12.0 GEOLOGY AND HYDROGEOLOGY

This section of the Environmental Impact Statement describes the natural characteristics of the site in terms of its geology, hydrogeology and the nature of the marine sediments. An assessment is made of the likely impact of the proposed scheme on these natural resources and, where necessary, mitigation measures are put forward to reduce the impact of the proposed gas storage facility and associated construction works.

12.1 Regional Setting

The geological regime has been established from reviewing information obtained from a number of sources:

- 1:10,000 geological mapping (provided by GSNI)
- Logs of Larne-1, Larne-2 and New Mills-1 boreholes
- 2D seismic survey results undertaken around Larne Lough in 1980s
- 3D seismic survey of northern part of Larne Lough undertaken in 2007
- Field mapping work in 2007/08

The area of interest is located in the Larne Basin that is situated in the Midland Valley terrain between Northern Ireland and the SW of Scotland (Figure 12.1). The SW portion of the Larne Basin lies onshore in Northern Ireland. The sedimentary fill of the basin comprises deposits of Carboniferous to Tertiary age, predominantly Permo-Triassic. It is non-compliantly resting on Ordovician and Silurian basement rocks of the Longford Down Inlier/Southern Uplands Massif (both Caledonian).

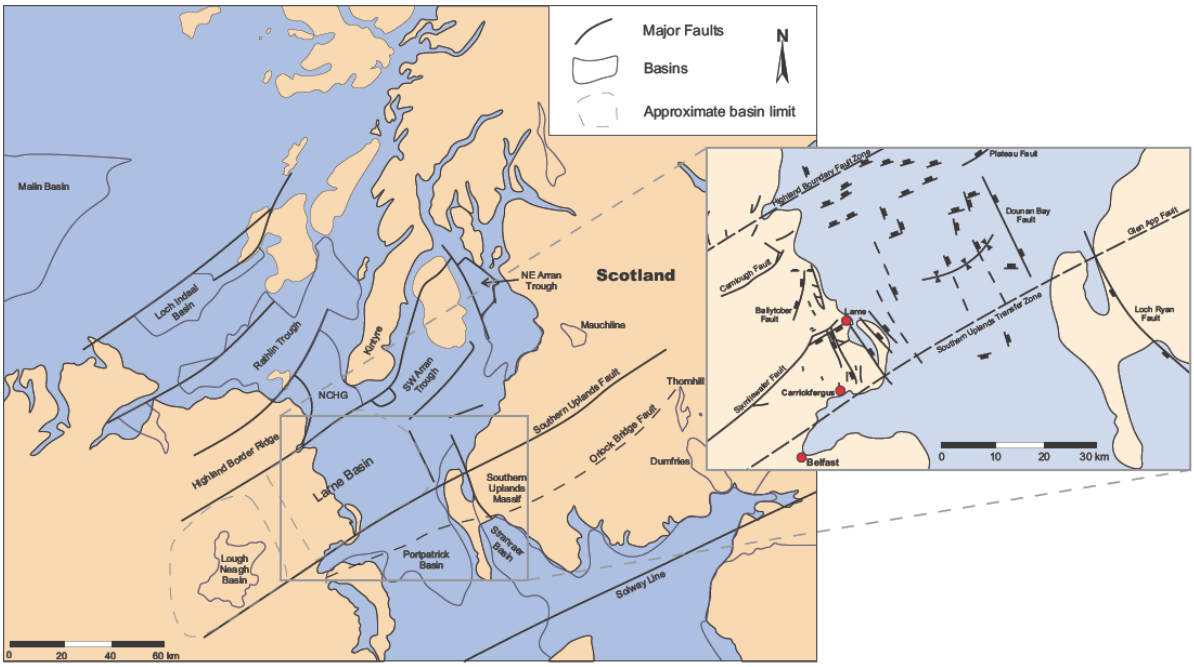

Figure 12.1 Larne Basin and major Caledonian faults; structural insert map, based on seismic data and published geological maps

(modified after Shelton, 1997)

The evolution of the Larne Basin began with several phases of crustal extension in association with synsedimentary faulting, half-graben development and sporadic volcanism during the Carboniferous period.

Permo-Triassic NE-SW extension, subsequent to significant erosion of Carboniferous clastic deposits due to regional inversion tectonics at the end of the Variscan Orogeny, led to the development of a complex arrangement of half grabens and normal faults. This extension resulted in the Larne Basin in a largely continental deposition of Permo-Triassic strata of up to 3,000 m in thickness. Lower Permian sandstones and conglomerates (potential reservoirs for hydrocarbons) are up to 440 m in thickness. These sediments are covered by Upper Permian limestone, shales, marls and evaporates, some of which may laterally vary in thickness and facies. The evaporates including the basal Magnesian Limestone are members of the Belfast Harbour Evaporate Formation (BHE) which is regarded as an equivalent of the Zechstein. This formation is the primary target of the Larne Lough gas storage project for the construction of the storage caverns. The evaporates are covered by the Permian Connswater Marl Formation (CMF). For stratigraphically equivalent sediments in the East Irish Sea, a deposition of alluvial fanglomerates passing basinwards into fluvial and aeolian sandstones at the basin margin is suggested. These are inferred to grade further into basin centre shaley and evaporatic playa lake deposits.

During the Mesozoic, the ongoing subsidence of the basin led to fluvial and aeolian accumulation of units of the Lower Triassic Sherwood Sandstones Group (SSG). The sedimentation of these sandstones was followed by the deposition of shales, siltstones and thin sandstones of the Upper Triassic Mercia Mudstone Group (MMG). The latter are interbedded with three major halite sequences, Ballyboley, Carnduff and Larne Halites (in order of decreasing age).

Rapid uplift and erosion during the Jurassic and Cretaceous periods are largely responsible for the insignificant thicknesses or absence of sedimentary formations in the Larne Basin. Onshore, lower shallow marine Jurassic mudstones and subordinately limestones are overlying Triassic deposits in many places. These units are generally 25 to 100 m thick.

Sporadic relicts of thin karstified beds of Late Cretaceous chalk have been reported. They are in many places capped by Paleocene basalt lava extrusions up to 800 m in thickness (British Tertiary Igneous Province; BTIP). The volcanic activity is understood to be the result of an uplift, and again, NE-SW extension and faulting. NW-SE (WNW-ESE) extensional faulting is imaged on seismic from the onshore and offshore Larne Basin. The basalt extrusions comprises of a Lower Basalt Formation, an Interbasaltic Formation and the Upper Basalt Formation. Maximum preserved thickness of the Lower Basalt Formation area of up to 530m was recorded in Lough Neagh. An unknown amount of basalt has been removed by erosional processes. Onshore Northern Ireland Tertiary dykes are predominantly oriented NW-SE whilst offshore they display rather NNW-SSE to N-S trends.

A phase of compression caused regional uplift and erosion during the Miocene. In the Larne Lough area an axis of uplift is centred on the Lough itself where the Permian salt is most

thickly developed. The uplift resulted in the erosion of the basalts which results in a clearer resolution of the salt sequence on seismic data below Larne Lough (Figure12.2).

