Internship

2nd year engineering School

2013/2014

ÉCOLE NATIONALE SUPÉRIEURE D'INGÉNIEURS DE LIMOGES

Phosphorus balance and thermal stratification of Vombsjön lake

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Université de Limoges

Spéciality

Water & Environnement

Acknowledgments

First, I would like to thank Mr Kenneth PERSSON, head of Research at Sydvatten who managed this project and allowed us to come to Sweden. Then I thank Mrs Linda PARKEFELT, Research leader at Sydvatten, who took so much time to help us and involved a lot in our project.

I would also like to thank Mrs Geneviève FEUILLADE, my french teacher at ENSIL (National Engineering School of Limoges), for having followed the advancement of the project and given me some precious advice.

My thought also goes to the employees of Sydvatten working at Vombverket treatment plant who gave their time to help me with the equipment

I'm not forgetting three of my friends, Nicolas CHARLOT, Kevin TAVARES and Ibrahim SALL, who helped me a lot with their good advice.

Table of contents

Figures presented

Tables presented

Introduction

Sydvatten AB, located in South of Sweden, is one of Sweden's largest producers of drinking water. This company, owned by 16 municipalities, produces drinking water of a high and consistent quality for 900,000 inhabitants of Scania region.

Scania covers less than 3% of Sweden's total area, but the population of approximately 1,260,000 represents 13% of Sweden's total population. Thus, Sydvatten which has been implanted there since 1966, provides water supply for almost 8% of Swedish population, which is actually a big deal for a 70 employees society.

One of Sweden's particularities is that drinking water is taken from lakes. Indeed 8,7 % of Sweden's area is lake water. To compare, in France only 0,3 % of total area is water.

Sydvatten takes its water from Bolmen lake in Småland, Vombsjön lake in Scania and even Ringsjön lake also in Scania if there is a problem with the two others. This water is treated by two purification plants, Vombverket and Ringsjöverket, and distributed to the population with a 2,300 liters per second flow.

This internship and project took place in Vombsjön lake and at Vomberket purification plant and was managed by Mr Kenneth Persson, head of Research and Mrs Linda Parkefelt, Research leader at Sydvatten. It was about phosphorus balance and thermal stratification in Vombsjön lake.

Around of Vombsjön lake, there is huge agricultural areas which provide it by its inlets with a lot of phosphorus. This can lead to an eutrophication phenomenon and algal blooms which represent a big problem, especially for a lake which is to supply high quality drinking water.

The project consisted in studying the phosphorus behaviour during the summer, the impact of some parameters on it, and the thermal stratification. To achieve this, we've been going out on the lake every day for one month, in July, and collecting data at different points in the lake.

The results we finally got and exploited, should provide Sydvatten an overview on the phosphorous balance of Vombsjön lake during the summer and help anticipating potential bad phenomena which could occur in the future.

This report, relating the project, will begin with a state of the art, that is to say a resume of the current situation of the lake and an explanation of the nature of the problems it is faced with. Following a part relating the material and the methods used to achieve the project, we will present the results and the conclusions.

I State of the arts

1. Vombsjön lake

1.1 Generalities about the lake :

Vombsjön lake (***figure 1***) is situated in the South of Sweden, in the Scania region. It is 20 km to the East of Lund and lies in the municipalities of Lund, Eslöv and Sjöbo. This lake is mostly surrounded by agricultural land, meadows, pastures and forests.

Compared to others Swedish lakes, Vombsjön lake is not that big, with a surface of around 12 km^2 and a maximum depth of 16 metres.

The following table (*table 1*) sums up the main information about Vombsjön lake :

Table 1 : Main information about Vombsjön lake (from Wikipedia)

Location	Scania, Sweden
Coordinates	55°40′N 13°35′E
Surface area	11,97
Water volume	78,274 km^3
Average depth	6,6 m
Maximum Depth	16 m
Watershed Surface	447 km^2

Vombsjön lake is a fresh water reservoir of Sydvatten. Water is pumped with a 1 m^3/s flow, filtrated so that particules, reeds and muds get separated and the water goes into ponds of artificial infiltration. The water seeps slowly through the alluvium of gravel and sand to a natural ground water storage facility. After two or three months the water is pumped up to one of the 120 wells and on to the Vomb Water Purification Plant for final processing.

Figure 1 - Vombsjön lake in July

1.2 Inlets and Outlets :

Vombsjön lake has four inlets and one single outlet (figure 2). The main inlet is Björkaån and is situated in south east of the lake, and the two others are Torpsbäcken and Borstbäcken situated at North East and North West of the lake. The last one, at the North East between 2 and 3 doesn't appear on most of the maps and there are no data about it, so we do not take it into account. Concerning the outlet, it is called Kävlingeån and is in the North West.

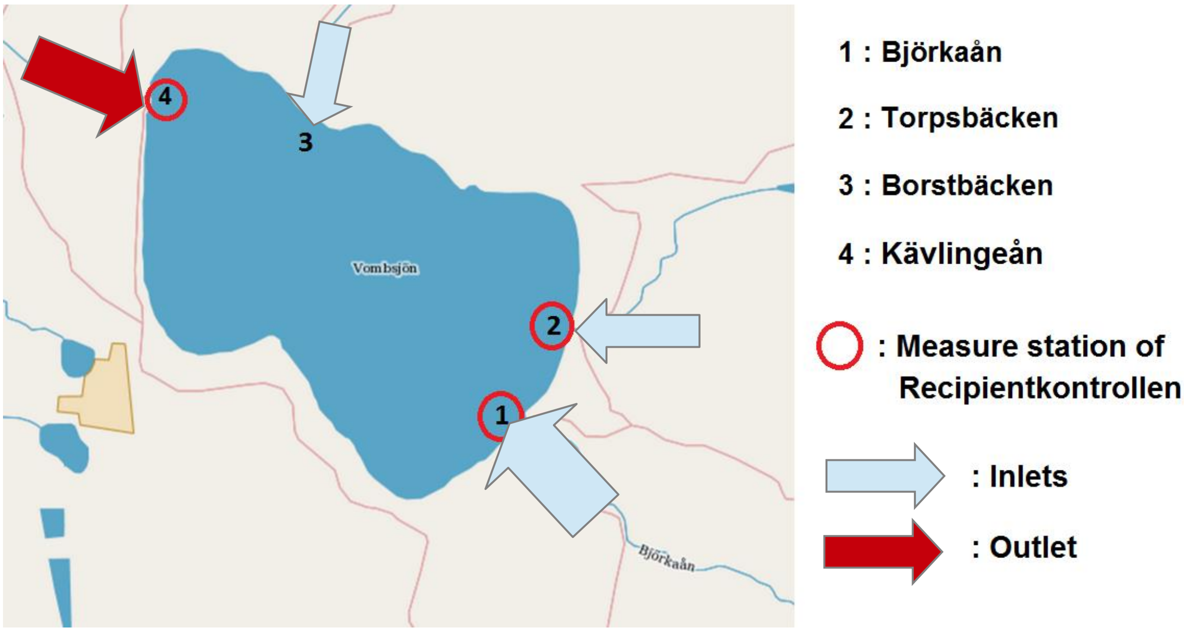


Figure 2 - Map of Vombsjön lake and its inlets and outlets

<u>1.3 The catchment area :</u>

The catchment area (*figure 3*), which extends to the East of the lake, has a surface area of 447 km^2. As the lake is situated in a wild area and far from big towns, it is mostly rounded by forests, meadows, pastures and agricultural land.

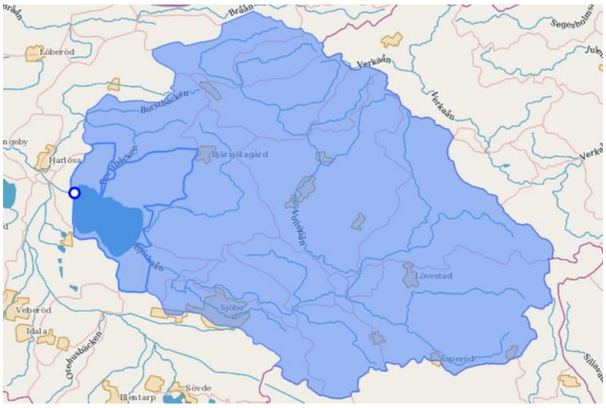


Figure 3 - Vombsjön lake catchment area

Agricultural areas, because of fertilizers that are added on the fields, are big sources of phosphorus and is carried into the lake.

This can lead to a phenomenon which is not wished for a lake providing drinking water : the eutrophication.

In a few words, this happens when there is a big quantity of nutrients and organic matters such as phosphorus in a lake, enabling the algal growth, and leading to a slow degradation of the lake and the quality of its water.

2. Vombsjön lake and the eutrophication phenomenon

<u>2.1 The eutrophication phenomenon :</u>

Eutrophication is the result of a high concentration of organic matters and nutrients in an aquatic system (lake, ocean, river). Algae take up nutrients and consume oxygen dissolved in the water for their growth, creating a state of hypoxia (lack or absence of oxygen) if no more oxygen is supplied.

Algal growth and oxygen depletion in the water finally disrupt the ecosystem causing a reduction in specific fish and others animals. Moreover, the algae produce toxins which are harmful to animals and humans. The water becomes cloudy, typically coloured in a shade of green. Eutrophication also decreases the water quality and when it interferes with drinking water treatment, health problems can occur.

As it is the limiting factor of algal growth, the phosphorus is considered as the nutrient mainly responsible of the eutrophication phenomenon in freshwater systems.

Weathering and land runoffs bring phosphorus into the lake water. The phosphorus is transported as phosphate dissolved in the water, the main form of phosphorus in aquatic systems, or adsorbed to particles. Once it is in solution, phosphate is consumed by algae and following the death of the algae, it sinks to the bottom. It is the same for the phosphorus that is adsorbed to particles which directly sinks to the bottom (*figure 4*).

Thereby the main part of phosphorus, is concentrated at the bottom of the lake and bound to the bottom sediments.

The phosphorus contained in sediments can be released into the water when the eutrophication phenomenon becomes more and more severe. Generally, aerobic conditions are considered to promote phosphorus sorption by the sediments and anoxic conditions to favor phosphorus release. This is generally an important factor for lake eutrophication.

Thus, when a study about the eutrophication in a lake is led, it is important to follow the phosphorus cycle (*figure 4*) and it can be interesting to see how much phosphorus is bound to the bottom sediments.

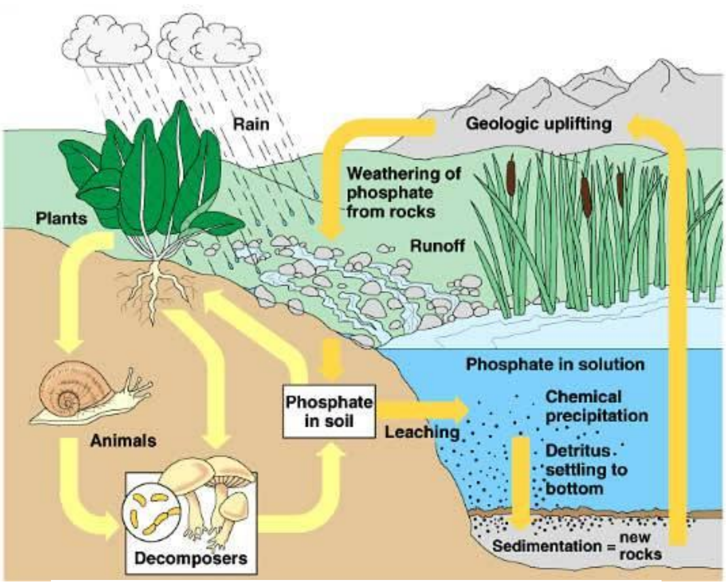


Figure 4 - The phosphorus cycle

2.2 The fractions of phosphorus bound to the bottom sediments :

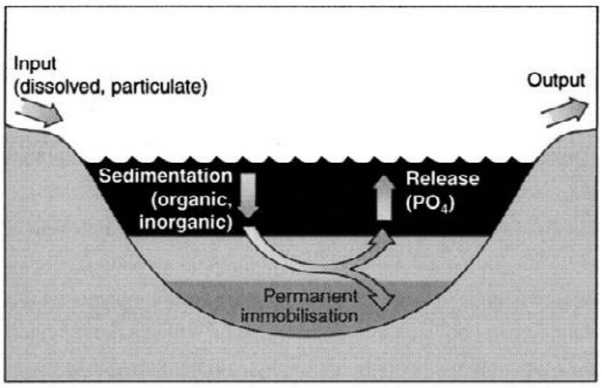
Since it is where the quantity of phosphorus is the highest in the lake, it is really important to study bottom sediments and fractions of phosphorus in the sediments (*figure5*)

When the phosphorus is entering the lake, a certain amount of it is retained in the sediments. The retention percentage depends on the hydraulic retention time, as demonstrated through empirically established models of the Volenweider type :

$$P_{lake} = \frac{P}{1 + Tw^{0,5}} ,$$

relating in-lake phosphorus (Plake) to inlets concentration (P) and hydraulic residence time (Tw).(Vollenweider, 1976; OECD, 1982)

When it sinks to the bottom, the phosphorus can be bound to iron (Fe), Aluminum (Al), Calcium (Ca) and organic matters (Org).



