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Southern Water Services AMP7 Programme

Design Report

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Table of Contents

Section 1: Introduction 6

Section 2: Background 7

2.1: Aim of the Project 7

2.2: Proposed Development Area 7

2.3: Information Review 7

2.3.1: ICW Sizing Requirements 7

2.3.2: Ground Investigations 8

2.3.3: Topographical surveys 9

2.3.4: Service mapping 10

2.3.5: Preliminary Ecological Appraisal (PEA) 10

2.3.6: Biodiversity Net Gain (BNG) Assessment 10

2.3.7: Arboricultural Constraints Report 10

2.3.8: Flood risk assessment (FRA) 11

Section 3: Integrated Constructed Wetland Design 12

3.1: ICW Performance 14

3.2: ICW Aims 14

3.3: ICW Design 14

3.3.1: Flood Mitigation Area 15

3.3.2: ICW Operation 15

3.3.3: ICW Layout 16

3.3.4: Landscape Fit 17

3.3.5: Ecosystem services 17

Section 4: Construction & Landscaping 21

4.1: Construction Works 21

4.2: Wetland Planting & Landscaping 23

4.2.1: Wetland Cell and Flood Mitigation Area Planting 23

4.2.2: Hedging & Shrubs 24

4.2.3: Grass and Wildflower Seeding 25

4.3: Mitigation Measures During Construction & Landscaping 25

Section 5: Operations and Maintenance of ICW 26

Section 6: Summary 27

Appendix A: Staplefield WTW Data 28

Table of Figures

Figure 1: Proposed ICW development site east of existing Staplefield WTW and north of River Ouse. 6

Figure 2: Lixnaw ICW – Co. Kerry, Ireland. 13

Figure 3: Clonaslee ICW – Co. Laois, Ireland. 13

Figure 4: Proposed ICW Layout. 17

List of Tables

Table 1: Expected ICW Loading Concentrations 8

Table 2: ICW treatment cell areas 16

Table 3: Main stages of ICW construction works 22

Table 4: Wetland and Flood Mitigation Area planting - species and numbers 23

Table 5: Hedgerow planting - species and numbers 24

Table 6: Shrubs planting - species and numbers 24

Section 1: Introduction

An Integrated Constructed Wetland (ICW) is proposed for the supplementary treatment of final effluent (FE) discharges from the existing Water Treatment Works (WTW) at Staplefield, West Sussex. The existing WTW provides treatment for the agglomeration of Staplefield. The WTW provides primary and secondary treatment through electro-mechanical treatment of the incoming wastewaters, with Ferric dosing being applied prior to the on-site septic tanks for phosphorus management. Discharges from the WTW are currently to a boundary drain adjacent to the works, which flows into the River Ouse, directly south of the works.

The ICW is designed with an emphasis on the reduction of phosphorus from the FE waters generated on-site. This is in line with Asset Management Period 7, 2020-2025. The implementation of the ICW as a Nature-Based Solution (NBS) for the reduction of phosphorus, will provide multiple benefits to the site and surrounding area. The ICW concept implements a Landscape-Fit approach to the design, as well as Ecosystem Services as outlined by the Convention on Biological Diversity (CBD). This includes, but not limited to; net gains in biodiversity levels on-site and immediate area, enhanced carbon sequestration, stormwater retention and mitigation, improved habitat aesthetics, educational/research opportunities, and cost-effectiveness for the development and operation.

This report provides details on the design of the ICW for the supplementary treatment and management of wastewaters at Staplefield. VESI Environmental Ltd. has been subcontracted by GTB on behalf of Southern Water (SW), tasked with developing the Staplefield ICW.

Figure 1: Proposed ICW development site east of existing Staplefield WTW and north of River Ouse.

Section 2: Background

The Environment Agency (EA) regulates wastewater treatment works (WWTW). Proposed phosphorus limits are being imposed by the EA and Southern Water is implementing procedures to comply with these new limits. As part of these implementation procedures, an Integrated Constructed Wetland (ICW) is being developed as a nature-based solution for additional phosphorus reductions in order to meet the proposed consent limits for the existing water treatment works (WTW) at Staplefield, Haywards Heath, West Sussex, UK.

2.1: Aim of the Project

This ICW is based upon the Integrated Constructed Wetland concept, which explicitly integrates total water management, ecological reanimation and biodiversity enrichment. The main purpose of the ICW is phosphorus reduction. The ICW will also provide a range of ecosystem services and will also provide treatment for a wide range of pollutants, including further reduction of licenced parameters Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS), as well as nutrients (ammonia, nitrates), pathogens (E. coli, enterococci, and coliforms) and emerging pollutants (pharmaceuticals, nano-metals, and micro-plastics).

2.2: Proposed Development Area

The Staplefield ICW is proposed for construction adjacent to the existing WTW. The ICW development area is immediately east of the existing WTW and provides an area of 3.4ha. The site is a gently sloping field grading from north to south. The current land use is agricultural (arable). The proposed development area lands provide for the location of the ICW, which will include treatment cells, embankments, access roads and flood mitigation area.

2.3: Information Review

An initial assessment and review of an ICW for Staplefield WTW was undertaken by VESI in early 2023. This study included the feasibility of an ICW for the site, with assessment of loading, site location, landscape, geology, hydrology, soils, and topography within the proposed development area undertaken.

Further investigations and assessments were carried out as part of this design stage and the ICW design is developed to account for any site requirements and constraints. These include ground investigations, topographical surveys, service mapping, ecological appraisal, cultural and historical assessment and arboricultural appraisal.

2.3.1: ICW Sizing Requirements

Monitoring data received was reviewed to understand the flow and characteristics of the effluent to be managed and treated through the ICW. Table 1 provides a summary.

Table 1: Expected ICW Loading Concentrations

Parameter	BOD (mg/l)	Suspended Solids (mg/l)	Phosphorus (mg/l)	Iron (mg/l)
Expected average concentration at ICW inlet	6	7	1.5	
Permit consent limits (AMP7)	80	120	0.5	4
PE	220			
Average Flow (l/s)	1.25			
Design Flow (l/s)	4			
Max hydraulic Flow (l/s)	10			

Graphed data for both influent and effluent from the existing WTW are provided in Appendix A following this report.

2.3.2: Ground Investigations

Soils were logged and tested on site through ground investigations, including excavation, as well as through laboratory analysis. Onsite investigations were carried out by Analytical Construction Services (ACS). Onsite clay soils will provide the suitable building material for the ICW cells and access roads, as well as ensuring the necessary containment is achieved.

Published information shows the site to be underlain by superficial deposits comprising alluvium and Weald Clay. Solid geology comprises the Upper Tunbridge Wells Sandstone, which is part of the Wealden Group and principally comprises fine-grained sandstone, siltstones and silty mudstones.

Ground investigation works were undertaken between 9th and 16th January 2023 by ACS Testing Ltd and comprised six soakaway tests; 16 trial pits excavated to between 1.5m and 4m below ground level (bgl) and five window sampling holes, driven to 6m depth bgl. The Factual Report has been received and reviewed.

The investigation showed a 0.3-0.4m thickness of topsoil above dark brown mottled clay. A dark blue/grey alluvial clay was encountered in all of the trial pits that extended beyond 1.5m (TP11-TP16 inclusive), encountered at depths between 2m and 3m bgl. The blue clay was also encountered in WS2 and WS 3 at 4.2m bgl and 4m bgl respectively and is thought to be associated with the adjacent River Ouse. This material may be present elsewhere on the site but was not encountered due to trial pits across the proposed ICW site itself only extending to 1.5m bgl. Bedrock was not encountered.

