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Macro chemistry, nutrients, and heavy metals in River Bø-elva upstream and downstream Bø sewage treatment plant - 2023.

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Summary

During the period 26.04.2023 – 06.11.2023, 20 water samples have been taken weekly in River Bø-elva , both upstream and downstream Bø sewage plant (BSP), located in Midt-Telemark municipality, Norway. The upstream site was located about 100 m upstream the discharge point from BSP, the downstream site about 300m downstream. According to the results, the concentrations were significantly higher downstream BSP for the following compounds, ranked according to concentrations: $Cl^- > Na^+ > Ca^{2+} > NO_3^-$-N $> K^+ > Mg^{2+} > NH_4^+$-N = Al > Mn.

Except for Mn and Fe, the concentrations of heavy metals in River Bø-elva were never recorded above detection limits for the analysis method, neither upstream nor downstream. Also, the concentration of Tot-P was almost identical at both sampling sites, i.e. 5,7 ± 1,1 mg P L^{-1}, primarily because of the effective phosphorous precipitation by use of poly-aluminium chloride (PAX-18) at BSP. Tot-N the concentrations varied a lot at the two sites during the investigated period, i.e. from 674 - 2040 mg N L^{-1} upstream BSP and from 598 - 4340 mg N L^{-1}. Because of these large variations, primarily in the concentration of organic N, it was not possible to reveal significant differences in Tot-N between the two sampling sites.

According to the Norwegian classification guidelines, the overall chemical pollution status of River Bø-elva, according to Tot-N was "**Bad**" at both locations. Regarding Tot-P, acidification and heavy metal, the river was classified as "**Very Good**".

Contents

Preface

I praise my Allah, the almighty, merciful, and passionate, for providing me this opportunity and granting me the capability to proceed successfully. There are no proper words to express my deep gratitude and respect for my research advisor, Professor Espen Lydersen. He has supported me academically and emotionally since the days I began my research at the University of south-East Norway, campus Bø. His immense knowledge, patience, motivation, and valuable advice have enabled me to complete this research study in time. Besides my advisor, my sincere thanks must also goes to other staff members who generously not only gave their time to listen to me but also offered their valuable comments toward improving my work.

This journey would not have been possible without the support of my parents and family who not only supported me emotionally and financially but also prayed for me throughout this long time. Especially I am indebted to my ‘Khanji and Abbu’ for their love, encouragement, and prayers all the time. They are comforting in the paradises. Their smiling faces and praying lips are still shining in my heart. I heartily dedicate this research to my ‘Khanji and Abbu”. I must also thank my grandmothers (Ammi and Dado), Uncles, and brothers (Dost, Usman, Shoaib and Umar) for their love and encouragement. Last but not least I am grateful to my dearest Muhammad Yahya Khan for supporting me most positively throughout this long agonizing period that I have spent thousands of miles away from my home. It was his love that raised me up again whenever I got weary.

The research appears in its current form due to the assistance and guidance of several people. The administrative staff of the Department of Ecology and Environmental Management. University is memorable not only for its prompt support but also for its kind care.

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1 Introduction

During the last decades environmental problems especially fresh water is of worldwide concern because of chemical and biological contaminations (Crini & Lichtfouse, 2018). Surface water quality continually decline because of untreated or poorly treated wastewater is discharged into them (Ospanov et al., 2021). Unregulated rise in the anthropogenic burden on natural resources would cause a global disturbance of the natural equilibrium (Ospanov et al., 2021). Causes of water pollutions are industrial wastes, mining activities, sewage and waste water, pesticides and chemical fertilizers and urban development (Crini & Lichtfouse, 2018). According to the Norwegian pollution regulations part 4 chapter 11, wastewater is consider to be both industrial waste water, sanitary water and storm water (Norwegian-pollution-regulations, FOR-2004-06-01-931). Clean water is fundamental for all kinds of life and ecosystems. Rapidly increasing demand of fresh water and depleting water quality, demand wastewater treatment and water reuse (Kesari et al., 2021).

According to Norwegian pollution regulation, treatment plants are "Any plant for handling waste water which consists of one or more of the following main components: drainage network, treatment plant and discharge device" (PollutionRegulations, FOR-2004-06-01-931). The treatment of wastewater involves four fundamental techniques: physical, mechanical, biological, and chemical methods (Raouf et al., 2019). The wastewater treatment process has 4 potential stages of cleaning, Primary, Secondary, Tertiary and Quaternary treatments (in some cases).

Figure 1 *Bø sewage wastewater treatment plant (Skarweld AS, 2014).*

"**Primary treatment**" is the first phase of the purification process, which mostly focuses on physically removal of large particles and floating debris from the raw sewage. It is the first stage in a multi-stage treatment process that transforms raw wastewater into a form that may be released into the environment or sent to another facility for additional treatment. In order to protect downstream treatment processes and increase overall treatment efficiency, primary treatment is essential (Henze et al., 2008).

"Secondary treatment", The biological breakdown of dissolved organic carbon and uptake of nutrients are the main goals of secondary treatment. In addition secondary treatment often include precipitation of phosphorous and organic matter by use of different inorganic Al and Fe salts (often named PAX'es), producing sludge, which is transported to other facilities for further treatment/use (Henze et al., 2008).

"Tertiary treatment" the procedure that eliminates contaminants especially nitrogen and phosphorus that secondary treatment was unable to sufficiently remove. Sand filters, microstraining, and other techniques are used in this process. This treatment is considered to be advanced wastewater treatment (European-Environment-Agency, 2000).

"**Quaternary treatment**" is the step beyond primary, secondary, and tertiary treatment procedures. It involves further treatment procedures meant to enhance the treated wastewater's quality even more to satisfy strict legal requirements or make certain reuse applications possible. Main objectives behind this treatment to remove antibiotics, pesticides, drugs, micro plastics from water (Colubris).

On a global level, 42% of domestic wastewater is improperly handled, endangering both living health and ecosystems (Naylor, 2023). The treatment ratio is higher in developed countries than in developing countries. Developed countries treat on average 74% of their wastewater in wastewater treatment plants (WWTPs), compared with 4,2% in undeveloped countries. According to WHO and UNICEF, about 3.1 billion people have access to sewage systems around the globe with connection to sewage treatment plants in 2017 (Zhang et al., 2021). China ranked 1^{st} with the most urban WWTPs all across the world with the highest treatment capacity or capability (Zhang et al., 2021). They have a treatment capability of approximately 193 million tons every day. Wastewater treatment according to the latest data, provided by Environmental performance index (EPI), Danmark is leading the world with 100 EPI score, Norway ranked 29 with 64.3 EPI points. Pakistan ranked 129 with 0.1 EPI points (Environmental_Performance_Index, 2022).

The Norwegian pollution regulation document, part 4-Drainage, provide guidelines about all waste water treatment and treated water discharge in detail (Norwegian-pollution-regulations, FOR-2004-06-01-931). This regulation, has set standards for water treatment facilities for purification in chapter 14 (Norwegian-pollution-regulations, FOR-2004-06-01-931). According § 14.2, The phosphorus content of the wastewater must be at reduced by at least 90% reduced, and 70% for nitrogen. (Norwegian-pollution-regulations, FOR-2004-06-01-931).

1.1 Different challenges for today's wastewater treatment plants in Norway

The flush toilet was put into use in Norway in the early 20th century with a wiring network that leads the wastewater into the nearest stream or river. This created a lot of problems with odours and fouling when piped into rivers, lakes, fjords and sea. (Norwegian_Environmental_Agency, 2023). The water quality of fresh water and sea eventually became very bad, and many user interests required action, thus starting a comprehensive development of treatment plants in the early 1970s (Norwegian_Environmental_Agency, 2023).

Today, there are still several old treatment plants and wiring networks that have not been upgraded since 1970s. The average age of municipal wastewater networks with known age in Norway is 34 years, and 14 percent of municipal wastewater networks have unknown age (Berge & Onstad, 2022). In 2021, 0.7% of the wiring network was renewed in Norway. Old wiring can create several problems for the treatment plants, such as leakage, capacity problems, clogged/blocked pipes, and lack of separation of wastewater and stormwater. Municipal reports to the Norwegian Environment Agency from 2018 documented 2 717 wastewater facilities in Norway with a capacity of more than 50 (pe) (Statistisk_sentralbyrå, 2019). They processed wastewater from 87% of the people living in Norway. 2% of the population had direct discharges (untreated wastewater), 22 % had mechanical or other treatment, while 63 % of the population was linked to advanced treatment plants (chemical and/or biological treatment).

Stormwater is also a challenge for the treatment plants, this stormwater runs off surfaces and into the drainage system, and especially in densely built-up areas with a lot of impermeable surfaces, stormwater can be problematic for sewage treatment plants. It can lead to capacity problems because the treatment plants are designed to handle wastewater and not additional overwater (Statistisk_sentralbyrå, 2019).

Climate change leads to changes in rainfall patterns and there will be more extreme rainfall, which also leads to more stormwater (Norwegian_Environmental_Agency, 2023). Large amounts of stormwater lead to high-flow in drainage systems can lead to overflow of wastewater reaching the environment untreated (Norwegian_Environmental_Agency, 2023).

1.2 Revision of the EU sewage directive

On 26 October 2022, the European Commission presented a proposal for a revised sewage wastewater directive. The Directive was adopted in 1991 and is one of the oldest directives that still applies (EU_Commission, 2022a). This proposal for a revised sewage directive sets stricter requirements than the current directive. Today, the directive applies discharge from urban areas with organic matter load ≥ 2 000 pe for fresh water and ≥ 10 000 pe for sea. The revised sewage directive will further reduce pollution and extend the scope to apply to densely populated areas with total discharge ≥ 1 000 pe. It is also proposed new cleanup requirements designed to reduce emissions of micropollutants bacteria/viruses, microplastics, drug residues and environmental toxins that can be transported with ocean currents (EU_Commission, 2022a). Norwegian Environmental Directorates have summarized important points in the proposal for a revised sewage directive on its website:

- The area of operation is expanded, at the same time as the distinction between freshwater and marine recipients are removed.
- The definition of dense housing is changed and made more concrete.
- Minimum secondary cleaning will apply to all densely populated areas ≥ 1 000 pe.
- The requirements for degree of purification for nitrogen removal and phosphorus removal are being tighten up.
- All treatment plants that receive ≥ 100 000 pe must have both phosphorus and nitrogen removal, in addition to a fourth cleaning step to remove micropollutants.
- The fourth cleaning step must be financed by a national authority.
- Discharge of municipal wastewater from densely populated areas between 10 000 pe and 100 000 pe may have to undergo both tertiary and quaternary cleaning by latest 2040, if the recipient's condition or use makes it necessary.
- Energy efficiency becomes an integral part of the permits.
- The sewage sector must be energy neutral by 2040, a requirement that includes everyone facilities receiving ≥ 10 000 pe.

- Changes have been proposed that specify how discharges to water via external treatment plant (indirect emissions) must be assessed when determining emission limits for IED companies (Industrial companies).
- Penalties must be introduced for breach of requirements, and it is assumed that these must be effective, proportionate and act as a deterrent.

The EU directive on sewage is now under revision (Norwegian_Environment_Agency, 2022). The purpose of the revised directive is: "to protect people and ecosystems from the remaining sources of insufficiently treated wastewater, and to provide a predictable framework, better transparency and management of the waste sector. In addition, the audit of the directive contributes to achieving the goals of the green given, achieving climate neutrality in 2050, zero pollution in 2050, transition to a circular economy and restoration of biological diversity, as well as supporting work with public health and the sustainability goal of "ensuring sustainable water management and access to water and good sanitation for all".

As a result of the proposal for a revised wastewater directive, significantly stricter requirements will be imposed for many treatment plants, with significant costs for the sewage sector. It will cost billions of kroner for the municipalities, the responsible level for compliance with the treatment requirements.

1.3 Other emission sources with phosphorus and nitrogen emissions

Fish farming is the biggest source of discharge of nutrient salts along the coast from Lindesnes to Nord Kapp. The emissions of nutrient salts (phosphorus and nitrogen) come from remains of fish feed and fish excrement, and Norway is the world's largest exporter of farmed salmon with > 1 100 registered aquaculture facilities in Norway (Norwegian_Environment_Agency, 2023).

In 2022, Guerrero and Sample published a NIVA-report dealing with source-distributed inputs of nitrogen and phosphorus to Norwegian coastal areas basically from sewage, industry, agriculture, aquaculture, and background sources (Sample, 2024). The report concluded that the Norwegian aquaculture was far the biggest emitter of phosphorus to Norwegian coastal, with 11 836 tonnes in 2020, followed by sewage with 1 239 tonnes. Regarding nitrogen, background sources was the main contributor (69 447 tonnes), with aquaculture as the second largest emitter (68 643 tonnes)

For Vest-Viken water area, where Telemark is included, total amounts of P and N to coastal areas in 2022, were 236 tonnes and 14 066 tonnes, respectively. The contribution for manmade sources was 79,2% for P and 55,1% for N. Of manmade sources, 187 tonnes P and 7 753 tonnes N were, discharged from sewage plants, 25,6% for P and 38,6% of N. The main anthropogenic P emitter in Vest-Viken was agriculture (104 tonnes, i.e. 44,1% of the manmade sources), while agriculture was the largest manmade N source (3 966 tonnes) accounting for 51,5% of the anthropogenic N-sources in Vest-Viken.

Based on data received from Øyvind Kaste (NIVA, Grimstad), i.e. the same database used by Guerrero and Sample (2022), The River Skiens-elva (at Skotfoss, outlet of Lake Norsjø) transported 35,3 tonnes of P and 2 337 tonnes of N in 2021. Thus, based on the data above, The River Skiens-elva contributed with 15% of P (35,3 tonnes/236 tonnes) and 16,6% of N (2337 tonnes/14066 tonnes) to the total discharge of these compounds to the Vest-Viken coastal areas. The downstream areas from Skotfoss to the river outlet is not included in this estimate. The annual contribution from the Bø sewage plant in 2021 was 0,173 tonnes P and 18,7 tonnes N, which means this plant contributed with 0,5% and 0,8% of the Total-P and Total-N to the River Skiens-elva at Skotfoss in 2021.

The purpose of this study was to analyse the influence of Bø sewage plant (BSP) on the River Bø-elva regarding main chemistry, Tot-P, Tot-N and heavy metals. Accordingly, 20 weekly water samples were collected during the period 26.04.2023 – 06.11.2023, both upstream and downstream of Bø sewage plant (BSP). This is also in line with the letter (dated 03.07.2023) from the State Administrator in Vestfold and Telemark which imposed action-oriented recipient monitoring in line with the water regulations for sewage plants that are regulated according to the pollution regulations chapter 14. The purpose of this letter is to clarify to which extent discharges from the sewage facilities influence the water body at local scale.

2 Material and methods

2.1 Study area description.

River Bø-elva is located in Midt-Telemark municipality in Telemark County, Norway. The geography surroundings are hills, forests and farmlands. The River Bø-elva, stretching 33.5 kilometers, is formed by the convergence of several small streams. River Bø-elva starts at the outlet of Lake Seljordvatnet in Seljord municipality and enters Lake Norsjø within the Midt-Telemark municipality (Figure 2.1.1). River Bø-elva is classified as a water type R106 according to (Direktoratsguppen-vanndirektivet, 2018). The upstream and downstream (Mannebru) site in the river, related to Bø sewage plant (BSP) are located < 200 m a.s.l.. The distance between both sampling stations is about 400 m. The discharge water outlet from Bø sewage plant (BSP) is in the middle of the river, and the distance from BSP down to the downstream site (Mannebru) is about 300 m. Mannebru was chosen because of assumed optimal mixing of the discharge water from BSP.

The total catchment area station Mannebru in River Bø-elva is 850,27km^2 (Table 2.1.1). The catchment area of Mannebru ranges from 25 m to 1536 m a.s.l. (Table 2.1.1). With an average discharge of 566.04mm yr^{-1} averaging precipitation of 947.06mm yr^{-1}, the catchment area indicates a 41% evapotranspiration rate (Table 2.1.1). The diverse landscape comprises 62% forest area, 19% bare rock, 5.6% lakes, 4.8% bogs, and 3.8% agricultural lands. Urban areas make up only 0.32% of the total area (Table 2.1.1).

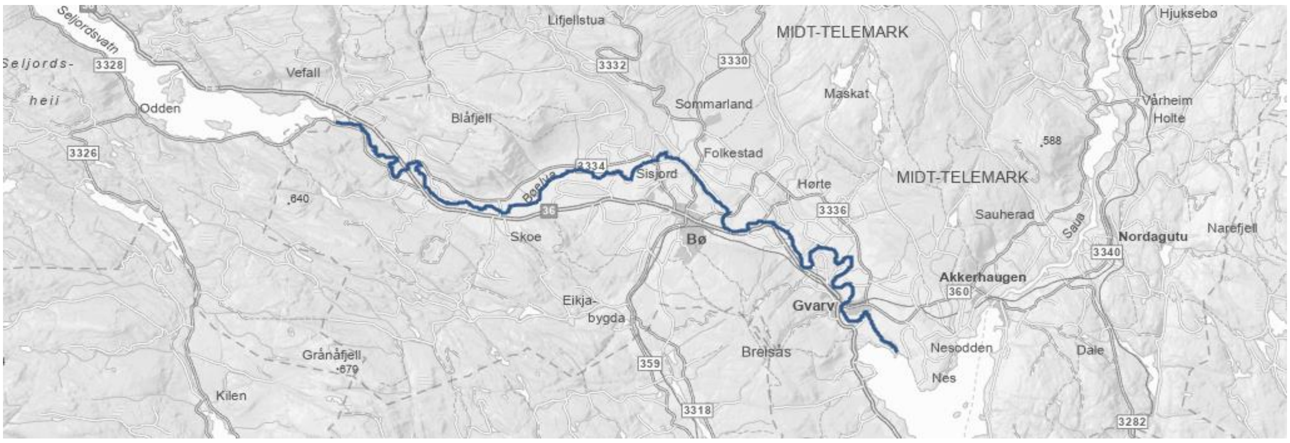

__Figure 2.1.1__ River Bø-elva starts from the outlet of Lake Seljordsvatnet in Seljord municipality and meanders and enters Lake Norsjø within the Midt-Telemark municipality.

Table 2.1.1 *Characteristics of the Rive Bø-elva catchment upstream from Mannebru station in the Midt-Telemark municipality, Telemark County (Water course no. 016CA31). The Norwegian Water Resources and Energy Directorate (NVE) data were obtained through (NEVINA).*

Heigh min	Heght max	Catchment	Hydrology Mean discharge	Hydrology Mean discharge	Air Temp. annual	Precip./snow melt May	Precip./snow melt May	Precipetation May-Sept	Precipitation Oct-April
m a.s.l.	m a.s.l.	km^2	Ls-1 Km^2	mm yr^1	°C	mm	mm	mm	mm
25	1536	850,27	17,95	566,04	1,29	302,46	134,27	458,11	488,96
Lake	**Agriculture**	**Forest**	**Bog**	**Bare rock**	**Urban**	**Clay**	**Unclassified**		
%	%	%	%	%	%	%	%		
5,62	3,8	61,7	4,76	18,86	0,32	0,01	4,95		

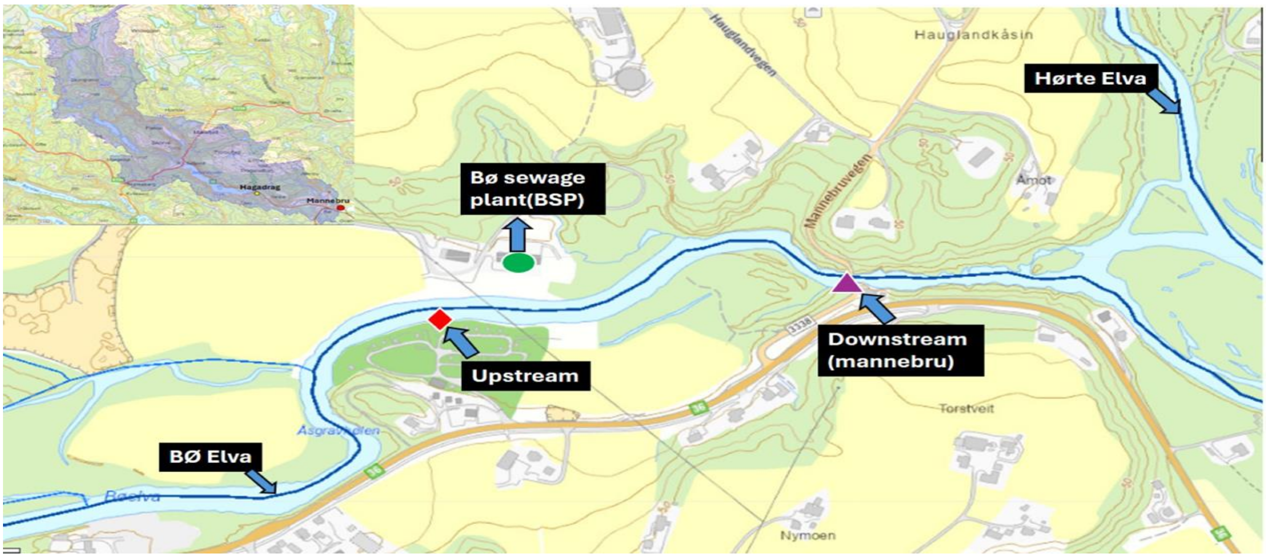

Figure 2.1.2 *Water catchment and details about the study area. A small map up-left corner (catchment violet) shows the total water catchment area at Mannebru (downstream site). The yellow solid circle (see up-left corner) indicates Hagadrag water flow station, the start of the River Bø-elva. Top right corner, is the water flow station in River Hørte-elva. Red triangle is the upstream sampling site, green circle is the Bø Sewage Plant (BSP), and violet triangle is the downstream sampling site. This part of River Bø- elva is classified as Water-type R105 (Direktoratsguppen-vanndirektivet, 2018).*

2.2 Estimates of water discharge at Mannebru in River Bø-Elva

The Norwegian Water Resources and Energy Directorate (NVE) has a water discharge station in River Bø-elva at Hagadrag, near the outlet from Lake Seljordvatn. Hagadrag is located approximately 15 km upstream from our water sampling sites, upstream and downstream from Bø sewage plant (BSP) (Figure 2.1.2). NVE also operates a waterflow station in the River Hørte-elva, located a few hundred meters downstream from the Mannebru water sampling site in River Bø-elva.

Due to the influence of waterpower regulations on the runoff from the upstream catchment at Hagadrag, use of water discharge data from this station for the station at Mannebru is inadequate. This inadequacy arises due to the substantial catchment area between the two sites, Hagadrag and Mannebru. Thus, we sought to estimate the additional waterflow originating from the Hagadrag - Mannebru catchment. Utilizing data from the NVE database (NEVINA.no), this catchment area is approximately 122.66 km² (Table 2.2.1). Due to hydrological and topographical differences between the western and eastern parts of this catchment, we divided this catchment into two sub-catchments, east and west of the River Bø-elva. This division was achieved by physically cutting the catchment from an A4 paper printout, along the mid-river line of River Bø-elva, before weighing the two parts on a Sartorius AX124 analytical balance. Based on these weights, we estimated the areas of the two sub-catchments, named Catchment west and Catchment east.

Table 2.2.1 *The NVE database (NEVINA.no) provided the estimated watershed area (km2) between Mannebru and Hagadrag, as well as the mean water flow (in mm yr-1 and L s-1km-2) for the eastern and western portions of this catchment.*

Station	Catchment	Catchment area km^2	Mean discharge $mm\ yr^{-1}$	Mean discharge $L\ s^{-1}km^{-2}$
Mannebru	Total	850,27	566,04	17,95
Hagadrag	Total	727,61	589,37	18,69
Mannebru - Hagadrag	Total	122,66		
Mannebru - Hagadrag	Catchment west	45,57	307,6	9,75
Mannebru - Hagadrag	Catchment east	77,09	554,1	17,56

Catchment west and Catchment east, was thereafter divided into 5 western sub-catchments and the 11 eastern sub-catchments (Table 2.2.2). Data on catchment area (km^2) and average mean runoff ($L\ s^{-1}\ km^{-1}$) from all the 16 sub-catchments were taken from (NEVINA.no). The 5 western catchments (35,29 km^2) covered 77% of the whole western catchment area (45,57 km^2), while the

11 eastern catchments covered about 80% (61,56 km^2) of the entire eastern catchment (77,09 km^2) (Table 2.2.2) (Appendix A).

*<u>**Table 2.2.2** East and west catchments with their sub-catchments. The western catchment consisted of 5 sub catchments, the eastern catchment Of 11 sub-catchments. The table contains mean water flow both in mm yr^{-1} and L $s^{-1}km^{-2}$, catchment area (km^2), and max and minimum height above sea level (m a.s.l.).</u>*

Catchment west	Catchment no.	Catchment area km^2	Mean water flow mm yr^{-1}	Mean water flow L $s^{-1}km^{-2}$	m a.s.l. min	m a.s.l. max
Øverbomoen	West 1	1,87	307,9	9,74	110	463
Graveevju	West 2	8,13	387,29	12,28	100	637
Jønneberg	West 3	3,87	322,94	10,24	100	398
Forberg	West 4	1,31	305,54	9,69	100	389
Lortebekk	West 5	20,11	272,45	8,64	32	398
Total	West 1-5	35,29				
Total west	All catchments-West	45,57	307,6	9,75	32	637
Sondbø	East 1	2,84	528,92	16,77	102	850
Nyheim	East 2	0,54	344,76	10,93	100	627
Haugen	East 3	1,12	394,77	12,52	100	662
Varegarden	East 4	1,04	469,68	14,89	100	810
Fiskebekk	East 5	3,03	518,76	16,43	100	814
Sigelhus	East 6	2,93	424,24	13,45	100	781
Breskelia-1	East 7	1,21	308,48	9,78	99	499
Breskelia-2	East 8	1,22	303,11	9,61	92	503
Juvsåa	East 9	36,12	669,26	21,21	65	1270
Folkestad	East 10	8,59	345,17	10,94	60	769
Folkestaddalen	East 11	2,92	271,22	8,6	60	214
Total	East 1-11	61,56				
Total east	All catchments-East	77,09	554,1	17,56	60	1270
River Hørte	Total catchment	156,77	491,26	15,58	95	1206

To calculate the area weighted runoff from the eastern and western catchment by we have made the following approaches:

Catchment west:

- S(Catchment area*Mean annual water flow)$_{1-5}$/Total catchment area (45,57 km^2).

  where 1-5 is the total of the 5 sub-catchments used in the equation.