P-forms in the sediment:

- Dissolved (PO_4, organic P)
- Particulate

Iron:	Fe (III) hydroxides, Fe (OOH), (ads.)
	Strengite, Fe PO_4
	Vivianite, $Fe_3 (PO_4)_2$ 8 H_2O
Alum:	Al $(OH)_3$ (ads.)
	Variscite, Al PO_4
Calcium:	Hydroxyapatite, $Ca_{10} (PO_4)_6 OH_2$
	Monetite, Ca H PO_4
	Calcite (ads.)
Clay:	(ads.)
Organic:	"Labile"
	"Refractory"

Figure 5 - Schematic representation of phosphorus pathways, when entering a lake and some of the most important phosphorus compounds found in the sediments (from Sondergaard et al., 2011)

Depending on which element the phosphorus is bound to, the conditions for it to be released in the water are different. The aim is to give a more precise description of the potentials for phosphorus release from the sediments and to predict its future influence on lake water phosphorus concentrations.

The following fractions are those regarded as labile and can be released in solution :

- Iron bound (Fe-P)
- Labile bound (Lab-P)
- Organic bound (Org-P)

The iron bound fraction constitutes a majority of the phosphorus released from the bottom sediments in anoxic conditions.

Redox conditions at the surface of the sediment is the classical explanation of sediment water interactions. Einsele (1936) and Mortimer (1941) very early described how the phosphorus release was determined by redox-sensitive iron dynamics. In oxidized conditions, phosphorus is sorbed to iron (III) compounds, while in anoxia iron (III) is reduced to iron (II) and subsequently both iron and sorbed phosphate return into solution.

The phosphorus binding capacity of the oxygenated sediment layer decreases with increasing pH as hydroxyl ions compete with phosphorus ions. Thus, when the pH is higher, phosphorus in solution bounds to the bottom sediments and when the pH is lower, the phosphorus bound to sediments is released back into solution.

In aerobic conditions, the phosphorus contained in Org-P bound is degraded and in turn bounds to Fe-P or Labile-P. Thus, it indirectly contributes to phosphorus release in the lake.

The Labile-P is a fraction available for primary production.

2.3 The origins of phosphorus :

Phosphate adheres tightly to soil, so it is mainly transported by erosion from land to water. Once translocated to the lake, the extraction of phosphorus into water is slow, hence the difficulty of reversing the effects of eutrophication.

The sources of phosphorus (*figure 6*) are detergents, industrial and domestic run-off, and fertilizers. With the prohibition of phosphate-containing detergents in the 2008, industrial and domestic run-off and agriculture have emerged as the main contributors to eutrophication.

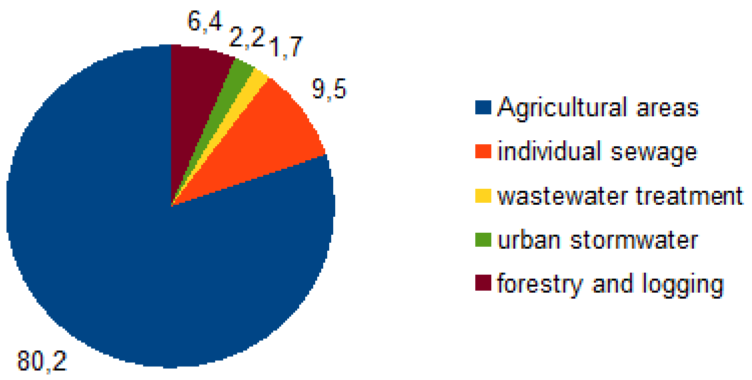


Figure 6 - The origins of phosphorus for Vombsjön lake (from "vattenweb")

This diagramme puts in light the fact that agricultural areas and individual sewage are the main source of phosphorus for Vombsjön lake.

3. Thermal stratification of the lake

3.1 What is the thermal stratification ?

Thermal stratification is the separation of the lake into three layers (*figure 7*) :

- Epilimnion which is at the top water of the lake. In spring and summer, this layer of water becomes warmer and its density lower. Influenced by the wind, it is well mixed and we can find dissolved oxygen at the same concentration throughout the layer.
- Metalimnion or thermocline, which is the middle layer. It is where we have the most important drop in water temperature and dissolved oxygen concentration.
- Hypolimnion which is the bottom water layer, with the higher density, lower temperature and dissolved oxygen concentration. Sometimes, it is even in anoxia state.

We can observe this stratification phenomenon when the weather is warmer in summer. The temperature of the upper layer of the lake increases and it's density decreases, while the layers deeper down keep the same temperature and density. Due to the difference of density, layers do not mix with each other.

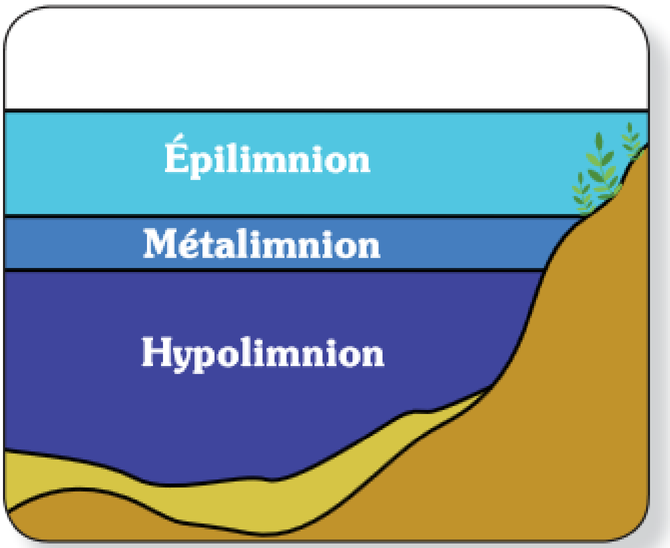


Figure 7 - Drawing of the thermal stratification

3.2 Bad effects of thermal stratification

As the different layers are separated by the thermocline, the oxygen that usually comes from the surface cannot access the bottom water of the lake and can only stay in the upper layer, the Epilimnion. Thus, as long as there is a thermal stratification on the lake, the bottom is not supplied with oxygen but full of organic matters. Moreover, the oxygen is consumed by the decomposition process, decreasing more and more the dissolved oxygen concentration. With severe thermal stratification in a lake, the quality of drinking water can be adversely affected.

4. The aim of the project

Considering the current situation and problems of the lake, it was important to do investigations on it.

First, we decided to focus on the phosphorus balance and most particularly on the phosphorus contained in and bound to the bottom sediments since it is where there most probably lies the highest quantity of this limiting nutrient.

To have an overview on the phosphorus balance, we needed to know how much phosphorus was coming into the lake through the inlets, leaving through the outlet, and how much was bound to the bottom sediments. And it is important to keep in mind that the phosphorus bound to the sediments can be released into the water.

Finally we wanted to investigate the lake to know if there were a stratification during the summer and if it was permanent or just for a temporary period of a few days.

II Material & Method

The investigations that have been done during the summer on the Vombsjön lake are divided into two parts :

- Bottom sediments sampling and analysis of the phosphorus fractions it contains. The goal of this study was to estimate the quantity of phosphorus bound to the bottom sediments in the whole lake. Thanks to the data about the inlets and outlet flows found on the internet, we are able to assess the phosphorus cycle and mobility.

- Checking some parameters, in the water at each meter of depth, which are water quality indicators. The most important parameters are the temperature and the dissolved oxygen because they permit to see if there is a stratification of the water in the lake during the summer and if there is a risk of phosphorus release due to anoxic conditions.

These two points are bound together and it is really interesting to study both of them, at the same time.

The following planning help to understand how the studies have been done during the summer :

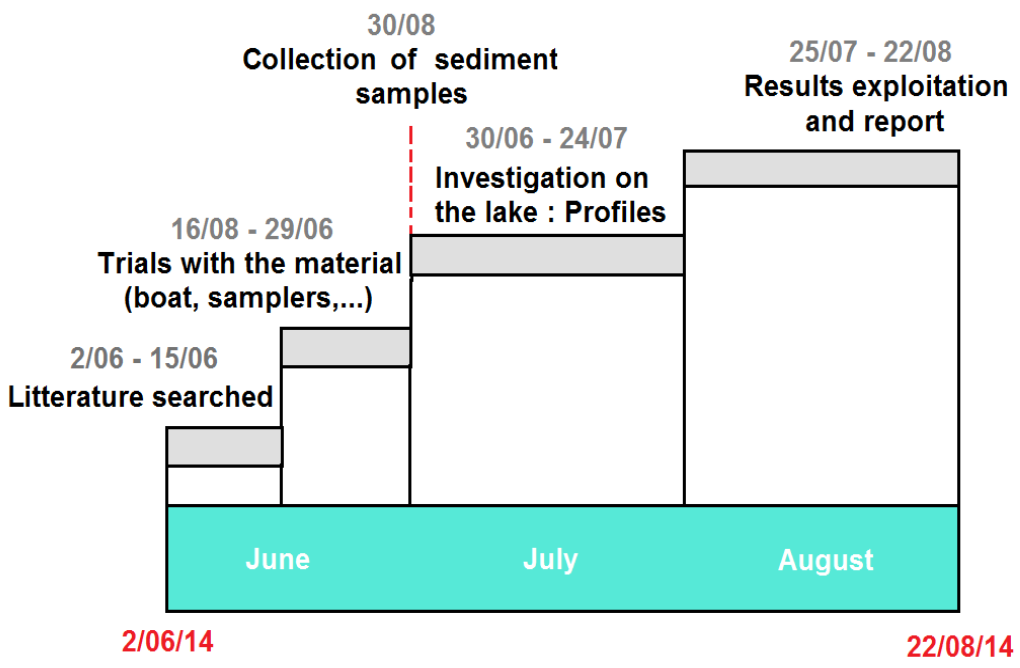


Figure 8 - Planning of the project

1. Bottom sediments sampling

1.1 The surface of the lake with accumulation bottom

To begin, it was important to know what was the surface of the lake where there were bottom sediments containing phosphorus, that is to say accumulation bottom. It is easy to recognize this bottom type by touching and smelling it. It smells like rotten-eggs it feels like really soft when we touch it, and it is really liquid.

Finally, there were accumulation bottom at 4 meters of depth but not at 2 meters, so we estimated that the depth limit to find it was 4 meters. Deeper, there is accumulation of phosphorus in the bottom.

The software Imagej permitted to calculate the area of the lake which depth was 4 meters and more. It just needs a picture of the lake, with the surface of the area to calculate, and a scale, and it gives the area in square meters.

1.2 Bottom sampling

The second step of bottom sediments studies was to sample the sediments. 3 points for sediments sampling have been chosen : two seven meters deep and one fourteen meters deep (*figure 11*).

It was important to keep the order of the different layers in the sediment sample, so that we could observe a vertical chronology of sediments deposits. In order not to mix the sediments when we are taking it, we need to use a particular tool which is called coring device (*figure 9*).

