

Phosphate Reduction and Mitigation (PRAM)

Wetland Calculations Technical Note - Llandysul, Tregaron, and Adpar

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1 Introduction

Under the Phosphate Reduction and Mitigation (PRAM) project, Arcadis has recently completed outline designs and supporting calculations for Cilgerran and Cenarth wetlands.

In addition, this technical note provides a summary of the estimated preliminary nutrient reductions and wetland area requirements in Llandysul, Tregaron, and Adpar if outline designs are to be undertaken at these locations under future project commissions It is envisaged that these additional wetlands could be potentially used to mitigate a significant portion of the cumulative nutrient budget in the Afon Teifi Special Area of Conservation (SAC) catchment upstream of Cilgerran and Cenarth, as a result of the new homes allocated within the current Ceredigion County Council (CeCC) and Carmarthenshire County Councils revised LDP (rLDP).

This technical note provides a summary of the estimated preliminary nutrient reductions and wetland area requirements using the following approaches:

- The P-K-C* model approach
- A plug flow model termed the k-C* model approach
- Regressions (or exponential decay) equations

P-K-C* Model

The P-K-C* model described in Kadlec and Wallace (2009)¹ is considered to be the most robust approach and is strongly recommended. This model is a 'First Order' reaction model. That is to say, the rate of reaction (the nutrient removal processes) assumed is dependent upon the concentration of the parameter in question. Such a model may be used either to derive a treatment area based upon target performance (load removal or outlet concentration), or else to derive the expected nutrient removal from a wetland with a particular treatment area.

The P-K-C* model is used to calculate the average estimated percentage of remaining contaminants (after treatment), for a given area and hydraulic loading rate (HLR). The parameters P, K and C* describe the way the contaminant of interest is processed within the wetland. C* is the 'background concentration' of a particular parameter, such as Total Phosphorus (TP). The background concentration is a parameter that represents an irreducible concentration that will exist in the water of a wetland that results from internal biogeochemical processes i.e. the contaminant would be present without the addition of the influent. It represents a concentration below which further removal of contaminant is impossible. K is the reaction rate, which describes the speed with which contaminants at any particular concentration (above C*) are removed from incoming water by the wetland. P is a parameter that describes both the hydraulic efficiency of the wetland, and the way in which contaminants 'weather' or breakdown as they pass through the wetland. Note that if contaminants are a mix of chemicals (e.g. TP), some of the chemicals that make up TP will break down more readily than others².

k-C* Model

The k-C* model has been widely applied to the design of treatment wetlands. As with the P-k-C* model, the k-C* model is a first order reaction model that similarly incorporates a background concentration value below which further nutrient removal is not possible.

Regression

There are numerous regression equations proposed in the literature to calculate the removal rates of different parameters, including TP. Different equations will have limitations on their input and output range and the

¹ Kadlec, R.H. and Wallace, S., 2009. Treatment wetlands. CRC press.

² Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals.

hydrological parameters used. The regression-based model is based on datasets generated from three Integrated Constructed Wetlands (ICWS): Glaslough, County Monaghan, Ireland; Northrepps, Norfolk; and Ingol, Norfolk³. The results of long-term monitoring have been combined to generate an exponential decay curve. The exponential decay curve equation has been used to estimate the size of the wetland required to achieve a desired outlet effluent quality for TP. A TP exponential decay curve has been carried out for a low flow scenario and a high flow scenario

2 Wastewater Treatment Works Summary

2.1.1 Phosphorus concentration

During the PRAM project, Dŵr Cymru Welsh Water (DCWW) provided Orthophosphate sampling data for the treated outflow from the Llandysul Wastewater Treatment Works (WwTWs) for the past 2 years where data exists. Figure 2-1 presents the average Orthophosphate at Llandysul WwTW. These values have been obtained to understand the fluctuations in TP concentrations and how that impacts the wetland area requirements and treatment efficiencies, compared to the 5 mg/l backstop limit, which will be imposed on both WwTWs over the DCWW Investment Programme period (ending 2032). Currently there is no TP permit limit at this WwTW location.

Orthophosphate sampling data was not provided for Adpar and Tregaron WwTW during the PRAM project. However, for Adpar WwTW, the annual average Orthophosphate performance of the final WwTW effluent over the last two years was previously provided during the ongoing Carmarthenshire Specialist Phosphate Advice project: in 2021, the phosphate performance was 4.8 mg/l and in 2022 it was 1.7 mg/l. For Tregaron, no data was provided on the phosphate performance. However, Tregaron WwTW has been designated a new TP permit limit of 2 mg/l, starting 2030 as part of the DCWW Investment Programme.

As a conservative basis, the wetland design calculations were undertaken based on the observed Orthophosphate concentration data (rather than TP observations) for the most recent 12 months period where data exists, but comparison was also made against the proposed 5 mg/l backstop limit for the WwTW outflow to check the implication on the wetland performance.

The average Orthophosphate concentration over the last year (Oct 2022 – Oct 2023) at Llandysul was 1.36 mg/l, and the year before that (Aug 2022 – July 2021) was 2.34 mg/l. As shown in Figure 2-1, there have been no record of incidents where the Orthophosphate concentrations exceed the 5 mg/l backstop limit. Therefore, it is worth considering whether the wetland would realistically receive a concentration of 5 mg/l considering the average is typically half of that. However, reaching 5 mg/l can still potentially occur with the fully permitted Dry Weather Flow (DWF) conditions as more new homes in future Local Development Plans (LDPs) are connected to the WwTW unless more process treatment is provided at the WwTW.



Figure 2-1: Average Orthophosphate concentration at Llandysul WwTW discharge – July 2021 to Oct 2023

Section 2.1.2 below details the DWF estimates and permitted values at Llandysul, Tregaron, and Adpar WwTWs whilst Section 2.1.3 provides a summary of key model inputs.

Section 3 and Section 4 of this technical note then show how the various Orthophosphate concentrations and other model inputs impact wetland requirements and nutrient reduction, for the different modelling approaches used.

2.1.2 Permitted Flows and Estimated Design Flows

Table 2-1 summarises the projected Dry Weather Flow (DWF) from Llandysul, Tregaron, and Adpar WwTW respectively when the proposed site allocations in the Local Development Plan (LDP) accounted for.

In order to calculate the existing and future developments DWF, the following equation has been used:

DWF = PG + I

Where:

P = population

G = water consumption

I = Infiltration rate

| | G – Water Consumption | I = Infiltration |
|---------------------|-----------------------|------------------|
| Existing Population | 50% | 144** |
| New Dwellings | 30%* | 108*** |

* irrespective of good construction of infrastructure

** (assuming 90% returned back into sewer) - assumed 160 l/p/d current consumption

*** 120 l/p/d for PCC - 90% returned to sewer

Table 2-1 Dry Weather Flow Estimation

| | Existing | | | | Proposed LDP Addition | | | Predicted Total | |
|-----------|--------------------------|------------------------------|---|---|-----------------------|-------------------|--------------------------|---------------------|--------------------------|
| WwTW | Population Equivalent | Consented DWF (m³/day) | Measured Q90 DWF - 2021 (m³/day) | Estimated Existing DWF (m ³ /day) | New Homes | New Population | Extra DWF (m³/day) | Total Population | Total DWF (m³/day) |
| Llandysul | 1534.3 | 689 | 326 | - | 131** | 301 | 42 | 1836 | 369 |
| Adpar | 1799.3 | 535 | 465 | - | 72*** | 166 | 23 | 1965 | 488 |
| Tregaron | 900 | 520.4 | - | 194 | 74 | 170 | 24 | 1070 | 218**** |

*Assumed average household occupancy rate as 2.3

** 5 units in CCC and 126 units in CeCC

*** 37 units in CCC and 35 units in CeCC

**** Measured Q90 DWF is currently not available at Tregaron and therefore the estimated DWF value was used for the baseline.

2.1.3 Summary of WwTW Model Inputs

Table 2-2 summarises the input data into the P-K-C* Model, k-C* and regression models.

Table 2-2 Influent Concentration and Design Flow Values

| WwTW | Ci, Influent Concentration (mg/l)* | Q, Design Flow (m³/day) |
|----------|---------------------------------------|-------------------------|
| | 1 36 (Oct 2023 to Oct 2022) | 689** |
| | 1.50 (061 2023 10 061 2022) | 369*** |
| Landveul | 2 34 (Aug 2022 to July 2021) | 689** |
| | 2.54 (Aug 2022 to Suly 2021) | 369*** |
| | 5 (backstop TP limit | 689** |
| | concentration) | 369*** |
| | 1.7 (P. performance 2022) | 535** |
| Adpar | | 488*** |
| Aupai | 4.8 (P. performance 2021) | 535** |
| | | 488*** |

| WwTW | wTW Ci, Influent Concentration (mg/l)* | |
|----------|---|--------|
| | 2 (New TP AMP8 permit limit) | 520** |
| Tregaron | | 218*** |
| Tegalon | 5 (backstop TP limit | 520** |
| | concentration) | 218*** |

*Influent concentration of Total Phosphorus

** Permitted Flow

*** Estimated Flow

For all three WwTWs, the estimated flow is lower than the permitted value. Therefore, the wetland design for this is primarily based on the estimated flow, but the permitted flow was also used for sensitivity testing purpose.

3 Initial Wetland Model Analysis

The following sections present the outcomes of the initial model development for nutrient removal at the proposed wetlands for Llandysul, Tregaron, and Adpar. A summary and interpretation of results is presented in Sections 4 and 5.

3.1 Llandysul

3.1.1 k-C* Model

The plug-flow k-C* model is based on the below equation; with the inputs and results summarised in Table 3-1 and Table 3-2, in which the input values are shaded in grey for clarity.

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m³/d), k: apparent rate coefficient (m/year), Ci: inlet TP concentration (gP/m³ or mg/l); C*: background Concentration (mgP/l); Ce=Target Effluent Concentration (mg/l)

The model was run with the following values:

 $C_{o:}$ The target TP concentration for the wetland is 1mg/l.

C*: The wetland background concentration is estimated at 0.05mg/l.

k: The apparent rate coefficient used was 12 m/year.

The analysis is undertaken for three different Ci values (1.36 mg/l, 2.34 mg/l and 5 mg/l) using the fully permitted DWF value of 689 m³/d at the WwTW, as well as the estimated DWF, which could increase the flow entering the wetlands as a result of the proposed allocations under the LDP.

Once the wetland area is calculated, the Hydraulic Retention Time (HRT) was determined using the following equation:

Where HRT (days), V= Wetland Volume (m³), Q=design flow (m³/d)

Table 3-1 Llandysul K-C* Permitted Design Flow Results

| Parameter | Design Scenario 1 – See Note 2 Values | Design Scenario 2 – See Note 2 Values | Design Scenario 3 – See Note 3 Values | Unit | Comment |
|-----------|--|--|---|------------------------------|---|
| Q | 689 | 689 | 689 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 4 |
| Ci | 1.36 | 2.34 | 5 | gP/m ³ or mg/l | Inlet TP concentration – see Table 2.2 |
| Се | 1 | 1 | 1 | mg/l | Target effluent concentration |

| Parameter | Design Scenario 1 – See Note 2 | Design Scenario 2 – See Note 2 | Design Scenario 3 – See Note 3 | Unit | Comment | |
|---|--------------------------------------|--------------------------------------|---|----------------|---|--|
| | Values | Values | Values | | | |
| C* | 0.05 | 0.05 | 0.05 | mg/l | Wetland background concentration (estimated value) – see Note 5 | |
| k | 12 | 12 | 12 | m/year | Apparent rate coefficient - see Note 6 | |
| Water depth | 0.2 | 0.2 | 0.2 | m | Treatment water depth – see Note 7 | |
| Total | 0.60 | 1.83 | 3.53 | ha | Estimated wetland area (ha) for the specified Ci and Ce | |
| area | 5,957 | 18,278 | 35,283 | m² | Estimated wetland area (m ²) for the specified Ci and Ce | |
| Wetland volume | 1,191.4 | 3,655.6 | 7,056.5 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce | |
| Hydraulic Retention Time (HRT) | 1.73 | 5.31 | 10.24 | days | The average time taken for water to pass through a wetland - see Note 8 | |

Notes

- 1. Design Scenario 1 is based on Ci value of 1.36 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2-2
- Design Scenario 2 is based on Ci value of 2.34 mg/l from the observed Orthophosphate values (Aug 2022 - July 2021), as per Table 2-2
- 3. Design Scenario 3 is based on Ci value of 5.0 mg/l from the backstop TP limit, as per Table 2-2 this is a hypothetical scenario mainly for sensitivity testing.
- Design flow for both Design Scenario 1, 2 and 3 is based on the fully permitted DWF of 689 m³/d, as per Table 2-2
- 5. C* value of 0.05 mg/l is assumed, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation
- Apparent rate coefficient is assumed as 12 m/year, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC – Titley Report (July 2022) by The Wye & Usk Foundation

- 7. Treatment depth is taken as 0.2 m, as per Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals
- Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/I TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24hrs may be needed.

| Parameter | Design Scenario 1 – See Note 2 | Design Scenario 2 – See Note 2 3 Design Scenario 3 – See Note 3 | | Unit | Comment | |
|---|--------------------------------------|--|---------|------------------------------|---|--|
| | Values | Values | Values | | | |
| Q | 369 | 369 | 369 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 4 | |
| Ci | 1.36 | 2.34 | 5 | gP/m ³ or mg/l | Inlet TP concentration - see Table 2.2 | |
| Ce | 1 | 1 | 1 | mg/l | Target effluent concentration | |
| C* | 0.05 | 0.05 | 0.05 | mg/l | Wetland background concentration (estimated value) – see Note 5 | |
| k | 12 | 12 | 12 | m/year | Apparent rate coefficient - see Note 6 | |
| Water depth | 0.2 | 0.2 | 0.2 | m | Treatment water depth – see Note 7 | |
| Total | 0.32 | 0.98 | 1.89 | ha | Estimated wetland area (ha) for the specified Ci and Ce | |
| area | 3,190 | 9,789 | 18,896 | m² | Estimated wetland area (m ²) for the specified Ci and Ce | |
| Wetland volume | 638.1 | 1,957.8 | 3,779.2 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce | |
| Hydraulic Retention Time (HRT) | 1.73 | 5.31 | 10.24 | days | The average time taken for water to pass through a wetland - see Note 8 | |

Table 3-2 Llandysul K-C* Estimated Design Flow Results

Notes

- 1. Design Scenario 1 is based on Ci value of 1.36 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2-2
- 2. Design Scenario 2 is based on Ci value of 2.34 mg/l from the observed Orthophosphate values (Aug 2022 July 2021), as per Table 2-2
- 3. Design Scenario 3 is based on Ci value of 5.0 mg/l from the backstop TP limit, as per Table 2-2 this is a hypothetical scenario mainly for sensitivity testing.
- Design flow for both Design Scenario 1, 2 and 3 is based on the estimated DWF of 369 m³/d, as per Table 2-2
- 5. C* value of 0.05 mg/l is assumed, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation
- Apparent rate coefficient is assumed as 12 m/year, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC – Titley Report (July 2022) by The Wye & Usk Foundation
- 7. Treatment depth is taken as 0.2 m, as per Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals
- Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24 hrs may be needed.

3.1.2 P-K-C* Model

The P-K-C^{*} Model builds on the results of the k-C^{*} model results shown in Table 3-1 and Table 3-2, specifically the total wetland area, which is used the derive the hydraulic loading rate (q) (m/yr).

The P-K-C model is defined as¹:

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{-P}$$

C_i = Influent concentration of contaminant (mg/l) C_e = Effluent concentration of contaminant (mg/l) C* = Background concentration of contaminant (in the wetland water column) (mg/l) k = Rate coefficient for reduction of contaminant (m/yr) P = Apparent no. of tanks in series (PTIS – dimensionless) q = Hydraulic loading rate (m/yr)

Table 3-3 summarises the P-K-C* inputs and outputs for the permitted Q(Orthophosphate Oct 2023 – Oct 2022 scenario), and the permitted Q (Orthophosphate August 2022 – July 2021) and the permitted Q (5 mg/l backstop limit). Table 3-4 summarises the inputs and outputs for estimated Q with the same three scenarios. The input values are shaded in grey for clarity and Italic text in italics are information related calculating hydraulic loading rate (q).

Table 3-3 Llandysul Permitted Design Flow P-K-C* Results

| Parameter | Design Scenario – See Note 1 Value | Design Scenario 2 – See Note 2 Value | Design Scenario 3 – See Note 3 Value | Unit | Comment |
|--|---|---|---|-----------------------|---|
| Ci | 1.36 | 2 34 | 5 | ma/l | Influent concentration of |
| | | 2.01 | | | Table 2.2 |
| C* | 0.022 | 0.022 | 0.022 | mg/l | Background concentration of Total Phosphorus (estimated value) – see Note 4 |
| Р | 2 | 2 | 2 | - | Apparent no. of tanks in series |
| k | 10 | 10 | 10 | m/yr | Rate coefficient for reduction of Total Phosphorus – see Note 5 |
| Design Flow | 689 | 689 | 689 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 6 |
| Total annual hydraulic throughput | 251,485 | 251,485 | 251,485 | m³/yr | Design Flow (m³/d) X 365 |
| Total wetland area | 5,957 | 18,278 | 35,283 | <i>m</i> ² | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-1 (from k-C* Model) for each Design Scenario |
| q | 42.217 | 13.759 | 7.128 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²) |
| Amount of remaining contaminant. | 1.07 | 1.25 | 1.41 | mg/l | NB. treated discharge from the wetland cannot |
| Ce - C* | 79.94 | 53.80 | 28.34 | % | be less than the background |

| Parameter | Design Scenario – See Note 1 Value | Design Scenario 2 – See Note 2 Value | Design Scenario 3 – See Note 3 Value | Unit | Comment |
|---------------------------------------|---|---|---|------|--|
| | | | | | concentrations, as it is not possible to achieve i.e. background concentration will always be present |
| Treatment efficiency of wetland | 20.06 | 46.20 | 71.66 | % | % of contaminant removed |

Notes:

- 1. Design Scenario 1 is based on Ci value of 1.36 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 2.34 mg/l from the observed Orthophosphate values (Aug 2022 July 2021), as per Table 2.2
- 3. Design Scenario 3 is based on Ci value of 5.0 mg/l from the backstop TP limit, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- 4. C* value of 0.022 mg/l is assumed, based on Kadlec & Wallace report (2009) for the median flow-weighted TP concentration in 85 relatively undeveloped basins of the United States. It also states levels are very low in Florida Everglades, often in the range of 0.006-0.010. Free Water Surface (FWS) wetlands receiving low strength wastewater. Kadlec & Wallace report (2009) also advises C* typical values of 0.010 0.040 mg/l for rainfall driven FWS systems.
- 5. For total phosphorus (TP) reduction, Kadlec & Wallace report (2009) advises that adjustment of the rate constant using a temperature coefficient , Θ , is not a good model with the equation $k_T = k_{20}\Theta(^{T-20})$ where T is the operating temperature. Studies of FWS wetlands in cold climates gave a median value of 0.986, meaning that the rate constant decreased with increasing temperature. It is therefore more appropriate to look at actual rate constants from existing FWS wetlands. Kadlec & Wallace report that the median rate constant for 282 studied wetlands was 10.0 m/yr.
- Design flow for the Design Scenarios 1, 2 and 3 are based on the fully permitted DWF of 689 m³/d, as per Table 2.2

