PLANNED REMEDIATION MEASURES

OF SOIL AND GROUNDWATER

AT THE ex-HEL.PE. DEPOT TERMINAL

IN LARNACA, CYPRUS

TECHNICAL DESCRIPTION

Prepared

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1. INTRODUCTION

The Environmental Baseline Report (EBR) has concluded that risks to groundwater and future users of the land need to be reduced.

The objectives of the proposed remediation program are:
- To protect future uses of the land from contaminants in soil and groundwater
- To fulfil HEL.PE's responsibilities under relevant local environmental and permitting rules
- To reduce HEL.PE's liabilities and enhance the value of the land
- To honour HEL.PE's commitments to be a responsible organization
- To permit the safe redevelopment of the land to any land use

The following remediation actions will be undertaken to achieve the above objectives:

1. **Recovery of Light non aqueous phase liquid** (free oil product) at selected borehole locations.
2. **Remediation of soil in the vadose zone** to prevent further groundwater hydrocarbon contamination by leaching and percolation processes and to protect the health of future users of the land
3. **Groundwater remediation** in order to destroy or remove dissolved hydrocarbon contaminants.

2. SITE DETAILS

The Depot Terminal in Larnaca started **operation in 1948**. Some parts of the terminal were built later around 1970's and 1980's. **The terminal has been owned by HEL.PE. since 2003**.

The total surface area of the plot is about **52.900m^2.**

The ex-Depot terminal of HEL.PE. in Larnaca included totally 19 storage tanks. In 17 of them petroleum products were stored.

All tanks and pipelines were removed from the site by the end of June 2021.

3. REMEDIATION ALTERNATIVE SOLUTIONS

The main generic remediation solutions are:

A) Excavation of contaminated soils and disposal off site as hazardous waste in permitted facilities.
B) Excavation of contaminated soils followed by ex situ technologies on site (e.g. biopiles).

C) Implementation of in situ (without excavation/ abstraction) technologies (e.g. in situ chemical oxidation; soil vapour extraction; in situ biostimulation).

D) Containment and isolation of contaminated soil using vertical or horizontal cover barriers.

E) Systematic monitoring of natural attenuation processes such as aerobic / anaerobic / co-metabolic biodegradation, chemical degradation, sorption, dispersion, dilution which act over time.

The main remediation alternative solutions are presented synoptically in diagram 1 below :

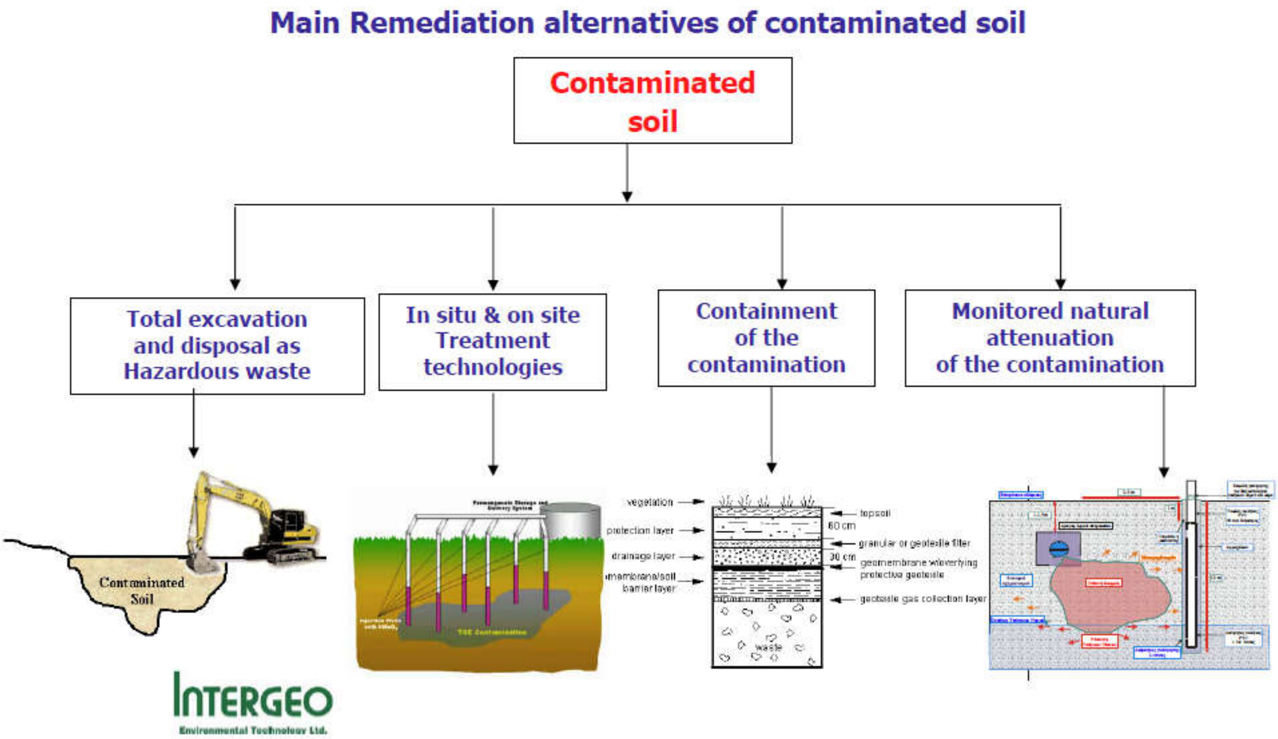


Diagram 1 : Main remediation alternatives of contaminated soil.

The selection of the most appropriate remediation solution should take into account the following parameters:

- Physico-chemical characteristics of the contaminants pollutant
- Extent of existing contamination
- Geological and hydrogeological characteristics of the unsaturated zone and the hydraulic communication with the potential receptor
- International best practice examples for decontamination in similar cases
- Experiences of implementation of decontamination technologies applied in similar climatic and hydrogeological conditions
- Available financial and technical capabilities

- Cost effectiveness of the method
- The wider social acceptance of the remediation technology.
- Environmental impact of remediation
- Ensuring health and safety of workers and general public
- Time pressure concerning the completion of the remediation
- Regulatory permitting and/ or agreement
- Ability to gather evidence to validate effective remediation outcomes

4. SELECTION OF THE MOST APPROPRIATE SOIL REMEDIATION ALTERNATIVE

The extent of soil contamination encountered, according to the extended investigation of 2020-21 and May-June 2022, is detailed in the Environmental Baseline Report (EBR).

After the findings of an extensive soil and groundwater investigation (c.f. EXTENDED ENVIRONMENTAL SOIL AND GROUNDWATER INVESTIGATION (JUNE 2020, DECEMBER 2020-JANUARY 2021 AND JULY 2021 and May-June 2022) at the Site and completed remediation in some parts of the Site, a comparison of alternative soil remediation technologies was undertaken.

The results of this evaluation are presented in table 1 below.

Table 1: Comparison of the appropriate soil remediation alternative for the ex HEL.PE. Depot Terminal in Larnaca, Cyprus

Remediation method	Advantages	Disadvantages	Estimated duration
Total excavation of the contaminated soils and disposal as hazardous waste	1. Immediate solution for soil remediation especially for short amounts 2. Total removal of the contamination 3. The estate is afterwards suitable for any kind of use	1) **High expenses** 2) Need for extended earthworks that would need special HS precautions for the workers 3) Need to apply new backfill materials into the excavated space 4) Due to the high amount of the contaminated soil it is difficult for a disposal company to reach this capacity in a short time frame. Probably a Hazardous Waste Storage license with a sufficient capacity will be also needed.	For the specific terminal 6-8 months
In situ (without excavation) and on site (excavation and on site application) technologies	1. Cost effective solution 2. Immediate start also during operation of the terminal 3. No risk of atmospheric dispersal 4. No HS risks for the workers and employees of the terminal 5. The estate is afterwards suitable for any kind of use	1) Not any immediate solution, needs time 2) By the in situ implementation some residual contamination can remain at the site. 3) However, by the combined implementation of on-site treatment this residuals can be removed totally	For the specific terminal 15-36 months, depended on the target values
Containment of the contaminated soil	Relative low cost solution, Not any further groundwater contamination takes place	Passive solution that does not address the existing soil contamination **Not any further usage of the estate is possible** It has a specific duration	For the specific terminal 2-4 months
Natural attenuation procedure	Very low cost solution,	**Very passive technology** The environmental risk of the contamination remains at the site The procedure can be applied in locations with low environmental risk and only after operation cease Long term monitoring must be conducted throughout the process Not any sensitive usage of the estate is possible for the future	For the specific terminal more than 30 years (if not any new sources will appear)

Based on the performed evaluation **the most appropriate remediation solution for the contaminated soil at the former Depot terminal of HEL.PE. Cyprus in Larnaca is the application of the in situ soil remediation measures by means of various technologies as the Bioventing / SVE technology/ in situ chemical Oxidation.**

These technologies were shortlisted as likely to be technically viable, economically, environmentally and socially acceptable solutions. These technologies will be applied simultaneously or in series, this will be decided after some initial pilot tests at the site

The above in situ technologies **can be combined with on-site remediation measures (if recalcitrant contaminants render this necessary) using the bioremediation technology** which is based in the same principle. The treated soil by the onsite techniques can be disposed as inert waste or reused as backfill material outside of the area.

By the appropriate and safe application of the above remediation measures there is no risk of atmospheric dispersal, no health & safety risks for the workers and employees of the terminal and the land is left suitable for any kind of use (recreational/residential).

5. SELECTION OF THE MOST APPROPRIATE GROUNDWATER REMEDIATION ALTERNATIVE

After the findings of the performed **EXTENDED ENVIRONMENTAL SOIL AND GROUNDWATER INVESTIGATION (JUNE 2020, DECEMBER 2020-JANUARY 2021, JULY 2021 and May-June 2022)** at the ex-Depot terminal of HEL.PE. in Larnaca and the already performed remediation project in some parts of the installation, the comparison of all alternative groundwater remediation solutions for the specific site took place.