When it falls down through the water and finally into the sediments, the sediments get into the sediments sampler and because of the vacuum, stay in it when we take it up. We just need to put a cap in the opening of the sampler tube before taking it out of the water.

The 30th first centimeters of the bottom contains the labile phosphorus which can be released in solution. Phosphorus is present further down in the sediment as well but is regarded to be permanently bound and not to constitute a risk for phosphorus leakage.

In order to have a detailed analysis of the layers of the accumulation bottom, we decided to divide it in 4 samples sections : from 0 to 5 cm sediment depth, from 5 to 10 cm sediment depth, from 10 to 20 cm sediment depth and from 20 to 30 cm sediment depth.

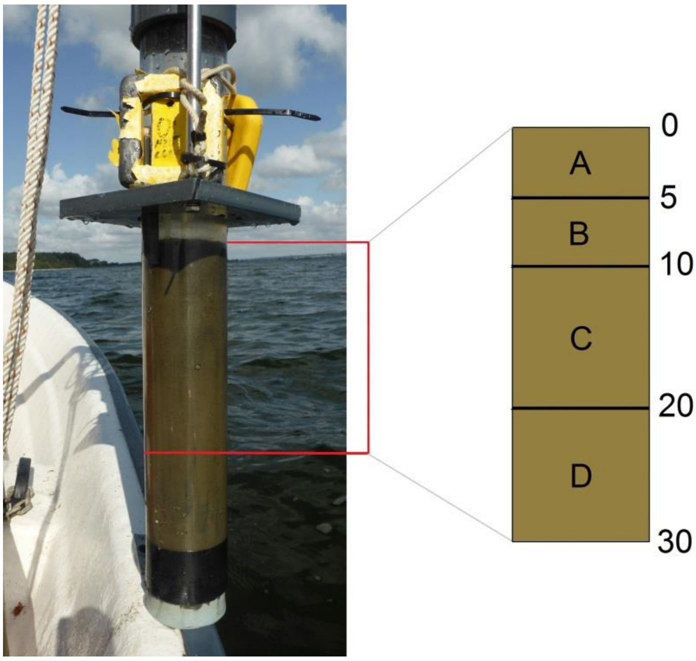


Figure 9 - Coring device also called sediment sampler

1.3 Analysis of the sediment samples

The samples have been sent to a laboratory based in Uppsala (Erkenlaboratoriet) which did the analysis because it requires a specific and expensive material that Sydvatten do not have.

2. Water profiles

In the study, it was interesting to follow the evolution of some parameters, at different point and each meter of depth, during the summer for two reasons :

- This gives information about the conditions and the behaviour of the lake during the summer, a period which favorises the eutrophication phenomenon because of the warmer weather, abundance of light and nutrients.
- It permits to see if there is a thermal stratification of the lake, a phenomenon that often occurs during summer time and influences oxygen concentration of the bottom water.
- We can see the state of the bottom of the lake with the dissolved oxygen concentration, which influences phosphorus release.

Thus, almost every day during the month of July, we've been out on the lake, by boat, and we've been checking some water parameters with a multi-parameter analyzing tool (*figure 10*). The multi-parameter has many sensors on it, one for each parameter that is studied and we just need to put it in the water and to read the values.

The water profiles have been done at 6 points of the lake, and the parameters which were studied were pH, temperature, dissolved oxygen concentration, redox and conductivity.

Figure 10 - picture of the multi-parameter tools and its sensors

3. Map of the points studied

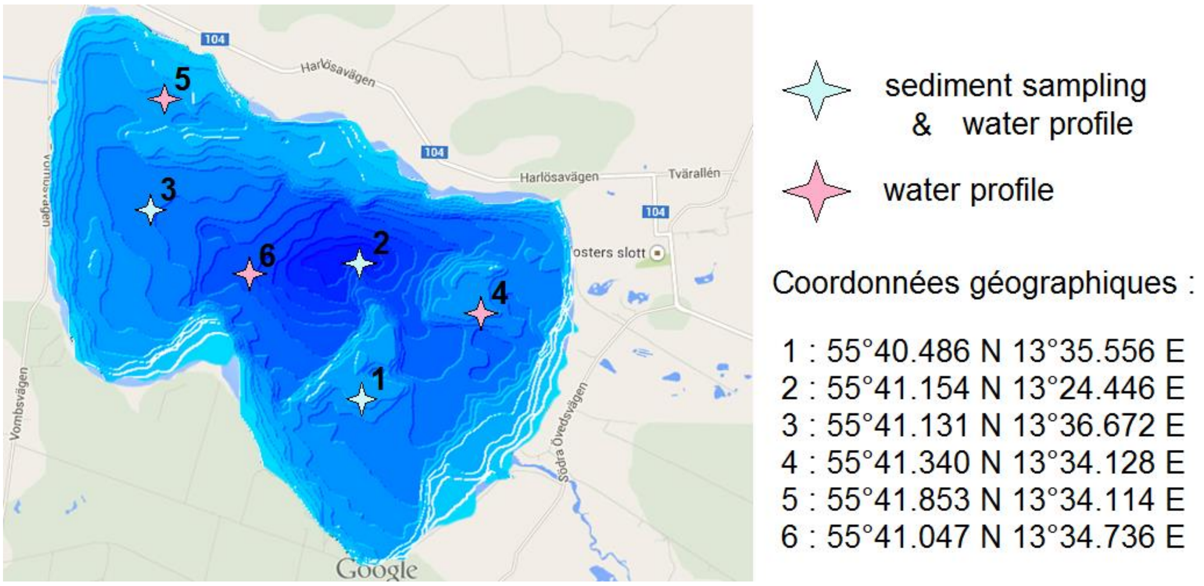


Figure 11 - Map of the studied points

4. Inlets and outlets; water flow and phosphorus concentration

In order to know if phosphorus is stocked into the lake or if it is released from the sediments, we had to calculate the total amount of phosphorus coming from the inlets and leaving through the outlet.

To achieve this, we needed to know the water flow and the phosphorus concentration of the water for each inlets and the outlet.

We have two ways to get the total phosphorus concentration from the different inlets and the outlet :

- SMHI, the Swedish Meteorological and Hydrological Institute, which predicts the weather and among other things, the water flow and the total phosphorus concentration in rivers, inlet and outlets. The data is used in a model (S-Hype) and gives a coarse approximation of the real situation.
- Recipientkontrollen is directly measuring the total phosphorus concentration in the water and other parameters at stations located next to the lake. However it is not getting any data from the third inlet, Borstbäcken (*figure 2*).

To finish, we used the second alternative presented above to get the phosphorus concentration of the water and got the water flow from SMHI.

III Results and discussion

1. Analysis on bottom sediments

1.1 Fractions of bound phosphorus

Thanks to the results from the analysis the laboratory have been doing on the bottom sediments, we can observe the different fractions of phosphorus present in the bottom sediment and how they change throughout the different layers of the bottom sediments.

We have been doing these analysis at 3 different points (point1-3, *figure 11*) and the results are as follows with one graph for each point (*figures 12, 13, 14*) :

