Environmental Statement

6 Water Quality

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6.1 *Introduction*

This chapter of the Environmental Statement (ES) concerns water quality. The Environmental Scoping Report (Halcrow, 2004) and the Town Planner's Scoping Opinion (Government of Gibraltar (GoG), 2005 – see Appendix A) both identify the need to address a range of water quality issues relating to the proposed Eastside development, including:

- Sediment plumes from dredging and land reclamation works during construction of Eastside;
- Pollution associated with discharges from surface and storm water drainage from Eastside; and
- Pollution affecting bathing water quality at local beaches.

It should be noted that at the time of preparing this ES, there were no plans for Eastside to include infrastructure that may cause the following pollution impacts on water quality:

- Pollution associated with water stagnation within enclosed water areas, such as a marina;
- Pollution associated with discharges and/or spillages from marina operations and vessels;
- Pollution associated with the handling and disposal of wastes from vessels;
- Pollution associated with sewage or wastewater discharges to the sea (it is planned that sewage and wastewater will be pumped into Gibraltar's municipal sewerage and treatment system); and
- Pollution associated with thermal water discharges to the sea (it is planned that sea water will not be used for the development's air conditioning system).

The potential for Eastside to cause impacts on water quality arising from activities affecting seabed sediments and the rubble tip is addressed in Chapters 7 and 8 respectively.

6.2 *Assessment Methodology*

6.2.1 *Data Collection*

Monitoring data with respect to the European Commission (EC) Bathing Waters Directive has been provided by the Environmental Agency. Other data sources are identified in Appendix B.

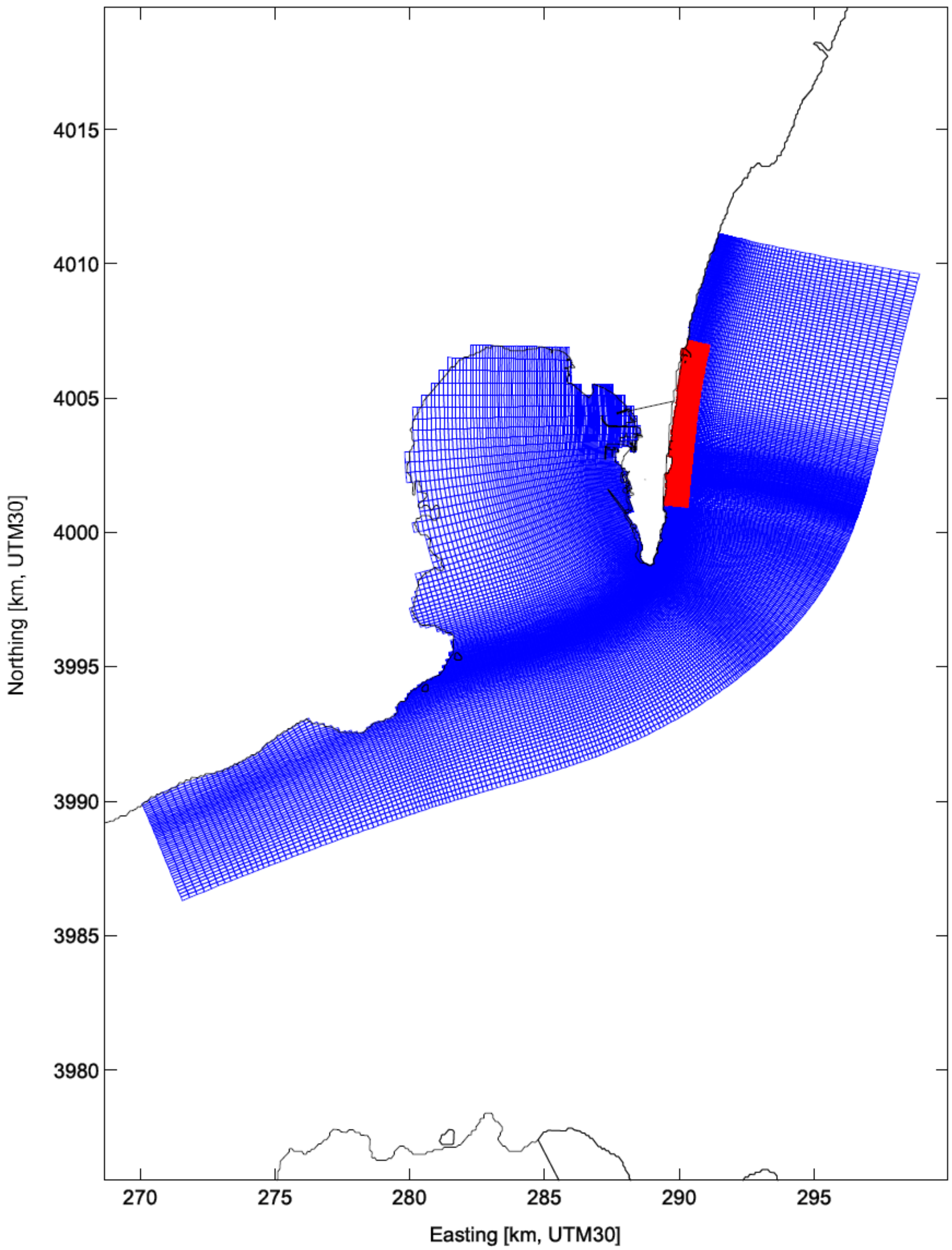
6.2.2 *Assessment Methodology – Dredging Induced Sediment Plumes*

The sediment plumes released from dredging and land reclamation activities were simulated using the Delft3D flow model developed as part of this study (see Appendix B). The flow model was linked with the Delft3D morphological module Delft3D-Online Morphology to include the processes of sediment dispersion, taking into account advection, diffusion and dispersion processes (see Section 7, Appendix D). Figure 6.1 shows the area of the grid used for sediment plume dispersion with the 3D component shown in red.

The results of the plume dispersion modelling are presented in two types of contour plots in Appendix D. The first set of plots (the 'time-percentage plots') shows the percentages of time that dredging could cause the sediment concentration to exceed 1mg/l in the bottom layer of the water column. The second set of plots shows isolines of the maximum (averaged over turbulence timescales of seconds to minutes) sediment concentrations that are expected to occur in the bottom layer of the water column around the dredging location.

The reader should refer to Section 7 of Appendix D for more detailed information.

Figure 6.1 Extent of Model Grid used for Sediment Plume Dispersion



6.2.3 *Assessment Methodology – Pollutant Dispersion*

The assessment of pollution impacts has been conducted by predicting the dispersion and fate of the pollutant. The particle tracking model Delft3D-PART was used to simulate pollutant dispersion for different pollutant discharge scenarios from the proposed Eastside development, namely:

- Surface and storm water run-off; and
- An unspecified conservative pollutant.

The model simulates the dispersion of pollutants by discharging particles at specified discharge rates and locations. Every particle represents a specific pollutant mass. Resulting concentrations of pollutants are defined by the relative number of particles present in a certain area at a certain time. Because the actual composition of the pollutants is not known, the initial discharge concentration of the pollutants used can be interpreted as an arbitrary, scalable value. The computed plume dispersion is therefore presented in a relative sense (i.e. presented as percentages of the initial concentration/mass rather than actual values).

To simulate the plume dispersion in a statistically realistic way, a total of one million particles were released at the identified discharge locations at specified discharge rates. This provided the statistical precision required.

The model represents many processes such as small-scale wind effects, local (ship-induced) currents, and small structures obstructing the flow, etc. by applying a diffusion / dispersion parameter. For particle tracking simulations, the horizontal dispersion coefficient is also time dependent, generally increasing with time. In the initial period of time after the release of the particles, the patch of particles is relatively small and the mixing of the particles is caused by small-scale turbulence effects only. However, after some time, the cloud of particles will have spread sufficiently such that larger-scale eddies and circulations will contribute to the mixing effect.

