Project and master thesis topics in water and wastewater engineering 2023/24

NTNU

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Introduction

The water and wastewater engineering group has introduced a procedure for the publication and distribution of project and master thesis topics 3 years ago. The new procedure aims at a **balanced** master student distribution among scientific staff in a **transparent** way and bridging the demand in ongoing research projects and student interests. One main priority of master student projects is the support of **ongoing activity and PhD students**.

A balanced distribution of students will increase the room for **adequate supervision** and support and increases the **spectrum of topics** covered by master thesis work. Even though there may be strong demand for specific topics, it should be noted that there is a need for diverse education, and that a master thesis is not a comprehensive specialisation, but a short-term project work where students are supposed to learn how to tackle a specific research question within limited amount of time. Many topics are related to each other and more focus on shared topics may be a way to facilitate.

The procure was adapted based on last years' experience. The main adjustment is the significantly shortened amount of time between the submission of desired topics by the students and the final distribution of topics. The process will be finished at the beginning of June.

The distribution procedure

1. Topic collection

Each professor suggests a maximum of 3 to 4 topics and each Prof. II suggests 1 to 2 topics. Submission deadline is the right **3rd of May**. All submitted topics should be in a matured stage, including supervisors, partners, financing (travel of the student, lab work) etc. The proposals should highlight the possibility for consecutive project and master topics, maybe already defining them in detail.

2. Internal review

After submission, topics will be reviewed internally. Possibilities for coalescence and collaboration will be identified and projects with high relevance will be prioritized.

3. Publication

The topics will be compiled and made available for the students via the internal website and by email, no later than **5th of May**. There will be a digital meeting with the students on the 11th of **May at 9:30**, where the projects will be presented.

4. Application phase

After the topics are published, students apply for their favorite topics. The topics are divided into two groups and students will need to pick three topics from each group (6 topics in total). The six topics selected must be ranked (1: favorite to 6: least favorite), and the ranking will be submitted via an online form that will be available on the master topic page (https://nettskjema.no/a/341663)

In addition, you are encouraged to write half a page letter (A4) to explain your motivation and justify the ranking of the selected topics. This letter of motivation is optional. Deadline for the application of the ranking and the motivation letter is on the **26th of May**.

5. Additional topics

Students will have the possibility to deliver independent project proposals, i.e. with external partners, until the end of the application phase, **26th of May.** These proposals will need to be as mature and well defined as possible. A template for the proposals will be provided on the webpage (https://www.ntnu.no/wiki/pages/viewpage.action?pageId=103910030).

6. Internal review and topic assignment

The ranking and the motivation letters will be evaluated. Topics will be distributed based on that evaluation. In case of many applicants for certain topics and the delivery of several strong motivation letters, distribution will be done by drawing lots.

7. Publication of results

Results will be published right after the review is finished, on the **13th of June**.

Topic overview

Master projects in Group 1

Number	Title	Supervisor(s)	Partner(s)
1.1	Application of Membrane bioreactor for treatment of dairy sewage	Stein Østerhus, Cynthia Hallé	Skala
1.2	Bicycle washing – wastewater emissions and treatment	Thomas Meyn	Trondheim Municipality
1.3	EU taxonomy in the water sector	Rita Ugarelli	-
1.4	Modeling of residual chlorine in premise plumbing and control of opportunistic pathogens	Charuka Meegoda, Cynthia Hallé	Sessile
1.5	Selection and implementation of future treatment technology for tunnel wash water	Thomas Meyn, Franz Tscheikner-Gratl	-
1.6	Wastewater quality and discharge requirement	Stein Østerhus, Cynthia Hallé	Skala
1.7	Development of novel method for biofilm characterisation	Cynthia Hallé, Mike Waak	SINTEF, Oslo VAV,

Master projects in Group 2

Number	Title	Supervisor(s)	Partner(s)
2.1	Artificial intelligence and machine learning for detection and localising leakages	Marius Møller Rokstad, Franz Tscheikner-Gratl, Prasanna Mohan Doss	-
2.2	Exploring the Impact of Design Rainfall on Green Infrastructure (GI) Placement: A Case Study of Risvollan Catchment	Franz Tscheikner-Gratl, Marius Møller Rokstad, Bardia Roghani, Spyros Pritsis	-
2.3	From lab to field. Exploring the combined usage of low cost out of water sensors	Franz Tscheikner-Gratl, Marius Møller Rokstad, Spyros Pritsis	-
2.4	Model Based Risk Assessment for Risvollan, Trondheim	Marius Møller Rokstad, Franz Tscheikner-Gratl	-

2.5	Modelling the hydraulics of in-house plumbing systems	Marius Møller Rokstad, Franz Tscheikner-Gratl	-
2.6	Pressure control strategies for water distribution systems	Marius Møller Rokstad, Franz Tscheikner-Gratl, Camillo Bosco	SINTEF
2.7	Quantitative failure assessment of Nature-based solutions	Marius Møller Rokstad, Franz Tscheikner-Gratl, Mahdi Bahrami, Bardia Roghani	-
2.8	SedTemp: Identifying sediment deposits from temperature signals	Franz Tscheikner-Gratl, Marius Møller Rokstad, Francois Clemens, Manuel Reguiro-Picallo, Antonio Moreno-Rodenas	Universidade a Coruna, Deltares
2.9	Sewer velocimetry	Francois Clemens, Franz-Tscheikner-Gratl, Marius Møller Rokstad	-
2.10	To dig or not to dig / that is the question	Franz Tscheikner-Gratl, Marius Møller Rokstad, Bardia Roghani	-
2.11	Using machine learning and artificial intelligence to reduce failures and leakages in drinking water pipes	Marius Møller Rokstad, Franz Tscheikner-Gratl, Stian Bruaset	SINTEF
2.12	Vulnerability Assessment of Green Infrastructure	Marius Møller Rokstad, Franz Tscheikner-Gratl, Mahdi Bahrami, Bardia Roghani	-

Detailed project descriptions: Group 1

Project Title	Application of Membrane bioreactor for treatment of dairy sewage
Type	Project and Master thesis
Supervisors/ Contacts	Stein Østerhus, Cynthia Hallé
Location	Trondheim

Project background

Skala utgjør Norges største og bredeste fagmiljø innen prosessteknologi og driftsstøtte til norsk matindustri. Vår jobb er å gjøre norsk matproduksjon mer bærekraftig, mer effektiv og mer konkurransedyktig.

Etter hvert som verden og matindustrien har utviklet seg, har vi bygget opp fagmiljøer som gjør oss til en erfaren og fremtidsrettet partner for spesielt matindustrien, men også til annen industri. Vår erfaring kombinerer vi med dedikert satsing på ny teknologi og løsninger. Blant disse teknologiene er **avløpsrenseteknologi.**

Case studie av renseanlegg for avløp fra meieri. Skala har levert et fullrenseanlegg som renser avløpet fra meieriproduksjon slik at det tilfredsstiller utslippskravene til direkte utslipp til resipient. Renseanlegget består av aktivslam-prosess kombinert med MBR, samt finsil for fjerning av partikler og avvanning av slam med skruepresse. Dette er det første anlegget i Norge som benytter MBR på rensing av meieriavløp. Tidligere har mange anlegg vært levert med samme teknologi, men uten MBR-filter. Skala ønsker at kandidaten ser på effekten MBR har på rensegrad. Hvilke utslippsparametre blir forbedret med MBR? Hvor mye ekstra rensing oppnår man med MBR? Hvordan påvirker variasjon i kvalitet og kvantitet i innløpsvannet til renseanlegget rensegraden? Renseanlegget er bygget slik at det er mulig å drifte med og uten MBR.

