Bellozanne STW Operation Strategy

Transport & Technical Services

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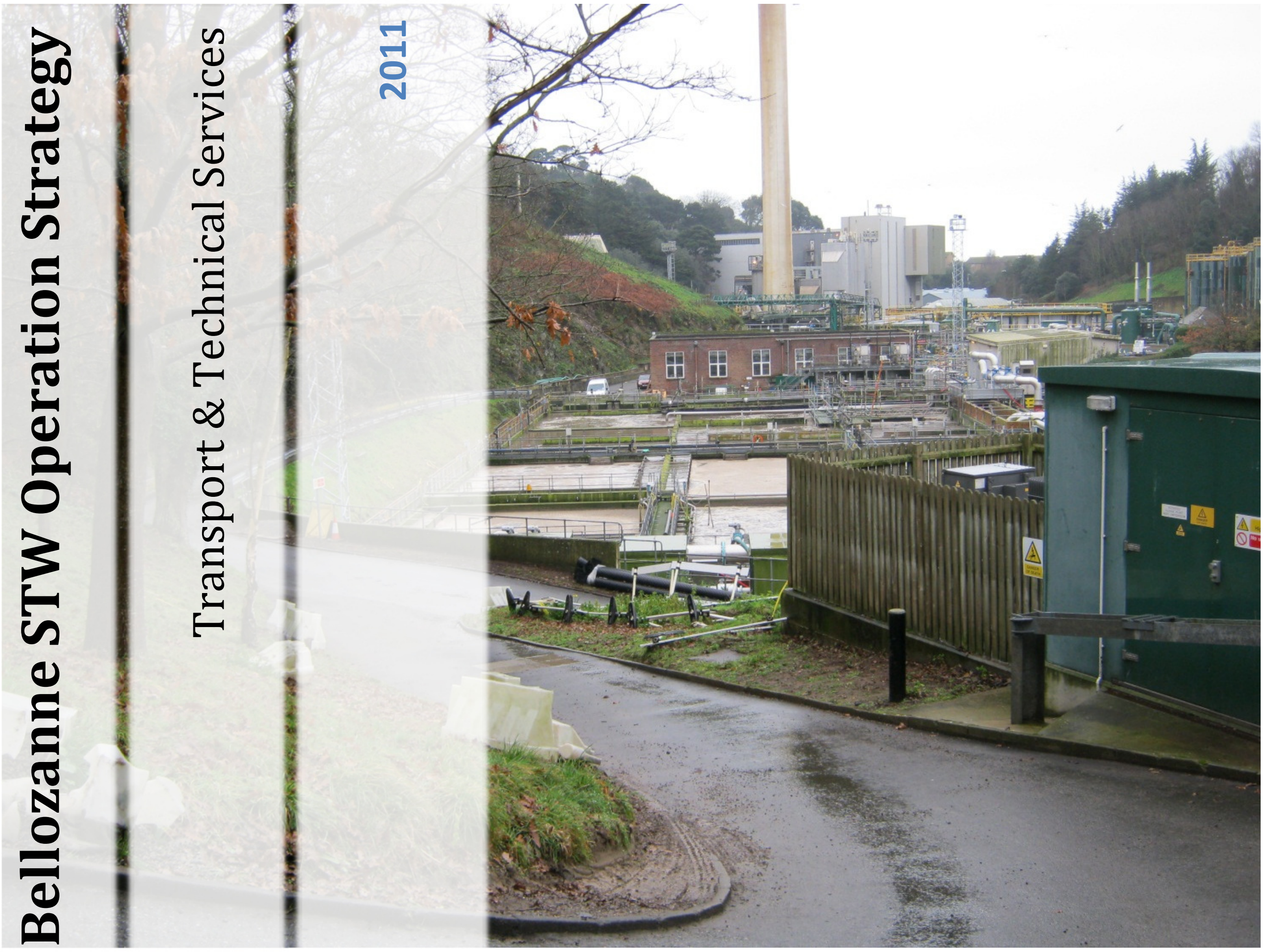

This document is intended to outline the strategy for operation of the Bellozanne Sewage Treatment Works operation as a starting point for further development of the Bellozanne Master Plan, followed by the Liquid Waste Strategy to meet the needs of the Island over the next 20 years.

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1.0 HISTORICAL BACKGROUND

Up until the 1950s, untreated sewage was discharged directly onto beaches causing public health concerns. It was therefore decided that the system should be re-built to modern standards and that all sewage should be treated before being discharged to the sea. Bellozanne Valley was an obvious choice for locating the sewage treatment works as, at that time, it was a relatively remote area and was the natural centre of the Island's drainage system.

Bellozanne STW was commissioned in 1959 as a Conventional Activated Sludge Plant (ASP) and designed to provide full treatment to produce an effluent to Royal Commission standards (30mg/l SS and 20mg/l BOD_5) for a population of 57,000. Through the years it has been continually improved and upgraded to take into account the change in flows, increased environmental standards and modern process technology.

In the early 1990s, it became evident that the sewage treatment works needed to be upgraded to increase its capacity and replace some of the outdated/ inefficient equipment. TTS also made the decision to install Ultra-violet (UV) disinfection at the STW to reduce bacteria levels in the effluent. The UV plant installed in the early 1990's was upgraded in 2003 with self-cleaning and more energy efficient units with applied dose monitoring facilities.

Based on an initial water quality survey carried out by the Centre for Research into Environment and Health (CREH) on the Trophic Status of St Aubin's bay in 1997, it was noted that St. Aubin's bay displayed some evidence of eutrophication in the nearshore area and potential for eutrophication in the bay itself. The report also noted that the nutrient removal from the Bellozanne STW effluent would be a *prudent precautionary step*. However, the report identified that the environmental status of the St Aubin's bay as inconclusive based on the limited survey and noted that the time constraints necessitated by the decision timescales for infrastructure investment at Bellozanne STW had not allowed a protracted, but possibly more prudent, data acquisition.

On the basis of the CREH Report on the Trophic Status of St Aubin's Bay (November 1997), it was agreed that the planned upgrade of the ASP should include a nutrient removal process that would decrease the amount of nitrogen entering St Aubin's Bay. Prior to the full implementation of the Water Pollution (Jersey) Law, 2000 on the 27 November 2000, the Public Services Committee issued a Discharge Certificate for Bellozanne STW in favour of itself which stipulated a stringent effluent quality for total nitrogen of no more than 10mg/l for a population equivalent of more than 100,000 and no more than 15mg/l for a population equivalent of less than 100,000. The Discharge Certificate also contained a relaxed set of conditions until 31 December 2001 and was extended for additional periods of time during construction.

Due to the valley restricting available construction land, there was insufficient aeration volume to achieve nitrification/ denitrification using the **Conventional ASP** as established in 1959. Instead, a new technique proposed by Degremont was used in providing a fixed film media within the aeration zones for organisms to grow and permit full nitrification (**Enhanced ASP**). In addition, four new final settlement tanks were constructed for the enhanced process. At the time the new plant was installed, it was the only full scale example in Western Europe to use this new technique.

