Cricklade County Way Project

Water Resources Development Strategy Study

Purton Road Bridge to Cricklade

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EXECUTIVE SUMMARY

This report is the Interim Report to the Cricklade Country Way Partnership and represents the completion of the first stage of the commission “A Water Resource Development Strategy for the Wilts & Berks Canal Network” awarded to Grontmij on 24 November 2006.

This report presents the water resource strategy for the section of the North Wilts Canal that will be restored as a part of the Cricklade Country Way (from Cricklade to Mouldon Hill). The study considers the long term viability of this section of canal independently of the main canal.

This has been a desk-based study with additional information collated through field trips and stakeholder liaison. The engineering options and associated costs have been assessed using Grontmij experience and available information. They should be treated as indicative options and costs at this time.

The canal route is from Purton Bridge in the south to Cricklade in the north. The route, which is 7.6km, crosses the catchments of the Rivers Ray and Key. For the purpose of this study it has been assumed that 5 locks will be required. The restored dimensions of the canal and locks were provided by the Wiltshire & Berkshire Canal Trust.

The study identifies all potential sources for the canal including rivers, reservoirs, groundwater, agricultural runoff and urban drainage. The potential yield and risks associated wit each source were assessed and it was concluded that the River Ray and River Key are the most reliable potential sources.

Following consultation with British Waterways and a review of previous studies it was decided to adopt a total net loss for the canal rather than build a value up from component losses (evaporation, seepage, leakage, etc.). Three net loss scenarios were adopted: A minimum net loss of 10 mmd^{-1}; a typical net loss of 20 mmd^{-1} and a maximum net loss equivalent to the British Waterways target value for a restored canal of 1.75 Ml/Km/wk. This latter figure is appropriate for an operational canal with typical boat traffic. As the canal will be an isolated section lock operations are expected to be minimal, however, the inclusion of the British Waterways guideline figure allows reference to be made to other restored canals.

An annual water balance analysis was carried out to assess the need for storage to balance the availability of water in winter and summer seasons. The Environment Agency was consulted in order to assess the likely conditions for the abstraction licenses on the Rivers Ray and Key. It was agreed that the use of natural flows and the use of a “hands off” flow equivalent to the natural 50 percentile flow (QN50) was a reasonable approach. Wet, average and dry winter and summer scenarios were analysed together with the 3 demand scenarios. Two abstraction scenarios were considered: winter abstraction only and all year round abstraction.

The water balance assessments demonstrate that there is sufficient water available such that the winter abstraction rates would not exceed 11% of the natural QN50 for the demand scenario of 20mmd^{-1} and 100 lock operations even during a dry winter. The average abstraction does not exceed 5% of the QN50. This increases to 27% of the QN95 for the worst case scenario of a dry winter and high canal demand.
This analysis also demonstrates that provided the winter storage can be found there are sufficient water resources to maintain the canal at a minimum depth of 1.35m even if no summer abstraction is included. The required storage reduced from 184.2 Ml for the winter only abstraction scenario to 130.2Ml for all year round abstraction and an average summer. The figure would reduce further to 96.6Ml if a wet summer was considered.

The engineering assessment looked at canal lining options, storage locations and pumping options. Indicative reservoir locations were identified and the size of the reservoirs and associated pumps and mains quantified. The assessment concluded that a canal lining of puddle clay should be adopted, reservoirs should be constructed below ground level and located so as to minimize pumping and infrastructure costs.

Assuming locally sourced clay and that only areas not crossing clay will need lining the cost of lining the canal is estimated to be £2.12M. The cost for the provision of storage and associated infrastructure is estimated to be £4.47M. Operations and maintenance costs are assumed to be 7.5% of he capital costs and amount to a maximum of £363K. The abstraction licensing cost will be £1,538 for an average summer increasing to £2163 for a dry summer.

The costs presented in this study are indicative and exclude any way-leave costs such as land purchase and planning application fees. The engineering costs are most sensitive to excavation costs and hence raising the reservoirs above ground (all or in part) would have a significant impact on costs.

It should be noted that while 125.9Ml storage is required to meet the demand for an average summer providing less storage capacity than this is a viable option. For example, providing 89Ml would meet the demand during a wet summer. It is recognised that the approach taken in the water balance assessment has been precautionary and it is therefore very likely that once local HOF conditions have been established and site investigations have been carried out to better assess typical canal losses the winter storage volume required will decrease.

The environmental scoping study has established that the link between water resources and water quality would need to be better understood in order to assess the impacts of a specific water resource solution and would indicate that a more detailed impact assessment would be required to assess any local HOF constraints and the impacts of any engineering options.

Given the indicative nature of the costs and the dependency on precautionary assumptions it is recommended that the Cricklade Country Way Partnership considers carrying out a feasibility study to assess the technical and economic viability of the proposed solution. The feasibility study will improve confidence in the engineering solution and the water resource analysis. Hydro-ecological studies would also be required to refine the local HOF conditions. We would recommend that hydrological monitoring observation be included in this study as it will assist in refining the water balance and assessing the high risk sources such as agricultural runoff and urban drainage. Moreover, The EA will require local flow measurement before authorising abstraction.

1 INTRODUCTION

This report is the Interim Report to the Cricklade Country Way Project and represents the completion of the first stage of the commission “A Water Resource Development Strategy for the Wilts & Berks Canal Network” awarded to Grontmij on 24 November 2006.

