

## Appendix 4A

### Long Sea Outfall Design Considerations

#### Introduction

The description herein is a summary of the conclusions of a number of reports and studies carried out by Dublin City Council prior to the application for planning permission for the Long Sea Outfall Tunnel (LSOT) in 2012. Its purpose is to inform on the complexity of the studies and the challenges of LSOT construction.

#### Identification of Long Sea Outfall Location Options

A number of studies were undertaken in order to identify appropriate long sea outfall locations, as outlined below. Five potential outfall locations were initially modelled and the results are included in the report entitled “Modelling the Impact of Ringsend Discharges in the Liffey and Tolka Estuaries and Possible Long Sea Outfall Discharges in Dublin Bay” October 2009. The study also provided information on the existing discharge and storm water outfall. However, it was conducted before the designation of the Rockabill to Dalkey Island SAC in 2012. Figure 1 shows the five locations that were initially modelled, on a bathymetric map of the bay.

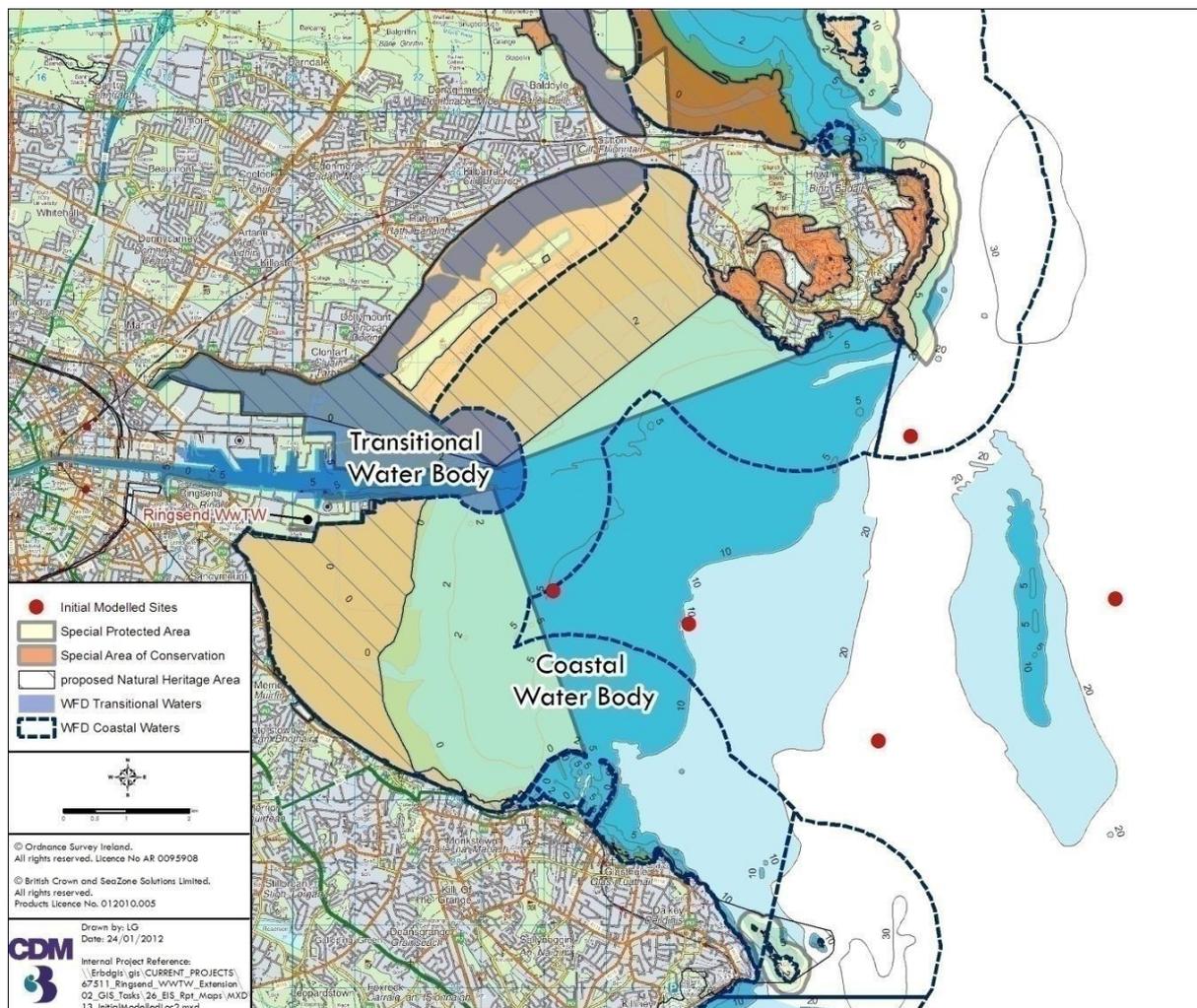


Figure 1: Initial Long Sea Outfall Modelling Locations Map (Rockabill to Dalkey Island SAC omitted)

