TOBIN

APPENDIX 11

Water Quality

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Appendix No. 11
Water Quality

TOBIN Consulting Engineers

APPENDIX NO. 11

WATER QUALITY

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SURFACE WATER AND GROUNDWATER HYDROLOGY

1 INTRODUCTION

This report, which was prepared following a desk study and site investigations at Derrinumera, addresses the surface water and groundwater environments in the region of the proposed development and existing landfill site. Relevant documents that were accessed comprised:

- Publications by the Department of the Environment, Heritage and Local Government (DoEHLG), the Environmental Protection Agency (EPA) and the Geological Survey of Ireland (GSI); and
- The original Waste Licence Application (No. 21-1) submitted to the EPA by Mayo County Council in 1998.

2 SURFACE WATER HYDROLOGY

Surface water hydrology for the site was addressed in the original Waste Licence Application submitted by Mayo County Council to the EPA in 1998. This document was prepared prior to lining of Cell No. 1 and the construction of a cut-off wall around the perimeter of Derrinumera Landfill. One of the main objectives of this cut-off wall, which was installed during the period April to July 2001, is to retain any leachate flowing from the waste body. The main findings from the 1998 report are included below together with results from recent hydrological investigations undertaken post-lining of Cell No. 1 and cut-off wall installation.

2.1 SURFACE DRAINAGE

The regional surface water drainage is shown on Figure 2.1.1. The subject site is located near the head of the Glaishwy River Catchment, which has a total area of 6.5km^2. Any surface runoff from the subject site flows to the Glaishwy River. The source of the Glaishwy River is located to the southeast of the site and this river is still only a small stream where it passes the landfill site to the east. There are no flow data available for the Glaishwy River. Further north of the subject site, a number of tributaries flow into the Glaishwy River as it flows north to Beltra Lough, which is situated approximately 3.5km to the north of the subject site. A river also feeds Beltra Lough from the north and another from the southeast, as well as a number of smaller streams from both east and west of the lake. Beltra Lough has a total catchment area of 98km^2. The outflow from the lake is the Newport River, which flows to the sea at Newport Bay. The Newport River has a total catchment area of 143km^2.

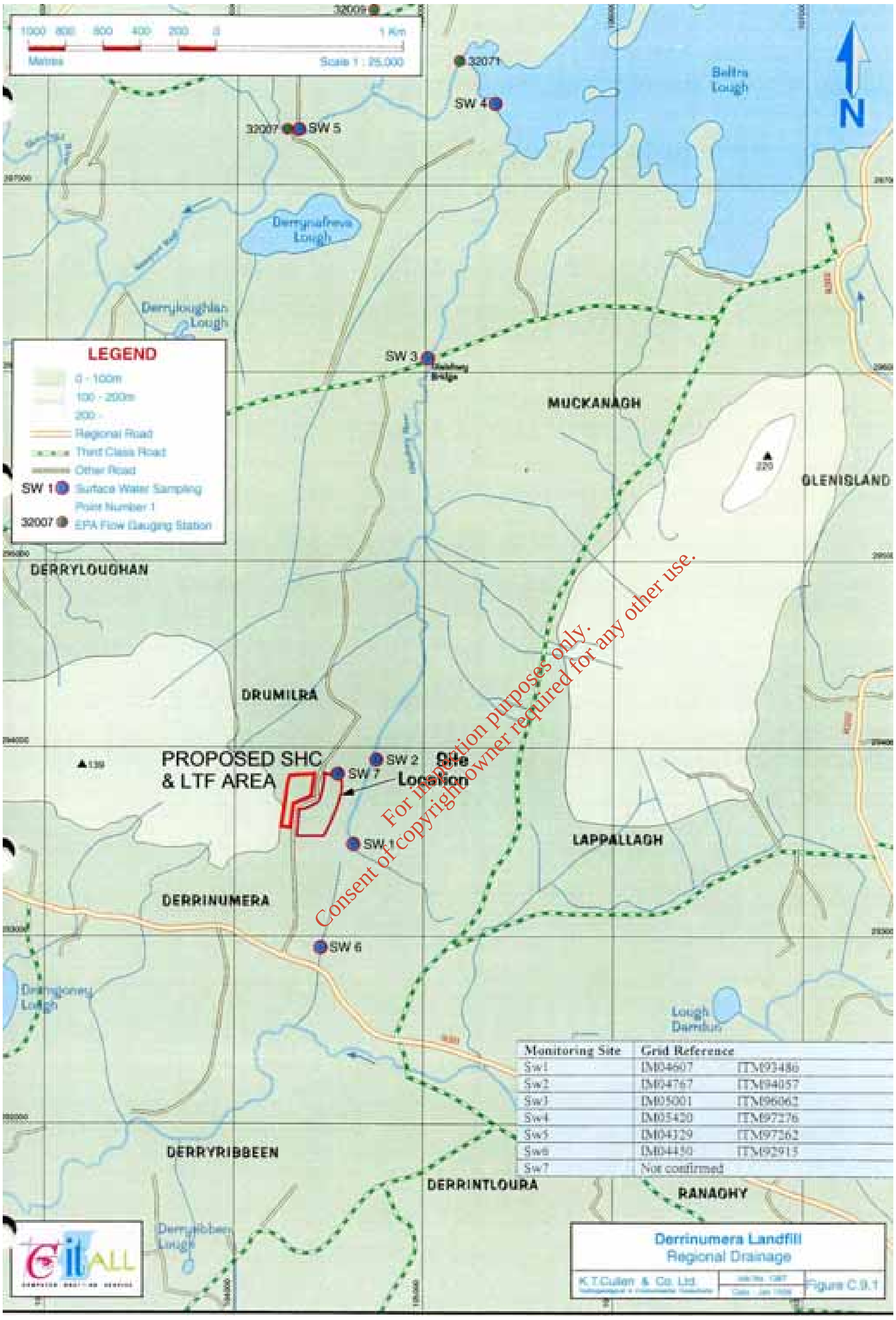


Figure 2.1.1 Regional Drainage

The ridge to the south of the landfill site represents a catchment divide. Any surface runoff or through flow from precipitation south of this ridge will eventually enter the Owennabrockagh River to the south, which flows to the sea at Clew Bay.

There are no other watercourses entering or leaving the subject site nor are there any areas of standing water with the obvious exception of the leachate ponds.

2.2 SURFACE WATER QUALITY

2.2.1 1997 ANALYTICAL DATA

Surface water samples were collected from 7 No. surface water monitoring stations (SW1 to SW7) on the 6th November 1997 as part of the study for the original Waste Licence application submitted to the EPA by Mayo County Council (Mayo County Council, 1998). These water samples were collected prior to the lining of Cell No.1 and construction of the cut-off wall around the perimeter of the landfill. The water samples were analysed in the Forbairt inorganic laboratory in Glasnevin. A wide range of chemical and metal parameters were requested for analysis. The locations of the sampling points are shown on Figure 2.1.1 above and the results of the analyses are presented in Tables in Appendix 12, Volume IV.

SW1 was established as an upgradient and background monitoring point. SW2, SW3, SW4 and SW5 are all located downstream on the Glaishwy River/Beltra Lough/Newport River system. SW6 is located on the stream to the south of the site and SW7 is a leachate sample taken from the outflow weir

SW1 is slightly acidic with a pH of 5.25. The reported conductivity, hardness and alkalinity are very low, as are the levels of calcium, magnesium, sodium and potassium. The iron, manganese and aluminium concentrations are slightly elevated. However, the samples were not filtered and these values represent total ion concentrations rather than dissolved ions. Suspended clay minerals may be the cause of these elevated concentrations. Ammonia is slightly elevated and organic carbon and COD are both high, while the dissolved oxygen is low. The quality of the water sampled at SW1 is good and appears to be predominantly rainwater flowing off the bog, which explains the low pH. The low concentrations of all the major ions suggest that there is little or no groundwater discharge upstream of this sampling point. The elevated organic carbon, COD and ammonia are indicative of decaying plant material which can be natural or may result from agricultural activities.

The sample collected from the leachate pond (SW7) had extremely high concentrations of sodium, potassium, iron, manganese, chloride and ammonia, as would be expected. The sample differed from the leachate sampled in MW6. The reported concentrations of many of the ions for the sample from SW7 such as magnesium, sodium, potassium, chloride and ammonia are reduced to between half and a third of the corresponding values detected in the leachate sample taken from MW6. This may be due to dilution of the leachate in the leachate pond by rainwater and possibly even groundwater. The conductivity and alkalinity values are also reduced by approximately the same proportions.

The effect of the leachate discharge can be seen in the chemistry of the samples taken from the 5 No. monitoring points on the Glaishwy River/Beltra Lough/Newport River system. However, these water samples were collected prior to the lining of Cell No. 1 and the construction of the cut-off wall around the perimeter of the landfill. The reported chemistry for SW4 in Beltra Lough and for SW5 in the Newport River are very similar to SW1, which is the upgradient monitoring point discussed above. The pH in SW4 and SW5 is slightly higher, the dissolved oxygen is significantly higher and the COD is lower. As with SW1 this water appears to be predominantly rainfall runoff and is of excellent quality. Only minor agricultural pollution was detected with levels of nitrate, nitrite and ammonia only slightly above background.

The effects of the leachate can be seen in the samples collected pre-lining of Cell No. 1 and cut-off wall construction, from sampling points SW2 and SW3 on the Glaishwy River. Concentrations of calcium, magnesium, sodium, potassium, iron, manganese, aluminium, nitrate, nitrite, chloride and ammonia are all highly elevated in SW2 but not as elevated in SW3. The degree of dilution between SW2 and SW3 is clear from the analytical results, with practically all levels of ions at SW3 significantly lower than at SW2. The extremely low dissolved oxygen and high BOD and COD at SW2 are similar to SW3.

SW6 on the stream to the south of the landfill site has very similar chemistry to SW1. The only noticeable high ion concentrations are the iron, manganese and aluminium values. The reason for these elevated concentrations, as explained above, is more than likely due to suspended clay particles in the sample, which was not filtered. The high level of 53mg/l suspended solids confirms this.

2.2.2 OCTOBER 2003 ANALYTICAL DATA

Surface water samples were collected from surface water monitoring stations SW1 to SW6 during October 2003 as part of routine monthly surface water monitoring. A water sample was also collected from the monitoring station labelled DSW-1, which is located on a diverted section of the Glaishwy River, immediately to the northeast of the landfill and slightly upgradient of SW2. These water samples were collected post-construction of the cut-off wall and lining of Cell No.1. The water samples were analysed by Connemara Laboratory Solutions (CLS) for a wide range of parameters. The locations of the sampling points are shown on Figure 2.1.1 and the results of the analyses are presented inAppendix 12, Volume IV, together with the standards quoted in the European Communities Quality of Surface Water Intended for the Abstraction of Drinking Water Regulations (S.I. No. 294 of 1989). These are considered the most appropriate standards with which to compare the analytical results.

In general, the analytical results indicate that the surface water quality is acceptable at all of the monitoring stations for the month of October 2003. However, evidence of slight surface water contamination was detected in the sample taken at SW2 in the form of elevated ammoniacal nitrogen and TON values in relation to the corresponding values for the other monitoring points. The reported ammoniacal nitrogen concentration for SW2 also exceeds the corresponding standard quoted in the Surface Water Regulations. It is not considered that the reported values for SW2, which is located immediately downgradient of the landfill site on the Glaishwy River, indicate significant groundwater contamination at this point due to the effect of leachate. Furthermore, the overall results reported for the sample taken at SW2 in October 2003 show a higher water quality in comparison to the results reported for sampling undertaken at SW2 in October 1997 pre-lining of Cell No. 1 and construction of the cut-off wall around the perimeter of the landfill to retain any leachate flowing from the waste body.

The reported copper concentrations in DSW-1, SW1 and SW4, and the reported iron concentrations for all of the monitoring stations exceed the corresponding standards quoted in the Surface Water Regulations. These elevated iron and copper concentrations may be attributed to naturally occurring high background levels as iron and copper can be present in significant amounts in soils and rocks such as the formations underlying the region of the proposed development.

3 GROUNDWATER HYDROLOGY

Overburden and bedrock hydrogeology were addressed in the original Waste Licence Application submitted by Mayo County Council to the EPA in 1998 (Mayo County Council, 1998). This document was prepared prior to lining of Cell No. 1 and the construction of a cut-off wall around the perimeter of Derrinumera Landfill. One of the main objectives of this cut-off wall, which was installed during the period April to July 2001, is to retain any leachate flowing from the waste body. The main findings from the 1998 report are included below together with results from recent hydrogeological investigations undertaken post-lining of Cell No. 1 and cut-off wall installation.

3.1 GROUNDWATER OCCURRENCE

Water ingresses were noted at depths varying from 1.0m to 2.75m below ground level in the trial pits excavated to the north of the landfill in 1997. The water inflows were derived from the fluvioglacial sand deposits in all of the trial pits in which these sands were encountered with the exception of 2 No. pits, which were dry (TP6 and TP7). Water inflows from the glacial sandy till were noted in TP9 and TP10 in which the fluvioglacial sands were absent.

Water inflows from the overburden were also noted in some of the groundwater monitoring wells installed at the subject site in 1997 (MW2s, MW3, MW4s, MW4d, and MW7). These inflows were noted at depths varying between 1.6m and 3.2m below ground level and with the exception of MW7, the inflows were observed at the base of the overburden immediately above the bedrock. However, the geological logs for these groundwater monitoring wells do not distinguish between the sandy glacial till and the fluvioglacial sands overburden sequences that have been identified elsewhere at the subject site. This is because these two deposits would be difficult to distinguish when logging a borehole being drilled using an Air Rotary type drilling rig. It is likely that both of these deposits are present at the locations of these boreholes and where they have both been identified elsewhere on the site, the fluvioglacial sand always underlies the sandy glacial till. Therefore, it is likely that the water ingresses noted in the overburden in the groundwater monitoring wells are derived from fluvioglacial sands.

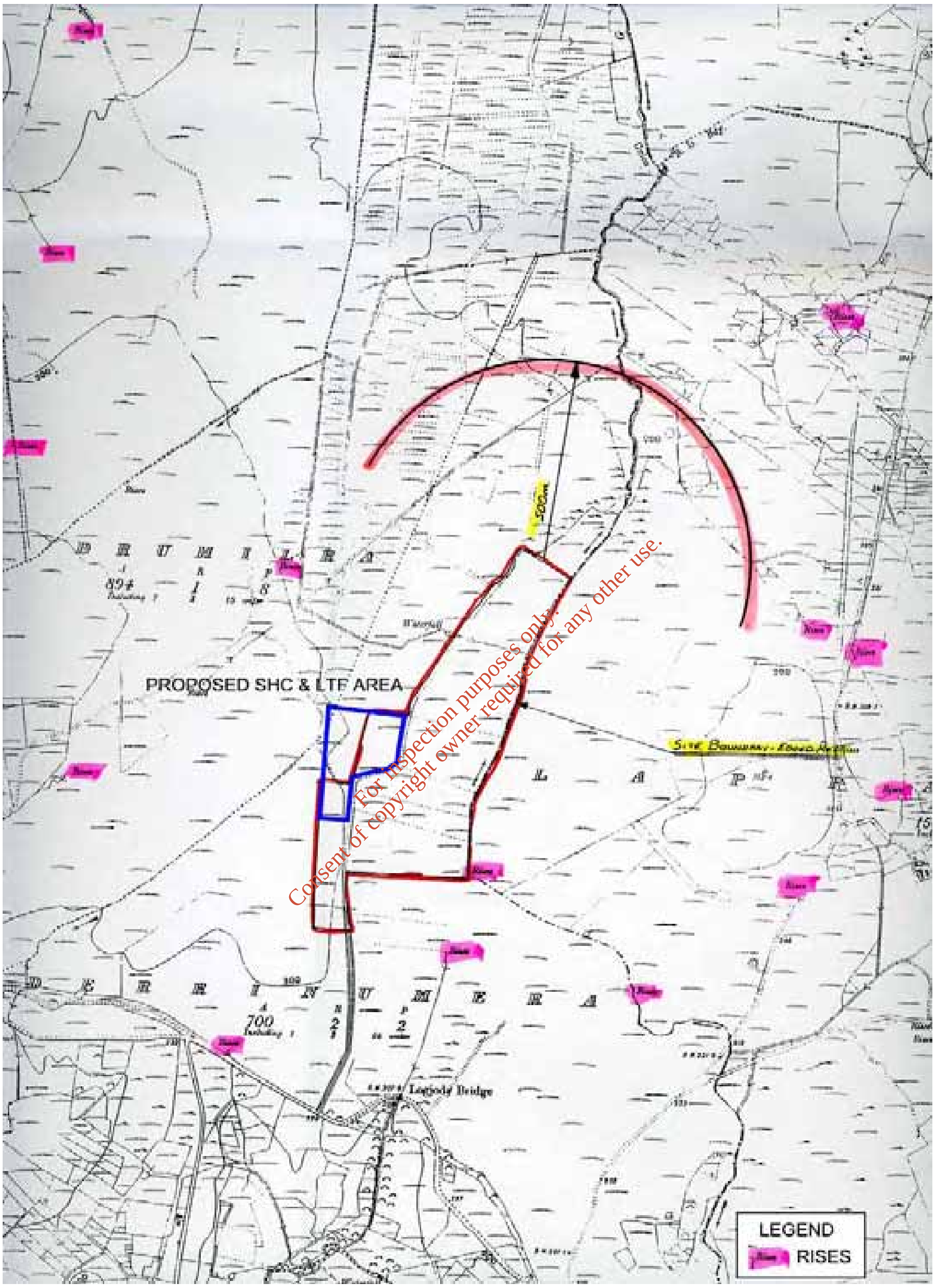
Shallow groundwater was encountered in the overburden in 4 No. of the boreholes installed in 2003 (MW20, MW21, MW24, and MW25). These inflows were noted at depths varying between 2.5m and 5.2m below ground level. In all cases the ingresses were noted at the base of peat overlying either clayey sand, sand, or sand and gravel.

Water inflows were also noted in the bedrock in 4 No. of the groundwater monitoring wells installed in 1997 (MW1, MW2d, MW3, and MW4d) at depths ranging from 5.0m to 19.5m below ground level. Water was encountered at shallow depths in 4 No. of the bedrock monitoring wells installed in 2003 (MW17, MW20, MW24, and MW27), at depths ranging from 5.1m to 8.0m below ground level. These water strikes occurred either at rockhead or within 1.6m of rockhead. A deeper water ingress was also encountered in MW20 at 14m below ground level.

3.1.1 WELL AUDIT AND SPRINGS (RISES)

A formal search of the GSI Well database has revealed that no abstraction wells are located within a 2km radius of the subject site.

A total of 6 No. rises have been identified west of the proposed development on the Ordnance Survey 1:10,560 scale map for the area. 2 No. more are evident to the south of the site and a further 2 No. are located southeast of the landfill site. These rises generally indicate springs or stream sources. The locations of all of these rises are shown on Figure 3.1.1. The 2 No. rises to the southeast are related to the Glaishwy River, and 1 No. of these rises is located at the head of this river. The other may be a spring that discharges to the Glaishwy River immediately to the southeast of the subject site. The other rises form the heads of streams that flow off the high ridge to the south of the subject site that acts as a catchment divide between the Glaishwy River and Owennabrockagh River catchments. None of these rises interact with the hydrogeological regime at the landfill site as they are not situated in the local catchment area for the site.



Source: Waste Licence Application EIS for Derrinumera, 1998

Figure 3.1.1 Water Rises in the Vicinity of Derrinumera Landfill

3.1.2 PERMEABILITY TESTING

Overburden and bedrock hydrogeology were addressed in the original Waste Licence Application submitted by Mayo County Council to the EPA in 1998 (Mayo County Council, 1998). As part of this application permeability testing, consisting of rising and falling head tests, was undertaken at the subject site. A summary of the results is presented in the Table C.6.3 in Appendix 9, Volume IV. The results of the permeability tests conducted in the bedrock monitoring wells demonstrate that the bedrock has low permeability. Four of the five bedrock wells tested had permeabilities in the range of 10^{-6} and 10^{-7}. MW7, located on the opposite side of the Glaishwy River from the landfill, had a higher permeability in the order of 8.9×10^{-5}. The permeability of the bedrock could vary as faults and/or fissures could exist which would be zones of enhanced permeability. Sub-vertical joints and fissures were observed in an area of bedrock exposure to the west of the subject site. These features may also exist in the bedrock in the vicinity of the drilling locations but the sub-vertical nature and narrowness of these features makes them difficult to intersect and identify in vertical intrusive boreholes. The driller reported easier than normal penetration through the bedrock encountered in MW24 at Location B suggesting possibly more fractured bedrock at this location.

The bedrock underlying the subject site is described as interbedded medium to coarse grained sandstones and conglomerates composed mostly of quartzite pebble clasts (Croaghmoyle Formation) (Long et al, 1992[1]). A provisional aquifer classification by the Geological Survey of Ireland describes the Croaghmoyle Formation as a Locally Important Aquifer that is moderately productive only in local zones (Ll). Most groundwater circulation in these rocks is in the upper weathered zone, along more permeable beds of limited extent and along fracture or fault zones. The flow is generally in localized zones with little or no continuity between them.

Water was encountered in 4 No. of the bedrock monitoring wells at depths ranging from 5.1m to 8.0m below ground level. These water strikes occurred either at rockhead or within 1.6m of rockhead. A deeper water ingress, described as a slight increase in water return, was also encountered in MW20 at 14m below ground level (6.6m below rockhead). This indicates that groundwater storage and movement is mostly in the weathered zone (that probably extends to 2m below rockhead) although deeper groundwater flow may occur in places. Any deeper groundwater flow is likely to be in joints, fissures or fractures that offer zones of enhanced permeability. The degree of weathering and hence permeability of the shallow bedrock will also vary laterally across the subject site.

As part of the original application to the EPA, permeabilities of 9.8×10^{-5}m/s and 1.3×10^{-4}m/s were measured in the 2 No. overburden monitoring wells tested (MW2s ad MW4s, respectively). 2 No. types of overburden were identified at the subject site during site

[1] Long, MacDermott, Morris, Sleeman, Tietzsch – Tyler, (1992) – “Geology of North Mayo”, Geological Survey of Ireland Publication

investigations in 1997, namely sandy glacial till and fluvioglacial sand. These two deposits would be difficult to distinguish when logging a borehole being drilled using an Air Rotary type drilling rig and consequently they are not distinguished on the geological logs for either of these boreholes. However, the logs for the trial pits that were excavated in this area suggest that both of these overburden sequences would be present in these boreholes. It is likely that the higher permeability value represents the fluvioglacial sand whilst the lower permeability value represents the sandy glacial till which would have a higher content of fines thus reducing the permeability of this formation.

3.2 GROUNDWATER FLOW DIRECTIONS

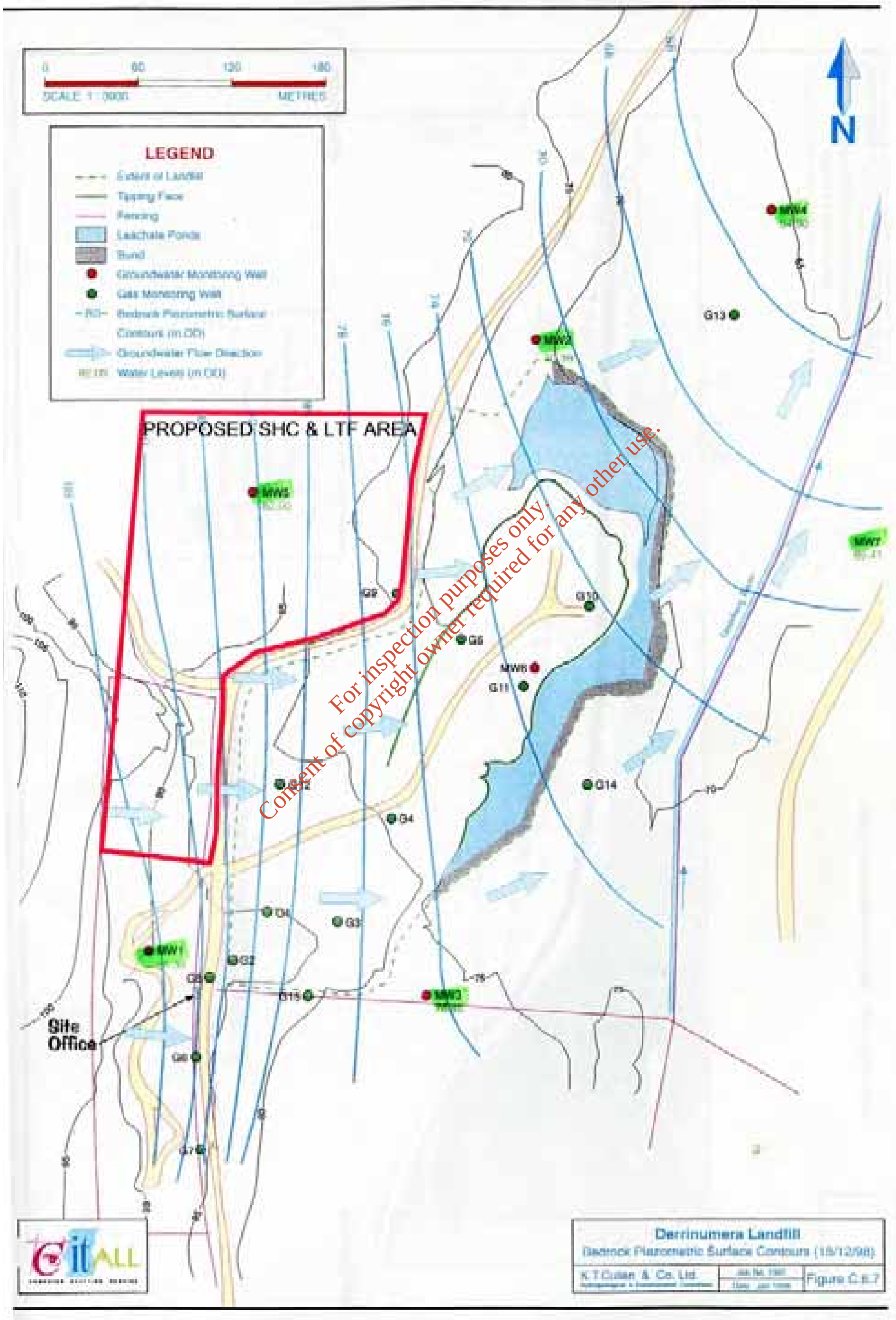
3.2.1 BEDROCK GROUNDWATER FLOW

Schematic bedrock piezometric surface contours have been produced indicating groundwater flow directions across the landfill site. These contours have been drawn from water levels measured in the bedrock monitoring boreholes. Monthly water levels were measured in the bedrock monitoring boreholes. Drawings have been created for the months of January, April, July and October in 2003 so that any effects of seasonal variation in water levels could be noted. These drawings (labelled Drawings 1 to 4) are presented in Appendix 12, Volume IV.

It can be seen from these drawings that groundwater flow in the bedrock is from west to east under the western half of the site. Under the eastern half of the site the flow turns more toward the northeast. The contours suggest that the Glaishwy River is a discharge zone for groundwater moving under the landfill, with groundwater on the opposite side of the river flowing in a northwesterly direction, toward the river. Therefore, any leachate that percolates down to the underlying bedrock watertable will flow east and northeast toward the Glaishwy River, under the cut-off wall. Given the groundwater flow direction it is likely that the main discharge zone to the Glaishwy River is to the northeast of the landfill site. Bedrock groundwater flow to the south of the catchment divide that occurs to the south of the subject site is expected to be toward the south.

These groundwater flow directions are the same as those identified on a bedrock piezometric surface contours drawing produced as part of the EIS submitted to the EPA in 1998 as part of the Original Waste Licence Application (Mayo County Council, 1998). The contours shown in this drawing, which is presented on Figure 3.2.1, are based on water levels measured on the 18th December, 1998. All of these measured levels and corresponding elevations are presented in the Tables in Appendix 9, Volume IV. These contours represent the winter season only.

This groundwater flow pattern appears to be consistent throughout the seasons as indicated on the 4 No. bedrock piezometric surface contour drawings, which represent the months of January, April, July and October, 2003. As would be expected water levels are slightly higher across the site during winter months. This is reflected in the drawing for January, as there is a slight downgradient shift in the 70mOD contour toward the discharge zone along the river in comparison to the other drawings. The contour recedes back upgradient during the summer and spring seasons indicating slightly deeper groundwater levels during these seasons.



Source: Waste Licence Application EIS for Derrinumera, 1998

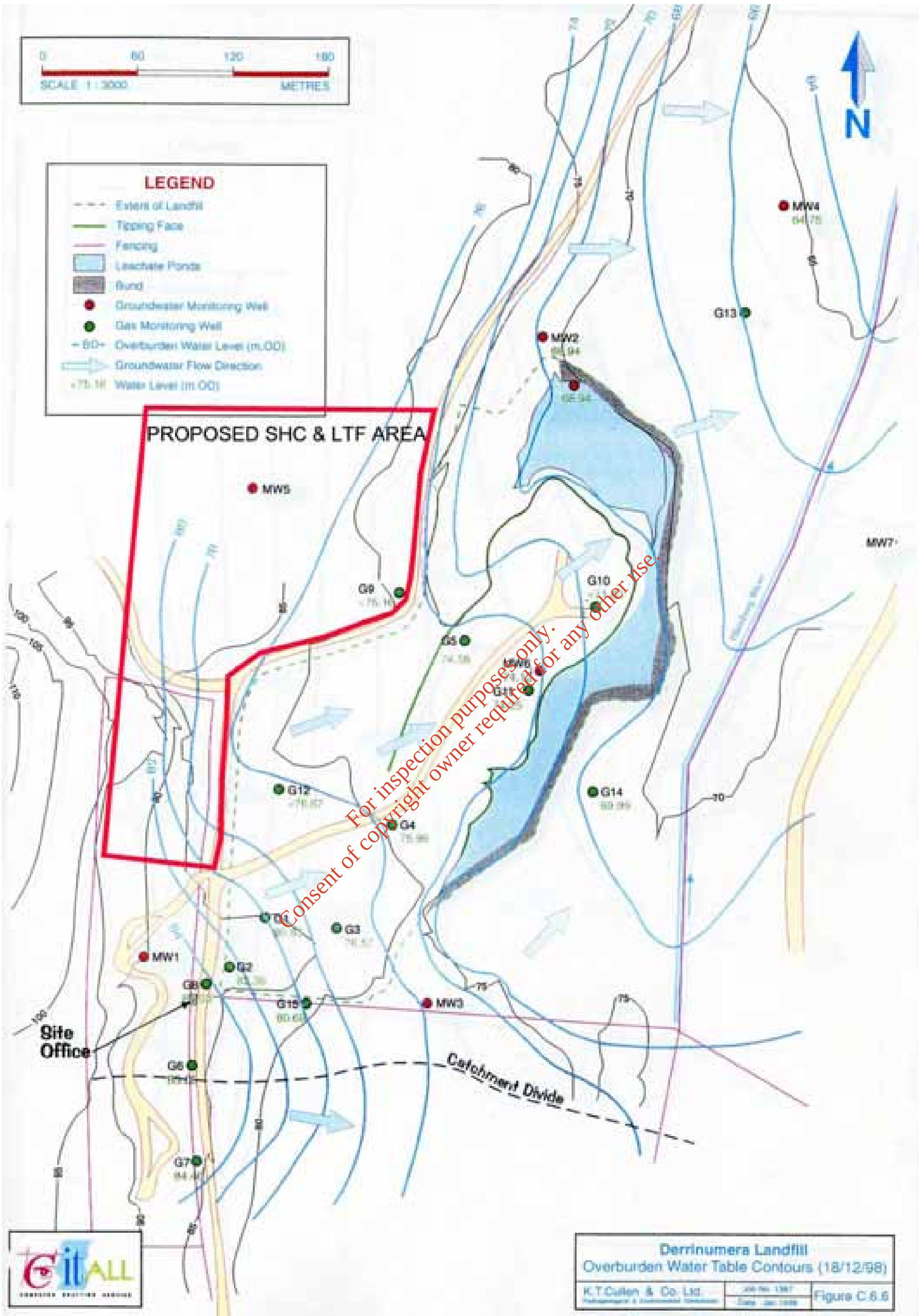
Figure 3.2.1 Bedrock Piezometric Surface Contours

3.2.2 OVERBURDEN GROUNDWATER FLOW

With regard to shallow groundwater flow directions, a schematic drawing of overburden watertable contours for the month of October 2003 was produced. This drawing is presented as Drawing 5 of Appendix 12, Volume IV. Insufficient data is available to produce overburden watertable contours for any other months. In general, the overburden flow pattern appears similar to the overall bedrock flow pattern, ie., west to east under the western half of the site, turning more toward the northeast under the eastern half of the landfill site. The cut-off wall, installed through the overburden and founded on bedrock around the perimeter of the landfill, will naturally disrupt the overburden groundwater flow. However, it is possible that a build-up of groundwater pressure over time on the inside of the cut-off wall could result in flow under the cut-off wall. Water moving immediately under the cut-off wall would then rise up into the overburden on the other side of the wall in an attempt to regain the natural flow through the overburden that has been disrupted by the cut-off wall.

