Chichester District Council

Strategic Growth Study

Wastewater Treatment Options for Chichester District

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Contents

GLOSSARY OF TERMS

AMP4	-	Asset Management Period 4 (April 2005 to March 2010)
AMP5	-	Asset Management Period 5 (April 2010 to March 2015)
AMP6	-	Asset Management Period 6 (April 2015 to March 2020)
ASP	-	Activated Sludge Plant
BAT	-	Best Available Technology
BOD	-	Biological Oxygen Demand
CAPEX	-	Capital Expenditure
CDC	-	Chichester District Council
COD	-	Chemical Oxygen Demand
DWF	-	Dry Weather Flow
(%)DS	-	(Percent) Dry Solids
EIA	-	Environmental Impact Assessment
EA	-	Environment Agency
FFT	-	Full Flow to Treatment
HC	-	Harbour Conservancy
hd	-	Head (of population)
hh	-	Households
HT	-	Humus Tank
ICA	-	Instrumentation, Control and Automation
LDF	-	Local Development Framework
LSO	-	Long Sea Outfall
LPA	-	Local Planning Authority
MBBR	-	Moving Bed Biological Reactor
MBR	-	Membrane Biological Reactor
MLE	-	Modified Ludzack-Ettinger Process
M&E	-	Mechanical & Electrical
NE	-	Natural England
NH3	-	Ammonia
OPEX	-	Operational Expenditure
PR09	-	Periodic Review of Water Price Limits 2009
PR14	-	Periodic Review of Water Price Limits 2014
PR19	-	Periodic Review of Water Price Limits 2019
PS	-	Pumping Station
PST	-	Primary Settlement Tank
RAS	-	Return Activated Sludge (Sludge Returned to Head of ASP)
SAS	-	Surplus Activated Sludge (Sludge Removed from ASP)
SF	-	Sand Filter
SSSI	-	A Site of Special Scientific Interest
SS	-	Suspended Solids
SW	-	Southern Water
WLC	-	Whole Life Cost
UWWT	-	Urban Waste Water Treatment
WwTW	-	Wastewater Treatment Works
%ile	-	Percentile

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1. INTRODUCTION

As part of preparation for the Local Development Framework (LDF), Chichester District Council (CDC) has been developing its Core Strategy which will form part of the development plan for the District. The front loading of this process has led to the identification of a number of key planning constraints, one of which is wastewater treatment capacity within the district.

MWH were appointed by CDC on 20th October 2009 to undertake the strategic study of sewage treatment options in Chichester District. The study is to provide an assessment of various scenarios that may be employed in order to meet the development requirements for the region as set out in the South East Plan, published May 2009.

Previous to the under-taking of this study, CDC have held a series of meetings with stakeholders from various organisations that were perceived as likely to play a key role in assessing and finding solutions to capacity issues. We have continued to involve these organisations in the study since they are key to the planning, approval and implementation of a solution(s) to the deficit of wastewater treatment capacity within the district. These agencies include but are not necessarily limited to:

- Southern Water (SW)
- The Environment Agency (EA)
- Natural England (NE)

Southern Water and the Environment Agency have both produced position statements which have been used as support materials to produce this document. The Harbour Conservancy (HC) have been involved in the latter part of the study since their interests lie with the impacts of any solution selected on the water quality of Chichester Harbour.

This report seeks to substantiate a number of options that may offer a solution to the current treatment deficit, identified in the south of the district, and make recommendations on the viability and sustainability of each option. Four main areas were identified to MWH for investigation:

1) Reduction of infiltration into the Chichester catchment
2) Reduce consumption of water by existing and new customers
3) Transfer flows from Chichester to an alternative discharge location
4) Treat wastewater to standards more stringent than those which can currently be achieved using Best Available Technology (BAT)

Each viable option, identified within these categories, will be developed into a high level scoped solution to break down the major elements required for the successful implementation of a suitable scheme. This then allows for consideration of the factors that may impact the viability of the various components of each option and allow for an initial top down appraisal of the whole life solution cost. The purpose of this report is not to identify how treatment quality within the district may be improved, it is to identify viable strategies for future growth and demonstrate that the required levels of development are feasible, without causing deterioration in treatment quality to that achieved currently.

It is the intention that this work will aid in the facilitation of the decision making process behind selection of suitable site(s) for strategic housing development, within the LDF.

2. PROBLEM STATEMENT

2.1. Identification of Deficit

CDC state the requirement of new housing, as laid out in the South East Plan, is 480 dwellings per annum[1] (9,600 from 2006-2026) across the district. This translates to 355 dwellings per annum (7,100 from 2006-2026)[2] in the south of the district, where the treatment capacity deficit has been identified. CDC have expressed the desirability of allowing for the planning of the majority of these new dwellings around the current Chichester catchment. The provision however will ultimately be distributed across all of the treatment works in the south of the district.

2.2. Approach to the Problem

For the ease of analysis, this report will therefore consider the feasibility of providing the entirety of the required housing provision for the south of the district, around the city of Chichester over the 20 year timeframe. It is envisaged that this will act as a 'worst case scenario' for placing additional load on the Chichester treatment works. Any solution therefore, capable of providing this level of treatment, should be sufficient to cover the actual number of dwellings constructed which feed into the existing Chichester catchment. Although housing windfall may also further increase load to Chichester Treatment works, a significant proportion of the yearly provision requirement will be allocated amongst the other 5 catchments in the south of the district and therefore the actual load to the works will remain less than the entirety of the 20 year provision requirement.

Evaluation of the current treatment headroom available at Chichester and each of the south district works has been performed. This study has then reassessed and will give recommendations on the capability of each site to accommodate future growth.

2.3. Key Concepts

There are a number of key concepts which are critical to the comprehension of the problem to be addressed. In order to allow their discussion throughout the report, a brief description of each follows.

2.3.1. Dry Weather Flow

Dry Weather Flow (DWF) is the flow to the treatment works based on a dry period of time. The traditional EA definition is "the average daily flow to the treatment works during seven consecutive days without rain following seven days during which the rainfall did not exceed 0.25 millimeters on one day". During this dry period, flows to the works are considered to be resultant from residential and trade usage and not from rainfall entering the catchment. The EA has recently revised the definition of DWF in consents adopting the 20th percentile (%ile) of an annual flow record for planning purposes.

There is variability in this statistic from year to year due to weather effects. EA policy setting out how compliance assessment is to be undertaken to account for variable weather has yet to be developed. For this study the current measured DWF has been calculated as the largest 20%ile of the previous three years

[1] Strategic Growth Wastewater Treatment Options for Chichester District Tender Document
[2] Meeting Record 4-11-09 v1.1 Document

certified flow data to the WwTW, where available, analysed in three consecutive one-year sets.

There are two figures of importance here; first, the consented value of DWF from the EA; secondly the yearly measured DWF based on flow data recorded at the works. The works measured DWF will vary somewhat, year on year, dependent on whether the year is particularly wet or dry and with the usage of water by the residents and businesses within the catchment. This measured value should not exceed the EA's consented value or the works would be considered in breach of its discharge license.

2.3.2. DWF Headroom

The difference in value between the yearly measured DWF and the consented DWF for a given wastewater treatment site gives rise to the concept of "DWF headroom". The difference between these two values gives an evaluation of the additional trade and domestic flow that may be passed to a treatment works for treatment without exceeding the current consented DWF figure for the works.

It should be noted that although a works may still possess additional headroom and therefore be able to receive additional flows, this does not imply there is additional treatment capacity within the works to remove additional pollutant load that would be present in any additional flows received. A works with considerable DWF headroom may still require a significant upgrade to provide the hydraulic capacity at the site to allow the receipt of those additional flows and/or allow sufficient treatment capacity to treat the additional pollutant load and produce an effluent of the required quality.

2.3.3. Infiltration

Infiltration is the flow into the network via cracks and leaks in the pipes comprising the network. Infiltration is particularly prevalent in older networks where ground conditions over time have caused the pipes to shift and break. Infiltration is usually expressed as a percentage of the estimated daily usage in the catchment, equal to the total population multiplied by the daily consumption figure (170 l/hd/day).

Typically infiltration is estimated at 40% when sufficient flow data is not available for formal analysis, however this value can rise to well over 100% in older catchments, where the network has deteriorated significantly over time. It should be noted that infiltration does not include storm water ingress from, for example, water leaking through manhole covers during a storm event. This is termed separately as storm ingress. Infiltration will occur to some degree, whatever the weather conditions and therefore the degree of Infiltration impacts the DWF flow to a works.

2.3.4. Per Capita / Per Dwelling Water Usage

Assessment of headroom available will give a volumetric figure by which the flow to the works maybe increased. This cannot be simply and directly converted to a number of dwellings due to the large variation in water usage from household to household. To allow further analysis and plan for the future, a figure must be set that is believed to accurately represent the average new build households water usage per day and flow returned to sewer.

There are significant variations in the selection of per capita flow returned to sewer, infiltration percentage and household occupancy around the UK dependent on the location, housing age, housing type etc. The SW assumption for daily flow returned to sewer per person is 170 l/hd/day[3] at the planning horizon. The EA is pushing towards 130 l/hd/day in the future although this is a long term goal, unlikely to be met within the timeframe of this study. Taking these values and a per household population of 2.4 people and allowing for infiltration into the new network (assumed at 40% as most of the new development is assumed to require new sewers [the existing Chichester catchment infiltration is > 100%]) this predicts approximately 570 l/hh/day with the EA pushing towards 440 l/hh/day in the future. 500 l/hh/day has been adopted for this study. This is proposed as a reasonable estimate, given the degree of confidence in the flow data with which it is being used and the uncertainties in infiltration allowance, returned flow to sewer and assumed household occupancy. This figure was agreed with Chichester District Council and the major stakeholders during the initial stages of this study.

It should be noted that increase and decrease in trade flows would also impact the available DWF headroom at a works. No significant change in trade flows is anticipated in the catchments of any of the works considered within this study; therefore the available headroom in each will be assessed purely in terms of change in flows from domestic properties.