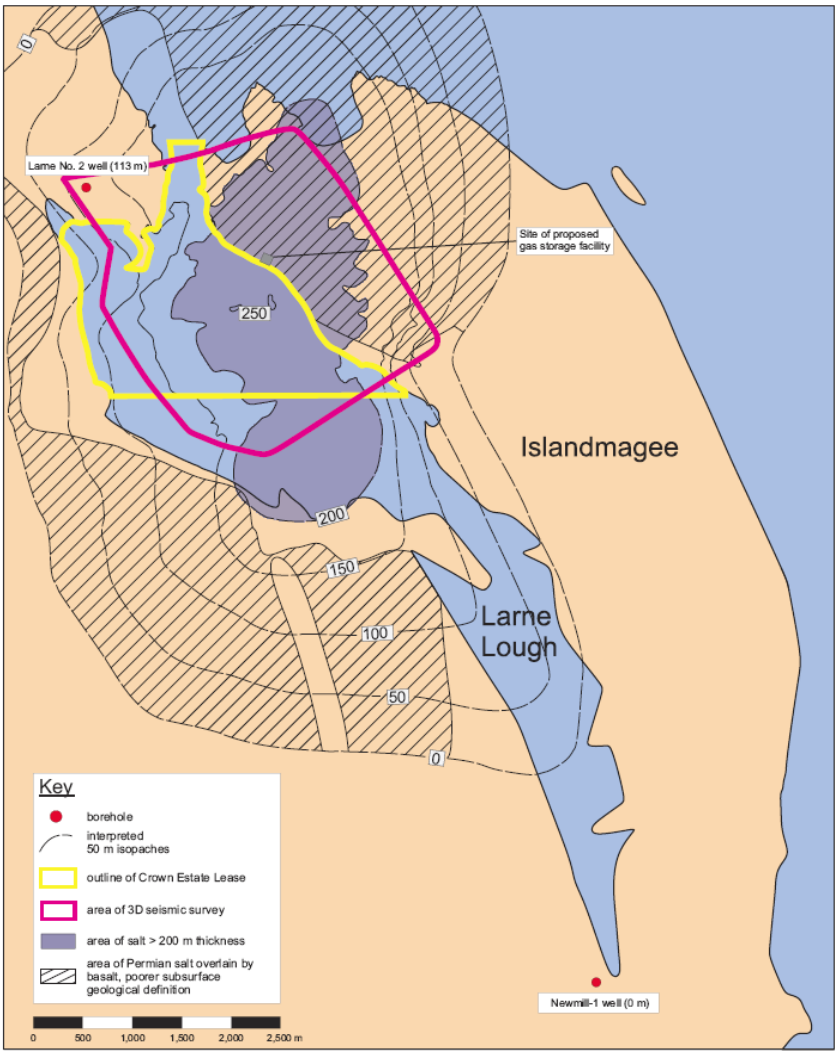

Figure 12.2 Regional isopach map for Permian salt in the vicinity of Larne Lough

Parallel to the adjoining Highland Boundary Fault Zone (HBF) and Southern Upland Fault Zone (SUF) normal faults in the south of the Larne Basin dip generally to the E (Variscan or Tertiary trend), those in the north dip to the NW striking WSW-ENE (Caledonoid). These feature strike slip elements.

The salt mine development in the Carrickfergus area is located in the saliferous beds of the Triassic MMG.

The Larne No. 2 well is the closest well to the area of interest. It encountered a Permian salt sequence reported to be very uniform, homogeneous and pure with virtually no interstitial clay or anhydrite. In appearance it may be similar to bedded Permian salt observed in locations in the Netherlands.

Table 12.1 Stratigraphic column of the Larne No. 2 Well

		from depth below MSL [m]	to depth below MSL [m]	vertical thickness [m]
Quaternary		**- 2.6**	**6.8**	**9.4**
	undifferentiated	- 2.6	6.8	9.4
Triassic		**6.8**	**1,546.3**	**1,539.6**
	Mercia Mudstone Group	**6.8**	**957.7**	**951.0**
	Knocksoghey Fm.	6.8	134.1	127.4
	Knocksoghey Fm. (u. p.)	6.7	103.3	96.6
	Coolmaghra Skerry	103.3	110.0	6.7
	Knocksoghey Fm. (l. p.)	110.0	134.1	24.1
	Glenstaghey Fm.	134.1	471.5	337.4
	Glenstaghey Fm. (u. p.)	134.1	257.0	122.9[1]
	Larne Halite	257.0	460.9	203.9[2]
	L. Glenstaghey Fm. (l. p.)	460.9	471.5	10.6
	Craiganee Fm.	471.5	902.5	431.0
	Craiganee Fm. (u. p.)	471.5	618.1	146.6
	Carnduff Halite	618.1	798.0	179.9
	Craiganee Fm. (m. p.)	798.0	861.7	63.7
	Ballyboley Halite	861.7	902.5	40.8
	Lagavarra Fm.	902.5	957.7	55.2
	Sherwood Sandstone Group	**957.7**	**1,606.0**	**648.3**
	U. Sherwood Sandstone	957.7	1,243.6	285.9
	Sherwood Upper Siliceous	1,243.6	1,546.3	302.7
	Sherwood Lower Siliceous	1,546.3	1,606.0	59.7
Permian		**1,606.0**	**2,870.3**	**1,264.3**
	Upper Permian	**1,606.0**	**1,813.0**	**207.0**
	Connswater Marl Fm.	1,606.0	1,672,1	66.1
	U. Permian Marls	1,606.0	1,672.1	66.1
	Anhydrite	1,672.1	1,676.7	4.6
	Belfast Harbour Fm.	1,676.7	1,813.0	140.9
	Siltstone	1,676.7	1,678.2	1.5
	Halite	**1,678.2**	**1,791.3**	**113.1**
	Magnesian Limestone	1,791.3	1,813.0	21.7[3]
	Lower Permian	**1,813.0**	**2,870.3**	**1,057.3**
	Lower Permian Sandstone	1,813.0	2,253.7	440.7[4]
	Lower Permian Volcanics	2,253.7	2,870.3	616.6[5]
Total Depth			**2,870.3**	

u. p.: upper part; m. p.: middle part; l. p.: lower part.

Contribution of Tertiary intrusive rocks to thickness: [1]25m, [2]14.3m, [3]7.6m, [4]9.8m, [5]4m.

12.1.1 Seismic investigations to reveal deep geology in Larne Lough area

A challenge to seismic surveying in the vicinity of Larne Lough is the areas with Tertiary basalt cover that have a significant influence on the quality of the data produced. Furthermore, the uncertain and independent distribution of low density halite and high density igneous intrusives can make interpretation of the data difficult.

A Vibroseis survey was carried out in 1981 along the western side of Larne Lough.

Islandmagee Storage Limited acquired a 3D-seismic programme using IMC Geophysics during October-November 2007. Two 2D seismic tie lines were also acquired to allow a correlation of the survey with the Larne No. 2 well. During the interpretation of the survey for Islandmagee Storage Limited by GEO International Ltd., regional gravity and high resolution aeromagnetic survey data were also integrated. The interpretation indicates an extension of the Permian salt sequence from the Larne No. 2 well underneath Larne Lough

