Annex 3

ARUP

European Bank for Reconstruction and Development

Šibenik Brownfield Urban Regeneration

Land Condition Appraisal

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Executive Summary

Arup has been engaged by the European Bank for Reconstruction and Development (EBRD) to prepare an appraisal of contamination and associated constraints to development at the Batižele site, a 22 hectare vacant former industrial site located on the coast to the north west of the urban centre of the City of Šibenik. This follows previous commissions undertaken by Arup in 2019 and 2020 to prepare a development strategy for the site and an initial contamination appraisal that recommended investigation to assess current conditions and reduce uncertainty in the remediation work required for development.

Arup's scope of work for this land condition appraisal was to design and manage the implementation of a suitable site investigation and to interpret the investigation data to give a better understanding of contamination distribution across the site and implications for future development, including the need for remediation and estimate of associated costs.

The scope of work was delivered in two stages. In Stage 1 three tasks were completed: review of additional desk study information; site visit to view current site condition, identify preferred exploratory hole locations and meet ground investigation contractors; and preparation of the specification for ground investigation and management of the ground investigation tendering process. In Stage 2 two tasks were completed: attendance on site during the site investigation and contract administration; and preparation of this land condition appraisal report.

The Batižele site has a long history of heavy industry, dating back to the 1890s when a carbide and fertilizer factory was developed. From the 1940s to 1990s the site was used for ferroalloy and graphite electrode production and operations ceased in the early 1990s, with dismantling and demolition of the buildings completed in 2002.

Remediation of land contamination was designed and implemented between 2007 and 2011 and is understood to have included extensive excavations and offsite disposal of contaminated soils. Independent validation of the remediation was undertaken in 2014 and supplemented in 2018 and concluded the site had been satisfactorily remediated except for the 'tar pit' and two areas requiring further material excavation and offsite removal. In 2018 the environmental regulator confirmed agreement with this conclusion. This remediation work has not been completed.

Since 2000 the site has been used for processing of silicomanganese slag and large stockpiles remain. The site has been used for informal waste disposal in the last decade, mainly construction waste with some domestic and commercial fly-tipped waste.

Following review of available data Arup defined a scope of site investigation to address key data gaps, particularly related to groundwater contamination and potential impact to the adjacent marine environment, and to improve the density of exploratory locations across the site.

In March 2023 the site investigation was completed comprising 8 trial pits, 5 boreholes, 7 marine sampling locations and a total of 34 soil, slag and marine sediment samples and 12 groundwater and seawater samples were analysed by an accredited laboratory.

Ground conditions were identified as made ground up to 9.7m thick overlying limestone bedrock. Made ground is absent along the eastern site boundary and is typically less than 2m thick across the southern part of the site. Made ground is thicker in the north west part of the site, typically exceeding 4m thick. During the investigation no visible or strongly odorous contamination was identified, except for suspected pieces of asbestos in two locations. Visible contamination is apparent at the location referred to as the 'tar pit', a concrete lined pit where cracks in the concrete are observed to seep tar.

Screening of the laboratory testing data against UK, Dutch and Croatian standards was undertaken to assess significance of contamination and inform the need for further remediation.

No soil contamination has been identified by the 2023 investigation that is so significant as to need excavation and offsite removal. However the presence of metals and polycyclic aromatic hydrocarbons (PAHs) mean the soil is unsuitable to remain exposed at the surface in a new development. Where not covered by buildings or hard cover, in soft landscaped areas, a layer of validated imported clean soil is necessary to prevent exposure of future site users to made ground soils.

Marine sediment sampling identified the presence of asbestos in samples from the northwest coast. In this area other anthropogenic material such as tyres and metal debris were observed. It is assumed these materials would be removed if this area is to developed as a beach and imported beach material placed. Excavated materials must be carefully managed as asbestos is potentially a risk if it is allowed to become airborne.

It is understood that the slag stockpiles will be removed from site and disposed of prior to development. The slag contains elevated metals and PAHs and, similar to other made ground soils, is unsuitable to remain exposed at the surface in a new development.

The groundwater screening assessment identified exceedances of the UK and Dutch Target Value screening criteria in all except one sample. However the Dutch Intervention Values are not exceeded in any groundwater sample and in summary low levels of groundwater contamination only are recorded. Seawater sampling identifies no contamination attributable to the site. Groundwater remediation is not required based on the available data.

As well as contamination, several other site-specific ground-related constraints will need to be considered in the design and construction of the future development and are likely to be addressed in conjunction with contamination. These other non-contamination related ground constraints include: obstructions such as massive concrete foundations, voids such as the furnace chambers; the 1200mm diameter stormwater drain; retaining walls; and steep slopes. Site levels should be designed with consideration of cut-fill balance to reduce costly offsite disposal.

Remediation tasks considered necessary for future development are:

- Offsite disposal of stockpiles of slag.
- Excavation and offsite disposal of the 'tar pit' and associated contaminated soils and validation testing.
- Excavation and offsite disposal of contaminated soil from two locations 'Between the old and new furnace chambers' and 'Between the main road and coast' and validation testing (required by environmental regulator).
- The investigations to date provide data across the site and no point sources of significant contamination except the 'tar pit' have been identified. However it is a large site with a complex industrial history and it is likely that during earthworks and construction localised contaminated soils will be encountered that have not been identified by investigations to date, related to local spills and releases. Remediation, most likely through excavation and offsite disposal of grossly contaminated soils (including visibly contaminated, tarry or oily, or highly odorous material), will be necessary and with appropriate validation of the works.
- Placement of a 600mm thick cover layer of validated clean soils to prevent exposure of made ground soil at surface in soft landscaped areas in private residential gardens and a 300mm thick cover layer in soft landscaping in publicly accessible areas.

A competent contractor should be employed to undertake the remediation works, capable of effectively managing the health & safety and environmental risks during site works such as associated with the presence of asbestos and gross contamination (such as associated with the 'tar pit'), the potential to encounter unforeseen hotspots of contamination and offsite disposal in accordance with Croatian waste regulations.

The remediation cost appraisal presented in the Arup 2020 report has been reviewed and updated based on the findings of the 2023 site investigation and other new information.

1. Introduction

1.1 Appointment

The City of Šibenik has identified Batižele, a vacant former industrial site 22 hectares in area, located on the coast to the north and west of the urban centre, as an asset with strong potential for strategic renewal and commercialisation. Batižele is co-owned by the City of Šibenik (CoŠ) and the Republic of Croatia (RoC).

In 2019 the European Bank for Reconstruction and Development (EBRD) engaged Arup to prepare a development strategy for the site, which was adopted by City of Šibenik in 2020. As part of the 2019 work Arup identified constraints to development associated with contamination and remediation works required and recommended further investigation to assess site condition and reduce uncertainty in the remediation work required for development.

In October 2022 Arup was appointed to design and manage the implementation of a suitable land condition survey, and to interpret the data to give a better understanding of the risks associated with current land condition and implications for future development, including the need for remediation.

The purpose of this report is to present a standalone land condition appraisal assessing contamination and ground conditions that present a potential constraint to development. The report describes the site investigation undertaken at the site, presents the interpretation of the data and identifies appropriate mitigation and associated cost estimates for future development.

1.2 Scope of work

The Arup scope of work has been delivered in two stages.

In Stage 1 three tasks were completed: review of additional relevant desk study information to understand the potential distribution of contamination at the site; site visit to view current site condition, identify preferred exploratory hole locations and meet site investigation contractors; and preparation of the specification for investigation and management of the investigation tendering process.

In Stage 2 two tasks were completed: attendance on site during the investigation and contract administration; and preparation of an interpretative report on contamination including recommended mitigation and estimated costs of remediation (this report).

1.3 Sources of information

The information sources utilised in the production of this report, include:

Observations from site:

- Observations from site walkover (November 2022) and observations from the site investigation (March 2023) and photos (Appendix A);

Previous study reports:

- Study of Organic Remediation of Residual Ingredients from Ferroalloy Production and Coal Graphite Products at TEF, Šibenik, ECOINA, 2002 and appendices. (Studija ekološke sanacije zaostalih sastojaka iz proizvodnje ferolegura i ugljeno grafitnih proizvoda TEF d.d. Šibenik, ECOINA, Zagreb, 2002 (+ PRILOZI)) [1].
- Environmental Impact Study for Targeted Intervention: Remediation of Remaining Remnants from Ferroalloy Production and Coal Graphite Electrodes, ECOINA, 2003 (Studija o utjecaju na okoliš ciljanog sadržaja za zahvat: Sanacija zaostalih ostataka iz proizvodnje ferolegura i ugljeno grafitnih elektroda TEF d.d. Šibenik, zaostalih nakon razgradnje proizvodnih postrojenja, ECOINA, 2003) [2].
- Site Rehabilitation of the former Electrode and Ferroalloy Factory in Šibenik, 2014, OIKON, 2014 (Izvješće o provedenom postupku sanacije lokacije bivše Tvornice elektroda i ferolegura u Šibeniku, Zagreb, OIKON, 2014) [3].
- Research Plan and Report on Implemented Works at the site of the former Electrode and Ferroalloy Factory, Šibenik, OIKON, 2018 (Plan Istraživanja I Izvješće o Provedenim Radovima, Lokacija bivše Tvornice elektroda i ferolegura, Šibenik, OIKON, 2018) [4].
- Site Status and Market Conditions: Šibenik Brownfield Urban Regeneration, Arup, 2019 *(Report A1) (p 96)* [5].
- Development Strategy Proposition: Šibenik Brownfield Urban Regeneration, Arup, 2020 *(Report B2.2) (p46)* [6].
- Action Plan and Implementation Priorities: Šibenik Brownfield Urban Regeneration, Arup, 2020 *(Report C2) (p32)* [7].

2023 Site investigation factual report and data:

- Environmental Ground Investigation and Laboratory Testing, Šibenik Brownfield Urban Regeneration, Former Factory of Electrodes and Ferroalloys site, Geotehnički Studio d.o.o., 2023 (Terenski i laboratorijski istražni radovi u svrhu utvrđivanja stanja okoliša, Urbana regeneracija brownfielda u Šibeniku, Područje bivše tvornice elektroda i ferolegura, Geotehnički Studio d.o.o., 2023) [8] (provided in Appendix C).

1.4 Use of report and limitations

This study presents an assessment of technical development constraints primarily related to ground conditions and brownfield characteristics.

This report has been prepared for and on behalf of the EBRD in response to their particular instructions. Except as provided in our agreement with EBRD, any other party using this information for any purpose whatsoever does so at their own risk and any duty of care to that party is excluded. Reasonable skill and care have been exercised within the timescale available and in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team by undertaking the assessment and preparing the report, it is possible that other ground contamination or conditions as yet undetected may exist and consequently reliance on this report must be limited accordingly.

2. Site description

2.1 Site location

The 22 hectare site is the former location of the Tvornica Elektroda i Ferolegura (TEF d.d.) factory for manufacture of electrodes and ferroalloys. It is located north west of the historic centre of the City of Šibenik, as shown in Figure 1 below. The site is located on the north bank of the River Krka estuary, a saline water body with very limited tidal range or response to flood conditions.

