AG2809 Project Sustainable Urban Planning - Assessments, Processes and Plans

Assignment 03c – Project report

Metals at the Beach - How toxic substances are impacting urban soil and Lake Mälaren

Bolinder Strand, Järfälla municipality (JM, 2022)

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Abstract

Soil is a fundamental building block of Earth, however, soil health is threatened by contaminations from human activities such as industries and boat harbours. In Järfälla municipality, the area Bolinder Strand has a long industrial history before it became a residential area. Bolinder Strand is located by Lake Mälaren, and the two local boat clubs in the area are high risk areas for soil contaminations. The aim of this report was to understand the state and effects of contamination in Bolinder Strand and provide recommendations for future management. Three questions were addressed which focus on contaminants present, management of soil, and suitable remediation techniques. The methods used for the study were four thematic literature reviews with focuses on case studies, scientific literature and general policy documents; three semi-structured interviews, significant document analysis and a stakeholder assessment. The results indicated the importance of understanding the roles and influence of the stakeholders involved in decisions and management of contaminated soil. It was also clear that a variation of contaminants were found in Bolinder Strand, where the challenge lay in the lack of consistency in assessments and data availability. Excavation was the most common method used to remediate Bolinder Strand's soil for development. However, there are several other possible remediation techniques such as bioremediation, which could be given more consideration. There is insufficient data on the state of soil pollution within the boat clubs which suggests a knowledge gap and opportunity for improvement. These results indicate significant limitations and challenges to properly managing soil contamination leading to three themes of recommendations being proposed regarding policy, general management and data availability. Soil contamination is a complex field of study which requires knowledge and understanding of multiple fields. Bolinder Strand was challenging to address with its history and development in different stages over two decades. Areas with a "cocktail mix" of contaminants, as in Bolinder Strand, are difficult to suggest specific remediation techniques for due to the complexities to consider such as soil composition, cost and effectiveness.

Sammanfattning

Jord är en av jordens grundläggande byggstenar, däremot hotas jorden av föroreningar från mänskliga aktiviteter, exempelvis industrier och båthamnar. I Järfälla kommun har området Bolinder Strand en lång historia av att vara en plats för industrier innan det byggdes till ett bostadsområde. Bolinder Strand ligger vid Mälaren och två lokala båtklubbar i området är högriskområden för markföroreningar. Syftet med denna rapport var att få förståelse för hur markföroreningar och dess effekter ser ut i Bolinder Strand och ge rekommendationer för förbättringar gällande hantering av förorenad mark. De tre frågeställningarna fokuserade på förekommande föroreningar, hantering av markföroreningar och lämpliga saneringstekniker. Metoder som användes i denna studie var litteraturstudier med fokus på fallstudier, vetenskaplig litteratur och övergripande policydokument; tre semistrukturerade intervjuer, dokumentanalys och en bedömning av involverade aktörer. Resultatet visade på vikten av att förstå roller och inflytande hos de aktörer som är involverade i beslut och hantering av områden med förorenad mark. Det var även tydligt att en variation av föroreningar hittades i Bolinder Strand, där utmaningen utgjordes av brist på metodiska bedömningar och datatillgänglighet. Schaktning var den vanligaste metoden som användes för att sanera områden i Bolinder Strand inför bostadsutvecklingen. Det finns däremot andra möjliga saneringstekniker, till exempel biosanering, som skulle kunna bedömas och övervägas som möjliga tekniker. Det finns otillräckliga uppgifter om markföroreningar inom båtklubbarna, vilket tyder på en kunskapslucka och det finns därmed möjlighet till förbättring inom detta område. Dessa resultat indikerar betydande begränsningar och utmaningar för att korrekt hantera markföroreningar, vilket leder till att tre övergripande rekommendationer föreslås gällande policy, övergripande hantering och datatillgänglighet. Markföroreningar är ett komplext studieområde som kräver kunskap och förståelse om flera områden. Bolinder Strand var utmanande att studera med tanke på dess historia och den långa bostadsutvecklingen i olika skeden. Områden med en "cocktail mix" av föroreningar, som setts i Bolinder Strand, är svåra att föreslå specifika saneringstekniker för, på grund av komplexiteten av att ta hänsyn till olika aspekter, exempelvis jordens sammansättning, kostnad och effektivitet.

List of Abbreviations

CO_2	Carbon dioxide
EU	European Union
ISTD	In-Situ Thermal Desorption
LSLU	Less Sensitive Land Use
PAH	Polyaromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
SEPA	The Swedish Environmental Protection Agency
SDS	Sodium Dodecyl Sulfate
SDG	Sustainable Development Goals
SGI	The Swedish Geotechnical Institute
SGU	The Geological Survey of Sweden
SLU	Sensitive Land Use
UN	United Nations
VOC	Volatile Organic Compound

1. Introduction

Soil is a fundamental natural resource that provides several key functions that are essential for sustaining life on the planet. Properly functioning soil is critical for supporting biodiversity, it is also depended on for many processes and ecosystem services such as nutrient cycling, which is important for food growing, making it the foundation for the food system and the plants that animals rely on for nourishment (Hillel, 2008; Liu et al., 2023). In addition to supporting agriculture and ecosystems, soil is also the largest carbon sink after the ocean (National Geographic, n.d., accessed 2024-10-10) playing a crucial role in the fight against climate change by absorbing atmospheric carbon dioxide (CO_2) and lowering greenhouse gas emissions. Its health therefore has significant implications for ecosystem and human health if the ecosystem services it provides are impacted. Contaminated soil also poses significant risk to human health directly through contact, inhalation and ingestion and can cause a wide range of health issues (Li et al., 2018).

Soil ecosystem services also play an important role in urban planning, helping to mitigate the effects of climate change, contributing to urban biodiversity, regulating water runoff and helping to prevent flooding (O'Riordan et al., 2021). Healthy soil can also help reduce the urban heat island effect by cooling the surrounding environment. However, contaminated soil can severely restrict land use options, often making it unsuitable for a range of activities, including farming, residential development, or recreation (Interview with environmental inspector from Järfälla municipality, 2024). The presence of hazardous substances like heavy metals, pesticides, or industrial chemicals often necessitates extensive remediation efforts before the land can be safely used again or be healthy enough to provide ecosystem services. This relates to an important SDG subtarget: 15.3 *"By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world"* (UN, n.d.-a, accessed 2024-10-01).

In Järfälla municipality there are numerous areas which have been identified as polluted by the municipality and classified by risk level (see map in Figure 1). The majority of the highest risk areas are located along the border of Lake Mälaren and are on the sites of active boat clubs. Corroborating this are the findings of the Stockholm County Administrative Board [Stockholm Länsstyrelse] who conducted a risk classification assessment specifically of boat clubs (Järfälla Miljö- och bygglovsnämnden, 2020). Five of Järfälla municipality's six boat clubs were placed in the highest risk category, as they have been active for many years. In areas where boats are maintained the ground can become polluted with toxic substances and small plastic particles from scraping or sanding of boat paint (Järfälla Miljö- och bygglovsnämnden, 2020). The paints used on boat hulls have historically contained harmful chemicals like copper, zinc, and lead in order to prevent buildup of biological materials, such as algae, barnacles, and mussels, on their hulls (Du et al., 2013). The historical contaminants have also been caused by previous industrial activities in Bolinder Strand (Järfälla, n.d., accessed 2024-11-28). These sources of pollution, especially in shoreline soils, can pose a larger threat than pollution in other areas as it can more easily enter the water system and contaminate a much larger area.

This connects to the SDG subtarget 14.1 *"By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution"* (UN, n.d.-b, accessed 2024-10-01). Bolinder Strand was chosen as a case study because it contains two of such boat clubs and presents an interesting case of shoreline, urban and industry related soil pollution.

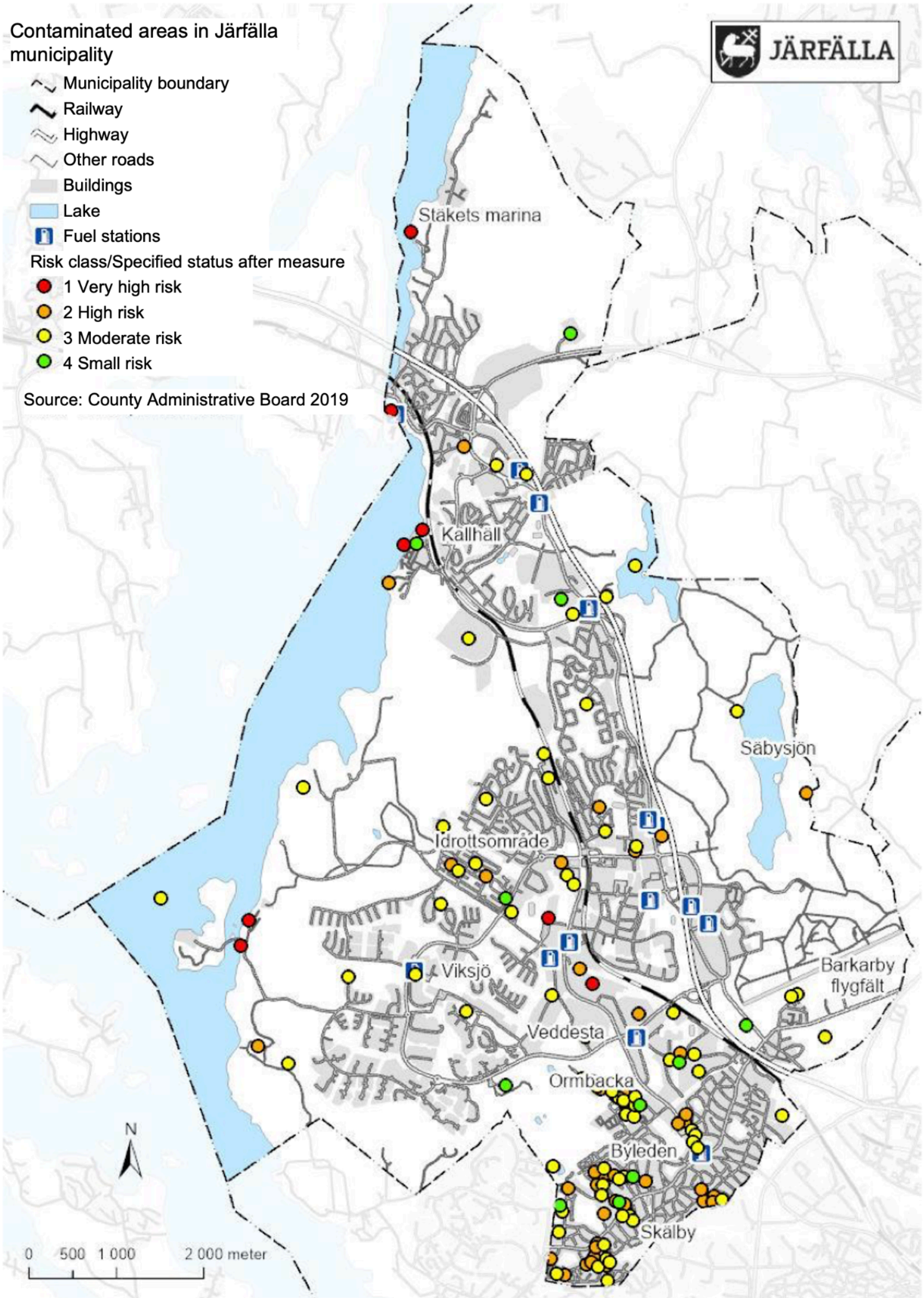

Figure 1. Map over areas in Järfälla municipality that is classified as contaminated (Järfälla, 2020). Translated legend by the authors.

1.1 Aim

The aim of this project is to understand the state of pollution in Bolinder Strand, where the pollution is and has been coming from, and how it is impacting the surrounding environment. Including, providing possible steps forward towards remediation of the soil contamination.

1.2 Research questions

Based on the background research and to achieve the aim, the following three research questions are to be addressed in this report.

1. What type of pollutants are found in the soil at Bolinder Strand? What effect can these pollutants have?
2. How are soil contaminants managed through policies and regulations?
3. What solution(s) are most suitable to support remediation of the polluted soil at Bolinder Strand?

1.3 Scope and limitations

The scope of this report will be focused on Bolinder Strand in Järfälla municipality, where soil pollution will be assessed and investigated. In this report, the terminology *contamination* and *pollution* will be used synonymously to refer to the presence of undesirable substances in soil. The main limitation of this study is in the complexity of the issue of soil contamination and the site specificity, properly understanding the problem requires extensive knowledge of chemistry, geology, hydrology, public health, planning, and various other subjects to get a comprehensive overview and suggest the most viable remediation and management techniques. Due to this, limitations include difficulty in finding and contacting relevant actors and specialists with the appropriate knowledge who are willing to participate in interviews. Additionally, accessing and understanding the information and material of soil assessments conducted in Bolinder Strand.