Based on the performed evaluation table the most appropriate remediation solution for the contaminated groundwater at **the former Depot terminal of HEL.PE. Cyprus in Larnaca is the application of the in situ groundwater remediation measures by means of Bioremediation technology or Chemical Oxidation and various pump and treat techniques** as Air stripping and activated Carbon filter which are identified as the most feasible and technically, economically, environmentally and socially acceptable solutions.

In prior or in parallel of the application of these technologies, **the appropriate Oil product recovery measures should be applied** in the groundwater at the site in specific areas (if present). The total removal of the floating oil product will significantly reduce the contamination load and subsequently the amount of the dissolved hydrocarbons in the groundwater.

These measures **are very cost effective in comparison to the other alternatives and can start immediately at the site.** These techniques are tried and tested on similar situations across Europe and have been found to be very cost effective in comparison to the other alternatives considered.

6. SOIL REMEDIATION

6.1 Objectives

The objectives of the proposed soil remediation program are:

- The protection of the environment and the coastline from the recorded soil and groundwater contamination at the specific site
- The fulfilment of the requirements of the environmental authorities. To demonstrably reduce soil contaminant concentrations to below the Suitable for Larnaca Levels (S4LL) published by the environmental authorities

6.2. General description of the soil remediation systems

The proposed remediation measures to be applied at the site are based on in situ and on site technologies, such as

a) In situ chemical Oxidation
b) Soil Vapor Extraction / Bioventing- Biosparging

These technologies will be applied simultaneously or in series, this will be decided after some initial pilot tests at the site

6.2.1 In situ chemical Oxidation

Chemical oxidation uses chemicals called “oxidants” to help change harmful contaminants into less toxic ones. It is commonly described as “**in situ”** because it is **conducted in place**, without **having to excavate soil or pump out groundwater for aboveground cleanup**. In situ chemical oxidation, or “ISCO,” can be used to treat many types of contaminants **like fuels, solvents, and pesticides.** ISCO is usually used to treat soil and groundwater contamination in the source area where contaminants were originally released.

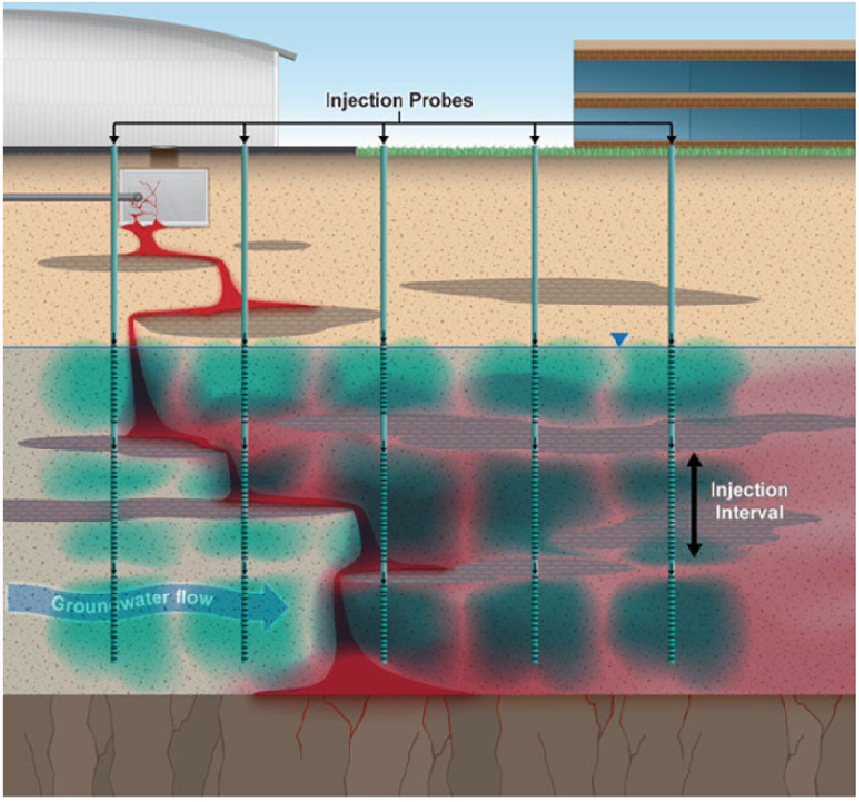
ISCO can be applied independently of other techniques or in combination with other in situ decontamination techniques.

The source area may contain contaminants that have not yet dissolved into groundwater. Following ISCO, other cleanup methods, such as pump and treat or monitored natural attenuation, are often used to clean up the smaller amounts of contaminants left behind.

When oxidants are added to contaminated soil and groundwater, a chemical reaction occurs that destroys contaminants and produces harmless byproducts.

To treat soil and groundwater in situ, the oxidants are typically injected underground by pumping them into wells. The wells are installed at different depths in the source area to reach as much dissolved and undissolved contamination as possible. Once the oxidant is pumped down the wells, it spreads into the surrounding soil and groundwater where it mixes and reacts with contaminants.

This injection can take place during drilling (Direct push method) with impermanent wells (drilling holes) (picture 1) or into permanent wells (injections wells) (pictures 2a and 2b).



Picture 1 : In situ chemical Oxidation (ISCO). Injection Method : Direct push injection (during drilling)

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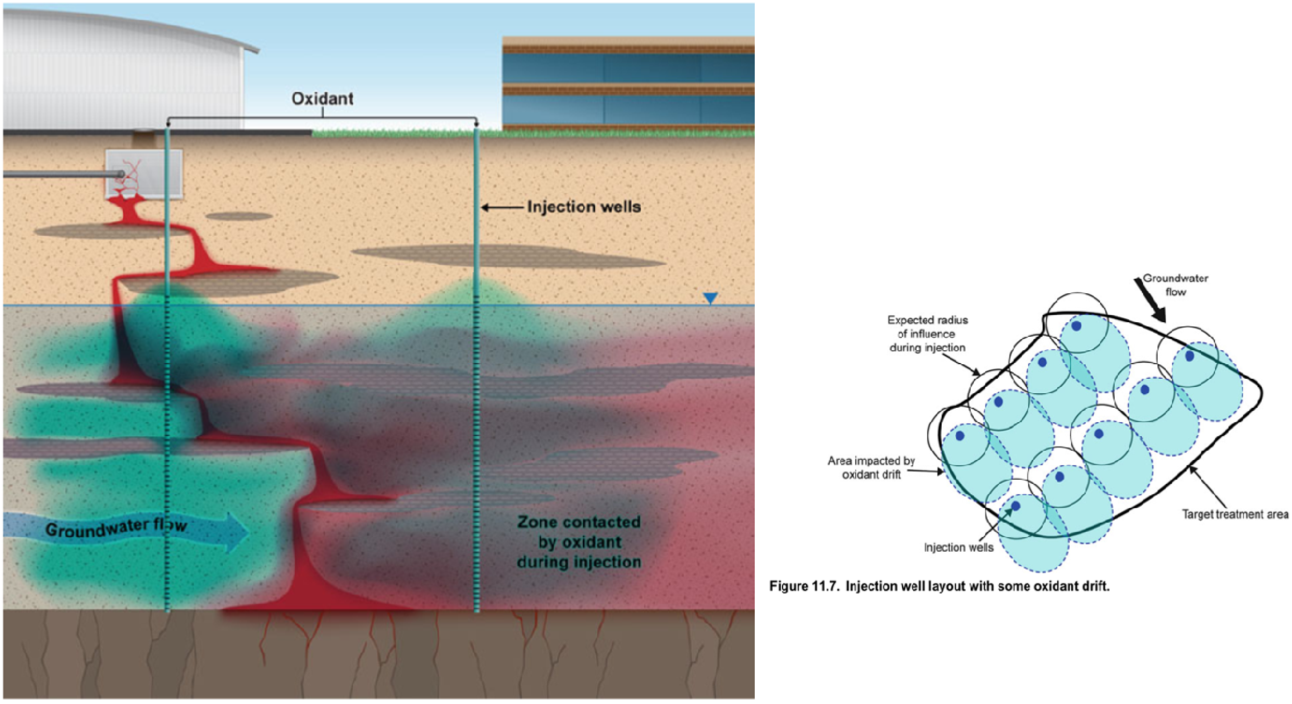
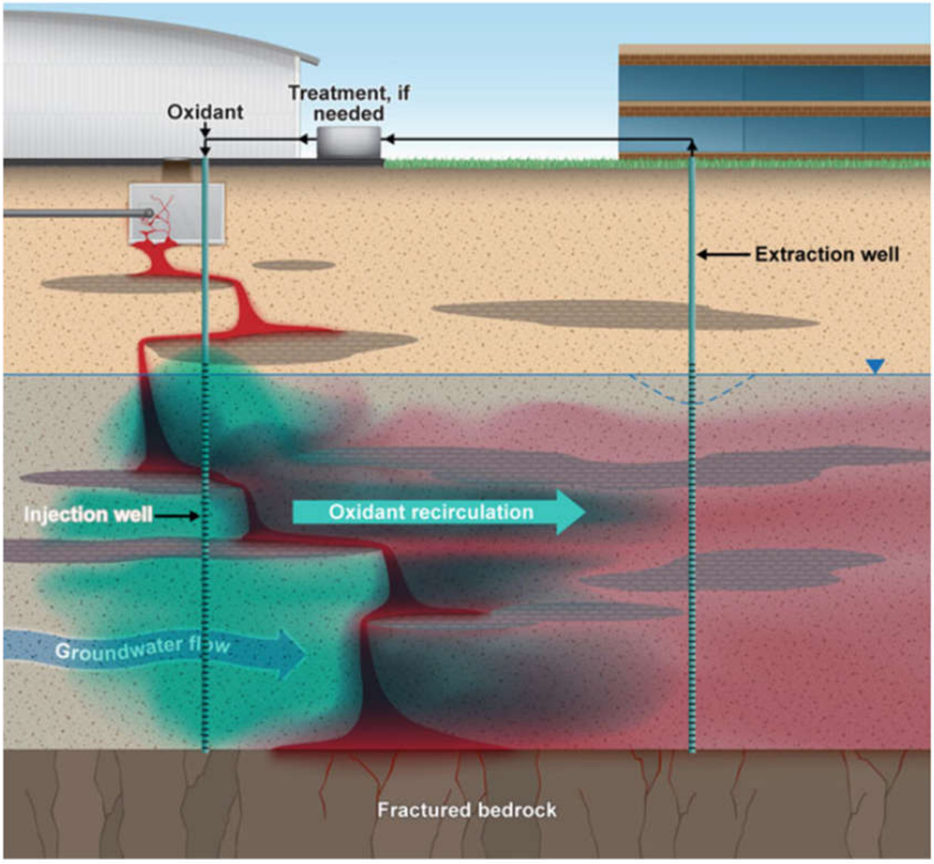
Picture 2a: In situ chemical Oxidation (ISCO). Injection Method : By means of existing injections wells (permanent wells)



