Chapter 9
Hydrogeology

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Chapter 9 Hydrogeology

9.1 Introduction

This chapter considers and assesses the likely significant effects with regard to Hydrogeology associated with both the construction and operational phases of the proposed Flood Defences West, hereafter referred to as the 'proposed development'. The chapter initially sets out the methodology used (Section 9.2), describes the existing hydrogeological environment (Section 9.3), examines the predicted impacts of the proposed development (Section 9.4), describes measures to mitigate identified significant effects (Section 9.5), and details the residual impacts (Section 9.6).

9.2 Methodology

This chapter has been prepared having regard to the Environmental Impact Assessment (EIA) Directive 2014/52/EU and the following guidelines:

- Institute of Geologists of Ireland (IGI) (2013) Guidelines for the Preparation of Soils, Geology and Hydrogeology Chapters of Environmental Impact Statements;
- Environmental Protection Agency (EPA 2015) Draft Advice Notes for Preparing Environmental Impact Statements; and
- Environmental Protection Agency (EPA 2017) Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports.

9.2.1 Study Area

The range criteria for assessing the importance of hydrogeological features within the study area (site boundary + 250m) and the criteria for quantifying the magnitude of impacts follow the TII guidelines and the EPA (2017) Draft Guidelines on the Information to be contained in Environmental Impact Assessment Reports.

9.2.2 Desk Study

A desk study of the study area of the proposed development was carried out in order to establish baseline conditions. The desk study involved collecting all relevant geological, hydrological, hydrogeological and meteorological data for the area. This included consultation with the following sources of information:

- Geologic maps, Geologic Survey of Ireland (GSI) (www.gsi.ie);
- Teagasc Subsoils Map (gis.epa.ie/Envision);
- Water Features, Rivers, and Streams, EPA (gis.epa.ie/Envision);
- Geological Survey of Ireland – Groundwater Body Characterisation Reports;
- Department of Environmental, Community, and Local Government on-line mapping viewer (www.myplan.ie);
- Protected areas, Biodiversity Ireland (maps.biodiversityireland.ie);
- Historic Maps from Ordnance Survey of Ireland (www.osi.ie);
- Aerial Photography from the Ordnance Survey of Ireland (www.geohive.ie).

9.2.3 Site Investigations

Ground investigations specific to the proposed development were commissioned by ROD and carried out by IGSL Ltd. in Q2 and Q3 of 2019 and included the collection of 36 samples comprised of:

- 15 no. cable percussion boreholes;
- 2 no. rotary core boreholes;
- 4 no. trial pits;
- 10 no. dynamic probes, two of which included window sampling;
- 5 no. groundwater monitoring standpipes, one of which included a water level datalogger; and

A suite of laboratory testing; including environmental/contamination tests.

The following ground investigation reports have been prepared in respect of the GI investigations and have been consulted in the preparation of hydrogeology impact assessment:

- IGSL (2019): Geotechnical Factual Report, Waterford City Public Infrastructure Project Ground Investigation.
- IGSL (2020): Geotechnical Interpretative Report, Waterford City Public Infrastructure Project Ground Investigation.
- O'Callaghan Moran & Associates (2020): Waste Characterisation Assessment, North Quays Waterford Port.

9.3 Description of Receiving Environment

9.3.1 Soils & Subsoils

Teagasc Mapping

The Teagasc soil mapping identifies Made Ground for the area surrounding and within in the study area. It is likely that the river is underlain by Alluvium and that the made ground on the north bank is underlain/mixed with Alluvium material. The parent material is listed as non-calcareous bedrock at surface within the lithosols and regosols soil group. These soils tend to be shallow, well drained mainly acidic minerals in the area.

9.3.2 Bedrock Geology

GSI Mapping

The bedrock geology of the surrounding area is complex, characterised by a faulted sequence of sediments and volcanics. The study area is predominantly underlain by green, green grey and grey slaty mudstones and green or pale grey siltstones of the Ballylane Formation. A single fault line is recorded running from the northwest to southeast across the study area. It is likely that the historic faulting in the vicinity of the site has either extended existing fracturing and/or has created additional fractures in the rock.

