TIDAL LAGOON CARDIFF

Chapter 9.0
Water Quality Processes

9.0 Water Quality Processes

9.1 Overview of existing situation

9.1.0.1 The Severn Estuary is the UK's second largest estuary with a tidal range in excess of 12m. The resultant strong tidal currents fundamentally affect the physical, chemical and biological properties of the Estuary. It is well mixed vertically as a result of the high tidal flows and shallow water depth. In 2009, the Severn Tidal Power – SEA Topic Paper: Marine Water Quality (DECC, 2010) reported that the Estuary receives an average freshwater flow of approximately 25 million m^3 /day of which around 1 million m^3 /day comes from sewage and industrial discharges. The SEA notes that there are a wide range of direct discharges into the Estuary including urban wastewater, industrial and power station discharges and a small number of discharges containing radioactive substances. In addition, there are various diffuse inputs occur, mainly from agriculture, but also to a lesser extent from shipping.

9.1.0.2 The Severn Estuary and Bristol Channel contain a large number of water bodies as defined by the Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, referred to as the Water Framework Directive (WFD) (EU, 2000).

9.1.0.3 The WFD water bodies most likely to be directly impacted by the Project are the coastal and transitional water bodies. There are also many connected water bodies, primarily rivers, that may also be impacted to some extent by the Project and which will need to be considered as part of a full WFD assessment. However, it is anticipated that many of the identified water bodies, in particular the rivers, will be screened out at an early stage of the impact assessment in relation to effects on water quality. A separate WFD screening report will be prepared for the Project (as detailed in Chapter 2 Proposed Approach) and submitted to the appropriate statutory authorities.

9.1.0.4 Appendix 9.1 Water Quality Processes Data Review and Gap Analysis provides further information on the coastal and transitional WFD water bodies in and around the study area. Not all water bodies will be affected by the Project, but the table provides an indication of the extent of transitional and coastal water bodies within the study area. The performance and objectives of each water body are presently under review by Natural Resources Wales (NRW) and the Environment Agency (EA). Table 9.1 presents the current and objective overall status for each water body as defined in 2009.

Table 9.1: Overall WFD water body status – current (2009) and objective

WFD water body type	Name	Approx. distance from Project (km)	Current overall status	Overall objective[1]
Transitional	Severn Upper	60	Moderate	Good Potential by 2027
Transitional	Severn Middle	30	Moderate	Good Potential by 2027
Transitional	Wye	30	Moderate	Good Status by 2027
Transitional	Bristol Avon	20	Good	Good Potential by 2015
Transitional	Usk	0	Moderate	Good Potential by 2027
Transitional	Severn Lower	0	Moderate	Good Potential by 2027
Coastal	Bristol Channel Inner North	5	Good	Good Status by 2015
Coastal	Bristol Channel Inner South	10	Moderate	Good Potential by 2027
Coastal	Bridgwater Bay	15	Moderate	Good Status by 2027
Transitional	Parrett	15	Moderate	Good Status by 2027
Coastal	Bristol Channel Outer North	35	Moderate	Good Status by 2027
Coastal	Bristol Channel Outer South	40	Good	Good Status by 2015
Transitional	Ogmore	50	Good	Good Status by 2015
Coastal	Swansea Bay	55	Bad	Good Potential by 2027
Transitional	Afan	65	Good	Good Potential by 2015
Transitional	Neath	70	Good	Good Potential by 2015
Transitional	Tawe	70	Good	Good Potential by 2015
Transitional	Loughor	110	Moderate	Good Status by 2027
Coastal	Loughor Outer	100	Good	Good Status by 2015
Coastal	Carmarthen Bay	80	Moderate	Good Status by 2027
Transitional	Tywi & Cywyn & Gwendraeth	115	Moderate	Good Status by 2027
Coastal	Pembrokeshire South	135	Good	Good Status by 2015
Transitional	Milford Haven Inner	165	Moderate	Good Status by 2027
Coastal	Milford Haven Outer	150	Moderate	Good Status by 2027
Coastal	Pickleridge Lagoon	160	Moderate	Good Status by 2027
Transitional	Solfach	180	Moderate	Good Status by 2027
Coastal	Barnstaple Bay	90	Good	Good Status by 2015
Coastal	Bideford Bay	95	Moderate	Good Status by 2027
Transitional	Taw / Torridge	100	Moderate	Good Potential by 2027
Coastal	Lundy	115	Good	Good Status by 2015
Coastal	Cornwall North	115	Good	Good Status by 2015

9.1.0.5 Following the revocation of the EU Shellfish Waters Directive (EU, 2006b), Shellfish Water quality is now protected by the WFD. The nearest Shellfish Waters to the

[1] Potential indicates the status for a Heavily Modified Waterbody as defined by the WFD.

Project are Swansea Bay and Burry Inlet on the Welsh coast and Taw/Torridge on the English coast. Locations are shown in Figure 5.2 of Appendix 9.1. The closest Shellfish Water, Swansea Bay, is approximately 50km from the Project.

9.1.0.6 Shellfish Harvesting Areas (or Designated Bivalve Mollusc Production Areas) are found at specifically designated locations within the Shellfish Waters. Classifications (A, B, C or Prohibited) are assigned annually for each harvested species, based on sampling of bacterial concentrations in the shellfish flesh and intravalvular fluid. The nearest harvested beds to the Project are in Swansea Bay. There are three currently monitored beds in Swansea Bay and these have consistently achieved Class B status in recent years. There is currently a single, active several order for mussels within the Bay: The Swansea Bay Mussel Fishery (CV and DM Thomas) Order 2012.

9.1.0.7 A number of designated Bathing Waters are found within the Severn Estuary and Bristol Channel. Locations are shown in Figure 5.2 of Appendix 9.1. Bathing Waters are protected by the revised Bathing Water Directive (rBWD) (EU, 2006a), which came into force in 2015. All bathing waters will be required to achieve at least the rBWD Sufficient class by the end of 2015.

9.1.0.8 Table 9.2 shows predicted Bathing Water performance against the rBWD classification standards. Performance is based on the four years of data 2010-2013, which may not be representative of long-term conditions. Predictions are as provided by NRW (2013) and the EA (2013).

Table 9.2: Predicted rBWD performance for Bathing Waters in the vicinity of the Project

Bathing Water	Predicted rBWD performance based on 2010-2013 sampling data
Minehead Terminus	Excellent
Dunster North West	Good
Blue Anchor West	Good
Burnham Jetty North	Poor
Berrow North of Unity Farm	Good
Brean	Good
Weston-super-Mare Uphill Slipway	Poor
Weston Main	Good
Weston-super-Mare Sand Bay	Good
Clevedon Beach	Good
Jackson's Bay Barry Island	Good
Whitmore Bay Barry Island	Good
Cold Knap Barry	Excellent

9.2 Scope of potential impact to be assessed

Overview of scope of water quality assessment

9.2.0.1 Water quality within the Severn Estuary and Bristol Channel reflects a dynamic balance between upstream inputs to the estuary, downstream flushing of the estuary (primarily by tidal action), and physical / chemical / biological processes occurring within the water column. The most significant inputs to the estuary are runoff from river catchments, wastewater discharges from sewerage catchments, and potentially discharges from private or industrial sources (including power stations). These inputs will form the focus of the marine water quality assessment.

9.2.0.2 The Project may cause a number of impacts, both on water quality processes and on other topic areas that are directly or indirectly affected by water quality. The scope of the water quality assessment has been driven by two main considerations. First, the impacts that could be caused by the Project, both on its own and in combination with other existing or proposed developments (see Chapter 3 Structure of the Environmental Statement). Second, evaluation of the Severn Tidal Power Strategic Environmental Assessment (SEA) topic paper on marine water quality (Parsons Brinckerhoff, 2010). The findings and recommendations of the SEA topic paper have been incorporated into the proposed water quality assessment scope.

9.2.0.3 The water quality assessment aims to provide the evidence needed to address the following objectives, which are taken from the SEA topic paper on marine water quality:

i. to avoid adverse effects on water quality in relation to water quality standards (as defined in the WFD, rBWD etc.);

ii. to avoid adverse effects on designated marine wildlife sites of international and national importance due to changes in water quality;

iii. to avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users;

iv. to avoid adverse effects on inherent water characteristics (temperature, salinity, pH) that could lead to adverse changes in water quality; and

v. to minimise risks of pollution incidents.

Potential impacts of the Project

9.2.0.4 The following points summarise the primary mechanisms by which the Project could affect the water quality environment and associated topics. These points will all be addressed by the water quality assessment. Impacts will be assessed both within the lagoon and through the wider estuarine environment.

i. Changes to the hydrodynamic regime (current flows and water levels) may affect the initial dilution, advection and dispersion of discharged pollutants. This may affect the concentration of pollutants and other water quality determinands in both space and time.

ii. Changes to the flushing time of the estuary may similarly affect water quality. This can occur both by altering the physical mixing of estuarine waters, and by altering the residence time of estuarine water with knock-on effects on water quality processes such as nutrient and oxygen cycles.

iii. Changes to estuarine salinity and temperature, and in particular the potential for stratification, could affect water column processes such as biological growth and oxygen or nutrient cycling.

iv. Changes to sediment movement and suspended sediment concentrations may impact on water quality processes – for example, the uptake of oxygen due to Chemical Oxygen Demand.

v. Changes to sediment movement and suspended sediment concentrations may directly affect the distribution and impact of contaminants associated with these sediments, such as metals.

vi. Changes to turbidity may affect light penetration through the water column. This could in turn affect growth rates for chlorophyll, phytoplankton and algae, and die-off rates for faecal bacteria and other pathogens.

vii. Complex water quality interactions will be considered. For example, changes to estuarine salinity, temperature or pH can affect rates of chemical interactions and biological processes.

viii. Changes to water quality and sediment processes may affect the growth of organisms such as macroalgae and reed beds, which could in turn further affect both water quality and hydrodynamics.

Spatial scales of impact

9.2.0.5 For the purposes of the water quality assessment, the study region has been divided into three areas.

9.2.0.6 **The Near Field (Zone 1)**: this is the area immediately adjacent to the Project which is directly hydraulically impacted and where pollutant sources can cause receiving water concentrations to vary significantly in the short- to medium-terms and seasonally. These sources include river and point sources adjacent to the Project.

9.2.0.7 **The Mid Field (Zone 2)**: this is the area close to the Project, which would not be expected to be significantly influenced by the hydraulic effects of the Project and from which pollutant discharges would lead to low or moderate variations in receiving water concentration in the short- to medium-terms and seasonally.

9.2.0.8 **The Far Field (Zone 3)**: this is the larger area of the Bristol Channel and Severn Estuary which is unlikely to be affected by the Project in terms of hydraulics and pollutant concentrations but where pollutants from sources can determine regional background levels.

9.2.0.9 The primary aim of defining these zones is to differentiate between the treatment of pollutants from these areas and the different data requirements for each. Further detail on the proposed water quality zoning is provided in Appendix A of Appendix 9.1.

Assessment scenarios

9.2.0.10 The water quality assessment will cover all scenarios that are required in support of the EIA:

i. **Baseline.** Conditions prior to the Project, against which the effects of the Project can be compared in order to establish the magnitude and significance of impacts;

ii. **Construction.** Impacts during the construction phase of the Project which would be phased over a number of years;

iii. **Operation and maintenance.** Impacts due to the Project throughout its anticipated life (120 years);

iv. **Operation and maintenance – cumulative.** Life-cycle impacts due to the cumulative effect of the Project and other cumulative developments (See Chapter 3);

v. **Mitigation.** Any decrease in the predicted impacts of the above scenarios resulting from mitigation measures;

vi. **Decommissioning.** Impacts due to any decommissioning scenarios proposed for the lagoon at the end of its life (120 years) (see Chapter 6); and

vii. **Climate change.** Any modifications to impacts over the life of the Project due to the effects of changing climate.

Legislative requirements

9.2.0.11 In line with the recommendations of the SEA topic paper on marine water quality, the principal legislative drivers for the Project are:

i. the WFD;

ii. the rBWD; and

iii. food hygiene regulations, principally EU Regulation 854/2004 for Products of Animal Origin and the corresponding Welsh and English Regulations.

9.2.0.12 The water quality considerations of these legislative drivers will be considered as part of the assessment.

Interfaces with other topic areas

9.2.0.13 The water quality assessment will be progressed in close conjunction with the coastal processes assessment (see Chapter 8 Coastal Processes, Sediment Transport and Contamination). The methods of assessment (e.g. modelling tools) and the required outputs (e.g. an understanding of the salinity, temperature and sediment regimes) are closely linked. Details of the proposed collaborative working approach will be detailed in a Modelling Work Plan. Further details of the Modelling Work Plan are provided in Chapter 2 Proposed Approach and Chapter 8.

9.2.0.14 The SEA topic paper on water quality identified specifically the uncertainty associated with calculations of suspended sediment concentration, and the knock-on effects on water quality processes. This area will be a primary focus when assessing links between water quality and coastal processes.

9.2.0.15 Water quality impacts may cause impacts on habitats in and around the Estuary. As such, water quality processes will be linked with a range of other topic areas including marine and freshwater fish, benthic ecology, marine mammals and birds.

9.2.0.16 Impacts on Bathing Waters may lead to direct human health impacts and associated social impacts. Impacts on Shellfish Waters could cause economic impacts. These links will be addressed within the wider assessment.

9.2.0.17 The water quality assessment will inform the overall WFD compliance assessment and the Habitats Regulations Assessment.

9.3 Existing baseline data, consultation and need for survey

9.3.0.1 Appendix 9.1 presents location and volume of existing data sources and data gaps. The following presents an overview of the key findings of the data review and gap analysis.

Existing data sources

9.3.0.2 The key providers of data in support of the water quality assessment are NRW, the EA, and the local water companies (Dŵr Cymru Welsh Water (DCWW) and Wessex Water). Supporting information will come from a variety of other sources including Cardiff Bay Harbour Authority, the British Oceanographic Data Centre, the UK Meteorological Office, the University of Wales, prior studies including the Severn Tidal Power SEA, and the scientific literature.

Hydrodynamic and sediment data

9.3.0.3 These are required for the water quality assessment, but will be primarily procured as part of the coastal processes assessment (see Chapter 8).

Rainfall and meteorological data

9.3.0.4 Rainfall data are required to help characterise discharge flows from river and sewerage catchments. Wind data are required because of the effect that wind can have on discharge plumes and mixing. Suitable data for the water quality assessment are available from existing sources.

River discharge flows

9.3.0.5 Flow data are required in order to help define pollutant discharge loads to the estuary. Historic monitoring data for large rivers are available from NRW and the EA. Smaller, ungauged rivers may be suitably represented using catchment modelling techniques, using the revitalised Flood Studies Report/Flood Estimation Handbook rainfall-runoff method. Suitable data exist for the water quality assessment and no further monitoring is proposed.

River water quality – chemistry and nutrients

9.3.0.6 River water quality data are required in order to help define pollutant discharge loads to the estuary. Data are available primarily from NRW and the EA. The available data represent a combination of routine monitoring and historic ad hoc sampling. Where data are insufficient, suitable values may be obtained using analytical techniques (either catchment modelling approaches or representative default values, depending on the location and significance of the river). Additional, targeted river sampling may be undertaken in support of the Project. If required, sampling will be focused on the potentially more significant discharges (based on large flow or proximity to the lagoon).

River water quality – bacteria

9.3.0.7 River water quality data are required in order to help define pollutant discharge loads to the estuary. Data are available primarily from NRW and the EA, supported by limited historic water company monitoring. Catchment modelling approaches may be used to estimate bacteria discharge loads for some catchments. However, the available data are somewhat limited in terms of geographical coverage and time span. Screening runs will be undertaken to determine the likely effects of the Project and the need for any further sampling which would be focused on the potentially more significant discharges (based on large flow or proximity to the lagoon).

Wastewater (sewage) discharge flows

9.3.0.8 Wastewater flows are required in order to determine pollutant loads from point sources of contamination. Flow data are available from a combination of water company sewerage network models and consented maximum flows. It is considered that sufficient information exists for the purposes of the water quality assessment and additional surveys are not required. However, information on industrial discharges may be difficult to obtain.

Wastewater (sewage) quality

9.3.0.9 Wastewater concentrations are required in order to determine pollutant loads from point sources of contamination. Water company discharges can be characterised through a combination of historic measurements, consented maximum values, and defaults derived from regional or national databases of measurements. Less information may be available for industrial discharges. A targeted programme of sampling may be required for selected key discharges if suitable concentration data cannot be identified or estimated.

Marine water quality – chemistry and nutrients

9.3.0.10 Marine water quality data are required to: establish baseline conditions; specify initial background concentrations and offshore boundary conditions for the marine water quality model; and calibrate and validate the water quality model. Data are available from: routine sampling by NRW and the EA; data collection undertaken in support of the Severn Tidal Power SEA and associated studies; and historic *ad hoc* monitoring. A large number of data are available covering a range of locations, points in time and water quality determinands. However, additional monitoring may be carried out in order to help define baseline conditions for the Project assessment and the cumulative impacts assessment. This monitoring will also help to define seasonal cycles of key determinands such as nutrients, algae, chlorophyll and phytoplankton.

Marine water quality – bacteria

9.3.0.11 Bacterial concentration data are required primarily to assess impacts at designated Bathing Waters and Shellfish Waters. Long-term monitoring data (by NRW and the EA) exist for all Bathing Waters, and also for Shellfish Waters though at a lower frequency. These existing data sets are sufficient to define historic performance at Bathing Waters, and at Shellfish Waters with wider margins of uncertainty. Screening runs will be undertaken to determine the likely effects of the Project and the need to carry out any additional bacterial sampling.

Determining river water sampling requirements

9.3.0.12 In order to determine the requirements for river water sampling, it is proposed to undertake screening runs using the existing (DCWW) Cardiff model. The model will be set up to run a baseline (no lagoon) and with the lagoon impoundment in place. The model will be run using data for the impounded area and discharge characteristics through the sluice gates and turbines. Rivers discharging to the study area will be modelled using a conservative tracer and the behaviour of this tracer will be tracked. Model runs will be undertaken for spring and neap tides. It is proposed to undertake the modelling for the prevailing wind direction and no wind scenarios only. If the presence of the lagoon impacts - for better or worse - the river discharge plume then it will be characterised to the appropriate degree (far, mid or near field). Using this information, existing water quality data for that river will be evaluated and the need for additional sampling and the determinands

required will be identified (e.g. nutrients, chemistry, or bacteria depending on sensitive receivers).

Survey requirements

9.3.0.13 Section 4 of Appendix 9.1 presents an outline survey scope in support of the water quality assessment. The key elements of the proposed survey scope are provided below.

9.3.0.14 Marine water quality surveys will be carried out to coincide (as far as is possible) with the oceanographic surveys that are progressing in 2015. Proposed locations for the marine water quality surveys are shown in Figure 3.19 of Appendix 9.1 (these may be subject to change due to local site conditions). These locations are considered sufficient to provide a baseline around the key areas of interest. Requirements for the marine water quality surveys are as follows:

i. A suite of water quality data will be obtained at the identified sample sites (1 to 8 as shown on Figure 3.19 of Appendix 9.1).

ii. Water samples will be collected at hourly intervals at multiple depths (near-surface, mid-depth and near-bed) for sites 1, 2, 4, 6 and 8. These will be analysed for salinity, temperature, Dissolved Available Inorganic Phosphorus, Dissolved Available Inorganic Nitrogen (as ammonia, nitrite and nitrate), Biochemical Oxygen Demand, Dissolved Oxygen, suspended solids, turbidity, chlorophyll a, and bacterial concentrations (*Escherichia coli* and intestinal enterococci). Secchi depth will also be measured at each site. A set of samples will also be taken to provide chlorophyll concentrations.

iii. For the remaining sites (3, 5 and 7), surface water quality samples will be collected at hourly intervals and analysed for salinity, temperature, Dissolved Available Inorganic Phosphorus, Dissolved Available Inorganic Nitrogen (as ammonia, nitrite and nitrate), Biochemical Oxygen Demand, Dissolved Oxygen, suspended solids, turbidity, chlorophyll, algal mass, and bacterial concentrations (Escherichia coli and intestinal enterococci). Secchi depth will also be measured at each site.

iv. A second sample replicate will be filtered, frozen and stored. This sample could then be used for later analysis of conservative determinands such as heavy metals if required.

v. Surveys will be undertaken both in winter (December to February) and in spring/summer (from March onwards). This will provide information on seasonal growth patterns.

9.3.0.15 Where appropriate and feasible, surveys will be conducted in key rivers identified by the screening runs detailed above. The need for river sampling will be based on the following rationale. River data for the key rivers identified by the screening runs and included in the Appendix 9.1, will be analysed. The analysis will focus on

whether the data provide a distribution suitable for use in WFD analysis. This would be done, for example, by correlating river flows with the samples taken. If existing data provide a sufficient distribution there will not be a need for river sampling. If river sampling is required then possible surveys are listed below:

i. Sampling will be undertaken as far downstream as is possible, but above the tidal limit. The exception is if there are practical reasons for sampling further upstream. For example, where access is limited or may compromise health and safety, or where it may be preferable to sample upstream of a large Wastewater Treatment Works so that the effects of the Works and the diffuse river load can be separated out. This will provide upstream boundary conditions to the modelling. Downstream of the tidal limit sources will be included explicitly within the model.

ii. The sampling requirements will depend on the quality of the distribution available for each determinand from existing data. If existing dry weather data are inadequate then sampling could be undertaken at three hourly intervals to provide a representative concentration. If existing data lack extreme events then the distribution may not be adequate. In this case, sampling should focus on a wet weather event. A weather forecast should be used to predict rainfall and sampling should commence prior to rainfall and for the duration of the event. These data will enhance the distribution for the river through the inclusion of extreme values. Alternatively, extreme events could be modelled but validation data for the modelling may be lacking in the absence of sampled wet weather events.

iii. If required, sampling should be undertaken under a number of different flow conditions, such as two dry weather periods and two wet.

iv. Surveys will be undertaken both in winter (December to February) and in spring/summer (from March onwards), to capture the seasonality in some determinands (e.g. nutrients). This seasonality reflects both temporal patterns of pollutant inputs to the river catchment (such as agricultural use of phosphates) and the dependence of various water quality processes on temperature.

v. The required determinands are likely to vary from river to river in accordance with the quality of data captured in Appendix 9.1 and the location of the river. For example, bacterial analysis is only relevant if it has potential to impact bacterially sensitive sites (e.g. bathing waters). The requirement will be specified following the screening assessment and further interrogation of the water quality data. However, samples required could include temperature, Dissolved Available Inorganic Phosphorus, Dissolved Available Inorganic Nitrogen (as ammonia, nitrite and nitrate), Biochemical Oxygen Demand, Dissolved Oxygen, suspended solids, and bacterial concentrations (*Escherichia coli* and intestinal enterococci).

vi. A second sample replicate will be filtered, frozen and stored. This sample could then be used for later analysis of conservative determinands such as heavy metals if required.

9.3.0.16 It is possible, although not probable, that there will be a need for targeted sampling of discharge concentrations from point sources (such as Wastewater Treatment Works or industrial discharges). This sampling will only be required in the event that the load from a potentially significant discharge cannot be calculated or estimated within reasonable bounds of accuracy (even when introducing a level of conservatism). The proposed survey requirements would be as follows:

i. Sampling will be undertaken as close to the outfall as possible.

ii. Sampling will be hourly for a period of 12 hours.

iii. Surveys will be undertaken under a number of different flow conditions, ideally two dry weather periods and two wet.

iv. Sampling will concentrate on those water quality determinands considered to be of most significance to the water quality assessment. The most likely requirement is for measurements of bacterial concentration, nutrients or Biochemical Oxygen Demand / Dissolved Oxygen.

v. If feasible, sampling will be taken to coincide with the marine and/or river water quality surveys outlined above.

Consultation

9.3.0.17 The primary stakeholders that will be consulted with regard specifically to water quality processes are NRW and the EA.

9.3.0.18 Additional stakeholders will be consulted on specific issues. These will include Natural England and the Marine Management Organisation.

9.4 Proposed assessment methodology

Background and approach

9.4.0.1 The proposed water quality assessment process aligns as far as possible with previous studies undertaken for similar projects in the region, most notably the Severn Tidal Power SEA and the Tidal Lagoon Swansea Bay EIA (TLSB, 2014).

9.4.0.2 The water quality assessment will follow best practice procedures for model development and calibration, impact assessment etc. It is designed to address the potential water quality impacts identified above.

9.4.0.3 The assessment will be undertaken in consultation with the key regulatory bodies including NRW, the EA, Natural England, the Marine Management Organisation, and Cefas.

Baseline

9.4.0.4 The first stage of the water quality assessment will be to establish baseline environmental conditions. The predicted effects of the Project will be compared to this baseline in order to quantify the level of impact and to inform the need for mitigation measures.

9.4.0.5 The baseline will expand on the data review and gap analysis presented in Appendix 9.1. It will draw on the best existing data sources and studies. These will be supplemented by targeted field surveys as outlined in Section 9.3.

Overview of approach

9.4.0.6 The water quality modelling assessment will adopt the following general approach:

i. development of modelling tools;

ii. screening assessments to define the model domain and areas of interest, plus the key pollutant sources and water quality processes; and

iii. a detailed assessment investigating changes to the baseline environment resulting from the Project, and considering the Project in isolation plus the cumulative impacts of other projects, and any relevant mitigation or compensation measures (such as managed retreat).

Model selection and development

9.4.0.7 A Modelling Work Plan (see Chapter 2 Proposed Approach and Chapter 8) is being developed to aid integration of the various study topics that will use the coastal numerical model. These include the coastal processes assessment (see Chapter 8) and the flood risk assessment (see Chapter 10 Flooding and Hydrology). The Modelling Work Plan will describe the various technical needs of these different topic areas, and explains how these needs will be managed to ensure efficient Project delivery and consistent outputs.

9.4.0.8 The water quality assessment will use the same underlying model as the coastal processes assessment. There are some requirements specific to the water quality assessment that will be addressed during the model development:

i. The model will need to extend up to the tidal limits of rivers.

ii. The model must be optimised for water quality runs. These runs may need to cover long timescales of a year or more, for instance to assess nutrients and algae/phytoplankton such that seasonal cycles are well-represented and a dynamic equilibrium is reached. To achieve this in realistic Project timescales, it may be necessary to reposition the model offshore boundary and reduce the mesh resolution (neither of which will deleteriously impact the quality of the water quality model predictions).

iii. A separate coarse water quality model may be required in order to generate boundary and initial conditions for the high resolution Bristol Channel/Severn Estuary model.

iv. A basic model of the Project may be required in order to investigate water quality effects within the lagoon. Issues of interest include: flushing times; retention of pollutants and pollutant decay; potential for 3D stratification; and potential for eutrophication and hypernutrification. Using a simple lagoon model for screening will help to determine the requirements of the detailed assessment, for example in terms of 3D processes.

9.4.0.9 In addition to the coastal/estuarine water quality modelling, models of some of the river catchments draining to the Severn Estuary and Bristol Channel will be constructed. Such models will comprise: a hydrological component in order to accurately represent time-varying flows; and a water quality component in order to determine pollutant loads for key determinands such as nutrients and bacteria. Detailed catchment models will only be required for larger rivers (with larger pollutant loads), for rivers discharging close to the Project area, and/or for rivers that cannot be suitably characterised using measured data.

9.4.0.10 In all cases, the modelling approach will adopt industry best practice and take due account of model accuracy, assumptions and uncertainty.

Model validation

9.4.0.11 The water quality model will be validated against the following parameters:

i. **Dispersion coefficients.** This will be undertaken using salinity data as part of the coastal processes assessment.

ii. **Water quality determinands.** These will include key determinands such as nitrogen, phosphorus and Dissolved Oxygen. The model will include appropriate depictions of oxygen processes such as Biochemical Oxygen Demand, sediment oxygen processes and ammonia decay. Interfaces with the coastal processes assessment will be established in order to address sediment issues such as the presence of fluid muds and the effect of these on Dissolved Oxygen, for instance.

iii. **Long-term water quality processes.** This will assess the model's ability to predict seasonal cycles of Dissolved Available Inorganic Nitrogen (DAIN), Dissolved Available Inorganic Phosphorus (DAIP), algae and water temperature. Validation will be undertaken using available existing long-term monitoring data for summer and winter. The proposed approach is to initially model winter conditions for DAIN and DAIP (which are effectively conservative), which will confirm that model loads and dispersion are accurately represented. Algal/phytoplankton processes will then be built in to ensure that these are represented correctly over the annual cycle. It will be

necessary to run the model for at least a year and possibly longer in order to reach dynamic equilibrium.

Water quality determinands

9.4.0.12 The water quality model will cover a wide range of determinands based on the WFD quality elements and other legislative drivers, including:

i. flushing;

ii. Dissolved Oxygen;

iii. Dissolved Available Inorganic Nitrogen;

iv. Dissolved Available Inorganic Phosphorus;

v. metals;

vi. organics;

vii. salinity;

viii. temperature;

ix. pH; and

x. phytoplankton.

