TULLYVOGHEEN HISTORIC LANDFILL
TULLYVOGHEEN,
CLIFDEN, CO. GALWAY

APPLICATION TO EPA
FOR
CERTIFICATE OF AUTHORISATION

VOLUME III. SECTION D - PART B

FURTHER INFORMATION – HYDROLOGY/TIER 3 GQRA/CSM OF FORMER TULLYVOGHEEN LANDFILL REPORT

29TH JUNE, 2020

Galway County Council

Tullyvogheen Historic Landfill, Clifden, County Galway

Further Information – Hydrology/Tier 3 GQRA Report

Volume I. Report

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1 INTRODUCTION

1.1 Project Background - 2014

Following a meeting on the 18th March, 2013 with Tony McInerney, Senior Engineer and Tom Dunworth, Senior Executive Technician Galway County Council, Mulroy Environmental were instructed to prepare a fee proposal for a Tier 2 Site Investigation and follow up Tier 3 Generic Quantitative Risk Assessment (GQRA) and if necessary a Detailed Quantitative Risk Assessment (DQRA) Assessment of Tullyvogheen Landfill, Clifden, County Galway (see Figures 1 to 3). The field works and the compilation of the report (together the "Services") were carried out for Galway County Council (the "client") in accordance with the terms of a contract, Proposal PRP213.05.04.2013, between Mulroy Environmental and the "client" dated 5th April 2013. A *'Tier 2 Site Investigation & Tier 3 Generic Quantitative Risk Assessment of Former Tullyvogheen Landfill'* was submitted to Galway County Council on the 9th July, 2014.

The recommendations of this report were as follows:

'1. It is recommended that surface water monitoring is continued by Galway County Council and the EPA at the 3 existing sites. However, it is recommended that another 4 surface water monitoring points are set up to assess the impact on the Owenglen River:

- *SW4 to be located to the west of the residence southwest of the site;*
- *SW5 to be located at the stream 5m upgradient of where it feeds into the Owenglen River;*
- *SW6 to be located on the Owenglen River upgradient of the confluence of the stream and the Owenglen River; and*
- *SW7 to be located on the Owenglen River upgradient of the confluence of the stream and the Owenglen River.*

The purpose of this is to determine if the contaminants identified within the surface water body culverted through the landfill are reaching and discharging to the Owenglen River at levels which would be a risk to downgradient receptors and/or the ecosystem which is a Special Area of Conservation (i.e. SAC No. 002031, The Twelve Bens/ Garaun Complex).

2. It is recommended that a Small Stream Ecological Risk Assessment is carried out on the stream downgradient of the site as per the Western River Basin District Project's Small Streams Risk Score Method Manual, December 2005.

3. Even though it is unlikely that the well located at the residence 400m from the site has been impacted by contaminated groundwater emanating from the site, it is recommended that, in the event that this well is used for livestock, that it is sampled and analysed for a comprehensive laboratory suite (i.e. identical to the laboratory suite used in this study).'

1.2 Project Background - 2019

Padraic Mulroy, Managing Director and Andrena Meegan, Project Manager of Mulroy Environmental Ltd. met with Mike Melody, Senior Executive Engineer and Tom Dunworth, Senior Executive Technician of Galway County Council on Tuesday, 24th September, 2019 to discuss any outstanding items before an application for a Certificate of Registration could be processed to the EPA for Tullyvogheen Historical Landfill. Mulroy Environmental were instructed to prepare a fee proposal for the carrying out of field works and for the compilation of a *Further Information – Hydrology/Tier 3 GQRA/CSM of Former Tullyvogheen Landfill Report* to address those recommendations contained within the *'Tier 2 Site Investigation & Tier 3 Generic Quantitative Risk Assessment of Former Tullyvogheen Landfill'* report issued in 2014.

1.3 General Setting

The site is approximately 2 km east of the town centre of Clifden and is located on a narrow country road that leads uphill approximately 660m from the Clifden to Galway National Road (the N59) which runs west to east (see Figures 1 and 2). At a distance of approximately 600m from the N59, the country road turns eastwards. Where the site is located, this country road has been constructed at the edge of a valley between a small mountain to the south and a large hill to the north. The valley is orientated in an approximate west to east direction (see Figure 3). The landfill to the south of the country road consists of a substantial infill operation where the valley was raised approximately 3.5m on the eastern side of the site and approximately 7-8m on the western side of the site (see Plate 1 below).

Plate 1. UAV Aerial photograph taken at 40m elevation taken from northern side of country road facing east showing eastern side of landfill, with roads depot on southern boundary

The landfill is located between a small mountain, Cooravoughil Mountain to the south and a number of large hills to the north in an area where the valley widens out into upland bog. A mountain lake, Lough Nambrackeagh, is located 350m to the northwest of the site. Clifden derives its water supply primarily from Lough Nambrackeagh. A small stream discharges from this lake and joins a larger stream which flows in a north to south direction along the country road leading to the landfill. This stream appears to originate from a small lake, Lough Cashleen located approximately 650m to the east of the site. This stream which runs in an east to west direction through the valley is culverted through the landfill before continuing in a south-westerly direction alongside the country road for a distance, then heading south-westwards and eventually joining the Owenglen River 735m to the south of the site (see Plate 2 below).

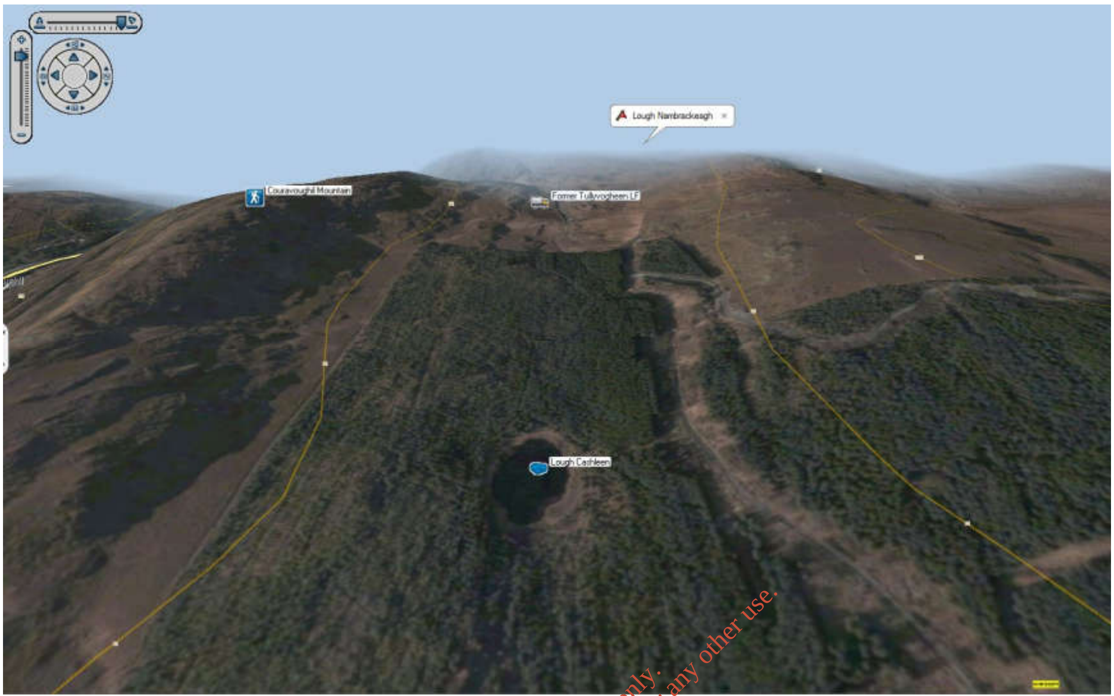


Plate 2. View of valley facing westwards showing Lough Cashleen in foreground in coniferous forest, Couravoughil Mountain to south of former landfill with Lough Nambrackeagh to northwest of site

The site is located in a rural and remote area and as a result there are very few properties located within its immediate vicinity (see Figure 3). No residential or commercial properties are located on the landfill site boundaries. The nearest inhabited residence is located 415m ‘as the crow flies’ southwest of the site along the country road that leads to the N59 (i.e. the main Clifden to Galway Road) which is located approximately 630m south of the site. Four residences exist along the northern side of the N59 road to the southwest, a distance of 620m from the site. *Cuirt Cregg*, a medium sized housing estate, is located further to the west along the N59 road, with the nearest property in the estate located 630m ‘as the crow flies’ from the site, as shown on Figure 3. Figure 3 also shows to the north of the N59, a Galway County Council compound containing a water treatment plant and pumping station located adjacent and west of the country road and an ESB substation located adjacent and east of the country road. These facilities are approximately 610m from the site (see Figure 3).

According to Galway C.C., the former municipal landfill at Tullyvogheen, Clifden, County Galway, was in operation between the years of 1984 and 1999. During this period it is estimated by Galway County Council that approximately 23,000 tonnes of mixed waste including domestic, commercial and construction & demolition (i.e. C & D) waste per annum was deposited annually (see Plate 3 following). The site area is 1.27 hectares (ha) and the total waste body is estimated at 114,000m^3 or 205,000 tonnes.

Plate 3. View of former Tullyvogheen Landfill from west of site entrance facing southeast

The site is currently used as a road depot by Galway County Council roads department with a 10,000l aboveground storage tank (AST) used for the storage of road bitumen (see Figures 4 & 5). It is understood that the bitumen, prior to use and transfer into the road maintenance vehicle, is heated by an in-built heater powered by gas provided by an on-site LPG tank (see Plate 4 below).

Plate 4. View of 10,000l aboveground storage tank used for the storage of road bitumen

The site was formerly used by Galway Fire Brigade for fire drills. A hardcore-covered area to the southeast of the entrance was dedicated for this purpose. This area is bordered by 1.5 metre high earthen berms to the north and east which separate it from the landfill (see Figures 4 and 5). Two 40-foot and a 20-foot truck container were used in the *'Fire Drill Area'* for the ongoing training of Galway Fire Brigade staff (see Plate 5). Another 20-foot container located in the north-western corner of the Fire Drill Area was used for the storage of fire-fighting equipment.

Plate 5. View of former Galway Fire Brigade *'Fire Dill Area'* to east of road depot area facing south

1.4 Guidance Background & Preliminary Risk Assessment

In the previous report, Mulroy Environmental reviewed the following Tier 1 report (see Appendix 1):

- Tier 1 Study/Tier 2 Indicative Work Programme and Costing, Comhairle Chontae na Gaillimhe, Tullyvogheen Landfill, Clifden, County Galway, 16th June, 2010.

The above Tier 1 Risk Assessment/Tier 2 Indicative Work Programme and Costing, as defined by Chapter 4 of the *EPA Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007*, was carried out by Galway County Council on the site. It should also be noted that an 'in-house' Tier 1 Risk Assessment was also carried out by Mulroy Environmental. The results of this are summarised in Table A1.1 in Appendix 1 which summarises the results of *'S-P-R Linkage Prioritisation'* on the former landfill. The detailed rationale behind the in-house risk assessment is also given in Appendix 1.

As can be seen from Table A1.1 in Appendix 1, the highest individual linkage proved to be for *'Leachate to SW'* at 70%. It should be noted that if the score is *'Greater than or equal to 70% for any individual SPR linkage'*, the Highest Risk (Class A) applies. It should also be noted that when each Local Authority carries out a Tier 1 Risk Assessment during their inventory of historic waste sites within their boundaries, typically a Highest Risk (Class A) is regarded as requiring a medium density Tier 2 Environmental Risk Assessment (i.e. Phase II Intrusive Site Investigation) with Generic Quantitative Risk Assessment.

Chapter 5 of EPA Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007 deals with the Tier 2 Site Investigation and Testing process and reporting requirements. The scope of works was drawn up following a review of all pollutant linkages identified within the Tier 1 report. In this case, particular attention was given to the *'Leachate to SW'* linkage which was 70% of the maximum score.

Chapter 6 of EPA Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007 deals with the Tier 3 process. There are two basic types of quantitative risk assessments: Generic Quantitative Risk Assessment, which uses relevant generic assessment criteria (GAC) (i.e. values which are generally applicable to an entire class or group e.g. based on proposed future land use) or guidelines, and Detailed Quantitative Risk Assessment which uses site-specific assessment criteria using RA tools and models. The decision on which type of QRA should be used is site specific and is dependent on the sensitivity of the site and also on confidence in the available data. In any case the quantitative risk assessment should be detailed enough to allow remedial measures to be proposed with certainty of a successful outcome. The assumptions made should always be clearly defined.

Prior to applying either a generic QRA or a detailed QRA, the site-specific information, on the leachate concentrations, surface water and groundwater quality, as well as information on the levels of landfill gas being produced, must be known. The following site investigation works have been drawn up to provide that information.

1.5 Site History

It is understood from the Tier 1 report that according to Galway C.C., the former municipal landfill at Tullyvogheen, Clifden, County Galway, was in operation between the years of 1984 and 1999. As stated previously, during this period it is estimated by Galway County Council that approximately 23,000 tonnes of mixed waste including domestic, commercial and construction & demolition (i.e. C & D) waste per annum was deposited annually. The site area is 1.27 hectares (ha) and the total waste body is estimated at 114,000m^3 or 205,000 tonnes.

A comprehensive site investigation was carried out as part of the 2014 risk assessment. This involved the excavation of a number of trialpits and the installation of groundwater/gas monitoring and leachate/gas monitoring wells on site. The location of the trialpits, boreholes and cross-sections of the site are provided in Figures 6 to 9.

2 OBJECTIVES

The objectives of the hydrological risk assessment are as follows:

- To further evaluate potential liabilities associated with historic and/or current uses of the site, and their impact on surface water quality (i.e. Owenglen River which is also a Special Area of Conservation);
- To evaluate potential liabilities associated with historic and/or current uses of the site on off-site residences and their residents;
- To evaluate potential liabilities associated with historic and/or current uses of the site on off-site farm livestock in the vicinity of the stream;
- Following the findings of the hydrological risk assessment to refine the Conceptual Site Model (CSM) if necessary; and
- If required, to make recommendations on the remediation of the site or mitigation measures to remove the afore-mentioned risks.

3 SCOPE OF WORKS/METHODOLOGY

3.1 Task 1. UAV Photogrammetric Survey & 4K Aerial Video

On the 29th September, 2019, Mulroy Environmental carried out a photogrammetric survey using a DJI Phantom 4 equipped with a 4K camera. Padraic Mulroy of Mulroy Environmental Ltd. is a licensed Specific Operator Permit (SOP) holder with the Irish Aviation Authority. Mulroy Environmental Ltd. hold the necessary insurance cover to carry out drone surveys on behalf of clientele within flight zones under the control of IAA Air Traffic Control (ATC) following the receipt of permission from the IAA ATC. The drone survey was carried out at an elevation of 40m above ground level. Dronedeploy software was used to create high definition photo-orthomosaics of the historic landfill site and the stream as far as SW4 to the south west of the site. A 3D model of the site was created was carried out on the site and the stream as far as surface water sampling point, SW4. The orthomosaic produced by the photogrammetric survey was utilised in the preparation of Figures 10-19.

Following the completion of the photogrammetric survey, a 4K video was taken of the source of the stream, Lough Cashleen, the site, Lough Nambrackeagh public water supply reservoir and the subject stream as far as its confluence with the Owenglen River. The purpose of the 4K video was to identify those characteristics of the river which were not accessible through a walk-over. It should be noted that stills of the 4K video have been used to prepare various photographic plates within this report.

3.2 Task 2. Invertebrate Kick Sampling

On the 28th of September 2019, Patrick McCabe, External Consultant and Padraic Mulroy of Mulroy Environmental Ltd. carried out a macroinvertebrate kick sampling programme at 5 surface waterbody locations within the Owenglen River catchment (see Figures 10-18). These are as follows:

- *KS1* – Sample taken on unnamed 1st order stream immediately downgradient from the Tullyvoheen landfill;
- *KS2* – Sample taken on unnamed 2nd order stream approx. 200m downstream from the Tullyvoheen landfill;
- *KS3* – Sample taken on unnamed 2nd order stream approx. 500m downstream from the Tullyvoheen landfill;
- *KS4* – Sample taken on Owenglen River (4th order) immediately upgradient of the confluence with the aforementioned unnamed stream; and
- *KS5* – Sample taken on Owenglen River (4th order) immediately downstream of the confluence with the aforementioned unnamed stream.

Samples were taken using a 2-minute 'kick' sampling method in adherence to *ISO 7828:1985.* A stone washing exercise was also undertaken to ensure that species that cling to stone surfaces (e.g. leeches and gastropods) were adequately collected. Each sample was preserved in situ with 70% Industrial Methylated Spirits (IMS) and delivered to AQUENS Ltd. located on the UCD Campus at Belfield, Dublin 4 for macroinvertebrate identification. A description of the processing and identification methodology is described in the AQUENS report included in Appendix 2. Section 4 of this report provides a detailed description of the hydrology of the site and shows through a series of plates, the locations of each of the

5 invertebrate kick sampling locations. The exact location of each of the 5 kick sampling areas are showing in detail on Figures 10 to 18.