2.3.5. Load Standstill

There are numerous examples of sites where the dry weather flow has been anticipated to increase above the EA consented value. In this situation, the EA will re-assess the site and review the DWF consent. Together with its flow discharge consent, the works will also hold a number of other consents relating to the discharge concentrations of a number of key pollutants such as ammonia and phosphorus although the actual consented pollutants will vary from site to site.

During the review of the works DWF consent, the EA will also look at revising the pollutant concentrations and a key concept in the way this will occur is that of Load Standstill. The main concern from discharging treated sewage to a water course is the mass of each pollutant that is released into the environment. The mass of pollutant released is equal to flow released in a defined time, multiplied by its concentration during that time period. To ensure that the treatment works does not cause deterioration in water quality over time, the mass of each pollutant should at least remain unchanged with any flow increase to the works. This is described by the equation below:

$$Flow_1 \times Concentration_1 = Flow_2 \times Concentration_2 = \text{Constant}$$

Thus, if an increased flow is allowed from the works that exceeds the consented DWF, the concentration of any consented pollutant at the works will need to be decreased sufficiently so that the mass of the pollutant leaving the works at least remains unchanged. Subject to water modeling, the EA may also decide to reduce the mass discharged or add a new consented pollutant, however in the absence of any firm decision on these figures, the load standstill principal as outlined above would be assumed.

2.3.6. Best Available Technology

There are numerous types of technology employed to deliver the required treatment standards across the wastewater treatment works of the UK and all around the world. Amongst the various pollutants consented for in the UK, there are commonly accepted levels of treatment that are known to be feasible from technological trials or current operating installations. These take the form of

[3] SW Planning horizon figure

minimum achievable effluent concentrations of each parameter, referred to as Best Available Technology (BAT) levels of treatment. These act as current real world limits of treatment and thus, in conjunction with load standstill, limit the level to which flows through a works may be increased by capping the level to which it is possible to decrease a pollutant concentration to.

In terms of this study, works that are already operating with one or more pollutant concentrations close to or at the BAT level for that determinand are severely limited by lacking the flexibility to increase the DWF and accommodate more treatment. Without challenging the BAT levels, there is only a finite and very limited amount of headroom left at any works currently in this position and thus this limit is responsible for the current headroom deficit within the district.

For the purposes of this study, the current assumed BAT levels for each of the main pollutants are given in Table 1, based on the minimum effluent pollutant levels that SW have currently accepted, across their sites in the UK:

Table 1 – Current South UK BAT Treatment Levels

Determinand Type	Consented Concentration	SW Reference Site
Suspended Solids	8 mg/l, 95%ile	Goddard's Green
BOD	5 mg/l, 95%ile	Horsham
Ammonia	1 mg/l, 95%ile [6 mg/l UT]	Lyndhurst
Total Nitrogen	9 mg/l Annual Average	Chichester
Phosphorus	1 mg/l Annual Average	Charing
Iron	1 mg/l Annual Average	Charing

2.4. Assessments of Existing treatment Works

There are 6 treatment works present within the south Chichester district in which a treatment deficit has been identified. The headroom available at each site, based on the current measured and consented DWF for each works is tabulated below:

Table 2 – Dry Weather Flow Headroom Analysis for WwTWs in the South Chichester District

WwTW	Consented DWF (m^3/day)	EA DWF (m^3/day) [Highest Tabulated] [4]	SW DWF (m^3/day) [5]	MWH DWF (m^3/day)	Minimum Headroom (m^3/day) [6]	Estimated Dwelling Capacity from April 2006 (hh) [7]
Bosham	1221	1072.6	871	1072	148.4	297
Chichester	13524	12000	12024	11889	1500	3000
Pagham	2309	2192.4	2139	2005	116.6	233
Sidlesham	5800	5196	5100	5193	604	1208
Tangmere	1500	1078.4	950	1078	421.6	843
Thornham	6565	6260	5715	6288	277	554

It should be noted that the SW figures apply to 2006 data which corresponds to the start of the 20 year time period to which this assessment applies. MWH and

[4] Table 1, EA Position Statement
[5] SW DWF assessments, back-calculated based on estimated values for remaining headroom from Table 2, SW Position Statement
[6] Assuming the least favourable of the various yearly DWF assessments available
[7] Based on household consumption figure of 500 l/hd/day

EA assessments represent the maximum assessed flow figures from the last 3 years which align with 2008 data which was known to be a wet year. The 2008 data also includes flows from any completed builds at the start of the 2006-2026 timeframe.

Using 2008 data to calculate available headroom could therefore be seen as a pessimistic approach to calculating remaining DWF headroom. Uncertainty with respect to future changes in climate however could lead to future, wetter years which would have associated higher measured DWF figures. If this transpires, it is possible that the EA would observe measured DWF figures in exceedance of the consented DWF figure for that works and then re-assess the consented DWF and pollutant consents. To capture a worst case scenario the currently available headroom at each works has been assessed based on the least favourable currently available DWF figures.

The estimated headroom is shown below for all the identified sites. The anticipated remaining headroom at the end of the April 2015 is calculated, based on the total planned housing provision in each catchment and the current DWF headroom.

Table 3 – Analysis of Estimated Remaining Headroom from April 2015 updated from 5 year housing land supply 2010-2015

WwTW	Estimated Headroom from April 2006 (hh)	Current housing to be constructed from 2006-->2015 (hh) [8]	Estimated remaining housing capacity from April 2015 (hh)
Bosham	297	117	180
Chichester	3000	2246	**754**
Pagham	233	22	211
Sidlesham	1208	311	897
Tangmere	843	446	397
Thornham	554	173	381
Lavant	1392 [9]	98	1294

Current housing figures are based on completions from 1st April 2006 to 31st March 2009, plus outstanding planning permissions as at 31st December 2009. Potential housing sites which do not yet have planning permission (e.g Roussillon Barracks) have been excluded from these figures.

From this analysis, there is currently sufficient DWF headroom available within all of the catchments to allow for all of the housing requirements to be completed by the end of April 2015. There also remains DWF headroom at each of the works for construction into AMP6, the 6th Asset Management Period for the UK water industries. However, unless the anticipated headroom at each works is specifically used to determine where new housing developments are located, the issue of treatment deficit will likely be encountered during 2016, assuming that the planned housing is constructed and occupied. It is therefore critical that any solution to overcome the identified deficit issue is completed early in AMP6 to ensure sufficient capacity to the 2026 horizon.

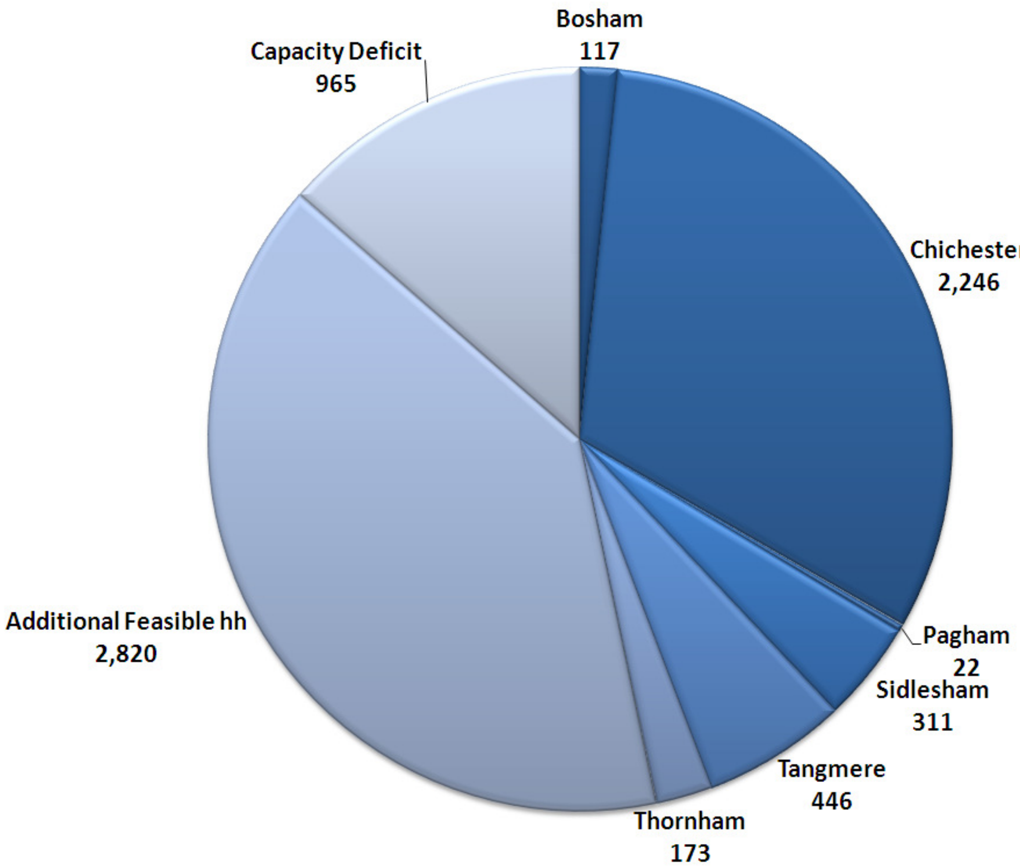
Prior to each AMP period, the major water utility companies prepare a Business Plan which they submit to OFWAT, detailing the key areas in which they require funding for asset maintenance and for schemes where population growth or quality improvements are anticipated. OFWAT they determine the level of funding they believe is appropriate and after the final determination and commencement

[8] Table 2, Southern Water Position Statement
[9] Figure agreed with SW based on measured DWF ≈1,000 m^3/day

of the AMP period, the various schemes commence. A suitable solution here would require funding through this process and since AMP5 is about to commence, would need to be included in SW's AMP6 Business Plan to secure funding.

Figure 1 depicts the current distribution of housing completions from 2006 and dwellings expected to come forward to 2015[8] as a fraction of the 7,100 dwellings required across the 20 year period.