Case study of a treatment plant for sewage from a dairy. Skala has delivered a full treatment plant that cleans the effluent from dairy production so that it meets the discharge requirements for direct discharge to the recipient. The treatment plant consists of an activated sludge process combined with MBR, as well as a fine sieve for the removal of particles and dewatering of sludge with a screw press. This is the first plant in Norway to use MBR for the treatment of dairy waste. In the past, many plants have been supplied with the same technology, but without an MBR filter.

Aim of the project

The aim of this project is to evaluate the benefits of Membrane Bioreactors (MBR) treatment process on the degree of purification of industrial wastewater.

Specific work description

The work will be designed to answer the following research question: Which emission parameters are improved with MBR? How much additional purification is achieved with MBR? How does variation in quality and quantity in the inlet water to the treatment plant affect the degree of purification? Design a treatment plant with the possibility to operate with and without MBR.

Specific requirements

Candidates are expected to have taken TVM4171 Wastewater treatment

Project Title	Bicycle washing – wastewater emissions and treatment
Type	Project and Master thesis
Supervisors/ Contacts	Thomas Meyn
Location	NTNU, Trondheim

Project background

Trondheim and its surrounding municipalities have a policy of no increase in private car usage as the city grows. Trondheim municipality has in addition a policy of 20 % decrease in private car usage by 2025. This requires a large-scale shifting of commuter and leisure transportation from car to walking, mass transit and bicycles. This shift needs to be consistent through the year, including winter.

Major roads and bicycle lanes in Trondheim are salted in winter, to keep the pavement free from snow and ice. Salt has a corrosive effect on the metal parts of a bicycle, and seasoned winter bicyclers will clean their bicycle regularly with a water hose, and apply oil and/or grease. When this is done indoors, municipal regulations apply to wastewater treatment. For draining a bicycle washing facility, an oil separator with a volume of at least 2 cubic meters is required. The municipal wastewater treatment plant does not have facilities for separating oil and grease from water, and this is the basis for this regulation. The separator is a significant expenditure for projects, particularly when existing parking garages are retrofitted with a bicycle washing facility.

The issue of bicycle cleaning wastewater treatment in winter is a yet-overlooked aspect of the green transition in arctic and sub-arctic societies, and a durable and universal solution is required. Municipal plans under revision aim to make bicycle washing facilities a requirement in new parking garages (for example, see Fig. 1), so demand for a solution can be expected to rise soon.

Fig. 1. Bicycle washing stand at Leuthenhaven bicycle hotel, Trondheim

Aim of the project

The aim of this project is to solve the problem of high-cost oil separators in parking garages with bicycle cleaning facilities.

Specific work description

A solution will likely involve a combination of the following tasks:

- To document the realistic emissions from bicycle washing
- To establish the criteria of successful treatment of bicycle washing wastewater
- To design a device that can be implemented and operated at bicycle washing facilities at significantly lower price than an oil separator, to reduce oil/grease contents to trace amounts
- Sampling and analysis, as well as piloting if time allows

Specific requirements

- This project is suited for students who would like to combine the topics water and urban transportation
- A practical approach to design and/or small-scale construction is recommended

What's in it for you?

- Make a significant contribution to the green transition by making bicycle washing legally simpler to connect to civil infrastructure
- Create a product that might become the basis for a business venture

Project Title	EU taxonomy in the water sector
Type	Project and Master thesis
Supervisors/ Contacts	Rita Ugarelli
Location	NTNU, Trondheim – but also digital (being the supervisor located in Oslo)

Project background

The EU Taxonomy is the first science-based classification that helps define which investments are environmentally sustainable. Its impact on water infrastructures represents technological challenges and opportunities to foster innovation that will guide the transition to a sustainable economy. There is broad consensus that water infrastructure plays a fundamental role in preserving natural resources and biodiversity and improving living conditions, thus contributing to the 2030 AGENDA and the achievement of the SDGs, especially SDG 6, 14 and 15, through the development of non-conventional water resources and the strengthening of climate resilience of communities and ecosystems. However it cannot be ignored that the water utilities are energy intensive, being responsible for 4% of global electricity consumption and other GHG emissions, which means the sector needs to make a great effort to address climate change and other environmental challenges.

The European Environmental Taxonomy encourages the financial sector to invest in green technologies that support the Green Deal objectives and policies. Water supply and sanitation activities are included in this Taxonomy in several of its objectives and in a cross-cutting manner in all of them. This represents an opportunity for the development of more sustainable infrastructure and a challenge for water sector operators, since it is not only a framework for assessing project and corporate financing, but also a technological challenge.

Aim of the project

The EU taxonomy is something new and still under development. It will play a role as a driver for technological transformation and innovation in water infrastructure. Understanding the EU taxonomy, its impact in the water sector's actors and assessing the terchnological impact and transforming effect of the taxonomy in the sector are the aims of the project/master.

The thesis will put the candidate in a unique position since the EU taxonomy topic is absolutely new and the market is much on need of support to understand its implications!

Specific work description

- Present the EU taxonomy and discuss its relevance in general
- Present the EU taxonomy and discuss its relevance specifically for the water sector
- Perform an assessment, based on the EU taxonomy indicators, for a selected case study proposed by the supervisor and discuss the results
- Provide practical insights for water sectors' actors, no yet prepared for the mandatory requirements of the taxonomy, on how to meet them in practice.

Specific requirements

No specific requirements, a part from knowing about water systems and treatment.

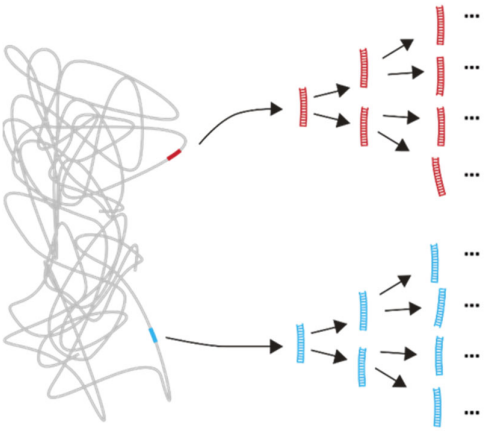
Project Title	Modeling of residual chlorine in premise plumbing
Type	Project and Master thesis
Supervisors/ Contacts	Charuka Meegoda/ Cynthia Hallé
Location	Trondheim

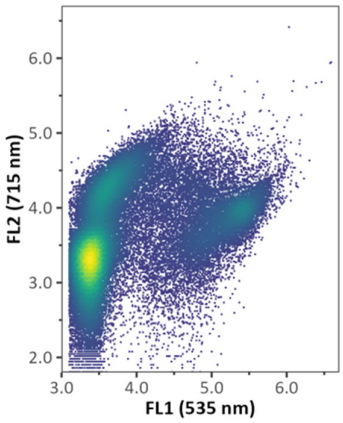
Project background

In several drinking water systems, monochloramine, also known as chloramine, is commonly used to ensure the safe water quality at customer taps. In the distribution network, chloramine is often preferred over free chlorine due to its stability and slow decay. However, chloramine decay is a concern in particularly in building plumbing systems, due to factors like high residence time and increased temperature which can lead to an increased risk of microbial regrowth and undesirable consequences.

To manage the safety of drinking water, it is necessary to understand the decay of chloramine and microbial regrowth in building plumbing systems. This project aims to build a chloramine decay model using data gathered from a pilot premise plumbing system. In addition, microbial regrowth in the premise plumbing system will be measured using state-of-the-art Flow cytometry technique (https://www.bnovate.com/bactosense). Flow cytometry will provide insights into the changes in microbial growth and the proportion of live and dead cells over time.

The insights from this study could help in managing the safety of drinking water in building plumbing systems, particularly by reducing the risk of microbial regrowth.





Aim of the project

The aim of this project is to establish a relationship between chloramine decay and microbial regrowth in the premise plumbing system using novel analytical method.