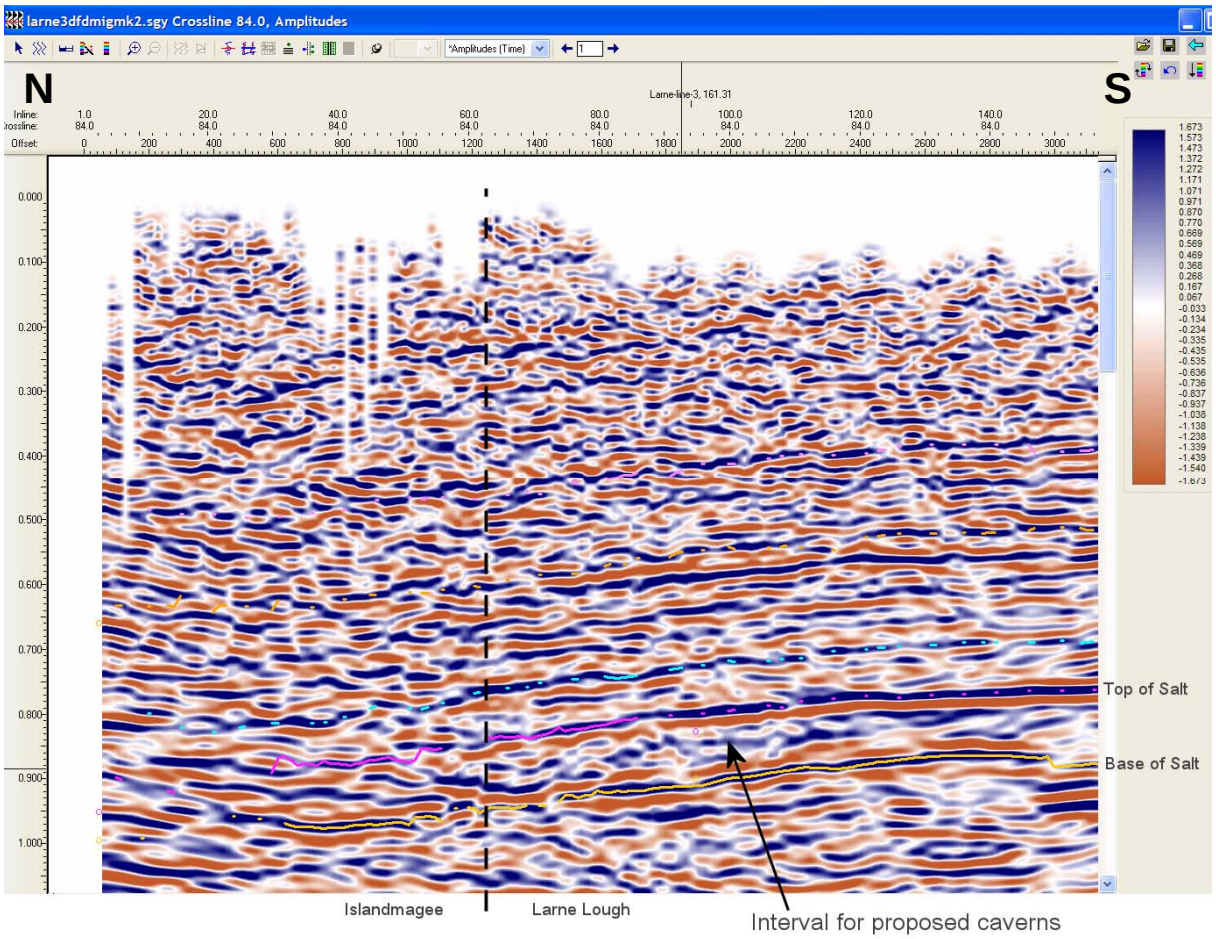

Figure 12.3 Imaging from seismic survey showing detail beneath Larne Lough

The top as well as the base of the Permian salt provide strong seismic reflections, shown in Figure 12.3. As a result of this interpretation, it was possible to contour the top of the Permian salt, which showed a regional dip to the NW within the area of seismic investigation. This surface is at depths of about 1,340m to 1,630m (Figure 12.4). The accuracy of the interpreted depths of the top of the Permian salt is estimated to be within 20–30m. It can be

seen from the available mapping (Figure 12.1, Figure 12.6) that there are faults which affect the salt interval, however on the mapping (Figure 12.6) it can be seen that these appear to be confined to the areas that are currently above sea level. It has been confirmed by the seismic survey that the area proposed for the caverns, beneath Larne Lough, is unfaulted.

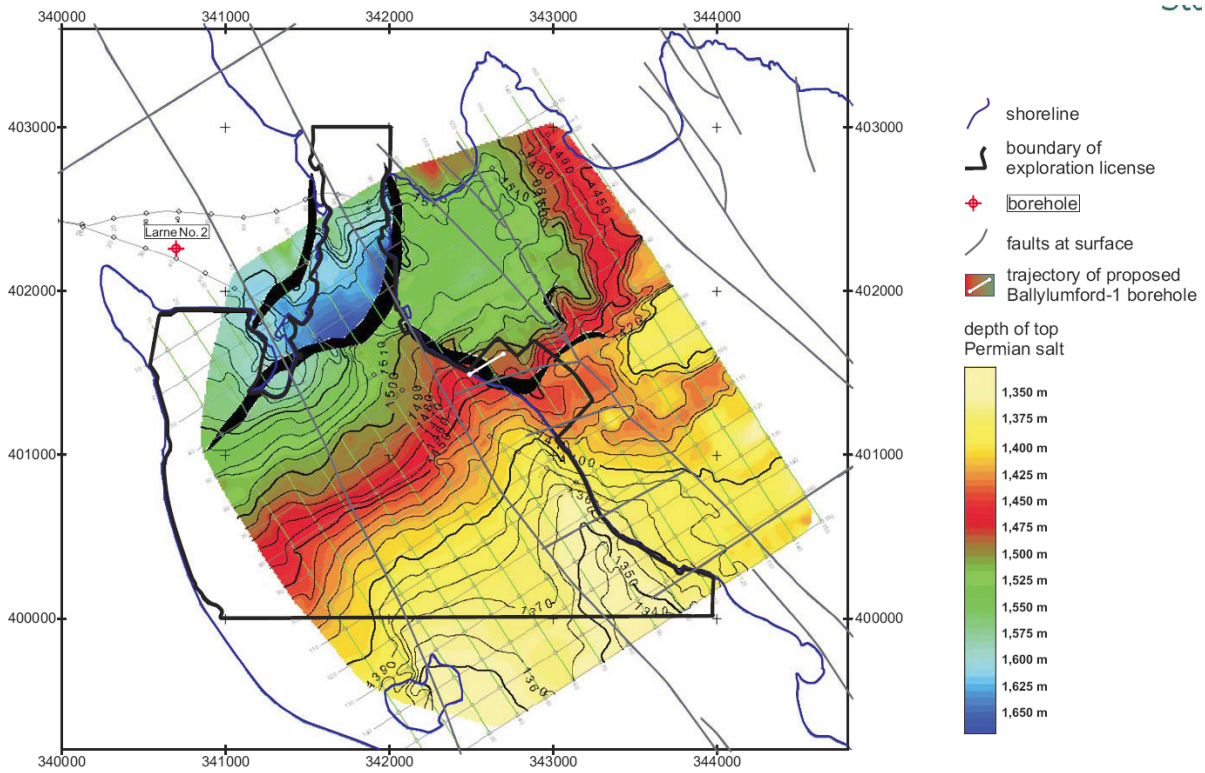

Figure 12.4 Depth map of the top of the Permian salt from 3D-seismic survey acquired in 2007

The shallowest depth of the top of the Permian salt was recorded along the south-eastern boundary of the 3D seismic area.

A further result of the interpretation of the seismic evaluation is an isopach map (Figure 12.5) illustrating the thickness of the Permian salt. The salt sequence thins out towards the edges of Larne Lough, and thus is characterised by a lenticular geometry. The variation of the formation thickness inferred from the 3D-seismic survey is significant as the thickness ranges between 0 and approximately 240m.

In order to confirm the seismic interpretation, data will need to be acquired from a borehole close to the area of the proposed caverns (or from the first borehole of the development). This will also allow cores to be cut and recovered across the Permian salt interval. The information collected in the well will provide the necessary data required to fully develop the design of the caverns for their use in the storage of natural gas.

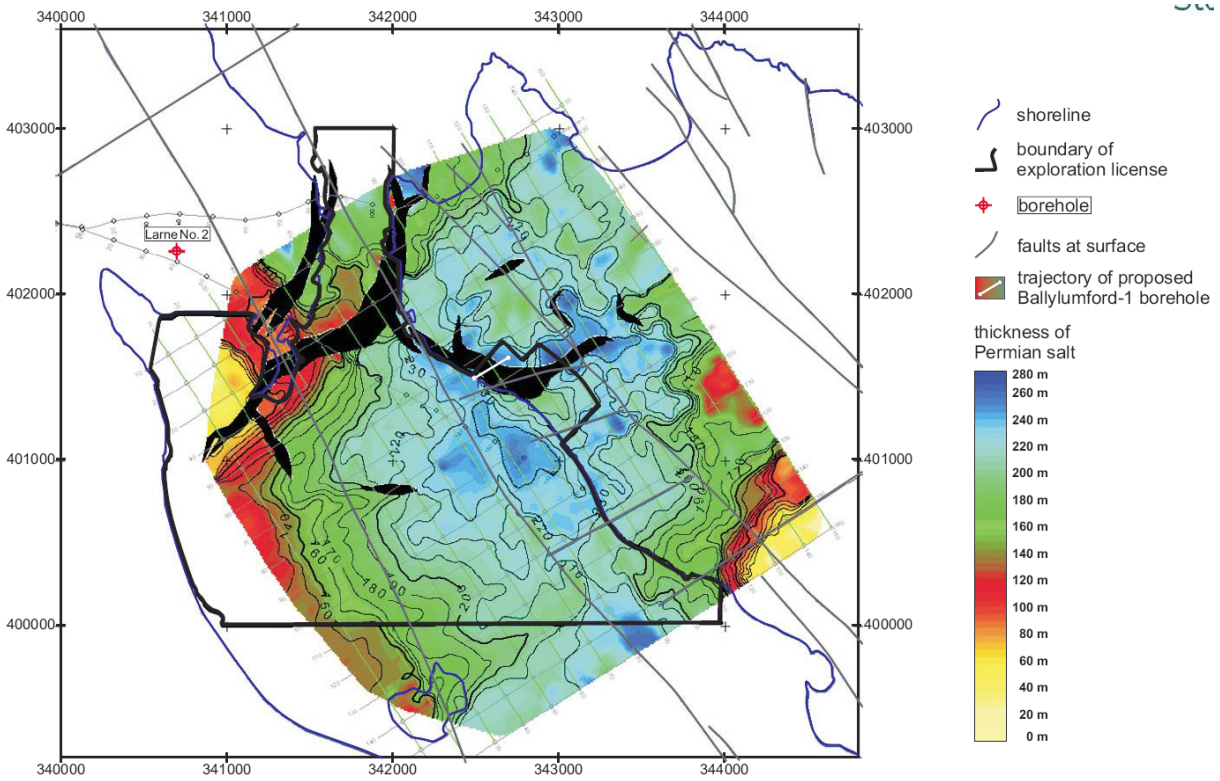

Figure 12.5 Isopach map of the Permian salt from 3D-seismic survey acquired in 2007