Figure 1 – Total Southern District Housing Requirement to 2026 (Figures in hh)



The housing requirement of 3,785 dwellings (3,315 anticipated to be constructed to April 2015, as detailed in Table 3, excluding Lavant since this district is categorised as being in the North of the district) remains in comparison to the total estimated remaining headroom in the six sites in the south of the district of 2,820. Thus the absolute housing deficit, assuming full allocation around all existing catchments, is 965 dwellings. However, since future developments are most likely to be desirable around the Chichester catchment, it must be assumed that all additional flow would enter this catchment alone.

With the assessed remaining headroom at Chichester WwTW of approximately 754 dwellings by April 2015, this leaves a future deficit of treatment capacity for about 3,764 – 754 households, approximately **3,000 households**.

The following sections cover a basic assessment of the likely capacity and future flexibility with respect to growth of each of the aforementioned sites. Plausible future consents are described in each case and are based on the principle of load standstill and limited to the current BAT limits detailed in Table 1, unless otherwise stated. Although not within the list of treatment works in the south of the district, Lavant WwTW is located just to the North of the current Chichester catchment. This close proximity to the current Chichester catchment obligates further investigation to identify if this works may also be utilised to create additional DWF headroom around Chichester. Lavant WwTW will therefore also be assessed as part of a viable solution. Figure 2 shows the location of each of the sites.

Figure 2 – Satellite Map of WTW Locations in or bordering the South of Chichester District

2.4.1. Bosham WwTW

Bosham WwTW is located to the South West of Chichester between Bosham Channel and Chichester Channel.

Figure 3 – Aerial Photo of Bosham WwTW

The works currently serves a population equivalent of 3,657 residents. The AMP5 works consents together with a conceivable future consent structure are tabulated below and the works DWF headroom listed in Table 3:

Table 4 – Feasible Future Consent Structures for Bosham WwTW

Determinand	Current or AMP5 Consent (mg/l unless stated)	Feasible Future Consent (Load Standstill)
DWF	1,221 m^3/day	1,357 m^3/day
Suspended Solids	45	40.5
BOD	50 [100 Upper Tier]	45 [90 Upper Tier]
Total N	10	9
Phosphorus	None	None anticipated

Since Bosham is already operating with a Total N consent close to the current accepted BAT level, there is very limited scope for increased headroom at the works if considering applying load standstill and up-rating the DWF.

The current treatment performance at Bosham indicates that the consents are being comfortably met currently apart from Total N which is very close to the current consent of 15mg/l. Modification to the exiting works methanol dosing system is planned under AMP5 to achieve the new Total N consent of 10mg/l however this is based on minimal projected growth within this catchment. Increasing development around the catchment to any significant degree may leave the works with additional DWF headroom but without the required treatment capacity to meet the 10 mg/l Total N consent. A significant upgrade to the works would be required and need to be completed if any substantial additional load is to be treated by the works. Due to the small increase in additional headroom that this would yield, even considering increasing the DWF consent and reducing the consented Total N to 9 mg/l, Bosham WwTW would be unable to provide sufficient additional treatment capacity to significantly address the identified treatment deficit. Extended use of and modification to Bosham WwTW cannot therefore be recommended as offering a significant contribution towards resolving the headroom deficit.

2.4.2. Chichester WwTW

Chichester WwTW is located to the South West of the City of Chichester, close to the North end of the Chichester Channel.

Figure 4 – Aerial Photo of Chichester WwTW

The works currently serves a population equivalent of 34,047 residents. The AMP5 consents are tabulated below, based on the works continuing to discharge into the Chichester Channel and the DWF headroom listed in Table 3. The harbour itself is a transitional and coastal water body and has a number of designations including an EU Special Protection Area under the Birds Directive, a Ramsar Site for the associated wetlands and as a Special Area of Conservation.

Table 5 – AMP5 Consent Structure for Chichester WwTW

Determinand	Current or AMP5 Consent (mg/l unless stated)
DWF	13,524 m^3/day
Suspended Solids	45
BOD	35 [70 Upper Tier]
Total N	9.0
Phosphorus	None

It should be noted that there is also a UV treatment requirement as a result of the Shellfish Waters Directive, due to the proximity of discharge to designated shellfish waters. There is currently no option to up-rate the consented DWF figure since the works consent will shortly be set at the current BAT treatment limit. This restricts any solution involving Chichester works itself to challenging the current accepted BAT Total N treatment limit or changing the works discharge point such that the discharge consent may be relaxed and DWF headroom increased.

Trade flows at Chichester Works are not anticipated to vary in the immediate future and therefore, DWF headroom capacity may be evaluated purely in terms of change in daily volume of domestic flow to the works.

2.4.3. Pagham WwTW

Pagham WwTW is located to the North East of Pagham Harbour.

Figure 5 – Aerial Photo of Pagham WwTW

The works currently serves a population equivalent of 8,221 residents. The current works consents, together with a conceivable future consent structure are tabulated below and the current estimated DWF headroom listed in Table 3:

Table 6 – Feasible Future Consent Structures for Pagham WwTW

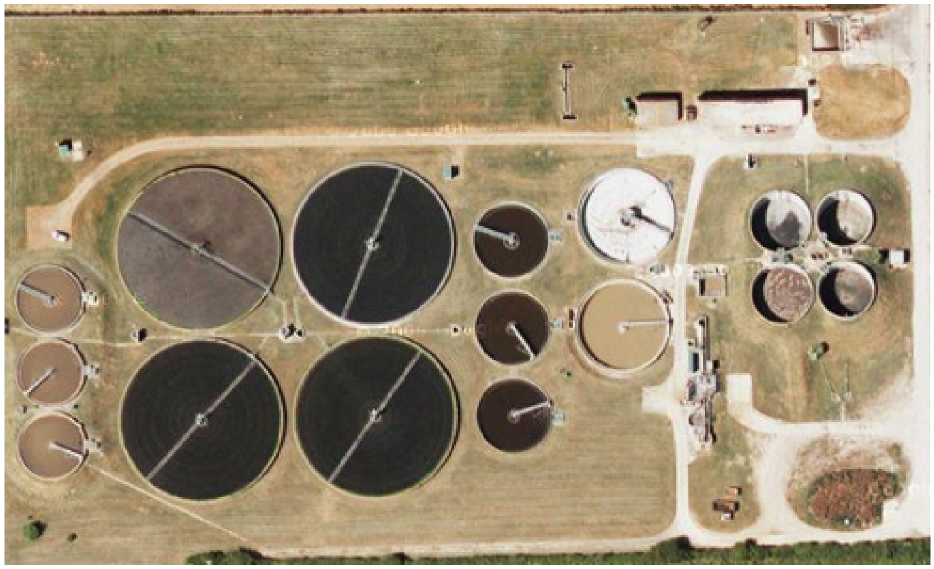
Determinand	**Current or AMP5 Consent (mg/l unless stated)**	**Feasible Future Consent (Load Standstill)**
DWF	2,309 m^3/day	5,772.5 m^3/day
Suspended Solids	25	8
BOD	15 [50 Upper Tier]	5 [17 Upper Tier]
Ammonia	5	1.7
Total N	None	Likely in the near future
Phosphorus	None	Possible in AMP6

Since Pagham WwTW is not BAT limited, there is significant scope for up-rating the consented DWF as shown by the feasible future consent above. The difficulty lies with the likelihood that Pagham WwTW may receive a Total N consent in the near future since the works discharges into Pagham Harbour and this which would likely limit flexibility for expansion. The site also receives flows from residences in both Chichester and Arun districts and therefore any headroom identified also needs to allow for growth within the catchments in the district of Arun serving the works. Finally, Pagham works is located a significant distance away from Chichester, complicating transfer of flow to the works.

2.4.4. Sidlesham WwTW

Sidlesham WwTW is located to the South of Chichester and to the West of Pagham Harbour.

Figure 6 – Aerial Photo of Sidlesham WwTW



The works currently serves a population equivalent of 26,841 residents. The current works consents are tabulated below and the current estimated DWF headroom listed in Table 3:

Table 7 – AMP5 Consent Structure for Sidlesham WwTW

Determinand	**Current or AMP5 Consent (mg/l unless stated)**
DWF	5,800 m^3/day
Suspended Solids	40
BOD	9 [64 Upper Tier]
Ammonia	3
Total N	15
Phosphorus	1 (Iron Upper Tier of 3 mg/l)

Sidlesham is currently limited at the BAT level for Phosphorus removal as the current consent is already set at 1 mg/l. Thus the remaining headroom at Sidlesham can be utilised but it is not possible to further increase the available headroom by consideration of the application of load standstill to the existing DWF and pollutant consents. The works capacity of the current works is stretched and although there is scope for additional treatment by the current works, it is likely an upgrade would be required to allow the full identified DWF headroom to be used.

2.4.5. Tangmere WwTW

Tangmere WwTW is located to the East of Chichester, to the East of Tangmere and South of the A27.