Picture 2b: In situ chemical Oxidation (ISCO). Injection Method : By means of existing injections wells (permanent wells)

To improve mixing, the groundwater and oxidants may be recirculated between wells. This involves pumping oxidants down one well and then pumping the groundwater mixed with oxidants out another well. After the mixture is pumped out, more oxidant is added, and it is pumped back (recirculated) down the first well. Recirculation helps treat a larger area faster (picture 3).



Picture 3: In situ chemical Oxidation (ISCO). Injection Method : By means of existing injections wells (permanent wells) and recirculation.

Another option is to inject and mix oxidants using mechanical augers or excavation equipment. **This may be particularly helpful for clay soil.**

The four major oxidants used for ISCO are permanganate, persulfate, hydrogen peroxide and ozone. The first three oxidants are typically **injected as liquids**. Although ozone is a strong oxidant, it is a gas, which can be more difficult to use. As a result, it is used less often.

Catalysts are sometimes used with certain oxidants. A catalyst is a substance that increases the speed of a chemical reaction. For instance, **if hydrogen peroxide is added with an iron catalyst,** the mixture becomes more reactive and destroys more contaminants than hydrogen peroxide alone, therefore this mixture is chosen for the specific site (Fenton solution) .

Following treatment, if contaminant concentrations begin to climb back up or “rebound,” **a second or third injection may be needed.** Concentrations will rebound if the injected oxidants did not reach all of the contamination, or if the oxidant is used up before all the contamination is treated. It may take several weeks to months for the contamination to reach monitoring wells and to determine if rebound is occurring.

ISCO works **relatively quickly to clean up a source area**. Cleanup may **take a few months or years,** rather than several years or decades.

The **use of ISCO poses little risk to the surrounding community**. Workers **wear protective clothing when handling oxidants,** and when handled properly, these **chemicals are not harmful to the environment or people.** Because contaminated soil and groundwater are cleaned up underground, **ISCO does not expose workers or others at the site to contamination. Workers test soil and groundwater regularly to make sure ISCO is working**.

ISCO is usually **selected to clean up a source area**, where it destroys the bulk of contaminants in situ without having to dig up soil or pump out groundwater for aboveground treatment.

Indicative locations of the (Direct push method) injection points within the site is shown in figure 1 attached.

The injection depth will be from 0,5 to 2,0 m depth in each drilling position were the contaminated part of the soil was encountered.

6.2.2 Soil Vapor Extraction / Biosparging technique

The proposed remediation measures include that application of Soil Vapour Extraction technique in combination with Biosparging technique. This will be applied subsequently and eventually in parallel with the ISCO technique depending on the progress of the remediation.

For both techniques the same boreholes will be used and also the same blowers. However, there will be systematic changes of injection and suction in the blower units at the site based on the hydrogeological conditions during the year (fluctuation of the groundwater table).

Soil vapour extraction, known as SVE, is the most frequently selected decontamination technique at contaminated sites. It is a relatively simple process that physically separates contaminants from soil. As the name suggests, SVE *extracts* contaminants from the *soil* in *vapo*r form. Therefore, SVE systems are designed to remove contaminants that have a tendency to volatilize or evaporate easily.

SVE removes *volatile* organic compounds (VOCs) and some *semi-volatile* organic compounds (SVOCs) from soil beneath the ground surface in the unsaturated zone—that part of the subsurface located above the water table. By applying a vacuum through a system of underground wells, contaminants are vacuumed to the surface as vapor or gas.

Often, in addition to vacuum extraction wells, air *injection* wells are installed to increase the air flow and improve the removal rate of the contaminant. An added benefit of introducing air into the soil is that it can stimulate *bioremediation* of some contaminants. Very often the same wells can be used for both techniques where some changes take place concerning the origin of the extracted air (subsurface of atmospheric).

SVE is sometimes called in situ volatilization, enhanced volatilization, in situ soil venting, forced soil venting, in situ air stripping, or soil vacuum extraction.

SVE can be applied in-situ and no amount of the contaminated soil has to be removed. The first step to constructing an SVE system is to install vapor extraction wells and injection wells (or air vents) in the contaminated area. Air injection wells use air compressors or blowers to force air into the ground. Air vents serve the same function as air injection wells, but are passive—instead of pumping air they just provide a passage for air to be drawn into the ground. When incoming air passes through the soil on its way to the extraction wells, contaminants evaporate out of the spaces between the soil particles and are pulled by the air to the wells and removed.

Vapor extraction wells are placed vertically and are designed to penetrate the lower portion of the unsaturated zone.

Vapors extracted by the SVE process are typically treated using carbon adsorption, incineration, catalytic oxidation, or condensation. The type of treatment chosen depends on which contaminants are present and their concentrations.

Carbon adsorption is the most commonly used treatment for contaminated vapors and is adaptable to a wide range of volatile organic compounds. Thus, soil-vapor extraction system consists of a strong vacuum pump, a water separator and an activated carbon filter.

When properly designed and operated, SVE is a safe, low maintenance process.

The vacuum pump has a maximum air removal capacity **of 250 m^3/h.** In each case the application of the calculated demanded sub - pressure differentiates the gas - liquid phase equilibrium of hydrocarbons in soil. Due to sub-pressure, hydrocarbons are transferred from the liquid to the gas phase, where they are sucked and led through the activated carbon filter.

The **proposed SVE technique (picture 4) will be combined with the Biosparging technique in order to address the contamination in the saturated soil and subsequently in the groundwater**.

Biosparging technology will be combined with SVE using the same equipment (blowers) and the same wells. The change from one technique to the other will depend mainly from the depth of the groundwater table.

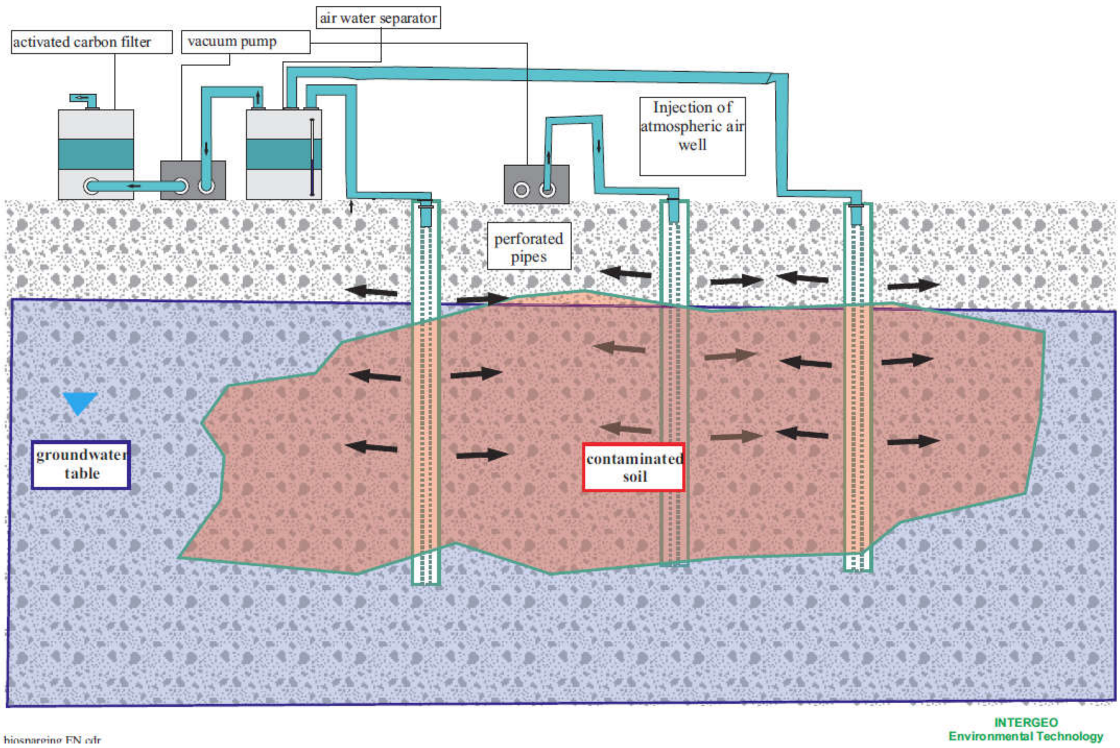
It is planned to apply SVE in months where the groundwater table is relative deep (estimated 1,0-1,2m bgs) and change to Biosparging in periods with shallow groundwater table is very shallow (0,4 – 0,6 m bgs)

The two different options for proposed soil remediation approach using Biosparging and SVE in alteration are shown in pictures 4 and 5 respectively.