A habitat assessment was carried out at each macroinvertebrate monitoring location. This included a description of the following:

- Stream width and depth;
- Substrate type;
- Flow type;
- Instream vegetation;
- Shading;
- Siltation; and
- Observed pressures.

In addition, a pre-calibrated YSI multiprobe was used to record the pH, dissolved oxygen (DO), electrical conductivity (EC) and temperature at each sampling site.

3.3 Task 3. Physico-chemical Parameter Field Testing

At each surface water sample location, approximately 1m upgradient of the sampling location, a Hanna HI9829 Multiprobe field meter probe was lowered below the surface and left in position for a minimum of 15 minutes. The following physico-chemical field parameters were measured and recorded for each of the 7 surface water monitoring locations:

- pH;
- Temperature,
- Oxidation Reduction Potential (ORP);
- Electrical Conductivity;
- Atmospheric pressure;
- Turbidity;
- Resistivity;
- Total Dissolved Solids (TDS),
- Salinity; and
- Seawater specific gravity (i.e. Density).

The HI9829 is equipped with a built-in GPS receiver and antenna that records the longitude and latitude for each monitoring point and guarantees position accuracy. Measurements from specific locations are tracked with detailed coordinate information that can be viewed immediately on the display.

All 3 measurement probes were calibrated in house prior to its use in the field. All 10 parameters are measured concurrently and for each field measurement, a 15-second duration is provided for. Each measurement of the 10 parameters with an average (i.e. mean) value calculated of the 10 values. All data was logged in the field, downloaded and managed by HI 929829 software (see attached table, Table 3 for summary of physico-chemical field parameters in following section, Section 6). The Hanna

Multiprobe was rinsed down with distilled water to remove any contaminants at the end of each of the 7 surface water sampling exercises.

At each sampling location, an underwater waterproof GoPro video camera was used to record video in order to help determine the extent of siltation at the bottom of the stream (i.e. lying on the gravels).

3.4 Task 3. Surface Water Sampling

Prior to sampling a fresh pair of latex gloves was used by the sampler. The surface water sample was taken using those parameter specific bottles provided by the laboratory. Sample bottles were provided by Chemtest UK and CLS of Rosmuc, County Galway. Each bottle and accompanying caps were rinsed out on 3 occasions prior to sampling with the sampler facing upstream into the flow making sure that where any disturbance was created that sufficient time had elapsed prior to rinsing and then taking the final sample. Each set of sample bottles was placed in a freezer box with ice packs to maintain the temperature at 4^{O}c while in transit to the laboratory.

Geotagged digital photographs were taken of water samples and water conditions during the time of sampling. A Surface Water Monitoring Log was prepared for each of the 7 surface water samples (see Appendix 3).

All of the chemical analyses were carried out by Chemtest Ltd. in the UK with the exception of the time sensitive parameters which were microbiological testing, BOD, COD and ammonia. This testing was carried out by CLS in Rosmuc, County Galway. These samples were hand delivered to CLS in Rosmuc within 3 hours of sampling on the 30th September, 2019. CLS are an INAB accredited laboratory.

For heavy metals analysis, as it was not possible to filter the surface water samples in the field, a 1-litre sample of unfiltered water from each of the 7 locations was delivered to City Analysts Ltd. at Ringsend, Dublin on the morning of the 1st October, 2019. Each of the 7 samples was then filtered through a 0.45 micron filter in the laboratory by vacuum pump and then spiked with nitric acid to ensure sample preservation in transit. City Analysts Ltd. are an INAB accredited laboratory.

All of the remaining samples were then sent in suitably chilled coolboxes by overnight courier to the laboratories of Chemtest Ltd. (ISO 17025/UKAS accredited laboratory) in the UK on the 1st October, 2019. Chemtest UK are a UKAS accredited laboratory. Strict chain of custody procedures are adhered to for ALL 3 laboratories. Chemtest Ltd., CLS and City Analysts Ltd. were selected, on the basis of Mulroy Environmental's laboratory QA/QC policy, to be the most appropriate laboratories for their tasks.

3.5 Task 4. Laboratory Testing

The laboratory suite for the 7 surface water samples was as follows:

Inorganic Analysis

- Heavy Metals – Antimony, Arsenic, Boron, Cadmium, Copper, Chromium, Iron, Lead, Manganese, Mercury, Nickel Selenium and Zinc;
- Total Dissolved Solids;
- Total suspended solids;
- Total alkalinity (as $CaCO_3$);
- Ammoniacal Nitrogen (as N) (Completed by CLS);
- Total Oxidised Nitrogen (TON) as N;
- Nitrates;
- Nitrites;
- Chloride (Cl^-);
- Fluoride (F^-);
- Sulphate (SO_4^{2-});
- Sulphides (S^{2-});
- MR-Phosphate as P; and

Major Cations and Anions

- Potassium (K);
- Sodium (N);
- Calcium (Ca); and
- Magnesium (Mg).

Oxygen Demand/Organic Carbon (Completed by CLS)

- Biological Oxygen Demand; and
- Chemical Oxygen Demand.

Microbiological (Completed by CLS)

- Total Viable Count (TVC)@22^{o}c;
- Total Viable Count (TVC)@37^{o}C;
- Total Coliform;
- Faecal Coliform;
- Enterococci; and
- *Clostridium perfringens.*

Trace Organic Analysis

- Volatile Organic Compound;
- Semi-volatile Organic Compound;
- Benzene, Toluene, Ethylbenzene, Xylenes and MTBE;
- Polyaromatic Hydrocarbons (PAHs) (17 speciated) to include Coronene;
- Organo-phosphorous pesticides; and

- Organo-chlorine pesticides & Acid Herbicides.

3.6 Task 5. Data Collation & Reporting

The field and laboratory results of geological, hydrogeological, hydrological and environmental information collated in 2014 and compiled in the *Tier 2 Site Investigation & Tier 3 Generic Quantitative Risk Assessment of Former Tullyvogheen Landfill'* report were re-visited to further evaluate potential environmental liabilities associated with soil/groundwater and surface water quality.

For this further information report, the recommendations of the 2014 report were implemented. As part of these recommendations, field and laboratory results of water ecology (i.e. invertebrate), aquatic chemistry, hydrological and environmental information were collated and interpreted with a view to evaluating further potential environmental liabilities associated with surface water quality.

<u>Hydrological Risk Assessment</u>

A risk assessment was undertaken to provide a basis for decision making, to ensure there would be no impact on the residence to the southwest of the site, its residents and farm livestock and to ensure that there will be no adverse impact to the environment particularly the Owenglen River, which is also a Special Area of Conservation, to the south and east of the site. A risk assessment is defined as a process of establishing, to the extent possible, the existence, nature and significance of risk. Risk is defined as the probability of the occurrence of, and magnitude of the consequences of, and unwanted adverse effect to a receptor.

There are 4(no.) stages involved in a risk assessment:

1. *Hazard Identification* – This will involve identifying contaminants of concern and will be achieved through the intrusive site investigation programme and the soil and groundwater sampling regime.

2. *Hazard Assessment Stage* - This stage involves the development of a Conceptual Site Model. Conceptual Models are described below.

3. *Risk Estimation Stage* – A Quantitative Risk Assessment is undertaken as part of this stage to determine risks to human health and the surface water and groundwater environments. The proposed Quantitative Risk Assessment for this contract is described in more detail below.

4. *Risk Evaluation Stage* – This stage involves recommendation of remedial works.

<u>Conceptual Model</u>

The risk to the surrounding environment will be further assessed based on the further hydrological data gathered, the new aquatic ecological data gathered and existing geological and hydrogeological information gathered through the previous 2014 site investigation programme. This information can be used to further delineate the previous 2014 conceptual site model of the underlying environment, in terms of identifying potential contaminants, pathways and sensitive receptors.

A conceptual model is defined as a textual and/or schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the basis of the information from the preliminary investigation and refined during subsequent phases of investigation. The development of a conceptual model is an essential basic component of the risk assessment process. The development of a conceptual model is an iterative process, which is progressively refined based on additional focused investigations.

The results of additional hydrological investigation, the previous 2014 site investigations and the development of a conceptual model should define all known aspects of the site that could impinge upon or affect the overall environment. The conceptual model will be based on the hazard – pathway – receptor concept, where:

- A hazard represents the inherently dangerous quality of a substance, procedure or event;
- A pathway is a mechanism or route by which a contaminant comes in contact with, or otherwise affects, a receptor; and
- A receptor is a human being, living organism, ecological system, controlled water, atmosphere, structures and utilities that could be adversely affected by the hazard. Surface water channels and springs are also considered to be sensitive receptors as the groundwater environment may provide baseflow to these features.

Generic Quantitative Risk Assessment (GQRA) of Soils (Completed)

As stated previously, a Generic Quantitative Risk Assessment uses relevant generic assessment criteria (GAC) (i.e. values which are generally applicable to an entire class or group e.g. based on proposed future land use) or guidelines. For this purpose Mulroy Environmental propose to use the following GAC for soils:

- UK Department of Environment, Food and Rural Affairs (DEFRA) - Contaminated Land Exposure Assessment (CLEA) Model – Soil Guideline Values, 2009 - Residential with plant, Allotment and Industrial/Commercial for sandy loam soil and 6% soil organic matter (SOM) (i.e. 12 SGVs published); [1]
- LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment, 2^{nd} Edition, 2011 – Residential Land-use, Allotment Land-use and Commercial Land-Use at 6% Soil Organic Matter (i.e. 82 SGVs published); [2]
- National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria) – Intervention and Target Values; [3] and

[1] The Contaminated Land Exposure Assessment (CLEA) Model is used to quantify the risk to the environment. CLEA is a risk-based computer model developed by the UK Department of Environment, Food and Rural Affairs (DEFRA) to aid in the determination the suitability of contaminated land sites for redevelopment/remediation. Instead of applying a set limit or standard to any one parameter, which may deem a site contaminated or unsuitable, the CLEA model takes contaminant and environmental factors into account to determine a site-specific risk. The risk of human health being affected by living or working on a site with contaminated soil would be dramatically lower in an urban setting such as an apartment surrounded by hard standing versus a house with a back garden, where children play and interact with the soil. The CLEA model takes such a risked based approach by modelling the possible effects of a number of key contaminants. Guideline values produced by the model indicate a level below which the site is considered safe. Above the guideline value, further investigation is required. Thus the CLEA guidelines provide an objective basis for decision-making, based on an assessment of risk to human health. A number of Soil Guideline Values (SGVs) have been calculated by DEFRA and have been published in an 'SGV series' of documents

[2] A joint workshop was held by the Land Quality Management Ltd. and the Chartered Institute of Environmental Health in 2009. This workshop used CLEA Model 1.04 to derive SGVs for 82 organic and inorganic common contaminants.

[3] When dealing with the Due Diligence Site Assessment of brownfield sites in Ireland a set of guidelines called the Soil Protection Guidelines, produced by National Institute of Public Health and the Environment of The Netherlands is generally used. The treatment of polluted soil and groundwater depends on the nature and the concentrations of the polluted substances present in it. The Soil Protection Guidelines used in The Netherlands is built on two values. These values, consisting of different ascending levels of concentration TV and IV are differentiated according to the nature of the pollution:

- Level TV is the target value. Pollutants above the TV level should be investigated more thoroughly. The question asked is: to what extent is the nature, location, and concentration of the pollutants of such a nature that it is possible to speak of a risk of exposure to man or the environment? ; and
- Level IV is the intervention value above which the pollutants should generally be treated. In order to assess the risk of any contaminants contained in the overburden on site as a result of historical practices, the results of the soils analysis are compared to the above levels with particular regard paid to Level IV.

- Waste Acceptance Criteria at Murphy Environmental Waste Facility (WA 129-02|) in Hollywood, Co. Dublin – Hazardous Waste Limit.[4]

Generic Quantitative Risk Assessment (GQRA) of Groundwater and Leachate (Completed)

The results of the groundwater analysis were compared to the Maximum Allowable Concentration (MAC) values of Statutory Instrument No. 81 (Quality of Water Intended for Human Consumption) of 1998 and the Parametric Values of Statutory Instrument No. 439 (Drinking Water Regulations) of 2000. The results of the groundwater analysis were also compared to the EPA Interim Guideline Values (IGVs) from *Towards Setting Guideline Values for The Protection of Groundwater in Ireland – Interim Report* and the Threshold Values from Statutory Instrument No. 9, European Communities Environmental Objectives (Groundwater) Regulations, 2010.

Generic Quantitative Risk Assessment (GQRA) of Surface Water

The results of the September 2019 surface water analysis were compared to:

- *S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989;*
- *S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007;*
- *S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations, 2009;*
- *S.I. No. 386, EC Environmental Objectives (Surface Waters) (Amendment) Regulations 2015;* and
- *S.I. 77 European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019.*

[4] The results of the soils analysis are compared to the values taken from Section A4 'Limit values for pollutant content for inert waste landfills' of Schedule A from the Waste Licence, WA 129-1 for the Murphy Environmental Inert Landfill at Gormanstown, County Dublin (see Appendix 3). These include the 'Total Pollutant Content' limits and the 'L/S = 10 l/kg Limits'. The purpose of comparison with these limits is to determine if an inert landfill such as thee landfill operated by Murphy Environmental would be capable of accepting contaminated soil from the site.

4 ENVIRONMENTAL SETTING

4.1 Introduction

This section describes the site's environmental setting including the site’s background (Section 4.2), topography and hydrology (Section 4.3). Detailed information on the soil, geology and hydrogeology of the area are not provided in this report as they are already provided in the 2014 report. However, all figures pertaining to the previous site investigation works (i.e. Figures 6 to 9) are provided in this report.

4.2 Site Background

As stated in the introduction, the site is located in a remote area. The site is approximately 2 km east of the town centre of Clifden. The site is located on a narrow country road that leads uphill approximately 660m from the Clifden to Galway Secondary Road (the N59) (see Figures 1, 2 and 3). At a distance of approximately 600m from the N59 the country road turns eastwards (see Plate 6 below).

Plate 6. 3D View of country road facing northeast showing nearest residence in foreground, Couravoughil Mountain to south of former landfill with Lough Nambrackeagh to northwest of site

Where the site is located, this country road has been constructed at the edge of a valley between a small mountain, Couravoughil Mountain to the south and a number of hills to the north. The valley is orientated in an approximate west to east direction. The landfill to the south of the country road consists of a substantial infill operation where the valley was raised approximately 3.5m on the eastern side of the site and approximately 7-8m on the western side of the site.

The site area is 1.27 hectares (ha) and the total waste body is estimated by Galway C.C. at 114,000m^3 or 205,000 tonnes. The site is currently used as a road depot by Galway County Council Roads Department with a 10,000l aboveground storage tank (AST) used for the storage of road bitumen (see Figures 4 & 5). It is understood that the bitumen, prior to use and transfer into the road maintenance vehicle, is heated by an in-built heater powered by gas provided by an on-site LPG tank (see Plate 4 previous).

The site was formerly used by Galway Fire Brigade for fire drills. Two 40-foot and a 20-foot truck container were used on site for the ongoing training of Galway Fire Brigade staff (see Plate 5 previous). Another 20-foot container was used for firefighting equipment storage.

4.3 Topography

The existing site and its surrounding property is illustrated in Figures 3. The existing site layout with topographical data is illustrated in 2 figures, Figures 4 and 5. Figure 4 shows the topography of the western half of the site and Figure 5 shows the eastern half of the site. The terrain in which the site is located is best described as 'Mountain heath' or highland blanket bog. The landfill is located in a glacial valley between Cooravoughil Mountain to the south and some large hills and an un-named mountain to the northeast. Both of these mountains are approximately 100m to 110m in elevation. The Shanakeever Mountains are located to the west and northwest of the site. The site is located where the valley widens out into upland bog.

Towards the eastern end of the site, the site slopes towards the north-eastern corner of the site where surface water was found to pond at approximately 50.4mAOD. This side of the site appears to be approximately 3m above natural ground level to the east of the site.

Towards the western end of the site, the site slopes from the north-eastern corner of the site to the west and southwest. This side of the site appears to be approximately 6-7m above natural ground level to the west of the site which is at approximately 43mAOD.

The highest area within the site would appear to be near the northern boundary to the east of the site entrance at approximately 51.87mAOD.

4.4 Hydrology

4.4.1 Regional Hydrogeology

The site is located in the periphery of Owenglen-Dauros-Culin-Traheen-Coastal Catchment and is part of Hydrometric Area 32/Erriff Clew Bay of the Western River Basin District. Its Water Management Unit is West Galway (see Figures 10, 11 & 12).