Catchment east:

- S(Catchment area*Mean annual water flow)$_{1-11}$/Total catchment area (77,09 km^2).

  where 1-11 is the total of the 11 sub-catchments used in the equation.

The data are presented in Table 2.2.1 and Table 2.2.2

Table 2.2.3 *Estimated catchment area (km^2) between Hagadrag and Mannebru and mean water flow from (L s^{-1} km^{-2} for the western and eastern part of catchment based on NVE data (NEVINA).*

East Catchment area km^2	R. Hørte Catchment area km^2	East/R.Hørte Ratio	East Mean water flow L s^{-1}km^{-2}	R.Hørte Mean water flow L s^{-1}km^{-2}	East/R.Hørte Ratio
77,1	156,8	0,4918	17,6	15,58	1,1271
West Catchment area km^2	**R. Hørte Catchment area km^2**	**West/R.Hørte Ratio**	**West Mean water flow L s^{-1}km^{-2}**	**R.Hørte Mean water flow L s^{-1}km^{-2}**	**West/R.Hørte Ratio**
45,6	156,8	0,2909	9,75	15,58	0,6259

Subsequently, we proceeded to calculate the water flow data at the Mannebru station. To achieve this, we utilized the average data obtained from the River Hørte-elva station regarding the catchment area and mean discharge. We then adjusted this information to the same average data parameters for both the sub-catchments, Catchment West, and Catchment East. These calculated values are present in Table 2.2.3, providing a comprehensive overview of the water flow characteristics at the Mannebru station and its associated sub-catchments.

Finally, we estimated the water flow at station Mannebru in River Bø-elva according to (Table 2.2.3) using the following equation:

Waterflow$_{Mannebru}$ (m^3 s^{-1}) = Waterflow$_{Hagadrag}$ (m^{3}s^{-1}) + Waterflow $_{R.Hørte}$ (m^{3}s^{-1}) *1,1271*0,4918 (*Contribution Eastern catchment*) + (Waterflow $_{R.Hørte}$ (m^{3}s^{-1})*0,6259*0,2909 (*Contribution Western catchment*)

Figure 2.2.2 shows that the water flow estimates in River Bøelva at Mannebru are much more relevant than using the Hagadrag data, and the water flow respond to precipitation (measured at Bø weather station) is much better taken care of by our estimates at Mannebru, by using the above estimated water flow function.

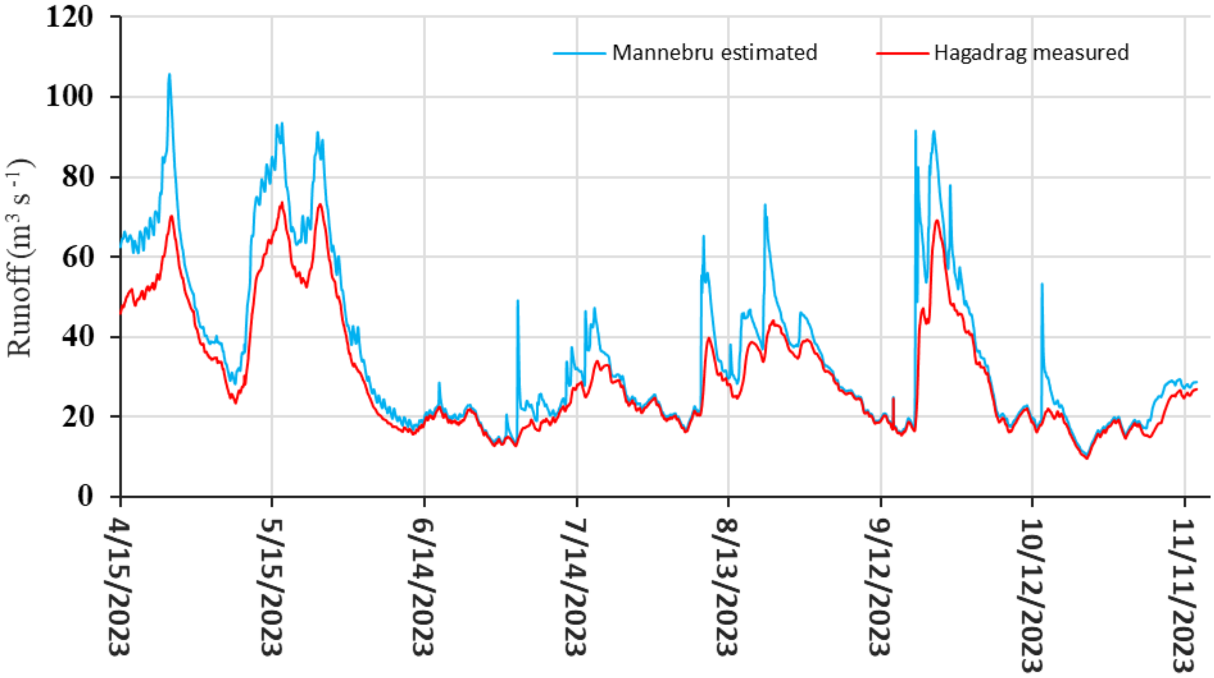

__Figure 2.2.1__ Water runoff (m^3 s^{-1}) *at station Hagadrag (measured) and water runoff* (m^3 s^{-1}) *at station Mannebru (estimated and used for the investigated period in 2023).*

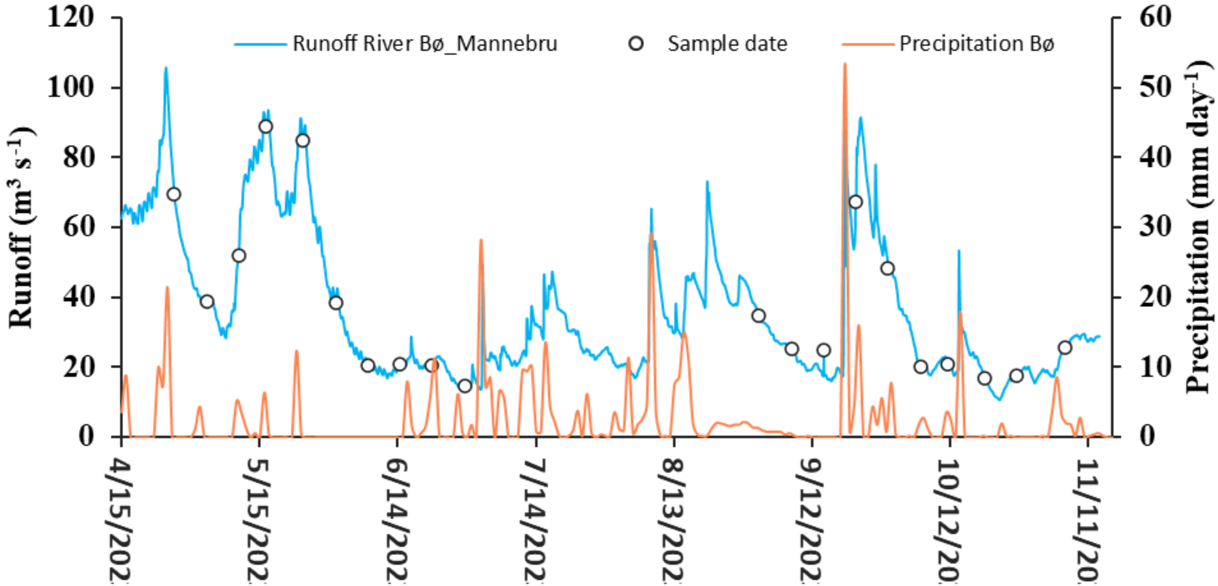

__Figure 2.2.2__ Estimated hourly water runoff (m^3 s^{-1}) at Mannebru and daily precipitation at Bø weather station. Circles represent the days of water sampling.

2.3 Water Sampling and analysis

40 Water samples have been collected during the perioud between 26.04.2023-06.11.2023 (20 sampling weeks) upstream and downstream the Bø sewage plant. The samples have been analysed for macro chemistry, Tot-P, Tot- N and heavy metals.

Figure 2.3.1 Sampling containers for sampling. 1000 mL PE bottle for macro-chemistry (in the back row). 100 mLr brown glass bottles for Tot-N and Tot-P (acidified by H_2SO_4) and heavy metals (acidified by HNO_3).

Figure 2.3.2 The sampling sites in River Bø-elva, upstream station (left), downstream station (right).

Sampling bottles were labeled with the name of the sampling site, date, and a unique running number for alle samples (Figure 2.3.1). pH, conductivity (K_{25} in mS cm^{-1}) and turbidity (in NTU) were measured in laboratory immediately after samples. pH was measured with a VWR-pH110 pH-meter, conductivity by a Hach Sension EC5DL conductivity meter, and turbidity with a Turbiquant 1100 IR turbidimeter for turbidity. Sulfuric acid (H_2SO_4) was added to bottles for total P and total N analyses, while nitric acid (HNO_3) was added to bottles for heavy metal analyses.

All analyses were performed by SGS Analytics Norway AS in Porsgrunn, and ALS Laboratory group, Oslo. All samples were sent together to these accredited laboratories at the end of sampling in December 2023 and analysed for the following parameters:

- SGS Analytics Norway AS: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}-N, SO_4^{-2}, Cl, NO_3^{-}- N, TOC, Tot-N and Tot-P,
- ALS: Ca, Mg, Na, Ba, Al, Fe, Mn, Pb, Cd, Hg, Zn, Cr, Cu, Ni, As, Mo, and V.

Results are included in Appendix B.

2.4 Statistics

Three software have been used for our statistical analysis, Excel, Minitab, and JMP statistical software. Excel has been used to do basic statistics average, median, and regression. Minitab for normal distribution tests, Mann-Whitey tests etc. As most of the variables deviated significantly for normal distribution, the Wilcoxon Signed-Rank test in JMP was used. Alle statistical data produced are attached in the appendix C.

3 Results and Discussion

3.1 Background

From the last few decades, it has been observed that different kinds of freshwater pollution threats sapping (Yang et al., 2022). The sources of these water pollution are complex to identify, so it is hard to assess how water quality reacts to these changes (Yang et al., 2022). Untreated or poorly treated wastewater effects water quality (de Liz Arcari et al., 2023). Sewage treatment plants are a significant part of municipal infrastructure (Yang et al., 2022). Typical sewage treatment plants are capable of removing organic compounds, nutrients, and suspended solids (Kim & Farnazo, 2017). The most common ways to treat sewage water are physical, biological, and chemical. There are 4 treatment types for wastewater, primary, secondary, tertiary and quaternary treatment. The treatment, procedure for the removal of suspended solids is often a combined physical and chemical treatment for removal phosphorus and organic matter, before a biological treatment process (tertiary treatment) for removal of inorganic N and remaining P from the initial physical/chemical processes (Kim & Farnazo, 2017). In quaternary treatment, removal of chemicals like antibiotics, pesticides, drugs, micro plastics are the primary target. Quaternary treatment is a new upcoming treatment step (Colubris).

There may be discrepancies between the discharge standard for treated water in different areas (FOR-2005-12-15-1691, 2005). Consequently, even if the wastewater treatment plant's effluent satisfies the discharge standard, it will still have variable effects on water quality when released into areas with stricter water environmental quality regulations (Yang et al., 2022).
Our research objective was to investigate whether discharge from Bø sewage plant (BSP) has an impact on the local water quality in River Bø-elva. Accordingly, analyses macro chemistry, nutrients, and heavy metals have been investigated in River Bø-elva, both upstream and downstream BSP. This is in line with the claim from the State Governments in Norway.

3.1.1 Laws and agreements about sewage treatment.

Norway is signatory of many agreements regarding wastewater pollution and environmental protection. These agreements seek to resolve transboundary environmental challenges, establishing uniform standards and collaboration. In the Oslo-Paris Conventions (OSPAR), the eight North Sea nations, Norway, Sweden, Denmark, Germany, the Netherlands, Belgium, France, and Great Britain came to an environmental pact known as the North Sea pact in 1987 (Andersen, 2021). The main goal of that agreement was to control the emission of environmental toxicants as, phosphate, nitrogen, and radioactive pollutants in the Northern Sea. Norway has the target to reduce emissions of nitrogen and phosphorus by 50% compared to the 1985 level. (Andersen, 2021).

Norway is not a member of the EU, but an EØS member state and thus closely bound to environmental policies with EU. Thus, Norway is part of the EU Urban Waste Water Treatment Directive (UWWTD) (EU_Commission, 2022b), established in 1991. Main objective of UWWTD is to protect human health and protect the environment from adverse effects of untreated sewage water (EU_Commission, 2022b). There were 2 main goals in this directive:

- Protect environment from sewage water from household and industries.
- Properly handling and treating wastewater from urban area and industrial areas.

In 2022 the commission revised the directive to update the standards on the basis of extensive impact assessment. The objectives of this 2022 revisions were (EU_Commission, 2022b):

- Pollution Reduction and Environmental Improvement.
- Improvement in water quality.
- Improved Sanitation Access.
- Improve water treatment techniques to remove micropollutants from water.
- Pathogen Monitoring Requirements.
- Transition to Circular Practices.

3.1.2 Norway's pollution regulation

Norwegian pollution regulation is the document of laws which contain guidelines and policies regarding protection safety, human health, environmental reserves, and the environment from pollution (FOR-2005-12-15-1691, 2005).

The main points of Norwegian pollution regulation (FOR-2005-12-15-1691, 2005) Include:

- Environmental Protection Act (Forurensningsloven in Norwegian)
- Air pollution regulation
- Water pollution regulation
- Waste management regulation.
- Chemical safety
- Conservation of nature
- International treaties

Part 4 of Norwegian pollution regulation regulates drainage. According to the last amendment, 1 June 2004 no. 93. Chapters 11 to 14 deal with safeguarding the environment from sewage water discharge (FOR-2005-12-15-1691, 2005).

Chapter 11.

The general guidelines in Chapter 11 cover drainage and are intended to safeguard the environment from the harmful consequences of wastewater discharge. Chapter 11, section 3, defines terms related to wastewater used during chapters 11-15-B. The broad rules in Chapter 11 are applicable to Chapters 12 through 15B, which deal with different pollution control and wastewater management. That chapter also provides guidance about report and areal divisions. The Environmental protection agencies have authority to make changes.

Chapter 12

Contains rules for the discharge of sanitary wastewater from residential structures, cabins, and similar businesses. That chapter deals with discharge of constructions with < 50 peperson equivalents (pe). Sections 12.8 and 12.9 deal with the concentration of BOF_5, phosphorus and TOC in discharge water. Chapter 12 has also guidelines for sewage plants regarding functioning, maintenance, designs, and sludge.

Table 3.1.2.1 *Cleaning requirements for treatment plants according to Norwegian pollution regulation Chapter 12 § 12.8 and §12.9 (Norwegian-pollution-regulations, FOR-2004-06-01-931).*

Area division	Status of recepiant	Purification status		
		Phosphorus(P)	BOF5	Suspended solids (SS)
Sensitive area and normal area	User interests	90%	90%	
	Risk of eutrophication	90%	90%	
	Non-user interest and eutrophication risk	60%		
Less sensitive area				20% 180 mg SSL^{-1}

Chapter 13.

This chapter specifies how municipal wastewater from small densely inhabited regions must be treated and discharged. But public sewers are not included in that act. According to that act, the municipalities are responsible also for these plants.

Chapter 14.

Containing regulations for wastewater treatment and discharge from urban areas containing ≥ 2 000 pe to fresh water, ≥ 2000 pe to estuaries, or > 10 000 pe to the sea.

According to Norwegian Environmental Agency, there were 2 754 wastewater facilities in Norway with a capacity > 50 pe. They processed wastewater from 88% of the population (Statistics_Norway, 2022). Only 2% of the population discharges wastewater untreated to the environment. 21% had mechanical or other simple treatment, while 65 % of the population was linked to advanced treatment plants (chemical and/or biological treatment). According to statistics, 4.8 million people connected to moderate- to large-scale wastewater facilities (> 50 pe). The approximately 750 000 people who made up the remaining population were linked to the about 320 000 small wastewater facilities with < 50 pe, which includes tiny individual facilities. These facilities typically consist of a sludge separator, maybe with an extra filtering device at the end. A total of about 1 480 tons of phosphorus and 19 500 tons of nitrogen are projected to be discharged from the municipal wastewater sector in 2022, including anticipated leaks and minor wastewater facilities with < 50 pe. The total estimated dry weight amount of sewage sludge used for various applications in 2022 was around 133 000 tons. Of this total, about 83% was supplied to soil producers, utilized in parks and other green areas, or utilized in agriculture.

3.2 Water chemistry

Our research objective were to alanyse the impact of BSP on the main chemistry, nutrients and heavy metals in River Bø-elvas, upstream and downstream BSP, 20 sample were taken weekly from both stations during the period 26.04.2023-06.11.2023.

The samples were analysed immediately after back from field (within an hour) for pH, conductivity and turbidity. The remaining water were stored in darkness at 4°C until analysed for all other parameters in December 2023, after the end of the sampling period.

The pH in River Bø-elva ranged from pH 6,08 - 6,77 (Table 3.2.1) (Figure 3.2.1), with only minor variations in average and median pH, i.e about pH 6.35 both upstream and downstream BSP (Table

3.2.1). The variation exists between up and downstream. Conductivity is higher in downstream from Bø sewage plant (BSP). Conductivity which we measured during our sampling time always warries between 16,7-23,5 mS cm^{-1}(Table 3.2.1) (Figure 3.2.1).

Turbidity was generally low and varied slightly. At the upstream site, it varies between 0,26 -1,39 NTU (average 0,62 ± 0,30 NTU, median 0,50 NTU), while the downstream site varied between 0,32-1,51 NTU (average 0,64 ± 0,33 NTU, median 0,54 NTU) (Table 3.1.1). Despite trends of rising turbidity with higher water flow and decreasing pH and conductivity with increased flow, none of the water chemical parameters studied shown any significant correlations with water flow (Figure 3.2.1).

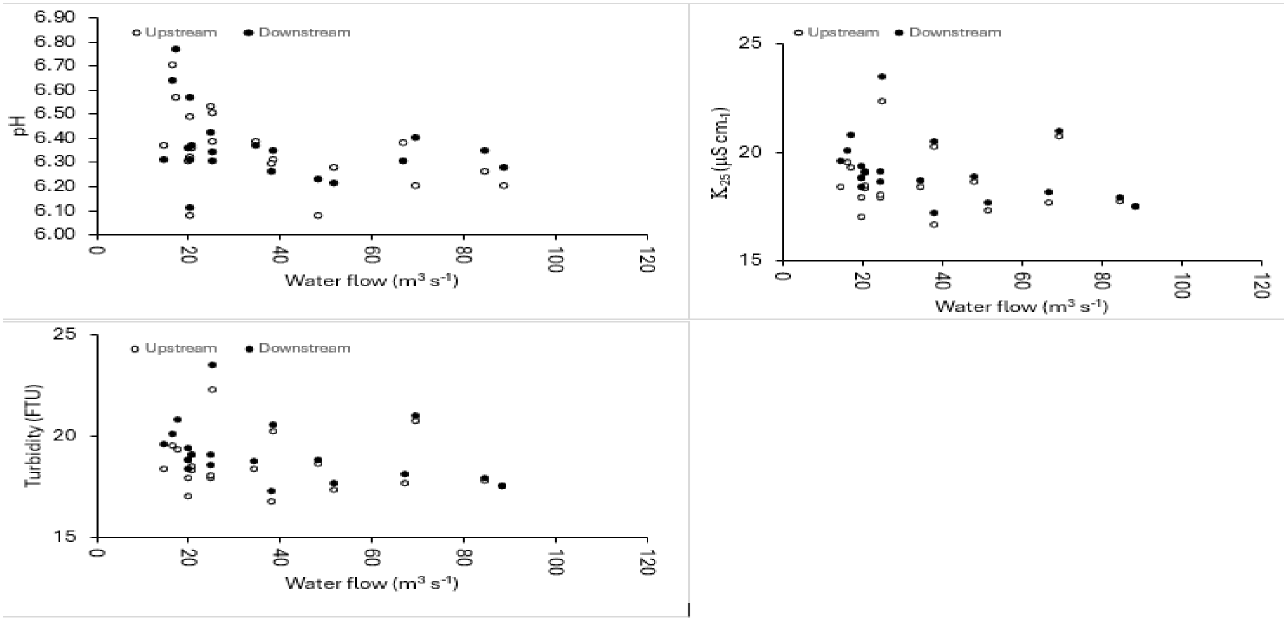

__Figure 3.2.1__ pH, conductivity, and turbidity relations with water flow in River Bø-Elva, both upstream and downstream BSP.

The base cations (Ca^{2+}, Mg^{2+}, $Na^{+,}$ and K^{+}) normally exhibited the highest concentration values at low water flow. The concentration of Ca^{2+} varied between 1,8 - 2,3 mg L^{-1}, Mg^{2+} between 0,26 - 0,27 mg L^{-1}, Na^{+} between 0,97 - 1,40 mg L^{-1}, and K^{+} between 0,19 - 0,37 mg L^{-1} (Table 3.2.1). Additionally, minor variations were found between the upstream and downstream stations for the main anions NH_4^{+}-N between 4.0 - 32.8 µg L^{-1}, SO_4^{-2} between 0.81 - 1.20 mg L^{-1}, Cl^{-} between 1.20 - 1.80 mg L^{-1}, NO_3^{-}-N between 59 - 320 µg L^{-1}, TOC between 3.5 - 7.0 mg L^{-1}, Tot-N between 598 - 4340 µg L^{-1} and Tot-P between 4 - 9 µg L^{-1} (Table 3.2.1).

According to Table 3.1.1, Tot-P (Total phosphate) showed no significant differences between the upstream anddownstream site. The difference is primarily for the max concentration value (Table 3.2.1), which was higher downstream. Thus, the contribution of Tot-P from BSP was too small to be analytically revealed in River Bø-elva at the downstream sites. The Tot-N concentrations varied significantly both upstream and downstream, and with very high maximum values, i.e. 2040 µg L^{-1} upstream, 4340 µg L^{-1} downstream (Table 3.2.1). Also, TOC (Total organic carbon) showed minor differences in the concentration up and down stream BSP.

Table 3.2.1 is the weekly chemical data of heavy metal from River Bø-elva. The heavy metals analysed were: Ba, Al, Fe, Mn, Pb, Cd, Hg, Zn, Cr, Cu, Co, Ni, As, Mo and V (Table 3.2.2). Except for Ba, Al, Fe and Mn, the remaining heavy metals were below the detectable limit for the method.

<u>Table 3.2.1</u> *<u>Average ± std, median, max and min values of macro chemical parameters in River Bø-elva, upstream and downstream of Bø sewage plant (BSP), during the studied period 26.04.2023 – 06.11.2023. Water runoff values are from the same hours as water sampling. N = 20. All data is present in Appendix B-2.</u>*

Site Bøelva	Sampling Date	Mannebru Discharge $m^3 s^{-1}$	pH	K_{25} µS cm^{-1}	Turbidity NTU	Ca^{2+} mg L^{-1}	Mg^{2+} mg L^{-1}	Na^{+} mg L^{-1}	K^{+} mg L^{-1}	NH_4^+-N µg L^{-1}	SO_4^{2-} mg L^{-1}	Cl^{-} mg L^{-1}	NO_3^--N µg L^{-1}	TOC mg L^{-1}	Tot-N µg L^{-1}	Tot-P µg L^{-1}
Upstream	average	37,47	6,35	18,53	0,62	2,05	0,31	1,06	0,24	12,6	0,91	1,31	122,8	4,51	945	5,7
Upstream	stdav	23,36		1,34	0,30	0,15	0,04	0,09	0,04	5,2	0,09	0,13	52,6	0,86	309	1,1
Upstream	median	25,36	6,34	18,33	0,50	2,10	0,30	1,05	0,23	11,9	0,87	1,30	110,0	4,40	824	5,5
Upstream	max	88,91	6,70	22,30	1,39	2,30	0,46	1,30	0,37	20,8	1,20	1,70	320,0	7,00	2040	8,0
Upstream	min	14,68	6,08	16,69	0,26	1,80	0,26	0,97	0,19	4,0	0,81	1,20	75,0	3,50	674	4,0
Downstream	average	37,47	6,36	19,19	0,64	2,04	0,31	1,09	0,25	15,7	0,93	1,36	138,6	4,55	972	5,7
Downstream	stdav	23,36		1,47	0,33	0,12	0,04	0,11	0,04	7,3	0,09	0,16	51,9	0,84	801	1,1
Downstream	median	25,36	6,35	18,95	0,54	2,00	0,30	1,10	0,26	15,9	0,91	1,30	135,0	4,35	776	5,5
Downstream	max	88,91	6,77	23,50	1,51	2,20	0,47	1,40	0,35	32,8	1,20	1,80	320,0	7,00	4340	9,0
Downstream	min	14,68	6,11	17,20	0,32	1,80	0,28	1,00	0,19	4,6	0,82	1,20	59,0	3,60	598	4,0

Tot-N is the sum of Organic-N and the sum of inorganic N, primarily NH_4^++ NO_3^-. As seen in Table 3.1.1, the majority of Tot-N is organic N. Accordingly, Tot-N is significantly correlated with turbidity. Also NO_3^--N had a significant correlation with turbidity both up and downstream, without having a good explanation for this, as NO_3^--N is not very much associated to particles.

Heavy metals like Ba, Al, Fe, and Mn have concentrations varying between 4.9 – 6.4 mg Ba L^{-1}, 85 - 217 mg Al L^{-1}, 71 - 198 mg Fe L^{-1} and 1,7 - 7,6 mg Mn L^{-1} upstream. The concentrations of these heavy metals at the downstream station (Mannebru) were slightly higher (Table 3.2.2), i.e. 4,7 - 14,2 mg Ba L^{-1}, 93 - 222 mg Al L^{-1}, 77 - 197 mg Fe L^{-1} and 2,3 - 9,8 mg Mn L^{-1}.