The reader should refer to Section 7 of Appendix B for more detailed information.

6.2.4 *Assessment Methodology – Bathing Water Quality*

To assess the impact of Eastside on bathing water quality, an inventory was made of pollution sources for microbiological contaminants and other contaminants (see Section 3, Appendix B). The discharges to the area can be summarised as follows:

- Sewage discharges - A sewage outfall discharges off Europa Point, but previous studies have shown that the discharge is moved out to sea by the currents and does not contaminate Gibraltar's beaches with microbiological contaminants;
- Stormwater discharges – A stormwater outfall discharges at the southern end of Catalan Beach, but it is understood that the stormwater discharge consists only of run-off from roads and other hard surfaces and is not thought to contain microbiological contaminants; and
- Beach users and swimmers - The main microbiological inputs to the bathing waters at Catalan Bay and Eastern Beach are likely to be beach users and swimmers, although other inputs (e.g. sea gulls and other birds) cannot be discounted.

The data input to the numerical model was based on two swimmers per metre of beach. Relevant contaminants from swimmers are coliform bacteria, nutrients and sun bathing oils. Simulations were carried out in which a series of continuous discharges was positioned along the beach in question, approximately along the one metre depth line, to represent the diffused nature of the pollutant sources. By scaling the discharges used in the numerical model with realistic order of magnitude for discharges of different contaminants, the order of magnitude of the concentrations of these contaminants on the beach was estimated, and the results evaluated on the basis of expert opinion.

The methodology is based on there being no change to inputs of contaminants resulting from Eastside, so any potential increase in their concentrations would be caused by reductions in flushing of the bathing waters as a result of hydrodynamic changes caused by Eastside. The impact of possible contaminant sources at locations other than the beach areas were not taken into account.

6.2.5 *Impact Significance*

The significance of predicted impacts was evaluated using the following criteria:

- Negligible - the impact is not of concern;
- Minor adverse - the impact is undesirable but of limited concern;
- Moderate adverse - the impact gives rise to some concern but it is likely to be tolerable (depending on its scale and duration);
- Major adverse - the impact gives rise to serious concern; it should be considered as unacceptable unless unavoidable by best practicable means;
- Minor beneficial - the impact is of minor significance but has some environmental benefit;
- Moderate beneficial - the impact provides some gain to the environment; and
- Major beneficial - the impact provides a significant positive gain.

6.3 Baseline Conditions

6.3.1 *Bathing Water Quality*

The EC Bathing Waters Directive 76/160/EEC establishes mandatory and guideline standards for water quality using three microbiological parameters (total coliforms, *Escherichia coli* and faecal streptococci) measured in a 100ml water sample. The standards are shown in Table 6.1.

Table 6.1 EC Bathing Waters Directive Water Quality Standards

Standard	Total coliforms	Escherichia coli	Faecal streptococci
Mandatory	10,000/100ml	2000/100ml	None
Guideline	500/100ml	100/100ml	100/100ml

The water quality of Gibraltar's beaches is monitored by the Environmental Agency against the EC Bathing Waters Directive's microbiological water quality standards. Monitoring takes place every year during the bathing season (April to September). The beaches monitored are Eastern Beach, Catalan Bay and Sandy Bay. The monitoring results for the years 2001 – 2005 are shown in Tables 6.2 and 6.3 in terms of the number of recorded water quality failures against the EC Bathing Waters Directive's mandatory and guideline standards.

Table 6.2 Bathing Waters Monitoring in Gibraltar 2001-2005 – Summary of Failures of Mandatory Standards

Bathing Water	Failures in 2001	Failures in 2002	Failures in 2003	Failures in 2004	Failures in 2005
Catalan Bay					
Total coliforms	0	0	0	0	0
Escherichia coli	0	0	0	0	0
Faecal streptococci	*	*	*	*	*
Eastern Beach					
Total coliforms	0	0	0	0	0
Escherichia coli	0	0	0	0	0
Faecal streptococci	*	*	*	*	*
Sandy Bay					
Total coliforms	No data	0	0	0	0
Escherichia coli	No data	0	0	0	0
Faecal streptococci	*	*	*	*	*

* No failures since there is no standard

Table 6.3 Bathing Waters Monitoring in Gibraltar 2001-2005 – Summary of Failures of Guideline Standards

Bathing Water	Failures in 2001	Failures in 2002	Failures in 2003	Failures in 2004	Failures in 2005
Catalan Bay					
Total coliforms	5	3	1	0	0
Escherichia coli	10	4	4	5	1
Faecal streptococci	0	1	0	0	1
Eastern Beach					
Total coliforms	5	4	1	0	0
Escherichia coli	9	6	4	5	0
Faecal streptococci	1	1	0	0	0
Sandy Bay					
Total coliforms	No data	0	0	0	0
Escherichia coli	No data	1	3	4	1
Faecal streptococci	0	0	0	0	0

Data provided by the Environmental Agency for years 2001-2005 shows that there were no failures under the mandatory standards for bathing water quality at Eastern Beach, Catalan Bay and Sandy Bay. However, there were various failures under the more rigorous guideline standards at all three bathing waters for all three microbiological parameters.

6.4 Predicted Impacts

6.4.1 *Construction Phase: Impact of Sediment Plumes*

Dredging and associated land reclamation works can cause large-scale releases of sediment into the water column, causing increased concentrations of the total suspended solids (TSS). While some waters naturally contain high TSS concentrations, for the EIA process it has been assumed that the coastal waters off eastern Gibraltar have low TSS concentrations of 1mg/l. This value allows the predicted increases in TSS to be assessed against a reference concentration and, given its low value, builds in a measure of conservatism to the impact assessment. While the actual conditions will vary considerably as a result of storms, algal blooms, etc, the use of 1mg/l as a background concentration establishes a conservative baseline against which impacts are assessed. Although an increase in TSS does not necessarily adversely affect water quality, it can affect other properties of water such as transparency and turbidity (i.e. reducing visibility through the water) and can have indirect impacts on the marine ecological receptors exposed to higher TSS.

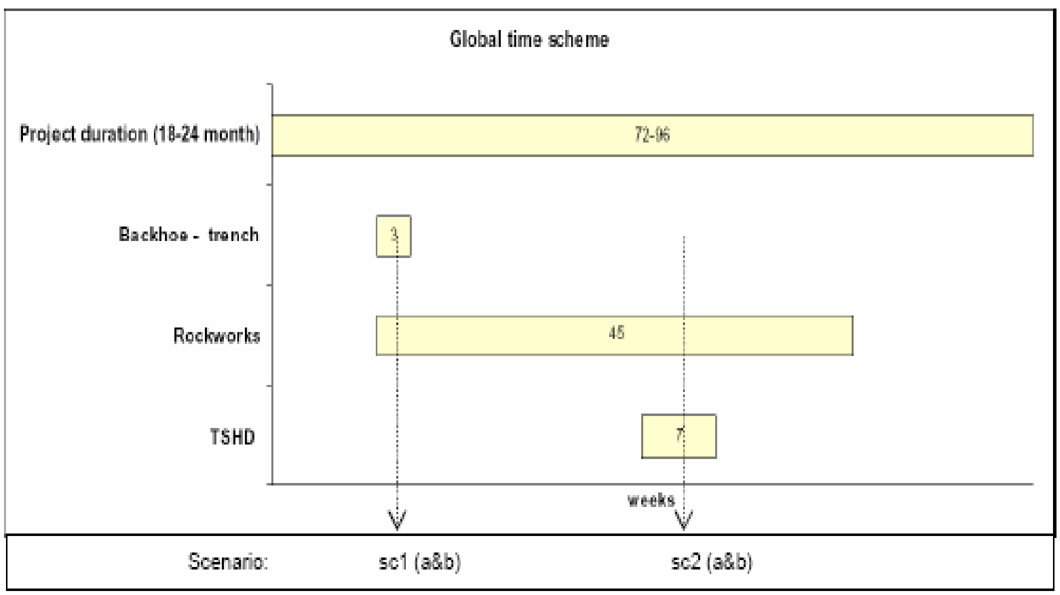
It should be noted that the nature and scale of the proposed dredging from the borrow areas using a trailing suction hopper dredger (TSHD) is likely to be similar to that undertaken at the southern borrow area for The Island project on the west side of Gibraltar.