Table 3-4 Llandysul Estimated Design Flow P-K-C* Results

| Parameter | Design Scenario – See Note 1 | Design Scenario 2 – See Note 2 | Design Scenario 3 – See Note 3 | Unit | Comment |
|--|------------------------------------|--------------------------------------|--------------------------------------|-----------------------|---|
| | Value | Value | Value | | |
| C _i . | 1.36 | 2.34 | 5 | mg/l | Influent concentration of Total Phosphorus - see Table 2.2 |
| C* | 0.022 | 0.022 | 0.022 | mg/l | Background concentration of Total Phosphorus (estimated value) – see Note 4 |
| Р | 2 | 2 | 2 | - | Apparent no. of tanks in series |
| k | 10 | 10 | 10 | m/yr | Rate coefficient for reduction of Total Phosphorus – see Note 5 |
| Design Flow | 369 | 369 | 369 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 6 |
| Total annual hydraulic throughput | 134,685 | 134,685 | 134,685 | m³/yr | Design Flow (m³/d) X 365 |
| Total wetland area | 3,190 | 9,789 | 18,896 | <i>m</i> ² | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-1 (from k-C* Model) for each Design Scenario |
| q | 42.218 | 13.759 | 7.128 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²) |
| Amount of remaining contaminant. | 1.07 | 1.25 | 1.72 | mg/l | NB. treated discharge from the wetland cannot |
| Ce - C* | 79.94 | 53.80 | 34.54 | % | be less than the background |

| Parameter | Design Scenario – See Note 1 Value | Design Scenario 2 – See Note 2 Value | Design Scenario 3 – See Note 3 Value | Unit | Comment |
|---------------------------------------|---|---|---|------|--|
| | | | | | concentrations, as it is not possible to achieve i.e. background concentration will always be present |
| Treatment efficiency of wetland | 20.06 | 46.20 | 65.46 | % | % of contaminant removed |

Notes:

- 1. Design Scenario 1 is based on Ci value of 1.36 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 2.34 mg/l from the observed Orthophosphate values (Aug 2022 July 2021), as per Table 2.2
- 3. Design Scenario 3 is based on Ci value of 5.0 mg/l from the backstop TP, as per Table 2.2 – this is a hypothetical scenario mainly for sensitivity testing.
- C* value of 0.022 mg/l is assumed, based on Kadlec & Wallace report (2009) for the median flowweighted TP concentration in 85 relatively undeveloped basins of the United States. It also states levels are very low in Florida Everglades, often in the range of 0.006-0.010. FWS wetlands receiving low strength wastewater. Kadlec & Wallace report (2009) also advises C* typical values of 0.010 – 0.040 mg/l for rainfall driven FWS systems.
- 5. For total phosphorus (TP) reduction, Kadlec & Wallace report (2009) advises that adjustment of the rate constant using a temperature coefficient ,Θ, is not a good model with the equation k_T = k₂₀θ(^{T-20)} where T is the operating temperature. Studies of Free Water Surface (FWS) wetlands in cold climates gave a median value of 0.986, meaning that the rate constant decreased with increasing temperature. It is therefore more appropriate to look at actual rate constants from existing FWS wetlands. Kadlec & Wallace report that the median rate constant for 282 studied wetlands was 10.0 m/yr.
- Design flow for Design Scenarios 1, 2 and 3 are based on the estimated DWF of 369 m³/d, as per Table 2.2

3.1.3 Regression

The regression results below are based on the phosphorus exponential curves shown in The Wye & Usk Foundation (July 2022) Wetland Feasibility, Design and Offsetting³. The results below are therefore an interpretation of those results rather than based on a published equation. Further research undertaken to date could not find a regression equation specific for wetland P removal. Therefore, there is low confidence in the results below and these should not be used for design purposes.

The inputs into the Regression model are based on the Orthophosphate values shown in Section 2.1.1 for the period between Oct 2023 - July 2021. Figure 3-1 and Figure 3-2 show derived TP exponential decay curve for a wetland under a low flow scenario and a high flow scenario for the average Orthophosphate concentration between Oct 2023 – Oct 2023. Figure 3-3 and Figure 3-4 show the derived TP exponential decay curve for a wetland under a low flow scenario and a high flow scenario for the average Orthophosphate concentration between August 2022 – July 2021.

However, one of the main limitations of this exercise is that the regression equation used in the analysis is based on a DWF of much lower value of circa 15 m^3 /day and TP level 5.6 mg/l for the low flow scenario and 79.83 m³/day and TP of 2.82 mg/l for the high flow scenario.

Therefore, the initial estimated wetland area was then normalised with the fully permitted design flow (689 m³/day) and estimated design flow (369 m³/day) to recalculate the wetland areas for low flow and high flow scenarios, as shown in Table 3-5. Table 3-6 summarises the wetland area requirements for the Estimated Design Flow, based on the Orthophosphate data set being used.



Figure 3-1 TP Regression Curve for Low flow scenario (with DWF of 15.41 m³/day) using Orthophosphate values (Oct 2023 -Oct 2022)



Figure 3-2 TP Regression Curve for High flow scenario (with DWF of 79.83 m³/day) using Orthophosphate values (Oct 2023 -Oct 2022)



Figure 3-3 TP Regression Curve for Low flow scenario (with DWF of 15.41 m³/day) using Orthophosphate values (Aug 2022 – July 2021)



Figure 3-4 TP Regression Curve for High flow scenario (with DWF of 79.83 m³/day) using Orthophosphate values (Aug 2022 -July 2021)

| Pagression | Permitted Q , Orthophosphate data (Oct 2023 - Oct 2022) | | Permitted Q , Orthophosphate data (Aug 2022 - July 2021) | | |
|---|--|--------------------|---|--------------------|--|
| Regression | Low Flow Scenario | High Flow Scenario | Low Flow Scenario | High Flow Scenario | |
| Desired TP value (mg TP/I) | 1 | 1 | 1 | 1 | |
| Initially Estimated Wetland Area (m ²) | 830.9 | 2,918.1 | 764.5 | 2,340.9 | |
| Normalised Wetland Area (m²)* | 37,148 | 130,471 | 34,180 | 104,662 | |

* The Normalised Wetland Area (m^2) is calculated by multiplying the Estimated Wetland Area with the ratio of Permitted Flow (689 m³/d) and mean flow used in the Titley Regression curve (15.41 m³/d).

| Regression | Estimated Q , Orthophosphate data (Oct 2023 - Oct 2022) | | Estimated Q , Orthophosphate data (Aug 2022 - July 2021) | | |
|---|--|--------------------|---|--------------------|--|
| | Low Flow Scenario | High Flow Scenario | Low Flow Scenario | High Flow Scenario | |
| Desired TP value (mg TP/I) | 1 | 1 | 1 | 1 | |
| Initially Estimated Wetland Area (m ²) | 830.9 | 2,918.1 | 764.5 | 2,340.9 | |
| Normalised Wetland Area (m²)* | 19,895.5 | 69,875 | 18,306 | 56,053 | |

Table 3-6 Summary of Regression Model Outputs for Llandysul for Estimated Q

* The Normalised Wetland Area (m^2) is calculated by multiplying the Estimated Wetland Area with the ratio of Estimated Flow (369 m³/d) and mean flow used in the Titley Regression curve (15.41 m³/d).

3.2 Adpar

As discussed in Section 2.1.1, no data was provided on the Orthophosphate concentrations or phosphate performance at Adpar WwTW. However, the average P performance over the last two years at Adpar WwTW were provided. Also, as discussed in 2.1.2, the projected DWF, as a result of the proposed allocations under the LDP could increase the flow entering the wetlands. Therefore, a number of calculations have been undertaken to understand the impact of the design and estimated flow, against the different Orthophosphate concentrations.

3.2.1 k-C* Model

As discussed in Section 3.1.1, the following are the same across all the models and therefore, Table 3-7 and Table 3-8 only present the other specific parameters and outputs related to the Adpar WwTW:

- K = 12 m/year
- C* = 0.05 mg/l
- Water depth = 0.20 m

Table 3-7 Adpar k-C* Permitted Design Flow Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--------------------------------------|---|---|-------------------|---|
| Q | 535 | 535 | m³/d | Design flow (Permitted Flow) - see Table 2.2 and Note 3 |
| Ci | 1.7 | 4.8 | gP/m ³ | Inlet TP concentration – see Table 2.2 |
| Се | 1 | 1 | mg/l | Target effluent concentration |
| Total wetland | 0.86 | 2.67 | ha | Estimated wetland area (ha) for the specified Ci and Ce |
| area | 8,578 | 26,690 | m² | Estimated wetland area (m ²) for the specified Ci and Ce |
| Wetland volume | 1,715.6 | 5,338.0 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce |
| Hydraulic Retention Time (HRT) | 3.21 | 9.98 | days | The average time taken for water to pass through a wetland - see Note 3 |

Notes:

- 1. Design Scenario 1 is based on Ci value of the average P performance (2022) of 1.7 mg/l, as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of the average P performance (2021) of 4.8 mg/l, as per Table 2.2. The 5mg/l backstop limit scenario was not specifically analysed considering that 4.8 mg/l already gives a very clear indication of this. Furthermore, in 2022 P performance of the WwTW outflow has significantly improved, therefore 5 mg/l (median value) is unlikely to be exceeded in any case.
- Design flow for both scenarios is based on the fully permitted DWF of 535 m³/d, as per Table 2.2 this is undertaken mainly for sensitivity purposes, should the full permitted flow be treated in the future.
- 4. Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24 hrs may be needed.

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--------------------------------------|---|---|-------------------|---|
| | Values | Values | | |
| Q | 488 | 488 | m³/d | Design flow (Estimated Flow) - see Table 2.2 and Note 3 |
| Ci | 1.7 | 4.8 | gP/m ³ | Inlet TP concentration – see Table 2.2 |
| Се | 1 | 1 | mg/l | Target effluent concentration |
| Total wetland | 0.78 | 2.43 | ha | Estimated wetland area (ha) for the specified Ci and Ce |
| area | 7,824 | 24,345 | m² | Estimated wetland area (m ²) for the specified Ci and Ce |
| Wetland volume | 1,564.9 | 4,869.1 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce |
| Hydraulic Retention Time (HRT) | 3.21 | 9.98 | days | The average time taken for water to pass through a wetland - see Note 4 |

Table 3-8 Adpar k-C* Estimated Design Flow Results

Notes:

- 1. Design Scenario 1 is based on Ci value of the average P performance (2022) of 1.7 mg/l, as per Table 2.2
- 2. Design Scenario 1 is based on Ci value of the average P performance (2021) of 4.8 mg/l, as per Table 2.2. The 5mg/l backstop limit scenario was not specifically analysed considering that 4.8 mg/l already gives a very clear indication of this. Furthermore, in 2022 P performance of the WwTW outflow has significantly improved, therefore 5 mg/l (median value) is unlikely to be exceeded in any case.
- 3. Design flow for both scenarios is based on the estimated DWF of 488 m³/d, as per Table 2.2
- 4. Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24 hrs may be needed.

3.2.2 P-K-C* Model

As discussed in Section 3, the following parameters are standard across all the P-K-C models and therefore are not presented in Table 3-9 and Table 3-10 below:

- C* = 0.022
- k = 10
- θ- = 0.986
- Water depth = 0.20 m

Table 3-9 Adpar Permitted Design Flow P-K-C* Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--|---|---|-----------------------|---|
| Ci- | 1.7 | 4.8 | mg/l | Influent concentration of Total Phosphorus - see Table 2.2 |
| Р | 2 | 2 | - | Apparent no. of tanks in series |
| Design Flow | 535 | 535 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 3 |
| Total annual hydraulic throughput | 195,275 | 195,275 | m³/yr | Design Flow (m3/d) X 365 |
| Total wetland area | 26,690 | 8,578 | <i>m</i> ² | <i>Active</i> cell area (i.e. excluding diving berms, spreader channels and level control |

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|---|---|---|------|---|
| | | | | structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario |
| q | 7.31 | 22.76 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²) |
| Amount of remaining contaminant, Ce - C* | 1.13 | 1.69 | mg/l | NB. treated discharge from the wetland cannot be less than |
| | 67.223 | 35.29 | % | the background concentrations, as it is not possible to achieve i.e. background concentration will always be present |
| Treatment efficiency of wetland | 32.77 | 64.71 | % | % of contaminant removed |

Notes

- 1. Design Scenario 1 is based on Ci value of the average P performance (2022) of 1.7 mg/l, as per Table 2.2.
- 2. Design Scenario 1 is based on Ci value of the average P performance (2021) of 4.8 mg/l, as per Table 2.2. The 5mg/l backstop limit scenario was not specifically analysed considering that 4.8 mg/l already gives a very clear indication of this. Furthermore, in 2022 P performance of the WwTW outflow has significantly improved, therefore 5 mg/l (median value) is unlikely to be exceeded in any case.
- 3. Design flow for both scenarios is based on the fully permitted DWF of 535 m³/d, as per Table 2.2

Table 3-10 Adpar Estimated Design Flow P-K-C* Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--|---|---|-------|---|
| Ci | 1.7 | 4.8 | mg/l | Influent concentration of Total Phosphorus - see Table 2.2 |
| Р | 2 | 2 | - | Apparent no. of tanks in series |
| Design Flow | 488 | 488 | m³/d | Design flow (Estimated Flow) – see Table 2.2 and Note 4 |
| Total annual hydraulic throughput | 178,120 | 178,120 | m³/yr | Design Flow (m³/d) X 365 |
| Total wetland area | 7,824 | 24,345 | m² | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario |
| q | 22.77 | 7.32 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²) |
| Amount of remaining contaminant, | 1.13 | 1.69 | mg/l | NB. treated discharge from the wetland cannot be less than the background concentrations, as it is not |
| Ce - C* | 67.23 | 35.29 | % | possible to achieve i.e. background concentration will always be present |
| Treatment efficiency of wetland | 32.77 | 64.71 | % | % of contaminant removed |

Notes:

- 1. Design Scenario 1 is based on Ci value of the average P performance (2022) of 1.7 mg/l, as per Table 2.2
- 2. Design Scenario 1 is based on Ci value of the average P performance (2021) of 4.8 mg/l, as per Table 2.2. The 5mg/l backstop limit scenario was not specifically analysed considering that 4.8 mg/l already gives a very clear indication of this. Furthermore, in 2022 P performance of the WwTW outflow has significantly improved, therefore 5 mg/l (median value) is unlikely to be exceeded in any case.
- 3. Design flow for both scenarios is based on the estimated DWF of 535 m³/d, as per Table 2.2

3.2.3 Regression

As discussed in Section 2, there is no Orthophosphate data for Adpar WwTW. Therefore, the Regression model cannot be undertaken.

3.3 Tregaron

As discussed in Section 2.1.1, no data was provided on the Orthophosphate concentrations or phosphate performance at Tregaron WwTW. However, Tregaron WwTW has been designated a new TP permit limit of 2mg/l, starting 2030 as part of the DCWW Investment Programme. Also, as discussed in 2.1.2, the projected DWF, as a result of the proposed allocations under the LDP could increase the flow entering the wetlands. Therefore, a number of calculations have been undertaken to understand the impact of the design and estimated flow, against the different Orthophosphate concentrations.

3.3.1 k-C* Model

As discussed in Section 3.1.1, the following are the same across all the models and therefore, Table 3-11 and Table 3-12 only present the other specific parameters and outputs related to the Tregaron WwTW:

- K = 12 m/year
- C* = 0.05 mg/l
- Water depth = 0.20 m

Table 3-11 Tregaron k-C* Permitted Design Flow Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--------------------------------------|---|---|-------------------|---|
| Q | 520 | 520 | m³/d | Design flow (Permitted Flow) - see Table 2.2 and Note 3 |
| Ci | 2 | 5 | gP/m ³ | Inlet TP concentration – see Table 2.2 |
| Се | 1 | 1 | mg/l | Target effluent concentration |
| Total wetland | 1.11 | 2.66 | ha | Estimated wetland area (ha) for the specified Ci and Ce |
| area | 11,119 | 26,628 | m ² | Estimated wetland area (m ²) for the specified Ci and Ce |
| Wetland volume | 2,223.8 | 5,325.7 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce |
| Hydraulic Retention Time (HRT) | 4.28 | 10.24 | days | The average time taken for water to pass through a wetland - see Note 4 |

Notes:

- 1. Design Scenario 1 is based on Ci value of new TP permit limit of 2.0 mg/l, as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 5.0 mg/l from the backstop TP, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- 3. Design flow for both scenarios is based on the fully permitted DWF of 520 m³/d, as per Table 2.2
- 4. Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/I TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24 hrs may be needed.

Table 3-12 Tregaron k-C* Estimated Design Flow Results

| Parameter | Design Scenario 1 - See Note 1Design Scenario 2 - See Note 2UnitValuesValues | | Unit | Comment |
|--------------------------------------|--|---------|-------------------|---|
| Q | 218 | 218 | m³/d | Design flow (Estimated Flow) - see Table 2.2 and Note 3 |
| Ci | 2 | 5 | gP/m ³ | Inlet TP concentration – see Table 2.2 |
| Се | 1 | 1 | mg/l | Target effluent concentration |
| Total wetland | 0.47 | 1.12 | ha | Estimated wetland area (ha) for the specified Ci and Ce |
| area | 4,661 | 11,163 | m² | Estimated wetland area (m²) for the specified Ci and Ce |
| Wetland volume | 932.3 | 2,232.7 | m ³ | Estimated wetland volume (m ³) for the specified Ci and Ce |
| Hydraulic Retention Time (HRT) | 4.28 | 10.24 | days | The average time taken for water to pass through a wetland - see Note 4 |

Notes:

- 1. Design Scenario 1 is based on Ci value of new TP permit limit of 2.0 mg/l, as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 5.0 mg/l from the backstop TP, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- 3. Design flow for both scenarios is based on the estimated DWF of 218 m³/d, as per Table 2.2
- 4. Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24 hrs may be needed.

