletdin model were therefore calculated based on the lake% of the drainage area, 0.21*air deposition+0.79*natural leaching, giving the used figures of 7.47 kg/km²/a for phosphorus and 257.53 kg/km²/a for nitrogen. The loading factors are presented in Table 5.

5 IMPACTS OF FORESTRY ON THE QUALITY OF SURFACE WATERS

Forestry accounts for 8 % of the phosphorus and 5 % of the nitrogen loading from human activities. The reduction of ditching has reduced the nitrogen loading to the waters, as increased fertilizing of the peat lands has increased phosphorus loading. (Vesiensuojelun suuntaviivat vuoteen 2015 Valtioneuvoston periaatepäätös (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015) 2007, 12–13.)

Forestry is estimated to cause 250-350 tons of phosphorus loading, and 3600-4100 tons of nitrogen loading annually. The amount is strongly influenced by the level of water protection measures in the process area. Ditching, cutting, and soil preparation have the most significant impacts on the increase in the run-off from the drainage area. These processes and fertilization increase the concentration of nutrients in the water flow from the drainage area. The increased nutrient loading is caused by a combination of these impacts. Loading from a forestry area is categorized as non-point source loading and it can be either as organic or inorganic solid matter or as dissolved organic substances and nutrients, out of which phosphorus and nitrogen are the most harmful to water systems. (Rissanen, Luhta & Joensuu 2004, 101.)

5.1 Impacts of forestry on the hydrology

The most significant forestry processes considering the impact on the hydrology are ditching, ploughing, and cutting. Ditching lowers the level of groundwater usually by some decimetres. In the middle of the field the groundwater level is higher than near the ditches, which will also have an impact on the growing of vegetation. The water storing capacity of the peat on the soil surface will improve due to the decrease on the groundwater level. On the other hand, evaporation is much lower in the dried marsh areas, compared to the ones in a natural state. The most significant impact caused by ditching is the alteration in the transportation of water. In the areas in a natural state marsh areas and small water basins in the dents of the soil store water and enable evaporation. When the area is ditched, those beneficial processes are lost and run-off increases. Therefore, run-off has been found as the main hydrological impact of ditching. (Kenttämies & Saukkonen 1996, III-3.)

Cutting has also a large impact on the run-off from the area. It is estimated that every 10 m³ of removed wood will increase the yearly run-off by 5-10 mm per hectare. Cutting reduces the interception and the consumption of water caused by trees. Precipitation to the surface of the soil will increase which will lead to the increase in the groundwater level, and in the run-off, especially in the areas of poor permeability. Cutting of spruce copse can double the yearly run-off in the area. The high flows, melting waters in spring, and downpours in summer, will be higher without retentive vegetation. The spring run-off from a felled areas can be over 30 % higher than from a forest. The impact of cutting is shorter than the impact of ditching because the evaporation will increase rapidly after vegetation grows back in the area. (Kenttämies & Saukkonen 1996, III–3.)

The impacts of ploughing are estimated to be similar to ditching, and it increases the impact of clear cutting according to Mustonen (1986). In principle the measures that increase biomass reduce runoff, and the measures that improve the water economy in moist forestry areas increase runoff. Hydrological changes also have an impact on water quality, as the changes in the runoff and ground water level influence on the leaching and matter content in the water. (CR 1987: 62, 177,180.)

5.2 Adverse effects of forestry processes

The most adverse impacts of forestry on the surface waters are caused by ditching, cutting, ground preparation included in the cutting, and by fertilization. Forestry processes have caused adverse effects especially in small water systems, such as ditches, brooks, and similar. Head waters with long retention times are also vulnerable to forestry (Vesiensuojelun suuntaviivat vuoteen 2015 Valtioneuvoston periaatepäätös (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015) 2007, 12–13.)

In addition to major forestry processes, for example logging roads, which are vital to forestry, can have negative impacts on the environment, especially on scenery, water systems, game, and environmental value of the area. The regional adverse impacts of roads always have to be assessed in the general plan of the logging road network. The impact on valuable nature reserves and their protective zones, as well as the local and long-range impacts must be taken into consideration when considering of a single logging road. (Hallman 2004, 25.)

5.2.1 Regeneration cutting

Regeneration cutting can be implemented in various ways. In clear cutting, the whole area is cut down, and regeneration is achieved by either planting or sowing. The common way to regenerate piny forests is the seed tree cutting. In seed tree cutting part of the trees in the area are left uncut, and they regenerate the forest naturally. A commonly used method in spruce forests is shelterwood cutting, in which regeneration mature forest is thinned many times, so that new seedlings begin to grow under the shelterwoods. Finally, all of the regeneration mature trees are removed. Natural regeneration can also be realized by a strip cutting system, in which forest is cut down from 60-100 meters wide strips, following a strip of uncut forest, as wide as the cut strip. (CR 1987: 62, 18–19.)

Regeneration cutting increases the amount and concentration of nearly all leaching components. In the research areas the results varied between 2 to 4 times the normal. The leaching was larger after the cutting in hydrophililic hardwood swamps compared to drier mineral soils. The amount of phosphate phosphorus increased after the cutting. The leaching of nitrogen increased more evenly in the research areas although the leaching from hardwood swamps was largest. From mineral soils nitrogen infiltrates to ground water as nitrate and the leaching will last for at least 10 years. Heavy ground processing increases the leaching of nutrients and especially solid matter from the cutting area significantly. The impacts of cutting and the ground processing in the research lasted for over 10 years. Protective zones were found to reduce the loading from the cutting area significantly. (Kenttämies & Saukkonen 1996, VII–2.)

5.2.2 Ground preparation

The goal of the ground preparation is to improve the physical and chemical quality of the soil so that seedlings have better conditions to grow. In addition, ground preparation eases the forest cultivation and therefore reduces costs. Ground preparation is nowadays used sometimes also in natural regeneration forests. (CR 1987: 62, 41.)

The preparation methods can be divided to ground exposing methods, and to ground mounding methods. Ground exposing methods include harrowing, patch scarification and ploughing. In harrowing, the mineral soil is revealed by making a constant track, usually with a tractor. Patch scarification is used to remove spots of humus from the surface of the mineral soil. In peatlands patch scarification is used to remove moss and most of the humus from the top of the peat layer. Ploughing is used to remove humus and part of the surface soil. The method is used especially in areas becoming swampy, and having a thick layer of humus. (Luoranen, Saksa, Finér & Tamminen 2007, 26–31.)

The ground mounding can be implemented by four methods. Inverted mounding, where soil is excavated by a special excavator bucket and dropped back to the same pit upside down, leaving the mineral soil on top, patch mounding, where the excavated soil is dropped upside down next to the pit, mounding with ditches, where a ditch is excavated in the area to improve the water economy of the area, and the excess soil is for mounding. Furrowing mounding is a similar method than mounding with ditches, with the difference that furrowing mounding is made just to get the soil material for mounds, not to alter the water economy. (Luoranen ym. 2007, 32–39.)

Ground preparation activities can have an impact on the leaching of dissolved substances, as well as on the erosion. Ground preparation, depending on the used measure, also affects the amount of runoff. For example in ploughed areas over 50 % of the ground is disturbed and exposing of mineral soils will increase. This will reduce evaporation and therefore, increase runoff and erosion. Breaking of humus layer and the increased temperature in the ground will cause the nutrients to mobilize, at the same time when most of the vegetation using the nutrients is destroyed. In Swedish lysimeter tests the results indicate that nitrogen leaching from a harrowed area is 1.6 times, and from ploughed area 3.6 times the value compared to a clear cutting area without using ground preparation. The phosphorus content in the areas can increase, but phosphorus is retained when the water infiltrates through mineral soil according to Rosen and Lundmark-Thelin (1986). The researches of the impact of ground processing on the water systems are still inadequate. (CR 1987: 62, 44, 46.)

5.2.3 Forest drainage

Forest drainage is used to improve the conditions for the growth of wood in swamp areas, or areas becoming swampy. The goal for forest drainage is to ensure that the water resources are as close to the optimum situation as possible. Forest drainage can be carried out by ditching, or by rehabilitation of existing ditches. Ditching is used to drain swamps which are in a natural state. (Hokajärvi (ed.) 1997, 29.)

The need for ditch rehabilitation is estimated based on tree stand, ground vegetation, and the condition of the ditches. Ceasing of the growth of the trees due to too moist soil in the forestry area indicates that the need for ditch rehabilitation is imminent. The overgrowing of the ditch and the increase in the amounts of sphagnum and other marsh vegetation, and the increased ground water level in the middle of the strip indicate insufficient drying effect of the ditches. As a consequence of the cutting, the need for ditch rehabilitation increases due to increased water amount. (Hokajärvi (ed.) 1997, 29.)

Always when ditch rehabilitation is planned, a water protection plan has to be drawn up at the same time. The basic principle is that the harmful matter for aquatic environment would be removed as little, and as short distances as possible. Solid matter has to be restrained from entering the water system and the amount of dissolved nutrients should be reduced by different types of clarification methods so that it´s close to the loading from the area in a natural state. Ditch rehabilitation can´t be done in the area of groundwater formation, or in the flood zones of a water system. In large areas, over 100 hectares, excavation work is divided to many years and the waters are first treated separately in smaller areas, before leading to the water system. (Hokajärvi (ed.) 1997, 33.)

Since erosion from the swamps, and forests in a natural state is very rare, forest drainage increases erosion significantly. Erosion is caused by three factors, excavation work, which as itself extracts solids to the water, excavated surfaces are sensitive to erosion caused by running water, and rain can wash the solid matter from the slope of the ditch. (CR 1987: 62, 88.)

The significance of the different factors is poorly known, but the loading at the time of excavation work has been found out to depend strongly on the moisture of the swamp, the humification of the peat, the weather conditions during the excavation work, and of the water amount in the excavated ditch. According to the experiences from the peat production areas the significance of the weather to the loading can be multifold. High contents of suspended solids have also been noticed during the time of maximum discharge (CR 1987: 62, 88–89.)

5.2.4 Fertilization

Fertilization is used to increase wood production and to adjust the amounts and relations of nutrients. Fertilization is needed because run-off water removes more nutrients from the soil than is collected from the atmosphere. Forestry actions, especially total harvesting, can also weaken the nutrient content of the soil. Plants need at least 16 different nutrients to grow. The main nutrients, nitrogen, phosphorus and potassium are needed more than other nutrients. (Vuokila 1987, 216.)

Mineral soils are needed to be fertilized mainly because of the lack of nitrogen, which is the only insufficient nutrient in stones and minerals. In peat soils the amounts of phosphorus and potassium are often insufficient, so both of these main nutrients are used to fertilize these areas. Using only main nutrients for fertilizing can, however, bind micronutrients from the soil and cause a deficiency of any of the needed nutrients. In fertilized areas has been noted at least the deficiencies of boron, copper, and zinc. (Vuokila 1987, 216.)

Leaching of nitrogen fertilizers from mineral soils has been studied in only one research in Finland. Saura et al. (1995) discovered that the leaching takes place in the first two years after the fertilization. In the first year the leaching was about 8 % and in the second year about 2 % of the amount of nitrogen in the fertilizer. Phosphorus fertilization doesn´t increase loading from the mineral soils as iron and aluminum in the soil bind phosphorus. (Finér, Mattsson, Joensuu, Koivusalo, Laurén, Makkonen, Nieminen, Tattari, Ahti, Kortelainen, Koskiaho, Leinonen, Nevalainen, Piirainen, Saarelainen, Sarkkola & Vuollekoski 2010, 19.)

Since the beginning of the year 2005 fertilizers used in peatlands has included iron in addition to phosphorus and potassium. Added iron binds the phosphorus in the fertilizer and therefore reduces leaching. Researches indicate that the new type of fertilizer wouldn´t cause loading to the nearby water systems if it is spread by manual labor and it´s taken care that the fertilizers don´t end up to any ditches. Often fertilizers are spread by a helicopter and then some of it will end in ditches. Peatland forests are also fertilized with wood ash, which contains a lot of iron and aluminum and therefore doesn´t cause a significant phosphorus loading. Barren peat soils have a poor holding capacity for phosphorus, but due to slowly soluble phosphorus type used in the fertilizers, the leaching is usually small. Acidic conditions can contribute to the leaching of phosphorus as the solubility of the fertilizer increase when pH decreases and in barren, acidic soils the amount of elements able to bind phosphorus is lower. (Finér et al. 2010, 19; CR 1987: 62, 75–76.)

5.3 Measures to reduce nutrient loading

The publication Vesiensuojelun suuntaviivat vuoteen 2015 Valtioneuvoston periaatepäätös (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015) (2007, 12–13) includes measures to reduce nutrient loading from forestry areas. These measures include improving the planning of ditching and fertilizing, leaving sufficient protective zones in the operation areas, taking into consideration drainage areas and forest patterns when planning the processes, taking also the small water systems into account, and by improving forestry processes, planning, monitoring, training of the staff, and the studying of the impacts.

Commonly used measures for water protection in forestry areas include the adjustments in the longitudinal slope fall of the ditch, by changing the alignment, untreated intervals in the clearing, and excavation processes, gradations, submerged dams, overland-flow fields, protective zones, sludge sumps, and sedimentation basins. (Joensuu 2002, 20.)