Figure 1 Boundary of site investigation

2.2 Site layout and current use

On 15th and 16th November 2022 the Arup team visited the site to observe conditions and inform planning of the site investigation. Photographs of the site to illustrate current site condition, from November 2022 (site visit) and March 2023 (site investigation) are included in Appendix A. Key features of the site are shown on Drawing 1.

The site is currently vacant. It is not securely fenced and is openly accessible to the public, in vehicles and on foot.

All industrial buildings from the former TEF factory dedicated to production of graphite electrodes and other products for use in the metals industry have been dismantled. Two large basements remain in the central east area, referred to as the furnace chambers, close to a smaller concrete structure referred to as the tar pit. Close to the chambers and the eastern site boundary are two entries into the limestone bedrock that access excavated cave-like void features.

Extensive areas of concrete hardstanding remain and in the southeast are used for public car parking. A large concrete jetty remains in the central part of the site.

Stockpiles of black slag are present across the site and particularly in the north and west. Remnant concrete structures such as water storage tanks and concrete bunkers used for slag processing remain.

Across large areas of the site construction waste (soil, gravel, concrete, tiles, wood, asphalt/tarmac) and a smaller quantity of commercial or domestic fly-tipped waste (plastic containers, packaging, shoes, clothes, electrical items) has been deposited.

Several small buildings remain within the site, the largest located in the far south of the site. Buildings are mostly in a poor state of repair.

The only significant utility known within the site is a stormwater drain (1,200mm diameter) that crosses the centre of the site and discharges west of the jetty.

Topographically the site is an extensive plateau. Limestone bedrock is at the surface in the eastern part of the site and is exposed indicating it has been cut along the eastern site boundary. Natural topography is likely to slope gently to the coast and variable thickness of fill has been placed in the west to create a level platform for factory construction. Placed fill is likely to be thickest in the natural valley feature (that has been filled) that extends inland from the bay north of the jetty.

3. Site history and previous remediation

3.1 Overview

The first recorded industrial development at the site was a small carbide factory in the 1890s. Carbide production expanded in the 1900s and 1910s and, with the addition of a cyanamide plant, became one of the first manufacturing plant in Europe for urea artificial fertilizer. In the 1920s, the plant was one of the largest sites in the world producing calcium carbide and cyanamide.

In response to the world economic crisis production decreased and the plant was then closed for several years in the 1930s. By the beginning of World War II, the site was re-opened as the TEF ferrous alloy production factory, processing manganese ore into ferromanganese, silicomanganese, silica gel, silicocalcium and ferromolybdenum. In the years following the end of the war, the plant was modernised to increase capacity and graphite electrode production was introduced at the site to respond to the requirements of the metal industry (steel, aluminium and other related industries). Production of carbon electrodes and ferroalloys for the steel and aluminium industries became increasingly important from the 1960s.

During the 1980s pressure to adopt more stringent environmental controls, particularly in relation to air pollution, adversely affected the facility. The factory finally closed in 1994 and over several years the facility was decommissioned. Dismantling and demolition of the buildings was completed in 2002. Since 2000s the western part of the site has used for an industrial operation comprising the crushing of slag to produce an aggregate for asphalt and concrete use. Reports estimated 800,000 tonnes of slag was originally present on site but this has been reduced significantly by the processing operations.

Available historical photographs and aerial images of the site are presented in Appendix B**Error! Reference source not found.**.

3.2 Historical sources of contamination

Three phases of site activities may have resulted in contamination at the site.

1890 to 1930s: Carbide and fertilizer plant

The main process comprised carbide chemistry activities, with production of calcium carbide, cyanamide, acetylenes and other carbide compounds. This process may have resulted in contamination of soils and groundwater with these compounds as well as nitrate, ammonia, and hydrocarbons associated with fuels, lubricating oils.

1940s – 1990s: TEF ferroalloy & graphite electrode production

Both ferroalloy and graphite electrode production release gas and dust containing phenol compounds, polycyclic aromatic hydrocarbons (PAHs) and benzene and acidic gaseous emissions containing sulphur dioxide and nitrogen dioxides.

Dust emissions may have led to widespread contamination of soils with these contaminants. In the early years of production process wastewater arising from graphite electrode production is understood to have been discharged into a soakaway, potentially resulting in contamination of soil and groundwater, in particular with PAHs, and possibly cyanides.

Other soil and groundwater contamination may have resulted from:

- Storage and use of raw ore and coke.
- Storage and transport of petroleum and coal products, including tar pits which may have led to direct contamination of groundwater.
- Fuel and diesel spills.
- Storage of ferromanganese slag.
- Demolition materials from site clearance with the potential for asbestos contamination.

Post-2000: Silicomanganese slag processing

The following sources of contamination were associated with slag processing:

- Stockpiles of silicomanganese slag.
- Disused fuel tanks and possible spills.
- Process water lagoons and associated wastewater management operations.
- Surface soil contamination with dusts arising from crushing operations.

3.3 Previous studies and remediation

3.3.1 2002-2003 Investigations and remediation options appraisal

The earliest reports on ground conditions at the site date from 2002 and 2003:

- Study of Organic Remediation of Residual Ingredients from Ferroalloy production and Graphite Products at TEF, Šibenik, ECOINA, September 2002 and appendices. (Studija ekološke sanacije zaostalih sastojaka iz proizvodnje ferolegura i ugljeno grafitnih proizvoda TEF d.d. Šibenik, ECOINA, Zagreb, 2002 (+ PRILOZI)) [1].
- Research works of drilling and laboratory tests in the area of disposed coal slag, ferromanganese slag and other types of waste at TEF, ECOINA, Zagreb, January 2003 (Izvješće o provedenim istražnim radovima bušenja i laboratorijskih ispitivanja na području odložene šljake ugljena, ferromanganske troske i drugih vrsta otpada na lokaciji TEF d.d. Šibenik, ECOINA, 2003) [9]
- Environmental Impact Study for Targeted Activity: Remediation of Remaining Remnants from Ferroalloy Production and Graphite Electrodes, ECOINA, December 2003 (Studija o utjecaju na okoliš ciljanog sadržaja za zahvat: Sanacija zaostalih ostataka iz proizvodnje ferolegura i ugljeno grafitnih elektroda “TEF d.d.” Šibenik, zaostalih nakon razgradnje proizvodnih postrojenja, ECOINA, 2003) [2].

The 2002 and 2003 reports provide a baseline study of the conditions of the site following decommissioning and clearance of most site buildings but before any remediation works were undertaken. The main previous contaminating activities are described and a remediation options appraisal for the areas of elevated contamination is presented.

3.3.2 2009-2011 Remediation works

Ground remediation works were designed and undertaken between 2007 and 2011. Several reports describe the proposed remediation:

- Environmental assessment at the location of the former electrode and ferroalloy factory in Šibenik with a program of additional investigative works, APO, Zagreb, 2006 (Procjena stanja okoliša na lokaciji bivše tvornice elektroda i ferolegura u Šibeniku s programom dodatnih istražnih radova, APO, Zagreb, 2006) [10].
- Environmental rehabilitation program of the former electrode and ferroalloy factory in Šibenik, APO, Zagreb, 2007 (Program sanacije okoliša bivše tvornice elektroda I ferolegura u Šibeniku, APO, Zagreb, 2007) [11].
- Amendment to the environmental rehabilitation program of the former electrode and ferroalloy factory in Šibenik, APO d.o.o., Zagreb, 2009 (Dopuna programa sanacije okoliša bivše tvornice elektroda i ferolegura u Šibeniku, APO d.o.o., Zagreb, 2009) [12].

The 2006 APO document was not available for review by Arup. The 2007 and 2009 reports were provided in May 2023. The 2007 report outlines the results of ground investigation and assessment of contamination at the site and the results are used to consider remediation options. The 2009 report provides an addendum to the 2007 remediation strategy which incorporates the results of additional intrusive investigation and remediation options appraisal.

Validation reports detailing the remediation works completed at the site do not appear to have been produced. However summary information is presented in later reports (Oikon, 2014 [3] and Oikon, 2018 [4]) indicating the following works were completed:

- Between 2009 and 2011 site clearance, soil remediation and removal of waste from site was undertaken. The works aimed to remove soils exceeding 40mg/kg total PAH (in accordance with Dutch criteria), with a project-specific criteria of 100mg/kg total PAH. Thermal treatment was proposed for the most contaminated soils (>1,000mg/kg) and it is understood 6,000m^3 of soil was thermally treated at a facility at Drniš. In addition non-hazardous waste was disposed of at Bikarac landfill.

From observation on site it is clear that large-scale excavation has taken place in the central southern part of the site (west of the furnace chambers), presumably part of the 2009-2011 remediation works.

3.4 Post-remediation condition

3.4.1 2014-2018 Validation of remediation works

Two reports have been reviewed that assess site condition and aim to validate the remediation works following the 2009-2011 remediation:

- Site Rehabilitation of the former Electrode and Ferroalloy Factory in Šibenik, 2014, OIKON, 2014 (Izvješće o provedenom postupku sanacije lokacije bivše Tvornice elektroda i ferolegura u Šibeniku, Zagreb, OIKON, 2014) [3].

- Research Plan and Report on Implemented Works at the site of the former Electrode and Ferroalloy Factory, Šibenik, OIKON, 2018 (Plan istraživanja i Izvješće o provedenim radovima, Lokacija bivše Tvornice elektroda i ferolegura, Šibenik, OIKON, 2018) [4].

The Oikon 2014 [3] report provides a review of the work carried out between 2007 and 2011 and includes testing of 12 near-surface soil samples collected in 2014 to validate the remediation works. Several locations are identified as exceeding the PAH threshold of 100mg/kg total PAH.

The Oikon 2018 [4] report presents additional soil validation testing (11 samples) in the locations of exceedances of the 2014 validation samples. It identifies three locations (see Figure 2) where remediation had not been achieved as proposed:

1. The tar pit;
2. 'Between the old and new furnace chambers';
3. 'Between the main road and coast'.

Oikon 2018 [4] recommends the following additional remediation is required and necessary to meet the standards agreed with the environmental regulator:

- Tar pit: 'It is recommended to empty the contents and remove the concrete construction of the tar pit (dimensions: 9 mx 7 m, depth 3 m, wall thickness 0.35 m). Excavation of a concrete structure can expect about 80m^3 of contaminated material, that is, the excavation of a tar pit will generate hazardous construction waste. Excavation of the soil southeast of the tar pit with an area of approx. 63 m^2' Oikon 2018 [4] identifies 80m^3 waste from the tar pit plus 63m^3 contaminated soil that is predominantly hazardous waste.

- Between the old and new chamber furnaces: Oikon 2018 [4] estimates 475m^3 soil contamination to be removed as likely non-hazardous waste.

- Between the main road and coast: This area did not have any failures of the PAH validation criteria but is an area identified as potentially contaminated soil due to previous waste disposal in this area. A volume of 5400m^3 requiring removal is estimated by Oikon.

Costs are estimated in Oikon 2018 [4] to remediate these three areas and to undertake sampling to inform waste disposal and validation sampling of the excavations.

The remediation works recommended by Oikon 2018 have not been completed.

Compared with good practice in the UK the number of validation samples collected (23 in total) for a site of this size is inadequate to confirm that all site soils (except the three locations) are suitable to remain exposed at surface in the future development.