The dredging and land reclamation works that are likely to take place for Eastside comprise the following key activities that can generate sediment plumes:

- Dredging trenches for sea defences by a backhoe dredger (BHD) and placing material on the seabed by a split hopper barge (SHB);
- Placement of rock for the sea defences, mainly by a side stone dumping vessel (SSDV); and
- Dredging of sand from the borrow area(s) and placement of sand for land reclamation by TSHD.

An indicative timeframe for these activities is shown in Figure 6.2.

Figure 6.2 Indicative Timeframe of Key Dredging and Marine Works



Two impact scenarios were used to assess the dredging and reclamation activities during the construction phase of Eastside (identified as sc1 and sc2 in Figure 6.2).

The impact assessment scenarios for Eastside were:

- Dredging and works for the trenches and sea defences (see sc1a and sc1b in Figure 6.2 and Figure 7.3a in Appendix D); and
- Dredging and land reclamation works (see sc2 in Figure 6.2 and Figure 7.3b in Appendix D).

The two impact scenarios were modelled for spring and neap tide conditions including waves, without wind influences. Scenario sc2a was also modelled with two typical wind conditions (wind direction west-south-west at speed of 10 m/s and wind direction east-north-east at speed of 10 m/s) because this scenario represented the worst case impact since it had the longest duration.

The following paragraphs for this impact assessment report the worst case scenario impacts for each scenario (i.e. sc1a, sc1b, sc2a and sc2b) in terms of:

- The geographic areas over which the assumed baseline TSS concentration (1mg/l) is exceeded for 90%, 50% and 5% of the time during the duration of the works; and
- The TSS concentrations in these areas.

Table 6.4 shows figures in Appendix D that represent the worst case scenario model results:

Table 6.4 Figure References for Appendix D

Figure Info / Impact Scenario	sc1a	sc1b	sc2a	sc2b
Layout and sediment plume sources	7.3a	7.3a	7.3b	7.3b
Impact area (% time TSS >1mgl)	7.4c	7.10c	7.15c	7.20c
Impact on TSS (increase TSS in mg/l)	7.6c	7.12c	7.17c	7.22c

Scenario sc1 - the dredging and works for the trenches and sea defences - represents the BHD dredging activities in combination with the SHB construction of the trenches, and includes SSDV activities. This scenario is subdivided into sc1a for the construction of the southern part of the sea defence and sc1b for the construction of the northern part of the sea defence. The following assessment is based on the worst case conditions arising during a spring tidal cycle.

The model predicts that for sc1a:

- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 90% of the time over the two-week duration of the works for nearshore (i.e. well within 1km distance offshore) coastal waters from Sandy Bay to the existing groyne along Eastern beach in front of the airport's runway. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 16mg/l to 512mg/l, with the highest concentrations immediately around the dredger;
- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 50% of the time over the two-week duration of the works for nearshore coastal waters from the pier to the south of Sandy Bay to just over the Spanish border. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 4mg/l to 8mg/l; and
- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 5% of the time over the two-week duration of the works for nearshore coastal waters from Europa Point to a point approximately 0.75km over the Spanish border. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 1mg/l.

The model predicts that for sc1b the findings are very similar to the results of sc1a but were generally moved 500m northwards. This change to the geographic area of the impact reflects a similar movement of the dredging and marine works under this impact scenario.

Scenario sc2 – the dredging and land reclamation works - represents the dredging of sand from one borrow area and the placement of the material at the reclamation site, and includes SSDV activities working on the sea defence. This scenario is subdivided into sc2a for dredging at the northern borrow area (total duration = seven weeks) and sc2b with dredging from the southern borrow area (total duration = seven weeks). The following assessment is based on the worst case conditions arising during a neap tidal cycle.

The model predicts that for sc2a:

- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 90% of the time over the seven-week duration of the works for coastal waters (i.e. up to approximately 3km to 4km offshore) from Sandy Bay to a point approximately 0.75km over the Spanish border (see Figure 6.3 overleaf). The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 4mg/l to 8mg/l, with much higher concentrations (512mg/l) immediately around the dredger where it operates in open sea at the northern borrow area and where sediment is placed in the reclamation areas at Eastside (see Figure 6.4);
- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 50% of the time over the seven-week duration of the works for coastal waters from Governor's Beach to a point slightly less than 1km over the Spanish border. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 4mg/l to 8mg/l; and
- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 5% of the time over the seven-week duration of the works for coastal waters from Europa Point to a point slightly more than 1km over the Spanish border. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 1mg/l.

