Irish Water

PROJECT:

# Ringsend Wastewater Treatment Plant | Upgrade Project

DOCUMENT:

# AGS Process Proving Summary Report

30 November 2017

# Document Control Sheet

| | |
|---|---|
| **Client:** | **Irish Water** |
| **Project Title:** | Ringsend Wastewater Treatment Plant \| Upgrade Project |
| **Document Title:** | AGS Process Proving Summary Report |
| **File Name:** | RGD-2JV-11-ZZ-RP-P-01200_PP_Summary_Report |

| **Table of Contents** ***(incl. Y/N)*** | **List of Tables** ***(incl. Y/N)*** | **List of Figures** ***(incl. Y/N)*** | **Pages of Text** ***(No.)*** | **Appendices** ***(No.)*** |
|---|---|---|---|---|
| Y | Y | Y | 13 | 1 |

| **Document Revision** | | | | **Document Verification** | | | |
|---|---|---|---|---|---|---|---|
| **Issue Date** *(DD/MM/YY)* | **Revision Code** | **Suitability Code** | **Author** *(Initials)* | **Internal Reviewer** *(Initials)* | **JV Reviewer** *As Per UPQP (Initials)* | **JV Approver** *As Per UPQP (Initials)* | **Peer Review** *(Initials or N/A)* |
| 22/11/17 | P01 | S3 | MBB | BdB | EZ | MH | N/A |
| 30/11/17 | P02 | S4 | MBB | BdB | EZ | MH | N/A |
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# List of Abbreviations

| | |
|---|---|
| AGS | Aerobic Granular Sludge |
| BOD | Biological Oxygen Demand |
| CA | City Analysts Limited |
| COD | Chemical Oxygen Demand |
| DCC | Dublin City Council |
| DO | Dissolved Oxygen |
| DWF | Dry Weather Flow |
| ILPS | Intermediate Lift Pumping Station[1] |
| MLSS | Mixed Liquor Suspended Solids |
| N/A | Not Applicable |
| PPS1 | Process Proving Step 1 |
| PPS2 | Process Proving Step 2 |
| PST | Primary Settling Tanks |
| PPU | Process Proving Unit |
| SAS | Surplus Activated Sludge |
| SBR | Sequencing Batch Reactor |
| SS | Suspended Solids |
| TKN | Total Kjeldahl Nitrogen |
| TN | Total Nitrogen |
| TP | Total Phosphorous |
| TSS | Total Suspended Solids |
| UWWD | Urban Wastewater Treatment Directive |
| WLC | Water Level Correction |
| WwTP | Wastewater Treatment Plant |
| VSD | Variable Speed Drive |

[1] Following primary sedimentation at the Ringsend WwTP, settled wastewater is pumped by the ILPS to the existing SBRs for secondary (i.e. biological) treatment.

# SECTION 1: INTRODUCTION

The Ringsend Wastewater Treatment Plant (WwTP) Upgrade Project consists of increasing the WwTP's capacity to treat a future Design Load of 2.4 million p.e.[2] to the required effluent standards. According to the Outline Design Period and Interim Detailed Design Period Reports, this upgrade will be accomplished with a Capacity Upgrade of 6 new Aerobic Granular Sludge (AGS) Reactors and the Retrofit of the existing Ringsend Sequencing Batch Reactors (SBRs) with the AGS Technology.

A Process Proving Program is being carried out at the Ringsend WwTP in Dublin to demonstrate the suitability of the AGS technology for application in the Ringsend WwTP Upgrade Project and to inform the design process. The specific technology being used during the Process Proving Program is the Nereda®[3] implementation of AGS provided by Royal HaskoningDHV.

The Process Proving Program comprises two distinct steps as follows:

PPS1. Process Proving Step 1 (PPS1) involved the operation of a small scale Process Proving Unit (PPU) to establish stable operating conditions followed by an extended period of testing at full project design flows/loads.

*The purpose of PPS1 was primarily used to establish the performance of the technology over a full calendar year, with particular reference to nutrient removal performance (nitrogen and phosphorus) and establishing the extent of its seasonal variation.*

PPS2. The second Process Proving step (PPS2) involves the full scale trial of the technology in a retrofit of one of the existing 24 SBR cells at the Ringsend WwTP and operating it at full project design flows/loads.