Model parameters and inputs (discharge scenarios)

9.4.0.13 Suitable model setup parameters will be adopted to address such issues as:

i. dispersion coefficients, bed roughness and eddy viscosity (these will all be determined during the model calibration and validation process);

ii. offshore boundary conditions (e.g. background levels for salinity and nutrients);

iii. rates and constants for water quality interactions;

iv. bacteria decay rates; and

v. tide and wind conditions.

9.4.0.14 Discharge sources (pollutant loads) will be rationalised as far as possible, since there are potentially a great many of these. Focus will therefore be placed on the most critical discharge sources – those with large pollutant loads and/or a discharge in close proximity to the Project (i.e. near-field and potentially mid-field). Less critical discharges (smaller and/or more distant, i.e. far-field) may be agglomerated or modelled in a simplified fashion.

9.4.0.15 Appendix 9.1 discusses the data sources that will be used for discharge identification and characterisation. The following discharges will be considered in the water quality assessment:

i. rivers;

ii. water company Wastewater Treatment Works;

iii. water company Combined Sewer Overflows;

iv. private wastewater sources; and

v. trade/industrial discharges.

Screening for the Water Quality Assessment

9.4.0.16 Screening runs to identify key rivers will be undertaken using the DCWW existing model (see above). In addition, screening will be undertaken to define the water quality model required for the full water quality assessment of the lagoons. Initial model screening runs will be used to:

i. refine the study area for the water quality processes assessment;

ii. define the detailed water quality modelling needs, in terms of model domain, resolution, setup (e.g. 2D or 3D), and interactions with the other modelling studies (coastal processes and flooding);

iii. prioritise the various identified pollutant discharges in terms of their potential significance to the study (e.g. high significance; moderate significance; low or negligible significance); and

iv. assign an indicative ranking to the identified sensitive receivers in terms of their potential impact by the Project (e.g. high impact; moderate impact; low or negligible impact).

9.4.0.17 The screening runs will model the movement of tracers discharged into the model at suitable locations representative of pollutant discharges. These tracers will either be modelled conservatively or with simple water quality processes such as exponential decay. The extent of the area impacted by the tracers will be used to help inform the required extent of the water quality assessment. Differences between baseline (present situation) and post-installation impacts will be considered; where these are low or negligible a detailed water quality assessment may not be required.

9.4.0.18 Model tracer releases will also be used to test the flushing behaviour of the proposed lagoon, and thus the potential residency time of pollutants released into the lagoon.

9.4.0.19 Screening model runs will tend to adopt conservative setup and input parameters. This means that any pollutant discharges or sensitive receivers that are screened out are very unlikely to affect or be affected by the Project.

Optimisation assessment

9.4.0.20 In parallel with the screening assessment, optimisation runs would be undertaken in conjunction with the Project engineers in order to assist in the definition of the lagoon based on known engineering or operational constraints.

9.4.0.21 For example, it could be considered that the flushing behaviour of the lagoon may lead to water quality issues. Flushing may be quite high close to the turbines but, compared to the existing situation, may be much reduced towards the shoreward side of the lagoon. This could in theory lead to a build-up of pollutants and associated water quality issues such as hypernutrification and eutrophication.

9.4.0.22 Optimisation runs would consider design options aimed at reducing these potential issues. Possible options might include the careful placement of turbines or sluice gates to maximise flows and flushing, or the introduction of additional sluice gates to achieve the same effect. In the case of the latter, the optimisation process would consider both the location of the sluices and their operational regime (i.e. at what states of the tide they would be opened, and how frequently) and the potential use of pumping.

9.4.0.23 It is likely that an optimisation process would go through a number of design iterations in order to achieve the best design while taking account of other Project constraints (see Chapter 5 Background to the Project and Site Selection and Chapter 6 Project Description).

Detailed assessment

9.4.0.24 The extent and nature of the detailed modelling assessment will be determined in part by the results of the screening assessment. The following points summarise the anticipated detailed assessment:

i. A full suite of water quality determinands will be modelled, unless these have been screened out at the screening stage. The determinands to be assessed will be based on the requirements of the relevant environmental legislation (primarily the WFD and rBWD).

ii. Detailed water quality processes and interactions will be modelled. In particular, these will cover the nitrogen, phosphorus, oxygen and algae/phytoplankton cycles. Suitable rates and constants for these processes will be defined and justified. The water quality assessment will, where appropriate, be integrated fully with the other modelling studies – for example, the influence of sediments (coastal processes study) on oxygen uptake.

iii. For WFD determinands such as nutrients and phytoplankton, the water quality model will be run for a full year to look at seasonal variation, and possibly for an additional year to check if dynamic equilibrium has been reached. The model production runs will be started in winter when water quality processes are at a minimum. Additionally, a further model run year may be required to establish the initial conditions, although it may possible to do these runs in a coarser (i.e. quicker) model grid and then pass the results to the fine model grid for the detailed assessment. These models scenarios will be run with no wind forcing, since wind effects tend to average out over the long term.

iv. For bacterial determinands, as used in the assessment of Bathing and Shellfish Waters, the water quality model will be run for a typical spring-neap tidal cycle. Seven wind scenarios will be considered – calm winds, plus mean winds from six direction sectors.

v. Potential Project impacts will be assessed by comparing the various assessment scenarios against the established baseline. Any change in water quality will be quantified in terms of magnitude, duration and potential effect on waterbody classification.

vi. Predicted impacts at receptors will be assessed over a suitable time period. This will be a full year for determinands that display seasonal cycles, and a typical spring-neap cycle for other determinands. For example, conservative pollutants such as metals, and pollutants that decay rapidly such as bacteria, will be assessed over a spring-neap cycle.

vii. Impact concentrations will be expressed as values that allow comparison against the various environmental standards of the WFD and rBWD (e.g. mean, 95-percentile or maximum values).

viii. The assessment scenarios will include a scenario that considers the Project in isolation, and a cumulative impacts scenario that considers the Project plus other existing or proposed developments in the study area.

Climate change scenarios

9.4.0.25 Climate change effects will be potentially important over the lifetime of the Project (120 years). The following points refer to the assessment of water quality under climate change scenarios:

i. There are no clear current guidelines relating to the assessment of water quality and pollutant discharges in conjunction with climate change.

ii. Impacts on water quality due to changes in estuarine hydrodynamics and dispersion following sea level rise can be modelled. Predicted future climate will be taken from UK Climate Projections (Defra, 2009). Water quality scenarios will be based on the coastal processes climate change scenarios,

since these will identify the timescales over which significant changes are likely to occur.

iii. Predicted changes in river flow due to changing rainfall patterns (higher rainfall) can also be assessed. Calculations can be made about how pollutant loads in rivers will rise as river flows increase, but these will be based on extrapolations from the present day rather than a detailed analysis of future catchment behaviour.

iv. The largest uncertainties relate to changes in sewerage networks in response to climate change. Climate change effects are not normally considered for sewerage schemes, as these are developed on a five year cycle and should, in theory, attempt to keep up with changes in rainfall, i.e. discharge volumes should remain the same or reduce. As it is unlikely that any water companies will look this far ahead in detail, the assessment will use best judgement, possibly supported by discussion with water companies regarding their long term strategies.

v. Any assessment of future loads will also accommodate population growth and how this might affect wastewater discharges. Future population is difficult to predict over more than 20 years.

9.4.0.26 In summary, climate change effects on the physical environment can be modelled, but predicting future loads is very difficult, especially as policy and legislation may tighten to accommodate climate change and other concerns.

9.4.0.27 The proposed approach is to model changes to hydrodynamics and river run-off resulting from projected climate change, but to assume that wastewater discharge loads will keep pace with these changes and remain relatively constant. It is proposed to discuss the approach for addressing climate change with NRW and the EA in order to ensure that Project expectations are met and that a suitable approach is agreed.

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Appendix 9.1

Water Quality Processes Data Review and Gap Analysis

TIDAL LAGOON POWER PLC

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

WATER QUALITY PROCESSES

Report Reference. P1914A_R3640_Rev3

Issued 23 February 2015

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0	17/10/2014	Working draft for review	KRM	NWB	NWB
1	26/01/2015	Final report incorporating data updates	KRM	CPM	CPM
2	18/02/2015	Updates to incorporate client comments	CPM	ESL	CPM
3	24/02/2015	Updates to incorporate client comments	CPM	ESL	CPM

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SUMMARY

Tidal Lagoon Power plc (TLP) is developing Project options in the Severn Estuary. The first Project to be developed is located between Cardiff and Newport, known as the Cardiff tidal lagoon. TLP has commissioned Intertek Energy & Water Consultancy Services (Intertek) to undertake a data review, data gap analysis and high level review of water quality processes in the Severn Estuary and inner Bristol Channel. The study will form the basis for survey specifications, discussions with regulators and stakeholders, and scoping of a water quality study for the Environmental Impact Assessment (EIA), initially for the Cardiff lagoon ('the Project').

The primary water quality drivers are those associated with identified sensitive waters, which include: Water Framework Directive (WFD) waterbodies; Bathing Waters; and Shellfish Waters.

Parallel studies are considering sediments/coastal processes and flooding issues.

Extensive water quality monitoring data sets have been obtained from Natural Resources Wales (NRW), the Environment Agency (EA), and other providers. Further data sets are likely to be obtained as the Project progresses.

The primary water quality data requirements are:

- to establish flows and concentrations for discharges entering the marine/estuarine environment;
- to define boundary conditions for the water quality model;
- to establish a baseline against which the potential effects of the Project can be assessed; and
- to determine rates and constants for water quality processes, and to identify seasonal cycles and interactions with (for example) sediments.

Many of the Project's water quality needs are adequately covered by existing data sources. However, the data gap analysis has identified several key areas where the Project would benefit from supplementing existing data with targeted field surveys. These areas are:

- Marine water quality (chemical and nutrient determinands). These data would help to establish baseline conditions and seasonal cycles. An indicative survey specification has been produced, which is designed to fit in with other planned survey activities.

Surveys will need to capture the seasonal cycle, and should therefore include measurement in both winter (no later than February) and spring/summer (when growth is occurring).

- River water quality (chemical, nutrient and bacterial determinands). These data will help to confirm discharge loads to the marine/estuarine environment. The focus should be on major rivers and rivers close to Project locations. Water chemistry and nutrients should ideally be sampled in both winter and spring/summer at least, for the reason given above.
- Wastewater quality (chemical and nutrient determinands). There is a possibility that surveys will be required in order to supplement existing data, but a detailed baseline assessment may indicate that suitable information already exists.
- Marine water quality (bacterial concentrations). There is a possible requirement for these surveys but they are presently considered unlikely. There may be value in obtaining samples anyway, in conjunction with the marine water chemistry/nutrient surveys outlined above.

There are still a number of unknowns in terms of the extent and quality of available data, the key water quality processes that will need to be considered, and the sensitive waters likely to be impacted by the Project. These unknowns will be reduced as the Project progresses. In particular, it is anticipated that screening model runs will be undertaken in order to establish potential water quality impacts due to the Project. This will allow the detailed modelling assessment to be targeted on the most relevant discharges, receiving waters and physical processes.

The high level review has considered: the historic performance of sensitive waters; key pollutant discharges to the marine/estuarine environment; and preliminary estimates of the effects of the lagoon(s) on hydrodynamics (current flows and water levels). This review has allowed an assessment to be conducted into the potential key impacts due to the Project.

Impacts are likely to be significant within the lagoons themselves and in the local WFD waterbodies. There is considered to be less potential for impact at Bathing and Shellfish Waters, which are more distant from the Project.

Refinement of the high level review will be possible once results from the water quality screening model runs are available.

CONTENTS

TABLES

FIGURES

LIST OF ABBREVIATIONS

AAR	Average Annual Rainfall
ABPmer	ABP Marine Environmental Research Ltd
ADCP	Acoustic Doppler Current Profiler
BADC	British Atmospheric Data Centre
BOD	Biochemical Oxygen Demand
BODC	British Oceanographic Data Centre
cBWD	current Bathing Water Directive
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CEH	Centre for Ecology and Hydrology
COD	Chemical Oxygen Demand
CREH	Centre for Research into Environment and Health
CSEMP	Clean Seas Environment Monitoring Programme
CSO	Combined Sewer Overflow
DCWW	Dŵr Cymru Welsh Water
DAIN	Dissolved Available Inorganic Nitrogen
DAIP	Dissolved Available Inorganic Phosphorus
DO	Dissolved Oxygen
EA	Environment Agency
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
FE	Final Effluent
FEH	Flood Estimation Handbook
FIO	Faecal Indicator Organism
FSR	Flood Studies Report
GQA	General Quality Assessment
ICES	International Council for the Exploration of the Sea
IDB	Internal Drainage Board
Intertek	Intertek Energy & Water Consultancy Services
LSO	Long Sea Outfall
MERMAN	Marine Environment Monitoring and Assessment National database

MIDAS	Met Office Integrated Data Archive System
NERC	Natural Environment Research Council
NMMP	National Marine Monitoring Programme
NRFA	National River Flow Archive
NRW	Natural Resources Wales
OS	Ordnance Survey
OSPAR	Oslo and Paris Convention
RBMP	River Basin Management Plan
rBWD	revised Bathing Water Directive
SAC	Special Area of Conservation
SOD	Sediment Oxygen Demand
SPA	Special Protection Area
TBT	Tributyltin
TCC	Total Cell Count
TLP	Tidal Lagoon Power plc
UKMO	UK Meteorological Office
UV	Ultra-violet
WFD	Water Framework Directive
WIMS	Water Information Management System
WwTW	Wastewater Treatment Works

1 INTRODUCTION

1.1 BACKGROUND

Tidal Lagoon Power plc (TLP) has commissioned Intertek Energy & Water Consultancy Services (Intertek) to undertake a data review, data gap analysis and high level review of water quality processes in the Severn Estuary and inner Bristol Channel.

The study is in support of water quality impact assessments for potential lagoon locations in the Severn Estuary. The focus at present is on the Cardiff lagoon at Peterstone Flats, but cumulative effects from other potential lagoon sites will also need to be considered. The study area for the data gap analysis is shown in Figure 1-1.

The data review, gap analysis and high level review will form a basis for survey specifications, discussions with regulators and stakeholders, and scoping of a water quality study for the Environmental Impact Assessment (EIA).

1.2 SCOPE OF WORK

Intertek will focus on the water quality elements of the study. This work will complement parallel studies into: hydrodynamic and sediment processes, undertaken by ABP Marine Environmental Research Ltd (ABPmer); and flooding, undertaken by Atkins. ABPmer has produced a separate High Level Review and Data Gap Analysis1 focusing in particular on hydrodynamic and sediment processes.

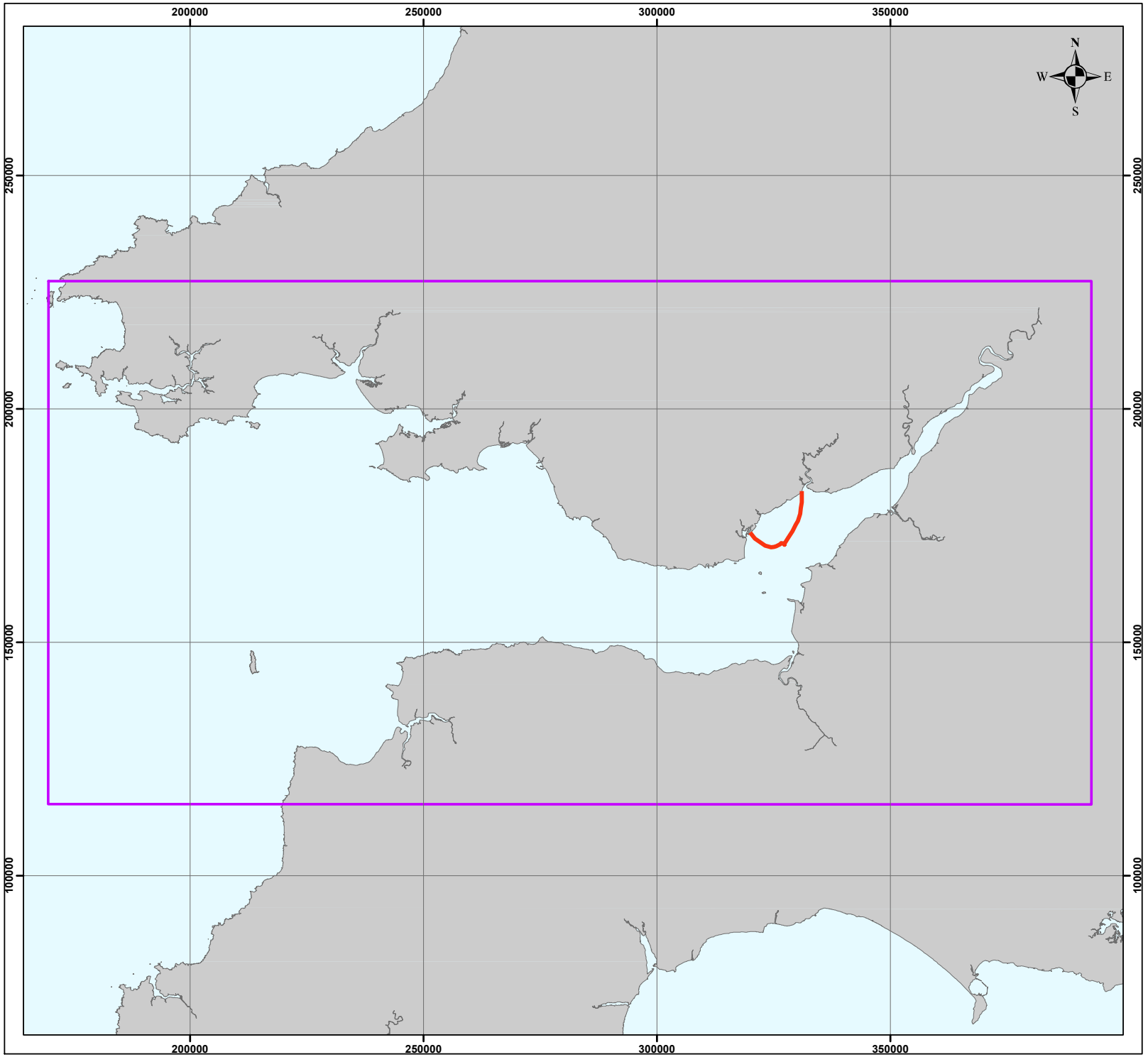
The water quality study will consider all processes and impacts that may be of relevance to water quality designations close to the Project and in the wider environment (Bristol Channel and Severn Estuary). In particular, a Water Framework Directive (WFD) assessment will ultimately be required. The WFD assessment will consider both coastal and transitional WFD waterbodies.

The present study is broken down into the following areas:

- **Data Review** – a review of available data sources.
- **Data Gap Analysis** – identifying gaps in the existing baseline data sources, and recommending whether these can be filled through targeted field surveys or alternative means (e.g. use of conservative assumptions plus sensitivity testing).
- **Surveys** – high level specification for any surveys and sampling that may be required.
- **High Level Review** – a review identifying significant discharges, potential impacts, water quality designations and key sensitivities, which in turn gives an indication of where the primary focus for the main study should be directed.

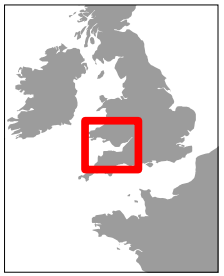
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 1-1: Study Area



Legend

- Cardiff Lagoon
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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2 WATER QUALITY ASSESSMENT – CONSIDERATIONS

2.1 WATER QUALITY DATA REQUIREMENTS

Water quality impacts, and potential mitigation measures, will be assessed using a coastal numerical model. This will have the ability to simulate hydrodynamics (water levels, current flows and dispersion), water quality processes (from simple decay to complex water chemistry processes) and sediment processes.

The model to be used in the planned assessments is the Severn Estuary model developed by ABPmer, which has previously been used for investigations into a proposed Severn Barrage. ABPmer, using this model, has undertaken preliminary investigations into the potential hydrodynamic impacts of the potential lagoon options. These preliminary results will help in determining the study area and scope of the water quality investigations.

Where a detailed assessment of microbiological impacts on the Bathing Waters at Barry is required it may be more efficient to use an existing Dŵr Cymru Welsh Water (DCWW) model (the Cardiff model). A decision on the use of this model will be undertaken following initial screening using both the Severn Estuary model.

Data with which to define the pollutant loads to the study area will be the most critical part of the water quality modelling exercise. Without an accurate description of the input loads it will not be possible to accurately define water quality (in terms of pollutant concentrations) and assess the impact of the Project. Confidence in the results of the study will be most significantly influenced by the ability to accurately define pollutant loads to the Bristol Channel and Severn Estuary.

The size and location of the Project also have a significant bearing on the data requirements:

- The location is an estuary – effectively a large triangle bounded by land along the two longer sides and the Irish Sea along the shorter side.
- Flushing of the estuary is limited to the boundary with the Irish Sea.
- There are a significant number of discharges to the estuary, both from rivers and from the large urban agglomerations along the Welsh and English coasts.
- Pollutants from these many sources are likely to remain in the estuary for long periods and will disperse over a wide area.

The model will therefore need to include a large number of pollutant sources and will need to be run to simulate long periods to allow full dispersion and mixing of pollutants, plus seasonal water quality cycles.

2.2 DEFINITIONS

For the purposes of the data review and gap analysis the study area has been divided into three areas:

- **The Near-Field (Zone 1):** the area immediately adjacent to the Project which is directly hydraulically impacted and where pollutant sources can cause receiving water concentrations to vary significantly in the short- to medium-terms and seasonally. These sources include local river and point sources adjacent to the Project.
- **The Mid-Field (Zone 2):** the area close to the Project, which would not be expected to be significantly influenced by the hydraulic effects of the Project and from which pollutant discharges would lead to low or moderate variations in receiving water concentration in the short- to medium-terms and seasonally.
- **The Far-Field (Zone 3):** the larger area of the Bristol Channel and Severn Estuary which is unlikely to be affected by the Project in terms of hydraulics and pollutant concentrations but where pollutants from sources can determine regional background levels.

The primary aim of defining these zones is to differentiate between the treatment of pollutants from these areas and the different data requirements for each. The Zones are described in Appendix A together with an indication of the data needs within each area. Data needs are indicated as Low to High. Typically Low refers to low level data such as statistical data (mean, standard deviation) or typical values for similar sources / waters. High refers to detailed time series data, typically hourly. Moderate generally refers to low frequency time series data (daily, weekly, monthly) or statistical distributions.

Zones are also sub-divided by pollutant types, based on how rapidly pollutants are lost from the system by decay or through other sink terms.

In general, pollutant sources furthest from the Project location need the least detailed description, and can generally be represented using a mean discharge load determined from typical flow and concentration. Discharges closer to the Project location will require more detailed description of loads, particularly how the load responds to events such as storms.

For the purpose of this document a load is the mass of pollutant discharged per second, and is the product of the discharge flow and pollutant concentration.

Discharges must be defined by three key parameters:

1) **Location**: the physical point at which the discharge enters the receiving water, normally referred to as the outfall. This may be some distance from the source of the pollutant – for example, a Wastewater Treatment Works (WwTW) may discharge via a subterranean pipe that passes into a Long Sea Outfall (LSO) that discharges many kilometres from the WwTW. For rivers, and discharges into rivers, the discharge location will typically be taken as the mouth of the river.
2) **Flow**: the discharge rate (in m^3/s) from the outfall, outfall pipe or river mouth. This rate may vary significantly with time, particularly in response to storm events or as the result of physical controls, e.g. tide-locking.

3) **Pollutant concentration**: the concentration (normally in mg/l) of pollutants within the discharge. This may also vary in response to e.g. treatment, rainfall, temperature or other factors.

It is also important to know if a discharge has undergone, or will undergo, any improvement or change, for example due to sewerage infrastructure upgrades. Changes to location, flow or concentration need to be captured and identified to ensure that outdated data are not used.

3 DATA REVIEW AND GAP ANALYSIS

3.1 KEY DATA PROVIDERS

The following key providers / sources of the required data have been identified:

- Natural Resources Wales (NRW);
- Environment Agency (EA);
- DCWW;
- Wessex Water;
- Cardiff Harbour Authority;
- British Oceanographic Data Centre (BODC);
- University of Wales (Cardiff and Swansea);
- UK Meteorological Office (UKMO);
- prior studies in the area, e.g. Severn Barrage;
- academic papers; and
- internet.

These have been supplemented by additional sources as appropriate.

3.2 HYDRODYNAMIC AND SEDIMENT DATA

Hydrodynamic, dispersion and sediment data requirements will be covered separately by ABPmer. However, Intertek will consult with ABPmer to ensure that any data sets which we hold or have access to are included and that the needs of the water quality model can be met by the existing data. Intertek has access to a number of bathymetric and Acoustic Doppler Current Profiler (ADCP) data sets that may be of use. Intertek also has experience of applying suitable marine dispersion coefficients in the study area, and access to a few (albeit poor quality) dye tracing data sets. Liaison between Intertek and ABPmer on these issues will ensure that the requirements of the water quality assessment are fully met by the model and supporting information.

3.3 RAINFALL AND METEOROLOGICAL DATA

3.3.1 Requirement

Rainfall data have a variety of potential uses within the study, including:

- driving river catchment flow models, if these are required;
- driving sewerage network models, if these are required; and
- calibrating the coastal model for particular identified events (e.g. storms).

Long-term time series data are required, ideally from measured sources.

Rainfall patterns are highly variable in space. For example, rainfall tends to be higher on upland areas due to orographic effects. It may therefore be

necessary to obtain multiple time series of rainfall in order to accurately represent differences across the study region.

Other meteorological data will be required for the study. In particular, wind speed and direction information are needed since these can cause wind drift currents and thus influence the transport of discharged pollutants. A statistical summary of the wind climate, based on long-term observations, is considered sufficient for study purposes. Data for several sites may be required in order to evaluate spatial variability across the study area. Ideally these sites would be close to sea level and near the coast, since these will best represent open water wind velocities across the Severn Estuary and Bristol Channel.

3.3.2 Available Data

Various suitable data sets are available from:

- UKMO;
- NRW and the EA;
- water companies; and
- internet sources, e.g. wunderground.com (particularly for wind data).

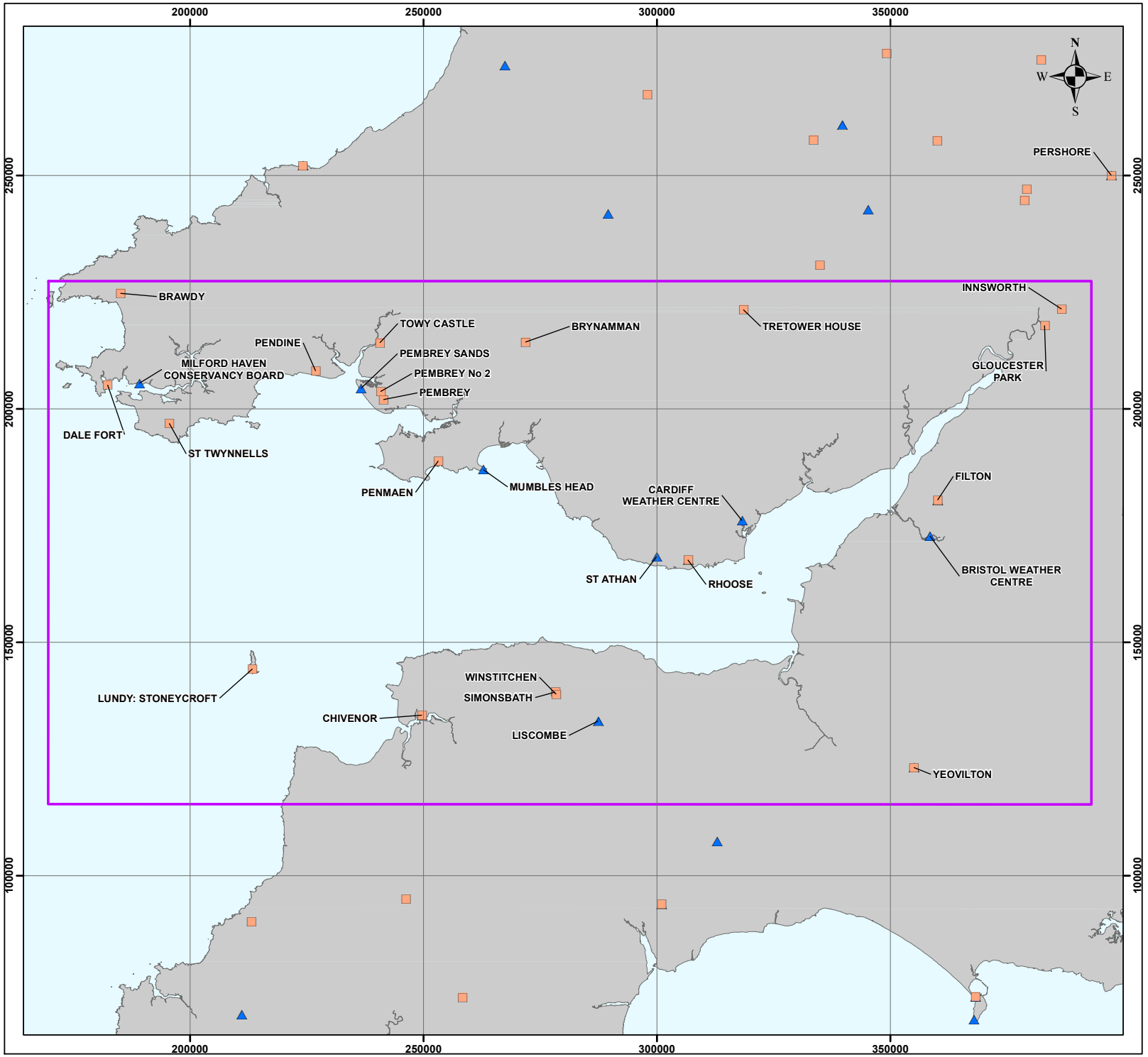
Figure 3-1 plots the locations of UKMO observational stations in the study area (as of 2012). Figure 3-2 plots the locations of rainfall stations run by both NRW/EA and the water companies, as identified by a search of the Met Office Integrated Data Archive System (MIDAS) maintained by the British Atmospheric Data Centre (BADC).