Figure 6.3 Percentage of Time TSS Concentration >1mg/l for sc2a

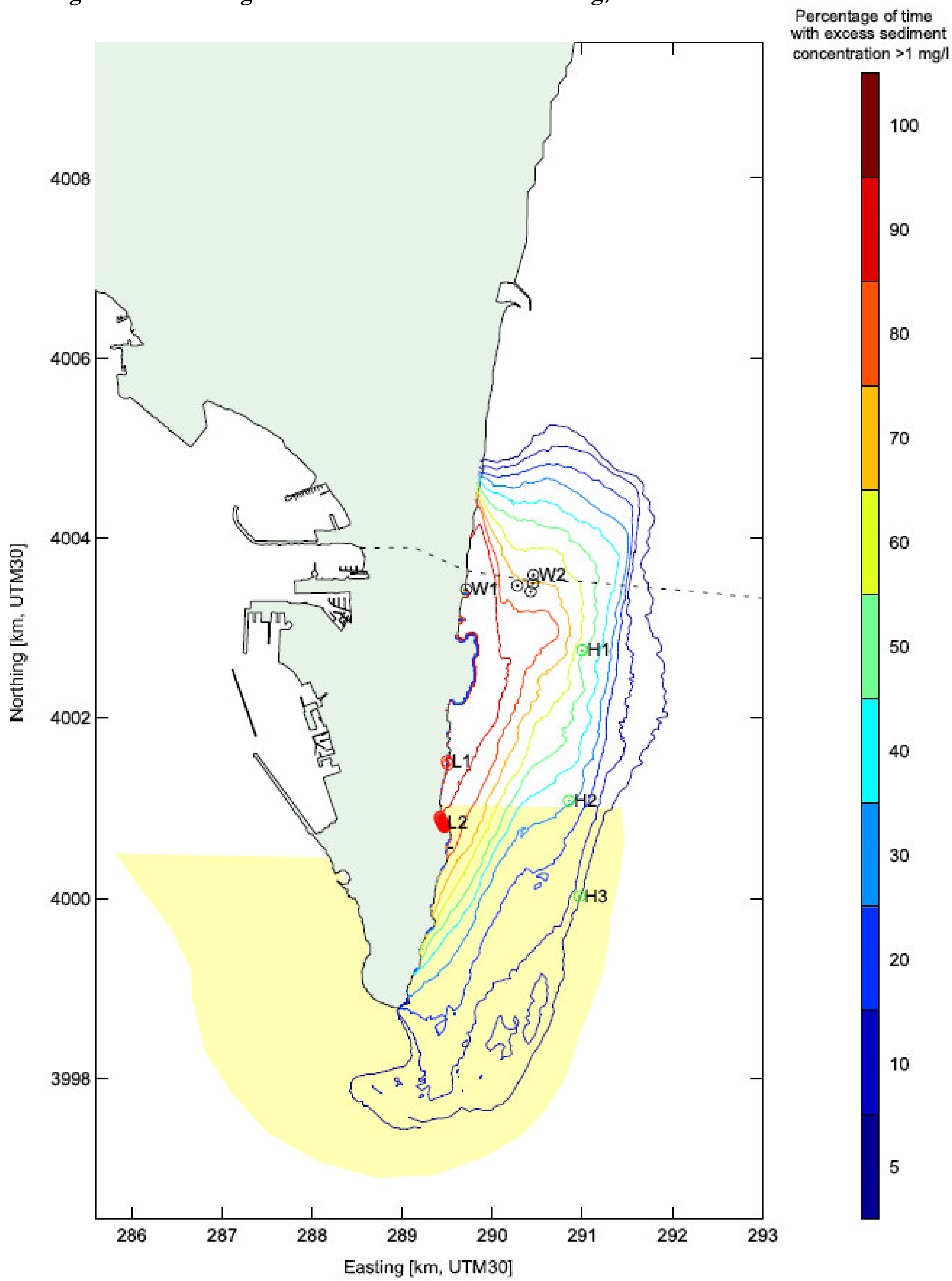
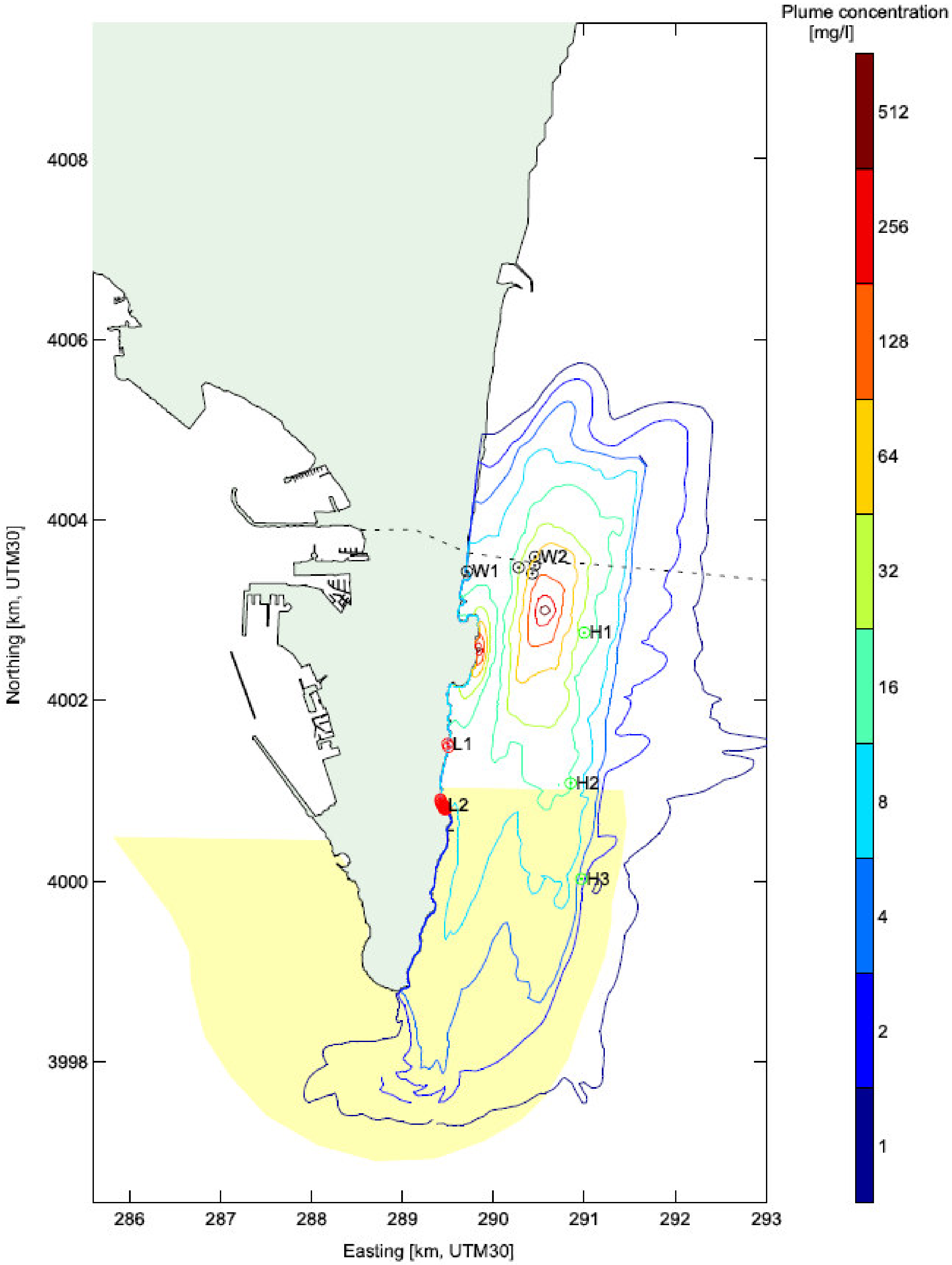


Figure 6.4 Maximum Expected TSS Concentrations and Plume Extents for sc2a



When sc2a is modelled with a west-south-west wind direction at 10m/s, the maximum expected plume in excess of 1 mg/l covers a larger water area across the Spanish border (compared to the sc2a situation without wind). The affected water area extends several kilometres north of the harbour of La Atunara where the reference concentration is exceeded during more than 80% of time. Under the no-wind conditions, the affected water area is smaller and extends approximately 1km across the Spanish border.

The model predicts that for sc2b:

- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 90% of the time over the seven-week duration of the works for coastal waters (i.e. up to approximately 3km to 4km offshore) from Europa Advance Battery to a point between the two existing groynes along Eastern Beach. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 4mg/l to 8mg/l, with much higher concentrations (512mg/l) immediately around the dredger where it operates in open sea at the southern borrow area and where sediment is placed in the reclamation areas at Eastside;
- TSS concentrations would increase over baseline conditions (assumed to be1mg/l) for up to 50% of the time over the seven-week duration of the works for coastal waters from Europa Point to the Spanish border. The model predicted that the maximum TSS concentrations in the sediment plume at these points would be approximately 2mg/l to 8mg/l; and
- TSS concentrations would increase over baseline conditions (assumed to be 1mg/l) for up to 5% of the time over the seven-week duration of the works for coastal waters from west of Europa Point (around Dead Man's Beach) to a point approximately 0.5km over the Spanish border. The model predicted that the maximum TSS concentrations of the sediment plume at these points would be approximately 1mg/l.

The following generic conclusions about can be drawn from the modelling:

- The maximum expected TSS concentrations would be lower during spring tide conditions than during neap tide, however the area of impact is greater during spring tide;
- Wind influences modelled for sc2 show that the area of the sediment plume can change significantly due to wind effects.

In terms of impacts on water quality, the proposed dredging and other works would generally create short-term (i.e. 2 to 7 weeks) increases to TSS concentrations in the coastal waters off eastern Gibraltar. The modelling results indicate that although large geographical areas can be affected by sediment plumes transported by hydrodynamic and wind conditions, the majority would experience increases below 10mg/l.

Smaller areas, particularly those areas at and around the dredging and reclamation works, will experience much larger increases above 500mg/l. Increases of this magnitude are to be expected around activities involving large dredging equipment such as a TSHD since it is in the nature of this dredging activity to spill some sediment into the water.