This report presents the options for the North Wilts Canal from Cricklade to Mouldon Hill which is an integral part of a time constrained lottery bid. The study considers the viability of the canal as a standalone section.

The report has been based upon available hydrological data, stakeholder liaison and field trips on 14th December 2006 and 6th February 2007. The engineering optioneering has been based on a desk study and aims to give indicative costs to the viable solutions.

2 BACKGROUND

Bills permitting the construction of the North Wilts Canal and a link between the Thames and Severn Canal received Royal assent on 2 July 1814 some four years after the completion of the main Wilts and Berks Canal. The canal linked the Main canal south of Swindon to the Thames and Severn canal at Latton, north of Cricklade. The original canal length was 8.3 miles (13.4 Km) with a fall of 58.8 ft (17.9 m) with 11 locks.

The original water resource for the canal was to be met by the main Berks and Wilts Canal with no additional water being taken from the Thames (above the 3,700 tons per day already supplied by the Wanborough feed). The Wilts and Berks Canal had been empowered to construct new reservoirs at Coate Water and Tockingham as well as deepening the summit sections to meet additional water resource demand.

The canal was decommissioned in 1914 and gradually fell into disrepair until the formation of the Wilts & Berks Canal Trust in 1997 (from the Wilts & Berks Canal Amenity Group) which aims to restore the canal.

This study identifies a water resource strategy for the restored canal that forms a part of the Cricklade Country Way (CCW). The assumed route for this canal is given in Drawing P0000377200\gla\101, Appendix 5. The canal route is from Purton Road Bridge in the south to Cricklade in the north. The route, which is 7.6km, crosses the catchments of the Rivers Ray and Key. For the purpose of this study it has been assumed that 5 locks will be required. Minor changes in the route will not impact on the optimum strategy for water resources.

The guidance set out in the document *Managing Water Resources*: *A good Practice guide to navigation authorities* (AINA, 2005)[10] has been adopted for this study. This document gives the typical sources and demands on a canal as follows in Table 1: -

Sources	Demands
Rivers	Lock operations
Reservoirs	Evaporation and transpiration
Streams, ditches and brooks	Leakage, seepage and percolation
Groundwaters	Abstractions and water sales
Discharges	Feeds to other waterways and watercourses

Table 1 - Sources and Demands

The abstraction of water from surface or groundwater sources may require a licence from the Environment Agency (EA). The EA strategy for managing abstractions is presented in the Vale of White Horse[2] and Thames Corridor Catchment Abstraction Management Strategies[3] and is summarised in Appendix 2.

3 POTENTIAL SOURCES

3.1 River Ray

The River Ray drains a catchment of about 80km^2 that rises south of Wroughton and flows northwards to join the Thames at Water Eaton about 1.5km to the east of Cricklade. The surface geology of the catchment is predominantly Kimmeridge Clay south of Swindon and Oxford Clay north of Swindon with outcrops of corallian limestone around Mouldon Hill and drift deposits that generally follow the course of the river.

The river flows adjacent to the canal between Purton Road Bridge and Mouldon Hill Country Park (MHCP). The river crosses the canal, flows through the park and then flows parallel to the canal some 1km to the east.

The VWHCAMS reports that low flows are augmented by discharges and that the ecology has adapted to these augmented low flows. Dry weather flow consent data provided in the VWHCAMS indicates that flows are augmented by 32.6 Ml/d.

Low flow analysis was carried out for the Ray using LowFlows 2000 (LF2K)[4]. It is recognised that LF2K is not an ideal method for catchments where base flows are substantially influenced by groundwater flows. However, the Ray is largely a clay catchment with a relatively rapid response to rainfall.

Figure 1 presents a comparison of the LF2K and the natural annual flow duration curve for the River Ray at Water Eaton (as given in VWHCAMS).

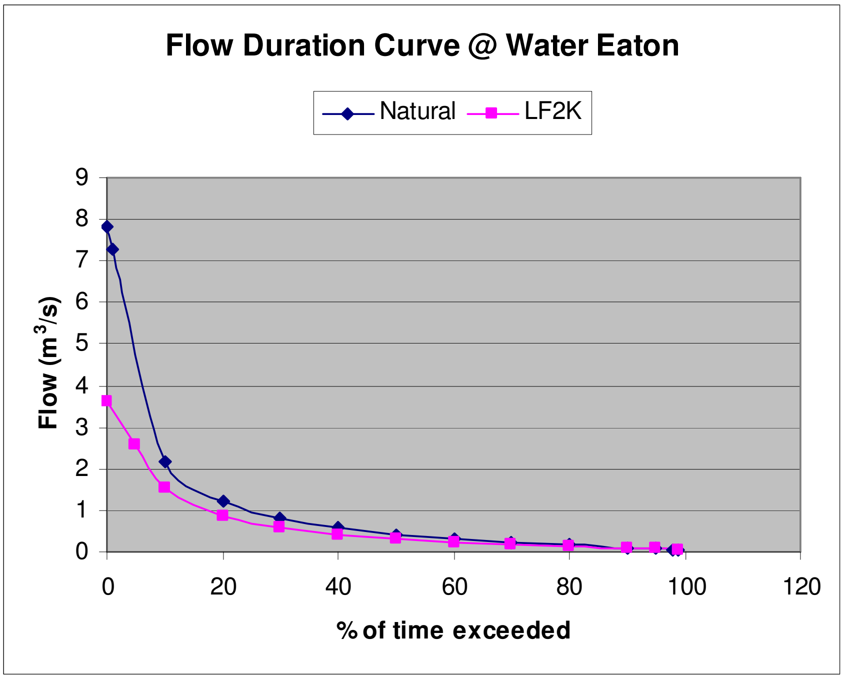

Figure 1 - Flow Duration Curve at Water Eaton

Scaling factors were calculated for each flow percentile. These factors allow the flow percentiles estimated using LF2K to be adjusted to reflect the actual flow percentiles anywhere in the catchment. This approach assumes that the scaling factors remain constant irrespective of location, however, it should give improved estimates of percentiles when compared to LF2K.