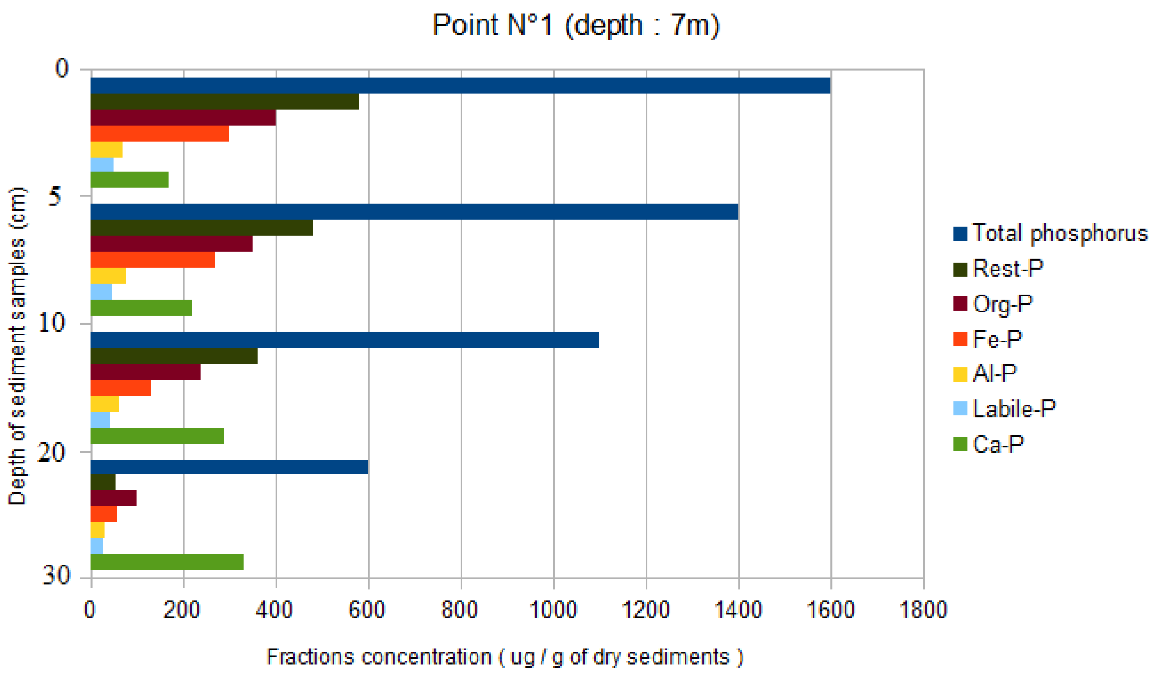


Figure 12 - Fractions of bound phosphorus at the first point

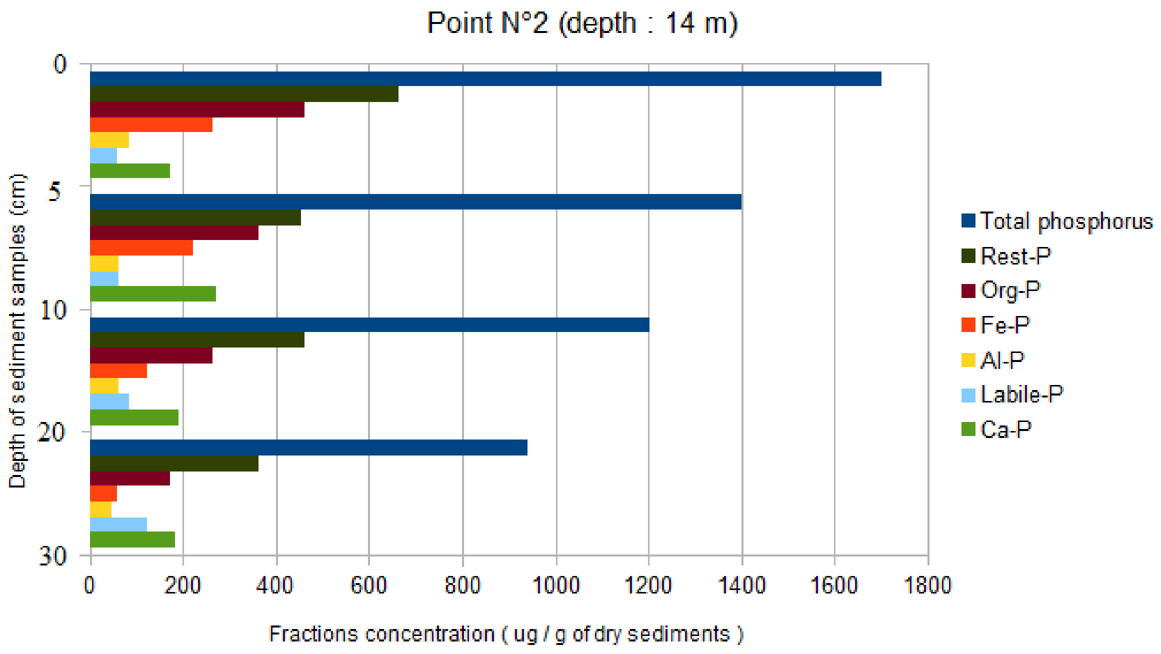


Figure 13 - Fractions of bound phosphorus at the second point

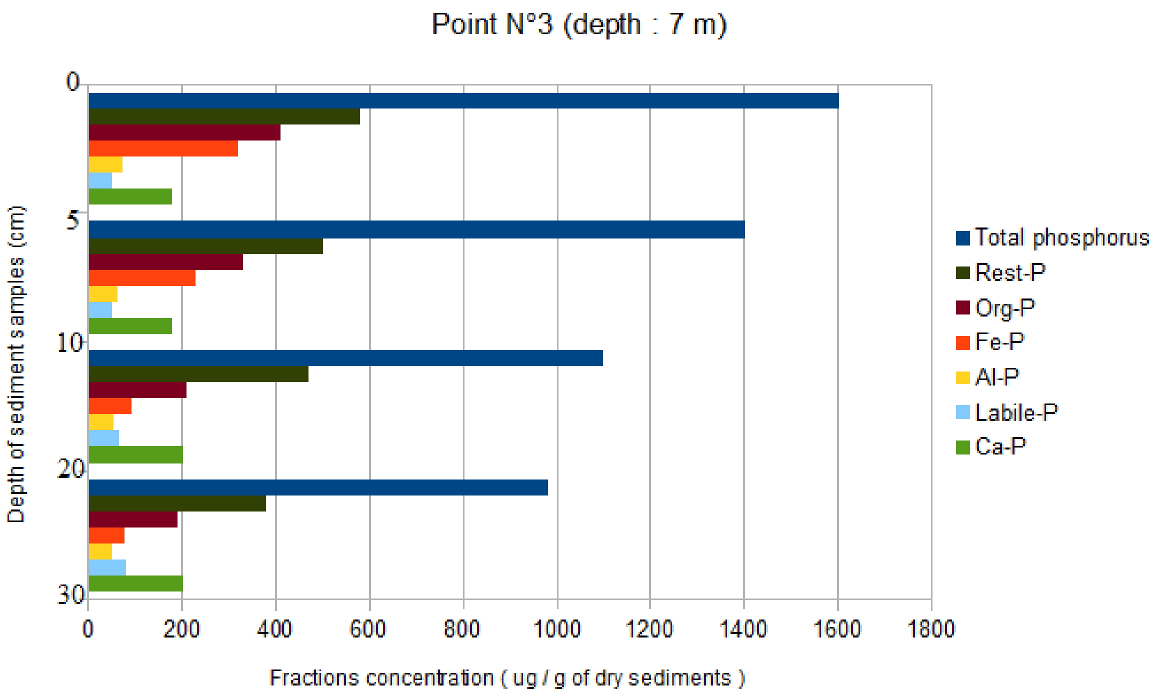


Figure 14 - Fractions of bound phosphorus at the third point

It appears that the main fractions in the bottom sediments are the iron, the organic and the residual fractions. However, only the iron and organic fractions are interesting for us in this study since they are the labile fractions.

First, we can observe in both points that the total phosphorus concentration in ug P/g of dry sediments is decreasing with the depth of the sediment layer.

Then, as they are the fractions which can be released in the water, and thus interesting to us in this project, we observe the iron, organic and labile fractions.

In the graphs, we can notice that for the iron and organic fractions, the concentration is decreasing with the depth of the sediment layer. Thus, in general, there is much phosphorus in the upper layer of bottom sediments that can be released in the water, that is to say in the most recent accumulation bottom. This appears logical since, depending on the conditions and oxygen concentration, the sediments at the interface sediments/water are constantly bounding and releasing the phosphorus in solution while in the sediments under them phosphorus is permanently bound to the bottom sediment. The labile phosphorus fraction is curiously increasing with sediment depth.

In the graph, we can also see that the concentration of the calcium fraction is doing exactly the opposite of the others. It could be because, in the under layers, it bounds with the phosphorus released by the others labile fractions. The aluminum fraction is quite constant throughout the sediment bottom layers.

1.2 Total amount of phosphorus in the lake sediments

With the results of the analysis, we have been able to calculate the total amount of phosphorus in the lake sediments of the entire lake. The calculations details are in the ***appendix N°1***.

We found these results (*table 2*) :

Table 2 - Total amount of phosphorus in the bottom sediments per fraction

Fraction of phosphorus	P-Fe	P-Org	P-Labile	P-Ca	P-Al	P-Rest	Total phosphorus
Total amount in Tons (T)	67,6	123,5	34,4	131,1	28,9	195,5	582,7

The fractions which could be released in solution are P-Fe, P-Org and P-Labile, so it is the ones that we are interested in. **The quantity of phosphorus releasable from the bottom sediments is the sum of these fractions : 225,5 Tons.**

2. Inlets and outlet

With SMHI (Swedish Meteorological and Hydrological Institute), we got the water flow from all the inlets and outlet and the phosphorus concentration from Recipientkontrollen.

However, we have the total phosphorus concentration for only two inlets : Bjorkaån and Torpsbäcken (*figure 15*).

There are no data for the two others, so we decided not to take them into account. Thus it is important to keep in mind that the values we finally got are **undervalued.**

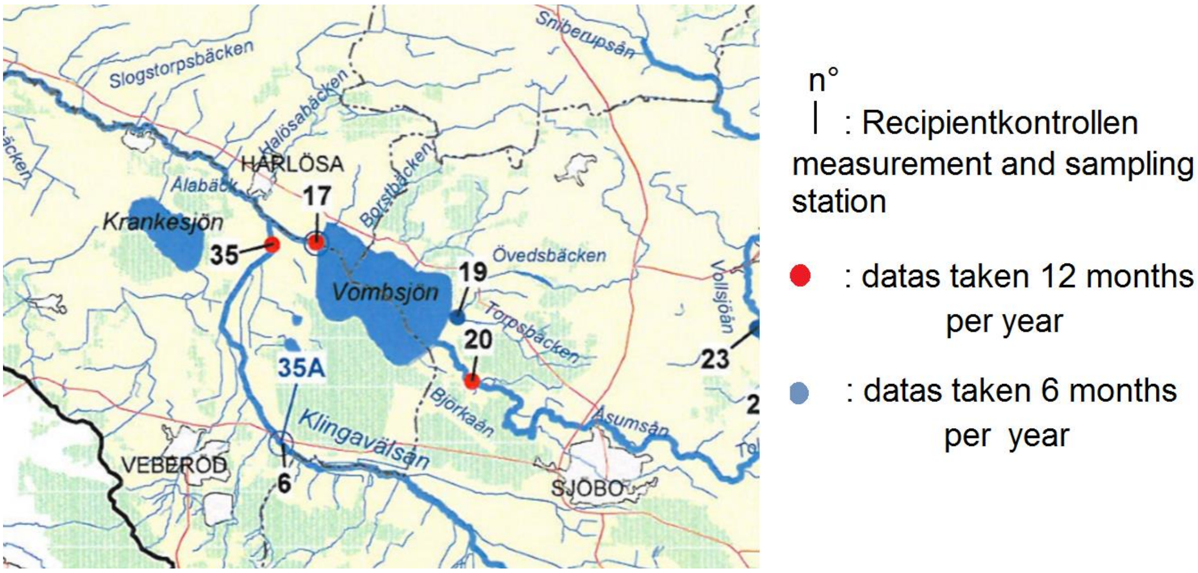


Figure 15 - Map of the sampling points of Recipientkontrollen (from recipientkontrollen website)

With the water flow and the total phosphorus concentration from the inlets and outlet, we could calculate the total amount of phosphorus coming into the lake and going out from the lake (***appendix N°2***).

The results are in the following table (*table 3*) :

Table 3 - Inlet / Outlet balance of phosphorus for 2012 and 2013

Inlet / outlet	Total amount of phosphorus (T/year)	
	2012	2013
Inlet 19	0,75	0,74
Inlet 20	5,3	4,93
Outlet 17	8,5	7,3
∑ inlets - Outlet	**-2,45**	**-1,63**

The first thing we can observe is that **there is more phosphorus leaving the lake than coming into the lake.** Yet among the phosphorus coming into the lake, a certain percentage of it sinks to the bottom.

The hypothesis we could admit is that :

- the total amount of phosphorus coming into the lake is undervalued. Indeed, we just took into account the phosphorus carried by two of four inlets.
- The values must be interpreted with care because the water sample in recipientkontrollen is taken only during one day in one or two month. So it can not represent the general or mean value of the phosphorus concentration.
- A lot of phosphorus is released from the bottom sediment.

Finally we can estimate that the amount of phosphorus entering and leaving the lake might be almost equal.

3. Water profiles

The longest part of our studies consisted in checking some parameters of the lake water at 6 points of the lake (*figure 11*). We've been doing it twelve times during the month of July, so 3 or 4 times a week. The data we collected provides us a great overview of the evolution of the lake conditions and most importantly the lake stratification, day by day.

The tables with the data for each point, each day, each parameter and each depth are in ***appendix 4***.

The parameters in which we are mostly interested in are the temperature and the dissolved oxygen concentration, since it is these ones which give us information about the thermal stratification of the lake and the conditions which influence phosphorus release.

4 graphics have been chosen to show the different profiles we can have (*figure 16, 17, 18, 19*).