Geotechnical Investigations (GI)

The ground investigations and reports outlined in section 9.2.3 have been consulted in the preparation of this EIAR.

Ground Investigations (GI) samples have been taken from areas to the west of Terminus Street Bridge to the westernmost section of the study area (between Ch.360 and Ch.1500, see Figure 4.1 in Volume 3 of this EIAR for chainage reference points). The findings of the GI are detailed in Chapter 8 Soils and Geology of this EIAR. In general, the subsoils found within the study area consisted of made ground typically found within the top 1 to 6.2m of the soils which consisted of a mixture of railway ballast, various granular, stone or cohesive fill, concrete and heterogenous waste. The made ground was underlain by silt which were typified by cohesive alluvial fines followed by a thin layer of organics and peat with an underlying layers of sandy gravelly silt to sandy gravel from cohesive glacial tills. The tills were underlain with weathered bedrock that was dense sand or gravel and cobbles.

Monitoring of groundwater levels at Plunkett Station

A Water level logger was installed in borehole (BH302) by IGSL in late 2019 to provide an insight as to whether this area was also susceptible to underground flooding from tidal ingress. Ground water level readings from this date are being provided by IGSL in regular intervals, with the last data batch received on the 22nd December 2020.

The borehole record for BH302 indicates bedrock very close to ground level, typically 1m to 3m below ground level (with potential local minima of 3m below ground level as suggested in some less detailed logs) with a relatively thin layer of granular overburden and made ground below existing pavement.

These findings are positive from a flood protection perspective, as bedrock is typically seen as a low permeability medium, except in localised zones where it is very weathered. As a comparison, the thicknesses of the granular overburden at the Flood Defence East and West locations which needed flood cut-off protection exceed 7m locally, with bedrock sometimes found over 15m below ground level.

A piezometer (with datalogger) was installed in BH 302 with a response zone in the granular overburden material in order to track the change of groundwater levels in this material. A groundwater level observation graph was produced using the datalogger readings. This graph was superimposed onto a graph of the River Suir levels for the same period to investigate if there was a correlation between the datasets. Based on the finding produced from the available datasets it would appear that:

i. The tidal fluctuations in the River Suir during the normal conditions (high tide up to 2.0m OD) have a near-negligible impact on the groundwater levels in BH302, which seem stable at around +1.00m OD.

ii. Tidal maxima during high water (above 2.0m OD) induces the rise in BH302 to the level of approximately 0.9-1.0m below the tidal maxima. The maximum reading in BH302 also lags behind the tidal maximum by approximately 3 hours.

9.3.3 Ground Contamination

As part of the intrusive ground investigations undertaken previously at the site, samples of the made ground (sample depths between 0.5 – 7m below ground level) were taken via the sources described in section 9.2.3, as part of the investigations by IGSL and were tested by ChemTest Laboratories, accredited Laboratory facility. Details of these ground investigations are outlined in Chapter 08.
The main findings from the soil analysis were as follows:

- All of the soil samples are classified as non-hazardous
- The pH of the soil samples ranged between 8.2 – 9.4;
- Elevated levels of Sulphate were noted in only one soil sample;

- Elevated levels of Chloride were noted in 6 of 15 soil samples
- Elevated levels of Total Organic Carbon (TOC) where recorded in 5 of the 15 soil samples above the hazardous Waste Acceptance Criteria (WAC).

No ground investigations were carried out within the car parking area(s) of Plunkett Station at this time however, as addressed in Chapter 8 Soils and Geology, soil sampling will be carried out to categorise the excavated material within the shallow impermeable trenches as per Waste Assessment Criteria (WAC) to ensure that the material is properly disposed of.