Figure 2 Areas requiring additional contaminated soil removal to achieve regulator approval (red polygons) (from Oikon 2018)

3.4.2 Regulator response

Information provided by City of Šibenik indicates the remediation programme for the site, proposed by APO in 2007 and the amendment to the program from 2009 [12], was approved by the Croatian environmental regulator (Ministry of Environmental Protection and Energy, Directorate for Environmental Impact Assessment and Sustainable Waste Management). A letter from the regulator dated 16 April 2018 indicates the approval was still valid and the standards agreed in 2009 were still relevant. In 2018 Oikon [4] identified the following remaining remediation tasks as required by the regulator:

- Excavation of contaminated soil in 2 locations;
- Removal of the 'tar pit' and associated contaminated soil;
- Test and dispose of the waste produced (from the 2 locations and tar pit);
- Validation testing of remaining soil at the site (at the 2 locations and tar pit).

3.4.3 2016 Slag volume estimate

In December 2016 a calculation of the remaining volume of slag was undertaken by Geodetska Mjerenja doo based on comparison of survey data from 2016 and 2003 for the northern part of the site. The total remaining quantity estimated was 51,037m^3. The current volume of slag remaining has been reviewed as part of this study.

4. Recent site investigation

4.1 Background

Data is available from previous site investigation at the site, and is included in the following reports:

- Study of Organic Remediation of Residual Ingredients from Ferroalloy production and Coal Graphite Products at TEF, Šibenik, ECOINA, 2002 and appendices. (Studija ekološke sanacije zaostalih sastojaka iz proizvodnje ferolegura i ugljeno grafitnih proizvoda TEF d.d. Šibenik, ECOINA, Zagreb, 2002 (+ PRILOZI)) [1].
- Research works of drilling and laboratory tests in the area of disposed coal slag, ferromanganese slag and other types of waste at TEF, ECOINA, Zagreb, January 2003 (Izvješće o provedenim istražnim radovima bušenja i laboratorijskih ispitivanja na području odložene šljake ugljena, ferromanganske troske i drughih vrsta otpada na lokaciji TEF d.d. Šibenik, ECOINA, 2003) [9]

Additional shallow soil validation sampling was undertaken in 2014 and 2018 by Oikon [3][4]. The previous site investigation locations are shown in Drawing 2.

4.2 Rationale for additional site investigation

Significant data gaps and uncertainties in the available data were identified by Arup, as follows:

- The majority of available data on ground conditions at the site pre-dates the remediation works and is c.20 years old. Further investigation is needed to assess the current site condition.
- Very limited data on groundwater level and quality is available for the site. Groundwater is anticipated to flow towards and discharge along the coast and therefore contamination of groundwater has implications for future development along the coast, such as a new beach area.
- Similarly limited testing of marine water quality and marine sediment has been undertaken adjacent to the site. This has implications for future development along the coast, such as a new beach area.
- The 2014 and 2018 soil validation testing identified exceedances of the criteria agreed with the regulator and indicated further remediation work would be required. The 2014 and 2018 validation testing was very limited in number of samples and site coverage and therefore further soil testing is necessary to improve confidence in the conclusions.
- Large quantities of slag remain on the site. Additional testing is required to confirm the content and uniformity of material and inform waste disposal route.

To address these data gaps and uncertainties a scope of investigation was developed comprising:

- Trial pits to enable shallow soil sampling;
- Boreholes, installed with groundwater monitoring wells to enable groundwater sampling;
- Sampling from slag stockpiles;
- Sediment and seawater sampling from locations close to the coast;
- Laboratory testing of soil, groundwater, seawater, marine sediment and slag.

Arup produced a specification for the investigation and managed the tendering process on behalf of EBRD. The ground investigation contractor Geotehnički Studio d.o.o., Zagreb, was appointed by EBRD to undertake the work.

4.3 2023 Geotehnički Studio investigation

4.3.1 Summary

The scope of the investigation is summarised in Table 1.

Table 1: Investigation summary

Exploratory hole type	No.	Minimum depth (mbgl)	Maximum depth (mbgl)
Machine excavated trial pit	8	0.2	3.0
Rotary cored borehole	5	14.0	15.0
Slag sampling	4	0	0.3
Marine sediment and seawater sampling	7	0	0.3

Shallow obstructions and other constraints were encountered in several exploratory holes, which could not be completed at the originally intended locations. Alternative locations were identified, which were generally within 20m of the originally intended position.

All investigation locations were surveyed to provide accurate coordinates and surface elevation. A drawing showing the investigation locations is presented as Drawing 3.

Samples of soil, groundwater, seawater, marine sediment and slag were taken during the investigation. A summary of the soil and water samples taken during the period are presented in Table 2.

Table 2: Summary of samples

Sample type	Number of samples
Soil from trial pits	14
Soil from boreholes	9
Marine sediment	7
Slag	4
Groundwater	5
Seawater	7

4.3.2 Trial pits

Eight trial pits were created by mechanical excavator, as shown in Figure 3. Soil samples were taken near surface (0.1-0.2m depth) in all trial pits and a second sample between 0.25 and 2m depth. A third sample was taken in TP-8 only at 2.5 to 3.0m depth. Fourteen samples in total were collected from trial pits.

Figure 3 Excavation of trial pit TP-5

4.3.3 Boreholes and groundwater monitoring

The five boreholes were drilled using rotary coring technique, as shown in Figure 4. Up to three samples were collected from each borehole for laboratory analysis, depending on the thickness of superficial deposits encountered. Bedrock samples were not sampled for chemical testing.

Figure 4 Drilling at borehole BH-4

A monitoring well was installed in each borehole. A summary of the monitoring wells is presented in Table 3 and their locations are shown on Drawing 3.

Table 3: Monitoring well installations

Exploratory hole ID	Ground level (mASL)	Total borehole depth	Response zone depth (mbgl)		Measured groundwater level
			Top	Base	mASL
BH-1	12.806	14.0	11.0	13.0	0.231-0.391
BH-2	12.637	14.0	11.0	13.0	0.232-0.312
BH-3	11.772	14.0	11.0	13.0	0.222-1.122
BH-4	11.041	15.0	12.0	14.0	0.336-0.641
BH-5	12.545	14.0	11.0	13.0	4.080-5.945

Permanent headworks comprising a lockable steel cover, concreted in place, were constructed to protect each well, as shown in Figure 5.

Figure 5 Lockable steel cover at borehole BH-3

Approximately two weeks after completion of the monitoring well installations, a separate visit was conducted to monitor groundwater levels, purge and sample the wells. Well head water quality testing was undertaken for temperature, pH, electrical conductivity, dissolved oxygen and total dissolved solids.

4.3.4 Marine sediment and water sampling

Marine sediment and seawater sampling was undertaken by a diver operating from a small boat as shown in Figure 6.

The subsurface topography was identified by the diver as steeply sloping. Marine sediment samples were taken from the upper 10cm of marine sediment, beneath seawater of 3.5 to 7.5m depth. Seawater samples were taken from the same location at mid column depth, typically around 2m depth.

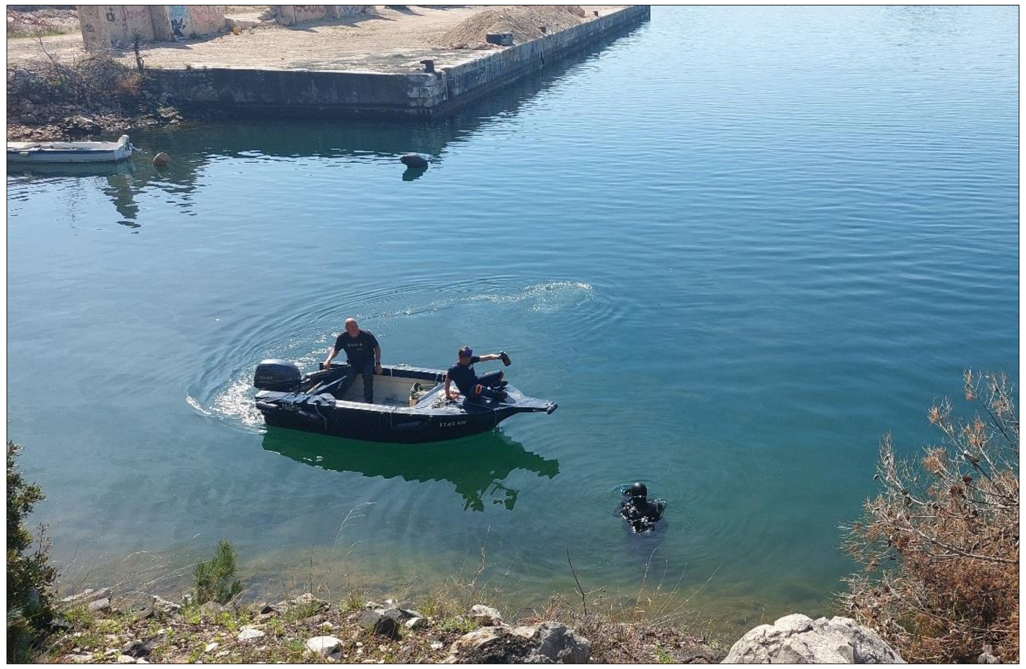

Figure 6 Marine sampling at location SEDIMENT-4

4.3.5 Slag

Samples of slag were collected from four locations across the site where a large stockpile of material is present, shown on Drawing 3. The mechanical excavator was used to excavate slag from 0.2m depth and a sample collected from the excavator bucket as shown in Figure 7.

Figure 7 Sampling slag from excavator bucket

4.3.6 Visible and olfactory evidence of contamination

During the 2023 investigation no odours or olfactory evidence of hydrocarbons, solvents or other organic contamination was recorded. The only evidence of contamination identified relates to suspected asbestos and to slag present in made ground, as shown in Table 4. Groundwater samples also showed no odour or sheen that would be indicative of contamination.

Table 4: Evidence of contamination recorded during 2023 investigation

Investigation location	Observation
TP-1	Suspected fragment of asbestos roofing material (recorded as 'salonite') 0.1-0.9m
TP-4	Suspected fragment of asbestos roofing material (recorded as 'salonite') 0-1.0m
TP-5	Slag 0-0.3m
TP-7	Slag 0-2.0m
TP-8	Slag 0-0.25m
BH-3	Slag in mixed made ground 0-4m
BH-4	Slag 0-0.3m, Slag in mixed made ground 0.3-1.6m
BH-5	Slag in mixed made ground 0-0.6m

4.3.7 Laboratory testing

The environmental chemical testing laboratories Hidro.Lab. d.o.o. and ALS Czech Republic s.r.o. were instructed by Geotehnički Studio to undertake laboratory testing of the samples, based on a testing schedule provided by Arup. The soil and water sampling test schedules are summarised in Table 5 and Table 6 respectively.