*The purpose of PPS2 operation was primarily to confirm the validity of the PPS1 results at full scale (i.e. eliminate any pilot scale effects) and to inform the design and implementation of the Capacity Upgrade and remaining SBR retrofits.*

This Process Proving Summary Report presents the results of the Process Proving Programme.

## 1.1 Design Loads

The design loading for the Process Proving Programme was developed based on historical Ringsend WwTP data (2009 to 2014) and the projected flow distributions of primary settled influent between the Retrofit SBRs and the new Capacity Upgrade at the future design WwTP loading of 2.4 million p.e. The design values are based on annual averages and 98th percentile values. This higher percentile is being used as the design basis of the full WwTP Upgrade Project in order to provide a robust process design capable of dealing with significant influent load variation while maintaining effluent quality.

In both PPS1 and PPS2 the design loading was based on the future load to the Retrofit SBRs. The specific loads used are shown in Table 1. The loads are normalised per volume of reactor.

[2] p.e. = Population equivalent. Defined in the Regulations as 'a measurement of organic biodegradable load'. A population equivalent of 1 (1 p.e.) means the organic biodegradable load has a five-day biochemical oxygen demand (BOD5) of 60g of oxygen per day.

[3] Nereda® Technology is a patented and proprietary technology for biological treatment of wastewater with aerobic granular biomass, branded with the registered trade name Nereda® which is owned by Royal HaskoningDHV.

**Table 1 Specific Design Loads to Retrofit SBRs**

| Outline Design Loads | Hydraulic (m3/m3.d) | BOD (kg/m3.d) | COD (kg/m3.d) | TSS (kg/m3.d) | KJN (kg/m3.d) | TP (kg/m3.d) |
|---|---|---|---|---|---|---|
| ***Average*** | 1.7 | 0.26 | 0.66 | 0.26 | 0.065 | 0.008 |
| ***98$^{th}$ Percentile*** | 3.25 (max) | 0.46 | 1.06 | 0.48 | 0.091 | 0.012 |

## 1.2 Effluent Requirements

In order to comply with European Union's Urban Wastewater Treatment Directive (UWWD), the Ringsend WwTP must achieve the Discharge Licence Requirements set out in Table 2.

**Table 2 Discharge Licence Requirements**

| Parameter | Unit | Value | Type |
|---|---|---|---|
| BOD | mg/l | 25<br>50 | Annual 95th Percentile<br>Annual Maximum |
| COD | mg/l | 125<br>250 | Annual 95th Percentile<br>Annual Maximum |
| TSS | mg/l | 35<br>87.5 | Annual 95th Percentile<br>Annual Maximum |
| Total Nitrogen | mg/l | 10 | Annual Average |
| Total Phosphorous | mg/l | 1 | Annual Average |

During Process Proving, the Minimum Effluent Requirements for the AGS technology in PPS1 and PPS2, were the same as these Discharge Licence Requirements, save where the Period is less than 12 continuous calendar months. Of these effluent standards, Total Nitrogen is the only one significantly affected by process temperature, therefore in order to account for process proving period in PPS2 of less than 1 year, it has been agreed that the minimum effluent requirement for Total Nitrogen will be adjusted based on the actual temperatures experienced by the process during that time. The method for Determining TN – T Adjusted is included as Appendix 1 of this Report

# SECTION 2: PROCESS PROVING STEP 1

## 2.1 PPS1 Period

The primary function of PPS1 was to use the Process Proving Unit (PPU) to prove the capacity of the AGS biological treatment process to meet the future effluent standards at the Ringsend WwTP shown in Table 2. The PPS1 Period (also referred to in some reports as Variable Flow Testing) was the 12 month operation of one of the PPU treatment lines at the future design volumetric loading rates to prove the ability of the process to meet future effluent standards while experiencing real time flow fluctuations.