9.3.4 Groundwater Bodies and Bedrock Aquifers

Groundwater is defined as water, which is stored in, or moves through, the cracks and pores of geologic formations of soils, rocks, and sand. The potential of rocks to transport and store water underground is highly dependent on the degree of permeability: the more permeable the rock, the greater the water transport ability. Sections 9.3.3.1 to 9.3.3.5 below provide a description of the groundwater features identified within the study area of the proposed development.

Groundwater monitoring was conducted with the installation of two (2) boreholes (BH301 and BH302) in late 2019 as part of the investigation for the proposed flood measures in front of Plunkett Station (IGSL, 2019) to determine if the area was susceptible to underground flooding from tidal ingress. Piezometers were installed in each of the boreholes to monitor groundwater levels using dataloggers with data recorded at regular intervals from May 2020 to December 2020. Data from the boreholes indicated that bedrock was within 1m to 3m below ground level (bgl) which would be indicative of a positive flood protection with the exception of localised areas where it is weathered and would provide groundwater flow pathways. Normal tidal influences (below 2.0 m OD) were found to have a near negligible impact on groundwater levels while tidal maxima at high tides above 2.0m OD induced a rise in groundwater up to 1.0m with a lag time of 3 hours behind high tide.

9.3.4.1 Aquifer Classification

The River Suir forms a groundwater divide which divides groundwater bodies connectivity in terms of flow and productivity. Between Chainage Ch.0.000 to Ch.950 of the proposed development (see Figure 4.1 in Volume 3 of this EIAR for chainage references), the bedrock underlying the study area is categorised as a Poor Aquifer (Pl) - bedrock which is generally unproductive except for local zones. The remaining portion of the study area, between Ch.950 and Ch.1500 falls within an area categorised as a Locally Important Aquifer (Ll) in which the bedrock is moderately productive only in local zones. The bedrock aquifer classifications for the study area were found using the Geological Survey Ireland (GSI) mapper website.

9.3.4.2 Groundwater Quality

The Mullinavat Groundwater body (GWB) (European Code IE_SE_G_149) is located within the north quays area of Waterford City and encompasses the study area of the proposed development in its entirety. The Waterford GWB (European Code IE_SE_G_155) contains areas within the south quays of the city stretching between Rice Bridge and the Waterford Distillery. Under Water Framework Directive (WFD), both the Waterford and Mullinavat GWBs were classified as having an overall good status for water quality and quantity for the 2013-2018 assessment period. The Mullinavat GWB is described as "Not at Risk" of not achieving at least good ecological or good chemical status/potential. The objective for Waterford City GWB is currently under review with regard to risk status.

9.3.4.3 Groundwater Vulnerability

The Geological Survey of Ireland (GSI) uses a matrix comprising four groundwater vulnerability categories to classify aquifer vulnerability. These categories are extreme (E), high (H), moderate (M) and low (L). The categories are based on the thickness of overburden which provides some reduction for contaminants migrating toward the groundwater table from the surface or near sub-surface. The 'Extreme' vulnerability classification is defined as overburden depths of less than 3m. A subset of the 'extreme' category termed 'Extreme with bedrock outcrop/subcrop' (X), relates to areas of bedrock outcrop or sub-crop of less than 1m, or within 30m of a location of point recharge i.e., a karst feature.

Groundwater vulnerability within the study area (see Figure 9.2 in Volume 3 of this EIAR) ranges from moderate to extreme vulnerability to pollution at the ground surface. This signifies that the subsoil cover along the northern banks of the River Suir forms a thin layer (generally <5m) of low to moderate permeability subsoil or made ground. A section of the proposed drainage works at located Plunkett Station is within the (X) groundwater vulnerability category. Table 9.1 below identifies the groundwater vulnerability of areas where the proposed development requires underground works such as excavation and piling.