Table 5: Soil laboratory test schedule

Location ID		Sample Depth (m)	Sample Date	Inorganics	Cyanide	PAH	TPH	PCB	Asbestos
Trial Pits	TP-1	0.1-0.9	14.3.2023	√	√	√	√	√	√
	TP-2	0.1-0.5	14.3.2023	√		√	√	√	√
	TP-3	0.1-0.5	14.3.2023	√	√	√	√	√	√
	TP-3	2.5-3.0	14.3.2023	√		√			√
	TP-4	0.1-0.5	14.3.2023	√	√	√	√		√
	TP-4	0.5-1.0	14.3.2023	√		√			√
	TP-5	0.3-0.5	14.3.2023	√		√	√	√	√
	TP-5	2.5-3.0	14.3.2023	√		√			√
	TP-6	0.1-0.2	14.3.2023	√	√	√	√	√	√
	TP-7	0.1-0.5	14.3.2023	√		√			√
	TP-7A	0-0.1	16.3.2023	√		√	√		√
	TP-8	0.1-0.25	14.3.2023	√		√			√
	TP-8	0.25-0.50	14.3.2023	√		√	√	√	√
	TP-8	2.50-3.0	14.3.2023	√		√			√
Boreholes	BH-1	0.2-0.6	17.3.2023	√	√	√	√	√	√
	BH-2	0.3-0.4	21.3.2023	√		√			√
	BH-2	0.4-1.0	21.3.2023	√	√	√	√	√	√

Location ID		Sample Depth (m)	Sample Date	Inorganics	Cyanide	PAH	TPH	PCB	Asbestos
	BH-3	0.1-0.5	15.3.2023	√		√	√	√	√
	BH-3	5.0-6.0	15.3.2023	√		√			√
	BH-4	0.1-0.3	13.3.2023	√		√			√
	BH-4	0.3-0.5	13.3.2023	√	√	√	√	√	√
	BH-4	4.0-4.5	14.3.2023	√		√			√
	BH-5	0.1-0.6	16.3.2023	√	√	√	√	√	√
Slag	slag 1		16.3.2023	√		√			√
	slag 2		14.3.2023	√		√			√
	slag 3		23.3.2023	√		√			√
	slag 4		23.3.2023	√		√			√
Sediment	sediment 1		24.3.2023	√		√	√		√
	sediment 2		24.3.2023	√		√	√		√
	sediment 3		24.3.2023	√		√	√		√
	sediment 4		24.3.2023	√		√	√		√
	sediment 5		24.3.2023	√		√	√		√
	sediment 6		24.3.2023	√		√	√		√
	sediment 7		24.3.2023	√		√	√		√

Table 6: Water laboratory test schedule

Location ID		Sample Date	Inorganics	Cyanide	PAH	TPH	PCB
Groundwater	BH-1	6.4.2023	√	√	√	√	√
	BH-2	6.4.2023	√	√	√	√	√
	BH-3	6.4.2023	√	√	√	√	√
	BH-4	6.4.2023	√	√	√	√	√
	BH-5	6.4.2023	√	√	√	√	√
Sea Water	M -SE1	24.3.2023	√	√	√	√	√
	M -SE2	24.3.2023	√	√	√	√	√
	M -SE3	24.3.2023	√	√	√	√	√
	M -SE4	24.3.2023	√	√	√	√	√
	M -SE5	24.3.2023	√	√	√	√	√
	M -SE6	24.3.2023	√	√	√	√	√
	M -SE7	24.3.2023	√	√	√	√	√

5. Ground conditions

5.1 Stockpiled materials

Two distinct types of material are present on site in stockpiles: slag and fly-tipped material. The approximate distribution of these stockpiles is shown on Drawing 1.

5.1.1 Slag

In the north of the site black and dark grey granular silicomanganese slag has been placed directly onto the natural ground surface and also on concrete hardstanding. Large stockpiles of slag remain, as shown on Drawing 1.

In December 2016 the total quantity of slag on site was estimated as 51,037m^3, based on comparison of topographical survey data. Since 2016 removal of slag off site has continued and the quantity remaining on site is estimated in 2023 to be 30,000m^3.

5.1.2 Fly-tipped material

Across large areas of the site construction waste and other waste has been deposited on the site in the last decade. This material appears to have been imported by small trucks and vehicles and informally tipped and is referred to in this report as fly-tipped material (see photos in Appendix A). The majority of this material appears to be construction related (soil, gravel, concrete, tiles, wood, asphalt/tarmac), and a smaller proportion is commercial or domestic fly-tipped waste (plastic containers, packaging, shoes, clothes, electrical items). Detailed inspection of all this material has not been undertaken and it may contain asbestos and other contaminated materials. The quantity of construction type waste on site is estimated as 4,000 to 6,000m^3 and fly-tipped commercial or domestic waste less than 1,000m^3.

5.2 Made ground

5.2.1 Historical placement of made ground

Made ground is considered to be any material placed by human activities above natural ground (excluding the stockpiles described above).

The thickness of made ground across the site is very variable. The natural ground surface is likely to have been limestone with thin natural soils sloping gently to the coast. A natural valley feature is likely to have extended northeastwards from the bay immediately north of the jetty. A stormwater sewer now follows this alignment. Prior to construction of the industrial facilities within the site, a suitably flat platform will have been created by cutting into the limestone along the eastern site boundary and placing fill of increasing thickness towards the coast and in the valley feature and northwestern part of the site. In the east of the site the furnace chambers and other structures will have been constructed in excavations into the limestone. As part of the remediation works undertaken in 2007-2011 large volumes of made ground and associated contaminated material, and likely also underground structures, were excavated and removed off site. The factory buildings are likely to have had massive concrete foundations extending to the limestone bedrock. Concrete hardstanding remains across much of the site. Made ground including a proportion of slag is common in the uppermost materials in the north of the site.

5.2.2 Made ground distribution

This development history has resulted in a complex distribution of made ground across the site overlying the natural limestone bedrock.

Granular fill over 4m in thickness extends across the northwest of the site. The thickest made ground has been recorded as 9.2m thick in BH-3, possibly along the route of the infilled valley features. Towards the eastern boundary made ground thins and is not present along the eastern boundary. In the southern part of the site made ground is typically 0.5 to 2m thick. The slag stockpile thickness is not included in these estimates.

5.3 Bedrock

Limestone bedrock is present across the entire site, at surface in the east and up to a maximum of 9.7m depth. The depth to bedrock recorded during the investigation is shown on Drawing 4. At outcrop it is observed to be highly fractured. Borehole logs record less fractured zones and zones where fractures are clay-filled.

5.4 Summary of stratigraphy

A summary of the stratigraphy encountered at the site is presented in Table 7.

Table 7: Summary of ground conditions encountered

Stratum	Top of stratum (mbgl)	Thickness range (m)	Typical thickness (m)	Description
Made ground	Ground level	0 to 9.7	>4m in northwest 0 to 2m in south	Black slag, locally concrete slab, typically over mixed granular fill with red-brown clayey matrix in northwest. Mixed granular made ground with brick, concrete and asbestos sheet pieces in south. Made ground granular fill is referred to as 'embankment' in the factual report.
Limestone bedrock	Ground level	unproven		Fractured limestone bedrock, locally fractures filled with red clay

5.5 Groundwater

During drilling groundwater was encountered between 8.4 and 12.5m below ground level. Subsequent groundwater monitoring has confirmed groundwater levels across the site at less than 1m above sea level, suggesting groundwater flow to the southwest and discharge along the coast.

Levels recorded in borehole BH-5 are anomalously high (up to 5.9mASL) and appears to be recording a perched groundwater level.

The two boreholes closest to the coast (BH-4 and BH-2) are highly saline, most likely due to the coastal influence. Groundwater quality data is discussed in detail in Section 6.

5.6 Coastal zone

The marine sampling observed the subsea ground level to fall steeply away from land. Along the coast and in the shallowest zone the ground surface is predominantly covered with cobbles, with little fine sediment. The diver reported the presence of anthropogenic material.

On the steep slope bordering the coast in the northern part of the site mature trees are established, and soils appear to be mixed made ground with some slag content.

6. Contamination risk assessment

6.1 Approach

In the absence of specific Croatian guidance for the assessment of contamination risk, the UK Land Contamination Risk Management (LCRM) guidance [14] has been used with the approach outlined in the Dutch Soil Remediation Circular 2013 [13] also considered.

The process outlined in the UK LCRM guidance follows a tiered approach to assessing risk which begins with an initial screening assessment known as a generic quantitative risk assessment (GQRA). The GQRA makes use of published assessment criteria and when a soil/ water concentration exceeds the screening value then further consideration is required. This can be more detailed consideration of the exposure pathways, further data collection to better understand the problem or remediation.

The risk assessment approach described in Annex 2 of the Dutch Soil Remediation Circular [13] follows a similar process to determine if significant contamination is present. Data is initially screened against a set of conservative criteria, if exceeded further assessment or remediation is necessary. This stepped approach to site specific risk assessment, with increasing data and assessment demands as conservatism reduces, is common across UK, Dutch and other continental European approaches.

The screening assessment (GQRA) is presented in the following sections and the potential risks have been considered in the context of a conceptual model of the site.

For this assessment, the laboratory analysis results and field data collected during the 2023 investigation have been screened against appropriate criteria in order to provide an initial assessment of the potential contamination status of the site. Where exceedances of the initial screening are identified the particular exceedance is considered in more detail to determine if further action, such as remediation, may be necessary.

6.2 Initial conceptual site model

6.2.1 What is a CSM?

The first stage of the risk assessment process is to define the ‘conceptual site model’ which is a representation of how contamination on the site may impact people and the environment.

The conceptual site model describes the sources of the contamination and the behaviour of the contamination in environmental media such as soil and groundwater, surface water and air. It also identifies and characterises human health and environmental receptors that may be exposed or impacted by the contamination and identifies the pathways that may be present that link the sources of contamination and the receptors.

The potential risks to human health and the environment have been considered in the context of a conceptual source-pathway-receptor model of the site, identifying:

- The contamination hazards associated with the site (the sources);
- The receptors at risk from the identified hazards; and
- The existence, or absence, of plausible pathways which may exist between the identified hazards and receptor.

For a risk to be present, all three elements (source-pathway-receptor) of a potential contaminant linkage must be present. ‘Remediation’ is not necessarily the removal of the source of contamination; ‘remediation’ could also be an action that breaks the pathway.

6.2.2 Sources

The site has a long industrial history as described in Section 3.2. The historic activity on site will contribute to the potential sources of contamination that may be present on site. A summary of the potential contaminant sources is provided in Table 8.

Table 8: Summary of potential contaminant sources

Potential source	Possible contaminants
Historical use as a carbide and fertilizer plant (1890 to 1930s)	Nitrate, ammonia Hydrocarbons associated with fuels, lubricating oils.
Historical use for ferroalloy & graphite electrode production (1940s – 1990s)	Airborne release: PAHs primarily Wastewater: with PAHs, and possibly cyanides and phenol. Solid waste disposal: PAHs, metals Other: hydrocarbons, metals, asbestos
Site dismantling and silicomanganese slag processing	Asbestos, hydrocarbons, metals

6.2.3 Receptors

Receptors both during construction and after completion of the future development include:

- Future users of the redeveloped site;
- Construction workers and neighbours during development of the site;
- Groundwater in the limestone beneath the site;
- The sea adjacent to the site.

6.2.4 Pathways

Potential pathways that may be present linking contamination sources to receptors include:

- Direct exposure of future users and construction workers to contamination in soil or dust;
- Leaching of contaminated soils into groundwater beneath the site;
- Release of contamination from redundant tanks to soil and groundwater; and
- Discharge of contaminated groundwater to the sea water.