The knowledge of the suitability, and sufficiency of the methods used to reduce loading from the forestry areas is very limited. As a general observation in many locations where such methods are used, it has been noticed that if suspended solids are given time to settle before the water body, settling has also occurred in large amounts. (CR 1987: 62, 91–92.)

5.3.1 Overland-flow fields

According to Rissanen et al. (2004, 115) an overland-flow field should be used as a primary clarification method for water. A functioning overland-flow field is very effective to retain solid matter and quite effective to retain dissolved organic matter. At best an overland-flow field can retain 70-100 % of the solid matter and 20-30 % of the organic matter. Most of the nutrients causing eutrophication in the water system are bound to solid matter, and therefore, in the best cases the overland-flow fields can retain 45-95 % of the nitrogen and 60 % of the phosphorus. In some cases though phosphorus has been noticed to absorb through soggy overland-flow fields to the water stream.

The best location for an overland-flow field is treeless or nearly treeless marsh area in a natural state and with a thick peat layer, such as a bog along the water system. The thickness of the peat layer should be at least one meter and the composition should be homogeneous and monotonous. An overland-flow field can be implemented in any slightly inclined field, which is covered by vegetation. Water has to be distributed equally to the field and it has to flow slowly through the vegetation or peat layer to be effective. The equal distribution can be implemented with, for example, a lateral discharge ditch. The inclination of the field shouldn´t be more than 1 % and the size of the field should be 1-2 % of the size of the drainage area in which the waters are treated. One overland-flow field shouldn´t be used to treat waters from an area larger than 30 hectares to avoid accumulation of large amounts of solid matter and nutrients in one location. (Rissanen et al. 2004, 115–116.)

5.3.2 Wetlands and sedimentation basins

A wetland can be either a natural habitat type or man-made water treatment method. A wetland is an area in a ditch, brook, river or other water body and its shore, which is always moist and for most of the year covered by water. The wetland usually has aquatic vegetation and hygrophytes. A multifunctional wetland is the most beneficial wetland type, as it also increases biodiversity, recreational use possibilities and diversifies the scenery in addition to water treatment. (Hagelberg, Karhunen, Kulmala & Larsson 2010, 4.)

A sedimentation basin removes only solid matter from the water whereas wetland can also remove some amounts of dissolved matter. Microbial activity in the wetland can remove nitrogen from the water and the vegetation can bind dissolved phosphorus and nitrogen. Wetlands are noticeably larger than sedimentation basins. A sedimentation basin is excavated in a ditch or a brook to collect solid matter. The impact is based on the decrease in the stream velocity, which makes the descending of solid matter possible. (Ruohtula (ed.) 1996, 7–8.)

According to Rissanen et al. (2004, 118–119), the stream velocity in the basin should be at maximum 1-2 cm/s, for also the fine particles to have enough time to descend, and the water should stay in the basin for at least an hour. The area of the basin should be 3-8m^2/drainage area hectare and the volume reserved for descending solids should be 2-5m^3/ drainage area hectare. The basin is excavated to a point of a ditch where the stream velocity naturally decreases. The basins have to be placed far enough from the outlet of the ditch, so that the water system doesn´t flood to the basin. The space reserved for the material removed from the basin has to be 2-3 times the area of the basin, and the excavated material can´t be placed in the flooding zone of the water system. One basin should be used at most to treat waters from an area of 30-40 hectares. The recommendation is that one basin would treat water from a drainage area of 10-15 hectares, when the basin is smaller and less material has to be removed during the process.

The experiences of using a wetland as a water clarification method in forestry areas are a few. In agriculture, wetlands have been used for many years and it´s discovered that the best results are received from wetlands containing deep open water sections, shallow sections, isthmuses, and small islands. Therefore, wetlands almost always require soil processing by machinery, and therefore, the leaching during the excavations can be so large that it´s harmful. More information is needed about the impacts in the forestry areas, before the method can be adopted widely. A well-planned combination of an overland-flow field and sedimentation basin can probably reach the same results. (Rissanen et al. 2004, 120.)

5.3.3 Clarification methods in ditches; submerged dams, sludge sumps

For s successful water protection, it´s important that the erosion of the ditch is as minimal as possible. The amount of erosion depends on the soil type of the ditch, stream velocity, discharge, and the longitudinal slope fall of the ditch. (Rissanen et al. 2004, 117)

The stream velocity can be decreased by building submerged dams at the bottom of the ditches with stones, wood, twigs, moraine sealed with peat, or filter fabric. Because of the corrosive impact of the flowing water, the advantage from light-weight structured dams is often short-lived, especially in cleared ditches. Durable, heavy-weight structured dams are so expensive and difficult to build that they should only be used in the most corrodible ditches. The most effective dam structure can be achieved by blocking the old corroded ditch from a long enough distance, and redirecting the water past the dam through an overland-flow field to the lower ditch. In addition to water regulation, the dams also collect some coarse suspended solids. (Rissanen et al. 2004, 117)

In ditch rehabilitation in erodible soils, the stream velocity should be decreased by leaving untreated intervals in the clearing and excavation processes. The length which is needed to leave untreated depends on the soil type and discharge, but it should always be at least 20 meters. The untreated intervals also collect some amount of coarse solid matter from the water, in addition to reducing the stream velocity. The retaining of solid matter can be improved by excavating a sludge sump above the untreated interval. It is also possible to excavate many sludge sumps in the ditch, with the distance of 100-200 meters from each other. (Rissanen et al. 2004, 117)

Sludge sumps are small pits in the ditches which are used only to collect solid matter during the working period. The size of the sludge sumps is 1-2 m^3 and they are not meant to be emptied. The effect of sludge sumps hasn´t been studied. (Joensuu 2002, 21.)

5.4 Water protection in the case of Lake Kankaistenjärvi

In order to reduce nutrient loading from the forestry area to Lake Kankaistenjärvi, several protection measures have been taken.

5.4.1 Actions planned in the area

On the visit to the site December 18th 2012, Environmental Manager of UPM Forest, Sami Oksa, and Forestry Manager of UPM Hämeenlinna area, Mikko Pirilä, presented the actions planned to reduce the nutrient loading from the forestry area to the lake, presented in Figure 3.

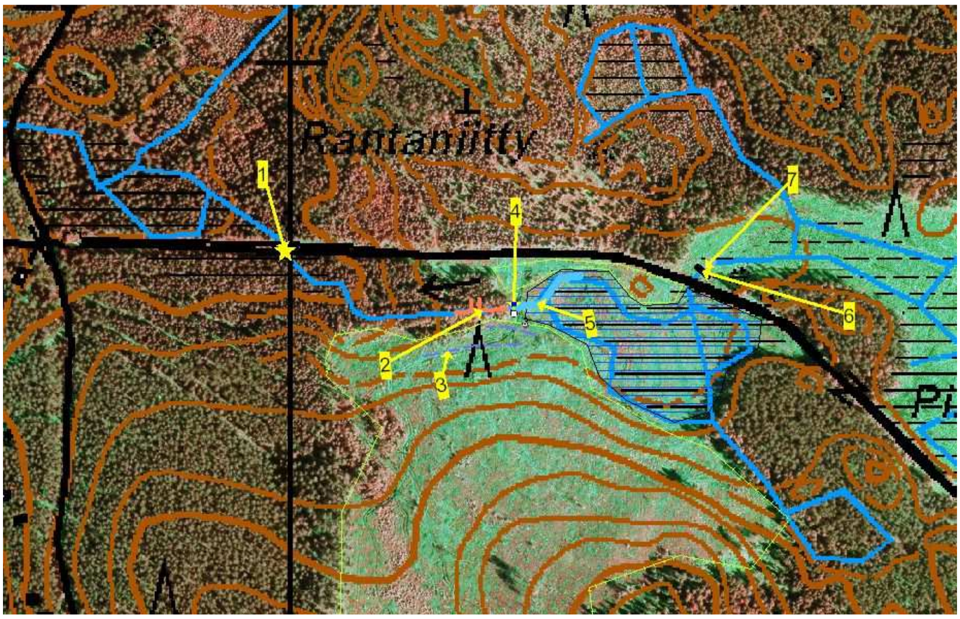


Figure 3 Map of the actions planned by UPM (Pirilä, e-mail 19.12.2012). Lake is located on the left side from the picture. Scale 1:5000.

On point 1 an old culvert from under the road is replaced by a new one. The new culvert will be installed higher than the present, which causes water to stay in the basin above the culvert for a longer time, which improves the settling of solids. The basin will be enlarged to increase the water storing capacity. On point 2 rocks are inserted to the ditch to slow the discharge. The aim is to compensate the increase of discharge caused by a submerged dam built in point 4. Two shallow drains were excavated in point 3 on the bottom of the Heinämäki hill on November 23rd 2012, to prevent run-off from the hill straight to the ditch. (Pirilä, e-mail 19.12.2012)

Submerged dams will be built in points 4 and 6, and points 5 and 7 indicate the estimations of the distance in the ditch where the water level will be equal. The first submerged dam (point 4) is estimated to raise the water level by 30-40 cm in the ditch above the dam, and the water level would be equal in the ditch on the length of 80 meters. In normal conditions the height of the discharge would be approximately 20 cm higher than the dam. Decreasing the speed of the discharge in a long distance, and the shallowness of the ditch improves the settling of solids and generates better conditions for the growth of aquatic vegetation, which also helps to purify the water. The ditch will also be deepened if possible, taking into consideration the risk of erosion. The latter submerged dam (point 6) evens out the peaks in the discharge. The dam will equalize the water level in the ditch on the length of approximately 20 meters. (Pirilä, e-mail 19.12.2012)

Work is carried out during a low discharge, and if needed the latter submerged dam will be used as a temporary dam, and made high enough. Extra height is removed when the work is done. (Pirilä, e-mail 19.12.2012)

5.4.2 Water protection measures used in the area

Crossover point for forestry equipment was constructed during the cutting process (Figure 4). The simple bridge out of tree trunks was constructed on the top of the ditch, to avoid mixing of the solid material to the ditch. If built on durable soil, crossover point significantly reduces loading caused by the crossing of ditch. After the crossover point is not used anymore, it has to be removed to avoid the decaying biological matter to enter the ditch.

Figure 4 Crossover point for forestry equipment

In order to reduce run-off from the Heinämäki hill to the ditch transporting water to Lake Kankaistenjärvi, two shallow drains were excavated in front of the hill (Figure 5). The shallow drain isn´t connected to the ditch network, as it is meant to store the run-off water. Shallow drains are excavated parallel to the hill from which the run-off is reduced.

Figure 5 Excavation of the shallow drains below the Heinämäki hill.

Out of the water protection measures presented in Chapter 5.4.1, submerged dams and sedimentation basin were carried out on February 11th 2013. The replacement of the old culvert was decided to be postponed to the spring/summer, due to soil frost in the ploughed road. Decreasing the stream velocity in the ditch by rocks was also postponed, due to difficulties estimating the impact because of the low discharge at that moment.

Submerged dams were constructed, as planned, in the points 4 and 6 of the plan. The structure of the dams consists of approximately 10 tree trunks and filter fabric. The construction was carried out at digging approximately 5*5 meter levelled pit in the ditch, placing trunks at the lower end of the pit, covering the pit and the trunks by filter fabric folded double, and covering the pit with peat, gravel and rocks, leaving open only the ditch channel. The dam in the point 4 is presented in Figure 6.

The distance between the submerged dams can be roughly estimated to be about 150 meters, in between there is a narrow ditch channel, less than one meter of width by estimation. The drainage area above the lower submerged dam in the point 4, can be roughly estimated to be 50 hectares.

Figure 6 Submerged dam constructed in the point 4 of the plan. Water flows from left to right.

A sedimentation basin was excavated in the point 1 of the plan (Figure 7). Because of the relatively high current in the point, due to downward slope and the submerged dam above, and of the erodibility of the basin, the basin was excavated to a shape of a curve. Other measures used to reduce erosion from the basin included adding stones to the ditch banks, and decreasing the slope of the ditch banks. The measurement of the basin is approximately 10*3 meters.

Figure 7 Sedimentation basin in point 1 of the plan. The inlet of the basin is located approximately in the middle of upper edge and the outlet in the middle left of the picture.

6 INTERPRETATION OF THE RESULTS

The results indicate that of the human activities especially scattered settlement contributes significantly to the phosphorus loading, whereas forestry has only a minor impact on the loading. However, the results of the modelling can only be viewed as estimations. More information is needed to determine the actual loading.

6.1 The level of the loading

As sampling results from the lake are so few, the level of the loading in this thesis is estimated based on mathematical modelling (Table 6).

Table 6 The estimated nutrient loading of Lake Kankaistenjärvi based on the VEPS and Bilaletdin systems.