Figure 3-1: UKMO meteorological stations in the study area

(Source: http://www.metoffice.gov.uk/)

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-2: UKMO and water company rainfall stations in the study area



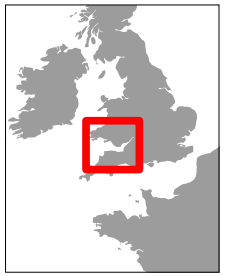
Contains Ordnance Survey data © Crown copyright and database right 2013

Legend

BADC Midas Station

- Hourly Rainfall
- Hourly rainfall from Water Authorities

Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

Intertek

Natural Quality Delivered

0 10 20 30 40 km

The website wunderground.com provides archived data (primarily wind, air temperature and pressure) for a number of stations across the study area. The stations of most use are likely to be Cardiff Airport and RAF St. Athans, which have approximately 18 and 10 years of data available respectively. Other data sets are available at (for example) Mumbles Head, Filton and Bristol Airport.

3.3.3 Sufficiency of Data

Although the full data sets have not yet been obtained (e.g. from UKMO, due to cost considerations), it is considered likely that the various identified data sets will between them be sufficient for study purposes.

If they are of suitable quality, the archived data from wunderground.com for Cardiff airport and RAF St. Athans should provide a source of wind data sufficient for study purposes.

If further wind data are required, the UKMO weather stations should provide a suitable source. At this time it is not proposed to request data from the UKMO until other sources have been thoroughly examined, due to the high costs of its data.

A combination of water company and UKMO data sets should be sufficient for obtaining the required rainfall data series.

3.3.4 Gap Analysis and Recommendations

There is considered be no requirement for further rainfall or meteorological data collection. In any event, additional data collection would be unfeasible due to the need to obtain long-term measurements of rainfall and other meteorological parameters.

In the event that suitable rainfall data are not available for a particular area (e.g. a local river or sewerage catchment), the recommended approach is:

- consider whether it is acceptable, in the overall context of the study, to directly use an alternative rainfall series from an adjacent or otherwise representative area;
- if this approach is not acceptable, identify a donor site where a suitable data set exists; and
- scale the rainfall series from the donor site to the site of interest using the ratio of Average Annual Rainfall (AAR) between the two sites (AAR is readily available e.g. from isohyetal maps).

3.4 River Discharge Flows

3.4.1 Requirement

River discharge flows are required to allow pollutant loads to the Severn Estuary and Bristol Channel to be accurately specified.

Realistic representation of river flows is also required because of the effect these might have on marine hydrodynamics, particularly in the case of the larger rivers such as the Severn and Wye. These hydrodynamic effects will be covered separately by ABPmer.

3.4.2 Available Data

River discharge locations are readily available from Ordnance Survey (OS) maps.

3.4.2.1 Gauged rivers

Most of the more significant river discharges in the study area are gauged by NRW and the EA. This gauging provides long-term records of river flow at 15-minute intervals, from which more general statistics can be obtained if required. These time-varying data are the preferred data source for rivers discharging to the near- and mid-fields, and can also be readily used in the far-field.

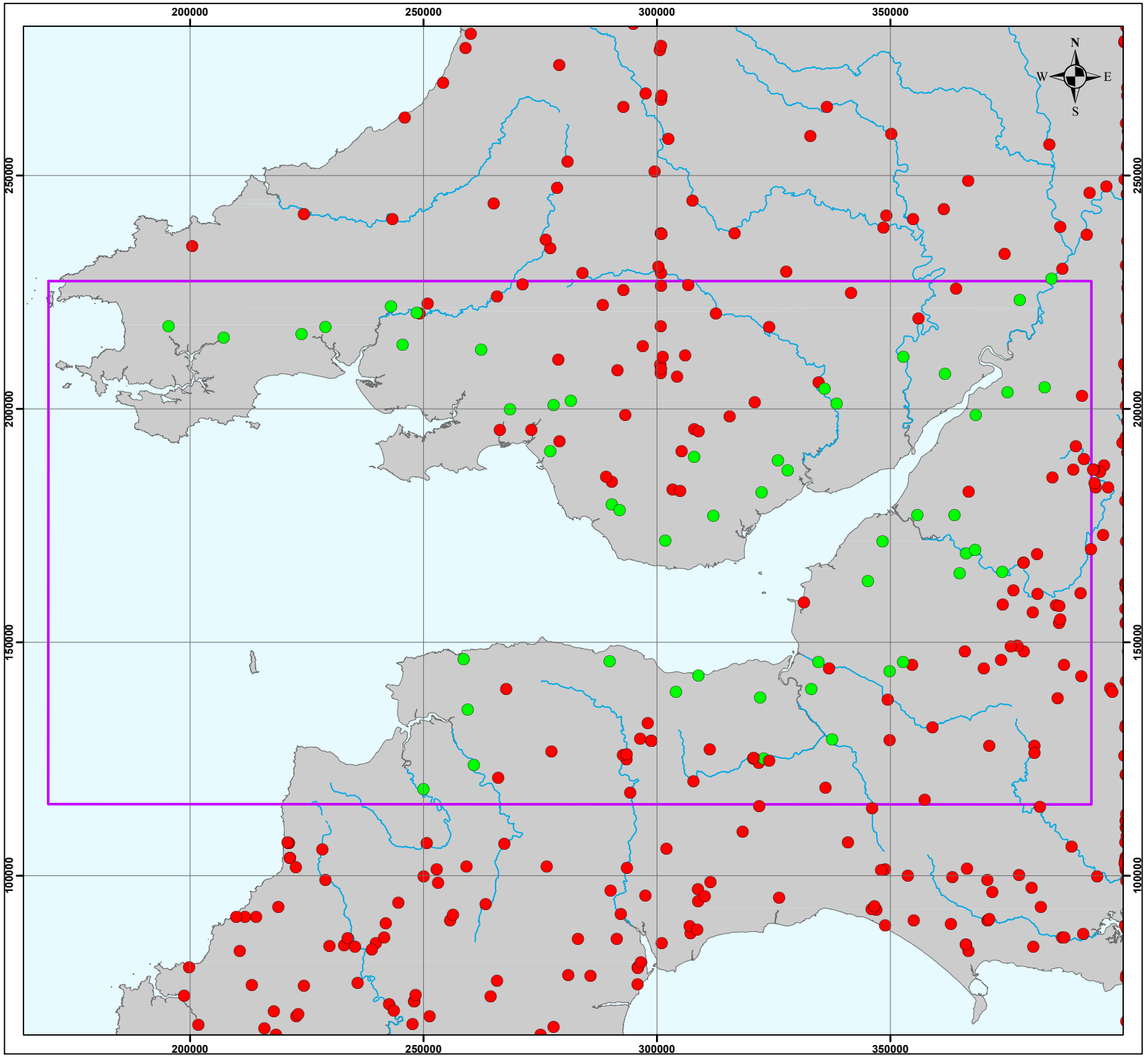
Figure 3-3 plots the location of all long-term river gauging stations in and around the study area. Flow data for the stations of most relevance to the tidal lagoon study have been obtained from NRW and the EA; these stations are indicated in green.

NRW and the EA also sometimes carry out local ad hoc gauging of rivers that do not have long-term gauges. The resulting flow data cover relatively short time periods. A small number of ad hoc gauging data have been obtained from NRW and the EA. These data are generally not sufficient in themselves for defining the river flow regime, but will be of some use in supporting the modelling-based approach proposed for ungauged rivers (see Section 3.4.2.2).

Summary river flow statistics, and time series of daily mean flow, are also available online via the National River Flow Archive (NRFA), maintained by the Centre for Ecology and Hydrology (CEH). Similar statistics are published by CEH in the UK Hydrometric Register[2]. These statistics may be acceptable for defining river flows in the far-field where high resolution time-varying flows are not required.

Some river flows within the study area are known to be highly managed, such as for the River Parrett draining the Somerset Levels. Care will need to be taken during the study to ensure that such discharge flows are suitably represented and any significant flow controls are accounted for. A first step will be liaison with the relevant Internal Drainage Boards (IDBs) in order to understand present management practices. The IDBs of most relevance to the Project are:

- Caldicot and Wentlooge Levels IDB;
- Lower Severn IDB;
- Parrett IDB;
- Axe Brue IDB; and
- North Somerset Levels IDB.



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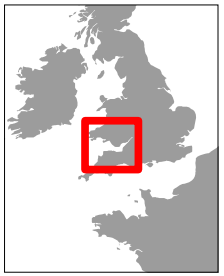
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-3: NRW and EA river flow gauging stations

Legend

EA River Gauging Flow Station

- Not Requested
- Data Requested
- Main Rivers
- Study Area



NOTE: Not to be used for Navigation

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File Reference	J:\P1914\Mxd\Report\ Fig3_3_River_Flow_Gauging_Stns.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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Natural Quality Delivered

0 10 20 30 40 km

3.4.2.2 Ungauged rivers

Not all rivers are gauged, particularly smaller rivers and streams. There may also be discharges from large urban or rural drainage systems, such as surface water sewers or wetlands. These can contribute to impacts if they carry a large pollutant load or if they receive discharges from misconnections in the main sewerage networks.

For the most part it should be possible for the study to ignore these smaller discharges on the basis that their pollutant loads are dwarfed by the larger river discharges. However, in some cases the smaller streams may be important – for example, if they happen to discharge into or in close proximity to one of the proposed lagoons (i.e. the near- and possibly mid-fields). In this case a realistic representation of their flow might be required.

A suitable approach for representing ungauged streams is to construct a hydrological model using data obtained from the Flood Estimation Handbook (FEH) CD-ROM. This provides details of the key characteristics for all UK river catchments, such as total catchment area, altitude, ground type and urban area. Using these catchment parameters, and a suitable input rainfall series, it is possible to construct a hydrological model that produces a time series of river flows for the ungauged catchment. This is achieved by applying the revitalised FSR/FEH rainfall-runoff method[3,4] (FSR = Flood Studies Report).

Any hydrological models constructed for the Project will need to be calibrated. Two main calibration approaches are available, depending on the availability of data:

- direct calibration against time series flows, summary flow statistics (such as percentiles), or ad hoc gauging data measured in the river itself; and
- use of model calibration parameters from a suitable donor catchment, i.e. a calibrated model for a river catchment that displays similar characteristics in terms of catchment size, altitude, land use etc.

In some cases, and particularly for rivers in the far and possibly mid-fields, it may be acceptable to scale flows directly from a gauged river to an ungauged river, using the ratio of their catchment areas. This approach is best attempted where the two rivers display similar catchment characteristics.

3.4.3 Sufficiency of Data

Suitable flow data sets for all of the main rivers have been obtained from NRW and the EA.

The approach proposed for characterising ungauged rivers has been used extensively to support water quality studies around the UK coast. It has been accepted by regulators such as NRW and the EA.

As such, the combination of gauged river flow data, and suitable approaches for representing ungauged rivers (hydrological modelling or scaling from donor catchments), will together provide sufficient information on river flow inputs to the study area.

3.4.4 Gap Analysis and Recommendations

It is considered that suitable river flow data exist for the purposes of the study. Additional flow sampling is therefore not required in support of the assessment.

3.5 River Water Quality – Chemistry and Nutrients

3.5.1 Requirement

River discharge concentrations are required to allow pollutant loads to the Severn Estuary and Bristol Channel to be accurately specified.

An understanding of river water quality may also be required as part of the WFD assessment into connected waterbodies.

River water quality needs to be considered in conjunction with any point sources of pollution on these rivers (see Sections 3.7 and 3.8), to ensure that the discharge loads are consistent and to avoid double-counting of pollutant loads.

Various nutrient and chemical determinands are of interest to the study, including:

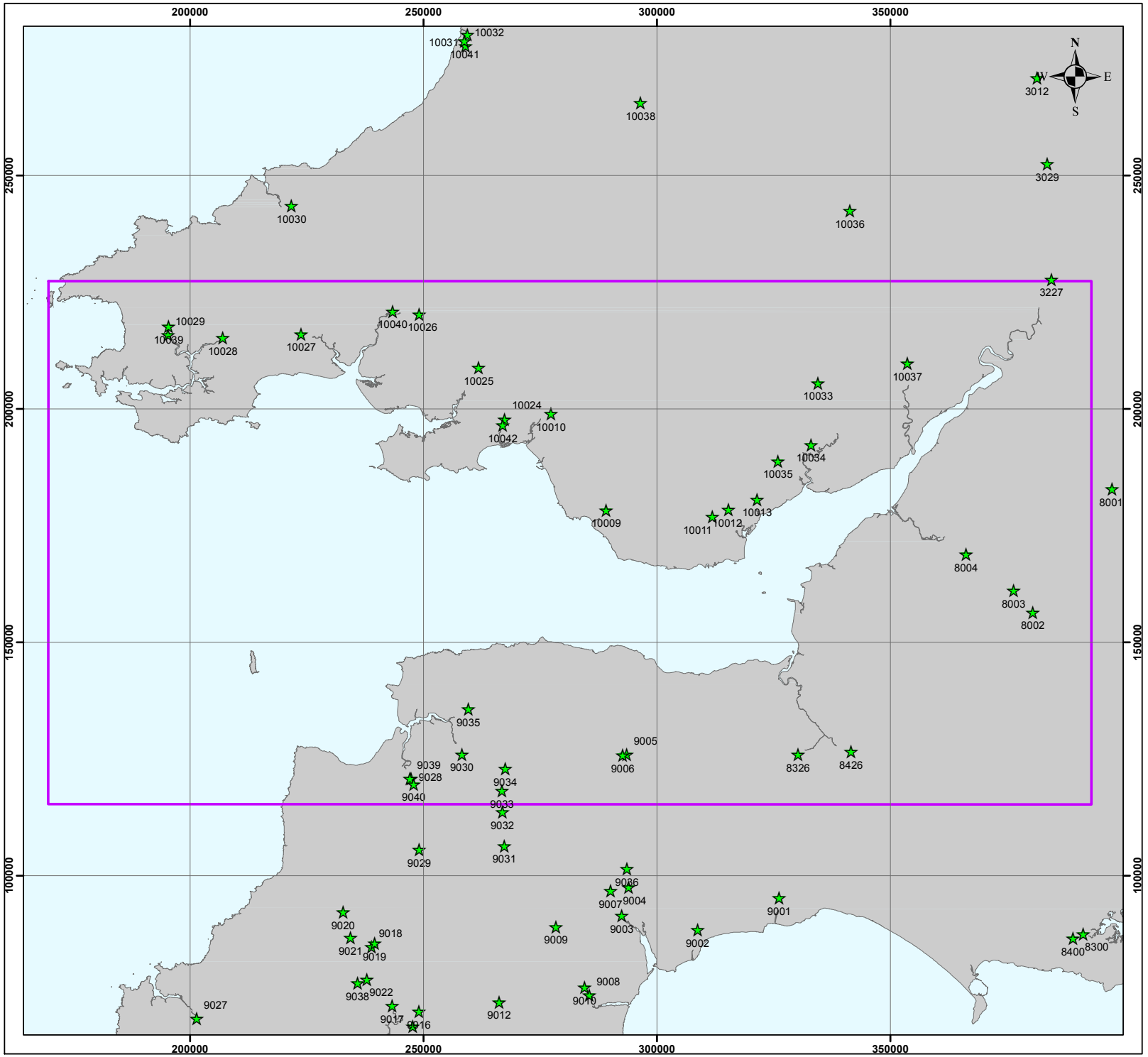
- Biochemical Oxygen Demand (BOD);
- Dissolved Oxygen (DO);
- phosphorus – Dissolved Available Inorganic Phosphorus (DAIP) measured as reactive orthophosphate (NRW/EA determinand code 0180);
- nitrogen – Dissolved Available Inorganic Nitrogen (DAIN) measured as nitrate-N (NO_3-N, NRW/EA determinand code 0117), nitrite-N (NO_2-N, NRW/EA determinand code 0118) and ammoniacal-N (NH_4-N, NRW/EA determinand code 0111);
- suspended solids; and
- conservative pollutants such as heavy metals and tributyltin (TBT).

3.5.2 Available Data

3.5.2.1 Measured concentrations

Historic river water quality monitoring data have been obtained from NRW and the EA. Most of the larger rivers are sampled regularly for a variety of determinands.

Figure 3-4 plots the primary locations of the routine river water quality monitoring undertaken by NRW and the EA.



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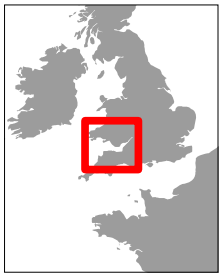
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-4: NRW/EA river water quality sampling sites

Legend

- Water Quality Sampling Site
- Study Area



NOTE: Not to be used for Navigation

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File Reference	J:\P1914\Mxd\Report\ Fig3_4_WQ_Sampling_Sites.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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Natural Quality Delivered

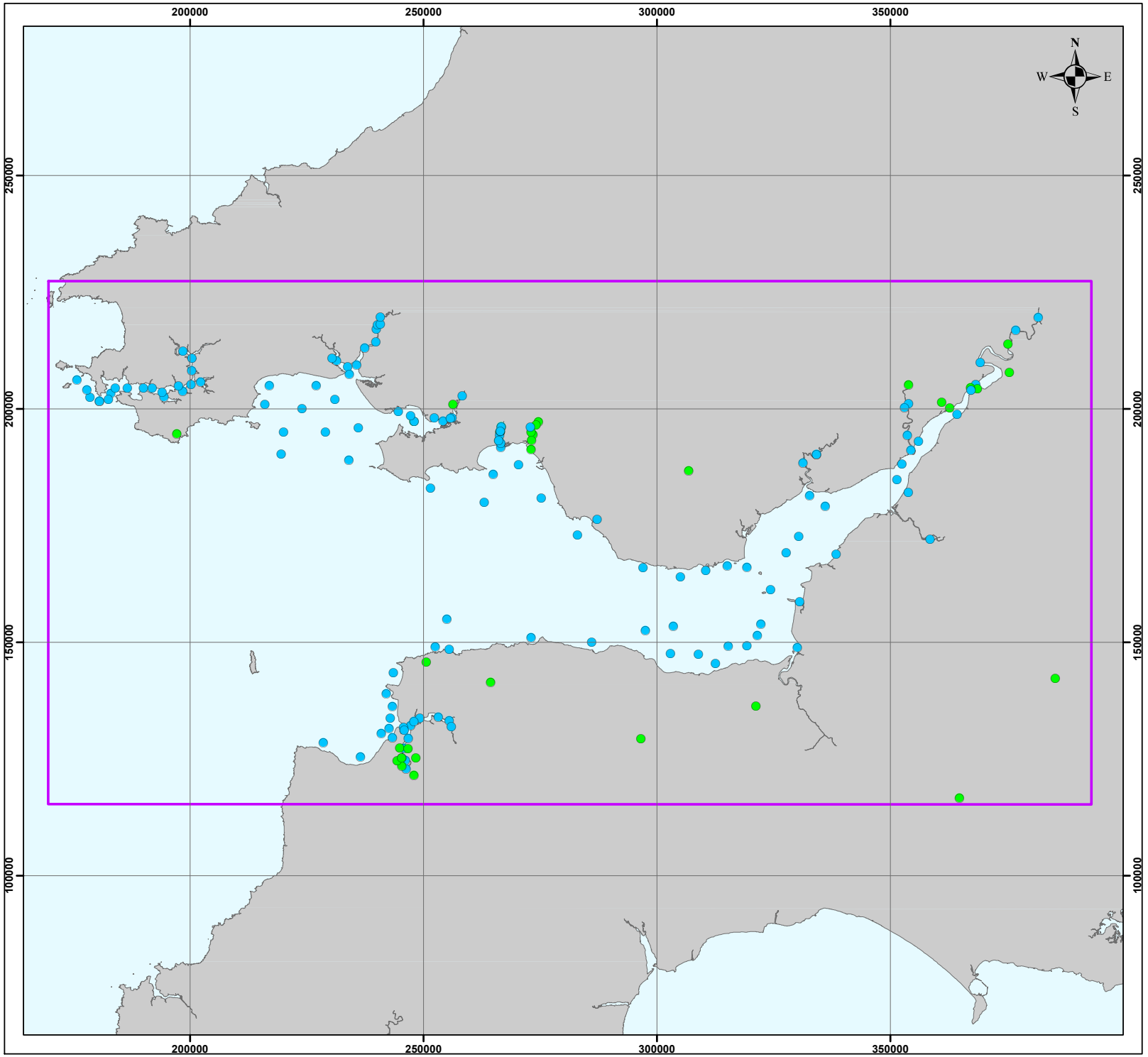
0 10 20 30 40 km

Additionally, ad hoc river sampling is sometimes undertaken by NRW, the EA and the water companies. This sampling may be in response to historic problems and may not accurately reflect any subsequent improvements made to address these problems. Data provided by NRW and the EA show a large number of locations where either routine or ad hoc river monitoring has been undertaken, covering a variety of important water quality determinands. Note, however, that some of these sites hold only a small number of data.

The following Figures present an overview of the availability of chemical and nutrient monitoring data for both freshwater and saline water locations in the study area, based on data obtained from NRW and the EA:

- Figure 3-5 shows locations (both freshwater and saline water) where DAIN measurements have been obtained from NRW and the EA.
- Figure 3-6 shows locations where DAIP measurements have been obtained.
- Figure 3-7 shows locations where DO, BOD and Chemical Oxygen Demand (COD) measurements have been obtained.
- Figure 3-8 shows locations where measurements of various metals have been obtained.
- Figure 3-9 shows locations where water temperature measurements have been obtained.
- Figure 3-10 shows locations where pH measurements have been obtained.
- Figure 3-11 shows locations where salinity measurements have been obtained.
- Figure 3-12 shows locations where chlorophyll measurements have been obtained.

In addition to the measured data sources discussed above, it will be possible to use representative concentration values for some rivers. This approach is most applicable to rivers in the far- and possibly mid-fields. It allows total discharge loads to the estuary to be adequately represented for the purposes of the water quality impact assessment. Ideally, representative concentration values will be taken from river catchments with similar characteristics. It will be possible, using analytical techniques, to consider the likely influence of any large point source discharges (such as WwTWs) on the overall river water quality, and to adjust river concentrations to reflect these inputs.



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SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

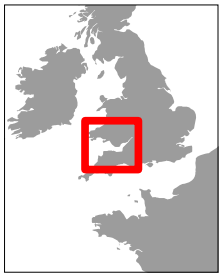
Figure 3-5: NRW/EA DAIN sampling sites

Legend

DAIN

Sample Type

- Freshwater
- Saline water
- Study Area



NOTE: Not to be used for Navigation

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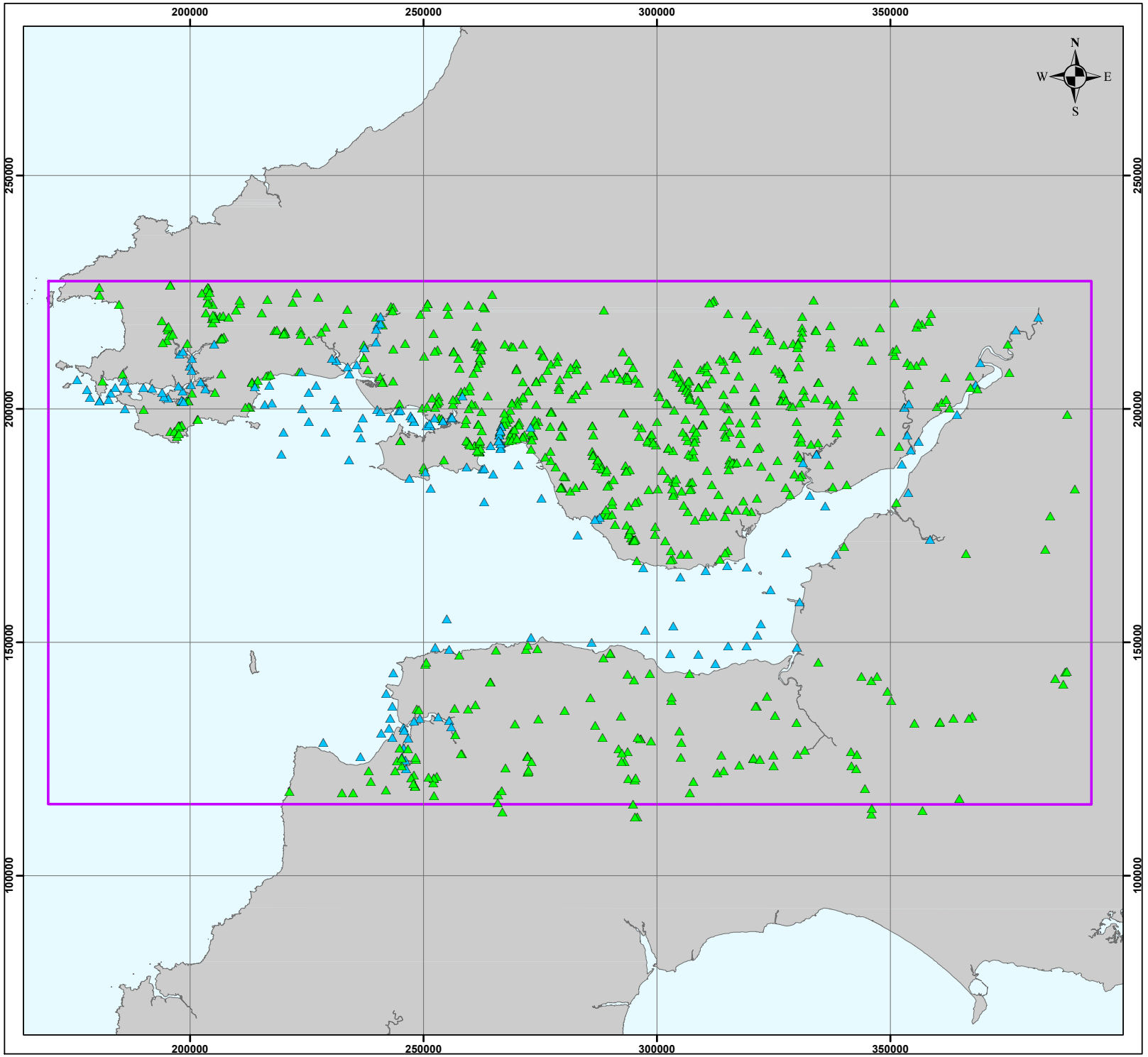
File Reference	J:\P1914\Mxd\Report\ Fig_3_5_DAIN_WQ_Sampling_Sites.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-6: NRW/EA DAIP sampling sites



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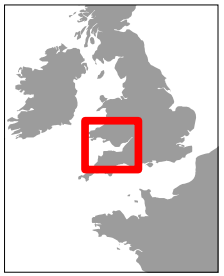
Legend