1.1 Current Operating Philosophy

All flows to the Bellozanne STW receive some form of treatment. Flow to full treatment (FFT) receives the following stages of treatment:

- **Preliminary Treatment**, comprising screening and aerated grit & grease removal.
  - *Two mechanically raked bar screens (duty/assist) are provided for the removal of coarse and settleable solids.*
  - *Three grit and grease removal channels are provided in an aerated tank. Grease removal tanks in the inlet works remove the fats, oils and grease coming to the works using dissolved air flotation.*

- **Primary Treatment**, comprising removal of settleable solids.
  - *Four circular primary settlement tanks are provided.*

- **Secondary Treatment**, comprising **Conventional ASP** which has been retrofitted since 2002 to form a high rate process (**Enhanced ASP**).
  - *There are three activated sludge lanes with anoxic and high rate aeration zones followed by twelve final settlement tanks which clarify the effluent from the aeration process prior to discharge to sea via the UV plant.*

The current FFT is approximately 600 l/s as a result of the capacity limitation of the ASP. Storm flows in the range 600 to 1100l/s receive preliminary and primary treatment. The existing inlet works and primary settlements tanks are designed treat this peak flow with the exception of the inlet screens. However, these additional capacities cannot be utilised due the potential for premature overflow at the downstream of the primary settlement tanks.

All flows up to 1100l/s then combine to receive tertiary treatment in the form of ultraviolet disinfection by a proprietary system prior to discharge to St. Aubin's Bay. The outfall discharges some 500m from the sea wall and is exposed at mid tide level.

1.2 Operational Constraints

Current key operational issues for the **Enhanced ASP** for compliance with the Discharge Permit (DC2000/07/01) are as follows:

- The **Enhanced ASP** has never been able to achieve consistent total nitrogen requirement with the total nitrogen level averaged at 25.8 mg/l between 2003 and 2010 for the **Enhanced ASP**, primarily due to limited anoxic tank volume and the level of nitrification in the aeration zone;

- Formation of microthrix and Nocardia filamentous organisms cause extensive foaming and solids carry over in the final effluent;
- Nature of the suspended solids in the final effluent from the **Enhanced ASP** produces lower kill from the UV disinfection process;
- The high rate process results in excessive energy costs (larger carbon footprint) and health & safety issues.
- This process has the side effect of creating 'sewage foam' in the plant;
- The requirement for recycling of mixed liquor for the denitrification process places a hydraulic restriction on the FFT to 600l/sec prior to storm overflow; and,
- Hydraulic distribution to the final settlement tanks is poor leading to uneven flow splitting and overloading of some tanks.

2.0 STATUTORY/ REGULATORY REQUIREMENTS

TTS are required to comply with the Discharge Permit for final effluent from Bellozanne STW entering St Aubin’s Bay. This effluent discharge is regulated by the Water Pollution (Jersey) Law, 2000.

The key international best practice legislations associated with discharges of wastewater to marine environments are the European Union Urban Wastewater Directive (UWWTD) 91/271/EEC and the Bathing Waters Directive 76/160/EEC. Also, the Water Framework Directive is the most extensive and important piece of legislation to emerge from the EU for the water environment. It requires that all inland and coastal waters achieve “good” environmental status by 2015.

The quality of Jersey’s streams has improved in recent years: just under half of the Island’s streams now have good or excellent biological water quality, compared to 1 in 5 ten years ago. However, despite these water quality improvements the Island still experiences elevated levels of nitrate in streams and groundwater compared to many other places in Europe[1].

As well as impacts on drinking water quality, excess nutrients in natural environmental waters have other unwanted consequences. These include growth of algal or bacterial populations leading to unsightly blooms, de-oxygenation of the water and harm to fish and other animals.

According to a study carried out by CREH[2] in 1997, approximately half of the nitrogen budget entering St Aubin’s Bay was from the STW, and half was from catchment sources. A further study done in 2007 suggested that the overall flux to St Aubin’s Bay of nitrogen had not changed appreciably, as a 17% reduction from inputs from catchment sources had been offset by a 10% increase in nitrogen from the STW effluent.

In order to reduce catchment based sources, a scheme has been designed by the Department of the Environment for Jersey (the DPP – Diffuse Pollution Project). This works in participation with stakeholders to identify and implement environmental best practice farming in Jersey in relation to nutrient and soil management in order to limit diffuse pollutant losses and bring about an improvement in water quality. The DPP has been in operation for two years and significant progress has being made in engaging with the farming community and encouraging changes in practice through dialogue and incentives.

TTS will ensure that all options assessed for the future operation of the Bellozanne STW will be in compliance with Jersey Law and international best practice legislations.

[1] Over the last 10 years about 60% of surface water samples taken by Jersey Water had nitrate levels of above 50 mg/l. Results from Department of the Environment island-wide borehole and well testing showed a similar percentage of samples exceeding 50 mg/l of nitrate in groundwater. This compares to a mean of around 3% of surface water and 15% of groundwater samples in the 27 countries of the EU.

[2] Estimation of Nitrogen and Phosphorus Budgets entering St. Aubin's Bay, C Stapleton, M Wyer, D Kay, Feb 1997

3.0 SECONDARY TREATMENT PROCESS

The conventional activated sludge process with **carbonaceous oxidation** has been in use since 1920s as a secondary treatment process. There are several examples of **nitrification /denitrification** plants in the UK. This variant originates from South Africa in the 1980s. Nitrifying ASPs are easy to operate but the addition of nitrification/ denitrification leads to requirement for a much larger plant, which is more complex and more difficult to operate.

3.1 Conventional ASP

The secondary (biological) treatment process, designed to substantially reduce the biological content of the wastewater. All municipal treatment plants treat either screened crude sewage or primary settlement tank effluent using aerobic biological processes. This biological treatment is based on the principle that where enough air is present, cultures of bacteria will form. Millions of bacteria and other tiny creatures live on a substrate, the organic material in the sewage, and convert it from complex carbohydrates, proteins and fats into carbon dioxide, water and nitrates. They literally 'eat' the sewage and remove harmful waste.

The carbonaceous oxidation process breaks down organic wastes present in sewage and the nitrification process converts ammonia into nitrite and then to nitrate in the presence of aerobic conditions.

Organic Matter Removal (**Carbonaceous Oxidation**):

Carbon + Activated Sludge + O_2 $\Rightarrow$ CO_2

(Organic matter) (Oxygen) (Carbon dioxide)

Nitrification:

NH_3 $\xrightarrow{\text{Nitrosomonas}}$ NO_2 $\xrightarrow{\text{Nitrobacter}}$ NO_3

(Ammonia) (Nitrite) (Nitrate)

Secondary treatment systems are classified as either suspended-growth, fixed growth or combinations thereof. In suspended-growth systems, such as activated sludge, the biomass is mixed with the sewage and air is forced into the process by means of blowers as at Bellozanne STW or mechanical aerators. Hence, their footprints are relatively smaller compared to the fixed growth systems like Trickling Filters.

In general, ASPs encompass a variety of mechanisms and processes that use dissolved oxygen to promote the growth of biological floc. This is termed mixed liquor and it substantially removes organic material. The process traps particulate material and can, under the correct conditions, convert ammonia to nitrite and nitrate and ultimately to nitrogen gas; this is referred to as denitrification.

The final step in the secondary treatment stage is to settle out the biological floc in final settlement tanks of radial flow type and produce an effluent containing very low levels of organic material and suspended matter. The sludge produced is constantly withdrawn from the tanks and returned to the inlet to the aeration tanks.