Figure 7 – Aerial Photo of Tangmere WwTW

The works serves a population equivalent of 4,312 residents. The current works consents, together with a conceivable future consent structure, are tabulated below and the current estimated DWF headroom listed in Table 3:

Table 8 – Feasible Future Consent Structures for Tangmere WwTW

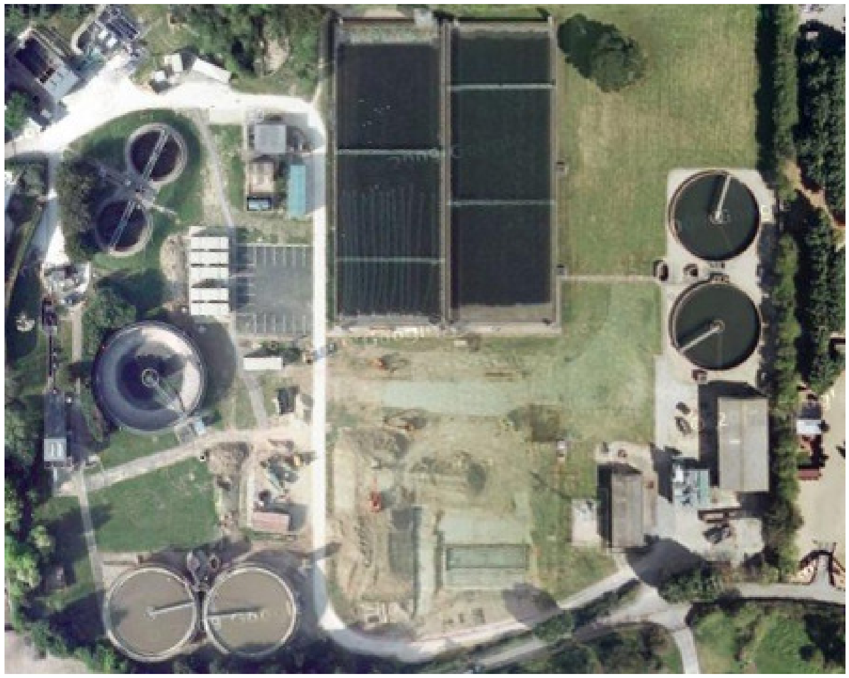
Determinand	**Current or AMP5 Consent (mg/l unless stated)**	**Feasible Future Consent (Load Standstill)**
DWF	1,500 m^3/day	3,000 m^3/day
Suspended Solids	20 [30 Winter]	10 [15 Winter]
BOD	10 [20 Winter]	5 [10 Winter]
Ammonia	3 [5 Winter]	1.5 [2.5 Winter]
Phosphorus	None	Possible within AMP6

To become BAT limited, the DWF figure at Tangmere could be doubled to 3,000 m^3/day, at which point, the BOD level would become BAT limited. This additional 1,500 m3/day of flow is almost identical to that calculated as required to meet housing demands to 2026 around Chichester. Thus, together with the estimated headroom remaining in 2015 as detailed in Table 3, it appears Tangmere works may be a viable site to provide the treatment capacity for the required growth around Chichester. The works however is currently close to reaching its loading limit; hence developing a solution suitable for treating these additional flows to the required discharge standard would necessitate a major upgrade to the current facilities at a significant cost.

2.4.6. Thornham WwTW

Thornham WwTW is several km West of Chichester, adjacent to Thorney Island.

Figure 8 – Aerial Photo of Thornham WwTW



The works currently serves a population equivalent of 20,089 residents. The AMP5 works consents, together with a conceivable future consents structure, are tabulated below and the current estimated DWF headroom listed in Table 3:

Table 9 – Feasible Future Consent Structures for Thornham WwTW

Determinand	Current or AMP5 Consent (mg/l unless stated)	Feasible Future Consent (Load Standstill)
DWF	6,565 m^3/day	7,294 m^3/day
Suspended Solids	60	54
BOD	30 [64 Winter]	27 [57.6 Winter]
Total N	10	9
Phosphorus	None	Not currently anticipated

Thornham WwTW will, during AMP5, adopt a Total N consent close to the limits of the current BAT, limiting the possible additional increase in development feasible from prorating the existing consents. The works is not ideally situated to transfer flows to and/or from any part of the Chichester catchment and again is shared between Havant and Chichester Districts: any headroom capacity developed at the works would need to be shared between the catchment growths in both districts. Finally the works will be extremely close to its loading limit after the reduction of the Total N consent from 15 mg/l to 10 mg/l which would necessitate a major upgrade to the works to allow for any significant growth. These series of issues prevent extended use of and modification to Thornham WwTW from being recommended as acting as any major contributor towards resolving the identified treatment deficit.

2.4.7. Lavant WwTW

Lavant WwTW is located just to the North of the City of Chichester. The works is not technically classed as being within the south of the district; however its location so close to the Northern Chichester catchment makes the works an interesting candidate for possible transfer of flows from Chichester.

Figure 9 – Aerial Photo of Lavant WwTW

The works currently serves a population equivalent of 2,326 residents. The current works consents, together with a conceivable future consent structure, are tabulated below and the current estimated DWF headroom listed in Table 3:

Table 10 – Feasible Future Consent Structures for Lavant WwTW

Determinand	Current or AMP5 Consent (mg/l unless stated)	Feasible Future Consent (Load Standstill)
DWF	1,696 m^3/day	3,392 m^3/day (2,882 m^3/day)
Suspended Solids	40	20 (23.5)
BOD	20 [56 Winter]	10 [28 Winter] (11.8 [33])
Ammonia	Currently none	Unknown
Phosphorus	Currently none	Possible within AMP6
Nitrogen	Currently none	Possible within AMP6

The current pollutant consents at Lavant offer a significant opportunity for increasing the consented DWF flow to the works since they are currently much greater than the accepted BAT limits. However, the quality of the receiving water is of concern to the EA and hence it is anticipated that the works would be the subject of a quality improvement scheme in the near future.

3. OPTION IDENTIFICATION AND ASSESSMENT

A number of panel sessions were carried out with senior engineers and technical experts within MWH. This allowed the production of a relatively exhaustive list of possible options to allow for future growth around Chichester. Three main categorisations of solutions were made: “At Source” solutions; “Transfer” solutions and “Improvement on BAT” solutions.

3.1. “At Source” Solutions

These range of solutions consisted of developing practices, systems or technologies that would reduce the per capita flow into the sewerage network and hence reduce DWF flow to works, stretching the available DWF headroom and allowing sufficient housing allocation.

Generally it is considered that “at source” solutions that prevent the flows entering the infrastructure in the first place form the most sustainable solutions. However, they depend very much on variable factors such a public uptake and specific successes with regard to infiltration reduction. They are therefore seen as unreliable and any benefit they may provide, difficult to quantify.

3.1.1. Reduce Infiltration Into Chichester Network

Infiltration is water that enters a sewerage system from the surrounding ground, most commonly this is through cracks in the sewer pipes or sewerage chambers.

The Chichester sewerage network is known to suffer from significant levels of infiltration and therefore, one possible solution in reducing the overall flow to Chichester Wastewater Treatment Works (WwTW) would be to reduce the volume of water that enters the sewerage network that feeds the WwTW.

However, it is notoriously difficult to achieve significant benefits from infiltration schemes. There is widespread evidence, both in the UK and globally, that expensive action to reduce I/I (inflow and infiltration) has often resulted in minimal improvement, and even the gains that have been made have proved short lived.

A Chichester Infiltration Study was originally proposed in Southern Water’s Business Plan for 2010 to 2015. However, this study has not been funded as a defined output in the recent OFWAT Final Determination. Southern Water is currently reviewing the prioritisation of work in the light of the Final Determination and will not be in a position to comment further until Easter 2010 at the earliest.

An Infiltration Study would require significant modelling, flow data recording, study of sewer records, consideration of ground conditions and selective visual inspection at manholes in appropriate conditions. This can take a significant period of time and therefore, even if the study were to proceed, the results might not be achievable in line with the timescale required (2017).

Another feature of infiltration schemes is that, even if the modelling and desktop studies suggest some discrete points where infiltration is entering the sewerage system, then remediation of these areas may not have the desired effect. Often rehabilitation works will result in the level of the groundwater table increasing and the flow entering the network through a different point (eventually through private laterals).

It should also be noted that there is never any guarantee that a particular level of infiltration reduction can be achieved and therefore it would not be appropriate to consider this option a certain solution to the issue in question.

In the case of Chichester, it is known that the catchment is particularly flat and suffers from surface water flooding. These types of catchment are less likely to achieve significant reductions in infiltration than those with a more varied topography.

Conclusion: the reduction of infiltration can be a sustainable method of reducing flows to the receiving sewage treatment works. However, the topography and history of flooding in Chichester District suggest that this might not be a catchment where a significant reduction in infiltration can be readily achieved. This fact, combined with the notorious unreliability of infiltration schemes and the necessary programme, means that it is highly unlikely that significant benefits in infiltration can be achieved within the timescales in question. It would be advantageous to better understand infiltration into the Chichester network and the extent to which this may be reduced. A study is recommended but until the results are published, this cannot be relied upon as an effective solution to guarantee future growth. It was therefore agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued any further as part of this study.

3.1.2. Reduce Per Capita Water Consumption

A reduction in the per capita consumption of water in Chichester District would have an equivalent reduction in the volume of wastewater received at Chichester WwTW. Portsmouth Water provides drinking water to the city of Chichester.

Portsmouth Water has proposed a number of water saving initiatives in their draft Water Resource Plan 2009 (dated May 2008). These include:-

- A targeted Mains Renewal Programme
- A Leakage Savings Initiative
- A Water Efficiency Programme which will include sending cistern devices to all customers starting in 2010/11.
- A programme of retrofitting of dual flush devices in existing toilets.

It should be noted, however, that at the time of writing this report the draft Water Resource Plan has not yet been agreed by DEFRA. Therefore, there is no guarantee at this stage that the above will be implemented in full.

Portsmouth Water's measurements show that the average amount of water used per person in a household has been rising steadily for many years. The implementation of water metering (evidence suggests a 10% reduction in water consumption) and other efficiency measures, combined with a public awareness campaign can contribute towards reducing this trend. A target of stabilising the per capita consumption is therefore considered more realistic compared to bringing about significant reductions.

It should also be noted that there is no guarantee that a particular level of per capita water consumption reduction can be achieved and therefore it would not be appropriate to consider this option a guaranteed solution to solving the wastewater treatment capacity problem. In addition, the reduction in water demand is the responsibility of Portsmouth Water (rather than Southern Water), who will have different company issues and objectives.

Conclusion: The reduction in per capita consumption is recommendable and should be promoted through the measures Portsmouth Water has raised in their Draft Water Resources Plan. Compulsory water metering is highly recommended since in the long term, this represents one of the most sustainable options for improving the efficiency of water usage. There is however, no guarantee that water reductions can be realised and the process falls outside the control of the stakeholders responsible for delivering the sewage treatment strategy. For these reasons it was agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued any further as a major solution as part of this study however it should be recommended for incorporation in future policy to help minimise the overall deficit issue.