On the basis of preferential dispersion characteristics, the environmental impacts of two of the five potential outfall locations (as shown in green on Figure 2) were then examined in further detail in “Preliminary Assessment of Long Sea Outfall Locations”, CDM/JBB, January 2010. This report considered the two outfall locations in terms of the Environmental Objectives (Surface Water) Regulations 2009, the Bathing Water Regulations 1992 and 2008, and the Dublin Bay Water Quality Management Plan priority objectives. It also involved a preliminary ecological assessment as described below.

The preliminary Appropriate Assessment screening of the two modelled outfall locations was carried out to establish whether there would be any significant negative impacts on Natura 2000 protected areas associated with these options. Natura Environmental Consultants were commissioned to undertake a Screening Assessment for each of the two options. The assessments concluded that although the discharge from the proposed long sea outfalls would result in a change in water quality in the vicinity of the outfall, no significant negative impacts were predicted for any existing or proposed Natura 2000 sites (or for the proposed SAC in the Kish Banks).

To further investigate potential long sea outfall discharge locations in Dublin Bay, a desk top study was undertaken to identify and map all known existing constraints on potential discharge locations. The potential constraints in Dublin Bay were broadly split into six categories, as outlined below:

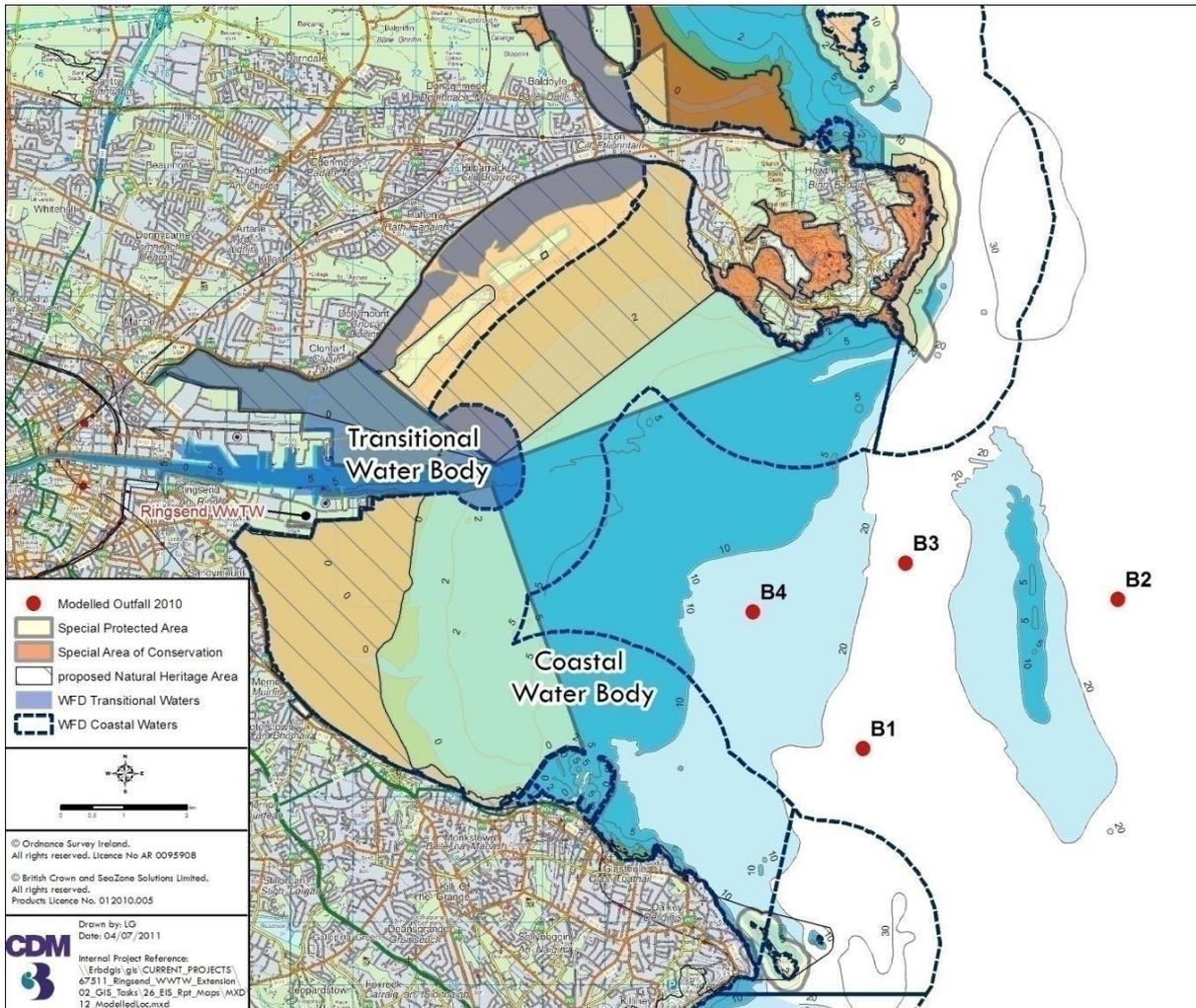
1. Operational – Dublin Port Company and Dún Laoghaire Harbour operations;
2. Environmental – Natura 2000 sites, National Heritage areas (NHAs), WFD water body classifications and nutrient sensitive waters;
3. Structures and Obstructions – Pipelines and cables and recorded shipwrecks;
4. Amenity – Bathing waters, sailing and boating and water sports;
5. Fisheries – Areas where different fishing methods are carried out; and
6. Geological – bathymetry and bedrock geology (prior to Marine Site Investigation).