The requirements of an ASP are good mixing with a DO concentration of 1 to 2mg/l in the aeration lanes and good settlement of the activated sludge in final settlement tanks. The thickened activated sludge formed in the final settlement tanks must be returned to the front of the ASP to provide an inoculation of organisms to ensure that the process can be maintained. A portion of this returned activated sludge is removed from the process at regular intervals to ensure that the mixed liquor suspended solids are retained within the operating range of 2000 to 3000mg/l.

The two principal control measures are Food/Activated Sludge Mass (F/M ratio) and sludge age.

F/M ratios are dependent on the incoming load, mixed liquor suspended solids concentration and aeration tank volume. An F/M of 0.2 to 0.3 is required for good carbonaceous treatment to achieve a consent of 20mg/l BOD. However, if full nitrification is required, an F/M of 0.08 to 0.1 would be required.

The sludge age is the length of time sludge spends in the ASP system before being removed. It is measured in days and needs to be 10 days as a minimum to ensure full nitrification throughout the year. This is because the nitrifying organisms (autotrophies) have a lower reproductive rate than the carbonaceous organisms and are washed out of the system at lower sludge ages.

The two principal configurations of ASPs can be classified according to their hydraulic flow characteristics as ‘Plug Flow’ or ‘Completely Mixed Flow’. Completely Mixed Flow is not suitable for nitrification because of the high F/M ratio. Bellozanne STW is designed with a Plug flow regime. These flow regimes are conventional ASPs which promote good settling sludge. They can be **carbonaceous, nitrifying or nitrifying/ denitrifying** process.

In plug-flow, flows pass through the reactor and are discharged in the same sequence in which they enter. The particles retain their identity and remain in the tank for a time equal to the theoretical detention time. This type of flow is approximated in long tanks with a high length-to-breadth ratio in which longitudinal dispersion is absent. Settled wastewater and recycled activated sludge enter at the head end of the aeration tank and are mixed by diffused-air or mechanical aeration. Air application is generally uniform throughout the length of the tank. During the aeration period, adsorption, flocculation and oxidation of organic matter occur. Activated-sludge solids are separated in a secondary settling tank.

Conventional plug flow ASPs are usually provided with a **selector** in which the RAS and incoming settled sewage are brought together with a high floc loading to promote good settling sludge. This is critical to good performance of the ASP.

Tapered aeration is a modification of the conventional plug-flow process. Varying aeration rates are applied over the length of the tank, depending on the oxygen demand. Greater amounts of air are supplied to the head of the aeration tank, and the amounts diminish as the mixed liquor approaches the other end. Tapered aeration is usually achieved by using different spacing of the air diffusers over the tank length.

Step feed is another modification of the conventional plug-flow process in which the settled wastewater is introduced at several points in the aeration tank to equalise the F/M ratio, thus lowering the peak oxygen demand. Generally, three or more parallel channels are used. Flexibility of operation is one of the important features of this process.

The **denitrification process** liberates the nitrogen from the nitrates by creating a demand for the oxygen present in the nitrates under anoxic conditions.

Denitrification:

NO_3 +carbon source (settled sewage) $\Rightarrow$ N_2

(Nitrate) (Nitrogen gas vents to atmosphere)

ASPs designed to denitrify are provided with anoxic zones at the front of the aeration lanes in which the mixed liquor solids are kept in suspension by mixers but no aeration is applied. In these zones of low or no dissolved oxygen, nitrate in the RAS is reduced to nitrogen gas by facultative anaerobes in the presence of a carbon source, which is usually settled sewage. The bacteria in the activated sludge start to consume the organics in the settled sewage, however they need oxygen. As no air is present in the anoxic zone the bacteria take the available oxygen from the nitrates and nitrogen gas is liberated as a denitrification process. In this way, 25% of the nitrate can be removed and solids flotation in the final tanks is avoided. If a total nitrogen limit is set, these anoxic zones have to be larger and recycling of mixed liquor (up to 4 x the incoming flow in dry weather) is required to achieve the standard of no more than 10mg/l of total nitrogen.

If an anaerobic zone or anoxic zones are incorporated into the process, it is possible to encourage a type of organism which will exhibit the property of luxury uptake of phosphorus in the aeration zone and phosphorus removal can be achieved. These nutrient removal plants have a larger overall volume and are more expensive to operate than a conventional plant.

3.2 Enhanced ASP

Increased loads can be treated by installing fixed film media within the aeration zones of the ASPs. The Kaldnes process does this, but coarse bubble aeration is required to develop a film on the fixed film media and this is less efficient than fine bubble diffusion in terms of oxygen transfer.

A number of patented processes have the overall effect of reducing the footprint required for a **Conventional ASP** system as follows:

- Degremont's Pegazur Process: Pegazur pellets are placed in the aeration zones and are impregnated with immobilised nitrifying organisms and thus a high degree of nitrification can be achieved even at an F/M of 0.2 but a high DO concentration of 3 to 6mg/l is required in the aeration lanes. This system contains polyethylene glycol biocubes, the nitrifying bacteria are attached to the biocubes as a biofilm. This keeps a high volume of bacteria within the aeration system unlike conventional activated sludge systems.

  Unfortunately, a high DO concentration of 3 to 6mg/l is required in the aeration lanes and this encourages the growth of a particular filamentous organisms (Nocardia) which cause banks of foam up to 1m deep in the aeration lanes at Bellozanne STW.

- Veolia's Integrated Fixed Film Activated Sludge (IFAS) process: This is based on the Kaldnes Moving Bed Bio Reactor (MBBR) process. This is similar to Degremont's process in that that the **Conventional ASP** would be modified to an IFAS process. There would be a combination of fixed film processes on the MBBR media and the suspended growth activated sludge system.

- Ovivo's Cleartec process: This is a process based on IFAS but utilises a different fixed film process with a woven fabric mounted in cages, which would provide a fixed film surface for the media to grow on. This would increase the amount of biomass that can be held in the lanes and intensify the process. There would also be a combination of fixed film processes on the fabric media and the suspended growth activated sludge system.

4.0 NITRIFICATION/ DENITRIFICATION AT BELLOZANNE STW

4.1 History

Although the Bellozanne STW was commissioned in 1959 for an equivalent population of 57,000, it takes flow from a resident population of 89,000 which increases to a summer peak population of 104,000 at present. Through the years it has been continually improved and upgraded to take into account the change in flows, increased environmental standards and modern process technology.

The process upgrade from **Conventional ASP** to **Enhanced ASP** completed in 2002 incorporated anoxic zones for denitrification, followed by Pegazur pellets in the aeration zones in an attempt to achieve full nitrification. As part of the enhanced process, recycling of the mixed liquor from the aeration tanks is required for effective denitrification and was incorporated.

The **Enhanced ASP** was completed in 2002 but the agreed annual average total nitrogen output levels were not met. The Discharge Permit under the Water Pollution (Jersey) Law, 2000 requires an annual average concentration of no more than 10 mg/l total nitrogen and suspended solids of no more than 35 mg/l on a 95 percentile basis. The annual average total nitrogen level averaged at 21.8 mg/l between 1995 and 2002 for the **Conventional ASP** and at 25.8 mg/l between 2003 and 2010 for the **Enhanced ASP**. The suspended solids levels are in compliance but the nature of the suspended solids has changed with the implementation of the **Enhanced ASP**.