3.1.3. Reduce Existing Connections to Wastewater System

Connections into the existing wastewater system can be reduced in a number of ways:

- Exploring ways of reducing highway flows. Potentially this could include financial incentives / disincentives to the Highways Authority to bear any cost in relation to the burden they place on the sewerage system. Currently the Highways Authority has no significant incentive to minimise their discharges to public sewers or to provide Sustainable Urban Drainage Systems (SUDS).

- Diverting surface water connections from combined systems to washouts or land drains. Detecting these connections can be problematic and often a full network modelling exercise is required to identify areas of the network where unusually high flows could indicate surface water connections.

- Rainwater harvesting. This could include:

  (i) Public water butts. A public engagement campaign would encourage the public to utilise these devices. Where this is combined with a metered supply there is a financial incentive in the reduced flow through the meter, saving on both water and sewerage charges.

  (ii) Collection of rainwater and use in WCs. This would be simple and effective (unlike water butts, this will be effective all through the year and much more significant in terms of flow reduction). Again, if combined with a metered supply this could provide a financial incentive.

  (iii) Also, replacing treated mains water used in industrial processes with rainwater could be a financially attractive option. Rainwater harvesting can have positive benefit/cost on commercial/industrial developments, where it might also be coupled with grey water re-use.

- Charging customers for surface water disposal on the basis of paved area of plot and/or type/size of house. This would be a more equitable basis than the existing one and OFWAT is keen that the industry should move in this direction. The OFWAT circular RD 35/03 is particularly relevant. One company has already gone some way to implementing charging on these lines, while others are committed and prepared to do the same

Conclusion: The majority of the flow reduction that could be realised as a result of implementing the above measures would be rainfall related flow. Preventing rain run-off from entering the sewerage system would not substantially affect the DWF figure since this figure is a measure of the flow in dry weather conditions. Therefore, although these measures would likely slightly depress the 20%ile value of a year’s flow data (from which DWF flow is calculated) they would not be anticipated to significantly alter any of the flow data below the 20%ile since this portion of the flows will generally have occurred under dry weather conditions. Hence, these measures cannot be recommended as effective strategies for increasing DWF headroom. For this reason it was agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued any further as part of this study

3.1.4. Urine Separation for Toilets in New Housing

Separation of urine and or faeces using specially designed toilet facilities allows concentrated waste to be removed and stored for treatment. This in turn prevents this pollutant load from entering the sewerage system and reaching the works for treatment. This practice will reduce loading onto the local wastewater treatment works and also can have additional benefits if the separated waste is processed into a usable by-product such as the processing and precipitation of the nutrients present into struvite, which may be used as a fertilizer.

This practice has a number of disadvantages in the context of this project:

1. To allow for at-source waste capture, specialist toilet facilities are required that are designed to collect and store these materials and/or transfer them to a centralised storage area. Retro-fitting these facilities into existing properties would only be possible at considerable expense and this really limits application to new-build schemes only.

2. The cost of running the system has been estimated in the region of £30-50 per person per year and thus residents would need to be willing to take part in any scheme or subsidy sought to cover these costs. In addition these costs assume a certain minimum partition level; a scheme involving too small a number of properties would not be economically viable.

3. Preventing urine from entering the system would reduce the loading onto the works but only have minimal impact on the volume of flow to the works since the actual volume of urine only represents a small fraction of the overall domestic generated flow. Therefore, even widespread adoption of this practice would be ineffective at significantly reducing catchment flows.

Conclusion: given the difficulties and expense of adopting this approach and the limited scope for DWF reduction as a result of implementation, this option cannot be recommended as a major strategy to reduce DWF flows. It can however be recommended to developers as an innovative technology that may be employed in new build developments with the benefit of struvite production becoming highly desirable in the near future as other sources of phosphorus containing fertilisers become more scarce, driving up their price. It was agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.1.5. Local Distributed Treatment for New Housing

Small scale treatment systems are available, designed to treat household waste on a small scale. These range from units designed to treat the waste of one household to larger scale systems that may treat the waste for an entire housing estate. It might appear possible that the use of these units might prevent flows from needing to be sent to local treatment works for processing and circumvent the identified problem of a lack of treatment capacity at the works. There are however many reasons why this approach would be unacceptable:

1. It is the type and quality of the receiving water that sets the treatment requirements of any wastewater treatment works. The effluent load entering a river is what will ultimately impact the conditions present in the watercourse and affect the flora and fauna that live there. Thirty small treatment works discharging 10 m^3 of flow a day would have the same

impact as one large works discharging 300 m^3 if the effluent qualities are comparable. Therefore just building another small scale works would be ineffective at increasing treatment headroom.

2. The EA are unwilling to grant discharge consents to private treatment systems when developments are in close enough proximity to an existing public sewer that could reasonably be connected into. This is for good reason, private systems are much more difficult to monitor and therefore carry significantly higher operational risk than public systems with poor maintenance or negligence of such schemes resulting in pollution of the receiving waters.

3. The effluent consents for the treatment works currently discharging into the various watercourses in the south of the district are already particularly stringent due to the sensitivity of the receiving waters with wetlands and bathing waters common features amongst many of them. A small scale works would also need to treat to these stringent levels for it to be acceptable to discharge without detrimental effects on the receiving water. The treatment available from the state of the art technology currently in use at the large municipal wastewater works cannot easily be duplicated in with significant confidence, on a small scale. The systems on the market for example, are not commonly designed to meet Total N consents or tight Phosphorus limits.

Conclusion: It would not be possible to recommend locally distributed treatment as a solution since these schemes have not generally been shown to operate effectively and as such the EA is unwilling to grant discharge licenses for them when a local public sewer system already exists which would be the case around Chichester. For this reason, it was agreed at the stakeholder meeting on 4th November 2009, that this option would not form part of a suitable solution and therefore would not be pursued any further as part of this study.

3.1.6. Local Recycling Schemes for New Houses

The “Code for Sustainable Homes” dated December 2006 provides standards for the efficiency of new housing.

In the Water Category, the following code levels are linked to the litres consumed per person per day as follows:

Code Levels 1 and 2: 120 litres per person per day

Code Levels 3 and 4: 105 litres per person per day

Code Levels 5 and 6: 80 litres per person per day

The document then gives practical examples of the measures required to achieve the flows designated to each category, as shown in the table below:

Table 11 – Design Features Recommended for Sustainable Homes

Code Level	1	3	6
Design Features Suggested to achieve required flow.	6/4 Dual Flush WC Flow Reducing / aerating taps throughout 6-9 litres per minute shower 18l max volume dishwasher 60l max volume washing machine	6/4 Dual Flush WC Flow Reducing / aerating taps throughout 6-9 litres per minute shower A smaller shaped bath 18l max volume dishwasher 60l max volume washing machine	6/4 Dual Flush WC Flow Reducing / aerating taps throughout 6-9 litres per minute shower A smaller shaped bath 18l max volume dishwasher 60l max volume washing machine 30% of the water requirement of the home to be provided from non-potable sources such as rainwater harvesting schemes

It is clearly desirable, for a catchment where there are constraints on the wastewater treatment capacity, for stringent standards to be imposed on the efficiency of any new housing.

Current calculations on remaining headroom are based on the standard of 170 litres per person per day. If this can be substantially reduced by imposing a high category of water efficiency to any new housing then this will reduce the cost of any new site upgrade (as subsequently described in this report) and will also extend the date by which any new construction is required.

In addition to the above measures, research has shown that the fitting of smart meters can significantly reduce water consumption. It allows the user to record and evaluate water consumption on-line. This gives the user a clearer idea of how much water is being used and allows them to look at trends in water consumption.

It should also be noted that experience from overseas points clearly to the need for post-construction audits in order to ensure that buildings constructed in accordance with the building codes actually perform to the required standards. Performance is also an issue at the regulatory level in England and Wales with alarmingly high proportion of new buildings currently not complying with basic energy regulations[12]. For the new water efficiency standards to be effective, enforcement of regulations needs to be improved

Conclusion: The adoption of high efficiency housing principles are highly commendable in an area where there is significant constraint on the wastewater network. It should be noted though that this only applies to new housing and there is no firm guarantee that adopting these measures will have an exact impact on the wastewater network flows. This option is to be recommended, however the options that involve infrastructure development shall be progressed without the impact of this option being taken into account.

3.1.7. Re-Use Effluent from Chichester STW

This option would comprise diverting the STW effluent to end users where the flows would be used for irrigation and would therefore not flow into the Chichester Channel.

This option has a number of disadvantages.

1. The nature of the end users requirements for irrigation water is rarely continuous and this complicates accounting for sufficient flow diversion from the typical discharge point as there are likely to be prolonged times when one or more of the end users do not require flow. This would necessitate discharge of this flow and lead to exceedance of the EA DWF consent.

2. Excessive irrigation of the surrounding areas, in order to dispense with sufficient flow to meet the DWF consent, has the potential to cause localised flooding.

3. There is a prevalence of salad crops grown in the Chichester district. The nature of this type of crop makes it extremely unlikely that wastewater effluent would be desirable as an irrigation source to the farmers or indeed licensed for such a use. It would therefore be necessary to identify another potential source of users which currently appears unlikely.

Conclusion: The lack of confidence in relatively continuous demand for final effluent and low likelihood it will be acceptable for use anyway means that this option is unlikely to be a suitable solution and was therefore ruled out at the stakeholder meeting on 4th November 2009.

3.1.8. Send Chichester Effluent to Local Drinking Water Treatment Works

The option is termed as “direct effluent re-use” and is a process whereby sewage effluent is treated to a sufficiently high quality so that it can be used as potable supply without dilution.

There are several major disadvantages with this option:

- Public Perception: there are currently no examples of direct effluent reuse in the UK. The public are unlikely to be amenable to such a concept and considerable bad publicity could result (e.g. at Hanningfield when an expose by the Sun newspaper lead to widespread public outrage and an alternative solution had to be sought).