In the PPS1 Period, the cycle time was fixed at 4 hours, the feed time was fixed at 1 hour and the feed flow was set at 0.000024 times the real time influent flowrate to the WwTP. This operation was selected to achieve a volumetric loading rate 18% higher than that of the existing SBRs and target the design loads shown in Table 1. The 18% increase was the difference between the current average load to the WwTP (based on historical plant data from 2009-2014) and the future average design load to the SBRs. The PPS1 Period commenced on June 28th 2015 and concluded on June 30th 2016. Results were excluded when PPS1 was not operated according to future design conditions due to technical issues (c. 5% of the results).

## 2.2 Process Proving Unit (PPU)

The PPU comprised 2 separate treatment lines (Lines 1 & 2), each with a dedicated Nereda® Reactor. Due to space constraints arising from the containerised-scale of the PPU, each reactor comprised a 600mm diameter cylinder, 6m in height (similar to full SBR scale water depth) with an overall reactor volume of 1.6 $m^3$. Photographs of the PPU are provided in Attachment A of this report.

Line 1 of the PPU was used for PPS1 throughout the full test period. The terms PPU and PPS1 (used interchangeably in the remainder of this report) refer to Line 1. Line 2 was provided for undertaking specific additional tests and trials offline from Line 1 (e.g. optimum seeding levels, spike testing) and as an overall back-up to the Line 1 unit. Line 2 was not used to establish the performance of the technology over the full calendar year and thus is not relevant to, nor reported on, in this report.

Influent for the PPU was obtained from the effluent of the primary settling tanks (PSTs) which was pumped continuously to the PPU influent buffer. Before the influent buffer, the wastewater was screened through a 3mm perforated plate filter. The purpose of screening was to prevent clogging of the small scale piping and equipment in the PPU. The influent buffer had a continuous inflow and overflow such that the influent within it always remained fresh. The influent buffer was continuously mixed to prevent settling.

The AGS technology applied involves simultaneous filling and emptying of the reactor with vertical 'plug-flow' during this combined 'fill-decant' phase. The effluent discharged from the top the reactor during the feed phase was collected in a dedicated effluent buffer from which samples were taken. Similarly, surplus sludge was also collected in a dedicated sludge buffer. The PPU was provided with chemical dosing capability to allow chemical precipitation of phosphorus to be carried out in the reactor if deemed necessary. The chemical dosing unit was not used at any stage during the 12 month PPS1 variable flow testing program.

The PPU was controlled by the Nereda® Controller which is the same advanced control software used at full-scale Nereda® AGS plants.

General operation and maintenance activities on the PPU were carried out on site by Royal HaskoninDHV with assistance from Celtic Anglian Water. Major maintenance and repair activities were carried out by the PPU's owner EPS Ltd.


**Figure 1 PPS1 Process Proving Unit**

## 2.3 PPS1 Monitoring

Online analysers and probes in the buffers and the reactors monitored the performance of PPS1 during the 12 month test period.

Flow proportional 24 hour composite samples of the influent and effluent were taken from the respective buffers during the reactor feeding phase by auto-samplers. On Mondays, Wednesdays and Fridays, samples were taken and sent to an external laboratory for water quality analysis. The external laboratory was initially City Analysts (CA) and from mid-August testing of samples was transitioned to Dublin City Council Central Laboratory (DCC) with approximately 2 additional samples per week being tested up to early November 2015. From the middle of November 2015, all composite samples were analysed solely by DCC Central Laboratory. Comparisons between the PPU influent buffer samples and samples of the influent to the SBRs were used to ensure the feed to the PPU was representative of the feed to the SBRs.

The sludge characteristics of the reactors mixed liquor and waste sludge were sampled and analysed by Royal HaskoningDHV.

## 2.4 PPS1 Loads

Table 3 compares the influent loading during the PPS1 Period with the future design loads to the SBRs in the Ringsend WwTP Upgrade Project. The loads are normalised per volume of reactor for comparison.