DAIP

Sample Type

- Freshwater
- Saline water
- Study Area



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File Reference	J:\P1914\Mxd\Report\ Fig_3_6_DAIP_WQ_Sampling_Sites.mxd
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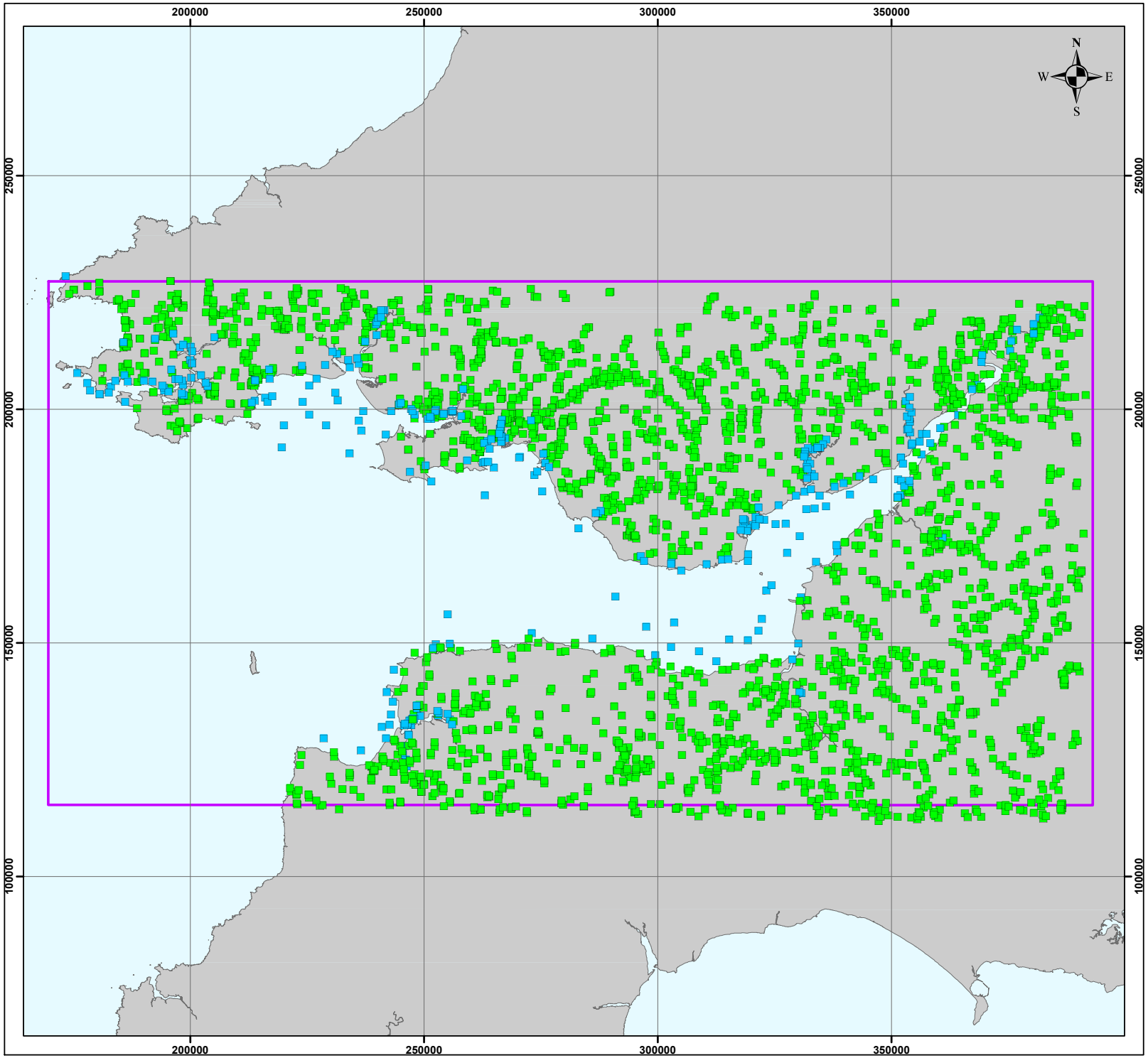
0 10 20 30 40 km

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-7: NRW/EA DO, BOD and COD sampling sites

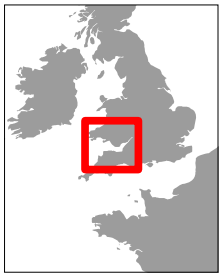


Legend

Oxygen

Sample Type

- Freshwater
- Saline water
- Study Area



NOTE: Not to be used for Navigation

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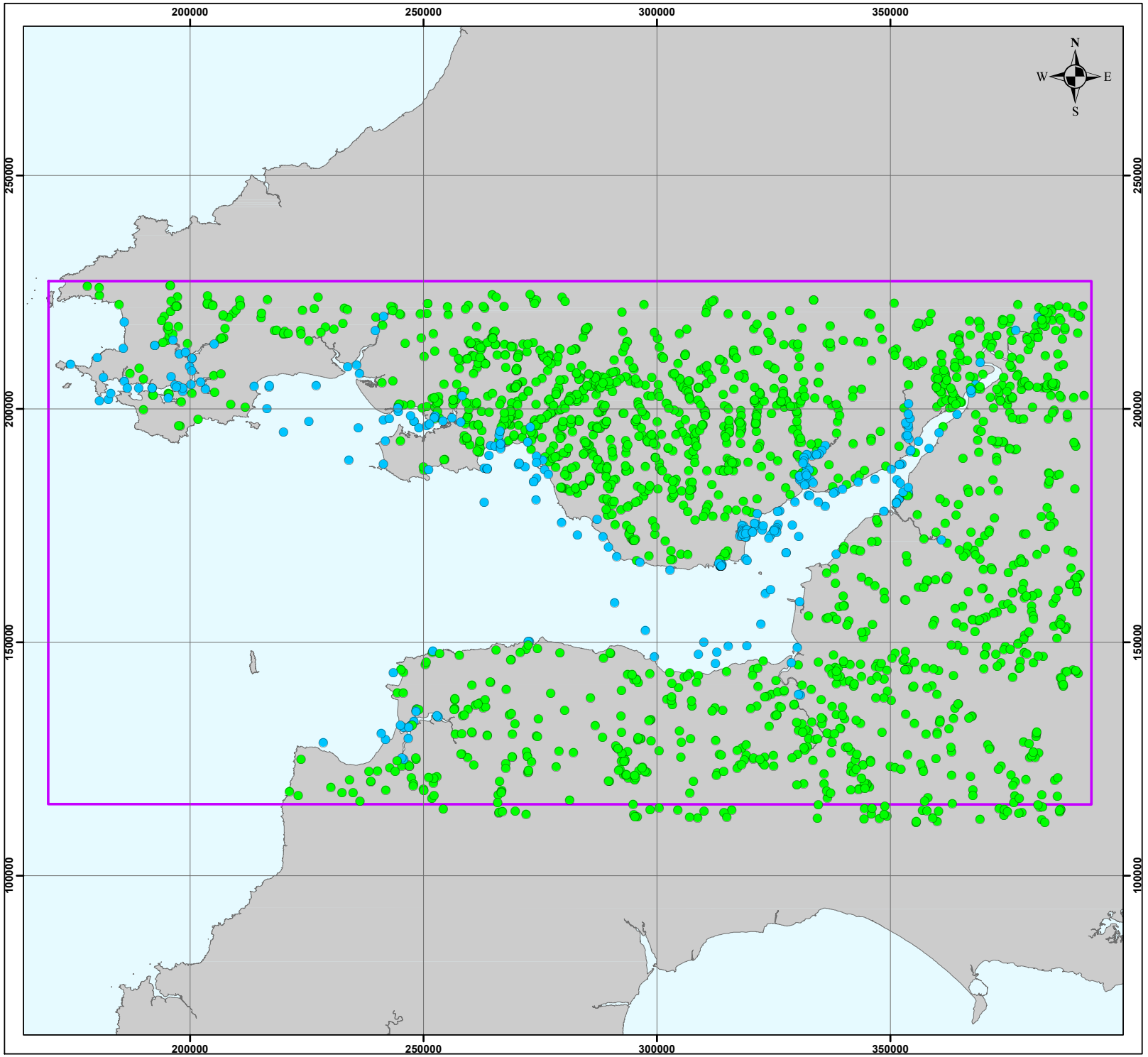
File Reference	J:\P1914\Mxd\Report\ Fig_3_7_Oxygen_WQ_Sampling_Sites.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40



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SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

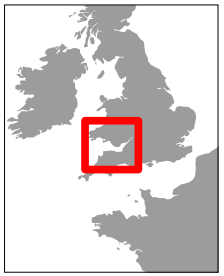
Figure 3-8: NRW/EA metals sampling sites

Legend

Metals

Sample Type

- Freshwater
- Saline water
- Study Area



NOTE: Not to be used for Navigation

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File Reference	J:\P1914\Mxd\Report\ Fig_3_8_Metals_WQ_Sampling_Sites.mxd
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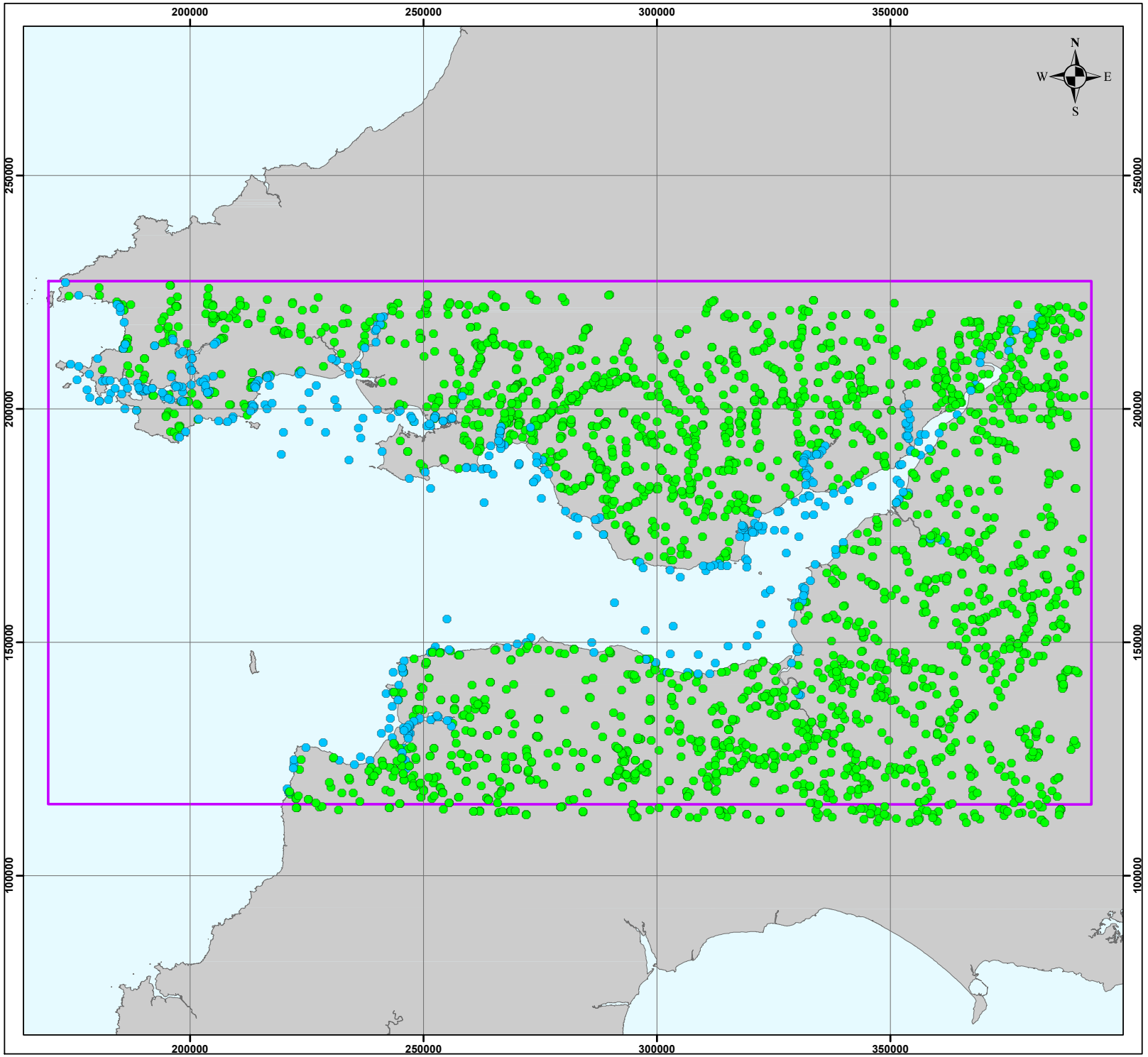
0 10 20 30 40 km



SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

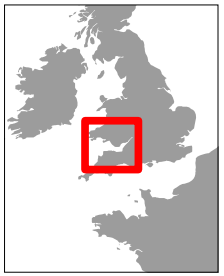
Figure 3-9: NRW/EA water temperature sampling sites

Legend

Temperature

Sample Type

- Freshwater
- Saline water
- Study Area



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Data Source	OSOD, EA, NRW
File Reference	J:\P1914\Mxd\Report\ Fig_3_9_Temperature_WQ_Sampling_Sites.mxd
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Reviewed By	Emma Langley
Approved By	Kevin McGovern

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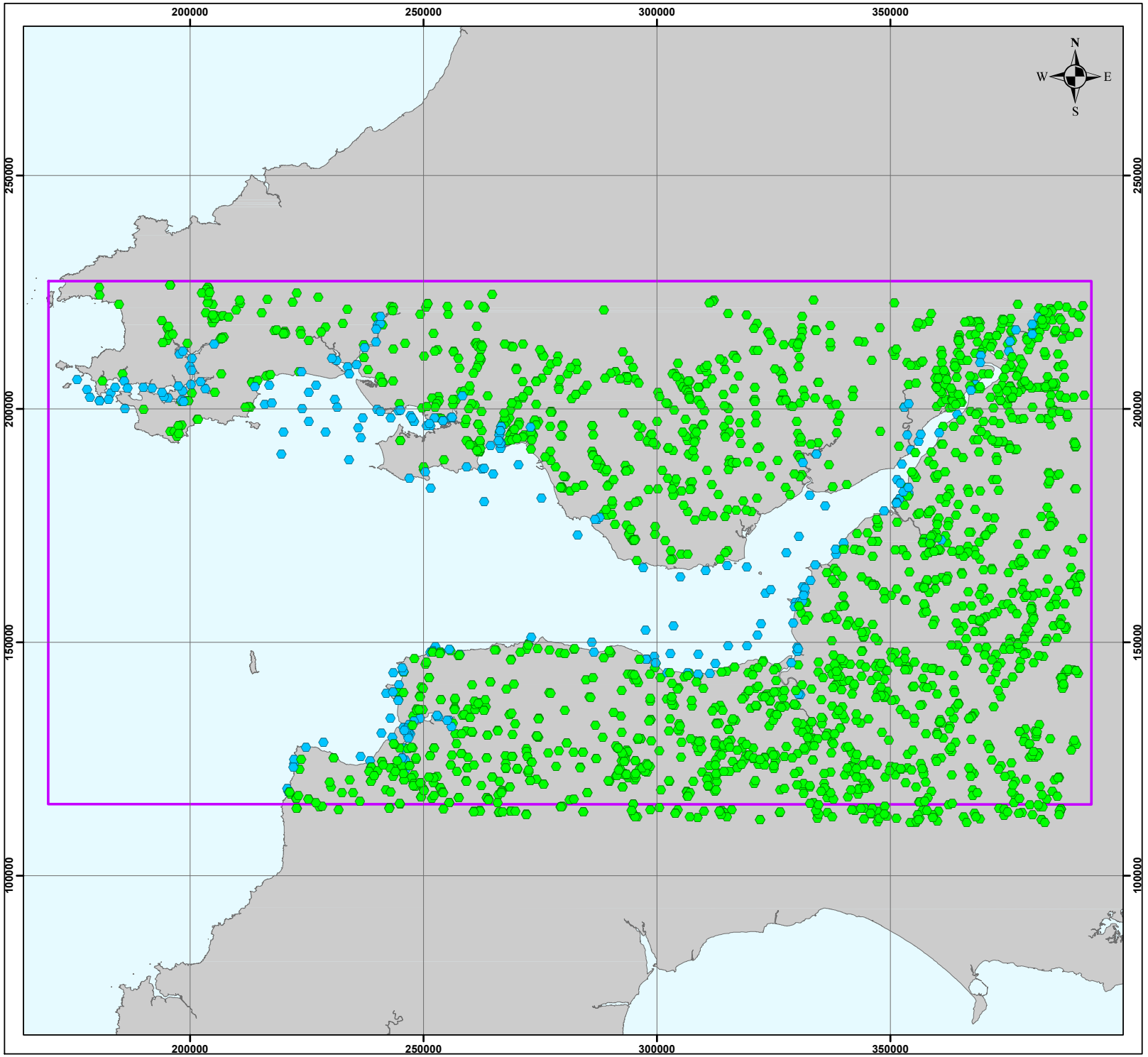
0 10 20 30 40 km

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-10: NRW/EA pH sampling sites



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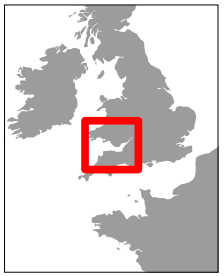
Legend

pH

Sample Type

- Freshwater
- Saline water
- Study Area



NOTE: Not to be used for Navigation

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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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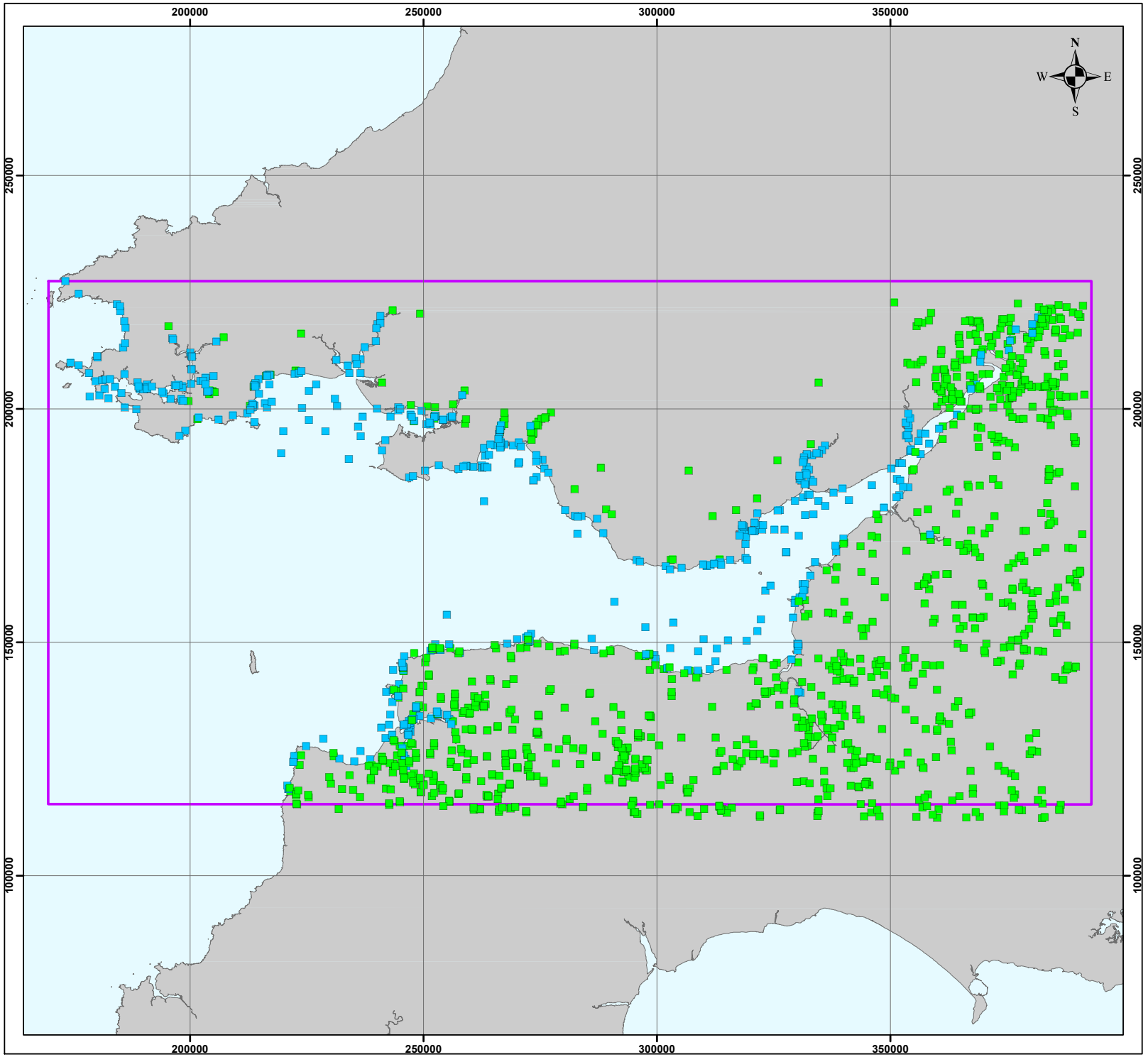
km
0 10 20 30 40

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-11: NRW/EA salinity sampling sites

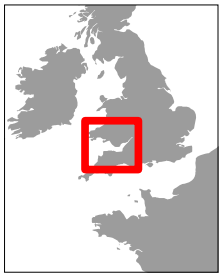


Legend

Salinity

Sample Type

- Freshwater
- Saline water
- Study Area



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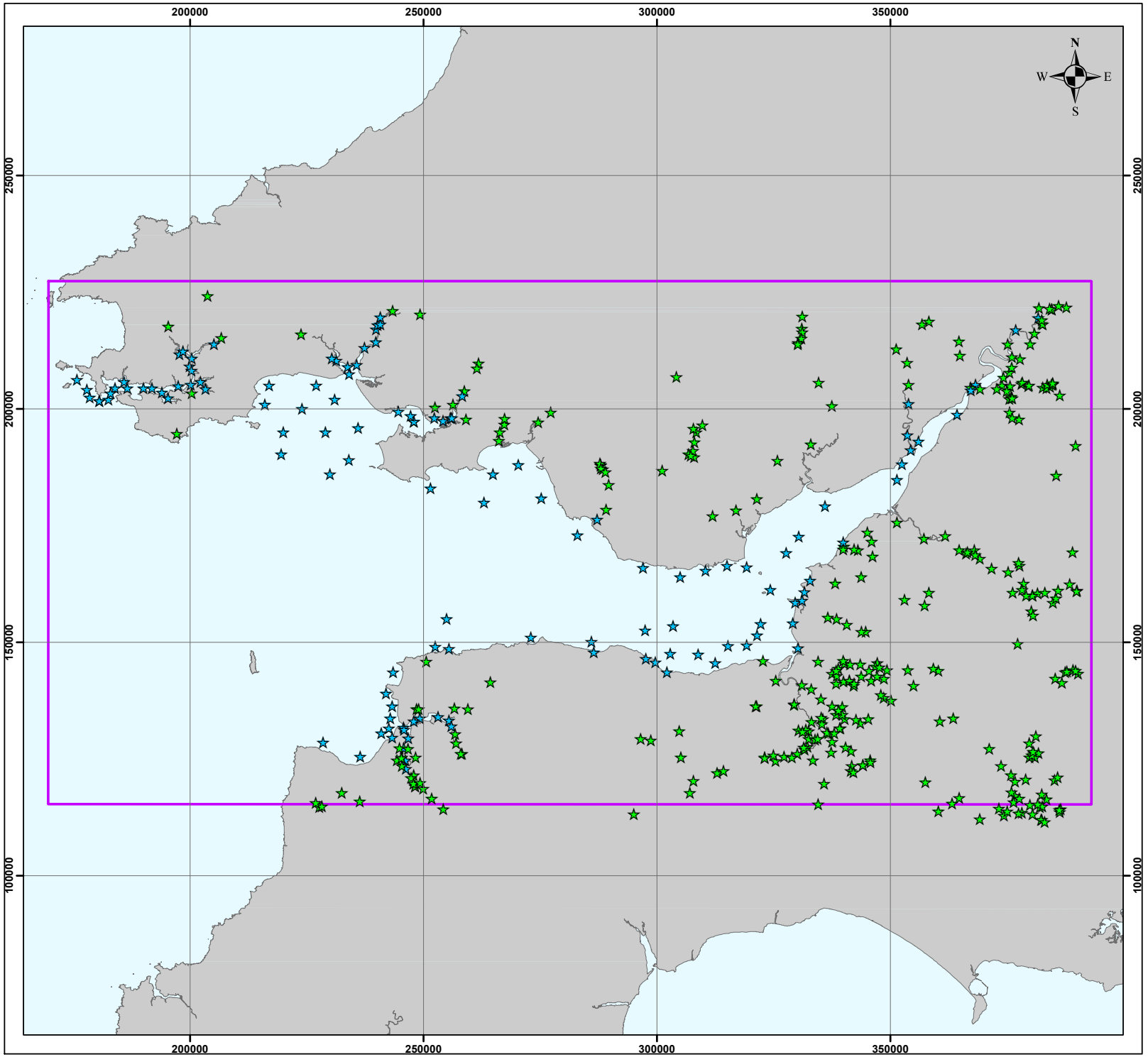
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40



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SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

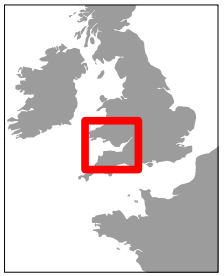
Figure 3-12: NRW/EA Chlorophyll sampling sites

Legend

Chlorophyll

Sample Type

- Freshwater
- Saline water
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

0 10 20 30 40 km

3.5.2.2 Catchment modelling

In the absence of suitable measured data, catchment modelling tools provide a potential means for deriving appropriate river discharge concentrations. A number of approaches exist, but they all follow the same general approach:

- construct a hydrological model of the catchment, as described in Section 3.5.2.2;
- define point and diffuse pollutant input loads to the catchment; and
- calibrate the catchment water quality model using measured pollutant concentrations at suitable points within the catchment.

For catchments that lack suitable calibration data, calibration parameters from donor catchments can be used. The donor catchment should be similar in terms of its key characteristics such as altitude, underlying geology and land use.

Catchment models can produce either statistical outputs such as mean concentrations, or time series of varying concentration driven by an input rainfall time series. In general, rivers closer to the Project will need to be represented in more detail in the study. Therefore, time-varying concentrations may be required for rivers discharging to the near and mid-fields, while rivers in the far-field can be characterised using simpler approaches.

3.5.3 Sufficiency of Data

Reasonable river water chemistry and nutrient data are available for most of the key rivers. However, there are some limitations to the available data sets:

- typically, wet weather sampling data are fewer in number than dry weather data, due to the lower frequency of wet weather conditions and the consequently decreased likelihood of capturing a wet weather event through regular but random sampling;
- some of the rivers may have a relatively small number of sampling data, which decreases the confidence that they accurately reflect river discharge loads; and
- a number of smaller rivers discharging close to the Project (in the near- and mid-fields) may be of potential significance to the study but have not been regularly sampled.

3.5.4 Gap Analysis and Recommendations

Methods exist for estimating or approximating river discharge loads, for example through the use of catchment models as described in Section 3.5.2.2. However, additional sampling of river water quality may be required to increase confidence in water quality model input loads. The sampling requirements will depend on the quality of the distribution available for each determinand from existing data. If the distribution is sufficient for WFD analyses then no further data collection will be required. Intertek proposes the following approach:

1) Rivers should be screened to establish those which are likely to be of most significance to the coastal water quality study. In general terms, the more significant rivers will be: rivers discharging very close to the Project; large (high flow) rivers discharging further away; and rivers that are likely

to carry significant pollutant loads, for example those which flow through large urban areas. River screening model runs will be undertaken in order to establish the relative significance of rivers to the overall water quality study. This will allow the rivers to be prioritised in terms of both survey requirements and the subsequent modelling assessment.

2) For those rivers identified as being potentially more significant or higher priority, existing data sets will be analysed in detail to determine whether or not the historic water quality sampling is sufficient for the study. If the data are insufficient, targeted river water quality sampling is recommended.

3) Sampling should be undertaken as far downstream as is possible, but above the tidal limit. The exception is if there are practical reasons for sampling further upstream. For example, where access is limited or may compromise health and safety, or where it may be preferable to sample upstream of a large WwTW so that the effects of the WwTW and the diffuse river load can be separated out. This will provide upstream boundary conditions to the modelling. Downstream of the tidal limit sources will be included explicitly within the model.

4) The sampling requirements will depend on the quality of the distribution available for each determinand from existing data. If existing dry weather data are inadequate then sampling could be undertaken at three hourly intervals to provide a representative concentration. If existing data lacks extreme events then the distribution may not be adequate. In this case, sampling should focus on a wet weather event. A weather forecast should be used to predict rainfall and sampling should commence prior to rainfall and for the duration of the event. These data will enhance the distribution for the river through the inclusion of extreme values. Alternatively, extreme events could be modelled but validation data for the modelling may be lacking in the absence of sampled wet weather events.

5) If required, sampling should be undertaken under a number of different flow conditions, such as two dry weather periods and two wet.

6) Consideration should be given to the seasonality of sampling. A number of determinands (including nitrates, phosphates and BOD/DO) will benefit from both summer and winter sampling. This seasonality reflects both temporal patterns of pollutant inputs to the river catchment (such as agricultural use of phosphates) and the dependence of various water quality processes on temperature.

7) Sampling should cover a suitable range of physical, chemical and nutrient parameters, such as those listed in Section 3.5.1.

3.6 RIVER WATER QUALITY – BACTERIA

3.6.1 Requirement

River discharge concentrations are required to allow pollutant loads to the Severn Estuary and Bristol Channel to be accurately specified.

River water quality needs to be considered in conjunction with any point sources of pollution on these rivers (see Sections 3.7 and 3.8), to ensure that

the discharge loads are consistent and to avoid double-counting of pollutant loads.