The above categorisation of strata is based on the proven descriptions and behaviour noted on the laboratory test sheets. The logged strata in the trial pits generally describes the material as silt while the corresponding material is generally described as clay on the window sample logs. Laboratory test records indicate that all of the materials tested are clays, not silts and that the sample described as a gravel in WS1 between 0.85m and 1.45m bgl is ‘very gravelly sandy CLAY’. Therefore, while the percentage gravel content is greater than other samples, this material still performs as a clay and other than topsoil, all of the materials to be excavated beneath topsoil are clays.

Groundwater was encountered as seepages in the trial pits, generally at the base of the pit at a depth of 1.5m bgl. However, investigation works were undertaken during heavy rainfall, and it is thus not possible to definitively determine the origin of this water. Groundwater was noted in the window sample holes between 0.3m bgl and 2.61m bgl although the upper 0.3m strike is thought to be perched water. TP6 and TP10 were recorded as being dry.

Five of the trial pits recorded instability of the pit sides resulting in collapse. These were TP3, TP5, TP6, TP7 and TP11. Four of these pits are located on the western half of the proposed ICW site. WS04, also positioned on the western side was noted to be unstable. The ground conditions on this half of the site may have an impact during construction and suitable methodology should be determined and agreed in detailed method statements prior to the commencement of works. It should be noted that the maximum depth of excavation will be 1.4m and that excavation side slopes will not be vertical. There is no direct information on soils in the Cell 1 area.

Infiltration tests were conducted in TP1, TP4, TP5, TP8, TP9 and TP10. The tests were terminated at an early stage by the engineer on site due to lack of progress in the tests.

The design of the ICW will involve cut and fill operations. Excavated materials will form the cell embankments. It is likely that the cells will be comprised of in situ impermeable clay soils or filled impermeable clay soils. Additional site-won clay material is available outside of the cell footprints to the south of the flood mitigation feature.

The 0.3-0.4m thickness of topsoil will be stripped and stored for use as a planting medium at the base of the cells and for landscaping purposes. Field and laboratory testing indicates the underlying clay material will have a very low permeability. However, the high fines content indicates careful treatment of the excavated materials will be required to ensure they are placed, puddled and compacted to the appropriate moisture content and during favourable weather conditions.

The anticipated earthwork cut volume is approximately 14,315.9m^3 and fill volume is approximately 14,011.12m^3. This leaves a net surplus of material (304.78m^3).

2.3.3: Topographical surveys

Surveys were carried out by Maltby Surveys Ltd, providing the topographical and infrastructural services information. The topographical information is critical in the design process. Due to the existing infrastructure, there will be a requirement to pump waters via a new pump station to the ICW from the WTW. Subsequent flows through and from the ICW will operate by gravity. The topographical information along with GI information has allowed the design to deliver a cut /fill earthworks with an excess of <305m^3, provided no unforeseen obstacles are encountered at construction stage.

2.3.4: Service mapping

Service mapping provides details of both above and below ground services. Setbacks are included in the design process to give appropriate distances for both construction and operational phases of the project. Services include the incoming sewer to the treatment works, which runs at an angle through the northwestern corner of the proposed ICW site. The active sewer will be retained in the ICW design to accommodate any maintenance works on the pipeline in the future. Other service elements such as overhead power lines, underground lines, drainage, pipework, ducting and cabling, are all factored in to the ICW site design. Appropriate setbacks are provided as required. In the instance of any encountered field drains, these will need to be blocked off (and removed as required) so as not to provide a conduit for water to flow from the ICW.

2.3.5: Preliminary Ecological Appraisal (PEA)

A Preliminary Ecological Appraisal (PEA) was produced by Mott MacDonald in January 2022. This report outlines the habitat types present onsite, the potential suitability of habitats within the site for various species and the suitability of the site for the creation of new wetland habitats in relation to potential ecological constraints.

A variety of additional surveys are recommended as well as a suite of mitigation measures that would ensure that the receiving natural environment is not negatively affected by the proposed development.

The site is considered to be suitable for the creation of new wetland habitats, with no major ecological constraints present. The proposed works are predicted to have a significant positive impact on the environment and wildlife. This is subject to further survey and the appropriate implementation of proposed mitigation measures.

For additional detail, please refer to the original report.

2.3.6: Biodiversity Net Gain (BNG) Assessment

A BNG assessment has been prepared by Mott MacDonald. There is a requirement to increase the biodiversity value of the site. The design and landscaping of the ICW and Flood mitigation area will provide the required habitat units to meet the BNG targets.

2.3.7: Arboricultural Constraints Report

Mott MacDonald carried out an arboricultural constraints report for the proposed development area and adjacent lands. The purpose of this report was to detail the constraints to development posed by existing trees, identify trees or areas of arboricultural significance and to support the detailed design of the scheme in relation to minimising or avoiding impact on trees.

The study identified 30 individual trees, 13 tree groups and 4 hedges and placed each into a category based on their quality. A map provided alongside the report shows the location of each individually labelled tree, outlining their root protection zones. Recommendations are also outlined in the report, which outline the recommended actions in relation to carrying out the proposed development while avoiding negative impacts on trees.

2.3.8: Flood risk assessment (FRA)

A Flood Risk Assessment has been prepared by Mott MacDonald for the proposed development. The proposed ICW development lies within the flood risk zone (up to 1:100 year + climate change). There is a requirement to provide a suitable (volume to volume) mitigation area.

Details of the Flood Mitigation Area (FMA) is provided in the accompanying drawings and Section 3.3.1.

Section 3: Integrated Constructed Wetland Design

ICWs consist of a series of densely vegetated wetland cells with free surface water flow, the basic hydrological mechanism for the influent flowing through the system. The ICW design endeavours to optimise natural biological, chemical and physical processes for pollutant reductions in a way that is synergistic with the local aquatic and terrestrial communities, while not incurring negative impacts on adjacent aquatic and terrestrial ecosystems.

The ICW concept explicitly integrates the following three objectives:

- The containment and treatment of influents within emergent vegetated areas using, wherever possible, local soil material.
- The aesthetic placement of the containing wetland structure into the local landscape towards enhancing a site’s ancillary values.
- Enhanced habitat diversity and nature management.

This emphasis on explicit integration facilitates processing synergies, robustness and sustainability that are not generally available in other constructed wetland designs. The benefits of ICWs are primarily due to larger scaling patterns and their greater biological complexity. ICW systems continue to be successfully applied to a range of effluent types in different situations when appropriate assessment, design and construction are conducted. The ICW design approach has the following critical criteria:

- Site assessment and site-specific design.
- Containment and cleansing of contaminated water on site, thus removing consequential environmental costs.
- A fully integrated infrastructure for containment and cleansing of waters.
- The appropriate building materials used in the construction are, ideally, found locally or on site.
- Robust system able to withstand extreme load variations, should they occur.
- Sustainable design and construction to ensure long operational life (50-100 years).
- Minimal management and capacity for self-regulation.
- The site is not irrevocably lost and is ideally enhanced.
- Appropriate plant species and distribution are used.
- Opportunities are provided for habitat development and biological diversification.
- An ecological approach rather than solely environmental approach is taken.