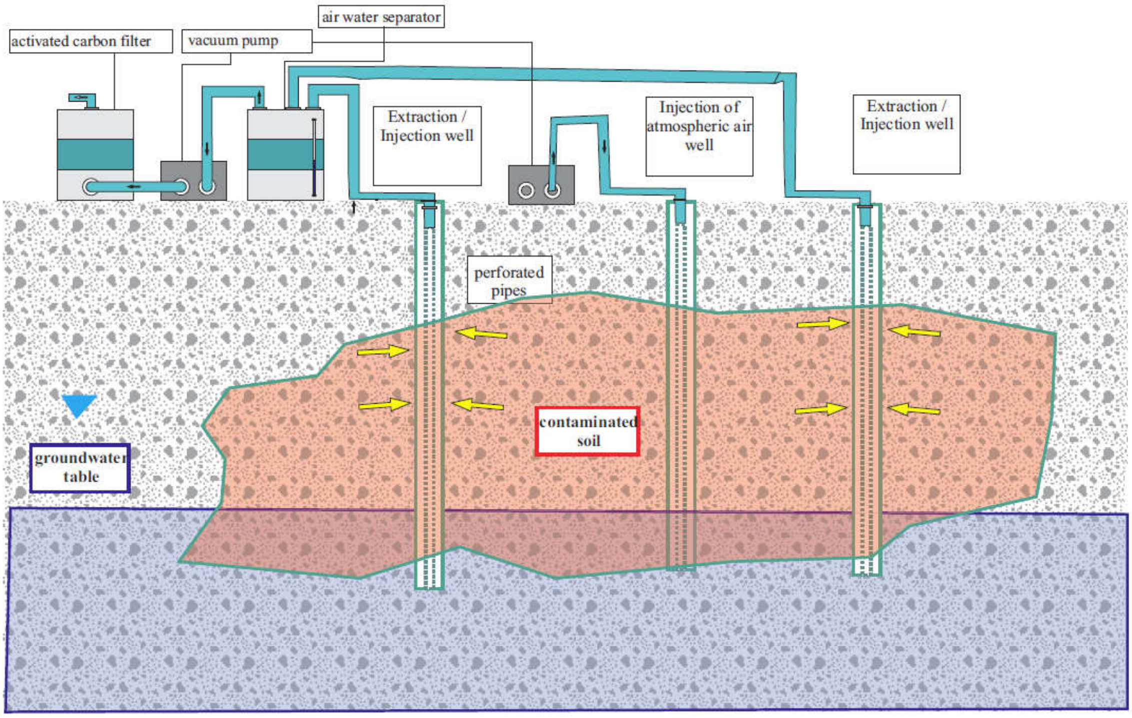
However, this will be also verified at the specific site and some modifications could be possible during the operation, if necessary.

This technique can be used for pollutants that are degradable in aerobic conditions (such as oil **pollutants with a chain length up to C30 and aromatics**)

The application of on site or in situ treatment of contaminated soils **are more cost-effective solutions** in rely to total excavation and disposal as hazardous waste alternative.



Picture 4: Application of Biosparging at the specific site during periods with high groundwater level



Picture 5: Application of SVE at the specific site during periods with low groundwater level

6.2.2.1 Construction of SVE wells

For the specific site the construction of shallow Soil Vapor Extraction (Bioventig) wells associated with respective Soil Vapor extraction/Bioventing units are suggested and their locations at the specific site will be finalized after a site visit and the approval of the responsible engineers of Helpe Cyprus. The indicative locations of the SVE wells and the SVE systems is shown in figure 2 attached.

The extraction wells will have a depth of 1,5-2,0 m below surface with a casing diameter of 2 inches with a drilling diameter of 3-4 inches. INTERGEO will provide the special slotted pipes that should be installed within the wells. The casing diameter of the pipes will be 4,5 inches.

The same wells will be used and Biosparging wells for the injection of atmospheric air into the ground.

Properly grain-sized filter gravel will be introduced into the well, in order to fill the annular space between the pipes and the borehole walls up to a depth of approximately 0,2m below ground level. Gravel filter will be of suitable type and composition (silica-dominated, preferably from river deposits). Furthermore, cementation or addition **of cement grout in the annular space** between the pipes and the borehole walls **for the top 0,2m of the well to act as seal**.

Each well should have temporary watertight cap until the SVE system is connected.

6.2.2.2 Description of above ground treatment installation

From these extraction wells (SVE wells) the extracted soil-gas will be leaded by means of special plastic pipelines directly to the SVE system. Four (4) to six (6) SVE systems will be installed close to the extraction wells. Each system will be connected with three to six (6) wells. These connection pipelines will be either placed within special excavated shallow trenches or will be placed on the ground surface.

Each SVE/Biosparging system will consist from the following items:

a) Blower
b) Air – water separator bin (170 lt barrel)
c) Activated carbon bin (170 lt barrel)

Each system will be enclosed within a metallic box in order to be discrete and not to arise any attention. The approximate dimensions of these boxes will be 2m X 1m X 1,70 m height (see photos 1 and 2).

Photos 1 and 2: Metallic protective box which will enclose each SVE/Biosparging system (also shown the air/water separator bin and also the activated carbon bin)

These units satisfy all the safety requirements for a storage Depot terminal with fuels.

The proposed position of all soil remediation systems is presented in figure 2 attached. It has to be noted the final position will be decided at the site together with responsible engineers of Helpe Cyprus.

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6.2.3 On site treatment of excavated contaminated soil

In the unlikely case that the in situ measures did not reach the target remediation values for the soil set by the local environmental authorities, **then an alternative remediation technology will be applied.** This is the on-site bioremediation method.

Bioremediation is a remediation technique that amplifies natural biological actions to remediate contaminated soil. Rather than using expensive environmental remediation equipment to remove untreated toxic materials and dispose of them elsewhere, bioremediation techniques use biological microbes to do the cleanup work.

The bioremediation process is a biological process that stimulates helpful microbes to use harmful contaminants as their source of food and energy. Certain microorganisms eat toxic chemicals and pathogens, digesting them and eliminating through changing their composition into harmless gases like ethane and carbon dioxide. Some contaminated soil conditions already have the right counter-microbes. Here, human intervention can speed up the natural remediation **by boosting microbial action (enhanced bioremediation)**.

In cases where the right microbes are low in numbers or entirely absent, bioremediation is enhanced by adding amendments — microbial actors like fungi and aerobic bacteria that are mixed into the soil. This simple process is called bioaugmentation, and it's highly effective to correct conditions quickly, as long as the right environmental conditions are present.

The proposed technique will be applied in case that certain areas with contaminated soil need an additional boosting by applying a certain additional treatment on the surface where the control of the environmental conditions is more easy to take place.

For this potential action the preparation of an additional Bioremediation cell within the site is necessary.

6.2.3.1 Construction of a preliminary Bioremediation cell

The design and construction of the bioremediation cell (if necessary) will be based on site-specific factors, taking into account the nature of the chemical substances and the site conditions (e.g. infrastructure, pavement).

The area that might be used for the storage or bioremediation of soil will be as follows:

- surrounded by a bund constructed to ensure containment of stormwater and leachate and prevent infiltration of external stormwater;
- constructed using approved materials (see below) so that all leachate is either confined to the lined area or directed to a collection pit
- constructed with a minimum gradient of 2% so that the final floor level has a gradient sufficient to enable surface water and leachate to drain to suitably lined sumps or pit.

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The collected water can be recycled into the bioremediation pad for moisture control or will be analysed at the end for its concentration in various parameters. If the leachate water reaches the quality standards of the local sewage system will be disposed at the nearby pit. If not the leachate water will be disposed as hazardous waste or treated on site by means of Granular Activated Carbon (GAC) filters.

The estimated preparation cycle is estimated between 1 or 3 weeks and the proposed amount per cycle is 500 t. The total preparation period is strongly depended on the final amount of the contaminated soil that has to be treated, but it is estimated not to exceed 20 days.

Construction of impermeable base layers
The option below using concrete is preferred to those using non-synthetic compacted clay liners, based on durability and performance. Design and construction will be based on site-specific factors, taking into account the nature of the chemical substances and the site conditions (e.g. soil and hydrogeology).

Materials and methods
Approved materials/methods for constructing bioremediation pad liners:
Concrete
• fine-pour concrete top layer—thickness to be based on quality requirements (wear, vehicle movements, etc.)
• 100 mm reinforced subgrade.
Estimated extent of the bioremediation cell: 30m X30m. The location for the proposed Bioremediation cell is shown in figure 2.

6.2.3.2 Operation of a preliminary Bioremediation cell

- **Soil preparation phase**

Initially, from the impacted backfill material-soil a separation phase of stones or other debris material will take place mechanically of manually. This will be carried out within the bioremediation cell. Then the remaining contaminated soil will be prepared for the bioremediation procedure. During the preparation phase quantities of biocatalytic liquids and microorganisms (if necessary) will be added to the soil piles. These, substances enable the stimulation of aerobic biodegradation of the contaminants through controlled-release oxygen and nutrient delivery. Via this mechanism, a significant and rapid decrease of the hydrocarbons in the soil is achieved and therefore the pollution is reduced based on biological mechanisms.

Hydrocarbon impacted soils have a lot of available carbon present but generally do not have sufficient available nitrogen present to support optimal bioremediation. The materials that will be used as additives will provide also a source of nitrogen to ensure adequate nitrogen is present for the indigenous microorganisms to utilize the available carbon (i.e., hydrocarbons).

Then irrigation of the soil will take place (approximately 20-30% on dry weight basis).