Table 3.2.2 *Weakly water chemical data on heavy metals from the River Bø-elva, both upstream and downstream of the Bø sewage plant (BSP), between February 26, 2023, and November 6, 2023. Water samples are taken at the same hour as the reported runoff.*

Site Bøelva	Sampling Date	Mannebru Discharge $m^3 s^{-1}$	Ba $\mu g\ L^{-1}$	Al $\mu g\ L^{-1}$	Fe $\mu g\ L^{-1}$	Mn $\mu g\ L^{-1}$	Pb $\mu g\ L^{-1}$	Cd $\mu g\ L^{-1}$	Hg $\mu g\ L^{-1}$	Zn $\mu g\ L^{-1}$	Cr $\mu g\ L^{-1}$	Cu $\mu g\ L^{-1}$	Co $\mu g\ L^{-1}$	Ni $\mu g\ L^{-1}$	As $\mu g\ L^{-1}$	Mo $\mu g\ L^{-1}$	V $\mu g\ L^{-1}$
Upstream	average	37,47	5,6	122,4	101,7	4,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Upstream	stdav	23,36	0,4	30,4	32,7	1,4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Upstream	median	25,36	5,6	117,5	94,2	4,3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Upstream	max	88,91	6,4	217,0	198,0	7,6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Upstream	min	14,68	4,9	86,1	70,9	1,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Downstream	average	37,47	6,1	125,5	103,6	5,0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Downstream	stdav	23,36	2,0	31,7	32,9	1,7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Downstream	median	25,36	5,8	118,0	91,6	4,5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Downstream	max	88,91	14,2	222,0	197,0	9,8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Downstream	min	14,68	4,7	93,2	76,5	2,3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

In order to identify any potentially significant differences between the upstream and downstream parameters, we decided to do a non-parametric Wilcoxon Signed-Rank test, as the majority of the variables showed large deviations from normal distribution. According to Wilcoxon Signed-Rank test, the downstream site showed significantly higher values for the following analysed parameters: K_{25}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}-, NH_4^{+}, NO_3^{-}, Al, and Mn (Table 3.2.3).

Bø sewage plant (BSP) uses precipitant agents (PAX-18) to retain phosphate and organic compounds from sewage. Compounds like Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}-, NH_4^{+}, NO_3^{-} are not precipitate out effectively through this precipitation process, they stay in solution as ions and thus released into the River Bø-elva. Because these substances are primarily dissolved ions, the conductivity (K_{25}) levels were always higher downstream the BSP. The higher concentration of aluminium downstream, is likely due to the use of Al-PAX (PAX18). The concentration increase as not much, but revealed analytically. As the pH downstream was relatively high (from pH: 6.11 -6.77), no Al toxicity should be expected.

Table 3.2.3 Analysed parameters with significant differences between downstream vs upstream concentrations from the BSP (D) by use of the non-parametric Wilcoxon Signed-Rank test. Statistical details in Appendix C-5.

Parameter	Unit	Average ± stdev	Median	Parameter	Unit	Average ± stdev	Median
ΔK_{25}	µS cm^{-1}	0,656 ± 0,423	0,585	ΔCa^{2+} (ICP-MS)	mg L^{-1}	0,020 ± 0,042	0,010
ΔMg^{2+} (ICP-MS)	mg L^{-1}	0,007 ± 0,009	0,005	ΔNa^{+} (ICP-MS)	mg L^{-1}	0,049 ± 0,034	0,050
ΔK^{+} (IC)	mg L^{-1}	0,010 ± 0,017	0,010	ΔCl^{-}	mg L^{-1}	0,050 ± 0,069	0,050
ΔNH_4^{+}-N	µg L^{-1}	3,1 ± 6,25	0,90	ΔNO_3^{-}-N	µg L^{-1}	15,85 ± 17,90	10
ΔAl	µg L^{-1}	3,01 ± 7,45	3,0	ΔMn	µg L^{-1}	0,439 ± 0,93	0,24

3.3 Pollution status of River Bø elva on both sampling stations

As mentioned in 2.1, River Bø-elva is water type R106 (vann-nett). The water frame directive has a classification mechanism through which they classify rivers (Moe et al., 2019). The criteria is to check the ecological and chemical status of the river. This classification divides water bodies related to 3 height categories, , based on height above sea level, i.e. m a.s.l. Status classes for both ecological and chemical status is very good, good, moderate, bad, and very bad (Moe et al., 2019). Our study is located < 200 m a.s.l. and thus classified as type R105 (Direktoratsguppen-vanndirektivet, 2018).

According to the water frame directive guidelines (Direktoratsguppen-vanndirektivet, 2018),the River Bø-elva is classified as a calcium-poor, clear water river (Ca: 1-4 mg L^{-1}; TOC < 5 mg L^{-1}). Based on these chemical criteria, and the fact that the sampling stations in the river are located < 200 m a.s.l., the River Bø-elva is classified as type R-105 at the sampling sites. However, as the catchment of River Bø-elva consists of large areas > 200 m a.s.l., we have also presented the reference values for the two other calcium-poor, clear water river-types (Table 3.1.4), type R-205 (200 – 800 m a.s.l) and type R-305 (> 800 m a.s.l.).

Regarding, acidification status in the river, the average ANC (Acid Neutralizing Capacity = SCa^{2+},Mg^{2+},Na^{+},K^{+} - SSO_4^{2-},Cl^{-},NO_3^{-}, on equivalent basis) was calculated to be 116 ± 10 meq L^{-1} upstream BSP and of 117 ± 8 meq L^{-1} downstream BSP. Accordingly, the river today has a very good ANC status. i.e. minor impacted by anthropogenic acidification. ((Direktoratsguppen-vanndirektivet, 2018), Tabel 7.4, p 104).

The Tot-P concentration in the River Bø-elva was 5,7 ± 1,1 mg L^{-1} both up and downstream. Thus, the status for Tot-P is "**very good**" in River Bø-elva (Table 3.3.1). The concentrations of Tot-N are relatively high, i.e. 945 ± 309 µg L^{-1} upstream and 972 ± 801 µg L^{-1} downstream (BSP). Based on the Water Framework Directive (Direktoratsguppen-vanndirektivet, 2018), the nitrogen status in the river classified as **"Bad"**. This categorization indicates that the river is substantial impacted by anthropogenic sources, primarily agricultural activities, primarily from the start of the river at the outlet from Lake Seljordvatn to the sampling sites, upstream and downstream BSP.

A significant contribution from the BSP to inorganic nitrogen levels, NO_3^- and NH_4^+ in River Bø-elva was revealed. In spite of low Tot-P concentrations, the river water quality is categorized as "Bad». Thus, to reduce nitrogen pollution in the river and enhance its overall ecological health, other actions are needed.

Table 3.3.1 *Reference values and class boundaries for Total-P and Total-N in rivers, type R105, R205 and R-305, according to the Direktoratsgruppen vanndirektivet (2018, Table 7.9. for Tot-P, Table 7.10 for Tot-N).*

	Total P mg L^{-1}	Total P mg L^{-1}	Total P mg L^{-1}	Total P mg L^{-1}	Total P mg L^{-1}	Total P mg L^{-1}
River type	Ref. value	Very good	Good	Moderate	Bad	Very bad
R105	6	1-11	11-17	17-30	30-60	> 60
R205	5	1-8	8-18	15-25	25-55	> 55
R-305	3	1-5	5-8	8-17	17-30	> 30
	Total N mg L^{-1}	Total N mg L^{-1}	Total N mg L^{-1}	Total N mg L^{-1}	Total N mg L^{-1}	Total N mg L^{-1}
River type	Ref. value	Very good	Good	Moderate	Bad	Very bad
R105	200	1-325	325-475	475-775	775-1350	> 1350
R205	325	1-550	550-775	775-1325	1325-2025	> 2025
R-305	250	1-400	400-550	550-900	900-1500	> 1500

3.4 Bø sewage treatment plant

Bø sewage treatment plant (BSP) is a wastewater cleaning facility located in Bø, Midt-Telemark, Norway. BSP facilitates the surrounding population and industry by treating their wastewater before it goes to River Bø elva. To efficiently treat wastewater, the Bø sewage treatment facility uses a variety of treatment techniques. Depending on the layout and capability of the plant, these procedures might involve tertiary treatment such as filtration or disinfection, secondary treatment like biological treatment, primary treatment like sedimentation, and preliminary treatment like screening and grit removal. Norway is part of the European wastewater directive. Sewage treatment regulation is according to EU wastewater directive. All sewage facilities should be according to regulations. As per the Norwegian pollution regulation, Bø sewage plant (BSP) is classified as a chapter 14 facility (Environment, FOR-2004-06-01-931).

Norwegian pollution regulation §14.2 guides to reduce the amount of Tot-P and organic matter (TOC) from receiving polluted water. There are some criteria through which water treatment facilities are categorized under Norwegian pollution regulation chapter 14 (FOR-2005-12-15-1691, 2005).

According to chapter 14.2

- Tot-P: The wastewater must have at least 90% less phosphorus than what is fed to the treatment facility.
- The wastewater should have at least 75% less total organic carbon (TOC) than what is given to the treatment plant, or the concentration should not exceed 125 mg O2 L^{-1} at discharge. TOC is measured as KOD_{Cr}, or chemical oxygen demand, BOD_5.
- The wastewater's TOC (total organic carbon), which is expressed as BOD_5 (Biological oxygen demand), should be decreased by at least 70% of the amount delivered to the treatment plant, or it should not exceed 25 mg O_2 L^{-1} at discharge.

Bø sewage Plant (BSP) deals mainly with 4 emissions. Tot-N, Tot-P, BOD_5 and KOD_{Cr}, the two last parameters for amount of organic matter, TOC). The BSP started in 2014 and their publish their progress report every year. To achieve the target of Tot-P and TOC, BSP uses precipitating agent (PAX-18) to precipitate out phosphorus (Tot-P) and total organic carbon (TOC). The use of PAX-18 keeps the pH > 6 during the precipitation process of P and TOC removal. Excess of Al-precipitants that are discharged into the River Bø-elva will not have a detrimental impact on the aquatic biology in the river,because of the high pH, which means that no acute toxic Al-forms will be present (Lydersen, 1990).

The amount of total phosphorus (Tot-P) was significantly reduced in the Bø sewage treatment plant (BSP). Within the investigation period, Tot-P was averagely reduced by 92 ± 6.3%, median reduction of 94% (Table 3.4.1). Thus, significant amount of phosphorus was successfully removed from the wastewater before release into the river. However, two times the decrease in Tot-P levels was < 90%, i.e. 80.6% and 85.2%. (Table 3.4.1). Although these decreases still represent a notable increase in phosphorus removal when compared to the influent wastewater, they could also be an indication of unpredictability or sporadic variations in BSP's treatment effectiveness throughout the monitoring period.

Furthermore, KOF_{Cr} and BOF_5 assessments showed lower dissolved oxygen (O_2) concentrations in the discharged water when compared to regulatory criteria. This indicates that the microbial breakdown of organic materials in the wastewater may have contributed to the BSP treatment operations reduction of oxygen levels in the effluent water. Both BOF_5 and KOF_{Cr} showed greater percentage decreases than the designated regulatory threshold, despite the lower oxygen contents. According to BOF_5 and KOF_{Cr} measurements, this shows that although the treatment procedures may have led to lower oxygen levels in the released water, they were successful in considerably lowering the organic pollution load, which complies with regulations. Overall, the findings point to significant reductions in phosphorus levels in treated wastewater that were typically attained by BSP, despite the occasional observation of treatment efficiency fluctuations. Furthermore, even though the released water had lower oxygen concentrations, the treatment procedures successfully decreased the amounts of organic contamination, adhering to regulatory requirements in this area.

Table 3.4.1 *Analysis of 24 hrs mixed samples of input, output and retention of Tot-P, KOF_{Cr} and BOF_5 from Bø sewage plant (BSP) during the investigated period 26.04.2023-06.11.2023. N = 8).*

Date/time	Output BSP $m^3 day^{-1}$	Output BSP L^{-s}	TOT- P BSP_{inn} mg P L^{-1}	KOF_{Cr} BSP_{inn} mg O_2 L^{-1}	BOF_5 BSP_{inn} mg O_2 L^{-1}	TOT- P BSP_{out} mg P L^{-1}	KOF_{Cr} BSP_{out} mg O_2 L^{-1}	BOF_5 BSP_{out} mg O_2 L^{-1}	TOT- P $BSP_{retenstion}$ %	KOF_{Cr} $BSP_{retenstion}$ %	BOF_5 $BSP_{retenstion}$ %
14.04.2023	3625	42,0	2,4	200	71	0,18	33	10	92,5	83,5	85,9
03.05.2023	1382	16,0	7,1	780	210	0,21	41	8	97,0	94,7	96,2
01.06.2023	1364	15,8	8,9	810	260	0,40	74	7	95,5	90,9	97,3
05.07.2023	2013	23,3	6,2	490	150	0,60	25	5	90,3	94,9	96,7
03.08.2023	1184	13,7	14,0	730	280	0,42	37	7	97,0	94,9	97,5
10.09.2023	1297	15,0	8,8	600	340	1,30	98	24	85,2	83,7	92,9
02.10.2023	1501	17,4	7,2	600	170	1,40	40	8	80,6	93,3	95,3
07.11.2023	1604	18,6	5,1	300	150	0,11	19	5	97,8	93,7	96,7
average	1746	20,2	7,5	564	204	0,58	46	9	92,0	91,2	94,8
stdav	800	9,3	3,4	222	86	0,50	27	6	6,3	4,9	3,9
median	1442	16,7	7,2	600	190	0,41	39	8	94,0	93,5	96,4
max	3625	42,0	14,0	810	340	1,40	98	24	97,8	94,9	97,5
min	1184	13,7	2,4	200	71	0,11	19	5	80,6	83,5	85,9

The daily discharge volumes into the River Bø-Elva from the Bø sewage treatment plant (BSP) varied across the study period, ranging from 1079 to 3625 cubic meters per day (m^3day^{-1}), or 12.5 to 42 litres per second ($L\ s^{-1}$) (Table 3.4.2 and 3.4.3). During the same period, the average estimated water flow of the River Bø-Elva was 28.6 cubic meters per second (m^3s^{-1}), to which these discharge quantities contribute very little. The impact of the sewage treatment plant's wastewater discharge on the River Bø-Elva is minimal due to the relatively low discharge volumes from the facility compared to the entire flow of the river. Table 3.4.2 and Table 3.4.3 demonstrate the little impact of BSP discharge on the River Bø-Elva, which is further corroborated by the analysis of measured parameters such as turbidity, chemical oxygen demand (KOF_{Cr}), and biochemical oxygen demand (BOF_5). The contribution of BSP to the River Bø-Elva ranged between 0.05 and 0.73 micrograms per litre (μgL^{-1}) for total phosphorus (Tot-P), a critical measure of concern in water quality management, with an average value of 0.25 ± 0.18 μgL^{-1} (Table 3.4.2). The average contribution from BSP to the River Bø-elva is still rather small, notwithstanding variations in Tot-P levels. Overall, the findings point to little to no impact that the BSP wastewater discharge has on the River Bø-Elva River, as evidenced by the modest discharge volumes in relation to the river's flow and the low concentrations of parameters that have been tested, such as turbidity and Tot-P. This demonstrates how well BSP's sewage treatment procedures mitigate any effects on the receiving water body.

According to the data concentration of BSP sludge is like $Cl^- > Na^+ > Ca^{2+} > NO_3^-$-N > $K^+ > Mg^{2+} > NH_4^+$-N = Al > Mn. The Bø sewage treatment plant (BSP) effluent has very high amounts of nitrate (NO3- -N). This is most likely because of microbial nitrification activities that take place during the facility's secondary treatment stage. This occurrence is the result of certain bacteria in the treatment system nitrifying ammonia (NH4+) to produce nitrate (NO3- -N). Human urine and faeces normally don't have a lot of nitrate in their chemical makeup. Rather, urea, which is present in urine, has the ability to transform into ammonia in some circumstances. Nevertheless, ammonia generated from the decomposition of organic matter or urea may go through nitrification in the secondary treatment stage at BSP, where aerobic conditions are maintained. This might result in the concentration of nitrate in the treated wastewater. Furthermore, the mean total phosphorus (Tot-P) levels prior to treatment at BSP (referred to as BSPin) are comparatively low (7.02 ± 2.09 µg P L-1, median 7.07 µg P L^{-1}), falling between the range of magnesium ions (Mg^{2+}) and ammonium nitrogen (NH4+-nitro).

*__**Table 3.4.2**__* *__Discharge (m^3 day^{-1}) of rinsed water from Bø sewage plant (BSP) to River Bø-elva at different dates during the investigation period 26.04.2023 – 06.11.2023. The effects on River Bø-elva from BSP on P (mg L-1) and turbidity (NTU) is based on constant outflow (L s^{-1}) of the reported daily output amounts of rinsed water from the BSP (m^3 day^{-1}). No overrun has been recorded during the investigated period.__*

Date/time	Output BSP m^3 day^{-1}	Output BSP L^{-s}	Orto-P BSP_{inn} mg P L^{-1}	Turbidity BSP_{out} NTU	Orto-P BSP_{out} mg P L^{-1}	Orto-P Reduction BSP %	Waterflow River Bø-elva m^3 s^{-1}	Respons BSP_{total} River Bø-elva µg P L^{-1}	Respons BSP_{total} River Bø-elva NTU
20.04.23 8:00	2262	26,2	5,25	1,81	0,15	97,1	65,87	0,06	0,0007
26.04.23 8:30	2691	31,1	3,91	3,85	0,32	91,8	71,25	0,14	0,0017
02.05.23 8:30	1536	17,8	5,15	3,66	0,27	94,8	38,82	0,12	0,0017
04.05.23 8:30	1382	16,0	4,43	0,82	0,13	97,1	38,77	0,05	0,0003
16.05.23 9:00	1349	15,6	7,37	1,22	0,72	90,2	89,56	0,13	0,0002
31.05.23 8:15	1215	14,1	10,76	1,61	0,20	98,1	39,10	0,07	0,0006
09.06.23 8:15	1114	12,9	6,62	4,18	0,32	95,2	18,83	0,22	0,0029
14.06.23 7:40	1079	12,5	10,30	5,06	0,46	95,5	21,13	0,27	0,0030
23.06.23 7:30	1112	12,9	10,60	2,10	0,25	97,6	22,10	0,15	0,0012
28.06.23 8:30	1112	12,9	7,30	3,81	0,17	97,7	14,32	0,15	0,0034
04.07.23 9:00	1486	17,2	7,89	4,36	0,11	98,6	23,58	0,08	0,0032
13.07.23 8:00	1484	17,2	8,80	3,06	0,40	95,5	34,70	0,20	0,0015
01.08.23 8:15	1118	12,9	9,26	5,00	0,35	96,2	20,25	0,22	0,0032
14.08.23 9:00	1499	17,4	9,42	3,65	0,22	97,7	29,32	0,13	0,0022
05.09.23 8:45	1292	15,0	10,76	9,30	0,98	90,9	26,53	0,55	0,0052
07.09.23 8:20	1227	14,2	5,84	4,56	0,44	92,5	25,03	0,25	0,0026
11.09.23 9:30	1243	14,4	6,00	6,64	0,66	89,0	18,99	0,50	0,0050
20.09.23 8:45	2680	31,0	6,98	4,66	0,30	95,7	61,94	0,15	0,0023
03.10.23 8:30	1463	16,9	4,46	1,55	1,08	75,8	30,44	0,60	0,0009
04.10.23 8:45	1432	16,6	5,51	1,42	1,08	80,4	24,39	0,73	0,0010
05.10.23 8:30	1354	15,7	5,25	3,19	0,18	96,6	20,10	0,14	0,0025
06.10.23 9:00	1420	16,4	7,34	4,97	0,25	96,6	20,03	0,21	0,0041
09.10.23 9:00	1303	15,1	7,20	4,70	0,26	96,4	21,22	0,18	0,0033
12.10.23 8:30	1266	14,7	5,45	4,51	0,38	93,0	18,89	0,29	0,0035
17.10.23 8:45	1362	15,8	7,82	0,71	0,47	94,0	22,61	0,33	0,0005
23.10.23 9:00	1246	14,4	7,07	0,99	0,54	92,4	12,63	0,62	0,0011
25.10.23 8:45	1227	14,2	6,23	2,13	0,26	95,8	16,22	0,23	0,0019
01.11.23 8:45	1144	13,2	7,40	0,13	0,22	97,0	18,85	0,15	0,0001
06.11.23 8:30	2845	32,9	3,19	1,63	0,16	95,0	25,39	0,21	0,0021
average	1481	17,1	7,02	3,29	0,39	93,9	30,7	0,25	0,0021
stdav	488	5,7	2,09	2,03	0,27	5,1	18,6	0,18	0,0014
median	1349	15,6	7,07	3,65	0,30	95,5	23,6	0,20	0,0021
max	2845	32,9	10,76	9,30	1,08	98,6	89,6	0,73	0,0052
min	1079	12,5	3,19	0,13	0,11	75,8	12,6	0,05	0,0001

In comparison to other dissolved ions and nitrogen compounds found in the wastewater, this shows that Tot-P's contribution to the BSP effluent is minimal. All things considered, it is more likely that microbial activity, especially nitrification during the treatment process, rather than direct inputs from human urine or feces, is what caused the high quantities of nitrate seen in the discharge water from BSP. Given the comparatively low amounts of Tot-P before treatment, phosphorus might not have had a significant impact on the composition of the effluent.

Table 3.4.3 *Estimates of contribution of Tot-P (mg L^{-1}), KOF_{Cr} and BOF_5 (both in mg O_2 L^{-1}) from Bø sewage plant (BSP) to the River Bø-elva ($Respons_{BSP}$ data) based on the analysed 24 hrs mixed samples presented in Table 3.2.1 (n = 8).*

Date/time	Output BSP m^3 day^{-1}	Waterflow River Bø-elva m^3 s^{-1}	TOT- P BSP_{out} mg P L^{-1}	KOF_{Cr} BSP_{out} mg O_2 L^{-1}	BOF_5 BSP_{out} mg O_2 L^{-1}	$Respons_{BSP}$ TOT-P µg P L^{-1}	$Respons_{BSP}$ KOF_{Cr} mg O_2 L^{-1}	$Respons_{BSP}$ BOF_5 mg O_2 L^{-1}
14.04.2023	3625	62,5	0,18	33	10	0,12	0,022	0,00008
03.05.2023	1382	38,7	0,21	41	8	0,09	0,017	0,00005
01.06.2023	1364	36,2	0,40	74	7	0,17	0,032	0,00003
05.07.2023	2013	21,7	0,60	25	5	0,64	0,027	0,00006
03.08.2023	1184	19,1	0,42	37	7	0,30	0,027	0,00005
10.09.2023	1297	20,2	1,30	98	24	0,97	0,073	0,00007
02.10.2023	1501	34,6	1,40	40	8	0,70	0,020	0,00006
07.11.2023	1604	28,3	0,11	19	5	0,07	0,012	0,00007
average	1746	33	0,58	46	9	0,38	0,029	0,00006
stdav	800	14	0,50	27	6	0,34	0,019	0,00002
median	1442	31	0,41	39	8	0,24	0,024	0,00006
max	3625	62	1,40	98	24	0,97	0,073	0,00008
min	1184	19	0,11	19	5	0,07	0,012	0,00003

The contribution of heavy metals from BSP is almost negligible (Table 3.1.2). During the investigation period, most of the HM was almost below the detection limits. But Ba, Al, Fe, and Mn were observed significantly higher from detection limits as mentioned above in Chapter 3 Table 3.1.2. The precipitation process at BSP successfully co-precipitates heavy metals, leading to insignificant contributions to the River Bø-Elva. According to data between the year 2018-2023 dry weight concentrations of Heavy metals in sludge from BSP document is dry weight concentration (Table 3.4.4). The concentration of heavy metals in the sludge from BSP stays under allowable levels as per Norwegian laws. For this reason, the BSP sludge is categorized as quality class I, mainly because of the copper, zinc, and mercury contents (Table 3.4.5) (Ministry of Health and Care, FOR-2003-07-04-951).

Table 3.4.4 *Dry weight and concentrations of heavy metals is sludge from the Bø sewage plant from 14.11.2018 – 14.11-2023 (N = 31).*

DW %	Cd mg kg dw^{-1}	Pb mg kg dw^{-1}	Hg mg kg dw^{-1}	Ni mg kg dw^{-1}	Zn mg kg dw^{-1}	Cu mg kg dw^{-1}	Cr mg kg dw^{-1}
21,4	0,30	4,82	0,37	6,12	253	70	14,3
3,9	0,04	1,46	0,15	1,94	40	8,1	9,7
20,8	0,30	4,60	0,36	5,70	250	69	11,0
41,8	0,36	7,50	0,84	14,0	370	86	57,0
17,8	0,21	0,50	0,17	4,00	190	53	5,6
32	31	31	31	31	31	31	31

Table 3.4.5 Quality classes of sludge according to the Norwegian regulations.

Metal	Concentrations	Quality classes			
		0	**I**	**II**	**III**
Kadmium (Cd)	mg kg dw^{-1}	0,4	0,8	2	5
Led (Pb)	mg kg dw^{-1}	40	60	80	200
Mercury (Hg)	mg kg dw^{-1}	0,2	0,6	3	5
Nickel (Ni)	mg kg dw^{-1}	20	30	50	80
Zink (Zn)	mg kg dw^{-1}	150	400	800	1500
Kopper (Cu)	mg kg dw^{-1}	50	150	650	1000
Cromium (Cr)	mg kg dw^{-1}	50	60	100	150

4 Conclusion

In this study, we set out to investigate the effects of Bø sewage plants (BSP) on River Bø-elva. The goal to achieve in this research is to see macro chemistry, nutrients, and heavy metals in River Bø-elva upstream and downstream (Mannebru) of Bø sewage treatment plant (BSP). See the significance of different variables between the two sampling stations (upstream and Mannebru) and compare/relate the results with Governmental environmental requirements of river water chemistry.

To find out the effects of BSP on River Bø-elva we must know the water flow at Mannebru (downstream). We have NVE-water flow station Hagadrag which is 15 Km upstream from Mannebru. There is a big catchment area of around 122,66 km² between the station and Mannebru. The equation to find water flow at Mannebru is explained above in the method part of the study (Chapter 2.2).

pH and conductivity have no significant correlation with water flow in the river. But turbidity has a positive correlation with water flow in the river. The pH remained above 6 during the research period. However, we haven't found any chemical parameter significantly correlated with water flow. We find out some parameters significant up and downstream. Non-parametric Wilcoxon Signed-Rank test was used to identify any potentially significant differences between upstream and downstream parameters because most of the variables have quite big deviations from a normal distribution. K_{25}, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}-, NH_4^{+}, NO_3^{-}, comparison to NH_4^{+}-N downstream of BSP, the substantially greater quantity of NO_3^{-}-N suggests extensive microbial nitrification. NO_3^{-} -N was unexpectedly found in high concentration considering the composition of human urine and faeces.

Most of the heavy metals in River Bø-elva were almost absent or hardly above the detection limit. Ba, Al, Fe, and Mn. Al, and Mn were found significant differences up and downstream (Mannebru) of BSP. Have values above the detection limit. Al is significantly different downstream from upstream because the use of (PAX-18) as precipitant agent to precipitate out phosphate from wastewater. This means Al is not toxic to the environment in any way. Mn has higher concentration downstream because of its high redox potential.