The annual average ammonia nitrogen averaged at 6.5 mg/l between 1995 and 2002 for the **Conventional ASP** and at 19.9 mg/l between 2003 and 2010 for the **Enhanced ASP**. The annual average nitrate nitrogen level averaged at 13.8 mg/l between 1995 and 2002 for the **Conventional ASP** and at 5.3 mg/l between 2003 and 2010 for the **Enhanced ASP**.

The annual average coliform count since the installation of the UV plant in the early 1990's was significantly lower prior to the conversion to the **Enhanced ASP**. Despite the upgrades completed in 2003, the disinfection process has not returned to the level in the 1990's.

4.2 Improvements

During the first half of 2006, additional works were carried out to reduce the total nitrogen output from the STW to meet the requirements of the Discharge Permit. These works proved to have an immediate beneficial effect and the total nitrogen has reduced since these modifications were carried out. However, the reduction in the nitrogen level has not been significant enough to meet the requirements of the Discharge Permit for the total nitrogen.

The Pegazur pellets were no longer readily available and due to the loss of these pellets by natural abrasion, those in Lane 3 were used to top up the other cells and replaced with Meteor pellets. However, these only work well with coarse bubble diffusers and not the fine bubble diffuser system in Bellozanne. This is because the biological film on the Meteor pellets is removed by the scouring action by the fine bubbles.

A Process Optimisation Study carried out in 2009 identified a number of possible short to medium term options to address some of the shortcomings. Aeration zone media was proposed to be rectified in the medium term, perhaps by adopting a phased approach of one lane at a time. Regardless of the approach, it was considered important that all works fit in with the long term plans for sewage treatment in Jersey. On this basis, further works have been carried out in 2009/2010 to improve the performance of the **Enhanced ASP**:

1. The selector zones at the head of the aeration lane encourage the growth of denitrifying organisms at higher F/M ratio by by-passing part of the RAS to the downstream of the selector zones.

   The selector zones have been modified / renewed to improve the sludge characteristics, as measured by SSVI[3]. This permits the plant to run at higher mixed liquor solids and eradicate the filaments for improved settleability and overcome foaming problems.

2. Baffles have been constructed in the anoxic zones to improve the plug flow arrangements and reduce short circuiting in the lanes. Additional mixers have been installed in the new anoxic compartments. However, the existing mixers have not been modified as they are unlikely to result in further process improvements.

3. Standby RAS pumps with associated pipework and controls have been installed to improve the security of the system, as well as providing for process variations by discharging a proportion of the flow to the downstream of the selector zones.

4. Process options (alternative to Meteor and Pegazur pellets) were identified for the medium term, with a view to providing a robust system for better reliability. Based on the evaluation, the preferred option was to undertake the Cleartec installation in Lane 3 only on a trial basis to replace the Meteor pellets and installation in the other lanes would depend on satisfactory performance being demonstrated during the trial.

   The supplier had indicated that full nitrification can be achieved within the aeration zones (Ammonia-N <3mg/l at aeration zone outlet for a 5 day period). However, due to inadequate anoxic zone volume, it would not be possible to guarantee the annual average total nitrogen level without the addition of external carbon source. However, the supplier would also explore the possibility of managing the return liquor load (balancing) to achieve the total nitrogen level if deemed desirable.

   It was noted that the trial would give an indication of the level of nitrification (in the aeration zones only. The supplier was unable to guarantee the level of denitrification to achieve the total nitrogen level because they are constrained by the available volume in the anoxic zones. Furthermore, it would not be possible to isolate the process in one lane to verify the level of nitrogen removal in it with the installation of the new media (Mixed liquors from Lanes 1 to 3 are combined in the aeration outlet channels and settled in the final settlement

[3] Settled Sludge Volume Index as a measure of settleability

tanks, resulting in combined RAS from Lanes 1 to 3). In view of these constraints, the trial procedures and sampling protocol were agreed in advance as a compromise.

4.3 Issues with Nitrification/ Denitrification

The Process Optimisation Study carried out in 2009 concluded that the ASP is undersized for the present and future conditions, and will not achieve the total nitrogen limit. The performance of the STW is and has always been adversely affected by the limited hydraulic gradient. Flow distribution at each stage of the process is unsatisfactory. TTS have continued with its efforts to improve the performance of the works together with monitoring of the water quality in St Aubin's Bay.

In 2009/ 2010, TTS has been involved in further attempts on process upgrades to improve the performance of the **Enhanced ASP** and funding in excess of £1,000,000 has been utilised with minimal success. The Bellozanne STW effluent quality continues to be in line with a **Conventional ASP** with limited nitrification.

Despite the various attempts by TTS to improve the nitrification and significant supply of oxygen in the aeration zones, nitrification has been limited due to the nature of the process and potential inhibitory effect of the incoming sewage. The overall process continues to be unstable with unpredictable results.

Effective denitrification requires recycling of the mixed liquor from the aeration tanks. However, every time the mixed liquor return pumps are switched on at present, the filament problem is made worse, there are associated foaming problems and the process becomes unstable. Some temporary works have been completed to stabilise the process and allow recycling of the mixed liquor and improve reliability of the denitrification in the anoxic zone. However, the recycling has not proven to be successful.

Non-compliance of effluent quality in accordance with the Discharge Permit continues to persist with respect to total nitrogen due to lack of nitrification/ denitrification. Nature of the suspended solids in the final effluent from the **Enhanced ASP** produces lower kill from the UV disinfection process, as initially identified by the UV plant manufacturer and as demonstrated by the results between 1995 and 1998 from the **Conventional ASP**

5.0 DISCHARGE CONSENT

5.1 Background to Setting the Discharge Consent

Prior to the full implementation of the Water Pollution (Jersey) Law, 2000 on the 27 November 2000, the Public Services Committee issued a number of Discharge Certificates in favour of itself, including a Certificate for Bellozanne STW. When it was issued, the Certificate contained two sets of conditions; a relaxed set of conditions for the period up until 31 December 2001 and a more stringent set of conditions that would apply thereafter.

Variations to the Certificate have been issued for additional periods of time since then to extend the relaxed total nitrogen limit to no more than 20mg/l of total nitrogen due to ongoing problems with the treatment process.

5.2 Issues with Meeting the Discharge Consent

The **Enhanced ASP** at Bellozanne STW has failed to achieve consistent effluent containing no more than 10mg/l of total nitrogen and, on occasions, suspended solids ever since the process modifications were completed in 2002. The ASP is undersized and would not achieve the total nitrogen limit and the process continues to be unstable.

5.3 Current Position with the Regulator

The Discharge Permit requires the annual average total nitrogen concentration to be less than 10mg/l and suspended solids less than 35mg/l (on a 95 percentile basis). The low level of total nitrogen was stipulated as a precautionary step on the basis of the St Aubin's Bay being potentially "sensitive" to nitrogen as a result of the 1997 study by CREH on the Trophic Status of St Aubin's bay. This is covered further in Section 6.0.

A number of meetings have been held with the Regulator on works being carried out to improve the nitrogen removal element of the ASP process. To date, a total amount in excess of £2,000,000 has been spent on process improvements since 2002.

At a meeting held in early 2009, TTS noted that the 10 mg/l total nitrogen limit was too stringent and not achievable. It was agreed that an update on the trophic status of St Aubin's Bay should be carried out based on data acquisition over a two-year period to determine the level of total nitrogen that would be acceptable from the exiting the sewage treatment works with no detrimental effects on the environment. This study was carried out over an agreed period in 2009/ 2010 as identified in Section 6.2.3.