Using the criteria for assessment of significance of impact from Section 6.2.5, the worst case findings can be summarised as follows:

- There will be a negligible impact on the water quality of the water areas affected by increased TSS less than 10mg/l;
- There will be a minor adverse impact on the water quality of the water areas affected by increased TSS from 10mg/l to 50mg/l;
- There will be a moderate adverse impact on the water quality of the water areas affected by increased TSS equal to or greater than 50mg/l;

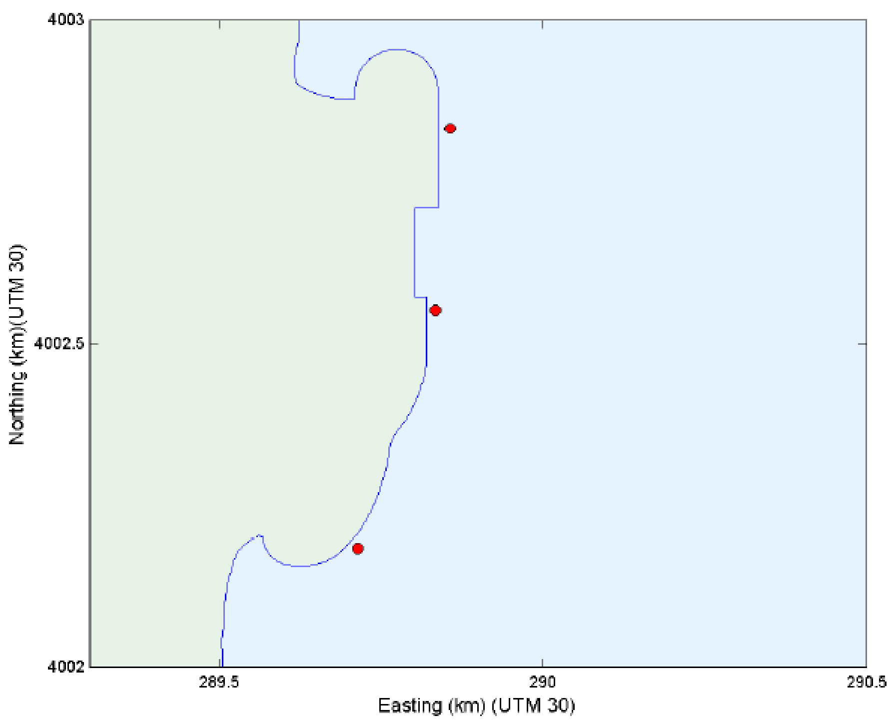
- The impact on water quality decreases rapidly with distance from the dredger at the borrow areas and decreases very rapidly with distance from the reclamation areas at Eastside; and
- The adverse impact on water quality will be short-term in duration; that is, lasting for a number of weeks (i.e. two weeks for sc1 + seven weeks for sc2) over a construction period that could last for up to two years.

6.4.2 *Operation Phase: Impact of Surface and Storm Water Run-off*

At Eastside, it is assumed that the drainage will discharge into the sea via outfalls and although the drains accepting surface water run-off from roads, paved areas and roofs will have by-pass interceptors, there could be an adverse impact on the quality of receiving waters.

The numerical model simulated the discharge of run-off water from three indicative outfall locations in the development due to rainfall of 50mm/hour. The three indicative discharge locations are indicated in Figure 6.5. The total resulting discharge is established as 2,100l/sec based on an approximate drained surface area and a short period of heavy rainfall. The total discharge rate was divided equally over the three outfalls to give a discharge rate of 700l/sec per outfall.

Figure 6.5 Surface and Storm Water Run-off Discharge Points



The buoyancy effect of the run-off water was modelled with the particle tracking model by discharging the particles into the top layer of the water column and restricting the vertical dispersion to limit the spreading of particles in the vertical direction. The duration of the run-off discharge was set to one hour and the numerical model was used to simulate two days of plume dispersion on a spring tide to predict the maximum extent of dispersion.

Figures 6.9 and 6.10 show the resulting maximum expected relative plume concentrations in the top layer of water during the one hour storm water discharge for northward and southward currents respectively. This result shows that the impact of the one hour discharge is limited. A minor adverse impact occurs close to the development, with maximum concentrations higher than 10% of the source concentration close to the run-off sources reached (where the undiluted discharge is 100%), but this does not affect bathing waters at beaches.

The impact on nearby beaches and their bathing waters (at 1km) is small, with relative concentrations of 1 to 2%.

Figure 6.6 Relative Plume Concentrations for Surface and Storm Water Run-off (northward current)

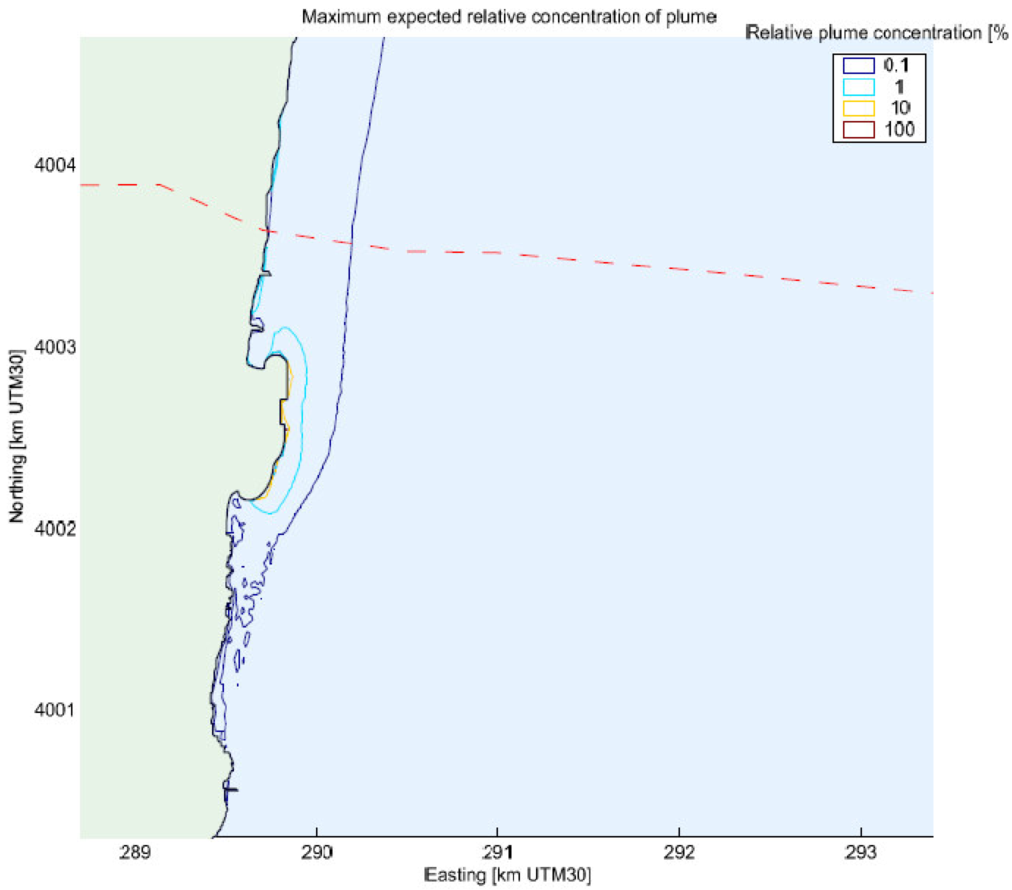
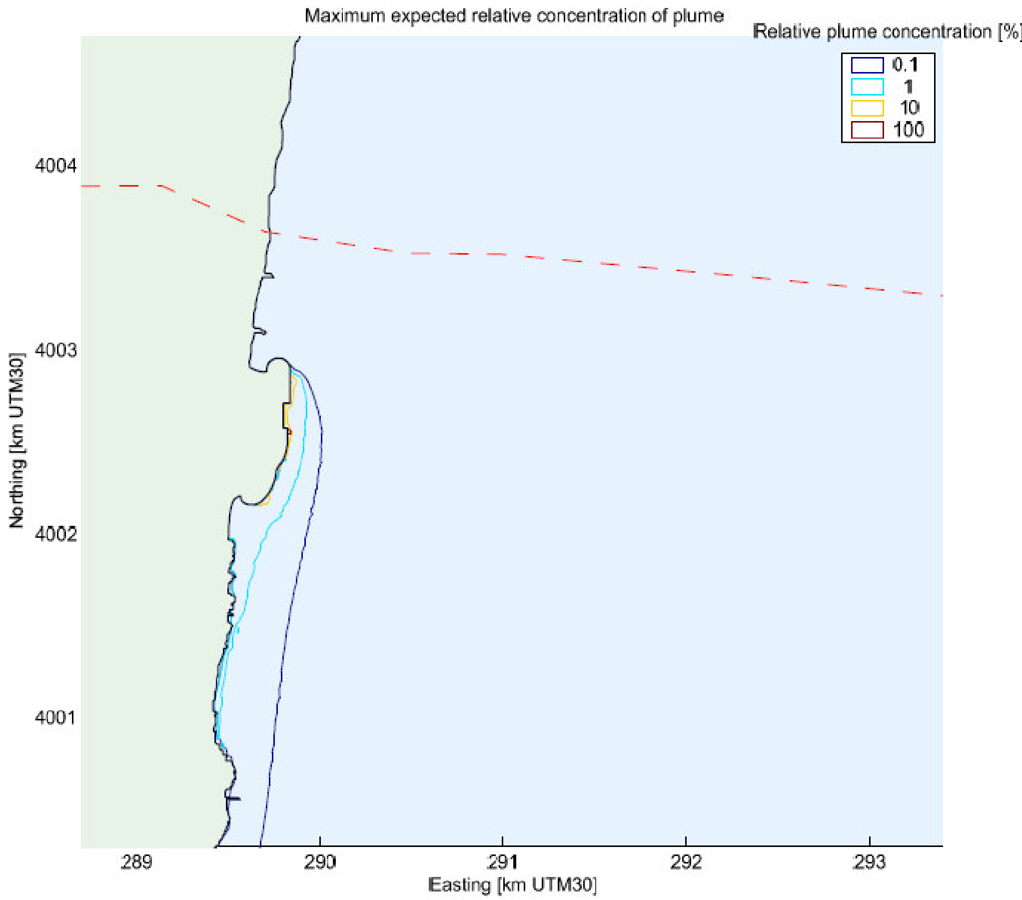