It is understood that a number of years after the infilling of waste at Tullyvogheen Landfill commenced, the stream which runs through the site was culverted. The stream is culverted approximately 27m to the east of the site (see Figure 5). This stream appears to originate from a small lake, Lough Cashleen located approximately 650m to the east of the site (see Figure 13). This stream appears to run the full length of the landfill (i.e. 260m) and exits to the west of the landfill before continuing in a south-westerly direction alongside the country road for a distance, then heading south-westwards and eventually joining the Owenglen River 735m to the south of the site.

4.4.2 Public Water Supply

A mountain lake, Lough Nambrackeagh, is located 350m to the northwest of the site. Clifden derives its water supply primarily from Lough Nambrackeagh (see Figure 14). Water is extracted from this reservoir at the southern end and piped to a water treatment plant located downgradient on the national road, N59 (see Plates 7 & 8). It should be noted that a small stream also discharges from this lake at the southern end and joins the above-mentioned larger stream which flows in a north to south direction along the country road (see following section, Section 4.4.9).

Plate 7. Water extraction/pumping plant located on the southern end of Lough Nambrackeagh

Plate 8. Galway County Council/Irish Water - Water Treatment plant located at corner of country road and national road N59 (note guesthouse to west of plant and ESB substation to east of site)

4.4.3 Flooding

A review of flooding archives indicates that no flood events have occurred in the vicinity of the site. In addition it should be noted that areas prone to flooding are typically noted in historical mapping. A review of all major editions of ordnance survey mapping for the Tullyvogheen area indicates that no evidence of flooding exists.

4.4.4 Water Framework Directive Status

A study carried out by the Western River Basin Management Body under the Water Framework Directive in 2008 has classed the *'Owenglen-Dauros-Culin-Traheen-Coastal Catchment'* Surface Water Body, in which the site is located as *'1a – At Risk'* (see Appendix 4). This risk assessment has not been updated by the Western River Basin Management Body for 2010-2015.

4.4.5 EPA Monitoring of Catchment

The EPA have carried out biological monitoring upgradient and downgradient of the confluence at which the above-mentioned stream joins the Owenglen River (see Figures 10-12). The upgradient point is located approximately 310m to the east of the confluence of the subject stream with the Owenglen River upgradient of Waterloo Bridge. The downgradient point is located 1.3km downgradient and to the west of the confluence just downgradient of Ardbear Old Bridge on the southern edge of Clifden town. In 2018, a biological quality value (Q-Rating) of *Q4-5* or *'High'* status has been given by the EPA for the upgradient point and a biological quality value (Q-Rating) of *Q4* or *'Good'* status has been given for the downgradient location which is adjacent to the Ardbear Old Bridge in Clifden town (see Appendix 4 for EPA monitoring point desk study records). Records for the upgradient station started in 1986 at which point it was given a Q-Index of 5. In 2014, the Q-Index changed to 4 and in 2018 an improvement to a

Q4-5 was observed. Records for the downgradient station started in 1986 at which point it was given a Q-Index of 4. In 1994, the Q-Index improved to Q5 but in the following years the site returned to a Q-Index of 4.

4.4.6 Source of Stream

The valley contains a meandering stream flowing in an approximate east to west direction which rises from Lough Cashleen which is located approximately 690m to the east of the site in a Coillte Coniferous Forest Plantation (see Figures 13 and Plate 9 below). It is understood that a number of years after the infilling of waste at Tullyvogheen Landfill commenced, the stream which runs through the site was culverted (see Figures 4-5). The stream is culverted 27m from the eastern boundary of the site.

Plate 9. UAV aerial photograph of Lough Cashleen taken at 40m elevation from the northern side facing in a southerly direction (note the stream exits the Lough on its western side i.e. to the left of the photo.

4.4.7 Upgradient of Historic Landfill/Surface Water Monitoring Point SW1

The stream exiting Lough Cashleen appears to be the main contribution to the culverted stream which is channelled under the landfill via a 900mm concrete culvert (see Plates 10 & 11 following). It should be noted that the upgradient surface water monitoring point, SW1 was taken from this stream before it enters the storm manhole via a 475mm ID concrete pipe (see surface water monitoring logs in Appendix 3). Please see an inventory of all 7 surface water monitoring points in the attached table, Table A3.1 in Appendix 3. In addition, it also receives a 475mm ID concrete pipe from a culverted stream to the north of the site. This is a smaller stream than the stream from Lough Cashleen which rises to the north of SW1 to the north of the country road, is culverted under the road, piped through the bog via a 475mm concrete pipe and feeds into the afore-mentioned manhole.

There are also a 300mm ID concrete pipe from a land drain to the south and south-eastern boundary of the site. This serves to remove ponded water from this area which results from run-off from Couravoughil Mountain to the south of the site. This land drain follows the southern and eastern boundaries where it discharges into the culverted stream manhole via a 300mm concrete pipe (see Figures 4 & 5 and Plates 10, 11 & 12 following). A smaller 150mm ID concrete pipe from a land drain located just to the east of the landfill drains surface water from the eastern side of the landfill berm (see Plate 10).

A 900mm ID concrete pipe exits this manhole in a westerly direction. This pipe appears to run the full length of the landfill (i.e. 260m) and exits to the west of the landfill (see Plates 10, 11 & 12 following and Figures 13 and 14).

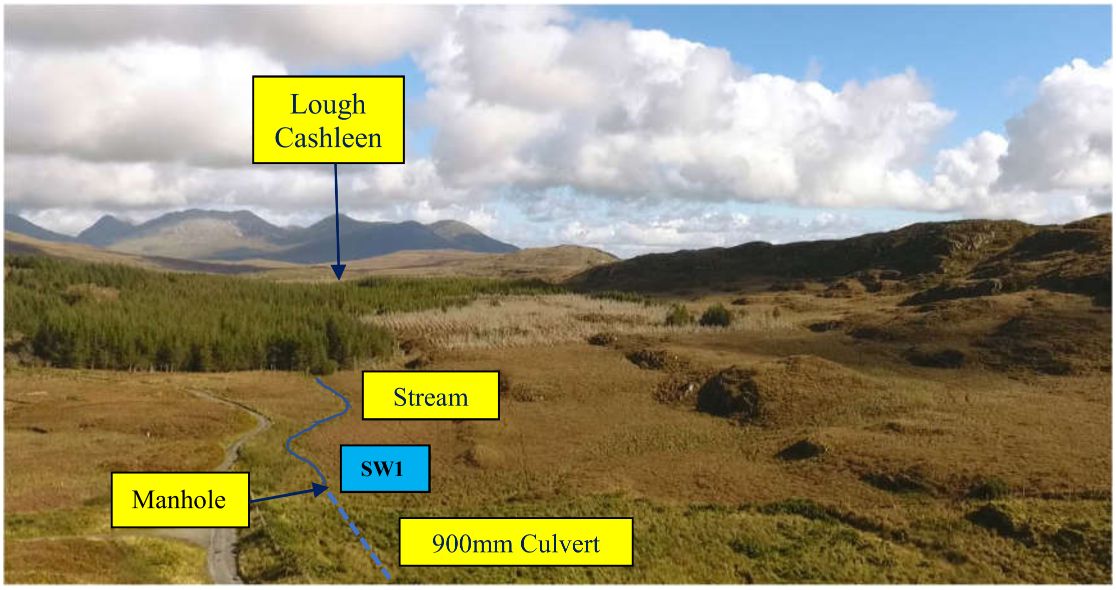


Plate 10. UAV aerial photograph taken at 40m elevation from the northern side of the country road landfill showing Coillte Forestry to east where Lough Cashleen is located side facing in a easterly direction (note stream exiting forestry flowing towards site to manhole where after it is culverted.

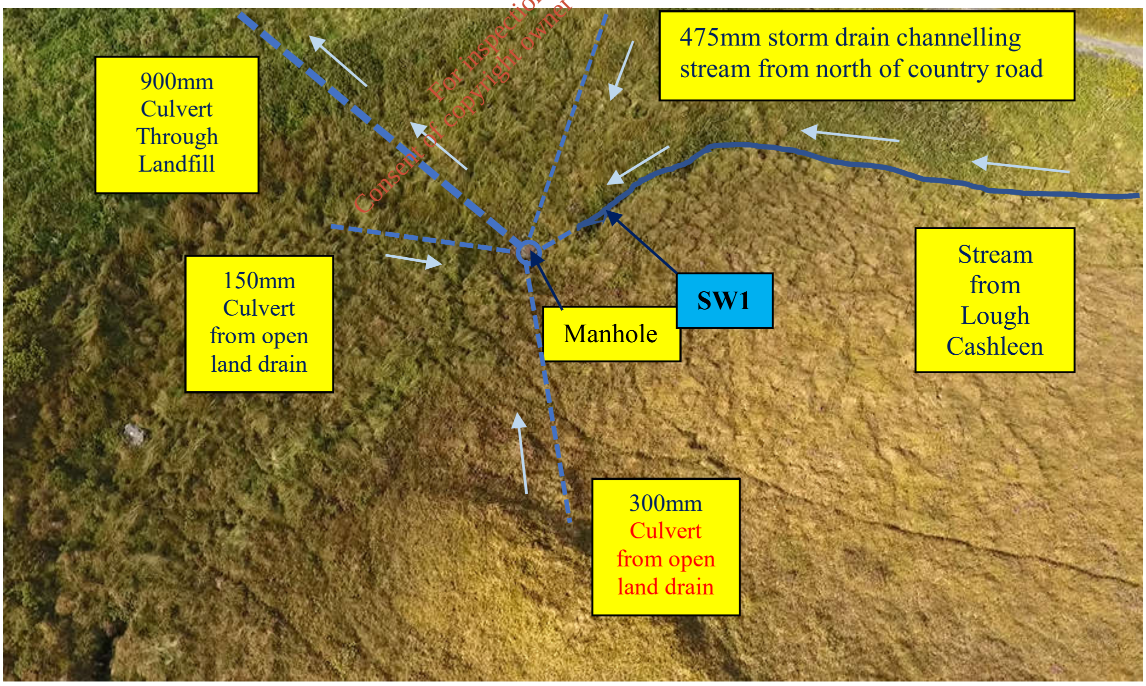


Plate 11. UAV aerial photograph taken at 40m elevation from the southern side of the country road to the east of the landfill showing position of stream from Lough Cashleen from east and culverted stream to north of country road entering manhole and culvert exiting & running through the landfill

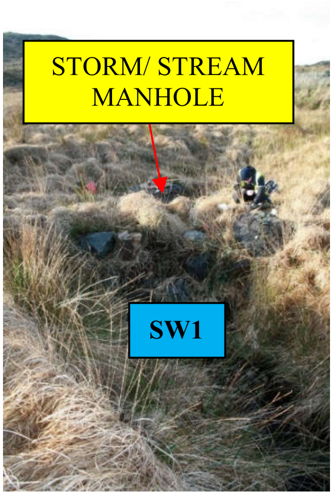


Plate 12. To east of site facing westwards towards landfill showing stream feeding into storm access manhole and surface water monitoring location SW1 manhole

4.4.8 Downgradient of Historic Landfill/Surface Water Monitoring Point SW2 & Invertebrate Kick Sampling Location KS1

This stream, which runs in an east to west direction through the valley, is culverted through the landfill before continuing in a south-westerly direction alongside the country road for a distance, then heading south-westwards (see Figures 15). The 2nd surface water sample, SW2 was taken at this unnamed 1st order stream (see Surface Water Monitoring Logs in Appendix 3). In addition, the 1st invertebrate kick sample was taken at this location (see Plates 13 and 14 below and following, and Figures 14 & 15).

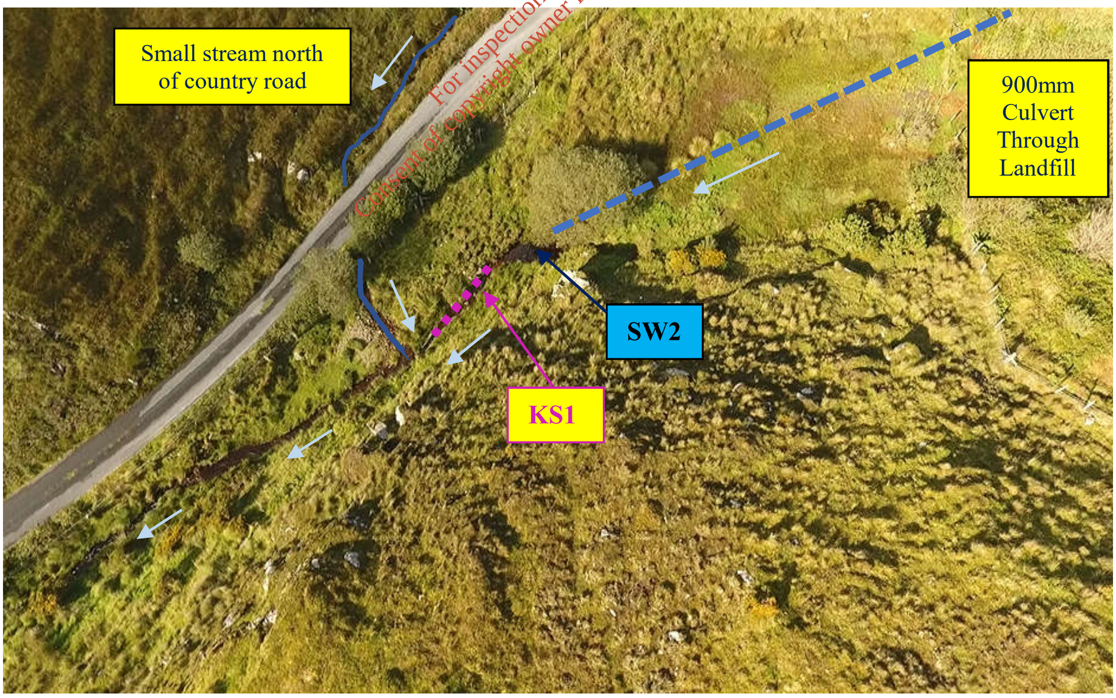


Plate 13. UAV aerial photograph taken at 40m elevation from the southern side of the country road to the west of the landfill showing culverted stream exiting landfill and flowing to the east of country road (note small stream from the north of the country road feeding in downgradient of SW2.

Plate 14. To west of site facing northeast showing culvert discharge point to west of landfill (note iron deposit)

A land drain was observed on the south-western boundary of the site (see Figure 4). This also serves to remove ponded water from this area which results from run-off from Couravoughil Mountain to the south of the site. This land drain appears to discharge into the stream at a point immediately adjacent and to the south of the culvert discharge point.

4.4.9 *Lough Nambrackeagh (Drinking Water Reservoir) Stream feeding into Subject Stream*

A lowland lake, Lough Nambrackeagh, is located 350m to the northwest and hydraulically upgradient of the site (see Plate 15 below and Figure 14). Clifden derives its water supply primarily from Lough Nambrackeagh. A small stream discharges from this lake and joins the afore-mentioned stream approximately 95m to the west of the landfill (see Plate 11 following).

Plate 15. UAV aerial photograph taken at 40m elevation from the south-eastern corner of Lough Nambrackeagh Reservoir (note outlet from reservoir is a stream that feeds into the subject stream to the north of SW3.

4.4.10 Downgradient of Historic Landfill/Surface Water Monitoring Point SW3 & Invertebrate Kick Sampling Location KS2

The 3rd surface water sample, SW3 was taken downgradient of the confluence with the Lough Nambrackeagh stream, on this unnamed 2nd order stream (see Surface Water Monitoring Logs in Appendix 3). In addition, the 2nd invertebrate kick sample was taken at this location (see Figure 15 and Plates 16 & 17 following).