According to the Norwegian guideline document, the overall chemical pollution status is classed as "**Bad**" at both locations due to the high concentration of Tot-N in the River Bø-Elva (Direktoratsguppen-vanndirektivet, 2018). The same guideline document classifies the acidity status and heavy metal concentrations as "**Very Good**" indicating that they are both low (Direktoratsguppen-vanndirektivet, 2018).

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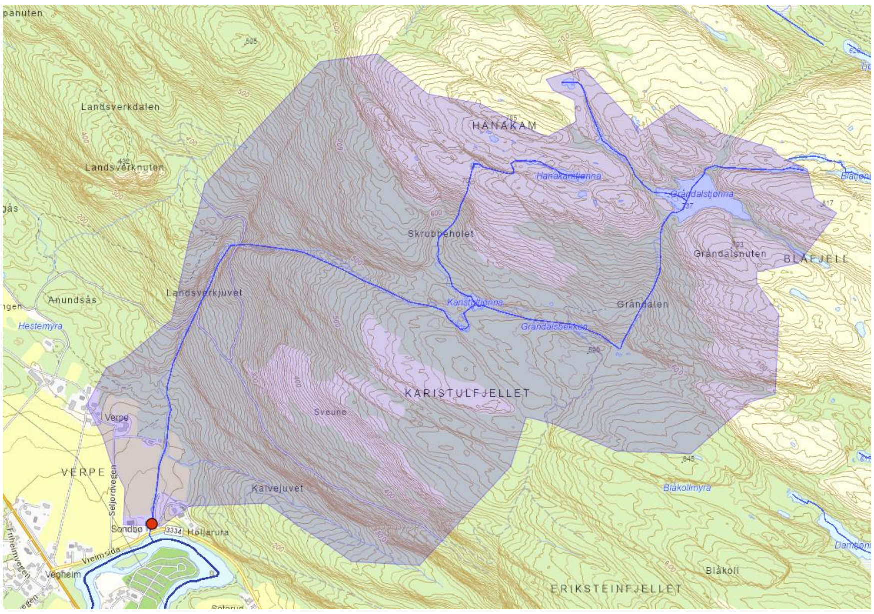
6 Annexes

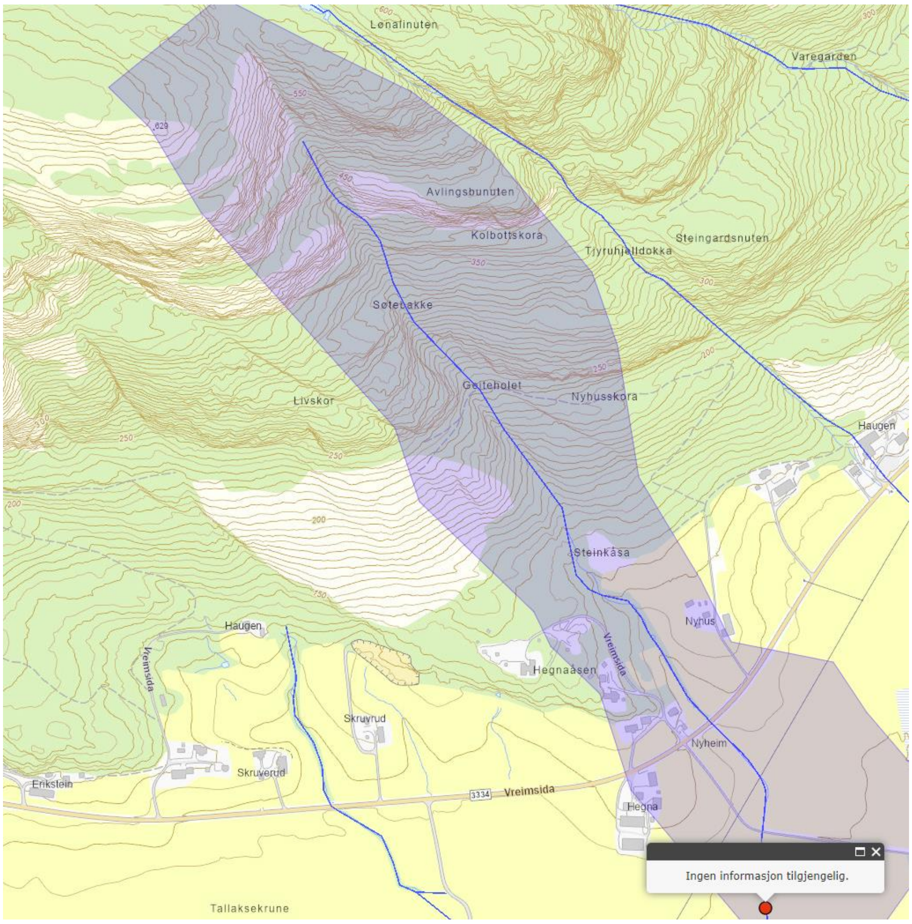
Appendix A Maps and catchmentdata from the subcatchments used for estimation of discharge at station Mannebru in the River Bø-elva by using (NEVINA.no).

Appendix A-1 Station East-1 Sondbø



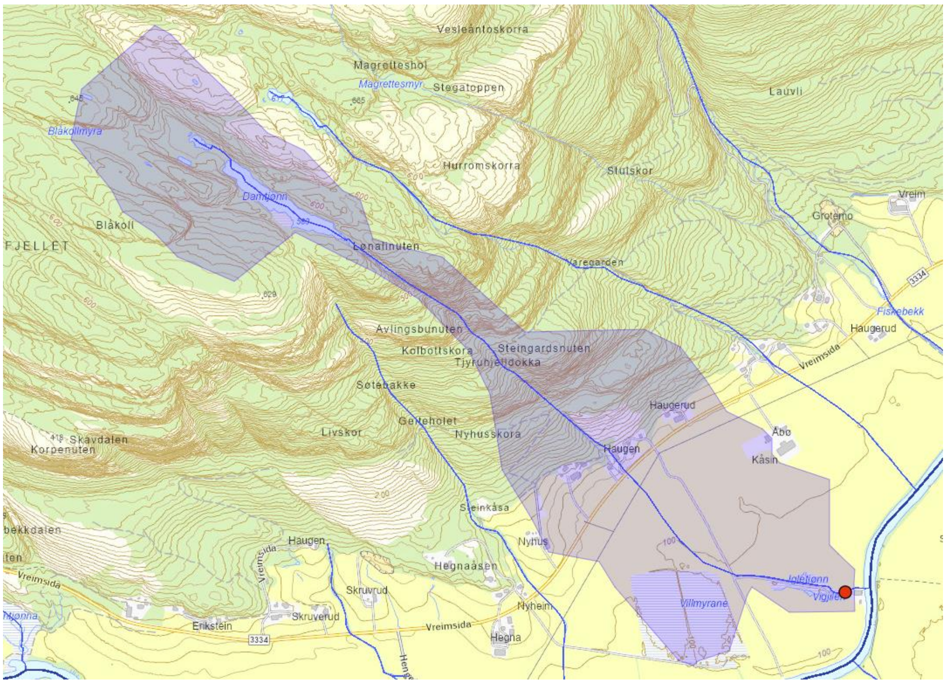
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 161	27 161
Vassdragsnummer	016.CA5	016.CA5
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○ 0 % ○ 20 % ○ 40 %	
Nedbørfeltparametere		
Areal (km²)	2,84	2,84
Middelavrenning 1961-1990 (mm/år)	528,92	528,92
Middelavrenning 1961-1990 (l/s/km²)	16,77	16,77
Minimum høyde (m)	102	102
Høyde 10 % (m)	217	217
Høyde 25 % (m)	400,5	400,5
Høyde 75 % (m)	676	676
Maksimum høyde (m)	815	815
Sjø (%)	1,25	1,25
Bre (%)	0	0
Skog (%)	68,73	68,73
Dyrket mark (%)	2,38	2,38
Myr (%)	1,12	1,12
Leire (%)	0	0
Snaufjell (%)	20,14	20,14
Urban (%)	0	0
Uklassifisert areal (%)	6,25	6,25
Effektiv sjø (%)	0,09	0,09
Effektiv sjø - Tilløp (%)	-999	-999
Feltlengde (km)	2,59	2,59
Feltlengde - Tilløp (km)	-999	-999
Elvelengde (km)	3,8	3,8

Appendix A-2 Station East-2 Nyheim



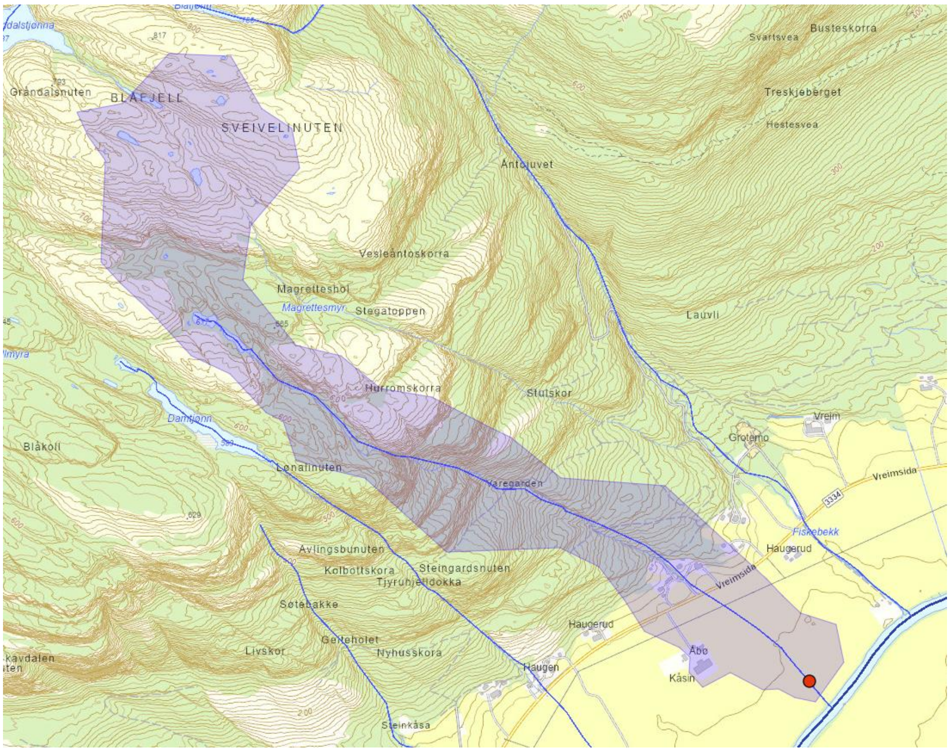
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 172	27 172
Vassdragsnummer	016.CA5	016.CA5
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○0 % ○20 % ○40 %	
Nedbørfeltparametere		
Areal (km²)	0,54	0,54
Middelavrenning 1961-1990 (mm/år)	344,76	344,76
Middelavrenning 1961-1990 (l/s/km²)	10,93	10,93
Minimum høyde (m)	100	100
Høyde 10 % (m)	102	102
Høyde 25 % (m)	113,5	113,5
Høyde 75 % (m)	413	413
Maksimum høyde (m)	627	627
Sjø (%)	0	0
Bre (%)	0	0
Skog (%)	64,24	64,24
Dyrket mark (%)	29,4	29,4

Appendix A-3 Station East-3 Haugen



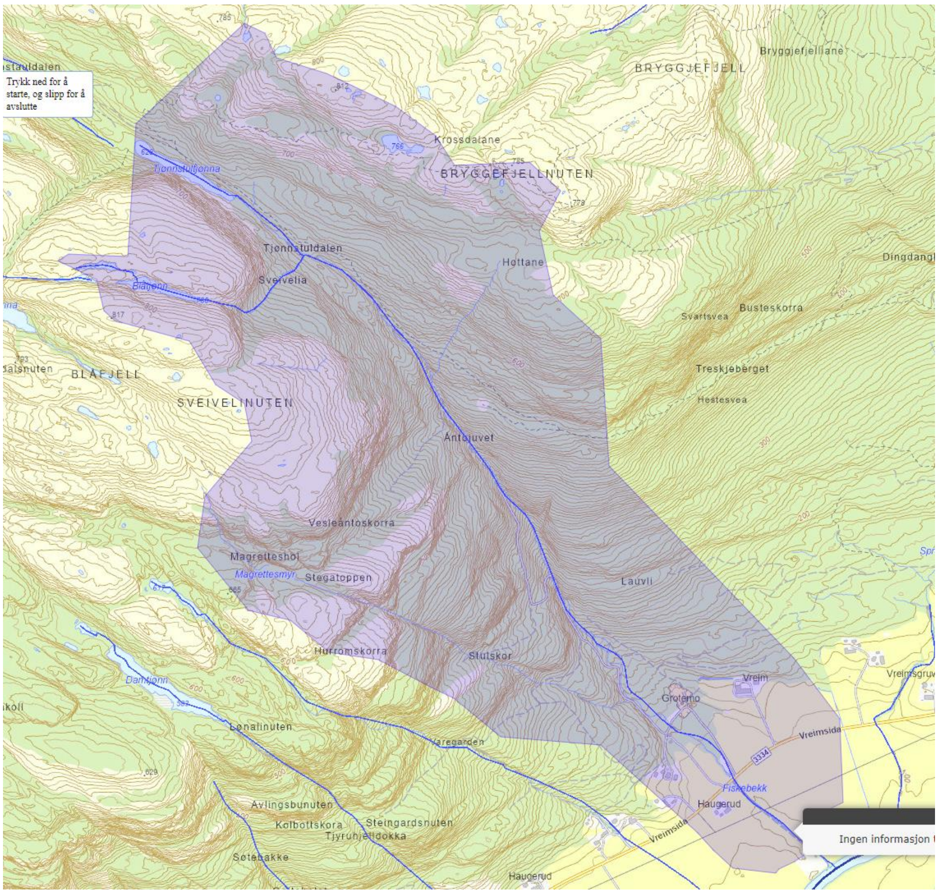
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 176	27 176
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○ 0 % ○ 20 % ○ 40 %	
Nedbørfeltparametere		
Areal (km²)	1,12	1,12
Middelavrenning 1961-1990 (mm/år)	394,77	394,77
Middelavrenning 1961-1990 (l/s/km²)	12,52	12,52
Minimum høyde (m)	100	100
Høyde 10 % (m)	101	101
Høyde 25 % (m)	103,5	103,5
Høyde 75 % (m)	599	599
Maksimum høyde (m)	662	662
Sjø (%)	1,9	1,9
Bre (%)	0	0
Skog (%)	53,96	53,96
Dyrket mark (%)	31,53	31,53

Appendix A-4 Station East-4 Varegarden



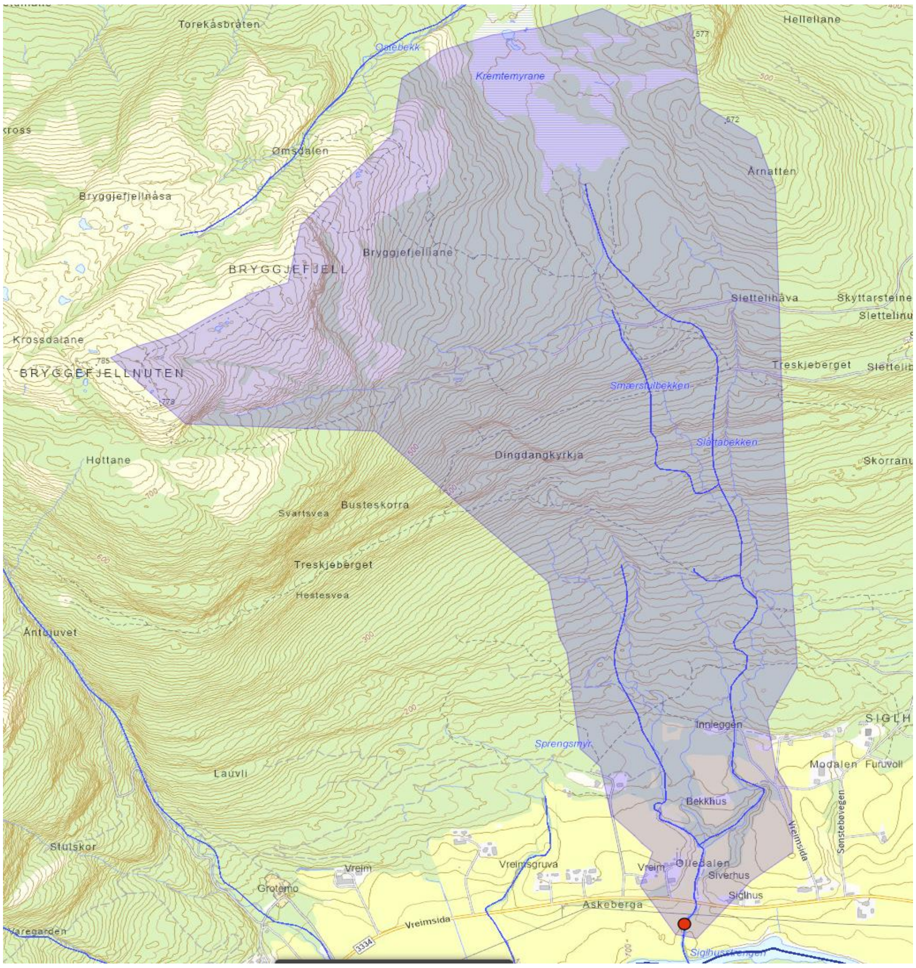
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 184	27 184
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	◯ 0 % ◯ 20 % ◯ 40 %	
Nedbørfeltparametere		
Areal (km²)	1,04	1,04
Middelavrenning 1961-1990 (mm/år)	469,68	469,68
Middelavrenning 1961-1990 (l/s/km²)	14,89	14,89
Minimum høyde (m)	100	100
Høyde 10 % (m)	104	104
Høyde 25 % (m)	197,5	197,5
Høyde 75 % (m)	690,5	690,5
Maksimum høyde (m)	810	810
Sjø (%)	0,9	0,9
Bre (%)	0	0
Skog (%)	41,53	41,53
Dyrket mark (%)	16,59	16,59

Appendix A-5 Station East-5 Fiskebekk



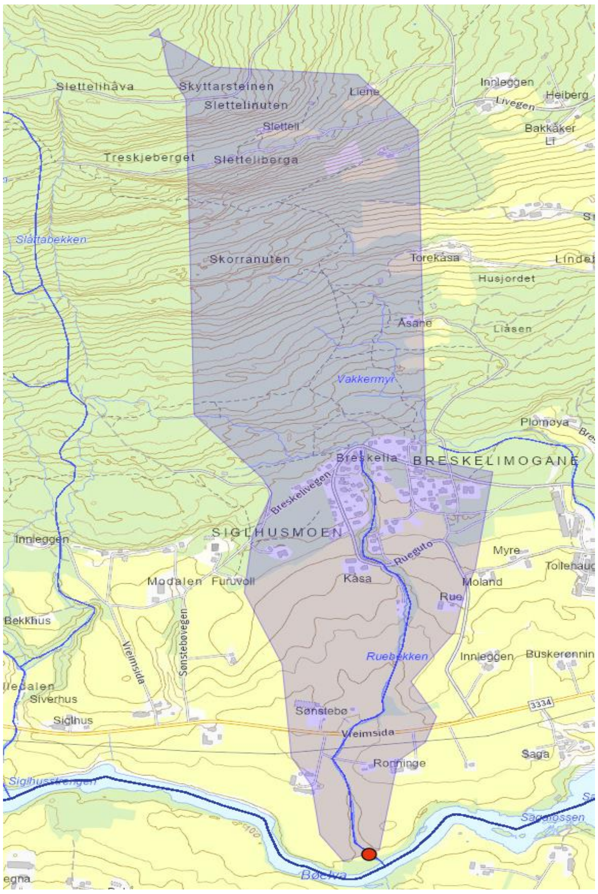
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 188	27 188
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	0 % 20 % 40 %	
Nedbørfeltparametere		
Areal (km²)	3,03	3,03
Middelavrenning 1961-1990 (mm/år)	518,26	518,26
Middelavrenning 1961-1990 (l/s/km²)	16,43	16,43
Minimum høyde (m)	100	100
Høyde 10 % (m)	120	120
Høyde 25 % (m)	304	304
Høyde 75 % (m)	707	707
Maksimum høyde (m)	814	814
Sjø (%)	0,74	0,74
Bre (%)	0	0
Skog (%)	64,69	64,69
Dyrket mark (%)	8,4	8,4

Appendix A-6 Station East-6 Sigelhus



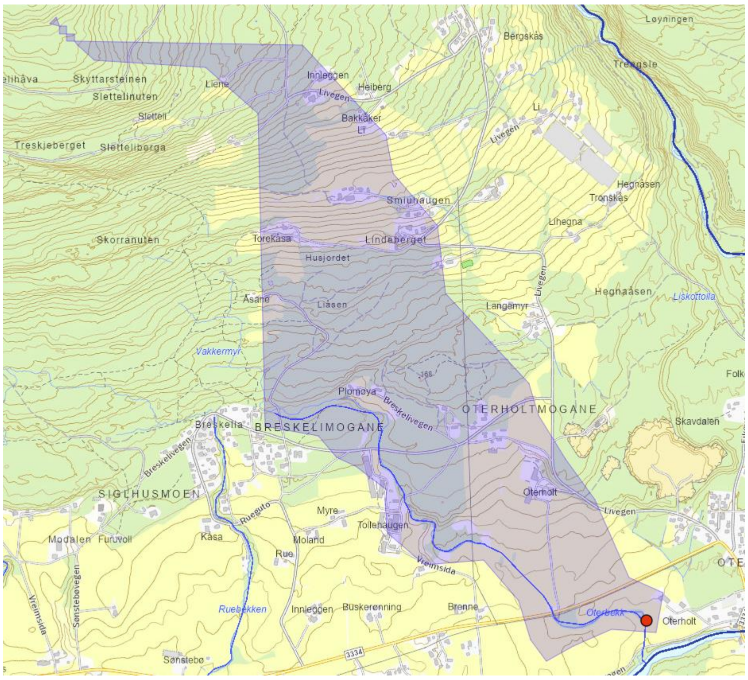
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 190	27 190
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○0 % ○20 % ○40 %	
Nedbørfeltparametere		
Areal (km²)	2,93	2,93
Middelavrenning 1961-1990 (mm/år)	424,24	424,24
Middelavrenning 1961-1990 (l/s/km²)	13,45	13,45
Minimum høyde (m)	102	102
Høyde 10 % (m)	139	139
Høyde 25 % (m)	262	262
Høyde 75 % (m)	549,5	549,5
Maksimum høyde (m)	781	781
Sjø (%)	0,02	0,02
Bre (%)	0	0
Skog (%)	82,68	82,68
Dyrket mark (%)	4,95	4,95

Appendix A-7 Station East-7 Breskelia 1



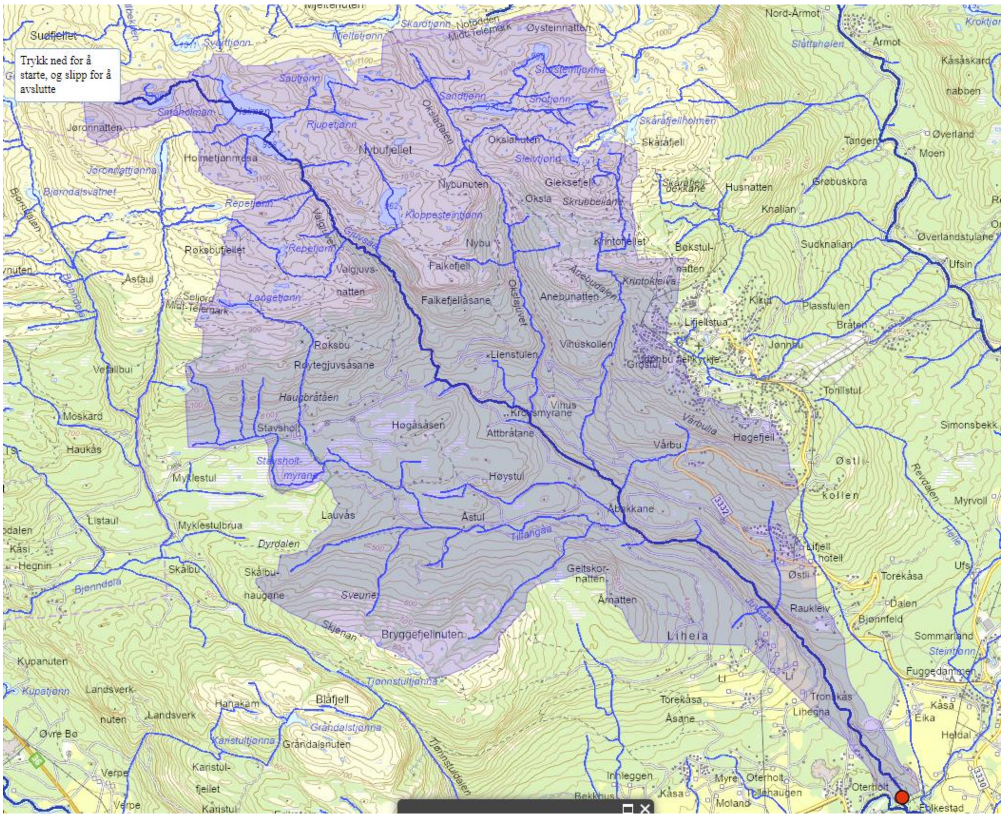
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 194	27 194
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○ 0 % ○ 20 % ○ 40 %	
Nedbørfeltparametere		
Areal (km²)	1,21	1,21
Middelavrenning 1961-1990 (mm/år)	308,48	308,48
Middelavrenning 1961-1990 (l/s/km²)	9,78	9,78
Minimum høyde (m)	99	99
Høyde 10 % (m)	113	113
Høyde 25 % (m)	130	130
Høyde 75 % (m)	279,5	279,5
Maksimum høyde (m)	499	499
Sjø (%)	0	0
Bre (%)	0	0
Skog (%)	63,43	63,43
Dyrket mark (%)	30,63	30,63