- The treatment requirements are certain to be prohibitively expensive in the context of this scheme both in terms of capital and operational expenditure and, in general terms, effluent re-use is only considered commercial feasible in resource zones where there is a considerable deficit in water supply over future years

Conclusion: for the significant reasons stated above, it was agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.1.9. Aquifer Recharge

Aquifer recharge is a process whereby the effluent from a sewage treatment works is injected into an aquifer, potentially for subsequent abstraction for drinking water purposes or in lieu of drinking water abstracted further up the groundwater catchment.

Normally, the course of investigations would be as follows:

- Undertaking of detailed water quality sampling of the wastewater treatment effluent to gain a full understanding of the constituents.

- Desk study work and site investigations to determine the geology and hydrogeology of the underlying aquifer. In the case of Chichester it is known that the geology has additional complexity due to structural faults and folds and therefore this stage could involve significant investigations. However structural complexity typically enhances the feasibility of artificial recharge.

- Modelling of the aquifer recharge to determine whether there would be any derogation of local environment and ground water quality.

As the aquifer beneath Chichester is used for drinking water abstraction, it is likely that the Environment Agency will require any effluent to be treated to drinking water quality. This will certainly involve treatment using membranes (ultra-filtration) and potentially reverse osmosis depending on the requirement to reduce total dissolved solids levels. Depending on the levels of other chemicals in the sewage effluent and the geology of the local area then further treatment processes may be required (e.g. iron / manganese treatment, dissolved oxygen correction).

Ultrafiltration and reverse osmosis would be prohibitively expense in the context of this scheme, both in terms of capital and operational expenditure and in general terms. Effluent re-use is only considered commercial feasibility in resource zones where there is a considerable deficit in water supply over future years. It is not clear whether this is the case in the Chichester district. Portsmouth Water do not currently have a water deficit issue but the Environment Agency may take a wider view as the Southern Water resources zone further to the east is water resources constrained. Indeed the Environment Agency are particularly keen to establish effluent reuse in the south-east of England (where feasible) as a water resources solution.

The site investigations may establish that aquifer recharge can be achieved without interfering with drinking water abstraction (e.g. it can be injected into a point in the aquifer that passes straight to sea in lieu of drinking water that would otherwise be necessary to lose to the sea in order to prevent seawater advance into the aquifer). The feasibility of this approach is considered a reasonable possibility in the case of Chichester as the aquifer is understood to be unconfined– however if proved feasible it may be possible to reduce the treatment requirements making the artificial recharge option more cost effective. It should also be noted though that there is known to be significant flooding issues in some areas of the Chichester District and aquifer re-charge has the potential to contribute to this problem. Similarly contact with landfills and other anthropogenic features due to higher groundwater levels has the potential to deteriorate the groundwater quality. Any solution would have to evaluate these two issues and would have to determine a solution that avoided the risks, if any, from these two hazards.

Conclusion: further investigations would be required to establish the full scope of an aquifer re-charge option. It is likely, however, that a stringent discharge consent would be applied requiring extensive and expensive treatment processes to be applied prior to the effluent entering the aquifer. This would make this option commercially unacceptable in areas such as Chichester where it is understood there is not a significant local supply-demand deficit in the short to medium term. Aquifer recharge may also contribute to local flooding or water quality issues that require further investigation and evaluation. It was therefore agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued any further as part of this study.

3.2. "Transfer" Solutions

The following options consider either the transfer of flows to a treatment works other than Chichester STW or the transfer of housing development to locations where flows would enter the catchment of a treatment works other than Chichester STW.

3.2.1. Transfer Excess Chichester Flows to Tangmere STW

The analysis of Tangmere works indicates that there is still room for growth with the current pollutant consents appearing to indicate that DWF flow to the works may be doubled should load standstill be applied.

Tangmere works is located sufficiently close to Chichester that a flow transfer from the existing North East part of the catchment or transfer of flows from new housing developments around this location would, at first examination, appear likely to be feasible. Transferring flows from new build developments would be preferable since diverting flows from an existing catchment would result in a much more complex and costly scheme.

Conclusion: This option appears promising, the current site consent appears to indicate some flexibility and that, with a suitable site upgrade and transfer pipeline, would allow for a significant increase in headroom. It was therefore agreed at the stakeholder meeting on 4th November 2009 that this option would be progressed to better understand its viability.

3.2.2. Develop at Tangmere rather than at Chichester

This option is clearly similar to option 3.2.1. Should it not be feasible to construct a transfer pipeline, development of new housing around Tangmere could pass flows into the existing catchment. This would, given a suitable on-site process upgrade and new consent structure, allow for sufficient development to meet the requirements for additional housing provision in the district, albeit away from central Chichester.

Conclusion: This option can be viewed as a subset of 3.2.1. and since this option is to be given further consideration, it will become apparent whether flow transfer is a significant issue and that developing at Tangmere instead would be required. This therefore does not require consideration as a separate option.

3.2.3. Transfer Excess Chichester Flows to Sidlesham STW

Sidlesham is a large treatment works which, with the current headroom analysis, will still have significant headroom capacity into AMP6. Flows could be transferred to Sidlesham works for treatment from Chichester. A long sea outfall (LSO) from Chichester might also allow for additional headroom increase by allowing for a relaxation of the current consents.

The estimated headroom identified at Sidlesham would allow for slightly over 2 additional years of housing provision at the required rate. Although reasonable, this would not provide long term development and further increase in headroom is currently limited by the 1mg/l Phosphorus consent that is already in force at the works and even without this, somewhat limited by the 15 mg/l Total N consent already in place as a result of the Urban Waste Water Treatment Directive. To allow for any further DWF increase, it would be necessary to find another mechanism to influence the required discharge consent from the works.

Changing the point of discharge of the works from the current location into Pagham harbour may, if suitably located, allow for consent relaxation. Sidlesham WwTW itself is not located far from the coast giving rise to the possibility of transferring flow across land to a coastal point and then using a long sea outfall pipeline so that effluent may be discharged at a point which marine dispersion modelling indicates will rapidly disperse any remaining pollutants.

The main problem lies with the fact that the peak loadings at Sidlesham are already stretching the works to its limit. Significant additional loading onto the works, although acceptable during low season, would be expected to lead to treatment failures during peak tourism events. The works therefore would not be suitable for treatment of significant additional load until the completion of a large upgrade to the works which, as of now, would not be likely to receive funding until the start of AMP6.

Conclusion: Although this option may prove to be a viable solution, simply treating additional flow at Sidlesham is not an option due to the works already operating so close to its loading limit. Although additional headroom may be realised by changing the works discharge to a long sea outfall, this would then result in the construction of a pipeline to pump flows from Chichester to Sidlesham for treatment, followed by further pumping of flows from Sidlesham to the LSO for discharge.

Given that Sidlesham works would require an upgrade, the construction of two separate pipeline projects, at least 2No. additional pumping stations and the construction of an LSO it seemed clear that instead modifying Chichester works and constructing one pipeline to an LSO would be a substantially less complex and equally viable solution. This would therefore be a more appropriate scenario for consideration and allows for this option to be disregarded at this stage. It was therefore agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.2.4. Discharge Part of Chichester Effluent to a different Watercourse

It may be possible to pass part or all of the effluent from Chichester WwTW to a point where it discharges into a separate water course. The difficulty here is that all of the reasonably sized water courses in the region are already receiving flow from one or more water treatment works. Using any of these water courses to absorb additional flow from Chichester would increase the loading on that water course, unless loading was lowered sufficiently in the effluent from the other wastewater treatment facility/facilities discharging into it.

For example, effluent might be transferred from Chichester, across to the Bersted water course near Bognor. This however joins with Aldingbourne Rife which is already receiving effluent from Tangmere. To prevent additional loading entering the water course, it would be necessary to improve the current treatment standards at Tangmere, which would require a major upgrade to that works and at that point it would become more desirable to Transfer flows to Tangmere for treatment rather than needing to construct a much lengthier and more complicated pipeline from Chichester WwTW to carry a proportion of effluent to Bersted.

Conclusion: Although the option might allow for additional flow to be treated at Chichester, it would appear to be an unnecessarily complicated scheme to embark upon. It does not appear to offer any additional benefits over the transfer of flows to another works and localised treatment there and as such does not appear to be a particularly attractive option. The only additional discharge point identified that would be suitably large to accept sufficient flows and would not be constrained by sharing with another water treatment works is the English Channel which would require the construction of an LSO, and this is considered separately. It was therefore agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.2.5. Connect Effluent Discharge from Chichester STW to Long Sea Outfall

As described in section 3.2.3, although Chichester will be BAT limited by the current Total N consent, it would be possible to increase the DWF to the works if suitable modifications could be made to allow the relaxation of the current consent. The “no deterioration” policy prevents consent relaxation in the case of Chichester to protect the receiving waters of the Chichester Channel. Therefore, the obvious challenge is to change the point of discharge to one which will enable a less stringent consent to be applied. This would allow an increase in DWF flow to the works without decreasing pollutant levels in the effluent and would therefore increase the effluent load from the works. This would be satisfactory when the discharge point can offer sufficiently rapid dilution/dispersion of the effluent to minimise any environmental impact.

As stated in section 3.2.4, there are no inland water courses that would allow for this modification and this leaves the English Channel itself as the only viable alternative discharge point for the works. This option would therefore comprise of the construction of a long sea / marine outfall and transfer of some or all of the treated effluent from Chichester via a pipeline to the coast. This would offer the additional benefit of negating any non-storm discharge of effluent into the Chichester Channel.

It would be necessary to upgrade the works at Chichester to handle the additional flows; however the main difficulty would come from the design and construction of a suitable LSO. The long pipeline to the coast and the construction of the LSO itself would make this a very expensive option and there may be significant issues with passing a pipeline down through land which may be designated as SSSI or another similar restriction.

Conclusion: Although the scheme is likely to command a significant cost of implementation, the sustainability credentials would appear good. Relaxation of the current consent would allow for energy reduction in treatment at Chichester and may prevent chemical addition from becoming a requirement at the works in the near future. The solution would also reduce loading into Chichester Harbour and would therefore be environmentally beneficial to the surrounding wetlands.