The bedrock ridge to the south of the site office is a catchment divide and any water falling south of this divide will enter the Owennabrockagh River Catchment to the south.

An overburden watertable contour map was also produced as part of the EIS submitted to the EPA in 1998 with the original Waste Licence Application (Mayo County Council, 1998). The contours shown in Figure 3.2.2 are based on water levels measured on the 18th December, 1998. These contours represent the winter season only, and also the pre-cut-off wall construction situation. On the basis of the contours plotted on this map, the shallow groundwater flows in a north-easterly direction from the site office towards the Glaishwy River, via the landfill. Mounding of groundwater/leachate occurs in the landfill, which causes local variations in groundwater flow directions but the dominant flow direction remains toward the northeast. The overall shallow groundwater flow direction is the same on the original 1998 map as the map based on October 2003 shallow water levels i.e., flow is to the northeast.



Source: Waste Licence Application EIS for Derrinumera, 1998

Figure 3.2.2 Overburden Water Table Contours

3.2.3 VERTICAL HYDRAULIC GRADIENTS AND RECHARGE AND DISCHARGE ZONES

Comparison of the bedrock piezometric surface contours and the overburden watertable contours for the month of October 2003 suggest that there are slight upward hydraulic gradients in places where the piezometric surface contours are slightly higher than the overburden contours. This is most notable in the low-lying area to the north of the landfill site where the bedrock piezometric surface contours converge on each other indicating that this area is the main discharge zone to the Glaishwy River. This is confirmed by comparing the reduced water levels measured on the 8th of October 2003 in the recently installed bedrock and overburden groundwater monitoring wells MW24 and MW25 in this area. The reduced water level in the bedrock monitoring borehole (MW24) was 65.96mOD level compared to a slightly deeper reduced water level of 65.66mOD in the adjacent overburden monitoring borehole (MW25). These measurements suggest a slight upward hydraulic gradient in this area. The driller reported easier than normal penetration through the bedrock encountered in MW24 at Location B, suggesting possibly more fractured and hence permeable bedrock at this location. The reduced water levels in the bedrock boreholes were deeper than the reduced water levels in the overburden boreholes at all of the other recent drilling locations on this date, indicating downward hydraulic gradients in these areas.

Slightly upward gradients may also exist in some areas under the landfill that may encourage some upward flow from the bedrock to the waste body. However, the volume of groundwater moving from the bedrock to the waste body is expected to be insignificant for the following reasons;

1. The upward gradient is minor (and probably seasonal),
2. The peat below the waste is likely to act as a low permeability barrier,
3. The permeability of the bedrock is low.

Given the permeabilities presented in Section 3.1.2 above, there is greater potential for groundwater to enter the waste body from the overburden as opposed to the bedrock, particularly from the higher permeability fluvioglacial sands. However, based on observations during installation of gas monitoring wells in the main recharge zone to the west and southwest of the landfill, these sands are not common in the overburden upgradient of the landfill. Sandy till above either boulders or bedrock was encountered in these boreholes. As discussed above, this till is expected to have a permeability in the order of 10^{-5} or 10^{-6} m/s. The permeability of the bedrock could vary as faults and/or fissures could exist, which would be zones of enhanced permeability.

Downward hydraulic gradients have been identified on the higher ground to the west indicating that this is the likely main recharge area for groundwater that circulates under the landfill. The high ground to the west and southwest of the landfill acts as a recharge zone for both the overburden and bedrock. Bedrock and overburden flow from this area is to the east and southeast through, under and around the landfill, toward the main discharge area along the Glaishwy River.

These observations represent the situation in October and that seasonal variations in vertical hydraulic gradients are likely. The water levels measured in the recently installed overburden and bedrock groundwater monitoring boreholes on the 8th of October, 2003 are presented in Table 3.2.1 below.

Table 3.2.1 Water levels in monitoring boreholes MW17 to MW28 measured on 8th October, 2003

Overburden boreholes	SWL (mbgl)	Reduced water level (mOD)	Bedrock boreholes	SWL (mbgl)	Reduced water level (mOD)
Location A					
MW26	0.44	67.71	**MW27**	0.83	67.67
MW28	0.57	67.61			
Location B					
MW25	0.68	65.66	**MW24**	0.27	65.96
Location C					
MW21	0.18	68.92	**MW20**	0.78	68.39
MW23	0.8	68.37	**MW22**	1.37	68.13
Location D					
MW18	0.24	70.99	**MW17**	0.37	70.96
MW19	0.29	71.21			

An upward hydraulic gradient was also identified to the north of the site in the hydrogeological investigations undertaken in 1998 and submitted to the EPA as part of the original Waste Licence Application (Mayo County Council, 1998). Slightly upward hydraulic gradients were also suggested in the landfill itself, whilst downward hydraulic gradients were identified near the site office on the higher ground. These observations are based on water levels measured during the winter season.

3.3 GROUNDWATER QUALITY

3.3.1 1998 ANALYTICAL DATA – MONITORING BOREHOLES MW1 TO MW7

Groundwater samples were taken from all 6 No. bedrock groundwater monitoring wells and the leachate monitoring well on the 5th January, 1998 as part of the study for the original Waste Licence Application submitted to the EPA by Mayo County Council (Mayo County Council, 1998). These water samples were collected prior to the lining of Cell No.1 and construction of the cut-off wall around the perimeter of the landfill. The results of water samples collected in 2003, post cut-off wall construction and lining of Cell No.1, are discussed in the following sections. The inorganic laboratory at Forbairt, Glasnevin, carried out chemical analysis of all samples collected in 1998. Analyses were conducted for a wide range of chemical and metal parameters. The analytical results are presented in the Table C.6.4 in Appendix 12, Volume IV. The results are discussed below.

3.3.1.1 Upgradient monitoring wells

MW1 and MW5 are located to the west of the site and are considered to be upgradient wells. Certain parameters are elevated above the Maximum Admissable Concentrations (MAC's) for drinking water in Ireland in results reported for both of these wells. The pH values reported for these wells are between 9.5 and 10.0, which is highly alkaline and exceeds the MAC that ranges from 6-9. The magnesium and potassium concentrations are two to three times higher than the MAC. The nitrite is six times the MAC in MW1 and also exceeds the MAC in MW5. The sodium concentration of 98mg/l reported for MW1, while not exceeding the MAC is slightly elevated, as is the nitrate level of 11mg/l reported for MW1. The organic carbon content is elevated in MW1 in comparison with the concentrations reported for the other bedrock groundwater monitoring wells. The calcium levels of 4.2mg/l and 7.5mg/l reported for MW1 and MW5, respectively, are very low.

3.3.1.2 Leachate monitoring well

MW6 is positioned on the landfill and the reported chemistry is typical of leachate generated from domestic and commercial waste. The ammonia, sodium, chloride and potassium concentrations are all extremely high in comparison to the corresponding MACs in the Drinking Water Regulations. Iron, manganese, aluminium, sulphur, chromium, phosphorous, zinc, nickel and boron are also highly elevated. The conductivity and alkalinity are an order of magnitude higher than in the upgradient monitoring wells. The pH is close to neutral (7.5) and the temperature measured in the field was high (21 degrees Celsius), as are the reported BOD and COD levels.

3.3.1.3 Downgradient monitoring wells

MW2d, MW3, MW4d and MW7 are all located downgradient of the landfill. Analysis of the chemistry reported for these wells indicates that the bedrock groundwater abstracted from these wells is in breach of the MAC's quoted in the Drinking Water Regulations for a number of parameters. However, these groundwater samples were collected prior to the lining of Cell No. 1 and construction of the cut-off wall.

The manganese and barium levels exceed the MAC in MW2d and the reported concentrations for calcium, iron, zinc and strontium are all elevated. In contrast to the upgradient monitoring wells, the reported laboratory pH value of 7.7 is neutral, and the magnesium, sodium and potassium are normal. The parameters that are most obviously elevated in the leachate, such as ammonia, chloride, sodium, potassium are low in MW2d. The nitrate and nitrite concentrations are also low for this borehole.

Similar to the upgradient wells, the pH reported for MW3 is high (10). The reported magnesium, sodium and potassium concentrations are approximately half those detected in MW1 but are still considered to be elevated. As with the upgradient wells, chloride and sulphate appear elevated when compared with the other downgradient wells. Nitrate is low in MW3 but nitrite is slightly elevated and ammonia exceeds the MAC.

MW4d and MW7 have similar chemistry with some notable exceptions. Calcium concentrations, although not particularly elevated are higher in these wells than in MW1, MW3 and MW5, while magnesium levels are much lower. Sodium and potassium concentrations are higher in MW4d than in MW7, while the reported iron and aluminium concentrations for both of these boreholes exceed the corresponding MAC's reported in the Drinking Water Regulations. Manganese exceeds the MAC in MW7 and barium exceeds the MAC in both wells, the reported concentration being particularly elevated in MW7. Nitrite exceeds the MAC in MW4d and the reported ammonia level in MW7 is greater than the MAC. The reported concentrations for chloride and sulphate are lower than those detected in the upgradient monitoring wells.

3.3.1.4 Conclusions of 1998 Groundwater Sampling in MW1 to MW7

Elevated concentrations for a number of parameters were reported for both upgradient and downgradient boreholes. It was concluded that the upgradient monitoring boreholes (MW1 and MW5) were being polluted by a source upgradient of the landfill. The source of this upgradient pollution had not been identified at the time of drafting the original Waste Licence Application submitted to the EPA by Mayo County Council (Mayo County Council, 1998). Of the downgradient monitoring boreholes, MW3 displayed the most similar chemistry to the upgradient boreholes. The other 3 No. downgradient boreholes (MW2d, MW4d, and MW7) all displayed slightly elevated levels of various parameters, but generally were less polluted than the upgradient boreholes. It was concluded that the landfill may be contributing contaminants to the bedrock (before lining of Cell No.1 and construction of the cut-off wall) but the impact is less than pollution from a source upgradient of the landfill. It is unlikely that the contamination detected in MW7 is derived from the landfill site, given its location on the opposite side of the Glaishwy River.

3.3.2 OCTOBER 2003 ANALYTICAL DATA – MONITORING BOREHOLES MW17 TO MW28

The newly installed downgradient bedrock and overburden groundwater monitoring boreholes (MW17-MW28) were purged of water on the 7th and 8th October, 2003 by TES assisted by Mayo County Council personnel (post lining of Cell No.1 and construction of the cut-off wall). These boreholes were installed in September 2003 at 4 No. locations on either side of the cut-off wall to the north, northeast, east, and southeast of the landfill. 7 No. of the monitoring wells (MW17, 18, 19, 22, 24, 25 and 27) were purged using an MP1 submersible pump. Due to technical difficulties with the MP1 submersible pump, which were most likely caused by ingress of fines into the pump inlet, the remaining 5 No. monitoring wells (MW20, 21, 23, 26 and 28) were purged using a disposable bailer.

TES's normal protocol used in respect of groundwater sampling is that 3 No. "borehole volumes" (BHV) of water should be purged and/or wellhead stabilisation of electrical conductivity (EC) and pH should be achieved prior to the collection of samples, as recommended by the EPA (EPA, 1995). It should be noted that a borehole volume includes both the volume of water present in the piezometer and the volume of water standing in the drilled annulus of the borehole. 3 No. BHV's had been purged prior to sampling and wellhead stabilisation of EC and pH had been reached in all of the monitoring wells with the exception of 3 No. wells (MW17, 20 and 27). Due to slow recovery of water levels in the boreholes only 2 BHV's could be purged from MW17 and MW27. Only 2 No. BHV's were purged from MW20 given the large borehole volume calculated for this deep bedrock well and the manual bailing purging technique utilised in this borehole (due to technical problems with the MP1 submersible pump). However, wellhead stabilisation of pH and EC had been reached in all 3 No. of these monitoring wells (MW17, 20 and 27) prior to sampling.

Groundwater samples were collected from all of the boreholes on the 8th October, 2003. In the case of the boreholes that were purged on the previous day (7th October) a further 'piezometer volume' was purged immediately prior to sampling on the 8th October. Samples were collected from each of the monitoring wells using dedicated sampling bailers. The sample containers were filled directly from the dedicated bailers.

3.3.2.1 Field Hydrochemistry Measurements and Observations

Electrical conductivity (EC), pH and temperature were recorded at all boreholes during purging and sampling on the 7th and 8th of October, 2003 and this data is presented in Appendix 12, Volume IV.

The EC values recorded were in the range 691 and 6250microS/cm. The lowest values were measured in the monitoring boreholes situated at Location A (MW26 to MW28). These were in the range of 691 to 920µS/cm. Higher EC values in the range of 1151 to 1405µS/cm were measured in the boreholes MW17 to MW19. All of these values are within the MAC of 1,500microS/cm at 20°C quoted in the Drinking Water Standards (SI No. 81 of 1988).

Much higher EC values in the range 2360 to 6250µS/cm were measured in the monitoring boreholes MW20 to MW25. The liquid purged from the boreholes MW20 to MW23 had a strong foul odour and a green or brown colour. No olfactory evidence of contamination was noted in the liquid purged from the boreholes MW24 and MW25 although the liquid was described as having a green or brown colour.

pH values recorded at each borehole were within the range quoted in the Drinking Water Standards of 6.0 to 9.0.

3.3.2.2 Laboratory Analysis

ALcontrol Geochem, who are a UKAS and ISO 17025 accredited laboratory, carried out chemical analyses on the water samples. A suite of parameters were requested for analysis based largely on the 'Baseline Groundwater Monitoring Parameters' listed in the EPA Landfill Monitoring Manual (EPA, 1995). However, several other parameters were added to this list so that sufficient parameters were included in order that groundwater could be fully characterised and a comprehensive groundwater quality dataset could be acquired. These parameters included organics, inorganics, metals, and major anions and cations.

The results of all water analyses are presented in Appendix 12, Volume IV, together with the Maximum Admissible Concentrations (MAC's) quoted in Statutory Instrument No. 81 of 1988 (Drinking Water Standards in respect of quality of water intended for human consumption) and the Parametric Values quoted in Statutory Instrument No. 439 of 2000 (European Community Drinking Water Regulations) S.I. No. 439 of 2000 came into force on 1st January 2004, which amended S.I. No. 81 of 1988). The MAC's and parametric values quoted in the Drinking Water Standards (S.I. No. 81 of 1988 and S.I. No. 439 of 2000) are considered the most appropriate standards with which to compare results. List I and List II substances as defined in Statutory Instrument No. 41 of 1999 (Protection of Groundwater Regulations) are also identified in this table of results. The introduction of List I substances to groundwater is prohibited whilst discharges of List II substances are to be limited so that groundwater contamination is prevented.

Typical leachate mean concentrations for most of the parameters requested for analysis (taken from the EPA "Landfill Operational Practices Manual" – (EPA, 1997)) are also listed in the table of results for the purposes of comparison and to assess the level of any contamination identified in the analytical results. It was also considered prudent to include the EPA Guideline Values for the Protection of Groundwater as listed in an Interim Report entitled 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland' (EPA, 2003) for reference.

Certain parameters such as DO, BOD, COD, Total Solids, TON, and TOC do not have MAC's specified in the Drinking Water Regulations, nor are there Parametric Values quoted for these parameters in S.I. No. 439 of 2000. In cases where there are no standards or guidelines with which to compare analytical results, the reported concentrations for each individual parameter were assessed relative to each other. Reported concentrations that are in excess of the Drinking Water Regulation MAC's are highlighted in light brown in the table of results presented in Appendix 12, Volume IV. Parameters that have elevated concentrations in some boreholes relative to concentrations reported for other boreholes are highlighted in light green.

3.3.2.3 Discussion of Results

The reported concentrations for most of the parameters are within the corresponding MAC's listed in the Drinking Water Regulations. However, concentrations in excess of the corresponding MAC's have been reported for 12 No. of the parameters analysed. These parameters include EC, ammoniacal nitrogen, nitrite, chloride, potassium, sodium, barium, boron, calcium, iron, magnesium, and manganese.

Other parameters, whilst not in breach of the corresponding MAC's (where they are quoted), are elevated in some boreholes in relation to values reported for other boreholes. These parameters include BOD, COD, TOC, TON, Total Hardness, Total Alkalinity, Sulphate, Phosphate, Chromium, and Nickel.

As evident on the table of analytical results, the most elevated concentrations have been reported for boreholes MW20 to MW25 (Locations C and B). The locations of these boreholes are shown on Figure 3.4.1, Appendix 12, Volume IV. The reported values for EC, ammoniacal nitrogen, chloride, sodium, barium, calcium, and manganese are in excess of the corresponding MAC's in all 6 No. of these boreholes. In addition to these parameters, the reported values for nitrite in MW22 and MW24 exceed the corresponding MAC's, as do the results for potassium in MW20 to MW24, boron in MW22, iron in MW20 to MW23, and magnesium in MW22 and MW23.

The reported values for COD, TOC, total alkalinity, and sulphate are elevated in boreholes MW20 to MW25 in relation to the other boreholes, although they do not exceed the corresponding MAC's where they are quoted in the Drinking Water Regulations. Total Solids are also elevated in monitoring boreholes MW20, MW21, MW22, MW24, and MW25 in relation to the other boreholes. Similarly, elevated concentrations in relation to results reported for other boreholes are evident in terms of BOD and boron in MW20, MW21 and MW23, total hardness and phosphate in MW20 to MW24, TON in MW24, chromium in MW22 and MW23, iron in MW24 and MW25, magnesium in MW20, MW21 and MW24, and nickel in MW21 to MW23.

As well as breaching the MAC's in monitoring boreholes MW20 to MW25, the reported concentrations for manganese and barium in all of the other monitoring boreholes (MW17 to MW19 and MW26 to MW28) are also in excess of the corresponding MAC's. However, the detected concentrations for manganese are of a similar order of magnitude in all of the monitoring boreholes suggesting that manganese may be naturally occurring at elevated concentrations in the groundwater. With the exception of the high barium concentration reported for MW17, the barium results for MW18, MW19 and MW26 to MW28 are much lower than the values reported for boreholes MW20 to MW25. The reported concentrations for ammoniacal nitrogen are in excess of the corresponding MAC in all of the monitoring boreholes with the exception of MW26 where the detected level is slightly below the MAC, although the values reported for monitoring boreholes MW20 to MW23 are significantly higher than the results reported for the other boreholes.

In addition to these parameters, the reported values for EC and chloride are elevated in boreholes MW17 to MW19 in relation to the values detected in boreholes MW26 to MW28, although they do not exceed the corresponding MAC's quoted in the Drinking Water Regulations, and they are significantly lower than the results reported for these parameters in monitoring boreholes MW20 to MW25. The reported calcium concentrations for MW18, MW19, MW26, and MW27 are elevated in relation to the value detected in MW28 but do not exceed the corresponding MAC's and are significantly lower than the calcium results detected in MW20 to MW25. However, the calcium result for MW17 does exceed the corresponding MAC but it also is lower than the calcium values reported for MW20 to MW25.

3.3.2.4 Conclusions of October 2003 Groundwater Sampling in MW17 to MW28

Contamination has been detected in the recently installed downgradient groundwater monitoring boreholes either side of the cut-off wall at 4 No. locations to the north, northeast, east and southeast of the landfill. On the basis of field observations and the analytical results the highest levels of contamination are occuring at Locations C and B. Much lower levels of contamination have been detected at Location D with very little evidence of contamination reported for the monitoring boreholes installed at Location A.

Elevated levels of contamination have been detected in both the deep bedrock monitoring boreholes located inside and outside the cut-off wall at Location C (MW22 and MW20). Similarly, elevated levels of contamination have been detected in the bedrock monitoring borehole located outside the cut-off wall at Location B (MW24). Given the bedrock groundwater flow directions discussed previously; this suggests that there is movement of contaminated groundwater in the bedrock, under the cut-off wall. However, contamination of overburden groundwater outside the cut-off wall has also been detected in boreholes at Locations B and C. Given the bedrock groundwater flow directions in the area, this would suggest a possible movement of contaminated groundwater in fissures present in the bedrock, below the cut off wall. This would then rise up into the overburden on the other side of the wall in an attempt to regain the natural flow through the overburden, which has been disrupted by the cut-off wall.

In conclusion, it is considered that the cut-off wall is functioning as designed as the wall is preventing the passage of contaminated groundwater from moving through the cut-off wall, with the any groundwater retained by the wall being diverted to a balancing lagoon located to the north of the site. The cut-off wall is keyed into the bedrock but there appears to be some migration of contaminated groundwater through the upper weathered bedrock zone, under the cut-off wall.

3.3.3 SEPTEMBER AND OCTOBER 2003 ANALYTICAL DATA – MONITORING BOREHOLES MW1 TO MW9

As part of the routine quarterly sampling schedule agreed with the EPA, September 2003 groundwater samples were taken from monitoring boreholes on site including boreholes MW1 to MW9. These water samples were collected post lining of Cell No. 1 and construction of the cut-off wall. A revised parameter listing for quarterly groundwater sampling has been agreed with the EPA. With the exception of boreholes MW1, MW4d and MW8d, this list is significantly shorter than the parameter lists analysed for the October 1997 sampling event in boreholes MW1 to MW7, and the October 2003 sampling in boreholes MW17 to MW28. The agreed basic list of parameters to be analysed quarterly in each monitoring borehole includes pH, EC, ammoniacal nitrogen, TON, TC, chloride, phosphate, and total and faecal coliforms. Additional parameters to be analysed quarterly in boreholes MW1, MW4d, and MW8d include fluoride, cyanide, boron, calcium, cadmium, chromium, copper, iron, lead, magnesium, mercury, nickel and zinc.

The suite of parameters requested for analysis for each of the boreholes for the September 2003 sampling event, was as agreed with the EPA with the exception of the boreholes MW1, MW4d, and MW8d. Only the basic list of parameters described above were analysed for each of these boreholes in September. This was due to a shortage of sampling bottles during the September sampling event. Because of this, water samples were taken from these 3 No. boreholes during the routine monitoring undertaken in October, and analysis was conducted on each of these samples for the additional quarterly parameters required for these boreholes. Therefore, the data presented in Appendix 12, Volume IV for the additional quarterly parameters described above for monitoring boreholes MW1, MW4d, and MW8d, are October results, whilst all other reported concentrations are for groundwater samples collected in September. Only temperature and water levels were recorded at the other monitoring wells in October (with the exception of the sampling undertaken at the newly installed boreholes MW17 to MW28). Connemara Laboratory Solutions (CLS) carried out chemical and microbiological analyses on the water samples.

The results of all water analyses are presented in Appendix 12, Volume IV, together with the Maximum Admissible Concentrations (MAC's) quoted in Statutory Instrument No. 81 of 1988 (Drinking Water Standards in respect of quality of water intended for human consumption) and the Parametric Values quoted in Statutory Instrument No. 439 of 2000 (European Community Drinking Water Regulations) S.I. No. 439 of 2000 came into force on 1st January 2004, which amended S.I. No. 81 of 1988). The MAC's and parametric values quoted in the Drinking Water Standards (S.I. No. 81 of 1988 and S.I. No. 439 of 2000) are considered the most appropriate standards with which to compare results. List I and List II substances as defined in Statutory Instrument No. 41 of 1999 (Protection of Groundwater Regulations) are also identified in this table of results. The introduction of List I substances to groundwater is prohibited whilst discharges of List II substances are to be limited so that groundwater contamination is prevented. The MAC's quoted in the Drinking Water Standards (S.I. No. 81 of 1988) are considered the most appropriate standards with which to compare results.

Typical leachate mean concentrations for most of the parameters requested for analysis (taken from the EPA "Landfill Operational Practices Manual" – (EPA, 1997)) are also listed in the table of results for the purposes of comparison and to assess the level of any contamination identified in the analytical results. It was also considered prudent to include the EPA Guideline Values for the Protection of Groundwater as listed in an Interim Report entitled 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland' (EPA, 2003) for reference.

Certain parameters such as TON and TC do not have MAC's specified in the Drinking Water Regulations, nor are there Parametric Values quoted for these parameters in S.I. No. 439 of 2000. In cases where there are no standards or guidelines with which to compare analytical results, the reported concentrations for each individual parameter were assessed relative to each other. Reported concentrations that are in excess of the Drinking Water Regulation MAC's are highlighted in light brown in the table of results presented in Appendix 12, Volume IV. Parameters that have elevated concentrations in some boreholes relative to concentrations reported for other boreholes are highlighted in light green.

3.3.3.1 Discussion of Results

The reported concentrations for most of the parameters are within the corresponding MAC's listed in the Drinking Water Regulations. However, concentrations in excess of the corresponding MAC's have been reported for 5 No. of the parameters analysed. These parameters include EC, ammoniacal nitrogen, iron, and Total and Faecal Coliforms. Other parameters, whilst not in breach of the corresponding MAC's (where they are quoted), are elevated in some boreholes in relation to values reported for other boreholes. These parameters include TC, TON, chloride, phosphate, copper, lead and nickel.

As evident on the table of analytical results, the most elevated concentrations have been reported for borehole MW8s. The reported values for EC and ammoniacal nitrogen are in excess of the corresponding MAC's in this borehole and the reported values for TC, chloride and phosphate are elevated in relation to the other boreholes, although they do not exceed the corresponding MAC's where they are quoted in the Drinking Water Regulations. The shallow MW8s monitoring borehole is located on the downgradient side of the landfill and immediately to the northeast of the landfill site, inside the cut-off wall. The contamination detected in this borehole is likely to be derived from leachate percolating from the waste body in this area. Contamination was not detected in the adjacent deeper MW8d monitoring borehole.

Ammoniacal nitrogen values in excess of the corresponding MAC were also detected in boreholes MW2s, MW3 and MW7. Iron concentrations in excess of the corresponding MAC were reported in MW1 and MW4d. However, these elevated concentrations may be attributed to naturally occurring high background levels as iron can be present in significant amounts in soils and rocks such as the formations underlying the subject site. The reported TC concentration for MW1, and the TON value for MW3 are both elevated in relation to the other boreholes. The copper and lead concentrations reported for MW1 are elevated in relation to the values detected in MW4d and MW8. Similarly, the reported nickel concentration for MW4d, is elevated in relation to the values detected in MW1 and MW8. Elevated total and faecal coliform counts were detected in MW7.

MW1 is located to the southeast and upgradient of the waste body. MW3 is located to the south and downgradient of the waste body and MW2s and MW4d are located to the north and downgradient of the waste body. MW3 and MW4d are both located outside the cut-off wall, and MW2s is located inside the cut-off wall. MW7 is located to the east of the landfill site on the opposite side of the Glaishwy River.

3.3.3.2 Conclusions of September and October 2003 Groundwater Sampling in MW1 to MW9

Any contamination in MW1 is likely to be derived form a source upgradient of the landfill site. There was no contamination detected in the only other upgradient monitoring borehole (MW5), with the exception of an elevated Total Coliform count. However, total coliforms grow naturally in soil and are not indicative of contamination of a faecal origin. Evidence of contamination was detected in both of these upgradient boreholes in the 1998 sampling event.

Contamination which is most likely due to leachate migration from the landfill has been detected in MW8s which is located downgradient and inside the cut-off wall to the northeast of the landfill. Contamination was not detected in the adjacent deeper MW8d monitoring borehole.

Contamination in MW2s and MW3 is most likely derived from leachate that has percolated from the waste body. As MW3 is located outside the cut-off wall it is possible that the contamination detected at this borehole is historical contamination that occurred prior to construction of the cut-off wall. Evidence of contamination was also detected in the 1998 sampling event for MW3. Neither MW2s nor MW3 are located directly downgradient of the waste body, considering the groundwater flow directions described above. There was no evidence of contamination detected in either MW2d, which is located immediately outside the cut-off wall to the northwest of the landfill, or in MW4s which is also located outside the cut-off and downgradient of the landfill to the north of the landfill. On the basis of these results it is not considered that there is any contamination in MW4d due to leachate from the landfill. Only slight evidence of contamination was detected in MW2d and MW4d in the samples taken from these boreholes in 1998 prior to lining of Cell No.1 and construction of the cut-off wall.

Given its location and considering the groundwater flow directions discussed above, it is unlikely that the contamination detected in MW7 is derived from the landfill site. It is possible that the microbial contamination measured in this monitoring borehole, is derived from faeces of animals grazing or foraging around the wellhead and may not be a repeatable result.

These observations are based on a limited number of parameters for all of these boreholes with the exception of boreholes MW1, MW4d, and MW8d.

3.4 Groundwater Vulnerability and Protection

3.4.1 Aquifer Classification

A provisional aquifer classification by the Geological Survey of Ireland (Long et al, 1992) describes the Croaghmoyle Formation as a Locally Important Aquifer, which is moderately productive only in local zones (Ll). Most groundwater circulation in these rocks is in the upper weathered zone, along more permeable beds of limited extent and along fracture or fault zones. The flow is generally in localized zones with little or no continuity between them.

The Quaternary sediments play an important role in the groundwater flow regime of the region. Low and moderate permeability materials where sufficiently thick can restrict recharge, and provide protection to any underlying groundwater resources. High permeability materials, such as fluvioglacial sands, can allow a high level of recharge, provide additional storage to underlying bedrock aquifers, and where sufficiently thick and laterally extensive can be an aquifer in its own right. The GSI classify sand and gravel deposits as aquifers when they have a minimum extent and saturated thickness of $1km^2$ and 5m, respectively. The fluvioglacial deposits underlying the subject area do not meet these criteria and hence are considered to be a non-aquifer material.

3.4.1.1 Vulnerability Assessment

The Geological Survey of Ireland has produced guidelines on groundwater vulnerability mapping that aim to represent the intrinsic geological and hydrogeological characteristics that determine how easily groundwater may be contaminated by human activities. Vulnerability depends on the quantity of contaminants that can reach the groundwater, the time taken by water to infiltrate to the water table and the attenuating capacity of the geological deposits through which the water travels. These factors are controlled by the types of subsoils that overlie the groundwater, the way in which the contaminants recharge the geological deposits (whether point or diffuse) and the unsaturated thickness of geological deposits from the point of contaminant discharge (DoEHLG et al, 1999[2]).

For vulnerability assessments with regard to bedrock aquifers the relevant geological layer is the subsoil between the release point of contaminants and the top of the bedrock. Any unsaturated bedrock layer is not considered as it is assumed that bedrock has little or no attenuation capacity due to its fissure flow characteristics. Groundwater encountered in low or moderate permeability tills or peats or other non-aquifer subsoils is not considered to be a target. Therefore, where low and/or moderate permeability subsoils overlie the bedrock it is the thickness of subsoil between the release point of contaminants and bedrock that is considered when assessing vulnerability of bedrock aquifers, regardless of whether the low or moderate permeability materials or other non-aquifer materials are saturated or not (Daly, 2001)[3].