All the known potential constraints were compiled onto one map of Dublin Bay as shown in Figure 2. Keeping the results of the preliminary modelling in mind and areas with the least constraints were highlighted for further water quality modelling. A full discussion of the constraints is contained in a report entitled “Constraint Mapping of Dublin Bay” (CDM, 2010).

Following the results of the preliminary modelling of potential outfall locations, the hydraulic model was further developed and then used to predict effluent dispersion, plume trajectories and compliance with EU Water Quality standards in Dublin Bay for a further four locations. These four potential outfall locations were selected for further modelling based on the preliminary modelling and the constraints identification exercise, as shown in Figure 2. These are referred to as Locations B1 to B4 and are shown in Figure 3 in relation to the environmental protected areas and the WFD water bodies.

The results are discussed in the following section and a full discussion of the dispersion characteristics is available in “Ringsend Long Sea Outfalls Modelling Results” CDM and DHI, January 2011.





**Figure 3: Modelled outfall locations and protected areas in Dublin Bay (Rockabill to Dalkey Island SAC omitted)**

### Selection of Long Sea Outfall Location

The results of the further modelling showed that Locations B1, B2 and B3 had preferential dispersion characteristics, with protected areas and amenity areas unaffected by the dispersion plume. Location B4 was eliminated from further consideration due to the unfavourable dispersion characteristics at that location. The modelled outfall locations were also assessed based on technical, environmental and cost factors.

Cost of the long sea outfall is proportional to the length of tunnel, therefore, Location B2 was eliminated as it was the least preferred option offering no perceived advantages in terms of dispersion characteristics or water quality for the additional cost.

Locations B1 and B3 offered similar characteristics with respect to dispersion characteristics and absence of impact on protected areas and amenity areas. Both locations were shown to be least affected by the restrictions identified in the constraints maps in Figure 2. However, it was decided to proceed with Location B3 due to its more central location with respect to Dublin Bay.

Following the results of the modelling it was decided to advance with Location B3 as the preferred long sea outfall point.

## Long Sea Outfall Design and Construction Considerations

### Construction Compound

The area selected for a possible construction compound is shown on Figure 4.



**Figure 4: Ringsend WwTP- and Tunnel Compound Site Location**

The compound site layout would be finalised by the successful contractor. The required site would be approximately 250 m x 90 m in size. The spoil handling facility should be sufficient to hold a minimum of two days' worth of spoil output as it will not be possible to operate the spoil disposal transport operation on a 24/7 basis. A significant portion of the construction compound would be required for a slurry separation plant to separate the spoil from the slurry to enable the reuse of the slurry.

HGV movements during construction would need to be separated from smaller/ private vehicles where possible and dedicated walkways provided to separate vehicle and pedestrian movements. A one-way system for HGV movements would be put in place.