Specific work description

The work decription will be determined with the student

Specific requirements

Candidates are expected to have taken TVM4110 Water chemistry and/or TVM4173 Drinking water treatment

Project Title	Selection and implementation of future treatment technology for tunnel wash water
Type	Project and Master thesis
Supervisors/ Contacts	Thomas Meyn, Franz Tscheikner-Gratl
Location	NTNU, Trondheim

Project background

Norway has around 1150 road tunnels with a total length of approximately 800 km. In urban areas, where space is limited, and traffic load is high, road tunnels are often a preferred solution. For example, in the Oslo and Akershus region, there are 55 tunnels with a total length of 37 km. To maintain traffic safety and increase lifespans of the tunnels, tunnels are normally cleaned 1 to 12 times per year, using high pressure water jets and soap. Approximately 60-100 L water, mixed with 0.5-1% soap is used to clean one meter of tunnel. Wash water does contain a cocktail of pollutants consisting of e.g. heavy metals, different PAHs, soap, microplastic (e. g tire wear), road salt etc. The concentrations of the pollutants substantially exceeding that of normal road runoff and has caused acute toxicity of e.g. amphibians in nature-based treatment ponds. While various projects evaluate possible treatment future solutions, a strategic framework for the selection of the “best technology” is missing right now. The problem at hand is complex and driven by multiple criteria, such as treatment efficiency, costs, maintenance needs, lifetime, environmental impact, policies, and legislation etc.

This project is related to two ongoing research projects, collaborating with Statens Vegvesen, Nye Veier AS, Aquateam COWI and Aalborg University.

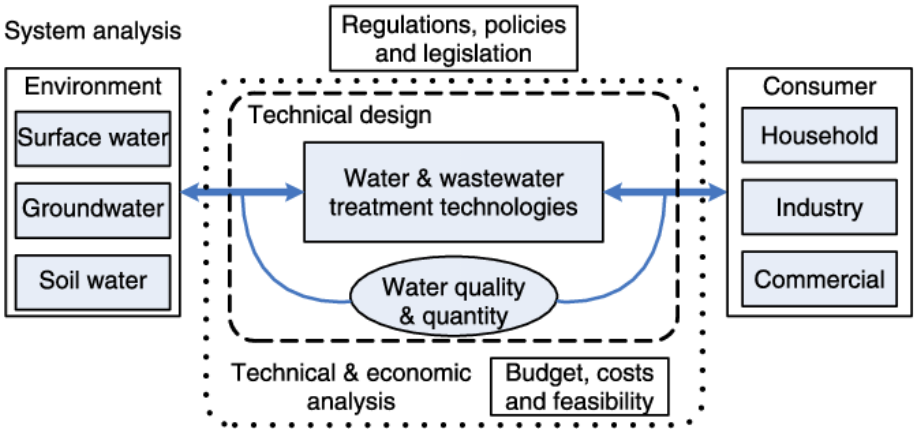


Fig.1. Approaches to water treatment problem analysis and their respective scopes (Hamouda et al. 2009)

Aim of the project

The aim of the project is to develop a decision support system that allows the Norwegian Road Authorities and other relevant parties to assess and compare different treatment solutions for tunnel wash water, in dependence on their economic, social and environmental impact and other relevant criteria. The decision support system will be applied to the case study of Bjørnegårdtunellen in Sandvika, which is related to the ongoing upgrade of the E18 highway between Sandvika and Oslo. Furthermore, the this is to give concrete recommendations about a possible implementation of the new treatment, including the design, dimensions, material selection, monitoring and process control, waste management etc.

Specific work description

Project work autumn 2023

- Literature study on state of the art regarding tunnel wash water quality and treatment and decision support systems
- Identify relevant criteria for the decision support system, including approaches for how to quantify them.
- Evaluate various methods for decision support systems, including weight and utility elicitation
- Optional: Follow the course TEP4223 – Livssyklusanalyse, to get familiar with the Live Cycle Assessment methodology.

Master project spring 2024

- Finalize the decision support system and apply it by using the results and information collected in the ongoing project
- Evaluation of efficiency and environmental impact for the different treatment options
- Scenario and robustness analysis, what happens if the surrounding conditions change
- Ranking
- Practical implementation

Specific requirements

- This project is perfectly suited for students that would like to combine the topics water and roads
- Interest in data evaluation / modelling / programming
- Bonus: Previous experience with decision support, life cycle assessment and environmental impact analysis, i.e. from course TEP4223 – Livssyklusanalyse, which could be also followed in the autumn

What's in it for you?

- Get familiar with a pressing water management problem in Norway, and contribute to best solution section
- Project related to real life challenge
- Work in a small team with PhD and Post Doc
- (Co)-author and publish a scientific paper with your name on it

Project Title	Industrial wastewater quality and discharge requirement
Type	Project and Master thesis
Supervisors/ Contacts	Stein Østerhus, Cynthia Hallé
Location	Trondheim

Project background

Om Skala:

Skala utgjør Norges største og bredeste fagmiljø innen prosessteknologi og driftsstøtte til norsk matindustri. Vår jobb er å gjøre norsk matproduksjon mer bærekraftig, mer effektiv og mer konkurransedyktig.

Etter hvert som verden og matindustrien har utviklet seg, har vi bygget opp fagmiljøer som gjør oss til en erfaren og fremtidsrettet partner for spesielt matindustrien, men også til annen industri. Vår erfaring kombinerer vi med dedikert satsing på ny teknologi og løsninger. Blant disse teknologiene er **avløpsrenseteknologi.**

Specific work description

Case studie av renseanlegg for avløp fra meieri. Skala har levert et forrenseanlegg som renser avløpet fra meieriproduksjon slik at det tilfredstiller utslippskravene til utslipp på kommunalt avløpsnett. Renseanlegget består av finsil, beluftet buffertank, flotasjon og avvanning. Skala ønsker at rensegraden til renseanlegget undersøkes med hensyn til relevante parametre i nye BAT krav. Basert på analysene kan studenten undersøke om utvidelse vil være nødvendig for at anlegget skal tilfredsstille fremtidige krav, eller om tilstrekkelig rensegrad oppnås ved kommunalt renseanlegg. Hvilke ekstra rensetrinn vil måtte installeres for å tilfredsstille kravene til fullrensing?

Case study of a treatment plant for sewage from a dairy. Skala has delivered a pre-treatment plant that cleans the effluent from dairy production so that it meets the discharge requirements for discharge into the municipal sewage network. The treatment plant consists of a fine sieve, aerated buffer tank, flotation and dewatering.

Aim of the project

Skala wants the purification degree of the treatment plant to be investigated with regard to relevant parameters in new waste water directive. Based on the analyses, the student can examine whether expansion will be necessary for the facility to meet future requirements, or whether a sufficient degree of purification can be achieved at a municipal treatment plant. Which additional cleaning steps will need to be installed to meet the requirements for full cleaning?

Specific requirements

Candidates are expected to have taken TVM4171 Wastewater treatment

Project Title	Development of novel method for biofilm characterisation
Type	Project and Master thesis
Supervisors/ Contacts	Cynthia Hallé, Mike Waak
Location	NTNU, Trondheim

Project background

Biofilms are complex communities of microorganisms that adhere to surfaces and form a protective layer of extracellular polymeric substances (EPS). They can form in various environments, including drinking water systems.

Biofilms in drinking water systems can cause a range of problems, including reduced water quality, increased bacterial contamination, and the development of pathogens. Biofilms can also lead to corrosion and the formation of deposits within the system, which can ultimately result in reduced water flow and damage to equipment.

Overall, the presence of biofilms in drinking water systems is a concern for public health and requires careful management to ensure the provision of safe and high-quality drinking water.

Bacterial growth depends on numerous factors including water quality, nutrient, temperature, etc. Historically, measurement of assimilable organic carbon has been used as an indicator of bacterial regrowth in drinking water supply but the method is labour intensive. SINTEF and NTNU are working on a novel protocol for determination of bacterial growth base on flow cytometry which as the potential to be automated for online monitoring.