CAMS and Resource Availability

The River Ray lies within the VWHCAMS[2]. The Ray is grouped together with the Rivers Cole, Ock and Ginge Brook Chalk and Upper Greensand into Water Resource Management Unit (WRMU) 1. The individual status of WRMU1 is "water available", however, this is overridden by the status of the downstream assessment point on the Thames at Teddington which is classified as "over-abstracted". Hence, WRMU1 is given a status of "no water available".

The VWHCAMS[2] states that any abstraction within WRMU1 would be subject to a local hands off flow (HOF) condition and a HOF condition of the Q50 at Teddington. This was confirmed at a meeting with the Thames Region of the Environment Agency (EA). Furthermore, it was confirmed by the EA that any local HOF condition would be assessed on a case by case basis.

For the purpose of this study a precautionary approach was taken to HOF. The following assumptions were adopted:

- Abstraction conditions should be based on natural flows as it cannot be assumed that STW discharges will be available into the future.
- A local HOF condition of the natural Q50 (QN50) should be assumed.
- It is desirable for abstraction not to exceed 10% of natural flow. This is precautionary and is consistent with the lower limit as recommended by UK Technical Advisory Group (UKTAG, 2006).

This approach gives HOF conditions of 3.28Ml/d at Purton Road Bridge and 3.70Ml/d at Water Eaton.

3.2 River Key

The River Key drains an area of 29km2. The river rises to the west of Purton and flows north-east to its confluence with the Thames at Cricklade. The catchment is underlain by Oxford Clay with alluvial deposits following the course of the river.

The River Key crosses the Wilts & Berks canal via an aqueduct about 1km south of Cricklade. It then flows parallel to the proposed canal route some 300m to the east until it passes under Swindon Road just east of the canal terminus.

The river is ungauged so the flow duration curve has been estimated using LF2K. It has been assumed that the same correction factors are applicable as for the River Ray. There is no means of validating this assumption without assessment against observed flows, however, given the similarities between the underlying geologies of the two catchments this approach is likely to give more accurate flows than the adoption of LF2K without any correction.

The River Key lies within the same WRMU as the River Ray so the same HOF assumptions have been made for this study. This approach gives a HOF condition of 9.46 Ml/d at the aquaduct when the river crosses the canal.

3.3 Groundwaters

A number of groundwater sources were identified during a site visit on 14 December 2006 which were discussed further with the EA. Table 2 on the following pages summarises these sources and the potential yield.

The potential yield of these sources and groundwater in general was discussed with the EA Thames Region who stated that there was a presumption against licensing further groundwater abstractions on the basis that the EA is working to maintain and where possible restore base flows in the Ray catchment . Hence, the CAMS status of these sources has been set at “no water available”. Information presented by Scott Wilson Kilpatrick (1998)[5] and anecdotal information from the EA does suggest that the quality of groundwater needs careful consideration before these sources can be considered as viable options.

ID	Name	Location	Description	Typical Yield	Potential quality issues	Potential environmental issues	Borehole depth	CAMS status
1	Springs along railway cutting in Old Town, Swindon	SU 142 832	Springs issuing from base of sand unit (outlier) within Kimmeridge Clay. The unit is largely overlain by mudstone and the outcrop area is extremely limited. However, the unit may receive some downwards leakage from overlying Portland Beds (sand).	Estimated as 1 – 2l/s (86 – 172m^3/day) during site visit on 14/12/06 (may include contribution from springs issuing from base of Portand Beds). Potential recharge to springs: 1) infiltration area of Portland Beds and Kimmeridge Clay sand unit combined (1.5km^2) = 945m^3/day 2) Infiltration area of Kimmeridge sand unit outcrop only (0.5km^2) = 315m^3/day	Contaminants associated with urban runoff as very short travel time to springs	Impact on flows in receiving watercourse (tributary to River Ray)	N/A	No water available
2	Upper Corallian (Red Down Sand, Coral Rag) and Lower Corallian sand confined by overlying Kimmeridge Clay	Between SU 138 835 and SU 124 865	Principal aquifer unit is Coral Rag (sandstone/limestone, 6 – 10m thick), although boreholes abstract from the Red Down Sand. Corallian strata dip to the south, so source of recharge is the unconfined Corallian immediately to the north. Artesian conditions can occur	Typically 15 – 150m^3/day, but yield can be negligible. The confined Corallian aquifer is downfaulted against the unconfined aquifer in the vicinity of the canal. These faults may hydraulically isolate the confined aquifer from the unconfined, restricting though flow and therefore yield at this location.	Possible issue if limited through flow (see below) Red Down Sand can contain high iron	Impact on other abstractors, although most if not all former abstraction boreholes in the area appear to be disused	10m – 135m (depth increases down dip to south)	No water available
3	Kellaways Sand and Cornbrash confined by Oxford Clay	Between SU 138 835 and SU 104 934	BGS map indicates that Great Western Railways boreholes (225m deep) intersected this aquifer. The Kellaways Beds comprise clay with some sand units, while the Cornbrash comprises limestone with thin clays and marls.	Typically <85m^3/day Yield may be reasonable at Cricklade (and the aquifer may receive water from the Thames to the north through the overlying river terraces), but is likely to decline down dip (particularly south of the northwest Swindon faults) and be poor in the Swindon area.	Potentially poor water quality. Aquifer usage more than a few km down dip of the outcrop area is generally restricted as water quality deteriorates, with increases in salinity, iron etc.	Impact on other abstractors, although many former abstraction boreholes are now disused. Impact on rivers where aquifer hydraulically connected	80m (Cricklade) - 225m (Swindon) Dip increases down dip to south	No water available