The tunnel inlet shaft would be constructed using diaphragm walls, necessitating lagoons or a series of tanks for handling displaced bentonite slurry. These large tanks and construction plant such as the crane would require engineered foundations.

Site drainage should preferably be provided for separate surface and foul water. Petrol interceptors would be required in the surface water system for run-off from hard standing areas. Surface water discharge ideally would be to a sewer. Foul sewage would need to be tankered offsite, discharged to

a pumped sewer line or a septic tank. Fire and emergency points would be located at appropriate points on the site.

Following LSOT construction, the compound and equipment would be decommissioned. The adjacent outfall culvert would then be diverted into the shaft which would be capped and the site cleared on construction completion.

### Onshore Tunnel Inlet Shaft

The inlet shaft would be constructed onshore on the Poolbeg Peninsula. The estimated finished internal diameter of the tunnel inlet shaft could be as high as 20 m but may be smaller depending upon the eventual tunnelling construction technique adopted. Therefore, the maximum total excavated external diameter is estimated to be 22.5 m. Based on a preliminary conceptual design (CDM/JBB, 2011), the tunnel inlet shaft invert is likely to be between 66 m and 110 m below existing ground level. The final selected depth would depend on a combination of the vertical alignment selected for the tunnel section and geotechnical considerations made by the contractor.

The tunnel excavation operation would commence from the tunnel inlet shaft which would be used to service the tunnel with equipment and material requirements for the duration of the project. Spoil and slurry waste from tunnel construction would be brought to the surface through the inlet shaft. Therefore, the tunnel inlet shaft would be designed for three purposes:

- Temporarily use as launch pit for tunnelling operations and access to tunnel during tunnel construction stage as the onshore shaft construction must guarantee a safe working environment;
- Temporary use as a connection chamber to make final connections to offshore diffuser shaft; and
- Permanent use as conveyance pipe for WwTP final treated effluent.

The tunnel inlet shaft sinking and lining construction methods would be governed by contractor preference, the depth of the overburden and the requirement to prevent ingress of groundwater. The construction of the inlet shaft and its excavation are strongly interlinked. For the inlet shaft to be sunk in permeable ground conditions, the first things to decide are both how to keep the shaft dewatered and provide ground support during construction. In general, a diaphragm wall is used and there are two options:

- Dewatering of the shaft by drawdown of the groundwater table during the construction phase. Use of a retaining wall system as ground support.
- Application of an impermeable vertical and horizontal shaft lining or lowering the permeability of the ground by grouting (Ground freezing could be applied also). Use of a retaining wall system as ground support. Vertical impermeable lining and retaining wall are normally combined.

The tunnel inlet shaft wall structural and shaft lining design would be governed by the contractor's choice of construction technique and preferences, both of which would be heavily influenced by existing geotechnical, geological and hydrogeological conditions at the proposed shaft location. The selection of shaft construction technique, structural design and shaft lining design, should, therefore, be left to the contractor.

### Tunnelled Section

The tunnelled section would be approximately 9,000 m long with a finished internal diameter of about 5.0 m. The tunnelled section would run between the base of the tunnel inlet shaft (located onshore) and the base of the tunnel outlet riser diffuser shaft (located 9,000 m offshore) in marine water depths (to seabed) of greater than 25 m below Lowest Astronomical Tide (LAT). The tunnel drive would

commence at the tunnel inlet shaft and excavate eastwards towards the diffuser shaft. The basic hydraulic design parameters for the tunnel section are:

- Average daily flow: 7 m<sup>3</sup>/s
- Maximum design velocity: 0.7 m/s (preferred)
- Maximum daily flow: 13.8 m<sup>3</sup>/s

The marine site investigation results showed that tunnelling in deeper bedrock offered the best conditions for tunnelling because the bedrock is mostly stable for the tunnel diameter being considered and of low permeability. Based on available geotechnical data, it is likely that the major part of the tunnel could be advanced without active face support. The marine site investigation borings show the bedrock to be weathered / fractured over the top 5 – 10 m. In accordance with tunnel design practice it was recommended that the top of the tunnel should be kept twice the excavated diameter (= 13 m approx.) below rockhead in good/fair rock quality conditions and three times the diameter (= 19.5 m approx.) in poor conditions such as those encountered onshore where the tunnel inlet shaft was proposed to be located.