2. Background

2.1. Soil functioning

To address soil contamination it is important to understand what soil is and how it functions. Soil is a mixture of organic and inorganic compounds which becomes a fertile substrate when infused with water (Hillel, 2008). What is equally important is the porosity of soil, the “pores” between elements which allow for the movement of gases and liquids to enter the system. This is a crucial function as the water that is in the soil pores is what enables the movement of nutrients and pollutants through the system (Morgado, Loureiro & Gonsález-Alcaraz, 2018). A visual representation of soil structure is shown in Figure 2.

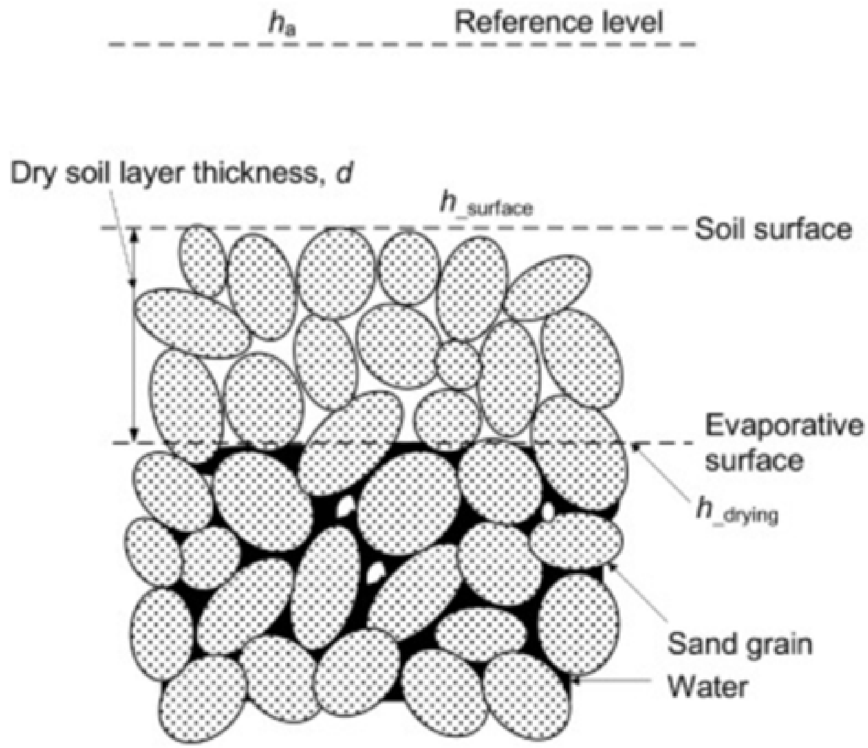

Figure 2. Soil structure (Cui, 2013).

In the event of soil pollution the structure and characteristics of the soil play a large role in how they move through the system. The example can be used of heavy metals which are often pollutants from boat clubs. These elements are naturally occurring in soils in trace amounts and are vital for proper soil health and functioning (Wang et al., 2024). However, due to human activity we often introduce excessive amounts into the soil, up to 2 orders of magnitude above what is stable, leading to soil toxicity. The soil is able to process heavy metals if they are kept at low enough concentrations but this requires them to have time to be processed. Therefore, it is important that these elements are kept stationary in the soil, if water were to enter the system, metals could move from the soil into other systems such as rivers and lakes. Metals in a soluble state are also much more toxic, that is when they are the most bioavailable to microorganisms and plants (Lejon et al., 2008).

The main factor which determines the transferability of metals is the amount of organic matter in the soil as it binds to the metals (Lejon et al., 2008). Other important factors are: pH (lower pH equates to higher transferability), ionic strength, soil texture (clay binds more metal than sand), pore structure, and temperature (Sherene, 2010). Soil functioning is very complex and difficult to model, making it complicated to account for in urban and regional planning.

2.2 Human health related to soil

Addressing soil pollution is essential for safeguarding human health. Long-term exposure to heavy metals, for example, has been linked to neurological and cognitive impairments, while organic compounds can disrupt hormonal functions, which can have lifelong consequences (Li et al., 2018). Urban soil often contains various contaminants that pose risks to both the environment and human health. Heavy metals such as cadmium, chromium, arsenic, copper, zinc, lead, and mercury frequently accumulate from sources like industrial waste, road dust, and the weathering of infrastructure (Greinert, 2015). According to Setälä et al. (2017) unsealed urban soils can act as critical sinks for heavy metals, mitigating pollution in nearby water bodies.

The variability in historical pollutants, industrial activities, vegetation, and urban landscapes across different cities requires site-specific approaches to remediation and management. Conducting research and expanding knowledge on the significance of urban soil and its effects on human health are necessary steps to safer and healthier urban environments (Evans et al., 2000). Strategies such as soil remediation, urban green space design, and regular monitoring of soil quality can significantly reduce exposure to harmful pollutants.

2.3 Soil remediation techniques

The remediation of contaminated soil is a complex, but essential process to mitigate the aforementioned health and environmental risks while also restoring the soil’s functionality. Soil remediation techniques address contamination through a variety of approaches, typically classified into physical, chemical, thermal, and biological methods ((Lee et al., 2024). These methods are often combined to enhance their effectiveness and suitability for specific site conditions (Finnegan et al., 2018). Ultimately, the choice of soil remediation method depends on natural factors such as contaminant concentration, soil composition, environmental conditions, and the extent of contamination (Finnegan et al., 2018). Other political considerations are timeline, available funding and intended use. Often, a combination of methods tailored to the specific needs of a site provides the most effective and sustainable results.

2.4 Soil policy

As described in the previous sections, there is an extensive issue with contaminated soil worldwide. To address these challenges and complexities, the European Union [EU] has a strategy specifically addressing soil (European Commission, n.d., accessed 2024-11-27) and, the EU member state Sweden has the Environmental Code that is a national legal framework which addresses different environmental aspects, among other contaminated areas (Järfälla Miljö- och bygglovsnämnden, 2020). The Environmental Code has parts that are based on EU-wide legal frameworks that are required by the member states to implement (Sveriges riksdag, 1993). The Swedish legal framework has several chapters, of which some of them are specifically relevant for the context of soil contamination (SEPA, 2024; Järfälla Miljö- och bygglovsnämnden, 2020).

The Swedish Environmental Protection Agency [SEPA, Naturvårdsverket in Swedish] (SEPA, 2024a) specifically mentioned chapter two, ten and twenty-six, while Järfälla Miljö- och bygglovsnämnden (2020) also highlighted chapter nine and fifteen of the Environmental Code. The chapters in the Environmental Code address different aspects (Sveriges riksdag, 1993). Chapter ten addresses activities that cause the damage to the environment and who is responsible for a contaminated area, which also indicate that there are levels of responsibility that exist (Sveriges riksdag, 1993), which is similar to the Netherlands responsibility hierarchy (Rodrigues et al., 2009).

From another perspective, Sweden has several different stakeholders and actors involved with proposing and providing action plans, management plans or supervising areas of contamination (SEPA, 2023a-b). Examples of actors include municipalities, the Geological Survey of Sweden [SGU, Sveriges Geologiska Undersökning in Swedish], and the Stockholm County Administrative Board, as well as companies and universities (SEPA, 2023a). Related to these authorities and actors, are the importance of having a strong connection between the measures and actions taken by them to enhance an effective way to address contaminations through planning and soil policies according to Rodrigues et al. (2009). Additionally, Binner et al (2024) emphasize the need for soil policies and compliance with these. In addition to these policies, there is a relatively new initiative on EU-level, the “Soil Monitoring Law” that addresses the importance of healthy soils and that indicates a need for actions to restore contaminated soils (European Commission, n.d., accessed 2024-11-27).

2.5 History of Bolinder Strand

Bolinder Strand is named after Bolinder Mekaniska Verkstad [Bolinder Mechanical Workshop] which used to operate on the site. It was created in 1844 by the brothers Carl Gerhard and Jean Bolinder originally at a site on Kungsholmen and was moved to Källhäll in 1909 in order to expand, see Figure 3 (Järfälla, n.d., accessed 2024-11-28). Bolinder Strand was therefore an industrial area which housed one of Sweden’s main export companies. Many products were manufactured at the site, mostly metal tools such as meat grinders and stoves, with the main product being fishing boat motors (ibid). They were so successful that in the 1920’s, 80% of the world's fishing boat motors came from Bolinder Mechanical Workshop. The site changed hands several times and was still actively manufacturing products into the 1980’s (ibid). The location was chosen originally due to convenient land and water access, since Mälaren has access to the Baltic Sea. The historical industry on this site contributed significantly to local soil pollution and at the time no laws were in place to ensure proper remediation, leaving the area highly contaminated (Interview with environmental inspector from Järfälla, 2024).

Figure 3. Bolinder's factory in Kallhäll in 1913. Photographer: Olle Malmberg. Public domain.

Currently, Bolinder Strand is largely owned by JM, a development company which has transformed the once industrial site into a mixed-used space with residential and commercial buildings. This development started in 2001 when site analyses were performed by consultants. The industrial feel was maintained through the preservation of several old buildings, giving the site a unique identity (Järfälla, n.d., accessed 2024-11-28). In order to develop the site JM was obligated to remediate the soil to comply with municipal regulations and it is now considered as completed.

Lake Mälaren is an important resource as it is a drinking water source, with Norrvatten Görvälnverket drinking water plant located near Bolinder Strand which has been operating since the 1920's. It is the main source of drinking water for a large part of the Stockholm Region (Norrvatten, n.d., accessed 2024-11-28). However, there are two of the high risk boat clubs on the shoreline of Mälaren which are close to the protected water area and this drinking water facility. These boat clubs, Piluddens and Kallhäll boat clubs, have operated at the sites for a long time. Kallhäll boat club is the first boat club in Järfälla municipality and was founded in 1921 and was tied for many years to Bolinder Mechanical Workshop (Kallhäll Båtklubb, n.d.).

2.6 Soil characteristics in Bolinder Strand

According to SGU's map over soil types, the area of Bolinder Strand is composed of clay, silt and filling-materials (SGU, n.d., accessed 2025-01-07). Under these soil types lies the bedrock (J&W Energi och Miljö, 2001a). The filling-materials consist of a variation of materials such as rocks, clay, gravel, bricks, crushed rocks and material, sand, and scrap metals (J&W Energi och Miljö, 2001a). This characterizes the soil types present in the area, and is important to acknowledge when discussing the topic of soil contaminations as mentioned previously in the report.

3. Methodology

3.1 Data collection

To collect data for this project, two main methods have been used, (1) a literature review and (2) semi-structured interviews. The following sections will describe the work of each data collection method in more depth.

3.1.1 Literature review

The literature reviews conducted are divided into three themes related to the topic of soil contaminations, (1) Case literature, (2) Scientific literature and (3) General policy documents. These literature reviews were conducted to gain insights into previous studies on similar topics, and case studies of implementations and applications of solutions. This also included understanding the impacts different pollutants can have on water, plants, animals, and humans. Furthermore, case studies that use similar methods were reviewed to gain understanding and background to our decisions. Scientific and academic literature was also reviewed (E.g., Lejon et al., 2008; Rodrigues et al., 2009; Li et al., 2018), as well as gray literature such as organizational, governmental, and municipal documents (E.g., UN, n.d.-a,; Järfälla Miljö- och bygglovsnämnden, 2020; SEPA, 2023a). Examples of documents included, environmental and risk assessments, environmental technical assessments and other report documents related to Bolinder Strand (E.g., J&W Energi och Miljö, 2001a; JM, 2001). See Appendix A and B for information about literature reviewed.

The literature was collected via a variation of databases such as Scopus, Primo via KTH Library, Google Scholar and Web of Science. Keywords used included for example "Contaminated soil", "Polluted soil", "Solutions for polluted areas", "Boat clubs", "Marina", "Bioremediation", "Techniques", "Antifouling paint", "Petrol", "Water pollution", "Effects on ecosystems", "Health effects", "Toxic substances", "Soil policy", "Environmental assessments", and "Excavation". The keywords could be searched for individually and in combination with other keywords. The literature collected for further analysis was based on relevance for the individual literature reviews and this report, as well as factors such as geographical context and if the articles were peer reviewed.

3.1.2 Semi-structured interviews

Semi-structured interviews were conducted with three relevant actors (Table 1). These interviews aimed to gain understanding of soil contamination from a general perspective, as well as more specific of Järfälla municipality and Bolinder Strand. The Swedish Geotechnical Institute [SGI, Sveriges Geotekniska Institut in Swedish] was contacted due to its expertise on soil and land (SGI, 2023), where we received a response from a soil specialist from SGI. An environmental inspector at Järfälla municipality and a consultant from SWECO were contacted based on recommendation from contact persons. Attempts were made in contacting JM as they own and developed the land and were therefore responsible for overseeing the remediation of the soil, as well as both boat clubs, however no responses were received.