Table 9.1 Groundwater Vulnerability Within Study Area

Proposed Works	Groundwater Vulnerability Rating
Underground Impermeable Trench	Extreme (E)
Sheet Pile Installation (Riverside)	High (H)
Sheet Pile Installation (Landside)	High (H)
Drainage	High (H) to Extreme (X)

Groundwater Recharge

Groundwater recharge differs throughout the study area. Between Ch.0.50 and Ch.950 (see Figure 4.1 in Volume 3 of this EIAR for chainage references), the average groundwater recharge rate is 100 mm/year. This area of proposed development consists of Made Ground within the PI Bedrock Aquifer zone. The average groundwater recharge rate is 126 mm/year for the remaining section of the study area between Ch.950 and Ch.1100 due to the presence of Made Ground in the subsoil.

9.3.4.4 Groundwater Abstractions

There are no recorded public groundwater supplies or public water schemes located within the study area. Within the exception of two boreholes located on the south bank of River Suir, approx. 750m to 1km west of the study area, no other abstraction areas have been identified within 1.5km of the study area. The two (2) boreholes are listed as 2311SEW014 and 2311SEW017, both of which had been installed in June 1968. According to the GSI records, both boreholes are categorised as poor yield classes with yields below 40m^3/day. The 2311SEW014 abstraction area was listed for domestic use only while the 2311SEW017 is listed for industrial use and are for private use.

9.3.4.5 Site Hydrogeology

Given the proximity to the river and the topographical orientation towards the Suir valley, discharge from the Mullinavant GWB will be to the River Suir. Groundwater flow paths in the area north of the river will be very short due to the bedrock generally

being poorly permeable with the exception of fracture zones. Flow paths to the south may be longer however, as the proximity to the river is the dominant flow control.

9.3.5 Groundwater Dependant Terrestrial Ecosystems (GWDTE) /Special Areas of Conservation (SAC)

The hydrogeological sensitivity of European Sites which form part of the Natura 2000 Network were assessed with regard to the proposed development. The Lower River Suir Special Area of Conservation (SAC) (site code 002137) is the only European site located within the study area of the proposed development (see Chapter 7 Biodiversity for a detailed assessment of all European sites). This SAC consists of the freshwater stretches of the River Suir immediately south of Thurles, the tidal stretches as far as the confluence with the Barrow/Nore immediately east of Cheekpoint in Co. Waterford. The Suir and its tributaries flow through the counties of Tipperary, Kilkenny and Waterford.

There are no GWDTE present within the vicinity of the site.

9.3.6 Summary of Hydrogeological Features

The main features of importance identified at the site and in the study area are summarised in Table 9.1.

Table 9.2 Features of Importance

Feature	Importance	Criteria / Justification
Bedrock aquifer classified by the GSI as a Poorly Productive Aquifer which is productive only in local zones (Pl)	Low	A poorly productive aquifer is considered to be of low value on a local scale.
Bedrock aquifer classified by the GSI as a Locally Important aquifer which is moderately productive in local zones	High	A regionally important aquifer is considered to have a high quality or value on a regional scale
Lower River Suir SAC	High	European Site forming part of the Natura 2000 network*

* The River Suir is a hydrological feature of importance. The IGI guidance does not designate importance ranking to hydrological features, however the Transport Infrastructure Ireland (TII) (Guidelines for Hydrology for National Road Schemes, TII 2019) guidance states that if groundwater supports a river or surface water body ecosystem protected by EU legislation (e.g., Lower River Suir Special Area of Conservation (SAC)) that it should be considered an attribute of extremely high importance.

9.4 Description of Potential Impacts

This section describes the potential construction and operational impacts associated with the proposed development before mitigation measures are applied. Both direct and indirect impacts will be addressed for the construction and operation of the proposed development. The nature, extent and duration of the impacts will also be assessed.

The proposed development will involve the following activities that are being considered as part of the hydrogeology impact assessment:

- Excavation of made ground and soils to install a shallow impermeable trench from Ch.0.0 to Ch.360.