ID	Name	Location	Description	Typical Yield	Potential quality issues	Potential environmental issues	Borehole depth	CAMS status
4	Unconfined Corallian (Coral Rag) and Lower Corallian sand	Between SU 124 865 and SU 114 877	Principal aquifer unit is Coral Rag (sandstone/limestone, up to 10m thick)	Yield up to 150m^3/day but will be limited by aquifer thickness and recharge area and can be negligible (Coral Rag units are isolated from each other where the River Ray and tributaries have cut down into Lower Corallian sand and silt, and can be less than 400m^2 in area in the vicinity of the canal). Springs may be present along Ray Valley or at boundary with Kimmeridge Clay	Contaminants associated with runoff from roads, although area is predominantly rural.			No water available

Table 2 - Groundwater Sources

3.4 Coate Water Reservoir

The Coate Water reservoir, which is located some 2km east of Wroughton, originally supplied the Wilts & Berks Canal before the canal was closed in 1914. The reservoir has subsequently become a local nature reserve and has high amenity value (angling, rowing, etc). The site has been designated as a Site of Special Scientific Interest (SSSI) and is now jointly managed by Natural England and Swindon Borough Council.

Levels in the reservoir are managed according to a site management plan agreed between Natural England and Swindon Borough Council. Swindon Rangers Service reports that levels are maintained such that they do not vary more than about 100mm. It is understood that water levels are drawn down in late summer/early autumn to expose mud flats. It is reported that reservoir spill is discharged via a small stream to the River Cole.

Swindon Borough Council inspects the reservoir for compliance with the Reservoir Act 1975. They report that inspections occur every three to four years and that levels are drawn down via a siphon spillway. Spill is discharged via a small channel to the River Cole.

The potential yield of the reservoir has not been assessed for this phase of the study due to; the sensitivity of the ecology to changes in water level, the sensitivity of stakeholders to water level changes and the high engineering costs associated with transferring discharges from the reservoir to the River Ray and on to the canal. This source will be assessed during phase 2 of this study when the water resources for the whole canal are assessed.

3.5 Agricultural Runoff

Runoff and drainage from agricultural areas adjacent to the canal represents a potential source. The main issues with agricultural runoff are:

- Reliability during the summer
- Regulation
- Water Quality

The fields adjacent to the canal provide potential for topping up the canal during wet periods. Field drains feeding into the restored canal were observed during a site visit on 14 December 2006, examples can be found on the main canal near Wharf Farm. However, during average summers when the water table falls below the level of typical field drains and rainfall tends to runoff via surface drainage paths these sources will not be reliable.

In cases where field drains intercept the water table even during summer periods and are in effect contributing to the base flow of the River Ray it is unlikely that these discharges would be licensed. The EA made it clear to Grontmij that they are working to maintain and where possible reinstate base flows in the Ray catchment.

There is a risk that the water quality of agricultural runoff would lead to long term problems with water quality as contaminants accumulate in the canal. Further work would need to be carried out to assess this risk prior to developing these sources.

For the purposes of this study agricultural runoff has not been considered a primary source. It is accepted, however, that existing discharges will serve a useful purpose in topping up the canal and may well reduce the demand for water during wet periods.

3.6 Urban Runoff

Runoff from existing and planned urban areas represents a potential source. Examples of this already exist just north of Purton Road Bridge. The Northern Development Area to the east of Mouldon Hill is perhaps the area with most potential as a urban drainage source. However, as with agricultural drainage, there are three main risks associated with this source:

- Reliability during the summer
- Regulation
- Water Quality

Summer runoff is limited to storm runoff and is unreliable (generally more so than agricultural runoff). While balancing ponds or sustainable urban drainage systems (SUDS) can provide storage to both increase the reliability and make better use of discharges they are generally too small to provide reliable flow during the summer. The issue of regulation and the impact on dry weather flows is also a risk for urban runoff. The most significant issue associated with urban drainage is water quality. As with agricultural drainage the use of urban drainage can lead to the accumulation of contaminants if not removed prior to entering the canal or diluted through managing flows within the canal.

For the purpose of this study urban runoff will be treated as a secondary source once river abstractions have been excluded or found to be inadequate to meet the canal demand.