Plate 16. Digital photograph taken at point where stream from Lough Nambrackeagh joins subject stream (i.e. upgradient of SW3)

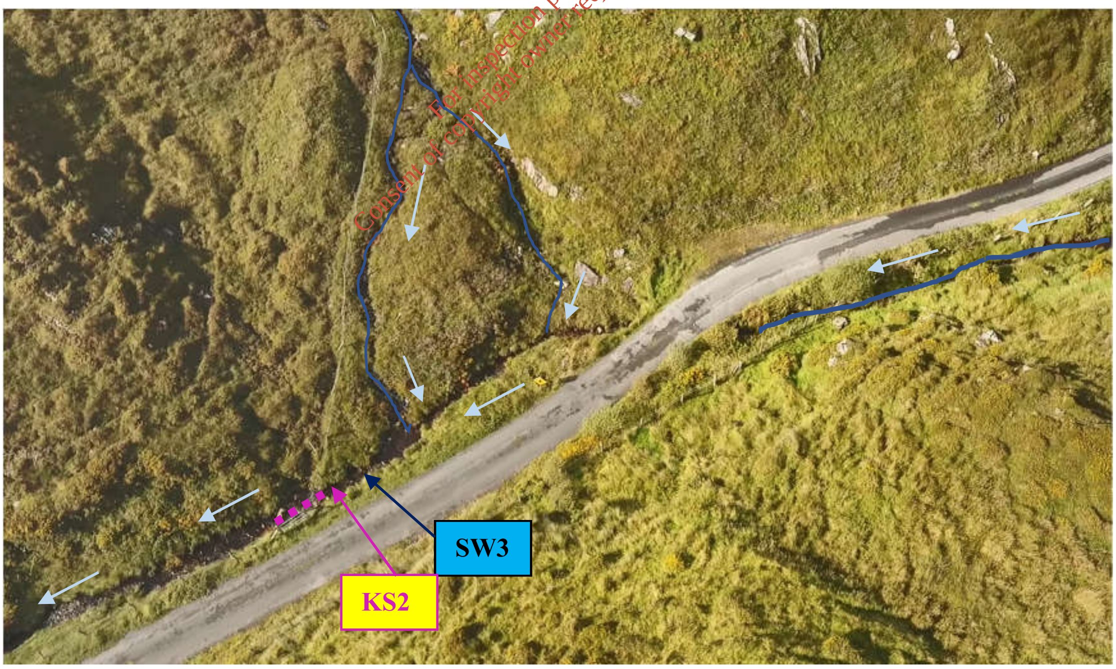


Plate 17. UAV aerial photograph taken at 40m elevation to the southwest of landfill at confluence of Lough Nambrackeagh stream with subject stream (note Nambrackeagh stream is divided upgradient of stream, note location of SW3 and KS2 downgradient of confluence)

4.4.11 Downgradient of Historic Landfill/Surface Water Monitoring Point SW4 & Invertebrate Kick Sampling Location KS3

The 4th surface water sample, SW4 was taken at a location approximately 460m to the southwest of the landfill where the stream, which is a 2nd order unnamed stream, passes through a sheep farm which is downgradient of the site (see Surface Water Monitoring Logs in Appendix 3). In addition, the 3rd invertebrate kick sample, KS3 was taken at this location (see Plates 18, 19, 20 and 21 following and Figures 16 & 17).

Plate 18. UAV aerial photograph taken at 40m elevation approximately 460m to the southwest of landfill at the western boundary of the sheep farm (i.e. note location of SW4 and KS3).

Plate 19. Photographs of SW4 surface water sampling area/KS3 invertebrate sampling area showing kick sampling in progress, sheep grazing and adjacent sheep farmshed.

Plate 20. Photograph of the kick sample net taken from KS3 showing a trout parr

Plate 21. Photograph of surface water sample taken at SW4 showing peat tannins

4.4.12 Downgradient of Historic Landfill/Surface Water Monitoring Point SW5

The 5th surface water sample, SW5 was taken at a location approximately 700m to the southwest of the landfill where the stream, which is a 3rd order unnamed stream, passes under the national road N59 (see Figures 17 & 18 and following Plates 22 & 23) (see Surface Water Monitoring Logs in Appendix 3). No invertebrate sample was taken in this area.

Plate 22. Photographs of SW5 surface water sampling area (note guest house to north of location with stream dividing property from residence to the west. Also note water treatment plant to northeast of location)

Plate 23. Photographs of SW5 surface water sampling area (note discharge pipe equipped with valve and services running in line with road)

4.4.13 Owenglen River/Upgradient of Confluence/Surface Water Monitoring Point SW6 & Invertebrate Kick Sampling Location, KS4

The 6th surface water sample, SW6 was taken on the Owenglen River, which is classed as a 4th order stream, at a location approximately 30m upgradient and to the east of the confluence of the stream with the Owenglen River. The 4th invertebrate kick sample location was taken in the same area (see Figure 18 and following Plates 24 & 25).

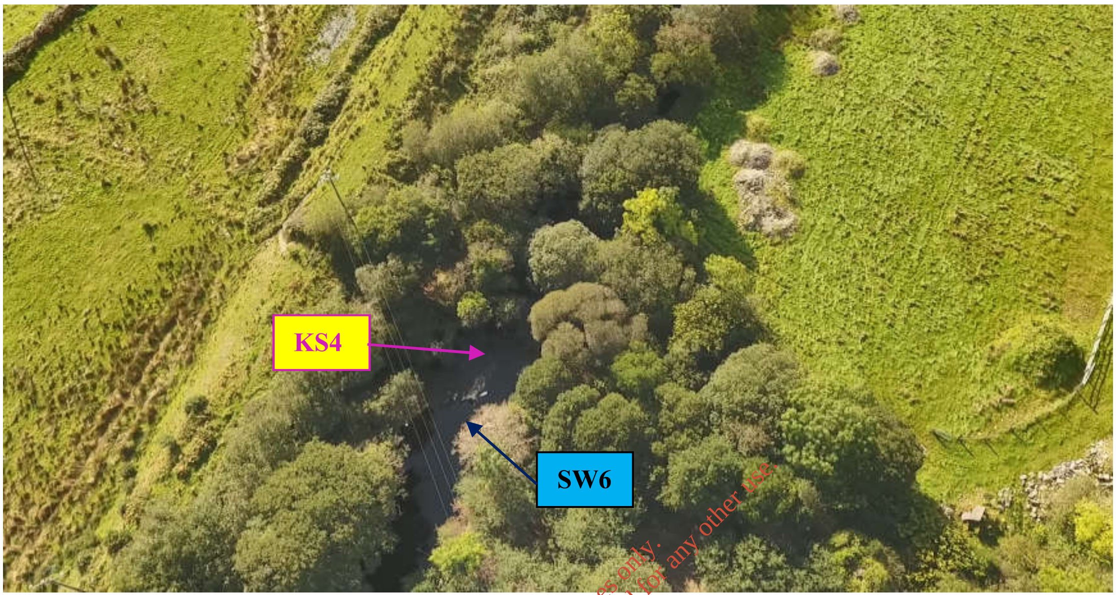


Plate 24. UAV aerial photograph taken at 40m elevation directly over the Owenglen River facing westwards (note locations of surface water monitoring point and invertebrate kick sampling location)

Plate 25. Photographs of SW6 surface water sampling area (note rock weir downgradient of sampling area)

4.4.14 Owenglen River/Downgradient of Confluence/Surface Water Monitoring Point SW7 & Invertebrate Kick Sampling Location, KS5

The 7th surface water sample, SW7 was taken on the Owenglen River, which is classed as a 4th order stream, at a location approximately 20m downgradient and to the west of the confluence of the stream with the Owenglen River. The 5th invertebrate kick sample location was taken in the same area (see Figures 18 and following Plate 26).

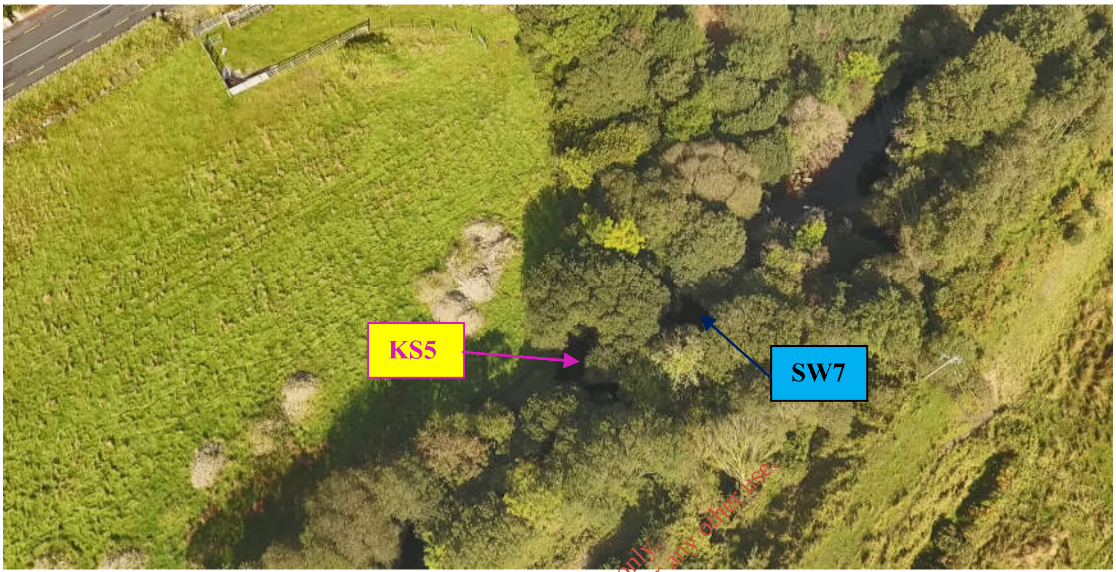


Plate 26. UAV aerial photograph taken at 40m elevation directly over the Owenglen River facing northwards (note locations of surface water monitoring point and invertebrate kick sampling location)

5 ECOLOGICAL ASSESSMENT

5.1 Results of Invertebrate Assessment

A total of 722 invertebrates were identified from the five 2-minute kick samples collected. A total of 46 taxa were recorded with representatives of most of the groups associated with *'Good'* status rivers observed (see Table 1 in AQUENS Ltd. report in Appendix 2). Based on the percentage composition of the macroinvertebrates recorded at KS1 and KS2, both sites were assigned a Q3 predominantly as a result of the lack of Group A taxa, despite the high diversity and abundance of Group B taxa (see Figure 15 and previous Sections 4.4.9 and 4.4.10 for detailed description of location). Although a heavy silt plume was observed when disturbing the stream substrate, an absence/low cover of filamentous algae and dissolved oxygen (DO) concentrations ranging from 80% - 91% supports a Q3 value (i.e. at a minimum) (see following table, Table 1).

Table 1. Habitat characteristics recorded at each kick sampling locations (KS1 to KS5)

Sample Location	Waterbody Width & Depth	Substrate Type (%)	Flow Type	Vegetation & Siltation
KS1	Wetted width: 100cm Average depth 10cm:	Sand: 5% Silt: 5% Gravel; 10% Cobble: 80%	Riffle: 10% Glide: 85% Pool: 5%	Heavy silt plume observed. No filamentous algae recorded.
KS2	Wetted width: 190cm Average depth: 17cm	Sand: 5% Silt: 5% Gravel; 10% Cobble: 80%	Riffle: 15% Glide: 80% Pool: 5%	Heavy silt plume observed. Low abundance of filamentous algae recorded.
KS3	Wetted width: 180cm Average depth: 15cm	Sand: 5% Silt: 5% Gravel; 10% Cobble: 80%	Riffle: 40% Glide: 55% Pool: 5%	Slight / Moderate silt plume observed. No filamentous algae recorded.
KS4	Wetted width: 10.9m Average depth: 65cm	Sand: 5% Gravel; 80% Cobble: 10% Boulder: 5%	Glide: 95% Pool: 5%	Slight silt plume observed. No filamentous algae recorded.
KS5	Wetted width: 9.9m Average depth: 65cm	Sand: 5% Gravel; 80% Cobble: 10% Boulder: 5%	Glide: 95% Pool: 5%	Slight silt plume observed. No filamentous algae recorded.

One site KS3, was assigned a Q4, largely due to the presence of Group A taxa and good representation of Group B taxa, with a high overall % EPT (i.e. *Ephemeroptera, Plecoptera, Trichoptera*). It should be noted that during sampling a trout parr was recorded within the sample (see previous plate, Plate xx). The slight to moderate silt plume observed, the low filamentous algae cover and DO concentration of 95% recorded at the site supports the Q4 classification (see Figure 16 and previous Section 4.4.11 for detailed description of location).

It was not possible to assign an accurate Q-Value for either of the sampling sites located on the Owenglen River (i.e. KS4 and KS5). This was due to the very low abundance of macroinvertebrates present in either sample, particularly KS5 where only 7 invertebrates from 2 taxa were recorded (see Figures 17 & 18 and previous Sections 4.4.13 & 4.4.14 for detailed description of location).

In summary, KS1 and KS2 have been assigned a Q3 which represents *'Poor'* ecological status, KS3 has been assigned a Q4 *'Good'* status, while KS4 and KS5 could not be attributed due to the lack of biological material in the sample (see Table 2 below).

Table 2. Invertebrate Sampling Location & Assigned Q-Value

Sampling Location	Q-Value	Ecological Status	Interpretation
KS1	Q3	Poor	Moderately Polluted
KS2	Q3	Poor	Moderately Polluted
KS3	Q4	Good	Unpolluted
KS4	-	-	Not Assigned
KS5	-	-	Not Assigned

5.2 Discussion

While KS1 and KS2 have been assigned a Q3, it is plausible that this is an underestimate of the Q-value given the relatively high % EPT scores observed (i.e. 49.1% and 45.4% respectively). It is important to note that the timing of sampling on small headwaters has been found to have a critical influence when trying to determine the ecological quality on these waterbodies (*Callanan et al., 2008).* [5] It is recommended that KS1 and KS2 (i.e. small headwater locations) are re-monitored in late spring (i.e. April)/early summer (i.e. May) to definitively determine these Q-values.

The macroinvertebrate assemblages recorded at KS4 and KS5 on the Owenglen River are unusual. A greater invertebrate abundance would be expected given the time of year of sampling. For instance, in 2018, a Q4-5 was recorded at the EPA WFD operational monitoring station (RS32O030200) located approximately 280m upstream from KS4. Typically, such low abundances recorded in larger rivers, occur after severe stress such as significant flooding events. On review of the flow data available from the hydrometric station (32004) situated 300m upstream on the Owenglen River, it is apparent that a substantial flow event occurred on the 30th August and the 1st of September, 2019 where a river flow of $41m^3/s$ was recorded (see Appendix 4). A review of the historical data which dates back to 1956 indicates

[5] *Callanan, M., Baars, JR. & Kelly-Quinn, M. Hydrobiologia (2008) 610: 245.*

that this flow was possibly the highest experienced at this station since recording began. Consequently, it is recommended that a kick sample at KS4 and KS5 should be taken next summer (i.e. 2020) preceding any flood events.

6 ENVIRONMENTAL SURFACE WATER RESULTS

6.1 Background

It is understood that the EPA carried out surface water sampling at 3 locations, SW1, SW2 and SW3 on 3 occasions during 2012. In 2014, the same 3 locations were used in the Tier 2 GQRA field work. Following consultation with Galway C.C. and following the recommendations of the 2014 report, a further 4 locations were identified in order to further delineate any impacts which the landfill may be having on the downgradient stream and the Owenglen River and its biota. Section 4 of this report provides a detailed description of the hydrology of the site and shows through a series of plates, the locations of each of the 7 surface water monitoring locations. All 7 locations are showing in detail on Figures 10 to 18.

6.2 Laboratory Suite

The laboratory suite for the 7 surface water samples was as follows:

Inorganic Analysis

- Heavy Metals – Antimony, Arsenic, Boron, Cadmium, Copper, Chromium, Iron, Lead, Manganese, Mercury, Nickel Selenium and Zinc;
- Total Dissolved Solids;
- Total suspended solids;
- Total alkalinity (as $CaCO_3$);
- Ammoniacal Nitrogen (as N);
- Total Oxidised Nitrogen (TON) as N;
- Nitrates;
- Nitrites;
- Chloride (Cl^-);
- Fluoride (F^-);
- Sulphate (SO_4^{2-});
- Sulphides (S^{2-});
- MR-Phosphate as P; and

Major Cations and Anions

- Potassium (K);
- Sodium (N);
- Calcium (Ca); and
- Magnesium (Mg).

Oxygen Demand/Organic Carbon

- Biological Oxygen Demand; and
- Chemical Oxygen Demand.

Microbiological

- Total Viable Count (TVC)@22ºc;

- Total Viable Count (TVC)@37^{o}C;
- Total Coliform;
- Faecal Coliform;
- Enterococci; and
- *Clostridium perfringens.*

Trace Organic Analysis

- Volatile Organic Compound;
- Semi-volatile Organic Compound;
- Benzene, Toluene, Ethylbenzene, Xylenes and MTBE;
- Polyaromatic Hydrocarbons (PAHs) (17 speciated) to include Coronene;
- Organo-phosphorous pesticides; and
- Organo-chlorine pesticides & Acid Herbicides.

The following table, Table 4 (Parts A & B) represents the results of the inorganic, oxygen demand and microbiological analyses on the surface water samples. The results of the Volatile Organic Compound (VOC), Semi-volatile Organic Compound (sVOC), BTEX, Polyaromatic Hydrocarbon (PAH), Organo-phosphorus, Organo-chlorine/Acid Herbicide analyses and Ion Balance assessment are located in a series of tables which are located in Appendix 5.

6.3 Data Assessment

The surface water results are compared against the following Generic Assessment Criteria (GAC) which are primarily for contaminated groundwater assessment but can be used to assess levels of contamination in surface water where GAC do not exist for a lot of trace organic compounds. A detailed description of the following Generic Assessment Criteria is given in Section 3:

- National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria) – Intervention and Target Values; [6] and

The surface water results are compared against the statutory limits from the following environmental regulations:

- *S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989*;
- *S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007*; and

[6] When dealing with the Due Diligence Site Assessment of brownfield sites in Ireland a set of guidelines called the Soil Protection Guidelines, produced by National Institute of Public Health and the Environment of The Netherlands is generally used. The treatment of polluted soil and groundwater depends on the nature and the concentrations of the polluted substances present in it. The Soil Protection Guidelines used in The Netherlands is built on two values. These values, consisting of different ascending levels of concentration TV and IV are differentiated according to the nature of the pollution:

- Level TV is the target value. Pollutants above the TV level should be investigated more thoroughly. The question asked is: to what extent is the nature, location, and concentration of the pollutants of such a nature that it is possible to speak of a risk of exposure to man or the environment? ; and
- Level IV is the intervention value above which the pollutants should generally be treated. In order to assess the risk of any contaminants contained in the overburden on site as a result of historical practices, the results of the soils analysis are compared to the above levels with particular regard paid to Level IV.

