

**Are wetlands efficient at absorbing nutrients? —a case study of  
selected wetlands in Uusimaa.**

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## **DEGREE THESIS**

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### **Abstract**

Humans, plants, and animals all benefit greatly from clean water. The world we live in today is always changing, and so is our environment. Human activities such as agriculture and urbanisation have an impact on our ecosystem by causing eutrophication and pollution, among others. To fight these environmental problems, humans chose to construct wetlands to reduce eutrophication. As a result, the goal of this study is to evaluate six wetlands in the western Uusimaa region and determine if they serve the function of trapping and retaining nutrients, to compare nutrients concentration at inflow and outflow positions and to analyse the land use and soil type of catchment areas and link them to nutrients runoff. The nutrient runoff from the catchment areas depends on the land use. Data were collected over an eight-month period and examined in laboratories - graphs, charts, and statistical analyses were also used to analyse the data set. The results of the statistical tests revealed that there was a significant difference in the level of phosphorus from catchment areas between inflow and outflow sites of Furuborgsvägen wetland: however, there was no significant difference between Söderlandsvägen and Västankvarnsvägen wetlands. Based on our sampling, I concluded that wetland 2 is the only wetland that functions optimally, i.e., it is the only wetland that prevents eutrophication: however, the other two wetlands are recently constructed and their efficiency will most likely improve over time.

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Language: English

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## 1 Introduction

Since the world's transition from an agrarian economy to an industrial one, we are confronted with an increase in environmental issues, including eutrophication, pollution, climate change, and resource depletion. Since the commencement of the industrial revolution, the world has witnessed significant urbanisation, population increase, and the need to feed an expanding population. As a result, agriculture became highly mechanised with the introduction of fertilisers to help crops grow to quickly to satisfy the increased demand. Excess fertilisers are swept off farmlands flowing into rivers, lakes, and seas, resulting in eutrophication (Arheimer et al., 2004).

Nutrient runoff from agricultural farmlands, industrial areas, and wastewater treatment plants can have a significant impact on aquatic ecosystems. The principal nutrients covered here are phosphorus and nitrogen, which serve as limiting nutrients in inland water, coastal seas, and oceans. High nitrogen discharge into aquatic habitats reduces species diversity and macrophyte growth in water bodies. This decline in diversity and growth of macrophytes is driven by the establishment of algal blooms on water surfaces, thereby limiting the penetration of sunlight into the water body which leads to a reduction in the plants ability to photosynthesize thus causing a state of hypoxia in aquatic ecosystems (Kujala et al., 2019).

According to Trepel (2010), there has been a significant pressure by European Union States to improve the quality of both ground water and surface water bodies and one of the ways to do so is by constructing wetlands. According to Shutes (2001), recent scientific investigation reveals that macrophytes, particularly the *Phragmites australis* and *Typha latifolia* found in wetlands, can effectively break down wastewater and absorb pollutants and pathogenic microorganisms. The common reed (*Phragmites australis*) and reedmace (*Typha latifolia*) are the most effective plants in demonstrating this property. The plants have large above-ground biomass (leaves) and below (underground rhizome system) soil surface, creating a matrix for nutrient and ion uptake. Subsurface plant tissues grow horizontally and vertically.

The Baltic Sea is subject to tremendous nutrients runoff from its surrounding countries, and this runoff causes the increase of cyanobacteria blooms, anoxia, and, subsequently, dead bottoms, resulting in severe ecological repercussions (Johannesson et al., 2015). A majority

of Finland's agricultural land area is concentrated in the southern and western regions; although the size is small, these agricultural lands account for a considerable share of the nutrients loading (Tattari et al., 2017).

According to Janse et al. (2019), wetlands play a crucial role in delivering ecosystem services such as clean water and biodiversity support. Wetlands play a vital role in purifying water via two processes: uptake and microorganism activity around rhizome (Dong et al., 2012). Many developed countries have found better techniques in using fertilizers and treating wastewater, on the other hand, surface water still remains contaminated with nutrients like phosphorous and nitrogen (Kujala et al., 2019).

The catchment areas of wetlands play a vital role in the seasonal or entire life span of the wetland. Wetlands are greatly affected by their geomorphological surroundings, surface and subsurface inflow (Leemhuis et al., 2016). The quantity of water in streams is affected by landscape metrics at the catchment and wetland level (Moreno-Mateos et al., 2008).

Turbidity measures the level of clarity in a water body, or, in other words, how transparent a body of water is (Kitchener et al., 2017). A high value of turbidity signifies that the water is cloudy or muddy, full of algae, plankton, and suspended particles; hence, we can't see through to a certain level. According to Mann et al. (2007) the acceptable level turbidity for drinking water varies between countries but should not exceed 1.0. A body of water with a turbidity level above 5.0 FNU can be easily detected.

### **1.1 Problem Statement**

Camara et al. (2019) define land use as the anthropogenic use of land and its resources. They further went ahead to establish a positive correlation between land use and water quality by stating that, runoff from highly urbanized areas contain metals, suspended particles, aerobics and these contaminants end up in water bodies. In Malaysia, increase in human activities such as infrastructural development mechanised agriculture and deforestation has led to low water quality (Camara et al., 2019).

Tong & Cheng (2002) reported that, run off from agricultural lands may be enriched with nutrients, whereas that from urban areas are filled with heavy metals, sulphate, sodium and these contaminants end up polluting water bodies. Rene et al. (2003) conducted a study in Shanghai and discovered that urbanisation had a negative impact on water quality. The

fast-growing population of the city of Shanghai has significantly increased the number of pollutants in and around the city, which is expected to impact the town's water quality severely.

Kändler et al. (2017) carried out studies on land use and water quality in the Czech-German-Polish triangle and concluded that, human activities on land leave undeniable repercussions on water quality. They also concluded that settlements and farmlands are the main causes of low water quality. In the same line of thought, Nielsen et al. (2012) reported that water quality managers around the world find it difficult to deal with nitrogen and phosphorous input into freshwater ecosystems. Water from farmland and settlement pose a significant treat to fresh water and this has become a threat that humans have to deal with as this polluted water reduces fresh water used.

## **1.2 Research Questions**

1. Does wetland soil type and land use of catchments areas determine the amount of nutrients that enters the wetlands?
2. To what extent does the wetland act as nutrient filter, that is., do they help curb eutrophication?
3. Is there a significant difference between nutrients between entering and flowing out of the wetland?

## **2 Theoretical Background**

### **2.1 Eutrophication**

The excessive enrichment of water bodies with nitrogen and phosphorus, is known as eutrophication (Chislock et al. 2013). Eutrophication encourages the growth of undesirable algae, causes hypoxia, and reduces the amount of water that is accessible for drinking, fishing, and recreational activities. (Mohammed and Khan, 2013).

In the Baltic Sea, nutrient inflow has increased over the last century, with major consequences for the biota (Rönnberg & Bonsdorff, 2004). Since the previous assessment in 2013, the status of eutrophicated areas has maintained a status quo, and showing no signs of improving. Nitrogen inputs are still high in the Baltic Sea proper, Gulf of Finland, and phosphorous concentration are high at all sub basin except for the Bothnian bay, and the Danish Straits (HELCOM 2023).

### **2.2 Wetlands**

According to WWF (2024), a wetland is a region that is permanently or occasionally submerged in fresh, brackish, or saltwater. Wetlands are regions where water nearly always appears at the surface or covers the soil (US EPA, 2023). Later sections of this thesis will address the significance, development, and current state of wetlands.

### **2.3 Importance of wetland**

Wetlands play an important part in our environment, with some of the benefits stated below:

#### **2.3.1 Serve as water purifier**

According to Ferreira et al. (2023), wetlands act as an absorber, retaining toxins from the water that enters before it goes out. These contaminants are frequently coming from farmlands, urban areas such as roadways, municipal and industrial wastewater treatment facilities, and landfill sites. Nutrients are filtered out in three ways: physically (sedimentation, volatilization, or sorption of contaminants), biologically (nutrient uptake by plants), and chemically as during chemical precipitation (Kostel, n.d).

According to Verhoeven and Meuleman (1999), wetlands benefit from being a complex ecosystem because it allows them to easily collect nutrients from flowing water. They have tall, extremely productive plants that can absorb nutrients. Due to the oxic and anoxic particles in their soils, organic matter can be broken down by unique pathways involving electron acceptors other than oxygen.

### **2.3.2 Wetland as a barrier against flooding**

kosteikko (2024), stated that wetlands in Finland are able to store excessive amount of water. They argued that the size of a wetland with respect to its catchment area is a determinant of the wetland's ability to retain water or not. A large wetland surrounded by a small catchment area stand a high chance of retaining nutrients. The vegetation in the wetland acts like barriers, slowing down the flow of incoming water, causing the nutrients to settle at the bottom which are then used for other purposes. For example, the Joussuo wetland in Pyhäjärvi has small catchment area compared to the wetland.

According to Narayan et al. (2017), wetlands along the coast are essential for minimising erosion. Wetlands act as a buffer, reducing the speed of winds that approach the mainland and surface. An example of this can be seen in the way mangrove wetlands assisted Hurricane Katrina in reducing her wind speed approaching the United States mainland by as much as 9.4 cm\km.

### **2.3.3 Serve as improving biodiversity.**

A large variety of flora and animals, particularly birds, can be found in wetlands (Bobbink et al., 2006). Because some animals eat the debris and large predators eat the little prey. Wetlands have been termed biological supermarkets due to their capacity to manufacture their own food (Watershed Academy | US EPA, 2024).

Wetlands provide shelter to a wide range of animal species, including fish, birds, reptiles, and amphibians (Functions & Values of Wetlands - Washington State Department of Ecology).

### **2.3.4 Wetlands as carbon sinks**

According to Mitsch et al. (2012) wetlands is the ideal environment to store carbon dioxide from the atmosphere. According to Li et al. (2024), play a vital role in reducing greenhouse gas and storing carbon which is used by plant during photosynthesis. Iqbal and Shang (2019) termed wetland as “kidney of the landscape” because of their ability to store carbon dioxide.

### **2.3.5 Wetland as ground water recharge**

According to Hensel and Miller (1991), wetlands aid in the resupply of ground water. Groundwater is utilised for irrigation and drinking, and these activities eventually cause the water to dry up. As a result, wetlands frequently serve as groundwater suppliers or replenishers. Acharya and Barbier (2000) concluded that wetlands help restock ground water during the dry season in the northern parts of Nigeria.

## **2.4 Where we are today**

In the recent past, wetlands were reputable for harbouring mosquitoes and carrying diseases. For this reason, early settlers began to alter or destroy the wetland by reclaiming the land without leaving out natural deteriorating factors of the wetlands such as climate change, human activities and droughts. An estimated 87% of wetlands are in a bad state as a result of human activities and natural factors such as urbanization, pollution, invasive species, climate change (Xu et al., 2019).

Verhoeven and Setter (2009) stated that more than 50% of peatlands, depressional wetlands and lake littoral regions in North America, Europe and Australia are lost. The main reason for this loss is caused by human activities such as intense agricultural use to feed the growing population, and urbanization. Turner et al. (1983) argue that in the United Kingdom wetlands extinction is on the rise because of highly productive farming practices, subsidised land drainage schemes and flood protection schemes.

According to Bergstrom et al. (1990), 41% of the United States of America’s coastal wetlands are located in Louisiana along the Gulf of Mexico coast. Human activity and salt water intrusion pose a threat to these wetlands. The loss of coastal wetlands in Louisiana is thought to be occurring at a pace of 104–155 km annually. Davidson (2014) evaluated

189 studies on wetland changes and concluded that, over time, wetland conversion and loss has exceeded 50%, reaching up to 87% since the beginning of the 18th century. Davidson's research is the first to evaluate published research studies on wetland loss and change on a global scale, and it has significantly improved our understanding of how wetlands have evolved around the world. However, Davidson (2014) acknowledges that the inconsistency of data on changes in wetland areas and scales in the published publications and reports makes the results somewhat unclear.

## 2.5 Examples of some successful Finnish wetlands

Wahlroos et al. (2015) conducted research on a number of wetlands (**Error! Reference source not found.**), including the Kilsoi stream, Niittu wetland, Lake Enäjärvi shoreline wetland, and Gateway wetland, to assess their ability to improve water quality and provide other ecosystem services. Between November 1, 2012, and December 31, 2013, they monitored water quality using both continuous and discontinuous sampling techniques. Waterfowls and other water birds were tracked using the standardised waterfowl round count method. After fourteen months of monitoring water quality, it was determined that water quality fluctuates across the four seasons, with rain, snowmelt, and construction work being identified as the primary variables affecting water turbidity negatively. However, the wetlands revealed the potential to reduce pollutants and this was largely dependent on season. It was discovered that the largest phosphorus decrease was 71% during heavy rain and snowmelt seasons.



**Figure 1. Nummela wetlands (Source: Scalgo live 2024)**

Berninger et al. (2012) observed that constructed wetlands can effectively maintain water quality whereas also providing multifunctional and socioeconomic benefits. This study investigated the ability of constructed wetlands to improve water quality. According to the study, nutrient runoff is influenced by land use, slope gradients, soil qualities, and cultivation practices, i.e., the more agricultural land, steep slope, and fine soil, the higher the nutrients flow from these farms. The investigations did, however, determine that the Hovi wetland is an example of a wetland with nutrient retention capability. From 1999 to 2007, this wetland was monitored using both manual and automatic water samplers. This wetland has a high sediment and phosphorus retention rate, estimated at 60-70%. Constructed in 1998, the Hovi wetland is said to be one of the main catalysts for the construction of wetlands in Finland due to its high nutrient retention levels.