Bacterial concentrations are likely to be an issue only in the event that the Project impacts sensitive receivers with bacterial quality standards, such as Bathing Waters and Shellfish Waters/Shellfish Harvesting Areas.

On the Welsh coast there are no Shellfish Waters close enough to the Project to be impacted. There are only three Bathing Waters at Barry, which would be only marginally impacted by the Project.

There are further Bathing Waters on the English side and if a lagoon was to be located in these areas, then detailed information on river bacteria loads would be required for this area.

The revised Bathing Water Directive (rBWD) considers two bacterial determinands as Faecal Indicator Organisms (FIO) – *E. coli* and intestinal enterococci. These are considered approximately equivalent to the current Bathing Water Directive (cBWD) determinands of faecal coliforms and faecal streptococci. As such, any of these determinands are of value to the Project.

3.6.2 Available Data

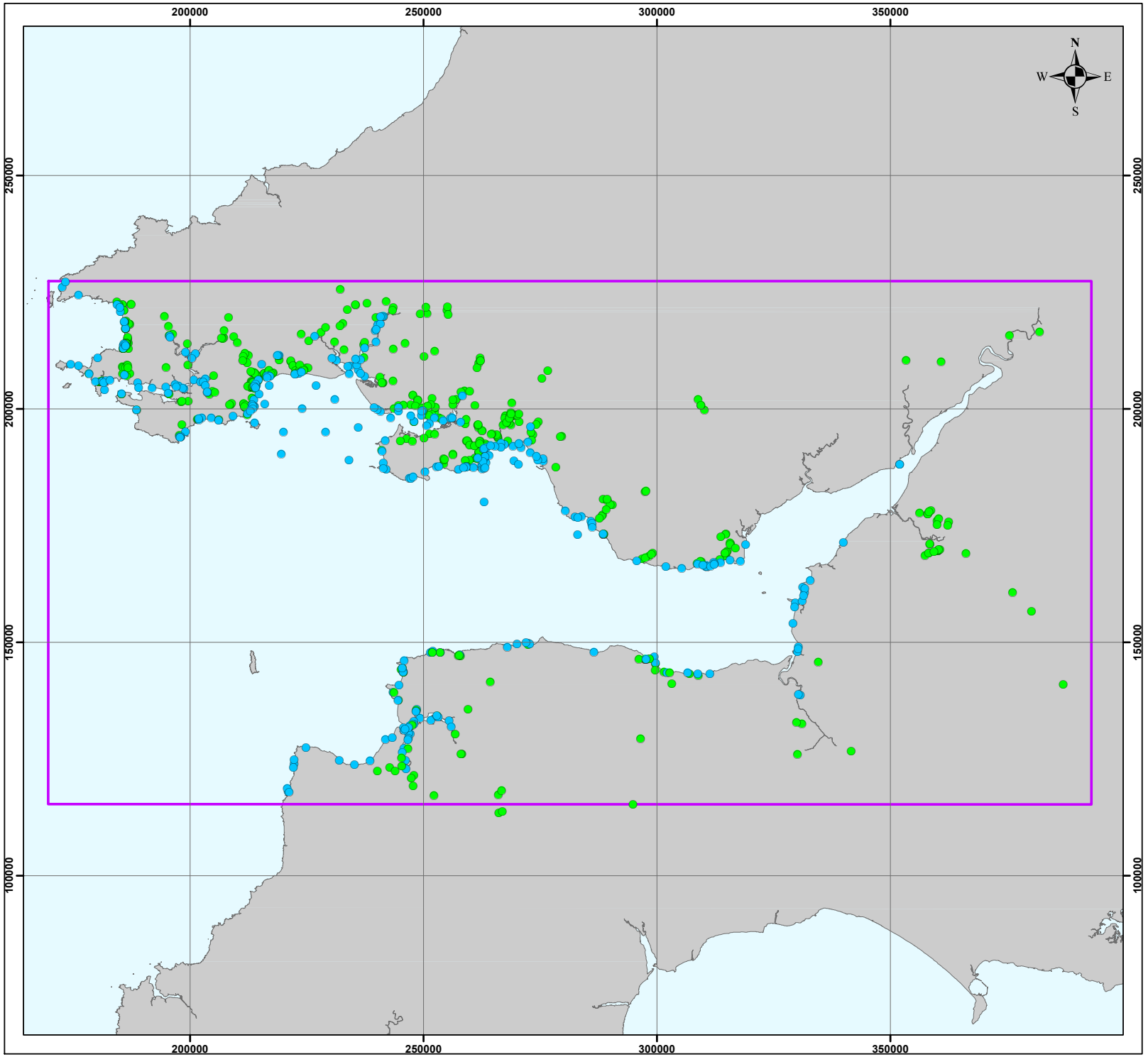
3.6.2.1 Measured concentrations

Figure 3-13 presents an overview of the availability of bacterial monitoring data for both freshwater and saline water locations in the study area, based on data obtained from NRW and the EA. Both routine and ad hoc sampling data are shown. Ad hoc sampling may be in response to historic problems and may not accurately reflect any subsequent improvement made to address these problems. The Figure indicates that bacterial water quality sampling is fairly limited in rivers close to the study area.

It is believed that Wessex Water undertakes microbiological surveys along the English coast and in local rivers. Data sets are held by Intertek for a number of local rivers from previous DCWW studies. The University of Cardiff and the Centre for Research into Environment and Health (CREH) have undertaken studies in the Severn Estuary and Bristol Channel and will be consulted.

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-13: NRW/EA Bacteria sampling sites

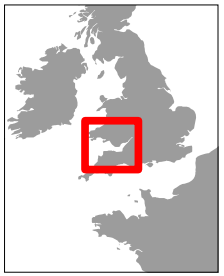


Legend

Bacteria

Sample Type

- Freshwater
- Saline water
- Study Area



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Datum	D_OSGB_1936
Data Source	OSOD, EA, NRW
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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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3.6.2.2 Catchment modelling

River catchment models can be used to define time-varying bacterial concentrations. Such models may be required for rivers discharging to the near- and mid-field zones for which suitable measured data are unavailable.

The approach to bacteriological catchment modelling closely mirrors that described for chemical and nutrient determinands in Section 3.5.2.2.

3.6.2.3 EA research study

The EA undertook a 2007 study into the fate and transport of particles in estuaries[7]. This focused on the Severn Estuary and Bristol Channel. Bacterial concentrations were defined for the main rivers discharging to the estuary. These concentrations were not based on local sampling but were calculated using a simplified catchment model. This catchment model provided a relationship between bacterial load and generic catchment parameters such as area and land use. The relationship was defined using data measured in six different areas around the UK, although none in the study area. As such, the derived loads are considered inferior to loads calculated from local measurements, but they may provide a useful sense check of study inputs and of Intertek's own catchment models.

3.6.3 Sufficiency of Data

Bacterial concentration data are only available for a few rivers close to the main study area. Furthermore, there are some limitations to the available data sets:

- Typically, wet weather sampling data are fewer in number than dry weather data, due to the lower frequency of wet weather conditions and the consequently decreased likelihood of capturing a wet weather event through regular but random sampling.
- Some of the rivers may have a relatively small number of sampling data, which decreases the confidence that they accurately reflect river discharge loads.
- A number of smaller rivers discharging close to the lagoons (in the near and mid-fields) may be of potential significance to the study but have not been regularly sampled.

3.6.4 Gap Analysis and Recommendations

The requirement to obtain suitable river bacterial data will be driven by the requirement to undertake detailed assessments at Bathing and Shellfish Waters. This requirement is not yet fully understood: it will depend in part upon decisions as to which lagoon options are considered further in detail, and in part upon the results of the water quality screening assessment (not yet undertaken). The screening assessment will provide an indication of the potential impacts of the Project on local Bathing and Shellfish Waters. This in turn will define the level of detail required in any marine water quality assessment that follows.

In the event that a detailed assessment of bacterial water quality is required, it is considered that the study could be strengthened by targeted river water quality field surveys. In such a case, the outline survey scope presented in

Section 3.5.4 for chemical and nutrient determinands applies equally to bacterial determinands.

3.7 WASTEWATER (SEWAGE) DISCHARGE FLOWS

3.7.1 Requirement

Wastewater discharge flows are required to allow pollutant loads to the Severn Estuary and Bristol Channel to be accurately specified. They may also be of use if there is a requirement to calibrate or validate the coastal model on individual (e.g. storm) events.

Wastewater will discharge either direct to the estuary or to rivers that subsequently drain to the estuary. In the case of the latter, an understanding of wastewater discharges will also be of relevance to gaining a sufficient understanding of river flows and concentrations (which will incorporate both point sources such as WwTWs and diffuse runoff from agriculture).

3.7.2 Available Data

A distinction is made between various different types of wastewater discharge:

1) Continuous discharges from water company WwTWs. These provide one of the primary background loads of BOD, ammonia, nitrogen and phosphorus to the receiving waters.

2) Continuous discharges from private sources such as septic tanks, and possibly private WwTWs associated with developments such as caravan parks or golf courses.

3) Intermittent (storm) discharges from water company Combined Sewer Overflows (CSOs). These provide an additional load of pollutants during high rainfall. While infrequent and short in duration, these events can contribute a significant additional input.

4) Industrial/trade discharges, e.g. from factories, if these do not enter the main sewerage system.

3.7.2.1 Water company WwTWs

Databases of consented discharges have been obtained from NRW and the EA. These contain locations and consented (maximum) discharge flows for a number of private sources within the study area. The NRW/EA consents databases identify the locations and types of consented point source discharges, and give the maximum consented flow (which can be used as a conservative indicator of the actual or typical flow). However, these databases are not always entirely accurate.

The most detailed information on WwTW discharge flows will be provided by water company records and/or sewerage network models. These produce long-term time series of flow in response to various inputs such as daily patterns of water usage and intermittent rainfall events.

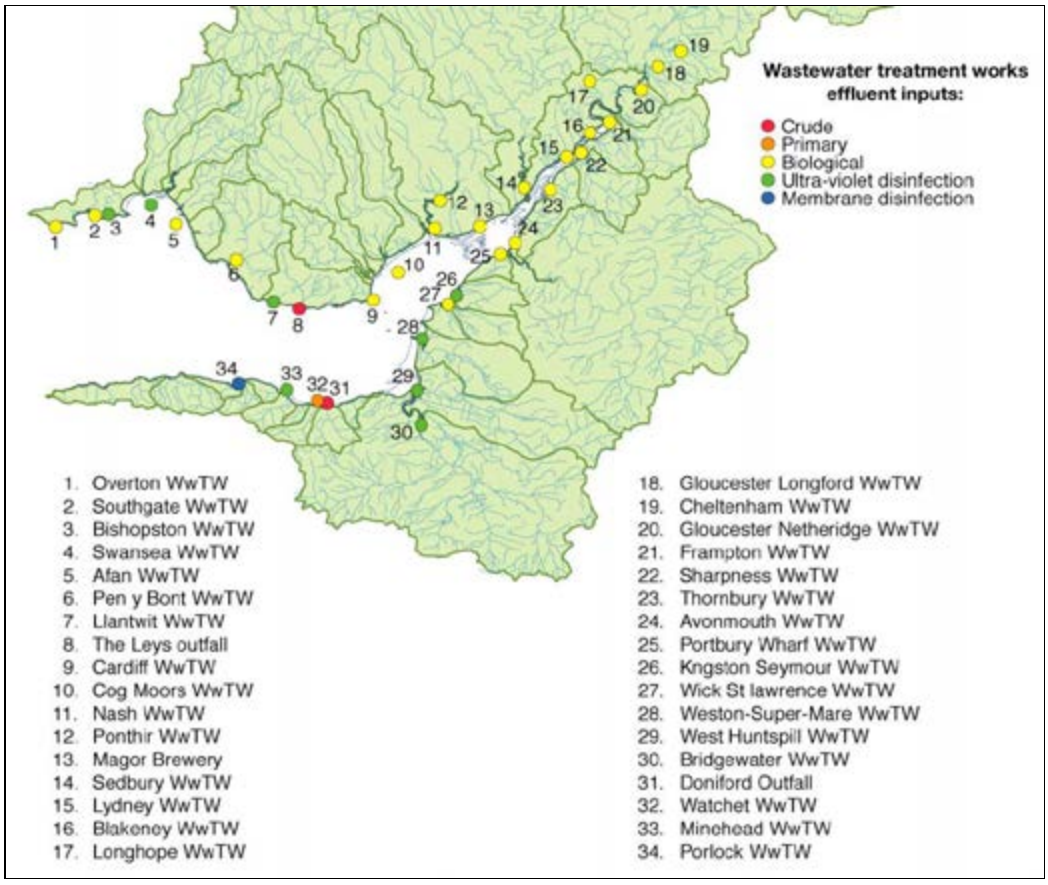
- Intertek can obtain network model output for the Swansea, Aberthaw, Cardiff West (Cog Moors WwTW), and Cardiff East/Central/St Mellons/Rhymney Valley/Western Valley (Cardiff WwTW) sewerage

catchments, based on previous studies undertaken for DCWW. A model is also available for the Newport catchment and a request for access has been made to DCWW. Information for other catchments along the coast has also been requested, e.g. Porthcawl/Bridgend and Llantwit Major.

- Wessex Water will be approached to establish what sewerage network information may be available for WwTWs on the English side of the estuary. These discharges are potentially very large since they will include significant urban areas such as Bristol, Avonmouth, Portishead, Clevedon, Weston-super-Mare etc.

Figure 3-14 gives an indication of the WwTWs that discharge to the Severn Estuary and Bristol Channel. Only the main WwTWs that serve populations of 2000 or more people are shown. The plot is taken from the EA's 2007 study into the fate and transport of particles in estuaries[10].

Figure 3-14: WwTWs discharging to the Severn Estuary/Bristol Channel



(Source: Environment Agency, 2007. Fate and transport of particles in estuaries. Volume IV: Numerical modelling for bathing water enterococci estimation in the Severn estuary. Science Report SC000002/SR4. March 2007.)

NB: Labels for 9 and 10, Cog Moors and Cardiff WwTWs, are transposed.

3.7.2.2 Private sources

Databases of consented discharges have been obtained from NRW and the EA. These contain locations and consented (maximum) discharge flows for a number of private sources within the study area.

Some smaller sources, such as private septic tanks, may not be included in these databases. Given the size of these discharges relative to (for example) WwTWs and rivers, for the most part these omissions can be ignored. However, in the case of sources that discharge in the near-field close to the lagoons, either directly or via rivers, it may be necessary to include them in the study. In such a situation, a study of maps and aerial/satellite imagery (e.g. using Google Earth) can identify dwellings that do not appear to be connected to sewer or included in the consents databases. Discharge flows can be estimated from dwelling size (i.e. population) and typical per-head-per-day production rates.

3.7.2.3 Water company CSOs

The most detailed information on CSO discharge flows will be provided by sewerage network models. These produce long-term time series of flow in response to various inputs such as daily patterns of water usage and intermittent rainfall events.

- As described in Section 3.7.2.1, Intertek can obtain network model output for a number of sewerage catchments, based on previous studies undertaken for DCWW. We have also applied for access to models of other catchments in the study area.
- Wessex Water will be approached to establish what sewerage network information may be available for WwTWs on the English side of the estuary. These discharges are potentially very large since they will include significant urban areas.

The extent to which CSOs need to be included in the study, and the manner in which they are represented, will depend in part upon their proximity to the Project or cumulative developments:

a) In the **near-field**, there will likely be a requirement to model CSO discharges explicitly using good time series flow data from verified sewerage network models.

b) In the **mid-field**, sewerage network model output should be used if available. Alternatively, it may be acceptable to estimate spill volumes based on catchment size (population) and use of a typical hydrograph from a modelled sewerage catchment. This latter approach should be treated with some caution since it relies on a number of assumptions. It is more suited to smaller catchments at some distance from the lagoons, where uncertainties in the approach are likely to be of limited significance to study results.

c) In the **far-field**, estimates of intermittent spill volume using the approach outlined above may be suitable. This approach allows intermittent spills to be included in the study without expending considerable effort on characterising CSOs that may be of minor or negligible significance. Alternatively, for CSOs that discharge to a river, it may be reasonable to model these discharges as part of the

river load rather than to separate them out and model them explicitly. Various analytical techniques exist to do this. Finally, it may be acceptable to ignore CSO discharges altogether (for example, if conservative screening runs indicate that these are of no relevance to the study).

3.7.2.4 Industrial/trade discharges

Databases of consented discharges have been obtained from NRW and the EA. These contain some information on industrial discharges to the Severn Estuary and Bristol Channel, but it is likely that there are omissions. It is considered unlikely that there will be significant industrial discharges within the Project area. It is recommended that further liaison with NRW and the EA is undertaken to identify any industrial sources considered to be significant; this may also include landfill site leachates.

3.7.3 Sufficiency of Data

Data on consented discharges have been obtained from NRW and the EA. Additional data are likely to be available from water companies. From consideration of the data already obtained and the data that are likely to be available, the following points may be made:

- There is likely to be sufficient information to characterise water company assets on the Welsh side of the estuary.
- Suitable information for water company assets on the English side of the estuary will exist, but it is presently unknown how easy this will be to obtain.
- The NRW and EA consents databases contain good information on discharges across the study area, but may suffer from a) occasional inaccuracies in the databases, and b) the conservatism inherent in using maximum consented flows rather than typical/mean flows.
- Some data on industrial discharges are available from the NRW and EA consents databases, but it is not clear how complete these are. Both NRW and the EA may be able to provide information on other industrial sources if these are believed to be of significance to the study. Even if other discharges are identified it may be difficult to obtain adequate information on their flows and loads.

3.7.4 Gap Analysis and Recommendations

It is considered likely that sufficient wastewater flow information will be available for the required studies. The greatest unknowns at the moment are the level of information that may be available from Wessex Water, and the level of information available on industrial discharges.

As such, wastewater flow surveys are not an anticipated survey requirement.

However, in order to counter some of the uncertainties that may exist in the data (for example, in the characterisation of industrial discharges), sensitivity testing would be undertaken on any discharges that:

- are identified as being potentially significant to the study; and
- have limited information available to characterise them.

Early screening runs would also be undertaken, in order to reduce as far as possible the number of discharges that will need to be considered in the later, more detailed phases of the assessment.

3.8 WASTEWATER (SEWAGE) QUALITY

3.8.1 Requirement

Wastewater discharge concentrations are required to allow the accurate characterisation of pollutant loads to the Severn Estuary and Bristol Channel. They may also be of use if there is a requirement to calibrate or validate the coastal model on individual (e.g. storm) events.

Wastewater will discharge either direct to the estuary or to rivers that subsequently drain to the estuary. In the case of the latter, an understanding of wastewater discharges will also be of relevance to gaining a sufficient understanding of river flows and concentration (which will incorporate both point sources such as WwTWs and diffuse runoff from agriculture).

3.8.2 Available Data

3.8.2.1 Water company WwTWs

The following data sources are available to help characterise pollutant concentrations (chemical, nutrient and bacterial) from water company WwTWs:

- Measured concentrations from the Final Effluent (FE). DCWW and Wessex Water will be approached for information on FE measurements at their WwTWs. It is anticipated that sampling data will be available for some, but not all, WwTWs. Some determinands, such as BOD, ammonia and suspended solids, will typically need to be measured as part of the WwTW's consent conditions. Full consents databases have been obtained from NRW and the EA. Other determinands, such as bacteria, will generally be sampled on a more ad hoc basis, unless the WwTW FE undergoes ultra-violet (UV) disinfection in which case bacterial data should be available from UV efficacy monitoring.
- Concentration values applied in previous studies that Intertek has undertaken for DCWW, for example in the Cardiff area. Microbiological data are available for the Cardiff and Swansea catchments. Broader water quality data are available from a previous study of the Loughor Estuary, and nutrient data are available for Swansea Bay. CREH will be consulted on potential data from studies of other catchments, e.g. historic studies for the Bridgend (Pen-y-bont) catchment. Pollutant sampling is also believed to have been undertaken in the Cardiff West catchment in 2003/4.
- Default concentrations assigned to each WwTW on the basis of treatment type and other considerations. Representative default values will be derived from:
    - data measured at other WwTWs in and around the study area, particularly in Wales where Intertek has undertaken much previous work for DCWW;

- data measured elsewhere throughout the UK (again, Intertek has built up a large database of typical concentrations over the years); and
- concentration values reported in the scientific literature, with a strong preference for those based on actual observations rather than theoretical considerations.

3.8.2.2 Private sources

Private sources such as septic tanks are generally not monitored for water quality. Discharge concentrations will therefore be assigned based on:

- consideration of consented limits, where relevant, accepting that these may be conservative compared to typical operational values; and
- default values determined from consideration of the treatment type plus a database of FE monitoring data from other locations and from the scientific literature.

3.8.2.3 Water company CSOs

CSO pollutant concentrations are generally not measured, except perhaps occasionally on an ad hoc basis (normally as part of a specific investigative study or in response to a perceived problem). Discharge concentrations will therefore be based on:

- any locally measured data, should these exist;
- any data collected in support of the tidal lagoons study, if such measurements are deemed necessary once all existing data have been fully collated and evaluated;
- data collected at WwTWs (preferably from the influent) during high flow / wet weather conditions, since these may be taken to indicate storm flow conditions within the sewerage network;
- concentration values applied in previous studies that Intertek has undertaken for DCWW, for example in the Swansea, Loughor and Cardiff area; and
- default concentrations based on values measured in and around the study area, elsewhere in the UK, or reported in the scientific literature.

3.8.2.4 Industrial/trade discharges

Databases of consented discharges have been obtained from NRW and the EA. These contain some information on industrial discharges to the Severn Estuary and Bristol Channel, but it is likely that there are omissions. Consent limits are likely to be conservative since they represent the upper end of the allowable discharge concentrations.

It is considered unlikely that there will be significant industrial discharges within the Project area. It is recommended that further liaison with NRW and the EA is undertaken to identify any industrial sources considered to be significant; this may also include landfill site leachates. In the event that suitable data are not available and a discharge is judged to be a potentially significant impacter, some monitoring or further work may be required to effectively characterise the discharge.

3.8.3 Sufficiency of Data

Data on consented discharges have been obtained from NRW and the EA. Additional data are likely to be available from water companies. From consideration of the data already obtained and the data that are likely to be available, the following points may be made:

- it is considered likely that sufficient information will exist to characterise discharge concentrations for the majority of the key discharges;
- discharge consent limits will tend to be conservative compared to actual concentrations;
- good sampling data may not be available for all required water quality determinands;
- there is likely to be little measured information for individual CSOs or private discharges, so generic defaults will have to be adopted; and
- industrial discharges are presently an unknown, and due to the range of industries and processes that may generate pollutants it may not be possible to estimate default concentrations in the same way as for sewage discharges.

3.8.4 Gap Analysis and Recommendations

It is possible that there will be a need for targeted sampling of discharge concentrations. This will be focused on:

- large (in terms of load) discharges to the near- and possibly mid-fields;
- discharges (e.g. industrial) where default concentrations cannot be estimated reliably; and
- water quality determinands that are considered to be most relevant to the study (for example, it may not be necessary to undertake bacterial sampling if screening runs suggests that Bathing Waters and Shellfish Waters are unlikely to be affected by the Project).

Other study approaches exist that could reduce or replace the need for additional sampling. For example, explicitly conservative discharge concentrations can be adopted. The disadvantage of this approach is that environmental impacts may be overestimated. Furthermore, identifying which discharges cause the greatest impact may be problematic, since there will be a skew towards those discharges modelled conservatively as compared to those modelled with more realistic loads.

Additionally, sensitivity testing offers a means for establishing whether the precise definition of discharge loads is of key importance to the study. A level of sensitivity testing can be undertaken during the screening assessments. If this testing indicates that impacts are relatively unresponsive to the pollutant loads released from certain discharges, it may be acceptable to adopt approximate or conservative concentrations for these, rather than put a lot of effort into trying to characterise them in detail.

3.9 MARINE WATER QUALITY – CHEMISTRY AND NUTRIENTS

3.9.1 Requirement

Data on the chemical and nutrient properties of the Severn Estuary and Bristol Channel, plus associated physical properties of the water column, are required by the study for:

- establishing a baseline against which the potential impacts of the Project can be evaluated;
- specifying offshore boundary conditions for the marine water quality model;
- setting initial background concentrations in the marine water quality model; and
- calibrating and validating the marine water quality model.

Various physical, nutrient and chemical determinands are of interest to the study, including:

- salinity (this may also be covered by ABPmer's inputs);
- temperature (this may also be covered by ABPmer's inputs);
- pH;
- Secchi depth;
- chlorophyll;
- algal mass (counts);
- phytoplankton mass (counts);
- BOD;
- DO;
- phosphorus – DAIP;
- nitrogen – DAIN as ammonia, nitrite and nitrate;
- suspended solids (this will also be covered by ABPmer's inputs);
- turbidity (this will also be covered by ABPmer's inputs); and
- conservative pollutants such as heavy metals and TBT.

The water quality assessment may also require an understanding of sediment interactions – for example, the role that Sediment Oxygen Demand (SOD) has on DO levels. Intertek will liaise with ABPmer in order to ensure that any such interactions are modelled robustly and consistently within the study.

3.9.2 Available Data

3.9.2.1 NRW/EA nutrient sampling

Historic marine water quality monitoring data have been obtained from NRW and the EA. Data are collected both during routine monitoring and during ad hoc surveys.

The data sets obtained from NRW and the EA show a large number of locations where marine water quality monitoring has been undertaken, covering a variety of important determinands. Note, however, that some of these sites hold only a small number of data.

The following Figures (in Section 3.5.2.1) present an overview of the availability of chemical and nutrient monitoring data for both freshwater and saline water locations in the study area, based on data obtained from NRW and the EA:

- Figure 3-5 shows locations where DAIN measurements have been obtained.
- Figure 3-6 shows locations where DAIP measurements have been obtained.
- Figure 3-7 shows locations where DO, BOD and COD measurements have been obtained.
- Figure 3-8 shows locations where measurements of various metals have been obtained.
- Figure 3-9 shows locations where water temperature measurements have been obtained.
- Figure 3-10 shows locations where pH measurements have been obtained.
- Figure 3-11 shows locations where salinity measurements have been obtained.
- Figure 3-12 shows locations where chlorophyll measurements have been obtained.

In general, there is a reasonable spread of chemical and nutrient monitoring locations through the study area, although there are only limited data in the offshore areas of the outer Bristol Channel. This may limit their usefulness for providing offshore boundary conditions for the water quality model.

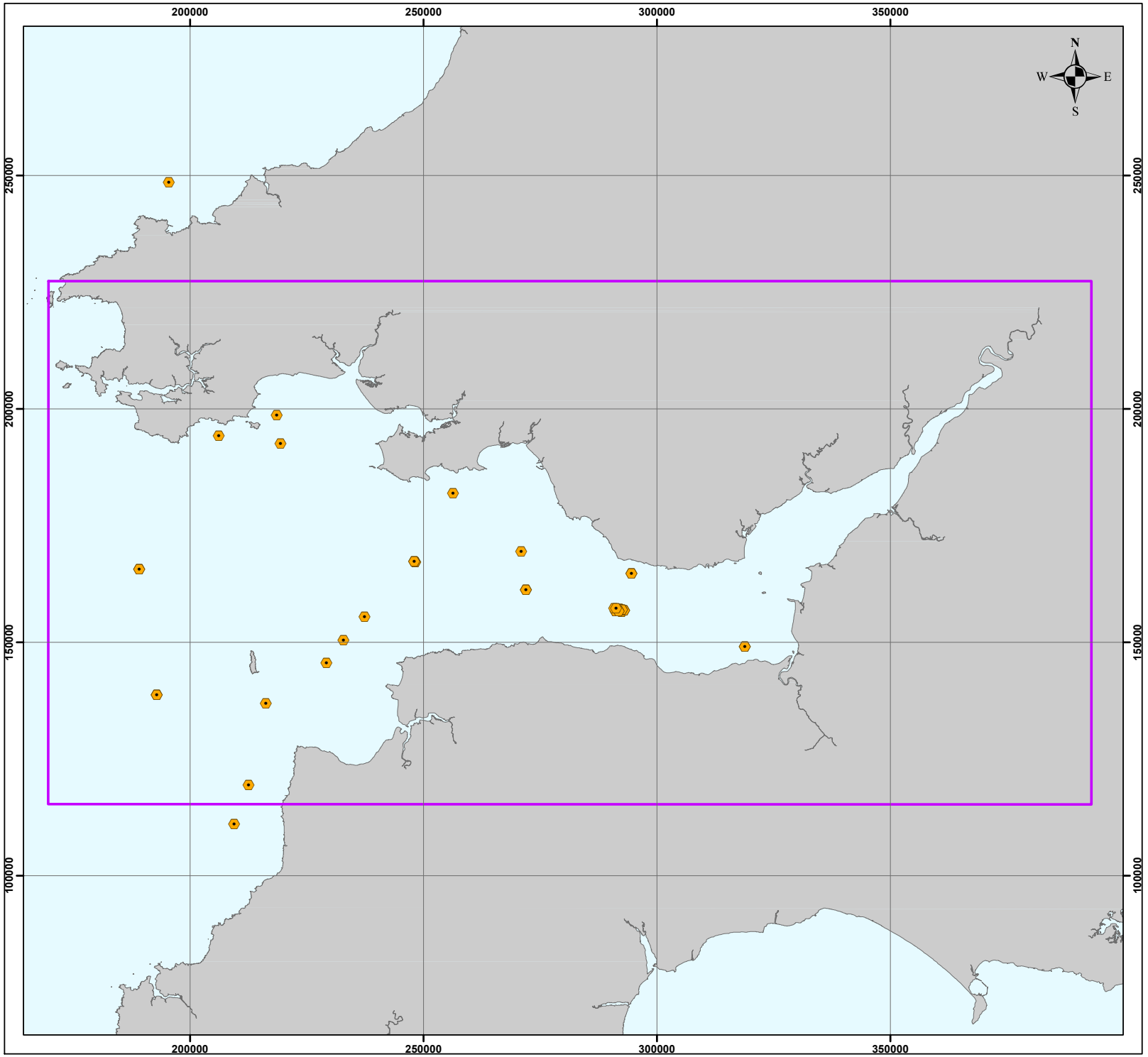
3.9.2.2 BODC MERMAN database

Additional water quality sampling data are available from BODC's Marine Environment Monitoring and Assessment National database (MERMAN). MERMAN holds water quality data collected under the Clean Seas Environment Monitoring Programme (CSEMP), which was previously known as the National Marine Monitoring Programme[5] (NMMP). CSEMP fulfils the UK's marine monitoring requirements as laid out under the Oslo and Paris Convention (OSPAR).