Appendix A-8 Station East-8 Breskelia 2



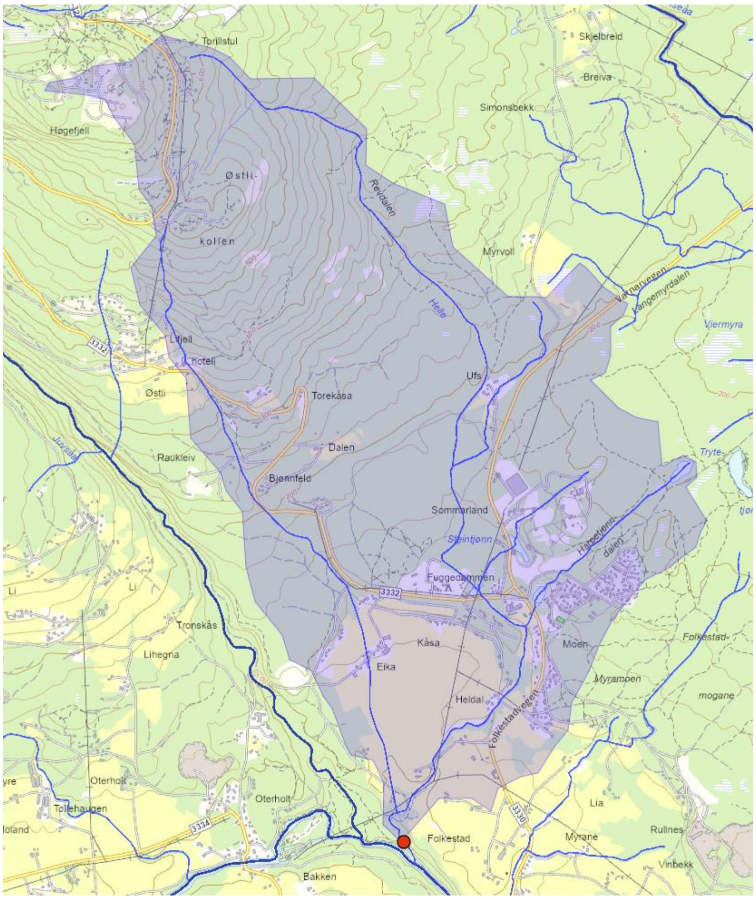
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 195	27 195
Vassdragsnummer	016.CA32	016.CA32
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	0 % 20 % 40 %	
Nedbørfeltparametere		
Areal (km²)	1,22	1,22
Middelavrenning 1961-1990 (mm/år)	303,11	303,11
Middelavrenning 1961-1990 (l/s/km²)	9,61	9,61
Minimum høyde (m)	92	92
Høyde 10 % (m)	108	108
Høyde 25 % (m)	132	132
Høyde 75 % (m)	235	235
Maksimum høyde (m)	503	503
Sjø (%)	0	0
Bre (%)	0	0
Skog (%)	60,81	60,81
Dyrket mark (%)	34,84	34,84

Appendix A-9 Station East-9 Juvsåa



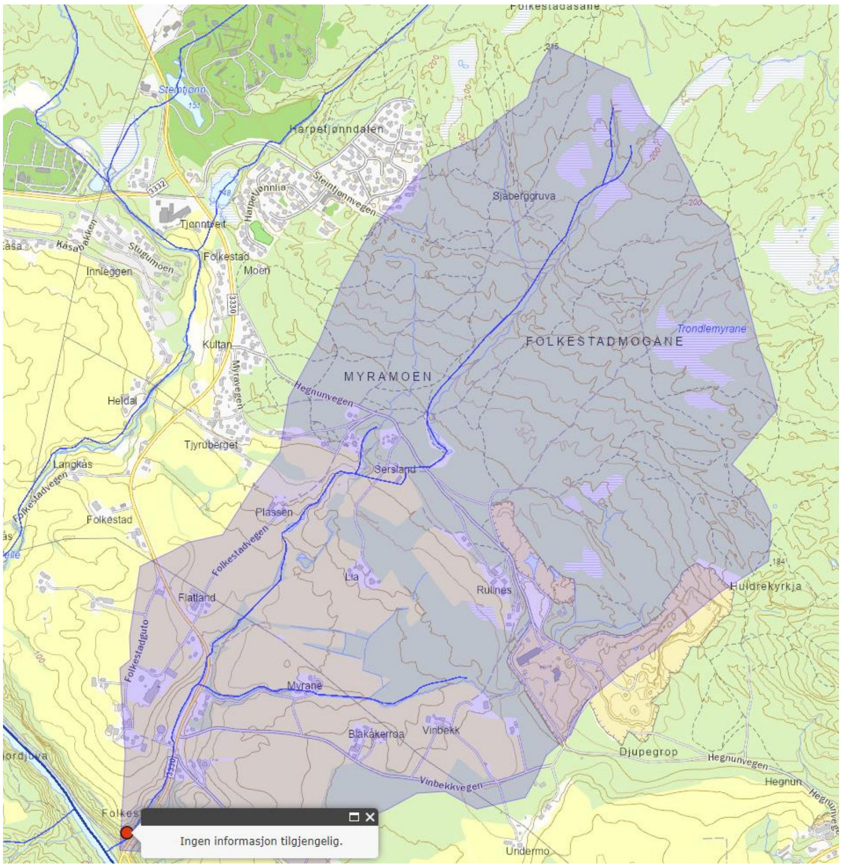
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 196	27 196
Vassdragsnummer	016.CA3Z	016.CA3Z
Vassdrag	Gjuvså	Gjuvså
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○ 0 % ○ 20 % ○ 40 %	
Nedbørfeltparametere		
Areal (km²)	36,12	36,12
Middelavrenning 1961-1990 (mm/år)	669,26	669,26
Middelavrenning 1961-1990 (l/s/km²)	21,22	21,22
Minimum høyde (m)	65	65
Høyde 10 % (m)	385	385
Høyde 25 % (m)	507,5	507,5
Høyde 75 % (m)	967	967
Maksimum høyde (m)	1 270	1 270
Sjø (%)	1,97	1,97
Bre (%)	0	0
Skog (%)	59,16	59,16
Dyrket mark (%)	0,83	0,83

Appendix A-10 Station East-10 Folkestad



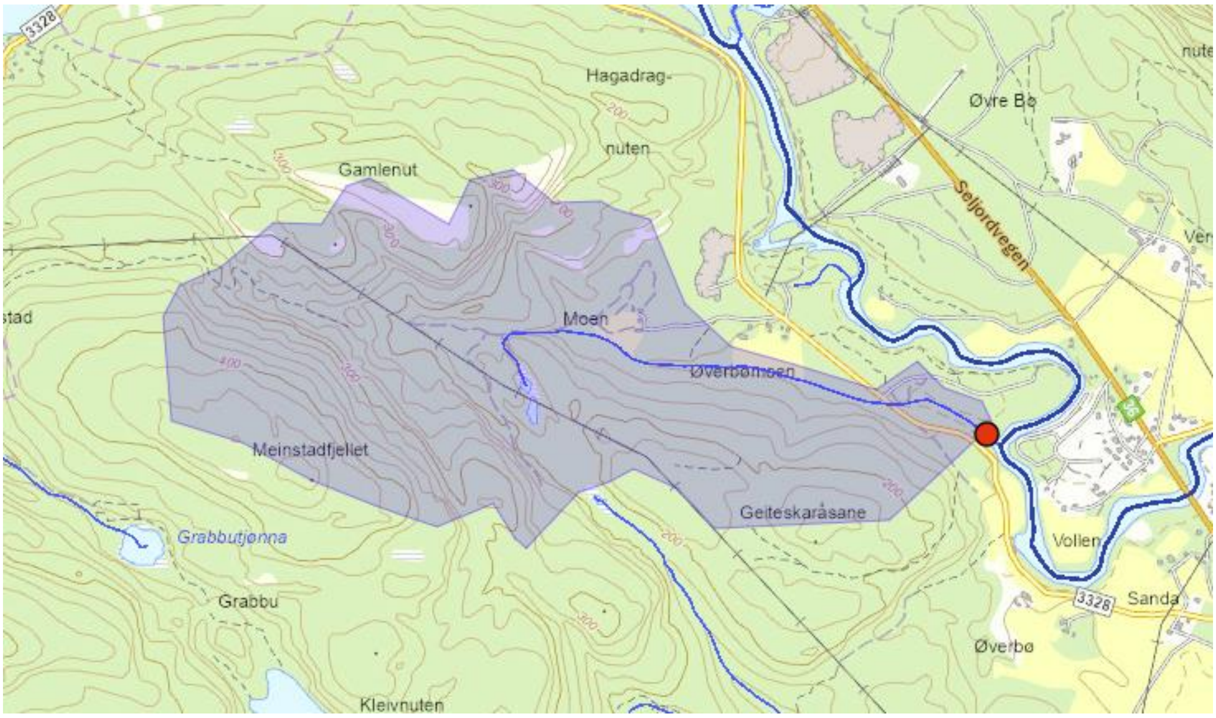
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 201	27 201
Vassdragsnummer	016.CA31	016.CA31
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	0 % 20 % 40 %	
Nedbørfeltparametere		
Areal (km²)	8,59	8,59
Middelavrenning 1961-1990 (mm/år)	345,17	345,17
Middelavrenning 1961-1990 (l/s/km²)	10,94	10,94
Minimum høyde (m)	60	60
Høyde 10 % (m)	123	123
Høyde 25 % (m)	158	158
Høyde 75 % (m)	355,5	355,5
Maksimum høyde (m)	769	769
Sjø (%)	0,26	0,26
Bre (%)	0	0
Skog (%)	79,66	79,66
Dyrket mark (%)	11,63	11,63

Appendix A-11 Station East-11 Folkestaddalen



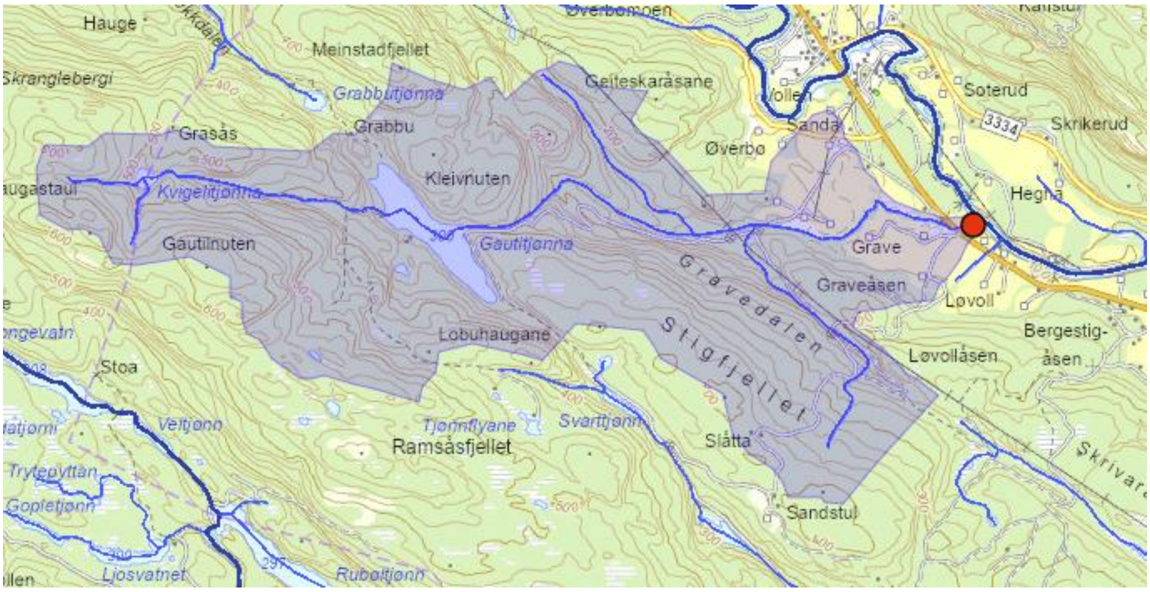
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 203	27 203
Vassdragsnummer	016.CA31	016.CA31
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○0 % ○20 % ○40 %	
Nedbørfeltparametere		
Areal (km²)	2,92	2,92
Middelavrenning 1961-1990 (mm/år)	271,22	271,22
Middelavrenning 1961-1990 (l/s/km²)	8,6	8,6
Minimum høyde (m)	61	61
Høyde 10 % (m)	117	117
Høyde 25 % (m)	128,5	128,5
Høyde 75 % (m)	176,5	176,5
Maksimum høyde (m)	214	214
Sjø (%)	0,11	0,11
Bre (%)	0	0
Skog (%)	67,25	67,25
Dyrket mark (%)	25,51	25,51

Appendix A-12 Station West-1 Øverbomoen



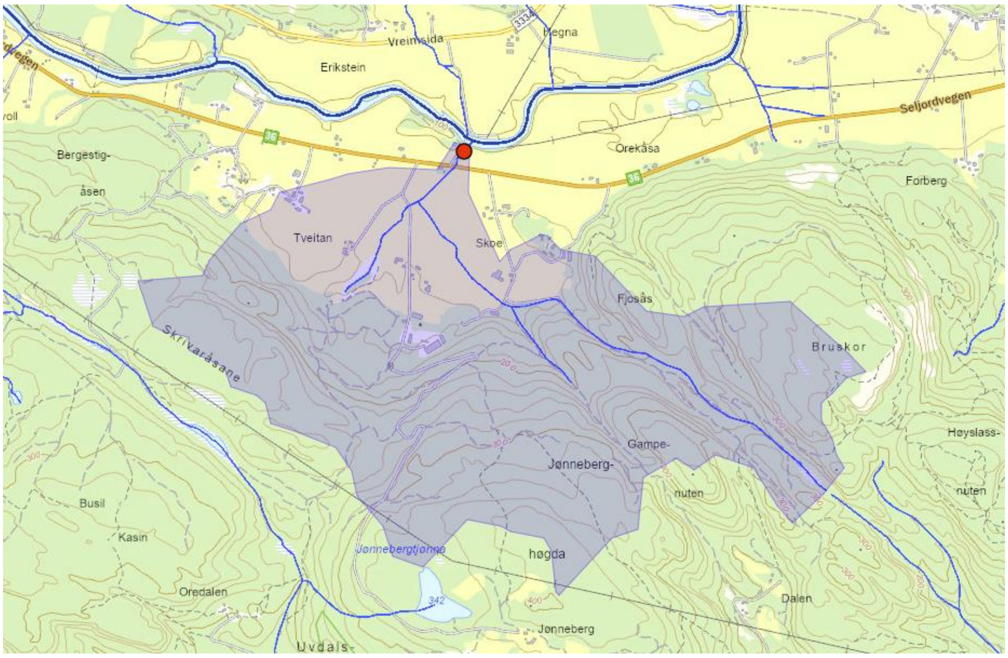
Parameternavn	Generert verdi	Editert verdi
ObjectId	27 003	27 003
Vassdragsnummer	016.CA6	016.CA6
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	0 % 20 % 40 %	
Nedbørfeltparametere		
Areal (km²)	1,87	1,87
Middelavrenning 1961-1990 (mm/år)	307,09	307,09
Middelavrenning 1961-1990 (l/s/km²)	9,74	9,74
Minimum høyde (m)	110	110
Høyde 10 % (m)	133	133
Høyde 25 % (m)	167,5	167,5
Høyde 75 % (m)	302	302
Maksimum høyde (m)	463	463
Sjø (%)	0,17	0,17
Bre (%)	0	0
Skog (%)	94,82	94,82
Dyrket mark (%)	1,44	1,44

Appendix A-13 Station West-2 Graveevju



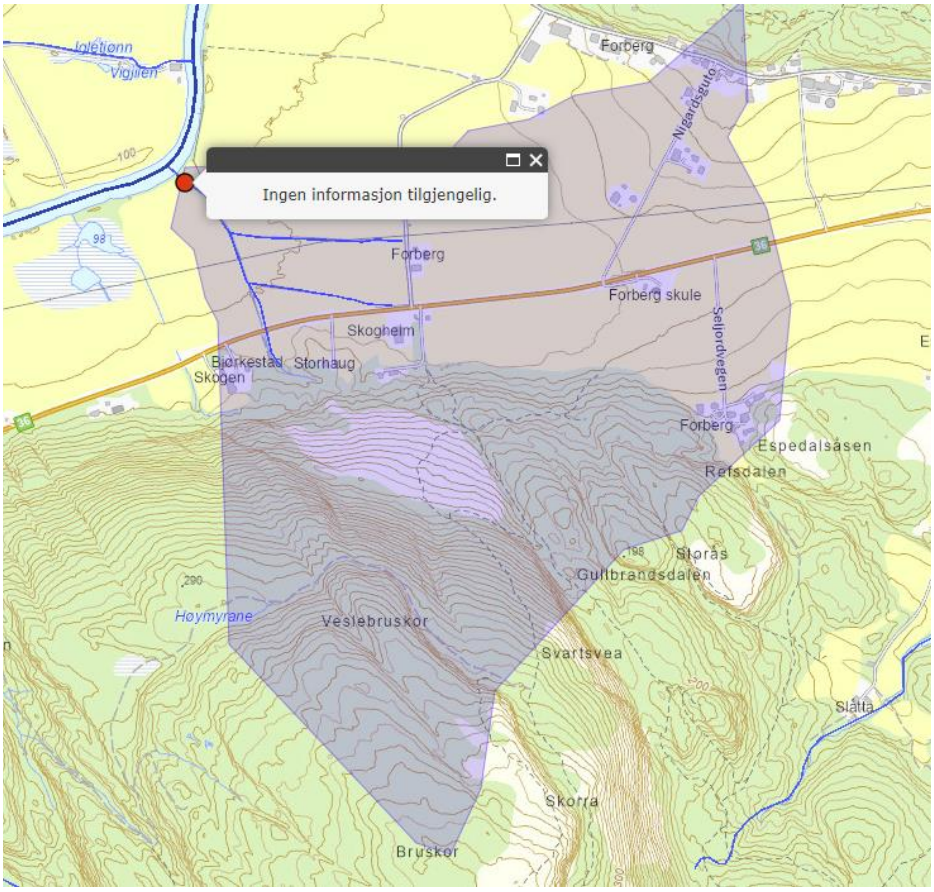
Parameternavn	Generert verdi	Editert verdi
ObjectId	26 998	26 998
Vassdragsnummer	016.CA6	016.CA6
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	0 % 20 % 40 %	
Nedbørfeltparametere		
Areal (km²)	8,13	8,13
Middelavrenning 1961-1990 (mm/år)	387,29	387,29
Middelavrenning 1961-1990 (l/s/km²)	12,28	12,28
Minimum høyde (m)	100	100
Høyde 10 % (m)	124	124
Høyde 25 % (m)	221	221
Høyde 75 % (m)	429	429
Maksimum høyde (m)	637	637
Sjø (%)	2,61	2,61
Bre (%)	0	0
Skog (%)	89,65	89,65
Dyrket mark (%)	6,68	6,68

Appendix A-14 Station West-3 Jønneberg



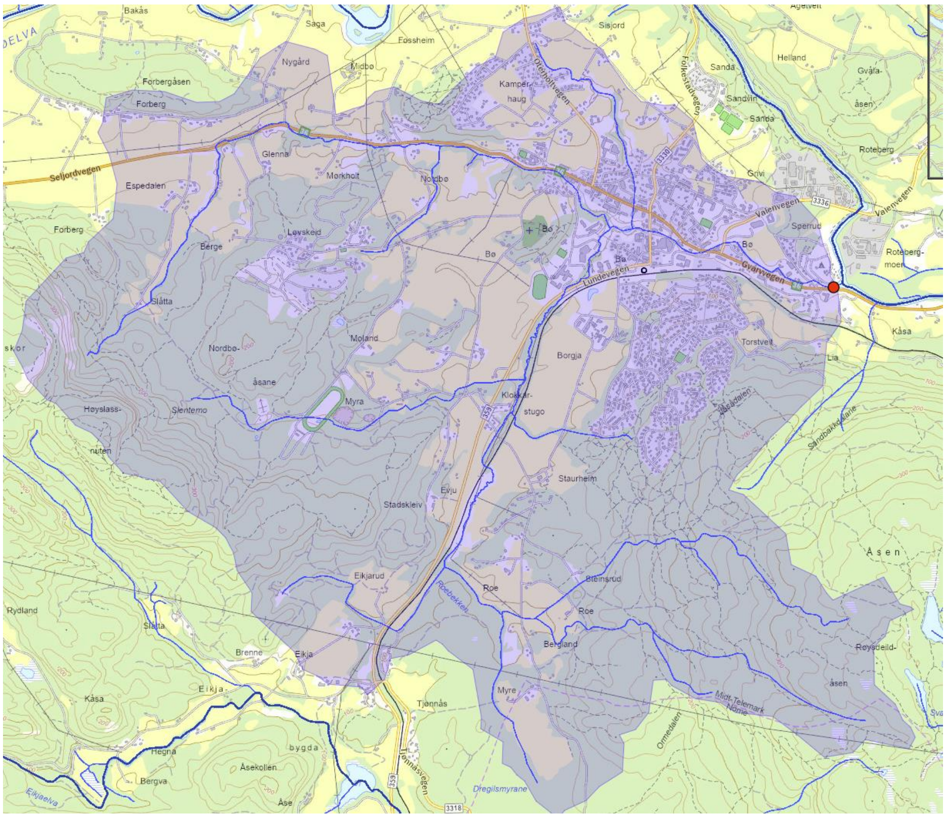
Parameternavn	Generert verdi	Editert verdi
ObjectId	26 988	26 988
Vassdragsnummer	016.CA6	016.CA6
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○ 0 % ○ 20 % ○ 40 %	
Nedbørfeltparametere		
Areal (km²)	3,87	3,87
Middelavrenning 1961-1990 (mm/år)	322,94	322,94
Middelavrenning 1961-1990 (l/s/km²)	10,24	10,24
Minimum høyde (m)	100	100
Høyde 10 % (m)	117	117
Høyde 25 % (m)	143	143
Høyde 75 % (m)	299	299
Maksimum høyde (m)	398	398
Sjø (%)	0,03	0,03
Bre (%)	0	0
Skog (%)	80,36	80,36
Dyrket mark (%)	18,28	18,28

Appendix A-15 Station West-4 Forberg



Parameternavn	Generert verdi	Editert verdi
ObjectId	26 995	26 995
Vassdragsnummer	016.CA4	016.CA4
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○0 % ○20 % ○40 %	
Nedbørfeltparametere		
Areal (km²)	1,31	1,31
Middelavrenning 1961-1990 (mm/år)	305,54	305,54
Middelavrenning 1961-1990 (l/s/km²)	9,69	9,69
Minimum høyde (m)	100	100
Høyde 10 % (m)	104	104
Høyde 25 % (m)	108,5	108,5
Høyde 75 % (m)	223,5	223,5
Maksimum høyde (m)	389	389
Sjø (%)	0	0
Bre (%)	0	0
Skog (%)	50,76	50,76
Dyrket mark (%)	46,61	46,61

Appendix A-16 Station West-5 Lortebekk



Parameternavn	Generert verdi	Editert verdi
ObjectId	26 982	26 982
Vassdragsnummer	016.CA4	016.CA4
Vassdrag	Bøelva	Bøelva
Kommune	Midt-Telemark	Midt-Telemark
Fylke	Vestfold og Telemark	Vestfold og Telemark
Klimapåslag		
Klimapåslag (RFFA-2018):	○0 % ○20 % ○40 %	
Nedbørfeltparametere		
Areal (km²)	20,11	20,11
Middelavrenning 1961-1990 (mm/år)	272,45	272,45
Middelavrenning 1961-1990 (l/s/km²)	8,64	8,64
Minimum høyde (m)	32	32
Høyde 10 % (m)	81	81
Høyde 25 % (m)	101	101
Høyde 75 % (m)	169	169
Maksimum høyde (m)	398	398
Sjø (%)	0,04	0,04
Bre (%)	0	0
Skog (%)	58,68	58,68
Dyrket mark (%)	24,29	24,29

Appendix B Analysis method and analytical results

Appendix B-1

Overview of analysed parameters and analytical method used at the two laboratories used for water chemical analysis, i.e. SGS Analytics Norway AS and ALS Laboratory group Norway AS.

		SGS Analytics Norway AS			AlS Laboratory group Norway AS			AlS Laboratory group Norway AS
Parameter	Short name	Method	Parameter	Short name	Method	Parameter	Short name	Method
Calsium	Ca^{2+}	SS-EN ISO 11885:2009	Aluminium	Al	W-SFMS-06	Magnesium	Mg	W-AES-02
Magnesium	Mg^{2+}	SS-EN ISO 11885:2009	Arsen	As	W-SFMS-06	Manganese	Mn	W-SFMS-06
Sodium	Na^{+}	SS-EN ISO 11885:2009	Barium	Ba	W-SFMS-06	Molydenium	Mo	W-SFMS-06
Potasium	K^{+}	ISO 11885	Calsium	Ca	W-AES-02	Sodium	Na	W-AES-02
Ammonium-N	NH_4^{+}-N	Internal	Cadmium	Cd	W-SFMS-06	Nickel	Ni	W-SFMS-06
Sulphate	SO_4^{2-}	ISO 10304, IC	Cobolt	Co	W-SFMS-06	Led	Pb	W-SFMS-06
Chloride	Cl^{-}	ISO 10304, IC	Chromium	Cr	W-SFMS-06	Vanadium	V	W-SFMS-06
Nitrate-N	NO_3^{-}-N	SS-EN ISO13395:1996	Copper	Cu	W-SFMS-06	Zink	Zn	W-SFMS-06
Total organic carbon	TOC	SS-EN -1484 Ed.1	Iron	Fe	W-SFMS-06			
Total nitrogen	Tot-N	Internal	Mercury	Hg	W-AFS-17V3b			
Total phosphorous	Tot-P	EN-ISO 15681-2-2018	Potasium	K	W-AES-02			

Appendix B-2 Analysis of major chemistry in River Bø-elva, upstream and downstream from Bø sewage plant, during the period 26.02.2023 – 06.11.2023.