The marine site investigation shows that the top of the bedrock is very uneven as shown on Figure 5. A conceptual vertical tunnel alignment based on preliminary conceptual design work is also shown in Figure 5. The tunnel would be constructed using a tunnel boring machine (TBM). These machines not only undertake the excavation of the ground; they mostly also provide support to the ground (tunnel face support and all round shield support for operatives) during tunnelling. This support can be just peripheral (like in the case of shield TBMs) or also be applied to the front (Earth pressure TBMs or Slurry Shields for instance). The final tunnel lining would be constructed using precast concrete elements which would be assembled and installed directly by the TBM. Tunnel driving control facilities, accommodation, toilets, electric power facilities, emergency facilities, air supply, tunnel segments erector, etc. would be all part of the TBM machine and located close to the extraction chamber. Compressed air working may be employed depending on the contractor's method of working.

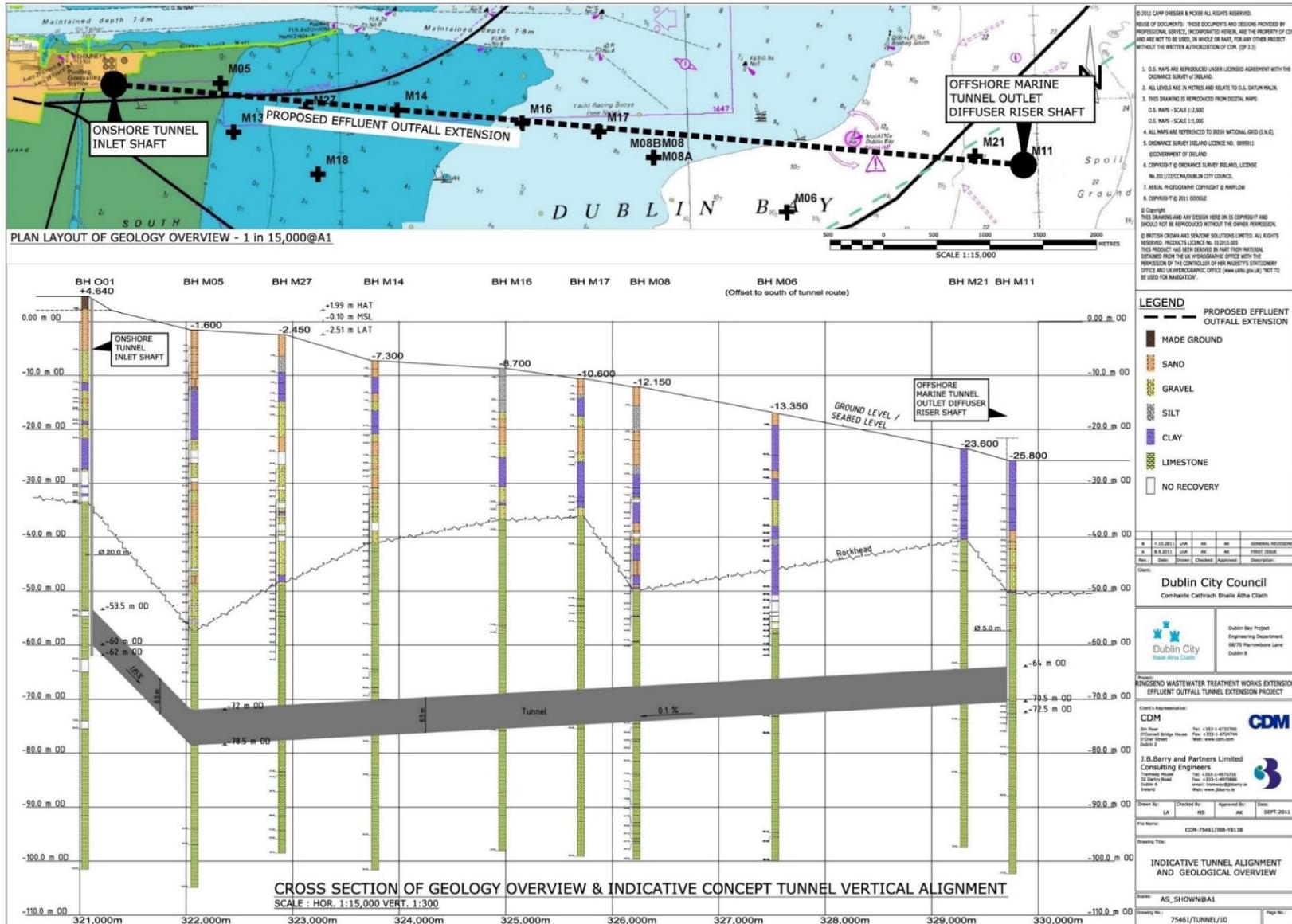


Figure 5: Plan and Cross Section of Tunnel Route

The slurry is a mixture of water and bentonite, a smectite clay mineral. Some additives improving certain properties of the slurry can also be applied. The main purpose of the slurry is to seal the tunnel contours in highly permeable ground conditions (“filter cake”), support the ground, transport of the cuttings and for cooling of the cutting tools.