- **Aeration phase (tiling procedure)**

After a standing time of 1 to 3 days ventilation (Aeration) on of the soil will take place by tilling for 1 to 3 days. Then a new sampling and on-site analyses will take place (PID measurements in selected soil samples).
During the bioremediation procedure selected soil samples will be analyzed in accredited laboratory (EN ISO 17025) for TPH (Total Petroleum Hydrocarbons) concertation.
Based on the results, the continuation of the procedure or its interruption will be decided (TPH <500 mg/Kg) and the next selected amount of contaminated soil will be prepared in the same way.
The clean soil will be removed and place onto the stockpile of clean soil for detailed testing.
All necessary HSE precautions (PPE material, soil covers, and leachate collection) will be applied by INTERGEO's personnel.

Furthermore, not any heavy construction will take place at the site.

- **Disposal of clean soil**

All clean soil based on the initial characterization by on site chemical analyses of TPH will be placed on the clean soil stockpile (special location outside of the bioremediation cell) for detailed testing.
Subsequently, if the target concentrations set by the local environmental authorities for residential purposes have been achieved, then the soil will be backfilled back to the site in the excavated areas

Alternatively the clean soil will be disposed off for further reuse in authorized receptors for construction and demolition waste (CDW) for recycling purposes

- **Environmental Soil investigation in the ex-stockpile - Bioremediation area**

When all the stockpiled material has been removed, environmental sampling will be conducted on the ground/surface area so as to ensure that no contamination has been transferred onto the surface or to the subsoil. At least ten (10) shallow soil borings will be applied in order to get representative soil samples for TPH analyses.
A relevant investigation report will be prepared and submitted to Helpe Cyprus and the environmental authorities .

Indicative locations of the SVE wells and units and of the onsite soil treatment at the ex HEL.PE. Depot terminal in Larnaca, Cyprus are presented in figure 2 attached.

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6.3. Monitoring program

Periodical measurements of the hydrocarbon concentration in the removed soil-gas, before and after its conveyance through the activated carbon filter, with the help of single use test tubes (Dräger.-Röhrchen), or with portable PID device monitor the decontamination progress, the absorption abilities of the filter and the appropriate time for replacing the activated carbon. These **measurements** will take place **on daily basis**.

Every three months soil-gas samples will be obtained for laboratory analyses of VOCs concentrations. The samples will be obtained in absorbing media (activated carbon tubes) from all SVE units.

Every **six months** a report will be prepared including synoptically the progress of the remediation, all on site measurements and chemical analyses results.

The progress of the remediation will be recorded as follows:

a) The comparison of the measured VOC concentration with portable PID in the extracted soil-gas from each SVE unit, every day
b) The comparison of the analysed VOC concentration in the extracted soil-gas from each SVE unit, every three months

6.4 Target of the soil remediation

Target of soil remediation will be the following concentrations :

The standards set by the authorities for the soil for **Recreational and residential use** (based **on the Relevant study from LQM).**

Estimated duration of this phase: **0 - 12 months,** Based on the target values set for the groundwater (see paragraph 7.6)

The criteria and measures that will be performed to confirm remedial goal is achieved will be:
According to performed periodical on site measurements by means of portable measuring devices (VOC concentration by PID) the decision to pause the SVE system will be taken if the measurements seem to be close to the target. This action will take place as follows :
Pause of the SVE/ Biosparging system **for one week** and obtain soil-gas samples from the SVE units. The chemical analyses of VOCs with emphasis in BTEX will confirm the completion or not of the remediation measures. If the encountered concentrations fulfill the target limit of 50 mg/m^3 (VOC concentration, maximum allowed concentration in the sol-gas in Austria and Germany), then a second sampling campaign will take place **after a-week time** and the same chemical analyses will be performed

If the obtained soil gas samples are below the target value of 50 mg/m^3 (VOC concentration) then a drilling and sampling campaign will take place in selected locations (over 30 points) in order to perform **chemical analyses in the soil in order to validate the completion of the remediation by comparing the hydrocarbons concentration with the required remediation limits (S4LL's) of the environmental authorities of Cyprus**.

Based on these results the successful completion of soil remediation can be certified or not.

If the chemical analyses do not fulfill the required limits, then the soil remediation will continue.

7. GROUNDWATER REMEDIATION

The groundwater remediation program includes mainly Oil Product Recovery measures.

Additionally and if it is necessary the application of in situ chemical oxidation measures will take place in order to address the dissolved organic contaminants.

7.1 Objectives

The objectives of the proposed groundwater remediation program are:

- The protection of the environment and the coastline from the recorded soil and groundwater contamination at the specific site
- The fulfilment of the requirements of the local environmental authorities and to reduce groundwater contaminant levels to below remedial targets presented in paragraph 7.6

7.2. General description of the groundwater remediation systems

The groundwater remediation program includes Oil Product Recovery measures and the application of in situ chemical oxidation in order to address the dissolved organic contaminants.

The proposed remediation measures to be applied at the site are in situ technologies:

a. Free product (LNAPL) recovery combined with activated carbon filter (pump and treat) for the separated water
b. In situ chemical oxidation of dissolved phase hydrocarbons

7.2.1 Oil product recovery

Oil product recovery will involve the construction of groundwater recovery wells mainly at locations where floating free product has been encountered and within the hot spot of the groundwater contamination.

These wells will be fitted with special automatic top-loading pneumatic pumps to recover LNAPL and shallow groundwater from a specific depth. The total amount of the recovered oil product and contaminated groundwater will not be higher than 25-30 m^3 per day, however this will be finalized after the performance of a short pilot test before the start of the remediation.

The extracted mixture of LNAPL and water will be passed through a mobile oil/ water separator unit. The separated free product (LNAPL) will be disposed off as hazardous waste.

The separated water will be treated by means a GAC (Granular Activated Carbon filter) and treated water will be discharged to the rain water drainage system or alternatively reinjected into the groundwater.

Estimated duration of the Oil product recovery procedure: **up to 3-6 months**.

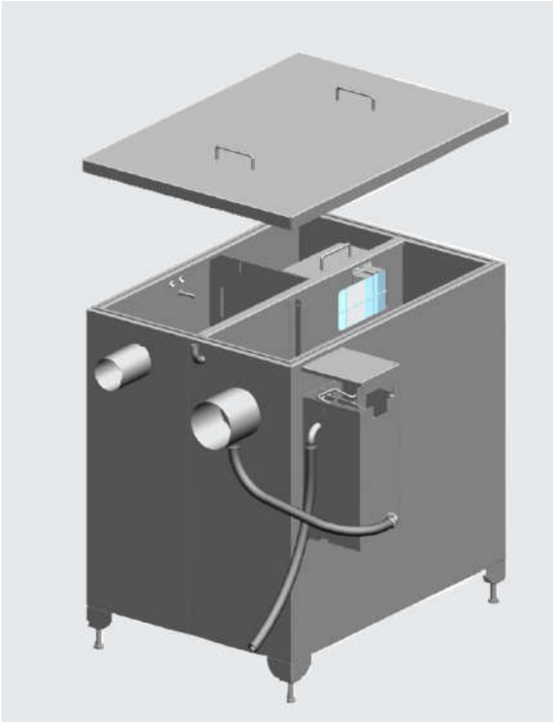
7.2.1.1. Description of above ground Oil water separator

The above ground mobile oil/water separator that will be used at the site, is designed to separate non-emulsified light liquids or low- water-soluble fluids with a specific gravity below 0,95 (gasoline, diesel, heating oils and other mineral oils) from effluent discharge. The Oil/Water Separator meets all of the requirements of strict European separation standards (DIN 1999 and EN-858).

A two-step separation process, gravity separation and removal of small oil particles by coalescing media elements, produce high removal efficiencies. The separated oil is automatically removed from the water surface and collected in an internal or external oil recipient.

The system includes an automatic draw-off device (ADD) for maximum environmental protection. The light fluids are constantly being removed from the water surface and collected in an integrated or external oil recipient. No stable emulsions can be formed. A large amount of the separated light liquid can be recovered without any interrupting the collection cycle of the Oil water separator.

The automatic drawoff device will collect the pure petroleum product, and not an oil-water mixture. The costly disposal of large quantities of oil and water mixtures is then eliminated.



Picture 6: The above ground mobile Oil-water separation that will be used

The residual hydrocarbon concentration in the effluent will not exceed 10 ppm.

7.2.2 Dissolved phase remediation

The separated water after the oil separator will be leaded to a GAC filter in order to adsorb the dissolved contaminants.

7.2.2.1 GAC filter

GAC filtration (picture 7) is recognized by the Water Quality Association as an acceptable method to maintain certain drinking water contaminants within the limits of the EPA National Drinking Water Standards. Organics that are readily adsorbed by activated carbon include:

- Aromatic solvents (benzene, toluene, nitrobenzenes)
- Chlorinated aromatics (PCBs, chlorobenzenes, chloroaphthalene)

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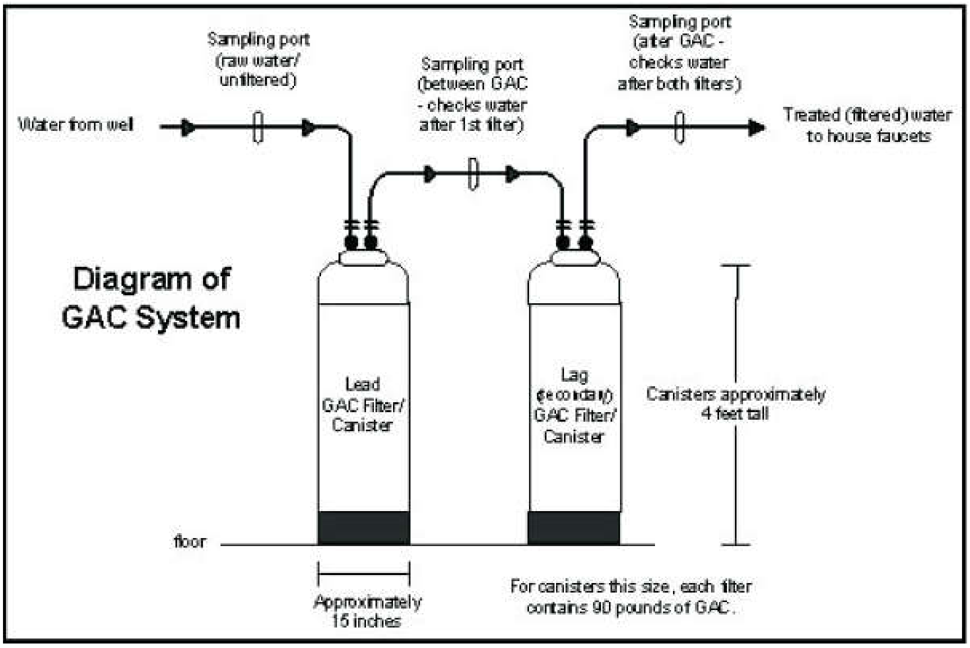
- Phenol and chlorophenols
- Polynuclear aromatics (acenaphthene, benzopyrenes)
- Pesticides and herbicides (DDT, aldrin, chlordane, heptachlor)
- Chlorinated aliphatics (carbon tetrachloride, chloroalkyl ethers)
- High molecular weight hydrocarbons (dyes, gasoline, amines, humics)

Various types of GAC are available for removing organics from water, however, the most frequently used carbon is coal-based carbon due to its hardness, adsorption capacity, and ease of availability.