Koskiaho et al. (2003) conducted research on the ability of built wetlands to retain agricultural fertilisers under boreal climates. The observed wetlands were in southern Finland, specifically Hovi, Alastaro, and the Flytträsk artificial wetlands. Total phosphorus, total nitrogen, nitrate+nitrate-N, ammonium, and total suspended particles were the monitored nutrients. The monitoring period lasted around two years, and they concluded that the wetland with the longest water residence time was the most effective at retaining nutrients, retaining approximately 25kg of total phosphorous and 300kg of total nitrogen per hectare.

It is worth mentioning that the examples given above are only a few out of many; there are many wetlands built throughout Finland. According to Alhainen (2016), the Finnish Wildlife Agency and Return of Rural Wetlands initiatives aided in the restoration of around 47 wetlands throughout Finland.

In summer 2023, a sharp rise in revived wetlands was detected in Finland. The Finnish Game Foundation, Italian hunting federation in cooperation with the Waterfowlers' Network, worked together to revive the Vitmossen, Leväjänkkä and the Viiskangas wetlands which serves as habitat for water birds (kosteikko 2024a).

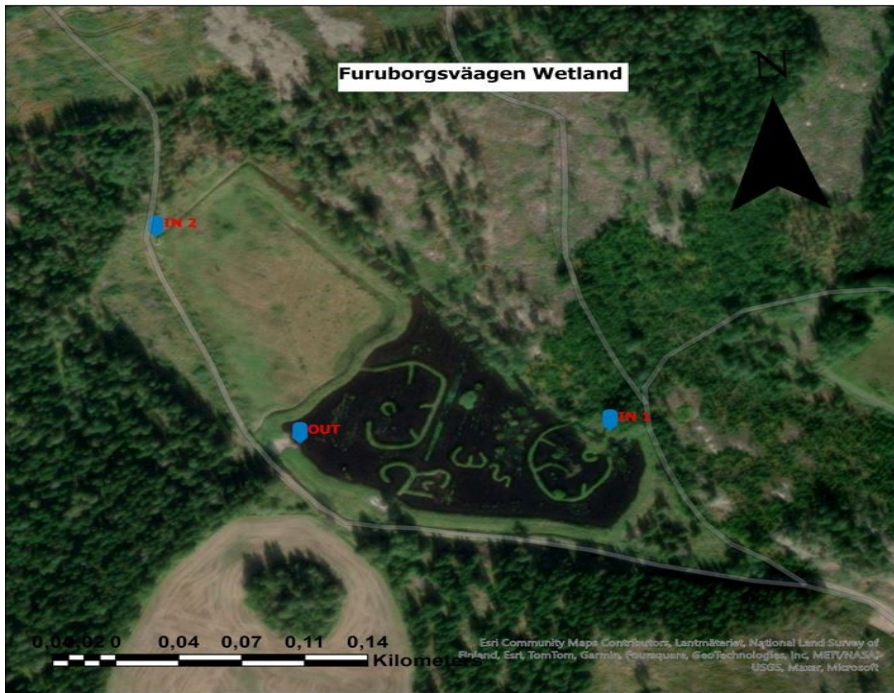
### **3 Methodology**

#### **3.1 Background of study area**

All six monitored wetlands were located in the western part of the Uusimaa region. Furuborgsvägen wetland (Figure 2) is in the municipality of Ingä at coordinates 60°05'03.6"N 24°08'47.3"E. This wetland, constructed in 2022, has two inflow and one outflow sites.

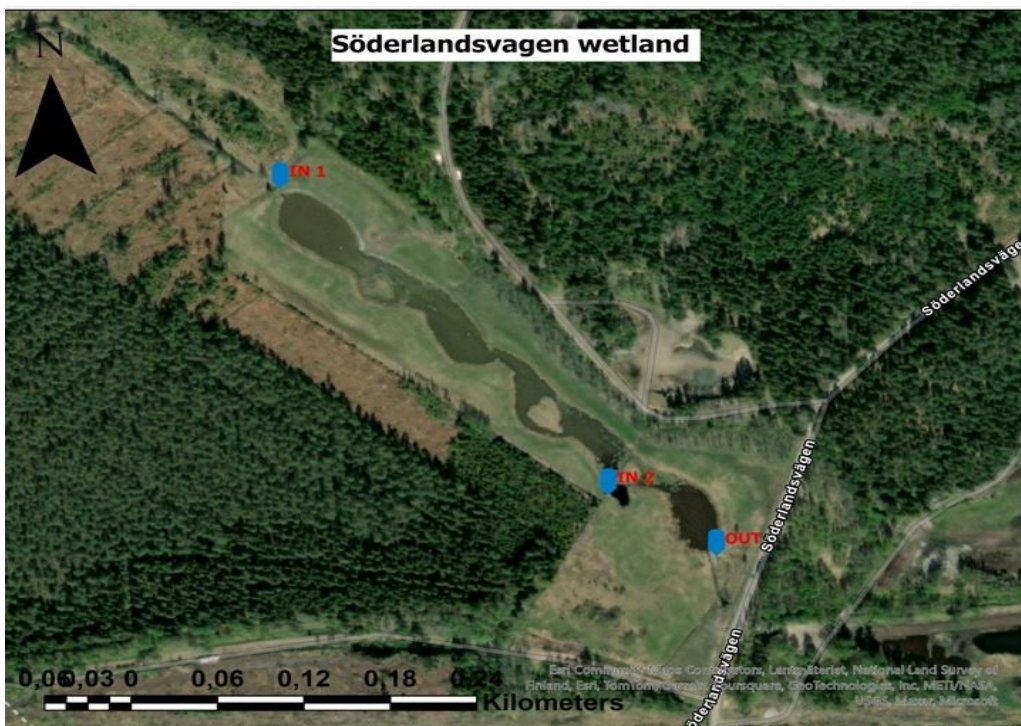
The second wetland I studied was Söderlandsvägen (Figure 3), which is in Ingä. It is around 2.6 hectares in size and was built in 2019. The wetland's exact location is 60°04'19.5"N 23°50'44.4"E. It has two inflow and one outflow, as does the former one.

The third wetland I studied was Västankvarnsvägen (Figure 4) (60°04'27.3"N 23°53'55.5"E), which covered approximately 1.1 hectares. It is approximately 2.5 kilometres west of the Västankvarn mansion and is a relatively new wetland. The wetland has a single inflow and outflow. For the sake of simplicity, the wetlands at th, Söderlandsvägen, and Västankvarnsvägen shall be referred to as Furu wetland, Söder wetland, and Väst wetland respectively.



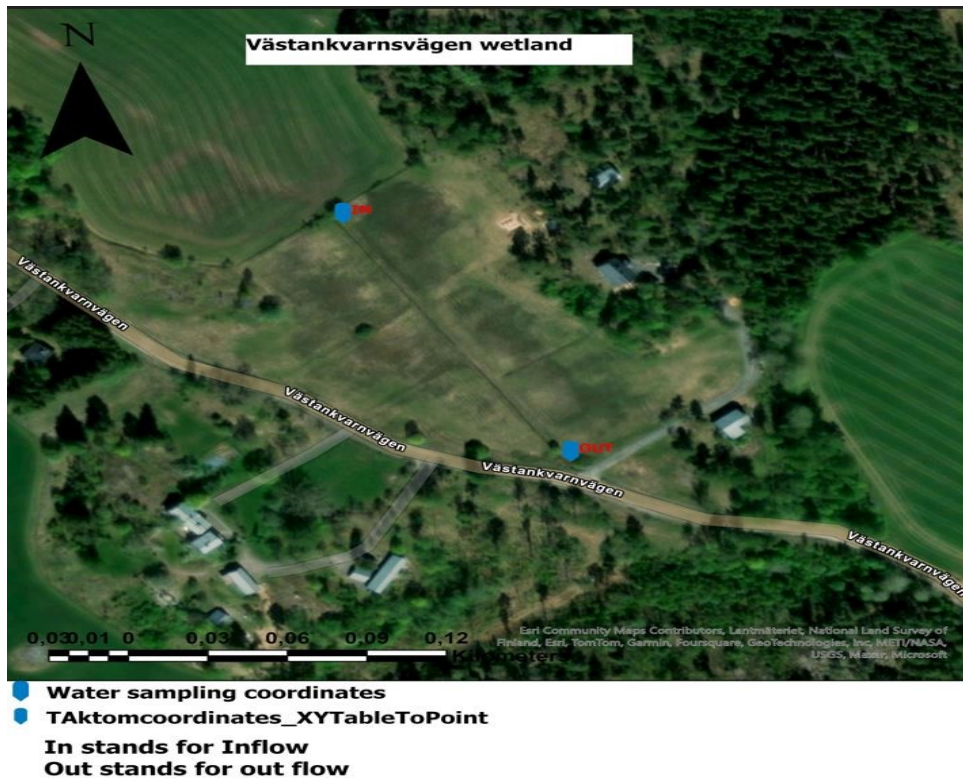
Water sampling coordinates  
 IN 1 stands for Inflow 1  
 IN 2 stands for Inflow 2  
 Out stands for Outflow

Figure 2. Furuborgsväagen wetland



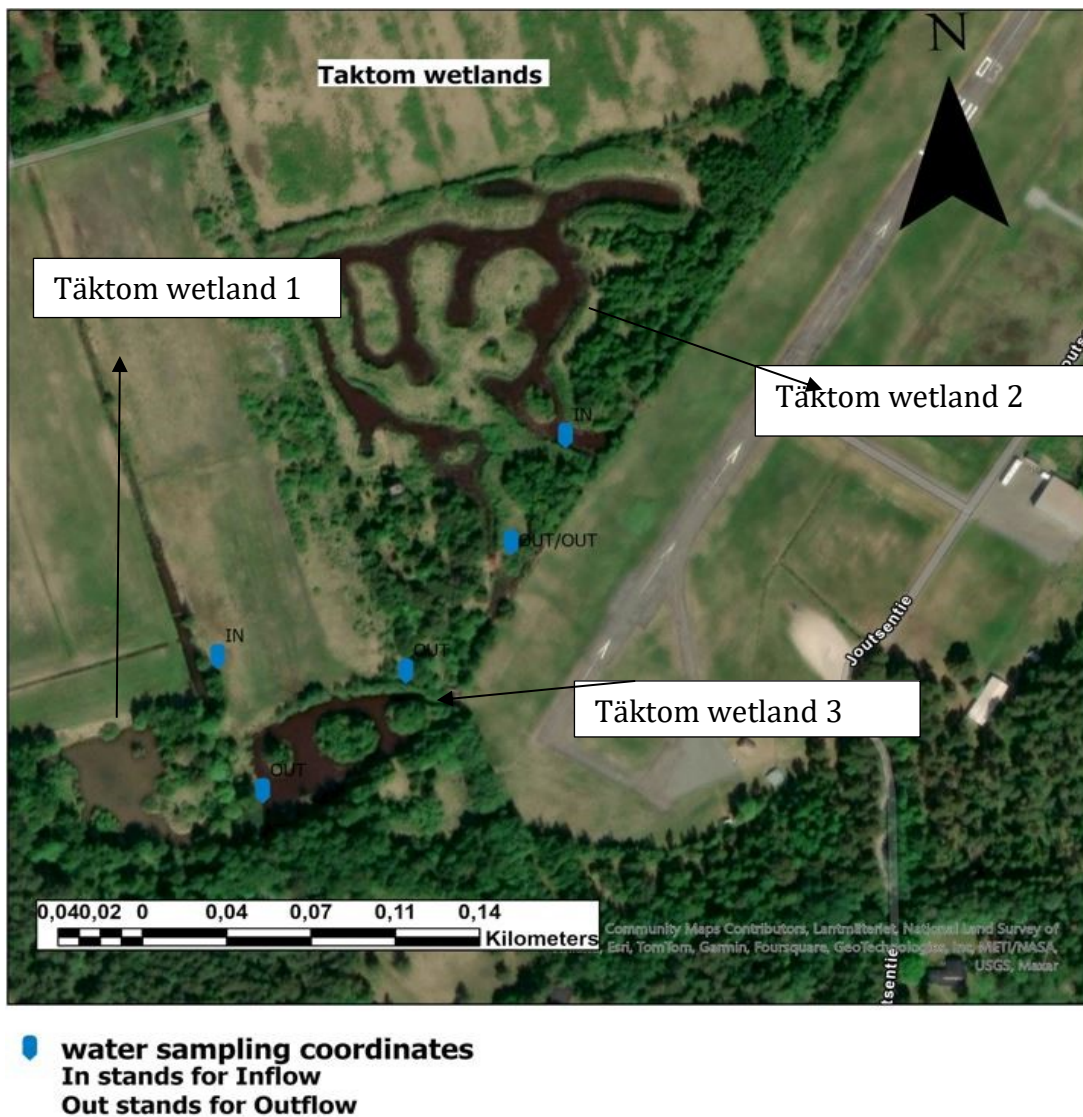
Water sampling coordinates  
 IN1 stands for Inflow 1  
 IN 2 stands for Inflow 2  
 Out stands for Outflow

Figure 3. Söderlandsväagen wetland



**Figure 4. Västankvarnsvägen wetland**

The second set of wetlands monitored were the Täktom wetlands (Figure 5), which are located further west of Uusimaa than the wetlands listed above. The Täktom wetlands are located in the municipality of Hanko. Wetland 2 is the largest, covering around 1.5 hectares, and was created in 2016. The wetland is extensively covered with wetland vegetation, such as *Osmanthus fragrans*. Wetland 3 was constructed in 2010 and covers around one hectare. Each wetland has one inflow and one outflow. It is worth noting that the outflow from wetland 2 flows directly into wetland 3, becoming the inflow of wetland 3. All three wetlands are close together and near Täktom Airport's runway. From now on, the wetlands will be called Täktom wetland 1, Täktom wetland 2, and Täktom wetland 3, as shown in the figure below.