Figure 2: Lixnaw ICW – Co. Kerry, Ireland.

Figure 3: Clonaslee ICW – Co. Laois, Ireland.

3.1: ICW Performance

The design of ICWs is such that incoming waters are held within a treatment cell for as long as hydraulically possible. Phosphorus removal in ICWs is driven by the uptake of phosphorus by vegetation, absorption and adsorption and sequestration within organic matter (soils, necromass, leaf litter). Phosphorus removal is an area-intensive parameter within wetlands. The ICW at Staplefield will provide supplementary treatment for the reduction of phosphorus in line with AMP 7 target of 0.5mg/l total phosphorus.

The multi-cell approach of the ICW enables the treatment cells to receive incoming wastewaters and through dilution, flow inhibition, active and passive treatment, reduce the dissolved and suspended contaminants. In turn, this multi-cell design prevents surges in through-flowing waters as they are being treated.

3.2: ICW Aims

The main aims of the ICW system are:

- achieve high treatment efficiency and assist in reducing Phosphorus concentrations.
- reduce long-term treatment, operation and maintenance costs

In addition to the above aims, an ICW will provide a range of ecosystem services, including:

- carbon sequestration (storage);
- avoidance of quick discharge of intercepted water by releasing water slowly from intercepting ICW cells;
- retrieval (recycling) of water-vectored materials such as metals and organic matter;
- develop new wetland-dependent resources;
- facilitate biodiversity and reanimation of habitats;
- facilitate awareness of the values of wetlands and act as a form of education.

3.3: ICW Design

The main factors taken into consideration when sizing an ICW include:

- Land availability;
- Land boundaries and setbacks;
- Hydraulic loading;
- Concentration of contaminants;
- Topography;
- Ground and site conditions and;
- Target limits.

Considering the factors listed above, the Staplefield ICW design consists of a series of 4 treatment cells, with a functional treatment area of 12,889m^2 (1.289 Ha). In addition to functional treatment area, the proposed development will consist of interconnecting roads for access and maintenance, gently sloped embankments for safety and maintenance, pipework to convey waters to, through and from the system, monitoring points at inlet and outlet pipe locations, and a distribution chamber. Flows will be pumped to the ICW from a new pump station within the existing WTW. The Process Control Philosophy (PCP) has set the expected Flow to Full Treatment (FFT) to the ICW at 4l/s. These flows may fluctuate dependent upon climatic conditions, however the ICW has been designed around this specific flow rate, with the capacity to receive higher flows (10l/s) when necessary.

The access roads (3.5m) will allow for ease and safe access for operation and maintenance, while also providing access (5m) for the farmer/landowner through the site and over incoming sewer pipeline. The Staplefield ICW is within agricultural lands and adjacent to public road (Cuckfield road).

3.3.1: Flood Mitigation Area

In accordance with requirements, flood mitigation is provided through the development of a Flood Mitigation Area (FMA) south of the proposed ICW area and north of the River Ouse.

This area provides for flood mitigation for a volume of 3480m^3. This area and volume are based on the modelled earthworks and ICW design. This provides both the necessary mitigation for the ICW development, but also creates an additional area of biodiversity and habitat creation. The FMA will consist of gently sloping embankments and a level base. The embankments and base will be planted with a range of plant, grass and wildflower species, with boulders scattered for habitat creation. A pair of twin 300mm pipework will connect the FMA to the River Ouse to facilitate incoming flood waters and subsequent draw down.

3.3.2: ICW Operation

The ICW is optimally designed to provide passive supplementary treatment to effluent from the WTW. Effluent from the WTW will be pumped to the distribution chamber at Cell 1. Waters will flow, by gravity, and sequentially through Cell 2, Cell 3 and Cell 4. Flow and water levels are controlled by means of adjustable 90° bends on the upstream end of interconnecting pipework (225mm diameter) between cells. These bends are set at a level to provide optimum water depth within the treatment cells. The operational water depth within each treatment cell will be between 150 mm and 200 mm, with capacity to allow for increased water depth during high rainfall events.

The ICW facilitates operational and compliance monitoring at locations within the system. This and other operational and maintenance tasks are described in more detail in the ICW operation and maintenance plan.

3.3.3: ICW Layout

A functional treatment area of 12,889m^2 (1.29 Ha) is provided over 4 treatment cells and flows are north to south. See drawing 752214-UAX-ZZ-ZZ-M2-EN-00003 (Proposed site layout) and 752214-UAX-ZZ-ZZ-M2-EN-00004 (Cross sections) for details on, configuration, cell base levels, and area. Cells will be constructed with a minimum of 500mm suitable subsoil for containment properties (1x10^{-8}m/s). This will be topped with 300mm layer of topsoil. Embankments within the cells will be a minimum of 1 meter high with slopes of 1:2.

See Table 2 for treatment cell areas.

Table 2: ICW treatment cell areas

Cell No.	Cell area
Cell 1	487m^2
Cell 2	5399m^2
Cell 3	4418m^2
Cell 4	2585m^2
Total ICW area	**12,889m^2**

Access to the ICW will be off Cuckfield Road (B2114) to the east of the site. A new access gate will be installed at the existing field entrance and connect with the new interconnecting ICW access roads. New stock proof fencing will be installed along the eastern site boundary and public road connecting with the new access gate. Interconnecting gravel access roads will be 3.5m wide for allow safe and ease of operational and maintenance purposes. A 5m wide access road is designed along the northern boundary to facilitate landowner access between adjoining fields. A 5m wide access road is designed between Cell 1 and Cell 2 to provide sufficient access requirements for the maintenance of the incoming sewer pipeline.

Treatment cells will be connected using 225mm diameter uPVC pipes that will be placed at the base of the wetland cells. Water levels within the system will be managed by placing adjustable bends on the outlet pipe of each cell. Inlet to the ICW will be from a new pump station that will pump flows to Cell 1. The discharge from the ICW, Cell 4 will be to a new manhole to connect to the existing Final Effluent (FE) pipeline upstream of the existing FE manhole and flow meter.

Wetland plant species are specifically chosen for both the wetland treatment area and surrounding embankments so that they are both functional and appropriately fit into the landscape and location. Further details are provided in Section 6 and accompanying Landscape Management Plan.

Figure 4: Proposed ICW Layout.

3.3.4: Landscape Fit

While the primary objective of the ICW is phosphorus reduction of the effluent from the existing WTW, the proposed development will provide many other benefits to the locality, such as promoting the conservation of wetland-dependant wildlife through reanimating lost wetland ecosystems and functioning as a potential educational and amenity resource in the locality. The layout, structure, and species composition of an ICW is carefully considered on the site level so that it is biologically and physiologically compatible with the proposed development area. As wetland areas, including ICWs provide a much-lost habitat for wetland-dependant species of invertebrates, fish, amphibians, birds, marginal and aquatic vegetation, the development of such a system can be expected to result in a net gain in local biodiversity, in addition to the treatment of contaminated wastewaters.

3.3.5: Ecosystem services

Natural Capital refers to both living and non-living features of the natural world that are of value to society (CIEEM, 2022). Examples of natural capital include wetlands, forests, rivers, land and biodiversity as a whole. Stocks of natural capital provide various 'ecosystem services', which we as humans can benefit from. For example, wetlands can provide services such as nutrient cycling, carbon sequestration, biodiversity enrichment, habitat creation and flood alleviation, to name some.