**Table 3 Comparison of PPS1 Loading to Design Loading**

| **Average Loads** | **Hydraulic (m3/m3.d)** | **BOD (kg/m3.d)** | **COD (kg/m3.d)** | **TSS (kg/m3.d)** | **KJN (kg/m3.d)** | **TP (kg/m3.d)** |
|---|---|---|---|---|---|---|
| Design | 1.7 | 0.26 | 0.66 | 0.26 | 0.065 | 0.008 |
| PPS1 Period | 1.76 | 0.28 | 0.64 | 0.24 | 0.070 | 0.012 |
| % of Design Load | 101% | 108% | 96% | 91% | 106% | 148% |
| ***98th Percentile Loads*** | ***Max Hydraulic*** *(m3/m3.d)* | ***BOD*** *(kg/m3.d)* | ***COD*** *(kg/m3.d)* | ***TSS*** *(kg/m3.d)* | ***KJN*** *(kg/m3.d)* | ***TP*** *(kg/m3.d)* |
| Design | 3.25 | 0.46 | 1.06 | 0.48 | 0.091 | 0.012 |
| PPS1 Period | 3.38 | 0.43 | 0.89 | 0.38 | 0.102 | 0.019 |
| % of Design Load | 104% | 92% | 84% | 78% | 111% | 153% |

Table 3 shows that, with the exception of TP, the average load of each parameter to PPS1 during the year of the PPS1 Period was within ±10% of the design load. Somewhat more variation is seen in the 98th percentile loading which is not unexpected given the multiple years of data on which those results are based.

Overall the loading of PPS1 during PPS1 Period is considered to be representative of the Project Design loading for the SBRs with the exception of TP. No historical data was available on Total Phosphorus (TP) in the PST effluent prior to the start of PPS1, and it was assumed that the levels would be the same as those in the WwTP raw influent. During the process proving program, however, it was found that phosphorus levels in the PST effluent (i.e. influent of the PPU) were elevated due to Bio-P activity occurring in the existing SBRs. The elevated levels were the result of reactive-P recycling through the sludge liquor return flows. This can be clearly seen in the TP graph contained in Attachment B. In the future WwTP Upgrade Project, a phosphorus fixation step is proposed to be included in the sludge processing stream to address the enhanced biological phosphorus removal activity of the AGS technology (i.e. to prevent the release of phosphorus from the sludge stream and its recycling within the water stream of the plant) therefore the levels of phosphorus experienced in the influent of PPS1 during the reporting period were significantly higher than those that will be experienced in the future situation when the Upgrade Project is fully complete. With the P-Fixation process stage in place it is expected that future TP levels after the PSTs will be comparable to those seen in the WwTP's raw influent.

## 2.5 PPS1 Effluent Quality

The purpose of PPS1 was to demonstrate that the Nereda® AGS technology can be used to treat the Ringsend wastewater to the required effluent standards. In Table 4, the results from the full calendar year of the PPS1 Period are compared with the Urban Waste Water Treatment Directive requirements.

**Table 4 Effluent Performance during the PPS1 Period**

| Effluent Parameter (mg/l) | Effluent Standard | PPS1 Period |
|---|---|---|
| | Annual | 28/6/15 – 30/6/16 |
| TN – Average | ≤10 | 6.9 |
| TP – Average | ≤ 1 | 1.0 |
| BOD – Average<br>BOD – 95th percentile<br>BOD – Maximum | N/A<br>< 25<br>< 50 | 5.5<br>10.9<br>14.0 |
| COD – Average<br>COD – 95th percentile<br>COD – Maximum | N/A<br>< 125<br>< 250 | 40.6<br>61.0<br>82.0 |
| TSS – Average<br>TSS – 95th percentile<br>TSS – Maximum | N/A<br>< 35<br>< 87.5 | 9.1<br>22.0<br>34.0 |

During the full year of the PPS1 Period, the AGS technology was able to comfortably achieve the 95th Percentile effluent standards for BOD, COD and TSS and no *'not to exceed'* values (Upper Tier failures) were recorded. During the 12 calendar months of testing, PPS1 was also able to comfortably achieve the effluent standard for a yearly average TN of 10 mg/l or less.

With respect to Total Phosphorus, the results from PPS1 met the effluent standard, notwithstanding the fact that process performance was negatively influenced by a number of factors. Some of the factors were considered specific to the Pilot Scale of the PPU installation while others can be addressed at full scale with operational control. Furthermore the TP feed concentration is expected to be significantly lower in the future when the Upgrade Project is complete (and the P-Fixation facility in particular is operational). Finally, and as previously noted, standard implementation of the AGS technology includes facilities for occasional chemical dosing with metal salts to precipitate phosphorus in the process units. If/when required, a very small amount of chemical dosing is used to assist the biological process in further reducing TP levels. It should be noted that while such chemical facilities were available to be used in PPS1, the decision was made relatively early in the testing period that no such dosing would be undertaken during the 12 months in order to determine the performance of the biological process on its own.