The expected tunnelled section construction progress rates for a 9,000 m long tunnel are as follows:

- Hours of TBM operation - 24 hours / day, 7 days / week
- Long Average tunnel advance rate - 16.5 m/day
- Tunnelled Section TBM drive duration - 18 months

A primary tunnel lining would be constructed using precast concrete elements which are assembled and installed directly by the TBM. The maximum finished internal diameter of the tunnelled section would be 5.0 m which would result in a drilled tunnel diameter of up to 6.5 m, allowing for 0.5 m thick liner rings and 0.5 m for overbreak. The width of the tunnel segments used to complete a tunnel ring would be 1.2 m approx. with up to six tunnel segments per tunnel ring. The primary tunnel lining would be smooth bore, designed for the full ground loading and can be designed to be suitable also for the expected tunnel operating conditions without the need for secondary lining.

### Tunnel Outlet Diffuser Shaft:

The purposes of the tunnel outlet diffuser shaft would be to:

- Provide a temporary construction shaft area for making the final transition structure connections between the diffuser shaft and the tunnelled section below, i.e., the diffuser shaft construction must guarantee a safe working environment for final connection purposes; and
- Use as the permanent WwTP final treated effluent riser.

The principles of offshore diffuser shaft construction are the same as those for the onshore inlet shaft. However, many restrictions would apply to the marine environment in which the diffuser shaft has to be sunk. The depth of the diffuser shaft is controlled by the requirements of the vertical tunnel alignment and it would be prudent to keep the shaft as shallow as possible.

The inner shaft diameter has to meet the hydraulic requirements for the diffuser shaft structure. Hydraulic analysis indicates that the diffuser shaft internal diameter will be of the order of 4.0 m or less.

The location of the existing discharge is shown in Figure 6. A larger diameter tunnel outlet diffuser shaft would be constructed at the new discharge location in Dublin Bay shown on Figure 5 and Figure 6. A diffuser head structure would be constructed at this location to enhance dispersion of the final treated effluent discharge. The diffuser head structure would extend to approximately 5 to 7 m above the seabed level. Seabed level is approximately 26 m below OD Malin at the site of the proposed diffuser shaft. At this location, marine sediments extend to approximately 9 m below seabed level. Marine sediments are underlain by glacial till down to bedrock at about 25 m depth below seabed.