Site Bøelva	Sampling Date	Mannebru Discharge $m^3 s^{-1}$	pH	K_{25} $\mu S\ cm^{-1}$	Turbidity FTU	Ca^{2+} $mg\ L^{-1}$	Mg^{2+} $mg\ L^{-1}$	Na^{+} $mg\ L^{-1}$	K^{+} $mg\ L^{-1}$	NH_4^+-N $\mu g\ L^{-1}$	SO_4^{2-} $mg\ L^{-1}$	Cl^- $mg\ L^{-1}$	NO_3^--N $\mu g\ L^{-1}$	TOC $mg\ L^{-1}$	Tot-N $\mu g\ L^{-1}$	Tot-P $\mu g\ L^{-1}$
Upstream	26.04.2023	69,63	6,20	20,70	0,86	2,10	0,34	1,20	0,28	10,0	1,00	1,50	180	4,4	771	7
Upstream	03.05.2023	38,60	6,31	20,20	0,26	2,20	0,33	1,20	0,26	10,2	1,00	1,50	130	4,4	1060	5
Upstream	10.05.2023	52,00	6,28	17,30	0,49	1,80	0,28	1,00	0,21	11,5	0,86	1,30	110	4,4	779	6
Upstream	16.05.2023	88,91	6,20	17,47	0,70	1,80	0,27	0,98	0,19	8,9	0,85	1,30	110	3,9	1150	6
Upstream	24.05.2023	84,70	6,26	17,74	0,70	1,90	0,27	1,00	0,21	4,0	0,84	1,30	130	3,7	674	6
Upstream	31.05.2023	38,34	6,29	16,69	0,44	1,80	0,26	0,97	0,19	9,7	0,81	1,20	110	3,7	1280	5
Upstream	07.06.2023	20,38	6,08	17,02	0,43	2,00	0,29	1,10	0,22	5,7	0,86	1,30	110	3,6	825	5
Upstream	14.06.2023	20,76	6,36	18,30	0,47	2,00	0,29	1,10	0,23	14,6	0,87	1,30	92	3,8	698	5
Upstream	21.06.2023	20,39	6,32	17,93	0,49	2,00	0,30	1,10	0,23	19,8	0,98	1,30	83	3,9	799	6
Upstream	28.06.2023	14,68	6,37	18,36	0,38	1,90	0,29	1,10	0,22	8,7	0,88	1,30	99	3,5	823	7
Upstream	31.08.2023	34,82	6,39	18,35	0,44	2,10	0,30	1,00	0,22	4,8	0,85	1,20	75	4,4	985	5
Upstream	07.09.2023	25,13	6,39	17,93	0,51	2,00	0,29	0,97	0,21	8,4	0,83	1,20	82	4,4	2040	4
Upstream	14.09.2023	24,94	6,53	18,02	0,51	2,10	0,29	0,98	0,21	12,2	0,82	1,20	84	4,4	768	4
Upstream	21.09.2023	67,12	6,38	17,64	1,39	2,10	0,34	1,00	0,25	16,7	0,89	1,20	140	5,6	786	7
Upstream	28.09.2023	48,34	6,08	18,60	0,85	2,10	0,34	1,00	0,26	18,2	0,87	1,20	130	5,6	1160	7
Upstream	05.10.2023	20,09	6,30	18,81	0,60	2,30	0,34	1,10	0,26	13,9	0,98	1,20	110	5,0	684	5
Upstream	11.10.2023	20,69	6,49	18,48	0,48	2,10	0,31	0,99	0,24	16,5	0,86	1,20	100	5,0	985	6
Upstream	19.10.2023	16,88	6,70	19,50	0,54	2,20	0,34	1,10	0,26	18,4	0,92	1,30	130	5,1	874	5
Upstream	26.10.2023	17,51	6,57	19,30	0,42	2,20	0,33	1,10	0,27	19,1	0,95	1,40	130	4,4	787	4
Upstream	06.11.2023	25,58	6,50	22,30	1,38	2,20	0,46	1,30	0,37	20,8	1,20	1,70	320	7,0	967	8
Downstream	26.04.2023	69,63	6,40	21,00	0,64	2,20	0,34	1,20	0,28	10,9	1,00	1,60	170	4,4	857	6
Downstream	03.05.2023	38,60	6,35	20,50	0,32	2,10	0,31	1,20	0,26	11,3	0,97	1,50	150	4,2	675	5
Downstream	10.05.2023	52,00	6,21	17,64	0,50	1,80	0,28	1,00	0,22	9,7	0,87	1,20	170	4,3	708	5
Downstream	16.05.2023	88,91	6,28	17,49	0,45	1,90	0,28	1,00	0,19	8,3	0,89	1,30	130	4,0	911	6
Downstream	24.05.2023	84,70	6,35	17,89	0,67	1,90	0,28	1,00	0,24	9,5		1,30	140	4,2	782	7
Downstream	31.05.2023	38,34	6,26	17,20	0,49	1,90	0,28	1,00	0,19	4,6	0,92	1,30	120	3,8	598	5
Downstream	07.06.2023	20,38	6,11	18,38	0,38	2,00	0,30	1,10	0,25	14,6	0,95	1,40	120	3,8	643	5
Downstream	14.06.2023	20,76	6,37	19,06	0,45	1,90	0,28	1,10	0,27	12,0	0,89	1,40	110	3,6	746	5
Downstream	21.06.2023	20,39	6,31	18,80	0,43	2,00	0,29	1,20	0,22	27,0	0,87	1,30	100	3,7	4340	5
Downstream	28.06.2023	14,68	6,31	19,59	0,62	2,00	0,30	1,10	0,26	13,5	0,91	1,50	150	3,8	928	6
Downstream	31.08.2023	34,82	6,37	18,72	0,54	2,10	0,30	1,00	0,21	5,0	0,84	1,20	59	4,5	762	5
Downstream	07.09.2023	25,13	6,34	18,58	0,77	2,00	0,29	1,00	0,21	24,4	0,82	1,20	90	4,6	812	6
Downstream	14.09.2023	24,94	6,42	19,09	0,59	2,10	0,30	1,10	0,23	32,8	0,85	1,30	93	4,2	686	5
Downstream	21.09.2023	67,12	6,30	18,10	1,51	2,00	0,34	1,00	0,26	17,6	0,89	1,20	160	5,9	770	7
Downstream	28.09.2023	48,34	6,23	18,84	0,85	2,00	0,33	1,00	0,28	17,7	0,91	1,30	140	5,4	923	6
Downstream	05.10.2023	20,09	6,36	19,38	0,64	2,10	0,32	1,10	0,27	17,1	0,89	1,30	120	4,9	739	6
Downstream	11.10.2023	20,69	6,57	19,09	0,49	2,10	0,32	1,00	0,26	17,1	0,93	1,20	120	5,0	992	5
Downstream	19.10.2023	16,88	6,64	20,10	0,53	2,20	0,34	1,10	0,26	22,1	0,96	1,30	140	5,1	814	6
Downstream	26.10.2023	17,51	6,77	20,80	0,37	2,20	0,33	1,20	0,28	18,1	1,10	1,50	170	4,6	714	4
Downstream	06.11.2023	25,58	6,30	23,50	1,51	2,20	0,47	1,40	0,35	20,1	1,20	1,80	320	7,0	1030	9

Appendix B-3 Analysis of major metals in River Bø-elva, upstream and downstream from Bø sewage plant, during the period 26.02.2023 – 06.11.2023.

Site Bøelva	Sampling Date	Mannebru Discharge $m^3\ s^{-1}$	Ba $\mu g\ L^{-1}$	Al $\mu g\ L^{-1}$	Fe $\mu g\ L^{-1}$	Mn $\mu g\ L^{-1}$	Pb $\mu g\ L^{-1}$	Cd $\mu g\ L^{-1}$	Hg $\mu g\ L^{-1}$	Zn $\mu g\ L^{-1}$	Cr $\mu g\ L^{-1}$	Cu $\mu g\ L^{-1}$	Co $\mu g\ L^{-1}$	Ni $\mu g\ L^{-1}$	As $\mu g\ L^{-1}$	Mo $\mu g\ L^{-1}$	V $\mu g\ L^{-1}$
Upstream	26.04.2023	69,63	6,19	159	124	5,98	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	03.05.2023	38,60	5,78	119	84,4	4,65	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	10.05.2023	52,00	5,32	133	101	5,50	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	16.05.2023	88,91	5,24	119	89,9	5,73	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	24.05.2023	84,70	5,54	130	107	5,72	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	31.05.2023	38,34	5,30	110	78,8	4,49	< 0,5	< 0,05	< 0,02	**4,74**	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	07.06.2023	20,38	5,17	101	73,2	3,66	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	14.06.2023	20,76	5,11	93,8	70,9	3,71	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	21.06.2023	20,39	4,93	86,1	75,5	3,89	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	28.06.2023	14,68	4,88	91	79,2	4,15	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	31.08.2023	34,82	5,53	110	98,5	4,67	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	07.09.2023	25,13	5,60	101	75,3	3,72	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	14.09.2023	24,94	5,55	102	81,8	3,58	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	21.09.2023	67,12	5,93	157	158	7,38	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	28.09.2023	48,34	6,12	153	139	5,26	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	05.10.2023	20,09	5,79	117	112	3,68	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	11.10.2023	20,69	6,25	118	108	3,73	**1,54**	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	19.10.2023	16,88	5,76	121	105	3,37	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	26.10.2023	17,51	5,76	111	74,8	1,66	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Upstream	06.11.2023	25,58	6,35	217	198	7,57	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	**0,26**
Downstream	26.04.2023	69,63	14,20	162	142	9,78	< 0,5	**0,0524**	< 0,02	**7,18**	< 0,9	**2,23**	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	03.05.2023	38,60	5,88	123	85,7	4,34	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	10.05.2023	52,00	5,34	142	100	5,42	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	16.05.2023	88,91	6,00	131	101	5,74	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	24.05.2023	84,70	5,47	115	88	5,18	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	31.05.2023	38,34	5,06	102	76,5	4,27	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	07.06.2023	20,38	5,13	98,1	76,6	3,79	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	14.06.2023	20,76	5,34	106	77,9	3,92	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	21.06.2023	20,39	5,42	95,9	84,6	5,35	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	28.06.2023	14,68	4,71	93,2	81,9	4,42	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	31.08.2023	34,82	5,47	113	95,2	4,70	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	07.09.2023	25,13	5,72	103	79,6	4,32	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	14.09.2023	24,94	5,58	99,8	83,7	3,98	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	21.09.2023	67,12	6,38	174	163	6,97	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	28.09.2023	48,34	5,88	149	142	6,28	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	05.10.2023	20,09	5,98	125	115	3,86	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	11.10.2023	20,69	5,84	123	102	4,59	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	19.10.2023	16,88	5,99	121	102	3,70	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	26.10.2023	17,51	5,86	111	78,4	2,29	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	< 0,2
Downstream	06.11.2023	25,58	6,71	222	197	7,97	< 0,5	< 0,05	< 0,02	< 4	< 0,9	< 1	< 0,2	< 0,6	< 0,5	< 0,5	**0,242**

Appendix C Statistical data

Appendix C-1 Correlation matrix for water discharge and chemical parameters in River Bø elva, both Upstream and Downstream the emission point from Bø sewage plant. Bold values as significant ($p < 0,05$).

Upstream	Discharge $m^3 s^{-1}$	pH	H+ $\mu eq L^{-1}$	K_{25} $\mu S cm^{-1}$	Turbidity FTU	Ca^{2+} $mg L^{-1}$	Mg^{2+} $mg L^{-1}$	Na^{+} $mg L^{-1}$	K^{+} $mg L^{-1}$	NH_4^+-N $\mu g L^{-1}$	SO_4^{2-} $mg L^{-1}$	Cl^- $mg L^{-1}$	NO_3^--N $\mu g L^{-1}$	ANC-1 $\mu eq L^{-1}$	ANC-2 $\mu eq L^{-1}$	TOC $mg L^{-1}$	Tot-N $\mu g L^{-1}$	Tot-P mg L-1	Org-N $\mu g L^{-1}$	Ca^{2+}(2) $mg L^{-1}$	Mg^{2+}(2) $mg L^{-1}$	Na^{+}(2) $mg L^{-1}$	Ba $\mu g L^{-1}$	Al $\mu g L^{-1}$	Fe $\mu g L^{-1}$
pH	**-0,479**																								
H+	0,434	**-0,974**																							
K_{25}	-0,154	0,337	-0,307																						
Turbidity	0,408	-0,020	0,026	0,368																					
Ca^{2+}	-0,418	0,416	-0,348	**0,669**	0,196																				
Mg^{2+}	-0,191	0,296	-0,244	**0,864**	**0,649**	**0,707**																			
Na^{+}	-0,254	0,113	-0,095	**0,837**	0,224	**0,505**	**0,727**																		
K^{+}	-0,201	0,278	-0,228	**0,908**	**0,577**	**0,704**	**0,979**	**0,804**																	
NH_4^+-N	-0,357	**0,446**	-0,382	**0,427**	0,374	**0,487**	**0,619**	0,321	**0,610**																
SO_4^{2-}	-0,166	0,190	-0,190	**0,870**	**0,454**	**0,569**	**0,878**	**0,902**	**0,908**	**0,521**															
Cl^-	0,033	0,100	-0,095	**0,812**	0,311	0,260	**0,664**	**0,884**	**0,741**	0,228	**0,842**														
NO_3^--N	0,127	0,110	-0,078	**0,768**	**0,718**	0,317	**0,850**	**0,703**	**0,858**	0,379	**0,812**	**0,817**													
ANC-1	**-0,535**	0,377	-0,309	**0,480**	0,055	**0,953**	**0,545**	0,355	**0,530**	**0,452**	0,383	0,019	0,074												
ANC-2	**-0,575**	0,317	-0,259	0,326	-0,180	**0,863**	0,316	0,282	0,326	0,292	0,225	-0,093	-0,151	**0,957**											
TOC	-0,063	0,311	-0,257	**0,634**	**0,731**	**0,604**	**0,883**	0,345	**0,802**	**0,641**	**0,613**	0,345	**0,709**	**0,477**	0,202										
Tot-N	-0,029	-0,053	0,040	-0,109	-0,083	-0,178	-0,108	-0,300	-0,185	-0,164	-0,213	-0,170	-0,109	-0,166	-0,199	0,044									
Tot-P	0,373	-0,276	0,259	0,354	**0,688**	-0,090	**0,477**	0,344	**0,465**	0,238	**0,450**	0,399	0,615	-0,177	-0,345	**0,448**	-0,226								
Org-N	-0,043	-0,076	0,058	-0,238	-0,205	-0,232	-0,254	-0,410	-0,329	-0,237	-0,348	-0,302	-0,276	-0,179	-0,172	-0,084	**0,985**	-0,323							
Ca^{2+}(2)	-0,239	0,391	-0,295	**0,752**	0,247	**0,861**	**0,698**	**0,443**	**0,712**	0,420	**0,493**	0,335	0,435	**0,763**	**0,641**	**0,634**	-0,065	0,077	-0,141						
Mg^{2+}(2)	-0,094	0,307	-0,242	**0,877**	**0,676**	**0,655**	**0,972**	**0,667**	**0,957**	**0,561**	**0,814**	**0,661**	**0,885**	**0,469**	0,232	**0,881**	-0,080	**0,514**	-0,232	**0,755**					
Na^{+}(2)	-0,033	0,002	0,019	**0,847**	0,251	0,374	**0,661**	**0,936**	**0,759**	0,184	**0,833**	**0,944**	**0,760**	0,171	0,093	0,297	-0,245	0,409	-0,364	**0,452**	**0,669**				
Ba	0,123	0,204	-0,148	**0,646**	**0,559**	**0,636**	**0,708**	0,271	**0,697**	0,393	**0,456**	0,317	**0,600**	**0,479**	0,269	**0,803**	0,074	0,300	-0,034	**0,801**	**0,790**	0,365			
Al	0,362	-0,011	0,038	**0,632**	**0,847**	0,282	**0,784**	0,433	**0,754**	0,337	**0,626**	**0,584**	**0,900**	0,066	-0,196	**0,816**	-0,060	**0,687**	-0,211	0,426	**0,839**	**0,529**	**0,750**		
Fe	0,274	0,048	-0,027	**0,562**	**0,903**	0,361	**0,800**	0,348	**0,736**	0,414	**0,586**	0,404	**0,806**	0,206	-0,062	**0,882**	-0,117	**0,740**	-0,252	**0,448**	**0,834**	0,376	**0,732**	**0,944**	
Mn	**0,658**	-0,309	0,251	0,231	**0,797**	-0,167	0,378	0,162	0,312	-0,033	0,316	0,341	**0,602**	-0,308	**-0,496**	**0,463**	-0,031	**0,783**	-0,128	-0,076	0,414	0,262	0,335	**0,771**	**0,770**

Downstream	Discharge $m^3 s^{-1}$	pH	H+ $\mu eq L^{-1}$	K_{25} $\mu S cm^{-1}$	Turbidity FTU	Ca^{2+} $mg L^{-1}$	Mg^{2+} $mg L^{-1}$	Na^{+} $mg L^{-1}$	K^{+} $mg L^{-1}$	NH_4^+-N $\mu g L^{-1}$	SO_4^{2-} $mg L^{-1}$	Cl^- $mg L^{-1}$	NO_3^--N $\mu g L^{-1}$	ANC-1 $\mu eq L^{-1}$	ANC-2 $\mu eq L^{-1}$	TOC $mg L^{-1}$	Tot-N $\mu g L^{-1}$	Tot-P mg L-1	Org-N $\mu g L^{-1}$	Ca^{2+}(2) $mg L^{-1}$	Mg^{2+}(2) $mg L^{-1}$	Na^{+}(2) $mg L^{-1}$	Ba $\mu g L^{-1}$	Al $\mu g L^{-1}$	Fe $\mu g L^{-1}$
pH	-0,300																								
H+	0,241	**-0,970**																							
K_{25}	-0,353	0,380	-0,384																						
Turbidity	0,191	-0,199	0,135	0,317																					
Ca^{2+}	-0,383	**0,616**	**-0,601**	**0,800**	0,159																				
Mg^{2+}	-0,157	0,159	-0,154	**0,835**	**0,698**	**0,659**																			
Na^{+}	-0,341	0,179	-0,168	**0,885**	0,197	**0,611**	**0,699**																		
K^{+}	-0,250	0,221	-0,199	**0,839**	0,493	**0,586**	**0,826**	**0,693**																	
NH_4^+-N	-0,461	0,265	-0,264	0,285	0,211	0,381	0,259	0,305	0,225																
SO_4^{2-}	-0,121	0,306	-0,224	**0,820**	0,300	**0,584**	**0,806**	**0,788**	**0,763**	0,000															
Cl^-	-0,133	0,059	-0,043	**0,834**	0,217	**0,486**	**0,663**	**0,878**	**0,720**	-0,003	**0,840**														
NO_3^--N	0,093	-0,006	0,033	**0,686**	**0,588**	**0,285**	**0,824**	**0,661**	**0,738**	0,008	**0,849**	0,746													
ANC-1	-0,410	**0,558**	**-0,590**	**0,556**	0,146	**0,875**	**0,448**	0,396	0,389	**0,547**	0,219	0,127	-0,027												
ANC-2	-0,473	**0,555**	**-0,583**	0,393	-0,169	**0,768**	0,145	0,313	0,167	**0,501**	0,032	0,039	-0,291	**0,933**											
TOC	0,011	0,136	-0,148	**0,547**	**0,829**	**0,477**	**0,872**	0,312	**0,655**	0,256	**0,525**	0,259	**0,664**	0,398	0,040										
Tot-N	-0,159	-0,066	0,033	-0,001	-0,084	-0,032	-0,054	0,267	-0,118	0,383	-0,112	-0,041	-0,110	0,178	0,260	-0,161									
Tot-P	0,307	-0,255	0,169	0,383	**0,837**	0,128	**0,677**	0,291	**0,490**		0,403	0,381	**0,666**	0,120	-0,172	**0,706**	-0,067								
Org-N	-0,160	-0,068	0,033	-0,048	-0,124	-0,053	-0,109	0,221	-0,167	0,372	-0,166	-0,089	-0,174	0,174	0,273	-0,205	**0,998**	-0,110							
Ca^{2+}(2)	-0,326	**0,538**	**-0,531**	**0,811**	0,307	**0,861**	**0,727**	**0,569**	**0,787**	0,377	**0,619**	**0,498**	0,419	**0,723**	**0,536**	**0,641**	-0,166	0,239	-0,196						
Mg^{2+}(2)	-0,166	0,182	-0,185	**0,857**	**0,682**	**0,664**	**0,988**	**0,702**	**0,867**	0,271	**0,787**	**0,662**	**0,812**	**0,461**	0,157	**0,873**	-0,052	**0,650**	-0,107	0,784					
Na^{+}(2)	-0,119	0,077	-0,079	**0,857**	0,194	**0,512**	**0,657**	**0,911**	**0,705**	0,044	**0,788**	**0,950**	**0,728**	0,174	0,092	0,263	0,037	0,311	-0,010	**0,506**	**0,669**				
Ba	0,357	0,118	-0,166	0,397	0,146	0,432	0,306	0,314	0,304	-0,083	0,289	0,404	0,261	0,239	0,202	0,155	-0,049	0,193	-0,065	0,331	0,316	**0,528**			
Al	0,343	-0,110	0,076	**0,522**	**0,782**	0,280	**0,814**	0,398	**0,627**	-0,033	**0,576**	**0,443**	**0,808**	0,092	-0,230	**0,842**	-0,144	**0,741**	-0,195	**0,446**	**0,817**	**0,507**	**0,442**		
Fe	0,273	-0,130	0,082	**0,501**	**0,852**	0,341	**0,826**	0,361	**0,644**	0,083	**0,487**	0,385	**0,714**	0,211	-0,112	**0,871**	-0,053	**0,777**	-0,099	**0,493**	**0,834**	**0,430**	**0,441**	**0,958**	
Mn	0,558	-0,339	0,246	0,276	**0,581**	0,098	**0,470**	0,241	0,315	-0,121	0,244	0,348	**0,496**	-0,016	-0,188	**0,429**	0,113	**0,617**	0,082	0,107	**0,462**	**0,440**	**0,728**	**0,756**	**0,774**

Appendix C-2 Regression analysis between discharge and physio-chemical parameters in River Bø-elva, both upstream and downstream the emission point from Bø sewage plant. Bold values as significant ($p < 0,05$).

Site	x	unit	y	unit	Regression	R^2	p
Upstream	**Discharge**	**$m^3 s^{-1}$**	**pH**	**-log[H^+]**	**pH = 6,47 - 0,0032x**	**0,299**	**0,033**
Upstream	Discharge	$m^3 s^{-1}$	H^+	µeq L^{-1}	[H^+] = 0,358 + 0,003x	0,188	0,056
Upstream	Discharge	$m^3 s^{-1}$	K_{25}	µS cm^{-1}	K_{25} = 18,86 - 0,009x	0,024	0,518
Upstream	Discharge	$m^3 s^{-1}$	Turbidity	FTU	Turbidity = 0,42 + 0,005x	0,024	0,518
Upstream	Discharge	$m^3 s^{-1}$	Ca^{2+} (ICP-MS)	mg L^{-1}	[Ca^{2+}] = 2,07 -0,001x	0,057	0,310
Upstream	Discharge	$m^3 s^{-1}$	Mg^{2+} (ICP-MS)	mg L^{-1}	[Mg^{2+}] = 0,30 -0,0001x	0,009	0,694
Upstream	Discharge	$m^3 s^{-1}$	Na^+ (ICP-MS)	mg L^{-1}	[Na^+] = 1,19 -0,0001x	0,001	0,890
Upstream	Discharge	$m^3 s^{-1}$	K^+ (IC)	mg L^{-1}	[K^+] = 0,253 -0,0003x	0,041	0,395
Upstream	Discharge	$m^3 s^{-1}$	NH_4^+-N	µg L^{-1}	[NH_4^+-N] = 15,6 -0,079x	0,128	0,122
Upstream	Discharge	$m^3 s^{-1}$	SO_4^{2+}	mg L^{-1}	[SO_4^{2+}] = 0,93 -0,0007x	0,028	0,483
Upstream	Discharge	$m^3 s^{-1}$	Cl^-	mg L^{-1}	[Cl^-] = 1,30 + 0,0002x	0,001	0,890
Upstream	Discharge	$m^3 s^{-1}$	NO_3^--N	µg L^{-1}	[NO_3^--N] = 112 + 0,286x	0,016	0,594
Upstream	Discharge	$m^3 s^{-1}$	TOC	mg L^{-1}	[TOC] = 4,60 - 0,0023x	0,004	0,792
Upstream	Discharge	$m^3 s^{-1}$	TOT-N	µg L^{-1}	[TOT-N] = 959 - 0,381x	0,001	0,904
Upstream	Discharge	$m^3 s^{-1}$	TOT-P	µg L^{-1}	[TOT-P] = 4,97 + 0,018x	0,139	0,105
Upstream	Discharge	$m^3 s^{-1}$	Org-N	µg L^{-1}	[Org-N] = 831 - 0,59x	0,002	0,858
Upstream	Discharge	$m^3 s^{-1}$	Ba	µg L^{-1}	[Ba] = 5,52 + 0,0023x	0,015	0,606
Upstream	Discharge	$m^3 s^{-1}$	Al	µg L^{-1}	[Al] = 104,8 + 0,47x	0,131	0,116
Upstream	Discharge	$m^3 s^{-1}$	Fe	µg L^{-1}	[Fe] = 87,4 + 0,38x	0,075	0,242
Upstream	**Discharge**	**$m^3 s^{-1}$**	**Mn**	**µg L^{-1}**	**[Mn] = 3,11 + 0,04x**	**0,433**	**0,002**

Site	x	unit	y	unit	Regression	R^2	p
Downstream	Discharge	$m^3 s^{-1}$	pH	-log[H^+]	pH = 6,44 - 0,0019x	0,090	0,199
Downstream	Discharge	$m^3 s^{-1}$	H^+	µeq L^{-1}	[H^+] = 0,404 + 0,0014x	0,058	0,306
Downstream	Discharge	$m^3 s^{-1}$	K_{25}	µS cm^{-1}	K_{25} = 20,02 - 0,0222x	0,125	0,127
Downstream	Discharge	$m^3 s^{-1}$	Turbidity	FTU	Turbidity = 0,54 + 0,003x	0,037	0,419
Downstream	Discharge	$m^3 s^{-1}$	Ca^{2+} (ICP-MS)	mg L^{-1}	[Ca^{2+}] = 2,11 -0,002x	0,107	0,160
Downstream	Discharge	$m^3 s^{-1}$	Mg^{2+} (ICP-MS)	mg L^{-1}	[Mg^{2+}] = 0,31 -0,0003x	0,028	0,485
Downstream	Discharge	$m^3 s^{-1}$	Na^+ (ICP-MS)	mg L^{-1}	[Na^+] = 1,25 -0,0006x	0,014	0,617
Downstream	Discharge	$m^3 s^{-1}$	K^+ (IC)	mg L^{-1}	[K^+] = 0,265 -0,0004x	0,062	0,288
Downstream	**Discharge**	**$m^3 s^{-1}$**	**NH_4^+-N**	**µg L^{-1}**	**[NH_4^+-N] = 21,0 -0,14x**	**0,217**	**0,041**
Downstream	Discharge	$m^3 s^{-1}$	SO_4^{2+}	mg L^{-1}	[SO_4^{2+}] = 0,95 -0,005x	0,015	0,623
Downstream	Discharge	$m^3 s^{-1}$	Cl^-	mg L^{-1}	[Cl^-] = 1,39 + 0,0009x	0,018	0,578
Downstream	Discharge	$m^3 s^{-1}$	NO_3^--N	µg L^{-1}	[NO_3^--N] = 131 + 0,21x	0,009	0,697
Downstream	Discharge	$m^3 s^{-1}$	TOC	mg L^{-1}	[TOC] = 4,54 - 0,0004x	0,000	0,963
Downstream	Discharge	$m^3 s^{-1}$	TOT-N	µg L^{-1}	[TOT-N] =778 - 0,414x	0,007	0,738
Downstream	Discharge	$m^3 s^{-1}$	TOT-P	µg L^{-1}	[TOT-P] = 5,17 + 0,014x	0,095	0,187
Downstream	Discharge	$m^3 s^{-1}$	Org-N	µg L^{-1}	[Org-N] = 623 + 0,40x	0,008	0,718
Downstream	Discharge	$m^3 s^{-1}$	Ba	µg L^{-1}	[Ba] = 4,97 + 0,03x	0,128	0,122
Downstream	Discharge	$m^3 s^{-1}$	Al	µg L^{-1}	[Al] = 108 + 0,47x	0,117	0,139
Downstream	Discharge	$m^3 s^{-1}$	Fe	µg L^{-1}	[Fe] = 89,2 + 0,38x	0,074	0,245
Downstream	**Discharge**	**$m^3 s^{-1}$**	**Mn**	**µg L^{-1}**	**[Mn] = 3,53 + 0,04x**	**0,311**	**0,011**

Appendix C-3 Regression analysis between K_{25} (mS cm^{-1}) and physio-chemical parameters in River Bø-elva, both upstream and downstream the emission point from Bø sewage plant. Bold values as significant ($p < 0,05$).