- *S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations, 2009.*
- *S.I. No. 386, EC Environmental Objectives (Surface Waters) (Amendment) Regulations 2015*; and
- *S.I. 77 European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019.*

6.4 Physicochemical Analysis

The results of the field multiprobe monitoring for each of the 7 surface water monitoring points are presented in Table 3.

The pH results ranged from 5.97 at the upgradient monitoring point SW1 to 6.81 at the downgradient monitoring SW4. All of the pH results were under 7 and as such, the surface water can be described as slightly acidic which would be regarded as normal for surface waters originating in upland peatland areas where commercial forestry plantations dominate the environment (see Table 3). Upland peat areas which have been extensively planted with coniferous trees have been found to generate low pH (i.e. <5) surface waters. It should also be noted that the bedrock type for the area (i.e. metamorphic schist bedrock) also influences the pH of surface waters in an area. It should be noted that the pH increased markedly from the upgradient monitoring point SW1 to the downgradient point from the historic landfill, SW2.

Electrical conductivity readings varied from 0µS/cm to 96.42µS/cm. The highest conductivity readings were observed at SW1 and SW2 with conductivity decreasing to low non-detectable levels at SW4, SW5 and SW6. A low EC reading (i.e. 46.9µS/cm) was also detected at SW7. Low conductivity readings would be regarded as normal for the subject area where there is an absence of sedimentary type rock (i.e. limestone) which would impart high dissolved cation concentrations, high alkalinity and subsequently high conductivity readings (see Table 3).

The highest Total Dissolved Solids (TDS) were observed at SW1 and SW2 with TDS levels decreasing to low, non-detectable levels at SW4, SW5 and SW6. A low EC reading (i.e. 23.45ppm) was also detected at SW7. These levels appear to be closely aligned with electrical conductivity levels (see Table 3).

The oxidation reduction potential (ORP) for the site range from a low of 86.83mV at SW2 to a high of 193.59mV at SW7. With the exception of the ORP for SW2, the ORP for the other 6 locations vary little (i.e. from 124.3mV to 193.59mV). It should be noted that the dissolved oxygen level for SW2 is noticeably lower than the other 6 locations at 8.35ppm. The other 6 readings are all greater than 9ppm which would be regarded as normal for well aerated surface water bodies. These results would suggest that the landfill is impacting on the oxygen levels and subsequently the ORP within the surface water passing through the site (see Table 3).

Turbidity levels are highest in SW1 and SW2 (i.e. 2.45 to 2.47FNU) and appear to decrease gradually as the sampling locations get further from SW1 and SW2 (see Table 3). It appears that the turbidity levels may be closely aligned with the level of peat tannins that were observed in the more upgradient samples. SW6 and SW7 had the lowest levels of tannins observed during sampling (please see Surface Water Monitoring Logs in Appendix 3).

Table 3. Results of Field Multiprobe Readings on Surface Water Samples taken from Locations SW1 to SW7 on stream adjacent to Tullyvogheen Historic Landfill and on the Owenglen River on the 30th September, 2019

Monitoring Date	Monitoring Time	Monitoring Point	Temperature	pH	mvpH [9]	ORP [1]	Conductivity [2]	Absolute conductivity [3]	Resistivity [4]	Total Disssolved Solids (TDS)	Salinity [5]	Seawater Density [6]	Atmosphere. Pressure [7]	DO	DO	Turbidity [8]
			°C			mv	µS/cm	µS/cm	MΩcm	ppm	PSU	σt	psi	%	ppm	FNU
30.09.2019	SW1	08:13:12	11.93	5.97	46.36	160.47	95.56	71.71	10084.88	49.81	-	0.00	14.46	86.08	9.13	2.45
	SW2	09:18:30	11.92	6.66	5.02	86.83	96.42	72.48	11285.45	48.24	-	0.00	14.46	78.62	8.35	2.47
	SW3	10:02:28	12.15	6.53	26.19	124.30	3.50	2.75	-	1.90	-	0.00	14.46	91.71	9.69	2.05
	SW4	11:00:15	12.10	6.81	-8.28	146.47	0.00	0.00	-	-	0.00	0.00	14.48	95.82	10.15	2.36
	SW5	11:57:49	12.12	6.54	17.33	155.92	-	-	-	-	-	0.00	14.48	94.08	9.96	1.92
	SW6	12:48:26	11.89	6.60	6.68	175.99	-	-	-	-	-	0.00	14.46	104.48	11.07	0.83
	SW7	13:11:42	11.86	6.37	30.88	193.59	46.90	35.20	22350.00	23.45	-	0.00	14.45	97.55	10.32	0.73

Notes:

1. ORP - signifies Oxidation Reduction Potential. Oxidation-reduction potential, or ORP, is a measurement that indicates the degree to which a substance is capable of oxidizing or reducing another substance. ORP is measured in millivolts (mV).

2. Conductivity (µS/cm) - Electrical conductivity is denoted by the symbol σ and has SI units of microsiemens per centimeter (µS/cm). If the conductivity changes along with the temperature change of a solution and it is a known characteristic, the conductivity measurement can be corrected to a reference tempe carefully measuring the solution temperature (typically 20 or 25°C)

3. Absolute Conductivity (µS/cm) - Absolute conductivity is an EC measurement without temperature compensation.

4. Resistivity (MΩcm) - Resistivity in water, measured in milliohm-meters, is the measure of the ability of water to resist an electrical current, which is directly related to the amount of dissolved salts in the water. Water with a high concentration of dissolved salts will have a low resistivity, and vice versa. Resist measured in Ohms.

5. Salinity (PSU) - Ocean salinity is generally defined as the salt concentration (e.g., Sodium and Chlorine) in sea water. It is measured in unit of PSU (Practical Salinity Unit), which is a unit based on the properties of sea water conductivity. It is equivalent to per thousand or (o/00) or to g/kg.

6. Seawater Density (σt) - Oceanographers use a density unit called sigma-t (σt). This value is obtained by subtracting 1.0 from the density and multiplying the remainder by 1,000. The σt has no units and is an abbreviated density of seawater controlled by salinity and temperature only. The σt of seawater increas increasing salinity and decreasing temperature.

7. Atmospheric Pressure (PSI) - PSI signifies 'Pounds per square inch'. Normal atmospheric pressure is 14.7 psi, which means that a column of air one square inch in area rising from the Earth's atmosphere to space weighs 14.7 pounds. Atmosphere. (atm) Normal atmospheric pressure is defined as 1 atmosphere

8. FNU - signifies 'Formazin Nephelometric Unit (FNU)' is similar to a Nephelometric Turbidity Unit (NTU) in that both measure scattered light at 90 degrees from the incident light beam, but the FNU is measured with an infrared light source as opposed to white light for NTU. FNU is most often used when re the ISO 7027 (European) turbidity method.

6.5 Laboratory Analysis

6.5.1 Total Suspended Solids

Despite the discoloration (i.e. brown taint) caused by peat tannins within the surface water samples, the results obtained for Total Suspended Solids for all 7 surface water samples were low at <5mg/l (see Table 4-Part A and surface water monitoring field logs in Appendix 3).

6.5.2 Total Hardness & Total Alkalinity

For the 7 surface water samples, Total Alkalinity ranged from 21mg/l in SW1 to 200mg/l in SW2. The Total alkalinity was considerably lower at SW1. Total alkalinity values varied very little from SW2 to SW7 (see Table 4-Part A).

The levels of Total Hardness found in all 7 samples for SW1 to SW5 ranged from 29mg/l to 37mg/l. The highest level of Total Hardness was at SW2. This contrasted significantly with the low levels (i.e. background levels of <15mg/l) of total hardness found in both water samples taken from the Owenglen River (i.e. SW6 and SW7) (see Table 4-Part A).

These levels of Total Alkalinity and Total Hardness are consistent with the type of 'soft' surface water present in the bedrock in the area (i.e. schist) which has low levels of calcium carbonate.

6.5.3 Ammoniacal Nitrogen, Nitrates & Nitrites

The result obtained for the upgradient surface water sample, SW1 for Ammoniacal Nitrogen was 0.032mg/l and was less than the Threshold Value of 0.07mg/l (i.e. AA-EQS) for ammonia from S.I. No. 272 Surface Water Threshold Value (see Table 4-Part A).

The results for the downgradient samples were 0.98mg/l, 0.64mg/l, 0.32mg/l and 0.145mg/l for SW2, SW3, SW4 and SW5 respectively which all exceeded the S.I. No. 272 Surface Water Threshold Value. It is possible that the low level of ammonia detected within the upgradient surface water sample is attributable to agricultural or forestry practices upgradient of the site (see Table 4-Part A).

However, it should be noted that the ammonia results for the downgradient samples likely indicate that the landfill is having a low to moderate impact on the surface water body. It is possible that other sources (i.e. farming, residential, commercial sources, etc) may also be impacting on the ammoniacal levels within the surface water body before it enters the Owenglen River. These results should be looked at in conjunction with the microbiological results for SW4 and SW5.

It is important to note that no ammonia was detected in the upgradient, SW6 or downgradient SW7 monitoring points on the Owenglen River. It is likely that this is down primarily to dilution within the larger Owenglen water body.

The results of nitrate analyses on the surface water samples show relatively low background levels in SW1, SW2 and SW3. Nitrates were detected at their highest level (i.e. 18mg/l) at SW4, with levels decreasing to 4.8mg/l at SW5. Low levels of nitrate were detected in the upgradient, SW6 monitoring point on the Owenglen River. No nitrates were detected in the downgradient, SW7 monitoring point. All nitrate levels were found to be below the S.I. 278 Parametric Value of 50mg/l (see Table 4-Part A).

No nitrites were detected in the 7 surface water samples (see Table 4-Part A).

These results are consistent with the previous nitrate results in 2014 and the testing carried out by the EPA in 2012 (see Appendix 4).

6.5.4 Anions (Chloride (Cl-), Sulphate (SO_4^{2-}) and Sulphide (S^{2-})

The results obtained for the 7 surface water samples for chloride ranged from 15mg/l to 36mg/l with the highest chloride levels found at SW1. The chloride results obtained for the surface water samples were all significantly lower than their respective Parametric Value of 250mg/l (see Table 4-Part A).

The results obtained for the 7 surface water samples for sulphate (SO_4^{2-}) ranged from <1mg/l to 2.3mg/l with the highest sulphate level found at SW7. The sulphate results obtained for the surface water samples were all significantly lower than their respective Parametric Values (see Table 4-Part A).

Sulphide (S^{2-}) levels were all lower than their respective Limit of Detection (see Table 4-Part A).

6.5.5 MR-Phosphate (as P) and Total Cyanide.

Six of the 7 Molybdate Reactive-phosphate results obtained were lower than their respective Limit of Detection (i.e. 0.05mg/l) (see Table 4-Part A). Molybdate Reactive-phosphates were detected in the upgradient sample from SW1 at 0.16mg/l. This result exceeded the S.I. No. 272 Surface Water Threshold Value of 0.035mg/l. This result would indicate a possible source of phosphates from farming and/or forestry hydraulically upgradient of the historic landfill and represents an increase on the phosphate levels found at the upgradient point in 2014 (i.e. 0.084mg/l).

No cyanides were detected within the 7 surface water samples taken on site.

6.5.6 Major Cations

The results obtained within the surface water samples for potassium ranged from below the Method Detection Limit (i.e. <0.5mg/l) in the Owenglen River sample locations to the highest level of 0.98mg/l in SW2 (see Table 4-Part A). Potassium levels decreased from SW2 to SW3 (i.e. 0.8mg/l), increased from SW3 to SW4 (0.83mg/l) and finally decreased again from SW4 to SW5 (i.e. 0.78mg/l). When comparing the current data to that obtained in 2014, the levels of potassium found in the downgradient samples SW2 and SW3 have decreased significantly from those levels found in 2014 (see Appendix 4).

The results obtained within the surface water samples for sodium ranged from 8mg/l to 22mg/l and were all significantly lower that their respective Parametric Value of 200mg/l (see Table 4-Part A). When comparing the current data to that obtained in 2014, the levels of sodium found in the downgradient samples SW2 and SW3 have decreased significantly from those levels found in 2014 (see Appendix 4).

The low levels of potassium are reflected in the Potassium/Sodium ratio which range from 0.02 to 0.05. A ratio greater than 0.4 generally would indicate an impact by domestic waste leachate (see Table 4-Part A).

The results obtained within the surface water samples for calcium ranged from below the Method Detection Limit (i.e. <0.5mg/l) in the Owenglen River sample locations to the highest level of 11mg/l in SW2. Calcium levels decreased from SW2 to SW3 (i.e. 9.7mg/l), decreased from SW3 to SW4 (9.1mg/l) and finally increased again from SW4 to SW5 (i.e. 9.6mg/l) (see Table 4-Part A).

The results obtained within the surface water samples for magnesium ranged from 1.3mg/l in the Owenglen River sample locations to the highest level of 2.4mg/l in SW2. Magnesium levels decreased from SW2 to SW3 (i.e. 2.1mg/l), remained the same from SW3 to SW4 (i.e. 2.1mg/l) and finally, like calcium levels, increased again from SW4 to SW5 (i.e. 2.3mg/l) (see Table 4-Part A). When comparing the current data to that obtained in 2014, the levels of magnesium found in the SW1, SW2 and SW3 have decreased significantly from those levels found in 2014 (see Appendix 4).

6.5.7 Heavy Metals

Of the 13 heavy metals analysed, the reported concentrations for all parameters are within their respective MAC Values quoted in S.I. No. 294, Parametric Values quoted in the S.I. No. 278 Drinking Water Regulations of 2007, S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009 Threshold Values and S.I. No. 386 EC Environmental Objectives (Surface Waters) Regulations 2015 (Threshold Values) (see Table 4-Part A) with the exception of:

- *Chromium*

For chromium, values of 6.8mg/l and 5.6mg/l were obtained in SW1 and SW2 respectively. These values were above the S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009 Threshold Value (AA-EQS) of 3.4mg/l.

- *Copper*

For copper, a value of 6mg/l was obtained in SW2. These values were above the S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009 Threshold Value (AA-EQS) of 5mg/l.

- *Iron*

Iron levels ranged from relatively low levels (i.e. 470mg/l to 520mg/l) on the Owenglen River at SW6 and SW7 to a range of 1,000mg/l to 2,500mg/l. The highest level at 2,500mg/l was found at SW2 immediately downgradient of the landfill. These levels were found to decrease as you proceed downstream from SW1 to SW5. All 7 values were above the S.I. No. 278 Drinking Water Regulations 2007 Parametric Value (i.e. 200mg/l) (see Table 4-Part A). These findings at SW2 are consistent with the level of ferric iron oxide (i.e. rust) precipitate found immediately downgradient of the discharge point and in the wetland area upgradient of the discharge point. When comparing the current data to that obtained in 2014, the levels of iron found in the SW1, SW2 and SW3 have increased significantly from those levels found in 2014 (see Appendix 4).

- *Manganese*

Manganese levels ranged from relatively low levels (i.e. 30mg/l to 31mg/l) on the Owenglen River at SW6 and SW7 to a range of 60mg/l to 200mg/l. The highest level at 200mg/l was found at SW2 immediately downgradient of the landfill. These levels were found to decrease as you proceed downstream from SW2 to SW4. The values for SW1 to SW5 were above the S.I. No. 278 Drinking Water Regulations 2007 Parametric Value (i.e. 200mg/l) (see Table 4-Part A). These manganese findings at SW2 are consistent with the level of ferric iron oxide (i.e. rust) precipitate found immediately downgradient of the discharge point and in the wetland area upgradient of the discharge point. Like iron, these values would be expected as manganese is typically reduced to its more mobile Mn^{2+} species and released or leached from soil and bedrock into groundwater during anaerobic (i.e. reducing) conditions. When comparing the current data to that obtained in 2014, the levels of manganese found in the SW1, SW2 and SW3 have increased significantly from those levels found in 2014 (see Appendix 4).

6.5.8 Oxygen Demand

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) analyses were carried out on the surface water samples. For Biological Oxygen Demand (BOD) analysis, a value below the detection limit of <1mg/l was obtained in all 7 samples (see Table 4-Part A).