**Figure 5. Tåktom wetlands**

### 3.2 Sampling.

Water samples were taken using a sampling stick. A marked bottle (**Error! Reference source not found.**) was tied to the sampling stick (Figure 7) and submerged in water to fill before being placed in a cooler (Figure 8). The entire process was carried out carefully, avoiding the sampling stick to touch the bottom and resuspend sediments, that can affect the results. After placing the bottle in the cooler, I used the YSI sensor (Figure 8) to measure abiotic variables in the water. I inserted the sensor into water and recorded the results as soon as they were steady. The abiotic variables measured include temperature, conductivity, salinity, dissolved oxygen (saturation % and mg l). At the end of each sampling

day, the marked water bottles were handed over to the LUVY laboratory, where variables such as total nitrogen and phosphorus, nitrite, nitrate, and phosphate were assessed.

The above process or monitoring was conducted once a month for eight months, from May to December 2023, for the Furuborgsvägen, Söderlandsvägen, and Västankvarnsvägen wetlands. For the Täktom wetlands, it was conducted once a month for two months, that is, April and September 2023.

### **3.3 Instrument equipment used during field sampling**



**Figure 6. Marked bottles**



**Figure 6. Sampling stick**



**Figure 7. Cooler**



**Figure 8. YSI sensor**

### **3.4 Statistical analyses**

Once I received the results from LUVY lab, I extracted and entered them into an Excel spreadsheet. Each variable (nutrients, soil type, and land use) and distinct wetlands had their own column, and the corresponding figures were imputed from top to bottom. Once the data were ready, I added the Analysis tool pack to my Excel sheet and used it to analyse the data. Wetlands with three variables (wetland 1 and 2) were examined using an ANOVA single factor test, whereas wetlands with two variables (wetland 3 and Tåktom wetland 1, 2 and 3) were analysed using a two-sample t-test assuming unequal variances. The alpha value or p value used was 5% (0.05), and any value less than the p value indicated that there was a significant difference; thus I rejected the null hypothesis.

Land use and soil type have been identified as factors that influence the amount of nutrients that flow into waterbodies. As a result, analysing these factors is an important step in this study. Land use and soil type variables retained for this study include forest areas, industrial areas, rocky lands, clay soil, peat soil, moraine soil, construction for residential and recreational areas.

### **3.5 Method of data extraction from Scalgo live**

Data on soil composition, proportion and percentage of the different land use of catchment areas were gotten from <https://scalgo.com/fr/>. To get the different composition of the land use and soil type of the catchment areas, I used the Watershed tool found in the upper tool bar. After clicking of watershed tool, I was presented with two options Depression-free flow and Flash flood mappings I choose the former. Clicking on any point of the map will show the watershed in dark green and a box in the bottom right corner show information about land use and soil type. In order to locate the wetlands in Scalgo live, I used the coordinates of the wetlands I got during my water sampling session, imputed these coordinates on Google maps which provided the exact location of the wetlands. I now had Google maps and Scalgo live opened side by side on my computer. So, I located the wetlands on Scalgo live and since I have the coordinates for all inflows and outflows positions. I clicked on the positions (inflows and outflows) on Scalgo live which showed the catchment area in dark green and a box at the bottom right corner popped up with information on the catchment area.

## 4 Results

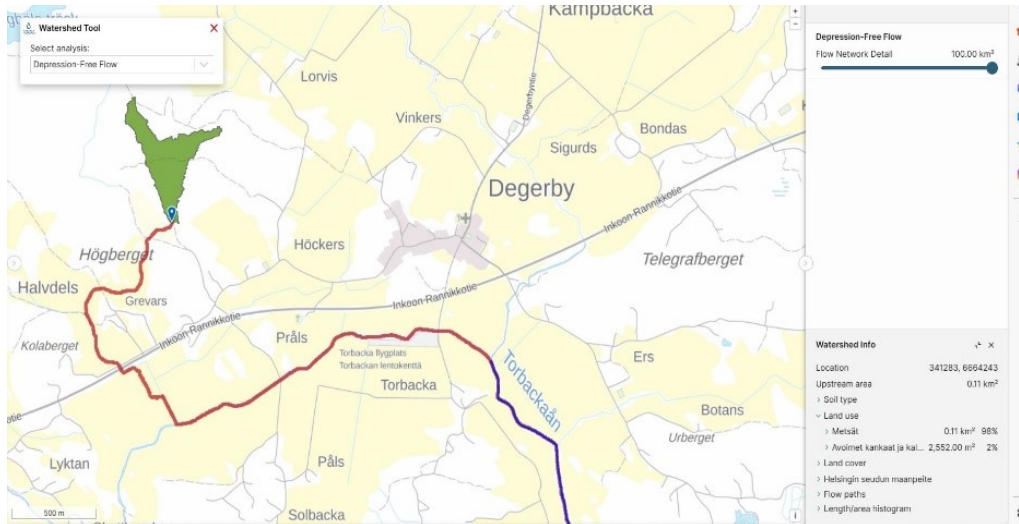
### 4.1 Land use characteristics of catchment areas linked to wetlands.

Table 1 is a summary of the different portions of land use within the catchment area of the various wetlands. The amount of nutrient flowing into the wetlands depends on the characteristics of the catchment area.

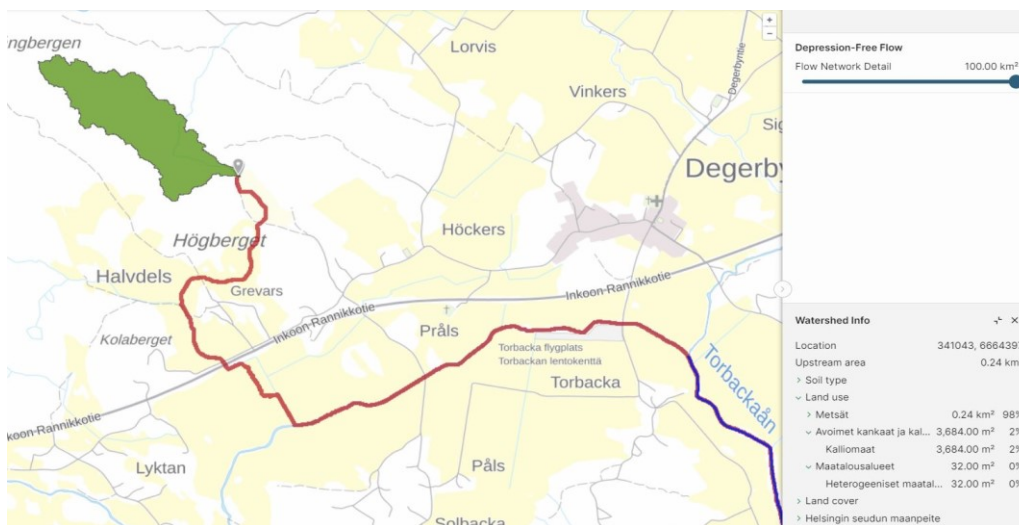
**Table 1. Proportion of water inflow from catchment areas.**

	Forest regions (%)	Fine soil (%)	Rocky land (%)	Agricultural areas (%)	Industrial areas (%)	Recreation activities (%)
Wetland 1 Inflow 1	98	2				
Wetland 1 Inflow 2	98		2			
Wetland 2 Inflow 1	64			32		
Wetland 2 Inflow 2	95				5	
Wetland 3	29			53	12	
Täktom Wetland 1	38			30		23
Täktom Wetland 2	99			1		
Täktom Wetland 3	21			31		44

Figure 9 shows the catchment areas associated with Furu wetland around inflow 1 while Figure 10 shows the catchment areas associated with Furu wetland around inflow 2. Most of the water flowing through the catchment areas originates from the forest. The catchment areas around inflow 1 is  $0.11\text{km}^2$  and that for inflow 2 is  $0.24\text{ km}^2$ .



**Figure 9, Land use characteristics of catchment area, Furu wetland inflow 1 (source: Scalgo Live 2024).**

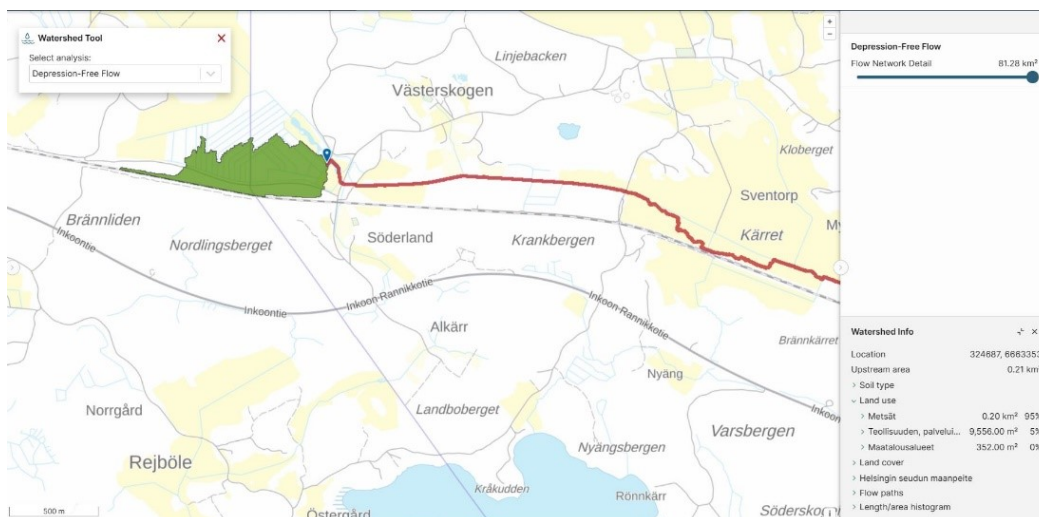


**Figure 10. Land use characteristics of catchment area of Furu wetland inflow 2 (source: Scalgo Live 2024).**

Figure 11 shows land use of catchment areas associated with inflow 1 of Söder wetland and Figure 12 represents the catchment areas linked with Söder wetland. The total land surface of the catchment area around inflow 1 and 2 are 2.25km<sup>2</sup> Km2 and 0.21km<sup>2</sup> respectively

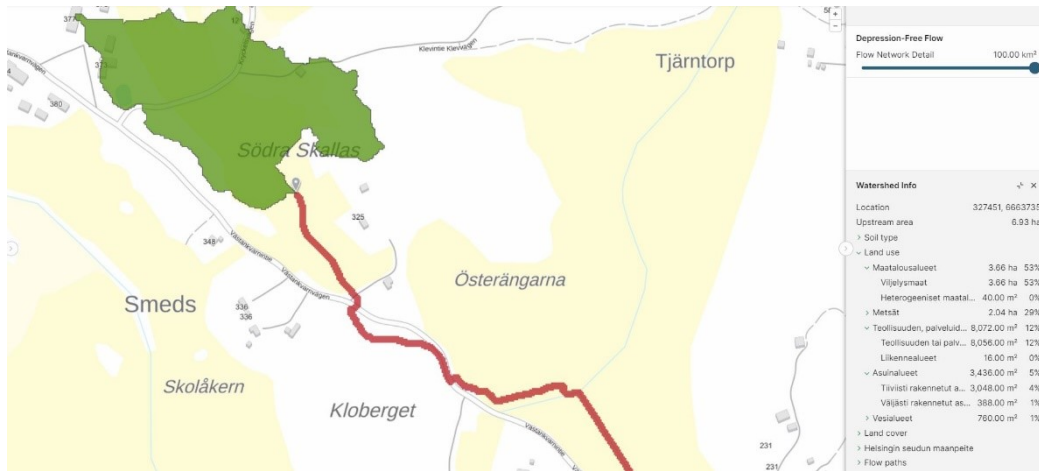


**Figure 11. Land use characteristics of catchment area of Söder wetland inflow 1 (source: Scalgo Live 2024).**



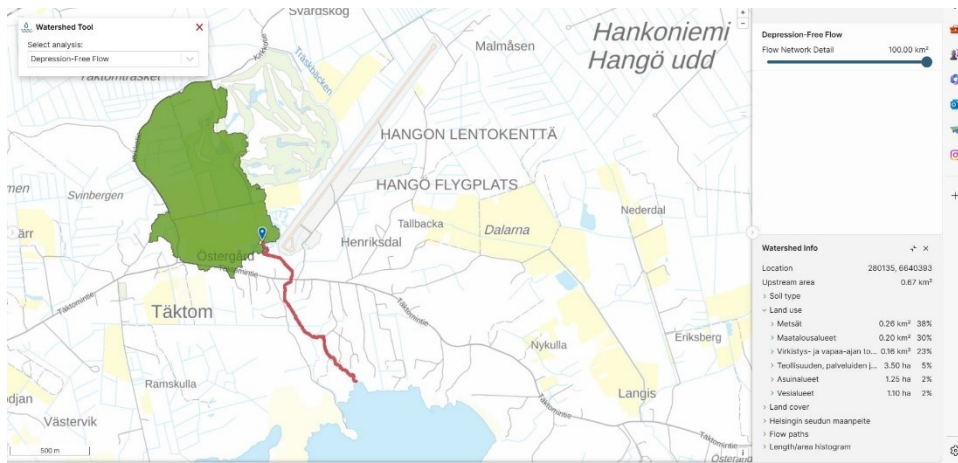
**Figure 12. Land use characteristics of catchment area of Söder wetland inflow 2 (source: Scalgo Live 2024).**

Figure 13 shows the land use around the inflow of Väst wetland. With a single inflow site, this catchment area has a total size of 9.93 ha.



**Figure 13. Land use characteristics of catchment area of Väst wetland (source: Scalgo Live 2024).**

The catchment area for Täcktom wetlands 1, 2, and 3 is depicted in Figure 14, Figure 15, and Figure 16. The catchment area of Täcktom wetland 1 has a 0.67km<sup>2</sup>, Täcktom wetland 2 has surface areas of 3492 and the surface area for Täcktom wetland 3 is 9.73 mother



**Figure 14. Land use characteristics of catchment area of Tåktom wetland 1 (source: Scalgo Live 2024).**



**Figure 15. Land use characteristics of catchment area of Tåktom wetland 2 (source: Scalgo Live 2024).**



**Figure 16. Land use characteristics of catchment area of Tåktom wetland 3 (source: Scalgo Live 2024).**

## 4.2 Soil type linked to catchment areas.

Table 2 depicts the proportion of soil types linked to each catchment area. The hydrology and ecology of the catchment areas are determined by the kind of soil. This thesis will contribute to a better understanding of this soil type, allowing for better conservation, restoration, and management efforts for wetlands.