Site	x	unit	y	unit	Regression	R^2	p
Upstream	K_{25}	$\mu S\ cm^{-1}$	Discharge	$m^3\ s^{-1}$	Discharge = 87,09 - 2,67x	0,024	0,518
Upstream	K_{25}	$\mu S\ cm^{-1}$	pH	$-log[H^+]$	pH = 5,62 + 0,039x	0,114	0,146
Upstream	K_{25}	$\mu S\ cm^{-1}$	H^+	$\mu eq\ L^{-1}$	$[H^+]$ =1,182 + 0,038x	0,094	0,188
Upstream	K_{25}	$\mu S\ cm^{-1}$	Turbidity	FTU	Turbidiy = -0,92 + 0,08x	0,136	0,110
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Ca^{2+} (ICP-MS)**	**$mg\ L^{-1}$**	**$[Ca^{2+}]$ = 0,63 +0,074x**	**0,566**	**0,000**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Mg^{2+} (ICP-MS)**	**$mg\ L^{-1}$**	**$[Mg^{2+}]$ = -0,20 + 0,027x**	**0,769**	**0,000**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Na^+ (ICP-MS)**	**$mg\ L^{-1}$**	**$[Na^+]$ = -0,009 + 0,064x**	**0,718**	**0,000**
Upstream	K_{25}	$\mu S\ cm^{-1}$	**K^+ (IC)**	**$mg\ L^{-1}$**	**$[K^+]$ = -0,268 + 0,027x**	**0,824**	**0,000**
Upstream	K_{25}	$\mu S\ cm^{-1}$	NH_4^+-N	$\mu g\ L^{-1}$	$[NH_4^+$-N] = -18,14 + 1,66x	0,182	0,060
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**SO_4^{2+}**	**$mg\ L^{-1}$**	**$[SO_4^{2+}]$ = -0,198 + 0,060x**	**0,757**	**0,000**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Cl^-**	**$mg\ L^{-1}$**	**$[Cl^-]$ = -0,174 + 0,08x**	**0,660**	**0,000**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**NO_3^--N**	**$\mu g\ L^{-1}$**	**$[NO_3^-$-N] = -436 + 30,2x**	**0,567**	**0,000**
Upstream	K_{25}	$\mu S\ cm^{-1}$	**TOC**	**$mg\ L^{-1}$**	**[TOC] = -2,98 + 0,40x**	**0,401**	**0,003**
Upstream	K_{25}	$\mu S\ cm^{-1}$	TOT-N	$\mu g\ L^{-1}$	[TOT-N] = 1409 -25x	0,012	0,649
Upstream	K_{25}	$\mu S\ cm^{-1}$	TOT-P	$\mu g\ L^{-1}$	[TOT-P] = 0,084 + 0,30x	0,125	0,126
Upstream	K_{25}	$\mu S\ cm^{-1}$	Org-N	$\mu g\ L^{-1}$	[Org-N] = 1863 - 56,8x	0,057	0,312
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Ba**	**$\mu g\ L^{-1}$**	**[Ba] = 1,75 + 0,21x**	**0,418**	**0,002**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Al**	**$\mu g\ L^{-1}$**	**[Al] = -143,1 + 14,3x**	**0,399**	**0,003**
Upstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Fe**	**$\mu g\ L^{-1}$**	**[Fe] = -152,1 + 13,7x**	**0,316**	**0,010**
Upstream	K_{25}	$\mu S\ cm^{-1}$	Mn	$\mu g\ L^{-1}$	[Mn] = 0,072 + 0,24x	0,054	0,327

Site	x	unit	y	unit	Regression	R^2	p
Downstream	K_{25}	$\mu S\ cm^{-1}$	Discharge	$m^3\ s^{-1}$	Discharge = 145,3 - 5,62x	0,125	0,127
Downstream	K_{25}	$\mu S\ cm^{-1}$	pH	$-log[H^+]$	pH = 5,62 + 0,039x	0,145	0,098
Downstream	K_{25}	$\mu S\ cm^{-1}$	H^+	$\mu eq\ L^{-1}$	$[H^+]$ =1,134 + 0,035x	0,14S78	0,094
Downstream	K_{25}	$\mu S\ cm^{-1}$	Turbidity	FTU	Turbidiy = -0,72 + 0,07x	0,100	0,174
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Ca^{2+} (ICP-MS)**	**$mg\ L^{-1}$**	**$[Ca^{2+}]$ = 0,62 +0,074x**	**0,658**	**0,000**
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Mg^{2+} (ICP-MS)**	**$mg\ L^{-1}$**	**$[Mg^{2+}]$ = -0,18 + 0,025x**	**0,735**	**0,000**
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Na^+ (ICP-MS)**	**$mg\ L^{-1}$**	**$[Na^+]$ = 0,02 + 0,063x**	**0,735**	**0,000**
Downstream	K_{25}	$\mu S\ cm^{-1}$	**K^+ (IC)**	**$mg\ L^{-1}$**	**$[K^+]$ = -0,162 + 0,021x**	**0,704**	**0,000**
Downstream	K_{25}	$\mu S\ cm^{-1}$	NH_4^+-N	$\mu g\ L^{-1}$	$[NH_4^+$-N] = -11,41 + 1,41x	0,081	0,223
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**SO_4^{2+}**	**$mg\ L^{-1}$**	**$[SO_4^{2+}]$ = -0,051 + 0,051x**	**0,672**	**0,000**
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Cl^-**	**$mg\ L^{-1}$**	**$[Cl^-]$ = -0,3596 + 0,089x**	**0,695**	**0,000**
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**NO_3^--N**	**$\mu g\ L^{-1}$**	**$[NO_3^-$-N] = -327 + 24,3x**	**0,470**	**0,001**
Downstream	K_{25}	$\mu S\ cm^{-1}$	**TOC**	**$mg\ L^{-1}$**	**[TOC] = -1,42 + 0,31x**	**0,299**	**0,013**
Downstream	K_{25}	$\mu S\ cm^{-1}$	TOT-N	$\mu g\ L^{-1}$	[TOT-N] = 156,2 -33,2x	0,176	0,074
Downstream	K_{25}	$\mu S\ cm^{-1}$	TOT-P	$\mu g\ L^{-1}$	[TOT-P] = 0,285 + 0,28x	0,147	0,096
Downstream	K_{25}	$\mu S\ cm^{-1}$	Org-N	$\mu g\ L^{-1}$	[Org-N] = 1320 - 26,2x	0,002	0,800
Downstream	K_{25}	$\mu S\ cm^{-1}$	Ba	$\mu g\ L^{-1}$	[Ba] = -4,09 + 0,53x	0,158	0,083
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Al**	**$\mu g\ L^{-1}$**	**[Al] =--91 + 11,3x**	**0,272**	**0,018**
Downstream	**K_{25}**	**$\mu S\ cm^{-1}$**	**Fe**	**$\mu g\ L^{-1}$**	**[Fe] = -112,1 + 11,2x**	**0,251**	**0,024**
Downstream	K_{25}	$\mu S\ cm^{-1}$	Mn	$\mu g\ L^{-1}$	[Mn] = -1,055 + 0,32x	0,076	0,327

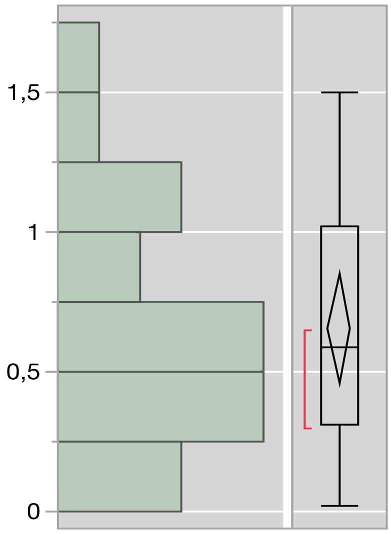
Appendix C-4 Regression analysis between Turbidity (FTU) and physio-chemical parameters in River Bø-elva, both upstream and downstream the emission point from Bø sewage plant. Bold values as significant ($p < 0,05$).

Site	x	unit	y	unit	Regression	R^2	p
Upstream	Turbidity	FTU	pH	-log[H^+]	pH = 6,36 - 0,0104x	0,000	0,933
Upstream	Turbidity	FTU	H^+	µeq L^{-1}	[H^+] = 0,465 + 0,014x	0,001	0,914
Upstream	Turbidity	FTU	K_{25}	µS cm^{-1}	K_{25} = 17,52 + 1,64x	0,136	0,110
Upstream	Turbidity	FTU	Ca^{2+} (ICP-MS)	mg L^{-1}	[Ca^{2+}] = 1,95 +0,11x	0,061	0,293
Upstream	**Turbidity**	**FTU**	**Mg^{2+} (ICP-MS)**	**mg L^{-1}**	**[Mg^{2+}] = 0,24 + 0,09x**	**0,457**	**0,001**
Upstream	Turbidity	FTU	Na^+ (ICP-MS)	mg L^{-1}	[Na^+] = 1,13 + 0,08x	0,063	0,286
Upstream	**Turbidity**	**FTU**	**K^+ (IC)**	**mg L^{-1}**	**[K^+] = 0,192 + 0,078x**	**0,333**	**0,008**
Upstream	Turbidity	FTU	NH_4^+-N	µg L^{-1}	[NH_4^+-N] = 8,61 + 6,48x	0,140	0,104
Upstream	**Turbidity**	**FTU**	**SO_4^{2+}**	**mg L^{-1}**	**[SO_4^{2+}] = 0,82 + 0,14x**	**0,206**	**0,044**
Upstream	Turbidity	FTU	Cl^-	mg L^{-1}	[Cl^-] = 1,22 + 0,14x	0,097	0,182
Upstream	**Turbidity**	**FTU**	**NO_3^--N**	**µg L^{-1}**	**[NO_3^--N] = 45,4 + 125,5x**	**0,516**	**0,000**
Upstream	**Turbidity**	**FTU**	**TOC**	**mg L^{-1}**	**[TOC] = 3,23 + 2,08x**	**0,535**	**0,000**
Upstream	Turbidity	FTU	TOT-N	µg L^{-1}	[TOT-N] = 998 - 85,6x	0,007	0,727
Upstream	**Turbidity**	**FTU**	**TOT-P**	**µg L^{-1}**	**[TOT-P] = 4,05 + 2,60x**	**0,445**	**0,001**
Upstream	Turbidity	FTU	Org-N	µg L^{-1}	[Org-N] = 944 - 217,5x	0,042	0,387
Upstream	**Turbidity**	**FTU**	**Ba**	**µg L^{-1}**	**[Ba] = 5,11 + 0,80x**	**0,312**	**0,010**
Upstream	**Turbidity**	**FTU**	**Al**	**µg L^{-1}**	**[Al] = 69,8 + 85,5x**	**0,717**	**0,000**
Upstream	**Turbidity**	**FTU**	**Fe**	**µg L^{-1}**	**[Fe] = 41,4 + 97,9x**	**0,815**	**0,000**
Upstream	**Turbidity**	**FTU**	**Mn**	**µg L^{-1}**	**[Mn] = 2,29 + 3,75x**	**0,635**	**0,000**

Site	x	unit	y	unit	Regression	R^2	p
Downstream	Turbidity	FTU	pH	-log[H^+]	pH = 6,42 - 0,09x	0,039	0,401
Downstream	Turbidity	FTU	H^+	µeq L^{-1}	[H^+] = 0,421 + 0,056x	0,018	0,569
Downstream	Turbidity	FTU	K_{25}	µS cm^{-1}	K_{25} = 18,28 + 1,42x	0,100	0,110
Downstream	Turbidity	FTU	Ca^{2+} (ICP-MS)	mg L^{-1}	[Ca^{2+}] = 1,96 +0,13x	0,094	0,188
Downstream	**Turbidity**	**FTU**	**Mg^{2+} (ICP-MS)**	**mg L^{-1}**	**[Mg^{2+}] = 0,24 + 0,09x**	**0,465**	**0,001**
Downstream	Turbidity	FTU	Na^+ (ICP-MS)	mg L^{-1}	[Na^+] = 1,19 + 0,06x	0,038	0,413
Downstream	**Turbidity**	**FTU**	**K^+ (IC)**	**mg L^{-1}**	**[K^+] = 0,213 + 0,057x**	**0,243**	**0,027**
Downstream	Turbidity	FTU	NH_4^+-N	µg L^{-1}	[NH_4^+-N] = 12,7 + 4,71x	0,045	0,371
Downstream	Turbidity	FTU	SO_4^{2+}	mg L^{-1}	[SO_4^{2+}] = 0,88 + 0,08x	0,090	0,212
Downstream	Turbidity	FTU	Cl^-	mg L^{-1}	[Cl^-] = 1,29 + 0,10x	0,047	0,359
Downstream	**Turbidity**	**FTU**	**NO_3^--N**	**µg L^{-1}**	**[NO_3^--N] = 78,9 + 93,6x**	**0,346**	**0,006**
Downstream	**Turbidity**	**FTU**	**TOC**	**mg L^{-1}**	**[TOC] = 3,20 + 2,12x**	**0,688**	**0,000**
Downstream	Turbidity	FTU	TOT-N	µg L^{-1}	[TOT-N] = 691 + 159x	0,195	0,059
Downstream	**Turbidity**	**FTU**	**TOT-P**	**µg L^{-1}**	**[TOT-P] = 3,93 + 2,78x**	**0,701**	**0,000**
Downstream	Turbidity	FTU	Org-N	µg L^{-1}	[Org-N] = 599 - 61,3x	0,037	0,433
Downstream	Turbidity	FTU	Ba	µg L^{-1}	[Ba] = 5,54 + 0,88x	0,021	0,540
Downstream	**Turbidity**	**FTU**	**Al**	**µg L^{-1}**	**[Al] = 76,9 + 76,1x**	**0,611**	**0,000**
Downstream	**Turbidity**	**FTU**	**Fe**	**µg L^{-1}**	**[Fe] = 48,8 + 85,9x**	**0,710**	**0,000**
Downstream	**Turbidity**	**FTU**	**Mn**	**µg L^{-1}**	**[Mn] = 3,13 + 3,01x**	**0,338**	**0,007**

Appendix C-5 Wilcoxon Rank Tests on water chemistry data (D = downstream – upstream) from the River Bø-elva.

ΔK25



Quantiles

100,0%	maximum	1,5
99,5%		1,5
97,5%		1,5
90,0%		1,347
75,0%	quartile	1,02
50,0%	median	0,585
25,0%	quartile	0,31
10,0%		0,159
2,5%		0,02
0,5%		0,02
0,0%	minimum	0,02

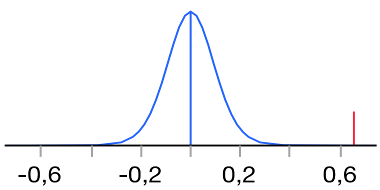
Summary Statistics

Mean	0,6555
Std Dev	0,4231769
Std Err Mean	0,0946252
Upper 95% Mean	0,8535529
Lower 95% Mean	0,4574471
N	20
N Missing	0

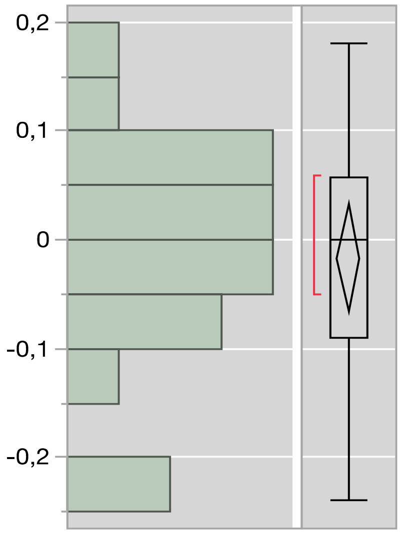
Test Mean

Hypothesized Value	0
Actual Estimate	0,6555
DF	19
Std Dev	0,42318

	t Test	Signed-Rank
Test Statistic	6,9273	105,0000
Prob > |t|	<,0001*	<,0001*
Prob > t	<,0001*	<,0001*
Prob < t	1,0000	1,0000



ΔH+



Quantiles

100,0%	maximum	0,18
99,5%		0,18
97,5%		0,18
90,0%		0,098
75,0%	quartile	0,0575
50,0%	median	0
25,0%	quartile	-0,09
10,0%		-0,218
2,5%		-0,24
0,5%		-0,24
0,0%	minimum	-0,24

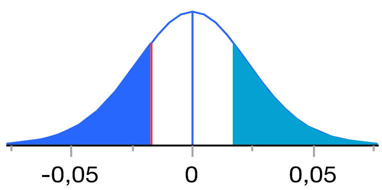
Summary Statistics

Mean	-0,017
Std Dev	0,1054863
Std Err Mean	0,0235875
Upper 95% Mean	0,0323691
Lower 95% Mean	-0,066369
N	20
N Missing	0

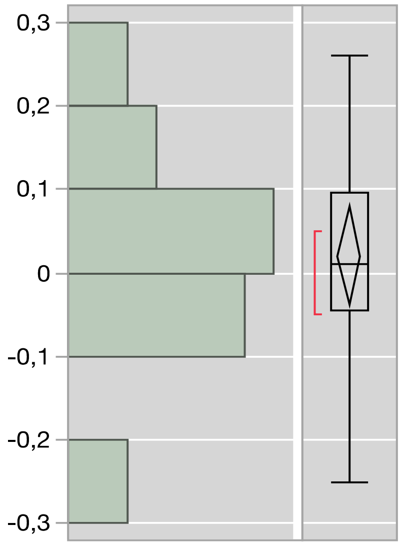
Test Mean

Hypothesized Value	0
Actual Estimate	-0,017
DF	19
Std Dev	0,10549

	t Test	Signed-Rank
Test Statistic	-0,7207	-14,5000
Prob > |t|	0,4799	0,6018
Prob > t	0,7601	0,6991
Prob < t	0,2399	0,3009



ΔTurbidity



Quantiles

100,0%	maximum	0,26
99,5%		0,26
97,5%		0,26
90,0%		0,229
75,0%	quartile	0,095
50,0%	median	0,01
25,0%	quartile	-0,045
10,0%		-0,204
2,5%		-0,25
0,5%		-0,25
0,0%	minimum	-0,25

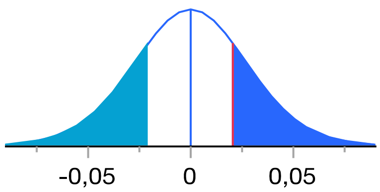
Summary Statistics

Mean	0,0205
Std Dev	0,124244
Std Err Mean	0,0277818
Upper 95% Mean	0,078648
Lower 95% Mean	-0,037648
N	20
N Missing	0

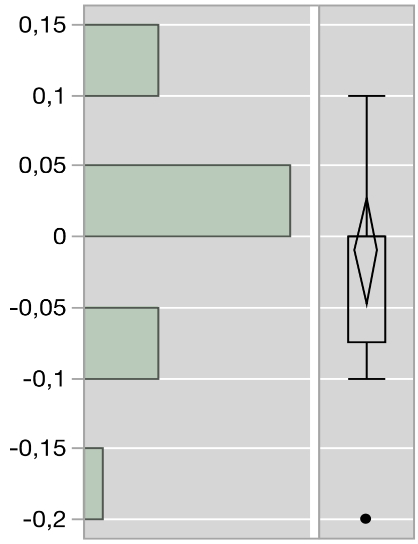
Test Mean

Hypothesized Value	0
Actual Estimate	0,0205
DF	19
Std Dev	0,12424

	t Test	Signed-Rank
Test Statistic	0,7379	25,0000
Prob > |t|	0,4696	0,3572
Prob > t	0,2348	0,1786
Prob < t	0,7652	0,8214



ΔCa2+



Quantiles

100,0%	maximum	0,1
99,5%		0,1
97,5%		0,1
90,0%		0,1
75,0%	quartile	0
50,0%	median	0
25,0%	quartile	-0,075
10,0%		-0,1
2,5%		-0,2
0,5%		-0,2
0,0%	minimum	-0,2

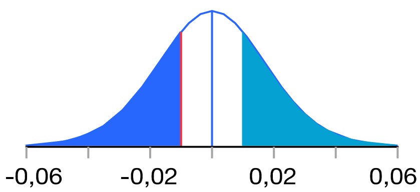
Summary Statistics

Mean	-0,01
Std Dev	0,0788069
Std Err Mean	0,0176218
Upper 95% Mean	0,0268828
Lower 95% Mean	-0,046883
N	20
N Missing	0

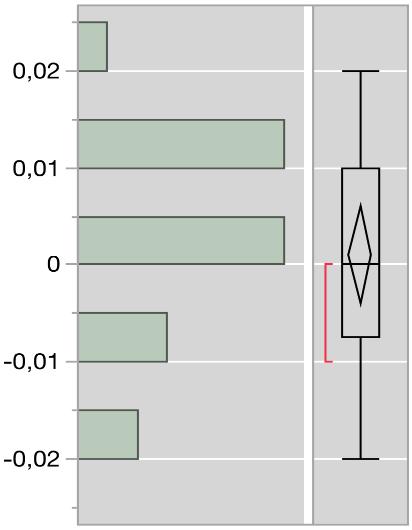
Test Mean

Hypothesized Value	0
Actual Estimate	-0,01
DF	19
Std Dev	0,07881

	t Test	Signed-Rank
Test Statistic	-0,5675	-10,0000
Prob > |t|	0,5770	0,7813
Prob > t	0,7115	0,6094
Prob < t	0,2885	0,3906



ΔMg2+



Quantiles

100,0%	maximum	0,02
99,5%		0,02
97,5%		0,02
90,0%		0,01
75,0%	quartile	0,01
50,0%	median	0
25,0%	quartile	-0,0075
10,0%		-0,019
2,5%		-0,02
0,5%		-0,02
0,0%	minimum	-0,02

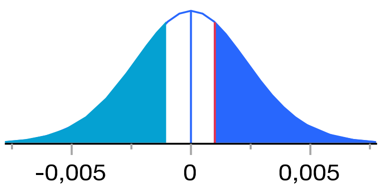
Summary Statistics

Mean	0,001
Std Dev	0,0107115
Std Err Mean	0,0023952
Upper 95% Mean	0,0060131
Lower 95% Mean	-0,004013
N	20
N Missing	0

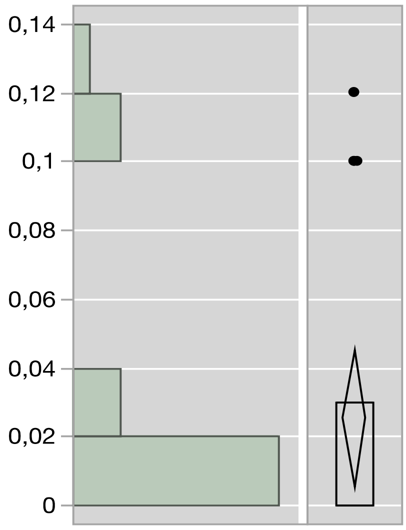
Test Mean

Hypothesized Value	0
Actual Estimate	0,001
DF	19
Std Dev	0,01071

	t Test	Signed-Rank
Test Statistic	0,4175	15,5000
Prob > |t|	0,6810	0,8328
Prob > t	0,3405	0,4164
Prob < t	0,6595	0,5836



ΔNa+



Quantiles

100,0%	maximum	0,12
99,5%		0,12
97,5%		0,12
90,0%		0,1
75,0%	quartile	0,03
50,0%	median	0
25,0%	quartile	0
10,0%		0
2,5%		0
0,5%		0
0,0%	minimum	0

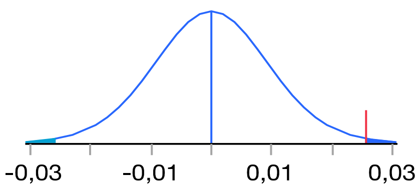
Summary Statistics

Mean	0,0255
Std Dev	0,042112
Std Err Mean	0,0094165
Upper 95% Mean	0,045209
Lower 95% Mean	0,005791
N	20
N Missing	0

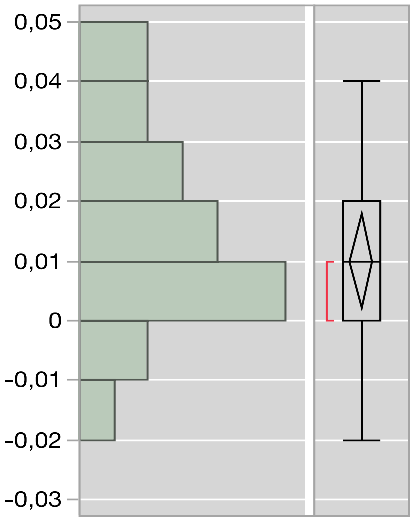
Test Mean

Hypothesized Value	0
Actual Estimate	0,0255
DF	19
Std Dev	0,04211

	t Test	Signed-Rank
Test Statistic	2,7080	66,0000
Prob > |t|	0,0139*	0,0078*
Prob > t	0,0070*	0,0039*
Prob < t	0,9930	0,9961