The following is a detailed description of some of the various ecosystem services that an ICW provides.

Biodiversity Net Gain

Biodiversity Net Gain (BNG) is the concept of approaching a development in such a manner that biodiversity benefits from the development, rather than being harmed by it. The aim of BNG is to help achieve an overall benefit for the environment, economy and society, rather than simply mitigating against a negative impact (CIEEM, CIRIA and IEMA, 2016). Ideally, net gain will be measured in such a manner that clients, stakeholders and the local community can see and understand the biodiversity increase as a result of applying this concept.

A Biodiversity Net Gain Assessment is pending for the project.

Carbon Sequestration

Carbon Sequestration is the process by which atmospheric carbon is removed from the atmosphere and stored, reducing levels of CO2 in the atmosphere. This process is described as a key component in the fight against climate change as CO2 is one of the major greenhouse gases produced by humans through a variety of activities.

While only occupying approximately 5-8% of the Earth's land surface, wetland habitats are thought to hold 20-30% of global soil carbon (Nahlik and Fennessy, 2016). As ICWs are designed to mimic the biological functions of a naturally occurring wetland habitat, they also act as important carbon sinks. While detailed studies relating to the carbon sequestration rate of ICWs specifically is yet to be carried out, studies of the use of other constructed wetland designs in sequestering carbon indicate that a value of 8.1 tonnes of CO_2 per Ha per year is achievable (Afiqah Rosli *et al.,* 2017). This equates to more than 10.45 tonnes of Carbon sequestered by the treatment area per year.

Nutrient Cycling

Nutrient cycling is the process whereby various nutrients are taken from the environment by organisms, only to be returned back into the environment at a later time. This cyclic process can also be influenced by humans through the use of fertilisers or the removal of crops from a field. Phosphorus and nitrogen are key examples, as both macronutrients are vital for plant and animal development but are also significant sources of nutrient pollution in high concentrations. Both of these macronutrients are leading factors in algal blooms in surface waters.

An ICW removes both phosphorus and nitrogen through a combination of physical, chemical and biological processes. Denitrification is just one of the processes that ICWs use to manage nitrogen and involves the activities of heterotrophic bacteria within the wetland biofilm. The densely planted ICW cells provide more carbon for these bacteria to utilise, resulting in higher denitrification rates. Other processes within an ICW include sedimentation, volatilization, sorption, assimilation and evapotranspiration. The accumulation of biomass and necromass within the ICW cells provide a sink for nitrogen as well as carbon, phosphorus and other nutrients.

Phosphorus removal in ICWs is driven by the uptake of phosphorus by vegetation, absorption, adsorption and sequestration within organic matter (soils, necromass, leaf litter). These mechanisms are responsible for the sizing requirement of an ICW system. The general cycling of phosphorus, unlike nitrogen, lacks a gaseous phase, meaning that it is either in solution in the water column, or suspended as solids flowing through. The critical removal mechanism for phosphorus is ultimately sequestration within the ICW treatment area. Phosphorus uptake by vegetation is minor in comparison to the sequestration of phosphorus. During initial operation of an ICW, the soils within the cell floor provide the primary binding media for phosphorus. Over time, as necromass and biomass accumulate within the cell, they provide for additional sequestration capacity. This prolongs the timeframe for any given treatment cell to become phosphorus saturated and its relative sequestration capacity to lessen. The sequestered phosphorus acts as a store, allowing it to be utilised by vegetation within the cell, as well as being available for microbial communities. There are further capacities for the sequestered phosphorus to be utilised in agriculture, as a land-spread or rotavated fertiliser. As global phosphorus production has already peaked, its availability, especially in a bioavailable form becomes far more valuable and sustainable generation must be sought.

Amenity, Education & Eco-Tourism

Due to their bespoke design, each ICW fits naturally into its landscape and provides a variety of amenity opportunities within it’s confines. ICWs allow people to get closer to nature by listening to the abundance of wildlife, photography or simply walking along the interconnecting pathways and taking in the view. The provision of access to Green-Blue spaces has been shown to provide substantial benefits to mental health (Braubach *et al*., 2021), and the ICW provides that through interconnecting pathways.

ICWs also act as exemplary educational tools, offering field teaching relating to biodiversity, nutrient cycling, habitat creation, carbon sequestration and more. An ICW at Staplefield can provide a variety of learning opportunities in an interesting and practical manner.

Eco-tourism is the use of natural areas by humans for the observation and appreciation of natural assets. ICWs provide excellent eco-tourism opportunities due to their aesthetically pleasing design, suitable and safe access, increased biodiversity levels and an overall feeling of closeness to the natural world; the latter being something that is often forgotten in today’s world.

Stormwater Management & Flood Alleviation

With regards to any human influence on surface water features, there is always a risk of altering flow regimes, resulting in scouring of riverbeds, mobilisation of sediment and, in extreme cases, instances of localised flood events. The Staplefield ICW is designed to receive all flows from the WTW including stormwater. The ICW has capacity to store these high volumes of water, providing hydraulic retention that releases the waters slowly at its discharge point to ensure that waters do not simply surge through the treatment cells and re-enter the environment. The dense vegetation within the cells also facilitates evapotranspiration which reduces the volume of water discharging from the ICW.

Section 4: Construction & Landscaping

4.1: Construction Works

The main earthworks involved in the development of the ICW include levelling, excavation and placement of soils for the enclosing embankments around each cell and for the access roadways. The ICW cells are generally constructed starting from the top (Cell 1) and working down the site to the final cell (Cell 4). As each cell is complete or near complete, it is planted so that the planting works are typically carried out down through the system, behind the main earthworks. This process will allow the start of commissioning of the ICW system as soon as the earthworks and planting are completed. After a full annual growth cycle has been completed for the site, allowing the vegetation to establish, the ICW can be fully commissioned.

The existing topsoils will be stripped and stockpiled for later use in the construction phase. The underlying soils will be excavated to form the cell base and side embankments. The construction of the ICW must ensure that the base and sides of the ICW cells are constructed to deliver the necessary containment ($1x10^{-8}$m/s) and stability. The base and embankments of the cells shall be tracked and compacted to achieve the required permeability uniformly over the entire cell area including the embankments. See drawing 752214-UAX-ZZ-ZZ-M2-EN-00009 for general arrangements.

Where there are any differences in ground conditions to those recorded through the Ground Investigations (GI) on-site, during construction any changes will need to be considered and the design updated by the design team.

There will be the requirement during works to demonstrate by means of field permeability testing within each cell that the required permeability value has been achieved. This is ideally carried out using in-field permeability test, using field Falling Head Tests (FHT) within each treatment cell (Min 2 no. FHT per treatment cell).

Following construction of the sub-base and its sealing, the stockpiled topsoil will be placed loosely on top of the finished sub-base material to a minimum depth of 200-300mm. Each cell base shall be level throughout. This surface layer is the final, finished layer. To facilitate rapid vegetation establishment, the topsoil is not to be compacted, as compacted soils inhibit the establishment and colonisation of the wetland plants. There may be slight variations to the layout and level of the ICW during construction, as required, so as to work within the confines of the site conditions and to utilise the characteristics of the site.