**Table 2. Proportion of soil type linked to catchment areas**

	Rocky land (%)	Sludge soil (%)	Fine grain (%)	Peat soil (%)	Clay soil (%)	Sandy soil (%)
Wetland 1 In1	98		2			
Wetland 1 In2	90					
Wetland 2 In1	31	28	23			
Wetland 2 In 2			12	76		
Wetland 3	52				48	
Täktom wetland 1						100
Täktom wetland 2						100
Täktom wetland 3						100

## 4.3 Furu Wetland

In this section, I analysed phosphorous, nitrogen and turbidity in all six wetlands.

### 4.3.1 Total phosphorous

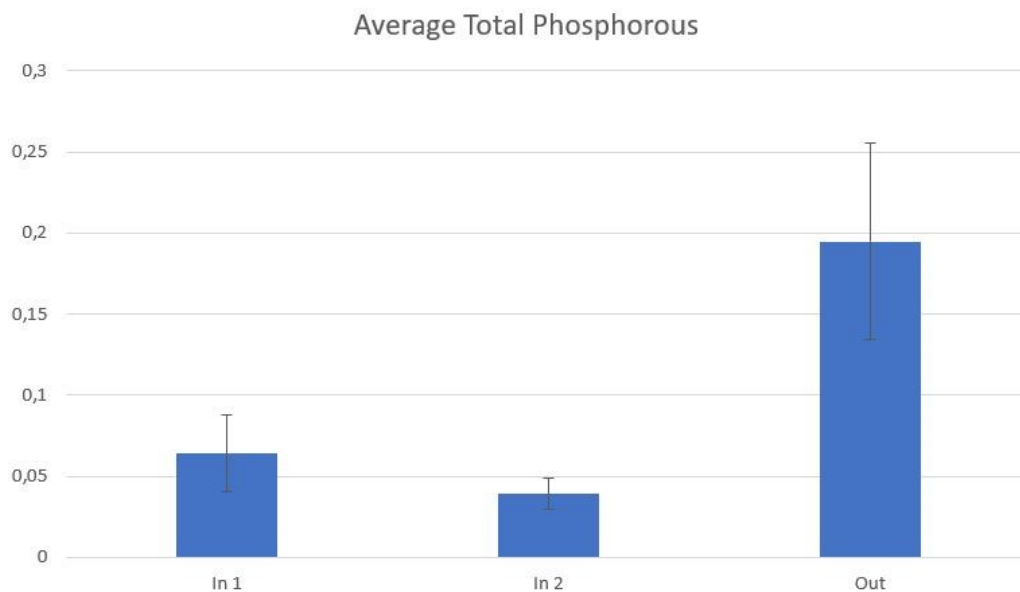
The total phosphorus graph (see Appendix 1) in wetland 1 during the monitoring period shows that the highest amount of phosphorous intake was recorded on June 19, 2023 (0.2mgP/l), while the lowest amount of total phosphorus inflow was recorded on

December 20, 2023 (0.16mgP/l). On August 18, 2023, the maximum total phosphorus output was 0.47mgP/l.

#### 4.3.2 Average total phosphorous

Figure 17 depicts the average total phosphorus and standard error (black lines running through the bars) for wetland 1 for both inflow and outflow positions. An ANOVA test was conducted, and with the alpha level at 5%, the P value was 0.017023, which was lower than the alpha level (5%), which means there is a significant difference in the level of phosphorous entering and exiting wetland 1.

The standard error line of the outflow bar is distant from the mean (the top of the bar), indicating that the total phosphorus amounts collected throughout the data collection (monitoring) period varied significantly. Meanwhile, the standard error of inflow 2 is not far from the mean, indicating that there is not much variation between total phosphorous values. I can also deduce that the amount of total phosphorus flowing out of the wetland was higher than what was entering the wetland.



**Figure 17. Average total phosphorous, Furu wetland, n=8**

#### 4.3.3 Nitrogen (NO<sub>3</sub>+NO<sub>2</sub>)

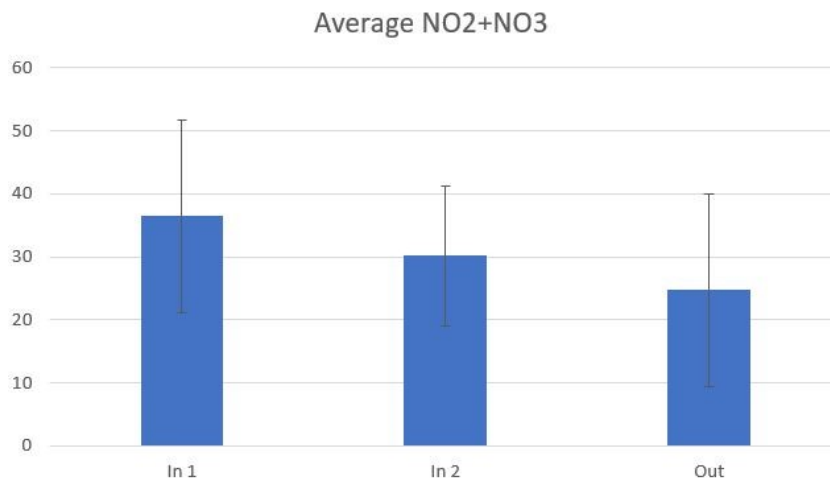
The highest inflow of combined nitrite and nitrate (see Appendix 2) was recorded on December 20, 2023, which stood at 110 µg/l, whereas the highest outflow was recorded during the same month, at 130 µg/l. It is worth mentioning that all values of 4.5 µg/l

represent  $\text{NO}_3+\text{NO}_2$  nitrogen concentration less than  $5 \mu\text{g/l}$ . The graph clearly shows a rising trend in the amount of nitrogen.

#### 4.3.4 Average Nitrogen ( $\text{NO}_3+\text{NO}_2$ )

Figure 18 depicts a graphical representation of the average nitrogen ( $\text{NO}_3+\text{NO}_2$ ) concentrations recorded during the monitoring season. The standard error is shown by a line that runs across the bars in the graph below. The standard error line overlaps on all three bars, indicating that there is no significant difference ( $P=0.0840374$ ,  $n=8$ ).

I also notice that the amount of nitrogen ( $\text{NO}_3+\text{NO}_2$ ) that flows into the wetland from both inflows is higher than the amount that flows out of the wetland; in other words, the wetlands act like a filter, filtering out nitrogen entering the wetlands.



**Figure 18. Average Nitrogen ( $\text{NO}_3+\text{NO}_2$ ), Furu wetland,  $n=8$**

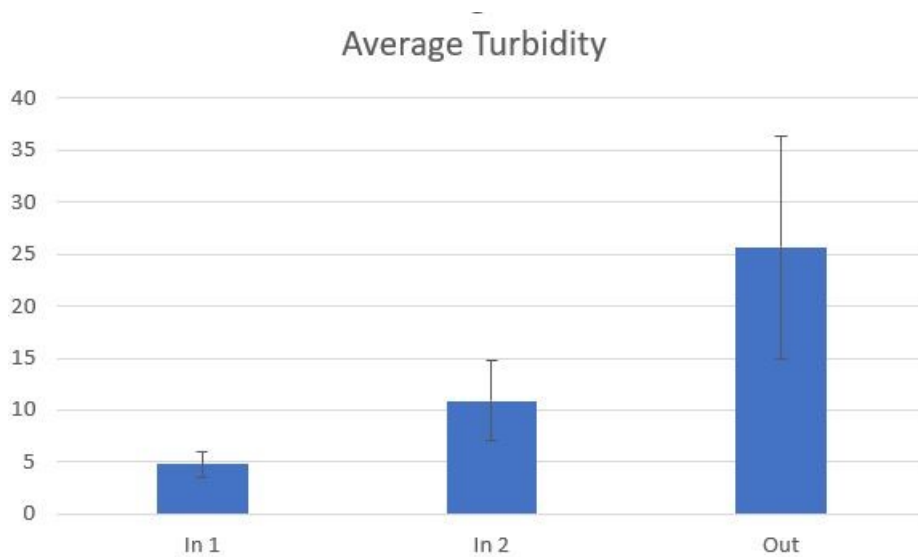
#### 4.3.5 Turbidity

The graph of turbidity for wetland 1 (see Appendix 3) shows that, from May to August, there was a steady rise in turbidity, with the highest turbidity recorded in August (94 FNU), whereas during the latter months, turbidity reduced and were in a more stable range (0.99–11 FNU).

#### 4.3.6 Average turbidity

Figure 19 is a representation of average turbidity in Furu wetland for the entire monitoring period. From the graph, I noticed that there is a rising trend in cloudy water. Inflow 1 had the clearest water, and the outlet of the wetland contained a lot of suspended particles. I

conducted an Anova test, and it showed that there is a significant difference between the turbidity of inflows and outflows ( $P = 0.100413$ ,  $n = 8$ ).



**Figure 19. Average turbidity, Furu wetland, n=8**

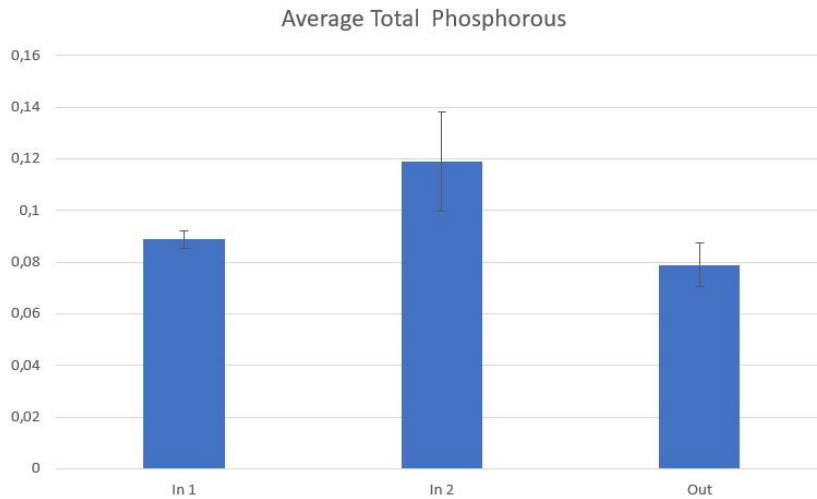
#### 4.4 Söder wetland

##### 4.4.1 Total phosphorous

The graph for total phosphorous for wetland 2 (see Appendix 4) shows that, throughout the monitoring period, the level of total phosphorous was relatively stable (between 0.039 and 0.21 mgP/l), except for September, where the phosphorous level for inflow 2 stood at 0.85 mgP/l.

##### 4.4.2 Average total phosphorous

Figure 20 shows the average total phosphorous and standard error for Söder wetland. I carried out an Anova test to determine the level of significance. The p values I got was 0.072204 which signifies that, there is no significance difference between phosphorous entering into and exiting the wetland.



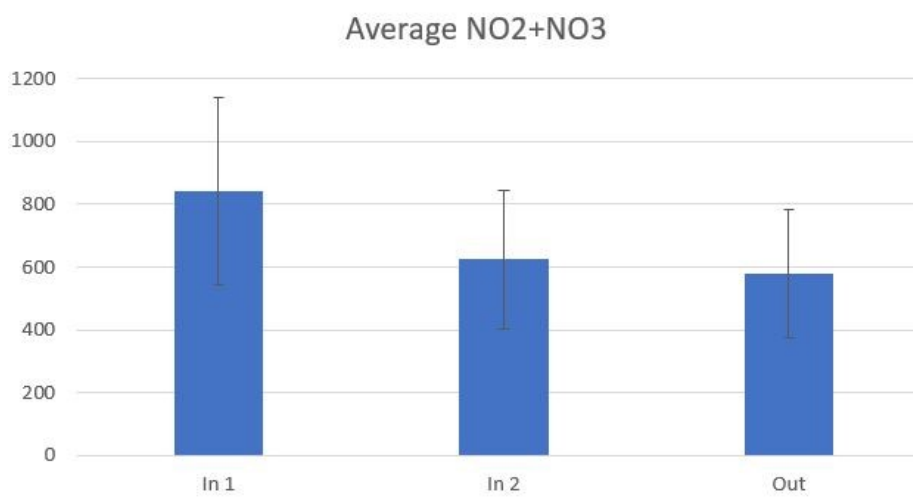
**Figure 20. Average total phosphorous, Söder wetland, n=8**

#### 4.4.3 Nitrogen ( $\text{NO}_3+\text{NO}_2$ )

The graph for combined nitrite and nitrate (see Appendix 5) shows that there was a high inflow and outflow of combined nitrogen between September and December. However, during the early months of monitoring, nitrogen concentration were relatively low.

#### 4.4.4 Average Nitrogen ( $\text{NO}_3+\text{NO}_2$ )

Figure 21 shows a graphical representation of the average of nitrogen inflow and outflow in Söder wetland. To determine the level of significance of nitrogen, I performed an Anova test ( $p = 0.741627$ ), and it showed that there was no significant difference between nitrogen entering and running out of the wetland.