The GSI vulnerability mapping guidelines allow for the assignment of vulnerability ratings from "extreme" to "low", depending upon the subsoil type and thickness. With regard to sites where low, moderate and high permeability subsoils are present, the following thicknesses of unsaturated zone are specified (DoEHLG et al, 1999);

Table 3.4.1. GSI Vulnerability Mapping Guidelines

Vulnerability Rating	**Subsoil Permeability (Type) and Thickness**		
	High Permeability (Fluvioglacial Sands)	***Moderate Permeability (Sandy Subsoil)***	***Low Permeability (Peat)***
Extreme	0 – 3.0m	0 – 3.0m	0 – 3.0m
High	> 3.0m	3.0 – 10.0m	3.0 – 5.0m
Moderate	N/A	> 10.0m	5.0 – 10.0m
Low	N/A	N/A	> 10.0m

NOTES: `
(1) N/A = Not applicable
(2) Precise permeability values cannot be given at present
(3) Release points of contaminants is assumed to be 1-2m below ground surface

On the basis of these GSI recommendations and site investigation data, a high vulnerability rating is assigned across the majority of the area surrounding the existing landfill with the exception of occasional small pockets of extreme vulnerability, such as the area around borehole MW1 to the southwest of the waste body, MW3 to the south of the west body, and

[2] DoEHLG, EPA, GSI (1999), "Groundwater Protection Schemes", Joint Publication
[3] Daly, (2001) "The role of sand and gravel deposits in vulnerability assessment and mapping". Paper presented at Annual IAH (Irish Group) Seminar entitled "Gravel Aquifers", 2001

MW2s and 2d immediately to the north of the waste body. The area around MW7 on the opposite side of the Glaishwy River is also classified as extremely vulnerable.

3.4.1.2 Resource Protection

The GSI Groundwater Protection Schemes allow for the combination of aquifer classification and vulnerability rating to give classifications of groundwater protection zones. The purpose of these zones is to place a control on the activities practised within a zone and thus provide protection to any underlying groundwater resources (DoEHLG et al, 1999). Using the GSI criteria and the Locally Important aquifer classification and High vulnerability category defined above, a resource protection classification of Ll/H (Locally Important Aquifer which is moderately productive only in local zones with high vulnerability) is assigned to the area surrounding the existing landfill site. A resource classification of Ll/E (Locally Important Aquifer which is moderately productive only in local zones with extreme vulnerability) is assigned to the local areas of extreme vulnerability described above.

3.4.2 Groundwater Protection Response for Landfills

The DoEHLG/EPA/GSI have prepared a Groundwater Protection Response Matrix for Landfills (DoEHLG et al, 1999) that define the suitability or unsuitability of various hydrogeological settings for landfill.

Given that there are local areas of extreme vulnerability, for the purposes of defining a groundwater protection response for the landfill site, it was considered prudent and precautionary to take an extreme vulnerability rating to represent the entire site surrounding the existing landfill. Therefore, based on the results of the site investigations and the aquifer and vulnerability categories defined above, a DoEHLG/EPA/GSI groundwater protection response of $R2^2$ is assigned to the subject site, which indicates that landfilling is acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence.

APPENDIX 12

Water Analysis Results – Historical & Recent

WATER ANALYSIS RESULTS –

HISTORICAL & RECENT

Historical Water Analysis Results

Table C.9.1 : Surface Water Quality at Derrinumera Landfill - 6/11/97

Parameters	Units	Glaishwy River System					South Drain	Leachate
		Back-ground	Down-stream	Glaishwy Bridge	Beltra Lough	Newport River	Logjody Bridge	Lagoon
		SW - 1	SW - 2	SW - 3	SW - 4	SW- 5	SW - 6	SW - 7
Field Measurements								
pH	pH units	5.25	7.23	6.40	6.20	6.25	6.25	7.10
Conductivity	uS/cm @ 25°C	109	802	262	97	106	150	4170
Dissolved Oxygen	%	47	7	77	100	89	72	4
Dissolved Oxygen	mg/l	5.0	1.1	8.3	10.9	9.5	7.8	0.3
Temperature	C	9.3	9.5	10.0	10.6	9.8	10.1	10.2
Laboratory Measurements								
pH	pH units	5.1	7.2	7.3	7.6	7.4	6.7	7.4
Conductivity	uS/cm @ 20°C	110	810	265	100	105	145	4500
Total Hardness	mg/l CaCO3	17	133	60	28	32	46	701
Total Alkalinity	mg/l CaCO3	<20	260	47	21	<20	30	1972
Non-Carbonate Hardness	mg/l CaCO3	-	-	13	7	-	16	-
Calcium	mg/l Ca	3.4	35	[illegible]	7.7	8.3	14	180
Magnesium	mg/l Mg	2.1	11.0	4.3	2.1	2.3	2.7	61
Sodium	mg/l Na	15	[illegible]	25	9.1	10	14	355
Potassium	mg/l K	<1.0	[illegible]	5.1	<1.0	1.1	<1.0	250
Iron	mg/l Fe	[illegible]	6.4	4.0	0.39	0.52	1.2	16
Manganese	mg/l Mn	[illegible]	1.3	0.72	0.03	0.06	0.41	9.0
Copper	mg/l Cu	[illegible]	0.02	<0.01	<0.01	<0.01	<0.01	0.08
Aluminium	mg/l Al	0.14	0.35	0.10	0.07	0.08	0.34	0.98
Nitrate	mg/l NO3	0.8	25	1.4	1.0	1.0	<0.5	<5
Nitrite	mg/l NO2	<0.01	0.31	0.95	0.02	0.02	<0.01	0.17
Chloride	mg/l Cl	27	114	46	18	18	24	500
Sulphate	mg/l SO4	5.6	7.6	8.8	3.7	3.8	11	<5
Total Ammonia	mg/l NH4	0.26	44	5.1	0.11	0.16	0.07	309
Non Purg. Org. Carbon	mg/l C	18	32	19	10	10	12	260
Cadmium	mg/l Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01
Chromium	mg/l Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09
Lead	mg/l Pb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	mg/l Hg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nickel	mg/l Ni	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.04
Zinc	mg/l Zn	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	0.59
Biochemical Oxygen Demand	mg/l	<2	9	<2	<2	<2	<2	330
Chemical Oxygen Demand	mg/l	65	155	45	35	25	45	1200
Suspended Solids	mg/l	<10	73	<10	<10	<10	53	340
Total Unoxidised Nitrogen	mg/l N	<2	42	5	<2	<2	<2	325

Table C.6.4 : Groundwater Quality at Derrinumera Landfill - 5/1/98

Parameters	Units	M.A.C.	Background		Leachate	Downgradient			
			MW - 1	MW - 5	MW - 6	MW - 2d	MW - 3	MW- 4d	MW - 7
Field Measurements									
pH	pH units	6 - 9	9.60	9.70	7.58	7.20	10.07	9.71	6.89
Conductivity	uS/cm @ 25°C	1650	640	960	9320	455	472	313	400
Temperature	°C	25	11.0	11.0	21.0	10.5	11.0	10.0	11.0
Laboratory Measurements									
pH	pH units	6 - 9	10.0	9.5	7.5	7.7	9.8	8.2	7.0
Colour	Hazen Units	-	< 5	< 5	2750	< 5	< 5	< 5	10
Conductivity	uS/cm @ 20°C	1500	820	990	12900	565	535	495	460
Total Hardness	mg/l CaCO3	-	361	513	782	253	183	176	176
Total Alkalinity	mg/l CaCO3	-	539	580	5750	280	275	252	211
Non-Carbonate Hardness	mg/l CaCO3	-	-	-	-	-	-	-	-
Calcium	mg/l Ca	200	42	75	66	75	75	41	41
Magnesium	mg/l Mg	50	90	120	150	16	40	18	18
Sodium	mg/l Na	150	98	53	1250	27	58	49	24
Potassium	mg/l K	12	33	27	570	3.4	16.0	14	4.8
Iron	mg/l Fe	0.2	0.01	0.02	[illegible]	0.13	0.01	0.37	0.76
Manganese	mg/l Mn	0.05	< 0.01	< 0.01	0.33	0.07	< 0.01	0.02	1.0
Copper	mg/l Cu	0.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium	mg/l Al	0.2	< 0.05	0.05	0.68	0.15	< 0.05	0.29	0.25
Nitrate	mg/l NO3	50	11	< 0.5	< 2	< 0.5	< 0.5	< 0.5	< 0.5
Nitrite	mg/l NO2	0.1	0.51	0.15	< 0.1	0.02	0.08	0.14	< 0.01
Chloride	mg/l Cl	250	86	43	1525	23	45	25	30
Sulphate	mg/l SO4	250	15	12	2.8	4.4	15	5.4	6.6
Total Ammonia	mg/l NH4	0.3	< 0.05	0.07	1322	< 0.05	1.2	< 0.05	2.9
Non Purg. Org. Carbon	mg/l C	-	31	5.6	530	2.2	6.2	2.7	5.9
Sulphur	mg/l S	-	6.2	3.7	27	2.2	5.3	2.6	1.4
Arsenic	mg/l As	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Tin	mg/l Sn	-	< 0.05	< 0.05	0.07	< 0.05	< 0.05	< 0.05	< 0.05
Mercury	mg/l Hg	0.001	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Chromium	mg/l Cr	0.05	< 0.01	< 0.01	0.25	< 0.01	< 0.01	< 0.01	< 0.01
Phosphorous	mg/l P	1.09	0.06	< 0.05	7.4	< 0.05	< 0.05	< 0.05	< 0.05
Zinc	mg/l Zn	5	< 0.01	< 0.01	0.34	0.38	< 0.01	0.09	0.31
Cadmium	mg/l Cd	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Lead	mg/l Pb	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Cobalt	mg/l Co	-	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.01
Nickel	mg/l Ni	0.05	< 0.01	< 0.01	0.13	0.02	< 0.01	0.01	0.03
Boron	mg/l B	2	< 0.01	< 0.01	7.7	0.05	0.02	0.11	0.02
Strontium	mg/l Sr	-	0.25	0.20	1.3	1.3	0.20	1.7	0.17
Barium	mg/l Ba	0.5	0.29	0.43	0.44	0.85	0.27	0.67	1.6
Biochemical Oxygen Demand	mg/l	-	-	-	120	-	-	-	-
Chemical Oxygen Demand	mg/l	-	-	-	2860	-	-	-	-

Note

M.A.C. = Maximum Admissible Concentration for Drinking Water (S.I. No. 81 of 1988)

< = Less than

All samples were filtered through GF/C grade filters prior to all analyses.

Recent Water Analysis Results

ANALYTICAL DATA - SW1 to SW6

Parameter	Units	Standards: S.I. no. 294 of 1989 - European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989	Standards: S.I. no. 41 of 1999 - Protection of Groundwater Regulations	Laboratory Results: SW-3 Oct. 2003	SW-4 Oct. 2003	SW-5 Oct. 2003	SW-6 Oct. 2003
LABORATORY RESULTS							
Electrical Conductivity (EC)	µS/cm	1000	-	170	162	105	231
Dissolved Oxygen (DO)	mg/l		-	98	99	89	87
Biochemical oxygen demand (BOD)	mg/l	5.0	-	3	1	1	1
Chemical oxygen demand (COD)	mg/l	40.0	-	74	19	25	13
Suspended Solids	mg/l	50.0	-	4	4	2	4
Volatile Suspended Solids	mg/l	-		4	4	4	4
Total alkalinity (as $CaCO_3$)	mg/l	-	-	<40	<52	<28	<48
Ammoniacal nitrogen (NH_4-N)	mg/l	0.2	II	0.04	0.02	0.014	0.07
Total oxidised nitrogen (TON)	mg/l	-		0.14	0.10	<0.1	<0.1
Chloride (Cl)	mg/l	250	-	28.1	26.1	18.2	25.8
Sulphate (SO_4)	mg/l	200	-	11.0	13.3	8.9	53.4
Boron (B)	mg/l	2.0	II	-	-	-	-
Calcium (Ca)	mg/l	-	-	<17	<17	<8.7	<29
Cadmium (Cd)	mg/l	0.005	I	<0.005	<0.005	<0.005	<0.0005
Chromium (Cr)	mg/l	0.05	II	<0.005	<0.005	<0.005	<0.005
Copper (Cu)	mg/l	0.05	II	0.035	0.057	0.011	0.022
Iron (Fe)	mg/l	0.2	-	<1.91	<1.34	<0.35	<1.94
Lead (Pb)	mg/l	0.05	II	<0.005	<0.005	<0.005	<0.005
Magnesium (Mg)	mg/l	-	-	3.2	3.1	2.4	4.1
Mercury (Hg)	mg/l	0.001	I	<0.0001	<0.0001	<0.0002	<0.0001
Nickel (Ni)	mg/l	-	II	<0.005	<0.005	<0.005	<0.005

Note: < = Less than

ANALYTICAL DATA - MW1 to MW9

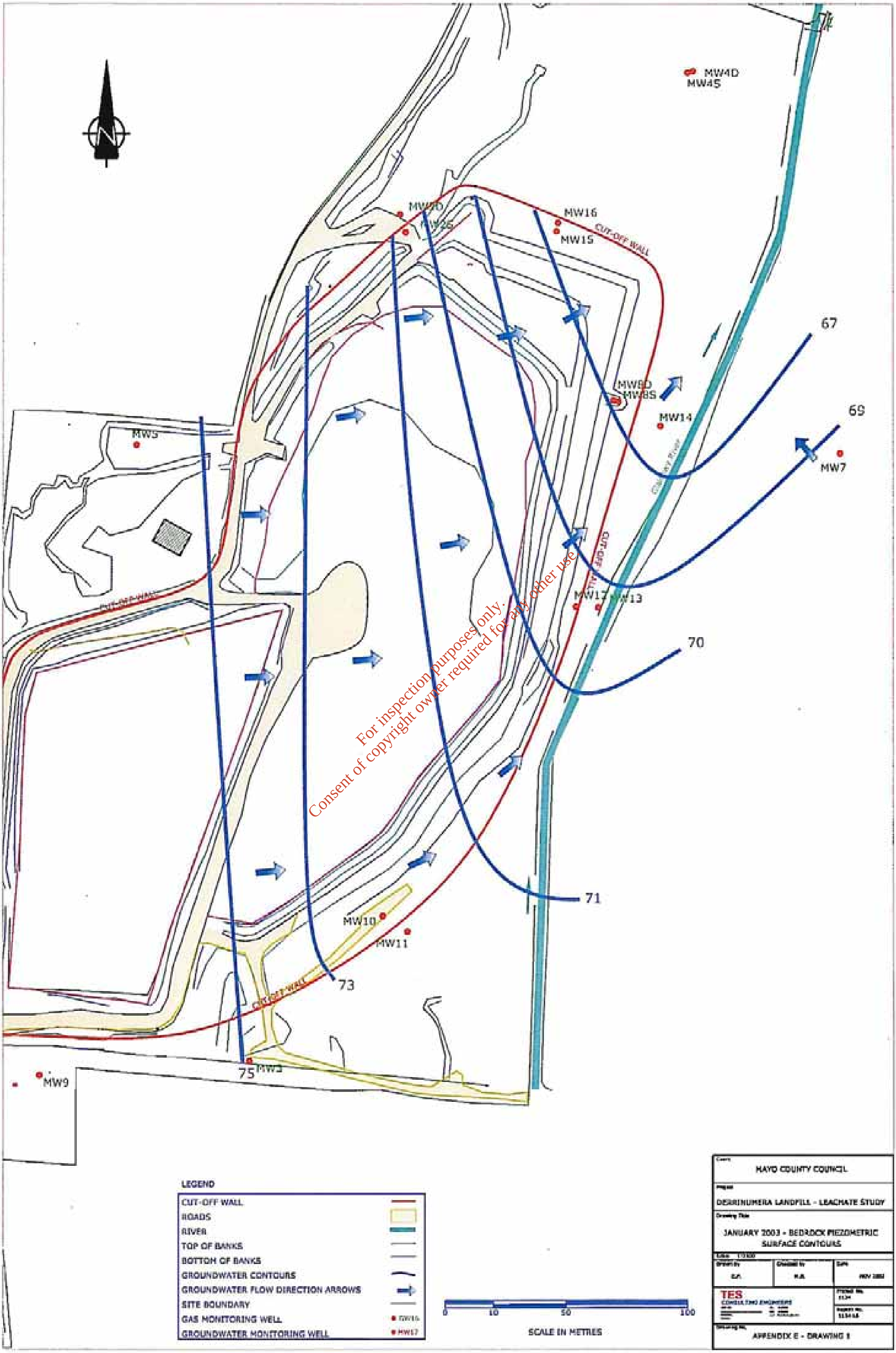
Parameter	Units	Standards: S.I. no. 81 of 1988 - Quality of Water Intended for Human Consumption Regulations MAC's	Standards: S.I. no. 439 of 2000 - European Community (Drinking Water) Regulations Parametric Values	Standards: S.I. no. 41 of 1999 - Protection of Groundwater Regulations	Guidelines: EPA Guideline Values - From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.	Guidelines: Mean Concentrations for Typical Leachate - From EPA Landfill Operational Practices Manual	MW-1	MW-2S	MW-2D	MW-3	MW-4S	MW-4D	MW-5	MW-7	MW-8S	MW-8D	MW-9
LABORATORY RESULTS																	
pH	units	6-9	6.5-9.5	-	6.5-9.5	7.2	7.2	6.5	7.3	6.3	6.8	7.5	7.3	6.5	6.8	7.3	6.1
Electrical Conductivity (EC)	µS/cm	1500	2500	-	1000	7789	667	443	559	373	447	522	494	332	1993	616	484
Ammoniacal nitrogen (NH_4-N)	mg/l	0.23	-	II	0.115	491	0.02	0.24	0.005	2.31	0.083	0.007	0.037	2.44	60.1	0.055	0.087
Total oxidised nitrogen (TON)	mg/l	-	-	-	-	-	0.12	<0.1	<0.1	0.35	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1
Total Carbon (TC)	mg/l	-		-	-	-	100	18	11	18	13	13	<7	14	63	11	11
Chloride (Cl)	mg/l	250	250	-	30	1256	34.1	29.4	29.6	27.1	34.1	28.7	28.3	34.8	191.7	48.7	37.0
Fluoride	mg/l	1	1	II	1	-	0.12	-	-	-	-	<0.02	-	-	-	0.02	-
ortho Phosphate (PO_4)	mg/l	3.35	-	-	0.03	3	<0.03	<0.03	<0.03	<0.03	0.051	<0.03	<0.03	<0.03	0.34	<0.03	<0.03
Cyanide (Total)	mg/l	0.05	0.05	I	0.01	<0.05	<0.1	-	-	-	-	<0.1	-	-	-	<0.1	-
Boron (B)	mg/l	2	1	II	1	[illegible]	0.2	-	-	-	-	0.2	-	-	-	0.2	-
Calcium (Ca)	mg/l	200	-	-	200	250	126.0	-		-	-	71	-	-	-	90	-
Cadmium (Cd)	mg/l	0.005	0.005	I	0.005	<0.01	<0.0005	-	-	-	-	<0.0005	-	-	-	<0.0005	-
Chromium (Cr)	mg/l	0.05	0.05	II	0.03	0.07	0.009	-	-	-	-	0.008	-	-	-	<0.005	-
Copper (Cu)	mg/l	0.5	-	II	0.03	0.04	0.027	-	-	-	-	0.005	-	-	-	0.006	-
Iron (Fe)	mg/l	0.2	0.2	-	0.2	54.5	3.40	-	-	-	-	1.16	-	-	-	0.15	-
Lead (Pb)	mg/l	0.05	0.01	II	0.01	0.1	0.011	-	-	-	-	<0.005	-	-	-	0.005	-
Magnesium (Mg)	mg/l	50	-	-	50	151	22.0	-	-	-	-	16	-	-	-	15	-
Mercury (Hg)	mg/l	0.001	0.001	I	0.001	0.0001	<0.0001	-	-	-	-	<0.0001	-	-	-	<0.0001	-
Nickel (Ni)	mg/l	0.05	-	II	0.02	0.1	<0.005	-	-	-	-	0.032	-	-	-	<0.005	-
Zinc (Zn)	mg/l	1	-	II	0.1	0.58	0.011	-	-	-	-	<0.005	-	-	-	0.014	-
Total Coliforms	counts per 100ml	0	0	-	0	-	<1	<1	<10	<1	<10	<10	18	160	<1	<10	<10
Faecal Coliforms	counts per 100ml	0	0	-	0	-	<1	<1	<10	<1	<1	<10	<1	160	<1	<10	<10

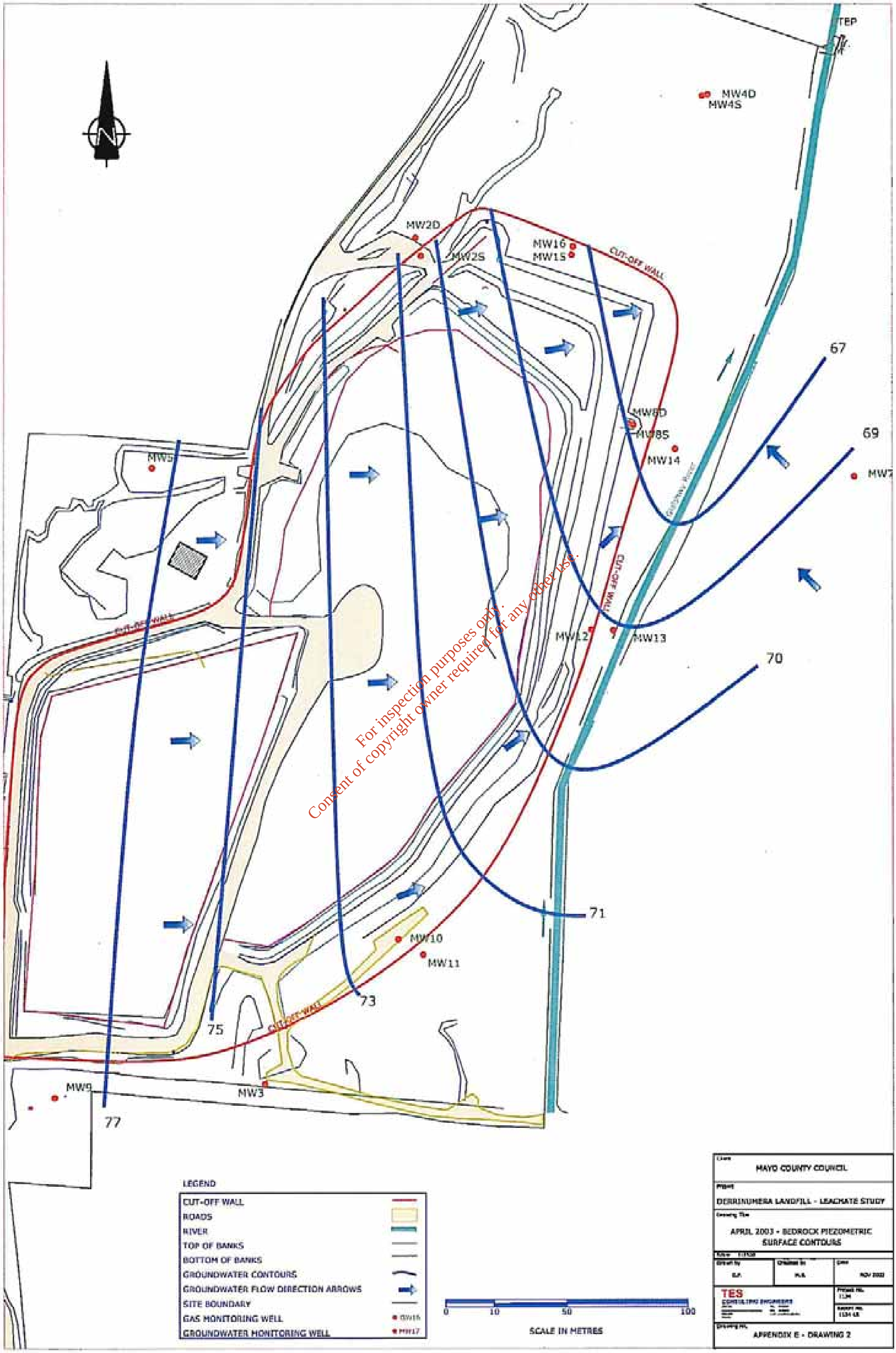
Note: M.A.C = Maximum Admissable Concentration
< = Less than

ANALYTICAL DATA - MW17 to MW28

Parameter	Units	Standards: S.I. no. 81 of 1988 - Quality of Water Intended for Human Consumption Regulations MAC's	Standards: S.I. no. 439 of 2000 - European Community (Drinking Water) Regulations Parametric Values	Standards: S.I. no. 41 of 1999 - Protection of Groundwater Regulations	Guidelines: EPA Guideline Values - From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.	Guidelines: Mean Concentrations for Typical Leachate - From EPA Landfill Operational Practices Manual	MW-17 8/10/03	MW-18 8/10/03	MW-19 8/10/03	MW-20 8/10/03	MW-21 8/10/03	MW-22 8/10/03	MW-23 8/10/03	MW-24 8/10/03	MW-25 8/10/03	MW-26 8/10/03	MW-27 8/10/03	MW-28 8/10/03
FIELD RESULTS																		
pH	units	6-9	6.5-9.5	-	6.5 - 9.5	7.2	7.11	7.10	6.99	7.03	6.91	6.98	6.94	6.75	6.73	7.08	8.07	6.78
Temperature	Degree Celsius	25	-	-	25	-	12.1	12.4	13.7	12.8	11.2	11.6	12.8	12.3	12.4	11.8	12.3	12.4
Electrical conductivity (EC)	µS/cm	1500	2500	-	1000	7789	1405	1263	1151	3360	4360	6250	6070	3210	2360	897	920	691
LABORATORY RESULTS																		
pH	units	6-9	6.5-9.5	-	6.5-9.5	7.2	6.64	6.39	7.18	6.96	6.75	6.97	6.99	6.63	6.65	6.59	6.68	6.27
Electrical Conductivity (EC)	µS/cm	1500	2500	-	1000	7789	1446	1265	1132	3371	3960	6195	5995	3094	2405	898	937	699
Dissolved Oxygen (DO)	mg/l	-	-	-	-	-	10	9.9	10.2	10.1	10	9.9	10	9.6	9.7	9.8	9.7	9.9
Biochemical oxygen demand (BOD)	mg/l	-	-	-	-	>798	4.0	4.0	6.0	15.0	51.0	8.0	26.0	8.0	10.0	7.0	4.0	10.0
Chemical oxygen demand (COD)	mg/l	-	-	-	-	3078	53.0	48.0	53.0	329.0	289.0	513.0	512.0	227.0	148.0	38.0	39.0	40.0
Total Solids	mg/l	-	-	-	1000	-	857.0	786.0	709.0	1883.0	2311.0	3097.0	530.0	1945.0	1490.0	850.0	560.0	456.0
Total Hardness	mg/l	60 MRC (**)	-	-	200	-	780.0	520.0	500.0	1040.0	1340.0	1680.0	1220.0	1040.0	200.0	540.0	60.0	460.0
Total alkalinity (as $CaCO_3$)	mg/l	30 MRC (**)	-	-	-	3490	500.0	410.0	380.0	1500.0	1430.0	2400.0	2330.0	1010.0	860.0	380.0	390.0	220.0
Ammoniacal nitrogen (NH_4-N)	mg/l	0.23	-	II	0.115	491	5.3	14.3	6.8	72.0	63.0	229.0	308.0	20.0	1.2	0.2	0.5	1.1
Nitrate (NO_3)	mg/l	50	50	-	25	2.4	0.9	8.0	0.7	0.8	0.6	0.7	0.7	6.2	0.7	0.7	0.8	0.8
Nitrite (NO_2)	mg/l	0.1	0.5	II	0.1	0.2	0.06	0.05	0.06	0.08	0.08	0.11	0.09	0.18	0.09	<0.05	0.06	0.06
Total oxidised nitrogen (TON)	mg/l	-	-	-	-	-	<0.3	1.9	<0.3	<0.3	<0.3	<0.3	<0.3	1.5	<0.3	<0.3	<0.3	<0.3
Total organic carbon (TOC)	mg/l	-	-	-	-	717	14.0	14.0	17.0	78.0	101.0	157.0	150.0	76.0	46.0	11.0	11.0	12.0
Chloride (Cl)	mg/l	250	250	-	30	1256	195.0	186.0	156.0	350.0	500.0	720.0	630.0	440.0	330.0	83.0	83.0	94.0
Fluoride	mg/l	1	1	II	1	-	0.4	0.3	0.3	0.4	0.5	0.6	0.5	0.6	0.4	0.2	0.3	0.3
Sulphate (SO_4)	mg/l	250	250	-	200	136	<3	<3	<3	9.0	10.0	20.0	17.0	6.0	4.0	26.0	23.0	<3
ortho Phosphate (PO_4)	mg/l	3.35	-	-	0.03	3	0.04	<0.03	<0.03	0.1	0.25	0.13	0.11	0.3	0.08	<0.03	<0.03	0.08
Potassium	mg/l	12	-	-	5	491	5.8	4.4	3.8	32.4	24.0	112.0	156.0	12.8	3.6	1.8	2.6	1.6
Sodium	mg/l	150	200	-	150	904	49.0	53.0	60.0	255.0	360.0	500.0	480.0	450.0	186.0	50.0	52.0	37.0
Cyanide (Total)	mg/l	0.05	0.05	I	0.01	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminium (Al)	mg/l	0.2	0.2	-	0.2	<0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (As)	mg/l	0.05	0.01	II	0.01	0.008	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	0.005	<0.002
Barium (Ba)	mg/l	0.5	-	-	0.1	-	10.52	1.65	1.66	15.51	14.57	19.36	14.36	12.54	6.29	2.03	2.02	1.0
Boron (B)	mg/l	2	1	II	1	7	<0.05	<0.05	<0.05	0.83	0.73	2.05	1.54	0.2	<0.05	<0.05	<0.05	<0.05
Calcium (Ca)	mg/l	200	-	-	200	250	236.3	186.1	164.2	377.0	446.9	376.6	301.6	423.4	354.9	131.5	136.5	88.2
Cadmium (Cd)	mg/l	0.005	0.005	I	0.005	<0.01	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Chromium (Cr)	mg/l	0.05	0.05	II	0.03	0.07	0.004	0.005	0.005	0.01	0.009	0.015	0.015	0.01	0.009	0.006	0.006	0.007
Copper (Cu)	mg/l	0.5	-	II	0.03	0.04	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron (Fe)	mg/l	0.2	0.2	-	0.2	54.5	0.049	0.105	0.056	0.218	0.32	0.566	0.366	0.16	0.125	0.039	0.036	0.082
Lead (Pb)	mg/l	0.05	0.01	II	0.01	0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005
Magnesium (Mg)	mg/l	50	-	-	50	151	12.58	7.52	8.42	44.39	45.59	70.07	57.47	30.19	15.93	9.94	10.38	9.33
Manganese (Mn)	mg/l	0.05	0.05	-	0.05	1.99	2.136	2.214	1.906	1.725	2.448	2.121	1.74	2.973	3.044	2.057	1.722	1.964
Mercury (Hg)	mg/l	0.001	0.001	I	0.001	0.0001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00009	0.00008	0.00028	0.00018	<0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/l	0.05	-	II	0.02	0.1	<0.01	0.012	<0.01	0.015	0.023	0.028	0.028	0.014	0.014	<0.01	<0.01	<0.01
Selenium (Se)	mg/l	0.01	0.01	-	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver (Ag)	mg/l	0.01	-	II	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (Zn)	mg/l	1	-	II	0.1	0.58	0.023	0.006	0.09	<0.005	<0.005	0.017	0.007	0.015	0.006	<0.005	0.013	<0.005