12.1.2 Surface geology in area of proposed facilities

The bedrock geology according to the published 1:50,000 geological map (Geological Survey of Northern Ireland, Sheet 21, Larne) comprises Tertiary basalts unconformably overlying Cretaceous limestone. The bedrock geology as shown in Sheet 21, supplemented by information from Islandmagee Storage's field studies is shown in Figure 12.6. The limestone is the Ulster White Limestone Formation, approximately 35 m thick, and is similar to the English Chalk, but has been 'baked' locally by the action of lava flows. The Lower Basalt Formation of the Antrim Lava Group is 250-450 m thick and is formed of olivine basalt lava flows. The tops and bottoms of individual flows are commonly vesicular and there are irregular layers between flows, known as boles, which are dark red, iron rich horizons created by intense tropical weathering in a previous geological era.

The Antrim Lava Group also contains isolated, massive flow banded andesites. A thickness of approximately 10m of weathered red beds marks the top of the Lower Basalt Formation. This is known as the Interbasaltic Formation and is also known as a source of iron and bauxite. Above this is 20 m of Upper Basaltic Formation. Consequently, the lithologies beneath the proposed site of the gas and leaching facilities can be expected to range from competent igneous rocks (basalt and andesite) and sedimentary rocks (limestone), to highly weathered engineering soils (weathered basalt).

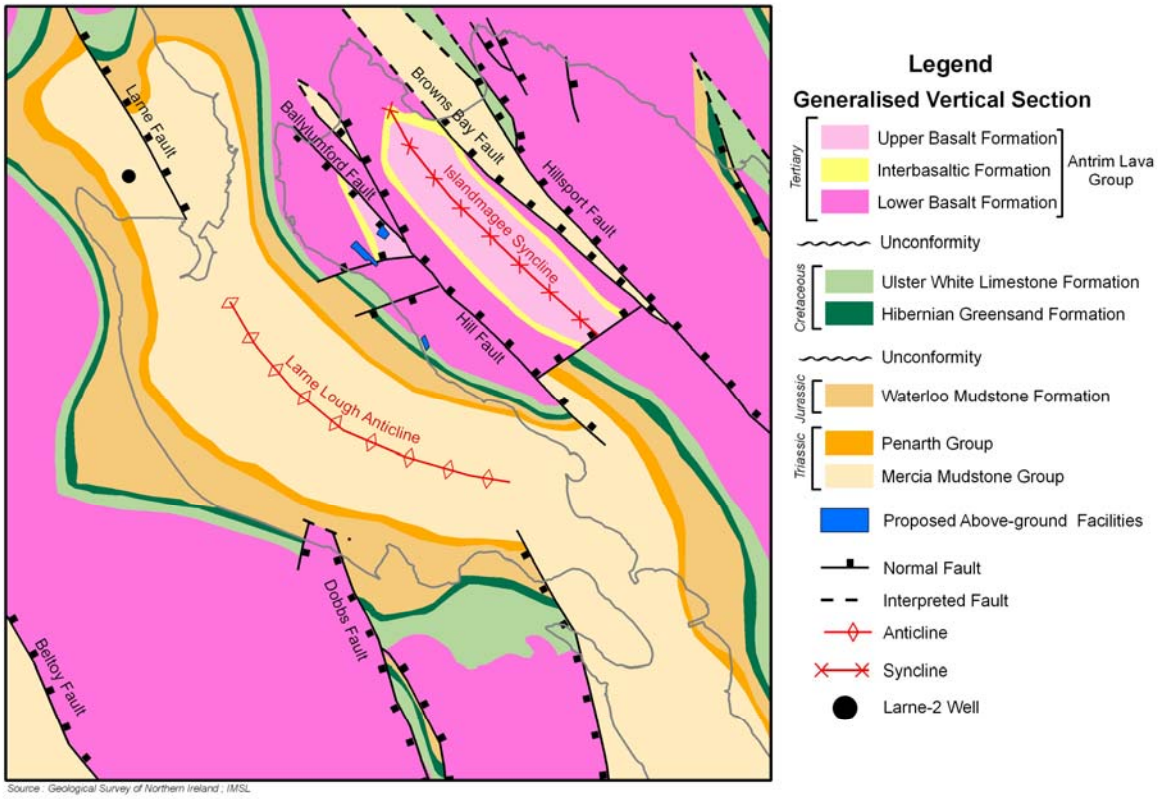

Figure 12.6 Surface Geology

Structurally, Islandmagee is a northwest-southeast trending syncline with the Upper Basalt Formation forming the core, and the high ground. This is adjacent to the Larne Lough anticline, below which is found the thickened Permian salt sequence. The bedding in the Ulster White Limestone Formation on the shore of the Lough dips northeast at 30°. Igneous foliation in the lavas of the Upper Basalt Formation (1 km to the east of the site) dip northwards at 20°. Major faults trend parallel and perpendicular to the synclinal axis. The Ballylumford Hill Fault is parallel to the axis and runs to the northeast of the proposed leaching plant. With a downthrow to the south, this brings the Lower Basalt Formation back to outcrop to the northeast. An un-named northeast-southwest trending fault cuts across the site from a point on the shore just north of the proposed vent stack, through the proposed gas plant, and to the south of the proposed leaching plant. The downthrow is to the north. A parallel fault about 350m to the south has a downthrow to the south. Between these faults, a local horst block is responsible for a short exposure of the Ulster White Limestone Formation along the shore.

The published geological map records superficial deposits of glacial till overlying bedrock over most of the site area.

The underlying bedrock at the proposed leaching plant is the Upper Basalt Formation (Plate 12.1), with the Interbasaltic Formation just down slope. The proposed gas plant is located on the Lower Basalt Formation and the proposed vent stack on the Ulster White Limestone Formation (Plate 12.2). The proposed wellpad area lies to the south on Ulster White

Limestone (c. 35m thick) overlying a thin Cretaceous sequence of Hibernian Greensand Formation (c. 10m thick), which in turn overlies the thick Triassic sequence.

Plate 12.1 Upper Basalt Formation at Leaching Plant Site

Plate 12.2 Ulster White Limestone outcropping on beach south east of Vent Stack area

The underlying bedrock at proposed site of the seawater intake pumping station is the Lower Basalt Formation (Plate 12.3).

Plate 12.3 Lower Basalt Formation at Sea Water Intake Pumping Station Site

The bedrock below the seabed under Larne Lough comprises the Triassic Mercia Mudstone Group (Plate 12.4) in the core of the anticline resulting from the Miocene uplift. The seismic data shows that the area of the proposed caverns is not faulted at the deep level of the Permian salt. The seismic imaging beneath the lough is excellent due to the absence of near surface basalts over the adjacent land areas.

Plate 12.4 Mercia Mudstone Outcropping on foreshore at Millbay

The cliffs on the eastern shore of Islandmagee are regarded as being important exposures of Triassic, Jurassic and Cretaceous era sedimentary rocks. At Portmuck, Mesozoic strata from the Lias Waterloo Mudstone Formation (Plate 12.5) to the Cretaceous Glenarm Chalk Member are well exposed in a series of coastal cliffs. The fossiliferous Jurassic Lower Lias Waterloo Mudstone Formation, some 200 million years old, is exposed as a foreshore outcrop of soft blue clay and limestone which forms a reef.