**Figure 21. Average nitrogen Söder wetland, n=8**

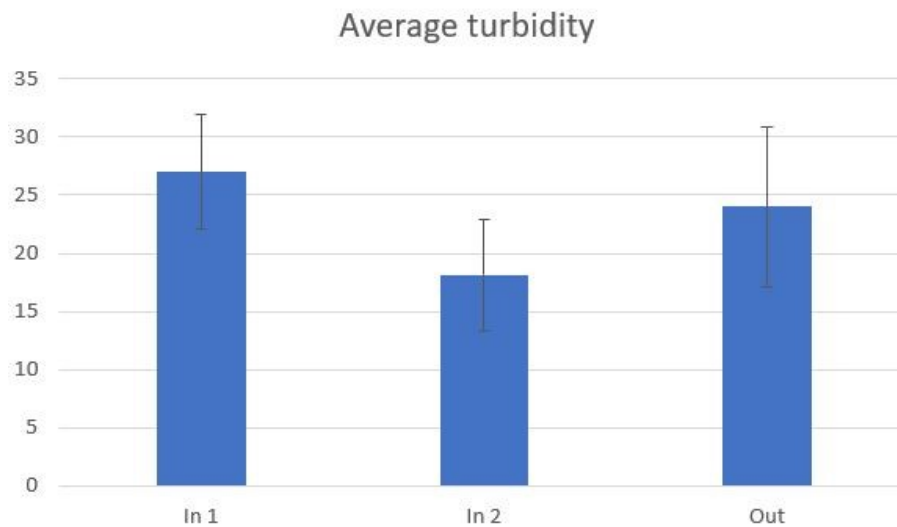
#### 4.4.5 Turbidity

From the graph for turbidity (see Appendix 6), I can say that there is an increasing trend in turbidity. Turbidity is low during the early months of monitoring and high towards the end of the monitoring period.

#### 4.4.6 Average total turbidity

Figure 22 shows the average water clarity and standard error for wetland 2 during the monitoring period. From the graph, I see that, water is more turbid in inflow 1 and inflow 2 has the lowest turbidity.

One can also see the standard error line on each bar graph, which represents the variation in turbidity data collected from the mean. I carried out an ANOVA test, and the p value was 0.910234, which signifies that there is no significant difference between the turbidity at the inflow and outflow sites of the wetland.



**Figure 22. Average turbidity, Söder wetland, n=8**

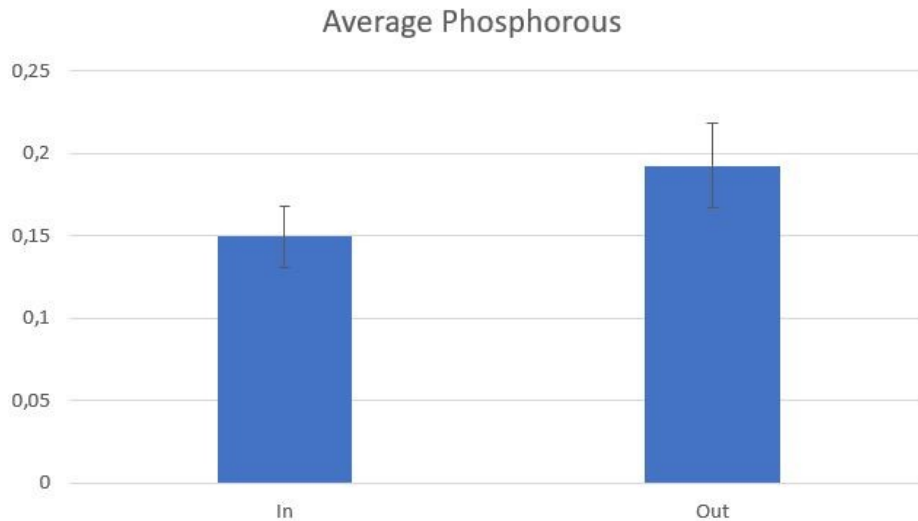
### 4.5 Väst wetland

#### 4.5.1 Total phosphorous

From the graph (see Appendix 7), the highest recorded values of inflow and outflow of phosphorous, 1 mgP/l and 0.91 mgP/l respectively, were recorded in October. The remaining months had relatively low phosphorous levels.

#### 4.5.2 Average total phosphorous

The values of average total phosphorous for Väst wetland is represented below (Figure 23). From the Anova test, I got p values as 0.19782, which implied that there was no significant difference between phosphorous entering and exiting the wetland.



**Figure 23. Average total phosphorous, Väst wetland, n=8**

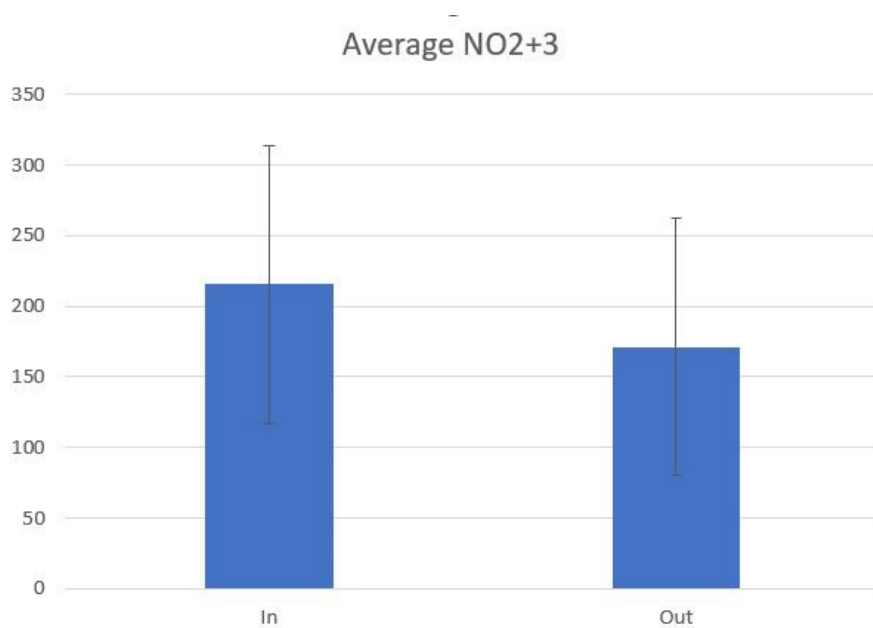
#### 4.5.3 Nitrogen (NO<sub>3</sub>+NO<sub>2</sub>)

The graph of combined nitrite and nitrate (see Appendix 8) depicts that the highest inflow and outflow of nitrogen (NO<sub>3</sub>+NO<sub>2</sub>) were recorded on December 20, 2023, with values of 800 µg/l and 730 µg/l for inflow and outflow, respectively. All values of nitrogen that were less than 5 µg/l were given a constant value of 4,5 µg/l to ease my analyses.

#### 4.5.4 Average nitrogen (NO<sub>3</sub>+NO<sub>2</sub>)

Figure 24 depicts a graphical representation of average nitrogen during the entire monitoring period. From the graph, I notice that, the amount of nitrogen that comes in is slightly higher than what goes out.

Also, with respect to the standard error, I notice that there is no significant difference between the amount of nitrogen that enters and exits the wetland (p = 0.74559347).



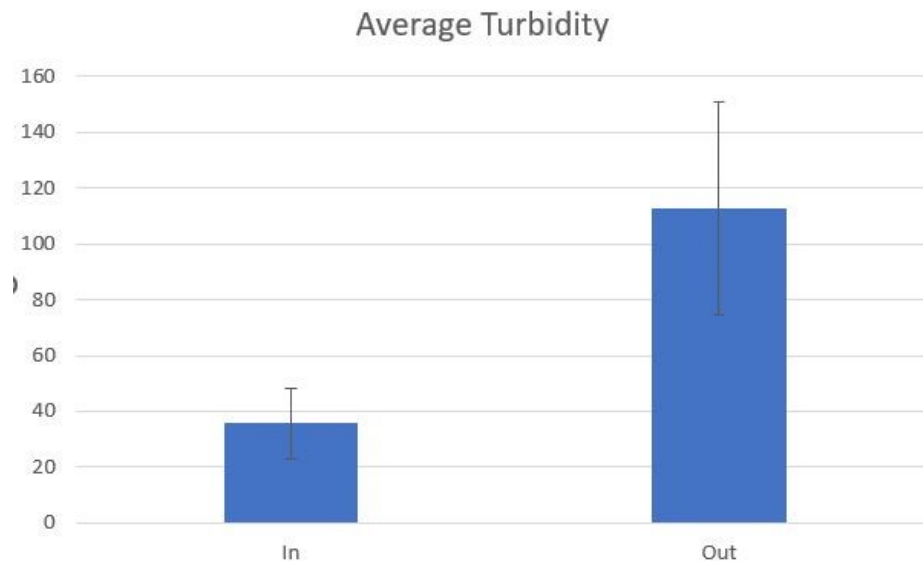
**Figure 24. Average combined nitrogen, Väst wetland, n=8**

#### 4.5.5 Turbidity

The graph for turbidity (see appendix 9) for Väst wetland shows that, water was more turbid during the beginning of the sampling period but towards the later months, turbidity was low.

#### 4.5.6 Average turbidity

Figure 25 represents the average turbidity of Väst wetland. From the graph I noticed that water is clearer at inflow positions than at outflow positions I the wetland. I conducted a statistical test, and it showed that there was a significant difference between water clarity at inflow and outflow positions ( $P= 0.04398$ ).

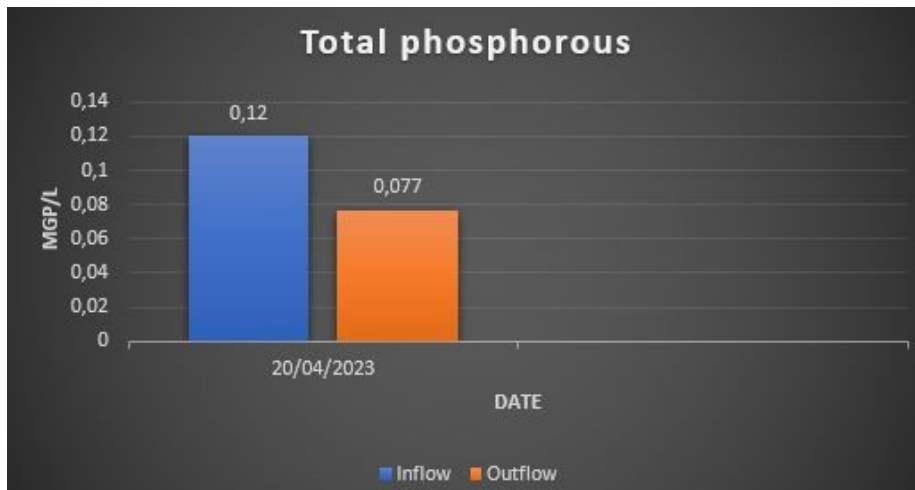


**Figure 25. Average Turbidity, Väst wetland, n=8**

#### 4.6 Täcktom wetland 1

##### 4.6.1 Total phosphorous

The graphical representation of total phosphorous (Figure 26) at inflow and outflow positions in Täcktom wetland 1 in April is represented below. From the graph, the inflow of phosphorous is higher than what flows out of the wetland.



**Figure 26. Total Phosphorous, Täcktom wetland 1**

#### 4.6.2 Nitrogen ( $\text{NO}_3+\text{NO}_2$ )

Nitrogen concentration for Tåktom wetland 1 is presented in Figure 27.

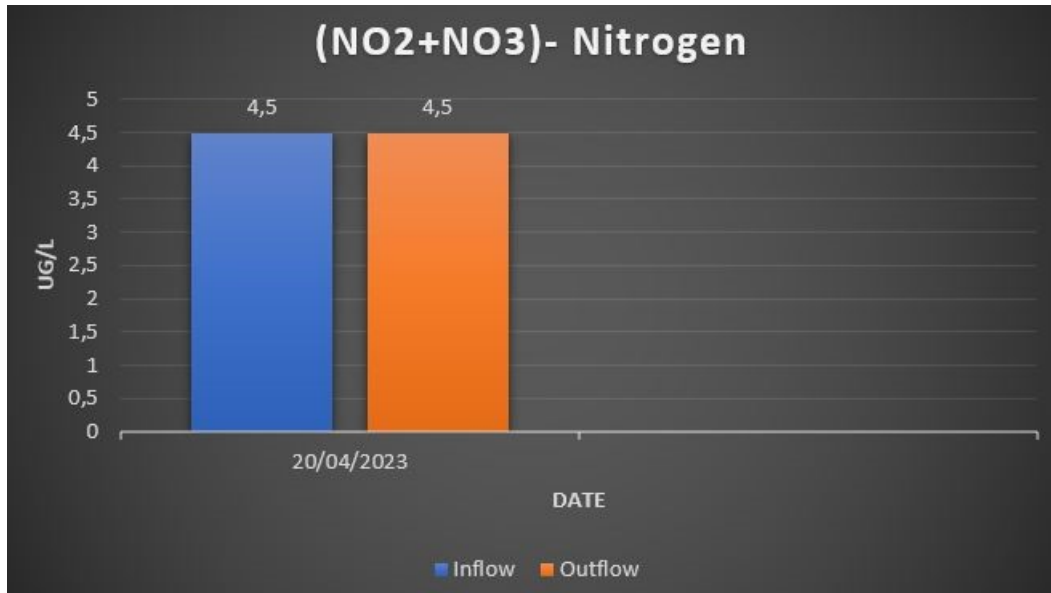


Figure 27. Nitrogen concentrations, Tåktom wetland 1

#### 4.6.3 Turbidity

The graphical representation of turbidity in Tåktom wetland 1 is presented in Figure 28. From the graph I noticed that, the water was turbid (contained suspended particles) at inflow and less turbid at the outflow position (42 FNU and 15 FNU respectively).