6.0 EUTROPHIC STUDIES OF THE ST AUBIN'S BAY

6.1 Sensitive Areas

Water bodies can be identified as Sensitive Areas under the UWWTD on three grounds:

(a) where they are found to be eutrophic or where they may in the near future become eutrophic if protective action is not taken;
(b) where they exceed or could exceed a specified concentration of nitrate - to protect water supply sources;
(c) where discharges affecting them are subject to more than secondary treatment to comply with the standards of other Directives - for example, advanced treatment required to meet the microbiological standards of the Bathing Waters Directive.

The status of St Aubin's bay was viewed as a potentially 'Sensitive Area' on the grounds identified in 6.1(a). The assessment below followed the Comprehensive Studies Task Team (CSTT) protocol for UK 'Sensitive Waters' definition.

6.2 History of Surveys of St Aubin's Bay

6.2.1 Nutrient Input Data Review – 1997 & 2008

A report prepared by CREH entitled 'Estimation of Nitrogen and Phosphorus Budgets entering St. Aubin's Bay, Jersey' (February 1997) assessed the importance of nutrient input from the effluent of the Bellozanne STW, relative to catchment sources, utilising available data. Where possible, the analysis was carried out on five year data sets. It was identified that that catchment management can also play an important part in reducing the nitrogen input, with catchment sources accounting for approximately half of the estimated nitrogen budget. The treatment for nitrogen and phosphorus at Bellozanne STW may significantly reduce nutrient loads but catchment sources would remain, particularly in the case of the nitrate input. Such sources would require an integrated strategy for catchment management and water quality control.

An additional report prepared by CREH entitled 'Nutrient Flux Source Apportionment for St Aubin's Bay, Jersey, 2007 (January 2008) included additional data review. It was noted that the "mean dissolved available inorganic nitrogen (DAIN) concentrations in the STW effluent were not significantly different between 1997 and 2007. However the dominant component of STW effluent DAIN changed from NO3-N (> 20 mg/l in 1997, < 4 mg/l in 2007) to NH3-N (< 4 mg/l in 1997 to > 20 mg/l in 2007). Despite installation of the Pegazur process, there is no evidence of a significant change in the overall inorganic nitrogen concentration in this major input to St Aubin's Bay".

The 1997 study of the trophic status of St. Aubin's Bay concluded that the bay should be considered as potentially eutrophic. Given that the 2007 nutrient input estimates were only slightly lower than those for 1997 CREH had no evidence to alter this conclusion.

Environmental Protection (EP) of the States of Jersey have been involved in implementing a pilot scheme over the last 2 years in order to tackle catchment inputs of nitrogen, one of the key assessed risks to the Island's water not meeting good status.

6.2.2 First Assessment - 1997

A survey was carried out by CREH at St Aubin's bay in 1997 based on data collection from only one summer season (27-02-1997 to 29-10-1997). The report submitted by CREH on the Trophic Status of St Aubin's Bay (November 1997) noted that St. Aubin's bay displayed some evidence of eutrophication in the nearshore area and potential for eutrophication in the bay itself. The analysis indicated that the sunshine hours during the limited survey period was possibly an anomaly. CSTT suggests that UK practice would be to base expenditure decisions on at least two years' data where that was available.

The report identified that the environmental status of the St Aubin's bay as inconclusive and noted that the time constraints necessitated by the decision timescales for infrastructure investment at Bellozanne STW had not allowed a protracted, but possibly more prudent, data acquisition. The report also noted that the nutrient removal from the Bellozanne STW effluent would be a prudent precautionary step.

6.2.3 Second Assessment – 2009/ 2010

A second comprehensive survey was carried out by CREH at St Aubin's bay in 2009 – 2010 based on data collection over a reasonable period (01-06-2009 to 01-07-2010). Thus the study provides a reassessment of the trophic status of St. Aubin's Bay, following a similar programme of empirical data collection and model prediction used in the original assessment, carried out in 1997. Both studies were designed to provide data suitable for application of the methodology proposed by the competent authorities of the British Government (CSTT, 1997).

The report submitted by CREH on the Reassessment of the Trophic Status of St Aubin's Bay (November 2010) concludes that St. Aubin's Bay is not subject to eutrophication, based on the observed data and CSTT model results. On this basis, St Aubin's Bay is not considered to be 'Sensitive Waters' and, therefore, any effluent discharges from Bellozanne STW will not require nitrogen removal in accordance with the UWWTD. However, additional data collection over more seasons to take into account of seasonal variations may be warranted in order to provide stronger evidence for moving forward with an informed choice.

It should also be noted that there has been no proven link between the nutrient contributions from the various sources and the sea weed generation as there are significant nutrient inputs from the various catchments sources.

Water Framework Directive is the most extensive and important piece of legislation to emerge from the EU for the water environment. It requires that all inland and coastal waters achieve "good" environmental status by 2015, and defines how this should be accomplished through the establishment of environmental objectives and ecological targets for surface waters. The Directive repeals the Shellfish and Freshwater Fisheries Directives, but sets at least equivalent standards for such waters. The States are currently implementing a pilot scheme in order to tackle catchment inputs of nitrogen, one of the key assessed risks to the Island's water not meeting good status.

As identified in the Data Review Reports of 1997 & 2008, the catchment management will play an important part in reducing the nitrogen input, with catchment sources accounting for approximately half of the estimated nitrogen budget. Such sources would require an integrated strategy for catchment management and water quality control.

7.0 PROPOSALS TO CONVERT FORM ENHANCED ASP TO CONVENTIONAL ASP

It has been recognised that the existing ASP at Bellozanne STW is undersized and would not achieve the 10mg/l total nitrogen limit despite the significant investment since early 2000 and the best efforts by TTS. The denitrification process at Bellozanne STW cannot guarantee the reduction in total nitrogen required by the Discharge Permit as the **Enhanced ASP** is unstable. As a result, it will be prudent to utilise the most robust process and establish an 'optimum' length of outfall based on the assimilative capacity of the receiving waters.

Based on the various activated sludge processes currently in use, the **Conventional ASPs** are the most robust and relatively easy to operate. They have been in use in the UK for over 70 years and the technology is well established. Nitrifying ASPs are also easy to operate but the addition of nitrification/ denitrification leads to a larger plant, which is more complex process and more difficult to operate as experienced at Bellozanne STW.

Based on the performance of the Bellozanne STW and an evaluation of the processes, it has been determined that the existing works can be converted to a **Conventional ASP** to meet the requirements of the UWWTD. Poor hydraulic distribution to the final tanks will be compensated by availability of excess capacity for a **Conventional ASP**. This would be part of a short to medium term strategy to meet the effluent quality requirements.

Without the need to recycle mixed liquor, there will be less hydraulic restrictions and there will be potential to increase the FFT from the current level of 600l/sec to 740l/sec. However, this will need to be investigated further before an FFT can be agreed

The nature of the suspended solids in the final effluent from a **Conventional ASP** is expected to improve kill from the UV disinfection process to a level prior to conversion to the **Enhanced ASP**. With the establishment of a stable process with the **Conventional ASP,** scum removal system can be installed at the final settlement tanks to further safeguard and improve the effectiveness of the UV disinfection process by reducing the solids carry over in the final effluent.

The report submitted by CREH on the Reassessment of the trophic status of St Aubin's Bay (November 2010) confirms that **St. Aubin's Bay is not 'Sensitive'** for the current level of discharge from Bellozanne STW at the existing outfall location.