3.3.2 P-K-C* Model

As discussed in Section 3, the following parameters are standard across all the P-K-C* models and therefore are not presented in Table 3-13 and Table 3-14 below:

- C* = 0.022
- k = 10
- θ- = 0.986
- Water depth = 0.20 m

Table 3-13 Tregaron Permitted Design Flow P-K-C* Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|--|---|---|-----------------------|---|
| C _i . | 2 | 5 | mg/l | Influent concentration of Total Phosphorus - see Table 2.2 |
| Р | 2 | 2 | - | Apparent no. of tanks in series |
| Design Flow | 520 | 520 | m³/d | Design flow (Permitted Flow) – see Table 2.2 and Note 3 |
| Total annual hydraulic throughput | 189,800 | 189,800 | m³/yr | Design Flow (m³/d) X 365 |
| Total wetland area | 11,119 | 26,628 | <i>m</i> ² | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario |
| q | 17.07 | 7.13 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput |

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment | | |
|---------------------------------------|---|---|------|---|--|--|
| | | | | (m³/yr) / Total wetland area (m²) | | |
| Amount of remaining | 1.18 | 1.72 | mg/l | NB. treated discharge from the wetland cannot be less than | | |
| contaminant, Ce - C* | 59.82 | 34.54 | % | the background concentrations, as it is not possible to achieve i.e. background concentration will always be present | | |
| Treatment efficiency of wetland | 40.18 | 65.46 | % | % of contaminant removed | | |

Notes

- 1. Design Scenario 1 is based on Ci value of new TP permit limit of 2.0 mg/l, as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 5.0mg/l from the backstop TP, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- 3. Design flow for both scenarios is based on the fully permitted DWF of 520 m³/d, as per Table 2.2

Table 3-14 Tregaron Estimated Design Flow P-K-C* Results

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment |
|-----------|---|---|------|---|
| Ci | 2 | 5 | mg/l | Influent concentration of Total Phosphorus - see Table 2.2 |
| Р | 2 | 2 | - | Apparent no. of tanks in series |

| Parameter | Design Scenario 1 – See Note 1 Values | Design Scenario 2 – See Note 2 Values | Unit | Comment | | |
|---|---|---|-------|---|--|--|
| Design Flow | 218 | 218 | m³/d | Design flow (Estimated Flow) – see Table 2.2 and Note 4 | | |
| Total annual hydraulic throughput | 79,570 | 79,570 | m³/yr | Design Flow (m³/d) X 365 | | |
| Total wetland area | 4,661 | 11,163 | m² | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario | | |
| q | 17.07 | 7.13 | m/yr | Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²) | | |
| Amount of remaining contaminant, Ce - C* | 1.18 | 1.72 | mg/l | NB. treated discharge from the wetland cannot be less than the background concentrations, as it is not | | |
| | 59.82 | 34.54 | | possible to achieve i.e. background concentration will always be present | | |
| Treatment efficiency of wetland | 40.18 | 65.46 | % | % of contaminant removed | | |

Notes:

- 1. Design Scenario 1 is based on Ci value of new TP permit limit of 2.0 mg/l, as per Table 2.2
- 2. Design Scenario 2 is based on Ci value of 5.0 mg/l from the backstop TP, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- 3. Design flow for both scenarios is based on the estimated DWF of 218 m^3/d , as per Table 2.2

3.3.3 Regression

As discussed in 2, there is no Orthophosphate data for Tregaron WwTW. Therefore, the Regression model cannot be undertaken.

4 Refined Wetland Model Analysis

Section 4 presents the further results from the P-K-C* model, which was deemed to provide the most robust approach. The results are based on larger wetland sizes currently being identified for the ongoing Carmarthenshire Action Plan (as part of the Carmarthenshire Specialist phosphate Advice project).

Wetland areas used in this final P-K-C* modelling exercise to estimate the wetland removal % efficiencies have been informed by the initial values obtained (in Section 3) from the K-C* model to achieve the intended 1 mg/l effluent outlet concentration.

Section 4.1, 4.2 and 4.3 present a summary of the P-K-C* model results for the Llandysul, Adpar and Tregaron wetlands respectively and the complete results can be found in Appendix A, Appendix B and Appendix C respectively.

These refined calculations in Section 4 are performed on the basis of having a minimum of six wetland cells at each WwTW location. On the other hand, the preliminary calculations in Section 3 are done on the basis of just two wetland cells at each WwTW location.

During the period of January to March, it was assumed that winter maintenance activities may be performed, which may reduce the available wetland treatment area by up to 50%, causing a lowered wetland performance. Therefore, effective annual TP removal quantities were also presented to reflect this possibility alongside the normal annual TP removal quantities for comparison. They show that the predicted outlet effluent quality following the wetland treatment is broadly as shown below when they are operating at an optimum level (without any winter wetland maintenance activities).

Current Wetland Scheme performance (see note below):

- At Llandysul 0.5 to 1.0 mg/l
- At Tregaron 0.5 to 1.0 mg/l
- At Adpar 1.0 mg/l

Also note that the above wetland outlet effluent quality values are based on the estimated WwTW DWF and the most recent observed inlet concentration values from the WwTW treated effluent (i.e. rather than the fully permitted DWF and backstop TP limit values, which were mainly used for sensitivity scenario testing purposes only). However, since observed concentration values are not available at Tregaron the 2mg/I AMP8 permit level was provisionally used for the wetland inlet concentration at this stage, but the observed values should be used to refine the current estimates.

4.1 Llandysul

| | | | P-K-C* model - 100% performance (Januar) March) | | lel – 50% Effective ce (Jan – Annual TP removal | | P-K-C* model - 100% performance | P-K-C*model - 50% performance (Jan - March) | | | | |
|-----------|--------------|------------------|---|--------|---|------------------------------|---------------------------------------|--|-------------------------|---------------------------------|-------------------|-------------------|
| | Ci (mg/l) | Q (m3/dav) | Wetland | Volume | HRT (days) | Removal efficiency (%) | Annual Tp removal | Removal efficiency (%) | Annual Tp removal | Annual TP removal (kg/yr) | Final Effluent TP | Final Effluent TP |
| | 1.36 | (113/day) 689 | 2.000 | 4000 | (uays) 5.81 | 52.61 | 179.94 | 31.96 | 26.95 | 161.91 | 0.64 | 0.93 |
| | 1.36 | 369 | 2.000 | 4000 | 10.84 | 73.47 | 134.58 | 50.34 | 22.74 | 123.67 | 0.36 | 0.66 |
| Llandvsul | 2.34 | 689 | 2.000 | 4000 | 5.81 | 52.61 | 309.60 | 31.96 | 46.38 | 278.57 | 1.11 | 1.59 |
| , | 2.34 | 369 | 2.000 | 4000 | 10.84 | 73.47 | 231.55 | 50.34 | 39.12 | 212.78 | 0.62 | 1.15 |
| | 5 | 689 | 2.000 | 4000 | 5.81 | 52.61 | 661.53 | 31.96 | 99.09 | 595.24 | 2.37 | 3.40 |
| | 5 | 369 | 2.000 | 4000 | 10.84 | 73.47 | 494.77 | 50.34 | 83.59 | 454.66 | 1.32 | 2.47 |

4.2 Adpar

| | | | | | | P-K-C* mod performanc | C* model - 100% performance (Jan – March) | | Effective Annual TP removal | P-K-C* model - 100% performance | P-K-C*model - 50% performance (Jan - March) | |
|--------|--------------|---------------|-----------------|----------------|---------------|------------------------------|---|------------------------------|--------------------------------------|---------------------------------------|--|-----------------------------|
| | Ci (mg/l) | Q (m³/day) | Wetland (ha) | Volume (m³) | HRT (days) | Removal efficiency (%) | Annual Tp removal (Kg/year) | Removal efficiency (%) | Annual Tp removal (Kg/year) | Annual TP removal (kg/yr) | Final Effluent TP (mg/l) | Final Effluent TP (mg/l) |
| | 1.7 | 535 | 1.0 | 2,000 | 3.74 | 38.82 | 128.87 | 22.18 | 18.16 | 114.81 | 1.04 | 1.32 |
| Advacu | 1.7 | 488 | 1.0 | 2,000 | 4.10 | 41.53 | 125.75 | 23.99 | 17.91 | 112.23 | 0.99 | 1.29 |
| Aapar | | | | | | | | | | | | |
| | 4.8 | 535 | 1.0 | 2,000 | 3.74 | 38.82 | 363.87 | 22.18 | 51.26 | 324.16 | 2.94 | 3.74 |
| | 4.8 | 488 | 1.0 | 2,000 | 4.10 | 41.53 | 355.07 | 23.99 | 50.57 | 316.88 | 2.81 | 3.65 |
4.3 Tregaron

| | | | | | | P-K-C* moo performane | lel - 100% ce | P-K-C* model – 50% performance (Jan – March) | | Effective Annual TP removal | | P-K-C* model - 100% performance | P-K-C*model - 50% performance (Jan - March) |
|----------|--------------|---------------|-----------------|----------------|---------------|------------------------------|--------------------------------------|--|--------------------------------------|--------------------------------------|--|---------------------------------------|--|
| | Ci (mg/l) | Q (m³/day) | Wetland (ha) | Volume (m³) | HRT (days) | Removal efficiency (%) | Annual Tp removal (Kg/year) | Removal efficiency (%) | Annual Tp removal (Kg/year) | Annual TP removal (kg/yr) | | Final Effluent TP (mg/l) | Final Effluent TP (mg/l) |
| | 2 | 520 | 1.5 | 3,000 | 5.77 | 52.40 | 198.91 | 31.80 | 29.76 | 178.95 | | 0.95 | 1.36 |
| | 2 | 218 | 1.5 | 3,000 | 13.76 | 80.59 | 128.25 | 58.33 | 22.89 | 119.08 | | 0.39 | 0.83 |
| Tregaron | | | | | | | | | | | | | |
| | 5 | 520 | 1.5 | 3,000 | 5.77 | 52.40 | 497.28 | 31.80 | 74.41 | 447.37 | | 2.38 | 3.41 |
| | 5 | 218 | 1.5 | 3,000 | 13.76 | 80.59 | 320.63 | 58.33 | 57.22 | 297.69 | | 0.97 | 2.08 |

5 Summary

This technical note provides a summary of the nutrient reductions and estimated wetland area requirements using the following approaches:

- The P-K-C* approach
- A plug flow model termed the k-C* approach
- Regressions (or exponential decay) equations

Using the approaches above, a number of scenarios have been run to understand the impact of the design and estimated flow, against the different Orthophosphate concentrations on the wetland area requirements and effectiveness.

The P-K-C* model is considered to be the most robust approach based on industry guidance. Therefore, this approach has been used in the final design analysis to understand the effectiveness of the current wetland proposals for Llandysul, Tregaron and Adpar.

Table 5-1 below summarises the wetland area requirements and effective removal of TP Llandysul, Tregaron and Adpar wetlands. The results show that the wetland areas of 2 ha for Llandysul, 1.5 ha for Tregaron and 1 ha for Adpar would provide sufficient treatment to mitigate for the proposed developments under the current CeCC LDP and CCC rLDP to deliver nutrient neutrality.

As mentioned before, the refined calculations performed in Section 4 are done on the basis of having a minimum of six wetland cells at each WwTW location although the preliminary calculations in Section 3 are done on the basis of just two wetland cells at each WwTW location.

Finally, it is important to build suitable additional contingency in the design approach to account for potential reduced wetland performance during the early wetland plant establishment period, winter maintenance months etc. Therefore, the current assessment approach would account for this, but ongoing monitoring of the wetland treatment performance is strongly recommended to inform future designs.

| Teifi S Total A | | Teifi SAC - Total Annual | Teifi | Total Annual Phosphorus | | P-K-C mod DCWW P | el, 6 wetland c performance d D\ | ells (using late ata + projecte WF) | st 12 months d estimated | P-K-C model, 6 wetland cells (using Backstop TP Permit + Full Permitted DWF) | | | | | Indicative |
|----------------------|----------------------------------|--|---|---|-------------------------|--|---|--|---|---|---|--|--|----------------------|---|
| Wetland Location | Downstream WwTWs Mitigated | Phosphorus Budget/ per Wetland Location (Kg TP/Year/Wetla nd) | Total House s/ per Wetlan d | Budget/ per Wetland Location/per home (Kg TP/Year/Wetla nd/home) | Wetland Area (m2) | Wetland annual TP removal – 100% performa nce nutrient credits(K g TP/year) | Wetland annual TP removal – Effective performan ce nutrient credits (Kg TP/year) | Max Housing No Unlocked - 100% wetland performan ce | Max Housing No Unlocked - Effective wetland performan ce | Wetland annual TP removal – 100% performan ce nutrient credits(Kg TP/year) | Wetland annual TP removal – Effective performan ce nutrient credits (Kg TP/year) | Max Housing No Potentially Unlocked - 100% wetland performance | Max Housing No Potentially Unlocked - Effective wetland performan ce | Wetland Area (m2) | Capital Cost + 50% contingency (£ -in M) |
| | Llandysul | | 100 | | | | | | | | | | | | |
| Llandysul | Pencader | 139.06 (see Note 1) | (see Note 1) | 0.748 | 20,000 | 135.600 | 124.540 | 181 | 167 | 661.530 | 595.240 | 885 | 796 | 20,000 | 0.900 |
| | Drefach/Felindre | | , | | | | | | | | | | | | |
| Adnar | Adpar | 60.51 | 78 (see | 0 776 | 10 000 | 128 870 | 114 810 | 166 | 148 | 363 870 | 324 160 | 469 | 418 | 10 000 | 0.450 |
| / (upu) | Capel Iwan | (see Note 2) | Note 2) | 0.170 | 10,000 | 120.070 | 114.010 | | 140 | | 024.100 | | 410 | 10,000 | 0.400 |
| | Tregaron | | | | | | | | | | | | | | |
| | Lampeter | | | | | | | | | | | | | | |
| PTP (SuV36/I | PTP (SuV36/h2) | 177.12 | 399 | 0.444 | 15 000 | 407 000 | 447.070 | 4000 | 4000 | 400.040 | 470.050 | 440 | 402 | 15 000 | 0.075 |
| Tregaron PTP (SuV36/ | | ((see Note 3) | Note 3) | 0.444 | 15,000 | 497.200 | 447.370 | 1008 | 1008 | 190.910 | 1/0.990 | 440 | 403 | 15,000 | 0.675 |
| Llanybydde | Llanybydder | | | | | | | | | | | | | | |
| | Llanfihangel-ar- arth | | | | | | | | | | | | | | |

| Table 5-1 Summary | / wetland area requirements | s and effective removal | of TP for Llandysul. | Tregaron and Adpar Wetlands. |
|-------------------|-----------------------------|-------------------------|----------------------|------------------------------|
| | | | | |

| Note 1 – Llandysul Wetland: | Note 2 – Adpar Wetland |
|--|---|
| Ceredigion County Council (CeCC) LDP Total Houses to mitigate = 126 (all 126 houses at Llandysul WwTW) CeCC LDP Total Annual Phosphorus Budget = 87.78 Kg TP/Year | Ceredigion County Council (CeCC) LDP Total Houses to mitigate CeCC LDP Total Annual Phosphorus Budget = 27.33 Kg TP/Year |
| Carmarthenshire County Council (CCC) LDP Total Houses to mitigate = 60 (5 houses at Llandysul WwTW, 44 houses at Pencader WwTW and 11 houses at Drefach/Felindre WwTW) CCC LDP Total Annual Phosphorus Budget = 51.28 Kg TP/Year | Carmarthenshire County Council (CCC) LDP Total Houses to mitig Capel Iwan WwTW) CCC LDP Total Annual Phosphorus Budget = 33.18 Kg TP/Year |
| Combined CeCC and CCC LDP houses to mitigate = 186 Combined CeCC and CCC Total Annual Phosphorus Budget to mitigate = 139.06 Kg TP/year | Combined CeCC and CCC LDP houses to mitigate = 78 Combined CeCC and CCC Total Annual Phosphorus Budget to m |
| | |

e = 35 (all 35 houses at Adpar WwTW)

tigate = 43 (37 houses at Adpar WwTW and 6 houses at

```
nitigate = 60.51 Kg TP/year
```

| Note 3 – Tregaron Wetland: Ceredigion County Council (CeCC) LDP Total Houses to mitigate = 330 (94 houses at Tregaron WwTW and 236 houses at Lampeter) CeCC LDP Total Annual Phosphorus Budget = 135.14 Kg TP/Year |
|--|
| Carmarthenshire County Council (CCC) LDP Total Houses to mitigate = 69 (30 houses at Lampeter WwTW, 22 houses at Package Treatment Plants, 10 at Llanybydder WwTW and 7 houses at Llanfihangel-ar-arth WwTW) CCC LDP Total Annual Phosphorus Budget = 41.98 Kg TP/Year |
| Combined CeCC and CCC LDP houses to mitigate = 399 Combined CeCC and CCC Total Annual Phosphorus Budget to mitigate = 117.12 Kg TP/year |

Appendix A Refined Wetlands Analysis with P-K-C* Model – Llandysul

| AUG | | | | | | 30192602 | | | |
|-----------------|--|---|--|--|---|--|---|---|--|
| | · | CALCUI | | | GBA: | Resilience - | Water | | |
| Ceredigion Cou | inty Council | | | | REVISION: | P01 | | | |
| | | | | | AUTHOR: | RG | | | |
| Wetland Sites - | Teifi Wetland | 5 | | | CHECKER: EBP | | | | |
| | | | | | APPROVER: | | | | |
| Process Design | Calculations - | Llandysul | | | DATE: | | | | |
| Permitted Q, O | rthophosphate | e Oct 2022 - 0 | Oct 2023 | | DOC. No: | | | | |
| Front Sheet | | | | | SHEET: | 1 | OF | 4 | |
| TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMM | 1ENTS | |
| 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | | |
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| TATEMENT (Inc. | high level des | cription of sit | e/process and p | urpose of ca | lculations) | | | | |
| | | | | | | | | | |
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| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Resilience - Water | | | | |
|---------------------------------|--------------------|---|---|-----------------------------------|--------------------------------------|-------------------------------|--|--|--|
| KEY | CLIENT | | | BEVISION: | PO1 | | | | |
| | CELENT. | Ceredigion County Council | | AUTHOR: | RG | | | | |
| Input values | PROJECT: | Walked Cher, TCC Walked. | | CHECKER: EBP | | | | | |
| Calculated values | | wetland Sites - Teiff Wetlands | | APPROVER: | 0 | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | |
| Assumed values | | Trocess besign calculations Elandysa | | DOC. No: | 0 | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | |
| | • | | | | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| C | | | | | | | | | |
| | mg/i | 25 | Influent concentration of Total Nitro | ogen | | | | | |
| Ci-TP | 111g/1 | 1.50 | Deduction of rotal Phose | Sphorus (Oct 2022 - Oct 2023) | | | | | |
| C TN | 111g/1 | 1.5 | Background concentration of Total | Nicrogen | | | | | |
| Стр | mg/i | 0.022 | Background concentration of lotal P | Phosphorus | | | | | |
| K _{TN} | m/yr | 11.18 | Rate coefficient for reduction of lot | al Nitrogen | | | | | |
| κ _{τρ} | m/yr | 10 | Rate coefficient for reduction of Tot | al Phosphorus | | | | | |
| K _{20-TN} | m/yr | 21.5 | Median value rate coefficient for rec | duction of Total Nitrogen | | | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total N | litrogen | | | | | |
| θ _{-TP} | - | 0.986 | Median Temp coefficient for Total P | hosphorus | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative value | ue) | | |
| Design Flow | m3/d | 689 | Input flow rate into here | | | | | | |
| Total annual hydraulic | m ³ /vr | 251485 | | | | | | | |
| throughput | | | | | | | | | |
| Total wetland area | m ² | 20,000 | Active cell area (i.e. excluding diving | g berms, spreader channels and le | evel control structures) | | | | |
| q | m/yr | 12.57425 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 10.26 | NB. treated discharge from the wetl | and cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | |
| contaminant, Ce - C* | % | 43.64 | | | | | | | |
| Treatment efficiency of wetland | % | 56.36 | % of contaminant removed | | | | | | |
| Total Phosphorus | | | | | | | | | |
| Amount of remaining | - | 0.63 | NB. treated discharge from the wetl | and cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | |
| contaminant, Ce - C* | % | 47.39 | | | | | | | |
| Treatment efficiency of wetland | % | 52.61 | % of contaminant removed | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|--------------------|---|---|-------------------------------------|--------------------------------------|-----------------------------|--|--|--|--|
| KEY | CLIENT | | | BEVISION: | PO1 | | | | | |
| | CELENT: | Ceredigion County Council | | AUTHOR | RG | | | | | |
| Input values | PROJECT: | Walked Cher, Trift Walked. | | CHECKER: EBP | | | | | | |
| Calculated values | | wetland Sites - Telfi Wetlands | | APPROVER: 0 | | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: | DATE: 24/11/2023 | | | | | |
| Assumed values | | Trocess besign calculations Elandysu | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | - | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| ć | mg/l | 25 | Influent concentration of Total Nitr | 2000 | | | | | | |
| Ci-m | mg/l | 25 | Influent concentration of Total Pho | sphorus (Oct 2022 - Oct 2023) | | | | | | |
| C* | mg/l | 1.50 | Background concentration of Total | Nitrogen | | | | | | |
| C* | | 1.5 | Dackground concentration of Total | Dheenherve | | | | | | |
| C TP | iiig/i | 0.022 | Background concentration of Total | Phosphorus | | | | | | |
| KTN | m/yr | 11.18 | Rate coefficient for reduction of for | Lai Nitrogen | | | | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of 1 of | tal Phosphorus | | | | | | |
| K _{20-TN} | m/yr | 21.5 | Median value rate coefficient for re | duction of Total Nitrogen | | | | | | |
| θ-τΝ | - | 1.056 | Median Temp coefficient for Total N | Nitrogen | | | | | | |
| θ. _т , | - | 0.986 | Median Temp coefficient for Total F | Phosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) | | | |
| Design Flow | m3/d | 689 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | m ³ /yr | 251485 | | | | | | | | |
| throughput | 2 | 10.000 | | | | | | | | |
| Iotal wetland area | m | 10,000 | Active cell area (i.e. excluding diving | g berms, spreader channels and lev | /el control structures) | | | | | |
| q | m/yr | 25.1485 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 15.30 | NB. treated discharge from the wet | land cannot be less than the backg | round concentrations, as it is n | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 65.12 | | | | | | | | |
| Treatment efficiency of wetland | % | 34.88 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| Amount of remaining | | 0.91 | NR treated discharge from the wot | land cannot be less than the backs | round concentrations, as it is n | ot possible to achieve i o | background concivill always be present | | | |
| contaminant Ce - C* | - | 68.04 | ND. treated discharge from the wet | iano cannot be less than the backg | round concentrations, dS It IS II | or possible to achieve l.e. | background conc will always be present | | | |
| Treatment efficiency of wetland | % | 31.96 | % of contaminant removed | | | | | | | |
| reatment enciency of wetland | 20 | 51.50 | % or contaminant renioved | | | | | | | |
| | | | | | | | | | | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|-------------------------|--------------------|-------------|-----------|----|---|--|
| | ARUADIS | CALCULATIONS | GBA: | Resilienc | | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | unen | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Vatlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tenri v | venanus | APPROVER: | 0 | | | |
| SUBJECT: | Drogoss Dosign Coloul | ations Llandword | DATE: | 45254 | | | |
| | Process Design Calcul | ations - Liandysui | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{P}$$