There is limited working area on-site for the stockpiling of materials, and the management of construction plant and equipment. A temporary construction compound is proposed north of the existing treatment works. This will be utilised to cater for stockpiling, plant, equipment and materials. A full traffic management plan will be required to ensure that vehicle access around and through the site is carried out in-line with best practice. Suitable mitigations and protections must be set in place to prevent any runoff from stockpiles, the construction compound, and any other activities on-site which may impact on watercourse and/or neighbouring properties. No earthworks will be undertaken within the root protection zones, which have been identified on-site through the Arboricultural Constraints Report (Mott MacDonald, August 2023).

Construction Management Plans and Method Statements will ensure that works for the ICW are carried out in-line with best practice, while also minimising double and triple-handling of materials on-site. These will also ensure that the ICW is constructed to the necessary standard to ensure the protection of groundwaters in the area and that the ICW is fit for purpose. This will include the handling of on-site soils that shall be excavated, placed and compacted, in order to preserve their structure and ultimately the integrity of the ICW structures. Adequate site control is required to manage the soil used in construction of any earthworks with the earthwork operations supervised by a suitably qualified and experienced engineer.

Table 3 below, provides a summary of the main stages of ICW construction works.

Table 3: Main stages of ICW construction works	
Stage 1	Setting out cell layouts
Stage 2	Stripping and stockpiling of on-site topsoil for use later in construction. Excavation of soils/subsoils to proposed finished level, layering, tracking and compaction of soils for cell liner - minimum depth of soil liner 0.5m (in-situ clay/silts). Removal and redistribution of any encountered unsuitable material within treatment cell. Any granular soils can be used along access roads across the site.
Stage 3	Creation of embankments: • sloping embankments ○ Cell 1-4: 1:2 • height of embankment ≥1.0 m • width of embankment tops min. 3.5-5 m wide (stability and access around the wetland) Placement in layers and compaction during construction. Seal must be proven at base of ICW treatment cells.
Stage 4	Distribution of topsoil (200-300mm) over the base of each cell as growing medium
Stage 5	Interconnecting pipework from distribution chamber, between treatment cells and from Cell 4 outlet.

Table 3: Main stages of ICW construction works	
Stage 6	Placement of riprap beneath interconnecting pipework (inlet and outlet) in each cell (inhibit encroachment of wetland vegetation, flow dispersal and access for sampling)
Stage 7	Planting each cell with emergent vegetation – Each cell planted with 6 plants/m^2.
Stage 8	Landscaping of ICW cells and embankment area Installation of post and mesh fencing, operation and maintenance access gates.
Stage 9	Construction of access roads around the ICW cells.

For further details on the construction are included in the accompanying Construction Management Plan.

4.2: Wetland Planting & Landscaping

The landscaping of the ICW site will include the planting of emergent and helophyte wetland species within each treatment cell and the flood mitigation area. There will also be marginal aquatic plants, grasses/wildflower, and some tree and hedgerow planting around the area.

4.2.1: Wetland Cell and Flood Mitigation Area Planting

A planting plan for each cell is provided in the tables below, for further landscaping detail please refer to Landscape Management Plan.

Table 4: Wetland and Flood Mitigation Area planting - species and numbers								
Wetland Planting [12889m^2]								
Common name	**Botanical name**	**% cover**	**Cell 1** **487m^2**	**Cell 2** **5399 m^2**	**Cell 3** **4418 m^2**	**Cell 4** **2585 m^2**	**F.M. Area** **930 m^2**	**Total plant number**
			Plant number					
Emergent wetland plant species								
Lesser pond sedge	Carex acutiformis	25	731	8099	6627	3878	1395	20,730
Reed Sweet Grass	Glyceria maxima	30	877	9718	7952	4653	1674	24,874
Lesser reedmace	Typha angustifolia	20	584	6479	5302	3102	1116	16,583
Greater reedmace	Typha latifolia	15	438	4859	3976	2327	837	12,437
Marginal wetland plant species								
Yellow flag	Iris pseudacorus	2	58	648	530	310	112	1658
Water mint	Mentha aquatica	1	29	324	265	155	56	829

Table 4: Wetland and Flood Mitigation Area planting - species and numbers

Purple loosestrife	Lythrum salicaria	1	29	324	265	155	56	829
Brooklime	Veronica beccabunga	1	29	324	265	155	56	829
Gipsywort	Lycopus europaeus	1	29	324	265	155	56	829
Marsh cinquefoil	Potentilla palustris	1	29	324	265	155	56	829
Marsh marigold	Caltha palustris	1	29	324	265	155	56	829
Meadowsweet	Filipendula ulmaria	1	29	324	265	155	56	829
Water forget-me-not	Myosotis scorpioides	1	29	324	265	155	56	829
Total plant number / cell			**2920**	**32,395**	**26,507**	**15,510**	**5582**	**82,914**

4.2.2: Hedging & Shrubs

Additional landscaping will be carried out around the ICW site using native hedges and shrubs.

Hedging will be planted along the southern site boundary, along the north of the Staplefield WTW access road. Additional shrubs will be planted between the ICW site and flood mitigation area.

Table 5: *Hedgerow planting - species and numbers*

Hedgerow [180 m]			
Common Name	**Botanical name**	**Plant number**	**Size**
Hawthorn	*Crataegus monogyna*	432	Height 60-80cm;
Blackthorn	*Prunus spinosa*	180	Winter planting: bare root stock;
Field Maple	*Acer campestre*	36	
Dogwood	*Cornus sanguinea*	36	April-September planting: root trainer stock
Dogrose	*Rosa canina*	36	
Total plant number		**720**	

Table 6: Shrubs *planting - species and numbers*

Common Name	**Botanical name**	**Plant number**	**Size**
Hawthorn	*Crataegus monogyna*	5	Height 60-80cm;
Blackthorn	*Prunus spinosa*	5	Winter planting: bare root stock;
Field Maple	*Acer campestre*	5	
Dogwood	*Cornus sanguinea*	5	April-September planting: root trainer stock
Dogrose	*Rosa canina*	5	
Total plant number		**25**	

4.2.3: Grass and Wildflower Seeding

The areas within the proposed ICW surrounding the treatment cells are to be shaped as part of the overall works, to integrate the ICW with the existing lands and proposed works. Subsequently, the sloped areas within the ICW and FMA will be seeded with Weald Native Origin Seed (WNOS) in a 20/80% composition of wildflower and grass mix appropriate to the site as determined by Weald Meadow Partnership (WNP). Total area to be seeded is 13,108m^2. Please refer to Landscape Management Plan for further detail.

4.3: Mitigation Measures During Construction & Landscaping

Risk mitigation measures will be employed during the construction of the proposed ICW to limit the impact the surrounding environment through proper management and supervision. Please refer to Construction Management Plan and Landscape Management plan for further details.

Mitigation measures include:

- ICW setting out will include provisions for exclusion areas;
- Construction of the cells will be undertaken in sequence starting from the upper end of the site down to the lower end;
- No construction will be undertaken at night or during very wet weather;
- A detailed construction method statement will be prepared and will be followed by the contractor;
- All construction will be supervised;
- The refuelling of plant or machinery will not be permitted at the ICW construction site;
- All planting will also be supervised, and only native species from reputable sources will be used; and
- All plants brought to the site for use in the wetland will be checked for the possible presence of invasive species.

Section 5: Operations and Maintenance of ICW

A number of different operation and maintenance requirements shall be undertaken on the ICW. An Operation and Maintenance Plan has been prepared as part of this design.