The Hibernian Greensands Formation is well exposed in the cliffs to the west of Portmuck Harbour and includes sandstone and marl of the Kilcoan Sands, Island Magee Siltstone and Belfast Marls Members. These are the best exposures of the Hibemian Greensands Formation in Northern Ireland and form the oldest Cretaceous sediments present here, dating from some 97 million years ago.

Further south, the Gobbins cliffs are noted for their lower tertiary amygdaloidal basalts, dating from approximately 60 million years ago, which contain a number of zeolite minerals; analcime, chabazite, cowlesite, gmelinite, gobbinsite, gonnardite, heulandite, levyne and mesolite have been found here. Some vesicles also contain calcite and travertine. Of particular note is the occurrence of gobbinsite and gonnardite; both are restricted in their occurrence elsewhere and the former takes its name from the cliffs themselves.

Plate 12.5 Waterloo Fossiliferous Mudstone (Cloughfin)

Older rocks occur at the southern end of the site with rock exposures on the foreshore at Cloghfin Port providing access to a succession of sedimentary spanning approximately 183

million years from the mid Triassic (approximately 220 million years ago) to the late Cretaceous (approximately 80 million years ago). The rocks at Cloghfin are notable for their abundance of invertebrate fossils, some of which have provided key information in researching the Triassic-Jurassic worldwide extinction event.

Due to the importance of their geological exposures, the foreshore and cliffs at Portmuck, the Gobbins and Cloughfin have all been designated as an Area of Special Scientific Interest (ASSI). Portmuck ASSI is 400m south of the proposed outfall alignment and 670m south of the intake route at its closest point (refer to Figure 3.7 in Chapter 3 "Site Description).

12.2 Hydrogeology

Information on groundwater conditions within the northern portion of Islandmagee is limited. The BGS/GSNI geoindex was searched in addition to NIEA Abstraction licensing data, NI Water Borewells, wells and springs data and NIEA monitoring data for the Water Framework Directive.

On a regional level the site of the proposed main gas plant, brine leaching plant and wellpad is classified as **Bm (f) "**Moderate potential productivity fracture flow" (Figure 12.7). No detailed information is currently available with regard to groundwater conditions in the area of the proposed facilities, however, given the geology, elevation and topography of the overall site, it is likely that the permanent "groundwater table" is relatively deep and that zones of transient, perched groundwater develop within the superficial deposits during periods of high rainfall.

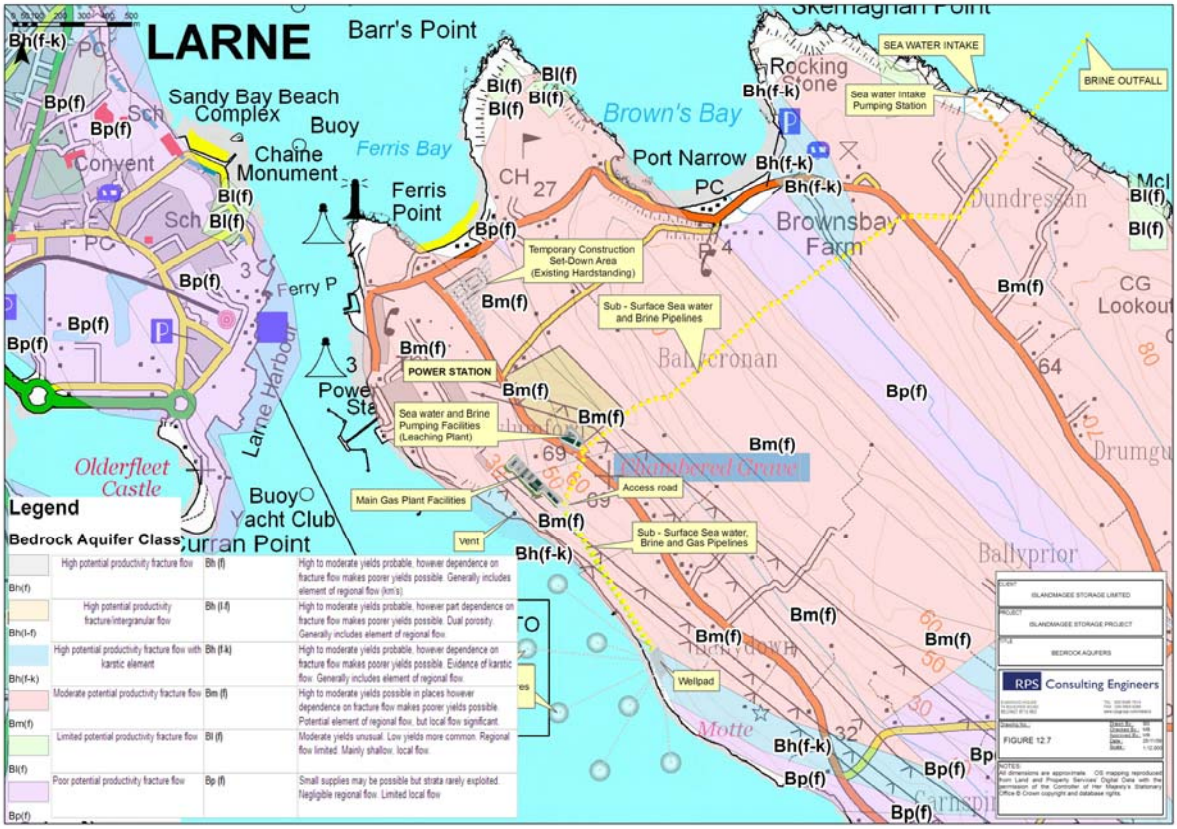

Figure 12.7 Bedrock Aquifer Status

Further investigation of the groundwater regime at each site will be required prior to detailed design of the facility. This is expected to consist of the installation and monitoring of piezometers within boreholes at each site.

Existing water abstraction on the northern portion of Islandmagee is mainly through surface water/springs. There is a superficial aquifer in an alluvium bed within the route of the sea water intake and brine outfall pipelines (Figure 12.8). There is one licensed abstraction from the spring here for a dairy farm on Browns Bay Road.

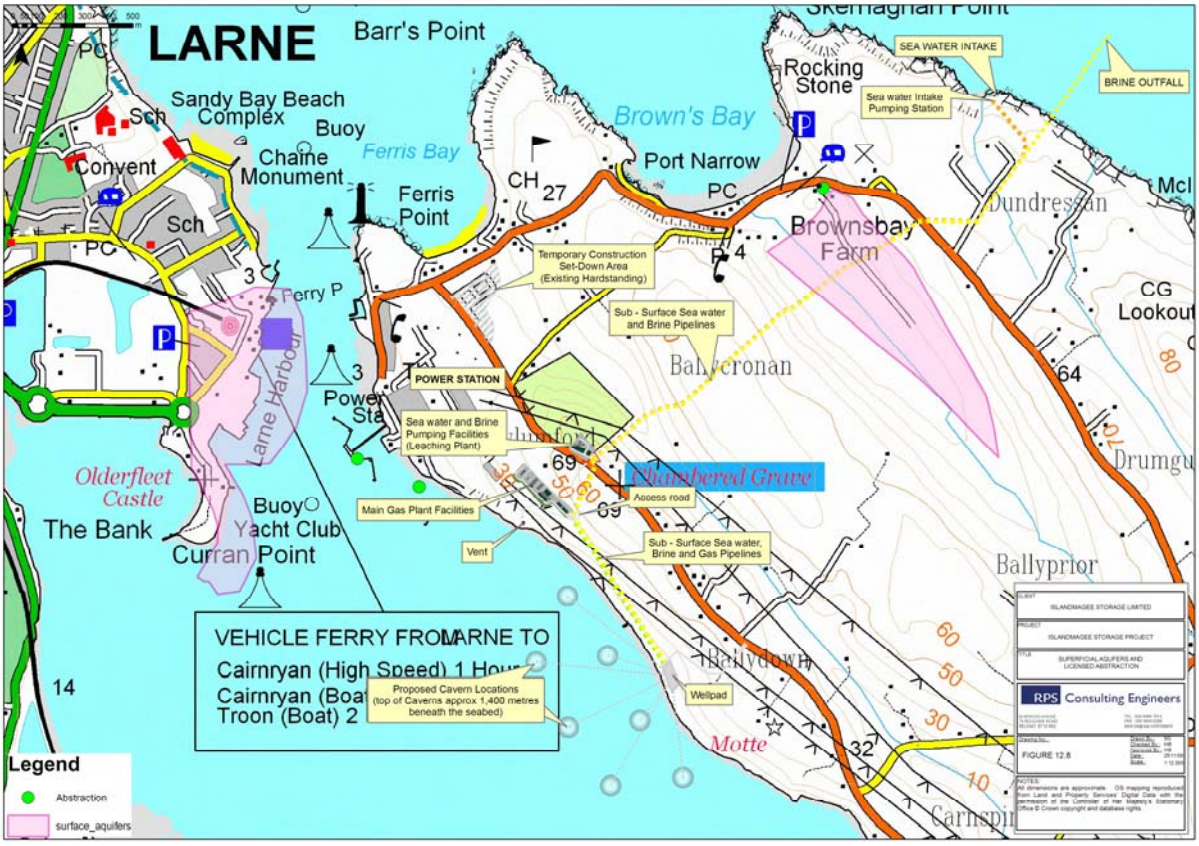

Figure 12.8 Superficial Aquifers

The only other licensed abstractions within the area relate to the power station and are for sea water. A disused spring has been noted at Millbay which is well outside the project area.