It is therefore proposed that the **Enhanced ASP** is converted back to a **Conventional ASP** to create a stable process and to meet or exceed the current effluent quality as outlined in Section 9.0. It should be noted that the regulatory/legal process will also have to be considered as part of this proposal and the anticipated implementation programme would be during the second half of 2013.

It is also proposed that further investigations are carried out to determine the optimum location in the long term for the effluent discharge as reviewed in Section 8.0 with potential improvements to the St Aubin's Bay and its environment.

8.0 OPTIONS FOR OUTFALL

8.1 Issues with Current Location

The final effluent from the Bellozanne STW is discharged via a short outfall into St Aubin's Bay near the First Tower area. The effluent is discharged via the outfall to mid tide level and is exposed for long periods; this is generally not advisable in a recreational area with direct exposure of effluent.

In 2010 the STW operated in storm conditions for periods in 130 days. The total storm flow being 318,422 m^3 which is 3 % of the total flow received at the works for that annual period. If the FFT is increased from the current level of 600l/sec to 740l/sec, the number of days of STW operation in storm conditions would drop from 130 days to 50 days.

With the improvements to the Variable Speed Drives at the First Tower Sewage Pumping Station, some of the storage available at the Cavern Storage Tanks could be utilised to further limit the storm overflows at the Bellozanne STW. However, significant further work will be required to quantify these benefits.

With a short sea outfall, there is always a potential risk of currents bringing back non-compliant effluent to shore during storm conditions and plant failures. Furthermore, potential exists for increased risks to the environment and of failure of EU Bathing Waters Directive should there be operational issues at the STW.

8.2 Extension of Outfall to Low Tide Level

The current length of outfall may require a higher quality of effluent to ensure the bay is not affected, however, longer lengths may impact on the offshore shellfish beds and Ramsar site so does not necessarily allow for a lower standard. It will therefore be necessary to establish an optimum location to ensure that both environmental and health criteria are satisfied.

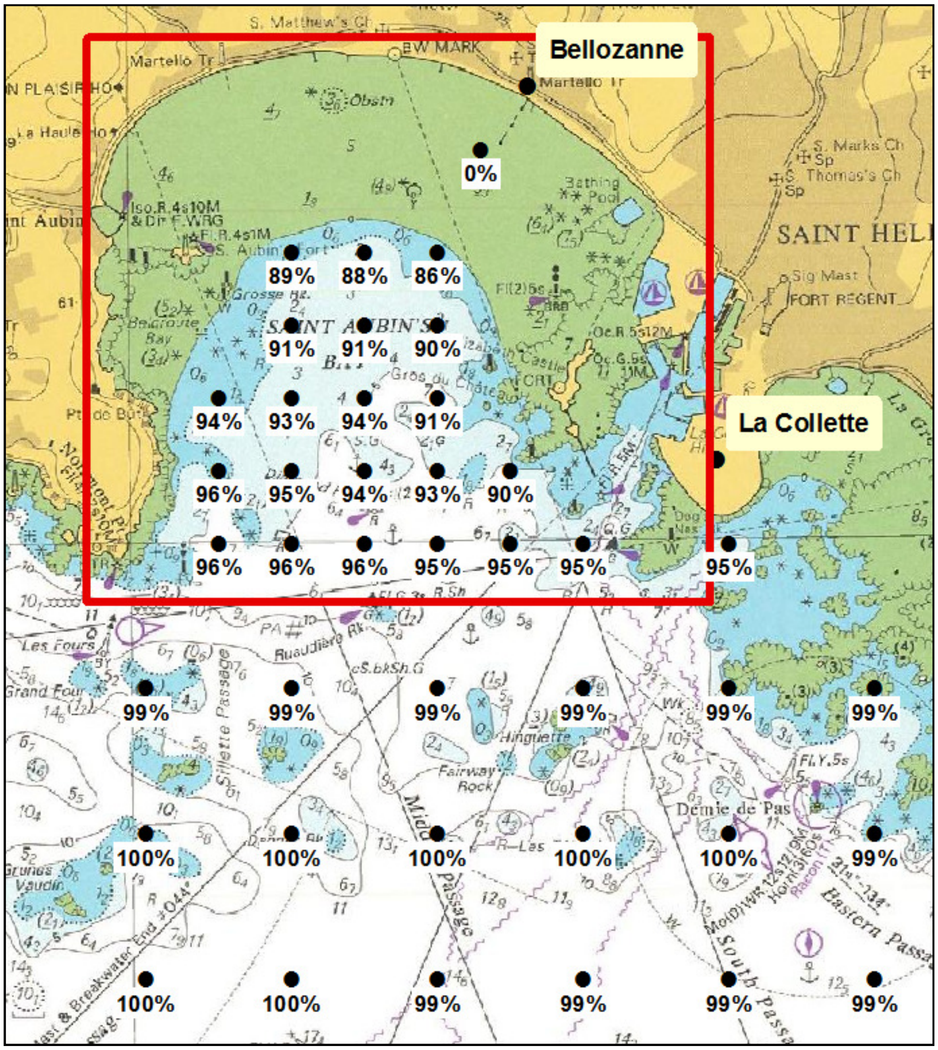
Best practice in the UK is to discharge final effluent beyond the current mid tide level to avoid the outfall being exposed for long periods.

For options involving potential discharges of treated effluent to St. Aubin's Bay, the following two alternative approaches can be considered:

1. Treatment of effluent to a level acceptable for discharge via the existing sea outfall.

2. Treatment of effluent to a level acceptable for discharge to deeper waters within the Bay for better dispersion and dilution via an optimum sea outfall below low tide level.

Based on the **Outfall Desk Study** prepared by Marcon Computations International Ltd. in April 2010, the relative impacts on water quality were assessed for St Aubin's Bay and beyond. Based on the Desk Study, the relative impact on the water quality of St. Aubin's Bay from the current Bellozanne STW outfall can be reduced by 86% by relocating the outfall to just below the low tide level, a distance of 1.5km from the seawall. However, any improvements that could be achieved by further extensions are marginal as shown below (extract from the Outfall Desk Study) and may impact on the offshore shellfish beds and Ramsar site.



An 'optimum' length of outfall, according to the degree of dilution and dispersion, must be established to ensure an effective long term solution in conjunction with the work at Bellozanne STW, particularly the selection of the **Conventional ASP** in the short term with its implications. The solution need to have due regard to engineering, environmental and economic considerations.

A summary of the strengths and weaknesses of the options for Compliance with the UWWTD is given in Table 1.

Treatment Process Option	Strengths	Weaknesses
Conventional ASP + discharge via the existing sea outfall	• Reduced operational cost and complexity. • Reduced energy cost and carbon footprint. • Stable effluent quality with disinfection. • No outfall extension with construction activities. • Low cost solution.	• Potential risk of currents bringing back non-compliant effluent to shore. • Increased risk of failure of EU Bathing Waters Directive should there be operational issues at the STW. • Increased risk to the environment should the STW fail. • Exposed outfall for long periods and not in accordance with Best Practice. • Public perception of the link between effluent outfall and sea weed growth. • Direct exposure of effluent to the public due to recreational activities. • Limited dilution and dispersion of effluent. • Potential impact on shellfish beds and the Ramsar site.
Conventional ASP + discharge via an optimum sea outfall	• Reduced operational cost and complexity. • Reduced energy cost and carbon footprint. • Reduced risk of failure of EU Bathing Waters Directive should there be operational issues at the STW. • Reduced risk to the environment should the STW fail. • Stable effluent quality with disinfection. • Outfall in accordance with Best Practice. • No direct exposure of effluent to the public due to recreational activities. • Improved dilution and dispersion of effluent.	• Potential risk of currents bringing back non-compliant effluent to shore. • Additional potential construction difficulties (weather, ground conditions etc.). • Higher cost solution. • Potential impact on shellfish beds and the Ramsar site.