The NMMP/CSEMP data are mostly in the outer part of the Bristol Channel and are therefore of greatest potential use in defining background water quality

concentrations and model boundary conditions. Figure 3-15 plots the locations of available data.

The same NMMP/CSEMP data are accessible through other online portals, including those provided by the International Council for the Exploration of the Sea (ICES) and the European Marine Observation and Data Network (EMODnet). These portals may hold some additional monitoring data of use to the Project.



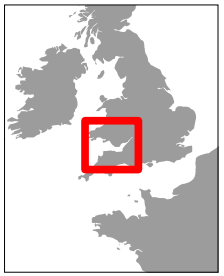
Contains Ordnance Survey data © Crown copyright and database right 2013

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-15: Water quality sampling data available from BODC MERMAN

Legend

- BODC MERMAN Sample Locations
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

Intertek

Natural Quality Delivered

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3.9.2.3 Bristol Channel Project

BODC also holds data from the Bristol Channel Project. These data have been obtained by Intertek.

The Bristol Channel Project was a study of the Bristol Channel and Severn Estuary coordinated by the Natural Environment Research Council (NERC) Institute for Marine Environmental Research (now Plymouth Marine Laboratory). The study comprised over 100 cruises undertaken between 1970 and 1983.

Data were collected on a range of physical and chemical parameters including temperature, salinity, chlorophyll, dissolved organic carbon, suspended matter, nutrients, DO and plankton. In total, almost 15,000 station profiles, almost 35,000 water samples (covering 34 parameters) and over 2,000 Secchi disk depths were obtained.

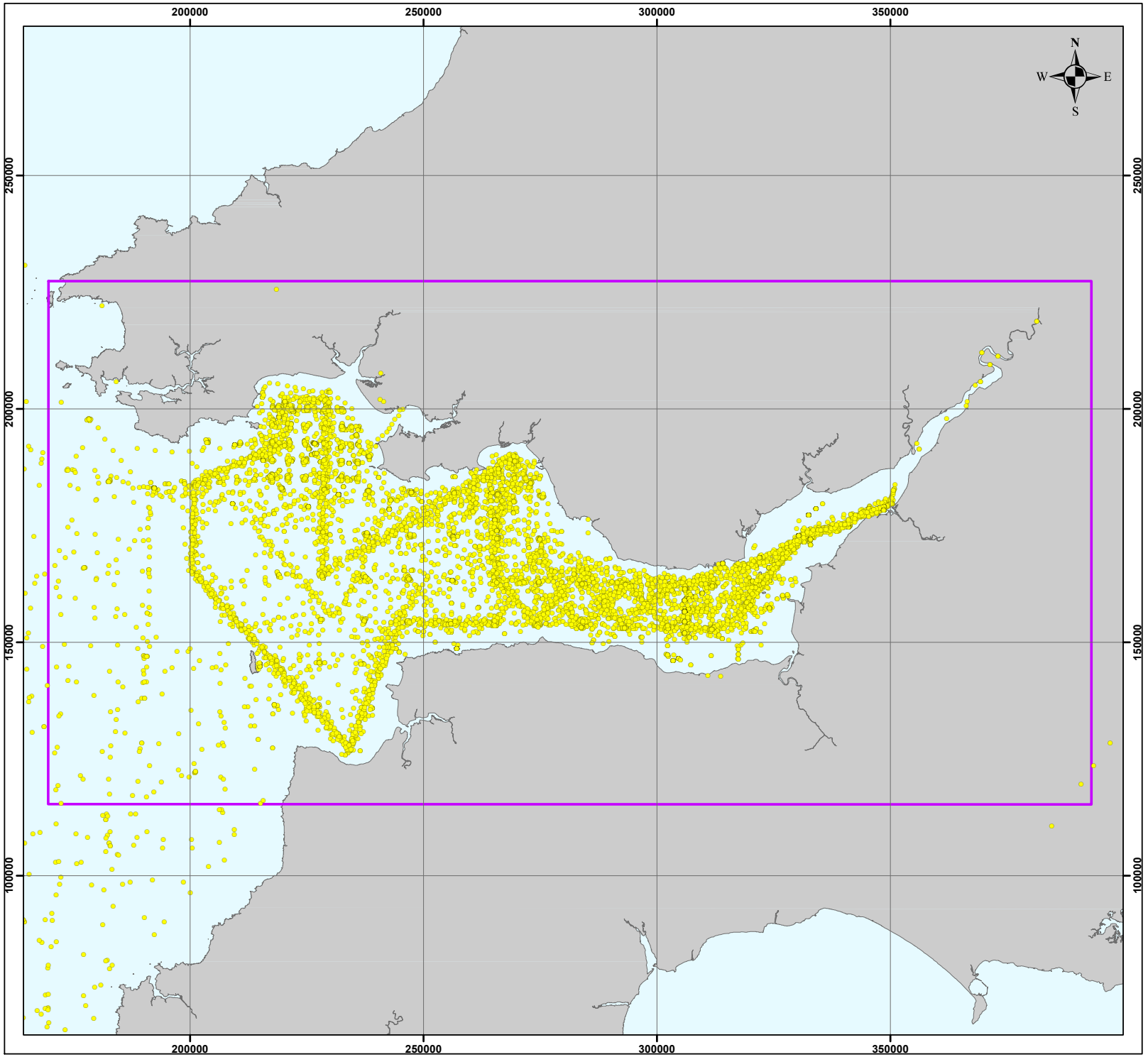
The following Figures give an overview of the coverage of the Bristol Channel Project data set, covering selected water quality determinands:

- Figure 3-16 shows locations where nutrient or DO monitoring was undertaken. The nutrient determinands measured include dissolved ammonium, dissolved nitrite, dissolved nitrate plus nitrite, dissolved total nitrogen, dissolved phosphate and dissolved total phosphorus.
- Figure 3-17 shows locations where monitoring of metals was undertaken. The metals considered were the dissolved fractions of cadmium, copper, manganese, lead and zinc.
- Figure 3-18 shows locations where temperature or salinity monitoring was undertaken.

There are few data in the upper reaches of the Severn Estuary but good spatial coverage in the middle and outer parts of the Bristol Channel.

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

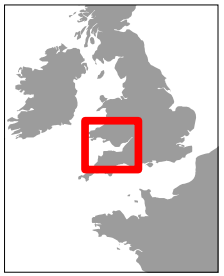
Figure 3-16: Bristol Channel Project nutrient and DO sampling sites



Legend

Bristol Channel Project sampling site

- Bristol Channel Project sampling site
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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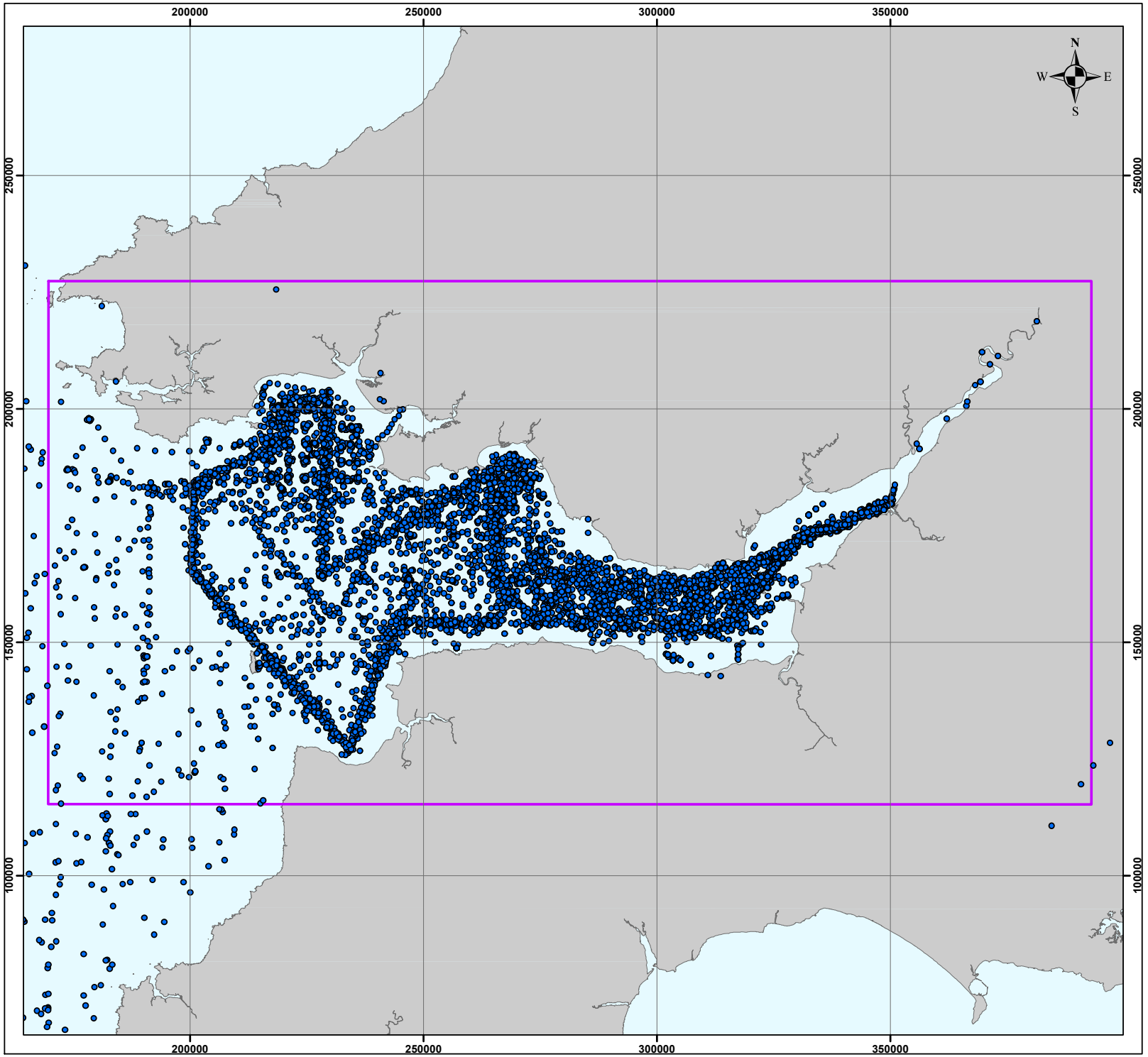
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

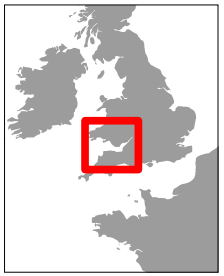
Figure 3-17: Bristol Channel Project metal sampling sites



Legend

Bristol Channel Project sampling site

- Bristol Channel Project sampling site
- Study Area



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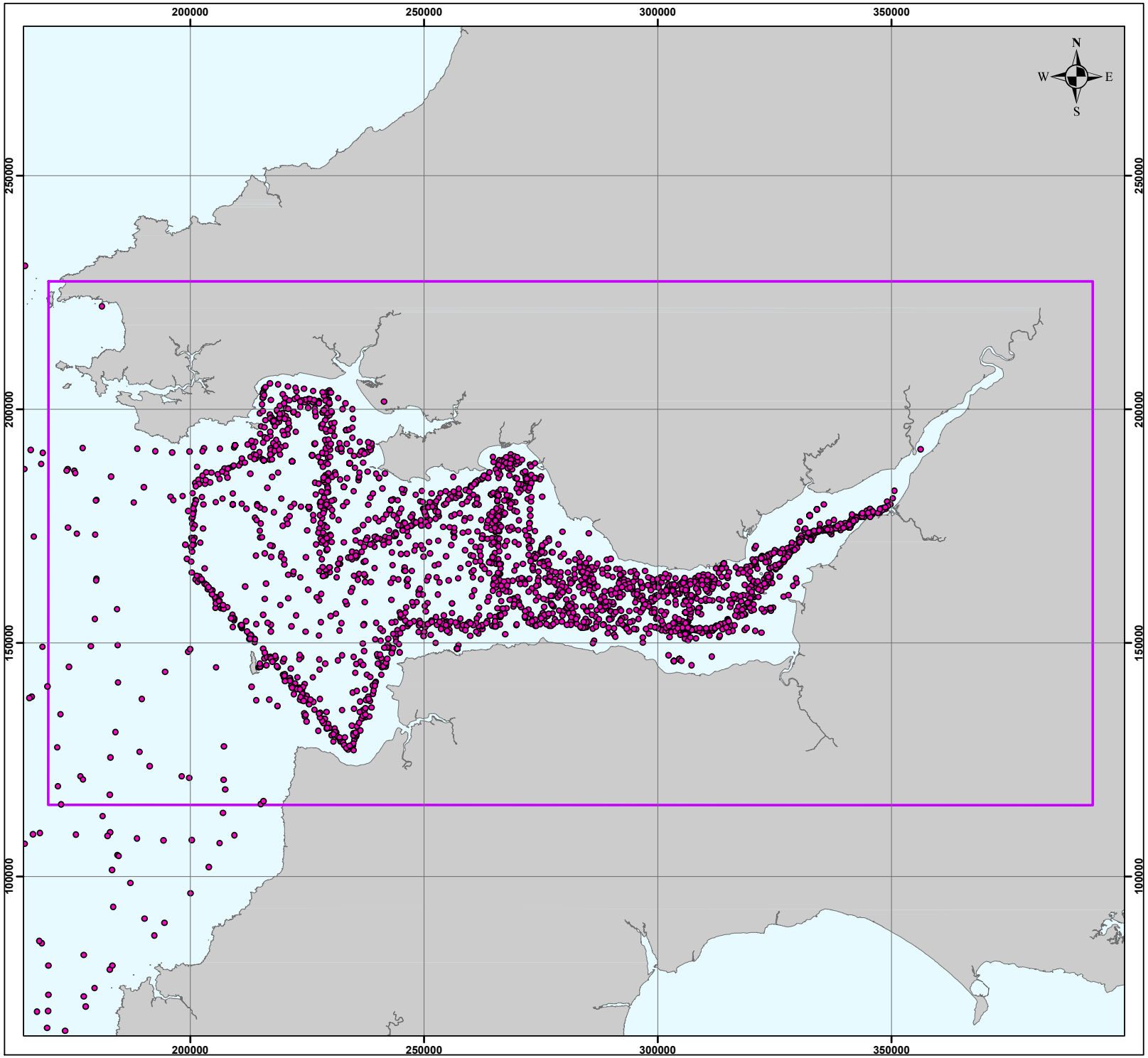
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

0 10 20 30 40 km

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

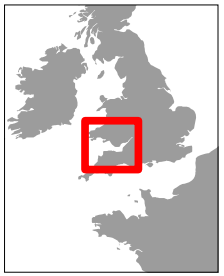
Figure 3-18: Bristol Channel Project temperature and salinity sampling sites



Legend

Bristol Channel Project sampling site

- Salinity and Temperature
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

Intertek

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3.9.2.4 Other data sources

Further marine water quality sampling may be available from universities or Cardiff Harbour Authority. Cardiff Harbour Authority holds a lot of data on water quality in Cardiff Bay, which discharges adjacent to the Project. These providers will be approached to see if their data will add substantively to the data sets already obtained.

3.9.3 Sufficiency of Data

The marine water quality data sets obtained to date offer a good geographical spread across the study area. However, a number of potential deficiencies are identified:

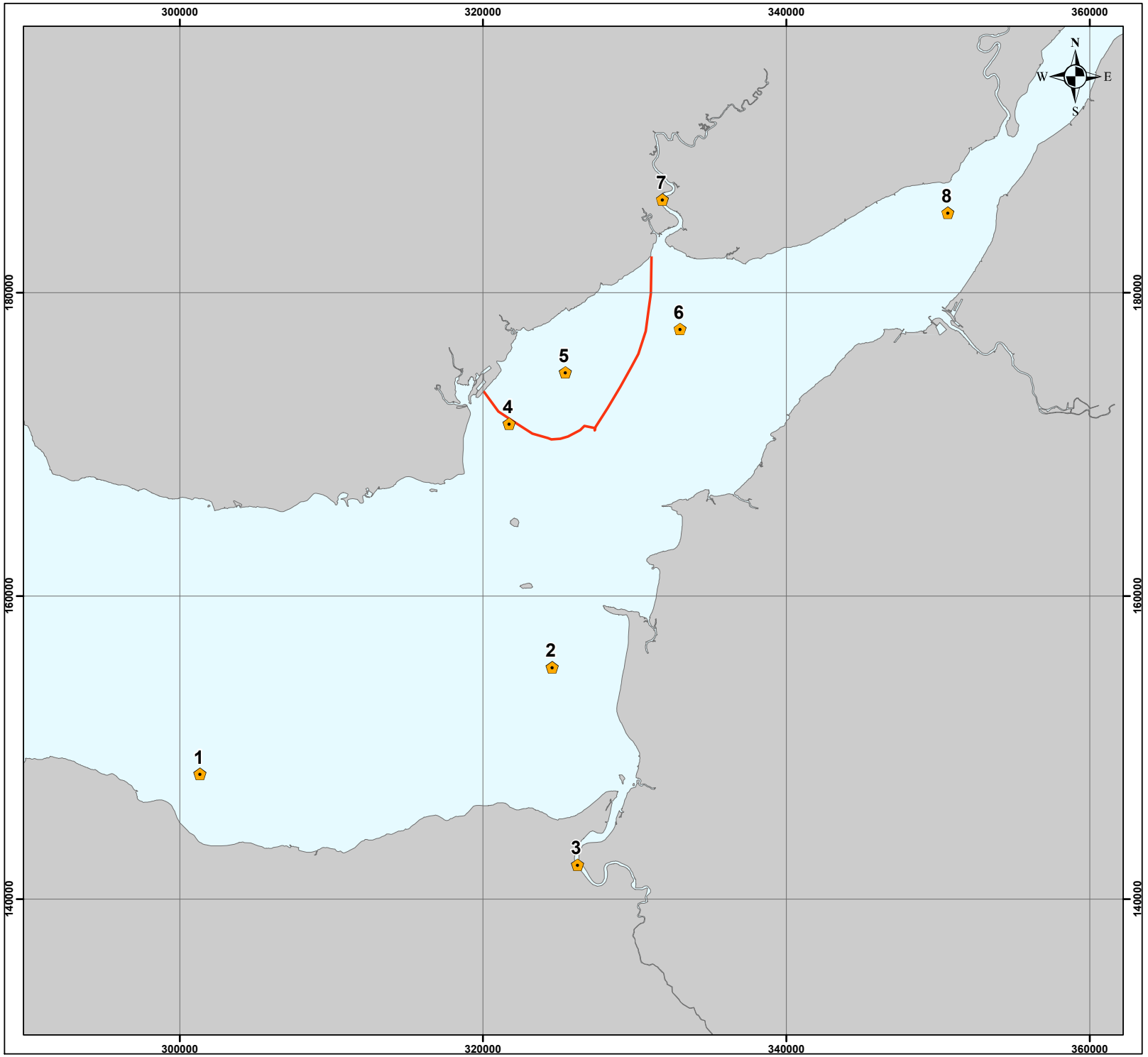
- The various data sets cover a range of locations, points in time and water quality determinands. Some determinands are very well represented in terms of Project requirements while others are less well represented, particularly in the near and mid-fields.
- The existing data may be insufficient to adequately describe seasonal cycles in water quality determinands such as nutrients, algae, chlorophyll and phytoplankton.
- Some of the data sets, particularly the Bristol Channel Project, are relatively old and may not accurately represent current inputs to the Severn Estuary and Bristol Channel. For example, changes in sewage treatment levels and farming practices may have altered nutrient inputs to the marine environment since the 1970s/early 1980s.

3.9.4 Gap Analysis and Recommendations

The existing data sources provide a good basis for the water quality assessment but do not fulfil every requirement of the Project. This presents a risk in terms of the technical quality of the water quality assessment, and also the acceptability of the assessment to Regulators and other stakeholders.

A programme of marine water quality field surveys will be undertaken in support of the Project. Given that a number of other oceanographic surveys are currently scheduled, the water quality sampling will be carried out to coincide with these. This will provide some essential model validation data which may not be available from other sources.

Following an initial review by Intertek, an outline scope for water quality sampling was drawn up and passed to TLP. This has been incorporated into a survey Technical Specification[6]. Figure 3-19 shows the proposed oceanographic and water quality survey locations. These are subject to change on further analysis by the Contractor e.g. navigational constraints.

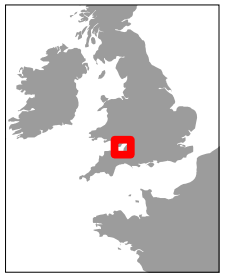


SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 3-19: Proposed locations for oceanographic and water quality surveys

Legend

- Survey Sites
- Cardiff Lagoon



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File Reference	J:\P1914\Mxd\Report\ Fig3_19_Survey_Locations.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

[redacted]

km
0 2 4 6 8

The following are incorporated in the latest survey Technical Specification:

- The coverage of the survey is considered sufficient to provide sample data around the key areas of interest.
- For the purposes of the water quality study, key water quality, nutrient and potentially phytoplankton data will be obtained at the identified sample sites (1 to 8).
- Water samples will be collected at hourly intervals at multiple depths (near-surface, mid-depth and near-bed) for sites 1, 2, 4, 6 and 8. These should be analysed for salinity, temperature, phosphorus (DAIP), nitrogen (DAIN as ammonia, nitrite and nitrate), BOD, DO, suspended solids, turbidity and chlorophyll a. Secchi depth will also be measured at each site.
- The potential requirement for phytoplankton specific surveys is discussed further in Chapter 12 Intertidal and Subtidal Benthic Ecology.
- For the remaining sites (3, 5 and 7), surface water quality samples will be collected at hourly intervals and analysed for salinity, temperature, phosphorus (DAIP), nitrogen (DAIN as ammonia, nitrite and nitrate), BOD, DO, suspended solids, turbidity, chlorophyll and algal mass. Secchi depth will also be measured at each site.
- The requirement for 30-minute sampling at site 6 is not considered necessary for water quality assessments.
- A second sample replicate will be collected which should be filtered, frozen and stored. This sample could then be used for later analysis of conservative determinands such as heavy metals if required.
- A second set of samples taken at the same locations in winter (December to February) will be undertaken, in addition to the summer surveys.
- Collection and storage protocols and minimum detection limits will be confirmed with NRW and the EA for all determinands prior to sampling and analysis.

We recommend the use of EA's Exeter laboratory for analysis, as this is relatively close and is accredited to the detection levels usually required by NRW and the EA.

We further recommend a series of surveys, with samples collected throughout the year to allow seasonal trends to be established. As a minimum, nutrient surveys should be conducted in winter.

Where feasible it is recommended that concurrent surveys be conducted in the larger rivers, particularly those that may be directly affected by the Project. These surveys will concentrate on key pollutants/determinands; phytoplankton surveys are not required in the rivers.

3.10 MARINE WATER QUALITY – BACTERIA

3.10.1 Requirement

Marine bacteria concentrations may be of use to the study for the following reasons:

- to provide a baseline against which the potential impacts of the Project may be assessed; and
- to allow calibration and validation of the marine water quality model.

It is undetermined at this stage to what extent bacterial impacts may be an issue to the Project. The key sensitive receivers in terms of bacterial concentrations are Bathing and Shellfish Waters/Shellfish Harvesting Areas. In the case of the Cardiff lagoon, the nearest such sensitive receivers are the Bathing Waters near Barry, which may be sufficiently distant that they are not affected by the Project. Screening model runs will be required in order to establish the likely effect of the Project on these sensitive receivers, and the requirement for considering them in detail during the water quality assessment.

3.10.2 Available Data

3.10.2.1 Bathing Water monitoring

Bacterial sampling data are available for all designated Bathing Waters. 20 samples per summer are obtained by NRW/EA, and most Bathing Waters will have 20 or more years of data available. However, it will only be appropriate to use those data which are representative of the present environment – for example, samples collected prior to significant upgrades in the local wastewater infrastructure will be discarded.

Table 3-1 lists the designated Bathing Waters in the vicinity of the study area. These are plotted on Figure 5-2 in Section 5.1.

Table 3-1: Bathing Waters in the vicinity of the Project

Bathing Water	Designated	E	N
Minehead Terminus	1988	297614	146397
Dunster North West	1988	299707	145647
Blue Anchor West	1988	302161	143509
Burnham Jetty North	1988	330322	148972
Berrow North of Unity Farm	1988	329114	154114
Brean	1988	329600	158500
Weston-super-Mare Uphill Slipway	1988	331092	158867
Weston Main	1988	331600	160700
Weston-super-Mare Sand Bay	1988	332838	163267
Clevedon Beach	1988	339914	171322
Jackson's Bay Barry Island	1988	312200	166570
Whitmore Bay Barry Island	1988	311450	166250
Cold Knap Barry	1988	309854	166455

3.10.2.2 Shellfish Water and Shellfish Harvesting Area monitoring

Designated Shellfish Waters are monitored for bacterial concentration. Typically just four samples are collected per year. This provides a useful indication of water quality but is too small a data set for use in water quality model calibration, or to determine long-term performance and trends. Bacterial sampling data have been obtained from NRW and the EA.

The nearest Shellfish Waters are Swansea Bay on the Welsh coast and Taw/Torridge on the English coast. Locations are shown in Section 5.1, Figure 5-1 and Figure 5-2. The closest Shellfish Water, Swansea Bay, is approximately 60 km from the Cardiff lagoon. This may be sufficiently distant that the Project will have only small or negligible impacts on the Shellfish Waters.

Shellfish Harvesting Areas (strictly Designated Bivalve Mollusc Production Areas) are found at specifically designated locations within the Shellfish Waters. Classifications (A, B, C or Prohibited) are assigned annually for each harvested species, based on sampling of bacterial concentrations in the shellfish flesh and intravalvular fluid. Intertek has obtained annual classifications dating back to 2000. The actual concentration data on which these classifications are based are available from the Centre for Environment, Fisheries and Aquaculture Science (Cefas). Shellfish flesh monitoring data are considered to be of limited value to the Project because:

- The link between shellfish flesh quality and Shellfish Water quality is complex and not fully understood, which means that shellfish flesh quality is of limited use as a model calibration parameter.
- The closest harvested beds to the Project are in Swansea Bay 60 km away.

3.10.2.3 EA research study

In 2007 the EA published a report into the fate and transport of particles in estuaries[7,8,9,10]. This investigated the physical and biological processes affecting bacterial concentrations in the Severn Estuary and Bristol Channel. Through fieldwork sampling and laboratory analysis, useful data were obtained for a number of key parameters, including:

- turbidity;
- suspended solids concentration and particle size distribution;
- bacterial concentration; and
- bacterial decay rates in seawater.

The findings of this study will be considered during the Project water quality assessment.

3.10.3 Sufficiency of Data

Bathing Water monitoring data represent a robust source of water quality information. They allow model predictions to be compared against a long-term statistical distribution of bacterial concentrations. However, the sampling frequency (roughly one sample every two weeks) does not allow the analysis of water quality variation over short timescales such as a tidal cycle.

3.10.4 Gap Analysis and Recommendations

As an indicator of long-term water quality performance, the Bathing Water bacterial monitoring data cannot be improved upon by any realistic sampling programme. They are considered sufficient for the purposes of assessing potential impacts arising from the Project.