6.3 Human health screening assessment

6.3.1 Generic assessment criteria (GAC)

To simplify the assessment of ground contamination risks, generic soil quality guideline values have been used for the initial screening of soil, sediment and slag contamination testing results. The generic assessment criteria (GAC) used are based on published assessment criteria from the UK and Netherlands as no risk-based generic assessment criteria are available for Croatia.

The soil, marine sediment and slag results have been compared to compared to human health GAC for both a 'residential without plant uptake' end use and 'commercial', produced by Arup in accordance with UK guidance. These scenarios assume that soft landscaping areas are managed, and residents will not be consuming home-grown vegetables. The UK GACs have been developed using a Soil Organic Matter (SOM) value of 6%, which has been selected based on the average SOM content of the soils sampled on site. The Arup UK GACs have been produced using the software Contaminated Land Exposure Assessment model[18]. The model estimates human exposure to soil contaminants for those potentially living, working and/or playing on contaminated sites over long time periods (chronic exposure). Full details on the input parameters and background research to generate the GACs can be provided upon request.

The soil, sediment and slag results have also been compared to Dutch Soil Remediation Intervention Values (DIV) taken from the Soil Remediation Circular 2013 [13]. The soil intervention values are intended to be representative of contamination levels above which there may be a risk to human health and ecosystems for all land use scenarios.

Where an intervention value is exceeded, site specific risk assessment is the next step to determine whether the risk is significant based on the intended use of the site.

In addition to the GACs described above the concentrations of metals in the soil samples were also compared to typical natural/background concentrations of metals in shallow soils in the Šibenik region which are described in the Geochemical Atlas of Croatia [16]. While these are not contamination risk based criteria they do provide context when considering the risks posed by metal contamination in the soils on site.

The results of the soil, sediment and slag screening assessment are presented in Appendix D. A total of 23 soil samples, seven sediment samples and four slag samples were screened.

6.3.2 Soil

The screening assessment (see Appendix D1) identified several samples where contaminants exceeded the human health GAC. A summary of these exceedances is presented in Table 9.

No contaminants have been reported in exceedance of UK GAC for a commercial end use.

No contaminants have been reported in exceedance of UK GAC for a residential end use and/or the Dutch Intervention values, with the exception of the following:

- Chromium concentrations in one sample exceed the Dutch Intervention Value (DIV) but are below UK GAC for a residential end use. The concentrations of chromium recorded within the soils across the site are within the typical range of background soil concentrations for the Šibenik region;
- Copper concentrations in eight samples exceed the DIV but are below UK GAC for a residential end use;
- Mercury concentrations in eight samples exceed the UK GAC for a residential end use but are below the DIV. Four samples only marginally exceed the screening criteria;
- Lead concentrations in seven samples exceed the UK GAC for a residential end use and exceed the DIV in four samples. Two samples record concentrations which are an order of magnitude above both the UK GAC and DIV (BH4 0.1-0.3m and TP1 0.1-0.9m);
- Vanadium concentrations in four samples exceed the DIV but are below UK GAC for a residential end use;
- Zinc concentrations in two samples exceed the DIV but are below UK GAC for a residential end use;
- The PAHs benzo(a)pyrene and benzo(b)fluoranthene in one sample and dibenz(ah)anthracene in four samples exceed the UK GAC for a residential end use. The total PAH concentrations in these samples are below the DIV.

The contaminant exceedances identified in the soil are generally in a small number of samples indicating contamination is not widespread across the site. These exceedances identified are not volatile contaminants and therefore risks to future site users are not deemed to be present where soils are located beneath buildings or hard cover. No soil contamination has been identified that is so significant as to warrant excavation and offsite removal. If soft landscaping areas are proposed, then a risk to future site users could arise from direct exposure to soils, however this could be mitigated by provision of cover layer of clean soil. The results indicate that the existing soils within the site may be suitable for re-use as part of the development.

6.3.3 Marine sediment

The screening assessment (see Appendix D2) identified several samples where contaminants exceeded the human health GAC. A summary of these exceedances is presented in Table 10.

No contaminants have been reported in exceedance of the UK GAC for commercial and residential end use and/or the DIV with the exception of the following:

- Asbestos, identified as chrysotile, was detected in three sediment samples (Sediment 5, 6 and 7 – all from the northwest coastline). The laboratory quantified the asbestos in all three samples as below the limit of quantification (<100 mg/kg equivalent to <0.01%);
- Lead concentrations in two sediment samples exceed the UK GAC for a residential end use and the DIV; and
- The PAH dibenz(ah)anthracene in one sediment sample exceeds the UK GAC for a residential end use. The total PAH concentrations in this sample is below the DIV.

Anthropogenic materials such as construction waste, tyres, metal and concrete has been observed along the northwest coast and this type of waste often contains asbestos. Low concentrations of asbestos (below the limit of quantification) have been identified in marine sediment. Asbestos is only a risk if fibres become airborne and this will only occur if the material is dry. Therefore it could present a risk during any earthworks that disturb the material if the sediment is disturbed and dried which could allow fibres to be released into ambient air.

The lead and dibenz(ah)anthracene exceedances are localised and marginal exceedances of the conservative criteria and do not indicate any significant widespread contamination within the marine sediment. There is a potential risk to construction workers who may come into direct contact with contaminated sediment, particularly during earthworks. However, exposure periods are generally shorter and can usually be reduced to an acceptable level through adoption of adequate health and safety procedures.

6.3.4 Slag

The screening assessment (see Appendix D3) identified some samples of slag where contaminants exceeded the human health GAC. A summary of these exceedances is presented in Table 11.

No contaminants have been reported in exceedance of the UK GAC for a commercial end use.

No contaminants have been reported in exceedance of the UK GAC for a residential end use and/or the DIV with the exception of the following:

- Chromium concentrations in two slag samples exceed the DIV and exceed the UK GAC for a residential end use in one sample;
- Copper concentrations in one slag sample exceed the DIV but are below UK GAC for a residential end use; and
- The PAHs benzo(a)pyrene and benzo(b)fluoranthene in one slag sample and dibenz(ah)anthracene in four samples exceed the UK GAC for a residential end use. The total PAH concentration in one slag sample exceeds the DIV.

It is understood that the slag stockpiles will be removed from site and disposed prior to development. It is likely that there will be some residual slag material in the made ground beneath the site. Slag or slag-containing made ground remaining on site would not pose a risk to future site users if the material was located beneath buildings or hard cover or with a cover layer of clean soils in soft landscaping areas.

There is a potential risk to construction workers who may come into direct contact with any contaminated slag during earthworks. However, exposure periods are generally shorter than those experienced by long term site users and can usually be reduced to an acceptable level through adoption of adequate health and safety procedures.

Table 9: Soil exceedances of general assessment criteria (GAC)

Determinand	Unit	No. Samples	Sample Concentration Range	Natural/Background Concentration Šibenik Region – Geochemical Atlas of Croatia	UK – Commercial Land Use		UK – Residential (No Plants) Land Use			Dutch Intervention Values		
					GAC	No. Samples >GAC	GAC	No. Samples >GAC	Location of Exceedance	GAC	No. Samples >GAC	Location of Exceedance
Chromium (total)	mg/kg	23	30.3 - 214	142.9 – 208.1	8,570	0	907	0	-	180	1	BH2 0.2-0.6m (214 mg/kg)
Copper	mg/kg	23	66.5 - 794	25.4 – 47.0	68,300	0	7,130	0	-	190	8	BH2 0.3-0.4m (530 mg/kg); BH4 0.1-0.3m (320 mg/kg); BH5 0.1-0.5m (264 mg/kg); TP3 0.1-0.5m (794 mg/kg); TP3 2.5-3m (232 mg/kg); TP5 2.5m (202 mg/kg); TP7 0.1-0.5m (204 mg/kg); TP8 0.1-0.25m (191 mg/kg)
Mercury	mg/kg	23	<LOD[1] – 9.02	0.06 – 0.17	58	0	1.2	8	TP1 0.1-0.9m (1.5 mg/kg); TP3 2.5-3.0m (1.3 mg/kg); TP5 0.3-0.5m (3.1 mg/kg); TP5 2.5-3m (6.5 mg/kg); TP6 0.1-0.2m (9.0 mg/kg); TP7A 0-0.1 m (1.7 mg/kg); TP7 0.1-0.5m (4.8 mg/kg); TP8 2.5-3m (1.5 mg/kg)	36	0	-
Lead	mg/kg	23	37.4 – 2,120	46.3 – 86.9	2,300	0	310	7	BH2 0.3-0.4m (341 mg/kg); BH4 0.1-0.3m (2,120 mg/kg); BH4 0.3-0.5m (393 mg/kg); BH5 0.1-0.5m (673 mg/kg); TP1 0.1-0.9m (1,602 mg/kg); TP2 0.1-0.5m (611 mg/kg); TP3 0.1-0.5m (413 mg/kg)	530	4	BH4 0.1-0.3m (2,120 mg/kg); BH5 0.1-0.5m (673 mg/kg); TP1 0.1-0.9m (1,602 mg/kg); TP2 0.1-0.5m (611 mg/kg)
Vanadium	mg/kg	23	35.3 - 397	141 - 178	9,000	0	1,200	0	-	250[2]	4	BH2 0.3-0.4m (397 mg/kg); TP2 0.1-0.5m (264 mg/kg); TP3 0.1-0.5m (297 mg/kg); TP4 0.5-1.0m (252 mg/kg)
Zinc	mg/kg	23	42.8 – 1,100	116 - 144	730,000	0	40,400	0	-	720	2	BH2 0.3-0.4m (742 mg/kg); BH4 0.1-0.3m (1,100 mg/kg)
Benzo(a)pyrene	mg/kg	23	0.005 – 4.81	-	35	0	3.2	1	BH4 0.1-0.3m (4.81 mg/kg)	40[3]	0	-
Benzo(b)fluoranthene	mg/kg	23	0.007 – 6.36	-	44.9	0	4.1	1	BH4 0.1-0.3m (6.36 mg/kg)	40[3]	0	-
Dibenz(a,h)anthracene	mg/kg	23	0.001 – 1.22	-	3.57	0	0.32	3	BH4 0.1-0.3m (1.22 mg/kg); TP4 0.1-0.5m (0.443 mg/kg); TP7 0.1-0.5m (0.321 mg/kg); TP8 0.1-0.25m (0.788mg/kg)	40[3]	0	-

Notes:

1 - LOD = Laboratory Limit of Detection

2 - Indicative Level for Severe Contamination

3 - Intervention Value for Total PAHs

Table 10: Marine sediment exceedances of general assessment criteria (GAC)

Determinand	Unit	No. Samples	Concentration Range	UK – Commercial Land Use			UK – Residential (No Plants) Land Use			Dutch Intervention Values		
				GAC	No. Samples >GAC	Location of Exceedance	GAC	No. Samples >GAC	Location of Exceedance	GAC	No. Samples >GAC	Location of Exceedance
Asbestos	mg/kg	7	Not detected - <100	Presence	3	Sediment 5, 6 and 7 (chrysotile <100 mg/kg)	Presence	3	Sediment 5, 6 and 7 (chrysotile <100 mg/kg)	100	0	-
Lead	mg/kg	7	39.9 – 838	2,300	0	-	310	2	Sediment 6 (687 mg/kg); Sediment 7 (838 mg/kg)	530	2	Sediment 6 (687 mg/kg); Sediment 7 (838 mg/kg)
Dibenzo(a,h)anthracene	mg/kg	7	0.001 – 1.22	3.57	0	-	0.32	1	Sediment 3 (0.493 mg/kg)	40[1]	0	-