	VEPS		Bilaletdin	
Source	kg P/a	kg N/a	kg P/a	kg N/a
Agriculture	24.80	597.92	24.17	401.95
Forestry	8.98	138.38	5.19	108.98
Scattered settlement	46.20	277.20	31.46	257.29
Natural leaching	61.93	1810.19		
Air deposition	35.22	1538.41		
Leaching			42.62	2001.77
Total	177.13	4362.10	103.44	2769.99

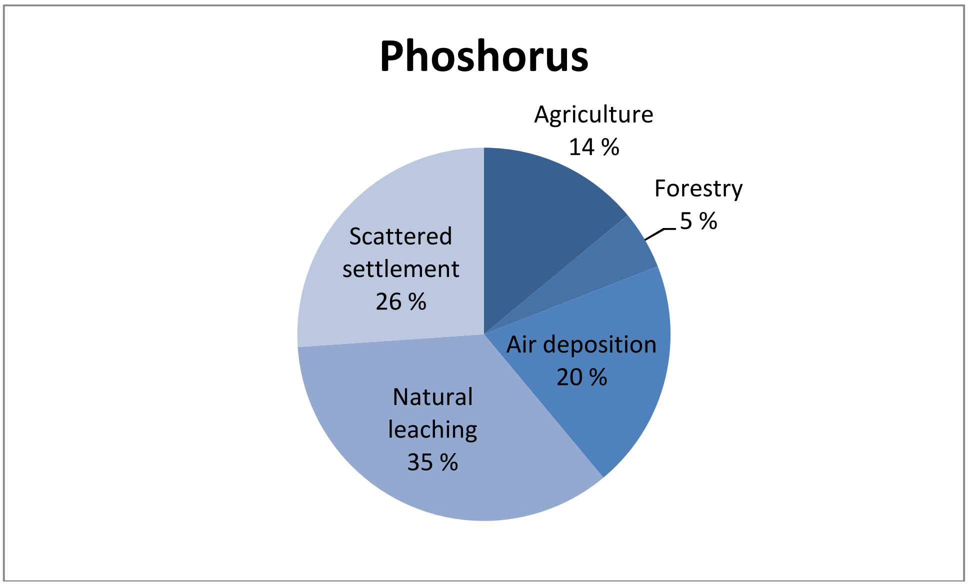


Figure 8 The distribution of phosphorus loading to Lake Kankaistenjärvi according to the VEPS system.

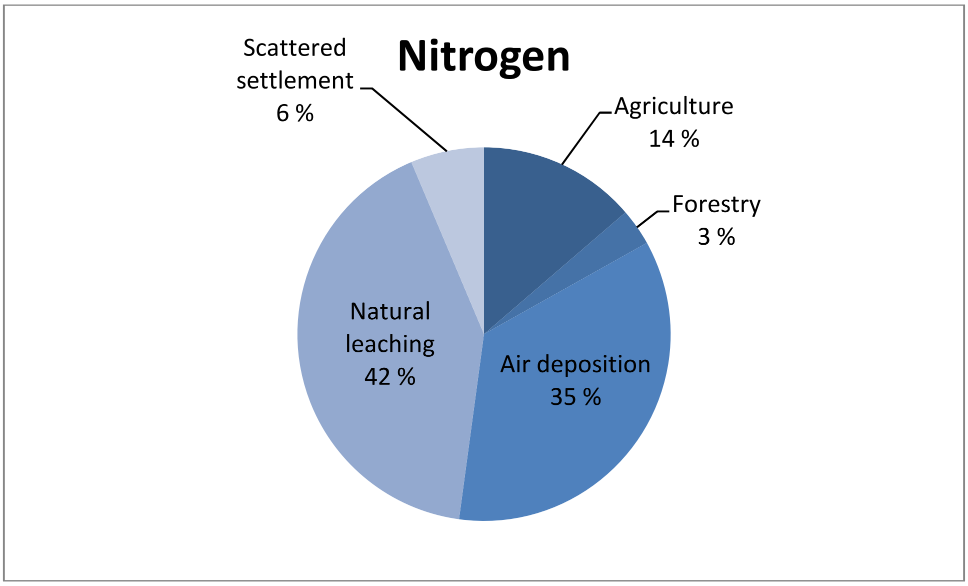


Figure 9 The distribution of nitrogen loading to Lake Kankaistenjärvi according to the VEPS system.

According to the results of VEPS system, natural leaching and air deposition are accountable for over half of the phosphorus loading. From the impacts of human activities, scattered settlement is the most significant, and forestry and agriculture only minor contributors (Figure 8). Nitrogen loading is mostly of natural origin according to the VEPS system (Figure 9). Noticeable from the results is especially that even though the area of agriculture is only 3 % of the drainage area, the impact on the loading is 14 %. Most likely the impact of forestry is more significant than shown in these results.

However, these results can only be viewed as suggestive, because the values of the system itself are based on the estimations which are not compared with the real local results, the specific loading values are not up-to-date, and because the usage in this case also has some uncertainties, such as using the values of the drainage area of Lake Katumajärvi to a smaller drainage area of Lake Kankaistenjärvi. The heavy forestry processes on the eastern side of the lake would increase the loading factors of forestry, if they were determined. Also, the estimating of the land-use in the smaller drainage area can have a minor impact on the results.

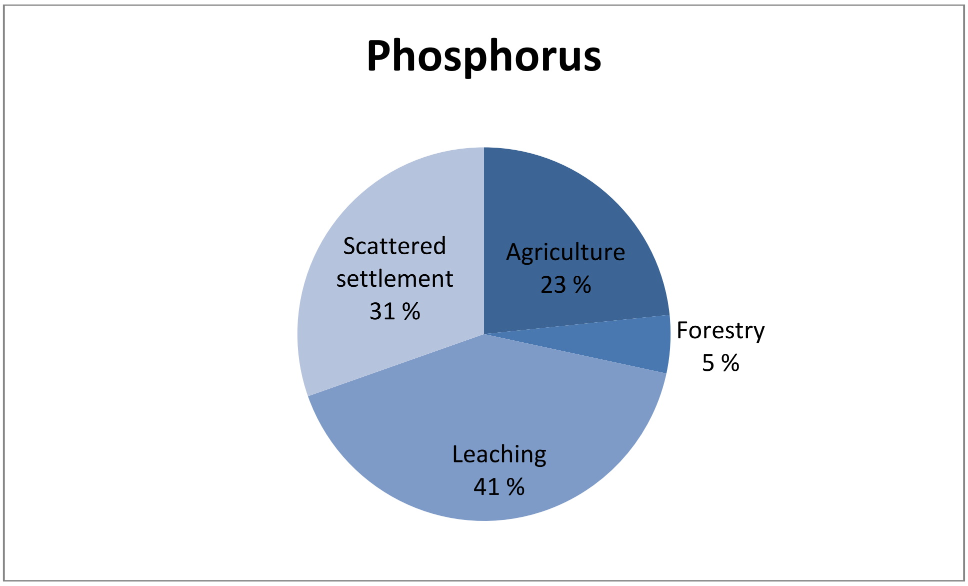


Figure 10 The distribution of phosphorus loading to Lake Kankaistenjärvi according to the Bilaletdin model.

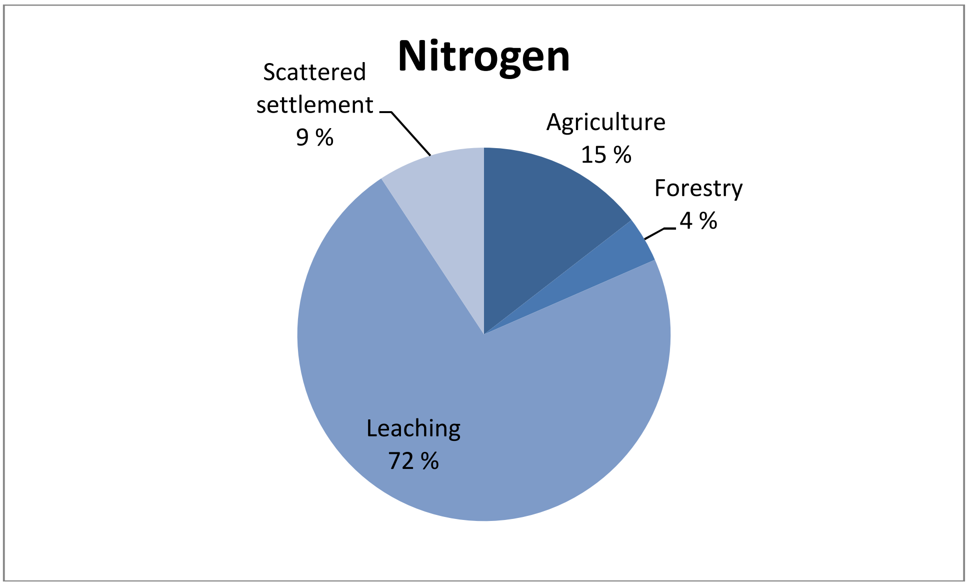


Figure 11 The distribution of nitrogen loading to Lake Kankaistenjärvi according to the Bilaletdin model.

According to the Bilaletdin model, scattered settlement and agriculture form over half of the phosphorus loading to the lake (Figure 10). When considering the reliability of the Bilaletdin model, it has to be taken into consideration that due to a lack of other available specific loading factors, the values in the VEPS system were used in Bilaletdin formulas. The VEPS values themselves have many uncertainties, presented in the previous chapter, and in addition, the VEPS values aren´t perfectly suitable for the Bilaletdin formula. To get more accurate results, the coefficients of the formula should be calibrated. Therefore, the results presented above should be viewed very critically, especially when considering phosphorus. The distribution of nitrogen loading was similar with both methods and can be viewed somewhat more realistic (Figure 11). However, sampling is needed to determine the real loading. As background information VEPS values can be considered more realistic.

6.2 The impact of the loading

Based on the modelling of the nutrient loading, loading of Lake Kankaistenjärvi is mostly of natural origin, but scattered settlement is also a major contributor especially in the phosphorus loading. Agriculture and forestry also have a smaller impact on the loading. However taking into consideration the factors presented in Chapter 6.1, the results of the modelling should be taken at most as background information. More information is needed about the local loading from forestry, scattered settlement, and agriculture to determine the real impact of the loading.

6.3 Estimation of the impacts of water protection methods on Lake Kankaistenjärvi

The most significant aspect of the water protection methods is whether the water speed decreases enough for the solid matter to descend. The sedimentation basin and submerged dams can´t remove the dissolved nutrients from the water, as a wetland can, but if the water speed decreases sufficiently, they can remove large amounts of solid matter, and nutrients bound to it. If water speed above the submerged dams decreases enough, aquatic vegetation can grow in the ditch. Aquatic vegetation can also retain small amounts of dissolved nutrients. Considering the measured loading from the area, reducing the amount of solid matter entering the lake could be sufficient to reduce the loading to a tolerable level.

Another significant aspect is the amount of erosion of the ditch and sedimentation basin. The submerged dams should decrease the water speed in the ditch in the cutting area and above, but between the lower submerged dam and sedimentation basin the water speed will increase due to the approximately 20 cm increase in the height difference, caused by the submerged dam. The height difference between the dam and basin can be estimated to be almost 5 meters in the distance of about 150m, making the bank angle about 3 %, which is the recommended maximum value, and therefore, can be large enough to cause erosion of the ditch and from the sedimentation basin, which is partly clay soil and therefore easily erodible. According to the plan, water speed between the dam and the basin will be reduced by adding stones to the ditch channel later in spring. The water speed and the erosion of the ditch, especially in the section between the dam and the basin, should be monitored.

The sedimentation basin in the point 1 of the plan can be viewed as the main method for reducing the nutrient loading from the forestry area. Compared to the information about the dimensioning of a sedimentation basin in Chapter 5.3.2, it seems that the size of the basin is too small to achieve the required remediation level. The sedimentation basin in the forestry area can be roughly estimated to have an area of 30-50 m², whereas the size of the drainage area above the point can be estimated to be over 50 hectares. It can be estimated that at least the fine clay particles don´t have enough time to descend to the bottom. The basin may, however, collect some amounts of heavier soil particles, and therefore reduce loading. To reduce erosion from the basin, it was excavated to a shape of a curve, the slope of the ditch was made gentle, and stones were added next to the ditch banks. It is important that the erosion from the basin is minimal.

Functional submerged dams should slow down the flow velocity in the ditch, which would reduce erosion, enable the solid matter to descend, and also enable the growth of aquatic vegetation. The ditch channel is, however, so small that the question is how much the stream velocity will decrease. It can be seen as a risk that either the water flows rapidly over the dam, especially in the time of maximum flow, or possibly the water will rise above the ditch channel. Because the structure of the dam is made from tree trunks, it is also possible that the water will flow through the dam from between the tree trunks, especially when the flow is small. Therefore, it is possible that especially at the time of small flows the dam will not make a significant difference to the flow speed. Tree trunks themselves will also dissolve some amounts of nutrients to the water, due to wearing effect of the water.

The impact of the water protection methods on Lake Kankaistenjärvi should be monitored by taking water samples from the ditch. To get a reliable estimation of the impacts, the water quality should be monitored by taking multiple samples during the next few years. Due to the excavation processes carried out in the winter, the nutrient loading will be relatively high during the first melting waters in the spring, and more sampling will be needed to determine the impact. Without the results, estimating of the impacts is only theoretical. Based on the information presented in the chapters 5.3.2 and 5.3.3, it can be, however, seen unsure if the measures taken are effective enough.

7 RECOMMENDATIONS

In order to maintain the high status of the lake, the changes in the lake as well as processes in the drainage area should be monitored. Based on the results of VEPS and the nature of the lake as head waters with a long retention time, it can be estimated that from human activities Lake Kankaistenjärvi is especially vulnerable to wastewaters of scattered settlement and forestry. Therefore, it is vital to reduce loading from these sources to a minimum.

7.1 Monitoring

To maintain the high status of the lake, changes in the lake, as well as processes in the drainage area should be monitored.