Table 1 – Options for Compliance with the UWWTD

The effluent from the Bellozanne STW could be discharged to the sea via the existing outfall or via an optimum outfall of length to be determined by further study, including marine and hydraulic modelling

It should be noted that the regulatory/legal process will also have to be considered as part of this proposal and the anticipated implementation programme for any required modifications to the outfall would be in 2014/ 2015.

Discussions with the Planning and Environment Department (PED) should be progressed as soon as possible to establish their views, potential concerns and/or any mitigation measures required, even if it is only at outline level, to ensure that the correct investigations are carried out. They will also need to be consulted regarding the survey work, particularly the intrusive elements such as sea bed geotechnical cores.

9.0 FUTURE STRATEGY AND PROPOSALS FOR MOVING FORWARD

The report on the Reassessment of the Trophic Status of St Aubin's Bay (November 2010) concludes that St. Aubin's Bay is not subject to eutrophication, based on the observed data and CSTT model results. On this basis, St Aubin's Bay is not considered to be 'Sensitive Waters' and, therefore, any effluent discharges from Bellozanne STW will not require nitrogen removal in accordance with the UWWTD. However, additional data collection over more seasons to take into account of seasonal variations may be warranted in order to provide stronger evidence for moving forward with an informed choice.

9.1 Sewage Treatment Works

Treatment of discharged effluent from the Bellozanne STW shall be in accordance with Article 4 of the UWWTD (91/271/EEC) and the discharge shall satisfy the requirements of Annex I.B as shown in Table 1 and summarised as follows:

- Biochemical Oxygen Demand (BOD_5) - 25mg/l
- Chemical Oxygen Demand (COD) - 125mg/l
- Total Suspended Solids - 35mg/l

However, further study has been carried out April 2011 to determine the effluent quality that could be achieved in terms of additional significant parameters and the modifications required for conversion to a **Conventional ASP** and the findings are summarised below.

The Conventional ASP treatment process has been modelled to have a better understanding of the expected effluent quality, including the level of nitrification with seasonal variations. Key design parameters (e.g. F/M ratio, air supply requirements, nitrification in summer and winter) have been established to review potential performance of the Bellozanne STW as a Conventional ASP and can be summarised as follows:

1. Convert to **Conventional ASP** based on a minimum 30:20 standard for SS:BOD;
2. Treat incoming flows of 600l/s (current FFT) and 740l/s (calculated FFT);
3. Assess the level of nitrification that could be achieved (seasonal variations) at increased FFT and an appropriate F/M ratio;
4. Establish potential effluent quality level that would be achievable in terms of NH_3 - N;
5. Confirm the scope of the modifications required (e.g. blower capacity, modifications to aeration system in the tanks, changes to anoxic zones etc. to assist in developing the budget estimate for the modifications; and,
6. Revisit the modifications required to improve the flow split to the ASP.

Based on the volume available within the existing aeration tanks, it is theoretically possible to sustain a higher degree of nitrification for the three design scenarios in the warmer months, albeit at higher operating costs. Due to the temperature dependency of the nitrification process, seasonal variation was modelled. The predicted 95%ile final effluent ammonia nitrogen level for the various design horizons are presented in the following table.

Design Horizon	FFT (l/sec)	Water temperatures in excess of 16 ^{O}C	Water temperatures in excess of 13 ^{O}C
2011 - Current FFT	600	10 mg/l NH_3 - N	20 mg/l NH_3 - N
2013 - Calculated FFT	740	10 mg/l NH_3 - N	20 mg/l NH_3 - N
2030 - Liquid Waste Strategy	810	10 mg/l NH_3 - N	25 mg/l NH_3 - N

If the water temperature drops to 10 ^{O}C during winter, the Ammonia Nitrogen level will be expected to be in the order of 30 mg/l.

In essence **Conventional ASP** will be returning the plant to its pre **Enhanced ASP** status but with increased serviced population and with the exception that the blowers will be adequate for nitrification and the additional final tanks will permit this plant to hold higher MLSS than it did in 1999. However the pre 2000 plant was not designed to nitrify and this plant will not nitrify better than 44% now (and 40% by 2030) in winter conditions. This will be better than the pre 2000 position. In the summer much better performance will be expected due to the higher temperatures and some significant denitrification will be achieved in the anoxic zone (up to 25% of Nitrate Nitrogen to Nitrogen gas).

It should be noted that these Ammonia Nitrogen levels are based on the theoretical load for domestic wastewater scenario. If the actual load is higher than the theoretical load, then the effluent quality values will be higher than the values above suggest. Further investigation will be required to determine the reasons for any increased loads and any mitigation measures required to deal with occasional high loads, including managing the return liquor load.

As the population increases, the plant's performance can be improved only with additional aeration volume and this will be considered together with any future **Enhanced ASP** as part of the Liquid Waste Strategy development.

In order to convert the Bellozanne STW to a **Conventional ASP**, the following modifications will be required:

1. Provide scum boards and scum removal equipment for all the final settlement tanks.
2. Remove the Pegazur pellets from Lanes 1 & 3 and keep the Ovivo curtains in Lane 3.
3. Reduce the size of the anoxic zones to the first pocket in each lane and extend the aeration pipework with diffuser membranes into the back two pockets of each lane of the present anoxic zones.
4. Reduce the number of diffuser membranes in the present aeration zones.

There will not be any need for modifications to the RAS pumping arrangement or selector zones. Provision of existing aeration blowers is more than adequate. However, it will be worthwhile to improve the flow split to the ASP with a distribution chamber as flow will always favour the first aeration lane unless flow control measures are undertaken.

The optimum operating condition for the ASP would be a MLSS of 3000 - 3500 mg/l with a RAS return of 0.5 DWF to 1.5 DWF. These conditions are readily achievable with the aeration volume and final settlement area available.

With the above modifications and operating conditions the STW will achieve a good carbonaceous treatment but with limited nitrification with seasonal variations as noted. On a 95%ile basis, the STW will achieve a 30 mg/l SS: 20 mg/l BOD standard. Seasonal ammonia levels of 10 mg/l NH_3 – N and 20 mg/l NH_3 – N can be achieved with water temperature > 16 ^{O}C and > 13 ^{O}C respectively. These are in line with the levels predicted by the model. It should be noted that this would represent an enhancement to the requirements outlined in the UWWTD with increased operating (energy) costs. With the increased nitrification, potential exists for denitrification in the final settlement tanks unless sludge draw-off is managed effectively.

The fitting of scum removal equipment will allow better solids capture in the final settlement tanks and will improve the performance of the UV disinfection plant to permit enhanced disinfection to comply with the Bathing Waters Directive.