The interviewees were contacted through email where the group and project was introduced. This included an explanation of the reasons the interviewee was contacted and how the interviewee could support the project. When answers were received from the interviewees, a date for an interview was scheduled and a consent form for participation was sent. The interviews were between 30 to 45 minutes to provide sufficient time to go through the planned questions and ask any additional follow-up questions.

Table 1. Overview of the three interviewees and their roles. This includes an overview of the language the interviews were conducted in and the theme of the interview.

Interviewee	Role of interviewee	Language	Interview theme
1	A soil specialist from SGI	English	Overall knowledge of soil, soil contaminations and different remediation methods.
2	An environmental inspector [Miljöinspektör] from Järfälla municipality	Swedish	Specifically how the municipality works with soil contamination, and the methods used for remediation.
3	An environmental consultant [Miljökonsult] with soil experience from SWECO	English	Overall process of assessing a contaminated area or an area for development, including remediation techniques used and how to manage soil pollution.

The interviews were semi-structured to have the possibility to ask follow-up questions which were not planned for beforehand. The three interviews were conducted through Zoom or Microsoft Teams. The structure of the interview was firstly to introduce the team and the project. Then, a few introductory questions were asked to let the interviewees introduce themselves and the work they are doing. This was followed by more specific questions regarding soil contamination and remediation techniques. The interviews ended with one or two open questions. Note that only written notes were taken during the interviews, where at least one group member took notes and another led the interview. The interviews were not recorded. See Appendix C for the interview questions.

3.2 Data analysis

After collecting data from the literature review and semi-structured interviews, the material was analysed. A stakeholder mapping was also developed based on the data collected.

3.2.1 Literature review

After collecting the literature, the different articles, documents and reports were analysed. The general process of reviewing the collected literature was firstly to read the abstract and conclusion. This was to know if the articles collected were relevant to use for this project. The articles identified as relevant, were read and interesting sections were highlighted. The articles were integrated into this report to support arguments and background information on the topic of soil contamination. They additionally provided case studies and knowledge which could be drawn upon and discussed in the context of Järfälla municipality and Bolinder Strand.

3.2.2 Semi-structured interviews

During the semi-structured interviews, written notes were taken by one or two group members. These meticulous notes were summarized, and the notes taken during the interview conducted in Swedish were translated. The information from the interviews were discussed and reflected in the group. The information gained from interviews provided general knowledge about challenges and opportunities related to the site as well as novel insights that have helped in making suggestions for steps forward. Furthermore, these insights and provided context changed the early projected outcome and required reconsideration of types of suggestions and recommendations. Additionally, the material from these three interviews were integrated in the result section, together with knowledge from the literature reviews.

3.2.3 Stakeholder assessment

The stakeholder assessment was conducted using information gathered from research and interviews. Results relied heavily on interpretation and assumptions.

4. Results

4.1 Stakeholder assessment

To understand the complex workings of soil contamination at Bolinder Strand it is first important to understand who is involved and what their roles are in relation to the quality of soil. To illustrate this the relevant actors have broken down into a venn diagram based on public and private entities (Figure 4). The public side has been further broken down into the levels they act on, at the national level we have governmental bodies such as The Stockholm County Administrative Board, and The Swedish Environmental Protection Agency [SEPA]. These bodies are responsible for setting standards regarding soil pollution targets and ensuring that they are being appropriately managed. Therefore, it is the regional actors, Järfälla municipality and Region Stockholm, who are the public bodies who mandate and enact these measures. The public sphere also contains actors at the local scale which have been considered to be residents, and ecosystems representing all non-human stakeholders.

In the private sphere there is JM, the main developer of Bolinder Strand and owner of the majority of the area. The standards set by the public entities required that JM assess and remediate the soil before development. The two boat clubs, Kallhälls Boat Club and Piluddens Boat Club, operate right on the shoreline and are an industry which may pollute the soil and water if improperly managed. Bolinder Mechanical Workshop is also represented as a stakeholder, the industry which previously owned and operated significant manufacturing on the site. While they are not a current actor, they contributed significant pollution which is now considered “historical pollution”. Finally, we have the current business owners who operate in the area.

Contractors were identified as the intersection of public and private. Various consultancies are private companies which have been highly involved at Bolinder Strand through contracted work by the municipality. SWECO is listed here as they were one of the interviewees and here represent consultancies in general, however other consultancies such as WSP were more commonly employed to conduct surveys and remediation throughout the development of Bolinder Strand. SGI is a research institute and therefore a governmental body, their involvement in the case of Bolinder Strand would be as a contractor to conduct surveys of the site, which would put them at the intersection of public/private.

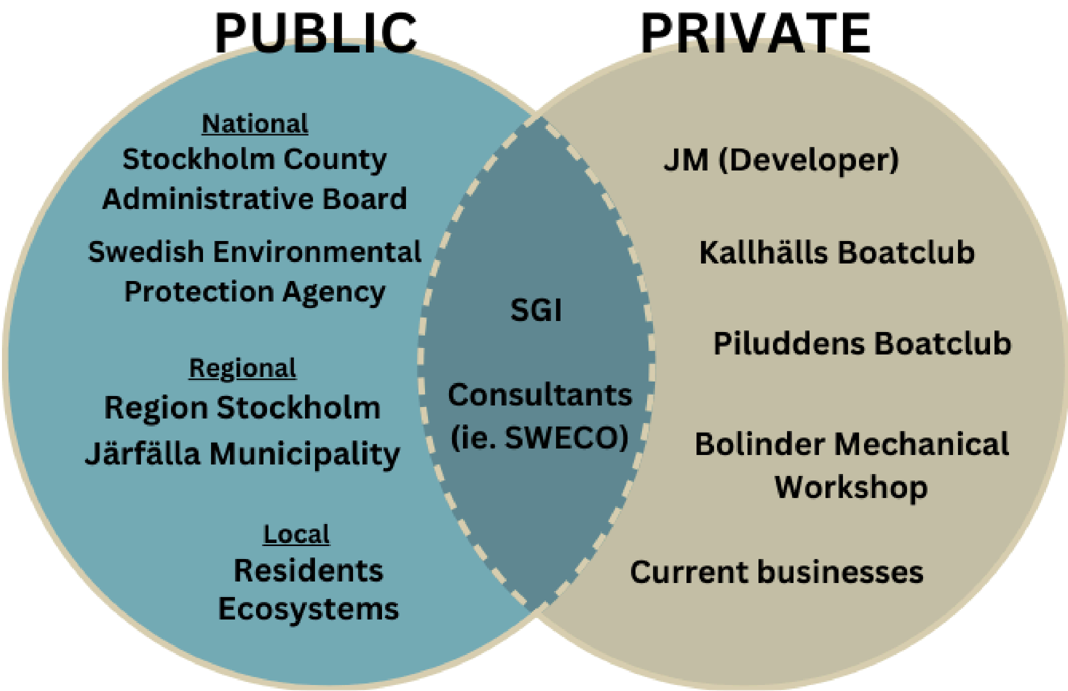

Figure 4. Mapping of actors related to soil at Bolinder Strand, separated by public and private entities.

To get a better understanding of the stakeholders roles and interests related to soil contamination it is useful to consider their power and interest levels. In this case power refers to the power to influence soil contamination levels and how soil is managed. Interest refers to how important soil contamination is to the actor and how it impacts them. A summary of results are listed in Table 2. These results are largely based on information gained from interviews and include a level of assumption regarding certain stakeholders interests, this should be considered to be an interpretation by the authors.

Those with high interest and high power levels are The Stockholm County Administrative Board and SEPA, as they are the ones setting expectations regarding soil management. Since they create these standards at a national level, the state of soil pollution overall is of high importance to them, however a specific site such as Bolinder Strand may be too specific to be of importance. Järfälla municipality also has high interest and high power levels as they are the ones who are meant to carry out these recommendations at the municipal level. Local soil contamination is of very high importance to the municipality as it impacts land-use options and can potentially have public health implications. The municipality manages soil contamination by contracting assessments and enforcing assessment and remediation before development. The most involved actor, JM, is also very concerned with soil pollution. The rules for soil management from the national level agencies cascade down to municipalities and ultimately fall on the developer to assess and remediate if they want to develop. JM is therefore where the funding is coming from to remediate soil, giving them the most direct power as, if the developer decides a site will be too costly to remediate they could also pull the project leaving the site to stay polluted. Finally, SGI can be considered to be within this category of high power and high interest, however their relationship may be more removed. As an entity, SGI conducts research to strengthen geotechnical knowledge to inform government agencies and support efficient construction work (SGI, n.d.). They conduct significant research on soil pollution and remediation and management which should ideally be a powerful voice to shape relevant government policy. However, their direct interest in Bolinder Strand would only be related to if they were contracted to conduct assessments.

Several actors may be considered to have a high level of power but low level of interest. For example, private land-owners such as the two boat clubs in Bolinder Strand would likely not be concerned with soil contamination if not required by government bodies. To exemplify this, Källhälls boat club environmental policy states that "it is important we do not increase [pollutant] levels [...] as we would be required to clean up our harbour plan and, in the worst case, our harbour basin" (Kallhäll miljöpolicy, 2021, translated). They were considered to still have power because the municipality itself cannot remediate on private land and it would therefore fall to the boat clubs themselves to remediate the soil. The municipality can put pressure on them but ultimately cannot step in further. Region Stockholm falls into the same category as, while they are a government body that technically has jurisdiction here, Bolinder Strand is likely too specific of a site for them to be concerned with.

On the other hand there are actors who are assumed to have high interest in the state of soil pollution but a low level of power to influence it. This includes the involved consultants, as they are likely interested in properly assessing and remediating soil to the best of their abilities but are limited to do exactly what is contracted of them for which seems to be highly dependent on budget and scope of the project. This section also includes residents and ecosystems as they are the actors as they will bear the brunt of any repercussions relating to soil contamination. The only actor in the case of Bolinder Strand not considered to have any power or interest in soil contamination is current businesses as they are unlikely to cause damage or be impacted by soil pollution. Bolinder Mechanical Workshop is a special case as they are no longer an active stakeholder even if they did contribute significantly to soil contamination levels.

Table 2. Summary of key actors, their level and method of influence, including assumed interest level.

Actor	**Level of Influence**	**Method of Influence**	**Assumed Interest Level**
The Stockholm County Administrative Board	National	Setting soil contamination standards and mandating management. Based on suggestions by SEPA.	Interest in soil contamination at a higher scale than Bolinder Strand.
The Swedish Environmental Protection Agency	National	Helping the Administrative Board set standards on soil contamination.	Interest in soil contamination at a higher scale than Bolinder Strand.
Region Stockholm	Regional	A general role overseeing the region.	No specific interest in soil contamination at Bolinder Strand.
Järfälla municipality	Regional	Responsible for meeting standards set by the Administrative Board and SEPA through the contracting of assessments.	High interest level as local soil contamination can impact how land can be used.
Residents	Local	No influence.	Interest in soil contamination in relation to human health.
Ecosystems	Local	No influence.	Very high interest as soil pollution can cause significant ecosystem degradation.
Consultants (i.e. SWECO)	Local	Contracted by the municipality or developers. Only able to do what is asked of them.	Likely interested in more fully assessing and remediating soil than what contracts demand.
SGI	National and local	Overall have a high influence on soil management by furthering research and making recommendations. Locally a lower level of power acting as contractors.	Interested in soil contamination at a broader scale and interest in Bolinder Strand through contracting.
JM	Local	In terms of Bolinder Strand JM has a high amount of power as they are the owners and the ones who remediated the area before development.	Their interest level is very high as soil needs to be to a certain standard for them to be allowed to develop.
Boat clubs, Kallhäll and Piluddens	Local	Power levels are high due to being on private land and they are operations which may contribute significant soil pollution.	Interest levels are low as they would not like to be made to remediate their soil.
Bolinder Mechanical Workshop	Local	Their power only comes from the historical influence of pollution.	N/A
Current Businesses	Local	No power.	No interest.

4.2 Contaminants

To understand the most suitable remediation techniques for Bolinder Strand, the first step is to have knowledge of the contaminants that are present in the soil. Based on the literature reviews and the interviews conducted, the findings are a large variation of contaminants - a “cocktail mix”. This variation of contaminants can vary from one assessed area to another area within Bolinder Strand (JM, 2001). Information in this section comes mainly from archival documents retrieved from the Stockholm County Administrative Board (See Appendix B).