Some of the main operation and maintenance procedures for the ICW are listed below:

- Treatment cell water level management;
- Influent and effluent monitoring – flow and quality;
- Vegetation monitoring & maintenance within treatment cells and across the site;
- Maintenance of access;
- Maintenance of inlet and outlet pipework;
- Maintenance of embankments - to provide for easy and safe access for monitoring; and
- Sediment/sludge management, primarily in Cell 1 and the FMA.

A suitably qualified person with experience in ICWs shall supervise the construction, monitoring, and maintenance of the ICW.

Safety considerations for both humans and animals are required and incorporated into the design of the ICW. Operational water depth is generally shallow (typically 150mm – 200mm deep) in ICWs.

An on-site person will be required on a regular basis to oversee the maintenance of the ICW. The Operation and Maintenance Plan will be finalised prior to the commissioning of the ICW. Training will be provided for the on-site operator to give guidance and ensure that the adequate procedures for the ICW system are implemented on an on-going basis.

Section 6: Summary

An Integrated Constructed Wetland (ICW) is designed directly east of the existing Staplefield Water Treatment Works (WTW). The purpose of the ICW is for the supplementary treatment of waters from the WTW with an emphasis on phosphorous reductions. The ICW design is a Nature-Based and Landscape-Fit approach to wastewater treatment and management, providing a bespoke and sustainable solution.

The ICW at Staplefield WTW will consist of a series of four cells, through which the treated waters from the WTW will be further reduced of its various dissolved and particulate constituents, with a particular focus on phosphorus reduction.

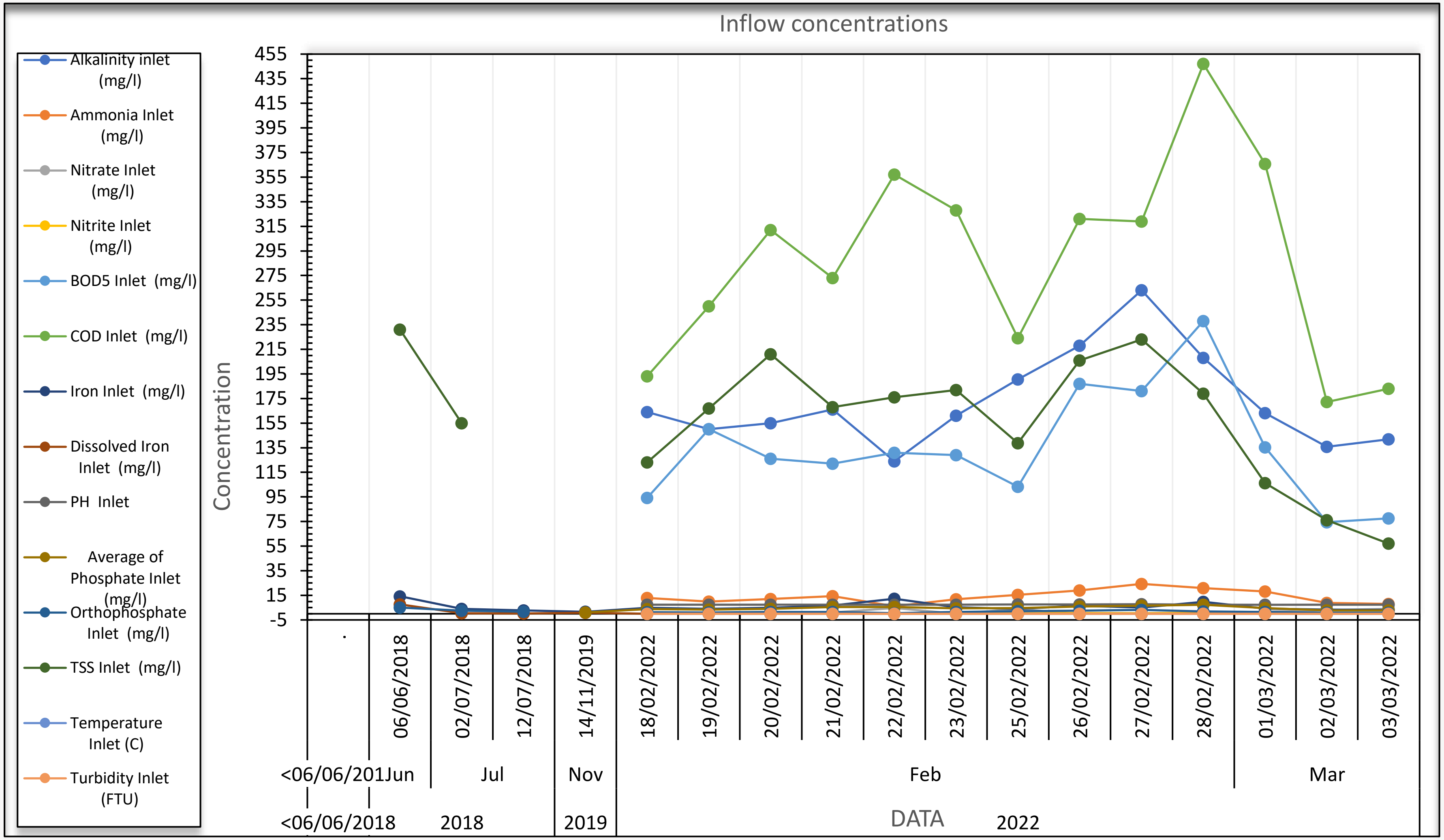
Appropriate flood mitigation measures have been designed for the site in respect of the proposed ICW design. These designed measures are presented as the Flood Mitigation Area located between the ICW site and River Ouse.

The proposed ICW treatment system and Flood Mitigation Area at Staplefield WTW will provide additional values through appropriate landscaping, so that its structure 'fits' into the local environment and enhances the aesthetic and biodiversity values of the site.

An Operation and Maintenance Plan has been prepared for the ICW to provide details of the various operation and maintenance procedures required for the system, to ensure the compliance, performance and sustainability of the system. This Operation and Maintenance Plan will be updated to account for any additional monitoring required prior to construction of the system.

Appendix A: Staplefield WTW Data

Project Name / Number:	STAPLEFIELD WTW / 752214
Document Number:	752214-UAX-ZZ-ZZ-RP-EN-00001