For Chemical Oxygen Demand (COD) analysis, values of 87mg/l, 59mg/l, 47mg/l and 42/mg/l were obtained in SW1, SW2, SW3 and SW4 respectively. These values were above the S.I. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989 MAC value of 40mg/l (see Table 4-Part A).

6.5.9 Microbiology

Total Viable Count at 22°C and 37°C, Total Coliform and Faecal Coliform (i.e. Thermo-tolerant *E. coli*), *Enterococci* and *Clostridium perfringens* analyses were carried out on the surface water samples (see Table 4-Part B). It should be noted that the Parametric Value for Total Coliform and Faecal Coliform (i.e. Thermo-tolerant *E. coli*), *Enterococci* and *Clostridium perfringens* analyses is '0' Colony Forming Units (CFUs) (i.e. these bacteria species must not be detected).

For Total Coliform analysis, values of 80CFUs/100ml, 90CFUs/100ml, and 70CFUs/100ml, were obtained in SW1, SW2 and SW3 respectively. For Faecal Coliform analysis, values of 20CFUs/100ml, 20CFUs/100ml, and 10CFUs/100ml, were obtained in SW1, SW2 and SW3 respectively. These results are slightly higher than those obtained in 2014 and would be expected given the potential for horizontal run-off of farm animal faeces in upland peat areas (see Table 4-Part B).

However, significantly higher levels of bacteria were found downgradient of SW3. For Total Coliform analysis, values of 1,230CFUs/100ml and 1,000CFUs/100ml, were obtained in SW4 and SW5 respectively (see Table 4-Part B). For Faecal Coliform analysis, values of 670CFUs/100ml and 540CFUs/100ml, were obtained in SW4 and SW5 respectively. For Enterococci analysis, values of 13CFUs/100ml and 23CFUs/100ml, were obtained in SW4 and SW5 respectively and for *Clostridium perfringens* analysis, values of 1CFUs/100ml and 4CFUs/100ml, were obtained in SW4 and SW5

Table 4. Results of Inorganic and Microbiological Laboratory Analyses on Surface Water Samples (SW1-SW7) taken from Adjacent Stream at Tullyvogheen Historic Landfill, Clifden, Co. Galway (30.9.19) Part A

Parameter	Units	*S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989* *MACs* *1.*	*S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007* *Parametric Values*	*S.I. No. 272, EC Environmental Objectives (Surface Water) Regulations, 2009)* *Threshold Values (AA-EQS)* *2.*	*S.I 386 EC Environmental Objectives (Surface Waters) Regulations 2015 (Lowest Threshold Values Taken)* *Threshold Values (MAC-EQS)* *3.*	*S.I 77 EC Environmental Objectives (Surface Waters) Regulations 2019 (Lowest Threshold Values Taken)* *Threshold Values* *4.*	SW1 (Upgradient)	SW2 (Downgradient)	SW3 (Downgradient)	SW4 (Downgradient)	SW5 (Downgradient)	SW6	SW7 (Downgradient)
Standard Chemistry													
Total Suspended Solids (TSS)	mg/l	50.00	-	-	-	-	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Total alkalinity	mg/l	-	-	-	-	-	21	200	190	190	190	180	180
Total Hardness (as CaCO3)	mg/l	-	-	-	-	-	29	37	33	31	33	< 15	< 15
Ammonia (as NH_3)	mg/l	-	-	0.07	-	-	0.032	**0.98**	**0.64**	**0.32**	**0.145**	<0.005	<0.005
Ammonium as NH4	mg/l	0.20	0.30	-	-	-	0.041	**1.26**	**0.82**	**0.42**	0.187	<0.01	<0.01
Nitrate NO_3	mg/l	50.00	50.00	-	-	-	< 0.50	< 0.50	< 0.50	18.00	4.80	1.10	< 0.50
Nitrite NO_2	mg/l	-	0.50	-	-	-	0.30	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
Chloride Cl^-	mg/l	250.00	250.00	-	-	-	36.00	34.00	28.00	27.00	29.00	23.00	15.00
Sulphate SO_4	mg/l	200.00	250.00	-	-	-	< 1.0	1.30	< 1.0	< 1.0	< 1.0	< 1.0	2.30
Sulphide S^{2-}	mg/l	-	-	-	-	-	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Total Cyanide	mg/l	0.05	0.05	0.01	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdate Reactive Phosphate (as P)	mg/l	0.50	-	0.035	-	-	**0.16**	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
Major Cations													
Potassium (K)	mg/l	-	-	-	-	-	0.52	0.98	0.80	0.83	0.78	< 0.50	< 0.50
Sodium (Na)	mg/l	-	*200.00*	-	-	-	22.00	18.00	16.00	16.00	17.00	8.00	8.10
K/Na Ratio							0.02	0.05	0.05	0.05	0.05	0.00	0.00
Calcium (Ca)	mg/l	-	-	-	-	-	7.90	11.00	9.70	9.10	9.60	< 5.0	< 5.0
Magnesium (Mg)	mg/l	-	-	-		-	2.20	2.40	2.10	2.10	2.30	1.30	1.30
Heavy Metals													
Antimony (Sb)	µg/l	-	5.00	-	-	-	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Arsenic (As)	µg/l	50	10.00	25.00	-	-	1	1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Boron (B)	µg/l	2,000	1,000.00	-	-	-	54	42	23	21	21	< 20	< 20
Cadmium (Cd)	µg/l	5	5.00	0.08	-	-	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080	< 0.080
Chromium	µg/l	50	-	3.40	-	-	**6.8**	**5.6**	2.4	2.0	2.3	1.9	<1.0
Copper (Cu)	µg/l	50	2,000.00	5.00	-	-	1	**6**	3	1	1	< 1.0	< 1.0
Iron (Fe)	µg/l	200	200.00	-	-	-	**1,700**	**2,500**	**1,600**	**1,200**	**1,000**	**470**	**520**
Lead (Pb)	µg/l	50	10.00	7.20	-	-	< 1.0	2	1	< 1.0	< 1.0	< 1.0	< 1.0
Nickel (Ni)	µg/l	-	20.00	20.00	-	-	< 1.0	2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Manganese (Mn)	µg/l	50	50.00	-	-	-	**160**	**200**	**120**	**60**	**65**	30	31
Mercury (Hg)	µg/l	1	1.00	-	0.07	-	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Selenium (Se)	µg/l	10	10.00	-	-	-	1	2	1	< 1.0	< 1.0	< 1.0	1
Zinc (Zn)	µg/l	3,000	-	50.00	-	-	21	**84**	16	20	14	17	19
Oxygen Demand/Organic Carbon													
BOD	mg/l	5	-	2.20	-	-	<1	<1	<1	<1	0	<1	<1
COD	mg/l	40	-	-	-	-	**87**	**59**	**47**	**42**	0	25	22

Note:

Cadmium - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all <40mg/l. Therefore, a Water Hardness Class I has been selected and as such, a cadmium AA-EQS of<0.08ug/l has been selected.

Copper - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all <100mg/l. Therefore, a copper AA-EQS of 5ug/l has been selected.

Zinc - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all greater than 10mg/l. Therefore, a zinc AA-EQS of 50ug/l has been selected.

450.00 (shaded yellow)	Values are shaded yellow and in RED bold where S.I. No. 272 Surface Water Reg. Threshold Levels are exceeded
450.00	Values are in RED bold where SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values are exceeded

< = Less than

'-' signifies analysis not carried out on sample or no SI No.293 of 1988 WQS, SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values, or S.I. No. 272 2007 Surface Water Reg., S.I. No. 386 2015 Surface Water Reg. or S.I. No. 77 2019 Surface Water Reg.Threshold Levels are available.

1. Thresholds have been determined based on A1 Category surface waters as defined by S.I. No. 294 of 1989 MACs. Where limits for A1 Category are not defined A2 or A3 limts have been applied

2. Nutrient thresholds have been determined based on Good Status (mean) limits. Specific pollutants have been determined based on MAC - EQS for inland surface waters. Ammonia Threshold Value refers to Total Ammonia (mg N/l) mean value

Table 4. Results of Inorganic and Microbiological Laboratory Analyses on Surface Water Samples (SW1-SW7) taken from Adjacent Stream at Tullyvogheen Historic Landfill, Clifden, Co. Galway (30.9.19) Part B

Parameter	Units	*S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989* *MACs* *1.*	*S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007* *Parametric Values*	*S.I. No. 272, EC Environmental Objectives (Surface Water) Regulations, 2009)* *Threshold Values (AA-EQS)* *2.*	*S.I 386 EC Environmental Objectives (Surface Waters) Regulations 2015 (Lowest Threshold Values Taken)* *Threshold Values (MAC-EQS)* *3.*	*S.I 77 EC Environmental Objectives (Surface Waters) Regulations 2019 (Lowest Threshold Values Taken)* *Threshold Values* *4.*	SW1 (Upgradient)	SW2 (Downgradient)	SW3 (Downgradient)	SW4 (Downgradient)	SW5 (Downgradient)	SW6	SW7 (Downgradient)
						Microbiological							
Total Viable Count @22^{o}C	CFU/100ml	-	-	-	-	-	620	870	410	1,400	0	1,200	900
Total Viable Count @37^{o}C	CFU/100ml	-	-	-	-	-	130	160	70	350	0	100	40
Total coliforms (i.e. Confirmed)	CFU/100ml	0	0	-	-	-	**80**	**90**	**70**	**1,230**	**1,000**	**220**	**240**
Faecal coliforms(i.e. Confirmed)	CFU/100ml	0	0	-	-	-	**20**	**20**	**10**	**670**	**540**	**80**	**190**
Enterococci	CFU/100ml	-	0	-	-	-	0	1	1	**13**	**0**	**33**	**27**
Clostridium pefringens	CFU/100ml	-	0	-	-	-	0	0	0	**1**	**0**	**12**	**2**

Note:

Cadmium - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all <40mg/l. Therefore, a Water Hardness Class 1 has been selected and as such, a cadmium AA-EQS of<0.08ug/l has been selected.

Copper - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all <100mg/l. Therefore, a copper AA-EQS of 5ug/l has been selected.

Zinc - Results of Total Hardness Analysis on 7 surface water samples range from <15ug/l to 37ug/l and are all greater than 10mg/l. Therefore, a zinc AA-EQS of 50ug/l has been selected.

450.00	Values are shaded yellow and in RED bold where S.I. No. 272 Surface Water Reg. Threshold Levels are exceeded
450.00	Values are in RED bold where SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values are exceeded

< = Less than

'-' signifies analysis not carried out on sample or no SI No.293 of 1988 WQS, SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values, or S.I. No. 272 2007 Surface Water Reg., S.I. No. 386 2015 Surface Water Reg. or S.I. No. 77 2019 Surface Water Reg.Threshold Levels are available.

1. Thresholds have been determined based on A1 Category surface waters as defined by S.I. No. 294 of 1989 MACs. Where limits for A1 Category are not defined A2 or A3 limts have been applied

2. Nutrient thresholds have been determined based on Good Status (mean) limits. Specific pollutants have been determined based on MAC - EQS for inland surface waters. Ammonia Threshold Value refers to Total Ammonia (mg N/l) mean value

respectively. It is possible that the increase in coliform type bacteria in this area of the river is as a result of animal faces run-off from hydraulically upgradient farmland and/or untreated or poorly treated septic tank effluent or percolate from residential or commercial property within the vicinity of the stream

6.5.10 Volatile Organic Compounds/Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) & MTBE

The results of the Volatile Organic Compounds analysis for the surface water samples are located on Table A5.1. The BTEX and MTBE results are also recorded in Table A5.1 located in Appendix 5. As can be seen from Table A5.1, all of the VOCs analysed were below their respective Method Detection Limits. [7]

6.5.11 Semi-Volatile Organic Compounds (sVOC)

The results of the Semi-Volatile Organic Compounds analysis for the surface water samples are located on Table A5.2 located in Appendix 5. As can be seen from Table A5.2, all of the sVOCs analysed were below their respective Method Detection Limits.

6.5.12 Polyaromatic Hydrocarbons (PAHs)

The Polyaromatic Hydrocarbons were completed as part of the Semi-Volatile Organic Compounds analysis. The results of the Polyaromatic Hydrocarbons (PAHs) analysis on the surface water samples are located as a subset within Table A5.2 located in Appendix 5. As can be seen from Table A5.2, all of the PAHs analysed were below their respective Method Detection Limits.

6.5.13 Organophosphorus Pesticides

The results of the Organophosphorus pesticide analysis on groundwater and the surface water samples are located on Table A5.3 located in Appendix 5. A total of 16 organophosphorus pesticides were analysed for as part of this analysis. As can be seen from Table A5.3, all of the organophosphorus pesticides analysed were below their respective Method Detection Limits.

6.5.14 Organochlorine Pesticides & Acid Herbicides

The results of the Organochlorine pesticide and Acid Herbicide analysis on the surface water samples are located on Table A5.4 located in Appendix 5. A total of 22 organochlorine pesticides were analysed for as part of this analysis. As can be seen from Table A5.4, all of the organochlorine pesticides analysed were below their respective Method Detection Limits.

6.5.15 Major Cation and Anion Ion Balance & Summary of Groundwater Quality

An ion balance was carried out on the results of the inorganic anion and cation analysis of the surface water samples. As can be seen from Table A5.5 (see Appendix 5), the largest % ion balance error was obtained for SW6 i.e. 17.57%. The remaining six surface water samples showed a % ion balance error of less than 10%. For surface water, an ion balance error of up to 10 per cent is generally acceptable.

[7] Where VOCs are detected they are highlighted in yellow. Where values are underlined, this indicates and exceedance of the corresponding Dutch Target Value. Where values are highlighted in Red bold, this indicates an exceeded of Dutch Intervention Value or of the 1988 Regulations, MAC values.

7 GENERIC QUANTITATIVE RISK ASSESSMENT

The Generic Quantitative Risk Assessment approach can be summarised as follows.

In line with the scope of works provided by Galway County Council, the surface water results for 2019 have been compared to Generic Acceptance Criteria (GAC) in Sections 6. These results have been reviewed in conjunction with the soil, groundwater, leachate and surface water results obtained in 2014.

For Generic Quantitative Risk Assessment, in assessing what poses the most risk to potential receptors only exceedances of soil and groundwater GACs are used. However, it should be noted that the surface water body, which was sampled and analysed should also be regarded as a receptor.

For soils, although the assessment of contaminants in CEN 10:1 leachate is useful, as an indicator of potential long-term leachability, 'Total Pollutant' content provides the most relevant data for risk assessment to potential receptors.

For groundwater risk assessment, although the assessment of contaminants in leachate is useful, actual groundwater contaminant concentrations provide the most relevant data for risk assessment to potential receptors.

The exceedances of the above-mentioned GACs can be summarised as follows:

The levels of phosphates, chromium, iron, manganese and coliforms within the surface water upgradient of the site suggest that the stream may have been impacted prior to entering the site.

However, the data obtained also suggests that the landfill is impacting on the quality of the surface water i.e. landfill leachate is entering the culvert and mixing with surface water. In effect, the landfill is impacting on the surface water body. However, the levels of key contaminants such as ammonia, iron and manganese found at 3 locations within the surface water body downgradient of SW2 (i.e. SW3, SW4 and SW5) are noticeably lower than SW2.

The results of the ammoniacal nitrogen, iron and manganese analyses on the surface water sampled at SW2, SW3, SW4 and SW5 suggest that any input of ammonia or other pollutants from the landfill are being diluted by the other streams and groundwater baseflow feeding into the stream downgradient of the site (e.g. the stream from Lough Nambrackeagh).

Given, the hydrology of the Owenglen River, the levels of ammonia, iron and manganese within the stream would be significantly diluted on entering the Owenglen River.

The following section, Section 8 Conceptual Site Model, deals with the concepts behind the above rationale in greater details.

8 REFINED CONCEPTUAL SITE MODEL

8.1 Conceptual Site Model (CSM) Rationale

Following on from the most recent surface water results, due to the exceedance of the generic assessment criteria for surface water and previously for groundwater, a refined conceptual model for the site has been collated in line with BS10175 (5) and CLR11 (6). The conceptual site model (CSM) identifies sources of contamination and receptors that could be impacted together with pathways, termed potentially complete pollutant linkages that connect the two. When a potentially complete pollutant linkage is identified, an estimation of the risk should be made which may involve further investigation or risk assessment. Table 5 records the potential pollutant linkages that have been identified at the site. Justifications for the identification of a potential pollutant linkage together with the likelihood are also discussed in Table 5. Please see Figure 19 for visual representation of the Refined Conceptual Site Model.