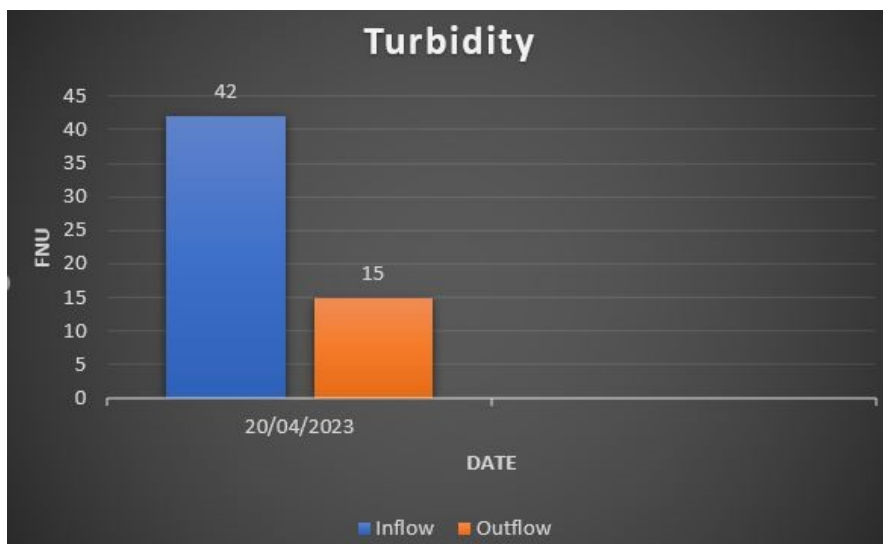


Figure 28. Turbidity, Tåktom wetland 1.

## 4.7 Tåktom wetland 2

### 4.7.1 Total phosphorous

The graph below (Figure 29) represents total phosphorus for Tåktom wetland 2 in April. There was little difference in Phosphorus flowing in and out of the wetland.

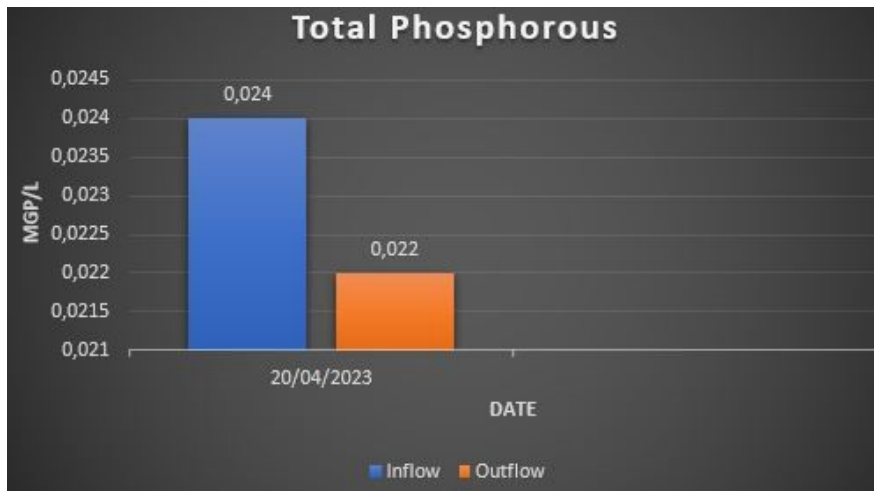


Figure 29. Total phosphorus, Tåktom wetland 2

### 4.7.2 Nitrogen ( $\text{NO}_3+\text{NO}_2$ )

The graph below (Figure 30) shows nitrogen concentrations in April. From the graph, I noticed that there was no significant difference between nitrogen concentrations at inflow and outflow positions.

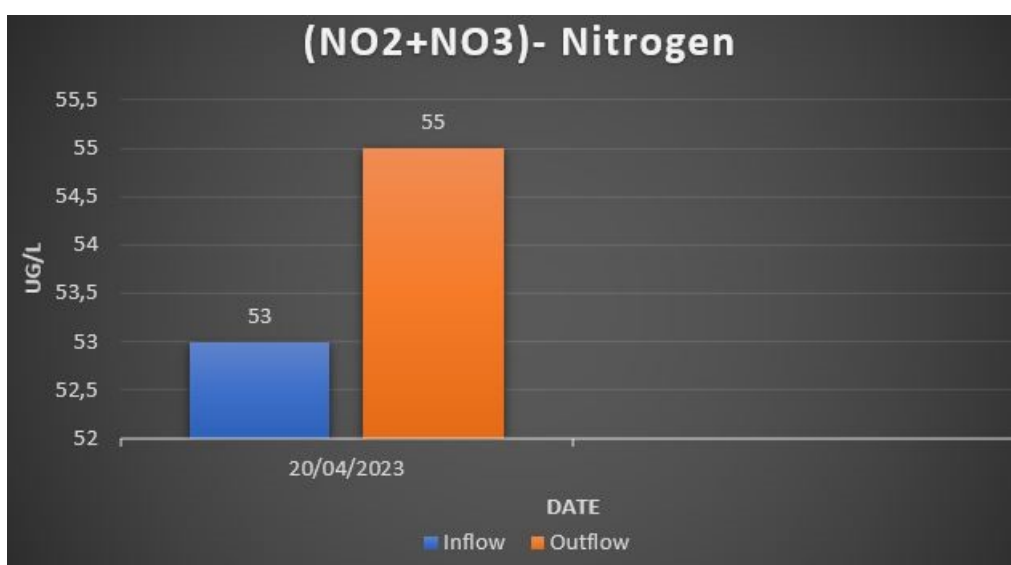


Figure 30. Nitrogen concentrations, Tåktom wetland 2

### 4.7.3 Turbidity

Turbidity was depicted in Figure 31. From the graph, I notice that, there was no significant difference in terms of water clarity at inflow and outflow positions.

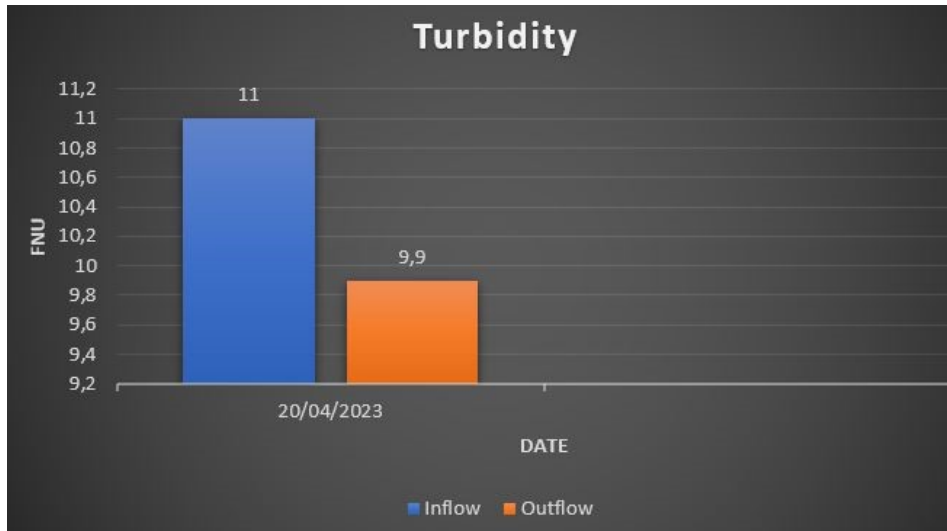


Figure 31. Turbidity, Tåktom wetland 2

## 4.8 Tåktom wetland 3

### 4.8.1 Total phosphorous

From the graph below (Figure 32) I notice that the difference in phosphorus concentration at inflow and outflow positions was highly insignificant.

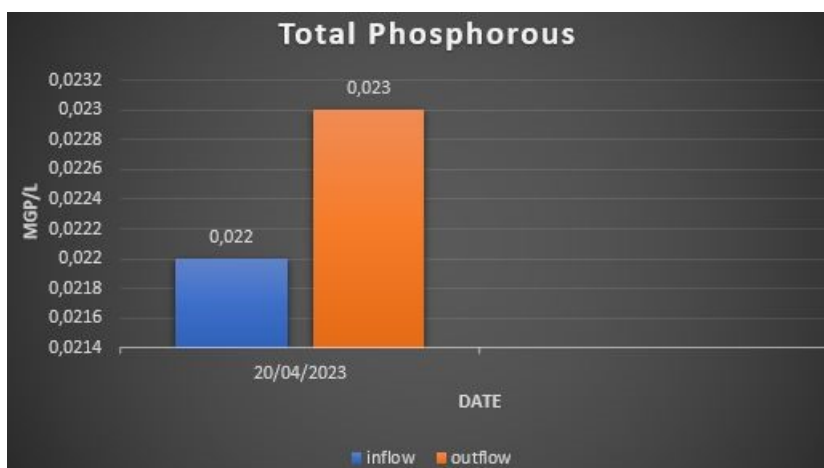
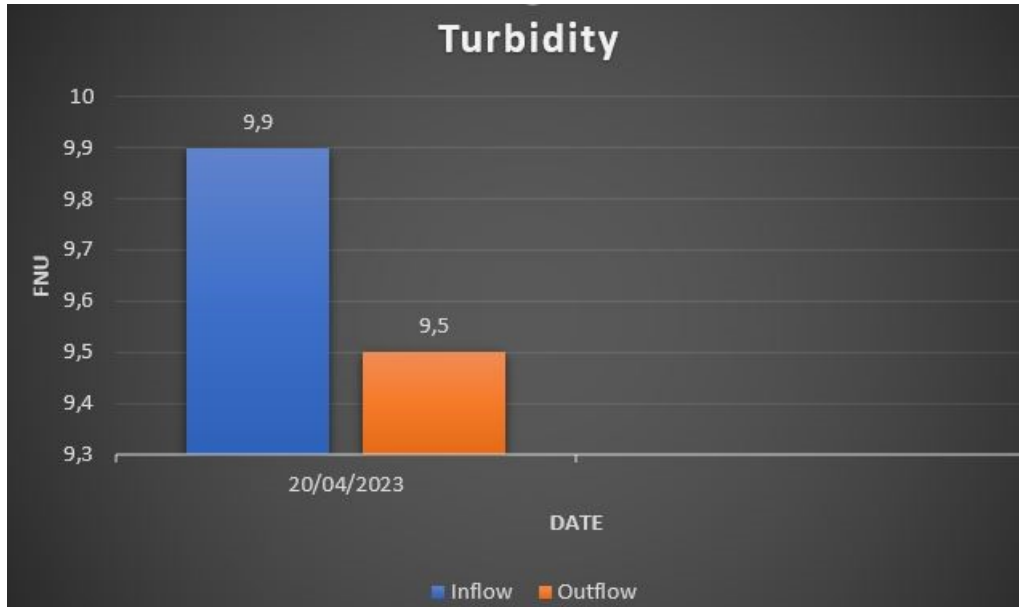


Figure 32. Total phosphorous, Tåktom wetland 3

### 4.8.2 Turbidity

Figure 33 shows turbidity in Tåktom wetland 3. From the graph, I notice very little difference (not significant) in turbidity at inflow and outflow positions, that is, the water clarity was almost same in both sites.



The

Figure 33. Turbidity, Tåktom wetland 3

### 4.8.3 Nitrogen (NO<sub>3</sub>+NO<sub>2</sub>)

From the graph (Figure 34) I noticed nitrogen concentration did not vary much at inflow and outflow sites.

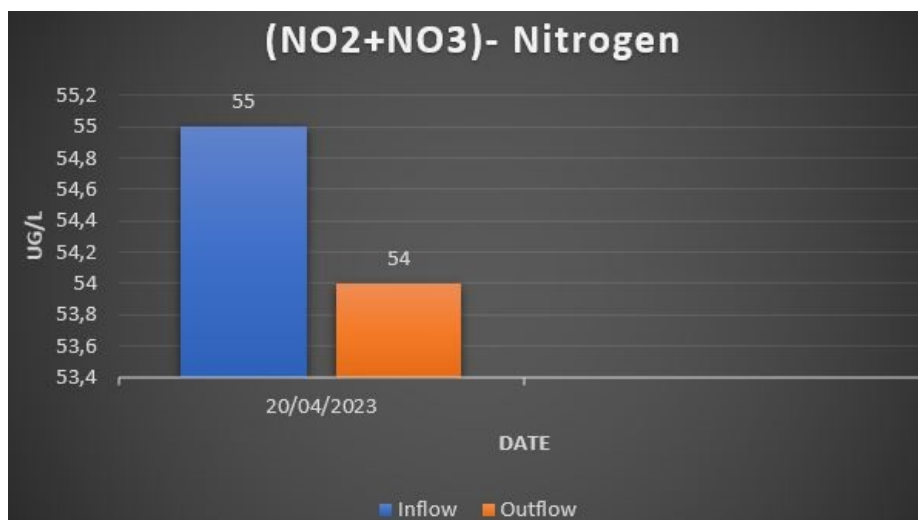


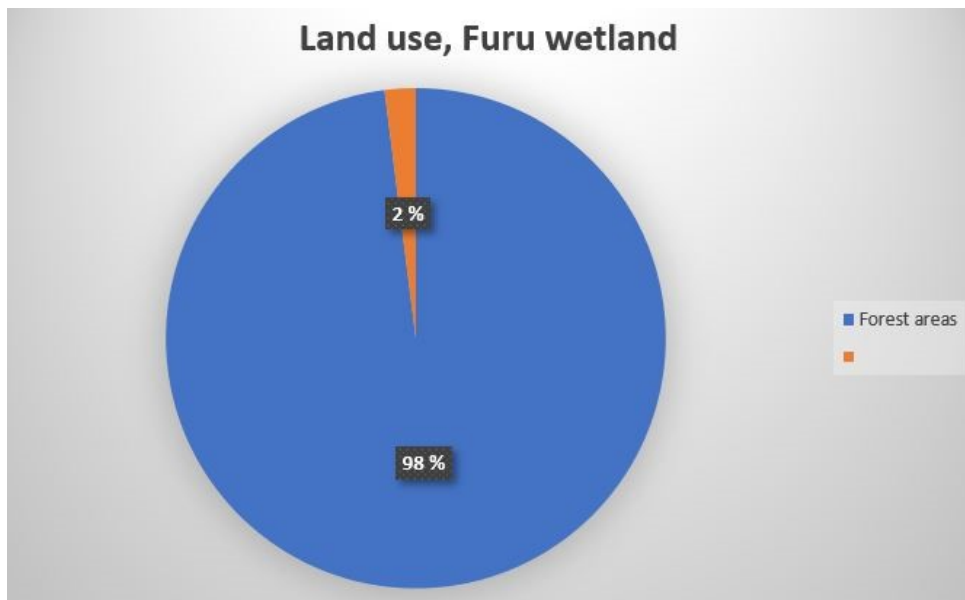
Figure 34. Nitrogen, Tåktom wetland 3

## 5 Discussion

In this section, I'll discuss the results with respect to my research questions or objectives.