Project Name / Number:	STAPLEFIELD WTW / 752214
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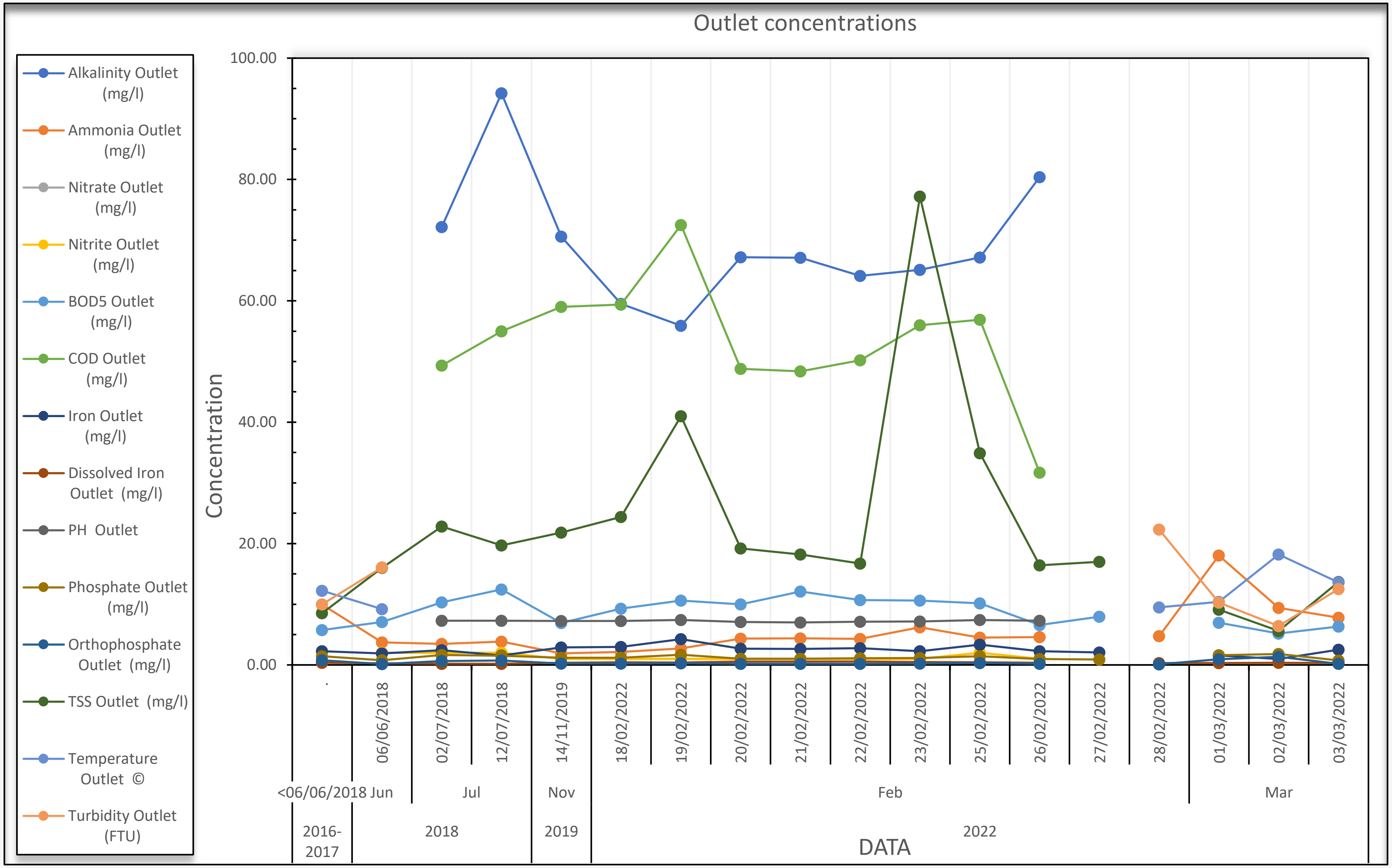

Project Name / Number:	STAPLEFIELD WTW / 752214
Document Number:	752214-UAX-ZZ-ZZ-RP-EN-00001

Inlet Concentrations (average)														
	Alkalinity inlet (mg/l)	Ammonia Inlet (mg/l)	Nitrate Inlet (mg/l)	Nitrite Inlet (mg/l)	BOD5 Inlet (mg/l)	COD Inlet (mg/l)	Iron Inlet (mg/l)	Dissolved Iron Inlet (mg/l)	PH Inlet	Average of Phosphate Inlet (mg/l)	Orthophosphate Inlet (mg/l)	TSS Inlet (mg/l)	Temperature Inlet (C)	Turbidity Inlet (FTU)
<06/06/2018 <06/06/2018 .														
2018							**7.01**	**2.74**			**3.06**	**193.00**		
Jun							**14.22**	**7.64**			**5.05**	**231.00**		
06/06/2018							14.22	7.64			5.05	231.00		
Jul							**3.41**	**0.29**			**2.07**	**155.00**		
02/07/2018							4.07	0.34			2.55	155.00		
12/07/2018							2.74	0.25			1.59			
2019							**1.58**	**0.82**		**1.07**				
Nov							**1.58**	**0.82**		**1.07**				
14/11/2019							1.58	0.82		1.07				
2022	**156.08**	**12.61**	**2.27**	**0.33**	**108.94**	**255.08**	**4.32**	**0.00**	**7.38**	**3.87**	**1.20**	**109.06**	**0.00**	**0.00**
Feb	**180.91**	**14.71**	**1.27**	**0.43**	**142.24**	**295.27**	**6.09**	**0.00**	**7.46**	**5.06**	**1.72**	**173.87**	**0.00**	**0.00**
18/02/2022	164.00	12.90	0.07	0.21	94.20	193.00	4.74	0.00	7.38	3.84	1.32	123.00	0.00	0.00
19/02/2022	150.00	10.00	0.07	0.20	150.00	250.00	4.05	0.00	7.35	3.34	1.10	167.00	0.00	0.00
20/02/2022	155.00	12.00	0.07	0.13	126.00	312.00	4.94	0.00	7.40	3.94	1.46	211.00	0.00	0.00
21/02/2022	166.00	14.30	1.09	0.43	122.00	273.00	6.71	0.00	7.40	5.48	1.42	168.00	0.00	0.00
22/02/2022	124.00	6.12	4.69	0.47	131.00	357.00	12.20	0.00	7.32	5.58	0.49	176.00	0.00	0.00
23/02/2022	161.00	11.70	0.07	0.53	129.00	328.00	5.19	0.00	7.42	4.45	1.48	182.00	0.00	0.00
25/02/2022	190.50	15.30	3.86	0.43	103.20	224.00	3.91	0.00	7.51	4.58	2.03	138.80	0.00	0.00
26/02/2022	218.00	19.00	0.07	0.61	187.00	321.00	6.61	0.00	7.55	5.91	2.48	206.00	0.00	0.00
27/02/2022	263.00	24.30	0.07	0.44	181.00	319.00	4.99	0.00	7.76	6.59	3.26	223.00	0.00	0.00
28/02/2022	208.00	20.90	0.07	0.90	238.00	447.00	9.79	0.00	7.43	7.32	1.89	179.00	0.00	0.00

Project Name / Number:	STAPLEFIELD WTW / 752214
Document Number:	752214-UAX-ZZ-ZZ-RP-EN-00001

Mar	**145.97**	**11.75**	**2.67**	**0.29**	**95.37**	**238.71**	**3.59**	**0.00**	**7.34**	**3.39**	**0.99**	**82.65**	**0.00**	**0.00**
01/03/2022	163.11	18.19	1.63	0.40	135.42	365.79	4.14	0.00	7.30	4.64	1.41	106.33	0.00	0.00
02/03/2022	135.70	8.77	2.89	0.22	74.46	172.18	3.34	0.00	7.35	2.79	0.76	76.12	0.00	0.00
03/03/2022	141.80	7.93	3.98	0.25	77.64	182.94	3.25	0.00	7.40	2.70	0.82	57.02	0.00	0.00
Average Inlet	**156.08**	**12.61**	**2.27**	**0.33**	**108.94**	**255.08**	**4.61**	**0.38**	**7.38**	**3.80**	**1.45**	**117.05**	**0.00**	**0.00**

Outlet Concentrations (average)