Aim of the project

The aim of the project is to participate in the development of novel method for sampling and analysis of biofilm in drinking water pipes. This thesis will explore novel methods to express the bacterial growth potential using state-of-the art monitoring tools.

Specific work description

Up to two student can select this tasks and specific work description will be determined with the students

Specific requirements

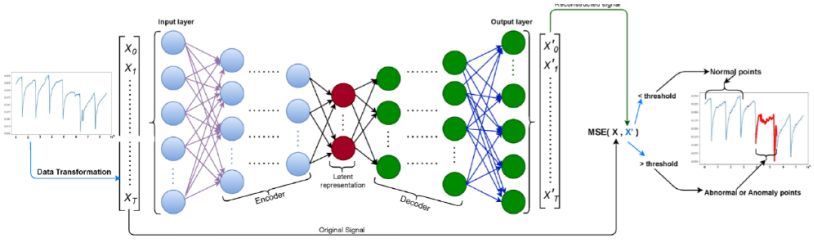
Candidates are expected to have an interest in drinking water quality, microbiology and have acquired some laboratory experience.

Detailed project descriptions: Group 2

Project Title	Artificial intelligence and machine learning for detection and localising leakages
Type	Project and Master thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl, Prasanna Mohan Doss
Location	NTNU, Trondheim

Project background

Increasing pipe burst rates is a concern for the Norwegian drinking water industry. Pipe bursts cause downtime for the drinking water distribution system, are often costly to repair, and lead to increased water loss volumes for the water utility. It is estimated that Norwegian water utilities currently loose 30 % of the produced drinking water through leakages, on average, compared to around 20 % in Sweden and 10 % in Denmark. Even though the topography and climate influence the occurrence of pipe burst and leaks, improvements can still be made in Norwegian drinking water networks, in order to reduce the water loss volume, and many utilities are actively working to reduce their losses, according to the national strategy aiming to reduce the losses to 20 %.



In order to manage and reduce leaks, it is important to have timely and accurate methods for identifying the leaks as they occur. The emergence of smart household water meters, combined with better and more fine-grained data from the utilities' SCADA systems, gives us the opportunity to apply novel artificial intelligence or machine learning methods to detect and localise leaks as they occur in the network, thereby allowing the utility managers to find and respond leaks faster. There are numerous examples of promising AI/ML methods for leak detection and localisation in the scientific literature, yet most of the applied methods have only been tested on artificial datasets. The remaining challenge is to apply the novel AI/ML methods on real case studies, demonstrate how efficient they can be at detecting/localising leaks in real scenarios, and identify their limitations in terms of data availability, quality etc.

Aim of the project

The project aims at selecting two or three artificial intelligence or machine learning methods, apply them to detect and localise leaks in a real Norwegian drinking water distribution system, and evaluate and compare their performance and applicability with regards to be applied in the Norwegian water sector in general.

Specific work description

- The proposed project will encompass: Literature study on the state-of-the-art for AI/ML methods for leak detection/localization, Select methods to try out in Norwegian a case study, Implement and apply methods for case study area, Evaluate performance, data needs, applicability of the methods

Specific requirements

Intermediate level knowledge of Python, MATLAB or R programming is recommended for this project.

Project Title	Exploring the Impact of Design Rainfall on Green Infrastructure (GI) Placement: A Case Study of Risvollan Catchment
Type	Project and Master thesis
Supervisors/ Contacts	Franz Tscheikner-Gratl, Marius Møller Rokstad, Bardia Roghani, Spyros Pritsis
Location	NTNU, Trondheim

Project background

Extreme rainfall events is one of the most significant issues endangering urban drainage infrastructure. According to Perkins-Kirkpatrick et al. (2020), flash floods are having a greater impact on many European cities (Fig. 1). These unusual events have already seriously harmed society, the economy, and the environment (EEA, 2022). Besides, extreme events' timing, frequency, intensity, spatial extent, and duration are all impacted by climate change (Field et al., 2012). In this regard, municipalities are starting to look for chances to increase the robustness of drainage infrastructure through better urban planning and utilizing cutting-edge technology in an effort to lessen the consequences of extreme events.

Fig.1. A regional train sits in the flood waters at the local station in Kordel, Germany, July 15, 2021.

Accordingly, in order to take the future effects of climate change into account properly, we must adapt the way we plan and design our drainage infrastructure. Instead of simply planning for the worst-case scenario, it requires policymakers to wisely allocate the budget and effort for future urban planning and maintenance actions by accounting for a wide range of factors under uncertainty. In the context of climate parameters, one of the biggest uncertainty can be related to predicted precipitation. To put it another way, for instance, if green infrastructure (GI) practices are placed and designed in an urban catchment under only one projected scenario (design rainfall with fixed parameters, e.g. distribution of rainfall intensity), it may fall drastically short of meeting the actual stormwater management needs if a different scenario is realized.

Aim of the project

The main goal of this project is to investigate the effects of the design rainfall hyetograph[1] shapes on the prioritization of GI placement sites in the case study area, Risvollan catchment. Here, where the maximum intensity occurs and how fast the maximum is reached is what differentiates one distribution from another. In this study, stochastic programming will be employed, as the extensively used modeling approach to determine facility location under uncertainty (Snyder, 2006). For this purpose, first, 1000 different distributions for the design rainfall intensity will be generated. In the next step, different GI practices will be defined as scenarios and the most suitable places for their placement will be determined (under the series of generated rainfalls). It should be noted that physical catchment characteristics should be analyzed to delineate potential GI placement sites and exclude unavailable locations. The desired criterion here is to minimize the total expected surface runoff in the catchment. It is intended that the results will be provided under various levels of the available budget (see Fig. 2 as an example).

The proposed approach can help urban planners determine where GI implementation is most needed, while also taking into account the uncertainty of design rainfall characteristics.

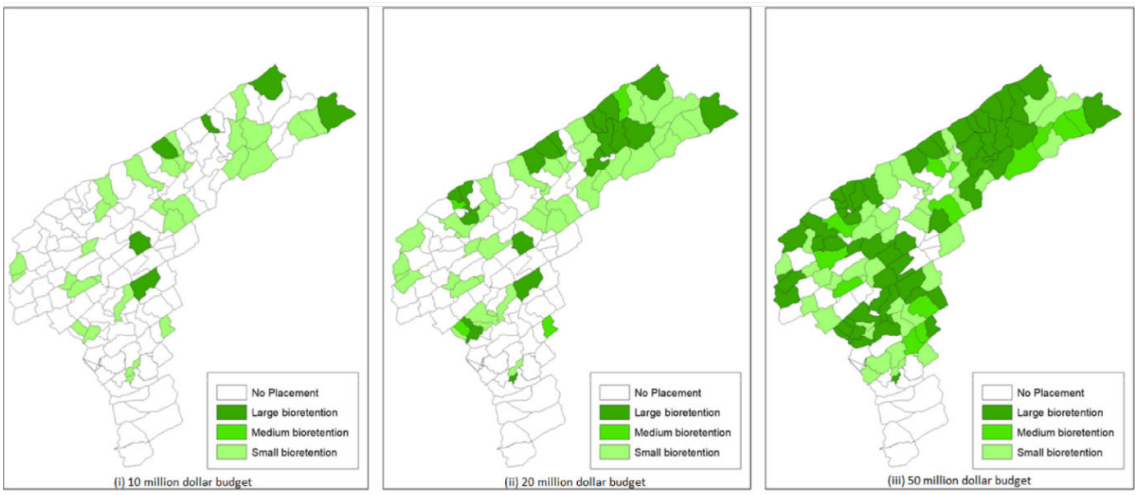


Fig. 2. Map of placed bioretentions and their level of installation for various levels of available budget (Barah et al., 2021).

Specific requirements

Candidates are expected to have good knowledge in SWMM and Python programming.