 C_i = Influent concentration of contaminant (mg/l)

 C_e = Effluent concentration of contaminant (mg/l) C* = Background concentration of contaminant (in the wetland water column) (mg/l)

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS - dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | |
|----------------|-----------------|-----------------------------------|----------------|------------------|--------------|------------------|--------------|-------|-------|
| | 5-015 | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | inty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | S | | | CHECKER: EBP | | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Llandysul | | | DATE: 24/11/2023 | | | |
| | Permitted Q, C | thophosphate | July 2021 - A | vug 2022 | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMM | /ENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
| DESIGN BASIS S | TATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | lculations) | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Resilience - Water | | | | |
|---------------------------------|--------------------|---|---|-----------------------------------|--------------------------------------|-------------------------------|--|--|--|
| KEY | CLIENT | | | GBA: REVISION: | PO1 | | | | |
| | CELENT: | Ceredigion County Council | | AUTHOR: | RG | | | | |
| Input values | PROJECT: | Wells of Charles Table Manhaoda | | CHECKER: EBP | | | | | |
| Calculated values | | wetland Sites - Teiff Wetlands | | APPROVER: 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | |
| Assumed values | | Trocess besign calculations Elandysa | | DOC. No: | 0 | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | |
| | | | | • | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| C | | | | | | | | | |
| | mg/i | 25 | Influent concentration of Total Nitro | ogen | | | | | |
| Ci-TP | 111g/1 | 2.54 | Deduction of rotal Phose | Sphorus (July 2021 - Aug 2022) | | | | | |
| C TN | 111g/1 | 1.5 | Background concentration of Total | Nicrogen | | | | | |
| Стр | mg/i | 0.022 | Background concentration of lotal P | Phosphorus | | | | | |
| K _{TN} | m/yr | 11.18 | Rate coefficient for reduction of lot | al Nitrogen | | | | | |
| κ _{τρ} | m/yr | 10 | Rate coefficient for reduction of Tot | al Phosphorus | | | | | |
| K _{20-TN} | m/yr | 21.5 | Median value rate coefficient for rec | duction of Total Nitrogen | | | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total N | litrogen | | | | | |
| θ _{-TP} | - | 0.986 | Median Temp coefficient for Total P | hosphorus | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | ie) | | |
| Design Flow | m3/d | 689 | Input flow rate into here | | | | | | |
| Total annual hydraulic | m ³ /vr | 251485 | | | | | | | |
| throughput | ,,,. | | | | | | | | |
| Total wetland area | m ² | 20,000 | Active cell area (i.e. excluding diving | berms, spreader channels and le | vel control structures) | | | | |
| q | m/yr | 12.57425 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 10.26 | NB. treated discharge from the wetl | and cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. b | packground conc will always be present | | |
| contaminant, Ce - C* | % | 43.64 | | | | | | | |
| Treatment efficiency of wetland | % | 56.36 | % of contaminant removed | | | | | | |
| Total Phosphorus | | | | | | | | | |
| Amount of remaining | | 1 10 | NB treated discharge from the wet | and cannot be less than the back | ground concentrations as it is no | nt nossible to achieve i.e. h | packground conc will always be present | | |
| contaminant. Ce - C* | % | 47.39 | the reaced abenarge from the wet | | | | on anays se present | | |
| Treatment efficiency of wetland | % | 52.61 | % of contaminant removed | | | | | | |
| cathere enderly of weatha | ,0 | | | | | | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 Recilience - Water | | | | | |
|---------------------------------|--------------------|---|---------------------------------------|--------------------------------------|--------------------------------------|-----------------------------|--|--|--|--|
| KEY | CLIENT: | | | BEVISION: | P01 | | | | | |
| | | Ceredigion County Council | | AUTHOR: RG | | | | | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | | | |
| Calculated values | | Wetland Sites - Telli Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: | DATE: 24/11/2023 | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| Gree | mg/l | 25 | Influent concentration of Total Nit | rogen | | | | | | |
| Citro | mg/l | 2.34 | Influent concentration of Total Ph | osphorus (July 2021 - Aug 2022) | | | | | | |
| C* ₁₁₁ | mg/l | 1.5 | Background concentration of Tota | l Nitrogen | | | | | | |
| C* | mg/l | 0.022 | Background concentration of Tota | l Phosphorus | | | | | | |
| - 19 k | m/vr | 11 18 | Rate coefficient for reduction of T | ntal Nitrogen | | | | | | |
| | m/y. | 10 | Rate coefficient for reduction of T | | | | | | | |
| k | mhr | 21.5 | Median value rate coefficient for r | eduction of Total Nitrogen | | | | | | |
| N20-TN | in/yi | 1 056 | Median Tamp coefficient for Total | Nitrogen | | | | | | |
| 0- _{TN} | | 1.050 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| U.TP | • | 0.980 | | Phosphorus | | | | | | |
| No of treatment stages | - | 3 | Average operating temperature | | | | | | | |
| p | | 6 | For one treatment stage i.e. 1 cell | in series/three treatment stages i e | 3 cells in series - P is 2 or 6 rest | ectively (conservative valu | ue) | | | |
| Design Flow | m3/d | 689 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | 3. | 254.405 | | | | | | | | |
| throughput | m ⁻ /yr | 251485 | | | | | | | | |
| Total wetland area | m² | 10,000 | Active cell area (i.e. excluding divi | ng berms, spreader channels and le | evel control structures) | | | | | |
| q | m/yr | 25.1485 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 15.30 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is n | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 65.12 | | | | | | | | |
| Treatment efficiency of wetland | % | 34.88 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 1.58 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is n | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 68.04 | | | | | | | | |
| Treatment efficiency of wetland | % | 31.96 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|-------------------------|--------------------|-------------|-----------|-----------|---|--|
| | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | unen | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Vatlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tenri v | venanus | APPROVER: | 0 | | | |
| SUBJECT: | Drogoss Dosign Coloul | ations Llandword | DATE: | 45254 | | | |
| | Process Design Calcul | ations - Liandysui | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_e - C^*}{C_i - C^*} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \end{array} \right]^{-P}$$

 C_i = Influent concentration of contaminant (mg/l)

 $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$

- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- (C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | | |
|--------------|---|-----------------------------------|----------------|------------------|--------------|---------------|--------------|--------------------|---|--|
| | UADIS | | CALCUI | | | GBA: | Resilience - | Resilience - Water | | |
| CLIENT: | Ceredigion Cou | inty Council | | | | REVISION: | P01 | | | |
| | | | | | | AUTHOR: | RG | | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | S | | | CHECKER: | EBP | | | |
| | | | | | | APPROVER: | | | | |
| SUBJECT: | Process Design | Calculations - | Llandysul | | | DATE: | 24/11/2023 | | ſ | |
| | Permitted Q, B | ackstop TP | | | | DOC. No: | | | | |
| SECTION: | ECTION: Front Sheet | | | | | SHEET: | 1 | OF | 4 | |
| ISSUE | TOTAL SHEETSAUTHORDATECHECKED BYDATE4RG29/11/23EBP30/11/23 | | APPROVED BY | DATE | COMME | NTS | | | | |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | | |
| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | alculations) | | | | |
| | | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Besilience - Water | | | | | | |
|--|----------------|---|--|-------------------------------------|--------------------------------------|----------------------------|--|--|--|--|--|
| KEY | CLIENT: | | | BEVISION: | P01 | | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | | |
| Input values | PROJECT: | Watland Sites Toifi Watlands | | CHECKER: | EBP | | | | | | |
| Calculated values | | wettand sites - Tenr Wettands | | APPROVER: | 0 | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | | | |
| | | | | | | | | | | | |
| Process Calculations | | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | | |
| C.m. | mg/l | 25 | Influent concentration of Total Nit | ogen | | | | | | | |
| C _{1-IN} | mg/l | 25 | Influent concentration of Total Pho | osphorus (Backston TP) | | | | | | | |
| C**** | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | | | | | |
| C* | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | | | | | |
| kau kau | m /vr | 11 18 | Bate coefficient for reduction of Total Nicrosen | | | | | | | | |
| K N | m hr | 10 | Rate coefficient for reduction of lotal Nitrogen | | | | | | | | |
| KTP K | m/yr | 21 5 | Nadion value rate coefficient for r | | | | | | | | |
| K _{20-TN} | m/yr | 21.5 | Median Value rate coefficient for h | duction of Total Nitrogen | | | | | | | |
| U-TN | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | | |
| U-TP | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | | |
| No. of the state o | •٢ | 8 | Average operating temperature | | | | | | | | |
| No. of treatment stages | - | 3 | For one treatment store is 1 cells | | | | | | | | |
| P Docigo Flow | - m2/d | 60 | For one treatment stage i.e. I cell | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) | | | | |
| Total appual hydraulic | 115/0 | 005 | input now rate into here | | | | | | | | |
| throughput | m³/yr | 251485 | | | | | | | | | |
| Total wetland area | m ² | 20.000 | Active cell area (i.e. excluding divir | g berms spreader channels and le | vel control structures) | | | | | | |
| n n | m /vr | 12 57425 | | | | | | | | | |
| Ч | 117 91 | 12.57725 | | | | | | | | | |
| Total Nitrogen | | | | | | | | | | | |
| Amount of remaining | - | 10.26 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. | background conc will always be present | | | | |
| contaminant, Ce - C* | % | 43.64 | | | | | | | | | |
| Treatment efficiency of wetland | % | 56.36 | % of contaminant removed | | | | | | | | |
| Total Phosphorus | | | | | | | | | | | |
| Amount of remaining | - | 2.36 | NB, treated discharge from the wetland cannot be less than the background concentrations, as it is not possible to achieve i.e. background conc will always be present | | | | | | | | |
| contaminant. Ce - C* | % | 47.39 | no. created abonarge from the we | | | | | | | | |
| Treatment efficiency of wetland | % | 52.61 | % of contaminant removed | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 Resilience - Water | | | | | | |
|---------------------------------|----------------|---|--|--------------------------------------|--------------------------------------|------------------------------|--|--|--|--|--|
| KEY | CLIENT | | | BEVISION: | PO1 | | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | | |
| Input values | PROJECT: | Watland Sites Taifi Watlands | | CHECKER: | EBP | | | | | | |
| Calculated values | | wettand sites - Teni wettands | | APPROVER: | 0 | | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: | TE: 24/11/2023 | | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | | |
| | | | | | | | | | | | |
| Process Calculations | | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | | |
| C.m. | mg/l | 25 | Influent concentration of Total Nit | rogen | | | | | | | |
| C _{1-IN} | mg/l | 5 | Influent concentration of Total Ph | osphorus (Backstop TP) | | | | | | | |
| C* | mg/l | 15 | Background concentration of Tota | Nitrogen | | | | | | | |
| C* | mg/l | 0.022 | Background concentration of Tota | Phosphorus | | | | | | | |
| C IP | m hr | 11 19 | Background concentration of rotal Nitrogen | | | | | | | | |
| KTN k | | 10 | Date coefficient for reduction of T | tal Nici Ogen | | | | | | | |
| K _{TP} | ri/yr | 10 | Rate coefficient for reduction of the | otal Phosphorus | | | | | | | |
| к _{20-тN} | m/yr | 21.5 | iviedian value rate coefficient for r | eduction of Lotal Nitrogen | | | | | | | |
| 0 _{-TN} | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | | |
| θ. _т ρ | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | | |
| Ť | °C | 8 | Average operating temperature | | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | | |
| p Datis | | 6 | For one treatment stage i.e. 1 cell | in series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | ie) | | | | |
| Design Flow | m3/d | 689 | input flow rate into here | | | | | | | | |
| throughput | m³/yr | 251485 | | | | | | | | | |
| Total wetland area | m ² | 10.000 | Active cell area (i.e. excluding divi | a berms spreader chappels and le | vel control structures) | | | | | | |
| | 111 | 25,1495 | Active cell area (i.e. excluding divi | ig bernis, spreader channels and le | ver control structures, | | | | | | |
| Ч | 11791 | 25.1465 | | | | | | | | | |
| Total Nitrogen | | | | | | | | | | | |
| Amount of remaining | - | 15.30 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. b | packground conc will always be present | | | | |
| contaminant, Ce - C* | % | 65.12 | | | | | | | | | |
| Treatment efficiency of wetland | % | 34.88 | % of contaminant removed | | | | | | | | |
| | | | | | | | | | | | |
| Total Phosphorus | | | | | | | | | | | |
| Amount of remaining | - | 3.39 | NB. treated discharge from the we | tiand cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. t | packground conc will always be present | | | | |
| Trootmont officions of workers | % 9/ | 58.04 21.06 | % of contaminant romand | | | | | | | | |
| reatment efficiency of wetland | % | 31.96 | % of contaminant removed | | | | | | | | |
| | | | | | | | | | | | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|------------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCOLATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | unch | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Llandwoul | DATE: | 45254 | | | |
| | Process Design Calcul | | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \end{array} \right]^{P}$$

 C_i = Influent concentration of contaminant (mg/l)

 $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | |
|--------------|--|----------------|----------------------|------------------|--------------|-------------|--------------|-------|
| | | | CALCUI | LATIONS | | GBA: | Resilience - | Water |
| CLIENT: | Ceredigion Cou | inty Council | | | | REVISION: | P01 | |
| | | | | | | AUTHOR: | RG | |
| PROJECT: | Wetland Sites - | Teifi Wetland | 5 | | | CHECKER: | EBP | |
| | | | | | | APPROVER: | | |
| SUBJECT: | Process Design | Calculations - | Llandysul | | | DATE: | 24/11/2023 | 1 |
| | Estimated Q, O | rthophosphate | e Oct 2022- Oct 2023 | | | DOC. No: | | |
| SECTION: | TION: Front Sheet | | | | | | 1 | OF 4 |
| ISSUE | TOTAL SHEETSAUTHORDATECHEG4RG29/11/23 | | CHECKED BY | DATE | APPROVED BY | DATE | COMMENTS | |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | |
| | | | | | | | | |
| | | | | | <u> </u> | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | Iculations) | | |
| | | | | | | | | |
| | | | | | | | | |

| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|----------|---|--|-------------------------------------|--------------------------------------|-------------------------------|---------------------------------------|--|--|--|
| KEY | CLIENT: | | | BEVISION: | P01 | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Wetland Sites Taif Wetlands | | CHECKER: | EBP | | | | | |
| Calculated values | | Wetiand Sites - Teni Wetiands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: | 24/11/2023 | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| CLTM | mg/l | 25 | Influent concentration of Total Nit | ogen | | | | | | |
| C _{i-TP} | mg/l | 1.36 | Influent concentration of Total Pho | sphorus (Oct 2022 - Oct 2023) | | | | | | |
| С* _{тм} | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | | | | |
| k _{tN} | m/vr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | |
| k _{TD} | m/vr | 10 | Rate coefficient for reduction of Total Plogen | | | | | | | |
| K20 TN | m/yr | 21.5 | Median value rate coefficient for re | eduction of Total Nitrogen | | | | | | |
| θ m | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | |
| e-in e-in | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | in oppholog | | | | | | |
| No. of treatment stages | - | 3 | ······································ | | | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell i | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | e) | | | |
| Design Flow | m3/d | 369 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | 37 | 134695 | | | | | | | | |
| throughput | m /yr | 134083 | | | | | | | | |
| Total wetland area | m² | 20,000 | Active cell area (i.e. excluding divin | g berms, spreader channels and le | evel control structures) | | | | | |
| q | m/yr | 6.73425 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 5.43 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. b | ackground conc will always be present | | | |
| contaminant, Ce - C* | % | 23.09 | | | | | | | | |
| Treatment efficiency of wetland | % | 76.91 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 0.36 | NB. treated discharge from the wetland cannot be less than the background concentrations, as it is not possible to achieve i.e. background conc will always be present | | | | | | | |
| contaminant, Ce - C* | % | 26.53 | | | | | | | | |
| Treatment efficiency of wetland | % | 73.47 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|--------------------|--|--|--|--------------------------------------|-------------------------------|--|--|--|--|
| KEY | CLIENT: | | | BEVISION [.] | P01 | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Wetland Sites Tail Wetlands | | CHECKER: | EBP | | | | | |
| Calculated values | | Wetland Sites - Telli Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | | |
| Assumed values | | The cost of the second se | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| C C | mg/l | 25 | Influent concentration of Total Nitr | | | | | | | |
| | mg/i | 25 | Influent concentration of Total Pho | ogen venhorus (Oct 2022 - Oct 2022) | | | | | | |
| С!-тр | mg/1 | 1.50 | Packground concentration of Total | Nitrogon | | | | | | |
| C* | | 1.5 | Deckground concentration of Total | Dheenherus | | | | | | |
| C TP | mg/i | 0.022 | Background concernitation of rotal Phosphorus | | | | | | | |
| R _{TN} | m/yr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of To | tal Phosphorus | | | | | | |
| K _{20-TN} | m/yr | 21.5 | Median value rate coefficient for re | eduction of Total Nitrogen | | | | | | |
| θ-τΝ | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | |
| θ _{-τ} | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell i | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | Je) | | | |
| Design Flow | m3/d | 369 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | m ³ /vr | 134685 | | | | | | | | |
| throughput | | | | | | | | | | |
| Total wetland area | m ² | 10,000 | Active cell area (i.e. excluding divin | g berms, spreader channels and le | vel control structures) | | | | | |
| q | m/yr | 13.4685 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 10.80 | NB. treated discharge from the wet | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | | |
| contaminant, Ce - C* | % | 45.95 | | | | | | | | |
| Treatment efficiency of wetland | % | 54.05 | % of contaminant removed | | | | | | | |
| Total Dhosphorus | | | | | | | | | | |
| Amount of remaining | - | 0.66 | NR treated discharge from the wetland cannot be less than the background concentrations, as it is not nossible to achieve i.e. background conc. will always be present | | | | | | | |
| contaminant. Ce - C* | % | 49.66 | No. treated discharge from the wet | | 5. cana concentrations, ds it is in | possible to demede i.e. i | sangiouna cone will diwuys be present | | | |
| Treatment efficiency of wetland | % | 50.34 | % of contaminant removed | | | | | | | |
| redunent enterity of wettand | ,. | 50131 | | | | | | | | |
| | | | | | | | | | | |

| 6 ^ | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|------------------|-------------|-----------|-----------|---|--|
| /- | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | latlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Dosign Coloul | ations Llandword | DATE: | 45254 | | | |
| | Process Design Calcul | | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + k \\ Pq \end{bmatrix}^{P}$$