## 2.6 PPS1 Conclusions

The results of the PPS1 period confirm that:

- The Influent loading to the PPU during the PPS1 Period was representative of the future design load to the SBR Retrofit element of the Ringsend WwTP Upgrade Project.
- The operating conditions in the PPU we representative of the SBR operating conditions
- Over the year-long PPS1 Period, the effluent from the AGS technology met the requirements of the UWWTD

# SECTION 3: PROCESS PROVING STEP 2

## 3.1 PPS2 Period

The primary purpose of the PPS2 Period was to prove continued stable operation of the AGS Technology at full scale. During this period a Ringsend SBR retrofit with AGS technology was operated according to design conditions for the Full Retrofit of the 24 SBR cells into AGS Reactors with the intention of proving that the required effluent quality could be achieved. The Operating Window for the PPS2 Period was therefore based on treating 1/24th of the future load to the Retrofit as shown in Table 1.

Operation under future design conditions took into account the variable flow to the ILPS, the planned Direct Pumping based feeding patterns, and the distribution of future flows between Element 2 and Element 3 of the Ringsend WwTP Upgrade Project. The cycle time was fixed at 4 hours.

The PPS2 Period commenced on the 18th of July 2017 and was completed on the 27th of October 2017.

A significant interruption to the consistent operation of the PPS2 Period occurred between the 16th and 23rd of August due to a failure of the ILPS feed pump VSD. On the day of the failure, the day the pump was returned to service, and the intervening dates the operation was not according to future conditions. Load and effluent data from the day of the failure and the day the pump was returned to service has been excluded from the PPS2 Period results. All other dates, between the 18th of July and the 27th of October were considered to represent operation in future conditions, including some minor interruptions which did not lead to significant deviations, and those results are included.

## 3.2 PPS2 Design

The design of PPS2 involves the conversion of Upper Deck SBR Cell 3B into a full AGS Reactor with the Nereda® Technology which can be fed independently of the remaining SBRs and thus be used to test performance of the technology at future design conditions.

The PPS2 design includes the ability to feed surplus sludge from the Upper Deck AGS Reactor to the Lower Deck SBR 6B directly below it allowing for further testing of potential optimizations for the Ringsend SBR Retrofit.

Influent for the AGS Reactor is obtained from the effluent of the primary settling tanks (PST) at the intermediate lift pumping station (ILPS) by a dedicated PPS2 feed pump with a design capacity of 6750 $m^3$/h. The pump operates independently of the other Block 3 SBRs feeding schedule.

Influent for the AGS Reactor is fed to the reactor's high inlet channel which supplies the influent distribution grid on the bottom of the reactor floor. Good distribution through the influent grid is dependent on good performance of the upstream process, namely screening, grit removal and primary clarification.

Effluent decants from the top of the AGS Reactor as it is displaced by the influent. Effluent is collected evenly across the reactor surface by 8 effluent launders fitted with V-notch weirs along both sides. Effluent from the launders flows to the existing drop pockets.

A high level sludge discharge grid is installed beneath the effluent launders and can be used for both Sludge Discharge and Water Level Correction (WLC) phases. Depending on the phase, the sludge is directed to an internal sludge buffer or the WLC is directed to a WLC Buffer. Water from the WLC buffer is pumped back to the Block 3 centre core. Sludge from the sludge buffer is pumped to the pre-reaction zone of Cell 6B. Depending on whether or not the sludge buffer is used for pre-thickening, supernatant from the sludge buffer may also be pumped to the Block 3 centre core.

Chemical dosing is planned for backup chemical phosphorus removal but due to construction delays was not available during the PPS2 period.

The Nereda® AGS Reactor is controlled by the Nereda® Controller advanced control software. Remote access and control is possible for all stakeholders anywhere they have an internet connection and online data is automatically transferred to the historian of Royal HaskoningDHV.

PPS2 is operated by Celtic Anglian Water, the WwTP operator with process support by Royal HaskoningDHV.