Note: M.A.C = Maximum Admissible Concentration
** M.R.C = Minimum Required Concentration specified in the Drinking Water Regulations (S.I. No. 81 of 1988)
< = Less than


MW4D
MW4S
MW9D
MW16
MW15
CUT-OFF WALL
MW8D
MW8S
MW14
67
69
MW7
MW5
CUT-OFF WALL
MW12
MW13
70
71
MW10
MW11
73
CUT-OFF WALL
75
MW1
MW9
LEGEND
CUT-OFF WALL
ROADS
RIVER
TOP OF BANKS
BOTTOM OF BANKS
GROUNDWATER CONTOURS
GROUNDWATER FLOW DIRECTION ARROWS
SITE BOUNDARY
GAS MONITORING WELL
GROUNDWATER MONITORING WELL
0
10
50
100
SCALE IN METRES
MAYO COUNTY COUNCIL
DERRINUMERA LANDFILL - LEACHATE STUDY
JANUARY 2003 - BEDROCK PIEZOMETRIC
SURFACE CONTOURS
TES
CONSULTING ENGINEERS
APPENDIX E - DRAWING 1



TEP
MW4D
MW4S
MW2D
MW2S
MW16
MW15
CUT-OFF WALL
67
MW8D
MW8S
MW14
69
MW7
MW5
CUT-OFF WALL
MW12
MW13
70
71
MW10
MW11
73
75
CUT-OFF WALL
MW9
MW3
77
LEGEND
CUT-OFF WALL
ROADS
RIVER
TOP OF BANKS
BOTTOM OF BANKS
GROUNDWATER CONTOURS
GROUNDWATER FLOW DIRECTION ARROWS
SITE BOUNDARY
GAS MONITORING WELL
GROUNDWATER MONITORING WELL
0
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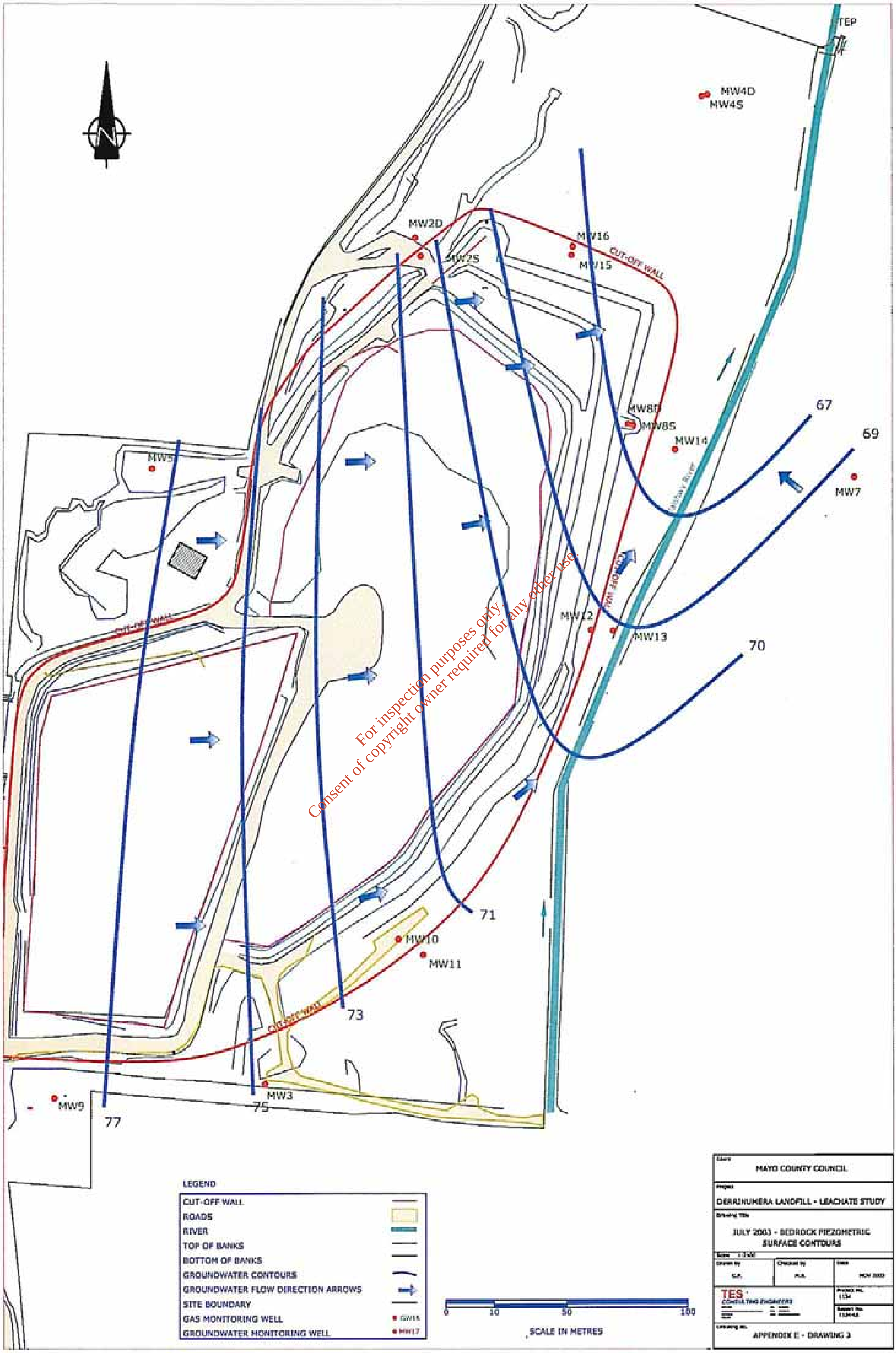
SCALE IN METRES
MAYO COUNTY COUNCIL
DERRINUMERA LANDFILL - LEACHATE STUDY
APRIL 2003 - BEDROCK PIEZOMETRIC SURFACE CONTOURS
NOV 2003
TES
CONSULTING ENGINEERS
1134
1134 LS
APPENDIX E - DRAWING 2


MW4D
MW4S
MW2D
MW2S
MW16
MW15
CUT-OFF WALL
MW8D
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MW5
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MW13
MW10
MW11
MW3
MW9
67
69
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71
73
75
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LEGEND
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GROUNDWATER CONTOURS
GROUNDWATER FLOW DIRECTION ARROWS
SITE BOUNDARY
GAS MONITORING WELL
GROUNDWATER MONITORING WELL
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50
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SCALE IN METRES
MAYO COUNTY COUNCIL
DERRINUMERA LANDFILL - LEACHATE STUDY
JULY 2003 - BEDROCK PIEZOMETRIC SURFACE CONTOURS
C.P.
M.A.
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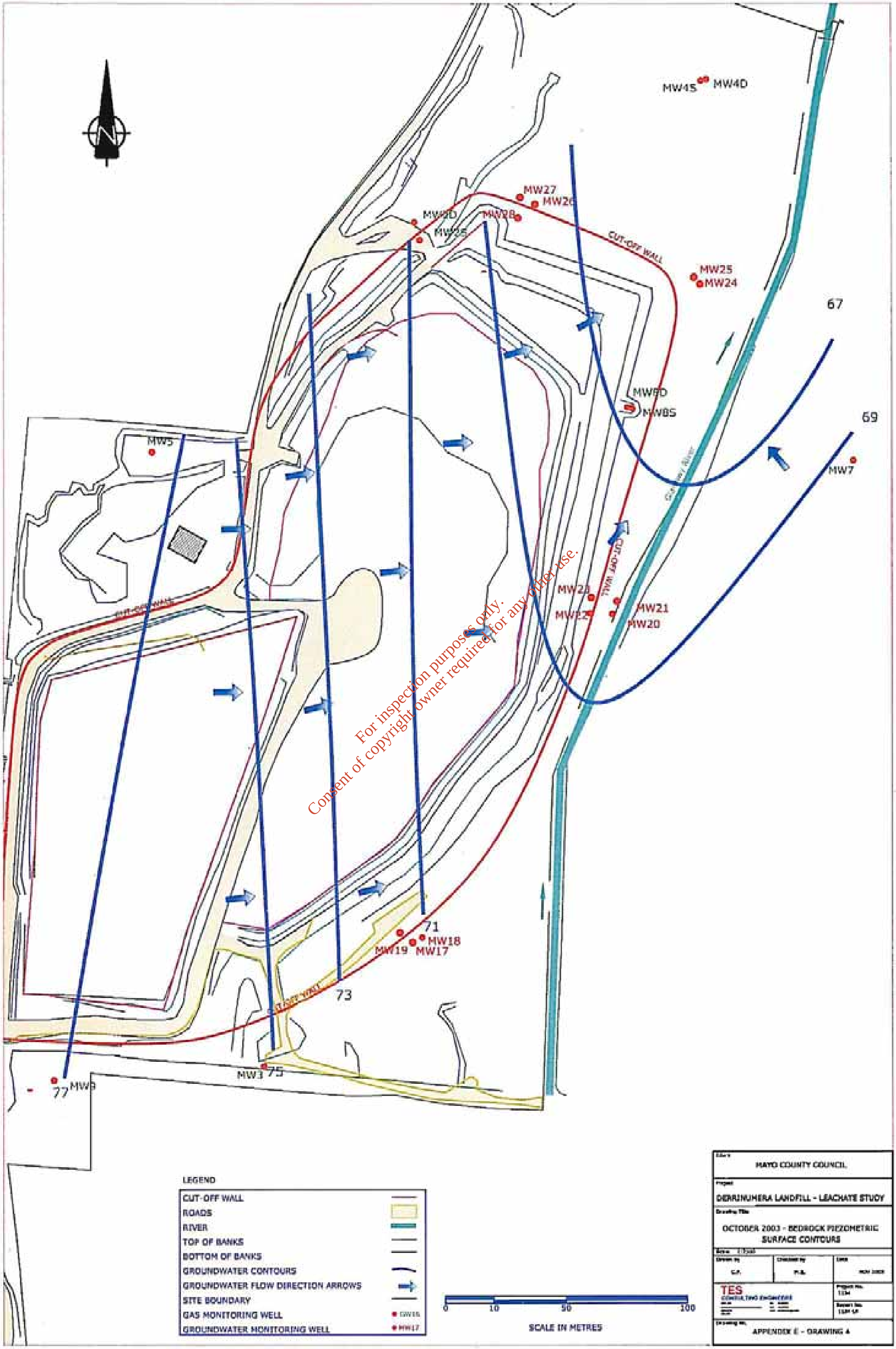
TES
CONSULTING ENGINEERS
APPENDIX E - DRAWING 3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MW4D
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MW6D
MW6S
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MW7
MW5
CUT-OFF WALL
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MW20
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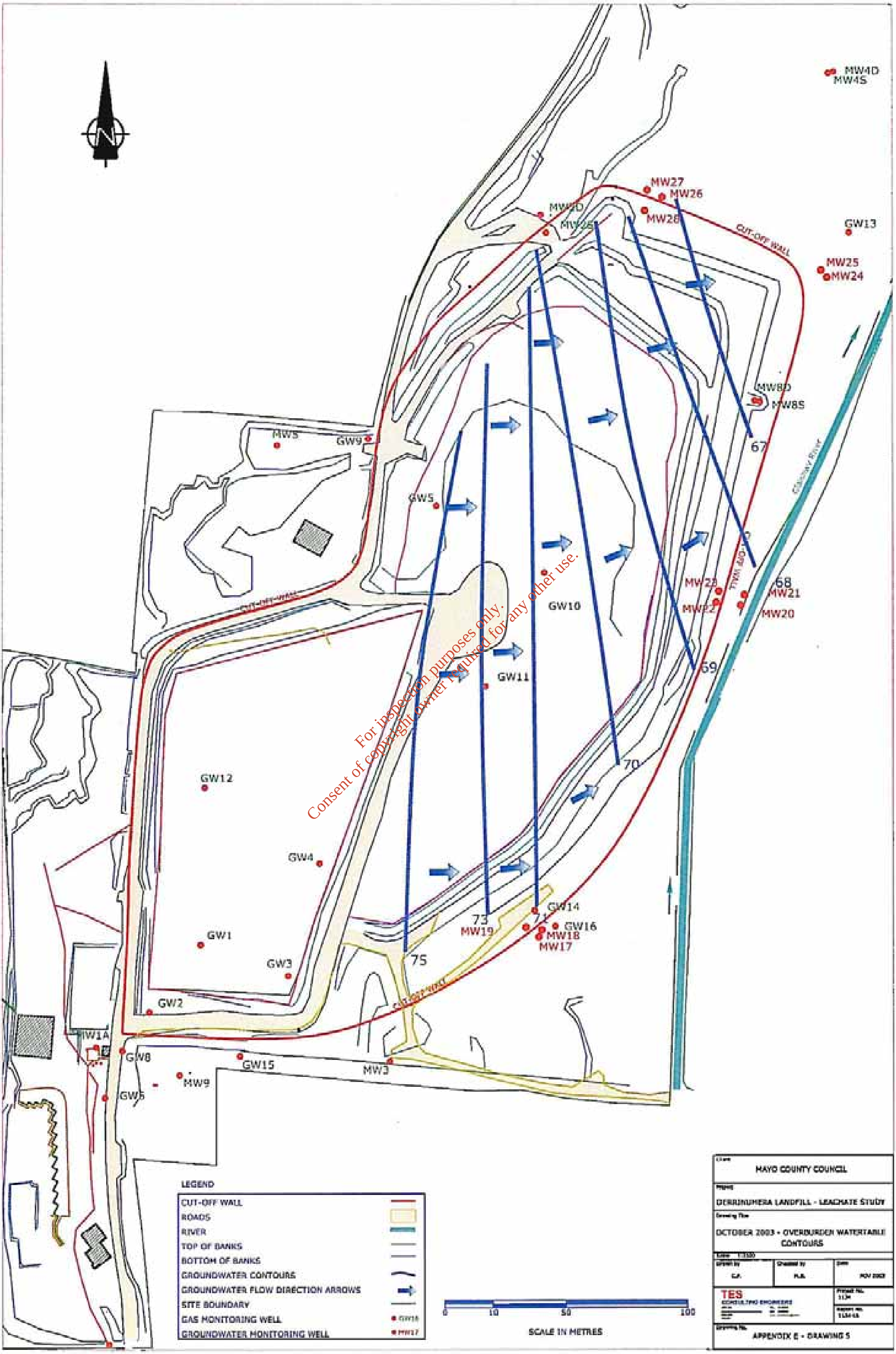
APPENDIX E - DRAWING 4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APPENDIX E - DRAWING 5

APPENDIX 13

Odour Impact Assessment

[TES & Odour Monitoring Ireland Ltd., 2003]

Appendix No. 13
Odour Impact Assessment

APPENDIX NO. 13

ODOUR IMPACT ASSESSMENT

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APPENDIX NO. 13

ODOUR IMPACT ASSESSMENT

1 INTRODUCTION

The operation of the current landfill and development of the proposed SHC & LTF in Derrinumura, County Mayo is faced with the issue of preventing odours causing impact to the public at large. The current and proposed operations will cover approximately 23.6ha. The current landfill consists of two engineered and lined Cells on top of an old unlined landfill body. Lined Cell No. 1 is currently temporarily capped, while Lined Cell No. 2 is the current waste deposition zone.

Three options are covered within this odour impact assessment for the development of the SHC, namely:

1. Interim solution using an existing sludge drier;
2. A new sludge drier and operations to be fully enclosed within a building;
3. A composting system consisting of conventional tunnel system (15,900 metric tonnes yr^{-1}) with all raw materials and finished composting product handling carried out indoors.

All odourous exhaust air from all proposed operations will be treated via a combination of wet scrubbing and biofiltration/activated carbon. It is expected that the combined wet scrubbing and biofiltration system will obtain a removal efficiency of at least 95% (manufacturers guarantees). The existing activated carbon system treating odourous air from the existing sludge drier in Castlebar WWTP was assessed using latest odour measurement techniques to determine an odour emission rate from it's operation.

Currently, all leachate is removed off-site to be treated in the Castlebar WWTP. It is proposed to install diffuse fine bubble aerators in the existing over ground storage tanks for treatment of leachate on-site. For the purposes of estimating the odour nuisance, it is assumed that the tanks will not be covered.

Utilising historical and measured odour emission data and atmospheric dispersion modelling techniques, the predicted overall odour impact of the following scenarios will be determined:

Scenario 1: Existing landfill operation assuming maximum input capacity;
Scenario 2: Existing landfill operations (maximum capacity) and proposed leachate treatment on-site utilising SBR diffuse fine bubble aeration;
Scenario 3: Existing landfill, leachate treatment and operation of interim sludge drier;
Scenario 4: Existing landfill, leachate treatment and operation of new sludge drying system (generic at this stage of development);
Scenario 5: Existing landfill, leachate treatment and proposed tunnel composting system;

The key odour impact sources within the landfill operation and other proposed processes are identified and possible odour minimisation strategies discussed. Contours of odour concentrations for the 98th and 99.5th percentile are predicted around the landfill, LTF and sludge drying/Composting operation in order to examine the extent of any odour impact and the effectiveness of considered odour minimisation protocols.

2 ODOUR CHARACTERISATION AND MODELLING

2.1 OLFACTOMETRY

Olfactometry using the human sense of smell is the most valid means of measuring odour (Dravniek et al, 1986) and at present is the most commonly used method to measure the concentration of odour in air (Hobbs et al, 1996). Olfactometry is carried out using an instrument called an olfactometer. Three different types of dynamic dilution olfactometers exist:

- Yes/No Olfactometer
- Forced Choice Olfactometer
- Triangular Forced Choice Olfactometer.

In the dynamic dilution olfactometer, the odour is first diluted and is then presented to a panel of screened panellists of no less than four (CEN, 2001) Panellists are previously screened to ensure that they have a normal sense of smell (Casey et al., 2003). According to the CEN standard this screening must be performed using a certified reference gas *n*-butanol. This screening is applied to eliminate anosmia (low sensitivity) and super-noses (high sensitivity). The odour analysis has to be undertaken in a low odour environment such as an air-conditioned odour free laboratory. Analysis should always be performed within 6 hours of sampling.

2.2 WHAT IS AN ODOUR UNIT?

The odour concentration of a gaseous sample of odourant is determined by presenting a panel of selected screened human panellists with a sample of odourous air and varying the concentration by diluting with odourless gas, in order to determine the dilution factor at the 50% detection threshold. The Z_{50} value (threshold concentration) is expressed in odour units (Ou_E m^{-3}).

Although odour concentration is a dimensionless number, by analogy, it is expressed as a concentration in odour units per cubic metre (Ou_E m^{-3}), a term which simplifies the calculation of odour emission rate. The European odour unit is that amount of odourant(s) that, when evaporated into one cubic metre of neutral gas (nitrogen), at standard conditions elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one European Reference Odour Mass (EROM) evaporated in one cubic meter of neutral gas at standard conditions. One EROM is that mass of a substance (n-butanol) that will elicit the Z_{50} physiological response assessed by an odour panel in accordance with this standard. *n*-Butanol is one such reference standard and 1 EROM is equivalent to 123ug of n-butanol evaporated in one cubic meter of neutral gas at standard conditions (CEN, 2001).

2.3 CHARACTERISATION OF ODOUR

The sense of smell plays an important role in human comfort. The sensation of smell is individual and unique to each human and varies with the physical condition of the person, the odour emission conditions and the individual's odourous education or memory. The smell reaction is the result of a stimulus created by the olfactory bulb located in the upper nasal passage. When the nasal passage comes in contact with the odourous molecules, signals are sent via the nerve fibres where the odour impressions are created and compared with stored memories referring to individual perceptions and social values. Since the smell is individual some people will be hypersensitive and some will be less sensitive (ansomia). Therefore, the sense of smell is the most useful detection technique available as it specialises in synthesising complex gas mixtures rather than analysing the chemical compound (Sheridan, 2000).

2.4 ODOUR QUALITIES

An odour sensation consists of a number of interlinked factors. These include:

- Odour threshold/concentration
- Odour intensity
- Hedonic tone
- Quality/Characteristics
- Component characteristics

The odour threshold concentration dictates the concentration of the odour in Ou_E m^{-3}. The odour intensity dictated the strength of the odour. The Hedonic quality allows for the determination of pleasantness/unpleasantness. Odour quality/characteristics allow for the comparison of the odour to a known smell (i.e. turnip, like dead fish, flowers). Individual chemical component identity determines the individual chemical components that constitute the odour (i.e. ammonia, hydrogen sulphide, methyl mercaptan, etc.). Once odour qualities are determined, the overall odour impact can be assessed. This odour impact assessment can then be used to determine if an odour minimisation strategy is to be implemented and if so, which technique.

2.5 PERCEPTION OF EMITTED ODOURS

Complaints are the primary indicators that odours are a problem in the vicinity of any facility. Perceptions of odours vary from person to person, each with their own individual fingerprint. Several conditions govern a person's perception of odour:

- **Control:** A person is better able to cope with an odour if they feel it can be controlled.
- **Understanding:** A person can better tolerate an odour if they understand its source.
- **Context:** A person reacts to the context of an odour as we do to the odour itself.
- **Exposure:** When a person is constantly exposed to an odour they may lose their ability to detect that odour. For example, a plant operator who works in the facility may grow immune to the odour.

From these criteria, we can predict that odour complaints are more likely to occur when:-

- A new facility locates in areas where people are unfamiliar with facilities;
- When a new process establishes within the facility;
- Or when an urban population encroaches on an existing facility.

The ability to characterise odours being emitted from the facility will help to develop a better understanding of the impact of the odour on the surrounding vicinity. It will also help to implement and develop better techniques to abate odours using existing technologies and engineering design.

2.6 ATMOSPHERIC DISPERSION MODELLING OF ODOURS: WHAT IS DISPERSION MODELLING?

Any material discharged into the atmosphere is carried along by the wind and diluted by wind turbulence. This process has the effect of producing a plume of air that is roughly cone shaped with the apex towards the source and can be mathematically described by the Gaussian equation. Atmospheric dispersion modelling has been applied to the assessment and control of odours for many years, originally using Gaussian form ISCST 3 and more recently utilising advanced boundary-layer physics models such as ADMS and AERMOD (Keddie et al. 1992). Once the odour emission rate from the source is known, ($Ou_E\ s^{-1}$), the impact on the vicinity can be estimated. These models can effectively be used in three different ways: firstly, to assess the dispersion of odours and to correlate with complaints; secondly, in a "reverse" mode, to estimate the maximum odour emissions which can be permitted from a site in order to prevent odour complaints occurring; and thirdly, to determine which process is contributing greatest to the odour impact and estimate the amount of required abatement to reduce this impact within acceptable levels (McIntyre et al. 2000). In this latter mode, models have been employed for imposing emission limits on industrial processes, odour control systems and intensive agricultural processes (Sheridan et al., 2002).

2.7 INDUSTRIAL SOURCE COMPLEX 3 (ISC3)

The model used is BREEZE Industrial Source Complex version 3(ISC ST 3 Ver.4.012). This model is recommended in Environmental Protection Agency (EPA) guideline on Air Quality Modelling for applications to refinery-like sources and other industrial sources. It is a straight-line trajectory, Gaussian-based model. It was also recently recommended (Complex 1 section) by the Irish EPA to model the potential odour impact from intensive agriculture, mushroom composting and tannery facilities (EPA, 2002). It is used with meteorological input data from the nearest representative source. The most important parameters needed in the meteorological data are wind speed, wind direction, ceiling heights, cloud cover, and Pasquill-Gifford stability class for each hour. ISC ST 3 is run with a sequence of hourly meteorological conditions to predict concentrations at receptors for averaging times of one hour up to a year. It is necessary to use many years of hourly data to develop a better understanding of the statistics of calculated short-term hourly peaks or of longer time averages.

3 ODOUR RESEARCH AND SOURCES OF INFORMATION

3.1 MEASUREMENT OF ODOUR EMISSIONS FROM LANDFILL/SLUDGE DRYING/COMPOSTING OPERATIONS

Eliminating all odours from operations to prevent objections from neighbours in close proximity to these facilities is difficult. Therefore, odour measurement is required in order to identify significant odour sources and to determine a correct minimisation/abatement strategy and/or to correctly site these facilities within the community. Recent research indicates that odours are intermittent, specific to a particular operation and may result in barely detectable levels. Even so, the human nose is very sensitive and an odourous compound does not have to be very strong to raise an objection.

The variability of sources (i.e. active face, daily cover, sludge processing, etc.), causes (changes in temperature increasing compound volatility) and environmental factors (meteorological effects), make it difficult to determine some objective limit for odour emissions. The problem is compounded by the fact that odour threshold concentration does not always correspond to its odour intensity (strength). This is an important factor to realise when assessing and implementing abatement/minimisation strategy for the treatment of odour emissions.

3.2 CHARACTERISTICS OF LANDFILL/SLUDGE DRYING/LEACHATE TREATMENT AND SLUDGE COMPOSTING ODOURS

Odours from landfill, leachate treatment, sludge drying and composting operations may arise due to:

- Fugitive landfill gas emission from waste which has temporary cover;
- Uncontrolled landfill gas leakages from side embankments within landfill;
- Volatilisation and airflow stripping of odourous gases from active face;
- Puff odour emissions from tipping and spreading of waste, etc.
- Puff odour emissions from screening and turning of raw material during composting;
- Development of anaerobic conditions within leachate treatment chamber;

- Non-uniform aeration of leachate promoting anaerobic conditions within leachate treatment chamber;
- Unnecessary splash events within leachate chamber promoting volatilisation of odourous compounds;
- Uncontrolled filling of aeration chamber;
- Puff odour emissions due to filling of sludge drier hopper;
- Odour emissions from unnecessary storage of raw sludge;
- Insufficient treatment of outlet odourous air stream from sludge drier;
- Puff odour emissions from sludge drier process due to filling and loading through operation;
- Development of uncontrolled anaerobic conditions within raw material during composting;
- Unnecessary mixing and pre-treatment of raw sludge materials outdoors;
- Insufficient covering/sealing of manhole/run-off access ports, etc.

Different odourous compounds are released; the most significant being organic acids (acetic acid, butyric acid; hexanoic acid), terpenes (limonene, alpha Pinene, alpha Cubebene), mercaptans (methanthiol, ethanthiol, etc.), amines (ethanolamine, dimethylamine, trimethylamine, etc.) and Hydrogen sulphide (Sheridan, 2003). Most of these compounds have very low odour threshold concentrations as illustrated in Table 3.1. Different concentrations and mixtures of these compounds can intensify or reduce odour threshold concentration, determined as synergism and antagonism, respectively. This emphasises the benefits of olfactometric techniques over alternative analytical chemical techniques.

Table 3.1 Odour threshold concentration of various odourous compounds commonly found in the air streams of different odourous processes

Compound name	Molecular Formula	Odour description	Odour threshold (ppm (v/v))
Mercaptans			
Allyl mercaptan	CH_2CHCH_2SH	Disagreeable, garlic	0.0001
Methyl mercaptan	CH_3SH	Rotten cabbage	0.0005
Propyl mercaptan	C_3H_7SH	Unpleasant	0.0005
Ethyl mercaptan	C_2H_5SH	Decayed cabbage	0.0003
Sulphides			
Hydrogen sulphide	H_2S	Rotten eggs	0.000515
Amines			
Trimethyl amine	$(CH_3)_3N$	Pungent, fishy	0.0004
n-Butyl amine	$CH_3(CH_2)NH_2$	Sour, ammonia	0.080
Organic acids			
Acetic acid	CH_3COOH	Sour	1.0
Butyric acid	$CH_3(CH_2)_2COOH$	Sweet rancid	0.0004
Valeric acid	$CH_3(CH_2)_4COOH$	Rancid	0.0008

(Sheridan, 2003)

3.3 Establishment of Odour Impact Criterion for Landfill/Leachate Treatment/Sludge Drying and Composting Odours

Odours from landfill, leachate treatment, sludge drying and composting operations arise mainly from the volatilisation of odourous gases produced from uncontrolled anaerobic digestion of organic matter and the volatilisation of odourous compounds due to surface airflow patterns. Some of the compounds emitted are characterised by their high odour intensity. A sample of a report carried out in the Netherlands ranking 20 generic and 20 environmental odours according to the "like or dislike" by a group of people professionally involved in odour management is illustrated in Table 3.2 (EPA, 2001).

Table 3.2 Ranking of environmental odours according to like and dislike (i.e. character)

Environmental Odours	Mean Ranking
Intensive agricultural farm	12.8 (Limit value 6.0 Ou_E m^{-3})
Waste water treatment plant	12.9 (Limit value 3.5 Ou_E m^{-3})
Green fraction composting	14.0 (Limit value 3.0 Ou_E m^{-3})
Landfill	14.1 (Limit value 3.18 Ou_E m^{-3})
Abattoir/Slaughterhouse	17.0 (Limit value 1.5 Ou_E m^{-3})

3.4 ODOUR ANNOYANCE CRITERIA

Commonly used odour annoyance criteria in Ireland, UK and Netherlands are illustrated in Table 3.3. Generally, odour concentrations should be below 6 Ou_E m^{-3} for 98th percentile in order to prevent complaints arising from existing intensive pig facilities in Ireland. In Holland odour concentrations should be below 3.5 and 3.0 Ou_E m^{-3} for the 98th percentile for wastewater treatment works and existing composting facilities. Through extensive intensity relationship studies, an odour impact criterion of 3.0 Ou_E m^{-3} was established for the assessment of the proposed extension of Boghborough landfill, London.

Table 3.3 Odour annoyance criteria for dispersion modelling

Concentration Limit Ou_E m^{-3}	Percentile value%	Application
Dutch (MPTER and Complex 1 Model)		
≤3.5	98	Wastewater treatment works existing site, rural area or industrial estate.
≤3.0	98	Compost facility existing site
English (ADMS model)		
≤5	98	Waste water treatment works Greenfield site,
Ireland (ISC ST Complex 1 section)		
≤3.0	98	Target limit for new pig production facility/Limit value for tanning and mushroom compost industry
≤6.0	98	Target limit for existing pig production facility
England (Complex 1 model)		
≤3.18	98	Acceptable guideline for elimination of significant odour impact in vicinity of landfill

(McIntyre et al. 2000; EPA, (2001); Long))

An odour threshold concentration of 1 Ou_E m^{-3} is the level at which an odour is detectable by 50% of the screened panellists. According to research on wastewater treatment works, the odour recognition threshold is approximately 3-5 times this concentration and is liable to cause offence (3-5 Ou_E m^{-3}). An odour impact criterion of ≤ 5 Ou_E m^{-3} is implemented in

England for wastewater treatment works (Newbiggin-by-the-Sea, Northumberland, 1993 Planning Board) and is accepted in planning applications for these facilities to limit odour impact (McIntyre et al., 2000).

As odours from landfills are considered more hedonically unpleasant than odour from intensive agricultural facilities, it would be prudent to limit the possibilities of odour impact and apply an odour impact criterion of ≤ 3 Ou_E m^{-3}. In accordance with the odour annoyance criterion above in Table 3.3 and in keeping with Irish EPA and Boghborough landfill recommendations, all residential dwellings will be located outside the ≤ 3 Ou_E m^{-3} contour for the 98th percentile in one year as determined by atmospheric dispersion modelling software. Longhurst et al., 1998 reported that for the Boghborough landfill, an odour concentration of ≤ 3.18 Ou_E m^{-3} could be described as faint but not offensive within 95% confidence intervals.

4 MATERIALS AND METHODOLOGY

4.1 SITE

The different distances and directions that the proposed landfill, leachate treatment and sludge drying/composting operation is located from the neighbouring dwellings are represented in Figure 4.1 and Table 4.1. As can be observed, the closest resident is approximately 1200 metres to the southwest of the proposed site. As the predominant wind direction in this country is south-westerly, and a significant distance exists, odour complaints are generally not received from this location.