Table 5. Identification of Potentially Complete Pollutant Linkages

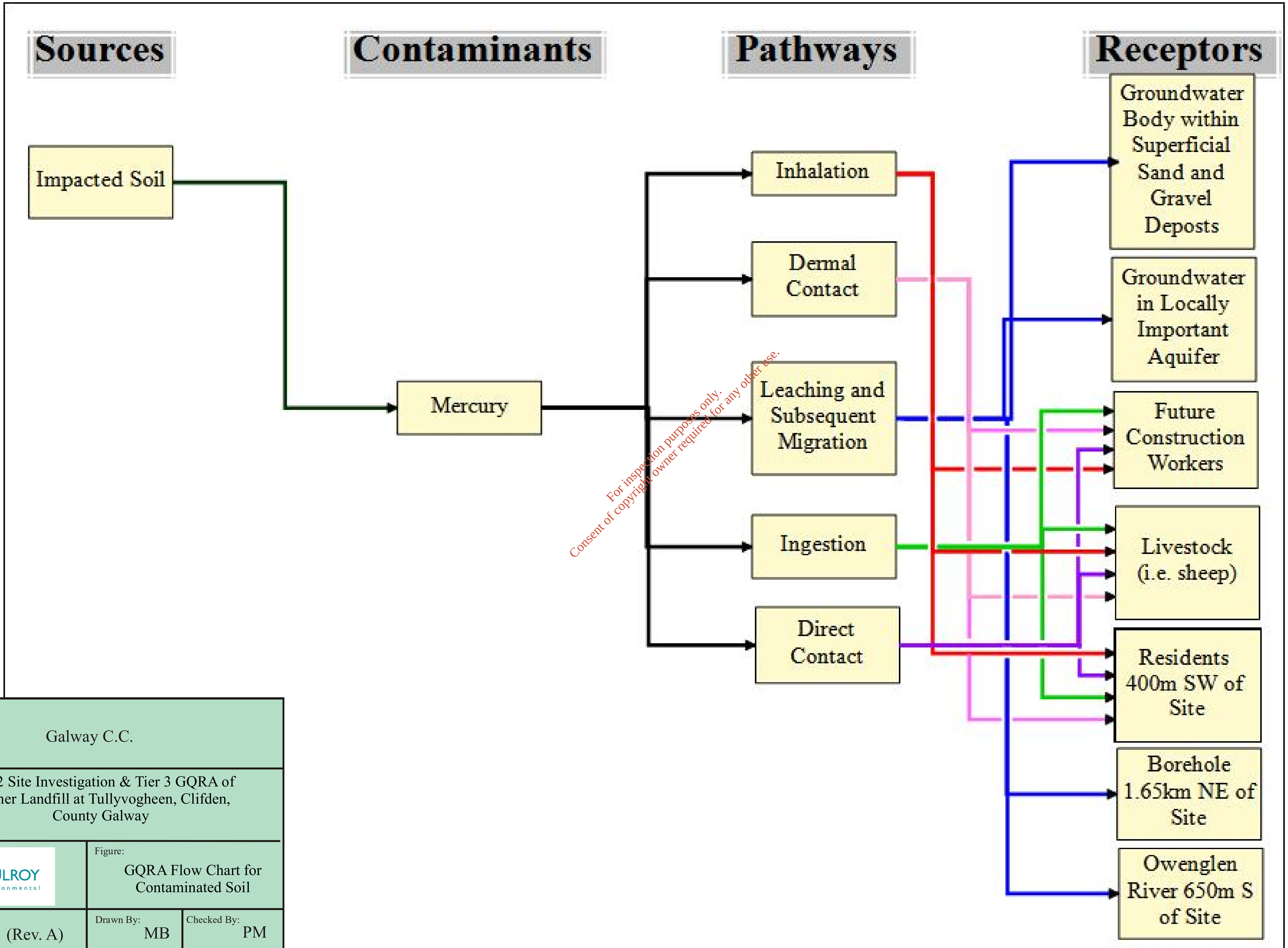
Source	Pathway	Receptor	Linkage?
Mercury impacted soil (i.e. gravel matrix)	Direct contact; ingestion, dermal contact and inhalation of dust and soils.	Residents of house to southwest of site	**Incomplete.** Site covered in 250mm capping with waste overlying soil - plausible pathway absent. Residents not expected to come into contact with underlying soil during routine activities.
		Livestock (i.e. sheep)	**Incomplete.** Site covered in 250mm capping with waste overlying soil - plausible pathway absent. Livestock not expected to come into contact with underlying soil during routine activities.
		Future construction workers	**Incomplete.** No structure proposed for landfill. However, construction workers for drainage works may come into contact with site soil although unlikely given depth under waste. However the use of suitable PPE and good hygiene measures should mitigate risks posed through this pathway.
	Leaching and subsequent migration	Groundwater in locally important aquifer	**Incomplete:** Pathway exists due to location of gravel soil lying directly on bedrock. However, given hydrophobic nature of Hg it is unlikely to migrate to aquifer. Mercury was not detected in groundwater or surface water.
		Groundwater (shallow) body within superficial sand & gravel deposits	**Incomplete:** Pathway exists due to location of gravel soil lying directly on bedrock. However, given hydrophobic nature of Hg it is unlikely to migrate to aquifer. Mercury not detected in groundwater or surface water.
		Owenglen River 650m to south of site	
		Well at residence 400m south of site & Borehole 1.65km to the northeast of the site	**Incomplete**. Plausible pathway absent due to distance to both boreholes and direction of groundwater flow for borehole to NE of site.

A process flow chart, Chart 1 showing the Source-Contaminant-Pathway-Receptor rationale has been prepared to explain the above table.

Table 5. Identification of Potentially Complete Pollutant Linkages (continued)

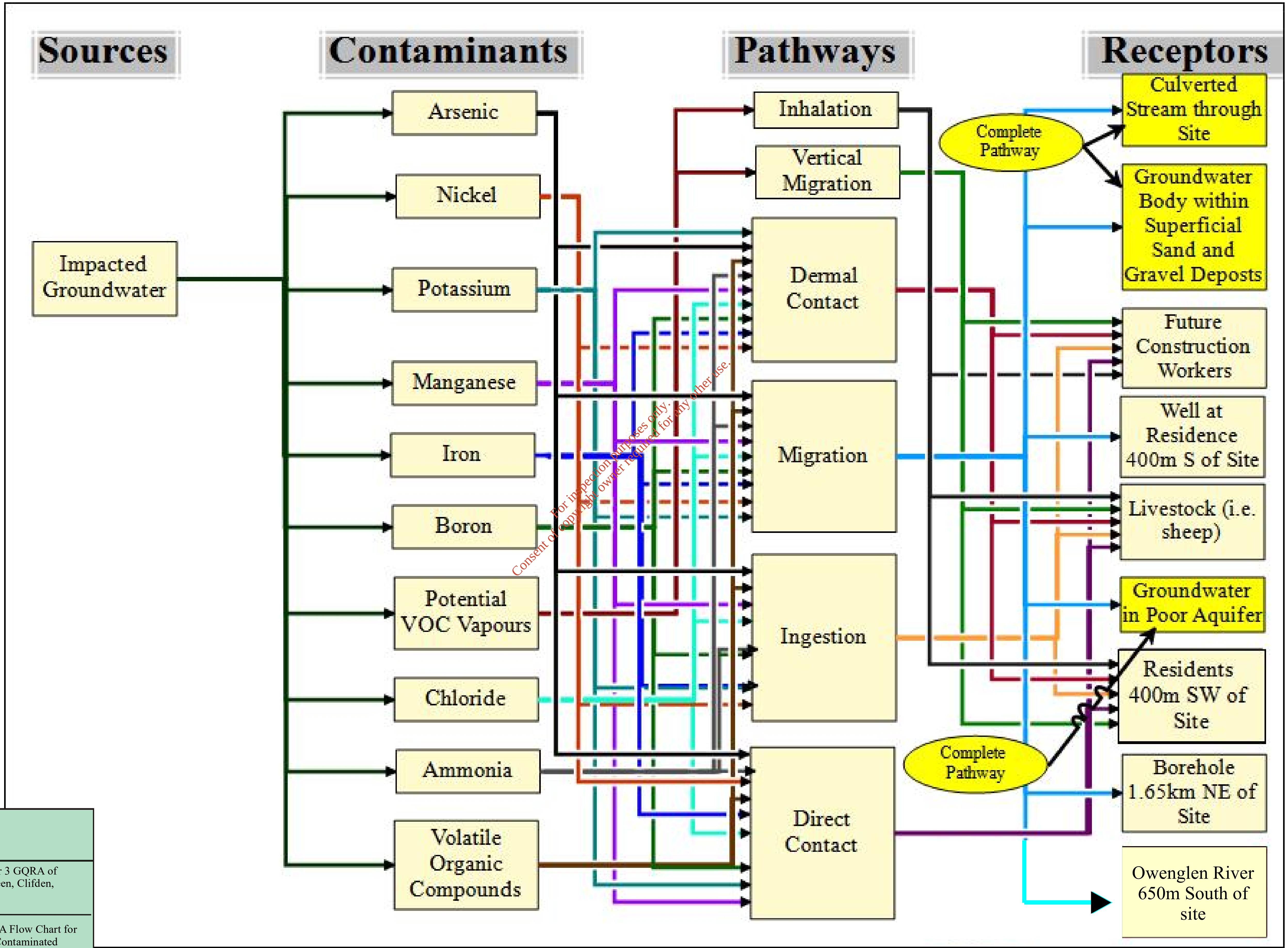
Source	Pathway	Receptor	Linkage?
Ammonia, chloride, potassium, arsenic, boron, iron, manganese, nickel, toluene, chlorobenzene, ethylbenzene, xylenes, Trimethylbenz-ene impacted groundwater	Direct contact; ingestion and dermal contact	Residents of house to southwest of site	**Incomplete.** Residence 400m to south of site on water mains. Plausible pathway absent.
		Livestock (i.e. sheep)	**Incomplete**. Plausible pathway absent due to distance for both boreholes and direction of groundwater flow for borehole to NE of site.
		Future construction workers	**Incomplete.** Construction workers may come into contact with groundwater (i.e. during pipe laying). However the use of suitable PPE and good hygiene measures should mitigate risks posed through this pathway.
	Migration	Groundwater in poor aquifer	**Complete:** Pathway present due to presence of permeable sands & gravels underlying waste in close proximity to underlying bedrock
		Groundwater (shallow) body within superficial deposits	**Complete:** Pathway due to presence of permeable sands & gravels underlying waste on site. Contamination in site groundwater may migrate vertically and horizontally.
		Stream flowing through site via culvert	**Complete:** Pathway due to presence of permeable sands & gravels underlying waste on site. Stream is culverted through site and is in contact with groundwater. Ammonia, chromium, copper, iron, manganese, and coliforms found in SW2.
		Owenglen River 650m to south of site	**Incomplete:** Ammonia, iron, chromium, copper, manganese, and coliforms found in SW2 sample but no chromium or copper at SW3 or SW4. Iron and manganese significantly diluted at SW4 and SW5. Biological Index Q4 at KS3 indicates that impact of landfill is being mitigated by dilution/attenuation prior to reaching downgradient farm. Stream is being diluted by other tributaries (i.e. Nambrackeagh stream) prior to reaching Owenglen River and is significantly diluted on feeding into Owenglen River. Possible other sources (i.e. animal faeces run-off, septic tank overloading, commercial etc) of ammonia and coliforms impacting surface water body downgradient of landfill at SW4 and SW5
		Well at residence 400m south of site & Borehole 1.65km to the northwest of the site	**Incomplete**. Plausible pathway absent due to distance to both boreholes and direction of groundwater flow for borehole to NE of site.
Potential vapours associated with toluene, chlorobenzene, ethylbenzene, xylenes, Trimethylbenz-ene impacted groundwater impacted groundwater	Vertical migration and inhalation of vapours	Residents of house to southwest of site	**Incomplete.** Low levels of toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene, in groundwater and not identified in surface water.
		Livestock (i.e. sheep)	**Incomplete.** Low levels of toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene, in groundwater and not identified in surface water. Livestock are not impacted as none on site.
		Future construction workers	**Incomplete**. Low levels of toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene, in groundwater and not identified in surface water. Vapours likely to migrate vertically and then dilute with air at the surface hence plausible pathway considered absent.

Chart 1. GQRA Flow Chart for Contaminated Soil (i.e Mercury)



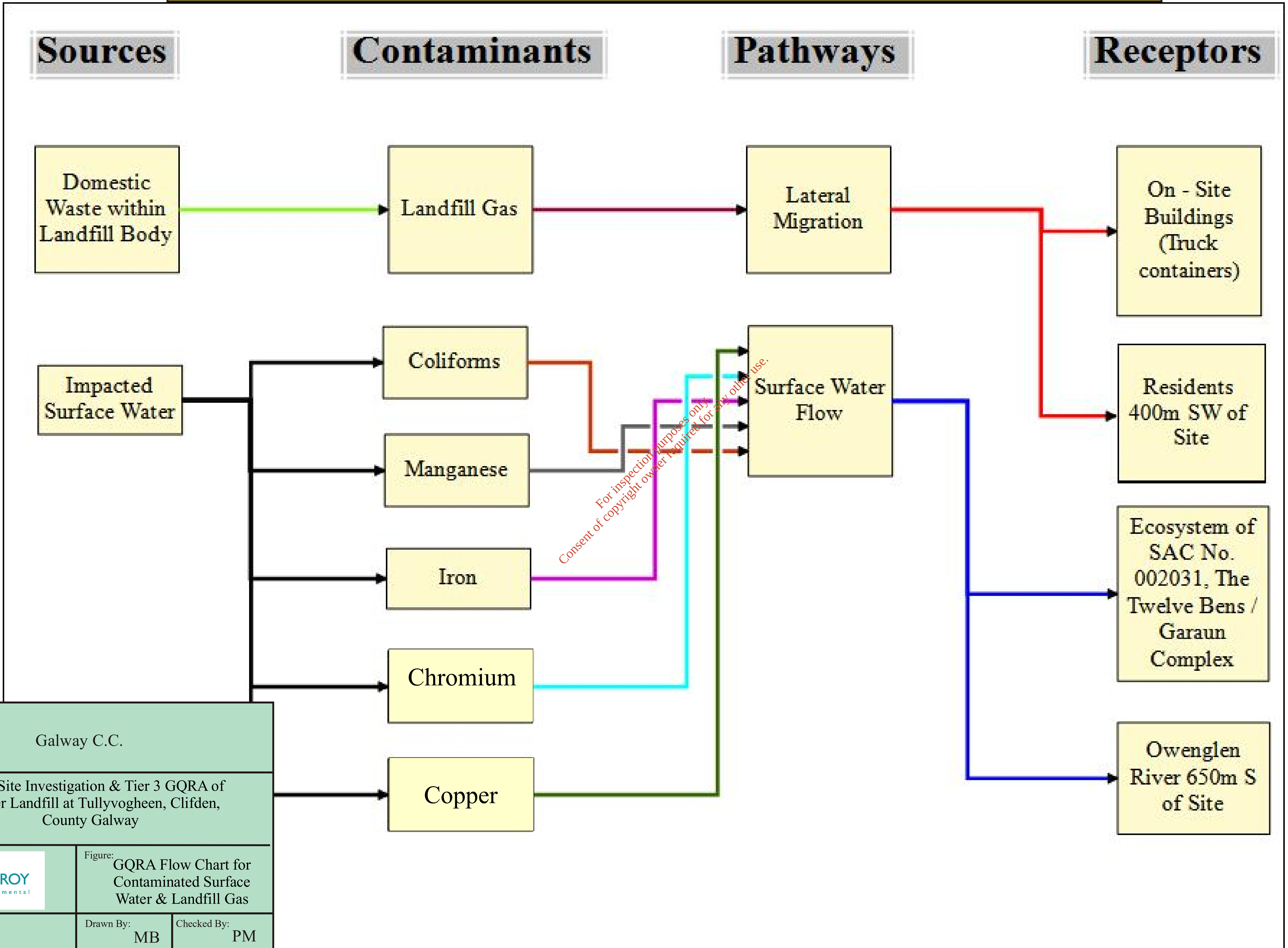
Client: Galway C.C.		
Project: Tier 2 Site Investigation & Tier 3 GQRA of Former Landfill at Tullyvogheen, Clifden, County Galway		
MULROY environmental	Figure: GQRA Flow Chart for Contaminated Soil	
Chart No.: 1 (Rev. A)	Drawn By: MB	Checked By: PM
Scale: NA	Date: 20th November, 2019	

Chart 2. GQRA Flow Chart for Contaminated Groundwater



Client:	Galway C.C.
Project:	Tier 2 Site Investigation & Tier 3 GQRA of Former Landfill at Tullyvogheen, Clifden, County Galway
MULROY environmental	Figure: GQRA Flow Chart for Contaminated Groundwater
Chart No.: 2	Drawn By: MB / Checked By: PM
Scale: NA	Date: 20th November, 2019

Chart 3. GQRA Flow Chart for Contaminated Surface Water & Landfill Gas



Client: Galway C.C.	
Project: Tier 2 Site Investigation & Tier 3 GQRA of Former Landfill at Tullyvogheen, Clifden, County Galway	
MULROY environmental	Figure: GQRA Flow Chart for Contaminated Surface Water & Landfill Gas
Chart No.: 3	Drawn By: MB / Checked By: PM
Scale: NA	Date: 20th November, 2019

A process flow chart, Chart 2 showing the Source-Contaminant-Pathway-Receptor rationale has been prepared to explain the previous table.