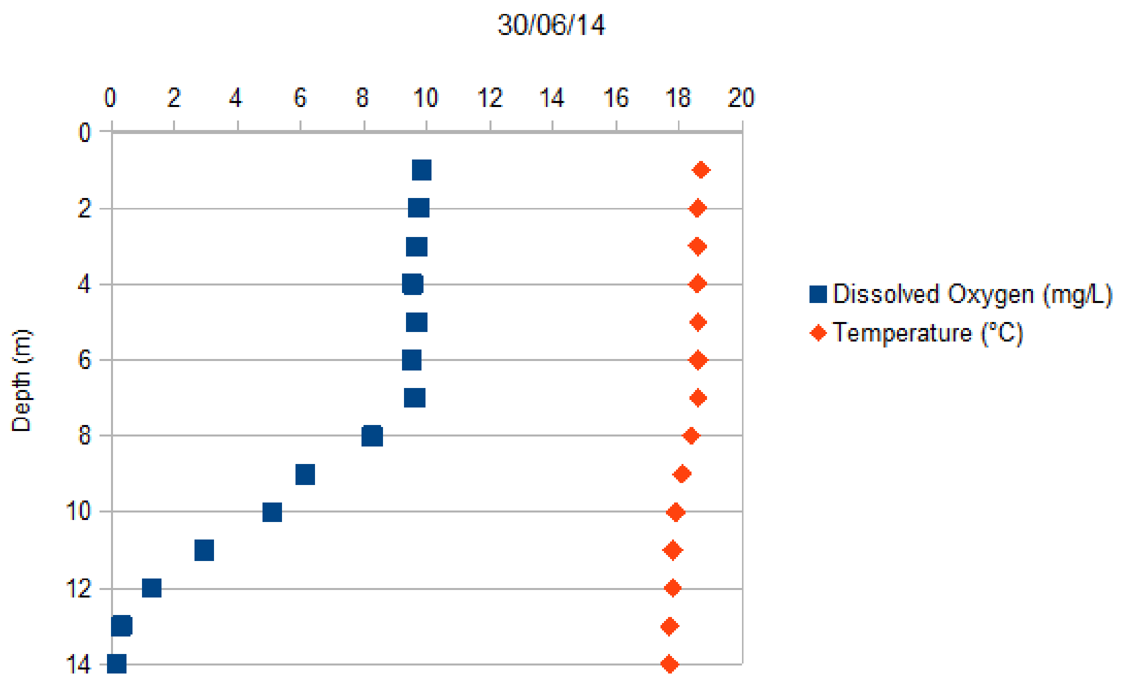


Figure 16 – Dissolved oxygen and temperature at point 2 – 06.30.2014

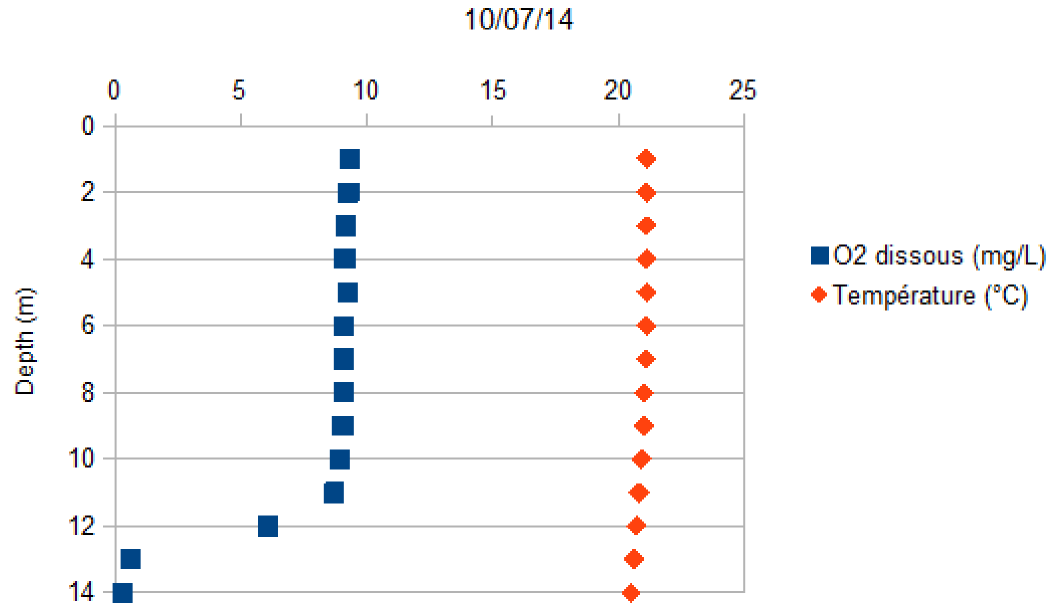


Figure 17 - Dissolved oxygen and temperature at point 2 – 07.10.2014

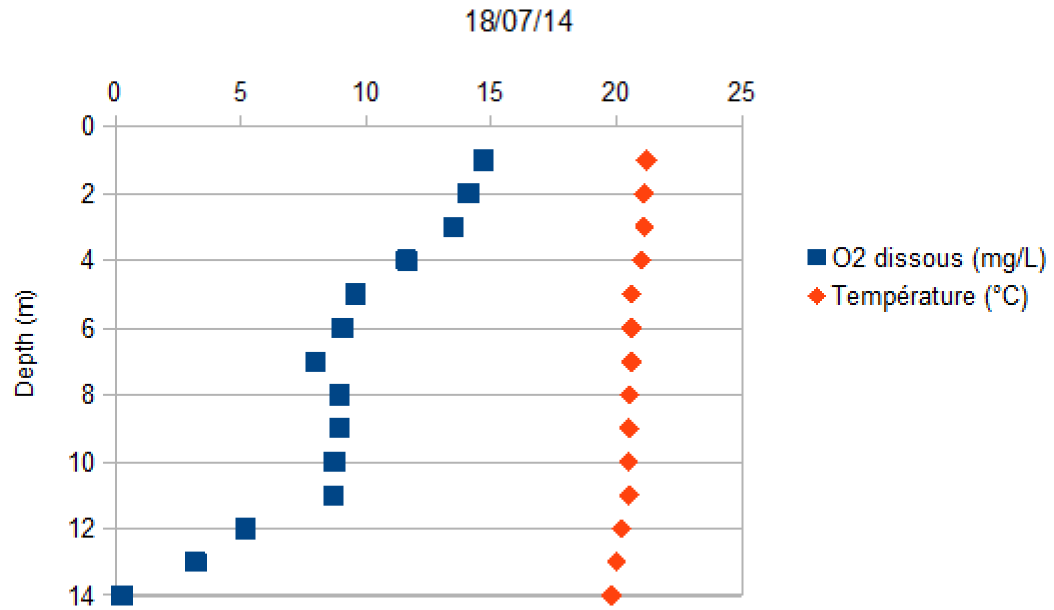


Figure 18 - Dissolved oxygen and temperature at point 2 – 07.18.2014

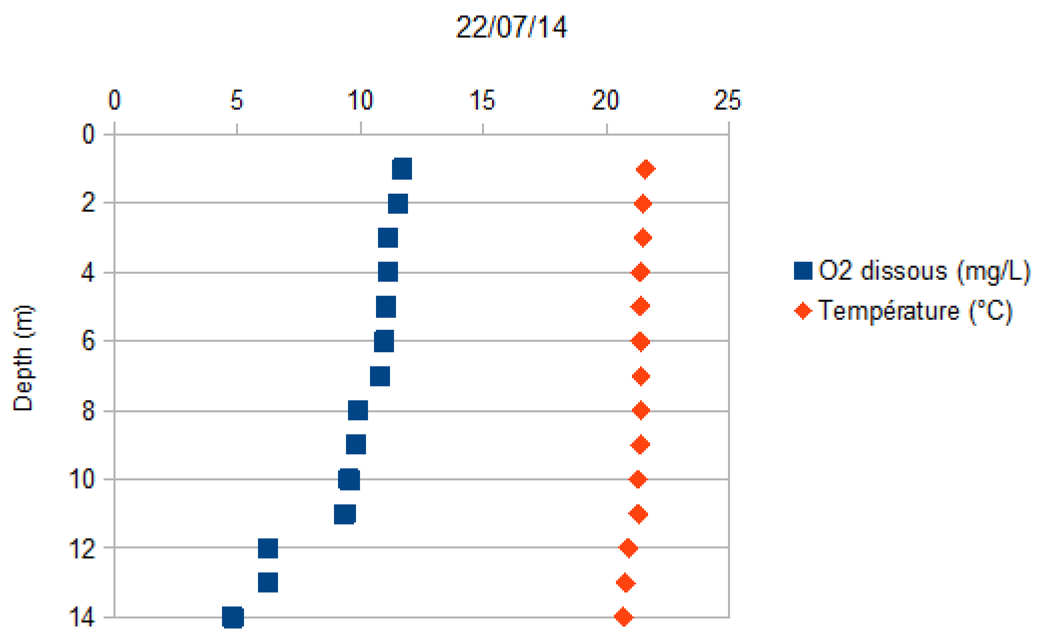


Figure 19 - Dissolved oxygen and temperature at point 2 – 07.22.2014

These graphs are profiles taken at point 2 since the depth (14 m) let us observe more clearly the different layers if there is a thermal stratification.

However, we can observe the same evolution at the 5 others points.

What our studies let us see, is that we do not observe a thermocline but we have an oxygen depletion in the bottom water. The oxygen depletion is a problem because it favorises phosphorus leakage.

Our observations during the month of July led us to the conclusion that it is possible to observe thermal stratification of the lake when the weather conditions are good (sun, no wind, hot air temperature). This stratification of the water can be a problem if it is steady and lasts during summertime. But in Sweden the weather conditions are constantly changing, and at Vombsjön lake, the thermal stratification appears and disappears all the summer long.

Unfortunately, we can observe that even without a thermocline there is still oxygen deplation in the bottom water, this is a bad news and will be the source of problems in the future. The phosphorus leakage it leads to will have a real impact on the general state of the lake and the eutrophication phenomenon.

CONCLUSION

This project was an investigation on the Vombsjön lake, which is a drinking water reservoir of Sydvatten. Its water, after many treatments at vombverket purification plant is distributed to 900.000 inhabitants in the South of Sweden.

Until now, Sydvatten has not had a lot of data about this lake, its behaviour during the year and so on. Yet, they really need to get information about it.

Nowadays, because of the use of fertilizers and detergents and individual sewage, the problem of the amount of phosphorus released in the nature and carried to lakes and the sea is raised. It leads to an eutrophication phenomenon which can have a huge impact on ecosystems and public health indirectly.

In this context, it is important that Sydvatten ensures the good quality of the lake and lead investigations to be aware of possible problems it can be faced with in the future.

It was obvious that the first thing to check was the phosphorus balance, as it is the main factor leading to the problem of eutrophication. The thermal stratification, as it can favorise this phenomenon, must be investigated.

Finally, after three month and a lot of time spent on Vombsjön lake, the conclusion is that the lake is in the warning state because of the oxygen depletion observed in the bottom water favorising the phosphorus leakage and indirectly the eutrophication phenomenon and the general quality of the lake water. The thermal stratification can be observed but not all the time during the summer, it is however still enough to create the state of oxygen depletion. Furthermore, the phosphorus balance and the inlets/outlet balance we have been studying tell us that the amount of phosphorus entering and leaving the lake might be equal, due to the underestimation of th phosphorus coming into the lake by the three inlets. Thus, it seems that not a lot of phosphorus is stocked in the lake bottom sediment.

Thanks to this study, Sydvatten now have more data about the lake and knows that the state of the lake is at risk and solutions need to be found to solve the eutrophication problem.

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Appendices

Appendix N°1 : calculation of the total amount of phosphorus in the bottom sediment

Appendix N°2 : Calculation of the total amount of phosphorus coming from the inlets and leaving throw the outlet in 2012 and 2013

Appendix N°3 : Water profile at each point for the month of July

Appendix N°1 : calculation of the total amount of phosphorus in the bottom sediment

I'll take an exemple to illustrate the way we calculate the total phosphorus at one point, the N°1 (it is the same process for the fractions)

When they got the samples we sent to them at the laboratory, people just took 20 mL from each.

They weighed the 20 mL sample in a contener, after the calcination the water was gone and they weighed the contener with the dry sediments. Knowing the weight of the container empty, they could find the weight of dry sediment contained in 20 mL of bottom sediments.

Sample	Container (g)	Container + sediment (g)	Container + Dry sediment (g)	dry sediment (g)	Depth (cm)
1A	5,3343	27,4228	7,6283	2,294	0 – 5
1B	5,276	28,227	8,522	3,246	5 – 10
1C	5,2857	28,9858	9,4533	4,1676	10 – 20
1D	5,3102	31,2743	13,0515	7,7413	20 – 30

The concentration of the fractions are given in ug/g of dry sediments. Thus we just have to multiply it with the weight of dry sediments to have the quantity in ug contained in 20mL of the sediment sample.

My process was to find the phosphorus contained in the 30th first cm of the sediment sampler and to extend it to the whole lake surface.

We know that the diameter of the sediment sampler measure 6,9 cm, so the section measure 37,4 cm^2. So we can calculate that 5 cm of the sediment sampler contains 187 mL and 10 cm contains 374 mL.

We have the quantity of phosphorus in 20mL so we just have to do an easy calcul to find how much there is in the appropriate volume (187 or 374 mL).

When it is done, the quantity of phosphorus from the 4 samples have to be summed to have the total phosphorus in the sediment sampler.