Notes:

1 – Intervention Value for Total PAHs

Table 11: Slag exceedances of general assessment criteria (GAC)

Determinand	Unit	No. Samples	Concentration Range	UK – Commercial Land Use		UK – Residential (No Plants) Land Use			Dutch Intervention Values		
				GAC	No. Samples >GAC	GAC	No. Samples >GAC	Location of Exceedance	GAC	No. Samples >GAC	Location of Exceedance
Chromium (Total)	mg/kg	4	58.6 – 2,041	8,570	0	907	1	Slag 2 (2,041 mg/kg)	180	2	Slag 1 (428 mg/kg); Slag 2 (2,041 mg/kg)
Copper	mg/kg	4	81.7 - 253	68,300	0	7,130	0	-	190	1	Slag 4 (253 mg/kg)
Benzo(a)pyrene	mg/kg	4	2.21 – 8.16	35	0	3.2	1	Slag 4 (8.16 mg/kg)	40[1]	0	-
Benzo(b)fluoranthene	mg/kg	4	2.85 – 13.5	44.9	0	4.1	1	Slag 4 (13.5 mg/kg)	40[1]	0	-
Dibenzo(a,h)anthracene	mg/kg	4	0.458 – 2.02	3.57	0	0.32	4	Slag 1 (0.458 mg/kg); Slag 2 (0.578 mg/kg) Slag 3 (0.67 mg/kg); Slag 4 (2.02 mg/kg)	40[1]	0	-
PAHs Total	mg/kg	4	20.269 – 77.259	-	-	-	-	-	40[1]	1	Slag 4 (77.259 mg/kg)

Notes:

1 – Intervention Value for Total PAH (sum of 10 PAHs - naphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, Indeno(1,2,3-c.d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene)

6.4 Water screening assessment

6.4.1 Assessment criteria

The water receptors identified in the conceptual site model comprise groundwater within the limestone bedrock and marine water in the sea adjacent to the site.

Selected published water quality standards (WQS) have been used for the initial screening of groundwater and marine water contamination testing results to identify potential risks that may need to be addressed.

The groundwater samples recorded electrical conductivity values (EC) ranging between 1,042 and 8,290 µS/cm, which is indicative of brackish conditions and salinity levels in groundwater sampled from two boreholes are high. Therefore it is considered highly unlikely that the groundwater would be suitable for use as a drinking water resource and therefore the groundwater results have not been compared to any published drinking water standards.

The Water Framework Directive (WFD) is the main driver for water protection in Europe and applies to all inland, transitional and coastal surface waters and groundwater. The WFD includes a list of Environmental Quality Standards (EQS) for pollutants for monitoring the quality of surface water bodies, which are transposed into water quality regulations in both Croatia [15] and the UK [17]. The WFD EQS values for salt water have been used for the initial screening of the groundwater and marine water data.

In the UK the environmental regulator has defined operational EQS values for other contaminants which are not listed in the WFD and these have also been used for this screening assessment.

The groundwater results have also been compared to Dutch Target Values (DTV) and Intervention Values (DIV) for groundwater taken from the Soil Remediation Circular 2013 [13]. Unlike soil, for groundwater two levels of criteria are defined, DTV and DIV. The DTV are intended to be indicative of concentrations in groundwater which represent a negligible risk to aquatic ecosystems. The DIV are representative of contamination levels above which there may be a risk to the aquatic ecosystem. Where an intervention value is exceeded, site specific risk assessment is undertaken to more accurately assess risks.

The results of the groundwater and marine water screening assessment are presented in Appendix D. A total of five groundwater samples and seven marine water samples were screened.

6.4.2 Groundwater

The screening assessment (see Appendix D4) identified several groundwater samples where contaminants exceeded the WQS. A summary of these exceedances is presented in Table 9.

All contaminants in groundwater have been reported below the WQS with the exception of the following:

- Copper marginally exceeds the salt water EQS in one sample but is below the DTV in all samples;
- Zinc exceeds the salt water EQS in three samples but is below the DTV in all samples; and
- Fluoranthene exceeds the salt water EQS and DTV in two samples but is below the DIV. Naphthalene in two samples and phenanthrene in one sample exceeds the DTV but is below the DIV.
- All contaminants are below the DIV in all groundwater samples.

In general, the groundwater testing indicates low levels of contamination. The metals exceedances (copper and zinc) are marginally above the EQS and DTV and an order of magnitude below the DIV. Naphthalene and phenanthrene do not exceed the EQS or DIV, but marginally exceed the DTV. The PAH fluoranthene exceeds EQS and DTV in two locations (BH5 and BH3), but does not exceed DIV. It is possible that leaching from the made ground beneath the site may be a contributory source to the contaminants recorded within the groundwater.

The proposed development will be predominantly buildings and hard cover with a proportion of soft landscaping (parks, gardens). This will limit the amount of recharge through made ground and into groundwater and hence limit the leaching of made ground. Therefore it is considered that risks to groundwater from infiltration in the made ground beneath the site are low and groundwater concentrations will reduce in the long term.

Groundwater beneath the site is considered to discharge to the coastline. As groundwater moves beneath the site towards the coast it is diluted by infiltrating rainwater and contaminants naturally attenuate. Where groundwater discharges into seawater significant dilution will occur as the flow rate in the seawater body (even close to the shore) is orders of magnitude higher than the groundwater discharge.

It is considered unlikely that the future development will result in significant change in current conditions beneath the site and risks to the sea are therefore unchanged post-development and are considered to be low.

6.4.3 Marine water

The screening assessment (see Appendix D5) identified some marine water samples where contaminants exceeded the WQS. A summary of these exceedances is presented in Table 13.

All contaminants in the marine water samples have been reported below the salt water EQS with the exception of the following:

- Aluminium concentrations in all seven samples exceed the EQS.
- Cadmium and zinc exceed the EQS in one sample (out of seven), concentrations in all other samples are below the laboratory limit of detection; and
- Copper and lead exceed the EQS in two samples (out of seven), concentrations in all other samples are below the laboratory limit of detection.

There are no exceedances related to PAHs, indicating the low levels of several PAHs observed in groundwater are not impacting marine water quality.

The elevated aluminium concentrations in all marine water samples are unlikely to be unrelated to the site as all groundwater aluminium concentrations are below the recorded marine water concentrations and groundwater water quality standards are not exceeded. In general, the marine water samples indicate a small number of localised exceedances of cadmium, copper, lead and zinc. However these exceedances are not attributed to contamination from the Batižele site as groundwater samples from the site recorded significantly lower concentrations than the marine water samples. There is insufficient data to conclude the source of these metals, however based on the available data it does not appear that contamination on the site is having a significant adverse impact on marine water quality.

Table 12: Groundwater exceedances of published water quality standards (WQS)

Determinand	Unit	No. Samples	Concentration Range	Croatia and UK Water Quality Standards – Salt Water			Dutch Water Quality Standards (Groundwater)				
				EQS	No. Samples >EQS	Location of Exceedance	Target Level	No. Samples >Target Value	Location of Exceedance	Intervention Level	No. Samples >Intervention Value
Copper	µg/l	5	1.83 – 4.93	3.76[2]	1	BH2 (4.93 µg/l)	15	0	-	75	0
Zinc	µg/l	5	3.59 – 17.9	7.9[2]	3	BH2 (17.9 µg/l); BH4 (10.4 µg/l); BH5 (11.6 µg/l)	65	0	-	800	-
Fluoranthene	µg/l	5	<0.01 – 0.0442	0.0063[1]	2	BH2 (0.0208 µg/l); BH5 (0.0442 µg/l)	0.003	2	BH2 (0.0208 µg/l); BH5 (0.0442 µg/l)	1	0
Naphthalene	µg/l	5	<0.01 – 0.123	2[1]	0	-	0.01	2	BH3 (0.123 µg/l); BH5 (0.0274 µg/l)	70	0
Phenanthrene	µg/l	5	<0.01 – 0.0132	-	-	-	0.003	1	BH2 (0.0132 µg/l)	5	0
1 – Croatia EQS and UK EQS as listed in WFD 2 – UK EQS											

Table 13: Marine water exceedances of published water quality standards (WQS)

Determinand	Unit	No. Samples	Concentration Range	Croatia and UK Water Quality Standards – Salt Water		
				EQS	No. Samples >EQS	Location of Exceedance
Aluminium	µg/l	7	16.9 – 84.4	15[2]	7	M-SE1 (84.4 µg/l); M-SE-2 (67.5 µg/l); M-SE3 (16.9 µg/l); M-SE-4 (70.9 µg/l); M-SE-5 (34.8 µg/l); M-SE-6 (30.2 µg/l); M-SE-7 (17.9 µg/l)
Cadmium	µg/l	7	<1 – 1.86	0.2[1]	1	M-SE-1 (1.86 µg/l)
Copper	µg/l	7	<1 – 69.9	3.76[2]	2	M-SE-4 (4.02 µg/l); M-SE-6 (69.9 µg/l)
Lead	µg/l	7	<4 – 25.1	1.3[1]	2	M-SE-1 (25.1 µg/l); M-SE-2 (14.8 µg/l)
Zinc	µg/l	7	<8 - 608	7.9[2]	1	M-SE-1 (608 µg/l)
1 – Croatia EQS and UK EQS as listed in WFD 2 – UK EQS						

6.5 Risk evaluation

6.5.1 Soil, slag and marine sediment

Potential exposure and impacts associated with contamination in soil, slag and marine sediments are considered both during construction and following development of the site.

As noted above the contaminant exceedances identified in the soil are generally in a small number of samples indicating contamination is not widespread across the site. No soil contamination has been identified that requires excavation and offsite removal, however made ground soils are unsuitable to remain at the ground surface following development. In areas of proposed soft landscaping a risk to future site users could arise from direct exposure to soils, however this could be mitigated by provision of cover layer of clean soil.

Asbestos was recorded in three marine sediment samples from the northwest coast at the site, quantified at low concentrations (<0.01%). No asbestos was recorded in any other soil samples from the site. In two trial pits (TP1 and TP4) a suspected fragment of asbestos roofing material was identified but laboratory testing did not identify the presence of asbestos in these trial pits. Asbestos is only a risk if fibres become airborne and this will only occur if material is dry. If the marine sediment is disturbed or excavated and allowed to dry out fibres could be released into ambient air. During construction works, health and safety precautions designed by a competent contractor should be taken to avoid release of airborne asbestos fibres. If the marine sediment is left in situ and undisturbed the risks are considered to be low as the samples were taken below the water level. If the northwest coast is to be developed for a beach, removal of anthropogenic material will be necessary (tyres, metal, concrete, etc) and this material must be disposed of appropriately due to the potential presence of asbestos. Beach development is expected to include import of beach material (as at Banj Beach).