**Figure 2 PPS2 Nereda® Installation in Former Ringsend SBR 3B**

## 3.3 PPS2 Monitoring

Online analysers and probes in the influent channels, reactors and effluent streams monitor the performance of the AGS Reactor.

Samples of the influent and effluent of the reactor are taken on work days by auto-samplers. All samples are 24 hour flow proportional composites. The influent is taken from the high inlet channel during Feed/Decant and the effluent from the central drop pocket during the same period. The influent and effluent samples are analysed by the Dublin City Council (DCC) Central Labs. Comparisons between the samples from the inlet channel to the PPS2 AGS reactor and samples of the influent to the SBRs were used to ensure the feed to the AGS reactor was representative of the entre plant.

The sludge characteristics of the reactors' mixed liquor and waste sludge is sampled and analysed on site by the WwTP Operator Celtic Anglian Water with guidance from Royal HaskoningDHV twice per week. The distribution of granules in the mixed liquor is also measured on site once per week.

## 3.4 PPS2 Loads

Table 5 compares the influent loading during the PPS2 Period with the future design loads to the SBRs in the Ringsend WwTP Upgrade Project. The loads are normalised per volume of reactor for comparison.

**Table 5 Comparison of PPS2 Loading to Design Loading**

| **Average Loads** | **Hydraulic (m3/m3.d)** | **BOD (kg/m3.d)** | **COD (kg/m3.d)** | **TSS (kg/m3.d)** | **KJN (kg/m3.d)** | **TP (kg/m3.d)** |
|---|---|---|---|---|---|---|
| Design | 1.7 | 0.26 | 0.66 | 0.26 | 0.065 | 0.008 |
| PPS 2 Period | 1.6 | 0.34 | 0.62 | 0.21 | 0.07 | 0.009 |
| % of Design Load | 93% | 129% | 94% | 81% | 107% | 118% |
| **98th Percentile Loads** | **Max Hydraulic** (m3/m3.d) | **BOD** (kg/m3.d) | **COD** (kg/m3.d) | **TSS** (kg/m3.d) | **KJN** (kg/m3.d) | **TP** (kg/m3.d) |
| Design | 3.25 | 0.46 | 1.06 | 0.48 | 0.091 | 0.012 |
| PPS 2 Period | 2.4 | 0.44 | 0.76 | 0.31 | 0.093 | 0.012 |
| % of Design Load | 75% | 96% | 72% | 64% | 102% | 97% |

The table and figures show the loading to the PPS2 AGS Reactor was near or above the average values of the operating window. The 98th percentile values were also near or above the design values for many parameters. The only parameter for which the PPS2 load was more than 10% below the average design value, is TSS. Historical data (2009-2014) from the ILPS was used to determine the operating window values. While there has been no notable change in the TSS load to the head of the WWTP, some changes to the plant's operation have likely contributed to the reduction in suspended solids load to the biological process at the ILPS. The most notable operational change believed to influence TSS load was eliminating the practice of co-settling surplus activated sludge in the PSTs from the start of PPS2 operation. Given that the PPS2 period was only 3 months in comparison to the 12 for PPS1 It is not surprising there is more variability in the PPS2 loads from the design values

## 3.5 PPS2 Effluent Quality

Table 6 compares the effluent quality results from the PPS2 AGS Reactor during the PPS2 Period with the final effluent standards.

**Table 6 Effluent Performance during the PPS2 Period**

| Effluent Parameter (mg/l) | Minimum Effluent Requirement | Nereda® Reactor 3B |
|---|---|---|
| | Annual | 18 July – 27 Oct |
| TN – Average<br>TN – Average (T-Adjusted*) | < 10<br>< 8.1 | 6.1 |
| TP – Average | < 1 | 1.1 |
| BOD – Average | -- | 6 |
| BOD – 95th percentile | < 25 | 9 |
| BOD – Maximum | < 50 | 20 |
| COD – Average | -- | 46 |
| COD – 95th percentile | < 125 | 56 |
| COD – Maximum | < 250 | 88 |
| TSS – Average | -- | 14 |
| TSS – 95th percentile | < 35 | 26 |
| TSS – Maximum | < 87.5 | 38[4] |

* The calculation of the Temperature Adjusted TN standard is included in Appendix 1.