7.1.1 Lake

The visibility depth is good, and a simply measured indicator of the water quality. Visibility can be measured by a white plate with a diameter of 20 cm on the end of a string, and a measuring tape. The Protective Society of Lake Kankaistenjärvi should find active members from each sides of the lake, to measure the visibility, for example, once in two weeks, and inform the results to the Protective Society of the lake, which should maintain a long-time record of the changes in it. If the results are available from around the lake and from a long time, the changes in the future can be estimated and also localized.

In the same way, residents on the lakeside can keep a diary or take pictures of the amounts of aquatic vegetation, blue-green algae, slime build-up of the stones on the shore and in the fishing nets. The active fishermen on the lake could keep a record of the catch sizes and the relative amounts of black clams and valuable fishes. Committing lakeside residents to the monitoring of the lake is vital to achieve affordable and extensive observations of the changes in the lake.

Human observations about the unmeasured changes can, however, only be viewed suggestive. If residents have noticed deterioration in the lake, the actual measurements should be conducted by a professional. Records maintained by the residents on the lakeside can also be used as a starting point, based on which the analyzes can be focused more efficiently.

7.1.2 Drainage area

The Protective Society of Lake Kankaistenjärvi should maintain an active role in monitoring the activities taking place in the drainage area of the lake and aim to cooperate with the largest landowners in the area.

Forestry is usually only a small contributor in the nutrient loading of a surface water system, but in head waters with a long retention time, such as Lake Kankaistenjärvi, it can be one of the major contributors. Most of the drainage area of Lake Kankaistenjärvi is forest, and used for forestry by both individual forest owners and a private forestry company. Due to these factors, and the oligotrophic state of Lake Kankaistenjärvi, it can be regarded as a vulnerable lake to loading from forestry processes. It is important that the forestry operators in the area take the lake into consideration in all forestry processes, and preferably discuss the processes with the Protective Society and environmental operators.

Even though only about 3 % of the drainage area is used for agriculture, the impact on the loading of both phosphorus and nitrogen is 14 %, according to the VEPS system. Agriculture is commonly the major loader of water systems, and even if it´s only a minor part of the land use in the drainage area, it can have a significant impact. Protective zones should be used in the fields and the need for the fertilizers should be thoroughly estimated and carefully dispersed to avoid leaching to the ditches transporting water to Lake Kankaistenjärvi. Both the Best Environmental Practice, and Best Available Techniques should be used in the processes.

7.2 Scattered settlement

According to the results of VEPS, scattered settlement causes over one fourth of the phosphorus loading to the lake. Therefore, special attention should be paid to the level of wastewater treatment in the area. Most of the respondents in the inquiry answered to have a dry toilet at their disposal. In the usage of a dry toilet, the most important factor is where the final disposal of the excrements is. The excrements should be handled so that run-off, or ground water can´t come into contact with the excrements at any point. Also, in the toilet system, entering of the water to the container of excrements has to be prevented. Liquid material shouldn´t be allowed to flow freely out from the container, especially if the toilet is near any water system.

Another commonly used wastewater system in the area was a holding tank, which is relatively safe for the aquatic environment. The risks of the holding tank are leaking or overflowing of the tank, or misbehaviour, such as emptying of the tank to the surroundings, in order to reduce costs. Therefore, all the holding tanks should be equipped with overflow sensors and the amounts of wastewater emptied from the tank and entering the tank should be estimated, as mentioned in the Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (209/2011), presented briefly on chapter 4.2.3.

Also, the grey wastewaters should be treated before releasing them. About 7 % of the respondents answered that the grey wastewaters aren´t treated in their property, and about 10 % of the respondents having a separate sauna didn´t treat their grey wastewaters. Wastewater treatment on these sites should be brought up to date. Washing of cars and carpets near the lake should be avoided, or at least done with environmentally friendly detergents, such as tall oil soap. Carpets can´t be washed on the shore of the lake.

7.3 High standards of forestry practise considering water protection

In all forestry processes, both the local and the long-range impacts on the environment should be taken into consideration. The impacts should be estimated based on the drainage areas, instead of a single water system. All of the water systems in the process area have to be taken into consideration, even the smallest ditches and brooks. All impacts of the processes should be estimated, and if needed, suitable water treatment methods have to be adopted. The impacts and treatment methods depend very strongly on the location and soil type of the process area. Therefore, planning has to be done individually for every site of forestry processes. The processes should always be carried out using the Best Environmental Practice.

In cutting areas, at least five meter wide protective zones should be left in every water system, including ditches and brooks. If the terrain is steep, the protective zone has to be wider. In some cases large trees can be felled in the protective zone, if it can be done so that the falling trees or the forestry equipment don´t break the soil in the protective zone, or disturb the water system in any way. Ground vegetation and small trees can´t be removed from the zone. Stumps can´t be extracted from the zone and the ground preparation can´t be done to the zone.

In the cutting process large clear cutted areas should be avoided, and rather done in smaller sections, to reduce the increase in run-off and leaching. Biological material should not be allowed to enter the water systems, and therefore, logging waste should be removed from nearby the water systems. For example, the needles of conifer trees contain large amounts of nitrogen which is released to water when decaying. Stump extraction should be carefully considered in slopes, because it will increase the run-off, and also the leaching, to the water system below.

Ditching should be avoided if possible and rather rehabilitate existing ditches. If excavating new ditches is inevitable, excavation should take place during the low discharge, the excavation should start from the furthest point of the water system, and it is vital that water treatment measures are used in the ditch. The solid matter can be collected with, for example, an overland-flow field, a sedimentation basin or wetland.

When planning the fertilization of a forest, the soil type of the area and location of the fertilization area in the drainage area have to be taken into consideration. In porous mineral soils nitrogen should be avoided due to high leaching. Phosphorus and potassium can be used in mineral soils, as potassium isn´t harmful in an aquatic environment and phosphorus is bound by iron and aluminum compounds. The use of phosphorus in marsh areas will cause high amounts of leaching, especially if the iron and aluminum contents in the ground are low and if the phosphorus is easily soluble. Therefore, phosphorus fertilizers used in marsh areas should contain iron, to which the phosphorus is bound and leaching reduces. As peatland fertilizers, slowly soluble phosphorus should be used. Spreading method should always be selected individually to each area, to minimize the leaching.

The used ground processing method should be selected so that the leaching from the area is minimal. Especially ploughing disturbs large soil areas and causes mobilization of nutrients, and should therefore be avoided. The banks of ditches and streams can´t be processed, and in slopes ground processing should include unprocessed intervals, to avoid forming of a consistent track.

Crossing of ditches, brooks, and other water systems with forestry equipment should be avoided, to avoid the mixing of solid material to the water systems. If a water system has to be crossed, it has to be done in an area of the strongest soil and small water flow. If the water system is needed to be crossed more often, a crossover point has to be constructed. If the crossover point is made from tree trunks, it has to be removed after it isn´t needed anymore, to avoid the decaying wood from entering the water system. When operating with heavy equipment, it has to be taken care that the tracks of their wheels don´t lead water to ditches or brooks.

7.4 Other recommendations based on the inquiry

Based on the results of the inquiry, it can be seen that all of the lakeside residents don´t know the demands of the new Government Decree on Treating Domestic Wastewater in Areas Outside Sewer Networks (209/2011), passed on March 2011. In the inquiry 62 % of the respondents answered to question 11 (Appendix 3.) that their wastewater treatment fulfills the requirements of the decree, which, based on the content of the decree seems unrealistic. Out of the respondents 36 % answered that they don´t know. Only one of the respondents answered that their wastewater treatment doesn´t fulfill the requirements. Some of the respondents also presented a wish to be informed about the requirements of the new decree.

Many respondents also answered that the water level has decreased significantly over the years and it affects their housing and leisure time activities negatively. Out of the 47 respondents to question 28 about the seasonal changes in the water level, 30 answered to have noticed large seasonal variations in the water level, and out of them 10 responded to experience difficulties due to the low water level. The Protective Society could conduct a larger research of the changes in the water level and consider whether it would be reasonable to raise the water level.

7.5 Further studies

The results presented in this thesis must be viewed critically, as they are based on modeling and estimations, due to the lack of sampling results. More sampling is needed for the accurate estimation of the significances of the loading sources.

To get realistic information about the loading of the lake, extensive sampling is needed from both of the major ditches leading water to Lake Kankaistenjärvi, as well as from the outlet ditch. In the northern part sampling points should be selected so that it is possible to estimate the contribution of the agricultural area separately. In the eastern part sampling should be used to estimate the impact of the water protection methods in the area. Sampling from the outlet ditch enables the estimation of the nutrient balance of the lake. To estimate the internal loading, sediment of the lake should be studied. Some estimations of the internal loading can also be made by monitoring the oxygen level in the basins of the lake, and on the basis of the nutrient balance.

SOURCES

Bilaletdin, Ä., Frisk, T., Koskinen, K. & Wirola, H. 1992. Längelmäveden reitin vesiensuojelututkimus. Helsinki: Vesi- ja ympäristöhallitus.

Committee report 1987: 62. Metsä- ja turvetalouden vesiensuojelutoimikunnan mietintö. Helsinki: Maa- ja metsätalousministeriö.

Finér, L., Mattsson, T., Joensuu, S., Koivusalo, H., Laurén, A., Makkonen T., Nieminen, M., Tattari, S., Ahti, E., Kortelainen, P., Koskiaho, J., Leinonen, A., Nevalainen, R., Piirainen, S., Saarelainen, J., Sarkkola, S. & Vuollekoski, M. 2010. Metsäisten valuma-alueiden vesistökuormituksen laskenta. Helsinki: Suomen ympäristökeskus. Abstract in English.

Hagelberg, E., Karhunen, A., Kulmala, A. & Larsson, R. 2010. Käytännön kosteikkosuunnittelu. 3rd edition. Helsinki: TEHO-hanke. Abstract in English.

Hallman, E. . 2004. Metsänhoito. In Heinonen, P., Karjalainen, H., Kaukonen, M. & Kuokkanen, P. (ed.) Metsätalouden ympäristöopas. Helsinki: Metsähallitus, 22–26.

Helminen, H., Mäkinen, A. & Horppila, J. In Perttula, P. (ed.) 1995. Järvien ympäristöekologia. Turku: Turun yliopiston täydennyskoulutuskeskus.

Honkala, P. 2012. UPM:n hakkuut ja kantojennosto Kankaistenjärven Heinämäellä ja Sepänkallion ojalla. Kankaistenjärvensuojeluyhdistys ry. 31.10.2012.

Hulkko, H. Sent 13.12.2012. VEPS. [e-mail message]. Recipient Tomi Seppälä. Viewed 13.12.2012

Joensuu, S. 2002. Metsätaloudessa käytettävät vesiensuojelumenetelmät. In Kemppainen, S. (ed.) Metsätalouden vesistökuormituksen hallinta suopohjilla. Muhos: Metsäntutkimuslaitos, Muhoksen tutkimusasema, 19–24.

Jutila, H. 2012. Kankaistenjärven tila ja haasteet. Accessed 4th March 2013
http://www.kankaistenjarvi.fi/wp/wp-content/uploads/2012/08/Kankaistenjarven_tila.pdf

JätevesiA, Valtioneuvoston asetus talousjätevesien käsittelystä viemäriverkostojen ulkopuolisilla alueilla nro 209/2011. 10.3.2011.

Kaipainen, H., Bilaletdin, Ä., Perttula, H., Heino, H., Mäkelä, H. & Viitaniemi, S. 2002. Hauhon reitin kuormitusselvitys. Tampere: Pirkanmaan ympäristökeskus

Kenttämies, K. & Saukkonen, S. 1996. Metsätalous ja vesistöt. Helsinki: Maa- ja Metsätalousministeriö.

Luoranen, J., Saksa, T., Finér, L. & Tamminen, P. 2007. Metsämaan muokkausopas. Jyväskylä: Gummerus Kirjapaino Oy.

Maanmittauslaitos. Paikkatietoikkuna. Accessed 4th March 2013. http://www.paikkatietoikkuna.fi/web/fi/kartta

Martinmäki, K., Marttunen, M., Ulvi, T., Visuri, M., Dufva, M., Sammalkorpi, I., Ahtiainen, H., Lemmelä, E., Auvinen, H., Partanen-Hertell, M., Lehto, A., Väisänen, T., Mustajoki, J. & Ihme, R. 2010. Uusia menetelmiä järven kunnostushankkeen suunnitteluun. Helsinki: Suomen ympäristökeskus. Abstract in English.

Hokajärvi, T. (ed.) 1997. Metsänhoito-ohjeet. Vantaa: Metsähallitus.

Oravainen, R. 2012. Tulokset 31.10.2012 otetuista vesinäytteistä. Tampere: Kokemäenjoen vesistön vesiensuojeluyhdistys ry.

Pirilä, M. Sent 19.12.2012. Vs: Kankaistenjärvi. [e-mail message]. Recipient Heikki Tamminen. Viewed 6.1.2013

Rissanen, K., Luhta, P-L. & Joensuu, O. 2004. Vesiluonnon hoito. In Heinonen, P., Karjalainen, H., Kaukonen, M. & Kuokkanen, P. (ed.) Metsätalouden ympäristöopas. Helsinki: Metsähallitus, 97–120.