 C_i = Influent concentration of contaminant (mg/l) C_e = Effluent concentration of contaminant (mg/l)

 C^* = Background concentration of contaminant (ing/i) C^* = Background concentration of contaminant (in the wetland water column) (mg/l)

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| 2IUV | | | | | PROJECT No: | 30192602 | | | |
|---|---|---|---|---|---|--|--|---|--|
| | | CALCUI | | | GBA: | Resilience - | Resilience - Water | | |
| Ceredigion Cou | unty Council | | | | REVISION: | P01 | | | |
| | | | | | AUTHOR: | RG | | | |
| Wetland Sites - | Teifi Wetland | IS | | | CHECKER: | EBP | | | |
| | | | | | APPROVER: | | | | |
| Process Design | Calculations - | Llandysul | | | DATE: | 24/11/2023 | | | |
| Estimated Q, C | urthophosphat | e July 2021 - | Aug 2022 | | DOC. No: | | | | |
| Front Sheet | | | | | SHEET: | 1 | OF | 4 | |
| TOTAL SHEETSAUTHORDATECHECKED BYDATE4RG29/11/23EBP30/11/23 | | APPROVED BY | DATE | СОМ | MENTS | | | | |
| 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | | |
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| ATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | liculations) | | | | |
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| | Ceredigion Cou Wetland Sites - Process Design Estimated Q, O Front Sheet TOTAL SHEETS 4 A TATEMENT (Inc. | Ceredigion County Council Wetland Sites - Teifi Wetland Process Design Calculations - Estimated Q, Orthophosphate Front Sheet TOTAL AUTHOR 4 RG | CALCUI Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Llandysul Estimated Q, Orthophosphate July 2021 Front Sheet TOTAL AUTHOR DATE 4 RG 29/11/23 1 1 4 RG 29/11/23 1 1 | CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Llandysul Estimated Q, Orthophosphate July 2021 - Aug 2022 Front Sheet TOTAL AUTHOR SHEETS AUTHOR 4 RG 29/11/23 EBP 1 1 1 1 2 1 4 RG 29/11/23 EBP | CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Llandysul Estimated Q, Orthophosphate July 2021 - Aug 2022 Front Sheet TOTAL AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L AUTHOR L CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L R R <td>XDDS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: CHECKER: APPROVER: AUTHOR: CHECKER: APPROVER: Wetland Sites - Teifi Wetlands CHECKER: APPROVER: DATE: DOC. No: Front Sheet DOC. No: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV</td> <td>ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Ceredigion County Council REVISION: RG Wetland Sites - Teifi Wetlands CHECKER: EBP Process Design Calculations - Llandysul DATE: 24/11/2023 Estimated Q, Orthophosphate July 2021 - Aug 2022 DOC. No: Front Sheet TOTAL AUTHOR DATE CHECKER SHEET: 1 TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 CATEMENT (Inc. high level description of site/process and purpose of calculations) TATEMENT (Inc. high level description of site/process and purpose of calculations)</td> <td>ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Water Revelopion County Council AUTHOR: RG Wetland Sites - Teifi Wetlands AUTHOR: RG Process Design Calculations - Liandysul DATE: 24/11/2023 Estimated Q, Orthophosphate July 2021 - Aug 2022 DOC. No: Process Design Calculations - Liandysul Front Sheet SHEET: 1 OF TOTAL AUTHOR DATE CHECKER: SHEETS AUTHOR DATE COMI 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 ATE DATE DATE DATE DATE DATE AUTHOR DATE CHECKED BY DATE DATE COMI 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 ATE DATE DATE DATE DATE<!--</td--></td> | XDDS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: CHECKER: APPROVER: AUTHOR: CHECKER: APPROVER: Wetland Sites - Teifi Wetlands CHECKER: APPROVER: DATE: DOC. No: Front Sheet DOC. No: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV | ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Ceredigion County Council REVISION: RG Wetland Sites - Teifi Wetlands CHECKER: EBP Process Design Calculations - Llandysul DATE: 24/11/2023 Estimated Q, Orthophosphate July 2021 - Aug 2022 DOC. No: Front Sheet TOTAL AUTHOR DATE CHECKER SHEET: 1 TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 CATEMENT (Inc. high level description of site/process and purpose of calculations) TATEMENT (Inc. high level description of site/process and purpose of calculations) | ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Water Revelopion County Council AUTHOR: RG Wetland Sites - Teifi Wetlands AUTHOR: RG Process Design Calculations - Liandysul DATE: 24/11/2023 Estimated Q, Orthophosphate July 2021 - Aug 2022 DOC. No: Process Design Calculations - Liandysul Front Sheet SHEET: 1 OF TOTAL AUTHOR DATE CHECKER: SHEETS AUTHOR DATE COMI 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 ATE DATE DATE DATE DATE DATE AUTHOR DATE CHECKED BY DATE DATE COMI 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 ATE DATE DATE DATE DATE </td | |

| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 | | | | | | |
|---------------------------------|--------------------|---|--|-----------------------------------|--|------------------------------|--|--|--|--|--|
| KEY | CLIENT | | | GBA: | Resilience - Water | | | | | | |
| | CLIENT. | Ceredigion County Council | | | RG | | | | | | |
| Input values | PROJECT: | | | CHECKEB: | EBP | | | | | | |
| Calculated values | | Wetland Sites - Teifi Wetlands | | APPROVER: | 0 | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | | | |
| Assumed values | | Flocess Design Calculations - Liandysui | | DOC. No: | 0 | | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | | | |
| | | | | | | | | | | | |
| Process Calculations | | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | | |
| C C | | | | | | | | | | | |
| C _{I-TN} | mg/l | 25 | Influent concentration of Total Nitro | ogen | | | | | | | |
| C _{I-TP} | rng/1 | 2.34 | Initiation of Total Phos | Spriorus (July 2021 - Aug 2022) | | | | | | | |
| C ⁺ TN | mg/1 | 1.5 | Background concentration of Total | Nitrogen | | | | | | | |
| C* _{TP} | mg/I | 0.022 | Background concentration of lotal Phosphorus | | | | | | | | |
| κ _{τν} | m/yr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | | |
| k _{TP} | m/yr | 10 | Rate coefficient for reduction of Tot | al Phosphorus | | | | | | | |
| k _{20-TN} | m/yr | 21.5 | Median value rate coefficient for ree | duction of Total Nitrogen | | | | | | | |
| θ _{-TN} | - | 1.056 | Median Temp coefficient for Total N | litrogen | | | | | | | |
| θ. _{тр} | - | 0.986 | Median Temp coefficient for Total P | hosphorus | | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | e 3 cells in series - P is 2 or 6 resp | ectively (conservative value | ue) | | | | |
| Design Flow | m3/d | 369 | Input flow rate into here | | | | | | | | |
| Total annual hydraulic | m ³ /ur | 134685 | | | | | | | | | |
| throughput | , yi | | | | | | | | | | |
| Total wetland area | m² | 20,000 | Active cell area (i.e. excluding diving | g berms, spreader channels and le | evel control structures) | | | | | | |
| q | m/yr | 6.73425 | | | | | | | | | |
| Total Nitrogen | | | | | | | | | | | |
| Amount of remaining | - | 5.43 | NB. treated discharge from the wetl | and cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | | |
| contaminant, Ce - C* | % | 23.09 | | | | | | | | | |
| Treatment efficiency of wetland | % | 76.91 | % of contaminant removed | | | | | | | | |
| | | | | | | | | | | | |
| Amount of remaining | | 0.62 | NR treated discharge from the wetland spapet he less than the background concentrations, as it is not nessible to achieve i.e. background concentrations | | | | | | | | |
| contaminant Ce - C* | - | 26.53 | No. treated discharge from the wet | and cannot be less than the back | ground concentrations, as it is no | repossible to achieve i.e. | background conc will always be present | | | | |
| Treatment efficiency of wetland | % | 73.47 | % of contaminant removed | | | | | | | | |
| reatment enciency of wetland | 20 | /3.4/ | 76 of contaminant renioved | | | | | | | | |
| | | | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|--------------------|--|--|-----------------------------------|--------------------------------------|------------------------------|---|--|--|--|
| KEY | CLIENT | | | BEVISION: | P01 | | | | | |
| | CELENT. | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Wells of Charles Tells Wells of | | CHECKER: | EBP | | | | | |
| Calculated values | | wetland Sites - Teiff Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Handysul | | DATE: 24/11/2023 | | | | | | |
| Assumed values | | Trocess besign calculations Elandysu | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | - | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| ć | mg/l | 25 | Influent concentration of Total Nitro | 200 | | | | | | |
| | mg/l | 25 | Influent concentration of Total Phos | nborus (July 2021 - Aug 2022) | | | | | | |
| C* | mg/1 | 1.5 | Rackground concentration of Total I | Nitrogon | | | | | | |
| C* | | 1.5 | Dackground concentration of Total | heer here | | | | | | |
| C TP | mg/i | 0.022 | Background concentration of rotal Phosphorus | | | | | | | |
| K _{TN} | iii/yr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of Tot | al Phosphorus | | | | | | |
| k _{20-TN} | m/yr | 21.5 | Median value rate coefficient for rec | duction of Total Nitrogen | | | | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total N | litrogen | | | | | | |
| θ _{-τ} | | 0.986 | Median Temp coefficient for Total P | hosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | | 3 | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative value | ue) | | | |
| Design Flow | m3/d | 369 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | m ³ /vr | 134685 | | | | | | | | |
| throughput | | | | | | | | | | |
| Total wetland area | m [*] | 10,000 | Active cell area (i.e. excluding diving | berms, spreader channels and lev | vel control structures) | | | | | |
| q | m/yr | 13.4685 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 10.80 | NB. treated discharge from the wetl | and cannot be less than the backg | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 45.95 | | | | | | | | |
| Treatment efficiency of wetland | % | 54.05 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| Amount of remaining | | 1 15 | | | | | | | | |
| contaminant Ce - C* | - | 1.15 | ND. LIEALEU UISCHAIge ITOM LIE WELL | and cannot be less than the backg | giouna concentrations, dS IL IS N | or possible to achieve i.e. | Dackground colle will diways be present | | | |
| Treatment efficiency of wetland | % | 50.34 | % of contaminant removed | | | | | | | |
| meatment enciency of wetland | 70 | 50.34 | % or contaminant removed | | | | | | | |
| | | | | | | | | | | |

| 6 ^ | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|------------------|-------------|-----------|-----------|---|--|
| /- | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | dici | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Llandwoul | DATE: | 45254 | | | |
| | Process Design Calcul | | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):



 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C: inlet TP concentration (gP/m3); C*: background Concentration (mgP/l); Ce=Target Effluent Concentration (mg/l)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | |
|--------------|-----------------|-----------------|----------------|------------------|--------------|-------------|--------------|-------|-------|
| | | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | |
| | | | 7 | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites | - Teifi Wetland | ls | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Llandysul | | | DATE: | 24/11/2023 | | |
| | Estimated Q, B | ackstop TP | | | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMM | MENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
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| | | | | | | | | | |
| DÉSIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | lculations) | | | |
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| | | | | | | | | | |

| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Resilience - Water | | | | |
|---------------------------------|----------------|---|---|-------------------------------------|--|------------------------------|---------------------------------------|--|--|
| KEY | CLIENT | | | BEVISION: | PO1 | | | | |
| | CELENT: | Ceredigion County Council | | AUTHOR | RG | | | | |
| Input values | PROJECT: | Wells of Charles Table Manhaoda | | CHECKER: | EBP | | | | |
| Calculated values | | wetland Sites - Teiff Wetlands | | APPROVER: | 0 | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Llandysul | | DATE: 24/11/2023 | | | | | |
| Assumed values | | Trocess besign calculations Elandysa | | DOC. No: | 0 | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | |
| | - | | | | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| C | mg/l | 25 | Influent concentration of Total Nitr | ogon | | | | | |
| C _{I-TN} | mg/l | 25 | Influent concentration of Total Pho | sphorus (Backston TP) | | | | | |
| C* | mg/l | 15 | Background concentration of Total | Nitrogen | | | | | |
| C* | | 0.022 | Background concentration of Total | Phosphorus | | | | | |
| C TP | mg/i | 11 19 | Background concentration of Total | tal Nitrogon | | | | | |
| KTN I. | 111/yi | 11.10 | | | | | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of 10 | tal Phosphorus | | | | | |
| К _{20-ТN} | m/yr | 21.5 | Median value rate coefficient for re | duction of Lotal Nitrogen | | | | | |
| 0 _{-TN} | - | 1.056 | Median Temp coefficient for Total I | Nitrogen | | | | | |
| θ_ΤΡ | - | 0.986 | Median Temp coefficient for Total F | Phosphorus | | | | | |
| Ť | °C | 8 | Average operating temperature | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | |
| p Datis | | 6 | For one treatment stage i.e. 1 cell in | n series/three treatment stages i.e | e 3 cells in series - P is 2 or 6 respe | ctively (conservative valu | e) | | |
| Design Flow | m3/d | 369 | input flow rate into here | | | | | | |
| throughput | m³/yr | 134685 | | | | | | | |
| Total wetland area | m ² | 20.000 | Active cell area (i.e. excluding divin | g berms, spreader chappels and le | wel control structures) | | | | |
| | | 6 72425 | Active cell area (i.e. excluding diving | g bernis, spreader channels and le | ver control structures) | | | | |
| q | m/yr | 6.73425 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 5.43 | NB. treated discharge from the wet | land cannot be less than the back | ground concentrations, as it is no | possible to achieve i.e. b | ackground conc will always be present | | |
| contaminant, Ce - C* | % | 23.09 | | | | | | | |
| Treatment efficiency of wetland | % | 76.91 | % of contaminant removed | | | | | | |
| | | | | | | | | | |
| Total Phosphorus | | 1.22 | ND treated discharge from the cost | land second by lass they the bard | and an | | entered and will always be assessed | | |
| Amount of remaining | - | 1.32 | NB. treated discharge from the wet | liand cannot be less than the back | ground concentrations, as it is no | . possible to achieve i.e. b | ackground conc will always be present | | |
| Treatment efficiency of wetland | 70 | 20.53 | % of contaminant removed | | | | | | |
| reatment enciency of wetland | 20 | /5.4/ | 20 OF CONtaminant rendoved | | | | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------------|----------------|--|---|-------------------------------------|--------------------------------------|-------------------------------|--|--|--|--|
| KEY | CLIENT: | | | BEVISION: | PO1 | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Watland Cites Taifi Watlands | | CHECKER: | EBP | | | | | |
| Calculated values | | wetland Sites - Telli Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Handysul | | DATE: | DATE: 24/11/2023 | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| E | mg/l | 25 | Influent concentration of Total Nitr | organ | | | | | | |
| Ci-m | mg/l | 25 | Influent concentration of Total Pho | ogen osphorus (Backston TP) | | | | | | |
| C* | mg/l | 15 | Background concentration of Total | Nitrogen | | | | | | |
| C* | | 0.022 | Background concentration of Total | Phosphorus | | | | | | |
| C TP | mg/i | 11 19 | Bate coefficient for reduction of Total | tal Nitrogan | | | | | | |
| KTN k | iii/yi | 11.18 | Rate coefficient for reduction of To | | | | | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of 10 | tai Phosphorus | | | | | | |
| к _{20-тN} | m/yr | 21.5 | Median value rate coefficient for re | duction of Lotal Nitrogen | | | | | | |
| 0. _{TN} | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | |
| θ _{-TP} | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| T | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | - | 3 | F | | | | | | | |
| P Design Flow | | 6 | For one treatment stage i.e. 1 cell i | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative value | ue) | | | |
| Design Flow Total appual hydraulic | mayd | 309 | input now rate into here | | | | | | | |
| throughout | m³/yr | 134685 | | | | | | | | |
| Total wetland area | m ² | 10.000 | Active cell area (i.e. excluding divin | g berms spreader chappels and le | vel control structures) | | | | | |
| | m hrs | 13 4695 | Active cell area (i.e. excluding divin | g bernis, spreader enamiels and le | ver control structures, | | | | | |
| Ч | 117.91 | 15.4065 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 10.80 | NB. treated discharge from the wet | tland cannot be less than the back | ground concentrations, as it is n | ot possible to achieve i.e. I | background conc will always be present | | | |
| contaminant, Ce - C* | % | 45.95 | | | | | | | | |
| Treatment efficiency of wetland | % | 54.05 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 2.47 | NB, treated discharge from the wet | tland cannot be less than the back | ground concentrations, as it is n | ot possible to achieve i.e. I | background conc will always be present | | | |
| contaminant. Ce - C* | % | 49.66 | the course assenting from the wet | | Joneen a dons, dont 15 h | | g | | | |
| Treatment efficiency of wetland | % | 50.34 | % of contaminant removed | | | | | | | |
| ,, | | | | | | | | | | |
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| | | | PROJECT No: | 3019260 | 2 | | |
|----------|-------------------------|------------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCOLATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | dici | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tenri V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Llandwoul | DATE: | 45254 | | | |
| | Process Design Calcul | | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):



 C_i = Influent concentration of contaminant (mg/l)

- Ce = Effluent concentration of contaminant (mg/l)
- C* = Background concentration of contaminant (in the wetland water column) (mg/l) k = Rate coefficient for reduction of contaminant (m/vr)
- P = Apparent no. of tanks in series (*P*TIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