The success of the solution would depend on marine dispersion modelling of the LSO to demonstrate that a suitable discharge location could be achieved to allow for sufficient relaxation of the existing consent to allow for the required increases in DWF. In addition it would be necessary to determine a suitable pipeline route from the current works to the coastline. It was therefore agreed at the stakeholder meeting on 4th November 2009 that this option would be progressed to better understand its viability.

3.2.6. Discharge Effluent from Chichester STW into Catchment of Another STW

This would involve transferring part of the effluent flow from Chichester into the catchment of another treatment works with flows then passing through that catchment to another treatment works for further treatment prior to discharge from that works.

This would, for example, be possible by transferring treated effluent from Chichester to the Bognor catchment. Flow would then pass through the catchment and be pumped to Ford Treatment works where it would have been combined with raw flow from Bognor and pass through another treatment process.

There are a number of disadvantages to this option:

1. This would effectively lead to double treating flow with negligible additional treatment benefit; in fact, it would have the effect of diluting influent flow to Ford treatment works which may reduce the overall load the works removed.

2. Ford treatment works itself may require a substantial upgrade to allow for this extra flow to be passed through the works and any additional capacity at this works would also need to be shared with any developments from Arun council.

3. The capacity in the most western Bognor catchment, where the transferred flows would need to be introduced, may well be limited and not allow for sufficient flow transfer from Chichester.

4. The solution offers poor sustainability credentials from the double treating and the requirement to pump flow from Chichester to the Bognor catchment that would then be pumped to Ford WwTW which then pumps the effluent out to discharge. A less energy intensive transfer of flows would be more desirable.

Conclusion: This solution appears to have a number of pitfalls and would be poor from a sustainability standpoint. Although it may offer a viable solution, it is felt that other, less complex, flow transfers would be preferable and that double treating should generally be avoided since this would waste energy in re-processing treated wastewater. It was therefore agreed at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.2.7. Inter-Catchment Transfer

Flows from an existing catchment may, by modification to the existing catchment, be diverted in such a way that the flow can be transferred for treatment at a different works to where they were originally. Network modelling is required to identify the best points of interception within the current catchment to intercept flows and transfer them to a point where they may be transferred.

Transferring flows from an existing catchment would be less desirable to transferring flows from new build developments since modifying the existing systems is likely to be far more complex than simply designing new systems to pass flows to the required transfer point.

Conclusion: This technique is likely to play a part in any transfer option unless the majority of future development around Chichester can all be designated within one area. Without a full modelling exercise it is difficult to estimate the extent to which the current catchment would require diversion and the complexity of the resultant changes to the network. It is likely that a transfer would be technically viable and therefore any solution anticipated to require a catchment transfer would not be ruled out on a technical basis. What may be true is the transfer would be ruled out due to the high cost involved in performing a complex catchment transfer. For the purposes of this study, the technique will continue to be considered as a possible mechanism within a transfer scheme however it will not be possible to provide a full evaluation of the feasibility of this part of the scope or give an accurate cost behind the required modifications.

3.2.8. Transfer Flows to Budds Farm STW

Budds Farm is a large wastewater treatment works located at Havant on the South Coast. It was proposed that flow from Chichester might instead be transferred to Budds Farm for treatment since the works is already treating a significant DWF and the additional flow from Chichester would not represent a significant increase. The difficulty here is that, although only a small fraction of the current works DWF, Budds Farm has been carefully planned so as to allow for growth within its catchments and transfer of flows from an additional source would use up what headroom remains far quicker than was anticipated. This will then result in a similar headroom deficit around Budds Farm which in turn, is currently already operating near to the BAT treatment limit for Total N and simply push the problem elsewhere.

In addition, the transfer pipeline required to transfer flows from Chichester, all the way along the coastline to Budds Farm would be highly complex with 20+ km of pipework requiring interstage pumping to pass flows all the way to Budds Farm.

Conclusion: It was felt that compared to other flow transfer options, this did not appear to be favourable. Budds Farm WwTW is located out of the district and serves a wider catchment including the borough of Havant and county of Portsmouth. Any additional capacity would need to shared with this wider catchment, necessitating a much larger scale scheme than just to provide the additional headroom to transfer flows from Chichester. The transfer pipeline would be significantly more complex than one to Tangmere, Lavant or even one from Chichester down to the coast. It also offered poor sustainability credentials from all the additional pumping required. Budds Farm also has limited additional DWF headroom and is soon anticipated to be subject to similar headroom constraints as have currently been identified at Chichester. It was therefore decided at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.2.9. Construct New Treatment Works

Constructing a new treatment works actually is subject to a lot of the same difficulties as discussed in section 3.1.5 when considering providing localised distributed treatment for new developments. It would be possible to purchase land and build an entirely new treatment works on the site however, all of the suitable receiving waters are currently being discharged to by one or more of the current treatment works in the district. Thus any newly constructed works would need to share the loading capacity of the receiving water with the works already discharging to that watercourse. This would reduce the effluent loading permitted at the existing works and most likely necessitate a large upgrade to improve the effluent quality, if indeed, the works is not already BAT limited by any of the consented pollutants.

Conclusion: In almost all cases, simply upgrading a currently operating works to accept additional flows would be cheaper than constructing an entirely new works and when there is no unused watercourse to discharge flows to, any new works will impact on the existing one sharing that water course anyway. This option is therefore not viable and it was therefore decided at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.3. “Improvement on BAT” Solutions

The following solutions look at the various technological improvements that may allow for the challenge of the BAT treatment levels achievable in the near future. The currently accepted BAT figures can be found in Table 1. The BAT limit that would be most desirable to lower would be the current Total N limit of 9mg/l since this is the consent which is currently limiting and further DWF increase at Chichester works and driving this study. This will therefore be the key compound given consideration within this section that suitable innovative technologies might be applied to in the future to improve treatment standards.

3.3.1. Provide Algae Farm Treatment of Effluent

There has been growing interest recently in Algae Farms as a possible technique for 'mopping up' residual nutrients in wastewater, prior to discharge. One of the main drivers behind Total N and Phosphorus consents is the prevention / minimization of Eutrophication in the receiving waters. Excess nutrients in the effluent can promote plant growth, such as algae, the growth of which disrupts the natural ecosystem in the water. Oxygen depletion can occur, affecting the natural aquatic life and causing a deterioration in water quality.

Although this makes algae growth extremely undesirable in water courses and wetlands, it is possible to harness this phenomenon and benefit from its affects. Algal farms promote the growth of algae, which in turn strips any nitrates, nitrites and phosphorus present. This further improves effluent quality and prevents the same process from occurring in the receiving water.

The difficulties with this approach include:

- The requirement of shallow tanks to allow sufficient light to penetrate to sustain reasonable growth prevents deep algal tanks from being utilised. This then requires a large surface area to provide sufficient volume.

- The land area required to produce a suitably large farm prevents the operation of such a scheme unless there is plentiful available land for development. Areas of $3m^2$ of farm per head of domestic population are not uncommon and often prohibitive, especially for larger works.

- The process is far more effective when operated on warmer land where growth is promoted; the UK does not have the best climate for successful algal farming year round.

- Ideally, CO_2 needs to be bubbled through the algae to further promote growth which complicates the process significantly requiring the provision of diffusers in the algal tanks and identifying a suitable source of CO_2.

- Reliability has been an issue on a number of installations in Europe where farms have rapidly deteriorated after commissioning giving doubt to whether this could be relied upon as process treatment stage.

This approach is being looked into by the Carbon Trust as a possible route of producing bio-fuels however the process is not yet commercially viable.

Conclusion: Although research and development of this process may in the future allow for suitable developments and application industrially, the current process is not suitably reliable and requires too much additional land use to be recommended as a suitable process for Chichester WwTW. It was therefore decided at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.3.2. 4 Stage Bardenpho & Methanol Dosing

There are a number of different technologies that are in use worldwide to achieve compliance when a Total N concentration limit is applied on the treated effluent from a wastewater treatment works. Currently, across SW sites, two main types of technology have been applied, dependent on the size and configuration of the existing works. For filter works and smaller sites, denitrifying sand filters have generally been selected as a Total N removing tertiary treatment system. For larger sites and those already with an activated sludge plants either the Modified Ludzack-Ettinger (MLE) process has been used or, for tighter Total N consents of 10 mg/l or below, a 4 Stage Bardenpho design was selected.

In the case of Chichester STW, a relatively large treatment works currently utilizing an MLE style ASP, the most likely future modification to the configuration would be to convert the existing ASP and add additional treatment volume to form a 4 Stage Bardenpho process. In this configuration, treatment passes through consecutive non-aerated and aerated zones. To achieve the desired treatment level it is necessary to recycle a large proportion of the flow from midway through the process, back to the front end of the plant and also, to dose methanol into the process to promote denitrification, an essential process in meeting a Total N consent. The 4 Stage Bardnepho is widely accepted as the optimal process for utilisation of carbon and minimisation of energy use with other comparable Total N treatment systems renowned for being particularly energy intensive techniques.

Conclusion: This is probably the most commonly used Total N system for stringent Total N consents and therefore the best understood. It is likely that this would be the process selected to upgrade Chichester WwTW in the future if the Total N BAT limit could be challenged and treatment performed to a lower level.

For the purpose of looking at the feasibility of a future treatment solution that might be considered suitable for improving treatment beyond the current Total N BAT limit of 9mg/l. The design of a 4 stage Bardenpho upgrade to Chichester will therefore be worked up at this stage, not currently as an option but as a future possible opportunity. This opportunity should then be considered alongside the options presented within this report in the future, should pilot trials give significant confidence that a process guarantee can be made at a suitably low Total N consent.

3.3.3. Tertiary Denitrification Processes

The most common dedicated tertiary denitrification technology in use is that of denitrifying sand filters, commonly moving bed sand filters or sometimes fixed bed systems in which oxygen free conditions are promoted and methanol is dosed to allow for denitrification. They are typically used downstream of a fully nitrifying process and enable a works which is nitrifying to achieve a total nitrogen consent. The methanol is dosed to provide carbon for the denitrification process. The sand in the sand filters acts as a fixed media for denitrifying bacteria to grow on. Denitrifying sand filters typically have medium capital and medium operating costs.