However, if the opportunity arises, there might be value in obtaining additional bacterial concentration data in conjunction with other surveys that are planned in support of the Project. These data would contribute to an understanding of spatial and temporal patterns of estuarine water quality, and would provide additional confidence in model outputs. A targeted monitoring program would aim to provide:

- time series of varying concentration across a tidal cycle, at one or more carefully selected locations within the estuary; and
- spot samples from different locations within the estuary in order to assess spatial variability and the extent of impacts.

4 SURVEY REQUIREMENTS

Based on information available at present, the Project water quality assessment will benefit from various supporting field surveys. These are summarised below; the referenced report Sections should be consulted for more detail.

Refinement of the survey scope may be possible based on the outputs of water quality screening model runs. These runs have not been undertaken at the time of writing. The screening runs will help to establish the potential spatial extent of Project impacts, and may remove some discharges, water quality determinands, or sensitive receiving waters (e.g. Bathing or Shellfish Waters) from further detailed consideration.

- River water quality (see Sections 3.5.4 and 3.6.4). Potentially in major rivers and rivers close to Project locations.
- Wastewater quality (see Section 3.8.4). Presently considered unlikely.
- Marine water quality – chemistry and nutrients (see Section 3.9.4). Likely to be required for establishing baseline conditions. Long-term monitoring may also be required to support Management Plans or mitigation options.
- Marine water quality – bacteria (see Section 3.10.4). Presently considered unlikely.

5 HIGH LEVEL REVIEW

5.1 SENSITIVITIES

Numerous sensitive receivers exist within the Severn Estuary and Bristol Channel. These will all be considered as part of the water quality assessment.

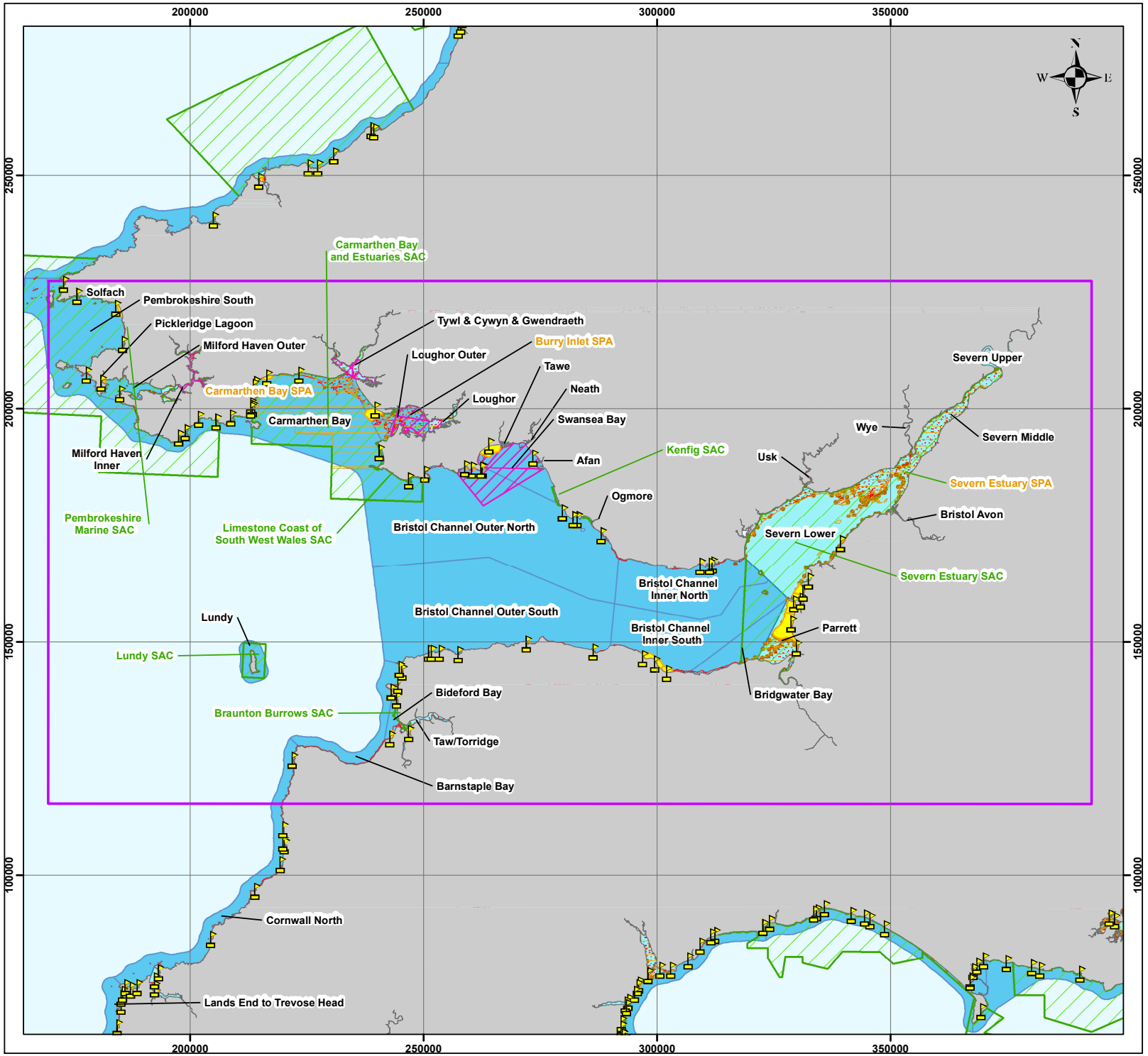
Figure 5-1 shows designated areas within the study area, as well as coastal and transitional waterbodies as defined by the WFD.

Figure 5-2 shows just the Bathing and Shellfish Waters plus eutrophic sensitive areas and saltmarsh extents.

Figure 5-3 plots the waterbodies in the study area as defined by the WFD. The plot shows the coastal and transitional waterbodies, but also the inland river and lake waterbodies. This is because there is a requirement as part of the WFD assessment to look at both directly affected waterbodies and any connected waterbodies.

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

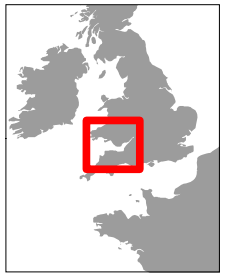
Figure 5-1: Designated areas and coastal/transitional WFD waterbodies



Contains Ordnance Survey data © Crown copyright and database right 2013

Legend

- Bathing Water Points
- Study Area
- Bathing Waters
- Shellfish Waters
- SAC
- SPA
- SSSI
- RAMSAR
- WFD Transitional Waterbodies
- WFD Coastal Waterbodies



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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Value Quality Delivered

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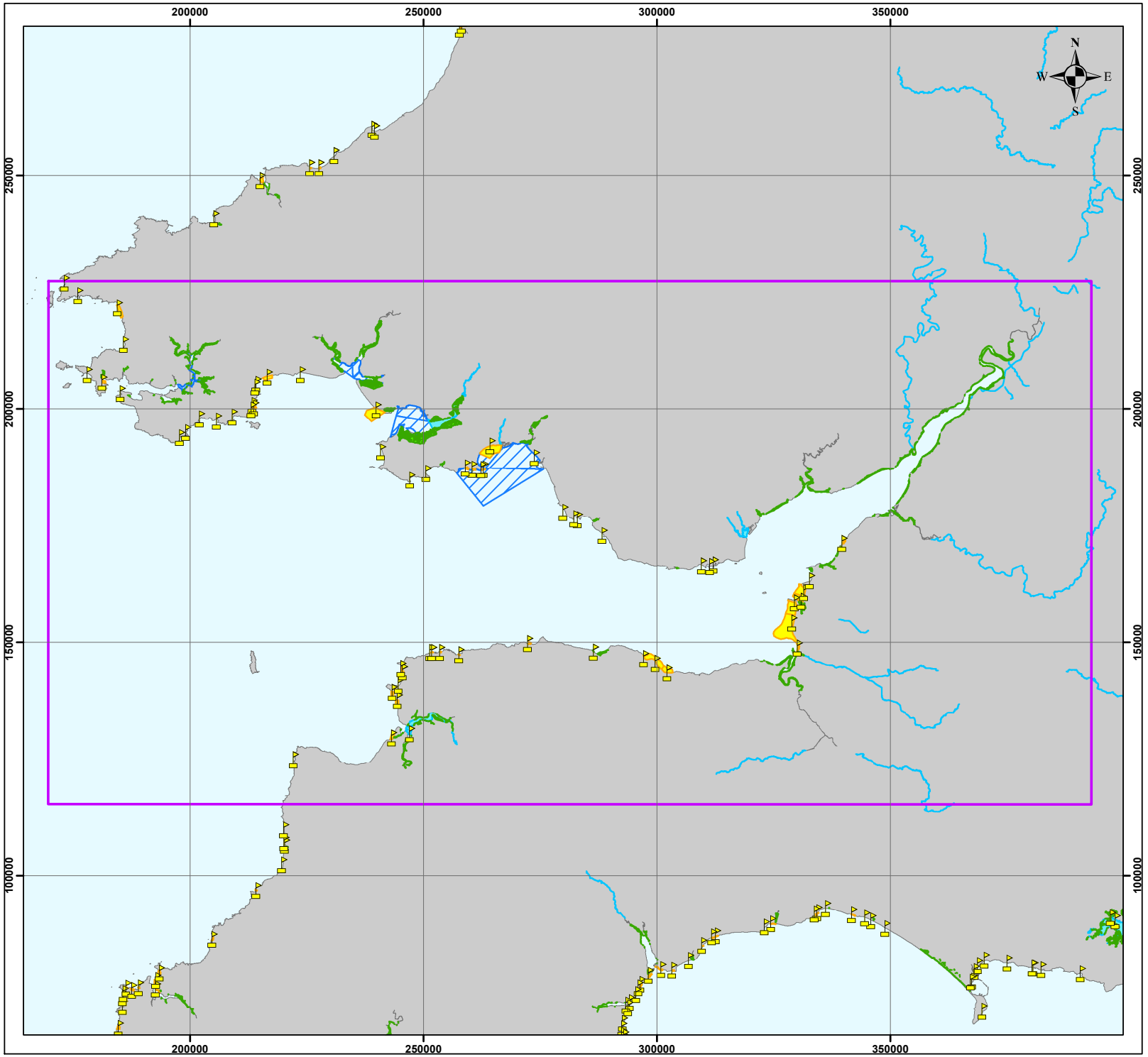
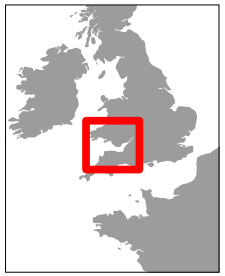
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-2: Bathing and Shellfish Waters, eutrophic sensitive areas and saltmarsh extents



Legend

- Bathing Waters
- River Eutrophic Sensitive Areas
- Saltmarsh Extents
- Coastal Eutrophic Sensitive Areas
- Bathing Waters Sensitive Areas
- Shellfish Waters
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

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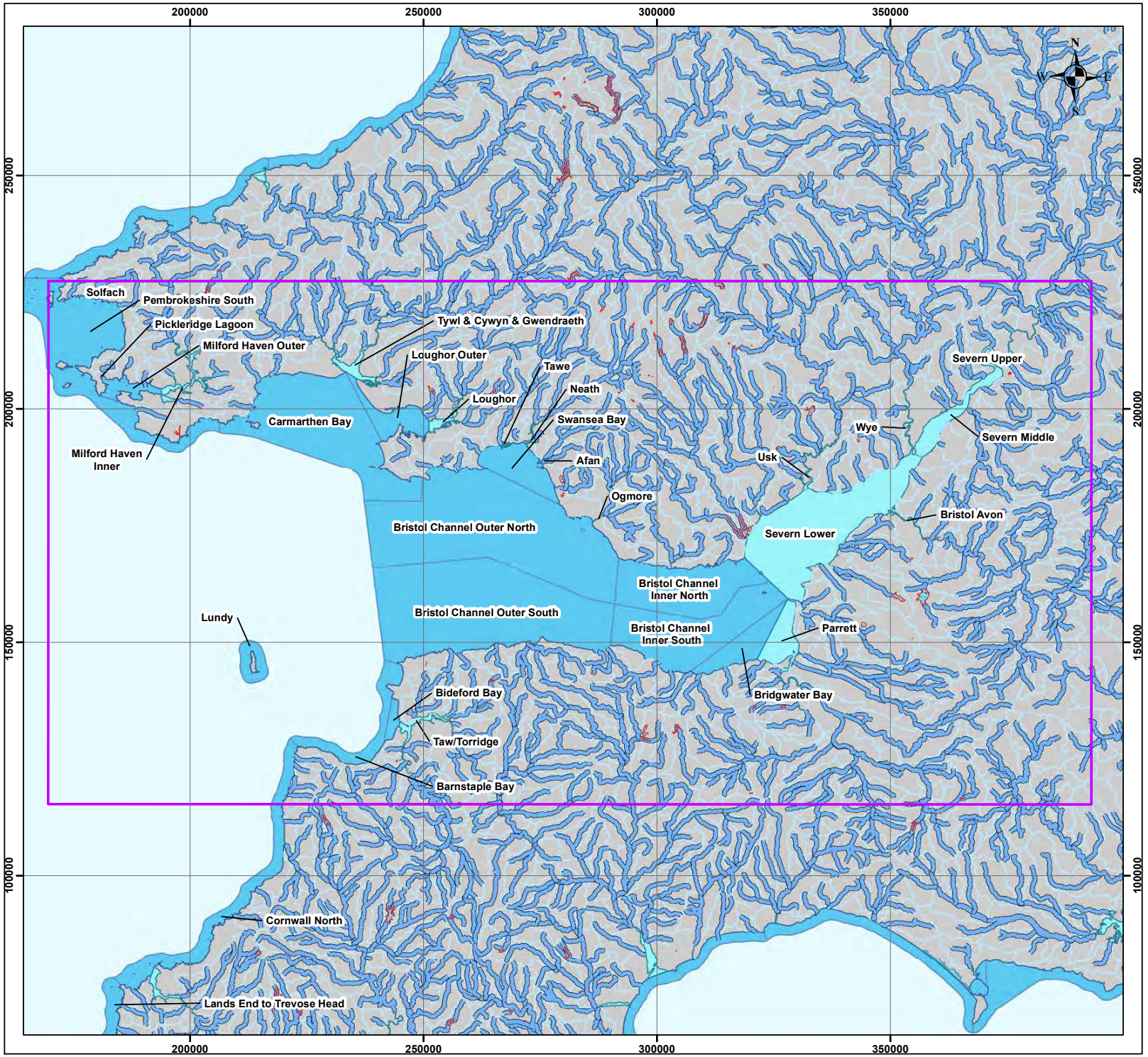
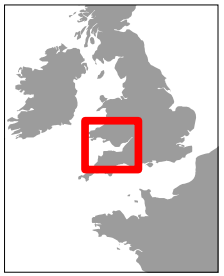
SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-3: WFD waterbodies



Legend

- WFD Lake Waterbodies
- WFD River Waterbodies
- WFD River Catchements
- WFD Transitional Waterbodies
- WFD Coastal Waterbodies
- Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

Intertek

Natural Quality Delivered

0 10 20 30 40 km

The various sensitive receivers will be affected to different extents by the Project. The likely impact of the Project on each sensitive receiver will depend on a number of factors, including:

- distance from Project;
- likelihood of water quality impact;
- key water quality determinands and processes for each sensitive water; and
- known water quality issues and/or present performance.

A preliminary review has been undertaken to establish which sensitive receivers are likely to experience significant water quality impacts (either negative or positive) due to the Project. They have been assigned an indicative ranking of: **high** potential impact; **moderate** potential impact; **low** potential impact (which includes negligible impacts). This will allow the focus of future investigations to be targeted towards the most critical receiving waters.

The preliminary review of sensitive waters is presented in Table 5-1. The following criteria have been evaluated:

- Approximate distance from the Cardiff lagoon.
- Relative magnitude of hydrodynamic impact. This is based on the initial investigations undertaken by ABPmer using the hydrodynamic/coastal processes model. An approximate magnitude (high, medium or low) has been assigned to each receiving water based on the predicted changes to current speed and (of lower importance) surface elevation.
- Indicative water quality zone. A zone (near-, mid- or far-field) has been assigned using the approach outlined in Section 2.2.

The review of sensitive waters will be updated as the Project progresses. In particular, the following information will help to refine the present, preliminary assessment of potential impacts:

- a full review of existing WFD status and key water quality drivers;
- results from the water quality screening runs regarding the spatial extent of impacts; and
- results from the water quality screening runs regarding the key water quality determinands and processes.

Table 5-1: Preliminary review of sensitive waters

Type	Name	Key determinands	Approx. distance from Cardiff lagoon (km)	Magnitude of hydrodynamic impact (cumulative)	Indicative water quality zone	Potential impact (cumulative)
Lagoon	Cardiff lagoon	All	n/a	High	Near field	High
WFD waterbody	*Severn Upper	WFD determinands	60	Medium	Mid field	Low
*transitional	*Severn Middle	WFD determinands	30	High	Mid field	Medium
^coastal	*Wye	WFD determinands	30	Medium	Near field	Medium
	*Bristol Avon	WFD determinands	20	Medium	Near field	Medium
	*Usk	WFD determinands	0	High	Near field	High
	*Severn Lower	WFD determinands	0	High	Near field	High
	^Bristol Channel Inner North	WFD determinands	5	High	Near field	High
	^Bristol Channel Inner South	WFD determinands	10	High	Near field	High
	^Bridgwater Bay	WFD determinands	15	High	Near field	High
	*Parrett	WFD determinands	15	High	Near field	High
	^Bristol Channel Outer North	WFD determinands	35	High	Mid field	Medium
	^Bristol Channel Outer South	WFD determinands	40	High	Mid field	Medium
	*Ogmore	WFD determinands	50	Medium	Mid field	Medium
	^Swansea Bay	WFD determinands	55	Medium	Far field	Low
	*Afan	WFD determinands	65	Low	Far field	Low
	*Neath	WFD determinands	70	Low	Far field	Low
	*Tawe	WFD determinands	70	Low	Far field	Low
	*Loughor	WFD determinands	110	Low	Far field	Low
	^Loughor Outer	WFD determinands	100	Low	Far field	Low
	^Carmarthen Bay	WFD determinands	80	Medium	Far field	Low
	*Tywi & Cywyn & Gwendraeth	WFD determinands	115	Low	Far field	Low
	^Pembrokeshire South	WFD determinands	135	Medium	Far field	Low
	*Milford Haven Inner	WFD determinands	165	Low	Far field	Low
	^Milford Haven Outer	WFD determinands	150	Low	Far field	Low
	^Pickleridge Lagoon	WFD determinands	160	Low	Far field	Low
	*Solfach	WFD determinands	180	Low	Far field	Low
	^Barnstaple Bay	WFD determinands	90	Low	Far field	Low
	^Bideford Bay	WFD determinands	95	Low	Far field	Low
	*Taw / Torridge	WFD determinands	100	Low	Far field	Low
	^Lundy	WFD determinands	115	Medium	Far field	Low
	^Cornwall North	WFD determinands	115	Low	Far field	Low
Bathing Water	Jackson's Bay Barry Island	Bacteria	15	High	Mid field	Medium
	Whitmore Bay Barry Island	Bacteria	15	High	Mid field	Medium
	Cold Knap Barry	Bacteria	15	High	Mid field	Medium
	Clevedon Beach	Bacteria	10	High	Mid field	Medium
	Weston-super-Mare Sand Bay	Bacteria	10	High	Near field	High
	Weston Main	Bacteria	15	High	Near field	High
	Weston-super-Mare Uphill Slipway	Bacteria	15	High	Near field	High
	Brean	Bacteria	15	High	Near field	High
	Berrow North of Unity Farm	Bacteria	20	High	Near field	High
	Burnham Jetty North	Bacteria	25	High	Near field	High
	Blue Anchor West	Bacteria	35	High	Near field	High
	Dunster North West	Bacteria	35	High	Near field	High
	Minehead Terminus	Bacteria	35	High	Near field	High
	Porlock Weir	Bacteria	45	High	Mid field	Medium
	Lynmouth	Bacteria	55	Medium	Far field	Medium
	Porthcawl group (4 BWs)	Bacteria	40	Medium	Far field	Low
	Swansea/Port Talbot group (6 BWs)	Bacteria	65	Medium	Far field	Low
	Gower group (3 BWs)	Bacteria	80	Medium	Far field	Low
	Ilfracombe/Bideford group (11 BWs)	Bacteria	75	Medium	Far field	Low
Shellfish Water	Swansea Bay	Bacteria	60	Medium	Far field	Low
	Burry Inlet	Bacteria	100	Low	Far field	Low

5.2 KEY SENSITIVITIES

This Section uses existing information to give an initial indication of the present performance of some of the sensitive receivers. This can be used as a measure of which receivers might be more sensitive to impacts resulting from the Project.

5.2.1 Bathing Waters

Table 5-2 shows the historic performance of Bathing Waters in and around the study area, for the last 11 bathing seasons. Performance is shown in relation to the standards of the cBWD which has applied historically.

Table 5-2: Historic cBWD compliance for Bathing Waters in and around the study area

Bathing Water	Bathing season										
	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Minehead Terminus	M	M	G	G	G	M	G	M	G	G	M
Dunster North West	G	M	M	M	M	M	M	G	G	M	G
Blue Anchor West	M	G	M	M	M	M	G	G	G	M	M
Burnham Jetty North	M	M	M	M	M	M	G	M	M	M	M
Berrow North of Unity Farm	M	G	G	M	M	M	G	G	M	G	G
Brean	G	G	G	M	G	M	M	G	M	G	G
Weston-super-Mare Uphill Slipway	M	M	M	M	M	M	M	M	F	M	M
Weston Main	M	M	M	M	M	M	M	M	G	G	G
Weston-super-Mare Sand Bay	G	G	M	G	M	G	G	G	M	G	G
Clevedon Beach	M	G	M	M	M	G	G	G	M	G	M
Jackson's Bay Barry Island	G	M	M	M	M	G	M	G	M	G	M
Whitmore Bay Barry Island	M	G	G	G	G	G	G	G	G	G	G
Cold Knap Barry	G	G	G	M	G	G	G	G	G	G	G
Key: G = Guideline; M = Mandatory (or Imperative); F = Fail											

The cBWD will be replaced in 2015 by the rBWD. The highest water quality classification of the rBWD ("Excellent") is stricter than the Guideline classification of the cBWD. Table 5-3 shows, for the same Bathing Waters, predicted performance against the rBWD classification standards. Performance is based on the four years of data 2010-2013 which may not be representative of long-term conditions. Predictions are as provided by NRW[11] and the EA[12].

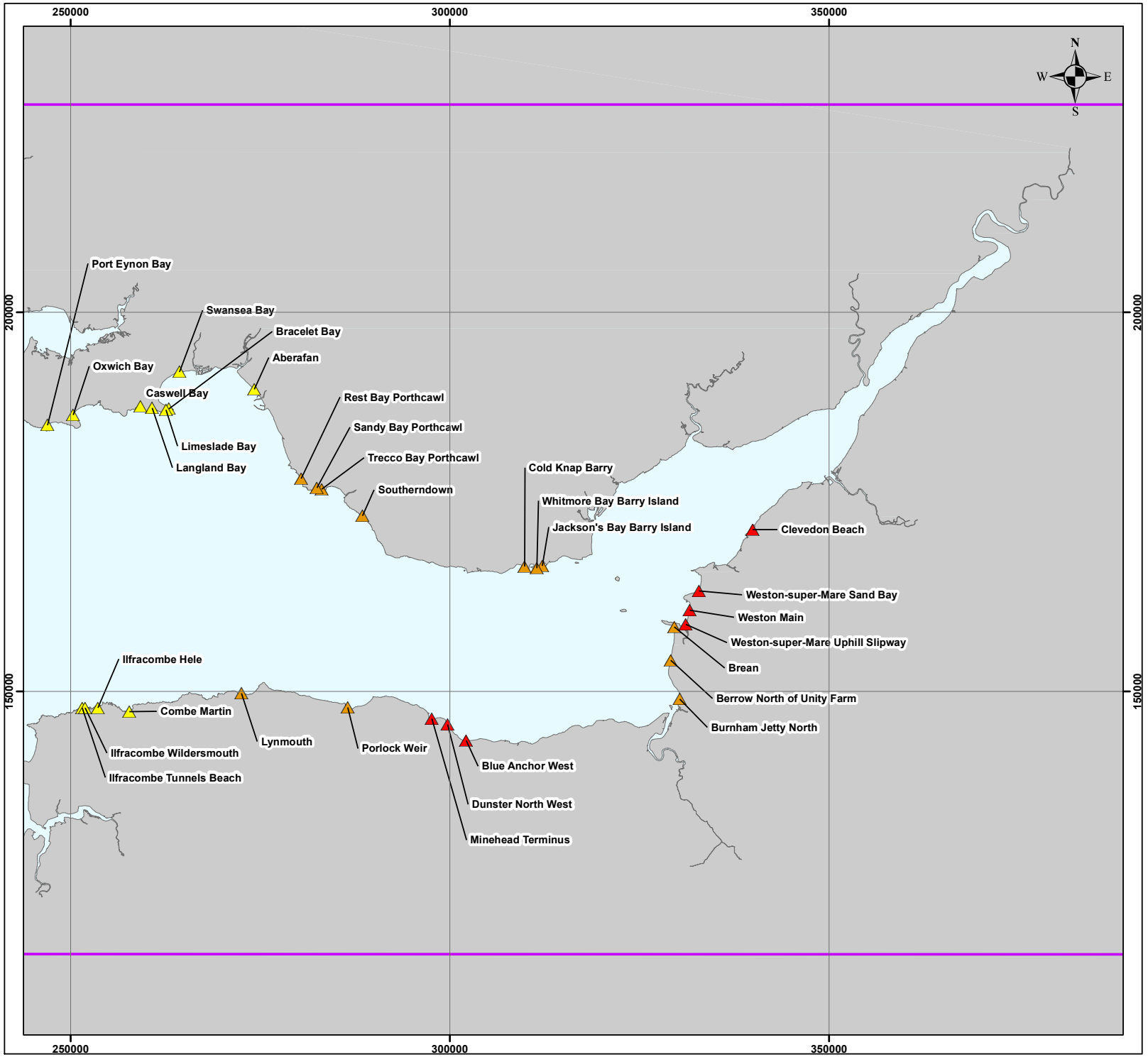
Table 5-3: Predicted rBWD performance for Bathing Waters in and around the study area

Bathing Water	Predicted rBWD performance based on 2010-2013 sampling data
Minehead Terminus	Excellent
Dunster North West	Good
Blue Anchor West	Good
Burnham Jetty North	Poor
Berrow North of Unity Farm	Good
Brean	Good
Weston-super-Mare Uphill Slipway	Poor
Weston Main	Good
Weston-super-Mare Sand Bay	Good
Clevedon Beach	Good
Jackson's Bay Barry Island	Good
Whitmore Bay Barry Island	Good
Cold Knap Barry	Excellent

Figure 5-4 is taken from the EA's 2007 study into the fate and transport of particles in estuaries[7]. It shows the designated Bathing Waters within the study area, and classifies these according to whether or not their bacterial concentrations are significantly affected by bacterial inputs from rivers/WwTWs, and/or by sediment transport processes (e.g. sequestration and release of bacteria in sediments). The study found that Bathing Waters on the English side of the estuary, near Bridgwater, were generally susceptible to both input loads and marine sediment processes. Conversely, those on the Welsh coast (around Barry and further west) were primarily influenced by just one of these two factors.

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-4: Causes of Bathing Water impacts, as predicted by the EA's 2007 study

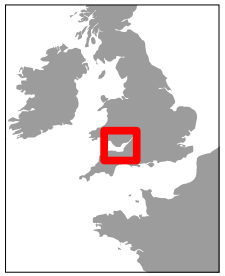


Legend

Bathing Water Monitoring Locations

- Type I: Affected by inputs & sediment transport
- Type II: Affected by inputs or sediment transport
- Type III: Unaffected by inputs & sediment transport

Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 5 10 15 20 25

5.2.2 Shellfish Waters and Shellfish Harvesting Areas

The nearest Shellfish Waters to the Project is Swansea Bay on the Welsh coast and Taw/Torridge on the English coast. Locations are shown in Figure 5-1 and Figure 5-2. The closest Shellfish Water, Swansea Bay, is approximately 60 km from the Cardiff lagoon. This may be sufficiently distant that the proposed lagoons have only small or negligible impacts on the Shellfish Waters.

The nearest harvested beds to the Project are in Swansea Bay. These beds have consistently achieved Class B shellfish flesh quality in recent years.

5.2.3 Rivers

The environmental performance of rivers adjacent to the study area can be indicated by looking at their historic performance. The most comprehensive recent sources of environmental performance are the EA's 2009 ("Cycle 1") River Basin Management Plans (RBMP) for Western Wales[13], the Severn[14] and the South West[15], produced for use in implementation of the WFD. Some of the classifications given in these RBMPs have seen subsequent ("draft Cycle 2") updates.