Appendix B Refined Wetlands Analysis with P-K-C* Model – Adpar

| | | | | | | PROJECT No: | 30192602 | | | |
|----------------|-----------------|------------------|----------------|------------------|--------------|-------------|--------------|-------|-------|--|
| | JADIS | | CALCUI | | | GBA: | Resilience - | Water | | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | | |
| | | | | | | AUTHOR: | RG | | | |
| PROJECT: | Wetland Sites | - Teifi Wetland | S | | | CHECKER: | EBP | | | |
| | | | | | | APPROVER: | | | | |
| SUBJECT: | Process Design | Calculations - | Adpar | | | DATE: | 29/11/2023 | | | |
| | Permitted Q, C | ci 1.7 (2022 P p | erformance) | | | DOC. No: | | | | |
| SECTION: | Front Sheet | | | SHEET: | 1 | OF | 4 | | | |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMI | MENTS | |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | | |
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| | | | | | | | | | | |
| DÉSIGN BASIS S | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | Iculations) | | | | |
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| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Recilience - Water | | | | |
|---------------------------------|----------|-------------------------------------|--|-------------------------------------|--|-----------------------------|---|--|--|
| KEY | CLIENT: | | | BEVISION: | P01 | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | | |
| Calculated values | | wettand sites - Tent wettands | | APPROVER: | 0 | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Adpar | | DATE: 29/11/2023 | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | |
| iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | |
| | | | | | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| Grav | mg/l | 25 | Influent concentration of Total Nit | rogen | | | | | |
| CLTP | mg/l | 1.7 | Influent concentration of Total Pho | osphorus (2022 P performance) | | | | | |
| C* _{TM} | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | | | |
| C* | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | | | |
| k _{mi} | m/vr | 11 18 | Rate coefficient for reduction of To | tal Nitrogen | | | | | |
| k | m/vr | 10 | Rate coefficient for reduction of To | tal Phosphorus | | | | | |
| kan an | m/vr | 21.5 | Median value rate coefficient for r | eduction of Total Nitrogen | | | | | |
| A | , ,, | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | |
| e | | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | |
| т | * | 0.580 | | riospilorus | | | | | |
| No. of treatment stages | - | 3 | Average operating temperature | | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell i | n series/three treatment stages i.e | e 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) | | |
| Design Flow | m3/d | 535 | Input flow rate into here | | | |) | | |
| Total annual hydraulic | 3, | 105.275 | | | | | | | |
| throughput | m /yr | 195275 | | | | | | | |
| Total wetland area | m² | 10,000 | Active cell area (i.e. excluding divir | g berms, spreader channels and le | evel control structures) | | | | |
| q | m/yr | 19.5275 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 13.60 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | |
| contaminant, Ce - C* | % | 57.88 | | | | | | | |
| Treatment efficiency of wetland | N % | 42.12 | % of contaminant removed | | | | | | |
| Total Phosphorus | | | | | | | | | |
| Amount of remaining | - | 1.03 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | |
| contaminant, Ce - C* | % | 61.18 | | | • • • • • • • • • | | - · · · · · · · · · · · · · · · · · · · | | |
| Treatment efficiency of wetland | ۶ ۱ | 38.82 | % of contaminant removed | | | | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|----------------|-------------------------------------|--|--------------------------------------|--------------------------------------|-----------------------------|--|--|--|--|
| KEY | CLIENT | | | BEVISION: | P01 | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Watland Sites Taifi Watlands | | CHECKER: | EBP | | | | | |
| Calculated values | | wetland Sites - Telli Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Adpar | | DATE: | DATE: 29/11/2023 | | | | | |
| Assumed values | | | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| C _{I-TN} | mg/l | 25 | Influent concentration of Total Nit | rogen | | | | | | |
| C _{i-TP} | mg/l | 1.7 | Influent concentration of Total Pho | osphorus (2022 P performance) | | | | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | | | | |
| k _{TN} | m/yr | 11.18 | Rate coefficient for reduction of To | otal Nitrogen | | | | | | |
| k _{τp} | m/vr | 10 | Rate coefficient for reduction of To | otal Phosphorus | | | | | | |
| k _{20.TN} | m/vr | 21.5 | Median value rate coefficient for re | eduction of Total Nitrogen | | | | | | |
| θτη | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | |
| θπ | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | - | 3 | ······································ | | | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell | in series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) | | | |
| Design Flow | m3/d | 535 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | ³ (| 105275 | | | | | | | | |
| throughput | ffi /yr | 1992/19 | | | | | | | | |
| Total wetland area | m² | 5,000 | Active cell area (i.e. excluding divir | ng berms, spreader channels and le | evel control structures) | | | | | |
| q | m/yr | 39.055 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 17.77 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 75.60 | | | | | | | | |
| Treatment efficiency of wetland | % | 24.40 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 1.31 | NB. treated discharge from the we | tland cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 77.82 | | | | | | | | |
| Treatment efficiency of wetland | % | 22.18 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|-------------------------|----------------|-------------|-----------|-----------|---|--|
| | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | latlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tenri V | Vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Process Design Calcul | ations Adnor | DATE: | 45259 | | | |
| | Process Design Calcul | ations - Aupai | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{-p}$$

 C_i = Influent concentration of contaminant (mg/l) C_e = Effluent concentration of contaminant (mg/l)

 C^* = Background concentration of contaminant (ing/) C^* = Background concentration of contaminant (in the wetland water column) (mg/l)

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | |
|---------------------------|-----------------|--|----------------|------------------|--------------|---------------|--------------|-------|--|
| | UADIS | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | inty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | s | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Adpar | | | DATE: | 29/11/2023 | | |
| Permitted Q, Ci 4.8 (2021 | | | erformance) | | | DOC. No: | | | |
| SECTION: | Front Sheet | | SHEET: | 1 | OF | 4 | | | |
| ISSUE | TOTAL SHEETS | TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROV 4 RG 29/11/23 EBP 30/11/23 LV | | APPROVED BY | DATE | СОММ | ENTS | | |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | alculations) | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | | | | |
|---------------------------------|----------|--|--|-------------------------------------|--|-----------------------------|--|--|--|--|
| KEY | CLIENT | | | BBA: REVISION | PO1 | | | | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: | Watland Sites Taifi Watlands | | CHECKER: | EBP | | | | | |
| Calculated values | | wetland Sites - Telli Wetlands | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: | Process Design Calculations -Adpar | | DATE: | NTE: 29/11/2023 | | | | | |
| Assumed values | | ······································ | | DOC. No: | 0 | | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| C _{L-TN} | mg/l | 25 | Influent concentration of Total Nit | rogen | | | | | | |
| C _{i-TP} | mg/l | 4.8 | Influent concentration of Total Pho | osphorus (2021 P performance) | | | | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Tota | Nitrogen | | | | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Tota | Phosphorus | | | | | | |
| k _{TN} | m/yr | 11.18 | Rate coefficient for reduction of To | otal Nitrogen | | | | | | |
| k _{tp} | m/yr | 10 | Rate coefficient for reduction of To | otal Phosphorus | | | | | | |
| k _{20.TN} | m/yr | 21.5 | Median value rate coefficient for n | eduction of Total Nitrogen | | | | | | |
| θτη | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | | | | |
| θπ | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | _ | 3 | | | | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell | in series/three treatment stages i. | e 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) | | | |
| Design Flow | m3/d | 535 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | m^3/m | 195275 | | | | | | | | |
| throughput | 111 / ¥1 | 155275 | | | | | | | | |
| Total wetland area | m² | 10,000 | Active cell area (i.e. excluding divir | ng berms, spreader channels and le | evel control structures) | | | | | |
| q | m/yr | 19.5275 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 13.60 | NB. treated discharge from the we | tland cannot be less than the back | kground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 57.88 | | | | | | | | |
| Treatment efficiency of wetland | % | 42.12 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 2.92 | NB. treated discharge from the we | tland cannot be less than the back | kground concentrations, as it is no | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 61.18 | | | | | | | | |
| Treatment efficiency of wetland | % | 38.82 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| GARCADIS | | | ONS | PROJECT No: | 30192602 | | | | |
|---------------------------------|----------|------------------------------------|---------------------------------------|--------------------------------------|---|-------------------------------|-------------------------------------|--|--|
| | | 0,12002,1110 | | GBA: | Resilience - Water | | | | |
| KEY | CLIENT: | Ceredigion County Council | | REVISION: | P01 | | | | |
| Input values | DROJECT: | | | | EPD | | | | |
| Calculated values | PROJECT. | Wetland Sites - Teifi Wetlands | | | 0 | | | | |
| Linked values | SUBJECT: | | | DATE: | 29/11/2023 | | | | |
| Assumed values | | Process Design Calculations -Adpar | | DOC. No: | 0 | | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 | | |
| | | | | | | | | | |
| | _ | | | | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| CI-TN | mg/l | 25 | Influent concentration of Total Ni | trogen | | | | | |
| C _{I-TP} | mg/l | 4.8 | Influent concentration of Total Ph | osphorus (2021 P performance) | | | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Tota | al Nitrogen | | | | | |
| С*тр | mg/l | 0.022 | Background concentration of Tota | al Phosphorus | | | | | |
| k _{IN} | m/yr | 11.18 | Rate coefficient for reduction of T | otal Nitrogen | | | | | |
| k _{to} | m/vr | 10 | Rate coefficient for reduction of T | otal Phosphorus | | | | | |
| K20 TN | m/yr | 21.5 | Median value rate coefficient for | reduction of Total Nitrogen | | | | | |
| θ m | - | 1.056 | Median Temp coefficient for Tota | Nitrogen | | | | | |
| тм А-т | | 0.986 | Median Temp coefficient for Tota | Phosphorus | | | | | |
| т | °C | 8 | | i nosphorus | | | | | |
| No. of treatment stages | - | 3 | Average operating temperature | | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell | in series/three treatment stages i.e | e 3 cells in series - P is 2 or 6 respe | ctively (conservative value) | | | |
| Design Flow | m3/d | 535 | Input flow rate into here | | | , | | | |
| Total annual hydraulic | 3, | 105.275 | | | | | | | |
| throughput | m /yr | 195275 | | | | | | | |
| Total wetland area | m² | 5,000 | Active cell area (i.e. excluding divi | ng berms, spreader channels and le | evel control structures) | | | | |
| q | m/yr | 39.055 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 17.77 | NB. treated discharge from the w | etland cannot be less than the back | ground concentrations, as it is not | possible to achieve i.e. back | kground conc will always be present | | |
| contaminant, Ce - C* | % | 75.60 | | | | | | | |
| Treatment efficiency of wetland | i % | 24.40 | % of contaminant removed | | | | | | |
| · | | | | | | | | | |
| Total Phosphorus | | | | | | | | | |
| Amount of remaining | - | 3.72 | NB. treated discharge from the w | etland cannot be less than the back | ground concentrations, as it is not | possible to achieve i.e. back | kground conc will always be present | | |
| contaminant, Ce - C* | % | 77.82 | | | | | | | |
| Treatment efficiency of wetland | 1 % | 22.18 | % of contaminant removed | | | | | | |
| | | | | | | | | | |

| | | | PROJECT No: | 3019260 |)2 | | |
|----------|------------------------|--------------|-------------|-----------|-----------|---|--|
| /- | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Adnar | DATE: | 45259 | | | |
| | Process Design Calcul | | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{-P}$$

 C_i = Influent concentration of contaminant (mg/l)

- C_e = Effluent concentration of contaminant (mg/l) C^* = Background concentration of contaminant (in the wetland water column) (mg/l)
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- (C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | |
|--------------|-----------------|-------------------|----------------|------------------|--------------|-------------|--------------|-------|--------|
| | JADIS | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites | - Teifi Wetland | S | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Adpar | | | DATE: | 29/11/2023 | , | |
| | Estimated Q, C | ;i 1.7 (2022 P pe | erformance) | | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMI | VIENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
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| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | lculations) | | | |
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| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 | | | |
|---------------------------------|----------------|-------------------------------------|--|---|-------------------------------|--------------------------------|-----------------------------------|--|
| KEY | CLIENT: | | | GBA: | Resilience - Water | | | |
| KL1 | CLIENT: | Ceredigion County Council | | REVISION: | PO1 BG | | | |
| Input values | PROJECT: | | | CHECKER | FBP | | | |
| Calculated values | i noizeit. | Wetland Sites - Teifi Wetlands | | APPROVER: | 0 | | | |
| Linked values | SUBJECT: | | | DATE: | 29/11/2023 | | | |
| Assumed values | | Process Design Calculations - Adpar | | DOC. No: | 0 | | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 | |
| | | | | • | | | | |
| Process Calculations | | | | | | | | |
| Doromotor | - | Value | Deferences /Commonts | | | | | |
| Parameter | Oliit | Value | References/Comments | - | | | | |
| CI-TM | mg/l | 25 | Influent concentration of Total Nitroger | | | | | |
| C _{I-TP} | mg/l | 1.7 | Influent concentration of Total Phospho | rus (2022 P performance) | | | | |
| С*ты | mg/l | 1.5 | Background concentration of Total Nitro | gen | | | | |
| С*тр | mg/l | 0.022 | Background concentration of Total Pho | phorus | | | | |
| km | m/vr | 11.18 | Rate coefficient for reduction of Total N | itrogen | | | | |
| K TO | m/yr | 10 | Rate coefficient for reduction of Total P | hosphorus | | | | |
| Kan | m/yr | 21.5 | Median value rate coefficient for reduct | ion of Total Nitrogen | | | | |
| ×20-1N | , y. | 1 056 | Median Temp coefficient for Total Nitro | | | | | |
| 0 _{-TN} | - | 1.056 | Median Temp coefficient for Total Nico | gen | | | | |
| 0 _{-TP} | - | 0.986 | Median Temp coefficient for Total Phos | phorus | | | | |
| No. of treatment stages | ٠ر | 8 | Average operating temperature | | | | | |
| NO. OF treatment stages | - | 5 | For one treatment stage i.e. 1 cell in ser | ies/three treatment stages i e 3 cells in | series - P is 2 or 6 respe | tively (conservative value) | | |
| P Design Flow | - m3/d | 488 | Input flow rate into here | les/ three treatment stages i.e 5 cens in | i series - r is z or o respec | | | |
| Total annual hydraulic | ins/d | 400 | input now rate into here | | | | | |
| throughput | m³/yr | 178120 | | | | | | |
| Total wetland area | m ² | 10.000 | Active cell area (i.e. excluding diving be | rms spreader channels and level contr | ol structures) | | | |
| 0 | m/vr | 17 812 | | | , | | | |
| 4 | , ;. | 1/1012 | | | | | | |
| Total Nitrogen | | | | | | | | |
| Amount of remaining | - | 12 94 | NB treated discharge from the wetland | cannot be less than the background co | ncentrations as it is not i | oossible to achieve i.e. backø | round conc will always be present | |
| contaminant, Ce - C* | % | 55.05 | | | , | | , | |
| Treatment efficiency of wetland | % | 44.95 | % of contaminant removed | | | | | |
| | | | | | | | | |
| Total Phosphorus | | | | | | | | |
| Amount of remaining | - | 0.98 | NB. treated discharge from the wetland | cannot be less than the background co | oncentrations, as it is not p | oossible to achieve i.e. backg | round conc will always be present | |
| contaminant, Ce - C* | % | 58.47 | | | | | | |
| Treatment efficiency of wetland | % | 41.53 | % of contaminant removed | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| ARCADIS | | CALCULATIONS | S | PROJECT No: | 30192602 Besilience - Water | | |
|---------------------------------|----------------|-------------------------------------|---|--------------------------------------|------------------------------------|----------------------------------|----------------------------------|
| KEY | CLIENT: | | | BEVISION: | P01 | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | |
| Input values | PROJECT: | Well-steps Tribuch | | CHECKER: | EBP | | |
| Calculated values | | Wetland Sites - Telfi Wetlands | | APPROVER: | 0 | | |
| Linked values | SUBJECT: | Process Design Calculations - Adnar | | DATE: | 29/11/2023 | | |
| Assumed values | | Process Design Calculations - Aupai | | DOC. No: | 0 | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 |
| | | | | | | | |
| Process Calculations | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | |
| | | | | | | | |
| CI-TN | mg/l | 25 | Influent concentration of Total Nitrog | en (2022 P | | | |
| C _{LTP} | mg/i | 1.7 | Influent concentration of Total Phosp | norus (2022 P performance) | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Total N | trogen | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total Pl | osphorus | | | |
| k _{tn} | m/yr | 11.18 | Rate coefficient for reduction of Tota | Nitrogen | | | |
| k _{TP} | m/yr | 10 | Rate coefficient for reduction of Tota | Phosphorus | | | |
| k _{20-TN} | m/yr | 21.5 | Median value rate coefficient for red | ction of Total Nitrogen | | | |
| 0-TN | - | 1.056 | Median Temp coefficient for Total Ni | rogen | | | |
| θ.τρ | - | 0.986 | Median Temp coefficient for Total Ph | osphorus | | | |
| Т | °C | 8 | Average operating temperature | | | | |
| No. of treatment stages | _ | 3 | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell in | eries/three treatment stages i.e 3 c | ells in series - P is 2 or 6 respe | ectively (conservative value) | |
| Design Flow | m3/d | 488 | Input flow rate into here | | | | |
| Total annual hydraulic | 3, | 170120 | | | | | |
| throughput | m"/yr | 178120 | | | | | |
| Total wetland area | m ² | 5,000 | Active cell area (i.e. excluding diving | perms, spreader channels and level | control structures) | | |
| q | m/yr | 35.624 | | | | | |
| | | | | | | | |
| Total Nitrogen | | | | | | | |
| Amount of remaining | - | 17.31 | NB. treated discharge from the wetla | nd cannot be less than the backgrou | nd concentrations, as it is not | possible to achieve i.e. backgro | ound conc will always be present |
| contaminant, Ce - C* | % | 73.64 | | | | | |
| Treatment efficiency of wetland | % | 26.36 | % of contaminant removed | | | | |
| | | | | | | | |
| Total Phosphorus | | | | | | | |
| Amount of remaining | - | 1.28 | NB. treated discharge from the wetla | nd cannot be less than the backgrou | nd concentrations, as it is not | possible to achieve i.e. backgro | ound conc will always be present |
| contaminant, Ce - C* | % | 76.01 | | | | | |
| Treatment efficiency of wetland | % | 23.99 | % of contaminant removed | | | | |
| | | | | | | | |
| | | | | | | | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|----------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | diicii | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | venanus | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Adnar | DATE: | 45259 | | | |
| | Process Design Calcul | ations - Aupai | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PPD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \end{array} \right]^{-p}$$

 C_i = Influent concentration of contaminant (mg/l) C_r = Effluent concentration of contaminant (mg/l)

 C^* = Background concentration of contaminant (ing/i) C^* = Background concentration of contaminant (in the wetland water column) (mg/l)