Whilst no evidence of gross contamination (such as oily, tarry or highly odorous material) was recorded in the site investigation exploratory holes and samples, hotspots of such contamination are likely to be encountered during earthworks. One such location has been identified from site observation, the ‘tar pit’. Any gross contamination encountered should be removed and disposed off site.

Risks to construction workers who may come into direct contact with contaminated soils during construction, particularly during earthworks, can be mitigated to an acceptable level through adoption of adequate health and safety procedures (such as PPE including gloves and overalls and dust prevention).

It is assumed the stockpiled materials on site (slag and fly-tipped materials) will be removed from site.

6.5.2 Groundwater and marine water

In general, the groundwater testing indicates low levels of contamination with the majority of contaminants recorded below the screening criteria. Elevated concentrations of metals and PAH contaminants have been recorded in some samples within the groundwater and it is possible that leaching of made ground could be a contributory source. However the concentrations of contaminants recorded in the groundwater are not indicative of significant contamination that would require remediation, considering groundwater at the site is not used as a drinking water source (due to natural salinity) and the only receptor is the adjacent marine water. The future development will be largely hard cover and buildings, which will limit infiltration and leaching.

Groundwater beneath the site is considered to discharge to the coastline. Where groundwater discharges into seawater dilution will occur as the flow rate in the seawater body (even close to the shore) is orders of magnitude higher than the groundwater discharge. Marine water sampling has not identified water contamination that is attributable to contamination on the site. It is considered likely that the future development will result in improvement in groundwater quality in the long term.

6.6 Revised conceptual model

Based on the 2023 investigation data and assessments presented in this section, the conceptual model in Section 6.2 has been revised to consider the plausible source-pathway-receptor linkages. The revised conceptual model is shown in Table 14.

Table 14: Revised conceptual site model

Source		Pathway		Receptor	Linkage?
Made ground soil, sediment and slag material (containing solid contaminants, asbestos fibres and hydrocarbons)	→	Dermal contact	→	Construction worker	Yes Can be mitigated by health and safety and site management procedures (including the use of appropriate PPE and dust suppression)
		Ingestion of soil/ soil dust	→		
		Inhalation of soil and soil dust	→		
			→	Site users and neighbours during construction	
	→	Dermal contact	→	Future site users of development	Yes Can be mitigated by removal of encountered gross contamination hotspots encountered during works and provision of clean cover in soft landscaping areas and removal of any gross contamination encountered
		Ingestion of soil/ soil dust	→		
		Inhalation of soil and soil dust	→		
	→	Leaching and infiltration	→	Groundwater in limestone bedrock Marine water quality	Not significant
Impacted groundwater	→	Dermal contact	→	Construction worker	No
		Ingestion	→	Assuming appropriate health and safety procedures are adopted	No
	→	Dermal contact	→	Future site users of development	No
		Ingestion	→		No
	→	Lateral migration	→	Marine water quality	Not significant

7. Remediation strategy

7.1 Approach to define remediation

When a former industrial or brownfield site is proposed for redevelopment, the contamination present within the site should be assessed and remediated to a standard that will ensure the redeveloped site has no adverse impact or unacceptable risks to future site users or the wider environment (including groundwater, coastal water and ecology). This approach is consistent in the UK and across continental Europe.

A staged approach to assessment and remediation of contaminated sites is implemented and is usually structured as follows:

- Desk study review of information on site history and previous polluting activities, previous remediation, site walkover and initial risk assessment and identification of data gaps.
- Site investigation (including soil and groundwater sampling and testing) to address any identified data gaps and uncertainties.
- Risk assessment to determine the remediation (if any) needed to protect site users and the wider environment and inform a risk-based remediation strategy.
- Implementation of remediation and collection of validation data to demonstrate the remediation has achieved the standards required.

The first three stages have been undertaken and are presented in this report. This section presents the remediation tasks that are required to address the risks identified in preceding sections.

As described in Section 6, a risk only exists where a source of contamination and a receptor and a pathway that links the source and receptor are all present. The revised conceptual site model (Table 14) presents the risks that must be addressed by remediation.

Note the term 'remediation' is used to refer to any action that is undertaken to remove the risk - this could be removal of the source (such as excavation of the soil contamination source) or it could be removing the pathway (such as placing a cover layer of clean soil that prevents exposure of future users to contaminated soil). Excavation of all soil exceeding the assessment criteria is not necessarily required, and in many cases it is good practice, cost effective and a more sustainable approach to keep material exceeding assessment criteria on site and break the pathway by preventing exposure with a cover layer of clean soil for example.

On all brownfield sites uncertainties will remain regarding the extent and characteristics of contamination present, as site investigation provides only limited information. At the Batižele site the 2023 investigation has given increased confidence in the remediation requirements for the purposes of this study. When the future development is more clearly defined the remediation requirements will need to be reviewed and may need revision to ensure the development-specific risks are adequately addressed.

7.2 Considerations for design of development layout and levels

For brownfield sites such as Batižele, the most efficient approach to site development is typically to undertake a phase of site enabling works that deals with contamination and other ground-related constraints when the proposed development layout is known.

7.2.1 Other ground-related development constraints

As well as contamination, several other site-specific constraints related to ground conditions will have implications for the future development. This report focusses on contamination aspects, however other below ground constraints will need to be considered in the design and construction of the future development and are likely to be addressed in conjunction with contamination and therefore are relevant to identify in this report.

The following other ground-related constraints have been identified during this appraisal:

- The site is extensively covered with concrete slab and several large concrete structures that will require breaking out to enable site development. Concrete is usually crushed and can be reused as aggregate either on site or off site.
- Below ground obstructions, such as massive concrete foundations, will be present related to previous buildings and facilities. Breaking out of below ground obstructions will be necessary where they will interfere with the proposed development, such as where site levels need to reduce (cut) or for new foundations. This concrete may also be crushed and reused as aggregate either on site or off site.
- Two large open chambers (basements) are present in the central eastern part of the site. Other as yet unidentified basements and voids may be present associated with the previous industrial use. Depending on the design of the development filling these structures with crushed concrete may be the preferred approach. However this may not be acceptable if new buildings or infrastructure are proposed in these areas, in which case the chambers may require breaking out.
- The design of the development site levels should consider the need for cut and fill:
  - Shallow limestone bedrock is present at surface in the east of the site and approximately 2m depth in the southern part of the site. Below ground excavation, for example for below ground car parking or basements, will be difficult due to strength of the rock.
  - Thick made ground (maximum c.10m thick) is present across the central and northwestern site areas. Piled foundations may be needed. In these areas excavation will be easier due to the unconsolidated character of the material. However localised soil contamination may be encountered (such as related to spills) and grossly contaminated soil will require offsite disposal (see below). Excavated soils will need to be re-used in a suitable location on site or disposed off site. If re-used in areas of soft landscaping a cover layer of clean soil will be needed (see Section 7.4).
  - If possible the development topography and site levels should be designed to allow for material such as crushed concrete and excavated soil to be re-used in the development, avoiding potentially costly offsite disposal of surplus material.
- A large retaining wall is located east of the jetty. The structural condition of this retaining wall has not been assessed. It is not known if this retaining wall and jetty will be retained in the future development.
- A stormwater drain (1200mm diameter) traverses the site in a northeast to southwest direction. The condition of this drain has not been assessed.
- Remains of drainage networks associated with the previous industrial uses are likely to be present and are of unknown condition and extent.
- Steep slopes are present along the coast.

These ground-related constraints (non-contamination related) are summarised in

Figure 8.

7.2.2 Contamination considerations for development layout and design

As identified in Section 6, contamination identified as requiring remediation measures to address risks is limited to:

- Occasional exceedances of metals, PAHs and asbestos have been identified in soils on site. This material can remain in place or can be re-used within the development if exposure of made ground soil at the surface in the finished development is prevented. This can be achieved by placing a cover layer of clean soil over the material in areas not covered by hard cover or buildings.
- In the vicinity of the tar pit a quantity of tarry soil is anticipated where tar has leaked through cracks in the concrete lining of the pit. All tarry material will require excavation and offsite disposal.
- As the removal of concrete hardstanding and earthworks proceeds localised hotpots of contaminated soil are likely to be encountered, caused by releases of fuel or liquids that entered the ground. Any visibly oily or odorous contaminated soils should be excavated and disposed off site.

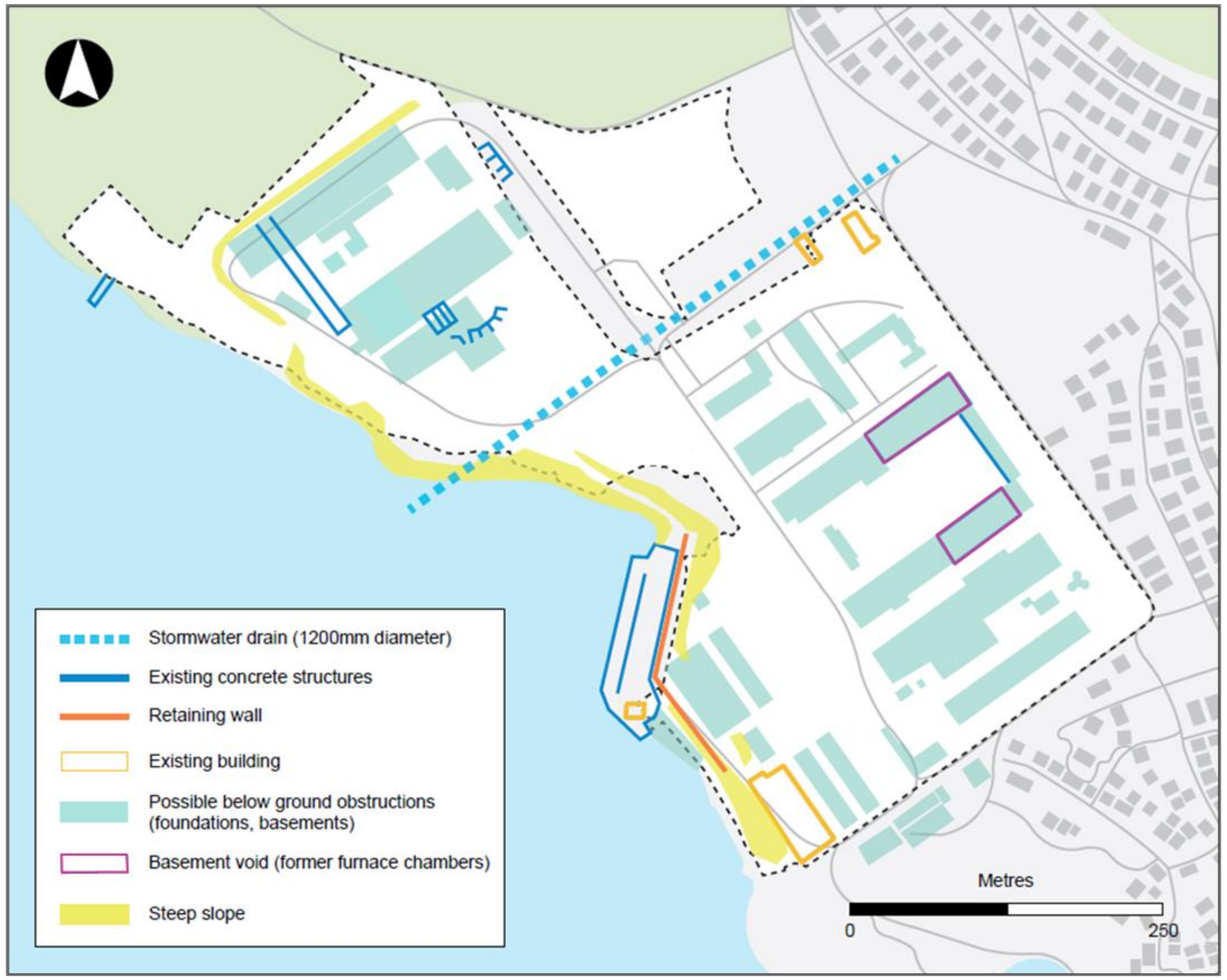

Figure 8 Geotechnical constraints plan (not contamination related)

7.3 Regulator requirements

As noted in section 3.4, several actions are required to address the remaining contamination concerns of the environmental regulator (defined in letter dated 16 April 2018):

- Excavation of contaminated soil in 2 locations (‘Between the old and new furnace chambers’ and ‘Between the main road and coast’);
- Removal of the 'tar pit' and associated contaminated soil;
- Test and dispose of the waste produced (from removal of tar pit and 2 soil locations);
- Validation testing of remaining soil at the site (following removal of tar pit and 2 soil locations).