References:

Barah, M., Khojandi, A., Li, X., Hathaway, J., & Omitaomu, O. (2021). Optimizing green infrastructure placement under precipitation uncertainty. Omega, 100, 102196.

European Environmental Agency (2022). "Economic losses from climate-related extremes in Europe". Accecced on 24th of April, 2023, https://www.preventionweb.net/publication/economic-losses-climate-related-extremes-europe.

Field, C. B., Barros, V., Stocker, T. F., & Dahe, Q. (Eds.). (2012). Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. Cambridge University Press.

Perkins-Kirkpatrick, S. E., & Lewis, S. C. (2020). Increasing trends in regional heatwaves. Nature communications, 11(1), 3357.

Snyder, L. V. (2006). Facility location under uncertainty: a review. IIE transactions, 38(7), 547-564.

[1] A hyetograph is a graphical representation of the distribution of rainfall intensity over time.

Project Title	From lab to field. Exploring the combined usage of low cost out of water sensors
Type	Project and Master thesis
Supervisors/ Contacts	Franz Tscheikner-Gratl, Marius Møller Rokstad, Spyros Pritsis
Location	NTNU, Trondheim

Project background

Traditional urban drainage flow sensors (e.g., submerged Doppler velocity sensors) are typically expensive and require regular maintenance, disincentivizing measurement campaigns that are necessary for managing urban drainage networks (Bertrand-Krajewski et al., 2021). A multitude of new sensors and measurement methods have emerged the last years aiming to remedy this situation. These new low-cost measurement approaches usually gravitate towards combining out of water sensors (usually made from relatively cheap off-the-shelf electronics) and novel data processing techniques to obtain the flow depth and velocity. While this direction seems promising for giving us a better overview of a buried infrastructure (i.e. UDN) that has hitherto been obscured to a big extend, it doesn't come without it's weak spots. Namely, these new techniques can have greater errors than the established sensors and often they have limitations that should be taken into account (Catsamas et al., 2022).

Aim of the project

Combining two low-cost sensors allows us to explore synergies between them. In this project a radar sensor (**Fig. 1**) will be installed side by side with a Raspberry Pi camera, monitoring an open channel under controlled conditions. The depth and velocity measurements from the radar sensor will be used to train a Convolutional Neural Network (CNN) that processes the camera footage to predict the same quantities (Meier et al., 2022). This approach has two main benefits; firstly, the traditionally costly task of obtaining calibration data for the CNN training is undertaken by the radar sensor (which can then stay in place as a redundant measurement device), and secondly the CNN can compensate for the bad performance of the radar sensor in low flow regimens by —pretty accurately, as shown by Meier et al. (2022)— extrapolating its predictions. This setup will then be tested in field conditions. The uncertainty of the measurements and predictions will be quantified and compared between lab and field conditions.

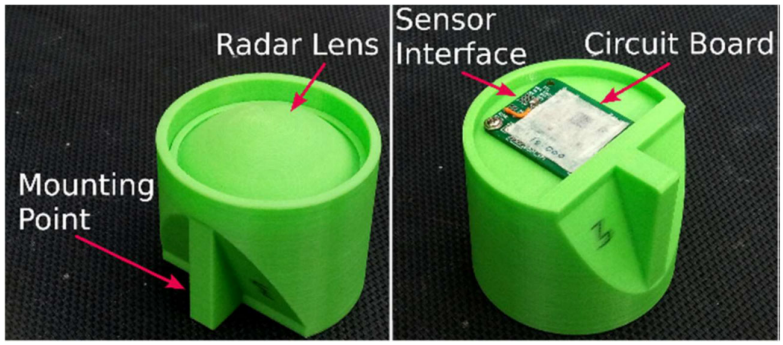


Fig. 1. BoSL radar sensor (Catsamas et al., 2022)

Specific work description

- Working with sensors. This means both getting comfortable installing and maintaining the sensors in the lab and field, and getting acquainted with their interfaces (open source firmwares).
- Data validation and data analysis.
- An introduction to Convolutional Neural Networks and Artificial Neural Network training in general.
- Quantifying measurement uncertainty

Specific requirements

Candidates are expected to have basic programming knowledge (Python and/or C). A practical mindset is also necessary since the bulk of the workload will be experimental.

References

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Catsamas, S., Shi, B., Wang, M., McCarthy, D.T., 2022. Characterisation and development of a novel low-cost radar velocity and depth sensor.

Meier, R., Tscheikner-Gratl, F., Steffelbauer, D.B., Makropoulos, C., 2022. Flow Measurements Derived from Camera Footage Using an Open-Source Ecosystem. Water 14, 424. https://doi.org/10.3390/w14030424

Project Title	Model Based Risk Assessment for Risvollan, Trondheim
Type	Project and Master Thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl
Location	NTNU, Trondheim

Project background

In recent decades there has been a strong movement to separate the urban wastewater flows by using separated sewer systems. Many systems are still hybrids where separated systems upstream connect to combined ones downstream. Even if the systems theoretically and ideally should be fully separated, they can still interact. This can occur when pipes are physically close to each other, or when elements of the systems are shared, such as sewer and stormwater pipes going through the same manholes.

The interaction in such multifunctional manholes may cause a whole host of problems. The foul sewer system can overload and cause backflow to buildings due to unintended inflow of stormwater. Even if that does not happen, the dilution of the sewage may increase the treatment need in the collecting wastewater treatment plant. Vice versa, seeping of sewage into the stormwater pipes may enable flows without treatment into the recipient or groundwater.

In Trondheim, one such system can be found in the Risvollan residential area. Interactions between the separated systems can be observed and seem to be connected to multifunctional manholes. To assess potential risks to the environment and inhabitants, different scenarios need to be evaluated using a hydrodynamic model of the area. Such a model has been created and tested, but due to lacking knowledge about the shared manholes, only inaccurate predictions are possible at the current stage.

Fig. 1. Left: Shared manhole with open sewer- and stormwater-pipes in the same trench which might interact during high flows. Right: Visautlisation of the existing Risvollan SWMM model.

Aim of the project

To improve the validity of the model predictions, more information related to these multifunctional manholes is needed. Field measurements should provide us with accurate information to update the hydrodynamic model, which in turn should improve the prediction accuracy.

Using the improved model, different scenarios should be defined and evaluated to assess the hydraulic behaviour of the system, and the associated risk of environmental pollution in the area, as well as the risk of backflow to households. This work represents a novel approach to the management of sewer systems.

Specific work description

During the project work, the student will get the opportunity to improve and evaluate the model of a real-world residential area. This will include field measurements to more accurately represent multifunctional manholes and the observed interactions between the supposedly separated systems, as well as using real-world measurement to calibrate the model.

Once the model is more representative of the Risvollan residential area, the student will use it to assess potential risks, such as backflow into individual households, undetected blockages, or the dilution of sewage.

Specific requirement

Candidates are expected to have a willingness for field visits, knowledge of Python, and SWMM.

Project Title	Modelling the hydraulics of in-house plumbing systems
Type	Project and Master thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl
Location	NTNU, Trondheim

Project background

Hydraulic models have been used for several decades to design and maintain the functionality of urban drinking water systems. The utilisation of EPANET or EPANET-based models have allowed managers of drinking water distribution systems to easily characterise the hydraulic conditions of complex networks, analyse future demand and failure scenarios, size new elements, identify critical links or weak points in the system, assess water quality aspects in the network, only to mention some of the uses of hydraulic models. Hydraulic models have made it considerably easier to design, optimise and maintain complex drinking water networks.

Conversely, the utilisation of hydraulic models for the design and maintenance of in-house plumbing is only in its advent. Despite the many potential benefits, both for design and operation, of digitizing the in-house plumbing systems in hydraulic models, the state-of-the-art for design of in-house plumbing systems involves an “analogue” approach to design, using standard chart values for pipe sizing etc. At the same time, research shows us that a more enhanced understanding and management of the risks in in-house plumbing systems, such as risk of legionella growth, biofilm accumulation, structural failures etc., is dependent on understanding the interaction between the hydraulics and water quality aspects of the in-house plumbing system. In other words, to reduce risks in in-house plumbing systems, we need a better and more detailed understanding of the hydraulics involved. To achieve this understanding, we can adapt already existing hydraulic models to in-house plumbing systems.