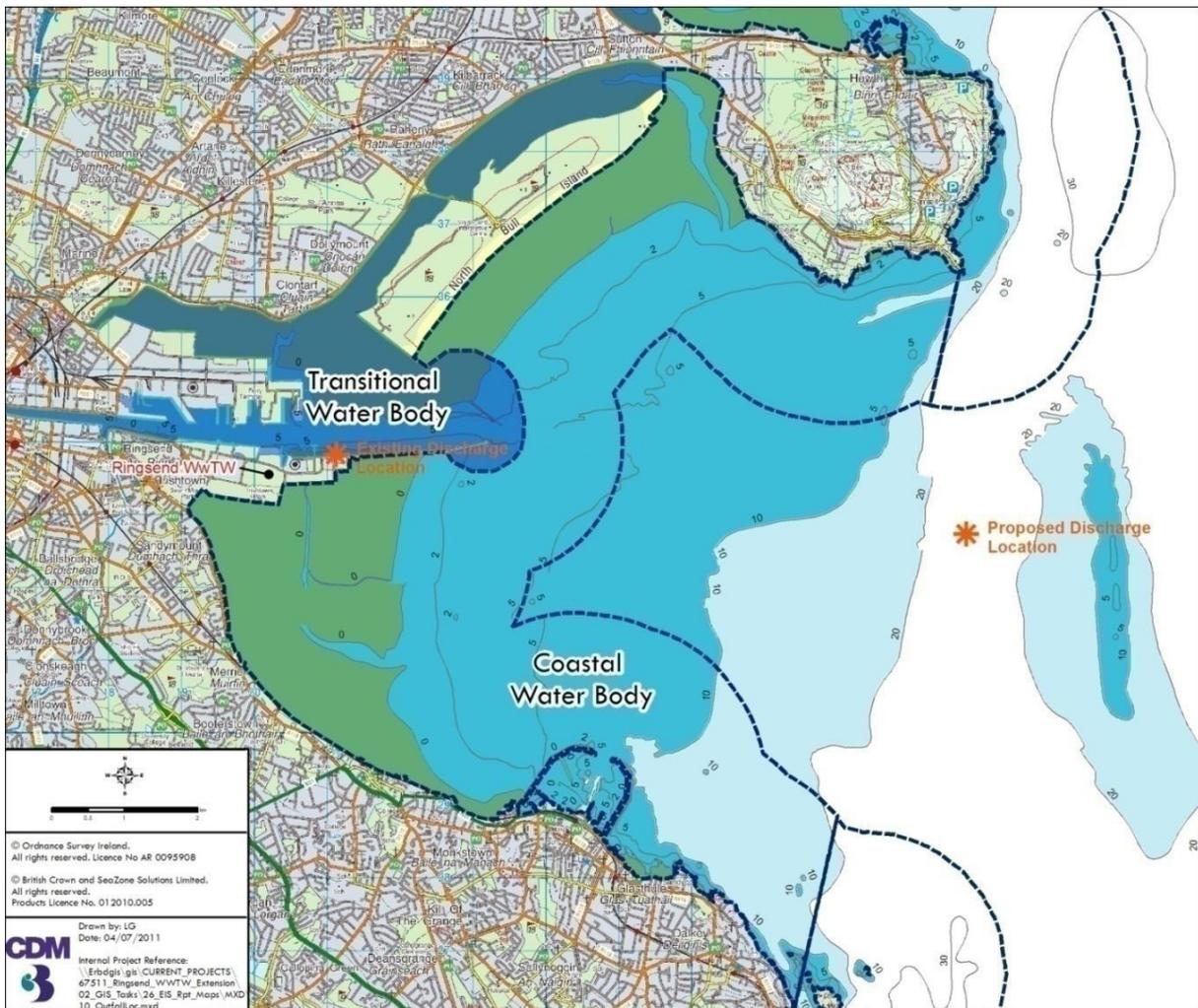


Figure 6: Selected Discharge Location (Rockabill to Dalkey Island SAC omitted)

Preliminary hydraulic analysis to date indicates that a single diffuser shaft about 4.0 m in diameter would be required with multiple diffuser heads mounted on top. However, the final configuration of the diffuser shaft including the number of diffuser heads would be determined following completion of the water quality dispersion assessment modelling/studies to be undertaken by the successful contractor as part of the detailed design development.

The time required to construct the diffuser shaft would be dictated by the chosen construction method, however, at least 6 – 8 months is a realistic time period to construct and fit out the diffuser shaft – after the initial allowance of approximately 6 months for design completion.

In compliance with the Design Build form of contract, details of the diffuser shaft sinking and lining construction methods would be governed by contractor preference and the depth of the seabed overburden materials. However, the contractors would be restricted to a large diameter drilling operation using a machine drill (with multiple drill bits/heads mounted within a single machine drill face) within a large thick-walled steel liner of extended length. This approach would be required because of the marine working environment whereby extended continuous shaft lining would be required.

Construction, drilling and installation operations would likely be undertaken using a fixed position large jack-up barge platform with the supporting legs positioned on the seabed for the full duration of the diffuser shaft construction works.

There are two primary methods of forming the diffuser connection/s into the tunnelled section. One method is to pre-drill the diffuser shaft to below proposed tunnelled section invert and then drive through this with the TBM. An alternative (and probably most preferred) is to pre-drill the diffuser shaft to several metres above the underlying tunnelled section and then mine through from below into the underside of the completed diffuser shaft.

### **Spoil Disposal**

It is estimated that some 580,000 cu m of spoil would need to be disposed of arising from tunnel operations. Options exist to dispose on land or at sea, subject to licence. Spoil disposal to sea would require a separate licence application process and full environmental assessment. The disposal to sea option would only be pursued if the impacts of this option are similar or lesser than the disposal to land option.

### **Power Supply**

To provide power to the tunnel inlet shaft site, electrical cables would be laid in accordance with the standard specification for ESB networks MV/LV Networks Ducting (Minimum Standards) within the ESB wayleave in the compensatory grassland and under Pigeon House Road during scheduled road strengthening and resurfacing works. In anticipation of this option proceeding, these enabling works have already been completed under the 2012 Planning Permission.