The effluent quality from Nereda® Reactor 3B during the PPS2 was compliant with the annual effluent standards as the minimum effluent requirements for BOD, COD, TSS and with the temperature adjusted minimum effluent standard for TN. Due to the warm temperatures in the months of the trial, the adjusted TN standard was lower than the yearly standard.

The effluent TP value during the PPS2 period is slightly above the annual effluent standard. A worsening of the biological phosphorus linked to the period in which the reactor was out of service due to the feed pump VSD failure is considered to have led to this elevated result. A typical correction which has been successfully applied in other Nereda® systems (including PPS1) is to induce sustained high loads for 1-2 days to stimulate biological phosphorus activity. This correction was not applied during the PPS2 period to prevent the temporary negative effect (2-4 days) of the high loads on compliance of the other effluent parameters with the minimum effluent requirements during the short PPS2 period. The decision to focus on other parameters over TP was taken because limited use of backup chemical dosing, as designed, would have been sufficient to bring TP back to compliant levels during the time while biological P removal was not optimal. The chemical dosing could not be applied because the construction and commissioning of the backup chemical dosing system for PPS2 has not yet been completed. It is estimated that less than 7% of the TP load during the PPS2 period would have required chemical dosing to meet the TP minimum effluent requirement. This is consistent with the dosing percentage at other Nereda® facilities including Garmerwolde in the Netherlands.

[4] TSS results in table and figure exclude a single data point of 52mg/l on the 25th July as it was considered a single instance of a Nitrogen stripping failure related to further development of denitrification after start-up. When the value is included, the PPS2 Period average TSS is still 14, the 95th percentile TSS is still 26 mg/l and the maximum TSS becomes 52 mg/l, thus the minimum effluent requirements are still achieved.

## 3.6 PPS2 Conclusions

The results of the PPS2 period confirm that:

- The Influent loading to the full scale AGS reactor during the PPS2 period was representative of the future design load to the SBR Retrofit element of the Ringsend WwTP Upgrade Project.
- The full scale AGS reactor achieved the UWWTD standards during the PPS2 Period with the exception of TP which was slightly above the target value of 1 mg/l. Had the planned backup chemical dosing been available there is no doubt that it would have achieved the standard.

# SECTION 4: CONCLUSION

The primary components of the process proving programme used to demonstrate the suitability of the AGS technology for application in the Ringsend WwTP Upgrade Project have been completed using the Nereda® implementation of AGS provided by Royal HaskoningDHV:

> The Process Proving Step 1 Period successfully demonstrated that the AGS technology was appropriate for treating Ringsend primary settled sewage to the required effluent standards at the future design loads over a full year of operation.
>
> The Process Proving Step 2 Period successfully demonstrated that the retrofit of an existing Ringsend SBR with the AGS technology was feasible. Furthermore, PPS2 successfully demonstrated that such a reactor is capable of treating Ringsend primary settled sewage to the required effluent standards at the future design loads.

Based on the results of the process proving programme, the planned implementation of the AGS technology at the Ringsend Wastewater Treatment Plant for the Retrofit of the existing SBRs and in the new Capacity Upgrade should enable the plant to be expanded to the proposed capacity of 2.4m PE while fully meeting the effluent requirements of the Urban Waste Water Treatment Directive.

# Appendix 1:
# CALCULATION OF TOTAL NITROGEN STANDARD DURING PPS2

**MODEL FOR CALCULATION OF TOTAL NITROGEN DURING PPS2**

**Introduction**

Whereas compliance of the Effluent with the total nitrogen (TN) parameter is based on a yearly average, the PPS2 period set out in the Call off Contract is less than a calendar year. Accordingly, to determine Effluent compliance with TN over the PPS2 Period the limit for TN needs to be adjusted to take into account temperature effects over the shorter PPS2 Period.

Table B1 shows the calculations used in the Outline Design for meeting the TN Effluent requirement of 10mg/l based on the design annual process temperature profile. Table B2 shows how to calculate the TN concentration to be achieved in the Effluent (i.e. the adjusted Minimum Effluent Requirement for TN) where the test period is shorter than one year.