Aim of the project

The project aims at creating and verifying a hydraulic model for a pilot-scale in-house plumbing system which is currently situated in the NTNU drinking water lab, and demonstrate how the model can be used to gain a more detailed insight in the workings of the in-house premise plumbing system, e.g., through identifying relevant parameters affecting the impact of structural failures, hydraulic residence times etc.

The development of the model will be based on the Premise Plumbing Modelling Tools, which is a Python package used for modelling premise-plumbing in EPANET.

Specific work description

- Literature study on state-of-the art in-house plumbing design
- Literature study on premise plumbing modelling tools (PPMT)
- Establish model based on physical representation of pilot rig
- Verify model with measurements on the pilot
- Demonstrate utilisation of model through modelling different scenarios

Specific requirements

Intermediate level knowledge of Python programming is recommended for this project.

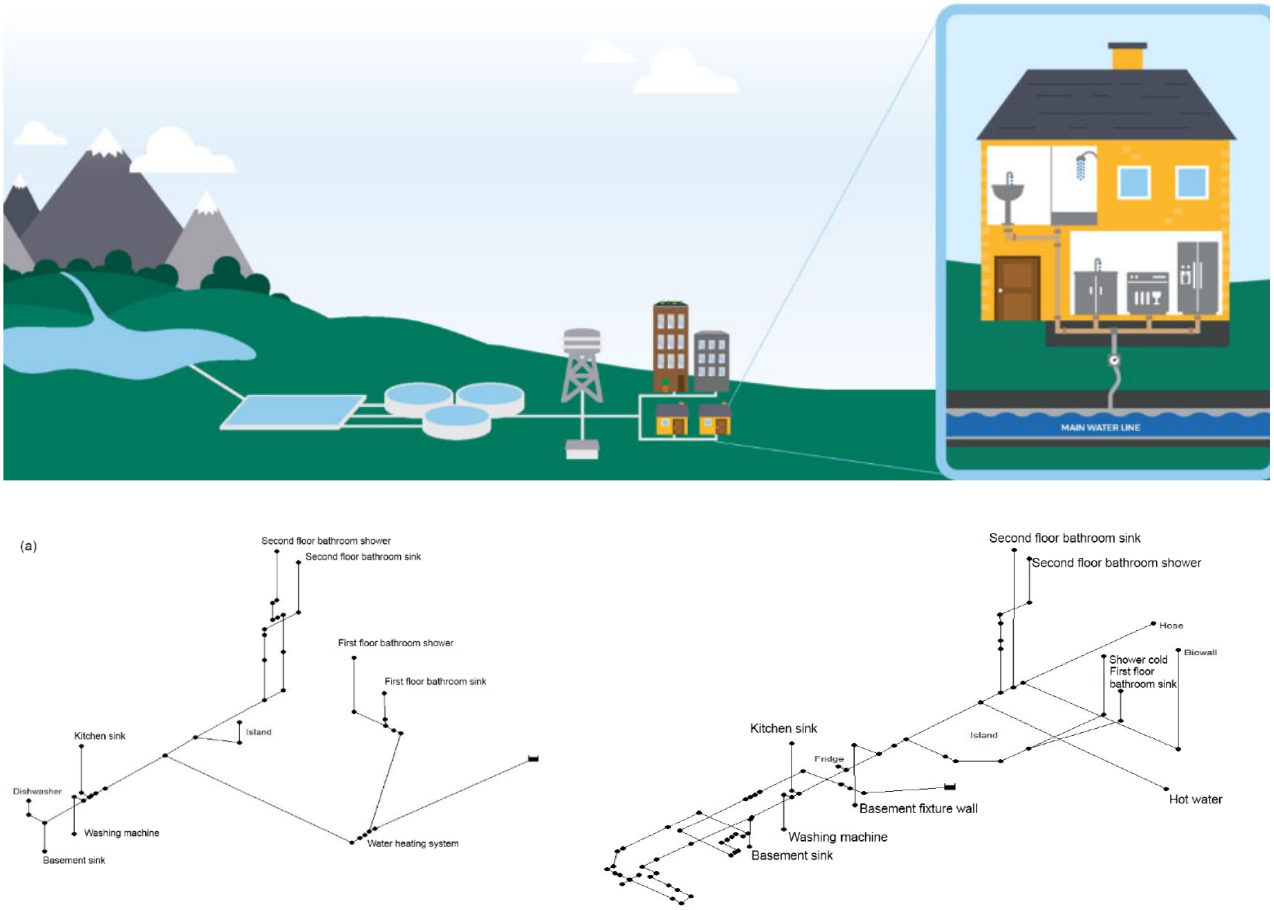


Fig. 1. *Illustration of EPANET model representation of inhouse plumbing cold and warm-water system in a case study example (from: https://www.epa.gov/emergency-response-research/premise-plumbing-decontamination and https://doi.org/10.1002/aws2.1280)*

Sources/references:

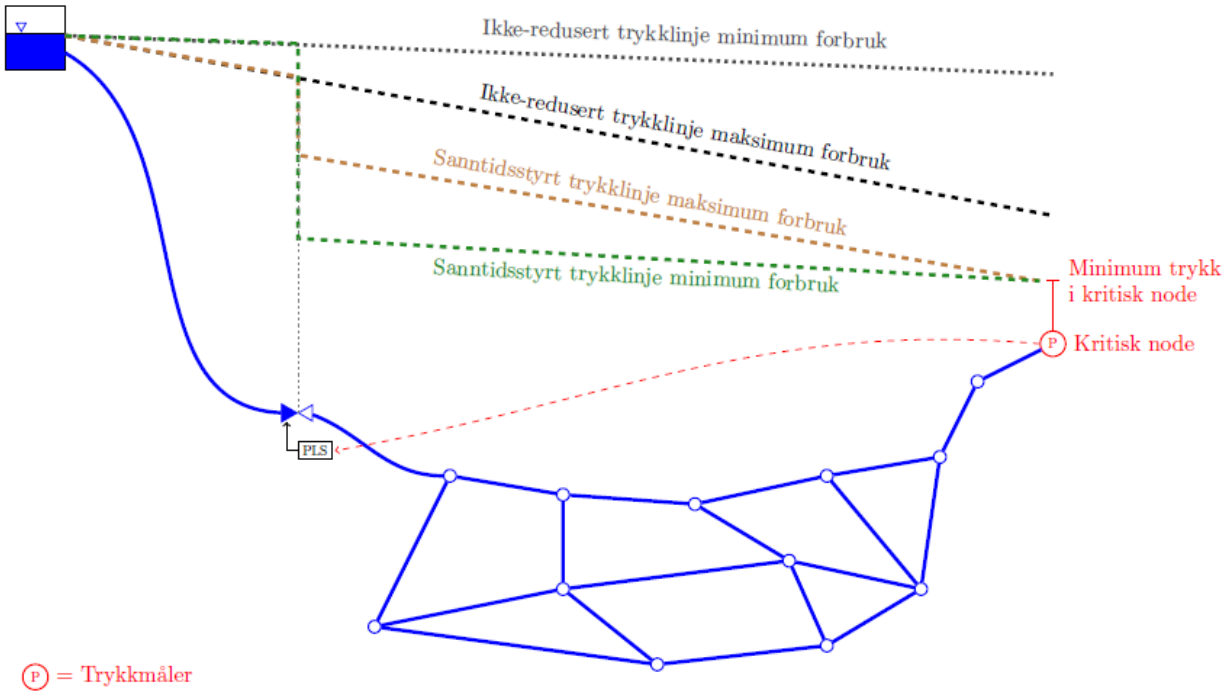
Palmegiani, M. A., Whelton, A. J., Mitchell, J., Nejadhashemi, P., & Lee, J. (2022). New developments in premise plumbing: Integrative hydraulic and water quality modeling. AWWA Water Science, e1280. https://doi.org/10.1002/aws2.1280

Project Title	Pressure control strategies for water distribution systems
Type	Project and Master thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl, Camillo Bosco
Location	NTNU, Trondheim

Project background

Water distribution systems (WDSs) are essential infrastructures in modern societies, delivering clean and safe drinking water to residential, industrial, agricultural and other users. WDSs can be described as complex hydraulic networks, which can utilise different types of control measures in order to perform its functions.