4 CANAL DEMANDS

4.1 Introduction

The AINA[1] good practice guide identifies the following demands for a typical canal:

Leakage, seepage and percolation
Evaporation and transpiration
Lock operation
Third party abstractions and water sales
Feeds to other waterways and watercourses

The dimensions of the restored canal, provided by the W&BCT, are given in Table 3.

Dimension	Minimum (m)	Desirable (m)
Bed width	4.27	5.33
Depth	1.37	1.50
Side slopes	1:2	1:2
Lock length	22.6	
Lock width	2.2	
Average lift	1.625	

Table 3 - Restored Canal Dimensions

These dimensions give minimum and desirable cross sectional areas of $9.6m^2$ and $12.5m^2$ respectively. The lock dimensions give a volume of $80.8m^3$ transferred per lock operation.

4.2 Leakage, Seepage and Percolation

Seepage is the diffuse loss of water via the bed and sides of a canal. It is dependent on the characteristics of the bed, the level of water in the canal and the surrounding groundwater level.

The indicative water balance analysis carried out by Scott Wilson (1998)[5] shows that seepage and leakage are likely to be the most significant losses from the canal. Seepage rates of 10, 20 and 30 mm d^{-1} were used to assess the need for canal lining. This report concluded that the water balance could be closed with a seepage rate of between 10 mmd^{-1} and 20 mm d^{-1}.

AINA define leakage as the serious and unplanned loss of water via defined channels from the canal. Scott Wilson made no allowance for leakage apart from lock leakage. The AINA guidance states that serious leakages can be expected to be rapidly detected, isolated and the leak checked and remedial works carried out. Hence, the guidance advises that leakage does not need to be taken into account in an assessment of the normal water demands. This approach was confirmed through discussion with British Waterways[6] who recommended a typical total loss of 1.75 Ml/km/wk for a restored canal.

A leakage, seepage and percolation loss of between 10 mm d^1 and 20 mm d^1 has been used for this study as representing the upper and lower limits to the losses for a restored canal with a puddle clay lining. The British Waterways estimate of 1.75 Ml/km/wk was also used as a reference value.

4.3 Evaporation and Transpiration

Evaporation will occur from open water while transpiration losses will occur from vegetation within and adjacent to the canal. The estimation of both these losses is complex and dependent on local conditions such as water depth, vegetation type and height and meteorological variables such as wind speed, solar radiation and humidity.

Met office estimates of potential evaporation (PE) for MORECS square 158, which covers the North Wilts canal are given in Table 4.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
14.6	18.0	36.3	56.2	85.7	89.5	96.7	81.9	55.4	33.7	19.5	13.3	600.8

Table 4 - Potential Evaporation (mm) for MORECS square 158

The PE provided by MORECS is for a reference crop (grass). These values can be converted to open water evaporation using a conversion factor (*f*) varying from 0.7 to 0.8 depending on the month (Shaw, 1988)[7].

These estimates of PET indicate that the peak daily open water evaporation rate is 2.2 mmd^{-1}. This estimate provides a reference for the loss estimates that will be used in this study. For the purpose of this stage of the study evapotranspiration losses have been lumped together with leakage, seepage and percolation losses. This is the approach recommended by British Waterways.

4.4 Lock Operation

The movement of water through a lock system is a function of boat movement, lock design and operation. For the purposes of this study a range of boat movements have been assumed based on guidance from British Waterways and the Project Steering Group. The following values were adopted: 0, 100 and 500 lock operations per year. It has been assumed that for each lock operation a volume equivalent to the lock area multiplied by the lift will be discharged through the lock.

4.5 Feeds to Other Waterways and Watercourses

Excess water is discharged from canals via spillways. These spillways are required to balance any inflow variations and so maintain a constant water level. It has been assumed that excess water can be lost from any section of the canal or passed to a downstream section via a by-pass channel. This ensures optimum use of water and minimises spills.

4.6 Summary of Losses

The loss scenarios are summarised in Table 5 as average daily demands. It has been assumed that the minimum loss attainable is 10 mmd^{-1} and the maximum loss is equivalent to the British Waterways target value for a restored canal of 1.75 Ml/Km/wk. This latter figure is appropriate for an operational canal with typical boat traffic. As the canal will be an isolated section lock operations are expected to be minimal, however, the inclusion of the British Waterways guideline figure allows reference to be made to other restored canals.

Pound	Description	Length[2] (m)	Lock discharge[3] (Ml/d)		Loss (Ml/d)		BW[1] (Ml/d)
			100 operations	500 operations	10 mmd^{-1}	20 mmd^{-1}	
001	Purton Rd Bridge to Pry Lock	1,787	0.022	0.111	0.076	0.153	0.447
002	Pry Lock to Cross Lanes	1,342	0.022	0.111	0.057	0.115	0.336
003	Cross Lanes to Hayes Knoll	987	0.022	0.111	0.042	0.084	0.247
004	Hayes Knoll to Key Aquaduct	1,802	0.022	0.111	0.077	0.154	0.451
005	Key Aquaduct to Calcutt Road	1,547	0.022	0.111	0.066	0.132	0.387
Total		**7,476**	**0.022**	**0.111**	**0.319**	**0.638**	**1.868**

[1] British Waterways target value of 1.75 Ml/Km/Wk
[2] Pound lengths exclude locks
[3] Lockage assumes one lock operation per boat movement

Table 5 – Average Daily Canal Demand (Ml/d)

5 WATER RESOURCE OPTIONS

5.1 Water Resource Scenarios

Viable water resource options must comprise combinations of the sources presented in section 3 that together can meet the demand of the canal as defined in section 4. However, only river abstraction together with winter storage can provide a reliable source for the canal. It is conceivable that the uncertainty associated with the other sources may be reduced through additional monitoring, however, until such data is available, the risk associated with groundwater, agricultural runoff and urban runoff are deemed to be too high to be considered as viable options.