Conclusion: This technology is already being utilised on SW sites successfully in meeting tight Total N consents. The technology is more commonly applied to smaller sites since the required operating column volume for large sites would require the installation of a very large number of columns. This would usually prove economically less desirable than constructing a single large ASP, unless space on-site is extremely limited. Since there is ample space for construction currently at Chichester WwTW, it is unlikely that this technology would be selected for this particular application.

Thus, it was decided at this stage the consideration of a site upgrade to a 4 Stage Bardenpho design would be most appropriate and therefore decided at the stakeholder meeting on 4th November 2009 that this option should not be pursued further as part of this study.

3.3.4. Moving Bed Biological Reactors

Moving Bed Biological Reactors (MBBRs) use floating polystyrene media on which bacteria attach and grow to provide wastewater treatment. MBBRs can be used for removing BOD and ammonia; in this application the reactors need some form of aeration. They can also be used for denitrification applications and use methanol as a carbon source to achieve this. This type of technology is well proven and established particularly in Scandinavian countries. The, typically have high capital and operating costs.

Conclusion: It is believed that this technique could be suitably applied as an upgrade to Chichester works; however the intensive nature of the process is not particularly a requirement in this particular case. There is ample land available for development at Chichester, where the old mineral media trickling filters have been decommissioned and demolished when the ASP was first constructed.

Since the energy required in operating an MBBR system through aeration and pumping is generally greater than that of a 4 Stage Bardenpho process and both systems require the addition of methanol as a carbon source, the 4 Stage Bardenpho would be most likely be adopted since sufficient land is available for its construction. It was therefore decided at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.3.5. Ion Exchange Technology

Ion exchange systems operate using a different underlying principle of chemical removal compared to the other techniques described within this section that rely on biological treatment. Ion exchange systems are more commonly utilised in drinking water production where they may be used to remove positive or negatively charged compounds from solution by exchanging them with species that are safe for human consumption. The technique is less commonly used in wastewater treatment although some success has been recorded in pilot trials for removing compounds such as ammonia from solution.

Flow is passed through a bed of ion exchange media and during which, species dissolved within the water are exchanged with similarly charged species present within the media and which would not be detrimental to the receiving waters when passed out in the works effluent. The media removes these species until it become saturated with them, after which they must be removed by regenerating the bed of media and allow the material to be restored to its original state and re-used.

The difficulty lies in applying such a processing technique for Total N removal. Total N measurement takes into account all of the nitrogen containing species present in the effluent. This includes ammonia which is present in solution as the positively charged NH_4^+ ammonium species and the negatively charged nitrate NO_3^{2-} and nitrite NO_2^- species. To control Total N levels within the effluent, it would therefore be necessary to remove sufficient quantities of any or all of these species so that when the concentrations of each are measured and summed together, the total is less than the works consented Total N. Since ammonium is positively charged however and nitrate and nitrite are negatively charged, a system allowing for the removal of all three species would require both Cationic and Anionic ion exchange mechanisms. A system combining both types of exchange would be significantly more expensive than one just utilising one type.

Nitrate and Nitrite are produced during Nitrification of ammonia within the treatment process and not commonly found in significant quantities in the works influent.

One alternative to installing an ion exchange system that is capable of removing both the positively charge ammonium ions and the negatively charged nitrate and nitrite ions would be to design a treatment system that would not biologically treat the ammonia and break it down into nitrate and nitrite but would still achieve the required biological carbon removal. This would just leave untreated ammonium in solution that could be removed using a single cationic ion exchange system. It would however, be particularly difficult to design a system that would sufficiently treat the carbonaceous material in solution to meet a BOD consent without also removing ammonia.

Another alternative would be to try and design a system that converted all of the ammonia to nitrate and nitrite under all flow and load conditions, so that these could then be removed by a single anionic ion exchange system. Again though, designing a works that would fully nitrify under all weather and flow and load conditions would require significant over-sizing of the biological treatment works, upstream of the ion exchange system to prevent spikes of ammonia ever entering the ion exchange system, failing to be removed and causing effluent Total N failures.

A significant difference between ion exchange and biological processes is the fact that biological processes convert nitrogenous compounds to a less harmful form, namely nitrogen gas which is released to the atmosphere. With ion exchange no conversion is achieved and the polluting species is simply removed from solution and fixed to the media. After the media is regenerated, which in itself is an additional chemical process step, the resulting regenerant solution still contains the polluting species but in a much more concentrated form (many thousands of mg/l) at a corrosive pH level (pH>11) and as such, still poses a significant disposal problem. The resulting regenerant normally requires additional treatment (such as ammonia stripping with sulphuric acid) which adds significant risk and cost to the process as a whole.

Conclusion: Ion exchange could be applied for additional removal of nitrogen containing compounds; however the system would be highly complex and expensive to operate due to the requirement of exchange capacity of both positive and negatively charged species. The power costs of operating the system are moderate but bed regeneration has high associated operating costs either requiring on-site chemical regeneration of the bed or removal periodically with fresh media. Although there may be an opportunity to configure the works to minimise the levels of either negatively charged or positively charged ammonia containing species and only apply one type of ion exchange capacity, this would represent a process risk should site operation prior to the ion exchange system fail to operate as intended. The complexity of operation of a relatively un-applied technique in wastewater treatment coupled with high operational costs and potential operating risks prevent this option from being recommended for further study at this time.

3.3.6. Membrane Bio-Reactors

Membrane Bioreactors are effectively activated sludge reactors which use a membrane separation stage rather than a clarification stage. An MBR offers significant process intensification in terms of volume required and therefore also process foot print than traditional activated sludge based processes. They achieve this by operating at very high bacterial levels; greater than is possible in a standard ASP where effective settlement would not be possible from such a highly concentrated activated sludge effluent and would therefore result in BOD and SS failures.

This is possible as the membrane separation replaces the traditional large gravity-driven final settlement/clarification stage by a physical separation stage by membrane filtration. The membrane modules can be placed directly within the ASP itself, removing the requirement for separate tanks with quiescent conditions for settlement and recycle of mixed liquors and effluent clarification. The physical barrier of the membrane then prevents solids from passing across into the effluent stream far more effectively than relying on gravity to settle out the material.

The high level of filtration offered by the membrane offers additional treatment benefits, compared to that of gravity settlement with MBR processes capable of meeting more stringent BOD and SS consents than would be achievable with an ASP followed by gravity based settlement and deep bed sand filtration. With the correct membrane type it is even possible to negate the requirement of UV treatment when required prior to discharge. This is because the fine filtration level achievable with some membranes also prevents pathogens from permeating and produces effluent with low enough pathogen levels to meet bathing or shellfish water directives without further treatment.

The intensive nature of the process however comes at the expense of extremely high operating costs. Historically aeration costs were usually prohibitively high and although in modern systems, hybrid membrane reactors have been built to include high efficiency fine bubble diffused air aeration zones in addition to the coarse bubble aeration required for membrane cleaning, MBR systems are only really attractive when process footprint is a significant design issue.

Conclusion: MBRs would allow for the treatment of Total N at Chichester but it is unlikely the technology would offer significantly improved Total N reduction than would be achievable in a well designed 4 Stage Bardenpho system. Since process footprint is not particularly an issue at Chichester WwTW the intensive nature of the technology is not attractive. The high aeration costs in comparison to standards ASP processes combined with the costs of cleaning and periodically replacing membrane modules is highly likely to make the whole life cost of an MBR solution unfavourable. It was therefore decided at the stakeholder meeting on 4th November 2009, that this option should not be pursued further as part of this study.

3.4. Options Selected for Further Investigation

From the consideration and analysis of the various options described in the previous sections, a short list of the most feasible/promising solutions was selected for more thorough investigation by MWH, CDC and the major stakeholders. These consist of three main options that initially appear viable to implement and one possible future opportunity that is currently not viable due to BAT limitations, but warrants further discussion.

Option 1: Treat additional flow and load at Tangmere WwTW, either by designation of increased development around the current Tangmere catchment or by transfer of sufficient flows from new build developments to the East of Chichester or re-direction of a sufficient proportion of existing flow within the Chichester catchment to Tangmere for treatment to allow development elsewhere around Chichester.

Option 2: Treat additional flow and load at Lavant WwTW by transferring sufficient flow from the North of the Chichester catchment to Lavant works, allowing development elsewhere around Chichester.

Option 3: Increase flows to Chichester WwTW and upgrade works to allow for the additional capacity. This would then require discharge of the works effluent via a long sea outfall to a point where modelling indicates that the discharge will have negligible impact on Chichester Harbour and allow the removal of the current Total N consent applied to the works.

Future Opportunity: Upgrade Chichester works to a configuration at which a tighter Total N consent than that of the currently accepted BAT level can be achieved allowing for effluent load standstill whilst increasing the consented DWF. This is not currently feasible, however with suitably planned and successfully executed pilot trials, may become a viable option in the future.

For each case, the scope of required work will be examined and detailed at a high level. This will then allow the solution to undergo a high level, top-down costing exercise to produce costs indicative of the required scope. The nature of the generation of these costs from a high level scope and without significant design input means they should not be taken as clear estimates of the final project costs, merely as another figure to allow comparison of each option.

For each case, a feasibility design for each scenario has been undertaken, allowing the production of an outline scope list. Top down estimates have then been produced using the MWH cost estimating database. This approach has allowed the generation of a CAPEX estimation for each project and the possible increase in OPEX for each site has also been calculated based on increased energy, chemical and maintenance requirements. From these figures, it has then been possible to carry out an estimation of the whole life cost of the implementation of the solution. Whole life cost calculations have all been carried out over 60 years with a 6% discount rate as typically used within the water industry. In all whole life cost calculations a 60 year civil replacement, 20 year Mechanical and Electrical (M&E) and 10 year Instrumentation, Control and Automation (ICA) replacement schedule has been assumed.