Norwegian WDSs are often prone to high operational pressures, due to topography and design requirements. It is well-known that high operational pressures may have negative effects for the WDS, such as increased leakage volumes, burst rates and energy consumption. Leakage losses are of particular interest in Norwegian WDS managers, as the losses are comparatively high – it is estimated that 30 % of the drinking water produced in Norway is lost through leakages, compared to around 20 % in Sweden, and 10 % in Denmark. Many Norwegian water utilities are working on reducing their water losses, and pressure reduction may be one cost-effective approach to achieve this.



The emergence of real-time control (RTC) allows us to take a more dynamic approach to the management of pressures in a WDS. By using remote sensors, smart water systems, connected to actively controlled valves and pumps (actuators), we can control pressures in such a way that they are adapted to the demand situation in the network at any given time, minimising the excess pressure, and thereby minimising the water losses. However, the before physically installing such pressure control schemes, one needs to test the viability of the proposed solution, which is usually done through hydraulic modelling. The proposed pressure control strategy is implemented in the hydraulic model, and the model is used to predict what the effect of the pressure reduction strategy will be, identifying critical points, how it needs to be operated under different scenarios, impacts on network vulnerability etc. Using the hydraulic model to identify and evaluate viable pressure control strategies is thus key in the planning.

Aim of the project

The aim of the project is to use hydraulic models to gain a deeper understanding of the viability, impact and practical limitations and drawbacks of different pressure control strategies has in Norwegian drinking water distribution systems, and the output of the thesis should provide recommendations for pressure management strategies for typical Norwegian water utilities.

Specific work description

- Perform a literature review of leakage reduction strategies for WDSs
- Perform a literature review on pressure management strategies in WDSs
- Define a strategy of pressure control for the selected Norwegian case study WDS
- Run simulations in an hydraulic model, to assess the results of the selected pressure reduction measures

Specific requirements

For this thesis a solid understanding of WDS hydraulic simulations is recommended.

Project Title	Quantitative failure assessment of Nature-based solutions
Type	Project and Master thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl, Mahdi Bahrami, Bardia Roghani
Location	NTNU, Trondheim

Project background

In the last few decades, with the emergence of concepts such as Sustainable Urban Water Management (SUWM), how we deal with urban stormwater and wastewater has been re-examined. The modern approach looks into ways to benefit from stormwater as a "resource" that can provide social, environmental, and economic benefits. Thus, various approaches have been introduced to facilitate water retention and infiltration, reduce the pressure on grey infrastructure and complement the traditional systems. These modern approaches are referred to as "Green" infrastructure. Green roofs, bioswales and rain gardens are all examples of GIs. These small-scale interventions are distributed throughout the catchment to help mitigate flood risk, preserve the environment, improve aesthetics, and enable a more circular usage of stormwater. However, proposed solutions and adopted measures have often been neglected throughout their lifecycle, resulting in uncertainties regarding performance efficiency based on type, combination, placement, and maintenance over their lifecycle. There are challenges on deciding the frequency of inspection and how to determine if maintenance is needed. Due to lack of resources and supervising schemes, only the most important GIs are monitored. The variety in GIs has also made them more difficult to manage, where different monitoring schemes, instruments and maintenance practices need to be applied for each type and instance of NBS.

Aim of the project

Failure in GIs function can occur due to instances of component failure such as clogging or decrease in infiltration rates. GIs comprise a variety of components with complex interrelations. To understand the root causes behind failures in GIs, the aim of this project is to collect failure data and investigate main causes of failure and failure modes of GIs through statistical analysis and fuzzy logic.

Specific work description

During the project, the student will visit various GIs to do an inspection on the conditions of GIs. Condition data and causes of failure will be collected from different types of GIs, complemented by interviews with GI operators or other professionals. This will be followed by statistical and/ or fuzzy analysis to compute the occurrence probability of various failure modes in GIs. Finally, maintenance and inspection methods for the recognized failure modes will be discussed and proposed.

Specific requirements

Candidates are expected to have a willingness for field visits, knowledge of Python/MATLAB programming, and a working knowledge of statistics.

Project Title	SedTemp: Identifying sediment deposits from temperature signals: *Approach to sedimentation in sewer and urban drainage systems based on temperature measurements.*
Type	Project and Master thesis
Supervisors/ Contacts	Francois Clemens, Franz Tscheikner-Gratl, Marius Møller Rokstad, Dr. Manuel Reguiro-Picallo, Antonio Moreno-Rodenas
Location	NTNU, Trondheim

Project background and aim

There is a lack of high quality data on the accumulation of solids in gully pots. This information is needed to optimise asset management and reduce flooding risks in urban areas. Within the H2020 EU project Co-UDlabs (https://co-udlabs.eu/) a new approach to obtaining high quality data on sediments deposits in (part of) a sewer system is underway since 2 years.

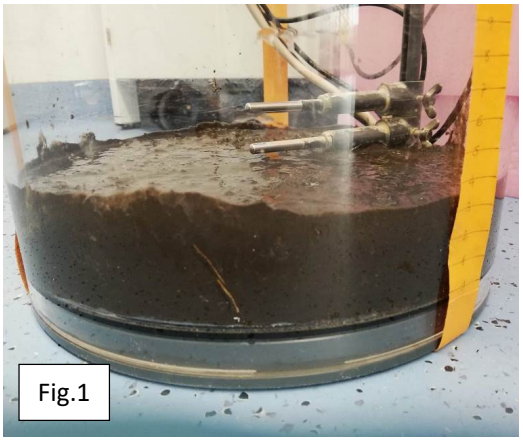


Fig.1

In this work, we present a new approach which uses high-resolution temperature data to identify sediments from changes in temperature dynamics between the water (wastewater or drainage water in UDS) and the sediment bed deposits. Since the heat transfer between both media can be predictably affected by the sediment thickness, we suggest a heat transfer model that relates the temperatures in the fluid and in the sediment layer to its thickness.

For this purpose, we are carrying out lab-scale experimental campaigns to develop monitoring systems for sediment accumulation in sewer pipes and gully pots. Regarding sediments in sewer pipes, this study was performed at Eawag (Zürich, Switzerland). The lab-scale model reproduced the daily pattern of temperatures in wastewater. Different sediment samples and several sediment thicknesses were tested (Fig.1). In addition, an active heat device was developed to measure the thermal properties. Results showed that temperature signal dampening at the bottom of the system was influenced by the thickness. Furthermore, hydrodynamic processes were numerically proven with the SWMM-HEAT software to have little effect on the heat transfer between the wastewater and the sediment bed.


Fig.2

Lab-scale experiments on sediment accumulation in gully pots is currently under development at Deltares facilities in a 1:1 setup (Fig.2). A similar concept is being used to measure sediment thickness based on temperature measurements. There is a temperature gradient between runoff and water remained in gully pots. Results shows that temperature gradients are dampened at the bottom of the gully pot due to the presence of sediments. Next step is to install field devices in real gully pots. First devices were already installed at Deltares campus (Fig.3).