Figure 6.7 Relative Plume Concentrations for Surface and Storm Water Run-off (southward current)



Overall, the model simulations indicated that the volumes of surface and storm water originating from the run-off from Eastside would reach bathing waters at Catalan Bay and other beaches in concentrations so low that a negligible impact is to be expected, even after a relatively heavy rain event.

6.4.3 *Operation Phase: Impact of an Unspecified Conservative Pollutant*

A conservative (in duration) scenario has been assessed to predict the potential (risk of an) impact associated with the discharge and plume of an unspecified conservative pollutant assumed to have the potential to adversely affect water quality. Therefore, this situation potentially represented a worst-case scenario for a pollution impact. However, it should be noted that a continuous discharge of this nature (e.g. duration) is generally unrealistic.

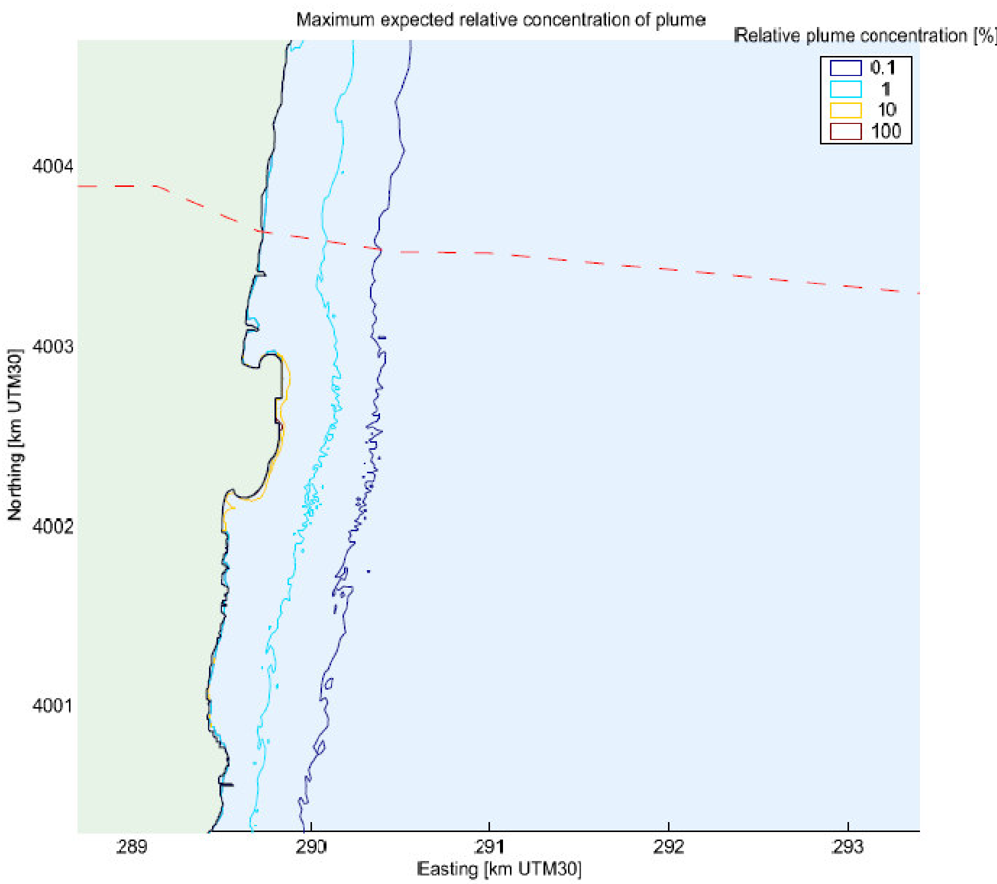
The set up of the numerical model was similar to the surface and storm water run-off scenario, but in this case the discharge lasted three days (rather than one hour) and the duration of the plume simulation was a complete spring-neap cycle (i.e. 15 days, rather than two days).

Figure 6.8 shows the relative plume concentrations predicted by the model. The maximum expected relative concentrations in the top layer in this three day discharge scenario were significant (above 10%) close to the proposed Eastside development. The plume with a concentration of 1% to 10% reached beyond Eastside over a distance of several kilometres to the north and south. The worst case impact on Catalan Bay is predicted to be about 10 to

20% of the source concentration and the worst case impact on Eastern Beach is predicted to be about 5 to 10% of the source concentration.

No assessment of significance is made for this impact since it is entirely hypothetical. However, it demonstrates that Eastside decreases current velocities directly to its south and north of the proposed development, which means that pollutants could reside for longer periods of time at these locations at Eastern Beach and Catalan Bay.

Figure 6.8 Relative Plume Concentrations for an Unspecified Conservative Pollutant



6.4.4 *Operation Phase: Impact on Bathing Waters*

The construction of Eastside could cause a change to the current flows along the coast which would affect the flushing capacity of the bathing waters and potentially impact upon water quality with respect to the standards required under the EC Bathing Water Directive.

The results of numerical modelling based on hydrodynamics and wave conditions indicate that currents and wave heights would be reduced at the southern end of Eastern Beach and the northern end of Catalan Bay where the beaches abut the boundaries of Eastside. As a result, the flushing capacity (i.e. exchange) of the water in these areas would be reduced.

Catalan Bay Beach

Based on interpretation of the numerical modelling (see Appendix B), it is concluded that the self-cleansing capacity of Catalan Beach will be minimally affected by the Eastside development. The water exchange rates in the bathing area are expected to be slightly reduced compared to the present situation. However, it is anticipated that algae growth and accumulation (which could reduce the transparency of the water) will not occur. The exchange of the bathing waters is also expected to be large enough to prevent the development of visual films of sun bathing oils and accumulation of litter and debris. No increased risk of violation of the EC Bathing Waters' Directive's guideline standards for safe bathing water quality with respect to coliform bacteria is expected at Catalan Bay.