The abstraction required was determined by assessing the annual water balance for each canal pound. The water balance was divided into winter (November to March) and summer (April to October) seasons to allow for different abstraction rules during these seasons.

Two abstraction scenarios have been considered:

i) Winter abstraction only
ii) Summer and winter abstraction

The annual water balance for each option was assessed for three demand scenarios (wet, average and dry summer) and three supply scenarios (wet, average and dry winter). These scenarios were based on observed flows for the Ray at Water of Eaton since 1974.

The number of days that flow exceeds the HOF (QN50) at Water Eaton for each scenario is given in Table 6.

Scenario	No. of days	Year[1]
Wet Winter	149	1982
Average Winter	118	1985, 1996
Dry Winter	54	1976
Wet Summer	117	1981
Average Summer	72	1982,1974
Dry Summer	17	1990

[1] Years closest to the average

Table 6 – Abstraction – Number of days for each scenario .

5.2 Assumptions

The following assumptions were made as the basis for the annual water balance analysis:

- Abstractions may occur when flow exceeds the HOF condition (QN50) (and depending on the abstraction scenario – winter only or winter and summer abstractions)
- Winter storage is at capacity at the end of every winter
- Winter abstractions must be sufficient to meet winter demand and to fill the winter storage by the end of the winter
- Canal demands remain constant
- For the summer abstraction scenario storage will not be drawn down on those days when the flow exceeds the HOF.

- Net inflows/outflows to the canal are negligible. This will lead to a precautionary water balance during the winter when the canal will be topped up by direct rainfall, runoff and potentially groundwater inflows.

5.3 Water Balance Results

The worst case winter scenario with respect to the required abstraction rate is for the British Waterways demand combined with a dry winter. This is an extreme scenario (maximum demand combined with minimum supply) but provides a reference point for the study. The results are given in Table 7.

Pound	Dry Winter		Average Winter		Wet Winter	
	Abstraction Rate	%Q50[1]	Abstraction Rate	%Q50[1]	Abstraction Rate	%Q50[1]
Purton Rd Bridge to Pry Lock	3.02	9.2%	1.38	4.2%	1.09	3.3%
Pry Lock to Cross Lanes	2.27	7.6%	1.04	3.3%	0.82	2.6%
Crosslanes Lock to Hayes Knoll Lock	1.67	6.1%	0.76	2.5%	0.60	2.0%
Hayes Knoll Lock to River Key	3.05	11.8%	1.39	4.7%	1.10	3.6%
River Key Aqueduct to End [2]	2.61	27.6%	1.20	12.6%	0.95	10.0%

[1] The %QN50 allows for the reduction in QN50 as a result of upstream abstractions.
[2] Abstraction for the Pound will be sourced from the River Key

Table 7 – Average Abstraction Rate (Ml/d) for a Demand of 1.75 ML/Week/Km

Even for this high demand the maximum percentage abstraction is 12.6% of the QN50. This falls to 10% of the QN50 for a wet winter and increases to 27.6% in a wet winter.

The results for the recommended demand of 20mmd^{-1} and 100 lock operations are presented in table 8.

Pound	Dry Winter		Average Winter		Wet Winter	
	Abstraction Rate	%Q50[1]	Abstraction Rate	%Q50[1]	Abstraction Rate	%Q50[1]
Purton Rd Bridge to Pry Lock	1.18	3.6%	0.54	1.6%	0.43	1.3%
Pry Lock to Cross Lanes	0.92	2.9%	0.42	1.3%	0.34	1.0%
Crosslanes Lock to Hayes Knoll Lock	0.72	2.3%	0.33	1.0%	0.26	0.8%
Hayes Knoll Lock to River Key	1.19	4.0%	0.54	1.7%	0.43	1.4%
River Key Aqueduct to End [2]	1.04	11.0%	0.48	5.0%	0.38	4.0%

[1] The %QN50 allows for the reduction in QN50 as a result of upstream abstractions.
[2] Abstraction for the Pound will be sourced from the River Key

Table 8 – Average Abstraction Rate (Ml/d) for periods when flow exceeds QN50

The water balance assessments demonstrate that there is sufficient water available such that the winter abstraction rates would not exceed 11% of the natural QN50 for the recommended demand scenario of 20mmd^{-1} and 100 lock operations even during a dry winter. The average abstraction does not exceed 5% of the QN50.

The reservoir volumes required to meet the summer demand are presented in Table 9. These volumes include 15% additional storage to account for reservoir losses (this is an indicative figure at this stage but represents 500mm loss for a 3m deep reservoir).