Fig.3

Specific work description

The idea is to use the sensor systems developed in a couple of gully pots in Trondheim as well. So far the system has been applied in Switserland, at the Deltares campus and a few locations in The Hague and Rotterdam in the Netherlands. In partial fulfilment of your M.Sc. study you are invited to join in and learn about environmental monitoring with emphasis on the following elements:

- Monitoring methods
- How do sensors work

- Thermodynamics
- Programming (data analysis)
- Experience how it is to participate in a collaboration with international researchers from Spain, Switserland and The Netherlands

We envisage you are being asked to design an experimental setup, implement this and perform the monitoring (that is: make sure the sensors are operated in a correct manner, perform data analyses, perform calibrations and communicate your results with fellow researchers).

Specific requirements

In order to be successful in this project you will need to:

- Be indifferent to getting 'dirty hands' (i.e. field work is involved)
- Have some interest in data analysis (preferably some Pyhton programming experience)
- Be a team player and have workable level in English (in writing and speaking)

Note: After finalizing the project you'll be invited to co-author an international scientific publication on the results obtained.

Project Title	Sewer velocimetry
Type	Project and Master thesis
Supervisors/ Contacts	Francois Clemens, Franz Tscheikner-Gratl, Marius Møller Rokstad
Location	NTNU, Trondheim

Project background and aim

When managing sewer systems, or urban drainage systems, known what happens inside can be helpful. For example: when you manage a wastewater system you prefer not have any stormwater connection discharging into it, tracking down these so-called misconnections is a very cumbersome and labor intensive process using existing methods. Within NTNU a new idea was developed to develop a method that uses simple and cheap means based on image velocimetry. This method is based on extracting motion from video sequences obtained by using a simple camera system (e.g. a GoPro). A first M.Sc. project at NTNU is underway and shows that the fundamentals of this approach work (indeed we can observe an increased water velocity in a wastewater system when stormwater is being discharged into it. Also the detection limits are being quantified. A next step in the development will encompass strategies for applying the camera systems in an effective and efficient manner to exploit them to the maximum.

Specific work description

With the known characteristics of the camera system (recoding speed, time resolution) and the capabilities of the several image postprocessing algorithms (i.e. Particle Image Velocimetry, Optical Flow and Particle Tracking Velocimetry) and the characteristics of the wastewater system a strategy for choosing the location to place the cameras has to be developed. The work will encompass:

- Using a hydrodynamic model to simulate the dynamic behavior of a wastewater system
- Develop an algorithm that optimized the information content given a wastewater systems and given an number sensors with known characteristics
- Possibly do some field tests (depends on your own interest and the time schedule as the project develops)

Specific requirements

To be successful in this project you need:

- not to shy away from mathematics and/or computer programming
- to like to learn about image processing using computer algorithms and applied metrology

Project Title	To dig or not to dig / that is the question
Type	Project and Master thesis
Supervisors/ Contacts	Franz Tscheikner-Gratl, Marius Møller Rokstad, Bardia Roghani
Location	NTNU, Trondheim

Project background

Modern sewer infrastructure faces major challenges in fulfilling public expectations concerning the functionality of the urban drainage infrastructure - the maintenance and rehabilitation of aging networks along with the adaptations needed to cope with a changing environment (e.g., climate change and/or urban development in the context of population increase/decrease). The focus of operating companies in places with long-lived sewer infrastructure is therefore transforming from new design and construction to redesign and asset management. It is unrealistic, however, to replace all sewers simultaneously. Localized repair, general rehabilitation and replacement are decisions that can be taken to improve the condition of sewers to acceptable levels of service. For rehabilitation of sewer systems manifold techniques exist, ranging from trenchless renovation methods over point repair up to open-cut replacement. The decision on which technique is applied on an operational level is often made either by experience/intuition or by simple cost considerations.

Fig. 1. Damaged sewers and exemplary repairs

Specific work description

The goal of this work is therefore:

- Assess the state of the art of rehabilitation techniques and their qualities, costs, advantages and disadvantages.
- Finding of influencing factors on the decision for sewer rehabilitation
- Find a proxy of lifetime for different techniques e.g., by eliciting expert knowledge?
- Combining the knowledge of existing techniques and decision variables into a multi-criteria decision analysis tool
- Definition of various rehabilitation scenarios and testing of the developed tool

Specific requirements

Intermediate level knowledge of Python, MATLAB or R programming is recommended for this project.

Project Title	Using machine learning and artificial intelligence to reduce failures and leakages in drinking water pipes
Type	Project and Master thesis
Supervisors/ Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl
Location	NTNU, Trondheim

Project background

Leakages from the Norwegian drinking water network is a known challenge in the water sector. Numbers from the national databank KOSTRA shows that there is an estimated average water loss of 30 % from Norwegian municipalities. The leakages are caused by structural failures in the pipes, corrosion and leaks in the gaskets. The leakage numbers from Denmark are less than 9 %, and Sweden around 20 %. The Norwegian topography and climate are more challenging than those in Denmark and Sweden, and are the causes for the increased leakage rates. However, the numbers also show that the Norwegian water sector need to improve the work to find and reduce leakages.

Aim of the project

A new project with 20 partners from the public and private sector which is financed by the Norwegian water sector will look at new and innovative solutions, methods and technologies in order to find and reduce leakage rates. The project starts in April 2021 and lasts until 2025. Part of the project will use machine learning in order to understand why and when leaks occurs, and will also work to estimate and assess the probability of future failures and leaks in the pipes.

The master thesis will work closely with the researchers at SINTEF who work with machine learning and asset management of drinking water networks, and will be part of the research project. This includes participation in meetings with municipalities and other partners in the project.

Specific work description

- Read up on tactical asset management in the water sector.
- Review different machine learning methods and how they may be suitable for use in water infrastructure.
- Use 1-2 machine learning methods on 2-3 Norwegian networks. Build different models and compare them in terms of how accurate they are in predicting failures/leakages.
- Estimate the cost savings a municipality can achieve by using machine learning in fighting leakages and failures.

Specific requirements

Intermediate level knowledge of Python or MATLAB is recommended for this project.

Project Title	Vulnerability Assessment of Green Infrastructure
Type	Project and Master thesis
Supervisors / Contacts	Marius Møller Rokstad, Franz Tscheikner-Gratl, Mahdi Bahrami, Bardia Roghani
Location	Trondheim

Project background

Green Infrastructure (GI) are effective stormwater management measures, but they are not invincible. Vulnerability in case of GIs refers to their susceptibility to damage or failure under certain conditions, which can impact their performance and ability to manage stormwater effectively, or provide other co-benefits. Some factors that can make GIs vulnerable include: (a) Extreme weather events: GIs are designed to withstand typical weather conditions, but they can be vulnerable to extreme rainfall events, or heavy snowfalls. Due to climate change, long-term rainfall events or rapid rainfalls can reduce their water retention capacities which can in turn increase the risk of urban flooding. (b) Lack of maintenance: GIs require regular maintenance to ensure their functionality. If not maintained properly, issues such as clogging or low vegetation cover can lead to reduced performance. (c) Poor design: GIs must be designed with the local climate, land-use patterns in surrounding areas, soil types, etc in mind. Poorly designed measures can be vulnerable to issues like erosion, ponding, or clogging which can impact their performance. The potential benefits of integrating GI practices with conventional drainage systems to reduce the vulnerability of grey infrastructure to flooding and climate change is threatened by the uncertainties that arise with their performance.

Aim of the project

Quantify stormwater system vulnerability to GI failure across a range of rainfall events and GI failure scenarios using the SWMM.

Specific work description

During the project, the student will model and run various modes of failure for GIs in a catchment, and assess the performance and vulnerability of the stormwater system to these failures. The effect of clogging, long-term rainfall events, decrease in infiltration rates, change of land-use, etc will be assessed by the student. This may be followed by an uncertainty analysis of the performance of GIs.

Specific requirements

Candidates are expected to have knowledge of hydraulic modeling with SWMM.