4.2.1 Historical contaminants

In Table 3, all of the contaminants are shown which have been measured and found in Bolinder Strand from pre-development i.e. assessments done around 2000 and 2001. The table shows the contaminants that have been found in different locations in Bolinder Strand which are above acceptable levels; the concentrations found of the compounds differ between these sites. This indicates a large variation of contaminants within Bolinder Strand, and the importance of understanding the soil health to know what risks and impacts these contaminants can have. Also, there are indications of oil contaminants in both the ground and in the groundwater in certain areas assessed (J&W Energi och Miljö, 2001b). Figure 6 illustrates the site specific areas where these contaminants have been found.

Several contaminants have been found which have concentration levels that are above threshold values from the SEPA as indicated by Table 3. The threshold values are determined depending on what land use is proposed to be in the area (J&W Energi och Miljö, 2001b). “Sensitive Land Use”, short SLU (in Swedish “Känslig markanvändning”, KM) and “Less Sensitive Land Use”, short LSLU (in Swedish “Mindre känslig markanvändning”, MKM) is described by SEPA (2024b) and are used in the documents from the Stockholm County Administrative Board regarding Bolinder Strand (See Appendix B). These two categories described threshold values of contaminant concentrations that are allowable for the soil to have depending on what the land will be used for (SEPA, 2024b). The term SLU refers to threshold values appropriate for an area which will be used for example as a playground or a neighbourhood, while LSLU refers to an area used for offices or industries (SEPA, 2023b). From a risk assessment conducted in Bolinder Strand by J&W Energi and Miljö (2001a), describe how the marine area is assessed as a LSLU area and the measures are therefore compared to threshold values for LSLU. Another example, from a more recent assessment done in Bolinder Strand also states an area used for gardens and parking are compared to LSLU values (Bjerking, 2021).

Table 3. Contaminants found in Bolinder Strand pre-development, if the concentration levels are above "Sensitive Land Use" (SLU) and/or "Less Sensitive Land Use" (LSLU), where the contaminants have been found and references. See Appendix B for references and more information about documents.

Contaminants	Concentration above SLU	Concentration above LSLU	Location	References
Aliphatics oil hydrocarbons		X	Marine area	J&W Energi och Miljö, 2001a
Arsenic	X		Marine area	J&W Energi och Miljö, 2001a
Cadmium	X		House A8	J&W Energi och Miljö, 2001b
Chromium	X	X	Marine area Area for industries and boat harbor	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Cobalt	X		Marine area House A8	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Copper	X	X	Marine area Area for industries and boat harbor Entrégården	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Lead	X	X	Marine area Area for industries and boat harbor Entrégården	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Nickel	X		Marine area House A8 Kajen and Lilla Torget	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Polyaromatic hydrocarbons (PAH)	X	X	Marine area Area for industries and boat harbor	J&W Energi och Miljö, 2001a J&W Energi och Miljö, 2001b
Vanadium	X		Kajen and Lilla Torget	J&W Energi och Miljö, 2001a
Zinc	X	X	Area for industries and boat harbor	J&W Energi och Miljö, 2001b

Figure 6. Contaminants map of Bolinder Strand from 2001, pre-remediation and development. (Illustration Bolinder Strand (JM, 2011) adapted by the authors).

4.2.2 Current contaminants

Due to ongoing developments for 20 years in the Bolinder Strand area, the most current assessments of contaminants are shown in Table 4 and Figure 7, and are from the years 2020 and 2022. These four contaminants were highlighted as they were found on land owned by JM, there are several other contaminants thought to be found in the marine area. A lack of documentation makes the problem of the marine area soil unclear but the four contaminants shown are relevant in both. However, these assessments were conducted due to findings of a container which contained traces of oil (Bjerking, 2021) and findings of chlorinated hydrocarbons in a building (Wescon miljökonsult, 2020). The container was located underneath a street, and when Bjerking assessed the risk of spreading of contaminants, there were no contaminants of high concentration levels that constituted a risk (Bjerking, 2021), however, contaminants with higher concentrations were found in the soil which had been in contact with the container (Järfälla, 2022). No recent documents assessing the soil pollution levels of Bolinder Strand more generally have been published, only very site specific cases such as this. This suggests that no large-scale assessment was conducted after the first pre-development assessment. See Appendix B for document list.

Table 4. Contaminants found in Bolinder Strand in the later part of development i.e. around year 2020-2022 including indications if the concentration levels are above "Sensitive Land Use" (SLU) and/or "Less Sensitive Land Use" (LSLU), including references. See Appendix B for references and more information about documents.

Contaminants	**Concentration above SLU**	**Concentration above LSLU**	**Location**	**Measure**	**References**
Aliphatic compounds	X	X	Birger Dahlerus väg	Excavation	Järfälla, 2022
Aromatic compounds	X	X	Birger Dahlerus väg	Excavation	Järfälla, 2022
Copper	X	X	Birger Dahlerus väg	Excavation	Järfälla, 2022
Polyaromatic hydrocarbons (PAH)	X	X	Birger Dahlerus väg Godsv. / Fabriksv.	Excavation	Järfälla, 2022 Järfälla, 2020

Since more recent documentation has not been conducted on the area as a whole there is no guarantee that it is entirely free of the contaminants originally discovered. While dig and dump is an effective method, soil specialists interviewed cited the release of bound pollutants during excavation which becomes mixed together (Interview with soil specialist at SGI, 2024). Additionally, remediated areas are only those areas which have been developed, meaning that the boat club areas have done no remediation due to continued activity (JM, 2001). Areas directly adjacent to developments also likely struggle with very similar pollutants and have received no remediation, making historical pollution an important consideration even today.

CURRENT CONTAMINANTS BOLINDER STRAND

Figure 7. Current contaminants map of Bolinder Strand, post-remediation and development. (Illustration Bolinder Strand (JM, 2011) adapted by the authors).

4.3 Available remediation techniques

Understanding the contaminants present in soil is crucial for selecting appropriate remediation techniques, however, this process is often complex (Lee et al., 2024). Contaminated soil frequently consists of a combination of substances that co-exist and can interfere with one another during remediation, making it challenging to address them simultaneously. Another challenge lies in the adsorptive behavior of contaminants, which refers to their tendency to attach to the surfaces of soil particles. This property enhances their ability to bind strongly to the soil, making them less mobile and more difficult to separate or extract. Contaminants can also impact soil biology, such as microbial populations and organic matter, potentially reducing the effectiveness of remediation efforts (Zabbey et al., 2017 referenced in Lee et al., 2024). Given these complexities, assessing and predicting suitable remediation methods remains a significant challenge.

Documents from the County Administrative Board indicate that the primary remediation method used is excavation and disposal (See Appendix B). This approach involves the mechanical removal of contaminated soil or waste from the subsurface, typically carried out using equipment such as excavators or backhoes and transporting it to an approved off-site treatment or disposal facility (Båtbranschens riksförbund, 2023). Excavation and disposal are the current standard methods for remediating contaminated areas, proven to be reliable and often delivering effective results. However this method also removes all living organisms, placing them in landfills where most can't survive. The soil is then usually replaced with sterile crushed rock. Although excavation and disposal is the main method used in Bolinder Strand, other methods do still exist (see Table 5). The physical methods involve using methods to either trap contaminants in place (immobilize them) or physically remove them from the soil or sediment (Thomé et al., 2019). One such method that falls under this category is soil washing, which separates soil particles based on their contamination levels, allowing cleaner fractions to be reused while heavily contaminated portions are treated or disposed of.

Chemical methods for soil remediation involve reactions that transform contaminants into less harmful or more stable forms (Thomé et al., 2019). These methods work by chemically breaking down, neutralizing, or binding contaminants. Stabilization and solidification techniques use materials like clay or cement to bind contaminants, reducing their mobility and preventing leaching into groundwater. Chemical oxidation, on the other hand, employs oxidizing agents like hydrogen peroxide to break down harmful substances into less toxic compounds. Thermal treatment involves heating contaminated soil to high temperatures to vaporize or destroy pollutants, particularly organic contaminants (Båtbranschens riksförbund, 2023). While effective, this method requires significant energy and can produce byproducts, making it more suitable for specific cases where alternative methods are less effective. Bioremediation employs living organisms such as microbes, fungi, or plants to degrade or absorb contaminants (Finnegan et al., 2018). This environmentally friendly approach is less invasive and helps preserve the natural structure and biodiversity of the soil. However, it is a slower process and may be more effective for moderate contamination levels.

Table 5. Description of remediation techniques, its estimated cost and efficiency. Including, references consulted.

Method	**Description**	**Cost**	**Efficiency**	**Reference**
Bioremediation	Use of microbes, plants, or fungi.	Low cost	Effective for contamination by petroleum hydrocarbons, chlorinated solvents, chlorophenols and a range of other organic pollutants.	Lee et al., 2024 Swedish Geotechnical Society, n.d.
Chemical oxidation	Oxidizing agents to break down contaminants into less harmful forms.	High cost	Effective for treating persistent contaminants in soil. Particularly good for petroleum contamination and much more effective if done with other techniques.	Lee et al., 2024 Wei et al., 2022
Excavation and Disposal	Soil is excavated and transported to a landfill disposal or further treatment.	Cost varies	Common and easiest method, removes anything present in the top layer.	Swedish Geotechnical Society, n.d.
Soil washing	Separation into different fractions using screens. To wet screening water is added to help separate the smaller particles from the larger ones.	Moderate cost	Effectively treats soils containing a wide-range of contaminants including volatile organic compounds (VOCs), SVOCs, fuels, inorganics, radionuclides, and munitions constituents.	Lee et al., 2024 FRTR, n.d.
Solidification	Encapsulation with binding agents (like cement) to create a solid structure.	Cost varies	Suitable for persistent and non-volatile organic pollutants such as PCBs, PAHs and halogenated pesticides.	Swedish Geotechnical Society, n.d.
Stabilization	Binding agents (like clay or activated carbon) mixed with soil to reduce mobility and leaching potential.	Cost varies	Suitable for persistent and non-volatile organic pollutants such as PCBs, PAHs and halogenated pesticides.	Swedish Geotechnical Society, n.d.
Thermal treatment	Heating the soil to high temperatures to break down or vaporize contaminants.	High cost	Suitable for contamination by chlorinated solvents. The method is also applicable to the treatment of other easily volatile groups of contaminants and solvents.	Lee et al., 2024 Swedish Geotechnical Society, n.d.

4.4 Contaminant specific remediation techniques

Generally, contaminated soils are often excavated, dug up, moved to new locations, and stored in landfills. However, this method is not ideal because it simply shifts the problem to a different place, leaving the contamination for future generations to deal with, rather than providing a permanent solution (Kuppusamy et al., 2017). Since most remediation technologies are tailored to specific site conditions, selecting the appropriate method is a challenging yet critical step in successfully remediating a contaminated site (Khan et al., 2004). While numerous technologies exist for treating contaminated areas, the choice of method is influenced by factors such as the nature of the contaminants, site characteristics, regulatory requirements, costs, and time limitations. Given the analysis of available methods and the specific conditions in Bolinder Strand, a potential recommendation knowing the contaminants are copper, polyaromatic hydrocarbons (PAH) and aromatic compounds and aliphatics can be made (see Table 6).

For copper a range of remediation techniques can be used (SGF, 2023). Excavation is particularly suitable for high-concentration zones of copper contamination, as it allows for the physical removal of the impacted soil; it involves the direct removal or treatment of soil. However, excavation is often labor-intensive, costly, and requires significant resources (Apori, 2018). Bioremediation, specifically phytoremediation (where plants are used for absorbing, stabilizing, or breaking down pollutants through their roots and natural biological processes) are more suitable for addressing low to moderate levels of copper contamination over large areas (SGF, 2023). Phytoremediation is often more economical, environmentally friendly, and sustainable (Apori, 2018). Phytoremediation, while environmentally friendly, is a more time-intensive approach, requiring extended periods to yield significant results compared to physical or chemical methods. Consequently, if time constraints are a major concern, phytoremediation may not be the most practical choice for the area.

Alternative methods, such as soil washing and stabilization/solidification, are also effective for remediating copper-contaminated soil. Soil washing is particularly efficient at removing copper in sandy or granular soils, where contaminants can be physically separated. However, its effectiveness is heavily influenced by soil type, rendering it less suitable for fine-grained soils like clay or silt, where contaminants are more tightly bound. Given that the soil in Bolinder Strand primarily consists of clay, silt, and filling materials (SGU, n.d., accessed 2025-01-07), soil washing would likely be a less practical solution for the site. In contrast, stabilization and solidification methods are well-suited for immobilizing copper in soils like those found in Bolinder Strand. By mixing binding agents such as cement with the contaminated soil, these methods effectively encapsulate or chemically bind the copper, reducing its mobility and potential environmental risks. Stabilization and solidification techniques are often considered a viable option due to their potential to immobilize contaminants, thereby reducing mobility and minimizing the risk of leaching into nearby water bodies (Apori, 2018). This approach could be promising for areas like Bolinder Strand and its shoreline environments but is high in cost.