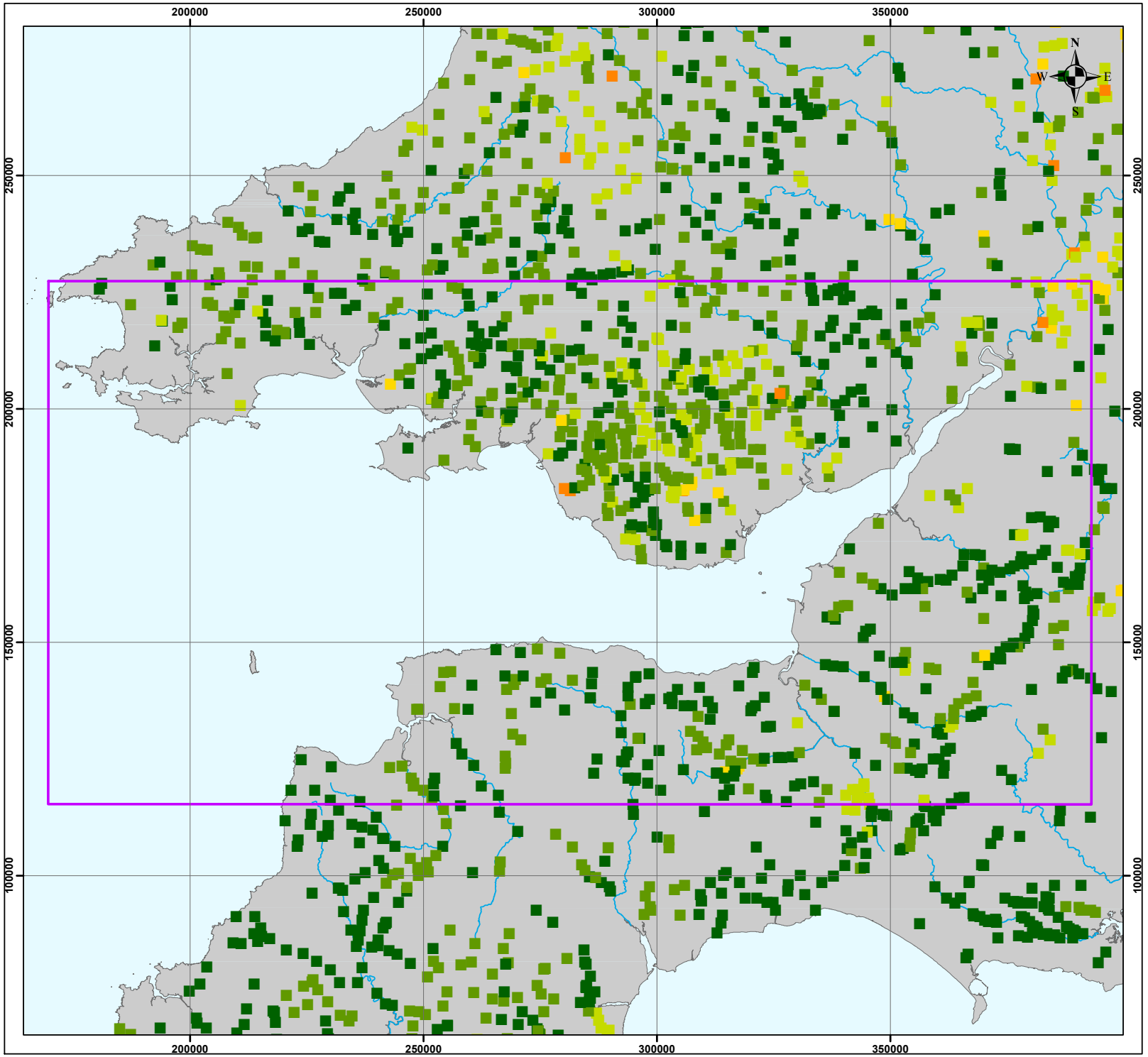
The RBMPs are presently being evaluated in terms of the key determinands and sensitivities for each identified WFD waterbody. In the meantime, an indication of river water quality performance can be obtained from the EA's most recent General Quality Assessment (GQA) scheme classifications. These predate the WFD RBMPs. The GQA scheme classifies river quality according to a number of measures, as follows:

- Figure 5-5 shows river performance for 2007 against the biology classification;
- Figure 5-6 shows river performance for 2009 against the chemistry classification;
- Figure 5-7 shows river performance for 2009 against the nitrate classification;
- Figure 5-8 shows river performance for 2009 against the phosphate classification.

Classifications A or 1 represent the best quality, dropping to F or 6 for the worst quality rivers.

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-5: GQA scheme river classifications – biology (2007)



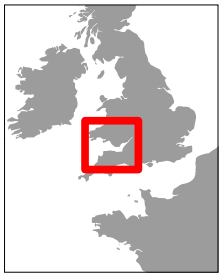
Legend

GQA Biology Results 2007

- a
- b
- c
- d
- e
- f

Main Rivers

Study Area



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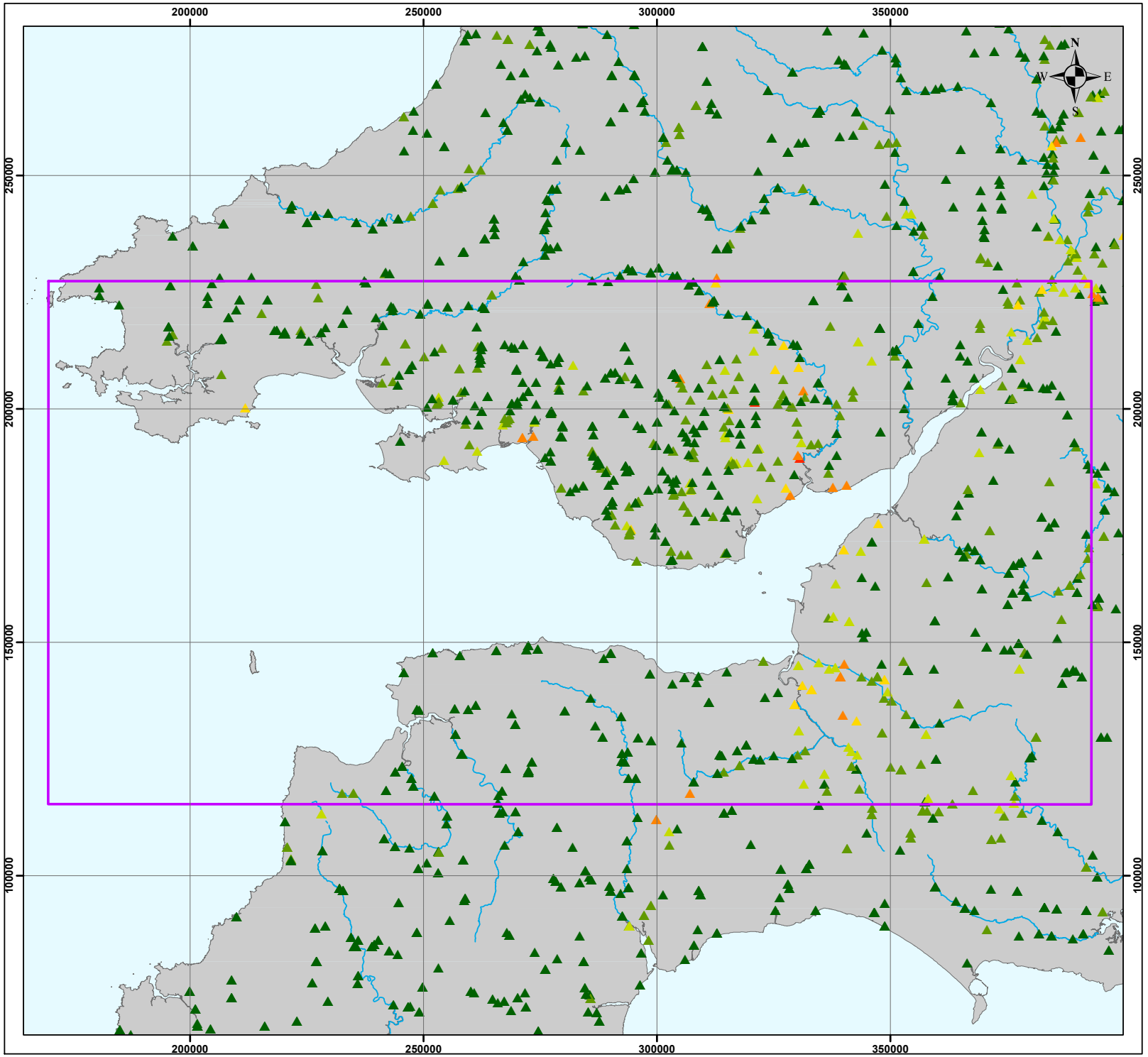
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-6: GQA scheme river classifications – chemistry (2009)



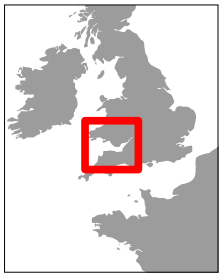
Legend

GQA Chemistry Results 2009

- A
- B
- C
- D
- E
- F

Main Rivers

Study Area



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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

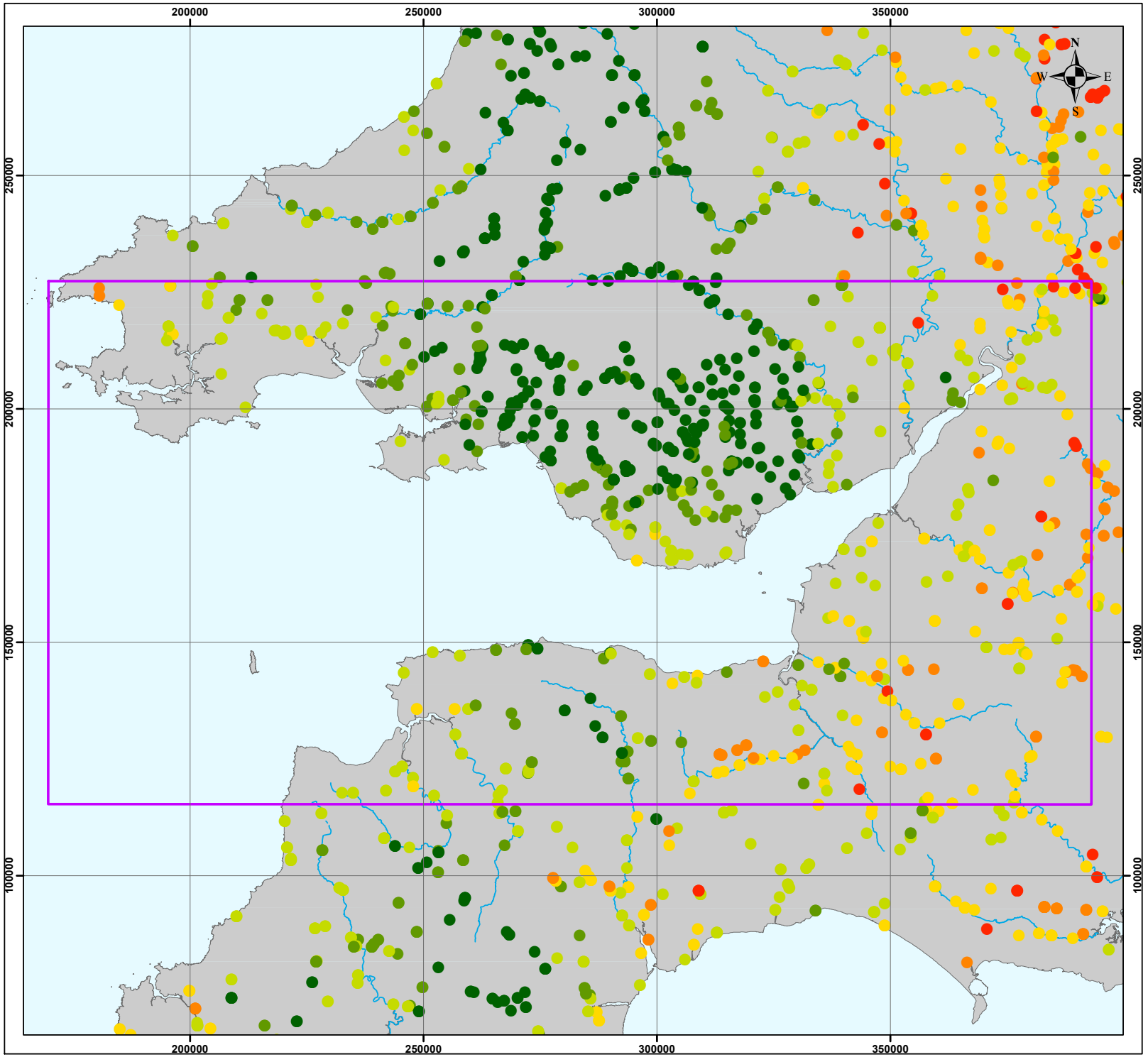
Intertek

Natural Quality Delivered

0 10 20 30 40 km

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-7: GQA scheme river classifications – nitrate (2009)



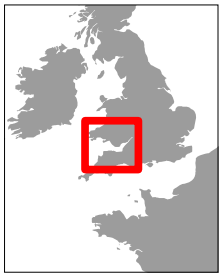
Legend

GQA Nitrate Results 2009

- 1
- 2
- 3
- 4
- 5
- 6

Main Rivers

Study Area



NOTE: Not to be used for Navigation

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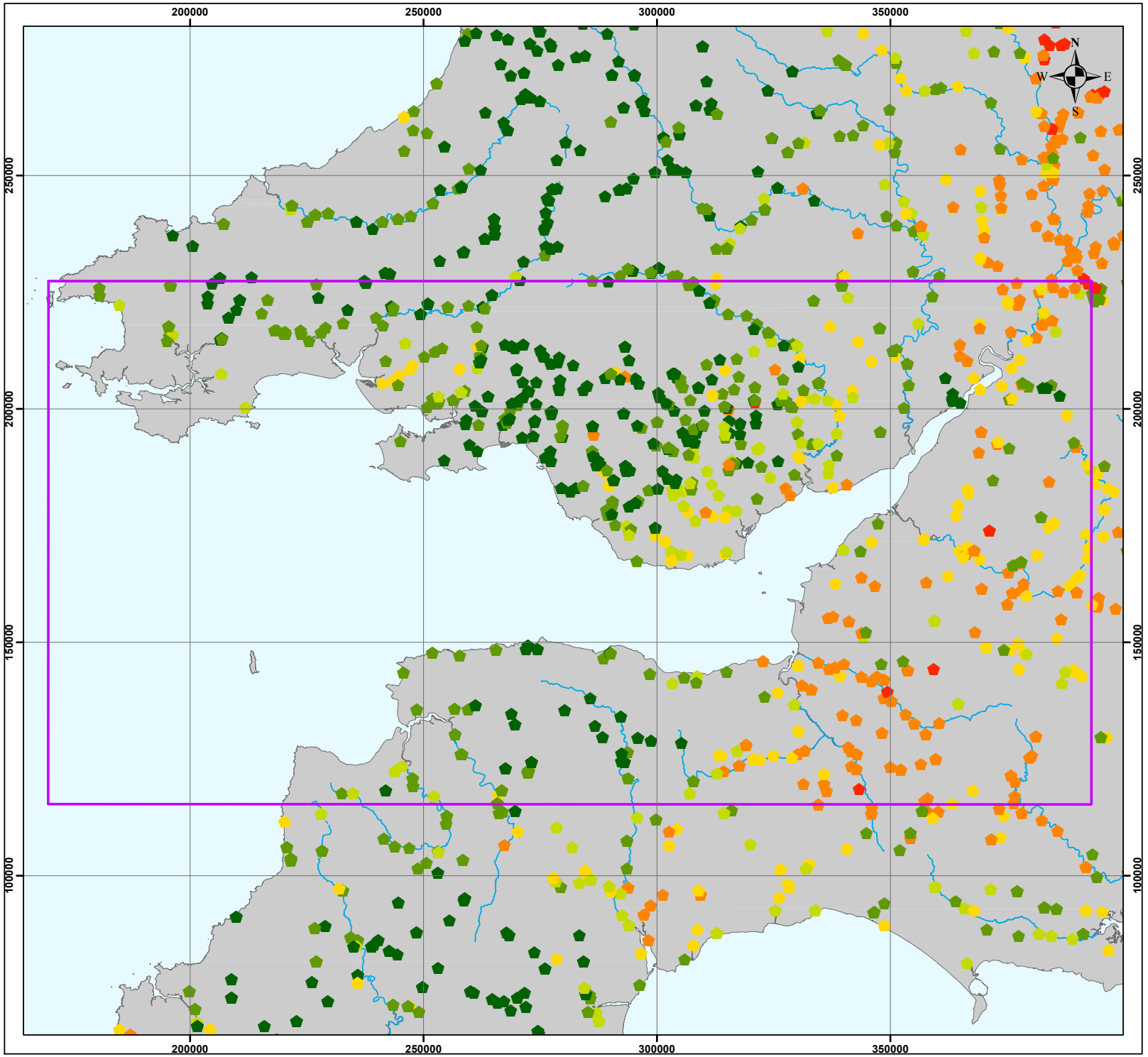
Data Source	OSOD, EA
File Reference	J:\P1914\Mxd\Report\ Fig5_7_GQA_Nitrate.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40

SEVERN ESTUARY LAGOONS - DATA REVIEW AND GAP ANALYSIS

Figure 5-8 GQA scheme river classifications – phosphate (2009)



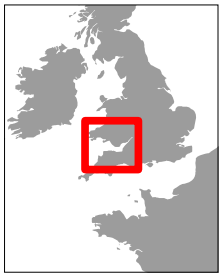
Legend

GQA Phosphate Results 2009

- 1
- 2
- 3
- 4
- 5
- 6

Main Rivers

Study Area



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Datum	D_OSGB_1936
Data Source	OSOD, EA
File Reference	J:\P1914\Mxd\Report\ Fig5_8_GQA_Phosphate.mxd
Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Kevin McGovern

km
0 10 20 30 40

5.3 KEY DISCHARGES

The major discharges to the Severn Estuary and Bristol Channel are the main rivers. These provide the bulk of the pollutant load, which is in turn derived from both point sources and diffuse runoff. The more distant (far-field) sources will tend to provide a relatively constant background load on which local (near- and mid-field) sources will be superimposed as more variable concentrations. The effect of these sources will tend to vary in proportion to load and proximity to the sensitive area or lagoon. Concentrations may show short-term changes in response to rainfall and may also show seasonal variation in response to rainfall and physicochemical processes.

In the absence of significant industrial discharges, the main point sources of pollutant loads in the study area are the water company assets (WwTW and intermittent discharges). These are particularly important in terms of bacterial concentrations but will also contribute substantial nutrient loads. Due to bacterial decay, the key water company assets will be those which discharge in relatively close proximity to the lagoons, and particularly those that discharge to the River Usk, Cardiff Bay and the coastline in between.

A detailed evaluation of the key discharges in terms of the water quality assessment will be possible when:

- full data on discharge flows and concentrations have been obtained (e.g. from the water companies) and evaluated; and
- screening model runs have been undertaken to establish the link between discharge loads and impact concentrations at the sensitive receivers.

5.4 POTENTIAL IMPACTS OF THE LAGOON ON PLUME DISPERSION

The lagoon will affect local hydrodynamics, which will in turn lead to changes in the trajectory and dispersion of local discharges. Discharges within the lagoon will be more significantly affected as the timing, location and local dispersion of the discharge plumes will be altered.

The discharges likely to be affected by the lagoon and the potential impacts of each are provided in Table 5-4. This table takes into account ABPmer's initial investigations into the hydrodynamic impact of the lagoon. The likely magnitude of hydrodynamic changes at each of the sensitive receivers is summarised in Table 5-1.

5.5 POTENTIAL CHANGES TO PERFORMANCE OF SENSITIVE RECEIVERS

Performance of sensitive receivers will be changed by the presence of the lagoons. Table 5-4 provides an initial indication of how performance may be affected in terms of WFD status and Bathing Water classification. Further information on the likely magnitude of hydrodynamic changes at each of the sensitive receivers is summarised in Table 5-1.

The effects of the status under other designations (e.g. Ramsar sites, Special Protection Areas (SPA) and Special Areas of Conservation (SAC)) are difficult to assess as these are largely based on ecological conditions, which may be adversely affected by changes in water quality but which are difficult to quantify.

Such changes will need to be assessed once changes in water quality are understood.

Further understanding of the potential water quality impacts at sensitive receivers will come from the water quality screening model runs, which have not been undertaken at time of writing.

Table 5-4: Estimated effects of lagoon on dispersion from key discharges and potential impacts on receiving water quality

Discharge	Potential impacts on receiving waters
Cardiff Lagoon	
River Usk (Ebbw River, Afon Llwyd)	Confinement of river plume between Cardiff lagoon will reduce local dispersion. Potential local impact and impact on the estuary water bodies of the Usk, Ebbw and Llwyd with potential increase in pollutant concentrations due to reduced flushing, especially on the flooding tide. Potential reduction in WFD status in transitional waters. Rivers should not be affected.
Cardiff WwTW and CSOs (Cardiff WwTW treated effluent, CSOs at Cardiff Eastern, Western Valley, Rhymney Valley, Kimberley Road, Cardiff Central)	Discharge direct to lagoon impoundment from WwTW and large CSOs. Load is derived from centre and west of Cardiff with large population equivalent. Potentially significant impact on water quality within the lagoon if flushing is relatively low. Potentially reduced impact on receiving waters outside of lagoon, especially Bathing Waters at Barry. Potential reduction in WFD status within lagoon impoundment.
Rhymney River	Discharge direct to lagoon impoundment. Potential to reduce dispersion of waters from the Rhymney River / estuary with potential impact on the estuary waterbody resulting from increase in pollutant concentrations due to reduced flushing. Potential impact on water quality within the lagoon if flushing is relatively low. Potentially reduced impact on receiving waters outside of lagoon, especially Bathing Waters at Barry. Potential reduction in WFD status within lagoon impoundment and transitional waters of Rhymney.
Rhynes/Reens (Gwent Levels)	Drainage channels discharging to the coast and lagoon waters. Low impact as small loads, but will affect water quality within lagoon. Lagoon may affect drainage due to change in water levels, but should not affect water quality as drains discharge via pumps, valves, penstocks etc. to prevent tidal ingress. Potential change in rhyne hydrology / flood risk. No change in WFD status.
Cardiff Bay	Lagoon may affect dispersion of plume from Cardiff Bay by blocking / restricting easterly dispersion on flood tide. Will not affect Cardiff Bay waterbody as tide cannot enter Bay impoundment. Change in dispersion may affect impact of Cardiff Bay discharge on Barry Bathing Waters. No change in status of Cardiff Bay.

Discharge	Potential impacts on receiving waters
Cardiff West / Cog Moors WwTW	Penarth CSO and Cog Moors WwTW discharge between the lagoon and Lavernock Point. Likely to be affected by changes in dispersion in this area. Load represents population of Cardiff West, Penarth, Barry, Sully and Wenvoe. Potential to affect Barry Bathing Waters.
Discharges west of Lavernock Point	Unlikely to be significantly affected by changes in circulation and dispersion, but some small changes may occur. Unlikely to affect status of waters west of Lavernock Point.

5.6 WATER QUALITY WITHIN THE LAGOON

5.6.1 Lagoon Water Quality

Hydrodynamics and dispersion within the lagoon will be increased in the areas near the turbines and reduced elsewhere, particularly in the areas most remote from the turbines, i.e. along the walls and shoreline. Flushing will also be reduced in these more remote areas. These effects will change the distribution of pollutants in the lagoons and may lead to local increases in pollutant concentrations that may affect water quality status or sensitive receivers.

The discharges likely to be affected and the potential impacts within the lagoon are provided in Table 5-4.

Further understanding of the potential lagoon water quality will come from the water quality screening model runs, which have not been undertaken at time of writing.

5.6.2 Effects of Lagoon Water Discharges

Water discharged from the lagoon may cause local changes in water quality as the lagoon will tend to cause an agglomeration of multiple existing discharges, i.e. those within the lagoon, into a single discharge through the turbines. As this discharge will have a relatively high speed it will tend to disperse rapidly into the waters surrounding the lagoon. Where the lagoon volume is large compared to discharge volumes, the lagoon discharge is likely to be of low concentration, particularly if the water entering the lagoon on the flood tide has relatively low pollutant concentrations.

In general the lagoon discharge may be expected to cause local changes in concentration around the discharge point, but would not be expected to significantly impact the receiving waters.

Further understanding of the potential water quality impacts at sensitive receivers will come from the water quality screening model runs, which have not been undertaken at time of writing.

5.7 POSSIBLE MITIGATION MEASURES

Mitigation measures are likely to be limited due to the nature of the changes in water quality caused by the lagoon, as these changes are due to the physical effects of the lagoon structure.

Mitigation is therefore likely to be dependent upon monitoring the effects of the lagoons to ensure these are no greater than predicted, or to provide early warning of potential impacts and triggering of intervention measures. As such, good baseline data from existing sources and specific surveys will be key to providing mitigation through Adaptive Management Plans.

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15) Environment Agency, 2009. River Basin Management Plan – South West River Basin District. December 2009, revised January 2011.

Appendix A Data Zoning

Zone 1 – Near-Field	Bacteria	BOD, ammonia and DO	Nutrients	Conservative pollutants
	Data needs: Low	Data needs: Moderate	Data needs: High	Data needs: High
Area influenced by the physical and hydraulic effects of the Project. Time-varying concentrations from sources immediately adjacent to the Project, e.g. local drainage catchment and industrial discharges. Zone 1 discharges lead to moderate or high concentrations that respond rapidly and measurably to short- and medium-term variations in load, e.g. storm events, and seasonal effects. Concentrations can vary significantly in the short-to medium-term and seasonally. Typically these must be represented as time-varying loads that respond to episodic events (e.g. storms).	May contribute a small background load, but which would not be expected to significantly affect compliance with standards.	Decay will generally remove the majority of effects of these sources, but they would be expected to contribute measurably to background concentrations. An approximation should be included that represents both a continuous (average / dry weather) component and a response to storm conditions.	Conservative nature of these pollutants generally requires an accurate description of load under normal (average / dry weather) and storm conditions. Sink terms should also be included where these are potentially significant.	Conservative nature of these pollutants generally requires an accurate description of load under normal (average / dry weather) and storm conditions. Sink terms should also be included where these are potentially significant.

Zone 2 – Mid-Field	Bacteria	BOD, ammonia and DO	Nutrients	Conservative pollutants
	Data needs: Low	Data needs: Moderate	Data needs: High	Data needs: High
Area close to the Project, which would not be expected to be significantly influenced by the hydraulic effects of the Project and from which pollutant discharges would lead to low or moderate variations in receiving water concentration in the short and medium-term, and seasonally. These pollutants will provide a continuous background concentration with some measurable variation in response to short- and medium-term variations in load, e.g. events and season. These sources would include river and point sources that lead to low or moderate background concentrations but would not be expected to be affected by the project, e.g. river, WwTW and Combined Sewer Overflow (CSO) discharges to the Severn Estuary and Bristol Channel within a distance of approximately 10 km of the project. Typically these can be represented as average continuous loads with a general representation of increased load during episodic events (e.g. storms).	May contribute a small background load, but which would not be expected to significantly affect compliance with standards.	Decay will generally remove the majority of effects of these sources, but they would be expected to contribute measurably to background concentrations. An approximation should be included that represents both a continuous (average / dry weather) component and a response to storm conditions.	Conservative nature of these pollutants generally requires an accurate description of load under normal (average / dry weather) and storm conditions. Sink terms should also be included where these are potentially significant.	Conservative nature of these pollutants generally requires an accurate description of load under normal (average / dry weather) and storm conditions. Sink terms should also be included where these are potentially significant.

Zone 3 – Far-Field	Bacteria	BOD, ammonia and DO	Nutrients	Conservative pollutants
	Data needs: N/A	Data needs: Low	Data needs: Moderate	Data needs: Moderate
The regional area, distant from the Project and unlikely to be affected by, or affect, the Project in terms of hydraulics and pollutant concentrations. However the hydrodynamics of this area and pollutants discharged from this area can determine regional conditions and background concentrations due to sources. While the Project would not be expected to affect these sources, or the local concentrations from these, they are important in setting the background levels. Long-term mixing of pollutants from these sources will provide a continuous background concentration with little measurable short - or medium-term variation but some seasonal change. These sources would include upstream rivers (e.g. Severn), distant rivers (e.g. Avon) and point sources from distant areas, e.g. WwTW and CSO discharges from Bristol, Weston-super-Mare etc. Typically these can be represented as average values forming a continuous load. Episodic events (e.g. storms) are not usually required except where large. This group also includes the model boundary conditions. Accurate definition is important for many pollutants to ensure boundaries do not cause a long-term artificial increase / decrease in concentration.	Decay will remove bacteria from these sources.	Decay will generally remove the effects of these sources. An approximation should be included as a minimum.	Dispersion will reduce concentrations to a low level around the project area. An approximation must be included as a minimum to define minimum background levels.	Dispersion will reduce concentrations to a low level around the project area. An approximation must be included as a minimum to define minimum background levels.