As the proposed development layout was not known when the regulator was consulted, these requirements were presumably defined with the aim of preparing the site for any future use.

The validation target agreed previously with the regulator is 100mg/kg total PAH.

This report reviews the need for remediation based on the new 2023 site investigation data and is based on current good practice and therefore differs slightly in the remediation identified as required in Oikon 2018 and by the regulator. However, it is considered prudent to assume the remediation previously approved by the regulator is still required. The subsequent section assumes the remediation previously required by the regulator will be undertaken.

The developer should consult the environmental regulator when the development design and remediation works are defined. It is possible that the regulator may require additional measures to those identified in this report.

7.4 Remediation for future development

The ground-related actions likely to be needed to take the site from its current state to be suitable for future development are identified below. Those considered to be ‘remediation’ for cost estimate purposes are identified and activities that would be undertaken regardless of contamination are not identified as ‘remediation’:

- Offsite disposal of stockpiles of slag [REMEDIATION].
- Offsite disposal of fly-tipped material.
- Removal and crushing of above ground concrete structures and concrete hardstanding.
- Removal and crushing of below ground obstructions (foundations and redundant utilities and furnace chambers) where necessary for future development.
- Assessment of condition of 1200mm overflow and replacement if necessary.
- Assessment of condition of retaining walls and natural steep slopes and improvement if necessary.
- Excavation and offsite disposal of the tar pit and associated contaminated soils and validation testing (against 100mg/kg total PAH validation criteria) [REMEDIATION]
- Excavation and offsite disposal of contaminated soil from 2 locations ‘Between the old and new furnace chambers’ and ‘Between the main road and coast’ (Figure 2) and validation testing (against 100mg/kg total PAH validation criteria) [REMEDIATION]
- Excavation and offsite disposal of grossly contaminated soils encountered during earthworks and construction (visibly contaminated, such as tarry or oily, or highly odorous material). Where such material has been removed validation is necessary to confirm all unsuitable material has been removed [REMEDIATION]
- Earthworks to create required development platforms and coastal profile.
- Placement of 600mm thick cover layer of validated clean soils to prevent exposure of made ground soil at surface in soft landscaped areas in private residential gardens and a 300mm cover layer in soft landscaping in publicly accessible parks and other open space [REMEDIATION]
- In areas identified for new beach, non-natural material (such as tyres and metal debris) should be removed. Imported clean beach material should be placed both above and below water level.
- During all site excavations and earthworks good occupational health & safety procedures and environmental site management procedures should be followed. Due to the possible presence of asbestos a competent contractor should advise on protection measures such as dust prevention/suppression and PPE.

7.5 Cost appraisal

The remediation cost appraisal presented in the Arup 2020 report has been reviewed and updated (Table 15) based on the findings of the 2023 site investigation and the interpretation presented in this report.

Table 15: Revised remediation cost appraisal

	A	B	C
Contamination or ground-related risk item	Remaining remediation activities required by the environmental regulator	Additional soil contamination encountered during construction phase that requires remediation	Beach and bathing area remediation
Likelihood of occurrence	**High**	**High**	**-**
Estimated cost (euro)			-
Cost range (euro)	90k to 240k	260k to 500k	-
Cost basis and assumptions	Regulator required remediation (recommended by Oikon 2018): • Removal of contaminated soil 'Between the old and new chamber furnaces' (475m^3 non-hazardous waste) 4800€ • Removal of contamination 'Between the main road and coast' (5400m^3 non-hazardous waste) 54540 € • Removal of the 'tar pit' and associated contaminated soil (143m^3 hazardous waste); 65923 € - 143000 € • Test and dispose of the waste produced (from removal of tar pit and 2 locations); (included above) • Validation testing of remaining soil at the site (following removal of tar pit and 2 locations). 10000€ allowance Estimate includes 20000€ allowance for documentation and management Oikon estimated the cost for this remediation as 579k kuna (Oikon 2018). Oikon 2018 hazardous waste rate of 411€/m^3 in 2018, adjusted for inflation to 461€. Oikon 2018 non-hazardous waste rate of 6€ /tonne in 2018, adjusted for inflation to 6.8 €/t (or 10.1 €/m^3 based on 1.5t/m^3 for soil) 2023 estimate for hazardous waste contaminated soil removal offsite and disposal provided by a Croatian waste contractor 650 to 1000 €/t More accurate rates for disposal and waste classification would reduce uncertainty in this cost estimate.	Assumes 500m^3 of contaminated soils encountered during works that requires offsite disposal as hazardous waste. Oikon 2018 hazardous waste rate of 411€ /m^3 in 2018, adjusted for inflation to 461€ 2023 estimate for hazardous waste contaminated soil removal offsite and disposal provided by a Croatian waste contractor 650 to 1000 €/t Estimate includes 20000€ allowance for documentation and management and 10000 € allowance for validation testing More accurate rates for disposal and waste classification would reduce uncertainty in this cost estimate.	In the Arup 2020 cost estimate an allowance for remediation to address contaminated groundwater discharge at the coast was included. However the 2023 site investigation has concluded this remediation is not likely to be required. This report identifies that non-natural objects such as tyres and metal objects should be removed from the bathing area and imported clean beach material should be placed above and below water level. No cost has been assigned in this table as this would be required regardless of contamination.
Location and influence on phasing	Central and southeast areas of site (see plan)	Localised hotspots of contamination could be encountered across the site during any excavation work. Hotspots of grossly contaminated soils (tarry, hydrocarbon-saturated or highly odorous) should be removed offsite. All other made ground may be acceptable to remain on site (either undisturbed or reused beneath buildings/hard cover or cover layer of clean soil). Approval of the environmental regulator may be necessary. Development levels should be designed to maximize retention of excavated contaminated soil on site.	

	D	E	F
Contamination or ground-related risk item	Remaining slag requires removal offsite	All areas of soft landscape should be covered with clean imported soil layer.	In-ground obstructions require removal and processing (e.g. concrete crushing)
Likelihood of occurrence		**High**	**-**
Estimated cost (euro)		115k	-
Cost range (euro)	[245k to 2.05 million €]	80k to 300k	-
Cost basis and assumptions	Previously a market for slag in road construction was identified and much material removed off site for this purpose. However no slag has been removed from site in the last 2 years and it is assumed a market is no longer available. Therefore it is assumed that remaining slag is a waste requiring offsite disposal. The Arup 2020 cost estimate for slag disposal assumed the quantity estimated in Oikon 2014 (6000m^3). However based on site observation and considering the 2018 estimate by Geodetska Mjerenja d.o.o. (51000m^3), a volume of 30000m^3 is estimated as some slag has been removed since 2018. Assumed crushed slag density 1.2t/m^3. Two cost estimates for slag disposal have been considered: • A cost estimate for disposal of slag has been provided by Batižele d.o.o. as 50€ per tonne plus haulage of 7€ per tonne. Total 2.05 million € • Oikon 2018 assumed slag would be non-hazardous waste and could be disposed at non-hazardous waste rate of 6€/t in 2018, adjusted for inflation to 6.8 €/t. Total 245k € No cost is assigned for removal of fly-tipped material as cost of removal this material confirmed by Batižele d.o.o. as being borne by City of Šibenik. The quantity of construction type waste on site is estimated as 4,000 to 6,000m^3 and fly-tipped commercial and domestic waste less than 1,000m^3. The quality of this material has not been assessed in this report. More accurate rates for disposal and waste classification would reduce uncertainty in this cost estimate.	Made ground soils should not be exposed at surface following redevelopment. In areas of soft landscaping (not covered by buildings and hard cover) a cover layer of clean soils should be placed. A cost has been estimated based on an area of 10% of the entire site area will be soft landscaped and requires imported clean cover (22000 sqm). A thickness of 600mm clean cover material is typical for residential gardens (450mm subsoil, 150mm topsoil) and 300mm in publicly accessible open space (150mm subsoil, 150mm topsoil) in UK. The cost estimate assumes the area is 20% residential gardens, 80% public open space. Assuming that the standard landscape solution would include 150mm of new topsoil this cost estimate allows for the additional cost for cover for protection from soil contamination. 4400sqm x 0.45m subsoil residential gardens plus 17600 x 0.15m subsoil public open space, gives a total volume 4620m^3. Based on UK rates 25€/m^3 to import and place clean soil. There are significant assumptions in this estimate and therefore a wide range has been assigned to reflect this uncertainty.	A cost was assigned in the Arup 2020 cost appraisal, however this has been removed in this revised cost appraisal as removal of in-ground obstructions is a construction activity that would be required irrespective of contamination, and is not remediation or contamination related.
Location and influence on phasing		All soft landscape (vegetation or soil-covered) will need imported soil to cover made ground soils. This includes residential gardens and coastal slope.	

	G
Contamination or ground-related risk item	Change in regulatory standards and requirements affects development
Likelihood of occurrence	**Low**
Estimated cost (euro)	-
Cost range (euro)	-
Cost basis and assumptions	There are no known imminent changes to contamination regulation in Croatia. Remediation approach presented is based on current UK and continental European methodology. The developer is advised to consult the environmental regulator when the development design and works are defined to confirm the proposals are acceptable. It is possible that the regulator may require additional measures to those identified in this report however the remediation identified in this report is based on good practice and the likelihood of significant additional measures is considered to be low. No cost assigned.
Location and influence on phasing	

References

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Drawings

Appendix A

Site Photographs (from Arup walkover in November 2022 and site investigation in March 2023)

Appendix B

Aerial Photographs and Historical Images

Appendix C

Geotehnički Studio Factual Ground Investigation Report, 2023

Appendix D

Contamination Data Screening Assessment

Appendix D1: Human Health Screening Assessment – Soil

Appendix D2: Human Health Screening Assessment – Sediment

Appendix D3: Human Health Screening Assessment – Slag

Appendix D4: Waters Screening Assessment – Groundwater

Appendix D5: Waters Screening Assessment – Marine Water