With the conversion of Bellozanne STW to a **Conventional ASP**, the plant would in effect be returned to the pre 2002 conversion when it regularly achieved the 30 mg/l SS: 20 mg/l BOD standard. It should be noted that this would be an enhancement to the requirements outlined in the UWWTD. Furthermore, potential exists for an increase in FFT from the current level of 600l/sec without any deterioration of the effluent quality

It is proposed that a detailed study is commissioned to produce a definitive scope of works required to achieve the conversion to a **Conventional ASP.** A BATNEEC (best available technology not entailing excessive cost) study is also proposed to deliver the most appropriate solution commensurate with the population served and assess the potential environmental impact of a change in treatment regime.

9.2 Effluent Outfall

Further to recommendations made in the Outfall Assessment Study completed in April 2010, additional surveys are required for detailed modelling of microbial and nutrient parameters to refine the model of the St Aubin's Bay and optimise the length of outfall against quality of effluent.

Carrying out the surveys earlier rather than later will help to refine the estimate of the sea outfall modifications but may require some repeat work if a significant period passes before the EIA is carried out. Discussions with the Planning and Environment Department (PED) should be progressed as soon as possible, even if it is only at outline level, to establish their concerns and what investigation and/or mitigation they will require to ensure that the correct investigations are carried out. They will also need to be consulted regarding the survey work, particularly the intrusive elements.

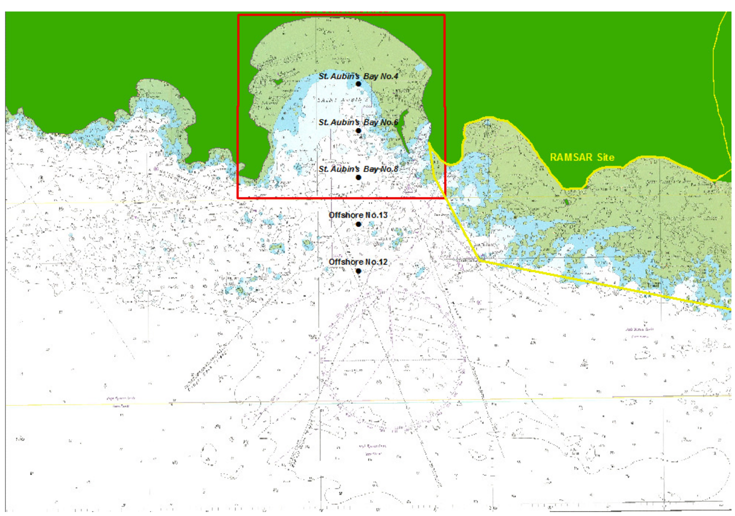
The various survey requirements can be outlined as follows:

1. Hydrographic Survey shall consist of:

   1.1 Bathymetric survey (1 week) to confirm accuracy of the Admiralty Chart for the area where the major masses of water are circulating.
   1.2 Seismic survey (sub bottom profiling) to resolve the first few metres of sea bed sediments (including sea bed samples to calibrate and validate the survey).
   1.3 Deployment of 3 bottom mounted Nortek Acoustic Doppler Current Profilers (ADCPs) and current meters for a 28-day period for recording data to validate model predictions.
   1.4 Drogue and/ or dye release from proposed outfall location(s) (3 locations at both spring and Neap tides with 5 drogues released at hourly intervals) to validate solute transport model.

   The extent of the bathymetric survey required for the outfall modelling study needs to be agreed but the 'ideal' coverage area will encompass the rocky shoals offshore of St. Aubin's Bay and potential outfall locations.

   The seismic survey should cover the locations from existing outfall to outfall locations 4 to 6 as shown below as a minimum.



2. Water Quality Survey shall consist of:

   2.1 Microbiological sampling and analysis to ascertain pollution sources and microbial decay rates in the ambient waters.
   2.2 Nutrient (nitrate, phosphate, chlorophyll, BOD) sampling.

   The sampling programme shall allow for sampling all river discharges and coastal waters at probably fortnightly intervals, and within the bay area over the course of at least one spring & neap tide.

   Water quality (nutrients and bacteriological) surveys shall be carried out within and just outside of St. Aubin's Bay, including CSOs near the shellfish beds.

3. Modelling (4 – 5 months) shall consist of:

   3.1 Both microbial fate and transport model.
   3.2 Eutrophication model.
   3.3 Models calibrated to predict impact of existing and potential outfall locations.

   Modelling (eutrophication and bacteriological) will be required to integrate the survey data and develop a solution appropriate for the States of Jersey.

   The extent of the fine mesh model shall be 50m and will cover the eastern shores of Jersey, including the SE Ramsar site.

   The model shall predict faecal coliform concentrations throughout the entire model domain. The model shall predict the future bathing water compliance of the beaches and historical data can be used to calibrate the model (should commensurate information be available relating to riverine/ outfall discharges).

   It will be necessary to allow for 15 No. scenarios (@1day simulation time each), assuming a 28 day tidal period simulation for:

   - River flows/loads (high & low, e.g. 50% & 95%ile exceedence flows)
   - Discharge flow/loads (high & low)
   - Wind conditions (prevailing and adverse)
   - Other options to be defined, e.g. selected discharges, optional treatment levels, etc.

   It is possible to use the water quality data recorded by CREH and/or States of Jersey for the recent and future studies but modelling would have a requirement for high temporal resolution data also (hourly samples over one day time period on a number of different dates). If necessary, this should be included in the scope of the future study by CREH.

   CREH are using the CSTT empirical model to estimate the eutrophic status of the coastal waters. The proposed model shall be able to determine the eutrophic status of the water body at any number of scales (Zone A or B or other spatial scales, possibly C) and how that may vary in time. Hence ideally the model would be calibrated against spring, summer, autumn and winter datasets.

4. Other Investigations including but not necessarily limited to:

   4.1. Seabed geotechnical cores.
   4.2. Condition survey of the existing outfall.

5. Environmental Impact Assessment (EIA) including but not necessarily limited to:

   5.1 Both microbial fate and transport model.
   5.2 Assessments for Marine Archaeology, Bio-diversity, Flora & Fauna, Crustaceans, Shipping, Oil Cargo, etc.
   5.3 Preparation of Scoping Report.
   5.4 EIA Document.

10.0 CONCLUSION & RECOMMENDATIONS

It will be necessary agree with PED any monitoring/ sampling required in the short, medium and long terms and agree a programme for the implementation of the strategy for the **Conventional ASP** at Bellozanne STW and an optimum outfall. It should be noted that the regulatory/ legal processes will also have to be considered as part of this strategy. The anticipated implementation programme for any ASP modifications would be during the second half of 2013 and any required modifications to the outfall would be in 2014/ 2015.

In view of the significant capital investment required to move forward, it is proposed that a steering group be set up to consider and agree the strategy presented here for the Bellozanne STW together with an optimum effluent discharge location. A TTS funding stream needs to be established at the earliest opportunity in accordance with the programme for the implementation of the strategy.

It is imperative that the PED and Environmental Health Department are consulted in order to adopt a positive and proactive approach to environmental health with safeguards in place at the Bellozanne STW as well as at the effluent discharge location at St. Aubin's Bay. It will be necessary to work with the Regulator to agree the framework for moving forward.

The assimilative capacity and the bacteriological quality of the receiving waters will be enhanced by an extended outfall to discharge below the low tide level at an optimum location. UV disinfection would continue to be provided and enhanced with a **Conventional ASP** at Bellozanne to safeguard the bacteriological quality for bathing waters and shellfish beds.