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C*

*Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | | | | PROJECT No: | 30192602 | | |
|--------------|-----------------|-----------------------------------|----------------|------------------|--------------|--------------|--------------|-------|-------|
| | UADIS | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | S | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Adpar | | | DATE: | 29/11/2023 | | |
| | Estimated Q, C | i 4.8 (2021 P p | erformance) | | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | СОМІ | MENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
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| | | | | | | | \Box | | |
| | | | | | | | | | |
| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | Iculations) | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIC | DNS | PROJECT No: | 30192602 Resilience - Water | | |
|---------------------------------|--------------------|--|---|-------------------------------------|--|-------------------------------|---------------------------------------|
| KEY | CLIENT | | | BEVISION: | P01 | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | |
| Input values | PROJECT: | Watland Sites Taifi Watlands | | CHECKER: | EBP | | |
| Calculated values | | wetland Sites - Telli Wetlands | | APPROVER: | 0 | | |
| Linked values | SUBJECT: | Process Design Calculations - Adpar | | DATE: | 29/11/2023 | | |
| Assumed values | | ······································ | | DOC. No: | 0 | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 2 | OF | 4 |
| | | | | | | | |
| Process Calculations | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | |
| C _{L-TN} | mg/l | 25 | Influent concentration of Total Nitro | ogen | | | |
| C _{i-TP} | mg/l | 4.8 | Influent concentration of Total Pho | sphorus (2021 P performance) | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | |
| k _{TN} | m/yr | 11.18 | Rate coefficient for reduction of Tot | tal Nitrogen | | | |
| k _{tp} | m/yr | 10 | Rate coefficient for reduction of Tot | tal Phosphorus | | | |
| k _{20.TN} | m/yr | 21.5 | Median value rate coefficient for re | duction of Total Nitrogen | | | |
| θ.τ. | - | 1.056 | Median Temp coefficient for Total N | Vitrogen | | | |
| θ.π | - | 0.986 | Median Temp coefficient for Total F | Phosphorus | | | |
| т | °C | 8 | Average operating temperature | | | | |
| No. of treatment stages | - | 3 | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell ir | n series/three treatment stages i.e | e 3 cells in series - P is 2 or 6 resp | ectively (conservative value | 2) |
| Design Flow | m3/d | 488 | Input flow rate into here | | | | |
| Total annual hydraulic | m ³ /vr | 178120 | | | | | |
| throughput | 111 / yi | 1/0120 | | | | | |
| Total wetland area | m² | 10,000 | Active cell area (i.e. excluding diving | g berms, spreader channels and le | evel control structures) | | |
| q | m/yr | 17.812 | | | | | |
| Total Nitrogen | | | | | | | |
| Amount of remaining | - | 12.94 | NB. treated discharge from the wet | land cannot be less than the back | <pre></pre> | t possible to achieve i.e. ba | ackground conc will always be present |
| contaminant, Ce - C* | % | 55.05 | | | | | |
| Treatment efficiency of wetland | % | 44.95 | % of contaminant removed | | | | |
| Total Phosphorus | | | | | | | |
| Amount of remaining | - | 2.79 | NB. treated discharge from the wet | land cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. ba | ackground conc will always be present |
| contaminant, Ce - C* | % | 58.47 | | | | | |
| Treatment efficiency of wetland | % | 41.53 | % of contaminant removed | | | | |
| | | | | | | | |

| KEY CLIENT: Ceredigion County Council REVISION: P01 Input values PROJECT: Wetland Sites - Teifi Wetlands AUTHOR: RG Calculated values SUBJECT: Process Design Calculations - Adpar O Assumed values SUBJECT: Process Design Calculations - Adpar DATE: 29/11/2023 SECTION: P-k-c 0 | |
|--|--------------|
| Imput values AUTHOR: RG Calculated values PROJECT: Wetland Sites - Teifi Wetlands APPROVER: 0 Assumed values SUBJECT: Process Design Calculations - Adpar DATE: 29/11/2023 SECTION: P-k-c 0 | |
| Input values PROJECT: Wetland Sites - Teifi Wetlands CHECKR: EBP Calculated values SUBJECT: Process Design Calculations - Adpar DATE: 29/11/2023 Assumed values SECTION: P-k-c DOC. No: 0 Process Calculations P-k-c 3 OF 4 | |
| Linked values SUBJECT: Process Design Calculations - Adpar DATE: 29/11/2023 Assumed values SECTION: P-k-c DOC. No: 0 Process Calculations P-k-c SHEET: 3 OF 4 | |
| Assumed values Process Design Calculations - Adpar Iterated values SECTION: P-k-c OF Process Calculations | |
| Iterated values SECTION: P-k-c 3 OF 4 Process Calculations Parameter Unit Value References/Comments | |
| Process Calculations Parameter Unit Value References/Comments | |
| Process Calculations Parameter Unit Value References/Comments | |
| Parameter Unit Value References/Comments | |
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| | |
| C _{F™} mg/l 25 Influent concentration of Total Nitrogen | |
| C* mg/ 4.6 million concentration of total performance) | |
| C TN IIIg/I I.3 Background concentration of rotal Nitrogen | |
| k mar 1112 Bate service in the interview of the interview | |
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| k more 215 Modia vulo at a contraction of Table Mitragen | |
| A Information of the second se | |
| Part of the second seco | |
| T C 2 2 Autors constitut framework for a constitut for | |
| No of treatment stages - 3 | |
| P - 6 For one treatment stage i.e. 1 cell in series/three treatment stages i.e. 3 cells in series - P is 2 or 6 respectively (conservative value) | |
| Design Flow m3/d 488 Input flow rate into here | |
| Total annual hydraulic | |
| throughput III/yr 1/01/0 | |
| Total wetland area m ² 5,000 Active cell area (i.e. excluding diving berms, spreader channels and level control structures) | |
| q m/yr <u>35.624</u> | |
| Total Nitrogen | |
| Amount of remaining - 17.31 NB. treated discharge from the wetland cannot be less than the background concentrations, as it is not possible to achieve i.e. background conc will always | be present |
| contaminant, Ce - C* % 73.64 | |
| Treatment efficiency of wetland % 26.36 % of contaminant removed | |
| | |
| Amount of remaining | : he present |
| containinant, Ce - C* % 76.01 | oc present |
| Treatment efficiency of wetland % 23.99 % of contaminant removed | |
| | |

| | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|----------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | diicii | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | venanus | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Adnar | DATE: | 45259 | | | |
| | Process Design Calcul | ations - Aupai | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be a follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \end{array} \right]^{P}$$

 C_i = Influent concentration of contaminant (mg/l)

- $C_e = Effluent concentration of contaminant (mg/l) C^* = Background concentration of contaminant (in the wetland water column) (mg/l)$
- C* = Background concentration of contaminant (in the wetland water column) (mg/l k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (*P*TIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- (C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

Appendix C Refined Wetlands Analysis with P-K-C* Model – Tregaron

| | | | | | | PROJECT No: | 30192602 | | |
|--------------|-----------------|-----------------------------------|----------------|------------------|--------------|---------------|--------------|-------|------|
| | UADIS | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | inty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | S | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Tregarron | | | DATE: | 24/11/2023 | | |
| | Permitted Q, P | roposed Permi | it | | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | СОММ | ENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | alculations) | | | |
| | | | | | | | | | |

| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Besilience - Water | | | |
|---------------------------------|----------|---|---|----------------------------------|---------------------------------------|------------------------------|--|--|
| KEY | CLIENT: | | | REVISION: | P01 | | | |
| | - | Ceredigion County Council | | AUTHOR: | RG | | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | |
| Calculated values | | fredalid Sites Tell freddilds | | APPROVER: 0 | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Tregarron | I Contraction of the second | 24/11/2023 | | | | |
| Assumed values | SECTION | | | DUC. NO: | 0 | | | |
| | SECTION. | P-k-c | | 511221. | 2 | OF | 4 | |
| | _ | | | | | | | |
| Process Calculations | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | |
| Gim | mg/l | 25 | Influent concentration of Total Nitrog | ren | | | | |
| CLTP | mg/l | 25 | Influent concentration of Total Phose | horus (Proposed Permit) | | | | |
| C* _{TM} | mg/l | 1.5 | Background concentration of Total Ni | trogen | | | | |
| C* | mg/l | 0.022 | Background concentration of Total Ph | nosphorus | | | | |
| k _{TM} | m/yr | 11.18 | Bate coefficient for reduction of Total | Nitrogen | | | | |
| krn | m/yr | 10 | Bate coefficient for reduction of Total | Phosphorus | | | | |
| Kanatu | m/yr | 21.5 | Median value rate coefficient for redu | iction of Total Nitrogen | | | | |
| θ | - | 1.056 | Median Temp coefficient for Total Nit | rogen | | | | |
| θ | | 0.986 | Median Temp coefficient for Total Ph | osphorus | | | | |
| т | - °C | 8 | | osphorus | | | | |
| No. of treatment stages | - | 3 | Average operating temperature | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell in s | eries/three treatment stages i.e | 3 cells in series - P is 2 or 6 respe | ectively (conservative valu | ue) | |
| Design Flow | m3/d | 520 | Input flow rate into here | | | | | |
| Total annual hydraulic | 37 | 180800 | | | | | | |
| throughput | m /yr | 189800 | | | | | | |
| Total wetland area | m² | 15,000 | Active cell area (i.e. excluding diving b | perms, spreader channels and lev | vel control structures) | | | |
| q | m/yr | 12.65333333 | | | | | | |
| Total Nitrogen | | | | | | | | |
| Amount of remaining | - | 10.31 | NB. treated discharge from the wetlar | nd cannot be less than the backg | ground concentrations, as it is no | t possible to achieve i.e. I | background conc will always be present | |
| contaminant, Ce - C* | % | 43.85 | | | | | | |
| Treatment efficiency of wetland | % | 56.15 | % of contaminant removed | | | | | |
| Total Phosphorus | | | | | | | | |
| Amount of remaining | - | 0.94 | NB, treated discharge from the wetlar | nd cannot be less than the backe | round concentrations, as it is no | t possible to achieve i.e. I | background conc will always be present | |
| contaminant, Ce - C* | % | 47.60 | | | , | | | |
| Treatment efficiency of wetland | % | 52.40 | % of contaminant removed | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| ARCADIS | | CALCULATIO | ONS | PROJECT No: | 30192602 Resilience - Water | | |
|---------------------------------|----------|---|--|-------------------------------------|--------------------------------------|----------------------------|--|
| KEY | CLIENT | | | BEVISION: | PO1 | | |
| | | Ceredigion County Council | | AUTHOR | RG | | |
| Input values | PROJECT: | Wetland Cites Taifi Metlanda | | CHECKER: | EBP | | |
| Calculated values | | wetland sites - Telli Wetlands | | APPROVER: | 0 | | |
| Linked values | SUBJECT: | Process Design Calculations - Tregarron | | | 24/11/2023 | | |
| Assumed values | | ······································ | | | 0 | | |
| Iterated values | SECTION: | P-k-c | | SHEET: | 3 | OF | 4 |
| | | | | | | | |
| Process Calculations | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | |
| C.m. | mg/l | 25 | Influent concentration of Total Nite | ogen | | | |
| Ci-m | mg/l | 25 | Influent concentration of Total Pho | sphorus (Proposed Permit) | | | |
| C* | mg/l | 15 | Background concentration of Total | Nitrogen | | | |
| C* | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | |
| C TP | m hrr | 0.022 | Background concentration of Total | tal Nitrogon | | | |
| N _{TN} | 111/ yi | 11.10 | Rate coefficient for reduction of To | tal Nitrogen | | | |
| K _{TP} | m/yr | 10 | Rate coefficient for reduction of To | tal Phosphorus | | | |
| K _{20-TN} | m/yr | 21.5 | Median value rate coefficient for re | eduction of Total Nitrogen | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total | Nitrogen | | | |
| θ _{-т} | - | 0.986 | Median Temp coefficient for Total | Phosphorus | | | |
| Т | °C | 8 | Average operating temperature | | | | |
| No. of treatment stages | - | 3 | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell i | n series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative val | lue) |
| Design Flow | m3/d | 520 | Input flow rate into here | | | | |
| Total annual hydraulic | m³/vr | 189800 | | | | | |
| throughput | 2 | | | | | | |
| Total wetland area | m | 7,500 | Active cell area (i.e. excluding divin | g berms, spreader channels and lev | vel control structures) | | |
| q | m/yr | 25.30666667 | | | | | |
| Total Nitrogen | | | | | | | |
| Amount of remaining | - | 15.34 | NB. treated discharge from the we | land cannot be less than the back | round concentrations, as it is no | t possible to achieve i.e. | background conc will always be present |
| contaminant, Ce - C* | % | 65.29 | | | | | |
| Treatment efficiency of wetland | % | 34.71 | % of contaminant removed | | | | |
| Total Phoenhorus | | | | | | | |
| Amount of remaining | - | 1 35 | NB treated discharge from the we | land cannot be less than the backs | round concentrations as it is no | it nossible to achieve i e | background conc will always be present |
| contaminant. Ce - C* | % | 68.20 | the deduce discharge nom the we | | | repossible to demere her | backs, band cone win analys be present |
| Treatment efficiency of wetland | % | 31.80 | % of contaminant removed | | | | |
| | | | | | | | |
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| | | | PROJECT No: | 3019260 | 2 | | |
|----------|------------------------|--------------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | dici | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Tragarran | DATE: | 45254 | | | |
| | Process Design Calcul | ations - fregation | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_e - C^*}{C_i - C^*} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{-p}$$

C_i = Influent concentration of contaminant (mg/l)

Ce = Effluent concentration of contaminant (mg/l)

- $\label{eq:cs} C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)} \\ k = \text{Rate coefficient for reduction of contaminant (m/yr)}$
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| ARCADIS | | | | | PROJECT No: | 30192602 | | | |
|----------------------|-----------------|-----------------------------------|----------------|------------------|--------------|-------------|--------------|-------|-------|
| | | | CALCUI | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites - | Teifi Wetland | S | | | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Treggaron | | | DATE: | 24/11/2023 | | |
| | Permitted Q, A | ssumed Backs | top/Current 7 | ГР | | DOC. No: | | | |
| SECTION: Front Sheet | | | | | | SHEET: | 1 | OF | 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMM | √ENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | |
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| DESIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | lculations) | | | |
| | | | | | | | | | |
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| ARCADIS | | CALCULATION | NS | PROJECT No: | 30192602 Resilience - Water | | | |
|---------------------------------|----------------|---|---|----------------------------------|--------------------------------------|------------------------------|--|--|
| KEY | CLIENT: | Corodigion County Council | | REVISION: | P01 | | | |
| | | Cerealgion County Council | | AUTHOR: | RG | | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | |
| Calculated values | | | APPROVER: | <u>'ER: 0</u> | | | | |
| Assumed values | SUBJECT: | Process Design Calculations - Treggaron | | DATE: | 24/11/2023 | | | |
| Iterated values | SECTION: | | | SHEET: | | | | |
| | | P-k-c | | | 2 | OF | 4 | |
| | | | | | | | | |
| Process Calculations | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | |
| 6 | mg/l | 25 | Influent concentration of Total Nitrog | en. | | | | |
| C _{LTN} | mg/l | 25 | Influent concentration of Total Phose | horus (Assumed Backston/Curre | ent TP) | | | |
| C* | mg/l | 1.5 | Background concentration of Total Ni | trogen | | | | |
| C* | mg/l | 0.022 | Background concentration of Total Ph | iosphorus | | | | |
| - 1P k-su | m/vr | 11.18 | Rate coefficient for reduction of Total | Nitrogen | | | | |
| | m/yr | 10 | Bate coefficient for reduction of Total | Phosphorus | | | | |
| Kan | m/yr | 21.5 | Median value rate coefficient for redu | rtion of Total Nitrogen | | | | |
| A | , y. | 1 056 | Median Temp coefficient for Total Nit | rogen | | | | |
| θ | | 0.986 | Median Temp coefficient for Total Pho | horus | | | | |
| т | °C | 8 | Average operating temperature | ospilor us | | | | |
| No. of treatment stages | - | 3 | werdge operating temperature | | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell in s | eries/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | ue) | |
| Design Flow | m3/d | 520 | Input flow rate into here | | | | | |
| Total annual hydraulic | ³ / | 199900 | | | | | | |
| throughput | ffi /yr | 189800 | | | | | | |
| Total wetland area | m² | 15,000 | Active cell area (i.e. excluding diving b | erms, spreader channels and le | vel control structures) | | | |
| q | m/yr | 12.65333333 | | | | | | |
| Total Nitrogen | | | | | | | | |
| Amount of remaining | - | 10.31 | NB. treated discharge from the wetlar | nd cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. b | background conc will always be present | |
| contaminant, Ce - C* | % | 43.85 | | | | | | |
| Treatment efficiency of wetland | % | 56.15 | % of contaminant removed | | | | | |
| Total Phosphorus | | | | | | | | |
| Amount of remaining | - | 2.37 | NB. treated discharge from the wetlar | nd cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. b | background conc will always be present | |
| contaminant, Ce - C* | % | 47.60 | | | | | | |
| Treatment efficiency of wetland | % | 52.40 | % of contaminant removed | | | | | |
| | | | | | | | | |

| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 Resilience - Water | | | | |
|---------------------------------|----------|---|---|------------------------------------|--------------------------------------|-------------------------------|--|--|--|
| KEY | CLIENT: | | | REVISION: | P01 | | | | |
| | - | Ceredigion County Council | | AUTHOR: | RG | | | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | | |
| Calculated values | | | | APPROVER: | OVER: 0 | | | | |
| Linked values | SUBJECT: | Process Design Calculations - Treggaron | | DATE: | 24/11/2023 | | | | |
| Assumed values | SECTION | | | | U | | | | |
| | SECTION. | P-k-c | | SHEET. | 3 | OF | 4 | | |
| | _ | | | | | | | | |
| Process Calculations | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | |
| CLITM | mg/l | 25 | Influent concentration of Total Nitrog | en | | | | | |
| C _{i-TP} | mg/l | 5 | Influent concentration of Total Phosp | horus (Assumed Backstop/Currer | nt Tp)) | | | | |
| С*ты | mg/l | 1.5 | Background concentration of Total Ni | trogen | | | | | |
| C* _{тр} | mg/l | 0.022 | Background concentration of Total Ph | losphorus | | | | | |
| k _{TN} | m/yr | 11.18 | Rate coefficient for reduction of Total | Nitrogen | | | | | |
| k _{TP} | m/vr | 10 | Rate coefficient for reduction of Total | Phosphorus | | | | | |
| K20 TN | m/yr | 21.5 | Median value rate coefficient for redu | iction of Total Nitrogen | | | | | |
| θ m | - | 1.056 | Median Temp coefficient for Total Nit | rogen | | | | | |
| e-in e-in | - | 0.986 | Median Temp coefficient for Total Pho | osphorus | | | | | |
| Т | °C | 8 | Average operating temperature | sspirol us | | | | | |
| No. of treatment stages | - | 3 | ······································ | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in s | eries/three treatment stages i.e 3 | 3 cells in series - P is 2 or 6 resp | ectively (conservative valu | ue) | | |
| Design Flow | m3/d | 520 | Input flow rate into here | _ | | | | | |
| Total annual hydraulic | | 189800 | | | | | | | |
| throughput | III /yr | 185800 | | | | | | | |
| Total wetland area | m² | 7,500 | Active cell area (i.e. excluding diving b | erms, spreader channels and lev | el control structures) | | | | |
| q | m/yr | 25.30666667 | | | | | | | |
| Total Nitrogen | | | | | | | | | |
| Amount of remaining | - | 15.34 | NB. treated discharge from the wetlar | nd cannot be less than the backg | round concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | |
| contaminant, Ce - C* | % | 65.29 | | | | | | | |
| Treatment efficiency of wetland | % | 34.71 | % of contaminant removed | | | | | | |
| Total Phosphorus | | | | | | | | | |
| Amount of remaining | - | 3.40 | NB. treated discharge from the wetlar | nd cannot be less than the backg | round concentrations, as it is n | ot possible to achieve i.e. I | background conc will always be present | | |
| contaminant, Ce - C* | % | 68.20 | the reaced abenation for the wetter | | | | g | | |
| Treatment efficiency of wetland | % | 31.80 | % of contaminant removed | | | | | | |
| | | | | | | | | | |
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| | | | PROJECT No: | 3019260 | 2 | | |
|----------------------------------|------------------------|--------------------|-------------|-----------|-----------|---|--|
| - | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | dici | AUTHOR: | RG | | | |
| PROJECT: Wetland Sites - Teifi) | | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tein V | vetialius | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Traggaran | DATE: | 45254 | | | |
| | Process Design Calcul | ations - Treggaron | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{P}$$