Sample	**Total phosphorus** **ug/g DS**	Weight of total Phosphorus (ug) **for 20 mL**	Weight of total Phosphorus (ug) for the section	total amount of phosphorus in one point (mg)
1A	1600	3670	34294	
1B	1400	4544	42460	
1C	1100	4584	85668	
1D	600	4645	86797	249

To have the total phosphorus, we did an average of the values found in the 3 points (here was just the first point) :

Average (mg) : 228

So we estimated that for a volume equal to the sediment samplet volume, there were 228 mg of total phosphorus. Finally we just need to calculate the ratio between the surface of the lake and the surface of the sediment sampler and to multiply our average :

Surface of the lake which depth is more than 4 meters : 9546530 m^2

Surface of the sediment sampler : 0,00373739 m^2

Surface of the lake / Surface of sediment sampler : 2554334113

Total amount of phosphorus in the lake : 2554334113 * 228 * 10^(-9) = 582,7 T

Appendix N°2 : Calculation of the total amount of phosphorus coming from the inlets and leaving throw the outlet in 2012 and 2013

Inlet 19

	Total fosfor µg/l	Total fosfor g/m3	Total Waterflow [m³/s]	phosphorus in g/s	amount of P in one month (T)	Total amount of P in one year (T)
10/02/2012	76	0,076	0,629	0,048	0,248	0,751
13/04/2012	30	0,03	0,0988	0,003	0,016	
18/06/2012	120	0,12	0,0583	0,007	0,037	
15/08/2012	160	0,16	0,0460	0,007	0,039	
11/10/2012	160	0,16	0,0867	0,014	0,073	
20/12/2012	79	0,079	0,813	0,064	0,339	
18/02/2013	40	0,04	0,799	0,032	0,171	0,740
15/04/2013	22	0,022	0,293	0,006	0,034	
18/06/2013	280	0,28	0,0752	0,021	0,111	
14/08/2013	270	0,27	0,0505	0,014	0,072	
25/10/2013	99	0,099	0,119	0,012	0,062	
11/12/2013	67	0,067	0,821	0,055	0,290	

Inlet 20

	Total fosfor µg/l	Total fosfor g/m3	Total Waterflow [m³/s]	phosphorus in g/s	amount of P in one month en T	Total amount of P in one year (T)
18/01/2012	46	0,046	10,5	0,483	1,251936	5,3
10/02/2012	40	0,04	5,64	0,2256	0,5847552	
15/03/2012	39	0,039	2,59	0,10101	0,26181792	
13/04/2012	33	0,033	1,32	0,04356	0,11290752	
15/05/2012	30	0,03	0,99	0,0297	0,0769824	
18/06/2012	57	0,057	0,666	0,037962	0,098397504	
11/07/2012	71	0,071	0,841	0,059711	0,154770912	
15/08/2012	37	0,037	0,495	0,018315	0,04747248	
17/09/2012	210	0,21	0,429	0,09009	0,23351328	
11/10/2012	51	0,051	1,59	0,08109	0,21018528	
12/11/2012	66	0,066	4,44	0,29304	0,75955968	
20/12/2012	85	0,085	6,75	0,57375	1,48716	
16/01/2013	43	0,043	8,92	0,38356	0,99418752	4,93
18/02/2013	42	0,042	6,79	0,28518	0,73918656	
14/03/2013	28	0,028	2,55	0,0714	0,1850688	
15/04/2013	14	0,014	2,91	0,04074	0,10559808	
14/05/2013	31	0,031	0,884	0,027404	0,071031168	
18/06/2013	61	0,061	0,784	0,047824	0,123959808	
10/07/2013	62	0,062	0,759	0,047058	0,121974336	
14/08/2013	60	0,06	0,449	0,02694	0,06982848	
12/09/2013	37	0,037	0,379	0,014023	0,036347616	
25/10/2013	72	0,072	1,3	0,0936	0,2426112	
13/11/2013	72	0,072	5,9	0,4248	1,1010816	
11/12/2013	64	0,064	6,89	0,44096	1,14296832	

Outlet 17

	Total fosfor µg/l	Total fosfor g/m3	Total Waterflow [m³/s]	phosphorus in g/s	amount of P in one month en T	Total amount of P in one year (T)
18/01/2012	51	0,051	13,5	0,7	1,8	8,5
10/02/2012	49	0,049	6,52	0,3	0,9	
15/03/2012	40	0,04	5,06	0,2	0,5	
13/04/2012	9,4	0,0094	1,24	0,0	0,0	
15/05/2012	28	0,028	1,19	0,0	0,1	
18/06/2012	23	0,023	0,753	0,0	0,0	
11/07/2012	26	0,026	0,993	0,0	0,1	
15/08/2012	140	0,14	0,624	0,1	0,2	
17/09/2012	200	0,2	2,74	0,5	1,5	
11/10/2012	160	0,16	2,45	0,4	1,0	
12/11/2012	110	0,11	2,77	0,3	0,8	
20/12/2012	91	0,091	5,91	0,5	1,4	
16/01/2013	61	0,061	12,7	0,8	2,1	7,3
18/02/2013	59	0,059	9,20	0,5	1,5	
14/03/2013	42	0,042	4,09	0,2	0,5	
15/04/2013	38	0,038	3,15	0,1	0,3	
14/05/2013	18	0,018	1,06	0,0	0,1	
18/06/2013	30	0,03	0,946	0,0	0,1	
10/07/2013	44	0,044	0,800	0,0	0,1	
14/08/2013	160	0,16	0,500	0,1	0,2	
12/09/2013	130	0,13	2,75	0,4	1,0	
25/10/2013	30	0,03	2,37	0,1	0,2	
13/11/2013	61	0,061	2,84	0,2	0,5	
11/12/2013	45	0,045	7,56	0,3	0,9	

Appendix N°3 : Water profile at each point for the month of July

POINT N°1

30/06/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	427,6	9,8	122,4	8,54	18,7
2	429,8	9,9	121,9	8,55	18,7
3	430	9,67	122,6	8,55	18,6
4	430,3	9,74	123,5	8,53	18,6
5	437,1	6,26	133,7	8,13	18,2
6	438,3	5,86	-23,6	8,04	18,1
7					

01/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	427,5	10,23	136,1	8,58	18,8
2	427,8	10,48	133,3	8,59	18,8
3	427,8	10,47	133,3	8,59	18,7
4	428,1	10,46	134,1	8,59	18,7
5	429,1	10,04	134,5	8,55	18,6
6	429	8,15	-105,5	8,3	18,4
7	424,1	0,76	-177,7	7,79	18,3

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	423,5	10,63	180,8	8,64	18,9
2	425	10,56	177,5	8,63	18,9
3	425,1	10,48	176	8,63	18,8
4	425,4	10,52	175	8,62	18,8
5	426	10,38	174,3	8,6	18,8
6	427,2	9,92	174,1	8,55	18,7
7	426,1	8,66	-134,5	8,32	18,7

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	422,1	12,74	78,3	8,81	20,6
2	421,7	12,8	79,1	8,8	20,4
3	421,1	12,51	79,7	8,78	20,2
4	427,1	10,52	82,7	8,63	19,5
5	429	9,7	83,6	19,4	19,4
6	435,9	5,11	-123,8	18,8	18,8
7	437,7	4,59	-81,1	18,7	18,7

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	412,9	12,34	89,8	8,78	21,5
2	412,8	12,4	91,3	8,77	21,5
3	413,4	12,26	93,7	8,74	21,3
4	424,1	9,74	98,7	8,54	20,1
5	433,5	6,95	104,1	8,28	19,1
6	435,1	4,1	-145,2	7,97	18,6
7					

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	412,9	12,34	89,8	8,78	21,5
2	412,8	12,4	91,3	8,77	21,5
3	413,4	12,26	93,7	8,74	21,3
4	424,1	9,74	98,7	8,54	20,1
5	433,5	6,95	104,1	8,28	19,1
6	435,1	4,1	-145,2	7,97	18,6
7					

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	424,7	8,81	128,5	8,47	21
2	424,6	8,72	127,7	8,48	21
3	424,7	8,74	127,6	8,48	21
4	424,8	8,73	127,5	8,47	20,9
5	424,8	8,53	-1,8	8,46	20,9
6	408	0,07	-60,2	7,65	20,7
7	409,2	0,06	-68,9	7,63	20,7

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	420,6	8,72	122,7	8,47	20,4
2	420,5	8,5	125,5	8,48	20,4
3	420,5	8,54	128,5	8,48	20,4
4	420,4	8,69	129,6	8,49	20,4
5	420,5	8,33	131,5	8,49	20,4
6	420,6	8,29	134	8,49	20,4
7	416	2,86	-115,5	7,86	20,3

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	410,4	12,82	104,6	8,88	20,9
2	413,9	11,31	108,6	8,75	20,8
3	414,4	11,27	111,8	8,73	20,7
4	415,1	10,75	114,3	8,7	20,7
5	415,7	10,68	116,3	8,71	20,7
6	421,3	8	121,2	8,41	20,5
7	417,6	1,01	-143,2	7,85	20,2

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	399,1	15,72	99,1	8,95	21,1
2	406,5	13,46	103,3	8,84	20,9
3	413,3	10,87	106,7	8,69	20,8
4	416,6	9,53	108,5	8,61	20,7
5	415,9	10,15	108,3	8,62	20,6
6	423,2	6,64	112,9	8,26	20,3
7	424,8	1,85	-62,4	7,85	20,2

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	405	10,96	96,6	8,64	21,1
2	405,3	10,79	98,9	8,63	21,1
3	405,6	10,63	102,8	8,62	21,1
4	405,7	10,65	104,7	8,62	21,1
5	405,7	10,61	106,9	8,62	21,1
6	406	10,5	109,4	8,6	21,1
7	406,4	10,47	111	8,59	21

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	387,7	12,38	119,4	8,85	22,3
2	387,4	12,19	122,1	8,83	22,2
3	387,2	12,07	127	8,82	22,2
4	396,5	10,86	131,4	8,71	21,5
5	399,2	10,76	133	8,68	21,3
6	402,8	9,89	134,9	8,59	21,2
7	400	0,37	-134	7,81	21,1

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	388,1	11,73	104,5	8,81	22,5
2	391,1	11,56	108,7	8,78	22,2
3	390,7	11,53	113,7	8,78	22,1
4	393,7	11,48	117,2	8,77	22
5	395,7	11,13	119	8,74	21,9
6	405,7	8,55	123,5	8,49	21,5
7	413	1,18	-120,8	7,83	21,3

POINT N°2

30/06/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	429,3	9,84	112,6	8,55	18,7
2	430	9,76	112,9	8,55	18,6
3	430,1	9,69	113,4	8,55	18,6
4	430,5	9,56	114	8,54	18,6
5	430,7	9,69	114,7	8,54	18,6
6	430,8	9,52	115,3	8,54	18,6
7	430,9	9,64	115,9	8,53	18,6
8	434	8,27	119,4	8,39	18,4
9	437,2	6,16	124,8	8,09	18,1
10	439,6	5,12	128,6	7,96	17,9
11	441,7	2,94	40,1	7,78	17,8
12	435,2	1,29	-25,9	7,67	17,8
13	431,6	0,33	-63,6	7,62	17,7
14	431,2	0,17	-76,6	7,61	17,7

01/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	429,5	9,5	196,9	8,52	18,8
2	429,8	9,4	189,2	8,52	18,7
3	429,8	9,55	187,4	8,52	18,7
4	429,9	9,43	185,6	8,51	18,7
5	430,4	9,15	182,5	8,48	18,6
6	431,5	8,61	181,6	8,44	18,6
7	431	8,72	180	8,44	18,6
8	430,8	8,92	178,3	8,46	18,6
9	430,6	9,04	177	8,46	18,5
10	431,1	8,74	176,4	8,43	18,5
11	441,7	4,08	185,2	7,87	18
12	440,3	4,26	-20,5	7,7	18
13	440,1	4,22	-31,4	7,65	18
14	439,9	4,2	-28,7	7,62	18

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	427,4	9,84	136,3	8,49	18,7
2	428,3	9,78	140,2	8,48	18,7
3	428,7	9,74	141,6	8,48	18,7
4	428,7	9,64	143,7	8,46	18,7
5	428,9	9,58	145,8	8,45	18,7
6	429,1	9,42	147,6	8,45	18,7
7	429,2	9,36	149,3	8,44	18,6
8	429,4	9,33	150,7	8,43	18,5
9	429,8	9,06	151,9	8,4	18,5
10	429,9	8,88	153,5	8,39	18,5
11	430	8,95	154,6	8,38	18,4
12	425,3	6,04	-127,6	7,95	18,4
13	415,8	2,84	-34,9	7,78	18,5
14	415	2,11	-16,4	7,71	18,5

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	409,9	14,3	88,7	8,83	21,3
2	412,8	13,88	89,7	8,81	20,8
3	420,5	12,01	92,8	8,71	20,1
4	427,6	10,22	95,4	8,61	19,5
5	428,3	10,04	96,2	8,59	19,4
6	429,1	9,52	96,8	8,55	19,3
7	433,4	6,81	102,5	8,23	18,7
8	433,2	6,9	103,3	8,24	18,7
9	433,7	6,43	103,9	8,19	18,6
10	434,4	6,12	104,9	8,13	18,5
11	35,4	5,21	107,9	8,03	18,5
12	434,9	2,48	-114,4	7,76	18,4
13	428,6	0,05	-67	7,68	18,3
14	428	0,03	-65,9	7,67	18,3