- The remediation of existing quay wall from Ch.285 to Ch.360 which includes the raising of the existing wall to meet the design level of 4.30mOD (Ordnance Datum).
- The installation of new steel sheet piles from Ch.360 to Ch.1090. The sheet piles will be installed from riverside (Ch.360 to Ch.900) and landside (Ch.900 to Ch.1090) c.1 metre in front and behind the existing quay wall respectively. The space between the front face of existing quay wall and the riverside sheet piles will be filled with Class 6 clean material.
- Upgrade works to the existing drainage system from Ch.0.0 to Ch.1090 and the provision of new drainage system consisting of 2 no. underground pumping stations and outfall structures.

See Figures 4.1 to Figure 4.20 in Volume 3 of this EIAR for chainage reference points.

9.4.1 Construction Phase

During the construction phase, the following activities may pose a potential impact on the hydrogeological regime:

- Excavation of Made Ground;
- Contamination of Soils; and
- Contamination of Groundwater.

The potential impacts pertaining to each of the aforementioned activities is detailed in the following sections.

Excavation of Made Ground

Excavation of made ground will be required for the construction of shallow underground impermeable trenches within the car park areas of Plunkett Station, and for the installation of two pumping stations within the Waterford to Dublin railway corridor. The excavated soil may be contaminated from leaks and spillage of fuels from road traffic within the car parking areas and from rail operations within the railway corridor.

The excavation of material is likely to have a *negative*, *imperceptible* and *permanent* impact on the soils environment due to the requirement to remove the material off-site and dispose or treat it in accordance with relevant legislation. However, any improvement to the quality of soils within the site of proposed development will have a corresponding benefit to the underlying groundwater resources due to the removal of a potential source of contamination for percolating water. Therefore, the overall likely impact of excavation activities on hydrogeology is *positive, slight* and *permanent*.

Contamination of Soils

There is the potential risk of localised soil contamination through leeching from construction plant and materials, spillages associated with construction activities, and dewatering within cofferdams. Best construction practices will be adhered to during construction phase and will minimise the risk of pollution to soils and consequently to the underlying aquifers. The potential impact is *negative, imperceptible* and *temporary*.

Should contaminated soils be encountered during the construction phase of the project their subsequent removal and disposal to an off-site licensed facility will be considered a *positive, slight to moderate* and *permanent* impact.

Contamination of Groundwater

Construction runoff from the site can pose a risk to groundwater due to potential infiltration of contaminated surface water to groundwater. The installation of sheet pile walls at depths to approximately 10m to 15m below ground surface (bgs) may provide a pathway to the shallow groundwater table from overlaying soils. There is a risk that the contaminants present in the made ground across the site may be brought to the surface during excavation works or driven down into underlying aquifer. The impact associated with driven piles is slight, as contaminated material will be dragged down into the underlying soil layers by shaft friction, however the displacement of these contaminants is not likely to be significant. The potential impact is *negative, slight* and *short-term*.

As sheet piles move through soils in order to reach their target depths, they may penetrate previously impervious soils that acted as a confining layer to contaminants, preventing their mobilization into the groundwater. This potential is considered slight negative effect on a localised area immediately surrounding the impacts due to the minimal amount of contaminants that could be transmitted to the underlying groundwater.

The Lower River Suir SAC is hydrologically linked to the proposed development as a section of the proposed flood defence measures is located within the mudflats of the SAC. Given that this SAC is predominantly a surface water system and is not sensitive in relation to groundwater flows, the main potential impact would relate to construction related contamination of the aquifer impacting the SAC water quality. The potential impact to the SAC water quality from construction related groundwater contamination would be *negative, imperceptible* and *temporary*.

9.4.2 Operation Phase

The potential for impacts during the operation phase have been assessed under the following headings:

- Groundwater Flow/Seepage;
- Contamination of Groundwater.