Ruohtula, J. (ed.) 1996. Kosteikkojen ja laskeutusaltaiden suunnittelu. Helsinki: Suomen ympäristökeskus.

Salonen, S., Frisk, T., Kärmeniemi, T., Niemi, J., Pitkänen, H., Silvo, K. & Vuoristo, H. 1992. Fosfori ja typpi vesien rehevöittäjinä - Vaikutusten arviointi. Helsinki: Vesi- ja ympäristöhallitus. Abstract in English.

Sarvilinna, A & Sammalkorpi, I. 2010. Rehevöityneen järven kunnostus ja hoito. Helsinki: Suomen ympäristökeskus. Abstract in English.

Vesiensuojelun suuntaviivat vuoteen 2015 Valtioneuvoston periaatepäätös. (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015). 2007. Helsinki: Ympäristöministeriö. Abstract in English.

Vesistöjen laadullisen käyttökelpoisuuden luokittaminen. 1988. Vesi- ja ympäristöhallitus. Helsinki.

Vesistökuormituksen arviointi- ja hallintajärjestelmä VEPS. 2006. Suomen ympäristökeskus. Accessed 27th November 2012. http://www.ymparisto.fi/default.asp?contentid=185329&lan=FI

Vuokila, Y. 1987. Metsänkasvatuksen perusteet ja menetelmät. 2nd edition. Porvoo. WSOY.

Wirola, H. & Santala, E. Mattopyykin lika kuormittaa vesistöjä. Site Editor Suomen ympäristökeskus. Accessed 28th March 2013. http://www.ymparisto.fi/default.asp?contentid=147113&lan=fi

INTERVIEWS

Lukanniemi, O. 2013. Nature management specialist. Metsäkeskus. Interview 5.3.2013.

Appendix 1

RESULTS OF THE SAMPLES TAKEN BY KVVY AND THE SAMPLING MAP

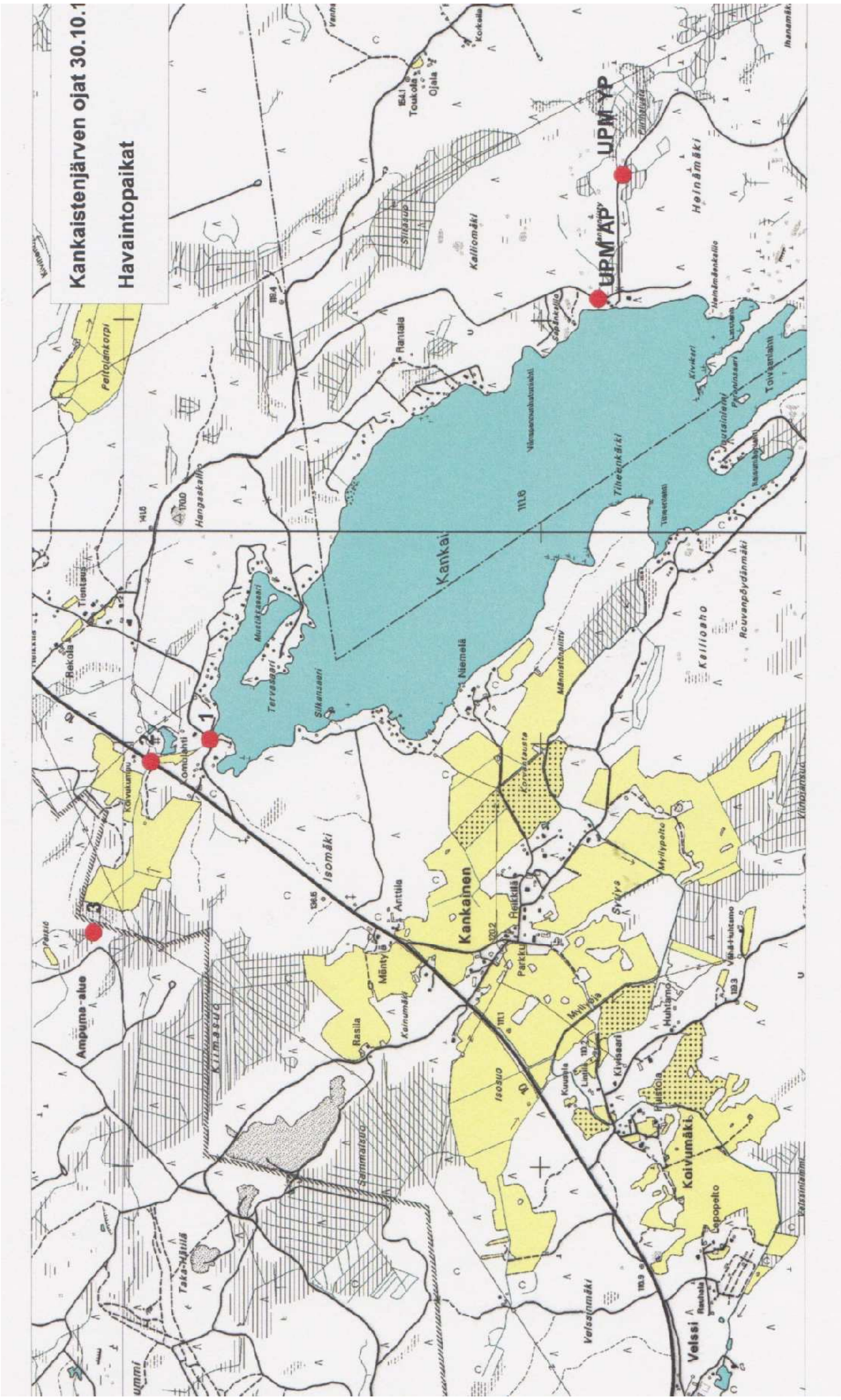
Kokemäenjoen vesistön vesiensuojeluyhdistys ry
Vesinäytteiden tutkimustuloksia

Liite 1, sivu 1/1

Hämeenlinnan järvitutkimukset (HAMELI)

Pvm.	Hav.paikka Syvyys (m)	Lämpöti °C	*Sameus FNU	*K-aine mg/l	*Sähkonj mS/m	*pH	*COD(Mn) mg/l O2	*Kok.N µg/l	*NO23-N µg/l N	*NH4-N µg/l N	*Kok.P µg/l	*po4-p µg/l	*Al.entero pmy/100 ml	*Lämpkolif pmy/100 ml
31.10.2012	**HAMELI / UPMOJAYP UPM oja yläpuoli** Klo 10:25; Näytt.ottaja AL; Virt. 0,024 m3/s;													
	0.2	2,4	2,8	1,6	5,1	5,5	47	1300	160	270	45	29	~2	~14
31.10.2012	**HAMELI / UPMOJAAP UPM oja alapuoli** Näytt.ottaja AL; Virt. 0,030 m3/s;													
	0.2	2,4	3,7	2,2	4,9	5,5	44	1200	180	200	40	25	~4	~16
31.10.2012	**HAMELI / KOMUOJA3 peltojen yläpuoli** Klo 12:30; Näytt.ottaja AL; Virt. 0,018 m3/s;													
	0.2	2,6	2,0	<1	4,1	5,1	46	750	<5	16	16	4	~4	~2
31.10.2012	**HAMELI / KOMUOJA2 10.tien ojarumpu** Klo 11:50; Näytt.ottaja AL; Virt. 0,055 m3/s;													
	0.2	2,4	7,3	3,6	8,1	4,8	65	1400	200	54	44	18	~6	160
31.10.2012	**HAMELI / KOMUOJA1 Komulahdenoja, laskee Kankaistenj. N-päässä** Klo 11:15; Näytt.ottaja AL; Virt. 0,100 m3/s;													
	0.2	2,0	5,3	2,2	9,4	5,3	55	1300	190	53	36	16	~14	54

FINAS akkreditoitu testauslaboratorio T064
* akkreditoitu määritys. Mittausepävarmuustiedot toimitetaan pyydettäessä.


Kankaistenjärven ojat 30.10.1
Havaintopaikat
UPM AP
UPM YP
1
2
3
Kankainen
Koivumäki
Velssi
Ampuma-alue
Kalliomäki
Heinämäki

Appendix 2

INQUIRY

Inquiry

Background information

1. Which of the next alternatives best describes your real estate in the drainage area of Lake Kankaistenjärvi?

○ Main residence

○ Recreational dwelling, used year round

○ Recreational dwelling, used in summer

○ I don´t own a real estate in the drainage area of the lake (continue to question number 15.)

○ Other, what?________________________________

2. For how long have you had the real estate in the drainage area of the lake?

○ Less than 5 years

○ 5-10 years

○ 10-15 years

○ Over 15 years

3. In which segment of the additional map does your real estate locate?

○ 1

○ 2

○ 3

○ 4

○ 5

○ I don´t know

4. Is there any alteration work planned in your real estate or water supply and sewage systems during the next five years?

____

____

____

5. Do you feel that a common waste collection point for the residents on the lakeside should be established?

◯ No ◯ I don´t know ◯ Yes

Wastewater treatment

6. How is the treatment of black wastewaters organized in your real estate?

◯ Sewer network

◯ Filter bed

◯ Holding tank

◯ Package treatment plant

◯ Infiltration system

◯ Dry toilet

◯ Other, what?___________________________________

7. If you answered 'dry toilet' to the question 6, what kind of dry toilet is in question?

◯ Dry toilet with solid tank

◯ Composting dry toilet

◯ Separating dry toilet

◯ Chemical toilet

◯ Other, what?___________________________________

8. How is the treatment of grey wastewaters organized in your real estate?

◯ Sewer network

◯ Filter bed

◯ Holding tank

◯ Package treatment plant

◯ Infiltration system

◯ No treatment

◯ Other, what?___________________________________

9. If you have a separate sauna in the real estate, how is the treatment of washing water organized?

◯ Sewer network

◯ Filter bed

◯ Holding tank

◯ Package treatment plant

◯ Infiltration system

◯ No treatment

◯ Other, what?___________________________________

10. If you have a holding and/or a depositing tank for wastewaters, where are they emptied?

____

____

____

11. Does your real estate in the current state fulfill the requirements of the decree of wastewater treatment in areas outside the sewer network, taking effect in the year 2016?

◯ No

◯ Yes

◯ I don´t know

12. Activities and their distances to the lake

- ☐ Residential building, distance to the lake in meters______________________________
- ☐ Separate sauna, distance to the lake in meters______________________________
- ☐ Separate toilet, distance to the lake in meters______________________________
- ☐ Disposal of the toilet waste, distance to the lake in meters______________________________
- ☐ Wastewater filter bed, distance to the lake in meters______________________________
- ☐ Wastewater infiltration system, distance to the lake in meters______________________________
- ☐ Wastewater holding tank, distance to the lake in meters______________________________
- ☐ Wastewater depositing tank, distance to the lake in meters______________________________
- ☐ Packet treatment plant, distance to the lake in meters______________________________
- ☐ Other activity, what? distance to the lake in meters______________________________

13. Do you wash your carpets or car near the lake (within about 200 meter radius)?

○ No ○ Yes

14. If you answered 'Yes' to the question number 13, estimate how many times a year you wash your car and/or carpets and with what washing agent do you use?

____

____

____

Fishing in Lake Kankaistenjärvi

15. How often do you fish in Lake Kankaistenjärvi?

◯ More often than once a week

◯ About once a week

◯ A few times a month

◯ Less frequently

◯ I don´t fish in Lake Kankaistenjärvi (please continue to question number 21.)

16. Have you noticed changes in the fish catches?

◯ Fish catches have decreased, when?___________________________________

◯ Fish catches haven´t changed

◯ Fish catches have increased, when?___________________________________

◯ I don´t know

17. Have you noticed changes in the relative amounts of black clams and valuable fishes?

◯ The amount of black clams has increased, when?___________________________________

◯ I haven´t noticed a change

◯ The amount of valuable fishes has increased, when?___________________________________

◯ I don´t know

18. Have you noticed slime build-up in your fishing nets?

◯ No

◯ Yes

◯ I don´t fish with fishing nets

◯ I don´t know

19. If you answered 'Yes' to the question 18, have you noticed the slime build-up to increase within the last five years?

- ◯ Slime build-up has increased
- ◯ I haven´t noticed a change
- ◯ Slime build-up has decreased
- ◯ Don´t know

20. If you answered 'Yes' to the question 18, have you noticed seasonal variation in the slime build-up?

- ◯ Slime build-up is most common in spring
- ◯ Slime build-up is most common in summer
- ◯ Slime build-up is most common in autumn
- ◯ I haven´t noticed seasonal variation
- ◯ I don´t know

Water quality

21. Have you seen blue-green algae in the lake and has it occurred more often within the last five years?

- ◯ I haven´t seen blue-green algae in the lake
- ◯ I have seen blue-green algae in the lake, but its occurrence hasn´t increased within the last five years
- ◯ I have seen blue-green algae in the lake and its occurrence has increased within the last five years
- ◯ I don´t know

22. Have you noticed changes in the visibility of the water?

- ◯ Visibility of the water has decreased, when?___________________________________
- ◯ Visibility of the water hasn´t changed
- ◯ Visibility of the water has increased, when?___________________________________
- ◯ En osaa sanoa

23. My answer to the previous question (number 22.) is based on

◯ on the results I have measured ◯ on my sensory observations

24. Have you noticed the slime build-up in the rocks on the shore to increase within the last five years?

◯ I haven´t noticed slime build-up in the rocks

◯ The slime build-up in the rocks hasn´t increased within the last five years

◯ The slime build-up in the rocks has increased within the last five years

◯ I don´t know

Aquatic vegetation (check the pictures at the end of the inquiry)

25. Have you noticed changes in the amount of aquatic vegetation within the last five years?

◯ The amount of aquatic vegetation has decreased

◯ The amount of aquatic vegetation has remained unchanged

◯ The amount of aquatic vegetation has increased

◯ I don´t know

26. Have you notice changes in the aquatic vegetation species?

◯ No

◯ Yes

◯ I don´t know

27. If you answered to the question 25. and/or 26. that you have noticed changes, describe the changes?

____

____

____

Generally

28. Have you noticed large seasonal variations in the water level?

◯ No

◯ I don´t know

◯ Yes, but it isn´t harmful to my real estate or leisure time activities

◯ Yes, and it is harmful for my real estate and/or leisure time activities

29. If you answered to the question 28. that you are experiencing disadvantages because of the varying water level, describe the variation and disadvantages.