For polyaromatic hydrocarbons (PAH) there are several established remediation options, thermal conduction, solvent extraction/soil washing, chemical oxidation, and bioremediation (Kuppusamy et al., 2017). Remediation of PAH contaminated sites remains a great challenge due to soil heterogeneity. For instance, the rate of remediation could be either fast or slow depending on the soil types and related factors and at times ends up producing transformed compounds that are more toxic than the original parent PAHs. In-situ thermal desorption (ISTD) uses heat to physically separate PAHs from the soil, however no excavation is required and is considered to be relatively safe and emits little to no PAH compounds into the atmosphere (Kuppusamy et al., 2016d). Effectively the method separates PAHs from soil, preventing contaminants from spreading to nearby water bodies. However the method is energy intensive and costly and also requires specialized equipment and expertise and also less effective in soils with high clay and silt content, like those in Bolinder Strand.

Soil washing is another method mentioned by Kuppusamy et al. (2016) which uses liquids like water, organic solvents, or biodegradable substances (like vegetable oils or humic acids) to loosen and remove PAHs from the soil. Once the PAHs are separated into the liquid, the liquid is either treated further or safely disposed of. Chemical oxidation can also be used which aims to degrade PAHs after their reaction with an oxidant injected into the soil. Different types of oxidants have been investigated ranging from the more commonly used ozone and Fenton's reagent. One other treatment technology that has gained wide approval for the treatment of PAH contaminated soils is bioremediation which is considered to be safe, eco-friendly and economical without simply enacting the transfer to another medium. Although the above physical, chemical and biological treatments have been shown to be effective in treating PAHs, there are still limitations in applying them to remediate field soils. PAHs can be strongly bound to the soil matrix, which slows down their release into the liquid phase for treatment.

Various soil remediation techniques have been employed to address aromatic and aliphatic compounds, including soil washing (Gitipour et al., 2013) and bioremediation (Guirado et al., 2023). The study by Guirado et al. (2023) evaluated bioremediation treatments using bacteria, plants, and fungi, both individually and in combination, to clean soil contaminated with aromatic and aliphatic compounds. Each of these organisms played a unique role in breaking down the pollutants and performed much better than natural attenuation, which relies solely on the soil’s native microbes and natural processes to do the job. Bacteria, introduced into the soil through bioaugmentation, used specialized enzymes to break down hydrocarbons effectively. Plants, such as *Medicago sativa* (alfalfa), improved soil conditions by releasing nutrients through their roots, which fed the bacteria and enhanced their activity. Fungi, like *Pleurotus ostreatus*, produced powerful enzymes that broke down complex hydrocarbon molecules into smaller, easier-to-degrade components. When bacteria, plants, and fungi were used together, the results were most effective, reducing 48% of the aliphatic compounds and 35% of the aromatic compounds in the soil. However one major difficulty is that aromatic compounds, especially the heavier and more complex ones, are much harder to break down than aliphatic compounds. These compounds tend to stick tightly to soil particles and organic matter, making them less accessible to the microorganisms and enzymes responsible for degradation. Additionally, the effectiveness of bioremediation depends heavily on the specific conditions of the contaminated site. Factors like soil texture, nutrient availability, pH, and temperature can vary widely, which can make results inconsistent and unpredictable. In order to proceed with bioremediation further testing regarding soil texture, nutrient availability, pH etc. would need to be done in Bolinder Strand. Ultimately Guirado et al. (2023) that the combined use of bacteria, fungi, and plants is the most effective approach, but it also requires significant resources and careful management. Maintaining optimal conditions for all three components over an extended period is necessary for success, which can make the process resource-intensive and time-consuming. Bioremediation could be a viable option for addressing aromatic and aliphatic compounds at Bolinder Strand. However, it would need to be carefully evaluated against alternative methods, weighing the benefits of its environmentally friendly but time-intensive and monitoring-dependent (requires careful monitoring to maintain optimal conditions for microbial activity (e.g., pH, temperature, and nutrient availability).

Gitipour et al. (2013) found soil washing to be effective, using a washing solution containing sodium dodecyl sulfate (SDS), to clean aromatic and aliphatic contaminants in soil. SDS works by breaking down and mobilizing hydrocarbon compounds, enabling their separation from soil particles. When the contaminated soil is mixed with this solution, larger particles, such as sand and gravel, which have less surface area and lower compound retention, are cleaned more effectively. In contrast, finer particles such as clay and silt tend to have higher surface areas and stronger binding to hydrocarbon compounds, making them more likely to retain pollutants and necessitating additional treatment or safe disposal for effective remediation. Given that the soil in Bolinder Strand predominantly consists of clay, silt, and filling materials (SGU, n.d., accessed 2025-01-07), soil washing may prove to be a less practical option due to the soil composition, as previously mentioned. Under optimal conditions, soil washing has demonstrated the ability to remove over 90% of hydrocarbon compounds from sand and gravel, showcasing its effectiveness (Gitipour et al., 2013. Some other limitations are also that the process generates secondary waste, including wastewater containing extracted compounds, which must be treated to prevent environmental pollution. Additionally, the fine particles that retain hydrocarbon compounds after washing often require further remediation or safe disposal.

Table 6. Possible remediation techniques for specific contaminants found in Bolinder Strand.

Contaminant	**Possible remediation techniques**
Copper	Excavation Bioremediation Soil washing Stabilization and solidification
Polyaromatic hydrocarbons (PAH)	Bioremediation Thermal conduction Solvent extraction/soil washing Chemical oxidation

Aromatic compounds (aromatic hydrocarbons)	Soil washing Bioremediation
Aliphatic compounds (aliphatic oil hydrocarbons)	Soil washing Bioremediation

5. Discussion

5.1 Found contaminants, effects and remediation

If the contaminants located at Bolinder Strand were to make their way into Mälaren it could have several negative consequences. This research has shown that heavy metals are the most problematic contaminants at the site with a variation of metals present, where specifically copper has been found in high concentrations (See Table 3 and 4). Copper is an important trace metal in soil but excessive amounts lead to ecotoxicity which is particularly harmful to soil bacteria (Wang et al., 2024). In water copper becomes bioavailable to plants and can bioaccumulate through the food chain to a level that becomes toxic to humans. If copper is present in drinking water it can also have negative impacts for people, which is a notable concern since Norrvatten drinking water source is nearby in Mälaren. In addition, several contaminants are found in the boat club areas, but there is no updated data since 2001. The uncertainty around the state of the soil in these areas is a significant consideration as pollutants are even more likely to enter lake Mälaren. When considering how best to address this issue using soil remediation techniques, it becomes clear that there is no easy solution (See Table 6). The soil contains several contaminants and what remediates one problem might make others arise. These techniques are often quite expensive with uncertain success rates, making it difficult for municipalities to expand their arsenal (See Table 5).

5.2 Stakeholders and soil policies

Another issue is the variation of stakeholders (Figure 4). Even if soil remediation was a straightforward task, it faces significant political and economic roadblocks. Soil is starting to gain recognition as an important environmental issue and groups like the Stockholm County Administrative Board, the SEPA and Järfälla municipality may have standards for soil but it can be difficult to enforce on private land. New EU directives on soil contamination also put pressure on municipalities to deal with a problem that is unclear how to solve (European Commission, n.d., accessed 2024-11-27). However, the biggest barrier to addressing soil contamination seems to be the financial aspect. As mentioned, soil remediation is a very expensive task, it requires hiring consultancies for sampling and testing on top of the actual cost of remediation. The only time there is enough money available to test and remediate soil is when there are development projects that are obliged to remediate the land to be granted building permits from the municipality (Interview with environmental inspector from Järfälla, 2024). This suggests that the actual state of soil health is not known in most areas and can only be speculated by considering what activities had been there previously.

Finding data about previously assessed sites is not straightforward either, while the data is technically available, it is hard to find and comes in the form of many separate documents from consultancies, as well as decisions from the municipality and reports from companies. There are standards for how soil should actually be assessed but since several consultancies might test the same site there are no documentation standards and the information is not compiled somewhere easily accessible. From the experience of collecting and reviewing documents from Stockholm County Administrative Board regarding Bolinder Strand, the documents are challenging to fully understand and interpret due to differences in the report framework, some documents are standalones as well as included as attachments in other documents. This also has required a mapping of what has been done already and what sites have not been assessed for soil contaminations.

5.3 Remediation techniques for Bolinder Strand

These factors combined make it apparent why excavation is the most commonly employed technique for remediation (and is what was used by JM when remediating Bolinder Strand), as it removes everything (See Appendix B). However, this technique is not cheap either and the soil is replaced with sterile dirt that is lacking in the necessary microbial diversity to provide ecosystem services (Liu, Y. et al., 2023). Finding new ways to tackle soil contamination will likely become a critical challenge in the coming years both in terms of remediation techniques as well as through policy, management and funding.

5.4 Limitations

The limitations with this study origins from the complexity of managing and understanding soil contaminations in specifically Bolinder Strand. The history of activities in the area, as mentioned previously, makes this both an interesting and challenging area to study and leads to limitations. Firstly, information of soil assessments and materials are tricky to find and when accessing the documents, the challenge has been to make sense and understand the different documents. The documents are from different years, going back to the early 2000s and are structured in different ways depending on the authors of the reports. Also, some documents were duplicates (i.e. occurred twice in the retrieved folder from Stockholm Administrative Board), only with different file names which was understood after reviewing all the documents and written notes of what each document was about. This is touched on in section 5.2. and describes one of the main challenges and limitations of studying soil contamination in Bolinder Strand.

Secondly, studying soil contaminations in-depth requires a lot of knowledge about soil, contaminants, effects and geology, to mention some examples. Interviews with experts on soil, remediation techniques and soil contaminations were conducted which was great to gain a better understanding of this topic. However, a limitation with the interviews was that we did not have the possibility to interview certain actors involved in Bolinder Strand such as JM or the local boat clubs located in the area. This is a limitation because these actors' knowledge and information on this topic is lacking in this report, thereby requiring an additional level of assumption.

6. Recommendations

From the results, improvements can be done in managing contaminated areas. Due to this, three themes of recommendations - *Policy*, *General management* and *Data availability* - are proposed to support Järfälla municipality with managing and addressing soil contaminated areas.

6.1 Policy

6.1.1 Recurring assessments

Shoreline soils near any development should be assessed every 5 years for contaminants regardless of future development plans, as well as every 2 years for boat clubs. Since shoreline areas are such a high risk, random samples near shoreline development should be taken on a rolling basis to measure the degradation of soil and alert about possible unsustainable contamination levels. This would allow Järfälla municipality to comply with the new EU policy on soil health and monitoring which requires this level of investigation (European Union Law, 2023). Boat clubs are known to be a polluting industry and should therefore be tested more often to ensure compliance with regulations. An increased surveillance may spur boat clubs to more proactively take care of their soils.

Relevant Actors: Järfälla municipality, consultant companies, developers, boat clubs. In line with current practice, these assessments would be mandated and enforced by the municipality where it would be up to developers and boat clubs to hire consultant companies to conduct soil assessments.

6.1.2 Follow-up assessments

Test for soil contaminants after developments are completed. Assessments and remediation are mainly done as a prerequisite to development, but additional tests should be done once developments are completed. This is due to contaminants emitted during site development. Elements captured in soil are released from excavation and emissions from machinery are likely to impact the area.

Relevant Actors: Järfälla municipality, consultant companies and development companies. This would be mandated and enforced by the municipality, requiring developers to contract consultants post-construction.

6.2 General Management

6.2.1 Remediation techniques

Low-effort, low-budget remediation techniques should be incorporated into standard urban landscaping practices. Bioremediation is a good example of a low-budget remediation technique, plants that are able to uptake soil pollution can be planted in problematic areas. Other considerations such as promoting shoreline wetlands could be explored for managing terrestrial pollution in water bodies. Finally, the addition of microbial rich soils to parks and planters could improve soil diversity, increasing the soil's ability to process pollutants and perform other ecosystem services.

Relevant Actors: Järfälla municipality, landscaping companies, developers. This recommendation would fall under the jurisdiction of the urban planning and environmental departments who would have the jurisdiction to plan for these types of urban landscape practices. Landscaping companies who have been hired by the municipality or developers should therefore follow the same guidelines.

6.2.2 Novel techniques

Try out more novel techniques. Research on soil remediation is ongoing and new techniques are being tested by researchers and consultants. Järfälla municipality could benefit from testing new remediation techniques in smaller areas which may prove to be more efficient and environmentally conscious than excavation. However, the success rates of novel techniques are often uncertain, and an unsuccessful trial could incur additional costs, as the area would need to be remediated again. Given the municipality's current financial constraints and that they are cutting funding for sustainability projects (Lindstedt, 2025), one recommendation could be partnering with researchers, which could open opportunities for grant funding, enabling remediation of contaminated soils that are not currently earmarked for development or to explore whether other municipalities have successfully implemented novel remediation methods that could be relevant for Järfälla as well.