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	409,4	11,97	89,2	8,74	21,3
2	409,8	12,43	92,3	8,73	21,2
3	415,3	11,27	95,8	8,65	20,9
4	428,2	9,39	99,3	8,53	19,7
5	429,1	9,04	101,8	8,51	19,5
6	429,8	9,06	102,7	8,5	19,4
7	430,7	8,64	103,9	8,47	19,3
8	432,2	7,67	106,5	8,35	19,2
9	434,8	6,2	110,6	8,17	18,9
10	436,7	4,73	114,6	8,01	18,7
11	437,6	4,13	115,9	7,95	18,6
12	425,2	0;06	-139,9	7,69	18,4
13	424,1	0,06	-142,8	7,68	18,4
14	423,9	0,12	-142,4	7,68	18,4

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	421,2	9,33	102,9	8,53	21,1
2	421,2	9,26	103,3	8,53	21,1
3	421,2	9,17	104	8,53	21,1
4	421,2	9,12	104,9	8,53	21,1
5	421,2	9,22	105,7	8,53	21,1
6	421,1	9,07	107,1	8,51	21,1
7	421,2	9,08	108,3	8,51	21,1
8	421,3	9,06	109,5	8,51	21
9	421,4	9,04	110,6	8,5	21
10	422,5	8,92	110,4	8,48	20,9
11	423,5	8,7	111,5	8,44	20,8
12	419,7	6,06	-144,9	8,12	20,7
13	408,6	0,64	-51	7,59	20,6
14	409,3	0,29	-100,8	7,59	20,5

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	422,1	7,72	220,1	8,4	20,6
2	422	7,79	219,6	8,41	20,6
3	422,2	7,72	219,2	8,4	20,6
4	422,4	7,68	219,4	8,39	20,6
5	422,4	7,62	219,5	8,38	20,6
6	422,4	7,68	218,8	8,38	20,6
7	422,4	7,7	218,8	8,37	20,6
8	422,5	7,7	218,4	8,36	20,6
9	422,8	7,59	218	8,35	20,6
10	422,9	7,62	219	8,33	20,6
11	423,1	7,52	218,4	8,31	20,6
12	414,2	2,53	72,9	7,83	20,6
13	413,8	0,08	-211,8	8,24	20,5
14	412,8	0,08	-184,1	7,88	20,5

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	415,3	10,21	136,3	8,69	20,6
2	416,1	9,65	137,1	8,63	20,6
3	416,4	9,42	137,6	8,62	20,6
4	416,3	9,64	138,1	8,62	20,6
5	416,8	9,5	139,4	8,6	20,6
6	417,3	9,35	140,3	8,58	20,5
7	417,2	9,42	140,5	8,58	20,5
8	417	9,42	142	8,57	20,5
9	416,8	9,3	141,5	8,57	20,5
10	416,6	9,17	142,7	8,56	20,5
11	416,7	9,32	142,8	8,57	20,4
12	417,6	8,95	143,3	8,52	20,4
13	420,8	7,49	146,2	8,37	20,3
14	416,3	0,81	-127	7,74	20,1

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	401,1	14,68	91,8	8,91	21,2
2	403,1	14,1	94,9	8,86	21,1
3	405	13,51	98,5	8,84	21,1
4	410,9	11,62	101,5	8,73	21
5	417,3	9,57	104,1	8,58	20,6
6	418,1	9,07	104,9	8,55	20,6
7	418,2	8	105,5	8,54	20,6
8	418,6	8,93	107,2	8,52	20,5
9	418,6	8,93	107,4	8,52	20,5
10	418,8	8,75	107,8	8,51	20,5
11	419,3	8,69	108,3	8,49	20,5
12	425,9	5,18	113,7	8,07	20,2
13	430,3	3,22	117,9	7,91	20
14	432,7	0,29	-183,6	7,78	19,8

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	393	12,35	107,5	8,75	21,5
2	393,2	12,3	107,5	8,74	21,5
3	393,3	12,2	107,6	8,75	21,5
4	394,2	12,2	108,1	8,73	21,5
5	394,7	12,13	108,5	8,72	21,4
6	394,7	12,02	109,5	8,71	21,4
7	396,7	11,78	110,3	8,68	21,3
8	397,8	11,63	112,4	8,64	21,3
9	408,7	9,39	115,6	8,42	21
10	412,8	8,35	119	8,29	20,8
11	421,2	6,09	124,3	8,01	20,4
12	422	5,81	127,1	7,94	20,4
13	430,6	2,9	-90	7,79	20,1
14	434,2	0,52	-159,1	7,74	20,1

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	398,7	11,7	104,4	8,76	21,6
2	398,5	11,52	111	8,75	21,5
3	398,8	11,09	116,7	8,7	21,5
4	399	11,1	120,7	8,69	21,4
5	399,6	11,02	125,7	8,68	21,4
6	399,5	10,97	128,1	8,67	21,4
7	400	10,79	131,1	8,66	21,4
8	404,9	9,89	134,2	8,57	21,4
9	406,2	9,79	134,1	8,54	21,4
10	407,9	9,54	135,9	8,5	21,3
11	408,1	9,35	138,2	8,49	21,3
12	415,6	6,25	144,4	8,16	20,9
13	416,4	6,23	146,6	8,1	20,8
14	416,5	4,79	-110	7,91	20,7

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	397,3	11,12	123,3	8,73	22
2	397,5	11,03	123,4	8,73	22
3	397,8	10,78	123,3	8,72	21,9
4	399,2	10,46	124	8,68	21,9
5	401,5	10,21	124,8	8,62	21,8
6	401,7	10,02	125	8,6	21,8
7	404,4	9,49	125,7	8,55	21,6
8	407,4	8,67	126,9	8,45	21,4
9	409,5	8,17	128,2	8,36	21,3
10	414,6	6,04	131,4	8,11	21
11	414,6	5,8	132,8	8,06	20,9
12	416	5,14	133,8	8	20,9
13	426,7	2	-122,8	7,79	20,6
14	424,5	0,36	-205,5	7,78	20,6

POINT N°3

30/06/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	429,3	9,72	121,9	8,55	18,7
2	428	9,79	121,8	8,54	18,6
3	429,9	9,6	121,9	8,53	18,6
4	430,5	9,45	122,6	8,51	18,5
5	431,3	9,09	123,6	8,46	18,5
6	438,5	5,31	132,4	8	18
7	424,5	0,04	-107,2	7,71	18

01/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	429,6	10,09	121,9	8,57	18,8
2	429,6	10,09	125,6	8,57	18,8
3	429,6	9,96	125,9	8,56	18,8
4	430,6	9,65	128,4	8,52	18,6
5	431,5	9,18	130,6	8,45	18,5
6	431,8	8,78	130,4	8,42	18,4
7	432,2	8,11	-143,3	8,31	18,4

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	428,4	9,84	118,8	8,52	18,8
2	428,6	9,8	119,5	8,51	18,8
3	428,8	9,56	120,4	8,51	18,8
4	428,8	9,78	122,6	8,5	18,8
5	429,3	9,56	123,9	8,48	18,8
6	429,4	8,51	-93,2	8,35	18,8
7					

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	428,4	9,84	118,8	8,52	18,8
2	428,6	9,8	119,5	8,51	18,8
3	428,8	9,56	120,4	8,51	18,8
4	428,8	9,78	122,6	8,5	18,8
5	429,3	9,56	123,9	8,48	18,8
6	429,4	8,51	-93,2	8,35	18,8
7					

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	412,5	13,63	67,2	8,79	20,8
2	412	13,62	68,2	8,79	20,8
3	411,9	13,6	67,9	8,78	20,8
4	413,9	13,22	69,6	8,77	20,6
5	419,1	11,78	72,9	8,68	20,2
6	431,8	7,81	77,6	8,36	19,3
7	428,9	3,41	-144,4	7,88	18,7

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	405	12,91	86,3	8,75	21,5
2	406,1	12,71	88,4	8,72	21,4
3	407,5	12,51	92,8	8,69	21,2
4	421,1	9,71	97,2	8,52	20,1
5	427,3	8,2	101,2	8,36	19,6
6	434,3	5,44	-93,8	8,06	18,8
7	430,2	2,79	-127,2	7,82	18,7

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	412,5	9,58	112,8	8,65	21,9
2	412,5	9,56	112,3	8,65	21,9
3	412,5	9,54	112,6	8,64	21,8
4	412,5	9,51	113	8,63	21,8
5	412,6	9,52	113,1	8,64	21,8
6	412,6	9,41	114	8,62	21,8
7	401,3	0,07	-182,8	7,84	21,3

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	420,3	8,11	133,5	8,43	20,6
2	420,3	7,88	134,5	8,43	20,6
3	420,2	7,99	135,8	8,43	20,6
4	420,3	7,88	138,2	8,42	20,6
5	420,3	7,91	139,2	8,42	20,6
6	420,3	7,94	140,9	8,41	20,6
7	420,3	8,02	145,8	8,4	20,6

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	414,4	11,06	132	8,73	20,7
2	416,1	10,19	131,1	8,66	20,6
3	417,8	9,01	136	8,57	20,5
4	417,7	8,93	135,1	8,58	20,4
5	418	9,15	138,3	8,56	20,3
6	417,9	9,13	138,1	8,56	20,3
7	418,4	8,9	137,9	8,53	20,3

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	406,3	14,39	126,7	8,94	21
2	408,9	13,15	127,7	8,87	20,8
3	410,4	12,47	128,5	8,84	20,7
4	410,2	12,37	129,2	8,8	20,6
5	410,3	11,85	129,9	8,78	20,6
6	415,1	10,46	131,9	8,66	20,5
7	422,8	6,67	137,1	8,3	20

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	378,4	13,19	106,2	8,83	22,5
2	378,4	13,17	108,5	8,83	22,5
3	378,7	13,25	110,2	8,83	22,5
4	379,2	13,25	112,2	8,81	22,4
5	380,9	13,23	114,4	8,8	22,3
6	385,7	12,79	117,4	8,75	22
7	401,3	1,12	-195,1	8,12	21,2

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	376,7	12,18	130,7	8,86	22,9
2	376,3	12,12	132,6	8,84	22,8
3	386,9	11,46	136,9	8,71	22,3
4	396,6	10,71	139,9	8,66	21,8
5	409,8	8,9	143	8,46	21,4
6	412,6	8	145,2	8,37	21,2
7	415,8	6,77	-126,3	8,22	21,1

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	379	11,84	128,3	8,82	22,8
2	379,6	11,96	129,1	8,82	22,7
3	386,6	11,53	130,2	8,77	22,4
4	389,1	11,5	131,6	8,76	22,3
5	389,1	11,52	131,8	8,78	22,3
6	389	11,53	132	8,79	22,3
7	416,5	5,6	144,1	8,08	22,1

POINT N°4

01/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	430	9,51	90,4	8,43	18,8
2	430,4	9,51	91,3	8,46	18,8
3	430,4	9,31	94,8	8,48	18,8
4	430,9	9,11	97,2	8,46	18,7
5	431,1	9,16	102,1	8,45	18,7
6	430,6	8,84	109,2	8,42	18,7
7	431,6	6,19	-125,2	8	18,6

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	426,1	10,11	234,8	8,58	18,9
2	426,9	10,37	227,6	8,58	18,9
3	426,8	10,29	224,3	8,57	18,9
4	426,9	10,29	222,3	8,56	18,9
5	427	10,26	219,8	8,55	18,8
6	427,1	10,23	217,9	8,54	18,8
7	427,5	9,78	29,7	8,51	18,8

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	422,7	11,73	110,8	8,68	20,2
2	422,9	11,71	111,5	8,65	20
3	423,6	11,28	113,7	8,58	19,9
4	428	10,15	113	8,53	19,4
5	431,4	8,32	115,7	8,34	18,9
6	436,5	6,45	118,7	8,12	18,6
7	435,8	6,24	120,3	8,07	18,6

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	412,1	12,04	93,7	8,77	21,4
2	412,1	12,29	98,8	8,75	21,4
3	421	10,46	102,5	8,64	20,6
4	425,1	10,33	104,1	8,62	20,3
5	429	9,26	106,5	8,53	19,8
6	432,2	7,87	109,5	8,4	19,5
7	442,2	2,65	-105	7,9	18,5