Eastern Beach
Based on interpretation of the numerical modelling (see Appendix B), it is concluded that the self-cleansing capacity of the southern end of Eastern Beach is expected to be affected by the Eastside development due to reduced flushing capacity / water exchange. It is expected that there will be an increased risk (over existing conditions) to water transparency, as well as an increased risk for the development of visual films of sun bathing oils and the accumulation of litter and debris. Also, it is expected that there will be an increased risk (over existing conditions) to the EC Bathing Waters' Directive's guideline standards for safe bathing water quality with respect to coliform bacteria.

However, revisions to the layout have reduced the northwards extension of the Eastside development to the extent that the southern end of Eastern Beach is more exposed to the open sea (compared to the previous layout) (see Supplementary Note to Appendix B).

Therefore, after construction, Eastside could have a minor adverse impact on bathing water quality at Eastern Beach with respect to the EC Bathing Water Directive. Despite the sensitivity of the impact with regard to the EC Bathing Water Directive, the significance of this impact is considered to be minor because:

- The area of impact would be very localised to one small location (i.e. southern end of Eastern Beach) and therefore the impact is not representative of the whole bathing water area;
- The impact cannot be confirmed since there is a risk that bathing water quality will be affected by changes to the flushing capacity / water exchange and this alone does not necessarily mean that water quality standards will be breached because other factors also affect this risk (e.g. source of pollutants, number and behaviour of beach users);
- The revisions to the layout may reduce the risk of this impact occurring; and
- The EC Bathing Water Directive's guideline values (but not mandatory values) for water quality are already exceeded under the existing conditions, including the existing flushing capacity of the waters.

It is estimated that there will be only a small risk that the transparency of the water will be reduced significantly due to the development of algae in the beach waters. Similarly, there will be only a small risk of the formation of visual films of sun-bathing oils and the accumulation of litter and debris. A minor adverse impact is predicted for the same reasons as given above.

6.5 Mitigation Measures

6.5.1 *Construction Phase: Impact of Sediment Plumes*

To reduce the magnitude and scale of impacts associated with dredging and reclamation, the following mitigation measures should be considered and implemented as part of the contract awarded for the marine works for Eastside. To reduce sediment suspension from the TSHD (CIRIA, 2000):

- Optimise trailing velocity, suction head and pump discharge with respect to one another to reduce sediment losses around the draghead;
- Try to reduce water intake by the suction head to increase sediment density and reduce need for overflowing;

- Apply return flow method if the TSHD has this facility to increase sediment density and reduce overflowing; and
- Avoid unnecessary overflowing through operational method.

6.5.2 *Operation Phase: Impact of Surface and Storm Water Run-off*

Although only a negligible impact is predicted, as a precautionary measure to mitigate against significantly adverse impacts associated with discharges of storm and surface water run-off, it is recommended that petrol/oil interceptors are included in the drainage system.

6.5.3 *Operation Phase: Impact of an Unspecified Conservative Pollutant*

This impact scenario is generally unrealistic, because it is so unlikely to happen. However, it does indicate the potential risk of an adverse impact on water quality at the beach areas adjacent to Eastside. Accordingly, this impact assessment reinforces the recommended mitigation measures identified with respect to surface and storm water run-off; that is, the need for petrol/oil interceptors in the drainage system.

6.5.4 *Operation Phase: Impact on Bathing Waters*

Overall, no specific mitigation measures are recommended concerning the impact on bathing water quality with respect to coliform bacteria. This is because:

- The existing water quality is such that it regularly exceeds the guideline standards under the EC Bathing Water Directive, which suggests that there is an existing pollution problem (not associated with Eastside) that needs to be addressed to prevent future failures; and
- The available data cannot confirm whether additional mitigating measures (e.g. improving the water exchange in the sheltered area at the southern end of Eastern Beach) are needed.

Nevertheless, it is recommended that the water quality at the southern end of Eastern Beach is monitored for bacteriological parameters with respect to standards under EC Bathing Waters Directive. Should monitoring confirm that water quality is adversely affected by reduced flushing capacity / water exchange, then small-scale measures to increase flushing capacity / water exchange should be devised. Such measures could include cascades where water flows over the rocks (forming the edge works for Eastside) from the sheltered area to the sea.

Mitigation measures are recommended concerning the impact on bathing water quality with respect to water transparency and oily films. It is recommended that beach maintenance be undertaken to regularly remove litter and debris from the southern end of Eastern Beach.

6.6 Residual Impacts

6.6.1 *Construction Phase: Impact of Sediment Plumes*

Even with the mitigation measures in place, it is unlikely that the residual impacts will be reduced significantly since modern dredging equipment tends to work very efficiently, for example, in terms of the accuracy of the draghead, increasing the density of the sediment pumped into the hopper and avoiding unnecessary overflowing. Accordingly, a range of negligible to moderate adverse residual impacts could arise.

6.6.2 *Operation Phase: Impact of Surface and Storm Water Run-off*

With the interceptors in place, the potential impact on water quality would be managed to leave a negligible residual impact, even in the immediate vicinity of the Eastside development.

6.6.3 *Operation Phase: Impact of an Unspecified Conservative Pollutant*
With the recommended measures in place, the risk of any residual impact on water quality would be very low.

6.6.4 *Operation Phase: Impact on Bathing Waters*
There would be a residual minor adverse impact on bathing water quality. However, if flushing is required, this mitigation measure should be planned so that it reduces the matter to a negligible residual impact.

6.7 *Cumulative Effects*

6.7.1 *Construction Phase: Cumulative Effect of Sediment Plumes*
The cumulative effect of Eastside in combination with other plans or projects (see Section 4.10) has been assessed for sediment plumes by using the same approach as described in Section 6.4.

The Both Worlds Project is not expected to involve dredging and reclamation that coincides with the dredging and reclamation for Eastside, and therefore no cumulative effect is predicted as a result of sediment plumes.

Accordingly, no mitigation measures are recommended and therefore there will be no residual cumulative effect.

6.7.2 *Operation Phase: Cumulative Effect of Surface and Storm Water Run-off*
The cumulative effect of Eastside in combination with other plans or projects (see Section 4.10) has been assessed for surface and storm water run-off by using the same approach as described in Section 6.4. The Both Worlds project at Sandy Bay does not affect this impact assessment.

Given the findings for Eastside alone (see Section 6.4) and because of the very limited size of the Both Worlds Project, no cumulative effects on water quality are predicted as a result of a discharge of surface and storm water run-off.

Accordingly, no mitigation measures are recommended and therefore there will be no residual cumulative effect.

6.7.3 *Operation Phase: Cumulative Effect of an Unspecified Conservative Pollutant*
The cumulative effect of Eastside in combination with other plans or projects (see Section 4.10) has been assessed for an unspecified conservative pollutant by using the same approach as described in Section 6.4.

Given the findings for Eastside alone (see Section 6.4) and because of the very limited size of the Both Worlds Project, no cumulative effects on water quality are predicted as a result of a discharge of unspecified conservative pollutants.

Accordingly, no mitigation measures are recommended and therefore there will be no residual cumulative effect.

6.7.4 *Operation Phase: Cumulative Effect on Bathing Waters*
The cumulative effect of Eastside in combination with other plans or projects (see Section 4.10) has been assessed for bathing waters by using the same approach as described in Section 6.4.

Given the findings for Eastside alone (see Section 6.4) and because of the very limited size of the Both Worlds Project, no cumulative effects on bathing water quality are predicted as a result of combined pollutant sources (e.g. swimmers, sewage discharges).

Accordingly, no mitigation measures are recommended and therefore there will be no residual cumulative effect.

6.8 Transboundary Effects

6.8.1 *Construction Phase: Transboundary Effect of Sediment Plumes*

The transboundary effect of Eastside on water quality in Spanish waters has been assessed for sediment plumes by using the same two scenarios as described in Section 6.4.