Relevant Actors: Järfälla municipality, consultants, researchers. This recommendation requires more partnership with current research, such as SGI, to inform about which new techniques would be the most appropriate for different cases. Similarly, consultancies may have similar suggestions about novel techniques. Potential partnerships between municipal government and research could provide funding for testing novel techniques.

6.3 Data Availability

6.3.1 Database

Create a database which compiles documents and data about soil pollution levels from consultancy assessments. The documents from assessments are technically available but difficult to access. In order to make more informed decisions about soil health and remediation it is important that this information can be readily accessed. This could be done not just for Bolinder Strand but for Järfälla municipality as a whole and could convey when assessments were conducted, by whom and what pollutants were found. This could also promote more standardisation of assessments by having more transparency about methodology between different assessments.

Relevant Actors: Järfälla municipality, consultancies. This task would fall to the municipal government to consolidate data from previous consultancies and make it accessible and comprehensible.

6.4 Steps forward

The starting point of the identified recommendations could be to firstly understand the current situation of conducted assessments and collect the information in a systematic way i.e. addressing recommendation *Data availability.* Secondly, low-budget techniques could be added into land management and landscaping practices to preserve soil health in urban environments as this would not require a large investment; recommendation *three*. Once these have been done Järfälla municipality could focus on policy recommendation *one* to start rolling assessments of shoreline areas to comply with the EU directive. Policy recommendation *two* of testing after developments are completed could be adopted and only be required for the completion of future developments. Recommendation *four* of trying new techniques does not have a timeline but should be considered when appropriate.

7. Conclusion

Documentation about Bolinder Strand considers the site to be fully remediated and "completed" according to records. However, the area is still listed as a location of high concern due to the boat clubs, historical pollution from industry and proximity to the shoreline. The information gathered during this process has highlighted a problem that is very complex to understand and equally difficult to address.

Soil is an entire ecosystem of organic and inorganic materials and contains a myriad of life-forms. If we want to preserve the ecosystem services of soil it is crucial that soil be kept in good health in all areas, including urban spaces. The several recommendations which have been identified could help work towards healthier soils and make pollution less transferrable into water bodies. These span policy, general management and data availability and relevant actors were highlighted who may be the most relevant to include in the adoption of these recommendations. The complexity of actors and their different levels of power and interest does not make the problem easier to solve, especially considering the price tag of remediation.

To conclude, soil contamination is extremely complex to address and work with, due to the variation - "cocktail" - of contaminants that exist, and the question of how to manage the pollutants in an effective way is not straightforward. Additionally, to know which techniques or methods are the best suited is also complex, because a variation of techniques exist with varying efficiencies. However, based on the analysis there are several interesting techniques that exist for soil remediation, even though excavation and disposal is still the most common method used and is the only technique employed in the remediation of Bolinder Strand, Järfälla municipality. The development of Bolinder Strand has been going on for two decades, and assessments and sampling of soil contaminations has been done in sections and by different consultancies. As can be seen from these results, soil contamination has likely changed over time from general degradation and continued use. General soil health calls for more attention in planning that values the ecosystem services it provides and can extend outside of remediation techniques. It is the hope of the authors that this report can provide some inspiration for further research and policy planning that can help Järfälla municipality meet their sustainability goals.

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Appendix

A. Literature from literature reviews

Here is a limited list of literature used in the literature reviews.

A1. Scientific literature reviewed

Evans, C. V., Fanning, D. S., & Short, J. R. (2015). Human-Influenced Soils. In R. B. Brown, J. Herbert Huddleston, & J. L. Anderson (Eds.), Agronomy Monographs (pp. 33–67). American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. DOI: https://doi.org/10.2134/agronmonogr39.c2

Greinert, A. (2015). The heterogeneity of urban soils in the light of their properties. *Journal of Soils and Sediments, 15*(8), 1725–1737. DOI: https://doi.org/10.1007/s11368-014-1054-6

Lejon, D. P. H., Martins, J. M. F., Lévêque, J., Spadini, L., Pascault, N., Landry, D., Milloux, M.-J., Nowak, V., Chaussod, R., & Ranjard, L. (2008). Copper Dynamics and Impact on Microbial Communities in Soils of Variable Organic Status. *Environmental Science & Technology, 42*(8), 2819–2825. DOI: https://doi.org/10.1021/es071652r

Li, G., Sun, G. ‐X., Ren, Y., Luo, X. ‐S., & Zhu, Y. ‐G. (2018). Urban soil and human health: A review. *European Journal of Soil Science*, *69*(1), 196–215. DOI: https://doi.org/10.1111/ejss.12518

Setälä, H., Francini, G., Allen, J. A., Jumpponen, A., Hui, N., & Kotze, D. J. (2017). Urban parks provide ecosystem services by retaining metals and nutrients in soils. *Environmental Pollution, 231*, 451–461. DOI: https://doi.org/10.1016/j.envpol.2017.08.010

Rodrigues, S. M., Pereira, M. E., Ferreira da Silva, E., Hursthouse, A. S., & Duarte, A. C. (2009). A review of regulatory decisions for environmental protection: Part I – Challenges in the implementation of national soil policies. *Environment International, 35*, 202-213. DOI: 10.1016/j.envint.2008.08.007.

A2. General policy documents reviewed

A2.1 Governmental documents

Sveriges riksdag. (1998, June 11). *Miljöbalk (1998:808)*. [online] URL: https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808/#K1 [Accessed 2024-10-17]

A2.2 Municipal documents

Järfälla Miljö- och bygglovsnämnden. (2020, December 17). *5.1 Bilaga 1, Handlingsplan: Handlingsplan för tillsyn av förorenande områden. Järfälla Kommun*. [online] URL: https://www.jarfalla.se/kommunochpolitik/politikochnamnder/namnder/miljoochbygglovsnamnden/miljoochbygglovsnamndenshandlingar2020/miljoochbygglovsnamnden20201215.4.21ac32b3176338e02e1afc4.html [Accessed 2024-10-17]

A2.3 Organizational documents

European Commission. (n.d-a). *Soil health*. [online] URL: https://environment.ec.europa.eu/topics/soil-and-land/soil-health_en [Accessed 2024-11-27].

European Union Law. (2023). *Document 52023PC0416, Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Soil Monitoring and Resilience (Soil Monitoring Law), COM/2023/416 final.* Article 8. [online] URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0416&qid=1706624227744

JM. (2001, October 15). *Översiktlig strategi för hantering av markföroreningsproblem - i olika delar av Bolindersområdet, Kallhäll* (Rapport ID 124611), [Retrieved from email contact with Länsstyrelsen Stockholm 2024-11-12 (stockholm@lansstyrelsen.se) when requesting documents of the Bolinder strand area ”EBH-object with id 124611”].

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B. Literature review of document from Stockholm County Administrative Board

Table B1. Documents reviewed from Stockholm County Administrative Board when requesting documents related to Bolinder Strand with ID "EBH-object with id 124611" through email contact with stockholm@lansstyreslsen.se).

File name	Date	Title	Author(s)	Dnr	Description	Location	Contaminants tested	High concentration of contaminants	Remediation techniques
Karta_01230009	2004	F d Bolinders Mekaniska verkstäder, Järfälla kommun	Stockholm County Administrative Board, Lantmäteriet, SGU		Maps over Bolinder Strand, includes map over soil types				
Del av detaljplaneprogram, Id 124611, 1999-05-21	5/21/1999	Ärendeblankett: Program för Kallhäll 1:22 (Bolinder Strand) P 8/98 K i Järfälla	Stockholm County Administrative Board		Form that aims to give reasons to develop close to Lake Mälaren in Bolinder Strand, includes a map and brief information of the contamination situation.	Bolinder Strand			
Riskbedömning och förslag till riktvärden, Id 124611, 2001-01-22	1/22/2001	Bolinder Strand, Kallhäll, Järfälla kommun - Fördjupad riskbedömning och förslag till platsspecifika riktvärden för föroreningar i mark	J&W Energi och Miljö	Jns 2000 46	Risk assessment of soil contaminations and guidelines for concentrations Note, not for the marine area	Bolinder Strand	Oil hydrocarbons Metals	Polycyclic Aromatic Hydrocarbons (PAH), Copper, Lead, Zinc and Chromium above LSLU in an area planned for industry activities and boat harbor. Cadmium, Cobalt and Nickel above SLU under house A8. Nickel and Vanadium above SLU in area Kajen and Lilla Torget. Copper and Lead above LSLU in the area Entrégården.	
Miljöteknisk undersökning marinaområdet, Id 124611, 2001-02-05	2/5/2001	Järfälla kommun, Bolinder strand, Kallhäll - Miljöteknisk undersökning för marina-området	J&W Energi och Miljö	2001 428	Environmental technical report of assessments done between Marsh 1999 and December 2000 with focus on testing metals and oil hydrocarbons.	Marine area Fabriksvägen, Hus J	Oil hydrocarbons Metals		

Efterbehandlings-strategi, Id 124611, 2001-10-15	10/15/2001	Översiktlig strategi för hantering av markförorenings- problem - i olika delar av Bolindersområdet, Kallhäll	JM		Document shortly explaining the measures taken or needed for specific sites with contaminations.	Seven locations in Bolinder Strand are assessed regarding site specific strategy			
Riskbedömning och förslag till riktvärden Marinaområdet, Id 124611, 2001-11-07	11/7/2001	Bolinder Strand, Kallhäll, Järfälla kommun: Marina-området - Fördjupad riskbedömning och förslag till platsspecifika riktvärden för föreningar i mark	J&W Energi och Miljö	2001 428	Risk assessment of the marine area, including background information regarding the contaminations, current and planned activities in the area, soil conditions and groundwater assessments. The document further includes assessments of the risk of the contaminants towards the environment and human health in which the author presents possible threshold values and different classifications.	Marine area		Lead, Copper, Chromium, Zinc, oil hydrocarbons and PAH above LSLU. Arsenic, Chromium and Nickel above SLU.	Excavation
Sammanfattning miljötekniska undersökningar, Id 124611, 2001-11-07	11/7/2001	Bolinder Strand, Kallhäll, Marina-området - Sammanfattning av utförda miljötekniska markundersökningar	J&W Energi och Miljö	2001 428	A summary of the soil examination done in the Marine area in 2001. These examinations were done to map the conditions before future development of the area. The examinations were done mostly around Hus L where there was a former "paint shop".	Marine area Property 1:22	VOC, metals, aliphatics and aromatic compounds	Lead, Chromium, Zinc, Copper, Iron, Oil, Aliphatic oil hydrocarbons and PAH above LSLU.	
PM Schaktarbeten, Id 124611, 2001-11-29	11/29/2001	PM angående hantering av förorenad jord i samband med schaktarbeten inom Marinaområdet i Kallhäll	JM		Information about the excavation work in the marine area, and how to deal with the contaminated soil. Guideline to follow in terms of the work.	Marine area		PAH, Lead, Copper, Nickel and Zinc above SLU.	