The treatment system of contaminated groundwater by dissolved hydrocarbons will consist of two pressure cylindrical vessels of about 700 lt capacity each. The materials of pressure equipment are carbon steel.

The treatment capacity of the GAC system will be 5 m^3/h. If it is necessary during the remediation procedure a second GAC system will be installed at the site.



Picture 7: Concept of groundwater treatment Granulated Activated Carbon

The treated water will be discharged to the rain water drainage system or alternatively reinjected into the groundwater

Photo 3: Typical GAC system for groundwater treatment applied by INTERGEO

Estimated duration of the groundwater remediation procedure (dissolved contaminants) : 3 –12months

7.2.2.2 In situ chemical oxidation

In situ chemical oxidation will be applied also for the groundwater. This will be achieved by the construction of special injection wells .

Injections wells for ISCO for the groundwater will be constructed at locations where not any free product is encountered proposed by INTERGEO and verified and approved by the managers of the Helpe Cyprus.

Totally twenty (20) injections wells up to depth of 4 m below ground will be constructed. These wells aim mainly to the injection of the oxidants to the saturate soil zone. This injection will be implemented systematically and periodically after constant time interval into the injection wells depending on the progress of the decontamination.

Catalysts are sometimes used with certain oxidants. A catalyst is a substance that increases the speed of a chemical reaction. For instance, **if hydrogen peroxide is added with an iron catalyst,** the mixture becomes more reactive and destroys more contaminants than hydrogen peroxide alone. Therefore this mixture is chosen for the specific site (Fenton solution) .

This action will enhance also the groundwater remediation from dissolved hydrocarbons.

7.3 Installation

7.3.1 Construction of Oil product recovery wells.

Twenty (20) new recovery wells should be constructed at the site. The location of the wells will be proposed by INTERGEO and verified and approved by the managers of the Helpe Cyprus construction of the wells.

The characteristics of the recovery wells will be the following:

The drilling diameter of the new recovery wells should be at least 8,0 inches and the depth of each well should be at least 4m below the ground surface.

INTERGEO will provide the special slotted pipes that should be installed within the wells. The casing diameter of the pipes will be 4,5 inches.

Properly grain-sized filter gravel should be introduced into the well, in order to fill the annular space between the pipes and the borehole walls up to a depth of approximately 0,5m below ground level. Gravel filter will be of suitable type and composition (silica-dominated, preferably from river deposits). Furthermore, cementation or addition **of cement grout in the annular space** between the pipes and the borehole walls **for the top 0,5m of the well to act as seal**.

After the completion of the construction, development and cleaning of the water well will take place in order to remove the solid particles (e.g. sand, clay) from inside the water well. Each well should have temporary watertight cap until the pumping equipment for Oil product recovery is installed.

7.3.2 Construction of injection wells for ISCO

Twenty (20) new injections wells are to be constructed at the site for the application of the in situ Chemical Oxidation (ISCO) as described above. The location of the wells will be proposed by INTERGEO and verified and approved by the managers of the Helpe Cyprus construction of the wells.

The characteristics of the recovery wells will be the following:

The drilling diameter of the new injection wells should be at least 6,0 inches and the depth of each well should be at least 4m below the ground surface.

INTERGEO will provide the special slotted pipes that should be installed within the wells. The casing diameter of the pipes will be 2,0 inches.

Properly grain-sized filter gravel should be introduced into the well, in order to fill the annular space between the pipes and the borehole walls up to a depth of approximately 1,0m below ground level. Gravel filter will be of suitable type and composition (silica-dominated, preferably from river deposits). Furthermore, cementation or addition **of cement grout in the annular space** between the pipes and the borehole walls **for the top 1,0m of the well to act as seal**.

After the completion of the construction, development and cleaning of the water well will take place in order to remove the solid particles (e.g. sand, clay) from inside the water well. Each well should have temporary watertight cap until the pumping equipment for Oil product recovery is installed.

Indicative locations of the Oil Product Recovery wells and of the Injection wells for ISCO procedure for the groundwater are presented in figure 3 attached.

7.3.3 Description of recovery pumps

From all recovery wells the free product will be removed by special pneumatic pumps.

For the pneumatic pump operation, compressed air is required. INTERGEO will provide the air supply through **an air compressor** close to the area of concern.

The recovery pumps that will be used are:

a) Submersible pneumatic automatic top loading pumps (estimated at least 20 pumps)

Or alternatively

b) Surface pneumatic pumps (estimated at least 20 pumps)

However, the final selection of the number and the type of the applied pumps will be decoded after a short pilot test at the site.

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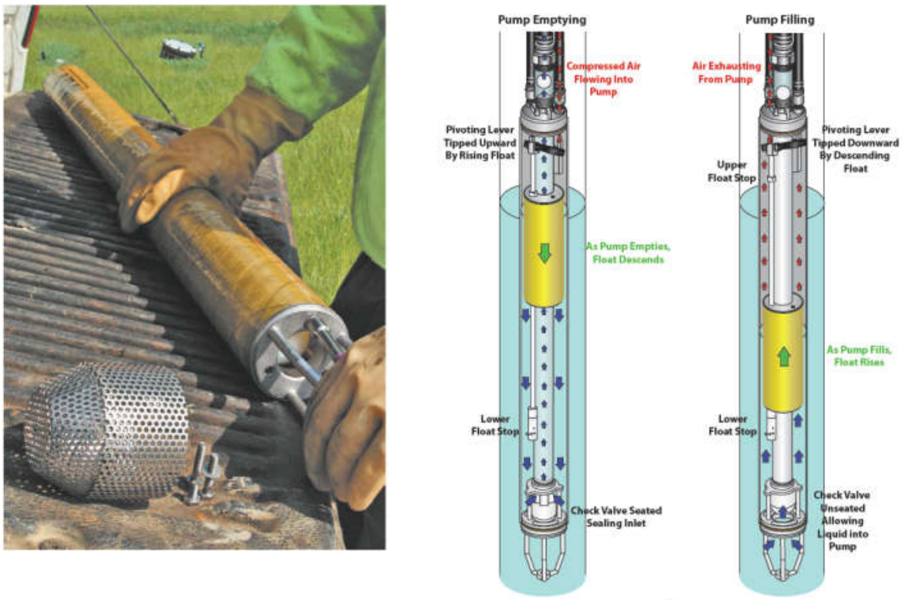
Automatic submersible pneumatic pumps – Top loading
The **Automatic submersible pneumatic pumps are** automatic air-powered pumps, which are developed specifically to handle unique pumping needs at remediation and landfill sites.
These pumps provide maximum capabilities and flow in a top inlet pump for 4" (101 mm) diameter wells having shorter water columns. They are designed for applications requiring an elevated inlet, such as pumping total fluids from wells contaminated with **LNAPLs**.

They will be installed (top loading point) 0,50 – 1,5m below the static piezometric level of the groundwater, depended on the results of initial pilot testing which will define the hydrogeological settings and the optimum recovery rates of the floating oil product.



Picture 8: Automatic pneumatic submersible recovery pumps and operational principal

They can reach flow rates up to 2,0 m^3 per hour in shallow groundwater level. However, the estimated flow rate that will be applied will be between **0,5 – 1,0 m^3/h** from each well.
The estimated radius of influence due to the already evaluated hydrogeological data from previous investigations will be approximately **10-13 m.**

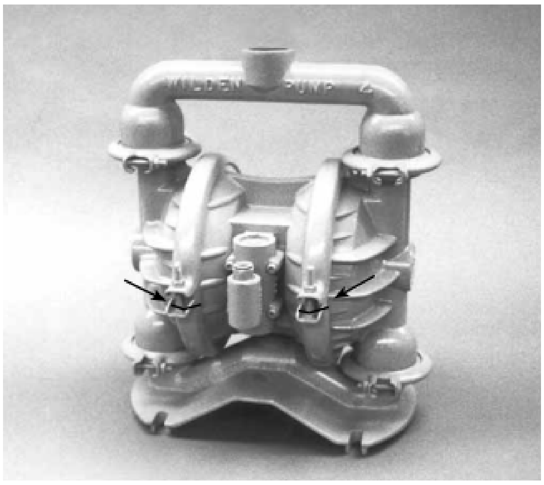
They are designed to handle difficult pumping challenges that other pumps can't, such as solvents, suspended solids, corrosives, temperature extremes, viscous fluids and frequent start/stop cycles.