The following paragraphs for this impact assessment report the transboundary effects of sediment plumes generated during construction of Eastside for a range of worst case impact scenarios (i.e. sc1a, sc1b, sc2a, sc2b, sc4a and sc4b), as described in Section 6.4, Figures 6.3 and 6.4, and cross-referenced to various figures in Appendix D (see Table 6.4) in terms of:

- The geographic areas over which the assumed baseline TSS concentration (1mg/l) is exceeded for 90%, 50% and 5% of the time during the duration of the works; and
- The TSS concentrations in these areas.

For impact scenario 1 (see Section 6.4), the greatest transboundary effect is expected during sc1b. In Spanish waters, the reference concentration of 1mg/l is exceeded during more than 80% of the time during neap tide conditions, decreasing to 5% at about 1.5km north of the boundary during spring tide conditions. The maximum expected TSS concentrations in Spanish waters are 4mg/l to 8mg/l.

The transboundary effects are less for sc1a. The reference concentration of 1mg/l is exceeded for 70% of the time and reaches a maximum concentration of 4mg/l to 8mg/l.

For impact scenario 2 (see Section 6.4), the greatest transboundary effect is expected during sc2a with dredging at the northern borrow area. In Spanish waters, the reference concentration of 1mg/l is exceeded during more than 90% of time during neap tide conditions (see Figure 6.3). The sediment plume with sediment concentrations above 1mg/l extends 5km northward from the border on spring tide conditions. For both spring and neap tide conditions, the maximum TSS concentrations are expected to be in the order of 64mg/l to 128mg/l (see Figure 6.4).

The transboundary effects are less for sc2b. The reference concentration of 1mg/l is exceeded for 80% to 90% of the time and reaches a maximum concentration of 8mg/l.

In terms of impacts on water quality, the proposed dredging and other works will generally create short-term (i.e. 2 weeks for sc1 and seven weeks for sc2) increases to TSS concentrations in the coastal waters off Spain. The modelling results indicate that maximum TSS concentrations from 64mg/l to 128mg/l can be reached due to sediment plumes dispersing from dredging activity within the northern borrow area. Increases of this magnitude are to be expected around activities involving large dredging equipment such as a TSHD since it is in the nature of this dredging activity to spill some sediment into the water. At the Spanish shoreline, the maximum TSS concentrations are expected to be between 8mg/l and 16 mg/l for sc2a and to be less than 8mg/l for all other impact scenarios.

Using the criteria defined in Section 6.2.5, the significance of worst case transboundary impacts of sediment plumes are assessed as follows:

- There will be a negligible transboundary effect on the water quality at the Spanish shoreline including beaches since all impact scenarios create increased TSS generally less than 8mg/l;
- There will be a moderate adverse transboundary effect on the water quality of Spanish water areas offshore because sediment plumes from dredging at the northern borrow area disperse northward and increase TSS by 64mg/l to 128mg/l;
- The transboundary effect on water quality decreases rapidly with distance from the dredger at the northern borrow area;
- There will be a negligible transboundary effect on the water quality of Spanish water areas offshore because sediment plumes from dredging at the southern borrow area do not disperse that far northward;
- The transboundary effect on water quality will be short-term in duration; that is, lasting for a number of weeks over a construction period that could last for two years.

To reduce the magnitude and scale of transboundary effects associated with dredging and reclamation, the following mitigation measures should be considered and implemented in a practicable and cost-effective manner as part of the contract awarded for the marine works for Eastside.

To reduce sediment suspension from the TSHD (CIRIA, 2000):

- Optimise trailing velocity, suction head and pump discharge with respect to one another to reduce sediment losses around the draghead;
- Try to reduce water intake by the suction head to increase sediment density and reduce need for overflowing;
- Apply return flow method if the TSHD has this facility to increase sediment density and reduce overflowing; and
- Avoid unnecessary overflowing through operational method.

To reduce sediment plumes from the northern borrow area:

- Undertake dredging in the southern borrow area to avoid the dispersion of a significant sediment plume into Spanish waters; and/or
- Undertake dredging from the northern borrow area as far south as possible to reduce the dispersion of a significant sediment plume into Spanish waters.

Even with the suggested measures for the TSHD in place, it is unlikely that the residual transboundary effects will be reduced significantly since modern dredging equipment tends to work very efficiently, for example, in terms of the accuracy of the draghead, increasing the density of the sediment pumped into the hopper and avoiding unnecessary overflowing. However, with the suggested measures relating to dredging at the borrow areas, the residual transboundary effect associated with sediment plumes from dredging at the northern borrow area could be reduced to a minor adverse or negligible transboundary effect.

6.8.2 *Operation Phase: Transboundary Effect of Surface and Storm Water Run-off*

The transboundary effect of Eastside on water quality in Spanish waters has been assessed for surface and storm water run-off by using the same approach as described in Section 6.4.

As shown in Figure 6.6, numerical modelling indicates that that surface and storm water run-off from Eastside is not expected to reach Spanish waters in concentrations generally less than 0.1% of the source concentration, and therefore negligible transboundary effect is predicted, even after a large rainfall event.

With the recommended measures in place for Eastside (i.e. petrol/oil interceptors are included in the drainage system), a negligible residual transboundary effect is predicted for water quality in Spanish waters.

The reader should refer to Section 7 of Appendix B for more detailed information.

6.8.3 *Operation Phase: Transboundary Effect of an Unspecified Conservative Pollutant*

The transboundary effect of Eastside on water quality in Spanish waters has been assessed for an unspecified conservative pollutant by using the same approach as described in Section 6.4.

Numerical modelling shows that for three days continuous pollutant discharge less than 1% of the initial concentration is expected to reach Spanish waters.

As explained in Section 6.4, no assessment of significance is made for this impact since it is entirely hypothetical. However, it demonstrates that the proposed Eastside development decreases current velocities directly to its south and north which means that pollutants can reside for longer periods of time at these locations at Eastern Beach and Catalan Bay, but not at Spanish beaches.

With the recommended measures in place for Eastside (i.e. petrol/oil interceptors are included in the drainage system), a negligible transboundary effect is predicted for water quality in Spanish waters.

The reader should refer to Section 7 of Appendix B for more detailed information.

6.8.4 *Operation Phase: Transboundary Effect on Bathing Waters*

The transboundary effect of Eastside has been assessed for bathing waters at Spanish beaches by using the same approach as described in Section 6.4.

Numerical modelling predicted that wave conditions and flow conditions would not change significantly in Spanish waters and at Spanish beaches to the extent that there were no hydrodynamic factors that may adversely affect the bathing water quality.

Therefore, no significant transboundary effect is predicted.

No mitigation measures are recommended and there would be no residual transboundary effect.

The reader should refer to Section 8 of Appendix B for more detailed information.

6.9 Uncertainty

The results of the modelling studies are valid given the applied assumptions and conditions. It should be noted, however, that when there is a significant change in these assumptions, the results may change. For example, the results of the sediment plume modelling may change with different dredging methods, different dredging locations and/or different sediment particle size distribution. In cases of relatively small differences (e.g. in the proportion of fine grained particles in the sediment), then linear scaling of the model results is possible. Uncertainty has been addressed by using the best available data to inform the modelling.

6.10 Summary

This chapter has assessed the potential impacts, cumulative effects and transboundary effects of Eastside on water quality.

During construction, the principal impact would be from sediment plumes released and dispersed during dredging resulting in increased suspended solids concentrations in the water column. Generally, TSS concentrations will only be significant (>512mg/l) in and around the northern and southern borrow areas and at the reclamation points at Eastside, and less significant with distance from the dredger. Nevertheless, mitigation has been recommended to minimise unnecessary sediment discharges during dredging.

During operation, water quality impacts associated with discharges of surface and storm water run-off will need to be mitigated using interceptors. Bathing water quality already fails to meet the guideline standards under the EC Bathing Waters Directive. Eastside may increase the risk of failures due to reduced flushing at the beach areas directly abutting the proposed development.