Table 4.1 Location and distance of nearest residents in relation to Derrinumera landfill flare

Resident Number	Approx. distance (Kilometre)	Direction relative to north (Degrees)
Nearest resident 1	1.4	239
Nearest resident 2	1.2	246

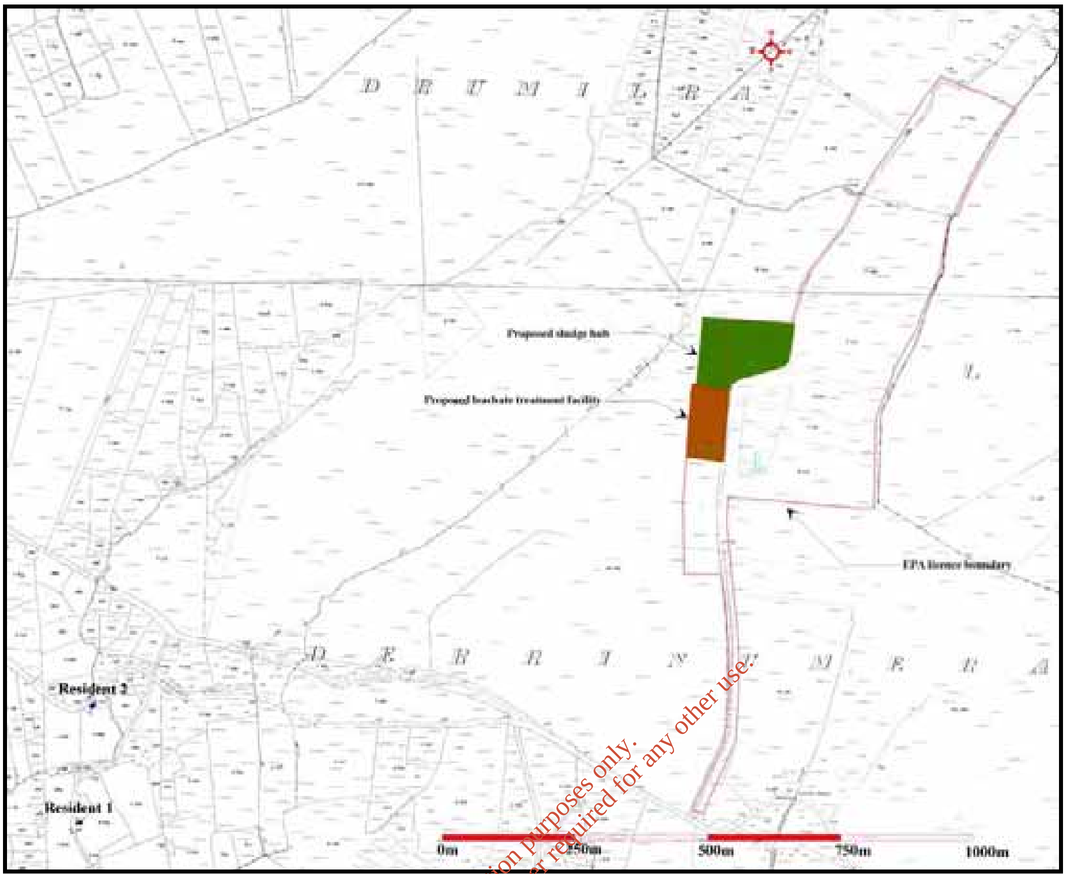


Figure 4.1: Arial diagram of Derrinumera landfill and composting facility and relative location of residents. ■ denotes nearest residences

4.2 ODOUR EMISSION RATE CALCULATION

The measurement of the strength of a sample of odourous air is, however, only part of the problem of quantifying odour. Just as pollution from a stack is best quantified by a mass emission rate, the rate of production of an odour is best quantified by the odour emission rate. For a chimney or ventilation stack, this is equal to the odour threshold concentration (Ou_E m^{-3}) of the discharge air multiplied by its flow-rate (m^3 s^{-1}). It is equal to the volume of air contaminated every second to the threshold odour limit (Ou_E s^{-1}). The odour emission rate can be used in conjunction with dispersion modelling in order to estimate the approximate radius of impact or complaint (Hobson et al, 1995). Area source mass emission rates/flux were calculated as either Ou_E m^{-2} s^{-1} or Ou_E s^{-1} depending if they are being represented as discrete point sources or area sources in the atmospheric dispersion model.

4.3 METEOROLOGICAL DATA

Three years worth of hourly sequential meteorology data was used for the operation of ISC ST 3. This allowed for the determination of the worst-case year scenario for the overall impact of odour emissions from the proposed landfill and composting operations on the surrounding population.

4.4 TERRAIN DATA.

Upon examination of terrain it was not considered that significant deviations in topography would be incorporated within the model. Only significant deviations in terrain are examined in modelling computations. Building wake effects are accounted for in the modelling scenarios as this can have a significant effect on the odour plume dispersion at short distances.

5 IMPACTS OF THE PROPOSED DEVELOPMENT

5.1 PROPOSED DEVELOPMENTS AND ODOUR GENERATION AND RELEASE POTENTIALS

5.1.1 Landfill Operations

The formation of odorous compounds at a landfill is usually limited to the active face, operational area, landfill gas extraction wells, discontinuous flare operation, leachate lagoon and insufficient temporary capping of cells.

As waste is taken into the landfill facility and filled into cells, anaerobic conditions will predominate, with the incomplete breakdown of polysaccharides, proteins and carbohydrates from organic matter. This incomplete methanogenesis process will allow for the release of volatile fatty acids, sulphur containing compounds, volatile organic compounds and nitrogen containing organics, which have low odour detection thresholds. The amount formed depends upon a variety of considered non-exhaustive factors including nature and moisture content of the waste, amount of oxygen present, and temperature generation inside the landfill. Any gases generated tend to rise through the deposited waste. This rate is affected by coverage methodology, operational procedures and management practices. The amount of gases emitted will vary from landfill to landfill and will be different for a single landfill at different times (e.g. physical soil type, changing landfill content, organic content of waste).

Once emitted into the air, landfill gases are carried on surface level winds. While this dilutes the gases with fresh air, it can also move them into communities. Naturally, wind speed and direction determine whether local residents will notice landfill odours so that the degree of the odour perception will vary greatly from day to day. At locations near the landfill, the worst time of the day may be early morning or late in the evening during a stable atmosphere and low wind speeds. This is when winds tend to be most gentle, providing the least dilution of the odours.

Odour have historically been regarded as nuisances rather than a direct health hazard (Young and Parker, 1984, Young and Heasman, 1985; WHO Guidelines, Sensory guidelines) and the extent to which odours spread away from the landfill depends primarily on source emission rates and weather conditions (wind speed, wind direction, temperature, pressure, humidity).

5.1.2 Derrinumera Leachate Treatment Plant Design.

Mayo County Council seek to include a leachate treatment facility in the scope of the current licence review, and while the design of the facility may be included in the DBO Contract at the proposed SHC, it is likely that the treated leachate will be finally pumped to the marine outfall discharge for treated municipal wastewater at Newport. It is most likely that BAT approaches to leachate treatment would be adopted and as such regard would be had to the general guidance as set out in the EPA's wastewater treatment manual (EPA, 1997).

While the exact layout and facility design is not currently known, the principal odour source associated with the facility will be the surface aeration system, therefore surface aerators will not be permitted in the final design. A diffused aeration system will be instead employed. These types of systems are in widespread use at municipal and industrial wastewater treatment plants throughout the country.

5.1.3 Derrinumera Sludge Drier Plant Design.

5.1.3.1 Interim (Temporary) Sludge Drier

The existing sludge drier at the Castlebar WWTP was assessed using latest odour measurement techniques to determine typical odour emission rates from similar type plant, which are proposed for use as an interim solution to sludge drying at Derrinumera.

At Castlebar WWTP there are two belt presses with no ventilation in the belt pressroom apart from the roller door that remains open constantly. In the sludge drying room there are two 24" fans on the side of the building that are running constantly during the operational hours. All the air from the process is vented through the stack. The stack is approximately 9 meters high. This stack consists of a 0.457 metre diameter vent with an average airflow rate of 2.49 m s^{-1}. There are two roller doors that also remain open constantly. One door is used for the removal of dried sludge using a tractor and dumper trailer and the other door for the dumping of imported wet sludge into a hopper. The hopper will hold anything from 0-8 tonnes. The hoppers surface area is approximately 8 m^2.

At present, there are difficulties with odours from the existing installation, but receptors in this instance are as close as 50 metres from the facility. Temporary relocation of a similar type interim sludge drying unit to Derrinumera, more than 1km from the nearest residence, and to be decommissioned as soon as the fully engineered drier is in place, would be the latitude sought by Mayo County Council in this respect.

At present, there are difficulties with odours from the existing installation, but receptors in this instance are as close as 50 metres from the facility. Temporary relocation of the unit to

Derrinumera, more than 1km from the nearest residence, and to be decommissioned as soon as the fully engineered drier is in place, would be the latitude sought by Mayo County Council in this respect.

A schematic of the temporary sludge drying process can be observed in Figure 5.1.

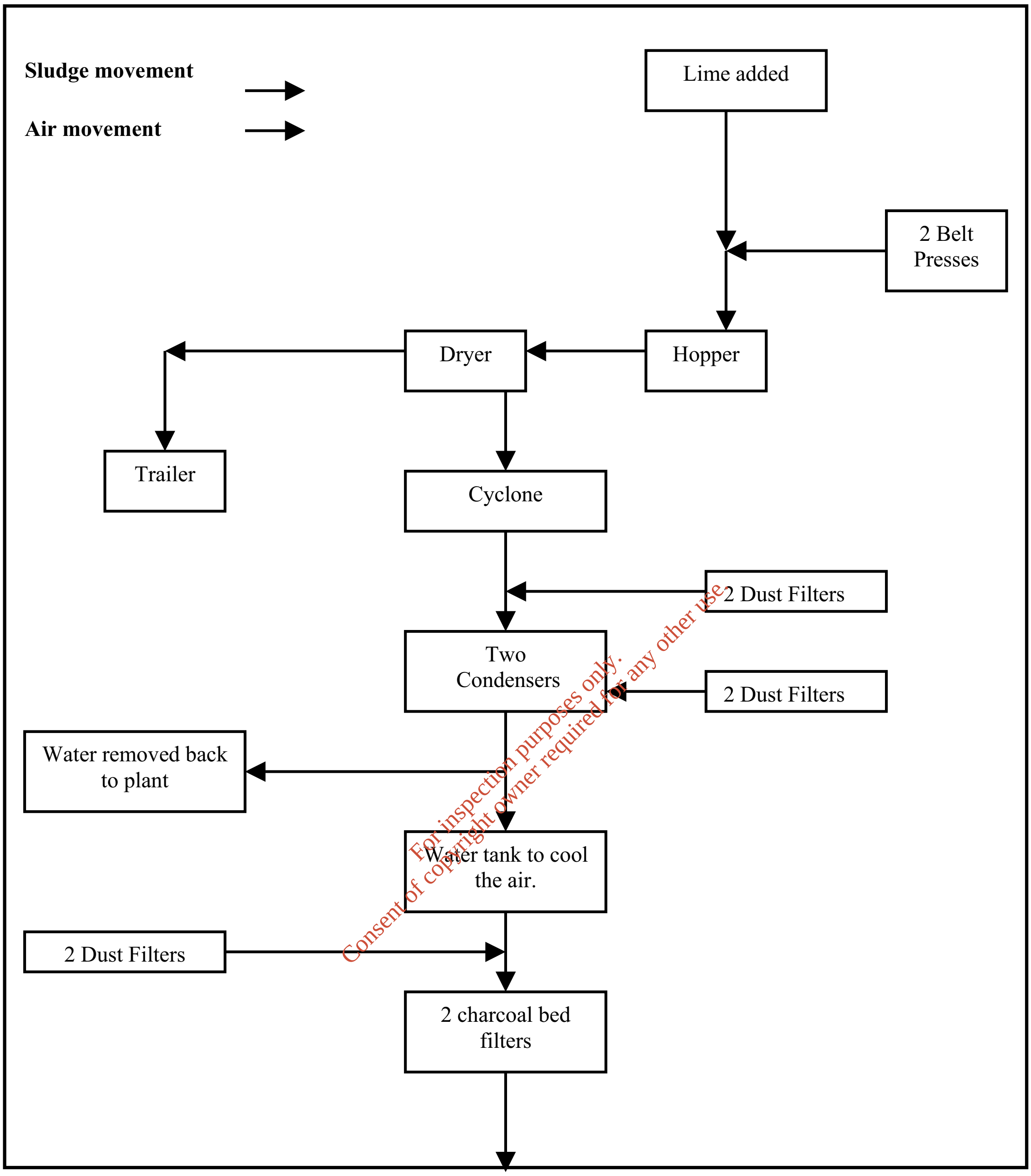


Figure 5.1. Schematic diagram of process control of the temporary sludge drier, Castlebar WWTP

5.1.3.2 Proposed new Sludge Drying System

It is proposed that the SHC would be constructed and operated under a Design Build Operate (DBO) contract for the reception, drying, temporary storage and sustainable re-use or disposal of treated municipal sludge collected from wastewater treatment plants throughout County Mayo. The likelihood is that the preferred method of production of bio-solids will be thermal drying using a fully engineered thermal drier, not to be confused with the temporary drying unit.

The SHC would stand on its own fenced site, with bio-solids manufacture separate from all other waste handling activities at the landfill. The dry solids (DS) content of the sludge entering the facility will range from small amounts of liquid sludge at 3%, with the bulk of it being dewatered to an average of 17.5 % DS.

Given the DBO nature of the proposal, details of the exact sludge treatment system are not currently known. However, the proposed SHC will be designed and operated to ensure full compliance with all environmental odour obligations that currently pertain to the licensed facility. The odour abatement capabilities of different types of sludge driers are detailed in Sections 3.2.5.4 and 3.2.5.4.9 in the EIS main text. In addition, good engineering practice will be incorporated into the SHC design to minimise its environmental impact.

5.1.4 Tunnel Composting Plant Design.

The composting system to be installed is a conventional tunnel system (16,840 metric tonnes yr^{-1}) with all raw material and finished composting product handling carried out indoors. A number of composting tunnels will be operated within the composting building. There will be preliminary mixing of sludge with woodchips before sludge is placed into each tunnel. After an appropriate period of time in the tunnel, the finished compost is removed, screened for woodchips and placed in the finished compost holding bay. All large screened fines are reintroduced back into the tunnel composting system. All odourous exhaust air will be treated via a combination of wet scrubbing and biofiltration. It is expected that the combined wet scrubbing and biofiltration system will obtain a removal efficiency of at least 95%.

5.1.4.1 Odour Formation and Release from Composting Operation

Odour Monitoring Ireland have identified the following relevant odour sources from the proposed composting facility:

- Acceptance and Pre-treatment of fresh sludge;
- Pre-composting;
- Composting tunnels;
- After treatment;
- Storage of finished compost.

This complete composting process will be maintained within one large building and all odourous exhaust air will be passed through a combined wet scrubbing and biofiltration system.

5.1.4.1.1 Acceptance of Fresh Sludge

Fresh sludge will be delivered to the facility each day. The sludge will be mixed with structured material (woodchips) and introduced into the composting tunnel process. The composting process will last 14 to 28 days. All odourous air formed within each composting tunnel will be removed and passed through a combined wet scrubbing and biofiltration system.

The sludge will arrive on site in sealed sludge skips/sludge tankers, which will not lead to the emissions of odours. The acceptance/unloading and mechanical treatment of the sludge will be performed inside the composting building. Negative ventilation of this building to a wet scrubber and biofiltration system will prevent the emissions of concentrated odour plumes to the atmosphere. The mixed sludge will be transferred to the composting tunnels on reception. Approximately 318 tonnes of fresh sludge are required every 1-week for a 15,900 tonnes yr^{-1} throughput. An odour emission rate of 57 Ou s^{-1} $tonne^{-1}$ is assumed for acceptance of fresh sludge (Table 5.2).

5.1.4.1.2 Composting Tunnels

After pre-treatment the sludge is transported to the composting tunnels in a front-end loader, where aeration will be employed to aid and control the composting process. In each tunnel, the prepared sludge will be piled to an approximate height of 2 to 3 metres. Aeration spigots on the floor of the composting tunnel will provide even aeration. Centrifugal fans controlled by differential pressure drop and temperature will maintain ideal conditions within the pile for the degradation of easily biodegradable organic matter. This process lasts approximately 2 to 4 weeks where 318 tonnes of material is aerated. An odour emission rate of 61 Ou s^{-1} $tonne^{-1}$ is assumed for the composting process (Table 5.2).

5.1.4.1.3 Post Treatment.

Following composting, the finished compost is sieved and all large fines are removed and reintroduced into the pre-composting process. An odour emission rate of 61 and 138 Ou s^{-1} $tonne^{-1}$ is assumed for post treatment process (Table 5.2).

5.1.4.1.4 Storage of Finished Compost.

The compost will be stored in the enclosed composting building. Emissions from the stored compost will be greatly reduced and stabilised (approximately 100 times less). It is important to prevent the compost from getting wet and to ensure it is stored properly as to prevent the generation of anaerobic conditions. All finished compost will be loaded into transport vehicles inside the composting building therefore preventing any puff odour emissions that may cause complaint. An odour emission rate of 0.6 Ou s^{-1} $tonne^{-1}$ is assumed for storage of finished compost (Table 5.2).

5.1.5 Odour Emission Factors from Individual Odour Sources During Landfill, Leachate Treatment, Sludge Drying/Composting Operation.

Odour Emission Factors for the Derrinumera Landfill Processes.

The following tables illustrate the specific odour emission rate/fluxes used to determine an overall odour emission rate from the landfill operations. Each odour source emission factor is presented as either an emission flux (Ou_E m^{-2} s^{-1}) or emission rate (Ou_E s^{-1}) depending on source characteristics. Each odour source descriptor and offensiveness level is also presented.

Table 5.1 Odour emission rate for each individual/proposed process within site boundaries

Odour source	Odour emission rate (Ou_E s^{-1} m^{-2})	Odour emission rate (Ou_E s^{-1})	Odour concentration offensive level/Odour descriptor *
Over ground Leachate storage tank 1, 2 and 3[1]	9.61		2.33 to 3.19 (musty/turnips/rotten)
Active Face[2]	9.25		3.29/2.68 (glue/sweet/rubbish/dustbin)
Tipping head[3]	92.5		3.29/2.68 (glue/sweet/rubbish/dustbin)
Daily cover on cells[4]	1.69		1.26 (Domestic waste/rotten eggs)
Temporary cap[5]	0.67		6.0 (musty/clay odour)
Flare gas vent [6] (Assuming 98% reduction)		602	1.8 (natural gas/pungent/rotten eggs)
Temporary sludge dryer Castlebar WWTP[7]		7388 (average H_2S=42 ppb)[11]	3.2/2.8 Musty, dank sulphurous odour
Loading hopper sludge drier Castlebar WWTP[8]	670 (average H_2S=55ppb)[11]		Rotten eggs/rotten cabbage/musty
New sludge drier proposed for installation at Derrinemura landfill[9]		7388	No data
Leachate treatment tanks 1, 2 and 3[10]		1029 X 3	Musty/dank

[1] denotes average of odour emission rates measured on landfills within Ireland by Odour Monitoring Ireland (n=9 samples);
[2] denotes average of odour emission rates measured on landfills within Ireland by Odour Monitoring Ireland (n=6 samples);
[3] denotes it is assumed that the odour emission is a conservative 10 times the odour emission of the active face due to tipping and movement of waste;
[4] denotes Odour emission rate estimates from Brogborough landfill site;
[5] denotes Odour emission rate estimates from Brogborough landfill site;
[6] denotes assumed that flare runs 24 hours per day and at a capacity of 250 m^3 h^{-1} attaining a DRE of 98%;

[7] denotes odour emission data generated from onsite measurements using olfactometry in accordance with PrEN13725 in Odour Monitoring Ireland's olfactometry laboratory. Airflow measurements were carried out in order to determine average airflow rate during maximum output operation. Four odour samples were taken and measured;
[8] denotes measured odour emission rate by Odour Monitoring Ireland in their odour measurement laboratory in accordance with PrEN13725 standard on olfactometry. Two samples were taken and measured;
[9] denotes previously measured experimental data; Odour Monitoring Ireland odour emission database, used as worst-case scenario;
[10] denotes previously measured experimental data; Odour Monitoring Ireland odour emission database;
[11] denotes average H_2S monitoring results utilising Odour Monitoring Ireland's H_2S real time gold leaf analyser (Jerome metre).

Odour Emission Data from Overall Composting Process for 15,900 tonnes yr^{-1} Throughput

Table 5.2. Odour emission factors for each individual process within composting operation

Process	Odour emission rate (Ou_E ton^{-1} s^{-1})
Acceptance of waste	57[12]
Composting tunnel	61[13]
After treatment	138[13]
Storage	0.6[13]

[12] Odour Monitoring Ireland database.

Table 5.3 Predicted overall odour emission rate from composting operation with and without considered abatement protocols implemented

Process	Odour emission rate (Ou ton^{-1} s^{-1})	Amount per frequency (Tonnes frequency^{-1})	Overall odour emission rate (Ou s^{-1})
Acceptance of waste	57	318 tonnes every 1 week	18,126
Composting tunnel	61	318 tonnes continuously	19,398
Post treatment	138	159 tonnes every 1 week	21,942
Storage	0.6	1400 tonnes continuously	840
Predicted overall odour emission rate			60,306[13]
Predicted overall odour emission rate (assuming 95% abatement)			3015

[13] A maximum assumed odour emission rate was used to calculate the odour emission rates from the composting system.

5.2 RESULTS

5.2.1 Odour Emission Data

Five data sets for odour emission rates were calculated to determine the potential odour impact of the landfill, sludge drying and composting operation utilising the individual process odour emission data in Tables 5.1, 5.2 and 5.3. These scenarios included:

1. **Scenario 1 :** Predicted overall odour emission rate from landfill operation (Table 5.4);
2. **Scenario 2 :** Predicted overall odour emission rate from combined landfill operation and leachate treatment facility (Table 5.5);

3. **Scenario 3 :** Predicted overall odour emission rate from combined landfill operation, leachate treatment facility and operation of interim sludge drying system (Table 5.6);
4. **Scenario 4 :** Predicted overall odour emission rate from combined landfill operation, leachate treatment facility and operation of new sludge drying system (i.e. location of new sludge drier to Derrinumera landfill) (Table 5.7);
5. **Scenario 5 :** Predicted overall odour emission rate from combined landfill operation, leachate treatment facility and operation of Compost treatment facility (i.e. location of in-vessel composting system to Derrinumera landfill) (Table 5.8);

Odour Emission Rates from Current Landfill, Leachate treatment, Sludge Drying/Composting Operations for Atmospheric Dispersion Modelling Scenarios 1, 2, 3, 4 and 5.

Table 5.4 to 5.8 illustrate the overall odour emission rate from the proposed Derrinumera integrated waste management site for the different proposed scenarios. Five scenarios were chosen to estimate the worst-case potential odour impact from the current/proposed Derrinumera site. Modelling scenarios representing different proposed operations within the site were performed to assess the phased development of these site for the most significant odour emission rate periods.

Table 5.4 Scenario 1 : Predicted overall odour emission rate from landfill operation during maximum emission event

Process	**Area sources odour emission flux (Ou s^{-1} m^{-2})**	**Exposed area (m^2)**	**Point source odour emission rate (Ou s^{-1} m^{-2})**	**Overall odour emission rates (Ou s^{-1})**
Leachate Lagoon Cell 1	9.61	144		1384
Over-ground storage tanks 1 to 3	9.61	245		2354
Active Face	9.25	237		2192
Tipping head	92.5	100		9250
Daily cover	1.69	630		1065
Temporary cap	0.67	14594		9778
Flare gas vent			602	602
Total emission from Scenario 1				**26,625**

Table 5.5 Scenario 2 : Predicted overall odour emission rate from landfill operation and leachate treatment during maximum emission event

Process	Area sources odour emission flux (Ou s^{-1} m^{-2})	Exposed area (m^2)	Point source odour emission rate (Ou s^{-1} m^{-2})	Overall odour emission rates (Ou s^{-1})
Leachate Lagoon Cell 1	9.61	144		1384
Active Face	9.25	237		2192
Tipping head	92.5	100		9250
Daily cover	1.69	630		1065
Temporary cap	0.67	14594		9778
Flare gas vent			602	602
Over-ground leachate treatment tanks 1 to 3	12.6	245		3087
Total emission from Scenario 2				**27,358**

Table 5.6 Scenario 3 : Predicted overall odour emission rate from landfill operation, leachate treatment and sludge drying using interim sludge drier, Castlebar during maximum emission event

Process	Area sources odour emission flux (Ou s^{-1} m^{-2})	Exposed area (m^2)	Point source odour emission rate (Ou_E s^{-1})	Overall odour emission rates (Ou s^{-1})
Leachate Lagoon Cell 1	9.61	144		1384
Active Face	9.25	237		2192
Tipping head	92.5	100		9250
Daily cover	1.69	630		1065
Temporary cap	0.67	14594		9778
Flare gas vent			602	602
Over-ground leachate treatment tanks 1 to 3	12.6	245		3087
Temporary Sludge Dryer			7388	7388
Temporary sludge drier hopper loading	670	8		5360
Total emission from Scenario 3				**40,106**

Table 5.7 Scenario 4 : Predicted overall odour emission rate from landfill operation, leachate treatment and sludge drying using new sludge drier, during maximum emission event

Process	Area sources odour emission flux (Ou s^{-1} m^{-2})	Exposed area (m^2)	Point source odour emission rate (Ou_E s^{-1})	Overall odour emission rates (Ou s^{-1})
Leachate Lagoon Cell 1	9.61	144		1384
Active Face	9.25	237		2192
Tipping head	92.5	100		9250
Daily cover	1.69	630		1065
Temporary cap	0.67	14594		9778
Flare gas vent			602	602
Over-ground leachate treatment tanks 1 to 3	12.6	245		3087
New Sludge Dryer			7388	7388
Total emission from Scenario 4				**34,746**

Table 5.8 Scenario 5 : Predicted overall odour emission rate from landfill operation, leachate treatment and Composting using tunnel-composting system during maximum emission event

Process	Area sources odour emission flux (Ou s^{-1} m^{-2})	Exposed area (m^2)	Point source odour emission rate (Ou_E s^{-1})	Overall odour emission rates (Ou s^{-1})
Leachate Lagoon Cell 1	9.61	144		1384
Active Face	9.25	237		2192
Tipping head	92.5	100		9250
Daily cover	1.69	630		1065
Temporary cap	0.67	14594		9778
Flare gas vent			602	602
Over-ground leachate treatment tanks 1 to 3	12.6	245		3087
Composting			6410	3015
Total emission from Scenario 5				**30,373**

Table 5.9 Summary of the individual area and points sources that are included in each of the scenarios used in the predictive atmospheric dispersion modelling to determine the odour impact in the surrounding vicinity of the Derrinumera site

Process	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Over ground Leachate storage tanks 1, 2 and 3	X				
Leachate lagoon Cell 1	X	X	X	X	X
Active Face and operational area	X	X	X	X	X
Tipping head	X	X	X	X	X
Daily cover	X	X	X	X	X
Temporary cap	X	X	X	X	X
Flare gas vent	X	X	X	X	X
Leachate treatment facility tanks 1, 2 and 3		X	X	X	X
Temporary sludge drying facility			X		
New proposed sludge drying facility				X	
Composting Biofilter					X

5.3 SUMMARY OF RESULTS OF ODOUR DISPERSION MODELLING

ISC ST 3 was used to determine the overall odour impact of the proposed Derrinumera Landfill, leachate treatment and sludge processing operation to be located in Derrinumera, County Mayo at as set out in odour annoyance criteria Table 3.3 and Tables 5.1 to 5.3. The output data was analysed to calculate:

- Scenario 1 : Predicted odour emission contribution of overall landfill operation (Table 5.4), to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.2).

- Scenario 2 : Predicted odour emission contribution of overall landfill and leachate treatment (Table 5.5), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.3).

- Scenario 3 : Predicted odour emission contribution of overall landfill, leachate treatment and interim sludge drying operation (Table 5.6), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.4).

- Scenario 4 : Predicted odour emission contribution of overall landfill, leachate treatment and new proposed sludge drying operation (Table 5.7), respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.5).

- Scenario 5 : Predicted odour emission contribution of overall landfill, leachate treatment and sludge composting operation (Table 5.8), respectively to odour plume dispersal at the 98th percentile for a odour concentration of 3.0 Ou_E m^{-3} (Figure 5.6).

- Comparison between predicted odour emission contribution of individual odourous processes landfill, leachate treatment, Interim sludge drying, new proposed sludge drying and Composting operation, respectively to odour plume dispersal at the 98th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.7).

- Comparison between predicted odour emission contribution of Scenarios 1, 2, 3, 4 and 5, respectively to odour plume dispersal at the 99.5th percentile for an odour concentration of 3.0 Ou_E m^{-3} (Figure 5.8) to examine the extent of any possible odour impact.

These computations give the odour concentration at each 100-meter x y Cartesian grid receptor location that is predicted to be exceeded for 2% (175 hours) and 0.5% (44 hours) of the year. Additionally, the 2 individual nearest residences were represented in the dispersion model to numerically predict the odour concentration at their location.

This will allow for the predictive analysis of any potential impact on the neighbouring locations while the landfill site and other proposed processes are in operation. It will also allow the operators of the facility to assess the effectiveness of their considered odour abatement/minimisation strategies. The intensity of the odour from the two or more sources will depend on the strength of the initial odour threshold concentration from the sources and the distance downwind at which the prediction and/or measurement is being made. Where the odour emission plumes from a number of sources combine downwind, then the predicted odour concentrations may be significantly higher than that resulting from an individual emission source. It is important to note that various odour sources have different odour characters and intensities. This is important when assessing those odour sources to minimise and/or abate. Although an odour source may have a high odour emission rate, its corresponding odour intensity (strength) may be low and therefore it is easily diluted. Those sources that express the same odour character as an odour impact will be investigated first for abatement/minimisation before other sources are examined as these sources are the driving force behind the character of the perceived odour.