During drilling operations the near surface layers will be cased to protect any potential aquifer for future use. The surface casing will be set before penetrating any Triassic salt layer allowing any regional fresh water aquifer (for example in the Cretaceous Ulster White Limestone Formation) to be cased off and isolated prior to the potential use of oil based drilling mud in subsequent well sections.

12.2.1 Soils

A soil map of the proposed site area was provided by the Department of Agriculture and Rural Development (Figure 12.9)

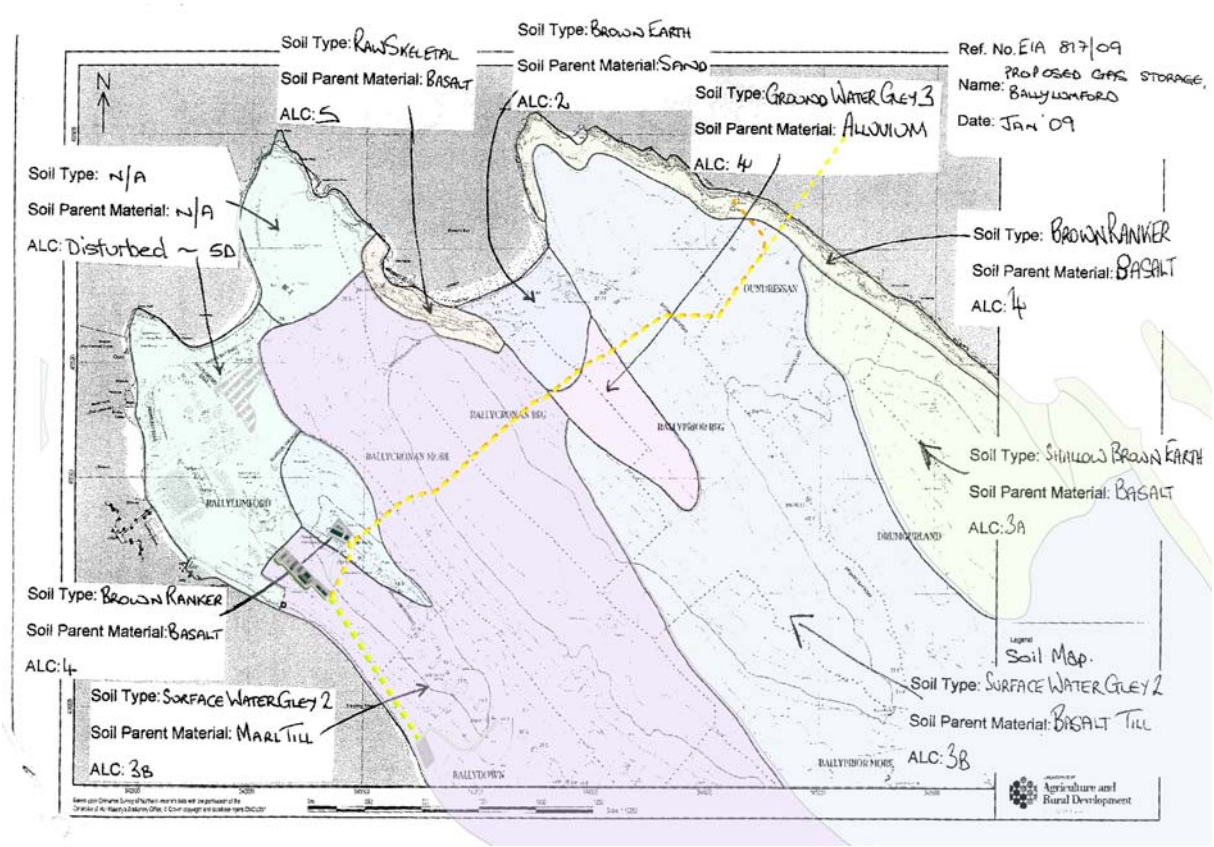

Figure 12.9 Soil Map

The soil map shows that main gas plant facilities and the majority of the pipeline route crosses soils classified as "Surface Water Gley". The National Soil Map and Soil Classification information paper (Cranfield University, 2007) describes these as seasonally waterlogged, slowly permeable soils, where precipitation inputs at the surface do not drain freely through the ground. The brine leaching plant is located within an area identified as "Brown Ranker", which are soils developed over non-calcareous material, in this case basalt. A short section of the pipeline route passes through an area of alluvium which has had the soil type classification of "Ground Water Gley". Ground water gley soils develop where drainage is poor because the water table is high. As already outlined in the previous section, this area is known to be a superficial aquifer, therefore the drainage across this area of the pipeline route will have to be examined in detail at the detailed design stage. Drainage is further considered in Section 12.3 below.

12.3 Drainage

Measures to ensure adequate management and control of both surface water and groundwater will be required to ensure the stability of the slopes surrounding the facilities and prevent erosion.

Detailed design of each part of the drainage system will be carried out in conjunction with the design of the facilities but the principles of the proposed drainage measures at the leaching plant and gas plant sites are outlined below and illustrated in Figures 12.10 and 12.11.

12.3.1 Leaching Plant Site

The drainage measures described below are shown schematically on Figure 12.10 which has been taken from a geotechnical feasibility study for the alternative site locations undertaken by consultants Hydrock. Due to the elevation of the leaching plant site and the surrounding topography, it is unlikely that groundwater will be encountered. However, should measures to control groundwater be required these would be likely to consist of inclined drains drilled into the base of the cut slopes to provide a preferential drainage path for water and prevent groundwater levels from rising within the rock mass immediately behind the cut slope faces.

Cut off drains may also be required at the crest and toe of the slopes to manage surface water runoff and shallow groundwater flows. Depending on groundwater levels and the permeability of the basalt rock mass (and subject to environmental constraints) it may be possible to discharge surface water runoff from buildings and hard surfaces at the leaching plant site to soakaway pits following appropriate treatment to remove oils and silt. The permeability of the Upper Basalt Formation will be governed by the degree of fracturing present within the rock mass and further ground investigation and testing will be required during front end engineering or detailed design to confirm the ground conditions and feasibility of soakaway drainage. In some cases it is possible to increase the rate of infiltration from soakaways by drilling boreholes from the base of the soakaway to intercept fractured zones at depth. Should discharge to soakaways not be possible then surface water collected at the leaching plant site will need to be discharged either to any existing drainage system within Ballylumford Road (if possible) or transferred to the system put in place for the main Gas Plant site, as described below. Flow attenuation/storage measures (e.g. buried storage tanks) will also need to be provided at the leaching plant site to control rates of discharge if soakaway drainage is not possible.

12.3.2 Main Gas Plant Facility Site

The drainage measures described below are shown schematically on Drawing 12.10. The majority of the gas plant platform will be hard surfaced or covered with buildings. Although this is beneficial in terms of limiting rates of infiltration into the fill materials used to construct the platform, a comprehensive surface water drainage system will be required to collect and dispose of surface water.

At this stage, it is proposed that surface water is managed via a network of drains and carrier pipes to a point near the access road at the southern end of the platform. From this point, a carrier pipe would be laid to discharge the water into a series of soakaways located within the field to the south east of the site.