____

____

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30. How do you feel that the status of the lake has changed in the course of years?

____

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31. Can you estimate what are the reasons for the changes?

____

____

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32. What kind of expectations and wishes do you have for the Protective Society of Lake Kankaistenjärvi?

____

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33. Free word (additional information for the questions)

____

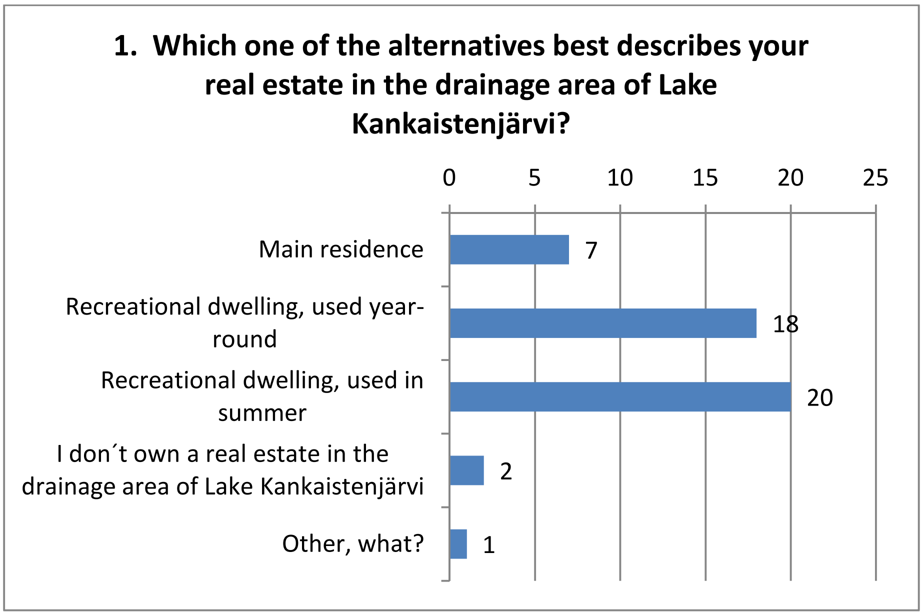
____

____

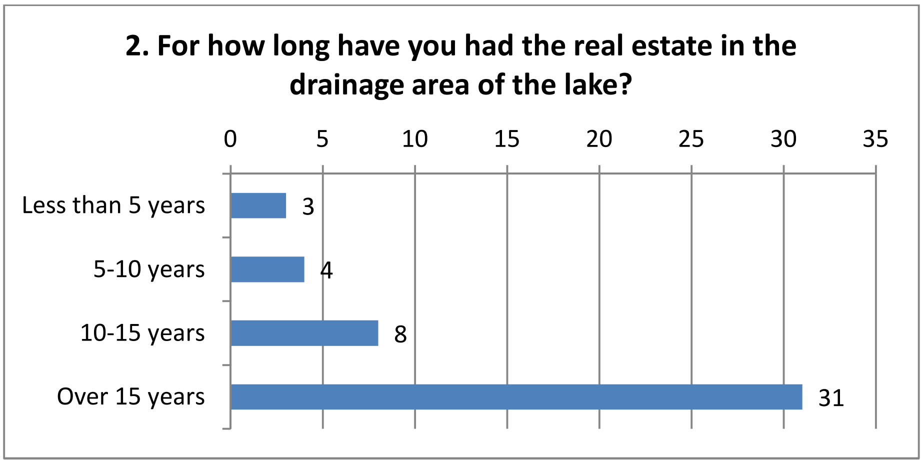
Appendix 3

SUMMARY OF THE RESULTS OF THE INQUIRY

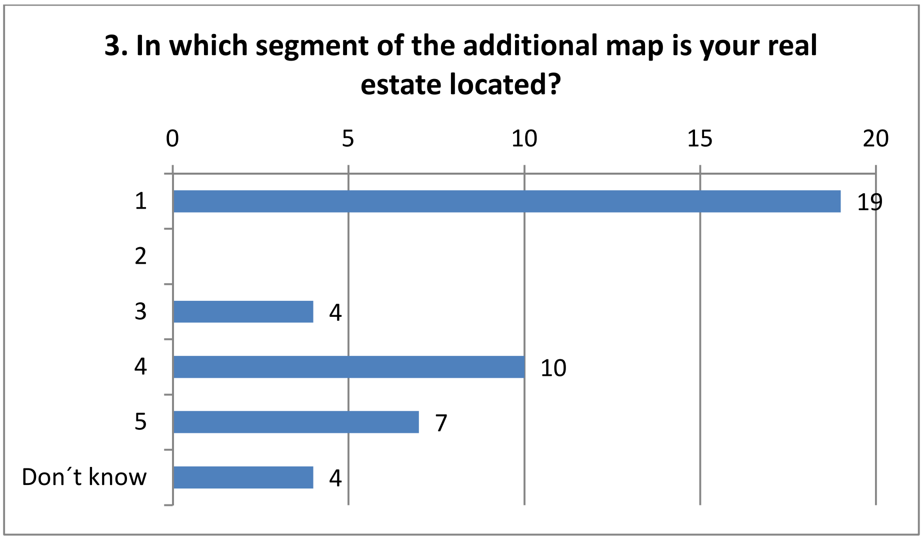
Summary of the results of the inquiry



48 respondents



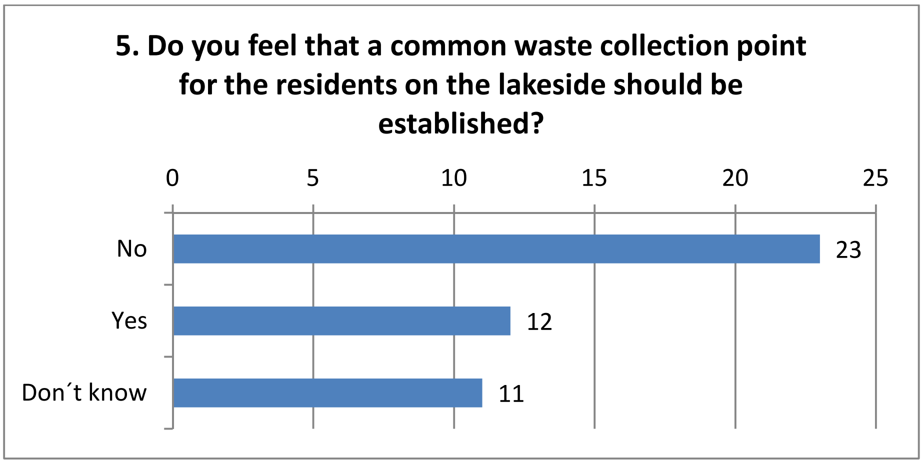
46 respondents



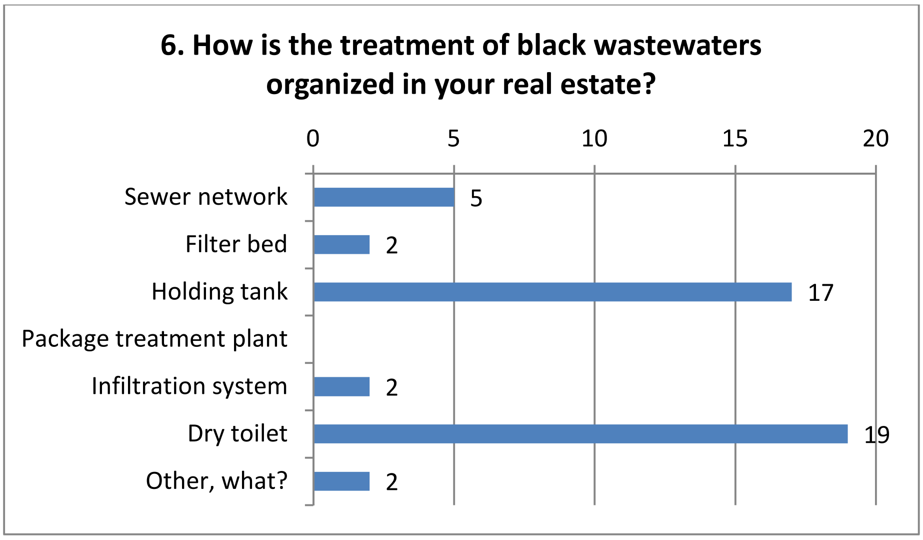
44 respondents

4. Is there any alteration work planned to your real estate or water supply and sewage systems during the next five years?