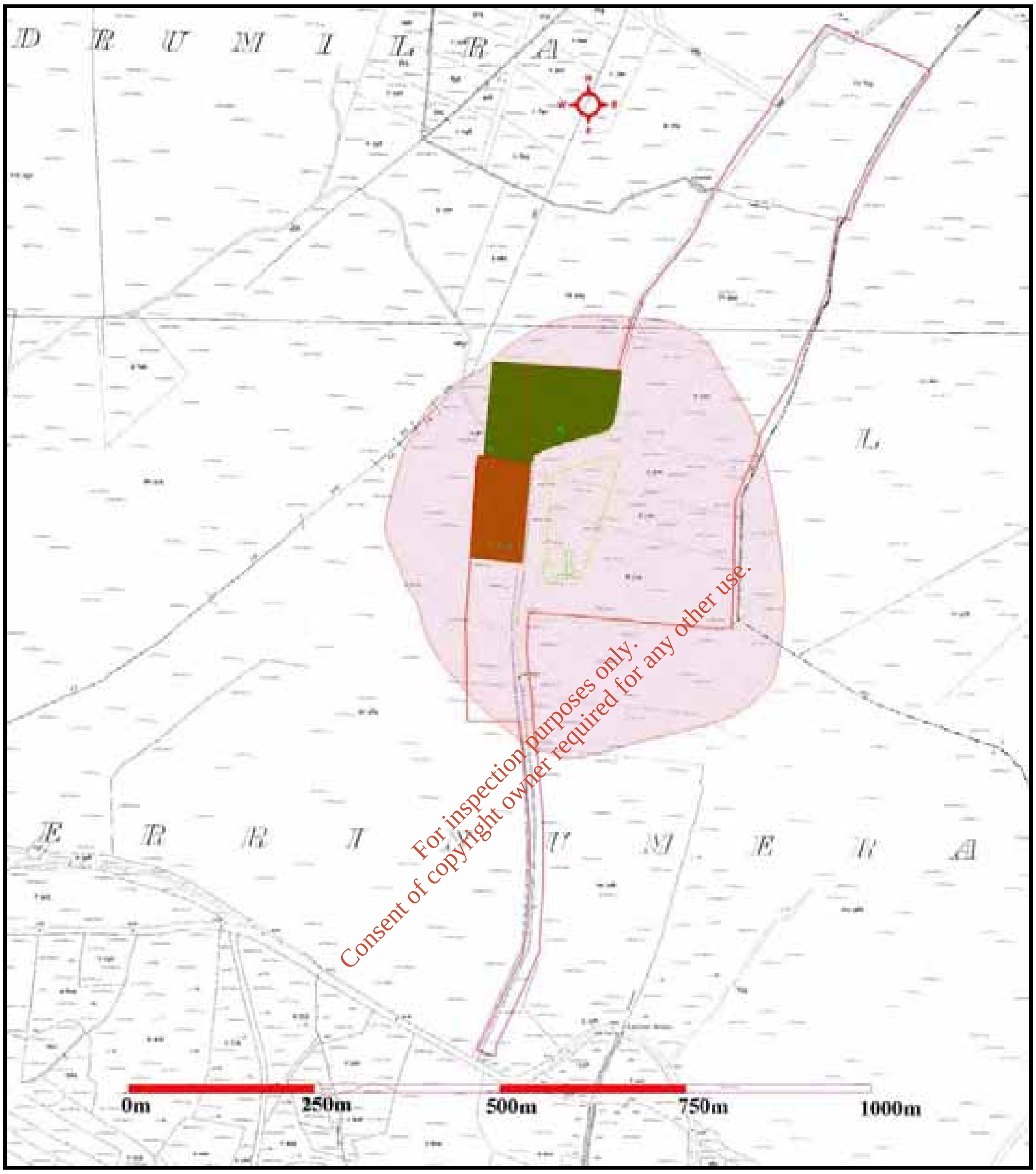


Figure 5.2. Predicted odour emission contribution of landfill process to odour plume dispersal for Scenario 1 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} ( ).

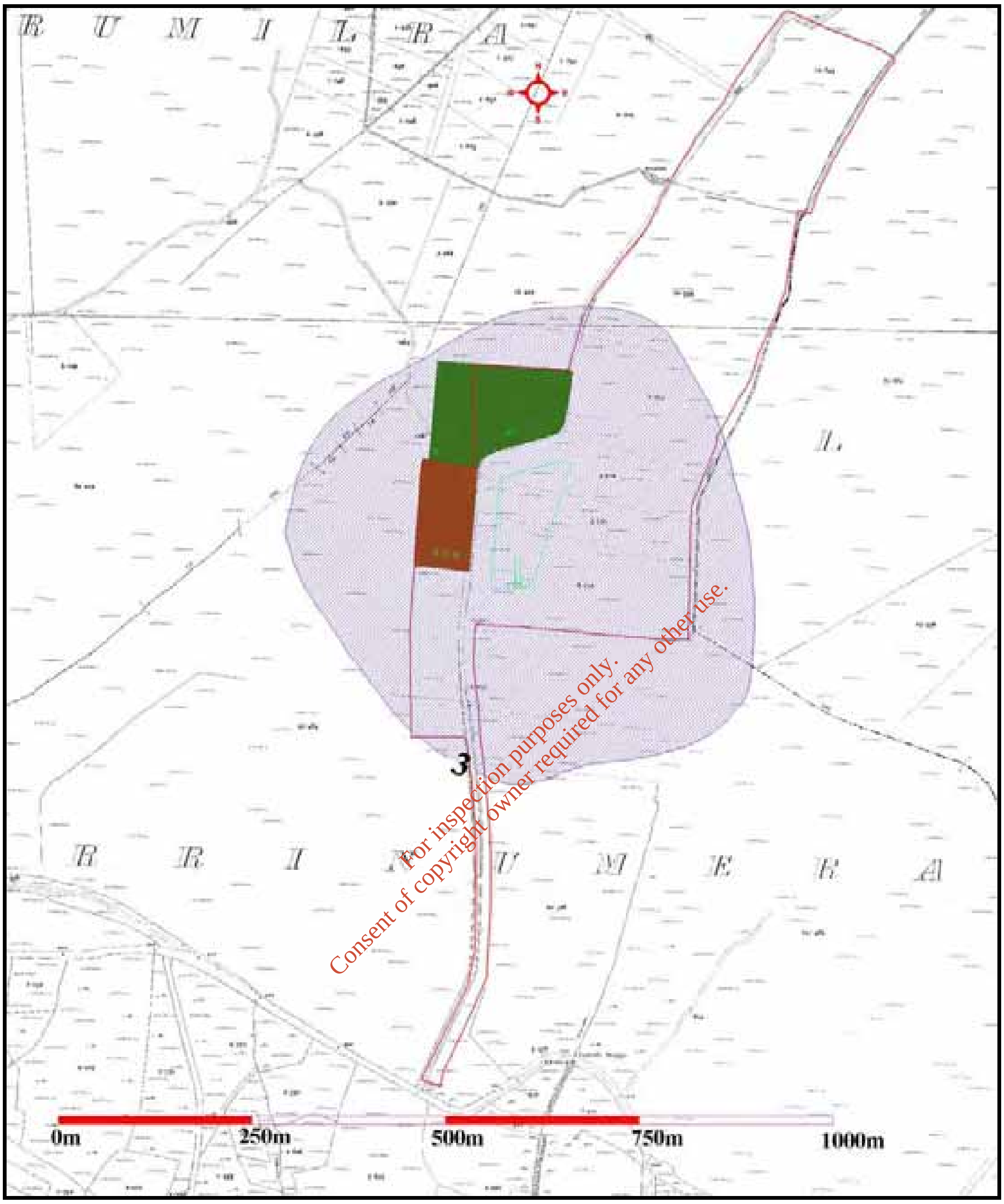


Figure 5.3. Predicted odour emission contribution of landfill and leachate treatment process to odour plume dispersal for Scenario 2 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} ( ).

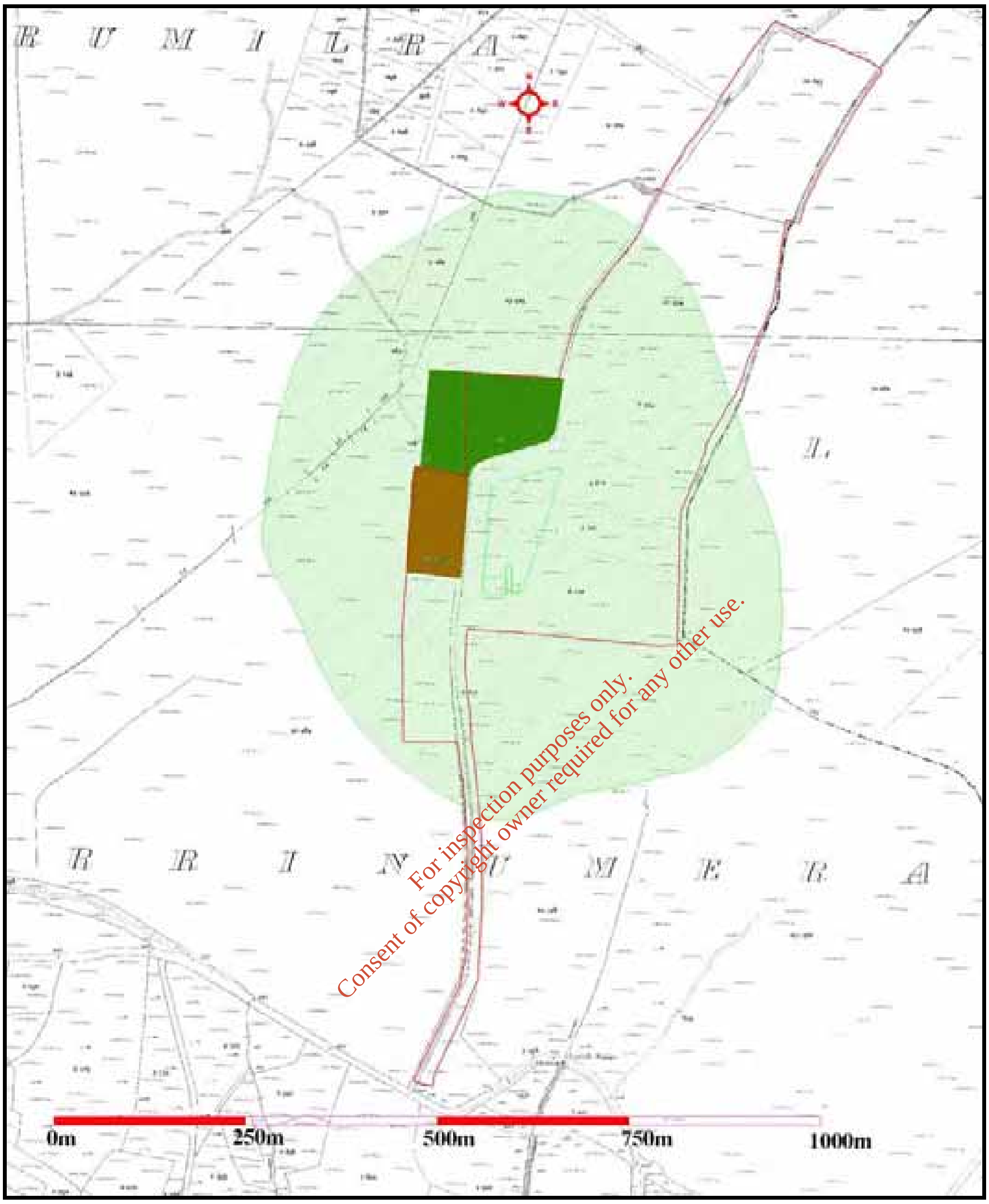


Figure 5.4. Predicted odour emission contribution of landfill, leachate treatment and interim sludge drying process to odour plume dispersal for Scenario 3 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} (——).

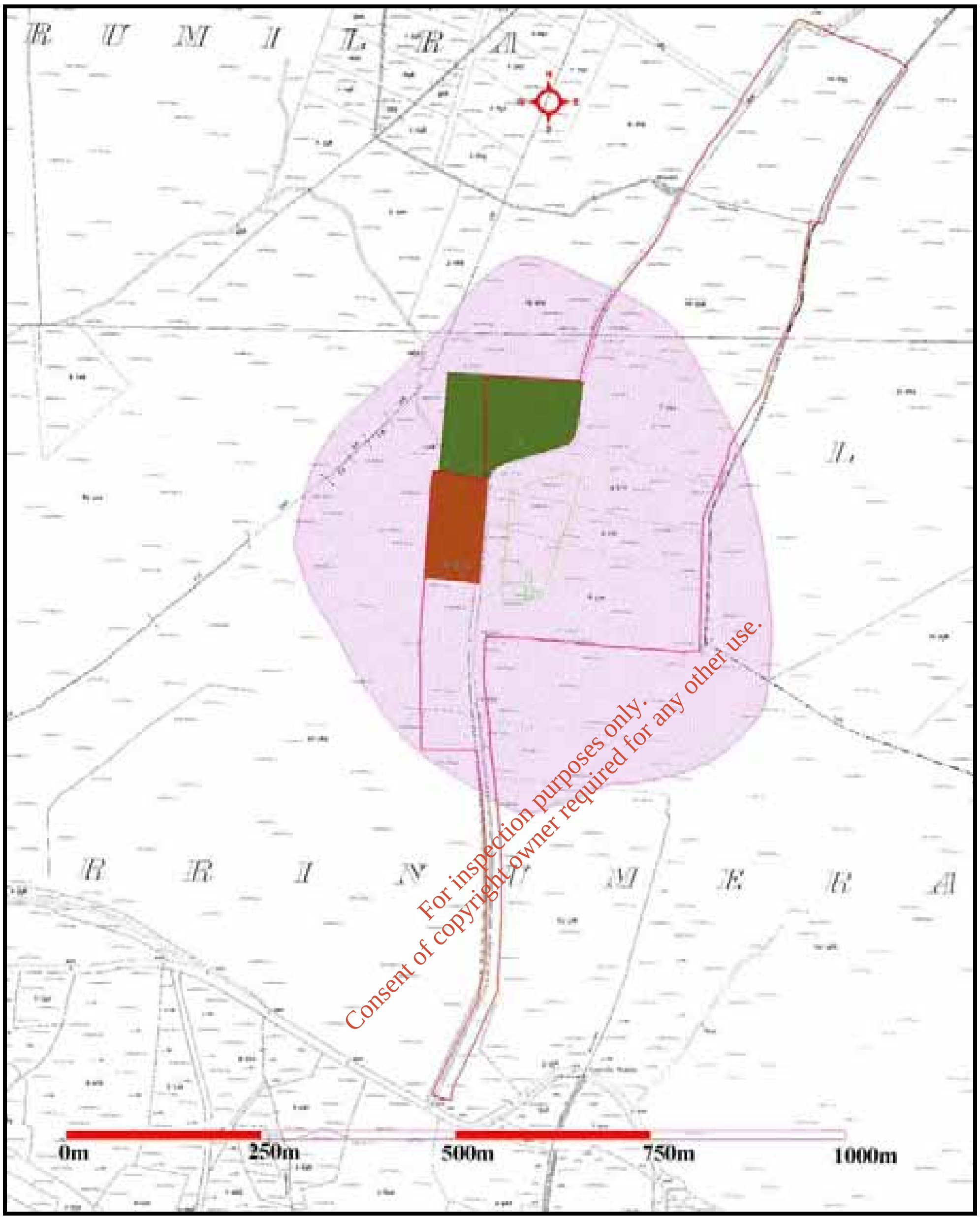


Figure 5.5. Predicted odour emission contribution of landfill, leachate treatment and new proposed sludge drying process to odour plume dispersal for Scenario 4 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} (——).

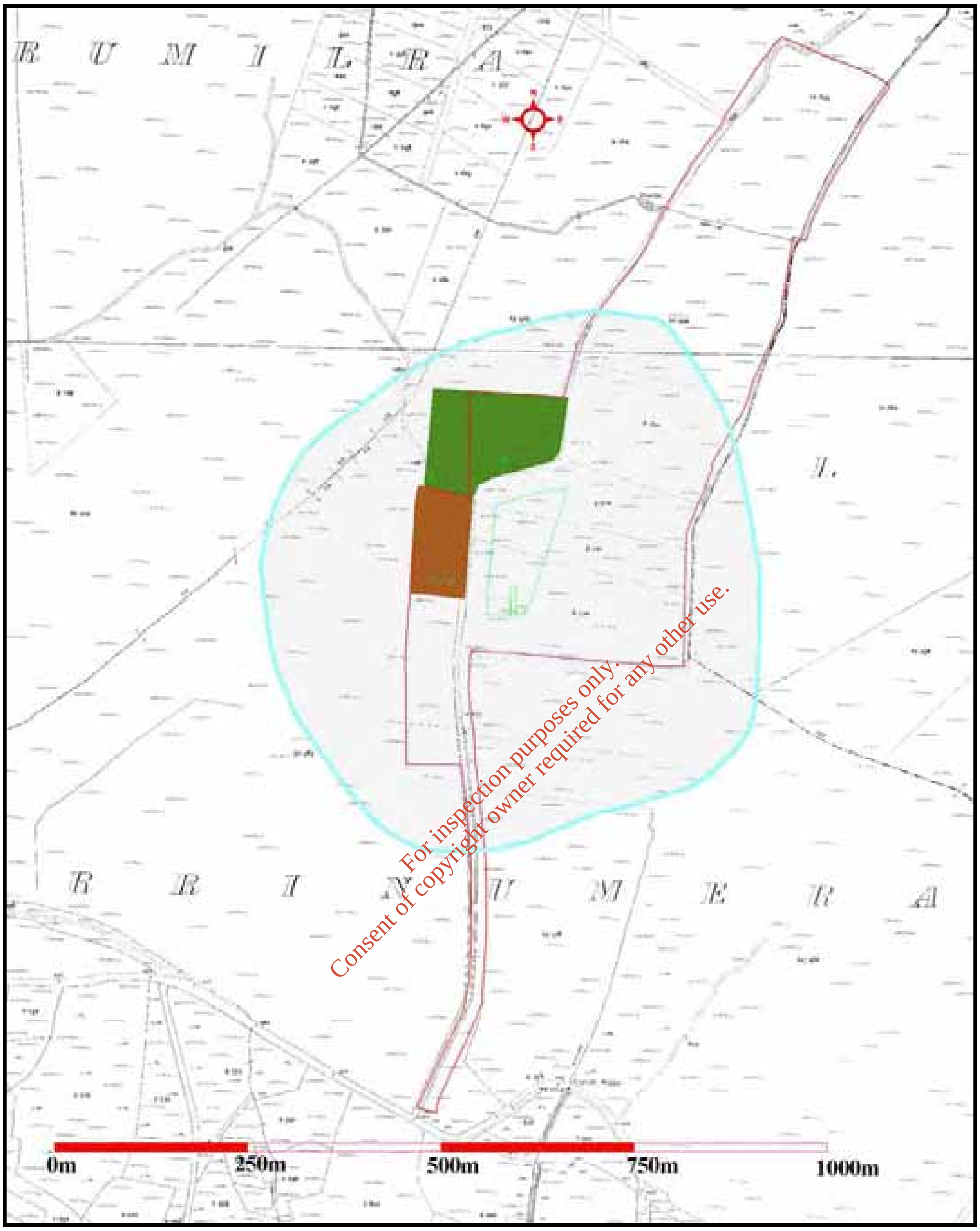


Figure 5.6. Predicted odour emission contribution of landfill, leachate treatment and Composting process to odour plume dispersal for Scenario 5 at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} (——).

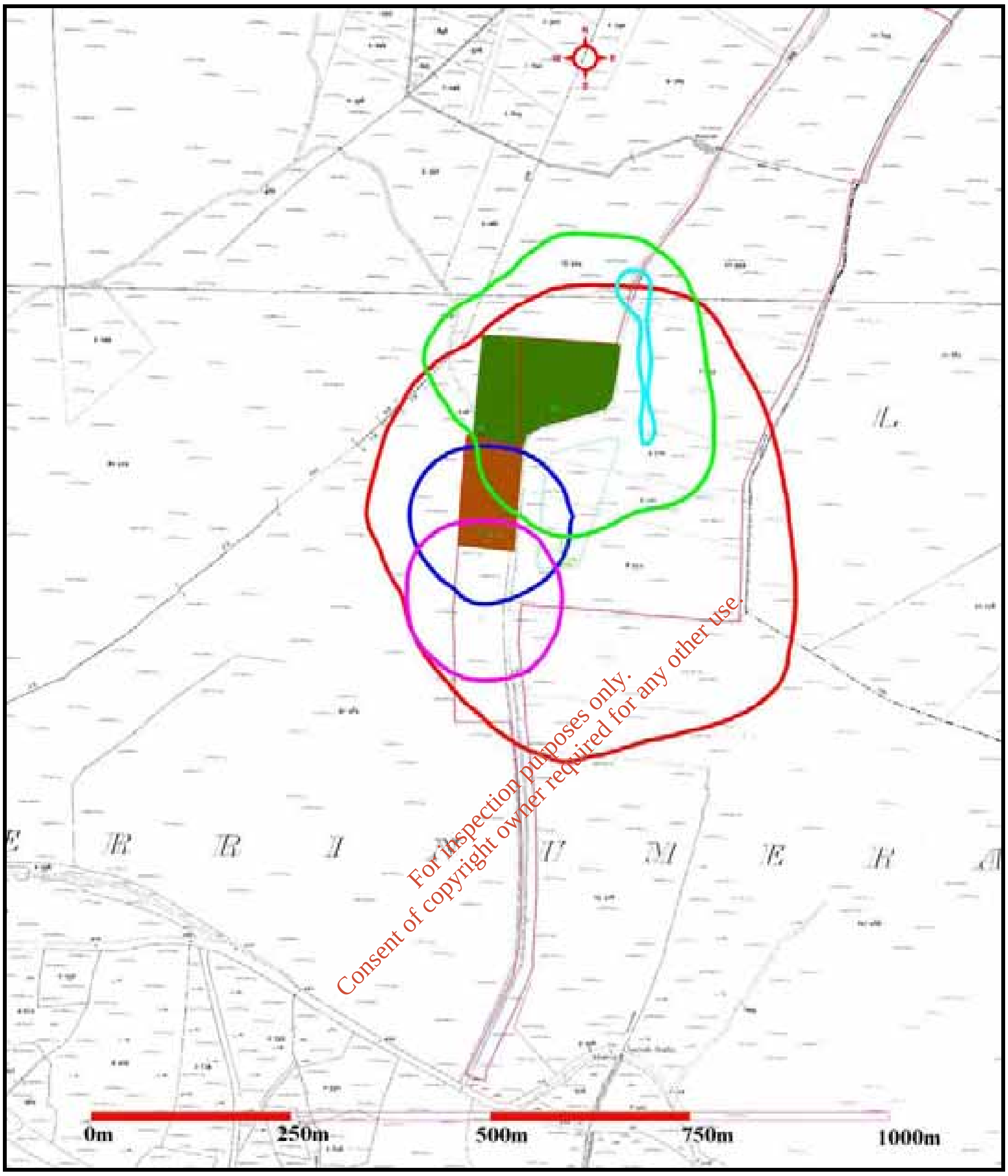


Figure 5.7. Comparison between predicted odour emission contribution of individual odourous processes, landfill (red line), leachate treatment (blue line), interim sludge drier (green line), new proposed sludge drier (cyan line) and tunnel composting (magenta line) to odour plume dispersal at the 98th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3}.

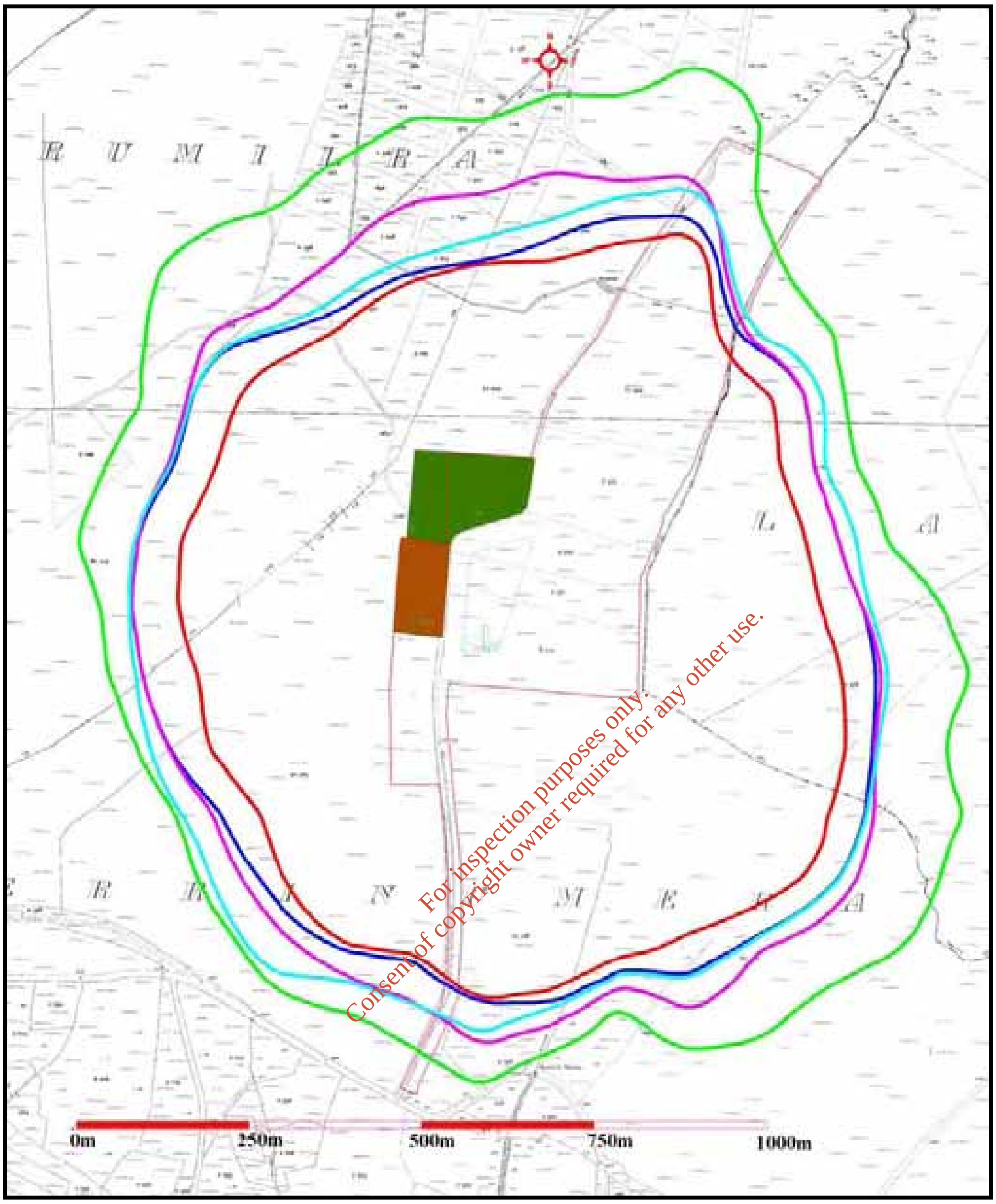


Figure 5.8. Comparison between predicted odour emission contribution of Scenario 1 ( ), Scenario 2 ( ), Scenario 3 ( ), Scenario 4 ( ) and Scenario 5 ( ) to odour plume dispersal at the 99.5th percentile for odour concentrations ≤ 3.0 Ou_E m^{-3} to examine the extent of any odour impact.

5.4 DISCUSSION OF RESULTS

5.4.1 Odour Plume Dispersal from Derrinumera Site for Scenarios 1, 2, 3, 4 and 5 for ≤ 3.0 Ou_E m^{-3} at 98^{th} Percentile.

5.4.1.1 Scenario 1

The plotted odour concentrations of ≤ 3.0 Ou_E m^{-3} for the 98^{th} percentile during maximum odour emission event from landfill is illustrated in Figure 5.2 (Scenario 1). As can be observed, it is predicted that no significant odour impact will be perceived in the vicinity of the operated landfill operation with all residents perceiving an odour concentration of less than 1.0 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. It is predicted that identified residents will perceive an odour concentration of between 0.1 Ou_E m^{-3} and 0.3 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. The odour impact is approximately 10 to 30 times lower than the proposed limit criterion presented in Table 3.3. In accordance with odour annoyance criterion in Table 3.3, and in keeping with current recommended odour annoyance criterion in this country, the landfill and composting operations will receive no complaints.

5.4.1.2 Scenario 2

The plotted odour concentrations of 3.0 Ou_E m^{-3} for the 98^{th} percentile following operation of a leachate treatment facility is illustrated in Figure 5.3 (Scenario 2). All residences in the vicinity will perceive an odour concentration less than 1.0 Ou_E m^{-3} for 175 hours of a worst-case meteorological year. It is predicted that all residences will perceive an odour concentration of between 0.25 Ou_E m^{-3} and 0.6 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. In accordance with odour annoyance criterion in Table 3.3, the current landfill and proposed leachate treatment facility will not cause odour impact on identified residences in the surrounding area.

5.4.1.3 Scenario 3

The plotted odour concentration of 3.0 Ou_E m^{-3} for the 98^{th} percentile during additional installation of the interim sludge drier is illustrated in Figure 5.4 (Scenario 3). It is predicted that all residences will perceive an odour concentration of between 0.35 Ou_E m^{-3} and 0.7 Ou_E m^{-3} for 175 hours in a worst-case meteorological year In accordance with odour annoyance criterion Table 3.3, there will be no odour impact in the vicinity of the current and proposed operations.

5.4.1.4 Scenario 4

The plotted odour concentration of 3.0 Ou_E m^{-3} for the 98^{th} percentile during installation of a new sludge drier is illustrated in Figure 5.5 (Scenario 4). It is predicted that all residences will perceive an odour concentration of between 0.30 Ou_E m^{-3} and 0.65 Ou_E m^{-3} for 175 hours in a worst-case meteorological year In accordance with odour annoyance criterion Table 3.3, there will be no odour impact in the vicinity of the current and proposed operations.

5.4.1.5 Scenario 5

The plotted odour concentration of 3.0 Ou_E m^{-3} for the 98th percentile during installation of a in-vessel composting system instead of the sludge drier is illustrated in Figure 5.6 (Scenario 5). It is predicted that all residences will perceive an odour concentration of between 0.30 Ou_E m^{-3} and 0.6 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. In accordance with odour annoyance criterion Table 3.3, there will be no odour impact in the vicinity of the current and proposed operations.

It must be emphasised that a worst-case meteorological year was used to assess worst-case dispersion estimates. The current odour emission rates from various processes within the landfill are based on current management practice. In keeping with the national waste policy, organic waste content of land filled waste must be reduced over a phased time frame. By year 14.5 of landfill operation, it is recommended that organic waste reduction will be at least 65%. This 65% reduction in organic matter content will reduce the formation of sulphur containing organics, organic acid and other odour precursors associated with incomplete methanogenesis. It is rational to suggest that odour emission rate estimates and hence odour impact area will reduce significantly (i.e. at least 30%) due to the implementation of these practices but until a landfill is in operation, it is impossible to predict how much reduction in odour emission flux can be achieved

5.4.1.6 Comparison Between Predicted Odour Plume Dispersal for Individual Odour Sources During Operation at the 98th Percentile for Odour Concentrations $\leq$ 3.0 Ou_E m^{-3}.

Figure 5.7 illustrates the contribution to odour impact distance from the individual odour sources for an odour concentration of $\leq$ 3.0 Ou_E m^{-3} for the 98th percentile. As can be observed, the current landfill will generate the largest odour footprint. If compared, the various odour sources can be graded as follows: Landfill is more odourous than the Interim sludge drier, which is more odourous than the Composting operations, which is more odourous than the Leachate treatment, which is more odourous than the new proposed sludge drier. Odour impacts distances are a combination of odour source characteristics, odour emission rates and dose response relationship studies. All these factors will be considered before selecting appropriate systems based on odour impact distances. Only odour source characteristics and odour emission rates are accounted for in this assessment.

5.4.1.7 Odour Plume Dispersal from Scenario 1, 2, 3, 4 and 5 for $\leq$ 3.0 Ou_E m^{-3} at the 99.5th Percentile (44 hours).

The plotted odour concentration for 3.0 Ou_E m^{-3} at the 99.5th percentile for Scenarios 1, 2, 3, 4 and 5 is illustrated in Figure 5.8. As can be observed in Figure 5.8, residents in the vicinity of the Derrinumera site will perceive less than 3.0 Ou_E m^{-3} for all Scenarios. Upon examination of numerical output files all residences in the vicinity of the current and proposed operations will perceive an odour concentration less than 1.0 Ou_E m^{-3} for the 99.5th percentile.

6 MEASURES TO MITIGATE ADVERSE IMPACTS

The following are the recommended mitigation measures for odour impact for each of the landfill and proposed developments.

6.1 ODOUR MINIMISATION/ABATEMENT STRATEGIES FOR THE LANDFILL AND LTF

The following odour minimisation strategies will be considered during the operation of the combined landfill and Leachate Treatment Facility (LTF), to be located in Derrinumera, County Mayo.