Groundwater Flow/Seepage

The steel sheet pile wall will be placed to a depth of up to 8.5m for landside and between 11 – 16m for the riverside sections and may act as barrier for natural groundwater flow towards the River Suir during low tide and may locally impact groundwater levels. While the groundwater seepage into the river at a local level may be restricted, it will be of minimal significance given that the majority of the outfall into the river is from precipitation and surface run-off from stormwater conveyance systems. Groundwater flow and seepage behind the proposed sheet pile wall will be redirected to the east and west behind the sheet pile wall. Any localised groundwater conduit flow will be managed by the upgraded trackside drainage. The potential effect of proposed development on groundwater flow is likely to be *negative, localised, imperceptible to slight,* and *permanent*.

During extreme weather events, the proposed sheet pile walls and the underground impermeable trench will reduce the risk of groundwater seepage into the rail infrastructure. The inclusion of filter drainage pipes along with the extension of existing stormwater pipes to the River Suir as part of the proposed development will help prevent backflow of the groundwater in the study area and help to mitigate flooding while only minimally impacting local hydrogeology. The significance of this impact is considered *positive, slight,* and *permanent*.

The sheet pile walls will also act as a barrier to saltwater intrusion into the groundwater within localised area along with stabilizing groundwater levels which are currently tidally influenced due to the direct connection with the River Suir. The sheet pile walls in this regard will have a *positive, slight* and *permanent* impact on groundwater seepage.

Contamination of Groundwater

During the operational phase, the area will be an urban environment covered in hard standing (sheet piles on the water edge with hard standing on the landward side of the piles). There are therefore no perceived activities which pose a risk of contamination to the hydrogeological features of importance during the operational phase of the proposed development.

9.5 Mitigation & Monitoring Measures

A project-specific Environmental Operating Plan (EOP) and a Construction Environmental Management Plan (OCEMP) have been prepared and appended to Chapter 4 of this EIAR (see Appendix 4.1 and 4.1A respectively). They will be maintained by the Contractor for the duration of the construction phase. The EOP will cover all potentially polluting activities and include an emergency response procedure. All personnel working on the site will be trained in the implementation of the procedures. As a minimum, the EOP for the proposed development will be formulated in consideration of the standard best practice. The EOP will include a range of site - specific measures that include:

- The successful Contractor will ensure that spill kits and hydrocarbon absorbent packs are stored in the site compound, and that operators will be fully trained in the use of this equipment.
- Earthworks shall be carried out such that surfaces promote runoff and prevent ponding and flooding.
- Runoff will be controlled and treated to minimise impacts to surface and groundwater.
- Temporary pumping of groundwater, if required, shall be treated by means of a temporary sedimentation tanks prior to discharge
- All hazardous materials will be stored within secondary containment designed to retain at least 110% of the storage contents.
- Temporary bunds for oil/diesel storage tanks will be used on the site during the construction phase.
- Contaminated material will be disposed of off-site for treatment at an appropriate licensed facility in accordance with the relevant waste management legislation. Alternatively, the material shall be covered while stored to remove the risk of surface water contamination.
- Safe materials handling of all potentially hazardous materials will be emphasised to all construction personnel employed during construction.
- Mitigation measures during the construction phase will include implementing best practice during excavation works to avoid sediment entering the River Suir (refer to Chapter 10 'Hydrology' of this EIAR for details).

Operation Stage

There are no mitigation measures associated with the operation phase of the proposed development with regard to Hydrogeology.

9.6 Residual Impacts

9.6.1 Construction Phase

The incorporation of the mitigation measures outlined in Section 9.5 results in the magnitude of any impacts during construction to be considered as *negative, imperceptible* and *temporary*.

9.6.2 Operation Phase

As there are no mitigation measures for the operation phase of the proposed development, the residual impacts remain as per the potential impacts outlined in section 9.4.1.

9.7 Difficulties Encountered

There were no difficulties were encountered during the hydrogeological impact assessment.

9.8 References

GSI maps: www.gsi.ie/mapping, accessed 01/03/2021

GeoHive historical mapping: http://map.geohive.ie/, accessed 01/03/2021

TII (2020) Light Rail Environment - Technical Guidelines for Development Ireland

EPA (2017) Guidelines on the Information to be Contained in Environmental Impact Assessment Reports