Anmälan om schaktarbeten, Id 124611, 2002-05-31	5/31/2002	Anmälan enligt miljöbalken avseende schaktarbeten i förorenad mark inom Marinaområdet, Bolinder Strand	Järfälla municipality	Mhn 2001 428	Decisions and terms from Järfälla municipality to JM which needs to be followed. This includes a summary of the background, future activities in the area, found contaminants and appendix with additional information.	Marine area		Contaminants have been find in several sampling sites, here is a summary of the contaminants find overall (more details on p. 5): Lead, Chromium, Zinc, Copper and PAHs above LSLU. Aliphatic hydrocarbons.	
Beslut om schaktarbeten, Id 124611, 2002-06-11	6/11/2002	Sammanträdesprotokoll: Anmälan enligt miljöbalken avseende schaktarbeten i förorenad mark inom Marinaområdet, Bolinder Strand	Järfälla municipality	18415-2 002-761	The document states Järfälla municipality "Miljö och bygglovsnämnd" decisions and regulations of which JM needs to comply with and follow according to the Environmental Code.	Marina area			Excavation
Anmälan avveckling verksamhet, Id 124611, 2003-02-10	2/10/2003	Anmälan om avveckling av verksamhet	Järfälla municipality	2003 07	Notification of liquidation of operations				Excavation
Avveckling av verksamhet, Id 124611, 2003-02-18	2/18/2003	Delegationsbeslut: Avveckling av verksamheten, Kallhälls Industrilackering AB på Fabriksvägen A 18 i Järfälla	Järfälla municipality	Mhn 2003 007	Measures to be taken by Kallhälls Inudstrilackering AB when closing the business in accordance with the Environmental Code as described and decided by Järfälla municipality.	Fabriksvägen A 18	Samples from the concrete to be done: AOX Aliphatic hydrocarbons Aromatic hydrocarbons Chromium (Cr) Lead (Pb) Zinc (Zn) Nickel (Ni) Cadmium (Cd) Copper (Cu)		

Slutrapport nedläggning, Id 124611, 2003-06-26	6/26/2003	Slutrapport från Kallhälls Industrilackering AB:s nedläggning/avflyttning från Fabriksvägen A 18, Järfälla kommun	WSP	2003 7	Report about the move / closing of the "paint shop". The document goes through the different measures done in the area. The document includes the "bilagor" that belongs to the document report.	Fabriksvägen A18	Samples from the concrete: AOX, alifatiska hydrocarbons, aromatiska hydrocarbons, Chromium, Lead, Zinc, Nickel, Cadmium, Copper		Excavation
Markundersökning ritning, Id 124611, 2004-01-22	1/22/2004		WSP		Map of soil assessment				
Provtagning, Id 124611, 2004-01-22	1/22/2004		WSP		Statistics and map over sample testing and sites.	Around house C			
Anmälan om användning av hus, Id 124611, 2004-03-26	3/26/2004	Anmälan om användning av hus C2-C3 för JM AB, Bolinder Strand i Järfälla	Järfälla municipality	Mhn 2003-00 0604	Järfälla municipality's decision of the report from JM regarding use of two buildings. The municipality does not require any measures to be taken by JM.	Building C2 - C3			
Översiktlig miljöteknisk undersökning sydväst om hus B, Id 124611, 2004-07-06	7/6/2004	Sydväst om Hus B, Bolinder Strand, Järfälla kommun - Översiktlig miljöteknisk undersökning av mark	WSP	2004 706	An environmental technical soil assessment of the area southwest of house B. Include lab results from the analysis of soil samples. However, it is difficult to interpret the results in detail.	Southeast of House B	Several compounds and contaminants were tested. Difficult to interpret the lab results.		
Revidering av undersökning sydväst om Hus B, Id 124611, 2004-09-14	9/14/2004	Undersökningsresultat för området sydväst om hus B, Bolinder Strand - komplettering	JM	2004 706	Complementary material from JM, including maps.	Area south-west of house B	Aliphatic C16-C35 above SLU		Systematic assessments of the soil - Sampling Excavation

Översiktlig Miljöteknisk Undersökning Hus B, Id 124611, 2004-09-20	9/20/2004	Hus B, Bolinder Strand, Järfälla kommun - Översiktlig miljöteknisk undersökning	WSP	2004 706	Environmental technical soil assessment of house B in Bolinder Strand showed contamination in two sites within the building.	House B	As, Arsenic Cd, Cadmium Co, Cobalt Cr, Chromium Cu, Copper Hg, Mercury Mn, Manganese Ni, Nickel Pb, Lead Vn, Vanadium Zn, Zinc Aliphatic compounds Aromatic compounds PAH	PAH, Hg and Ni above SLU	No measures are necessary
Miljöteknisk provtagning Kajen, Id 124611, 2006-02-28	2/28/2006	Bolinder Strand, Kajen, Järfälla kommun - Miljöteknisk provtagning	WSP	2005 581	Environmental technical sampling conducted in the area Kajen to map contaminants present in the soil. Includes information of the activities in the area, threshold values and land use activities, and recommended measures.	Kajen		PAHc and aliphatic compound found above SLU. Arsenic (2.4LSLU), Lead (3.7LSLU), Copper (1.4LSLU), Vanadium (1.25 LSLU) and Zinc (2.8LSLU) above SLU and LSLU.	
Anmälan om schaktning Kajen, Id 124611, 2006-05-22	5/22/2006	Anmälan avseende schaktning i förorenade massor inom kv. Kajen, del 2 (etapp 4-5), Bolindersområdet Järfälla kommun - enligt Miljöbalken 20§ Förordningen om miljöfarlig verksamhet och hälsoskydd	JM	2005 581	Reporting of excavation work when developing a new housing area in Bolinder Strand. However, part of the excavation work is conducted in soil that is contaminated.	Kv Kajen, part 2 (phase 4-5)			

Svar på slutrapport, Id 124611, 2007-11-22	11/22/2007	Slutrapport om markarbeten inom kv. Kajen, etapp 2 inom Bolindersområdet, Fabriksvägen, förorenad mark	Järfälla municipality	Mbn 2007 1341 (Mhn 2005-58 1)	Short final report of the remediation work done within kv. Kajen.	kv. Kajen Etapp 2 Fabriksvägen			
Översiktlig MMU, Id 124611, 2008-02-25	2/25/2008	Kallhäll 1:36, Entrégården - Bolinder, Översiktlig miljöteknisk markundersökning	Bjerking		An environmental technical soil assessment of Entrégården in Järfälla to give understanding of the contaminant in this area. The analysis of the soil was compared to the "Sensitive Land Use" thresholds values provided by SEPA. A summary of the assessments and results are presented and the reports from the contamination analysis.	Kallhäll 1:36 Entrégården Bolinder	Aliphatics Aromatic hydrocarbons PAH As, Arsenic Cd, Cadmium Co, Cobalt Cr, Chromium Cu, Copper Hg, Mercury Ni, Nickel Pb, Led V, Vanadium Zn, Zinc	Aliphatics (110 mg/kg Ts), Cu, PAH (0,42 mg/kg Ts, and 0,33 and 0,62 and 0,37), As (19 mg/kg Ts), Cu (170 mg/kg Ts and 210), Ni (45 mg/kg Ts), Cd (2,6), Pb (180) above SLU.	
Anmälan om efterbehandling Entrétorget-Entrégråden, Id 124611, 2008-05-23	5/23/2008	Delegeringsbeslut: Anmälan om efterbehandling och schaktarbeten enligt miljöbalken 28§, Entrétorget och Entrégården - Bolinderområdet i Järfälla, Bolinder Strand	Järfälla municipality	577-2008-45471	Järfälla municipality's decision regarding JM's report regarding excavation work and post-treatment. The municipality do not require any measures to be conducted by JM.	Entrétorget and Entrégården		Contaminants found with high concentration - Is not clear what elements.	Mentioned previous excavation done, and this describes a follow up measurement of the air quality.
MMU, Id 124611, 2009-09-09	9/9/2009	Markundersökniong vid Bolider Strand, Järfälla	ÅF Consult			Bolinder Terrassen			

PM markundersökning, Bolinderterrassen, Id 124611, 2009-09-09	9/9/2009	Markundersökning vid Bolider Strand, Järfälla	ÅF Consult		Soil examination and results, incl. map. Soil samples were taken from five sites within the area called Bolinderterrassen to gain understanding of the contaminants present.	Bolinder Terrassen	Alifatiska hydrocarbons Aromatic hydrocarbons PAH As, Arsenic Pb, Lead Cd, Cadmium Co, Cobolt Cu, Copper Cr, Chromium Ni, Nickel V, Vanadium Zn, Zinc	Cd (1.0), Cu (91), Pb (280), Zn (440) and PAH (6,6 and 4,4) above SLU.	
Illustrationsbild, Id 124611, 2011-06-10	6/10/2011	Illustration Bolinder Strand	JM		Map over Bolinder Strand				
Bolinder Port, översiktlig miljöteknisk markundersökning, Id 124611, 2012-09-27	9/27/2012	Bolinder Port, Järfälla kommun - Översiktlig miljöteknisk markundersökning	Bjerking		An overall environmental assessment of Bolinder Port due to new housing development at this site, and because soil contamination have been found in other areas in Bolinder Strand it is important to determine if there are contaminants present in Bolinder Port.	Bolinder Port	As, Arsenic Ba, Barium Pb, Lead Ca, Cadmium Co, Cobolt Cu, Copper Cr, Chromium Hg, Mercury Ni, Nickel Zn, Zinc V, Vanadium PAHs Aliphatic compounds Aromatic compounds		

Miljöteknisk markundersökning, Id 124611, 2015-01-23	1/23/2015	PM Miljöteknisk markundersökning - Kv Smedjan, Bolinder Strand, Järfälla kommun	Bjerking		Soil assessment conducted to determine if the soil contains contaminants, including groundwater samples were taken.	Kv Smedjan	As, Arsenic Ba, Barium Pb, Lead Cd, Cadmium Co, Cobalt Cu,Copper Cr, Chromium Ni, Nickel V, Vanadium Zn, Zinc Chlorinated solvents PAH Cyanid Hydrocarbons: Aliphatics, Aromatics, Bensen, toluen, etylbensen and xylen	Cu, Pb, Zn, Aliphatics, Co, and Ni above SLU Cu also above LSLU.	
Anmälan om efterbehandling, Id 124611, 2015-05-19	5/19/2015	Anmälan om efterbehandling och schaktarbeten enligt miljöbalken 28 § förordningen om miljöfarlig verksamhet och hälsoskydd för kv Smedjan - Bolinderområdet i Järfälla	JM		JM's report to Järfälla municipality to be able to start excavation work, where information about measures to comply with, risk of contaminants found and control measures are stated.	kv Smedjan (Kallhäll 1:22)		Zinc (Zn) and Copper (Cu). Chlorinated hydrocarbons in a pipe for groundwater	
PM Porluft, Id 124611, 2015-05-19	5/19/2015	PM Porluft - Kv Smedjan, Bolinder Strand, Järfälla kommun	Bjerking		Information about samples done from the air in the soil ("porluft") to gain understanding of present chlorinated hydrocarbons and the risk of spreading.	Kv. Smedjan	Chlorinated hydrocarbons	Two types of chlorinated hydrocarbons are above the threshold values for "low risk level" in one of the sample sites.	

Ritning entre, Id 124611, 2015-05-19	5/19/2015	Kv Smedjan, Bolinder Strand, Järfälla - Plan 10-11, Entréplan -1tr	JM		Detail plan	Kv. Smedjan			
Ritning, Id 124611, 2015-05-19	5/19/2015	Kv Smedjan, Bolinder Strand - Järfälla, Markplaneringsplan	JM		"Land planning plan"	Kv. Smedjan			
Föreläggande om sanering, Id 124611, 2015-06-02	6/2/2015	Delegeringsbeslut: Föreläggande om sanering vid förorenad mark, JM AB, Bolinder strand, kvarter C, Kallhäll 1:22	Järfälla municipality	577-789 -2015	Järfälla municipality "Miljö och bygglovsnämnd" - decisions on what measures need to be taken by JM, threshold values to compare with and decisions to comply with.	Block C			Excavation was proposed
PM - Bedömning schaktbotten, kv Smedjan, Id 124611, 2015-07-09	7/9/2015	PM Bedömning schaktbotten - Kv Smedjan, Bolinder Strand, Järfälla kommun	Bjerking		The consultancy bjerking conducted soil samples to determine if chlorinated hydrocarbons were present at the bottom and on the sides of an excavation site.	Kv. Smedjan	Chlorinated hydrocarbons		
Slutrapport - Bilaga 1, Id 124611, 2015-11-27	11/27/2015	Slutrapport - Sanering Kv Smedjan, Bolinder Strand, Järfälla kommun	Bjerking		Report of the sanitation work done. The report includes a detailed description of how the excavations were conducted.	Kv Smedjan	Chlorinated hydrocarbon, metals incl. oil contaminants in the area.		
Slutrapport - Bilaga 2 Id 124611, 2015-11-30	11/30/2015	Bilaga 2 - Mottagna massor Ragn-Sells Högbytorp			Excel sheet of transported amount of soil and invoice from this.	Smedjan / Gjutmästare Rosbergs väg			
Slutrapport - Bilaga 3, Id 124611, 2015-11-30	11/30/2015	Bilaga 3			Additional information to a report which include invoices from removal and transport of soil	Fabriksvägen			Excavation
Slutrapport, Id 124611, 2015-11-30	11/30/2015	Slutrapport - Marksanering vid kv Smedjan, område C, Bolinder strand, Järfälla kommun.	JM		Soil sanitation report	Kv. Smedjan Område C		Metals over SLU Chlorinated hydrocarbons	