Table 6.1 Considered odour minimisation strategies that can be used during the operation of the current landfill operations at Derrinumera, County Mayo

Process	Odour minimisation strategy
Active face/Operational area	Temporary cover using materials such as Hessian, mineral soil, clay cover and impermeable materials such as PVC. It is not recommended that misting systems be used constantly as they may increase the moisture content of the waste and therefore proliferate anaerobic conditions. Mist system will be only used when appropriate.
Exposed waste	Daily/Weekly cover using Hessian//Polythene/ soil won on-site
Landfill gas extraction wells	Attachment to landfill flare system. Landfill gas extraction wells are not considered significant odour sources in comparison to other odour sources within landfill
Leachate lagoon	All leachate will be removed under working height of leachate surface to maintain quiescence conditions. Any leachate treatment will employ the used of fine bubble diffuse aeration.
Fugitive landfill gas release	Sufficient temporary and permanent capping and connection of landfill gas extraction wells to landfill flare extraction system. Binding agents may also be added to surface to eliminate soil erosion during wet weather conditions. They may also seal porous soil structures and force landfill gas to follow the extraction system
Waste tipping	It is proposed that the tipping of significantly odourous waste will be limited during meteorological conditions that do not favour odour dispersion.
Landfill site management	An odour management plan will be implemented using resident data, meteorological data and site operator knowledge to investigate any odour complaints/potential odour complaints and implement remedial action using a developed common sense strategy.
Waste management strategy	It is proposed to reduce the organic fines content by up to 65%. This reduction in organic content will reduce odour emissions from landfill processes significantly. It must be emphasised that odour emission rates used in the development of this report do not take account of this reduction in organic matter content in land filled waste.

6.2 CONSIDERED ODOUR ABATEMENT TECHNOLOGY FOR TUNNEL COMPOSTING SYSTEMS

6.2.1 Wet scrubber

Absorption or scrubbing is a process in which waste air is mixed thoroughly with a scrubbing liquid. The components in the waste air are absorbed into this liquid phase. Sometimes chemicals are added to the scrubbing liquid (e.g. chemical scrubbers) to ionise or decompose the odourous compounds to less odourous compounds. Chemical scrubbers are commonly referred to as acid scrubbers, alkaline scrubbers and oxidising scrubbers. Catalysts can be incorporated into the design to enhance chemical reactions in the scrubbing liquid, therefore reducing chemical usage and improve cost effectiveness. A scrubber can be operated in either cross current or counter current mode. Most systems are packed with a random plastic media, while others rely on fine droplets to enhance absorption (e.g. mist scrubbers). The wet scrubber to be installed on the Composting building in Derrinumera will function as a acid scrubber removing and dampening the load of nitrogen containing organics to be treated by the biofiltration system. High nitrogen loads on the biofilter may kill odour-removing microbes; raise the pH of the medium and cause significant biomass growth, therefore causing significant operational problems for the biofiltration system.

6.2.2 Biofiltration System

Biofiltration is an air pollution control technology used for the abatement of odours and volatile organic carbons (Sheridan *et al*, 2000, Deshusses, 1997). It has been used in many industries for the end of pipe treatment of emissions including, waste water treatment plants (Wani et al, 1997), rendering plants (Lou et al, 1997), intensive agricultural facilities (Classen et al, 1999, Sheridan et al, 2002a) and polymer production plants (Hardy et al, 1995). The operational principle of a biofilter is that the contaminated air from a building is passed through a chamber, which contains a moist filter based media (organic and/or inorganic). The surface of the media is surrounded by a biofilm, where the microbes reside. As the contaminated air passes over the biofilm, it transverses the aqueous film, where the microbial consortium breaks downs the contaminants to water, carbon dioxide and inorganic salts. Biofilters are usually associated with high airflow rates and low concentration.

The design of biofilters for composting applications needs to be carefully optimised if the technology is to fulfil its potential. Initial studies have indicated that the packing medium and electrical running costs of a biofilter represent a high proportion of the overall cost (Sheridan et al, 2002c). For efficient operation, a filter material will provide optimum environmental conditions for the microbes (i.e. oxygen, temperature, humidity, nutrients and pH). The medium will possess uniform particle size, providing low pressure drop, minimal gas channelling, high reactive surface area and especially good mechanical strength that leads to negligible bed compaction in operation to minimise maintenance and media replacement

(Kiared et al, 1997). The addition of inert lightweight solids such as polystyrene beads and volcanic rock to the packing matrix to reduce compaction could lengthen the life span of organic packing materials (Sorial et al, 1997). The addition of granular activated carbon will enhance biofilter start-up time during cyclic process operation.

For odourous air emanating from composting facilities (high concentration of sulphur and nitrogen containing organics), a dual stage system will be considered. The media will preferably be composed mainly of inorganic medium structure, organic medium such as wood chips, marl/oyster shells/magnesium carbonate for pH control and an efficient moisturising system. Inoculation of the medium may be performed using activated sludge from a wastewater treatment plant. Prior to inoculation, the activated sludge will be checked to determine if the microbes of interest are present in the activated sludge. An air distribution system will be designed carefully to distribute the air evenly throughout the surface area of the medium. Maximum superficial air velocities of 100 m h^{-1} will be maintained in order to achieve maximum removal efficiency. Odour removal efficiencies of greater than 95% may be achievable if these protocols are followed (Sheridan et al. 2002 (c)). Alternatively a biotrickling system may be designed to effectively combine wet scrubbing and biofiltration within one system therefore reducing capital investment and operation costs.

In the case of this document an odour reduction efficiency of 95% will be assumed for the combined wet scrubbing and biofiltration system as recommended by the manufacturers.

7 CONCLUSIONS/RECOMMENDATIONS

It may be concluded that:

- A worst-case odour modelling scenario was chosen to estimate worst-case odour impact from the proposed site.
- No significant odour impact will be perceived in the vicinity of the operated Derrinumera site for Scenarios 1, 2, 3, 4 and 5; with all residents perceiving an odour concentration of less than 1.0 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. It is predicted that identified residents will perceive an odour concentration of between 0.1 Ou_E m^{-3} and 0.7 Ou_E m^{-3} for 175 hours in a worst-case meteorological year. The odour impact is approximately 4.3 to 30 times lower than the proposed limit criterion presented in Table 3.3. In accordance with odour annoyance criterion in Table 3.3, and in keeping with current recommended odour annoyance criterion in this country, the Derrinumera site operations will receive no complaints.
- When compared, the various odour sources can be graded as follows: Landfill is more odorous than the Interim sludge drier, which is more odorous than the Composting operations, which is more odorous than the Leachate treatment, which is more odorous than the new proposed sludge drier. Odour impacts distances are a combination of odour source characteristics, odour emission rates and dose response relationship studies. All these factors will be considered before selecting appropriate

systems based on odour impact distances. Only odour source characteristics and odour emission rates are accounted for in this assessment.

- All residents in the vicinity of the Derrinumera site will perceive less than 3.0 $Ou_E\ m^{-3}$ for all Scenarios for 44 hours in a worst-case year.

The operators of Derrinumera site, County Mayo are recommended to:

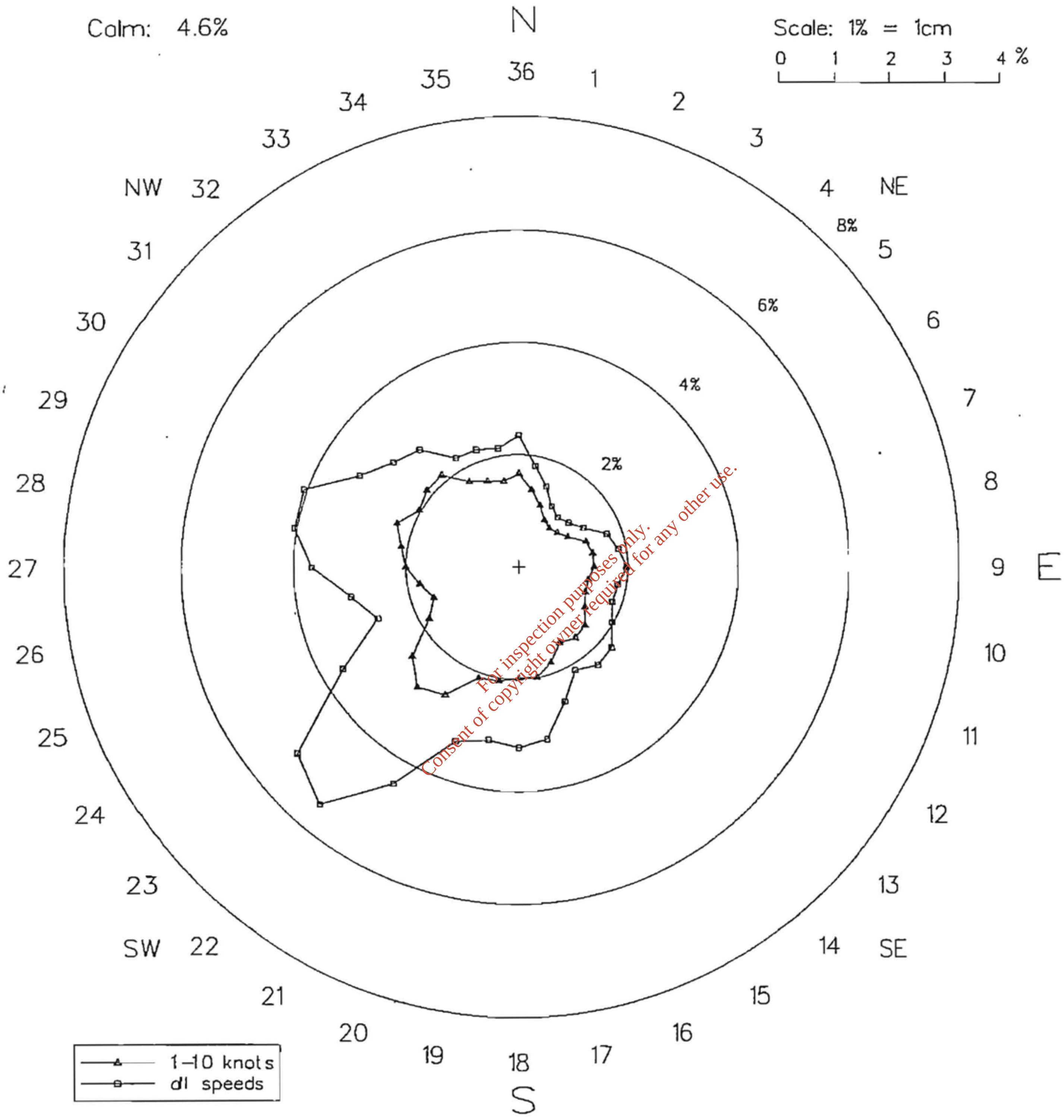
- Establish odour management protocols for the Derrinumera site including, strict meteorological data recording and sludge/waste inspection.
- Implement weekly odour inspection on odourous areas within the site boundary in order to maintain efficient odour management protocols.
- Provide sufficient temporary coverage to prevent volatilisation and stripping of odourous gases from exposed waste.
- Temporary cover active face with impermeable covers at weekends.
- Limit the tipping of highly odourous waste during meteorological conditions that may carry concentrated odour plumes towards close-by residences. All highly odourous waste will be covered immediately.
- Ensure fine bubble diffuse aeration system is employed for leachate treatment on-site in order to eliminate significant anaerobic events.
- Ensure all sludge-handling practices are carried out in-doors.
- Do not hold sludge on-site for elongated periods of time before treatment.
- Temporary cover all treated sludge with clay when landfilled in order to prevent odour events within landfill.
- To maintain good housekeeping practices, closed-door management strategy and to implement an odour management plan for the operators of the proposed composting plant. The composting operations will be maintained under negative ventilation to eliminate the release of puff odour emissions from the facility.

APPENDIX 14

Met Eireann Windrose for Claremorris

CLAREMORRIS 1970–1999

Percentage Frequency of Occurrence of Wind Directions



Percentage Frequency of Occurrence of Wind Speeds

+ less than 0.1

0	1–3	4–6	7–10	11–16	17–21	22–27	28–33	34–40	41–47	over 48	knots
4.6	13.9	20.1	27.7	25.2	6.2	1.9	0.3	+	+	+	%

mean wind speed: 8.7 knots

standard deviation: 5.5 knots

anemometer height: 12m

Meteorological Service, Glasnevin Hill, Dublin 9.

number of simultaneous occurrences of specified ranges of mean hourly wind speed and direction

Claremorris all months (january 1970 to december 1999)

direction in degrees	calm	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	56-63	over 63	total
010		842	1305	1526	941	145	25	1						4785
020		797	1095	1181	753	132	42							4000
030		732	883	934	620	87	23							3279
040		671	820	890	581	64	6							3032
050		703	889	915	592	112	9							3220
060		713	982	1124	699	124	15	2						3659
070		913	1212	1370	850	148	30	2						4525
080		957	1321	1377	1011	182	24	2						4874
090		985	1275	1409	1139	285	99	8						5200
100		830	1194	1421	1094	227	74	6						4846
110		932	1148	1385	1063	213	60	3						4804
120		1018	1153	1557	1152	250	61	4						5195
130		1024	1313	1895	1313	265	35	2						5847
140		1060	1403	1855	1398	214	51							5981
150		987	1347	1733	1281	179	24							5551
160		1037	1548	2134	1667	261	31	1						6679
170		1100	1723	2394	2297	506	116	8	1					8145
180		1054	1730	2414	2498	563	156	12	1	1				8429
190		1146	1839	2426	2241	430	101	5	1	4				8193
200		1073	1840	2594	2274	614	214	32	3	1	1			8646
210		1192	2064	3643	3321	1032	338	75	5					11670
220		1094	2001	4236	5064	1427	500	105	7	2	1			14437
230		1056	1790	3627	4934	1531	462	71	4	2				13477
240		876	1407	2522	3268	1046	306	43	4	1				9473
250		735	1358	2110	2071	492	183	26	8					6983
260		913	1498	2248	2378	652	192	42	13	1				7937
270		1066	1633	2552	2898	995	391	85	13	6				9639
280		1100	1701	2731	3335	1157	460	98	23	13				10618
290		1306	1866	2846	3293	931	336	54	18	8				10658
300		1167	1764	2400	2302	593	270	45	8					8549
310		1564	2073	1934	1454	407	140	21	6					7599
320		1770	2079	1740	1215	250	69	21	1					7145
330		1413	1562	1633	990	211	54	3						5866
340		1049	1370	1851	1280	223	54	5	1					5833
350		830	1289	1947	1359	153	34	7						5619
360		825	1365	2162	1562	207	43	1						6165
total	11973	36530	52840	72716	66188	16308	5028	790	117	39	2			262531

percentage frequency of simultaneous occurrences of specified ranges of mean hourly wind speed and direction

Claremorris all months (january 1970 to december 1999)

direction in degrees	calm	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	56-63	over 63	total
							wind speed in knots							
010		0.3	0.5	0.6	0.4	0.1	0+	0+						1.8
020		0.3	0.4	0.4	0.3	0.1	0+							1.5
030		0.3	0.3	0.4	0.2	0+	0+							1.2
040		0.3	0.3	0.3	0.2	0+	0+							1.2
050		0.3	0.3	0.3	0.2	0+	0+							1.2
060		0.3	0.4	0.4	0.3	0+	0+	0+						1.4
070		0.3	0.5	0.5	0.3	0.1	0+	0+						1.7
080		0.4	0.5	0.5	0.4	0.1	0+	0+						1.9
090		0.4	0.5	0.5	0.4	0.1	0+	0+						2.0
100		0.3	0.5	0.5	0.4	0.1	0+	0+						1.8
110		0.4	0.4	0.5	0.4	0.1	0+	0+						1.8
120		0.4	0.4	0.6	0.4	0.1	0+	0+						2.0
130		0.4	0.5	0.7	0.5	0.1	0+	0+						2.2
140		0.4	0.5	0.7	0.5	0.1	0+							2.3
150		0.4	0.5	0.7	0.5	0.1	0+							2.1
160		0.4	0.6	0.8	0.6	0.1	0+	0+						2.5
170		0.4	0.7	0.9	0.9	0.2	0+	0+	0+					3.1
180		0.4	0.7	0.9	1.0	0.2	0.1	0+	0+	0+				3.2
190		0.4	0.7	0.9	0.9	0.2	0+	0+	0+	0+				3.1
200		0.4	0.7	1.0	0.9	0.2	0.1	0+	0+	0+	0+			3.3
210		0.5	0.8	1.4	1.3	0.4	0.1	0+	0+					4.4
220		0.4	0.8	1.6	1.9	0.5	0.2	0+	0+	0+	0+			5.5
230		0.4	0.7	1.4	1.9	0.6	0.2	0+	0+	0+				5.1
240		0.3	0.5	1.0	1.2	0.4	0.1	0+	0+	0+				3.6
250		0.3	0.5	0.8	0.8	0.2	0.1	0+	0+					2.7
260		0.3	0.6	0.9	0.9	0.2	0.1	0+	0+	0+				3.0
270		0.4	0.6	1.0	1.1	0.4	0.1	0+	0+	0+				3.7
280		0.4	0.6	1.0	1.3	0.4	0.2	0+	0+	0+				4.0
290		0.5	0.7	1.1	1.3	0.4	0.1	0+	0+	0+				4.1
300		0.4	0.7	0.9	0.9	0.2	0.1	0+	0+					3.3
310		0.6	0.8	0.7	0.6	0.2	0.1	0+	0+					2.9
320		0.7	0.8	0.7	0.5	0.1	0+	0+	0+					2.7
330		0.5	0.6	0.6	0.4	0.1	0+	0+						2.2
340		0.4	0.5	0.7	0.5	0.1	0+	0+	0+					2.2
350		0.3	0.5	0.7	0.5	0.1	0+	0+						2.1
360		0.3	0.5	0.8	0.6	0.1	0+	0+						2.3
total	4.6	13.9	20.1	27.7	25.2	6.2	1.9	0.3	0+	0+	0+			

total number of observations = 262531 the entry "0+" indicates the percentage is between zero and 0.05

Table 3.2 Monthly and Annual Mean and Extreme Values for Claremorris (1961 – 1990)

MET éireann

CLAREMORRIS

monthly and annual mean and extreme values

1961-1990

lat. 53° 42' N
long. 8° 59' W
height 71 metres above mean sea level

	jan	feb	mar	apr.	may	jun	jul	aug	sep.	oct	nov	dec	year
TEMPERATURE *(degrees Celsius)*													
mean daily max.	7.2	7.6	9.6	12.0	14.5	17.0	18.4	18.2	16.1	13.2	9.5	7.9	12.6
mean daily min.	1.4	1.3	2.3	3.3	5.5	8.2	10.2	9.8	8.1	6.3	3.0	2.3	5.1
mean	4.3	4.5	5.9	7.6	10.0	12.6	14.3	14.0	12.1	9.8	6.2	5.1	8.9
absolute max.	13.1	13.3	20.1	22.3	25.1	29.8	30.5	27.2	23.3	19.9	15.4	14.3	30.5
absolute min.	-11.7	-17.1	-8.0	-5.5	-3.1	-0.4	0.6	1.1	-1.2	-4.0	-5.3	-8.3	-17.1
mean no. of days with air frost	9.7	8.9	6.8	3.9	0.8	0.0	0.0	0.0	0.0	1.1	6.1	8.3	45.6
mean no. of days with ground frost	16.0	14.9	13.2	11.5	5.9	1.0	0.2	0.3	2.0	4.4	13.1	14.5	97.0
RELATIVE HUMIDITY (%)													
mean at 0900UTC	91	91	88	84	80	81	84	87	89	92	92	92	88
mean at 1500UTC	86	79	74	69	68	72	73	75	77	81	85	88	77
SUNSHINE *(hours)*													
mean daily duration	1.45	2.11	2.87	4.40	5.08	4.64	3.79	3.81	3.10	2.39	1.81	1.11	3.05
greatest daily duration	7.8	9.2	11.7	13.7	15.1	15.6	14.8	13.7	12.3	10.1	8.6	7.0	15.6
mean no. of days with no sun	11	8	6	3	2	2	3	3	4	6	9	12	69
RAINFALL *(mm)*													
mean monthly total	120.8	83.2	95.5	62.3	77.9	71.1	63.8	96.6	104.3	124.6	118.8	124.1	1143.2
greatest daily total	33.1	27.9	27.5	19.8	42.0	74.6	38.8	55.0	41.6	59.5	49.2	41.0	74.6
mean no. of days with >= 0.2mm	22	17	21	17	18	16	17	19	19	22	21	22	230
mean no. of days with >= 1.0mm	18	14	17	12	14	12	11	14	15	17	17	17	178
mean no. of days with >= 5.0mm	9	6	7	4	6	4	4	6	7	8	8	8	78
WIND *(knots)*													
mean monthly speed	10.0	10.0	10.2	8.7	8.3	7.9	7.5	7.3	8.0	9.0	8.7	9.7	8.8
max. gust	96	85	74	57	62	54	66	54	91	70	70	79	96
max. mean 10-minute speed	59	48	45	36	41	36	39	33	60	46	40	51	60
mean no. of days with gales	1.2	0.9	1.0	0.1	0.1	0.1	0.0	0.0	0.2	0.4	0.5	0.7	5.2
WEATHER *(mean no. of days with...)*													
snow or sleet	6.5	5.4	4.7	1.9	0.3	0.0	0.0	0.0	0.0	0.1	1.7	3.5	24.1
snow lying at 0900UTC	2.6	1.4	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.1	6.3
hail	4.2	3.3	5.7	3.6	1.9	0.4	0.0	0.0	0.7	1.0	3.0	2.7	26.5
thunder	0.4	0.2	0.2	0.3	0.5	0.9	0.9	0.4	0.2	0.4	0.3	0.5	5.1
fog	4.4	2.7	1.9	2.4	1.7	2.3	2.3	4.1	4.1	4.6	3.6	3.7	37.9

APPENDIX 15

Archaeological Study of Development Site

[Gibbons, 1998]

Michael Gibbons BA MIAPA
Consultant Archaeologist
Market Street
Clifden
County Galway

Archaeological Report for the Formulation of a Waste Licence Application for the Derrinumera Landfill, County Mayo

This Report is based on a comprehensive desk study of an area within 3.5 km of the above Landfill Site. Appendix I and Figs. 1 - 3 show the Recorded Monuments listed by the Heritage Service (Department of Arts, Heritage, Gaeltacht and the Islands) within 3.5 km of the Landfill Site (Sites shown shaded Green). The Recorded Monuments listed in Appendix I and shown in Figs 1 - 3 are based on information held by the Sites and Monuments Record Office of the Department of Arts, Heritage, Gaeltacht and the Islands in Dublin. The Topographical Files and the finds Register of the National Museum of Ireland and relevant aerial photographs were also consulted for this Report. Also an area within 500m of the Landfill Site boundary was field walked to see if any previously unrecorded archaeological sites and monuments or finds were in existence (Fig. 4).

Archaeological Survey within 500m of the Landfill Site Boundary:

Four previously unrecorded possible Archaeological Sites were discovered by the writer during fieldwork (Sites A, B, C and D - Fig 4). One of these (Site D) is located within the area owned by Mayo County Council while the remaining three (Sites A, B and C) are located outside this area but within the 500m boundary (Fig. 4)

Site D - Possible Burial Mound

Site D is located within the Northern end of the area owned by Mayo County Council (Fig. 4 - Plate I). It consists of a sub-circular mound measuring approximately 20m in diameter. It is highest on its eastern side c. 2.2m high. The mound could be a pre-historic burial mound

(2,000 BC - 500 AD) or may be a natural feature. If the mound is to be interfered with in any future works at the Landfill Site it should be pre-development tested by a qualified Archaeologist under Licence from the Heritage Service of the Department of Arts, Heritage, Gaeltacht and the Islands. Only then will it be clear if the mound is of Archaeological importance or not. If the mound is a pre-historic burial mound it would be of regional significance.

<u>Site A - Possible Standing Stone</u>

Site A, a possible standing stone is located c. 240m outside the north-eastern boundary of the land owned by Mayo County Council (Fig. 4, Plate II). It is a conglomerate stone triangular in shape and measures 1.10m in height and 1m thick. It is located in cut away bog and may not be of archaeological importance. If it is it would be of local archaeological importance.

<u>Site B - Possible Standing Stones</u>

Site B, two possible standing stones, is located 210m outside the north-eastern boundary of the land owned by Mayo County Council (Fig. 4, Plate III). One of the stones is upright while the other is a possible rock outcrop. The upright stone is 1.10 high, 0.70m wide and 0.38m thick. The other stone lies on its side adjacent to the upright stone and is 0.38m above ground level. Its visible length is 1.25m and it is 0.75m thick. This site may not be of archaeological importance. If it is it would be of local archaeological importance.

<u>Site C - Possible Standing Stone</u>

Site C, a possible standing Stone, is located 30m outside the north-eastern boundary of the land owned by Mayo County Council (Fig. 4, Plate IV). The stone is 1.9m long, 0.85m wide and 0.65 thick. It may be a rock outcrop and of no archaeological importance. If it is it would be of local archaeological importance.

National Museum of Ireland Finds' Register

IA 1953:39 - This National Museum Of Ireland File No. states that some bog butter was found in a wooden container in the townland of Lappallagh in 1953. No precise location is given and the finding of bog butter is quite a common feature in Ireland. This find would be of local importance.

Discussion and Mitigation Measures

The potential impact of the Landfill Site on the cultural Heritage of the area is small. The only possible archaeological site to be directly effected by the Landfill Site is Site D. Prior to the development of the Landfill Site, Site D should be pre-development tested by a qualified archaeologist under Licence from the Heritage Service in the Department of Arts, Heritage, Gaeltacht and the Islands.

Michael Gibbons BA MIAPA
Consultant Archaeologist

APPENDIX I

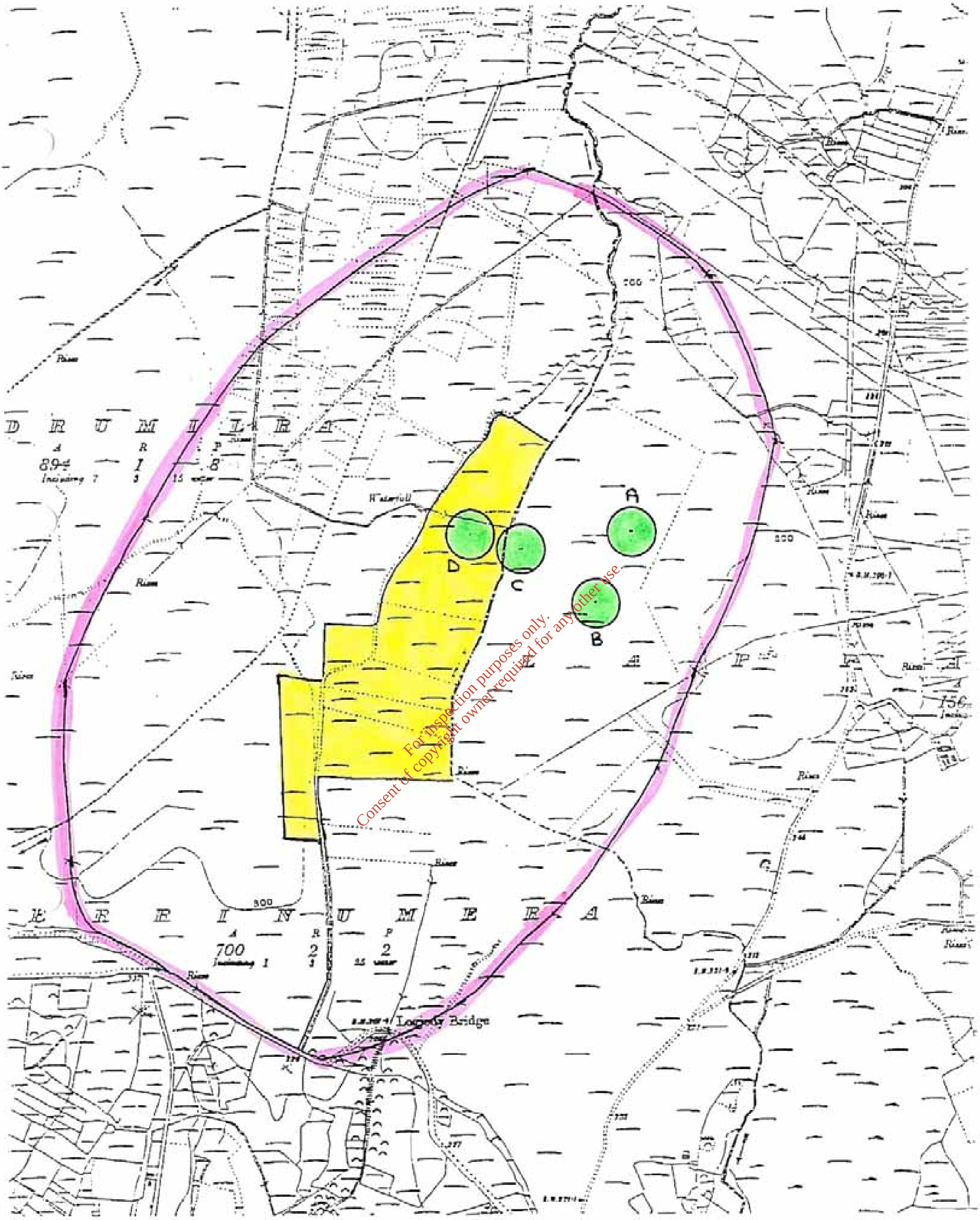


Fig. 4

Location of Possible Archaeological Sites within 500m of Landfill.

Land owned by Mayo Co. Council.

500m Boundary around Landfill Site.