	Alkalinity Outlet (mg/l)	Ammonia Outlet (mg/l)	Nitrate Outlet (mg/l)	Nitrite Outlet (mg/l)	BOD5 Outlet (mg/l)	COD Outlet (mg/l)	Iron Outlet (mg/l)	Dissolved Iron Outlet	PH Outlet	Phosphate Outlet (mg/l)	Orthophosphate Outlet (mg/l)	TSS Outlet (mg/l)	Temperature Outlet ©	Turbidity Outlet (FTU)
2016-2017		**9.96**			**5.75**		**2.25**	**0.35**		**1.41**	**0.77**	**8.52**	**12.24**	**9.99**
<06/06/2018		**9.96**			**5.75**		**2.25**	**0.35**		**1.41**	**0.77**	**8.52**	**12.24**	**9.99**
.		9.96			5.75		2.25	0.35		1.41	0.77	8.52	12.24	9.99
2018	**83.18**	**3.67**	**6.00**	**6.00**	**10.53**	**52.18**	**1.99**	**0.21**	**7.29**	**1.43**	**0.58**	**20.20**	**9.20**	**16.10**
Jun		**3.70**	**2.00**	**2.00**	**7.07**		**1.90**	**0.26**		**0.78**	**0.16**	**16.00**	**9.20**	**16.10**
06/06/2018		3.70	2.00	2.00	7.07		1.90	0.26		0.78	0.16	16.00	9.20	16.10
Jul	**83.18**	**3.66**	**4.00**	**4.00**	**11.39**	**52.18**	**2.01**	**0.20**	**7.29**	**1.59**	**0.69**	**21.25**		
02/07/2018	72.15	3.48	2.00	2.00	10.34	49.35	2.44	0.20	7.28	1.65	0.64	22.80		
12/07/2018	94.20	3.85	2.00	2.00	12.45	55.00	1.58	0.20	7.30	1.54	0.74	19.70		
2019	**70.60**	**1.90**	**1.00**	**1.00**	**6.93**	**59.00**	**2.87**	**0.34**	**7.25**	**1.20**	**0.24**	**21.80**		
Nov	**70.60**	**1.90**	**1.00**	**1.00**	**6.93**	**59.00**	**2.87**	**0.34**	**7.25**	**1.20**	**0.24**	**21.80**		
14/11/2019	70.60	1.90	1.00	1.00	6.93	59.00	2.87	0.34	7.25	1.20	0.24	21.80		
2022	**65.96**	**8.39**	**9.00**	**9.00**	**7.88**	**53.42**	**2.07**	**0.38**	**7.22**	**1.37**	**0.66**	**18.02**	**13.74**	
Feb	**65.96**	**4.24**	**9.00**	**9.00**	**9.81**	**53.42**	**2.85**	**0.45**	**7.22**	**1.18**	**0.23**	**29.99**	**9.50**	
18/02/2022	59.50	2.12	1.00	1.00	9.28	59.40	2.96	0.45	7.23	1.17	0.23	24.40		
19/02/2022	55.90	2.72	1.00	1.00	10.60	72.50	4.25	0.39	7.39	1.66	0.27	41.00		
20/02/2022	67.20	4.32	1.00	1.00	10.00	48.80	2.69	0.54	7.06	1.02	0.20	19.20		
21/02/2022	67.10	4.38	1.00	1.00	12.10	48.40	2.62	0.55	7.00	1.01	0.19	18.20		
22/02/2022	64.10	4.30	1.00	1.00	10.70	50.20	2.78	0.57	7.10	1.08	0.20	16.70		
23/02/2022	65.10	6.22	1.00	1.00	10.60	56.00	2.26	0.49	7.14	1.13	0.25	77.20		

Project Name / Number:	STAPLEFIELD WTW / 752214
Document Number:	752214-UAX-ZZ-ZZ-RP-EN-00001

25/02/2022	67.15	4.51	2.00	2.00	10.14	56.90	3.34	0.44	7.40	1.45	0.31	34.90		
26/02/2022	80.40	4.57	1.00	1.00	6.56	31.70	2.25	0.34	7.28	0.98	0.21	16.40		
27/02/2022					7.96		2.04			0.88		17.00		
28/02/2022		4.74						0.33			0.11		9.50	22.30
Mar		**12.53**			**6.13**		**1.51**	**0.33**		**1.50**	**1.00**	**8.81**	**14.16**	**9.19**
01/03/2022		18.03			6.95		1.55	0.31		1.59	0.93	9.11	10.40	10.29
02/03/2022		9.42			5.18		0.98	0.35		1.80	1.34	5.60	18.20	6.41
03/03/2022		7.79			6.31		2.50	0.33		0.75	0.17	13.67	13.60	12.54
Average Inlet	**71.21**	**9.01**	**16.00**	**16.00**	**6.60**	**53.46**	**2.19**	**0.35**	**7.24**	**1.41**	**0.75**	**11.97**	**12.44**	**10.15**

Inlet Concentrations (average)

	Alkalinity inlet (mg/l)	Ammonia Inlet (mg/l)	Nitrate Inlet (mg/l)	Nitrite Inlet (mg/l)	BOD5 Inlet (mg/l)	COD Inlet (mg/l)	Iron Inlet (mg/l)	Dissolved Iron Inlet (mg/l)	PH Inlet	Average of Phosphate Inlet (mg/l)	Orthophosphate Inlet (mg/l)	TSS Inlet (mg/l)	Temperature Inlet (C)	Turbidity Inlet (FTU)
<06/06/2018														
2018							**7.01**	**2.74**			**3.06**	**193.00**		
2019							**1.58**	**0.82**		**1.07**				
2022	**156.08**	**12.61**	**2.27**	**0.33**	**108.94**	**255.08**	**4.32**	**0.00**	**7.38**	**3.87**	**1.20**	**109.06**	**0.00**	**0.00**
Average Inlet	**156.08**	**12.61**	**2.27**	**0.33**	**108.94**	**255.08**	**4.61**	**0.38**	**7.38**	**3.80**	**1.45**	**117.05**	**0.00**	**0.00**

Outlet Concentrations (average)

Project Name / Number:	STAPLEFIELD WTW / 752214
Document Number:	752214-UAX-ZZ-ZZ-RP-EN-00001

	Alkalinity Outlet (mg/l)	Ammonia Outlet (mg/l)	Nitrate Outlet (mg/l)	Nitrite Outlet (mg/l)	BOD5 Outlet (mg/l)	COD Outlet (mg/l)	Iron Outlet (mg/l)	Dissolved Iron Outlet (mg/l)	PH Outlet	Phosphate Outlet (mg/l)	Orthophosphate Outlet (mg/l)	TSS Outlet (mg/l)	Temperature Outlet ©	Turbidity Outlet (FTU)
2016-2017		9.96			5.75		2.25	0.35		1.41	0.77	8.52	12.24	9.99
2018	83.18	3.67	6.00	6.00	10.53	52.18	1.99	0.21	7.29	1.43	0.58	20.20	9.20	16.10
2019	70.60	1.90	1.00	1.00	6.93	59.00	2.87	0.34	7.25	1.20	0.24	21.80		
2022	65.96	8.39	9.00	9.00	7.88	53.42	2.07	0.38	7.22	1.37	0.66	18.02	13.74	10.38
Average Inlet	**71.21**	**9.01**	**16.00**	**16.00**	**6.60**	**53.46**	**2.19**	**0.35**	**7.24**	**1.41**	**0.75**	**11.97**	**12.44**	**10.15**