### 5.1 Does wetland soil type and land use of catchments areas determine the amount of nutrients that enters the wetlands?

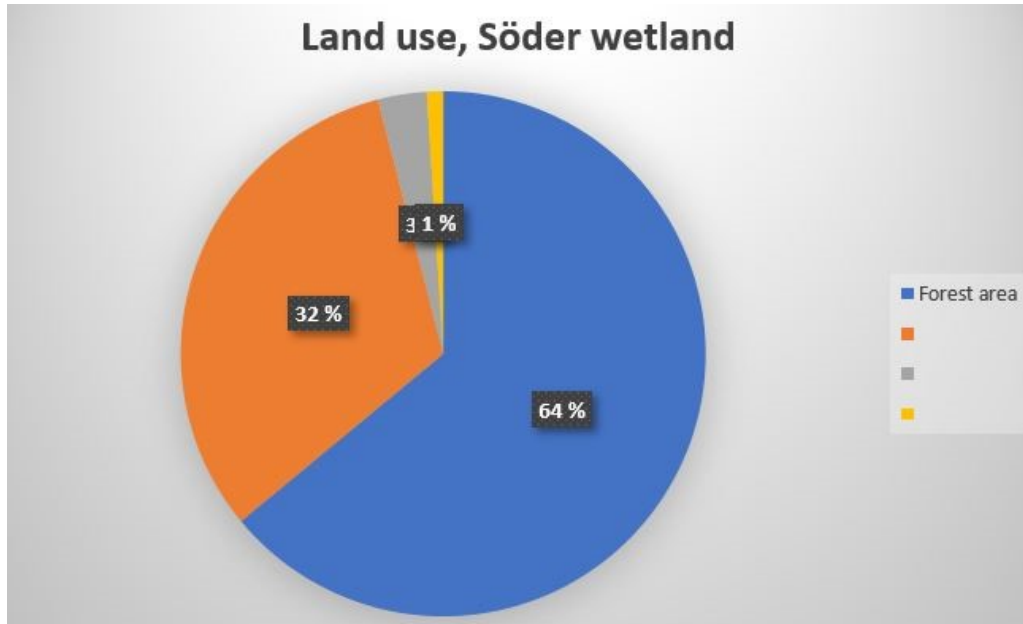
For wetland 1, (Figure 35), I noticed that the amount of phosphorous entering the wetland is relatively low, and this can be attributed to the fact that about 98% of the area is made up of forest landscape. There are little to no human activities around the catchment areas. Also, traces of phosphorus may come from agricultural farmlands (3200 ha). According to Hina et al. (2018), phosphorous and nitrogen are essential nutrients needed for plant growth. The amount of phosphorus needed for optimum growth is rarely sufficient; however, when there is excess, it is often washed off by running water.



**Figure 35. Land use Furu wetland**

Figure 36 shows percentages of land usage in Söder wetland. According to the chart, 64% of the area is forest, 32% is agricultural land, 3% is industrial, and 1% is residential. There are a lot more human activities in the catchment area than in Furu Wetland. The presence of a higher amount of phosphorous (than in wetland 1) is due to excess fertiliser in the farmlands being washed off into the wetlands. This claim is supported by Sharpley et al. (2001), who stated that phosphorus enters farmlands through the usage of fertilisers; the excess amount of fertiliser is being washed off by running water. Also, Bennett et al. (2001) stated that the global phosphorus cycle is being altered by human actions. The introduction

of fertilisers into farmlands, animal feed, and other products causes phosphorus concentration to increase, running the risk of runoff into aquatic ecosystems. It is worth noting that, the amount of phosphorous in Finnish forest has reduced considerably over the past years, and this has led to a reduced amount of phosphorus concentration in forest catchment areas (Holopainen & Lehtikoinen, 2022a).

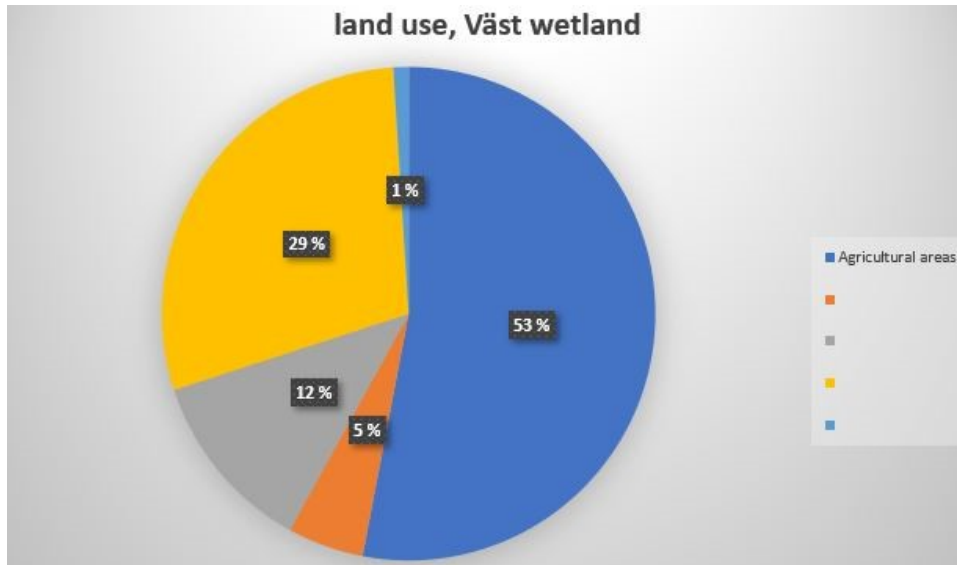


**Figure 36. Land use, Söder wetland**

Figure 37 displays the land use of the catchment area of Väst wetland, which includes 53% agricultural land, 12% industrial regions, 5% residential areas, 29% forest areas, and 1% water. Wetland 3 had the highest phosphorus inflow rate. More than half of the catchment area is made up of agricultural farmlands (53%, 36600 ha). Human activities are largely agricultural, which means that farmers employ fertilisers (containing phosphorus and nitrogen) to increase crop yield, and extra nutrients are carried off into the wetland during the rainy season. This claim is supported by Withers et al. (2014), who state that nutrient load from farm areas is an important factor used to determine eutrophication in water bodies. Holopainen and Lehtikoinen (2022b) stated that nutrient emissions from farmlands and urban areas into rivers and lakes have led to eutrophication of the aquatic ecosystem.

With respect to turbidity for Väst wetland, I noticed that, from the month of June, there is a steady reduction in turbidity at outflow sites. The same can be said for measurement of turbidity at point of inflows, where I witness a steady decrease in turbidity from the month of July.

the chart shows the percentage of land use of Furu wetland



**Figure 37. Land use, Väast wetland**

Land use for Täcktom Wetland 1 is primarily made up of forest areas (38%), agricultural farmlands (30%), and recreational areas (23%). Traces of phosphorus found in the wetland might be a result of runoff from agricultural lands. Another reason could be that the soil in the catchment area is primarily made up of sand, which cannot retain flowing water. Also, turbidity proved to be quite high. It strengthens our claim since there is a positive correlation between turbidity and phosphorous (Villa et al., 2019)

For Täcktom wetland 2, the land use of the catchment area is made up of forest areas (21%), farmlands (31%), and recreational areas (44%). Total phosphorous concentrations (in Täcktom wetland 2) were low compared to phosphorus for Täcktom wetland 1. Turbidity was low as well compared to turbidity in wetland 1 (low amount of phosphorus implied fewer suspended particles found in water).

Forest areas cover about 99% of the catchment area of Täcktom wetland 3, and the remaining 1% is made up of farmlands. The total phosphorus concentration in the wetland was low, as was the turbidity. In most soils, total phosphorous availability is low, averaging 0.6% (Crop Nutrition, 2023). So, I can conclude that the small traces of phosphorous found in wetland 3 are a result of the fact that there was not excess phosphorous available that could have been carried by runoff into the wetland.

The soil type for Täcktom wetlands (wetland 1, 2, and 3), are mainly sand soil. The sandy particles in sandy soil have large spaces between them compared to clay soil and is

therefore not ideal for water retention. Also, it is prone to erosion, that is, it can easily be displaced by the runoff of strong winds or human activities.

### **5.2 To what extent does the wetland act as nutrient filters, that is, does it help curb eutrophication?**

The wetlands were being examined to see if they retained nutrients or not. In wetlands 1 and 3, the amount of phosphorous flowing out of the wetland was greater than the amount entering the wetlands. This could be because wetlands are still relatively new and there are not enough plants to filter the phosphorus. This implies that the wetlands do not retain nutrients. Wetland 2 has proven to be the most effective wetland as the amount of phosphorous entering (inflows) into the wetland was higher than the amount of phosphorous leaving the wetland. Reddy et al. (1999) argued that, the higher the phosphorous retention rate of wetlands and streams, the higher the water quality of downstream and an overall reduction in eutrophication.

### **5.3 Is there any significant difference between nutrients entering and flowing out of the wetland?**

The variables being discussed here are phosphorous, nitrogen and turbidity. Total phosphorous concentration were significantly different at inflow and outflow positions of Furu wetland, that is, according to this study the amount of phosphorous flowing out is higher than then amount coming in. One of the important factors of wetland is to retain phosphorous reduce eutrophication downstream. So, if the phosphorous flowing out is higher than the amount entering it could mean that the wetland is inefficient in absorbing nutrients. Reddy et al. (1999b) reported that phosphorous is one of the main wetland nutrients limiting factor that prevent estuarine and freshwater ecosystem from having good qualities. Excess Phosphorous concentration in wetlands leads to the growth of algae which limit or reduces the amount of fresh water available. One way to improve the water quality of the wetland is by planting vegetation or allowing the existing vegetation to grow since the wetland is relatively new. Vegetation plays an important role in improving the water quality of wetlands; the vegetation absorbs these nutrients which are vital for the process of photosynthesis. Also, depending on the velocity of inflow, vegetation can serve as barrier against water flowing in at high velocity thus reducing the speed (Johannesson, 2008)).

The significance level of turbidity was tested with the use of Anova test and, there was a significance difference between turbidity at inflow and outflow positions. High level of phosphorous and turbidity are highly correlated (Carter et al., 2022), water bodies with a high phosphorous concentration will usually have a high level of turbidity since they both deal with suspended particles. Furu wetland had a high turbidity at its outflow and it was the same with of phosphorous concentration. High phosphorous concentration contribute massively to the growth of microalgae (Yaakob et al., 2021). Since these algae blooms are found at the surface of water, it impedes visibility thus high turbidity.

Total phosphorous and nitrogen concentration proved to be insignificant at both ends of Söder wetland, in other words, the wetlands maintained an almost same inflow and outflow of nutrients. The amount of phosphorus flowing out of the wetland is less than what is coming in the wetland which means that the wetland acts or serves like a “sponge” soaking up nutrients. Turbidity for the wetland showed no significant difference at both ends and this may be due to more optimal functioning.

Lastly, phosphorous and nitrogen concentration for Väst wetland proved to have no significant difference at both inflow and outflow positions. This might be due to the fact that the wetland is a relatively new wetland and the vegetation is not yet at optimum level to act as nutrient absorbers. Cottet et al. (2013) reported that, precipitation can increase the volume of runoff alongside contaminants into wetlands. Since there is no significant difference in the amount of nutrients flowing in and out of the wetland, During rainy season, the running water flows into the wetland with high velocity since there is little or no barriers (due to young vegetation), the water flows out with almost the same speed.

Turbidity were quite high and proved to be significantly different at both ends; with turbidity at outflow being higher than at inflow. This can be associated with the fact that the wetland has a high amount of phosphorous which leads to the growth of algae. This alga makes the water turbid.

#### **5.4 Gap Identification**

The length of the monitoring period; eight months (Furuborgsvägen, Söderlandsvägen and Västankvarnsvägen wetlands) and two months (for Täktom wetlands) is not enough time to draw meaningful conclusions as to whether the wetlands are functioning at an optimal

level and whether there are significant differences between nutrients at inflow and outflow sites. This establishes the need for further research and the researcher should aim at carrying out monitoring or data collection for quite a long time so as to have a more meaningful conclusion.

### **5.5 Limitation of this thesis**

The data collection period cuts across all 4 seasons in Finland. So, during winter it was difficult to collect water samples as the water channels were frozen at times. Also, during summer, the water channels ran almost dry and collecting of water samples was quite challenging. Some of the quality of the coordinates from Täktom wetlands could not be checked, which caused some of the data to be unclear. Also, it was quite challenging trying to collect data during winter due to very cold weather conditions.

## **6 Conclusion**

Following investigations and analysis, this study demonstrates that wetland 2 is the most effective wetland in terms of nutrient retention (phosphorous) and thereby curbing eutrophication. This is due to the fact wetlands 2 is the oldest of the wetlands, and the characteristics that help absorb phosphorus are at their peak among other reasons.

The importance of catchment areas in determining the quantity of nutrients that flow into wetlands cannot be overstated. This study demonstrates that the surroundings of wetlands influence what enters the wetlands. This study indicated that watershed areas with agricultural lands were key predictors of phosphorus concentration in wetlands.

It is worth mentioning that, conclusions cannot be made based on data for Tåktom wetlands because the data used in this study had a small sample size. To be able to draw important conclusions, the monitoring and data collection period needs to be lengthy.