Pound	Winter Only	Dry Summer	Average Summer	Wet Summer
Purton Rd Bridge to Pry Lock	43.0	40.0	30.4	22.6
Pry Lock to Cross Lanes	33.7	31.3	23.8	17.7
Crosslanes Lock to Hayes Knoll Lock	26.2	24.4	18.5	13.7
Hayes Knoll Lock to River Key	43.3	40.3	30.7	22.7
River Key Aqueduct to End	38.0	35.3	26.9	19.9
Total	**184.2**	**171.4**	**130.3**	**96.6**

Table - 9 Reservoir storage required for each demand scenario per pound (Ml)

This analysis demonstrates that provided the winter storage can be found there are sufficient water resources to maintain the canal at a minimum depth of 1.35m even if no summer abstraction is included. Introducing abstraction for an average summer scenario reduces the required storage quite considerably with the total decreasing by 33%. However, this will introduce a risk that the minimum demands of the canal will not be met during a below average summer.

6 ENGINEERING CONSIDERATIONS

6.1 Introduction

The optioneering of engineering solutions for the proposed supply of water to the Cricklade Canal was completed in order to provide approximate costs for the civil and electrical works associated with the successful operation of the canal throughout the summer months and provide for suitable storage during the winter months. Conveyance of water to an off channel storage facility as well as conveyance of water from the storage facility to the respective portion of the canal has also been addressed.

Canal refurbishment has been investigated with emphasis on the reduction of seepage losses through improved liner material in areas where high losses are expected. A high, medium and low seepage scenario have been calculated based on available seepage rates for the different types of material.

The outline assessment has been completed without any topographical survey information and several assumptions on infrastructure such as power supply, access and availability of materials have been made. In conjunction with the high, medium and low seepage scenarios cost estimates have been prepared to accommodate respective storage and conveyance system to indicate range of results.

6.2 Conceptual Design Methodology

For the purposes of the conceptual design, the canal and water supply scheme has been split into the following components;

i. Canal refurbishment in specific portions with different liner types.
ii. Abstract water from the identified resource.
iii. Supply Water to the identified areas for Storage.
iv. Storage of Water.
v. Supply of Water to the Canal Pounds.
vi. Overflows from the Canal and the Water Storage Locations.

6.2.1 Different Liners

In general there are several engineering methods being utilised worldwide to reduce seepage losses from canals.

The application of the different lining methods are linked to various factors such as geological conditions for the specific pound of canal, availability of natural materials close to the specific area, environmental conditions around the specific area, habitat requirements / constraints, long term maintenance considerations, specific land usage in the surrounding areas, foundation requirements from associated structures, topography and erosion prevention etc.

The basic principal is that the lining of the canal would greatly contribute to the reduction of seepage losses. Seepage losses are accepted from various BW reports to be as much as 75% of the total losses in the canal system. The consequence of an improved liner would thus be reduced seepage loss and thus a reduced volume of required storage in an off channel reservoir.

For the purpose of this report a total loss (seepage, evaporation, lockage and other maintenance) rate of 20mm/day with an additional loss allowance for 100 upstream boat movements has been assumed. These losses have been applied over the winter period (151 days). The assessment of storage volume has also made allowance for some abstraction and supply to the canal during the summer months. These abstractions have been assessed for Dry, Average and Wet summer seasons which vary the period of time which abstraction can be taken during the summer.

With reference to experience gained by British Waterways (BW) in the construction and maintenance of canals we have accepted that at this stage of the project only three lining types will be investigated. The theoretical reduced seepage rates are shown for each based on existing figures from reports used as reference for this study.

- Puddled clay liners
  A realistic seepage rate of 1mm/d can be achieved after successful completion of puddling on typical Oxford clays in a 1000mm deep layer.

- Reinforced Concrete liners
  A realistic seepage rate of 1mm/d can be achieved after successful completion of 100mm reinforced concrete liner.

- Bentonite / geotextile combination
  A realistic seepage rate of 5mm/d can be achieved after successful installation of geotextile and bentonite combination matting on the in situ material.

A total loss of 20mm/d clearly represents a precautionary estimate. However, until site surveys have been carried out it it is felt unwise to reduce this value.

6.2.2 Water Resource Locations

Indicative reservoir locations have been identified based on the following criteria:

- Within close proximity to the source and the canal to minimise engineering costs
- Not sited on a designated or non-designated protected area
- Founded below ground level to maintain the natural flood plain storage
- Preference given to sites on clay to minimise lining costs
- Sited so as to avoid any infrastructure such as roads, railways and buildings

For the purposes of the outline design checks it has been assumed that water can be abstracted from the River Ray and River Key adjacent to the canal.

Abstractions from each of the resource locations to the storage reservoir in each pound are assumed to be done by mechanical means ie pumps with a varying length of rising main connecting to the water storage reservoir. At this stage it was assumed that suitable power supply point is available within 1km from the pumping facility.

Provision has been made for single duty pump and one standby pump arrangement at each pump station to facilitate uninterrupted supply during maintenance or breakdowns. No provisions for alternative power supplies have been provided. For the outline costs it has been assumed that the pumps will each be working for 12hrs per day.

In all cases provisions have been made for standard brick building for the pumpstations. Rising mains are taken as buried UPVC in all cases.

Provision has been made for Telemetry control between storage reservoirs, pumping station and abstraction point at each abstraction.

Pumping station capacities and associated infrastructure have been sized for demand scenarios associated with losses of 20mm /day and 100 boat movements upstream and a dry, average and wet summer season.

6.2.3 Water Storage Locations

Potential locations for storage reservoirs have been identified for each pound. These locations are as shown in drawing P0000377200\GLA\106 – sheet 1 to 5 (Appendix 5). At this stage it has been assumed that the storage will be provided below ground. The below ground storage volumes have been calculated assuming vertical sides and a maximum depth of 1.5m. At this stage, the sizing of the storage has made no allowance for the effects of sedimentation.