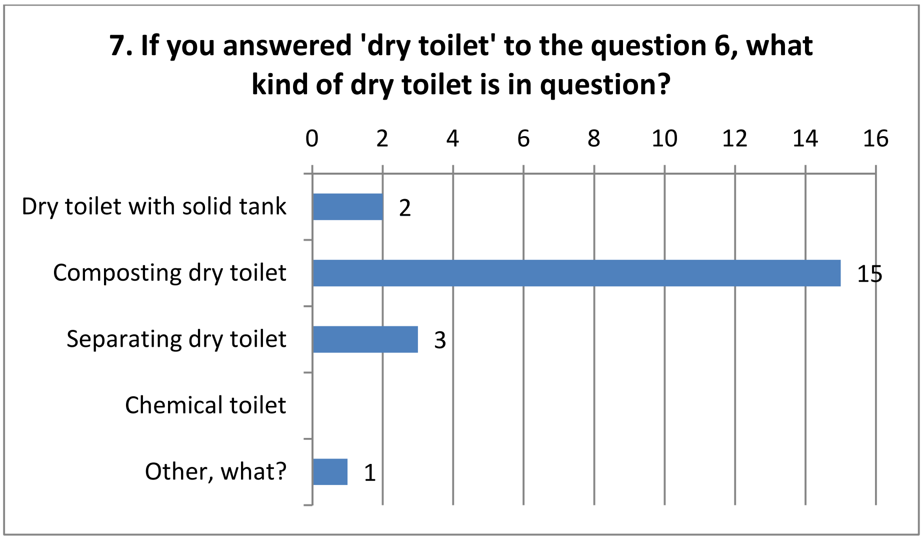
- 42 respondents



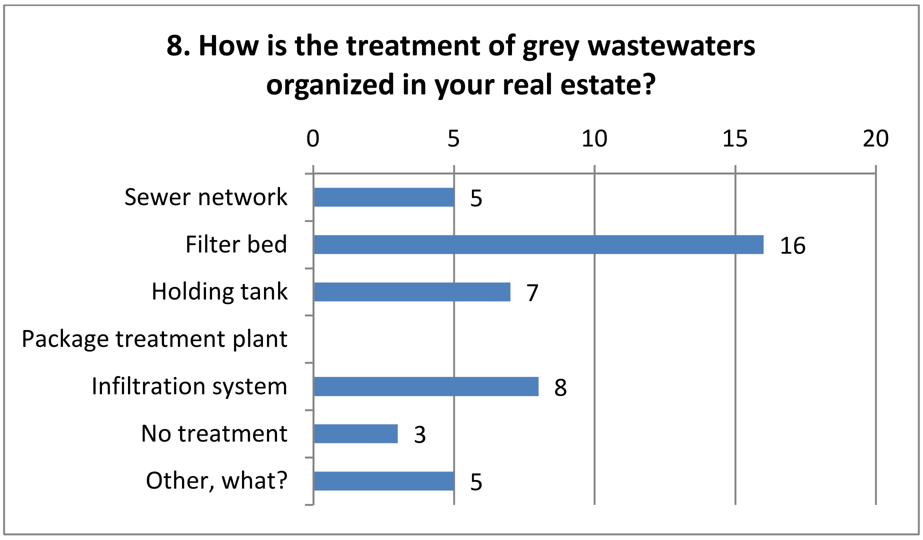
46 respondents



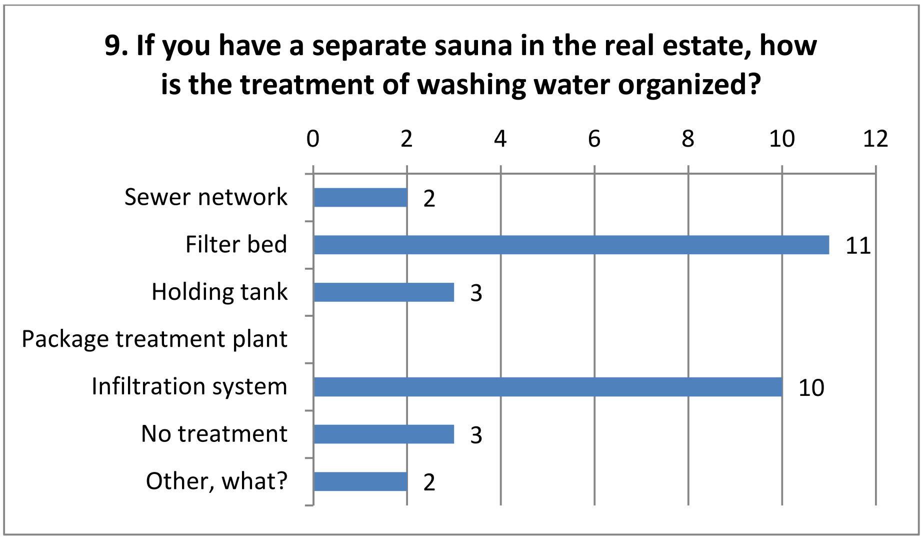
46 respondents, 47 used systems



21 respondents



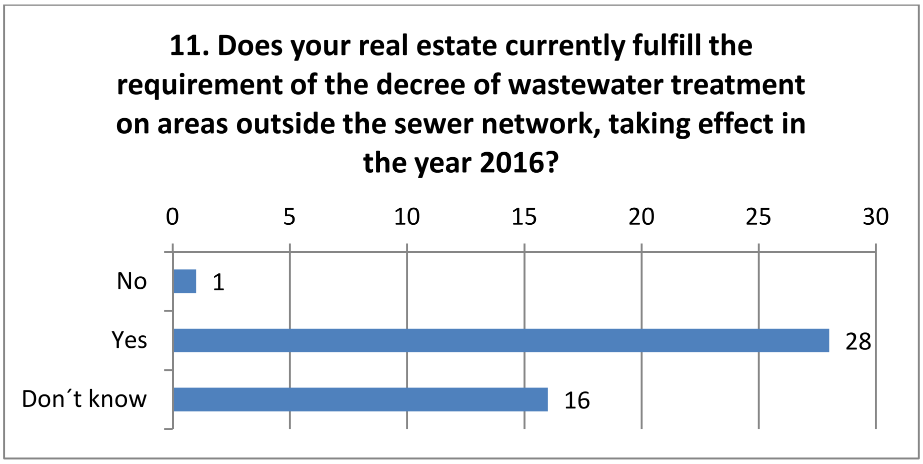
44 respondents



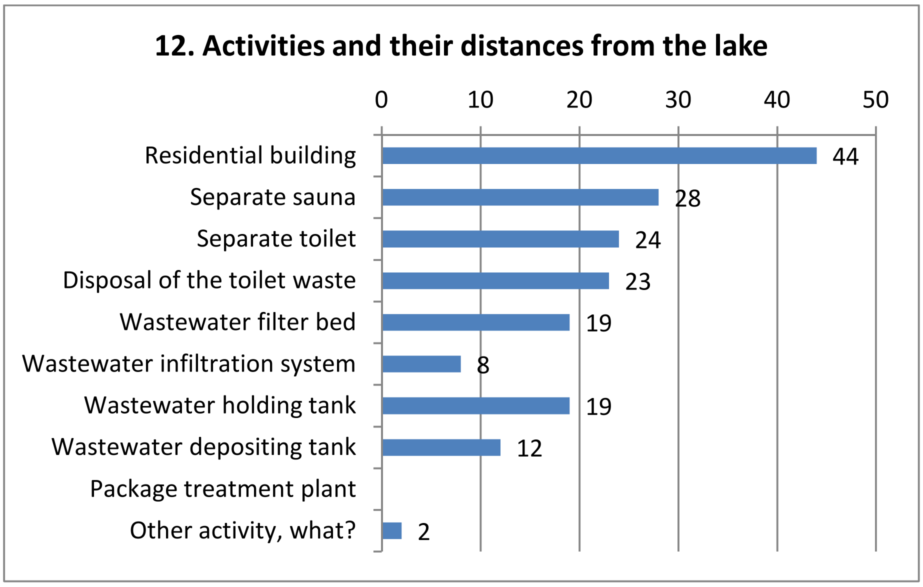
31 respondents

10. If you have a holding and/or a depositing tank for wastewaters, where are they emptied?

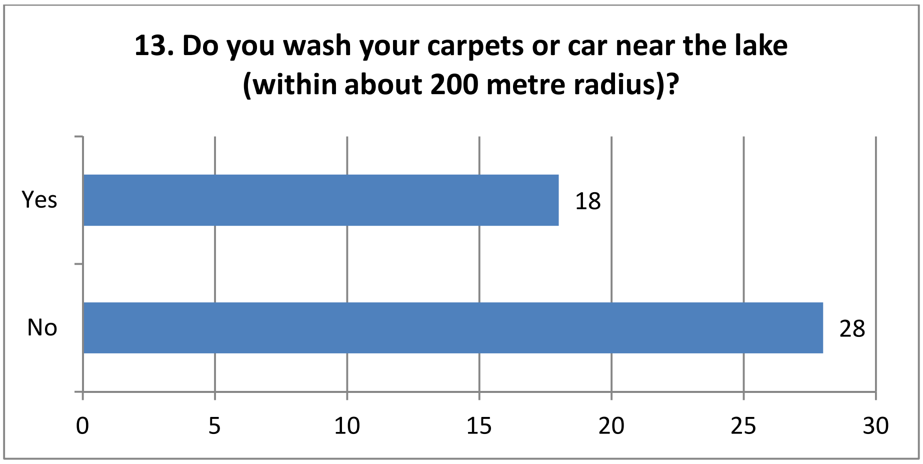
- 19 respondents



45 respondents



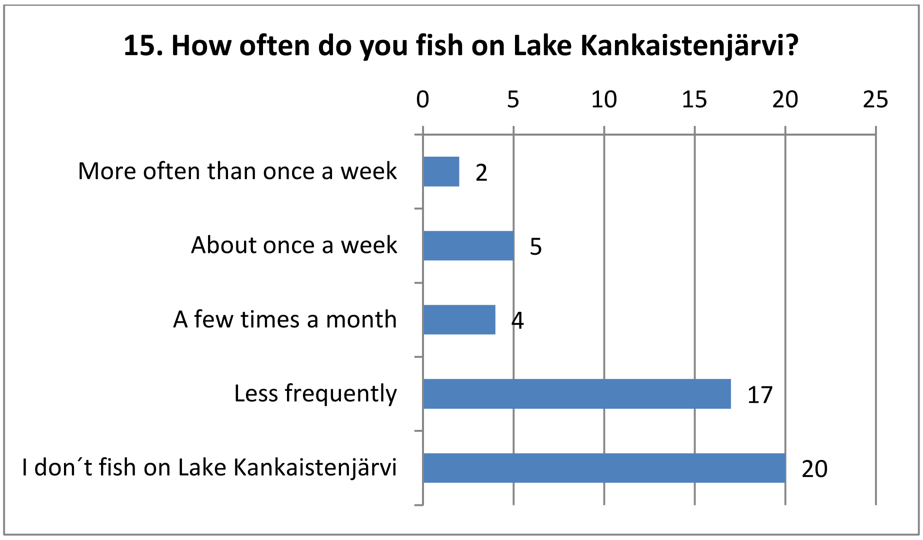
46 respondents



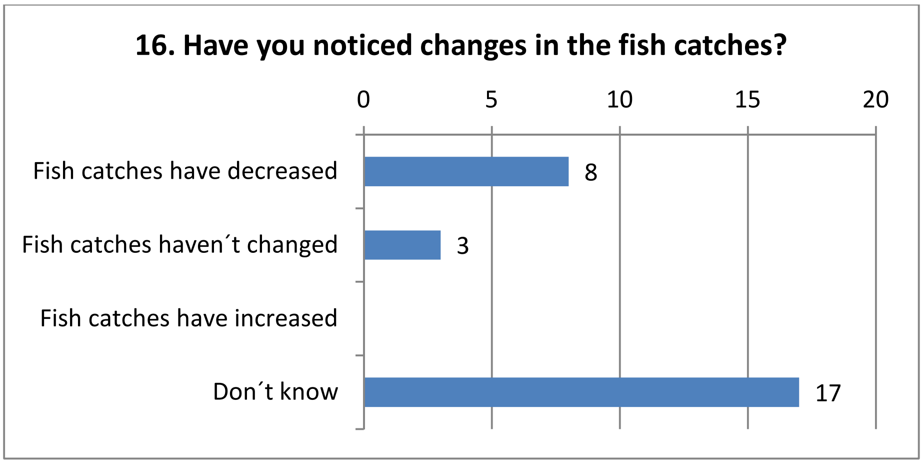
46 respondents

14. If you answered 'Yes' to the question number 13, estimate how many times a year you wash your car and/or carpets and with what washing agent do you use?