Table 5. Identification of Potentially Complete Pollutant Linkages (continued)

Source	Pathway	Receptor	Linkage?
Ammonia, chromium, copper, iron, manganese, and coliforms impacted surface water (SW2 results/directly downgradient of landfill)	Surface water/stream feeding into Owenglen River	Water quality of Owenglen River 650m to south of site	**Incomplete:** Ammonia, chromium, copper iron, manganese, and coliforms found in surface water sample from SW2. Results at SW6 and SW7 show that stream is not impacting on Owenglen River. Iron was only chemical exceedance, was upgradient and downgradient and is likely at a natural level. No difference in Coliform levels upgradient and downgradient. Stream is being diluted prior to reaching Owenglen River and is significantly diluted on feeding into Owenglen River. Biological Q-Index at KS4 and KS5 not possible due to storm event in early September but results indicate likely to be Q4-5. Other potential pollutants entering stream downgradient of landfill are causing a substantial increase in the coliforms from SW4 to SW5 (i.e. animal faeces run-off, septic tank overloading, commercial effluent, etc). These possible effluents may also impact on ammonia levels (i.e. if occurring)
		Ecosystem of SAC No. 002031, The Twelve Bens/ Garaun Complex	**Incomplete:** Results at SW6 and SW7 show that stream is not impacting on Owenglen River. Iron was only chemical exceedance, was upgradient and downgradient and is likely at a natural level. No difference in Coliform levels upgradient and downgradient. Stream is being diluted prior to reaching Owenglen River and is significantly diluted on feeding into Owenglen River. Biological Q-Index at KS4 and KS5 not possible due to storm event in early September but results indicate likely to be Q4-5. Other potential pollutants entering stream downgradient of landfill are causing a substantial increase in the coliforms from SW4 to SW5 (i.e. animal faeces run-off, septic tank overloading, commercial effluent, etc). These effluents may also be impacting on ammonia levels.
Landfill gas from domestic waste within landfill body	Lateral migration	Residents of house to southwest of site	**Incomplete:** In 2014, maximum methane levels were found in leachate well, LC1 at 1.1% with this decreasing to 0.5% after 60 seconds. Levels not high enough to present a risk to off-site residences nearest of which is 400m south of site.
		On-site buildings & enclosed areas. Owenglen River 650m to south of site	**Incomplete:** Truck containers on site are well vented and will not trap landfill gas thus preventing a potential build up. Monitoring indicated that landfill gas is not being produced at a level which would pose a risk to on-site or off-site receptors.

A process flow chart, Chart 3 showing the Source-Contaminant-Pathway-Receptor rationale has been prepared to explain the above table. Please see Figure 19 for visual representation of the Conceptual Site Model.

8.2 Sources of Contamination

8.2.1 Primary Source of Contamination

The primary source of contamination is the contaminated soil and waste within the landfill, and the impacted groundwater and leachate which have impacted on the surface water which is passing through the site.

8.2.2 Upgradient Sources of Contamination

The results of the surface water sample from SW1 suggest that the surface water has been impacted before it enters the landfill site. This is indicated by exceedances in chromate, phosphates, iron, manganese and Chemical Oxygen Demand (COD). Like in 2014, coliforms were again found in SW1. This contamination could have resulted from horizontal run-off of rainwater contaminated with animal faeces, the over application of artificial or organic fertilisers by the farming sector and/or the application of organic and/or inorganic fertilisers to trees by Coillte within the upgradient Coillte forest which surrounds Lough Cashleen. These sources have not been inputted into the Refined CSM.

8.2.3 Potential Downgradient Sources of Contamination

A review of the property and land to the north of the national road, the N59 indicates that there are other potential sources of contamination downgradient of the landfill which may be impacting on the quality of water within the stream. These can be summarised as follows:

- Horizontal run-off from livestock and over-application of fertilisers and pesticides to land;
- Septate/poorly treated domestic wastewater leaking or being discharged from on-site wastewater treatment plants (i.e. septic tanks) and/or poorly designed or over-loaded percolation areas;
- Commercial enterprises discharging untreated contaminated trade effluent and/or stormwater into the stream intentionally or unintentionally; and
- Leachate from construction and demolition waste or possibly domestic waste deposited as a result of recent housing developments to the west of the site and to the rear of properties which are adjacent to tributaries feeding into the subject stream.

These sources have not been inputted into the Refined CSM.

8.3 Pathways

Possible pathways to receptors can be summarised as follows:

- Direct contact; ingestion, dermal contact and inhalation of dust and soils;
- Leaching and subsequent migration from contaminated soils;
- Direct contact, ingestion and dermal contact with contaminated groundwater;
- Migration of groundwater via shallow sand aquifer and/or bedrock aquifer to downgradient wells or baseflow into surface water bodies;
- Vertical migration and inhalation of vapours from contaminated groundwater;
- Lateral migration of landfill gas to off-site property; and
- Surface water/stream feeding into Owenglen River.

The scope of the overall site specific risk assessment includes the surface water body which flows through the site. It should be noted that the stream flowing through the site is regarded as both a receptor and a pathway. It is regarded as a potential pathway or 'conduit' between the landfill and the Owenglen River 650m to the south of the site.

8.4 Receptors

The Owenglen River and its associate ecosystem of *SAC No. 002031, The Twelve Bens/ Garaun Complex* are a significant potential receptor to contaminants from the landfill.

The residence 400m to the south of site is regarded as a potential receptor. Likewise the water abstraction well on this property is regarded as a receptor although it is a considerable distance from the site. It should be noted that records show that the residence is on public water mains. It is not known if the water abstraction well is disused. It should be noted that Galway County Council requested that access be provided by the owner of this well to Mulroy Environmental Ltd. to facilitate sampling and laboratory analysis. Permission was not provided.

There are no other viable receptors such as water abstraction boreholes identified in the immediate vicinity of the site and more importantly downgradient of the site.

8.5 Complete Pollution Linkages

Complete pollutant linkages were identified in 2014 at the site with respect to:

- Migration of groundwater impacted with Ammonia, chloride, potassium, arsenic, boron, iron, manganese, nickel, toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene to:
  - Groundwater in poor aquifer;
  - Groundwater (shallow) body within superficial deposits; and
  - Stream flowing through site via culvert.

With the absence of recent data on groundwater, the above linkages remain valid in 2019. However, it should be noted that the 2019 round of sampling and subsequent analysis of surface water at upgradient (SW1) and downgradient points (i.e. SW2, SW3, SW4, SW5, SW6 and SW7) did not show elevated levels of chloride, potassium, arsenic, boron, nickel or trace levels of toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene which were found in the groundwater in 2014 (see Table 4-Part A).

Elevated ammonia, chromium, copper, iron, manganese, and coliforms were found in the surface water sample taken at SW2. **However, it should be noted that no chromium or copper was found at the downgradient point SW3 and that iron and manganese were significantly diluted at SW4 and SW5.**

The Biological Index Q4 found at KS3 indicates that impact of landfill is being mitigated by dilution/attenuation prior to reaching the downgradient farm. The stream is being diluted by other tributaries (i.e. Nambrackeagh stream) and groundwater baseflow from other uncontaminated areas prior to reaching the Owenglen River and it is then being significantly diluted while feeding into Owenglen River.

Results at SW6 and SW7 show that the subject stream is not impacting on the Owenglen River. Iron was only the chemical exceedance at SW6 and SW7, the levels found were similar and as such, the iron is likely at a natural level. No difference in Coliform levels were found upgradient or downgradient of the stream's confluence with the Owenglen River. As stated previously, the stream is being diluted prior to reaching Owenglen River and it is significantly diluted on feeding into Owenglen River. The determination of the Biological Q-Index at KS4 and KS5 was not possible due to a storm event in early September 2019 but it is expected that results would indicate a Q-index of Q4-5 if invertebrate testing was carried out again in May of 2020.

It is important to note that the levels of ammonia, potassium, sodium, calcium and magnesium have fallen considerably at SW2 and SW3 since 2014. Ammonia is regarded as a key contaminant and indicator of contamination by landfill leachate. This would indicate that the landfill is going through intrinsic remediation and that contaminants are breaking down naturally and being attenuated within the groundwater under the site and surface water passing through the site.

However, it is important to note that the high levels of coliforms found at SW4 and SW5 indicate that other potential pollutants are possibly entering the stream downgradient of the landfill and are causing a substantial increase in the coliforms from SW4 to SW5 (i.e. animal faeces run-off, septic tank overloading, commercial effluent, etc). These potential waste effluents may also be impacting/contributing to increased ammonia levels.

9 CONCLUSIONS

9.1 Soil & Groundwater Contamination

The results of the laboratory analysis on the soil in 2014 indicated that the soil (i.e. 2 soils samples out of 4) underlying the waste on site had been impacted by low levels of mercury contamination as a result of waste infilling.

The results of the laboratory analysis on the groundwater and leachate indicated that the groundwater in the vicinity of the site and downgradient has been historically contaminated by the waste infilling. Elevated levels of Ammonia, chloride, potassium, arsenic, boron, iron, manganese, nickel, toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene were indentified in the groundwater monitoring wells. These levels were identified at greater levels in the on-site leachate wells as expected. The highest level of contamination was identified in the downgradient boreholes to the west of the site.

The evidence suggests strongly that a contaminant plume exists on site which is emanating in an east to west direction along the valley following the culverted stream. Given the relative permeability of the underlying schist bedrock, it was concluded that most of the leachate generated on site is entering the culverted stream. This culvert was constructed along the course of the former stream which would have been located at the lowest point in the valley.

9.2 Impact on Human Receptors

Given the low levels of soil contamination identified on site, leachate generated from the soil is unlikely to impact on the residence 400m to the southwest.

Negligible risk is posed by landfill gas from the site to off-site residences given the age of the waste on site and the distance from the site.

Given the distance from the site, it is unlikely that contaminated groundwater is impacting on the residence to the southwest or on the water abstraction well located to the north of this property. It should be noted that this residence is known to be provided with public water mains.

9.3 Impact on Livestock

Given the low levels of soil contamination identified on site, leachate generated from the soil is unlikely to impact on the livestock in the surrounding areas.

Given the distance from the site, it is unlikely that contaminated groundwater is impacting on the residence to the southwest or on the water abstraction well located to the north of this property. It is not known if this well is used to provide livestock with drinking water.

9.4 Impact on Culverted Stream

As stated previously, elevated ammonia, phosphates, iron, manganese, and coliforms were found in surface water samples. However, it should be noted that faecal coliforms were also detected upgradient of the site at SW1.

With the absence of recent data on groundwater, the 3 linkages remain valid and complete in 2019. However, it should be noted that the 2019 round of sampling and subsequent analysis of surface water at upgradient (SW1) and downgradient points (i.e. SW2, SW3, SW4, SW5, SW6 and SW7) did not show elevated levels of chloride, potassium, arsenic, boron, nickel or trace levels of toluene, chlorobenzene, ethylbenzene, xylenes, 1,2,4-Trimethylbenzene which were found in the groundwater in 2014 (see Table 4-Part A).

Elevated ammonia, chromium, copper, iron, manganese, and coliforms were found in the surface water sample taken at SW2. **However, it should be noted that no chromium or copper was found at the downgradient point SW3 and that iron and manganese were significantly diluted at SW4 and SW5.**

The Biological Index Q4 found at KS3 indicates that the impact of the landfill is being mitigated by dilution/attenuation prior to reaching the downgradient farm. The stream is being diluted by other tributaries (i.e. Nambrackeagh stream) and groundwater baseflow from other uncontaminated areas prior to reaching the Owenglen River and it is then being significantly diluted while feeding into Owenglen River.

It is important to note that the levels of ammonia, potassium, sodium, calcium and magnesium have fallen considerably at SW2 and SW3 since 2014. Ammonia is regarded as a key contaminant and indicator of contamination by landfill leachate. This would indicate that the landfill is going through intrinsic remediation and that contaminants are breaking down naturally and being attenuated within the groundwater under the site and surface water passing through the site.

However, it is important to note that the high levels of coliforms found at SW4 and SW5 indicate that other potential pollutants are possibly entering the stream downgradient of the landfill and are causing a substantial increase in the coliforms from SW4 to SW5 (i.e. animal faeces run-off, septic tank overloading, commercial effluent, etc). These potential waste effluents may also be impacting/contributing to increased ammonia levels.

9.5 Impact on Controlled Waters (i.e. Owenglen River)

Results at SW6 and SW7 show that the subject stream is not impacting on the Owenglen River. Iron was only the chemical exceedance at SW6 and SW7, the levels found were similar and as such, the iron is likely at a natural level. No difference in Coliform levels were found upgradient or downgradient of the stream's confluence with the Owenglen River. As stated previously, the stream is being diluted prior to reaching Owenglen River and it is significantly diluted on feeding into Owenglen River. The determination of the Biological Q-Index at KS4 and KS5 was not possible due to a storm event in early September 2019 but it is expected that results would indicate a Q-index of Q4-5 if invertebrate testing was carried out again in May of 2020.

9.6 Overall Conclusions

The results of the surface water analysis indicate that the landfill site, although still impacting on the subject stream, is producing lower levels of contamination than in 2014. This is clear on reviewing the reduction in the ammonia, potassium and sodium levels. The combined results of the invertebrate assessment and the surface water quality assessment indicate that, where KS3 and SW4 are located, the stream has a *'Q4 – Good – Unpolluted'* status. This clearly indicates that the impact on the ecology of the stream shown at KS2 has not extended as far downstream as KS3. It is anticipated that with time, the levels of contamination within the leachate and the surface water will decrease and the ecosystem within the stream will continue to improve from Q3 to Q4 at locations KS1 and KS2. The high levels of oxygen present in the fast flowing stream will also assist in the mineralisation, oxygenation and breakdown of contaminants within the stream over time.

The results of the surface water and invertebrate assessment do not indicate that the Owenglen River is being impacted by the subject stream. As such, the findings of the appropriate assessment screening report of 2014 remain.

10 RECOMMENDATIONS

1. It is recommended that further invertebrate kick sampling is carried out in 2020 at KS1, KS2, KS4 and KS5 on the Owenglen River to determine the Q-Index. This should be carried out during optimal seasonal weather (i.e. May).

2. Even though it is unlikely that the well located at the residence 400m from the site has been impacted by contaminated groundwater emanating from the site, it is recommended that, in the event that this well is used for livestock, that it is sampled and analysed for a comprehensive laboratory suite (i.e. identical to the laboratory suite used in this study).

If you have any questions or require clarification with regard to any item of this report, please contact me at 086-8770380.

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3. Unless otherwise agreed the Services were performed by Mulroy Environmental Ltd. exclusively for the purposes of the client. Mulroy Environmental Ltd. is not aware of any interest of or reliance by any party other than the client in or on the Services. Unless expressly provided in writing, Mulroy Environmental does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and Mulroy Environmental disclaims any liability to such parties. Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.

4. It is Mulroy Environmental Ltd.'s understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without Mulroy Environmental be requested to review the report after the date hereof, Mulroy Environmental shall be entitled to additional payment at the then existing rates or such other terms as agreed between Mulroy Environmental and the client.

5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of Mulroy Environmental Ltd. In the absence of such written advice of Mulroy Environmental Ltd., reliance on the report in the future shall be at the client's own and sole risk. Should Mulroy Environmental be requested to review the report in the future, Mulroy Environmental Ltd. shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between Mulroy Environmental and the client.

6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the client and Mulroy Environmental Ltd. Mulroy Environmental Ltd. has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and Mulroy Environmental Ltd.. Mulroy Environmental Ltd. is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, Mulroy Environmental Ltd. did not seek to evaluate the presence on or off the site of asbestos, electromagnetic fields, lead paint, heavy metals, radon gas or other radioactive or hazardous materials.

7. The Services are based upon Mulroy Environmental's observations of existing physical conditions at the Site gained from a walk-over survey of the site together with Mulroy Environmental's interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The Services are also based on information and/or analysis provided by independent testing and information services or laboratories upon which Mulroy Environmental Ltd. was reasonably entitled to rely. The Services clearly are limited by the accuracy of the information, including documentation, reviewed by Mulroy Environmental and the observations possible at the time of the walk-over survey. Further Mulroy Environmental Ltd. was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services. Mulroy Environmental is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Mulroy Environmental and including the doing of any independent investigation of the information provided to Mulroy Environmental Ltd. save as otherwise provided in the terms of the contract between the client and Mulroy Environmental Ltd.

8. The Phase II or intrusive environmental site investigation aspects of the Services is a limited sampling of the site at pre-determined borehole and soil vapour locations based on the operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and Mulroy Environmental Ltd.] [based on an understanding of the available operational and historical information,] and it should not be inferred that other chemical species are not present.

9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan, but is (are) used to present the general relative locations of features on, and surrounding, the site.