The recovery pump that will be used is submersible compressed air-driven pump which fills and empties automatically. It also controls the fluid level in a well automatically. The pump fills (See picture 6) when fluids enter the top check valve. Air in the pump chamber exits through the exhaust valve as the fluid fills the pump. The float inside the pump is carried upwards by the fluids rising in the casing until it pushes against a stop on the control rod, forcing the valve mechanism to switch to the discharge mode. The switching of the valve causes the exhaust valve to close and the air inlet valve to open. This causes the pump to empty (see picture 6) by allowing compressed air to enter the pump. This pressure on the fluid closes the inlet check valve and forces the fluids up the discharge line and out of the pump through the outlet check valve. As the fluid level falls in the pump, the float moves downward until it pushes against the lower stop on the control rod, forcing the valve mechanism to switch to the fill mode. The outlet check valve closes and prevents discharged fluids from re-entering the pump. The filling and discharging of the pump continues automatically.

The separated water which is expected to be impacted by dissolved hydrocarbons will be leaded to the Treatment unit (activated carbon filter).

The total amount of the recovered oil product and contaminated groundwater will not be higher than **25-30 m^3 per day, however this will be finalized after the performance of a short pilot test before the start of the remediation**.

Surface pneumatic pumps : Air operated double diaphragm pumps



Picture 9: Surface pneumatic recovery pump

The diaphragm pump is an air-operated, positive displacement, self-priming pump.
Advantages:
• ATEX approved
• Resists corrosion for reliable performance and long life
• Heavy-duty design offers long life• Flow rates and sizes - Up to 189 lpm (50 gpm).
• Easy maintenance
• Modular air valve

Air Consumption for double diaphragm pump:

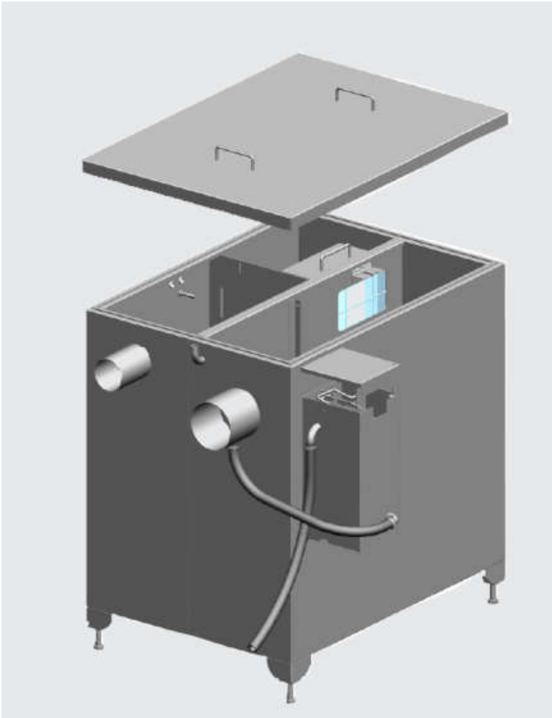
7.3.4. Description of above ground Oil water separator

The above ground mobile oil/water separator that will be used at the site, is designed to separate non-emulsified light liquids or low- water-soluble fluids with a specific gravity below 0,95 (gasoline, diesel, heating oils and other mineral oils) from effluent discharge. The Oil/Water Separator meets all of the requirements of strict European separation standards (DIN 1999 and EN-858).

A two-step separation process, gravity separation and removal of small oil particles by coalescing media elements, produce high removal efficiencies. The separated oil is automatically removed from the water surface and collected in an internal or external oil recipient.

The system includes an automatic draw-off device (ADD) for maximum environmental protection. The light fluids are constantly being removed from the water surface and collected in an integrated or external oil recipient. No stable emulsions can be formed. A large amount of the separated light liquid can be recovered without any interrupting the collection cycle of the Oil water separator.

The automatic drawoff device will collect the pure petroleum product, and not an oil-water mixture. The costly disposal of large quantities of oil and water mixtures is then eliminated.



Picture 10: The above ground mobile Oil-water separation that will be used

The residual hydrocarbon concentration in the effluent will not exceed 10 ppm.

7.4. Monitoring program

The monitoring program of the groundwater will include

- **On site measurements of the piezometric level and the thickness of the oil product** in all existing recovery wells at the specific area **(every day)** and adjustment of the depth of the submersible pump
- **On site measurements of the piezometric level and the thickness of the oil product** after the cease of the system **during weekends** in all existing recovery wells and monitoring wells at the specific area
- **The in situ measurements of physicochemical parameters** (EC, temperature pH, O_2 content and groundwater level) in the abstraction wells and monitoring wells and of the final discharge of the treated groundwater (EC, temperature pH, O_2 content and groundwater level) - **once a month**
- The organoleptical registration of the extracted groundwater **(every day)**
- The organoleptical registration of the treated groundwater **(every day)**
- The periodic control of the quality of the treated groundwater by taking periodic sample from the exit of the treatment unit for chemical analyses, for TPH and BTEX, **every week**
- The continuous control of the groundwater quality by taking periodic sample for chemical analyses (once every three months for **TPH and BTEX** in all wells without free phase , **every three months in all wells**
- The preparation of **periodic progress report to the client** (**every six months**)

The progress of the remediation will be recorded as follows

1)The comparison of the measured thickness of oil product in each recovery well every morning before start of operation (16hours recovery thickness)
2) The comparison of the measured thickness of oil product in recovery wells and monitoring wells every Monday before start of operation (64hours recovery thickness)
3)The comparison of the analysed TPH and BTEX concentrations in all wells without free phase oil product every three months

7.5 Health and safety precautions

INTERGEO will conform to the Occupational Health and Safety Legislation and the Employer’s requirements regarding Health and Safety.

The Site Remediation Action Plan will include specific safety measures to be implemented during the execution of works.

- **PPE**

List of minimum required PPE:
Safety Hard hat, safety shoes with isolated insole type S3, safety glasses with side-shields, high visibility vest fire retardant, long sleeves and long pants fire retardant, resistant cutting gloves type X3X3.

H&S plan - Air monitoring
PID instrument (type toxiRae PRO PID) and gas alert instrument (type micro clipx3) will be used during all remediation works. Specifically, VOCs, LEL and Oxygen measurements will be performed periodically in selected location throughout the site, especially close to the on site bioremediation cell (if implemented).

However, since the applied remediation techniques are in situ (without excavation) **not any environmental impact in the atmospheric air is expected.**

7.6 Target of groundwater remediation

Target of the oil product recovery measures **is to extinguish the floating free product** on the groundwater table at the specific area.

However, some dissolved hydrocarbons might remain in the thin horizon of water bearing strata as a contaminant after the completion of the oil product recovery measures. Therefore, it might be necessary that a further treatment for the dissolved contaminants by means of ISCO technique will be applied.

The proposed target of the groundwater remediation concerning the concentration of the dissolved hydrocarbons is the following concentrations in the thin horizon of water bearing strata : TPH in groundwater: **< 5 mg/l**

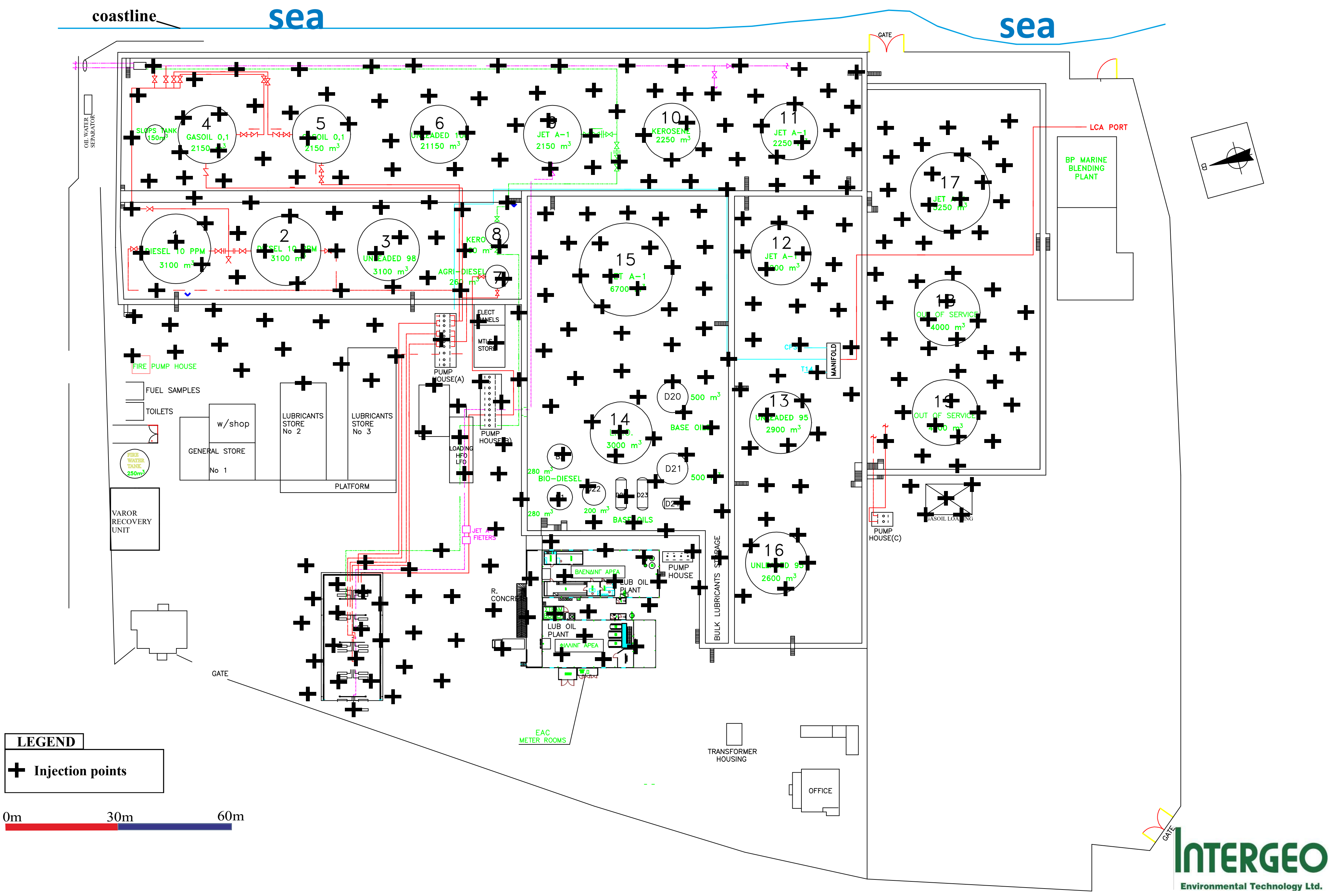
The above TPH concentration is proposed as this concentration is the maximum allowed concentration of surface or wastewater to be discharged into the sea at the Larnaca area. The above is a general practice in Europe and in Greece, especially in locations where the shallow aquifer or a thin water bearing strata has in any case groundwater quality not suitable for any use due to its location (e.g close to the sea water coastline, increased salt content)

If the remaining dissolved hydrocarbons concentration in the thin horizon of water bearing strata will be lower than the above proposed limit values , no further action will be applied.