In order to control surface water run-off and shallow groundwater flows from the area up slope of the proposed gas plant platform, a cut-off drain will be installed to a depth of, say 3m along the upslope edge of the platform. The cut off drain will consist of a half slotted pipe placed at the base of a trench that is backfilled to ground level with granular material. The

pipe would need to fall at a shallow gradient towards the southern end of the platform, where it could then be connected into the carrier pipe to discharge into the soakaways.

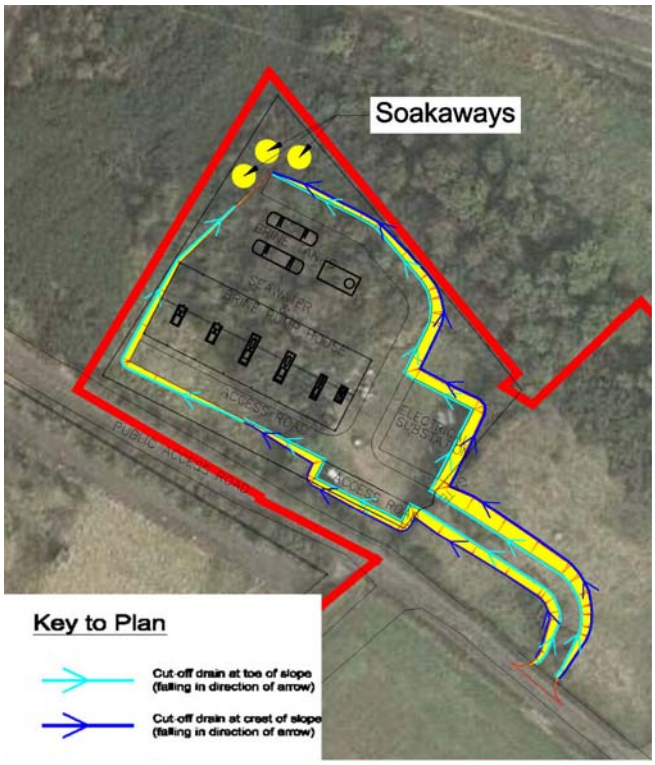

Figure 12.10 Schematic Drainage Proposal at Leaching Plant Site

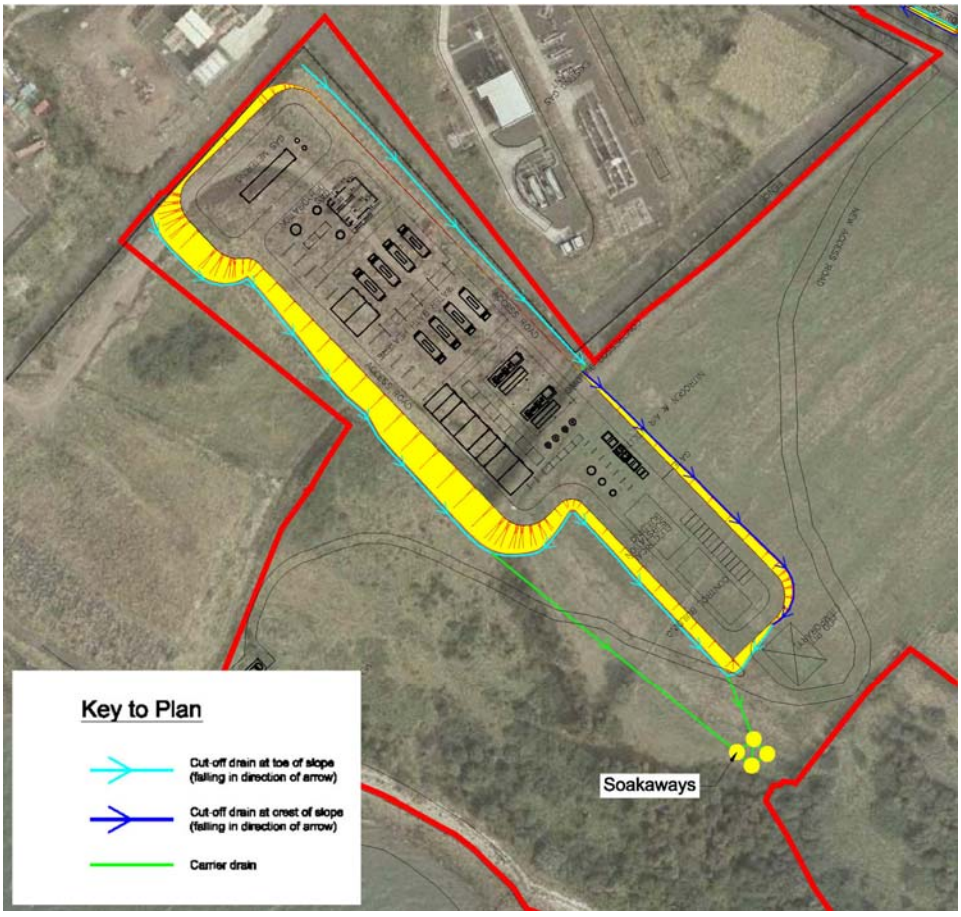

Figure 12.11 Schematic of Drainage Proposal at Main Gas Plant Facility

The existing farm access track that runs down the hillside immediately adjacent to the southern side of the sterile zone surrounding the existing AGI site and then continues downhill between former disposal Areas 2C and 2D (refer to section 3.2.6 in Chapter 3) follows the line of a valley, which is likely to concentrate surface water flows during heavy rain. Where the fill placed to form the gas plant platform crosses this valley, measures will be required to intercept any surface water flow in the valley and divert it into the cut-off drain on the up slope side of the platform or carry it in a separate carrier pipe/culvert running along the upslope edge of the platform and then connecting into the soakaways.

In order to control surface water that runs down the face of the proposed embankment, a toe drain will be required at the toe of the embankment slope. This will also discharge to the soakaways.

Measures to treat the surface water to remove oils and other contaminants and silt in order to comply with the conditions of any discharge consent can be installed in the field immediately upstream of the soakaways. As described above, it is thought that approximately 4m of clayey glacial till is present above rock head at the location shown for the soakaways. It will therefore be necessary to extend the soakaways down into the underlying bedrock. The soakaway positions shown on Figure 12.11 are close to the boundary between the Lower Basalt Formation and Ulster White Limestone Formation shown on the geological map on Figure 12.6. Detailed investigation will be required during front end engineering or detailed

design to confirm the ground and groundwater conditions and confirm the feasibility of soakaway drainage.

Another factor that will need to be taken into account in finalising the location and details of a soakaway system is the proximity of the landslip at the base of the hillside beneath the main gas plant facilities and the vent area. Further investigation of both the proposed soakaway location and the landslip will be required during front end engineering or detailed design.

12.3.3 Pipeline Routes

Particular emphasis is placed on ensuring that installed agricultural land drainage crossed by the pipelines is maintained/reinstated. In poorly drained areas, land drainage is required to enhance rooting conditions and structure in otherwise wet soils, and, on arable land, to extend the period during which soils may be cultivated without risk to soil structure. Drainage design varies according to soil type, cropping practice, landform, climate, and available technology.

At the detailed design stage, land drainage in each field will be carefully inspected and a record prepared. A pre-construction scheme will be developed in discussion with landowners/occupiers for those areas where such a scheme is deemed necessary. This may entail the installation of new header drains to intercept the existing land drainage, which will be cut by the pipeline trench. This serves to maintain the existing drainage system during the construction period whilst minimising the possibility of surface water from entering the working area. During actual construction, all drains encountered during trench digging operation are identified and recorded. An appropriate method of permanent reinstatement will be devised and agreed with the landowner/occupier or agent. Where the pipelines pass under a land drain the usual method of reinstatement is to install a replacement section of drain with a permanent, rigid support carrying it over the filled-in pipe trench. Where necessary, new lateral and header drains are laid to new outfalls to replace drains rendered inoperative by the pipelines.

12.4 Slope Stability

The overall/global stability of the hillside surrounding the proposed gas plant site will need to be verified at front end engineering or detailed design stage following a ground investigation to confirm the ground and groundwater conditions and provide information from which characteristic design parameters can be derived for the various material units present at the site.