**Table B1 – Outline Design calculations for Total Nitrogen (TN) based on design annual temperature profile**

| Design Frequency temperature over the year* | Reactor Temperature (°C) | TN (mg/l) | Contribution to yearly average TN (mg/l) |
|---|---|---|---|
| 0.5% | 9 | 14.0 | 0.07 |
| 2.3% | 10 | 13.1 | 0.30 |
| 7.5% | 11 | 12.2 | 0.92 |
| 14.4% | 12 | 11.2 | 1.61 |
| 10.9% | 13 | 10.1 | 1.10 |
| 8.4% | 14 | 9.5 | 0.80 |
| 6.9% | 15 | 9.2 | 0.63 |
| 9.7% | 16 | 8.9 | 0.86 |
| 15.0% | 17 | 8.6 | 1.29 |
| 11.5% | 18 | 8.3 | 0.95 |
| 7.2% | 19 | 8.0 | 0.58 |
| 5.7% | 20 | 7.9 | 0.45 |
| **Design Yearly Average TN (mg/l)** | | | **9.57** |

* the temperature value in the *"Reactor Temperature (oC)"* column covers a 1oC range of temperature centred on this value. For example, in the 4th row the temperature range covered by the 12oC value is all temperatures above 11.5 deg C and less than or equal to 12.5 deg C

**Table B2 – Formula for calculating the Minimum Effluent Requirement for TN where the test period is less than 12 calendar months**

| Measured Reactor Temperature Frequency during the PPS2 Period* (%) | Reactor Temperature (°C) | TN (mg/l) | Contribution to Minimum Effluent Requirement for TN (mg/l) |
|---|---|---|---|
| a | 9 | 14.0 | a x 14.0 |
| b | 10 | 13.1 | b x 13.1 |
| c | 11 | 12.2 | c x 12.2 |
| d | 12 | 11.2 | d x 11.2 |
| e | 13 | 10.1 | e x 10.1 |
| f | 14 | 9.5 | f x 9.5 |
| g | 15 | 9.2 | g x 9.2 |
| h | 16 | 8.9 | h x 8.9 |
| i | 17 | 8.6 | i x 8.6 |
| j | 18 | 8.3 | j x 8.3 |
| k | 19 | 8.0 | k x 8.0 |
| l | 20 | 7.9 | l x 7.9 |
| **Minimum Effluent Requirement for TN** (mg/l) where testing period is less than 12 calendar months. | | | **(Sum of** a x 14.0 + b x 13.1 + c x 12.2 + d x 11.2 + e x 10.1 + f x 9.5 + g x 9.2 + h x 8.9 + i x 8.6 + j x 8.3 + k x 8.0 +l x 7.9) **x 1.05** |

* the temperature value in the *"Reactor Temperature (deg C)"* column covers a 1degC range of temperature centred on this value. For example, in the 4th row the temperature range covered by the 12degC value is all temperatures above 11.5 deg C and less than or equal to 12.5 deg C.

### Table B3 – Calculation of the Minimum Effluent Requirement for TN during the PPS2 Period

| **TN Limit - Temperature Adjustment (Starting Jul 18)** | | | | |
|---|---|---|---|---|
| Reactor Temperature (oC) | Outline Design Frequency Distribution | Actual Frequency Distribution | Outline Design TN per Temp (mg/l) | Contribution to Minimum Effluent Requirement for TN (mg/l) |
| 9 | 1% | 0% | 14 | 0.0 |
| 10 | 2% | 0% | 13.1 | 0.0 |
| 11 | 8% | 0% | 12.2 | 0.0 |
| 12 | 14% | 0% | 11.2 | 0.0 |
| 13 | 11% | 0% | 10.1 | 0.0 |
| 14 | 8% | 0% | 9.5 | 0.0 |
| 15 | 7% | 0% | 9.2 | 0.0 |
| 16 | 10% | 2% | 8.9 | 0.2 |
| 17 | 15% | 3% | 8.6 | 0.3 |
| 18 | 12% | 38% | 8.3 | 3.2 |
| 19 | 7% | 24% | 8 | 1.9 |
| 20 | 6% | 33% | 7.9 | 2.6 |
| | | | Minimum Effluent Requirement for TN (mgN/l): | 8.1 |