ΔK+



Quantiles

100,0%	maximum	0,04
99,5%		0,04
97,5%		0,04
90,0%		0,039
75,0%	quartile	0,02
50,0%	median	0,01
25,0%	quartile	0
10,0%		-0,01
2,5%		-0,02
0,5%		-0,02
0,0%	minimum	-0,02

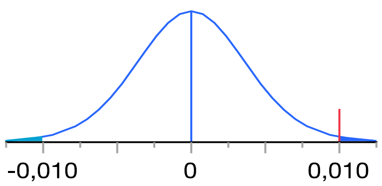
Summary Statistics

Mean	0,01
Std Dev	0,0165434
Std Err Mean	0,0036992
Upper 95% Mean	0,0177426
Lower 95% Mean	0,0022574
N	20
N Missing	0

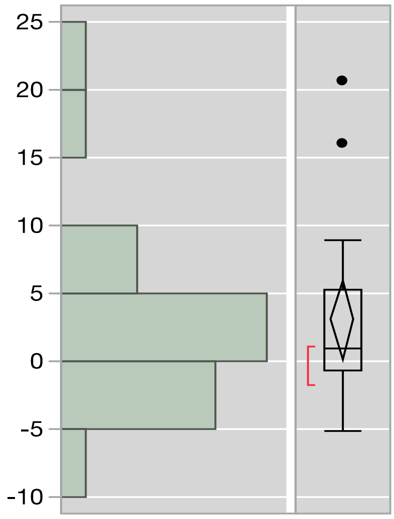
Test Mean

Hypothesized Value	0
Actual Estimate	0,01
DF	19
Std Dev	0,01654

	t Test	Signed-Rank
Test Statistic	2,7033	61,0000
Prob > |t|	0,0141*	0,0197*
Prob > t	0,0070*	0,0098*
Prob < t	0,9930	0,9902



ΔNH4+



Quantiles

100,0%	maximum	20,6
99,5%		20,6
97,5%		20,6
90,0%		15,29
75,0%	quartile	5,325
50,0%	median	0,9
25,0%	quartile	-0,675
10,0%		-2,52
2,5%		-5,1
0,5%		-5,1
0,0%	minimum	-5,1

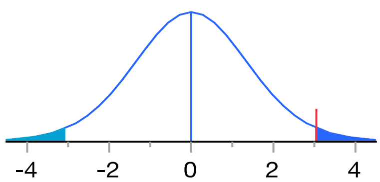
Summary Statistics

Mean	3,065
Std Dev	6,2495705
Std Err Mean	1,3974464
Upper 95% Mean	5,989889
Lower 95% Mean	0,140111
N	20
N Missing	0

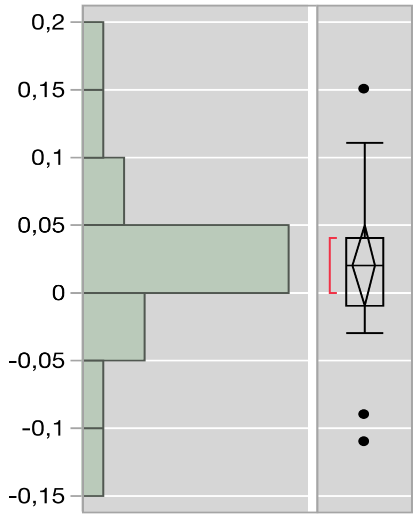
Test Mean

Hypothesized Value	0
Actual Estimate	3,065
DF	19
Std Dev	6,24957

	t Test	Signed-Rank
Test Statistic	2,1933	50,5000
Prob > |t|	0,0409*	0,0595
Prob > t	0,0205*	0,0298*
Prob < t	0,9795	0,9702



ΔSO42-



Quantiles

100,0%	maximum	0,15
99,5%		0,15
97,5%		0,15
90,0%		0,11
75,0%	quartile	0,04
50,0%	median	0,02
25,0%	quartile	-0,01
10,0%		-0,09
2,5%		-0,11
0,5%		-0,11
0,0%	minimum	-0,11

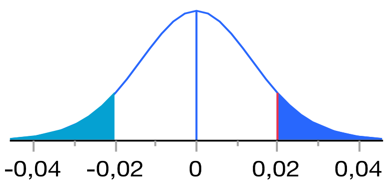
Summary Statistics

Mean	0,02
Std Dev	0,0616441
Std Err Mean	0,0141421
Upper 95% Mean	0,0497115
Lower 95% Mean	-0,009712
N	19
N Missing	1

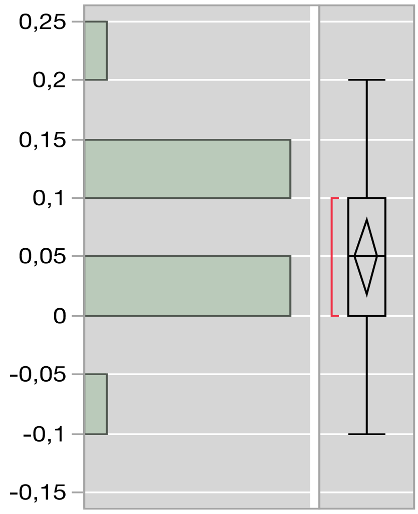
Test Mean

Hypothesized Value	0
Actual Estimate	0,02
DF	18
Std Dev	0,06164

	t Test	Signed-Rank
Test Statistic	1,4142	40,0000
Prob > |t|	0,1744	0,1119
Prob > t	0,0872	0,0560
Prob < t	0,9128	0,9440



ΔCl-



Quantiles

100,0%	maximum	0,2
99,5%		0,2
97,5%		0,2
90,0%		0,1
75,0%	quartile	0,1
50,0%	median	0,05
25,0%	quartile	0
10,0%		0
2,5%		-0,1
0,5%		-0,1
0,0%	minimum	-0,1

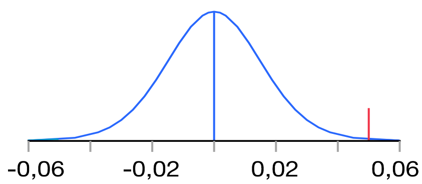
Summary Statistics

Mean	0,05
Std Dev	0,0688247
Std Err Mean	0,0153897
Upper 95% Mean	0,082211
Lower 95% Mean	0,017789
N	20
N Missing	0

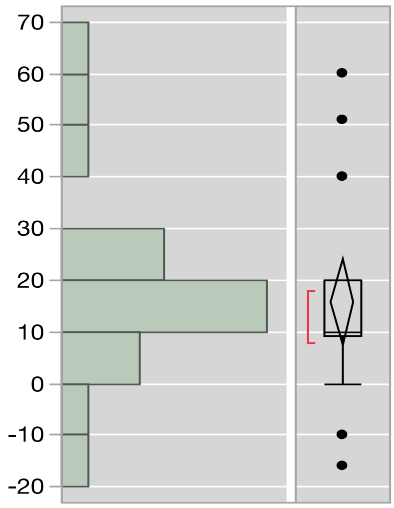
Test Mean

Hypothesized Value	0
Actual Estimate	0,05
DF	19
Std Dev	0,06882

	t Test	Signed-Rank
Test Statistic	3,2489	68,0000
Prob > |t|	0,0042*	0,0107*
Prob > t	0,0021*	0,0054*
Prob < t	0,9979	0,9946



ΔNO3-



Quantiles

100,0%	maximum	60
99,5%		60
97,5%		60
90,0%		49,9
75,0%	quartile	20
50,0%	median	10
25,0%	quartile	9,25
10,0%		-9
2,5%		-16
0,5%		-16
0,0%	minimum	-16

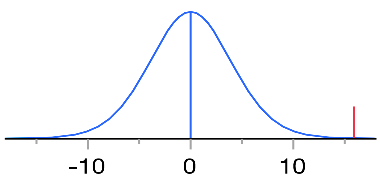
Summary Statistics

Mean	15,85
Std Dev	17,904057
Std Err Mean	4,0034689
Upper 95% Mean	24,229357
Lower 95% Mean	7,4706433
N	20
N Missing	0

Test Mean

Hypothesized Value	0
Actual Estimate	15,85
DF	19
Std Dev	17,9041

	t Test	Signed-Rank
Test Statistic	3,9591	86,5000
Prob > |t|	0,0008*	0,0005*
Prob > t	0,0004*	0,0003*
Prob < t	0,9996	0,9997



ΔTOC

Quantiles

100,0%	maximum	0,5
99,5%		0,5
97,5%		0,5
90,0%		0,3
75,0%	quartile	0,2
50,0%	median	0
25,0%	quartile	-0,175
10,0%		-0,2
2,5%		-0,2
0,5%		-0,2
0,0%	minimum	-0,2

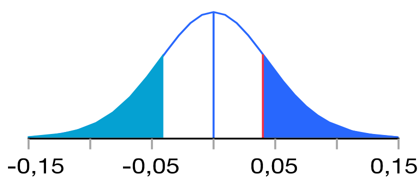
Summary Statistics

Mean	0,04
Std Dev	0,2010499
Std Err Mean	0,0449561
Upper 95% Mean	0,1340942
Lower 95% Mean	-0,054094
N	20
N Missing	0

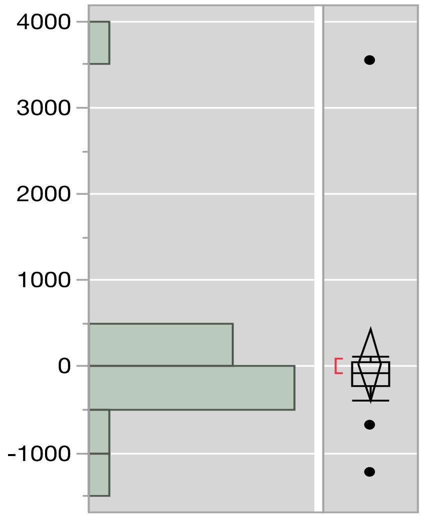
Test Mean

Hypothesized Value	0
Actual Estimate	0,04
DF	19
Std Dev	0,20105

	t Test	Signed-Rank
Test Statistic	0,8898	18,5000
Prob > |t|	0,3847	0,4742
Prob > t	0,1924	0,2371
Prob < t	0,8076	0,7629



ΔTot-N



Quantiles

100,0%	maximum	3541
99,5%		3541
97,5%		3541
90,0%		107,7
75,0%	quartile	61
50,0%	median	-65,5
25,0%	quartile	-233,5
10,0%		-652,3
2,5%		-1228
0,5%		-1228
0,0%	minimum	-1228

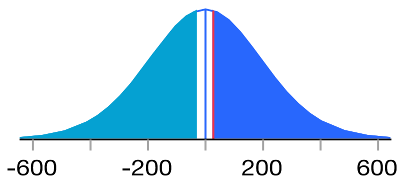
Summary Statistics

Mean	26,75
Std Dev	885,62282
Std Err Mean	198,03128
Upper 95% Mean	441,23424
Lower 95% Mean	-387,7342
N	20
N Missing	0

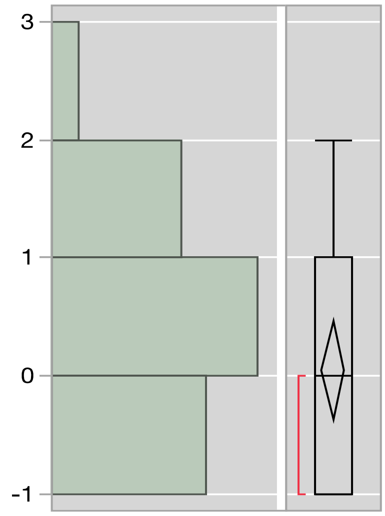
Test Mean

Hypothesized Value	0
Actual Estimate	26,75
DF	19
Std Dev	885,623

	t Test	Signed-Rank
Test Statistic	0,1351	-38,0000
Prob > |t|	0,8940	0,1650
Prob > t	0,4470	0,9175
Prob < t	0,5530	0,0825



ΔTot-P



Quantiles

100,0%	maximum	2
99,5%		2
97,5%		2
90,0%		1
75,0%	quartile	1
50,0%	median	0
25,0%	quartile	-1
10,0%		-1
2,5%		-1
0,5%		-1
0,0%	minimum	-1

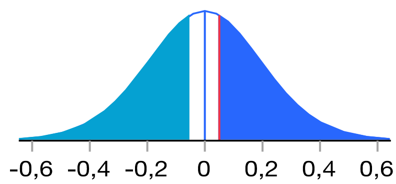
Summary Statistics

Mean	0,05
Std Dev	0,8870412
Std Err Mean	0,1983484
Upper 95% Mean	0,4651481
Lower 95% Mean	-0,365148
N	20
N Missing	0

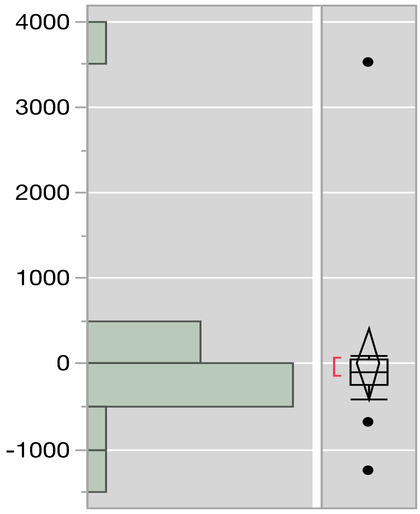
Test Mean

Hypothesized Value	0
Actual Estimate	0,05
DF	19
Std Dev	0,88704

	t Test	Signed-Rank
Test Statistic	0,2521	3,0000
Prob > |t|	0,8037	1,0000
Prob > t	0,4018	0,5000
Prob < t	0,5982	0,5000



ΔOrg-N



Quantiles

100,0%	maximum	3517
99,5%		3517
97,5%		3517
90,0%		94,8
75,0%	quartile	48
50,0%	median	-93
25,0%	quartile	-237
10,0%		-658,9
2,5%		-1252
0,5%		-1252
0,0%	minimum	-1252

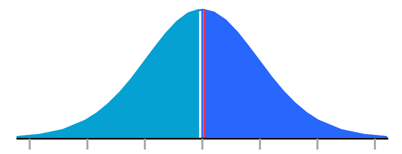
Summary Statistics

Mean	7,85
Std Dev	884,34753
Std Err Mean	197,74612
Upper 95% Mean	421,73738
Lower 95% Mean	-406,0374
N	20
N Missing	0

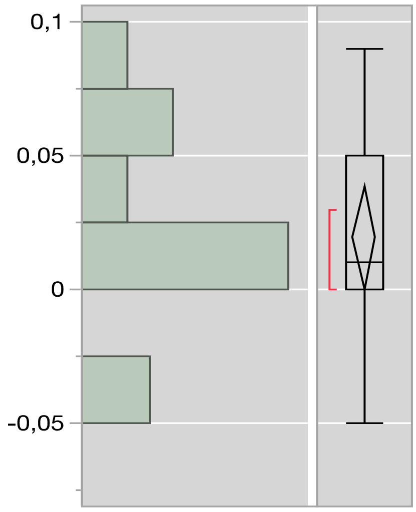
Test Mean

Hypothesized Value	0
Actual Estimate	7,85
DF	19
Std Dev	884,348

	t Test	Signed-Rank
Test Statistic	0,0397	-51,0000
Prob > |t|	0,9687	0,0571
Prob > t	0,4844	0,9715
Prob < t	0,5156	0,0285*



ΔCa



Quantiles

100,0%	maximum	0,09
99,5%		0,09
97,5%		0,09
90,0%		0,079
75,0%	quartile	0,05
50,0%	median	0,01
25,0%	quartile	0
10,0%		-0,05
2,5%		-0,05
0,5%		-0,05
0,0%	minimum	-0,05

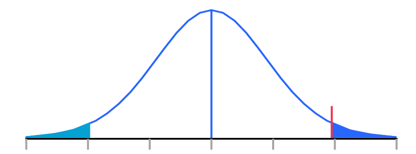
Summary Statistics

Mean	0,0195
Std Dev	0,0412279
Std Err Mean	0,0092188
Upper 95% Mean	0,0387952
Lower 95% Mean	0,0002048
N	20
N Missing	0

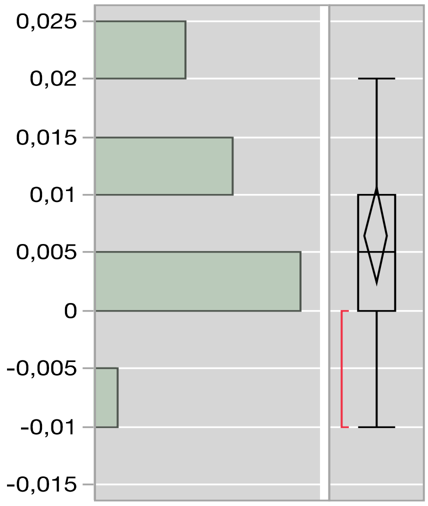
Test Mean

Hypothesized Value	0
Actual Estimate	0,0195
DF	19
Std Dev	0,04123

	t Test	Signed-Rank
Test Statistic	2,1152	60,0000
Prob > |t|	0,0478*	0,0395*
Prob > t	0,0239*	0,0198*
Prob < t	0,9761	0,9802



ΔMg



Quantiles

100,0%	maximum	0,02
99,5%		0,02
97,5%		0,02
90,0%		0,02
75,0%	quartile	0,01
50,0%	median	0,005
25,0%	quartile	0
10,0%		0
2,5%		-0,01
0,5%		-0,01
0,0%	minimum	-0,01

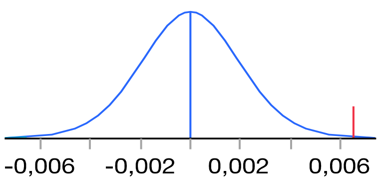
Summary Statistics

Mean	0,0065
Std Dev	0,0087509
Std Err Mean	0,0019568
Upper 95% Mean	0,0105956
Lower 95% Mean	0,0024044
N	20
N Missing	0

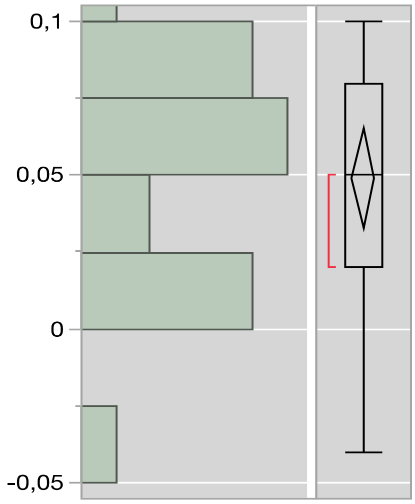
Test Mean

Hypothesized Value	0
Actual Estimate	0,0065
DF	19
Std Dev	0,00875

	t Test	Signed-Rank
Test Statistic	3,3218	69,5000
Prob > |t|	0,0036*	0,0078*
Prob > t	0,0018*	0,0039*
Prob < t	0,9982	0,9961



ΔNa



Quantiles

100,0%	maximum	0,1
99,5%		0,1
97,5%		0,1
90,0%		0,09
75,0%	quartile	0,08
50,0%	median	0,05
25,0%	quartile	0,02
10,0%		0,011
2,5%		-0,04
0,5%		-0,04
0,0%	minimum	-0,04

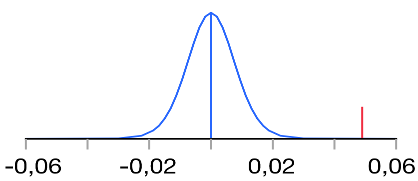
Summary Statistics

Mean	0,049
Std Dev	0,0343205
Std Err Mean	0,0076743
Upper 95% Mean	0,0650625
Lower 95% Mean	0,0329375
N	20
N Missing	0

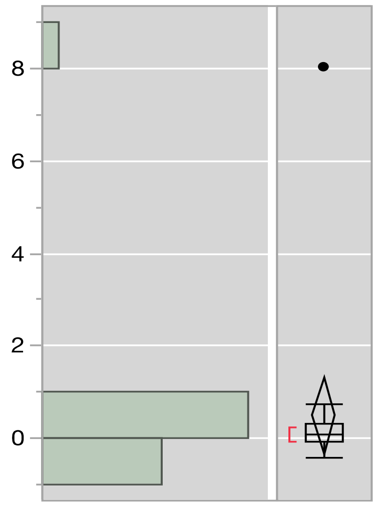
Test Mean

Hypothesized Value	0
Actual Estimate	0,049
DF	19
Std Dev	0,03432

	t Test	Signed-Rank
Test Statistic	6,3850	98,0000
Prob > |t|	<,0001*	<,0001*
Prob > t	<,0001*	<,0001*
Prob < t	1,0000	1,0000



ΔBa



Quantiles

100,0%	maximum	8,01
99,5%		8,01
97,5%		8,01
90,0%		0,733
75,0%	quartile	0,3275
50,0%	median	0,1
25,0%	quartile	-0,0675
10,0%		-0,24
2,5%		-0,41
0,5%		-0,41
0,0%	minimum	-0,41

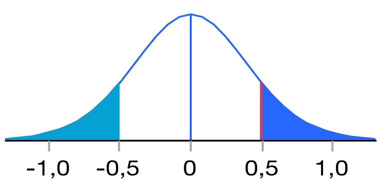
Summary Statistics

Mean	0,493
Std Dev	1,7910423
Std Err Mean	0,4004892
Upper 95% Mean	1,3312336
Lower 95% Mean	-0,345234
N	20
N Missing	0

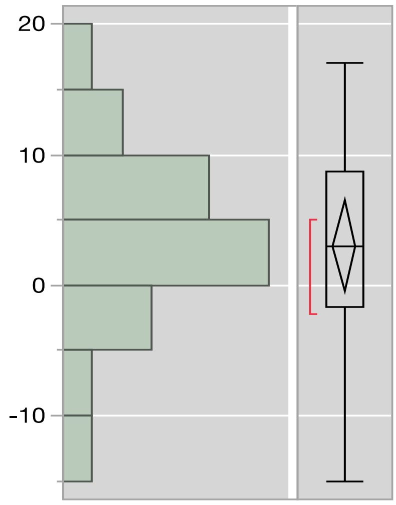
Test Mean

Hypothesized Value	0
Actual Estimate	0,493
DF	19
Std Dev	1,79104

	t Test	Signed-Rank
Test Statistic	1,2310	41,0000
Prob > |t|	0,2333	0,1302
Prob > t	0,1167	0,0651
Prob < t	0,8833	0,9349



ΔAl



Quantiles

100,0%	maximum	17
99,5%		17
97,5%		17
90,0%		12,18
75,0%	quartile	8,75
50,0%	median	3
25,0%	quartile	-1,65
10,0%		-7,6
2,5%		-15
0,5%		-15
0,0%	minimum	-15

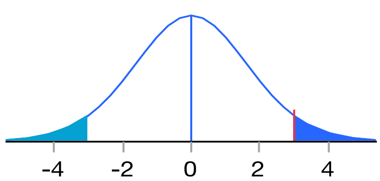
Summary Statistics

Mean	3,005
Std Dev	7,4458378
Std Err Mean	1,6649399
Upper 95% Mean	6,4897593
Lower 95% Mean	-0,479759
N	20
N Missing	0

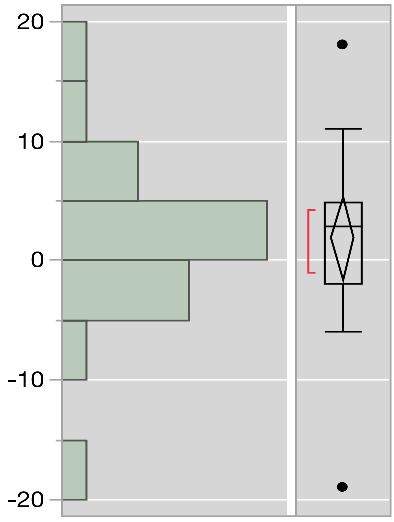
Test Mean

Hypothesized Value	0
Actual Estimate	3,005
DF	19
Std Dev	7,44584

	t Test	Signed-Rank
Test Statistic	1,8049	51,0000
Prob > |t|	0,0870	0,0612
Prob > t	0,0435*	0,0306*
Prob < t	0,9565	0,9694



ΔFe



Quantiles

100,0%	maximum	18
99,5%		18
97,5%		18
90,0%		10,9
75,0%	quartile	4,825
50,0%	median	2,85
25,0%	quartile	-1,975
10,0%		-5,73
2,5%		-19
0,5%		-19
0,0%	minimum	-19

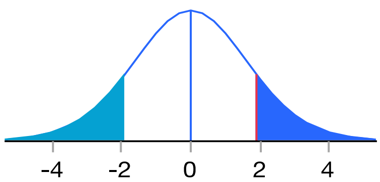
Summary Statistics

Mean	1,89
Std Dev	7,3640592
Std Err Mean	1,6466537
Upper 95% Mean	5,3364858
Lower 95% Mean	-1,556486
N	20
N Missing	0

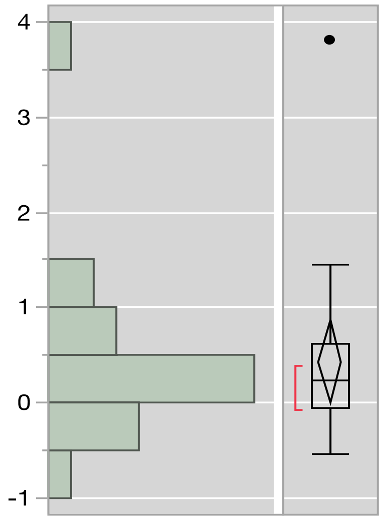
Test Mean

Hypothesized Value	0
Actual Estimate	1,89
DF	19
Std Dev	7,36406

	t Test	Signed-Rank
Test Statistic	1,1478	44,0000
Prob > |t|	0,2653	0,1032
Prob > t	0,1327	0,0516
Prob < t	0,8673	0,9484



ΔMn



Quantiles

100,0%	maximum	3,8
99,5%		3,8
97,5%		3,8
90,0%		1,416
75,0%	quartile	0,6225
50,0%	median	0,24
25,0%	quartile	-0,0575
10,0%		-0,4
2,5%		-0,54
0,5%		-0,54
0,0%	minimum	-0,54

Summary Statistics

Mean	0,4385
Std Dev	0,9310338
Std Err Mean	0,2081855
Upper 95% Mean	0,8742372
Lower 95% Mean	0,0027628
N	20
N Missing	0

Test Mean

Hypothesized Value	0
Actual Estimate	0,4385
DF	19
Std Dev	0,93103

	t Test	Signed-Rank
Test Statistic	2,1063	59,0000
Prob > |t|	0,0487*	0,0261*
Prob > t	0,0244*	0,0130*
Prob < t	0,9756	0,9870