This is due to the fact that after completion of the soil remediation and the removal of any potential contamination source the recorded low natural attenuation procedure (dissolution, decomposition, evaporation) will eliminate the low concentration within some months.

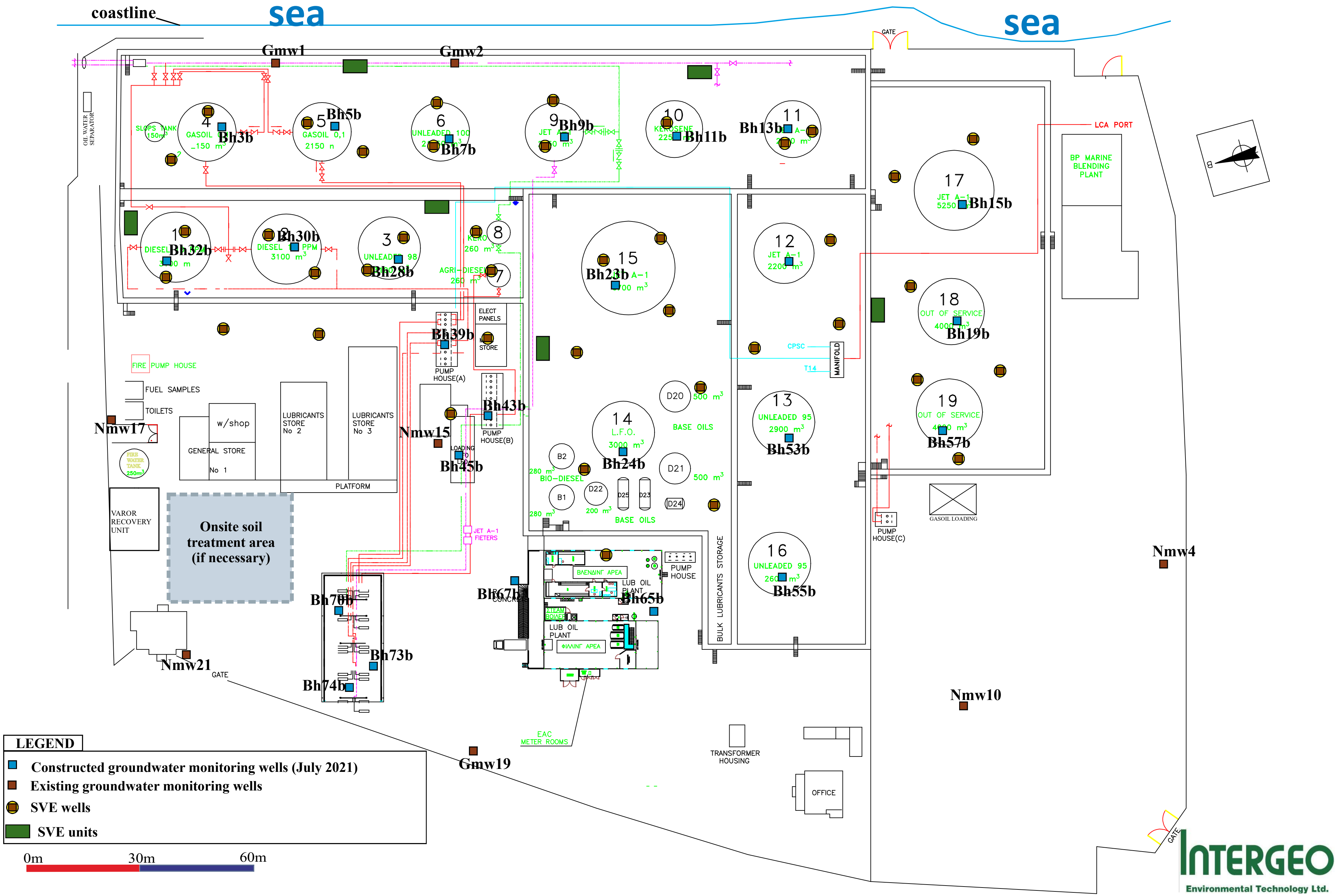
INTERGEO Environmental Technology		
Dr. Christos Vatseris Technical Director	**Lazaros Patrelis Project manager**	**Michalis Kouloumis Head of Cyprus Office**

Figure 1: Indicative locations of the Injection points to the soil for ISCO procedure at the ex HEL.PE. Depot terminal in Larnaca, Cyprus



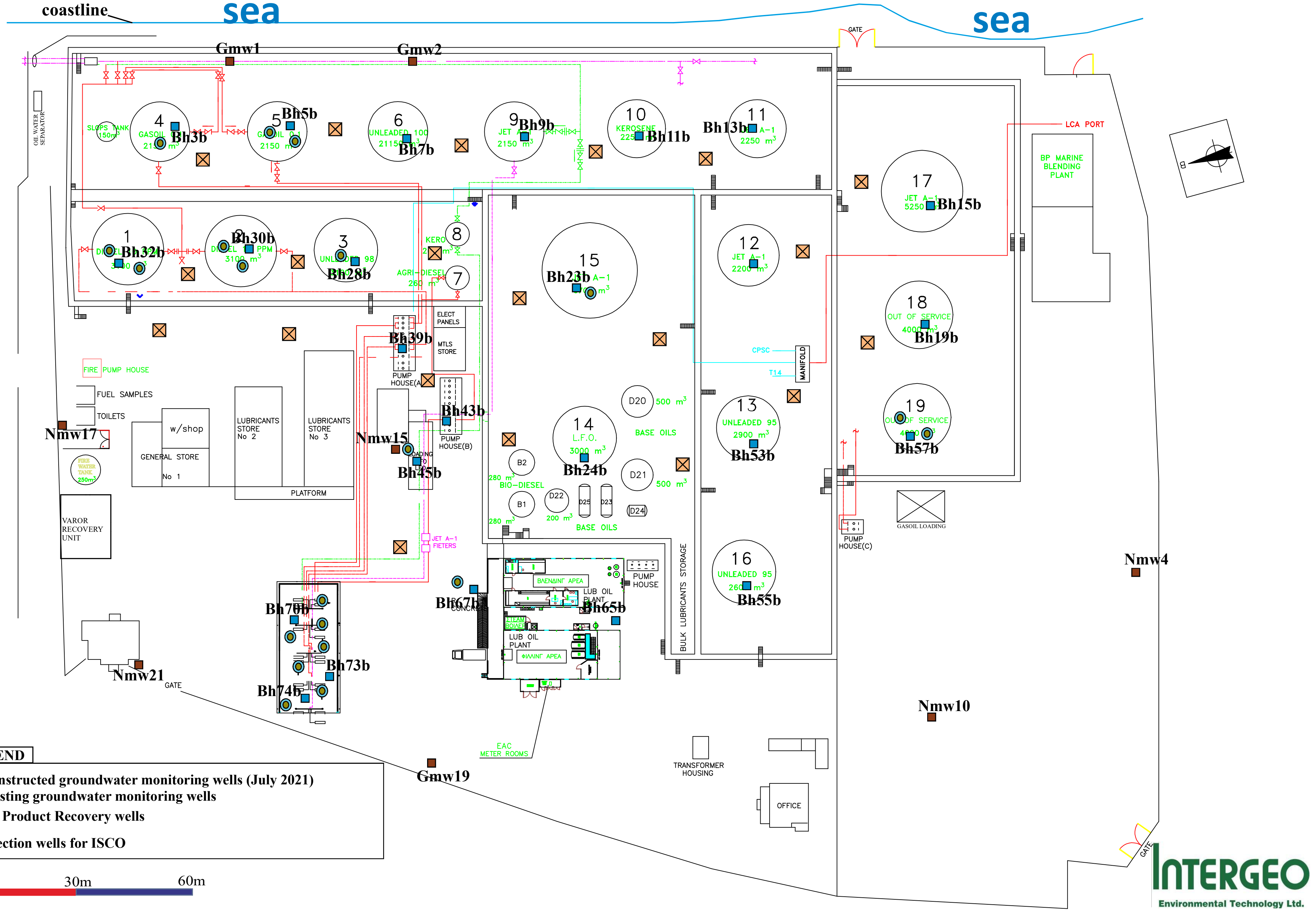
ex HELPE Terminal Lca-injection points.cdr

Figure 2: Indicative locations of the SVE wells and units and of the onsite soil treatment at the ex HEL.PE. Depot terminal in Larnaca, Cyprus



ex HELPE Terminal Lca-SVE wells-units-onsite treatment.cdr

Figure 3: Indicative locations of the Oil Product Recovery wells and of the Injection wells for ISCO procedure for the groundwater at the ex HEL.PE. Depot terminal in Larnaca, Cyprus



OPR_Injection wells.cdr