C_i = Influent concentration of contaminant (mg/l)

$$\label{eq:ce} \begin{split} C_e &= \text{Effluent concentration of contaminant (mg/l)} \\ C^* &= \text{Background concentration of contaminant (in the wetland water column) (mg/l)} \end{split}$$

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| | | | CALCU | | | PROJECT No: | 30192602 | |
|---|--------------------|-----------------|----------------|------------------|--------------|-------------|--------------|----------|
| | | | CALCUI | LATIONS | | GBA: | Resilience - | Water |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | |
| | | | | | | AUTHOR: | RG | |
| PROJECT: | Wetland Sites - | - Teifi Wetland | S | | | CHECKER: | EBP | |
| | | | | | | APPROVER: | <u> </u> | |
| SUBJECT: Process Design Calculations - Tregaron | | | | | | DATE: | 24/11/2023 | |
| Estimated Q, proposed Permit | | | | | | DOC. No: | | |
| SECTION: | CTION: Front Sheet | | | | | | 1 | OF 4 |
| ISSUE | TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMMENTS |
| P01 | 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | |
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| | | | | | | | | |
| DESIGN BASIS | STATEMENT (Inc. | bigh level des | crintion of si | te/process and n | urpose of ca | leulations) | | |
| | | ingineter acc | | .c/process and p | | | | |
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| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Besilience - Water | | |
|---------------------------------|--------------------|--|---|-----------------------------------|---------------------------------------|----------------------------|--|
| KEY | CLIENT: | | | REVISION: | P01 | | |
| | | Ceredigion County Council | | AUTHOR: | RG | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | |
| Calculated values | | | | APPROVER: | 0 | | |
| Linked values | SUBJECT: | Process Design Calculations - Tregaron | | DATE: | 24/11/2023 | | |
| Assumed values | SECTION | | | DOC. NO: | 0 | | |
| | SECTION. | P-k-c | | SHEET. | 2 | OF | 4 |
| | | | | | | | |
| Process Calculations | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | |
| CLITM | mg/l | 25 | Influent concentration of Total Nitro | ogen | | | |
| C _{i-TP} | mg/l | 2 | Influent concentration of Total Pho | sphorus (Proposed Permit) | | | |
| С*ты | mg/l | 1.5 | Background concentration of Total | Nitrogen | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total | Phosphorus | | | |
| k _{TN} | m/yr | 11.18 | Rate coefficient for reduction of Tot | al Nitrogen | | | |
| k _{τp} | m/vr | 10 | Rate coefficient for reduction of Tot | al Phosphorus | | | |
| k _{20.TN} | m/yr | 21.5 | Median value rate coefficient for re | duction of Total Nitrogen | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total N | litrogen | | | |
| θ-τρ | - | 0.986 | Median Temp coefficient for Total P | hosphorus | | | |
| т | °C | 8 | Average operating temperature | | | | |
| No. of treatment stages | - | 3 | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | 3 cells in series - P is 2 or 6 respe | ctively (conservative val | ue) |
| Design Flow | m3/d | 218 | Input flow rate into here | | | | |
| Total annual hydraulic | m ³ /vr | 79570 | | | | | |
| throughput | | | | | | | |
| Total wetland area | m ² | 15,000 | Active cell area (i.e. excluding diving | g berms, spreader channels and le | vel control structures) | | |
| q | m/yr | 5.304666667 | | | | | |
| Total Nitrogen | | | | | | | |
| Amount of remaining | - | 3.86 | NB. treated discharge from the wet | and cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. | background conc will always be present |
| contaminant, Ce - C* | % | 16.43 | | | | | |
| Treatment efficiency of wetland | % | 83.57 | % of contaminant removed | | | | |
| Total Phosphorus | | | | | | | |
| Amount of remaining | - | 0.38 | NB. treated discharge from the wet | and cannot be less than the back | ground concentrations, as it is no | t possible to achieve i.e. | background conc will always be present |
| contaminant, Ce - C* | % | 19.41 | 2 • • • • • | | | | - , |
| Treatment efficiency of wetland | % | 80.59 | % of contaminant removed | | | | |
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| ARCADIS | | CALCULATIO | INS | PROJECT No: | 30192602 Resilience - Water | | |
|---------------------------------|----------------|--|---|-----------------------------------|--------------------------------------|----------------------------|--|
| KEY | CLIENT: | | | REVISION: | P01 | | |
| | - | Ceredigion County Council | | AUTHOR: | RG | | |
| Input values | PROJECT: | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | |
| Calculated values | | | | APPROVER: | 0 | | |
| Linked values | SUBJECT: | Process Design Calculations - Tregaron | DATE: | 24/11/2023 | | | |
| Iterated values | SECTION | | | DUC. NO: SHEFT: | 0 | | |
| | SECTION. | P-k-c | | SHEET. | 3 | OF | 4 |
| | | | | | | | |
| Process Calculations | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | |
| C.m. | mg/l | 25 | Influent concentration of Total Nitros | ion | | | |
| | mg/l | 25 | Influent concentration of Total Phose | horus (Proposed Permit) | | | |
| C* ₁₁₁ | mg/l | 1.5 | Background concentration of Total N | itrogen | | | |
| C*170 | mg/l | 0.022 | Background concentration of Total P | nosphorus | | | |
| k _{TM} | m/vr | 11.18 | Bate coefficient for reduction of Tota | Nitrogen | | | |
| k _{rn} | m/yr | 10 | Rate coefficient for reduction of Tota | l Phosphorus | | | |
| Kao TN | m/yr | 21.5 | Median value rate coefficient for redu | uction of Total Nitrogen | | | |
| θ m | - | 1.056 | Median Temp coefficient for Total Ni | trogen | | | |
| e-in e-in | - | 0.986 | Median Temp coefficient for Total Ph | osphorus | | | |
| т | °C | 8 | Average operating temperature | osphoras | | | |
| No. of treatment stages | - | 3 | Werdge operating temperature | | | | |
| P | - | 6 | For one treatment stage i.e. 1 cell in | series/three treatment stages i.e | 3 cells in series - P is 2 or 6 resp | ectively (conservative val | ue) |
| Design Flow | m3/d | 218 | Input flow rate into here | | | | |
| Total annual hydraulic | ³ / | 79570 | | | | | |
| throughput | m /yr | 79370 | | | | | |
| Total wetland area | m² | 7,500 | Active cell area (i.e. excluding diving | berms, spreader channels and lev | el control structures) | | |
| q | m/yr | 10.60933333 | | | | | |
| Total Nitrogen | | | | | | | |
| Amount of remaining | - | 8.90 | NB. treated discharge from the wetla | nd cannot be less than the backg | round concentrations, as it is no | t possible to achieve i.e. | background conc will always be present |
| contaminant, Ce - C* | % | 37.87 | | | | | |
| Treatment efficiency of wetland | % | 62.13 | % of contaminant removed | | | | |
| Total Phoenhorus | | | | | | | |
| Amount of remaining | - | 0.82 | NB treated discharge from the wetla | nd cannot he less than the backs | round concentrations as it is po | t nossible to achieve i e | background conc will always be present |
| contaminant. Ce - C* | % | 41.67 | no. a cated discharge nom the weta | na cannor be less than the backg | | possible to demete her | seeks our a cone inn annays se present |
| Treatment efficiency of wetland | % | 58.33 | % of contaminant removed | | | | |
| | | | | | | | |
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| | | | PROJECT No: | 3019260 | 2 | | |
|----------|-------------------------|-------------------|-------------|-----------|-----------|---|--|
| | ARUADIS | CALCULATIONS | GBA: | Resilienc | e - Water | | |
| CLIENT: | Corodigion County Co | uncil | REVISION: | P01 | | | |
| | Cerealgion County Co | unen | AUTHOR: | RG | | | |
| PROJECT: | Wotland Sitos Toifi V | Votlands | CHECKER: | EBP | | | |
| | Wetianu Sites - Tenri v | vellands | APPROVER: | 0 | | | |
| SUBJECT: | Drogoss Dosign Coloul | ations Traggrap | DATE: | 45254 | | | |
| | Process Design Calcul | ations - Tregaron | DOC. No: | 0 | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

| C _e - C* | | 1+ | k | - <i>P</i> |
|---------------------|---|----|----|------------|
| C _i - C* | - | | Pq | |

 C_i = Influent concentration of contaminant (mg/l)

 $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

| ARCADIS | | | | | PROJECT NO: | 30192602 | | | |
|---------------------|--|--|--|--|--|--|---|--|--|
| | | CALCU | | | GBA: | Resilience - | Water | | |
| Ceredigion Cou | unty Council | | | | REVISION: | P01 | | | |
| | | | | | AUTHOR: | RG | | | |
| Wetland Sites - | - Teifi Wetland | 5 | | | CHECKER: | EBP | | | |
| | | | | | APPROVER: | | | | |
| Process Design | Calculations - | Tregaron | | | DATE: | 24/11/2023 | | | |
| Estimated Q, a | ssumed Backst | op/current T | Р | | DOC. No: | | | | |
| ECTION: Front Sheet | | | | | | 1 | OF | 4 | |
| TOTAL SHEETS | AUTHOR | DATE | CHECKED BY | DATE | APPROVED BY | DATE | COMN | /ENTS | |
| 4 | RG | 29/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | | |
| | | | | | | | | | |
| TATEMENT (Inc. | high level des | cription of sit | te/process and p | urpose of ca | lculations) | | | | |
| | | | | | | | | | |
| | Ceredigion Cou Wetland Sites Process Design Estimated Q, a Front Sheet TOTAL SHEETS 4 A A TEMENT (Inc. | Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Estimated Q, assumed Backst Front Sheet TOTAL SHEETS AUTHOR 4 RG Image: Construction of the structure Author A RG | CALCOU Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Tregaron Estimated Q, assumed Backstop/current T Front Sheet 1 4 RG 29/11/23 4 RG 29/11/23 | CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Tregaron Estimated Q, assumed Backstop/current TP Front Sheet TOTAL AUTHOR DATE CHECKED BY 4 RG 29/11/23 EBP Image: Checked By A RG 29/11/23 From Sheet Image: Checked By A RG 29/11/23 EBP Image: Checked By A RG 29/11/23 EMENT (Inc. high level description of site/process and p | CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Tregaron Estimated Q, assumed Backstop/current TP Front Sheet TOTAL AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 4 RG 29/11/23 EBP 30/11/23 4 RG 1000000000000000000000000000000000000 | Caredigion County Council REVISION: Wetland Sites - Teifi Wetlands CHECKER: Process Design Calculations - Tregaron DATE: Estimated Q, assumed Backstop/current TP DOC. No: Front Sheet SHEET: TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV LV Image: Checken Difference Image: Checken Difference Image: Checken Difference AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV | CALCULATIONS GBA: Resilience -1 Ceredigion County Council REVISION: RG Wetland Sites - Teifi Wetlands CHECKER: EBP APPROVER: Process Design Calculations - Tregaron DATE: 24/11/2023 Estimated Q, assumed Backstop/current TP DOC. No: SHEET: 1 TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV | CALCULATIONS GBA: Resilience - Water Ceredigion County Council REVISION: P01 AUTHOR: RG Wetland Sites - Teiff Wetlands CHECKER: EBP Process Design Calculations - Tregaron DATE: 24/11/2023 Estimated Q, assumed Backstop/current TP DC. No: Front Sheet TOTAL AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 | |

| ARCADIS | | CALCULATIO | NS | PROJECT No: | 30192602 Resilience - Wate | 30192602 Besilience - Water | | | | |
|---------------------------------|---|-------------|--|---|-------------------------------------|--------------------------------|--|--|--|--|
| КЕҮ | CLIENT: Ceredigion County Council | | | REVISION: | P01 | | | | | |
| | | | | AUTHOR: | RG | | | | | |
| Input values | PROJECT: Wetland Sites - Teifi Wetlands SUBJECT: Process Design Calculations - Tregaron | | | CHECKER: | EBP | | | | | |
| Calculated values | | | | APPROVER: | APPROVER: 0 | | | | | |
| Assumed values | | | | DATE: 24/11/2023 | | | | | | |
| Iterated values | SECTION: | | | SHEET: | DUC. NO: 0 | | | | | |
| | | Р-к-с | | - | 2 | OF | 4 | | | |
| | | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| CLTN | mg/l | 25 | Influent concentration of Total Nitro | gen | | | | | | |
| C _{i-TP} | mg/l | 5 | Influent concentration of Total Phos | Influent concentration of Total Phosphorus (assumed Backstopm/current TP) | | | | | | |
| C* _{TN} | mg/l | 1.5 | Background concentration of Total N | Background concentration of Total Nitrogen | | | | | | |
| C* _{TP} | mg/l | 0.022 | Background concentration of Total Phosphorus | | | | | | | |
| k _{tn} | m/yr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | |
| k _{TP} | m/yr | 10 | Rate coefficient for reduction of Total Phosphorus | | | | | | | |
| k _{20-TN} | m/yr | 21.5 | Median value rate coefficient for reduction of Total Nitrogen | | | | | | | |
| θ _{-τN} | - | 1.056 | Median Temp coefficient for Total Nitrogen | | | | | | | |
| θ | - | 0.986 | Median Temp coefficient for Total Phosphorus | | | | | | | |
| Т | °C | 8 | Average operating temperature | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in series/three treatment stages i.e 3 cells in series - P is 2 or 6 respectively (conservative value) | | | | lue) | | | |
| Design Flow | m3/d | 218 | Input flow rate into here | | | | | | | |
| Total annual hydraulic | m³/yr | 79570 | | | | | | | | |
| Total wotland area | ² | 15.000 | Active call area (i.e. avaluating diving barner, careador changels and laval control (structures) | | | | | | | |
| Total wettand area | H1 | 5,000 | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) | | | | | | | |
| q | ni/yr | 5.304666667 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 3.86 | NB. treated discharge from the wetla | and cannot be less than the back | ground concentrations, as it is r | ot possible to achieve i.e. | background conc will always be present | | | |
| contaminant, Ce - C* | % | 16.43 | | | | | | | | |
| Treatment efficiency of wetland | % | 83.57 | % of contaminant removed | | | | | | | |
| Tatal Dhaanhamu | | | | | | | | | | |
| Amount of remaining | | 0.97 | NR treated discharge from the wet | and cannot be less than the back | around concentrations as it is r | ot possible to achieve i e | background concivill always be present | | | |
| contaminant. Ce - C* | - % | 19 41 | ND. Treated discharge HOIII the Wells | and carnior be less than the back | Serveria concentrations, dS It IS I | or possible to achieve i.e. | background cone will always be present | | | |
| Treatment efficiency of wetland | % | 80.59 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
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| ARCADIS | | CALCULATIO | DNS | PROJECT No: | 30192602 Resilience - Water | 30192602 Reciliance - Water | | | | |
|--|-----------------------------------|--------------------------------|--|--|------------------------------------|--------------------------------|--|--|--|--|
| KEY | CLIENT: Ceredigion County Council | | | REVISION: | P01 | | | | | |
| | | | | AUTHOR: | RG | RG | | | | |
| Input values PROJECT: Calculated values | | Wetland Sites - Teifi Wetlands | | CHECKER: | EBP | | | | | |
| | | | | APPROVER: | 0 | | | | | |
| Linked values | SUBJECT: Process Design Calcula | | 1 Calculations - Tregaron | | 0 | | | | | |
| Assumed values | SECTION | | | DUC. NO: | U | | | | | |
| | SECTION: P-k-c | | | SHEET. | 3 | OF | 4 | | | |
| | _ | | | | | | | | | |
| Process Calculations | | | | | | | | | | |
| Parameter | Unit | Value | References/Comments | | | | | | | |
| Grav | mg/l | 25 | Influent concentration of Total Nitrog | zen | | | | | | |
| Citre | mg/l | 5 | Influent concentration of Total Phosp | Influent concentration of Total Phosohorus (Assumed Backstop/current TP) | | | | | | |
| С*ты | mg/l | 1.5 | Background concentration of Total Ni | Background concentration of Total Nitrogen | | | | | | |
| С*тр | mg/l | 0.022 | Background concentration of Total Phosphorus | | | | | | | |
| k _{TN} | m/vr | 11.18 | Rate coefficient for reduction of Total Nitrogen | | | | | | | |
| k _{rn} | m/yr | 10 | Bate coefficient for reduction of Trial Phosphorus | | | | | | | |
| | m/yr | 21 5 | Median value rate coefficient for reduction of Total Nitrogen | | | | | | | |
| θ | - | 1 056 | Median Temp coefficient for Total Nit | Median Pane contracts for Total Nitrogen | | | | | | |
| θ | | 0.986 | Median remp conficient for Total Photophorus | | | | | | | |
| Т | °C | 8 | Average negative temperature | | | | | | | |
| No. of treatment stages | - | 3 | | | | | | | | |
| Р | - | 6 | For one treatment stage i.e. 1 cell in series/three treatment stages i.e 3 cells in series - P is 2 or 6 respectively (conservative value) | | | | ue) | | | |
| Design Flow | m3/d | 218 | Input flow rate into here | _ | | | | | | |
| Total annual hydraulic | ³ / | 79570 | | | | | | | | |
| throughput | rri /yr | /33/0 | | | | | | | | |
| Total wetland area | m² | 7,500 | Active cell area (i.e. excluding diving berms, spreader channels and level control structures) | | | | | | | |
| q | m/yr | 10.60933333 | | | | | | | | |
| Total Nitrogen | | | | | | | | | | |
| Amount of remaining | - | 8.90 | NB. treated discharge from the wetla | nd cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | | |
| contaminant, Ce - C* | % | 37.87 | | | | | | | | |
| Treatment efficiency of wetland | % | 62.13 | % of contaminant removed | | | | | | | |
| Total Phosphorus | | | | | | | | | | |
| Amount of remaining | - | 2.07 | NB. treated discharge from the wetla | nd cannot be less than the back | ground concentrations, as it is no | ot possible to achieve i.e. I | background conc will always be present | | | |
| contaminant, Ce - C* | % | 41.67 | | | | | | | | |
| Treatment efficiency of wetland | % | 58.33 | % of contaminant removed | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| | | | PROJECT No: | No: 30192602 | | | |
|----------------------------------|---------------------------|------------------------------|-------------|--------------|----|---|--|
| /- | ARUADIS | CALCOLATIONS | GBA: | Resilienc | | | |
| CLIENT: | Caradigian County Council | | REVISION: | P01 | | | |
| | Cerealgion County Co | AUTHOR: | RG | | | | |
| PROJECT: | Wotland Sitos Toifi V | Notland Sites Taifi Watlands | | | | | |
| wellallu Siles - Telli Wellallus | | | APPROVER: | 0 | | | |
| SUBJECT: | Brocoss Design Calcul | ations Tragaron | DATE: | 45254 | | | |
| | Process Design Calcul | | | | | | |
| SECTION: | References | | SHEET: | 4 | OF | 4 | |

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{P}$$

C_i = Influent concentration of contaminant (mg/l)

- C_e = Effluent concentration of contaminant (mg/l)
- C^* = Background concentration of contaminant (in the wetland water column) (mg/l)
- k = Rate coefficient for reduction of contaminant (m/yr) P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.



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