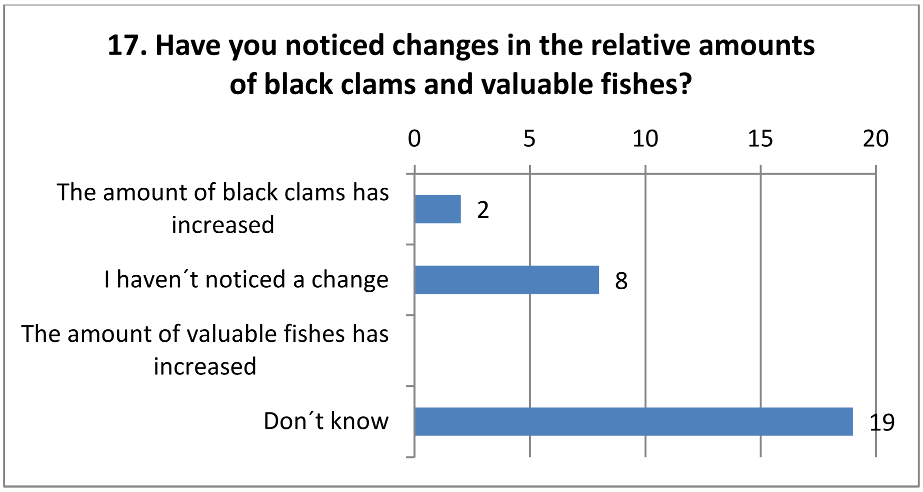
- 17 respondents



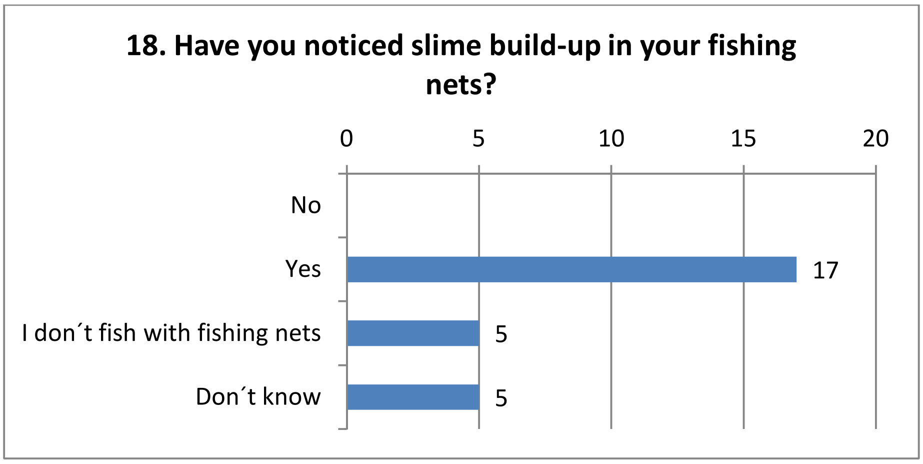
48 respondents



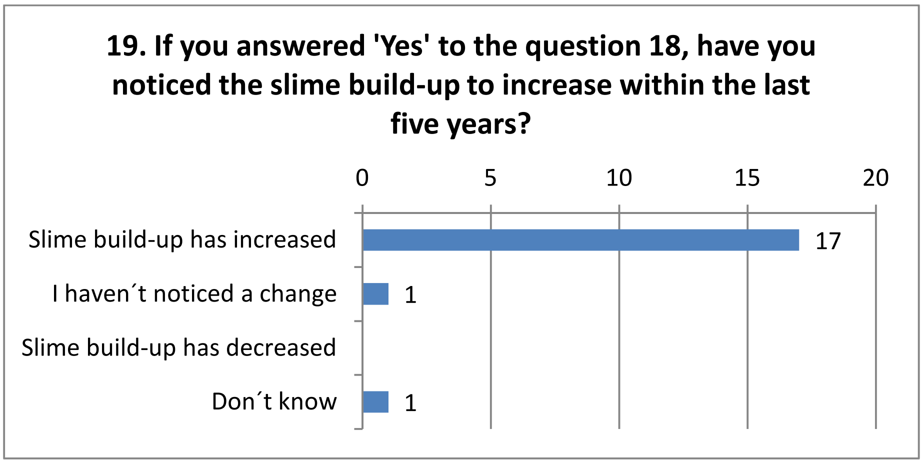
28 respondents



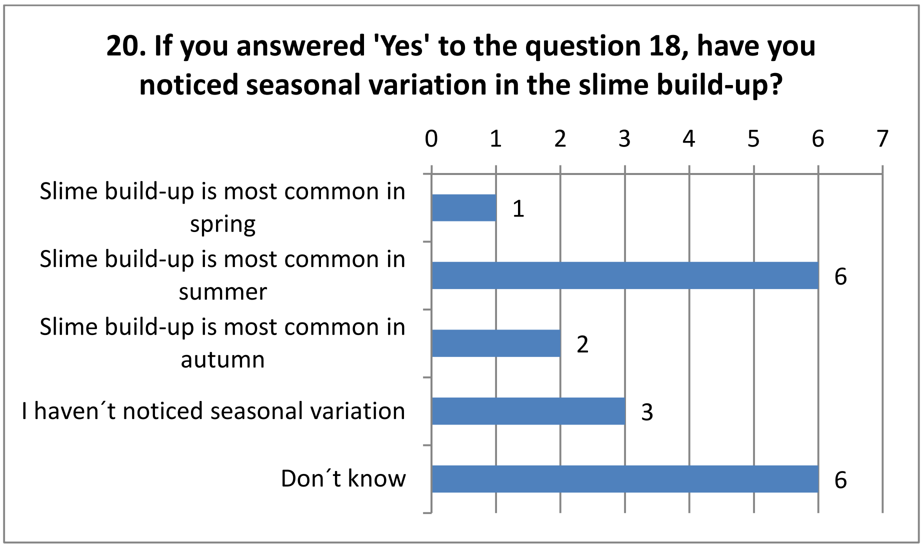
29 respondents



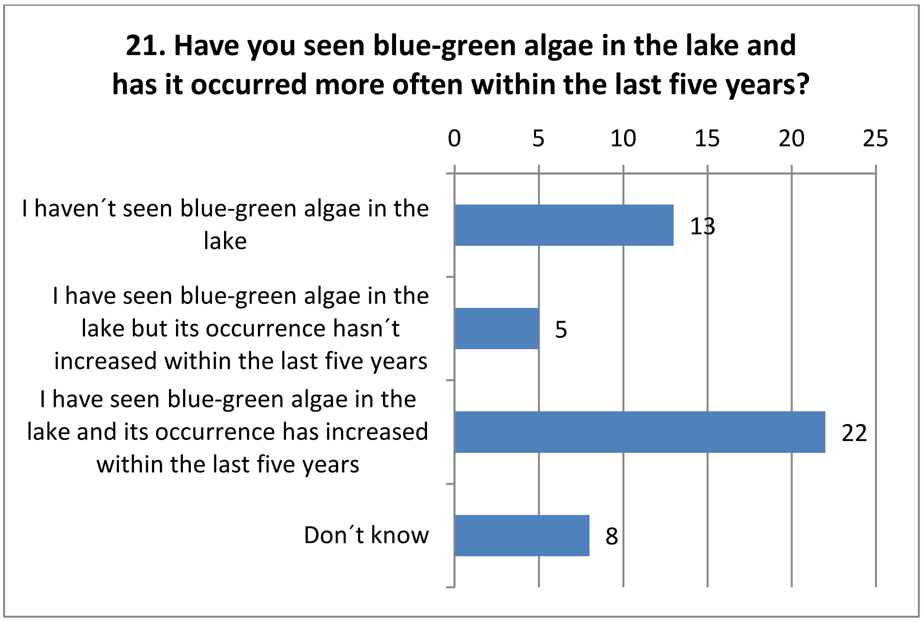
27 respondents



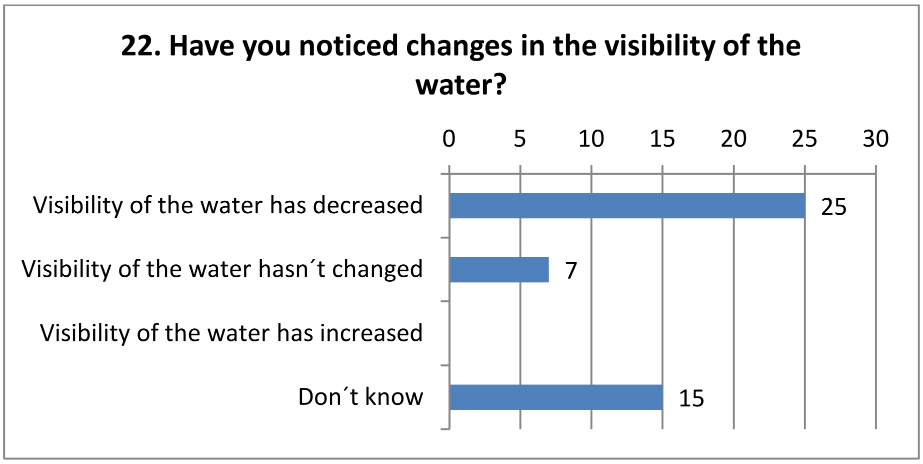
19 respondents



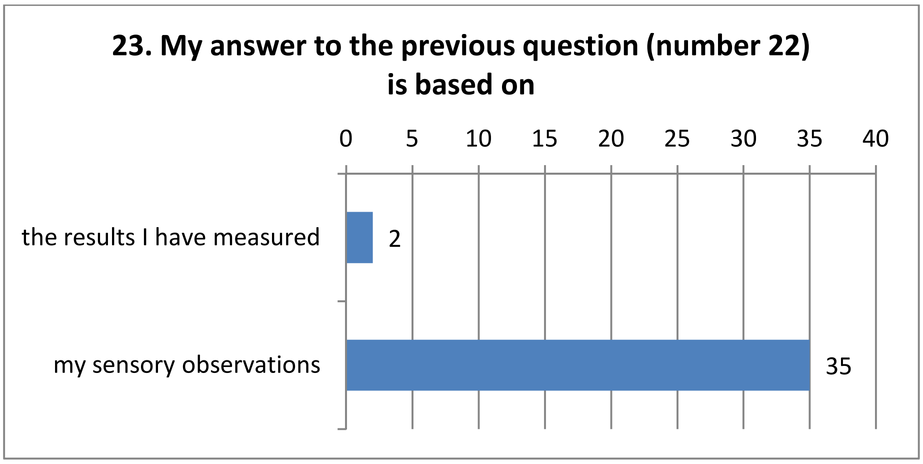
18 respondents



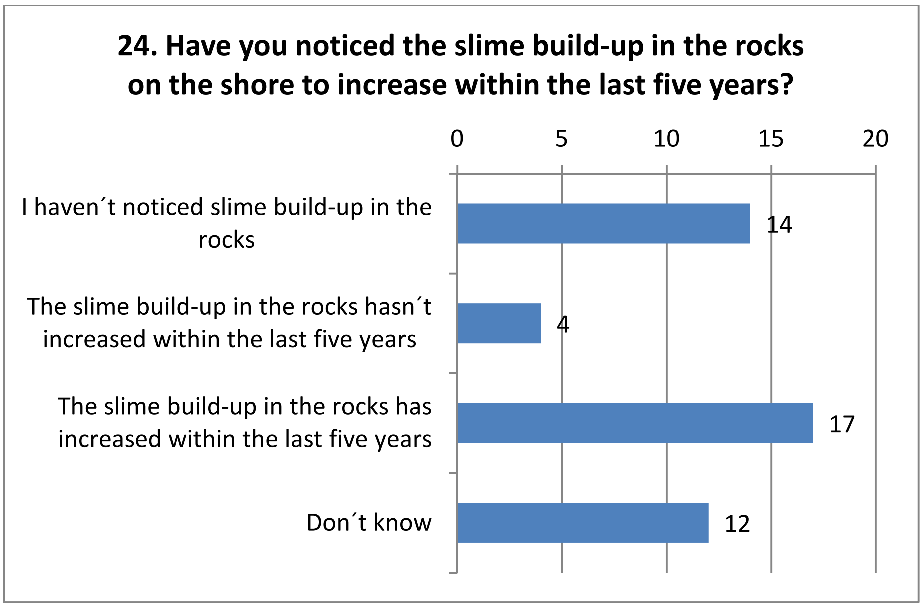
48 respondents



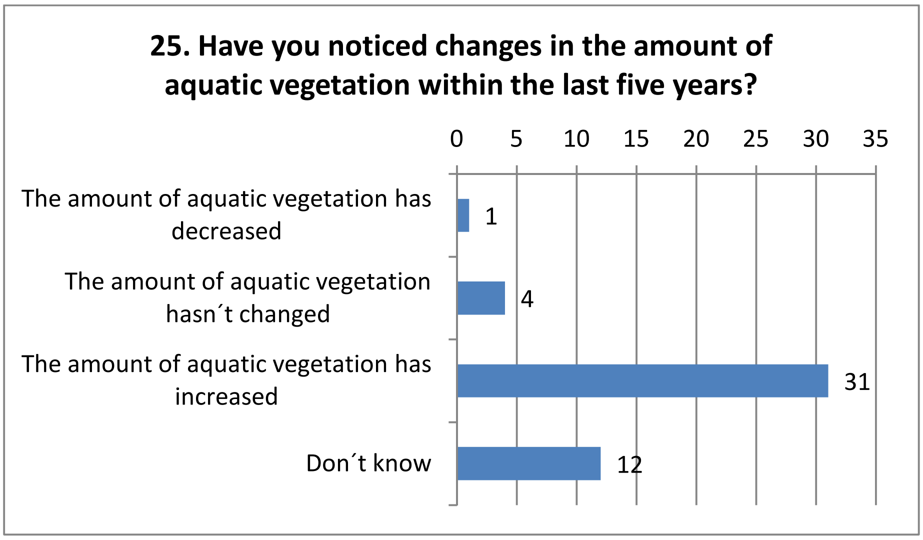
47 respondents



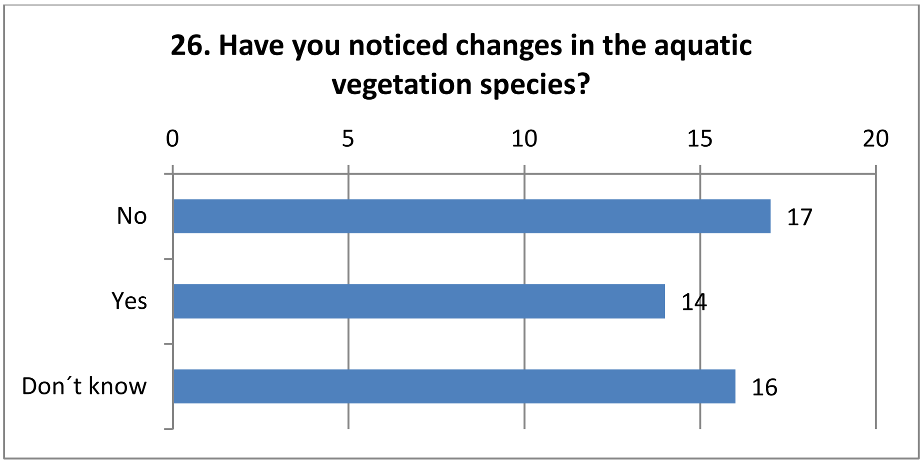
37 respondents



47 respondents



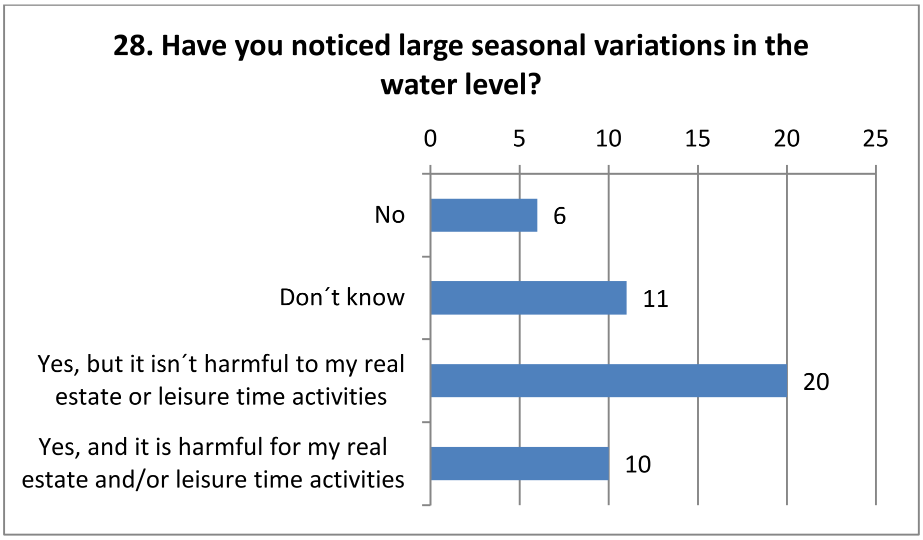
48 respondents



47 respondents

27. If you answered to the question 25. and/or 26. that you have noticed changes, describe the changes

- 23 respondents



47 respondents

29. If you answered to the question 28. that you are experiencing disadvantages because of the varying water level, describe the variation and disadvantages.

- 12 respondents

30. How do you feel that the status of the lake has changed in the course of years?

- 33 respondents

31. Can you estimate what are the reasons for the changes?

- 21 respondents

32. What kind of expectations and wishes do you have for the protective society of the lake Kankaistenjärvi?

- 27 respondents

33. Free word (additional information for the questions)

- 12 respondents