PM Porluft, Id 124611, 2016-08-30	8/30/2016	PM Analys av porluft i mark - Område A, Bolinder Strand, Järfälla kommun	Bjerking		Report of analysis of the air in the soil ("porluft") to determine the risk of chlorinated hydrocarbons and the concentration in the area.	Area A	Chlorinated hydrocarbons		
Kontrollmätning inomhusluft - Bilaga 3, Id 124611, 2016-11-08	11/8/2016	Rapport - Analys av luft	ALS Scandinavia AB		Measurements of the indoor air quality	Lgh 11005 Lgh 11004 Lgh 11003			
Kontrollmätning inomhusluft, Id 124611, 2016-11-08	11/8/2016	Kontrollmätning av klorerade kolväten inomhus i trapphus 1, vid kv Smedjan, Bolinder Strand			Measurements to determine if chlorinated hydrocarbons were found in indoor air, samples taken from three apartments on the bottom floor were taken.	Lgh 11005 Lgh 11004 Lgh 11003	Chlorinated hydrocarbons		
Mifo, Id 124611, 2017-08-10	8/10/2017				Three forms with (A) administrative information, (B) Description of the activities and area, (C) Contamination levels, (D) Possibility of spreading, (E) Risk assessment, (F) Communication and attachments such as maps are available to share.				
Anmälan, Id 124611, 2017-10-17	10/17/2017	Efterbehandling av förorenat område	Järfälla municipality		Form of post-treatment of contaminated area	Gjutmästare Rosbergs väg 3, Hus A17, A18, A1			
MMU, Id 124611, 2017-11-30	11/30/2017	PM Miljöteknisk markundersökning - Bolinder Terrass, Bolinderområdet, Järfälla kommun	Bjerking			Bolinder Terrass			When excavation work is done - Assessments of the soil are necessary

MTU, Id 124611, 2017-11-30	11/30/2017	PM Miljöteknisk markundersökning - Bolinder Terrass, Bolinderområdet, Järfälla kommun	Bjerking		Assessments conducted in Bolinder Terrass to examine if the soil contains contaminants, and the concentration.	Bolinder Terrass	As, Arsenic Cd, Cadmium Co, Cobalt Cr, Chromium Cu, Copper Hg, Mercury Ba, Barium Ni, Nickel Pb, Lead V, Vanadium Zn, Zinc Aliphatic compounds Aromatic compounds PAH Chlorinated solvents	As, Pb, Cu, Zn and PAH above SLU. Cu and PAH above LSLU as well. Chlorinated hydrocarbons were found in two sample sites.	Excavation
Anmälan, Id 124611, 2017-12-01	12/1/2017	Efterbehandling av förorenat område	Järfälla municipality		Form of post-treatment of contaminated area	Gjutmästare Rosbergs väg 3			
Beslut om försiktighetsmått, Id 124611, 2018-01-08	1/8/2018	Delegeringsbeslut: Beslut om försiktighetsmått vid efterbehandling av förorenat område, JM AB, Gjutmästare Rosbergsväg 3	Järfälla municipality		Järfälla municipality's decision and stated measures to be taken by JM regarding post-treatment of the contaminated area of Gjutmästare Rosbergsväg 3 as precautionary measures.	Gjutmästare Rosbergsväg 3 (Kallhäll 1:22)		Arsenic, Lead, and Zinc above SLU. Copper and PAH above SLU and LSLU.	
Slutrapport, Id 124611, 2018-04-19	4/19/2018	Slutrapport - Efterbehandling, Bolinder Terrass, Bolinderområdet Järfälla kommun	Bjerking		Report of the sanitation work done in an area in Bolinder Strand. Excavations were done in several smaller areas (5x5m).	Bolinder Terrass	Metals PAH	Arsenic above SLU in a sample from one sampling site.	Propose excavation to manage the PAH contamination and fill with "clean" soil
Anmälan, Id 124611, 2020-03-18	3/18/2020	Efterbehandling av förorenat område	Järfälla municipality		Form of post-treatment of contaminated area	Godsvägen/Fabriksvägen, Kallhäll 1:36		PAH levels found - Not clear if its high/low concentration	Excavation

Miljöteknisk markundersökning, Id 124611, 2020-03-20	3/20/2020	Bolinders strand, PM - Miljöteknisk markundersökning - Resultatrapport	Wescon miljökonsult		Assessment conducted due to planning to implement geothermal heat in areas previously cleaned from chlorinated solvents.		BTEX, VOC, PAH, Aromatic compounds, Aliphatic compounds, PFAS		
Beslut om försiktighetsmått, Id 124611, 2020-04-08	4/8/2020	Delegeringsbeslut: Beslut om försiktighetsmått vid efterbehandling av förorenat område, Bolinder Entré, Kallhäll 1:36, Godsvägen/Fabriksvägen	Järfälla municipality		Description of the precautionary measures needed to be taken by JM after measures conducted to treat the contaminated area.	Kallhäll 1:36, Godsvägen/Fabriksvägen		PAH and Cobalt above SLU.	
Fördjupad riskbedömning, Id 124611, 2020-12-15	12/15/2020	Bolinder strand, Kallhäll - Fördjupad riskbedömning klorerade kolväten	Wescon Miljökonsult		The risk assessment is done to determine the risk of chlorinated hydrocarbons towards human health and the spreading of the contaminant to Lake Mälaren. This is due to previous findings of chlorinated hydrocarbons.	Kallhäll 1:22	Chlorinated hydrocarbons		
Slutrapport sanering, Id 124611, 2021-01-27	1/27/2021	Reviderad Slutrapport - Marksanering vid Bolinder Entré, Kallhäll 1:36, Godsv/Fabriksv i Järfälla.	JM		Revised report of ground sanitation	Bolinder Entré Kallhäll 1:36 Godsv/Farbiksv.	Asphalt residues found among contaminated levels		Excavation
Anmälan, Id 124611, 2021-06-09	6/9/2021	Anmälan om avhjälpandeåtgärd inom förorenat område	Järfälla municipality		Notification of remedial action within a contaminated area	Birger Dahlerus väg, Kallhäll 1:22		Oil above LSLU found underneath a tank. More info. in Appendix.	Excavation
MMU, Id 124611, 2021-10-07	10/7/2021	PM Miljöteknisk undersökning - Bolinder strand, Järfälla kommun	Bjerking		This environmental assessment was conducted after finding oil contaminants underneath a street and a parking lot in 2021, and the aim was to examine its extent and risks with the contamination.	Purple shape	Aliphatic compounds Aromatic hydrocarbons BTEX	No concentration levels above threshold values SLU or LSLU.	Excavation

Slutrapport, Id 124611, 2022-05-12	5/12/2022	Slutrapport Marksanering vid påträffad cistern, Birger Dahlerus väg, Kallhäll 1:22, i Järfälla	JM		Report from JM about the sanitation work done after finding a cistern with water.	Found cistern Birger Dahlerus väg Kallhäll 1:22	Oil contaminations (Aliphatics and aromatic compounds) above LSLU. Aliphatics, aromatic compounds and PAH above SLU.		
Svar på slutrapport, Id 124611, 2022-08-08	8/8/2022	Slutrapport för efterbehandlingsåtgärder, oljeförorenad jord kring påträffad markcistern, Birger Dahlerus väg, Järfälla	Järfälla municipality	Mbn 2021-913	Report that summarizes the method used for cleaning the ground after founding a ground cistern, including results from soil samples and examination.	Ground cistern Birger Dahlerus väg	PAH above SLU PAH, Aromatic compounds, Aliphatics compounds, Copper above LSLU.		Excavation
Analysrapport, Id 124611	no date		SGAB Analitica		Sampling results				Excavation

C. Interview questions

C1. Interview questions for SGI

1. What is your area of expertise/role at SGI?
2. What have been the most surprising things you have learned about soil contamination?
3. Have you worked specifically with shoreline areas or harbours in your research?
    a. If yes, how are these sites unique in their pollution and remediation techniques?
    b. Which of these contaminants is of greatest concern?
2. The report mentions some uncertainties and issues regarding soil sampling (First, studies often take only a few small individual samples. Since contamination levels can vary a lot in boat storage areas, this approach can create a lot of uncertainty about the actual contamination. Second, the samples usually come from a depth of 0-0.5 metres below the surface at a single point. This means that the sample might include both heavily contaminated soil and less contaminated soil. If the goal is to understand the most contaminated top layer, this method can give a false impression of the contamination levels).
    a. So how could one try to handle such uncertainties?
    b. So there are four remediation techniques for soil that are mentioned in the report. <u>What are the key considerations when determining the most appropriate remediation technique,</u> (cost-effectiveness, risk reduction)?
    c. In your experience, which remediation technique has proven to be the most effective in addressing soil contamination?
3. How do you deal with a mixture (a cocktail) of contaminants in the same site?
4. Are there any promising/interesting remediation techniques which are new in the field?
5. What do you consider to be the biggest barriers to properly managing soil pollution in terms of government policies and management? What changes would you like to see?
6. Any other points or reflections you would like to add? Or is there anything that we have missed or should think about in our project work?

C2. Interview questions for Järfälla municipality

Note, the interview was conducted in Swedish and the questions were there for in Swedish. A translation of the question is also presented here.

1. Hur ser din roll ut inom kommunen?
   What is your role in the municipality?

2. Vad är din erfarenhet av markföroreningar?
   What is your experience with soil contamination?

3. Vilka är de största hindren du har upplevt när du arbetat med markföroreningar?
   What are the biggest barriers that you experience when working with soil contaminations?

4. Järfälla har ett dokument som heter ”Handlingsplan för tillsyn av förorenade områden” från 2020 av Miljö- och bygglovsnämnden. Har du varit med och tagit fram dokumentet eller vet du någon som har arbetat specifikt med detta dokument, och som vi möjligtvis kan kontakta? *Järfälla has a document called "Handlingsplan för tillsyn av förorenade områden" from 2020 by Miljö- och bygglovsnämnden. Were you affiliated with this or do you know more specifically who has worked with that document and if we can contact them? Are you developing/working on a new plan for contaminated areas?*
   a. Utvecklar/arbetar ni på kommunen med en ny plan för förorenade områden?
      Is the municipality developing or working with a new plan for contaminated areas?
   b. Finns det resultat från dessa markundersökningar?
      Are there results from these soil assessments ?
   c. Hur ser processen ut för att genomföra detta dokument?
      What does the process of conducting this document look like?
   d. Hur följer denna handlingsplan upp de resultat och framsteg som gjorts?
      How are the results and progress of this management plan followed up?

5. Vet du om den historiska markföroreningarna vid Bolinder Strand? *What do you know about the history of soil contamination at Bolinder Strand?*
   a. Finns det dokument som beskriver vilka föroreningar som har hittats där vid bedömning av ett konsultföretag eller annat?
      Are there documents that detail what contaminants have been found there from the assessment of a consultancy or other?

   b. Har båtklubbarna varit effektiva med att rengöra skroven från giftig färg? (I enlighet med stadgarna att ha gjort detta senast 2021)
      Have the boat clubs been effective in cleaning the hulls of toxic paint? (As per the bylaw to have done this by 2021)

6. Vilka är vanliga marksaneringstekniker som du har arbetat med eller som du vet om?
   What are common soil remediation techniques that you consider in your position?
   a. Vilka föroreningar är svårast att rengöra och sanera?
      Which contaminants are most difficult to clean?
   b. Hur hanterar man en blandning av flera olika föroreningar i samma område?
      How do you deal with a mixture of pollutants in the same area?
   c. Om man väljer att inkapsla ett förorenat område, vet du om det finns någon form av uppföljning eller testning av området?
      If you select to include a contaminated area, do you know if there is any form of follow-up or testing of the area?

7. Hur arbetar Järfälla med frågor kring förorenade mark som är privatägda? Finns det någon form av tillsyn eller uppföljningar som sker även om det är privat mark?
   How does Järfälla work with questions concerning contaminated soil which is privately owned? Does there exist any form of supervision or follow-up if it is on private land?
   a. Blir det mer komplicerat när det finns flera olika markägare vid sanering av mark?
      Does it become more complicated when there are several different land owners when remediating an area?
8. Vilka åtgärder finns generellt sätt när det kommer till att skydda strandnära områden från föroreningar?
   From a general perspective, what measures exist to protect shoreline areas from contaminations?

9. Vet du vilka olika aktörer som vanligtvis är med i diskussioner kring markföroreningar samt sanering av dessa?
   Do you know what actors are commonly part of discussions about soil contaminations and remediation methods?

10. Har du något du vill tillägga eller tips på saker vi bör inkludera i vårt projekt?
    Do you have anything you would like to add or recommendations we should include in our project?

C3. Interview questions for SWECO

1. What is your area of expertise?
2. Have you worked with Järfälla before?
3. What are the most important considerations when assessing the contamination levels of sites?
4. Have you worked specifically with shoreline areas or harbours in your research?
    a. If yes, how are these sites unique in their pollution and remediation techniques?
2. Are there any promising/interesting remediation techniques which are new in the field?
3. How do you deal with a mixture of contaminants in the same site?
    a. Is it possible to ensure that efforts at remediation do not negatively impact other pollutants? Are there techniques that remove multiple pollutants?
    b. Can you tell us more about the complexities of remediating soil? Which pollutants are easiest/hardest to remove?