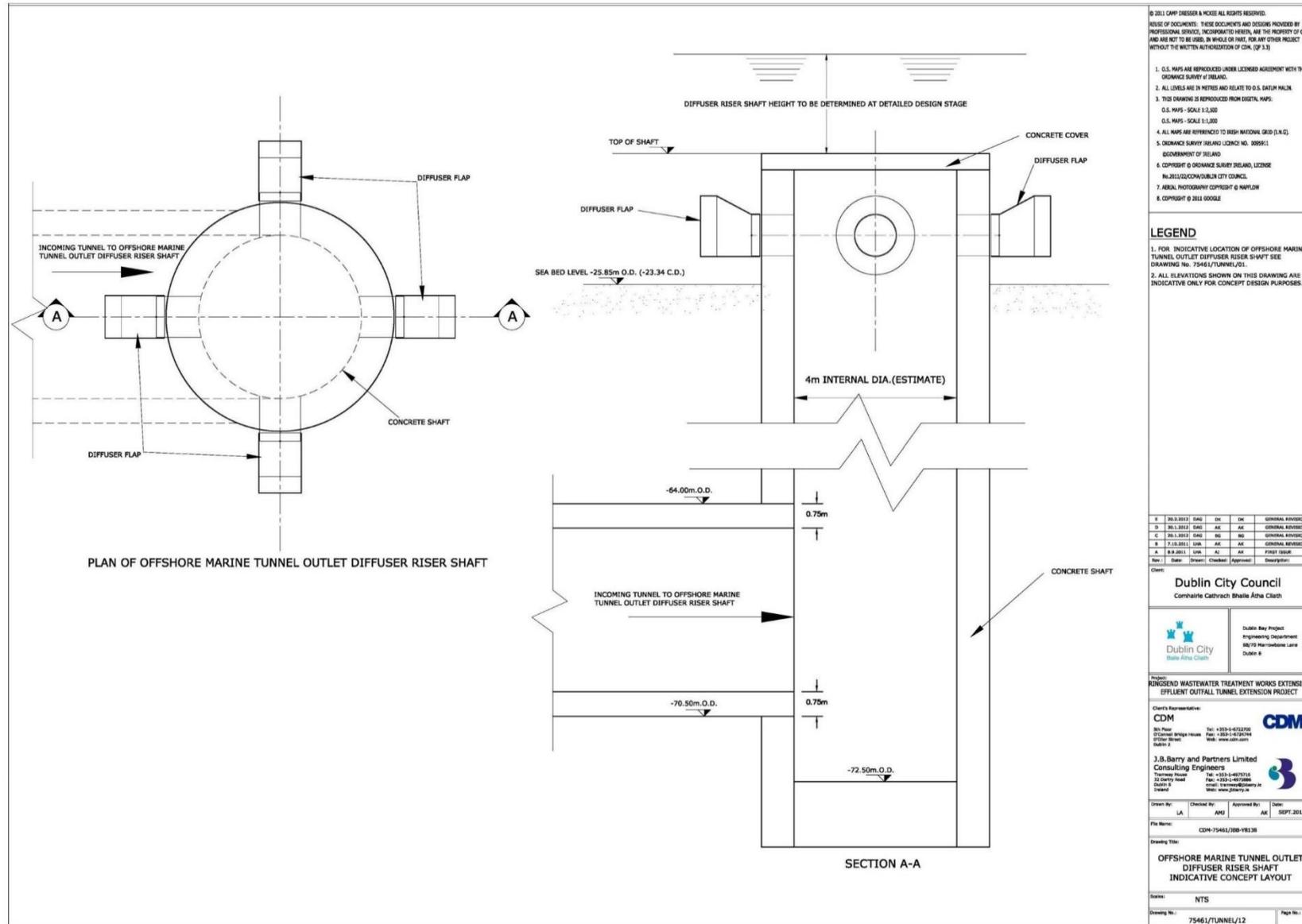


Figure 7: Sample drawing of Typical Tunnel Diffuser

## References

“Modelling the Impact of Ringsend Discharges in the Liffey and Tolka Estuaries and Possible Long Sea Outfall Discharges in Dublin Bay” October 2009

“Preliminary Assessment of Long Sea Outfall Locations”, CDM/JBB, January 2010

“Constraint Mapping of Dublin Bay” (CDM, 2010)

“Ringsend Long Sea Outfalls Modelling Results” CDM and DHI, January 2011