09/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	423,5	9,27	273	8,56	20,7
2	423,7	9,2	263,4	8,56	20,7
3	423,7	9,16	258	8,56	20,7
4	423,8	9,12	254,2	8,55	20,7
5	423,7	9,12	248,3	8,52	20,6
6	425,2	8,86	248,5	8,44	20,5
7	436,8	5,28	253,6	8,01	19,1

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	423,6	9,02	174,3	8,5	21,1
2	423,7	8,76	170,8	8,48	21
3	423,8	8,7	168,2	8,48	21
4	424,1	8,5	166	8,47	21
5	424,2	8,4	163,8	8,46	20,9
6	425,2	8,1	163,4	8,41	20,7
7	441	3,15	-97,6	7,91	19,2

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	419,9	8,02	302	8,48	20,5
2	419,8	8	295,5	8,47	20,5
3	419,9	8	289,1	8,48	20,5
4	419,8	7,83	284,6	8,47	20,5
5	419,6	7,91	276,5	8,47	20,5
6	420,7	7,84	268	8,46	20,4
7	422,5	7,67	265,5	8,4	20,4

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	411,3	11,84	136,6	8,87	20,8
2	413,5	10,99	136,6	8,78	20,7
3	414,3	10,54	137,3	8,74	20,7
4	414,6	10,29	137,4	8,73	20,7
5	414,7	10,55	133,9	8,73	20,6
6	414,8	10,57	136,6	8,72	20,6
7	416,4	9,64	137,1	8,63	20,6

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	398,8	14,97	76,5	8,89	21,3
2	400,7	14,35	81	8,83	21,3
3	413,8	10,71	87,7	8,66	20,9
4	415,8	9,88	91,7	8,6	20,8
5	417	9,29	94,7	8,56	20,7
6	418,2	9,09	96,7	8,53	20,6
7	418	9,21	97,5	8,55	20,6

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	400,3	11,19	101,6	8,65	21,3
2	400,4	11,28	101,2	8,65	21,3
3	400,7	11,21	100,3	8,66	21,3
4	401,5	10,94	100,8	8,64	21,2
5	403,4	10,57	101,2	8,6	21,2
6	408,6	9,5	102,9	8,49	21
7	425,1	5,11	109,8	8,04	20,4

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	398,4	11,1	162	8,76	21,6
2	398,8	11,34	160,9	8,74	21,5
3	399,2	11,04	159,1	8,72	21,5
4	400,9	10,73	158,5	8,68	21,4
5	402	10,52	158	8,66	21,4
6	414,7	7,27	162,5	8,29	20,9
7	438,1	0,53	-158,9	7,85	20,3

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	402,6	10,7	105	8,68	21,5
2	402,5	10,47	105,5	8,68	21,5
3	402,6	10,49	106,5	8,67	21,5
4	403	10,45	107,7	8,65	21,5
5	406,5	8,89	110	8,51	21,4
6	409,9	7,87	112,8	8,34	21,2
7	410	7,98	113,5	8,34	21,2

POINT N°5

01/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	429,1	9,65	206,6	8,55	18,7
2	429,4	9,96	200,8	8,55	18,7
3	430,9	8,82	198,3	8,41	18,4
4	431,2	8,32	-40,3	8,36	18,3

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	427,7	9,93	109,4	8,53	18,7
2	427,9	9,87	111,2	8,53	18,7
3	427,8	9,92	113,7	8,52	18,7
4	428	9,83	94,2	8,52	18,7

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	405,2	13,61	58,7	8,78	22
2	404,9	14,11	60,3	8,77	21,9
3	404,7	14,1	66,7	8,76	21,7
4	407,4	12,93	66,1	8,66	21,2

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	416,6	11,45	90,6	8,66	20,9
2	416,6	11,37	91,6	8,66	20,9
3	417	11,24	93	8,65	20,8
4	430,7	6,71	100,2	8,23	19,5

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	413,6	9,7	111	8,64	21,9
2	413,5	9,74	110,3	8,65	21,9
3	413,7	9,62	110,9	8,63	21,8
4	413,8	9,62	51,7	8,62	21,8

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	417,9	8,25	120,9	8,48	20,5
2	417,9	8,35	123,1	8,48	20,5
3	417,9	8,31	125,4	8,47	20,5
4	418	8,21	90,9	8,45	20,5

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	414,7	10,8	117,4	8,73	20,5
2	415,8	10,22	121,9	8,67	20,5
3	418,2	8,65	125,3	8,55	20,4
4	418,9	7,85	127	8,5	20,2

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	400,9	14,9	114,9	8,93	21,2
2	405,8	13,16	118	8,86	21
3	406,7	13,08	119,2	8,84	20,9
4	408,7	12,29	120,6	8,79	20,8

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	381	12,89	86,5	8,79	22,3
2	381,4	13,01	88,8	8,8	22,3
3	381,7	12,92	91,9	8,79	22,3
4	382,4	12,84	93,7	8,79	22,2

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	378,4	12,47	108,8	8,85	22,6
2	378,7	12,56	112,6	8,85	22,6
3	380,6	12,35	116,4	8,83	22,4
4	401,2	10,2	122,7	8,58	21,7

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	382,4	11,68	111,1	8,8	22,6
2	382,5	11,66	115,6	8,79	22,6
3	382,8	11,67	118,7	8,79	22,6
4	396,4	9,3	124,2	8,53	22,1

POINT N°6

03/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	425,9	10,55	100	8,6	18,8
2	426,8	10,24	102,9	8,57	18,8
3	427	10,22	106,3	8,57	18,8
4	427,9	10,04	108,1	8,54	18,7
5	428,4	9,82	113,9	8,52	18,7
6	428,3	9,79	116	8,53	18,7
7	429,9	9,09	118,9	8,45	18,6
8	430	9,06	120,6	8,44	18,5
9	428,9	8	-105	8,23	18,5
10					

07/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	420	12,6	74,1	8,79	20,5
2	420,2	12,55	75,8	8,78	20,3
3	420,3	12,34	77	8,77	20,2
4	422,6	11,41	79,2	8,7	19,8
5	428,5	9,23	82,2	8,53	19,5
6	430,9	8,06	83,8	8,39	19,3
7	434,3	6,36	86,9	8,19	18,8
8	434,9	5,73	88,7	8,13	18,6
9	432,5	1,08	-39,4	7,8	18,6
10	432,2	0,8	-40,8	7,77	18,6

08/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	408,2	12,69	82,4	8,75	21,4
2	408,4	12,73	85,5	8,74	21,4
3	409,2	12,41	87,5	8,72	21,3
4	426,6	9	95,1	8,46	19,6
5	430,7	7,73	99,5	8,33	19,2
6	431,9	7,27	101,3	8,28	19,1
7	434,4	6,09	103,9	8,15	18,8
8	435,5	4,98	-72,7	8,03	18,7
9					
10					

10/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	417,1	9,57	123,3	8,59	21,5
2	417,2	9,54	122,5	8,6	21,5
3	417,3	9,46	122,5	8,59	21,5
4	417,6	9,37	121,6	8,59	21,4
5	420,1	9,25	122,8	8,56	21,3
6	421,3	9,17	123,1	8,55	21,2
7	423	9,02	123,9	8,52	21,1
8	423,5	8,68	71,8	8,49	21
9	410,8	0,08	-169,7	7,67	20,6
10	410,4	0,06	-175,1	7,66	20,6

14/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	420,9	7,85	146,6	8,42	20,6
2	421	7,79	147	8,42	20,6
3	421	7,7	147,7	8,42	20,6
4	421	7,75	149,1	8,42	20,6
5	420,9	7,79	152,2	8,41	20,6
6	420,9	7,74	152,8	8,4	20,6
7	420,9	7,56	153,1	8,4	20,6
8	420,7	7,71	153,4	8,39	20,6
9	419,7	7,72	154,1	8,4	20,5
10	412,7	4,72	-136	7,82	20,4

17/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	414,3	10,91	136,8	8,73	20,7
2	415,5	10,02	139,1	8,68	20,6
3	416	10,06	138,8	8,66	20,6
4	416,4	9,76	140,5	8,63	20,6
5	417,9	8,95	142,2	8,56	20,5
6	417,3	9,11	141,6	8,58	20,4
7	417,9	8,67	143,4	8,54	20,2
8	418,5	8,37	143,6	8,5	20,1
9	419	8,39	144,2	8,48	20,1
10	425,5	3,98	-142,7	7,88	20

18/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	405,3	14,15	136,7	8,9	21
2	408,9	12,56	136,5	8,82	20,9
3	411	11,94	136,4	8,76	20,8
4	412,7	11,5	136,6	8,74	20,8
5	418,5	8,97	138,8	8,54	20,6
6	418,5	9,1	138,2	8,54	20,5
7	418,2	9,06	137,5	8,53	20,4
8	419	8,64	137,1	8,5	20,4
9	420,3	8,22	137,5	8,43	20,3
10	422,3	3,19	-46,7	7,82	20,2

21/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	382,2	12,67	83	8,77	22,3
2	382,5	12,7	88,2	8,77	22,3
3	384	12,91	94,4	8,79	22,1
4	391,6	11,9	101,6	8,68	21,8
5	396,1	11,33	104,1	8,62	21,6
6	395	11,62	106,6	8,65	21,5
7	394,9	11,6	108,1	8,66	21,5
8	399,5	10,95	111,8	8,6	21,3
9	403,9	9,94	114,4	8,49	21,2
10	425,2	0,33	-226,9	7,84	20,2

22/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	377,8	12,81	99,9	8,88	22,6
2	378,5	12,7	106,4	8,87	22,5
3	379,3	12,14	113,9	8,83	22,5
4	380,7	11,63	117,4	8,77	22,4
5	395,1	11,44	121,4	8,74	21,8
6	398,5	11,02	127,9	8,7	21,6
7	403	10,42	133	8,65	21,5
8	411,9	8,11	137,6	8,39	21,2
9	418,6	5,57	141,6	8,08	20,8
10	419,9	0,33	-201,9	7,82	20,6

23/07/14

Profondeur	Conductance (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temperature (°C)
1	381,8	12,16	139,5	8,83	22,7
2	382,4	11,95	139,9	8,84	22,7
3	383,7	9,95	143,3	8,61	22,3
4	393	11,06	141,8	8,73	22,2
5	394,8	10,77	141,6	8,72	22,2
6	392,7	11,09	141,4	8,73	22
7	412	6,74	149,5	8,19	21,3
8	416,2	4,97	152,5	8	21
9	421,2	3,3	155,6	7,83	20,7
10	419,9	0,37	-190,9	7,83	20,6

ABSTRACT

This report is about the phosphorus balance and the thermal stratification of Vombsjön lake which is situated in South of Sweden (Scania) and is a reservoir of drinking water for Sydvatten. Because of individual sewage, fertilizers and other sources of phosphorus, many lakes are faced with the problem of eutrophication. The aim of the project was to check the status of the lake and anticipate eventual future problems. To achieve this, a lot of data have been collected in the lake and exploited. The conclusion the project led us to is that the lake is faced with the problem of phosphorus leakage from the bottom sediment to the water due to oxygen depletion, increasing the already existing eutrophication of the lake. Sydvatten needs to quickly find solutions to remedy this problem for the future.

Le présent rapport traite de la stratification thermique et du bilan phosphorique du lac Vombsjön, situé au sud de la Suède (Scanie) et réservoir d'eau potable pour Sydvatten. A cause des eaux usées des particuliers, des fertilisants utilisés dans les champs et autres sources de phosphore, beaucoup de lacs suédois sont confrontés à la problématique actuelle grandissante de l'eutrophisation. Le but du projet était de dresser un diagnostic de l'état du lac pour ainsi anticiper d'éventuels problèmes futurs. Dans ce but, nous avons collecté un grand nombre de données que nous avons exploitées par la suite. Ce projet nous a menés à la conclusion que le lac fait face à un problème de relargage de phosphore par les sédiments du fond du lac dû à l'appauvrissement en oxygène, augmentant l'eutrophisation déjà existante du lac. Il faut donc que Sydvatten trouve des solutions à ces problèmes rapidement dans l'intérêt de son avenir.