Possible Archaeological Sites

RECORD OF MONUMENTS AND PLACES

as Established under Section 12 of the National Monuments (Amendment) Act 1994

COUNTY MAYO

Issued By
National Monuments and Historic Properties Service
1996

SHEET NO.- 068-

MON. NO.	SH/PL/TR	NAT. GRID	TOWNLAND	CLASSIFICATION
MA068-001---	068-/03/5	10365/29783	CLAGGARNAGH WEST [TIRA. BY.]	ENCLOSURE
MA068-002---	068-/03/6	10511/29768	BALLYTEIGE	ECCLESIASTICAL REMAINS
MA068-00201-	068-/03/6	10511/29768	BALLYTEIGE	CHURCH
MA068-00202-	068-/03/6	10511/29769	BALLYTEIGE	GRAVEYARD
MA068-003---	068-/04/1	10531/29825	BALLYTEIGE	ENCLOSURE
MA068-004---	068-/04/2	10635/29852	BALLYTEIGE	ENCLOSURE
M/ -005---	068-/04/2	10636/29839	BELTRA LOUGH	CRANNOG POSSIBLE
MA068-006---	068-/04/2	10677/29829	BELTRA LOUGH	CRANNOG POSSIBLE
MA068-007---	068-/05/1	9818/29642	FAULEENS [BURR. BY.]	ENCLOSURE
MA068-008---	068-/08/2	10664/29648	MUCKANAGH [CARR. BY. ISLD. PH.]	ENCLOSURE
MA068-00901-	068-/09/1	9816/29507	DERRYLOUGHAN MORE	ENCLOSURE
MA068-00902-	068-/09/1	9816/29507	DERRYLOUGHAN MORE	SOUTERRAIN
MA068-010---	068-/09/1	9815/29495	DERRYLOUGHAN MORE	MONUMENT
MA068-011---	068-/09/1	9826/29487	KNOCKNAGEEHA [BURR. BY.]	MONUMENT
MA068-012---	068-/09/1	9850/29490	DERRYLOUGHAN MORE	CRANNOG POSSIBLE
MA068-013---	068-/13/1	9789/29389	NEWPORT	ENCLOSURE
MA068-014---	068-/13/2	9911/29389	KNOCKAVEELY GLEBE	ECCLESIASTICAL REMAINS
MA068-01401-	068-/13/2	9913/29390	KNOCKAVEELY GLEBE	CHURCH
MA068-01402-	068-/13/2	9911/29388	KNOCKAVEELY GLEBE	GRAVEYARD
MA068-015---	068-/13/1	9855/29330	KILBRIDE [BURR. BY.]	MISCELLANEOUS
MA068-016---	068-/13/5	9902/29280	KILBRIDE [BURR. BY.]	ECCLESIASTICAL REMAINS
MA068-01601-	068-/13/5	9903/29280	KILBRIDE [BURR. BY.]	CHURCH SITE
MA068-01602-	068-/13/5	9903/29280	KILBRIDE [BURR. BY.]	GRAVEYARD
MA068-017---	068-/13/5	9925/29275	KILBRIDE [BURR. BY.]	HOLY WELL
MA068-018---	068-/13/3	9989/29325	CARRICKANEADY	SOUTERRAIN
3-019---	068-/13/6	9978/29237	LECARROW [BURR. BY.]	ENCLOSURE

SHEET NO.- 068-

MON. NO.	SH/PL/TR	NAT.GRID	TOWNLAND	CLASSIFICATION
MA068-023---	068-/14/5	10148/29279	CUILMORE [BURR. BY.]	ENCLOSURE
MA068-024---	068-/04/1	10580/29856	BALLYTEIGE	ENCLOSURE POSSIBLE
MA068-025---	068-/04/4	10525/29759	DERRYLOUGHAN EAST	CRANNOG POSSIBLE
MA068-026---	068-/04/5	10647/29724	MUCKANAGH [CARR. BY. ISLD. PH.]	PROMONTORY FORT POSSIBLE
MA068-027---	068-/09/5	9920/29431	BARRACKHILL	EARTHWORK POSSIBLE
MA068-028---	068-/13/3	9975/29368	KNOCKNATINNYWEEL	ENCLOSURE POSSIBLE

E 069- 1

SHEET NO.- 069-

MON. NO.	SH/PL/TR	NAT. GRID	TOWNLAND	CLASSIFICATION
1A069-001---	069-/04/5	11642/29736	SALLAGHER	OGHAM STONE
1A069-002---	069-/04/3	11677/29770	CRUMLIN [CARR. BY.]	HOLY WELL
1A069-003---	069-/05/4	10772/29588	BARNASTANG	ECCLESIASTICAL REMAINS POSSIBLE
1A069-00301-	069-/05/4	10772/29588	BARNASTANG	ENCLOSURE POSSIBLE
1A069-00302-	069-/05/4	10772/29587	BARNASTANG	BURIAL GROUND
1A069-004---	069-/05/4	10790/29615	KNOCKBAUN [CARR. BY. ISLD. PH.]	ENCLOSURE
1A069-005---	069-/05/4	10805/29606	KNOCKBAUN [CARR. BY. ISLD. PH.]	ENCLOSURE
A069-006---	069-/05/4	10831/29609	KNOCKBAUN [CARR. BY. ISLD. PH.]	ENCLOSURE
A069-007---	069-/09/1	10802/29530	BARNASTANG	ENCLOSURE
A069-008---	069-/05/5	10908/29601	KILHALE	RINGFORT (RATH \ CASHEL)
A069-009---	069-/09/2	10889/29505	MONAGARRAUN	ENCLOSURE
A069-010---	069-/16/5	11625/29264	BALLINVILLA [CARR. BY.]	ENCLOSURE
A069-011---	069-/16/5	11624/29221	MOUNTGREGORY	ENCLOSURE
A069-012---	069-/16/6	11694/29242	BALLYNEW [CARR. BY.]	ENCLOSURE
A069-013---	069-/16/6	11714/29257	CARROWNALTORE	ENCLOSURE
A069-014---	069-/16/6	11706/29226	BALLYNEW [CARR. BY.]	ENCLOSURE
A069-015---	069-/16/6	11722/29216	BALLYNEW [CARR. BY.]	ENCLOSURE
A069-016---	069-/07/2	11377/29685	BURREN [CARR. BY. AGLISH PH.]	ENCLOSURE
A069-017---	069-/08/1	11537/29654	DERRYLAHAN [CARR. BY.]	TOMB
A069-018---	069-/16/4	11562/29254	MOUNTGREGORY	CRANNOG
A069-019---	069-/16/3	11724/29341	BALLINVILLA [CARR. BY.]	SOUTERRAIN POSSIBLE
A069-020---	069-/16/6	11721/29282	CARROWNALTORE	MASS ROCK POSSIBLE

SHEET NO.- 077-

MON. NO.	SH/PL/TR	NAT.GRID	TOWNLAND	CLASSIFICATION
MA077-02201-	077-/11/5	10374/28789	RUSHBROOK	CHURCH
MA077-02202-	077-/11/5	10373/28788	RUSHBROOK	GRAVEYARD
MA077-02203-	077-/11/5	10374/28788	RUSHBROOK	ENCLOSURE
MA077-023---	077-/15/2	10370/28744	TAWNYEMON	CRANNOG
MA077-024---	077-/12/6	10675/28815	CORNAGASHLAUN	ENCLOSURE
MA077-02501-	077-/12/6	10692/28809	CORNAGASHLAUN	SWEATHOUSE POSSIBLE
MA077-02502-	077-/12/6	10693/28808	CORNAGASHLAUN	FULACHTA FIADH
MA077-026---	077-/12/6	10745/28802	RINNASEER	CORN DRYING KILN POSSIBLE
MA077-027---	077-/12/6	10712/28771	RINNASEER	CRANNOG POSSIBLE
MA077-028---	077-/15/6	10444/28633	KNOCKBRACK [BURR. BY.]	CRANNOG
MA077-029---	077-/16/4	10570/28663	DRUMNEEN [BURR. BY.]	CRANNOG
MA077-03001-	077-/16/5	10592/28660	DRUMNEEN [BURR. BY.]	ENCLOSURE
MA077-03002-	077-/16/5	10592/28661	DRUMNEEN [BURR. BY.]	CHILDREN'S BURIAL GROUND
MA077-031---	077-/16/2	10620/28708	CORNAGASHLAUN	CRANNOG
MA077-032---	077-/16/2	10627/28715	CORNAGASHLAUN	CRANNOG POSSIBLE
MA077-033---	077-/16/2	10629/28679	DRUMNEEN [BURR. BY.]	CRANNOG
MA077-038---	077-/03/1	10300/29212	DRUMILRA	ENCLOSURE POSSIBLE
MA077-039---	077-/03/2	10353/29188	DERRYRIBBEEN	ENCLOSURE
MA077-04001-	077-/15/5	10364/28668	COGAULA [BURR. BY.]	FULACHT FIADH
MA077-04002-	077-/15/2	10367/28671	COGAULA [BURR. BY.]	FULACHT FIADH
MA077-041---	077-/05/2	9920/29043	KNOCKNABOLEY	ENCLOSURE POSSIBLE
MA077-042---	077-/05/2	9921/29019	KNOCKNABOLEY	ENCLOSURE POSSIBLE

SHEET NO.- 077-

MON. NO.	SH/PL/TR	NAT. GRID	TOWNLAND	CLASSIFICATION
MA077-001---	077-/01/1	9835/29189	CARROW MORE [BURR.BY.]	ENCLOSURE
MA077-002---	077-/01/4	9839/29111	GORTAWARLA	ENCLOSURE
MA077-003---	077-/01/2	9929/29215	LECARROW [BURR. BY.]	ENCLOSURE
MA077-004--*	077-/01/3	9978/29234	LECARROW [BURR. BY.]	ENCLOSURE
MA077-005---	077-/02/5	10165/29073	BROCKAGH	CASTLE
MA077-006---	077-/02/6	10209/29108	DRUMGONEY	ENCLOSURE
MA077-007---	077-/05/3	9971/29063	KILTYROE	ENCLOSURE
77-008---	077-/05/3	9956/29007	KNOCKNABOLEY	ENCLOSURE
MA077-009---	077-/09/1	9783/28911	KNOCKYSPRICKAUN	ENCLOSURE
MA077-010---	077-/05/6	10005/28935	DERRYNARAW	ENCLOSURE
MA077-011---	077-/10/2	10110/28912	GORTEEN [BURR. BY. K.MAC. PH.]	ENCLOSURE
MA077-012---	077-/07/5	10380/28926	BALLINTLEVA [BURR. BY.]	ENCLOSURE
MA077-013---	077-/09/4	9793/28766	CROSS [BURR. BY.]	ENCLOSURE
MA077-014---	077-/09/2	9897/28840	KILMEENA	ECCLESIASTICAL REMAINS
MA077-01401-	077-/09/2	9898/28840	KILMEENA	CHURCH
MA077-01402-	077-/09/2	9896/28839	KILMEENA	GRAVEYARD
MA077-015---	077-/09/6	9958/28791	BOCULLIN	CRANNOG
MA077-016---	077-/10/1	10031/28880	ROEKILMEENA	BULLAUN STONE (S) POSSIBLE
MA077-017---	077-/10/4	10014/28757	BALLINLOUGH [BURR. BY.]	CHILDREN'S BURIAL GROUND
MA077-018---	077-/11/1	10277/28881	GORTNACLASSAGH	ECCLESIASTICAL REMAINS
MA077-01801-	077-/11/1	10278/28881	GORTNACLASSAGH	HOLY WELL
MA077-01802-	077-/11/1	10277/28881	GORTNACLASSAGH	CHURCH POSSIBLE
MA077-019---	077-/11/1	10314/28863	CLOGHER [BURR. BY.]	ENCLOSURE
MA077-020---	077-/11/2	10342/28864	CLOONCANAVAN	ENCLOSURE
MA077-021---	077-/11/4	10331/28794	CLOGHER [BURR. BY.]	CRANNOG
MA077-022---	077-/11/5	10373/28787	RUSHBROOK	ECCLESIASTICAL REMAINS

Plate I, Site D

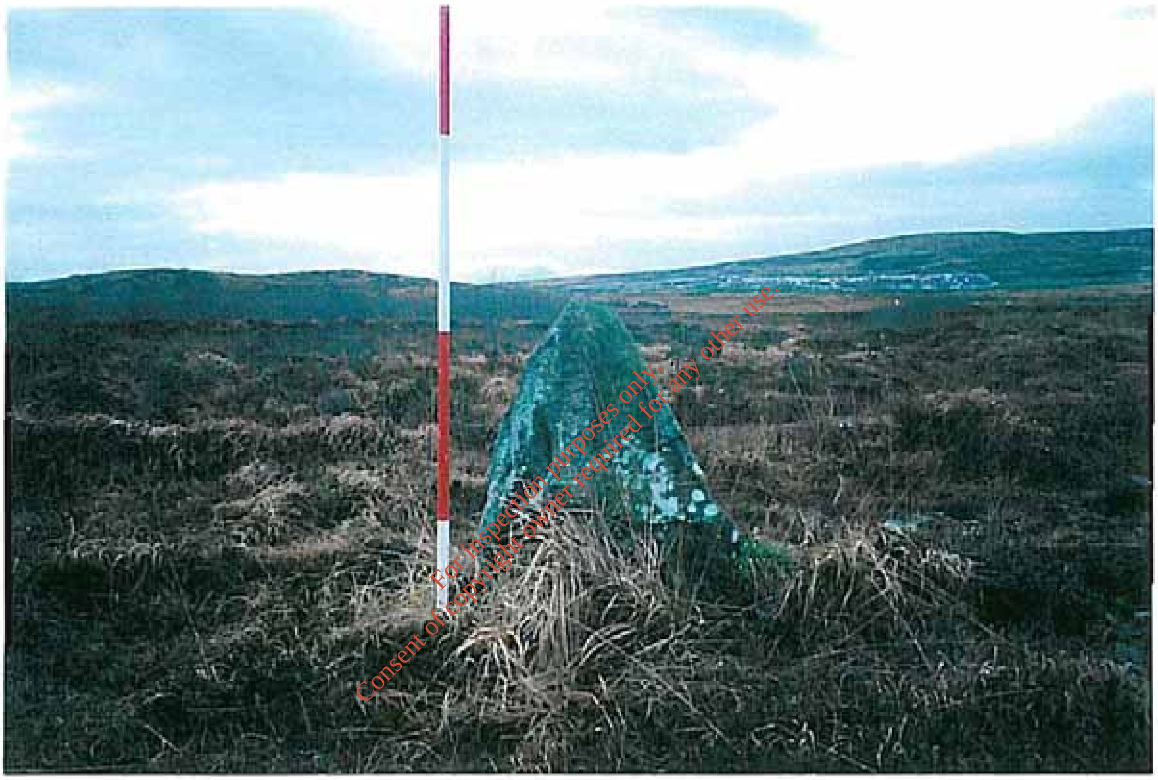


Plate II, Site A

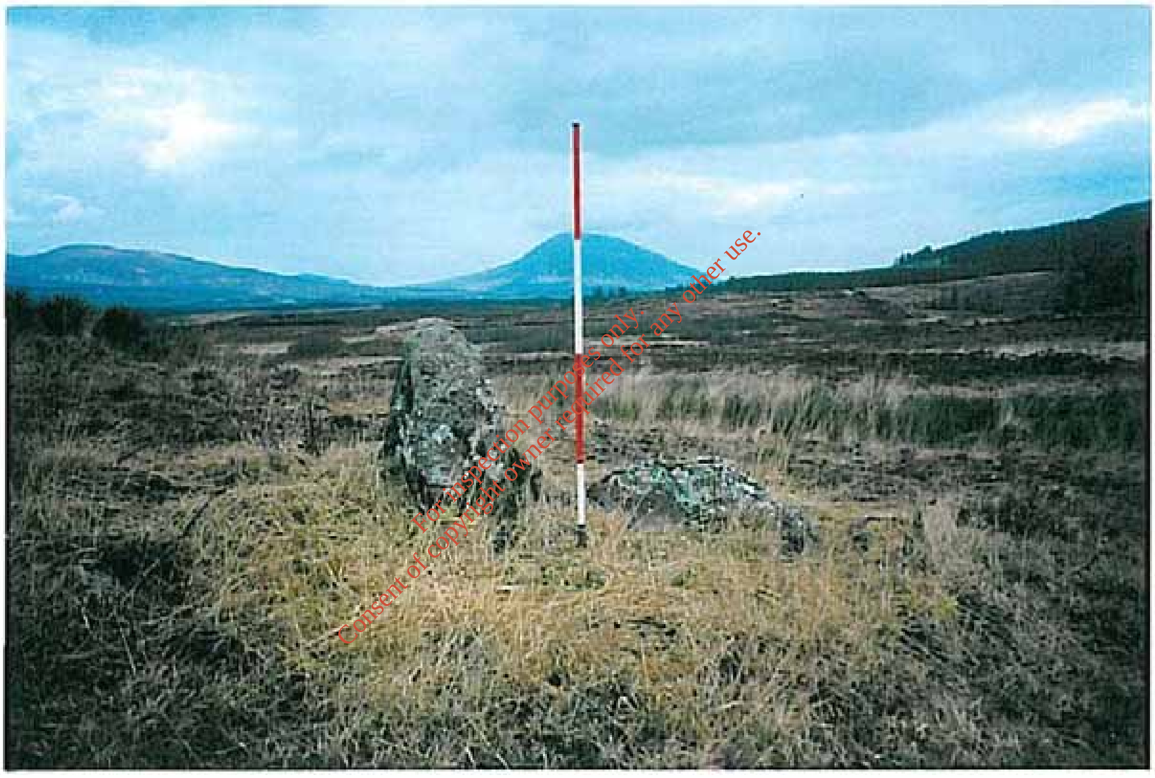


Plate III, Site B

Plate IV, Site C

APPENDIX 16

Preliminary Archaeological Assessment (Pipeline Route)

[Beirne]

DERRINUMERA SLUDGE HUB CENTRE

ROUTE SELECTION OF PROPOSED EFFLUENT RISING MAIN FROM SLUDGE HUB CENTRE

PRELIMINARY ARCHAEOLOGICAL ASSESSMENT

MAYO COUNTY COUNCIL

TOBIN CONSULTING, CIVIL AND STRUCTURAL ENGINEERS

Linda Beirne, MA Archaeologist (Mayo County Council)

Introduction

This preliminary archaeological assessment was undertaken on behalf of Tobin Consulting, Civil and Structural Engineers for Mayo County Council. An examination of the relevant Recorded Monument and Place Maps and Manual for Co. Mayo was carried out – Sheet Numbers 67 and 68 (Figures 1, 2 & 3), so as to assess the impact on known archaeological constraints.

A route selection for the proposed effluent rising main from Derrinumera Sludge Hub Centre will proceed from the from the existing landfill site in the townland of Derrinumera, Co. Mayo, through the townlands of Cartron, Cuilmore, Cloonshil, Drumlong and into Newport from where it will continue through the townlands of Caulicaun, Lisduff and finish at the Final Effluent Discharge Point on the northern shore in Rosmore townland.

The route of the proposed rising main will for the most part run west through and alongside the existing road from Derrinumera Landfill Site through to Newport (R311). The proposed rising main will then turn north through Main Street, Newport and then turn west again along Quay Road. From there it will turn northwest into the townland of Caulicaun where it crosses a river tributary and continues out along the Newport Channel peninsula in the townland of Rosmore to its exit point (Final Effluent Discharge Point) into Newport Bay (Orange Line on Figures 1, 2 & 3).

Archaeological Impact on Known Recorded Monuments and Places (RMP)

The Proposed Effluent Rising Main from Derrinumera Sludge Hub Centre will affect three (3) areas of archaeological interest or possible archaeological interest. All of these have been marked as one site in the colour purple on Figure 1 as they are all within the same area of constraint.

The proposed scheme will directly impact on two (2) known Recorded Monuments and Places (RMP), MA 067-03701 and MA 067-03702, both discussed below and noted on Figure 1.

One (1) river / tributary crossing will impact on the same RMPs (MA067-03701 & MA067-03702) as it is within the area of archaeological constraint. If the proposed rising main is to be routed below the river / tributary bed, it will be necessary for an underwater archaeological survey to be carried out by a qualified archaeologist under licence from the National Monuments Section, Department of Environment, Heritage and Local Government and the National Museum of Ireland.

The Recorded Monuments and Places are discussed below in numerical order, as they occur in the Recorded Monuments and Places Maps and Manual.
They are in no order of importance or preference.

Site No. 1 Recorded Monument and Place No MA067 – 03701

This RMP has been classified as an Enclosure and is located in the townland of Lisduff [Burr. By].

The proposed line of the rising main will run immediately south of the RMP and is within the area of constraint (Figure 1).

A qualified archaeologist under licence from the Department of Environment, Heritage and Local Government and the National Museum of Ireland should continuously monitor all trenches located within the constraint of this enclosure.

Site No. 2 Recorded Monument and Place No MA067 – 03702

This RMP has been classified as a Possible Hut Site and is also located in the townland of Lisduff [Burr. By.] – Possibly associated with Site No. 1.

The proposed line of the rising main will run immediately south of the RMP and is within the area of constraint (Figure 1).

A qualified archaeologist under licence from the Department of Environment, Heritage and Local Government and the National Museum of Ireland should continuously monitor all trenches located within the constraint of this possible hut site.

Site No. 3 River / Tributary Crossing

The proposed rising main will cross the River / Tributary southeast of RMP MA067-03701 and MA067 - 03702 (Figure 1).

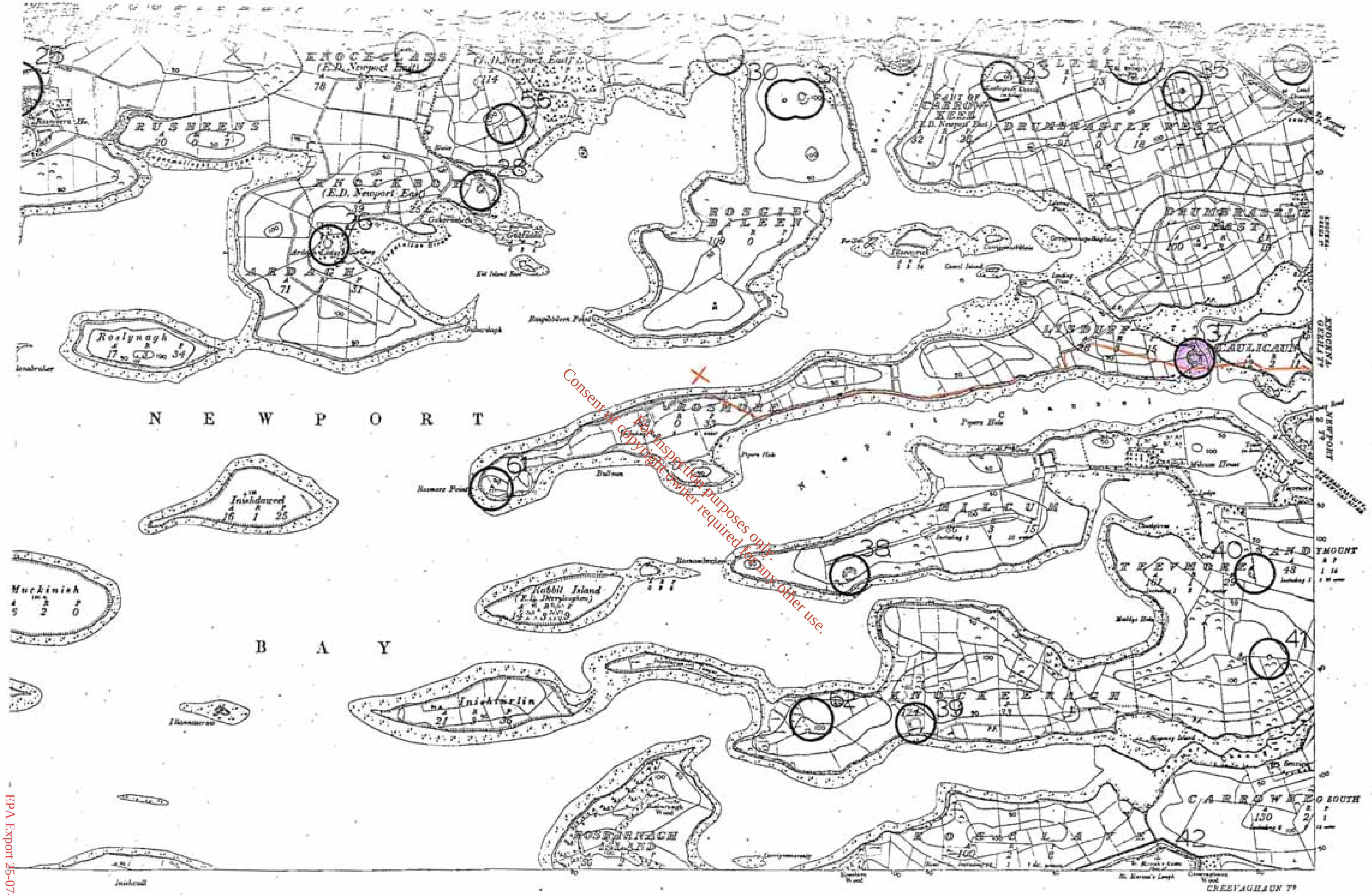
It is not known as yet whether the proposed rising main will be located above or below the river / tributary bed. If the proposed rising main is to be located below the river / tributary bed it will be necessary for an underwater archaeological survey to be carried out by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland, prior to the commencement of any works.

In addition to this, all dredged material should be monitored and scanned with metal detection devices by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland.

Recommendations

1. Pre-development testing to be carried out within the area of constraint of both Site No.1 (MA067 – 03701) and No. 2 (MA067 – 03702), by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland.
2. An underwater archaeological survey will have to be carried out on the river / tributary bed by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland, prior to the commencement of any works.
3. All dredged material should be monitored and scanned with metal detection devices by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland.
4. Continuous monitoring to be carried out within the constraint areas of Site No. 1, RMP No. MA067 – 03701 (Enclosure) and Site No. 2, RMP No. MA067 – 03702 (Possible Hut Site), by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland.
5. All other excavation works on the proposed scheme should be monitored by a qualified archaeologist under licence from the National Monuments Section, Department of the Environment, Heritage and Local Government and the National Museum of Ireland. The level and frequency of monitoring to be applied on the scheme should be agreed between the licensed archaeologist and the licensing section of the relevant Department of the Environment, Heritage and Local Government.
6. Any sections of the proposed rising main that do not run through and alongside the existing road should be field walked prior to the commencement of any works.

Linda Beirne MA
(Archaeologist, Mayo County Council)



al Constraint Map

...ation of archaeological sites and ...r boundaries on the ground.

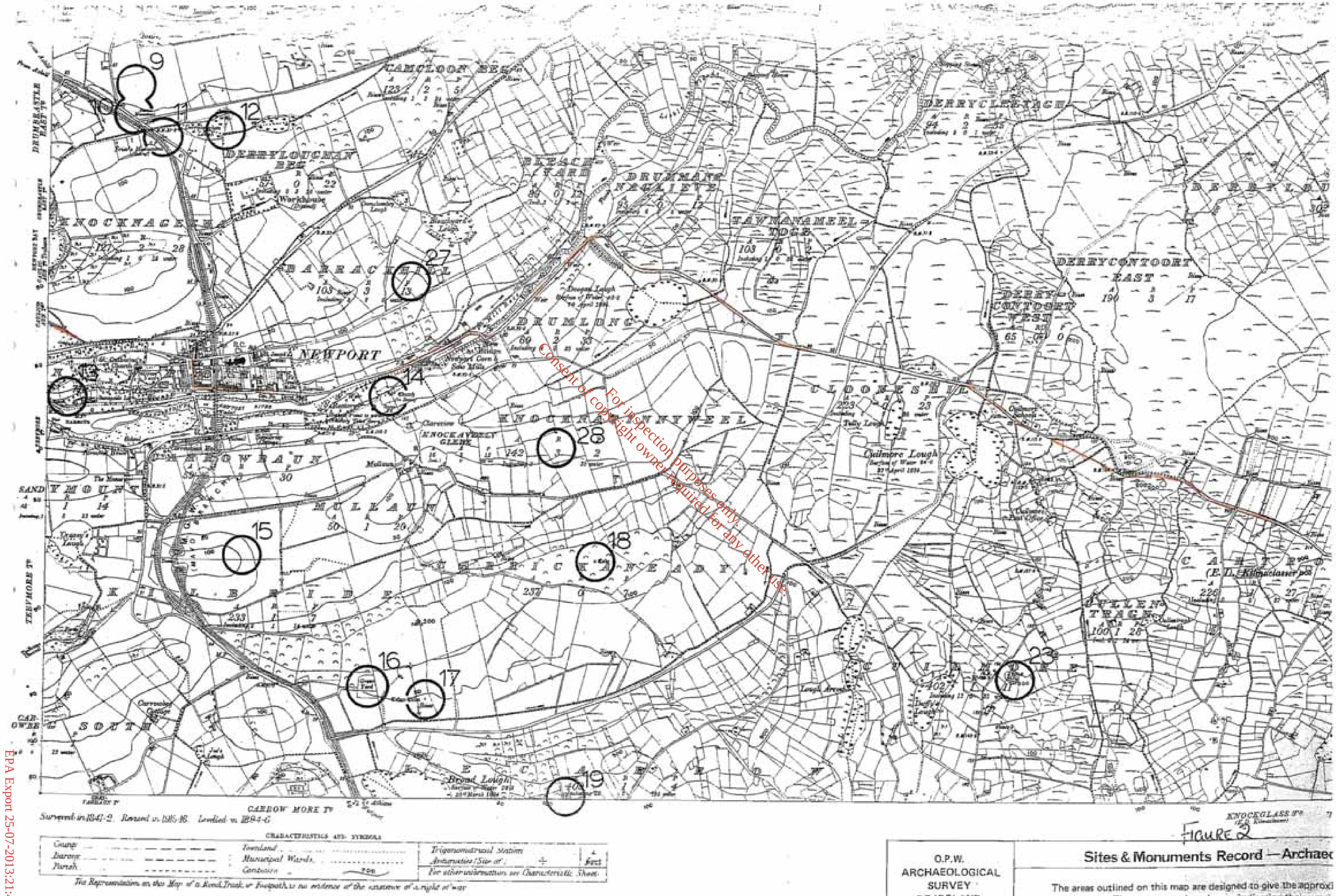
Date/Edition of map: 1920

Date of SMR details: September 199.

0 1 km

0 1 mile

FIGURE 1.



O.P.W.
ARCHAEOLOGICAL
SURVEY
OF IRELAND

Sites & Monuments Record — Archaeo

The areas outlined on this map are designed to give the approxi
monuments. They are not to be taken as indicating their precis

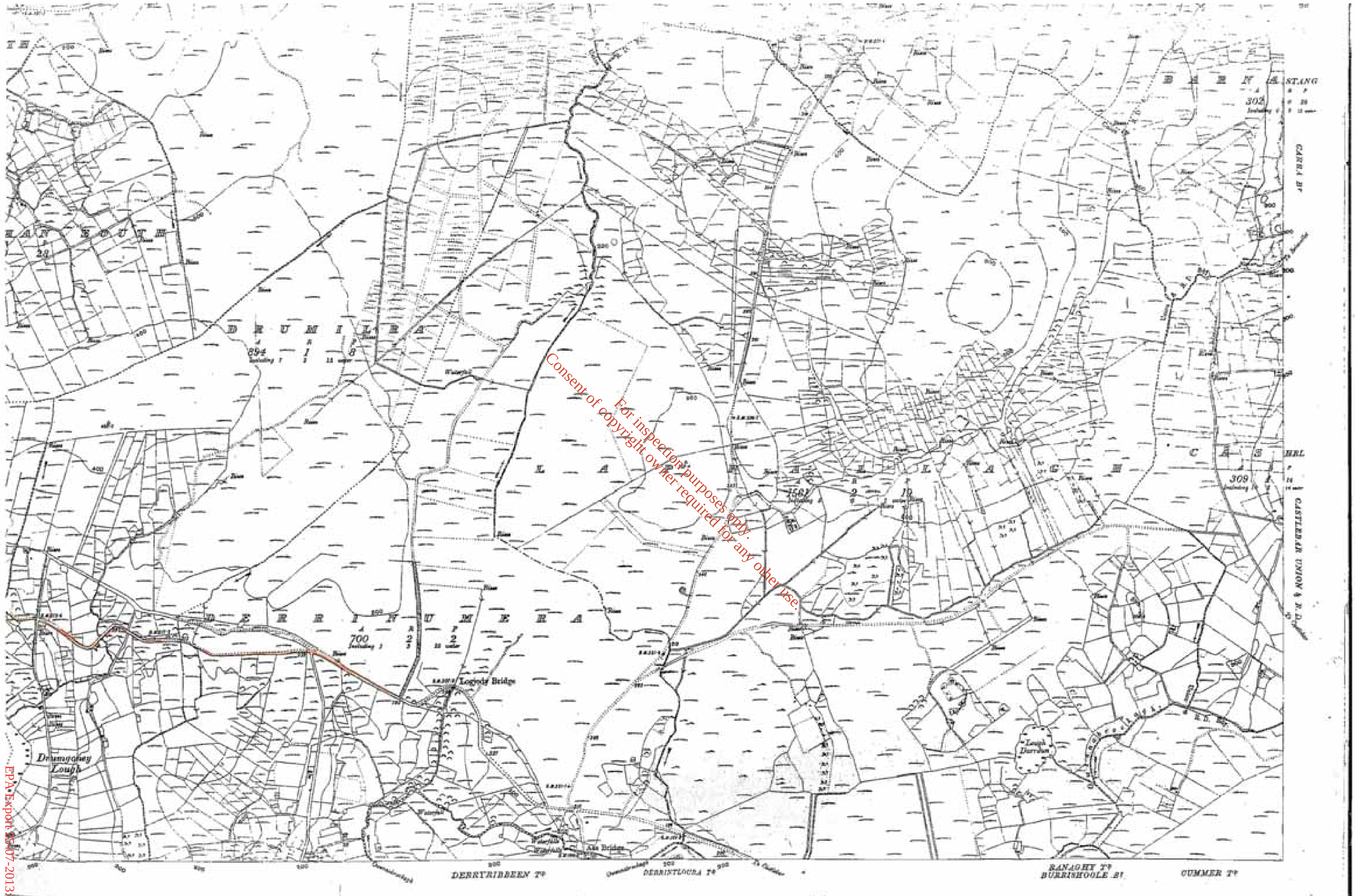


Figure 3

…ical Constraint Map

Date Edition of map

location of archaeologica… sites and…