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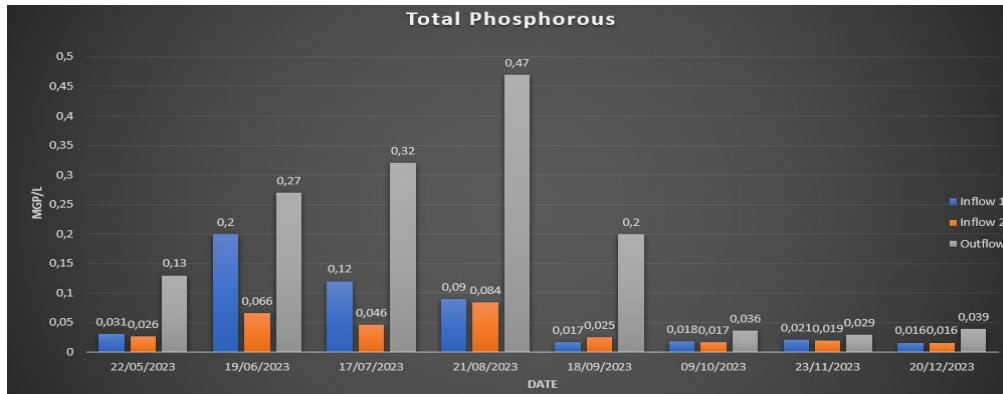
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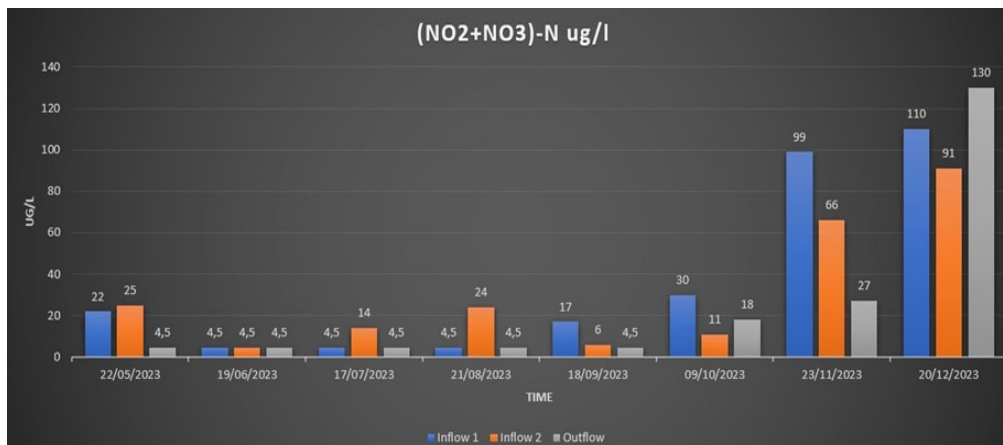
## 8 Appendix

### Appendix 1



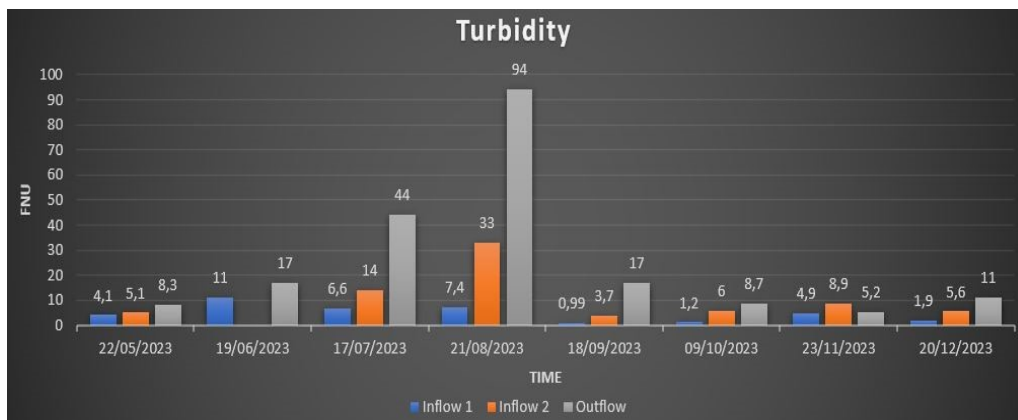
**Total phosphorous concentration Furu wetland**

### Appendix 2



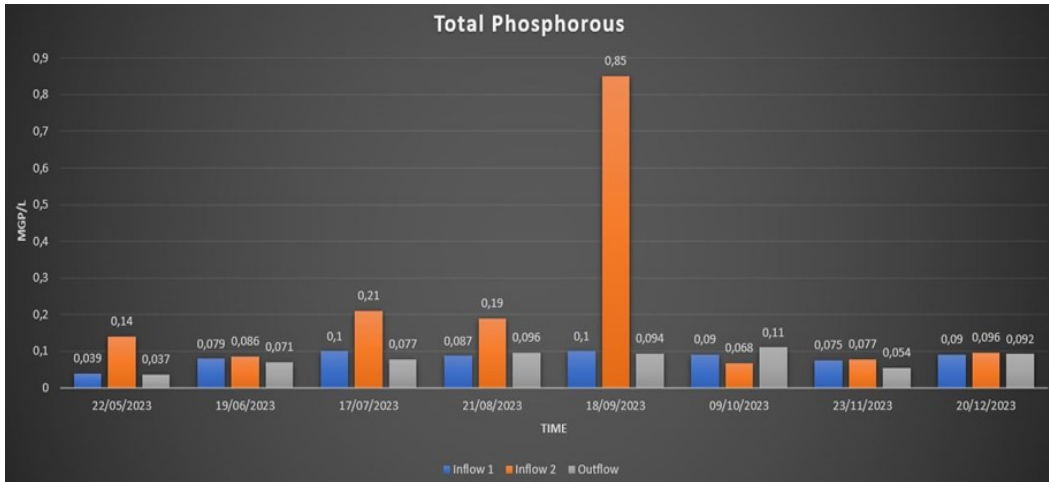
**Nitrogen concentration Furu wetland**

### Appendix 3



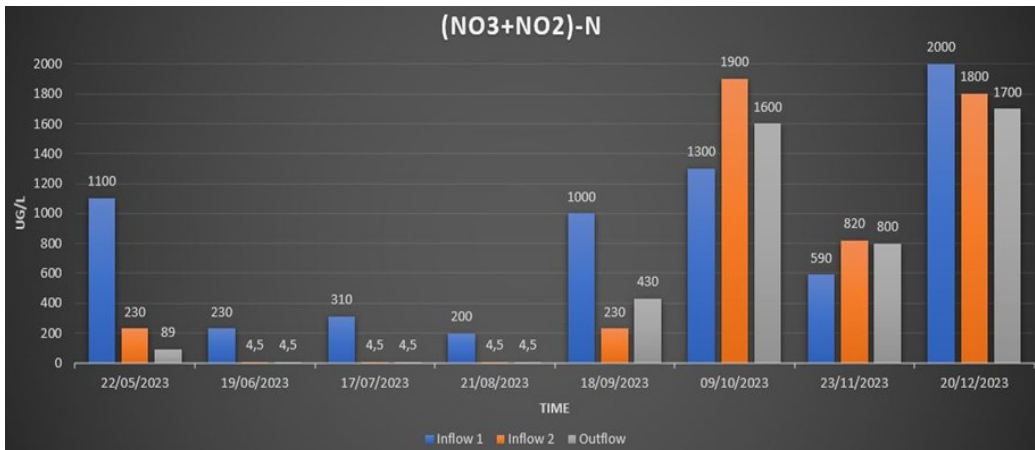
**Turbidity Furu wetland**

**Appendix 4**



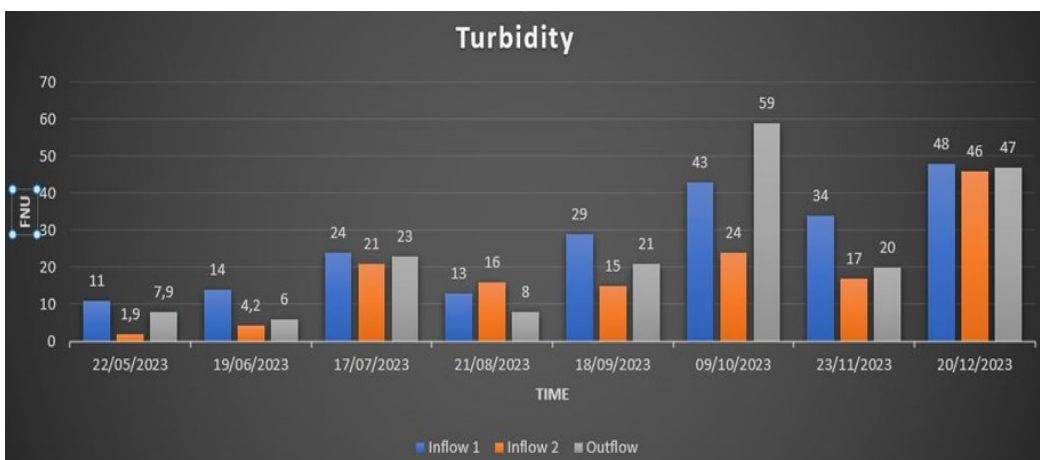
**Total phosphorus Söder wetland**

**Appendix 5**



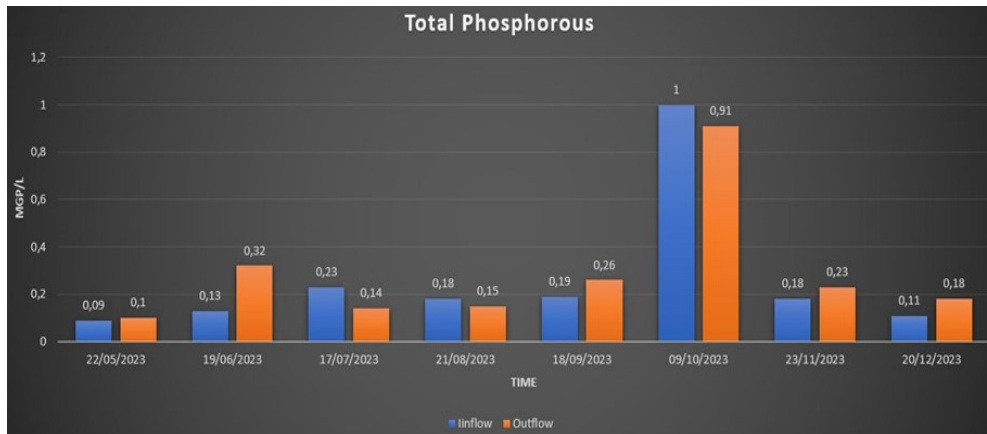
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**Appendix 6**



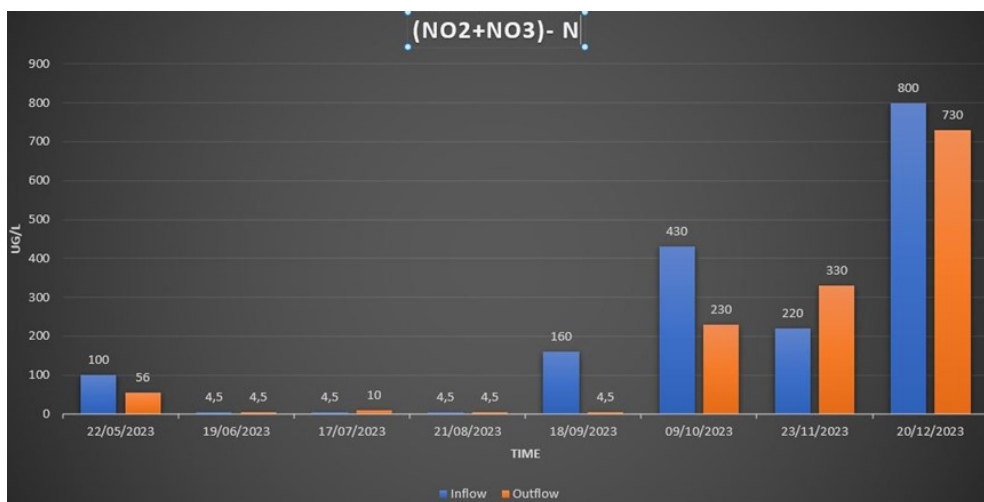
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## Appendix 7



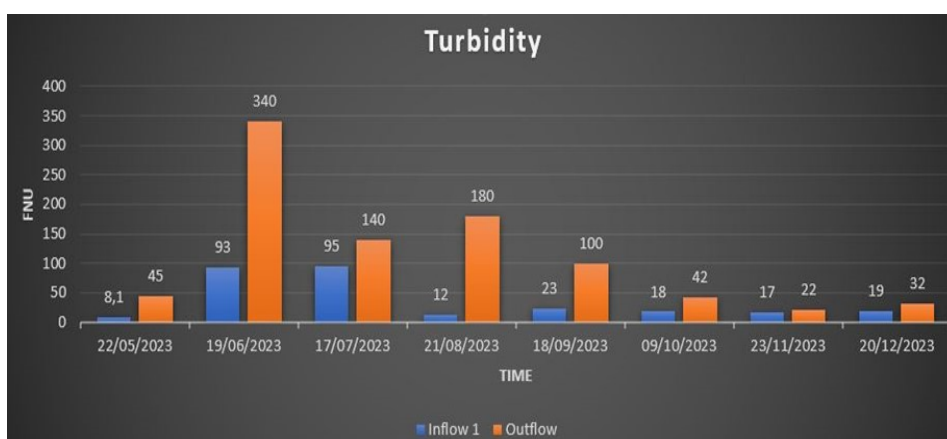
### Total phosphorus Väst wetland

## Appendix 8



### Nitrogen concentration Väst wetland

## Appendix 9



### Turbidity Väst wetland