12.4.1 Gas Plant Site

No evidence of large scale instability has been noted at the site and the deposition of significant volumes/thicknesses of fill material in disposal Areas 2C and 2D (refer to section 3.2.6 in Chapter 3) does not appear to have caused any obvious instability.

Local stability of the embankment slopes on the down slope side of the platform and cut slopes on the up slope side of the platform will be ensured through the adoption of appropriate reinforcement designs and construction methods/sequencing. Reinforced soil techniques will be used to ensure the stability of the embankment slopes and measures such as soil nailing or buttressing can be used to support the cut slopes.

If the ground investigation reveals areas where existing ground conditions are particularly poor, specific measures will need to be designed to ensure the stability of newly formed excavations. Such measures could include the use of embedded retaining walls (e.g. sheet pile walls or contiguous bored pile walls tied back using ground anchors which would enable top-down construction methods to be used, enabling support to be provided as excavation proceeds.

Proposals for the installation of groundwater and surface water control measures are described in 12.3 above. These measures will be important in controlling groundwater levels within the slopes and maintaining stability.

12.4.2 Leaching Plant Site

The existing disused quarry faces exposed at the proposed leaching plant site suggest that cut slopes within the basalt rock mass are unlikely to require heavy reinforcement or support. In order to ensure the safety of personnel working at the leaching plant it is anticipated that rock fall protection netting will be required to cover all exposed rock faces located close to access roads and buildings. The exposed rock faces would normally be inspected by a geotechnical engineer as excavation proceeds and if potentially unstable blocks/wedges of rock are exposed they can either be removed or supported using rock bolts, dowels and netting.

12.4.3 Wellpad Site

The wellpad site will be cut/filled to create a level platform, which will result in a cut face measuring 2.25m into the gently sloping hillside. This face will be graded to reduce the visual impact and retained by gabion walls for safety.

12.4.4 Sea Water Intake Pumping Station Site

The Sea Water Intake Pumping Station will be sunk into a shaft on the foreshore at Castle Robin Bay which will then be covered by a building. During construction/excavation of the shaft the shaft walls will be monitored and potentially unstable sections of rock will be stabilised using the techniques outlined above in 12.4.2 for the exposed rock faces at the leaching plant site.

12.5 Subsidence

Under the pressures created at the depth at which the salt caverns are created, salt behaves in a plastic fashion, a process known as “creep”. Although the pressure of the gas inside the caverns reduces the rate at which the salt creeps, over time the caverns will very gradually converge under the pressure of the overlying and surrounding rock. Detailed calculations on the predicted rate of creep and the implications for the cavern design will be undertaken at the detailed design stage, once a core sample of the salt beneath Larne Lough has been recovered from the first cavern borehole. However, a preliminary assessment of the likely rate of convergence and associated subsidence has been undertaken for this project by the Leipzig Institute of Rock Mechanics, based on their experience in working in similar gas storage projects where such creep is normal. More detail on this assessment is included within the Supplementary Technical Report included in Appendix 4.2 of this EIS.

The parameters used for the calculations are the distance between each of the cavern centres of 300m, a reference depth of 1,620 m and a period of 30 years of cavern operation. The prediction of cavern convergence has also been based on the assumption of an annual storage cycle throughout the lifetime of the project. The gradual loss of salt volume over time is conveyed one-to-one to the surface, where a very gentle subsidence bowl of a volume equivalent to the total volume loss of salt will form. The eventual subsidence of the ground surface (or sea bed, as these caverns are located beneath Larne Lough) is predicted to be shallow depression with a maximum depth of 28 centimetres above the vicinity of the caverns, reducing to zero within a distance of 1,000 m. The slope of subsidence does not exceed 0.4 mm/m; well below the 10 mm/m maximum recommended for mining operations in UK by the National Coal Board in 1975. The rate and slope of the depression will be insignificant in the context of causing impact to either the gas storage infrastructure, other gas or electrical infrastructure in the area, or any nearby buildings.

The outline design has predicted rates of cavern convergence based on the available information to ensure that from the rock-mechanical point of view, the values predicted for subsidence in the vicinity for the planned Islandmagee gas storage are not significant.

However, in order to prepare the final cavern design, core samples taken from the first cavern well will be tested to provide detailed information about the geo-mechanical properties such as strength and deformation as well as creep behaviour of the storage horizon and contiguous strata. From these the detailed design of the caverns and the operating pressure range will be determined for safety ensuring any subsidence is maintained within acceptable limits.

Owing to this behaviour and because internal cavern pressure will always be below lithostatic pressures a salt cavern will shrink or converge over its lifetime. The resulting loss of salt volume will be conveyed one-to-one to the surface, where a very gentle subsidence bowl of a volume equivalent to the total volume loss of salt will form.

12.6 Impact Assessment

The geological impact of the proposed scheme may be related to the potential loss or damage of existing outcrops and the exposure of the public to potential rockfall hazards. These issues are considered below.

12.6.1 Loss of Exposure

Good quality outcrops of Triassic-Cretaceous sedimentary and Tertiary igneous rocks are widely exposed in extensive cliff sections along the coastal fringes of Islandmagee. The nearby Portmuck, Gobbins and Cloghfin Port ASSIs have all been designated for their geological importance.

No geological features of significance to the scientific study of the Triassic-Cretaceous or Tertiary successions were identified in the vicinity of the above ground facilities.

Bedrock is not currently exposed at the site of the main gas plant facility and the wellpad. Bedrock is not currently exposed along the majority of the proposed sea water, brine and gas pipeline routes. There will therefore be no significant impact on exposure at these sites.

The site of the brine leaching plant is within a former basalt quarry and the quarry faces have exposed bedrock, however this bedrock is not considered to have any geological significance. Excavation for the leaching facility will create a fresh bedrock face which will give additional exposure and may enhance the geological value of the site. Impacts at this site are therefore considered to be minor positive.

The site of the sea water intake pumping station at Castle Robin Bay is not considered to have any exposures of geological significance; however there is a stack feature which is of moderate significance. The construction works associated with the sea water intake pumping station are not anticipated to have any impact on the stack as the works area will be located south west of the stack. It is not currently known what thickness of basalt lies beneath the sea water intake site and whether the sump and/or intake pipelines will extend into the Ulster White Limestone or Hibernian Greensand Formations. Should exposures of limestone or greensand be encountered during excavation, these will be recorded.

12.6.2 Rockfall

The new exposed rock faces at the brine leaching facility, the sea water intake pumping station and, to a lesser extent, the wellpad site will not pose a risk to the public as the sites will be secure during construction and operation. However, there may a potential risk to construction workers during construction and site personnel during the operation of the facility. Should there be a risk of instability of the rock face, the mitigation measures outlined in sections 12.4.1 and 12.4.2 will be implemented to ensure that the site remains safe throughout the construction and operational phases.

12.6.3 Aquifer Contamination

Although the abstraction of groundwater in the Islandmagee or Larne Lough area is thought to be limited, engineering best practice will be employed during the creation of the cavern access wells to ensure that no adverse impacts occur to the aquifer layers. During drilling operations, the near-surface layers will be cased to protect any potential aquifer for future use. The surface casing will be set before penetrating any Triassic salt layer, allowing any regional fresh water aquifer (for example in the Cretaceous Ulster White Limestone Formation) to be cased off and isolated prior to the potential use of oil based drilling mud in subsequent well sections.

Careful consideration will be given to drainage design and implementation from the initial phases of site clearance at the proposed sites of the brine leaching plant, gas facilities and wellpad to ensure that all surface runoff is controlled, treated and disposed of in an appropriate manner.

12.7 Residual Impacts

There will be no significant impacts to geology, hydrogeology or hydrology arising from the proposed gas storage facility at Islandmagee. The location of the above-ground facilities and pipeline routes does not encroach on the ASSI areas and whilst excavation of the pipeline routes and leaching plant site will result in the removal of some basalt, these outcrops are not of geological significance. The seismic mapping of the area and logging of the future caverns' wells, together with other ground investigation studies necessary during the detailed design phase, will be made available to the Geological Survey of Northern Ireland (GSNI) and should provide useful information for future study and enhance the understanding of the geological history of the area. The construction of caverns within the salt will cause a very gradual depression of the seabed and shoreline above the cavern area as the salt "creeps," with a maximum variation of 28cm from present day levels. The rate and degree of this subsidence is considered to be non-significant.