Seepage and groundwater infiltration are not assumed to be issues in the layout and costing of the storage locations. From a review of the geological information available storage reservoirs have been located on Oxford Clay areas and this should avoid the need for a special liner material for the reservoirs.

No provision has been made for land acquisition, access roads, safety or security fencing or any emergency overflow structures.

6.2.4 Water Supply to the Canal

From the storage locations it is assumed that the water is distributed to the canal by a small pumping station and section of rising main.

Abstractions from each of the storage locations to the canal in each pound are assumed to be done by mechanical means (i.e. pumps) with a varying length of rising main connecting to the water storage reservoir. For the purposes of costing it has been assumed that the length of rising main required is calculated from the proposed water storage location to the top end of the canal pound. At this stage it was assumed that suitable power supply point is available within 1km from the pumping facility.

Provision has been made for single duty pump and one standby pump arrangement at each pump station to facilitate uninterrupted supply during maintenance or breakdowns. No provision for alternative power supplies have been provide. Rising mains are taken as buried UPVC lines in all cases.

Provision has been made for Telemetry control between storage reservoir, pump station and canal at each abstraction.

6.3 Cost Estimates

All costing has been based on standard cost models and unit rates from previous studies.

6.4 Impact of Geology

Geological information has been collated at desk top level only. Different geological zones along the total canal pound are shown on drawing P0000377200\GLA\104(Appendix 5). Seepage calculations and requirements for different lining methods have been based on the different materials expected in each pound. The area of each pound underlain by a specific material was expressed as a percentage of the total pound length and is shown in the Table 10.

Pound	Description Of Geology	Pound Length (m)
1	90% Oxford Clay ; 10% Drift	1,787
2	40% Oxford Clay ; 60% Drift	1,342
3	100% Oxford Clay	987
4	70% Oxford Clay ; 30% Glacial Drift	1,802
5	60% Oxford Clay ; 40% Drift	1,547

Table 10 – Description of Geology

Any portion of the canal which is not underlain by Oxford Clay was considered to be susceptible to potential high seepage losses. Different liners were investigated for these portions of canal and alternatives compared on practicality, potential seepage reduction and price. Because of the general occurrence of Oxford Clay in each pound it was assumed that a sufficient volume of suitable natural liner material is available.

The success of the lining would be dependent upon a number of factors including the skill of those laying the material and also the quality of the clay available on site. A more detailed material investigation needs to be done before final designs can be started. Site investigation needs to be done to confirm overall assumptions on material occurrence, material properties and availability of materials.

6.5 Cost Estimate Summary

6.5.1 Capital cost components

As explained above, lining of the canal to reduce leekage/seepage would involve either, puddled clay, concrete or bentonite matting. Each of these would have a cost implication and typically these could range from £420/m for puddle clay lining to £580/m for concrete lining (not reinforced) to £635/m for a bentonite matting.

For a puddle clay liner with material available locally as expected in most of the pounds on the Cricklade Canal the above unit costs can be reduced to £230/m and with the percentages listed in the table above a total cost for lining all the required portions are shown in Table 11.
It is assumed that local puddled clay will be used where it is available.

Pound	Description Of Geology	Pound Length (m)	Puddled clay	Concrete	Bentonite
1	90% Oxford Clay ; 10% Drift	1,787	444,963.00	473,555.00	483,383.50
2	40% Oxford Clay ; 60% Drift	1,342	461,648.00	590,480.00	634,766.00

3	100% Oxford Clay	987	227,010.00	227,010.00	227,010.00
4	70% Oxford Clay ; 30% Glacial Drift	1,802	517,174.00	603,670.00	633,403.00
5	60% Oxford Clay ; 40% Drift	1,547	473,382.00	572,390.00	606,424.00
			2,124,177.00	2,467,105.00	2,584,986.50

Table 11 – Lining Cost

The costs to provide storage and to convey water from the river to storage and from the storage point to the canal is given in detail in Appendix 4. Summarised costs for these options are given below.

Reservoir	Dry Summer Cost	Average summer Cost*	Wet Summer Cost	O&M Costs for Dry summer
R001	£1,060,000	£885,000	£710,000	£79,500.00
R002	£870,000	£725,000	£580,000	£65,250.00
R003	£730,000	£615,000	£500,000	£54,750.00
R004	£1,080,000	£885,000	£690,000	£81,000.00
R005	£550,000	£475,000	£400,000	£41,250.00
R006	£550,000	£475,000	£400,000	£41,250.00
SUB – TOTAL =	£4,840,000	£4,060,000	£3,280,000	
DESIGN FEES =	£484,000	£406,000	£328,000	
TOTAL COST =	**£5,324,000**	**£4,466,000**	**£3,608,000**	**£363,000.00**

* Note that he average summer figures are based on a mathematical average figure derived from dry summer and wet summer figures.

Table 12 – Summarised Costs

The capital costs for infrastructure (pump stations, rising mains, telemetry) are based on three main scenarios:

- supplying the same demand (storage volume in reservoir) from the river for the worst case (ie dry winter of 54 days possible for abstraction only)
- supplying the same demand (volume required in canal) from the storage reservoir for the average case (ie average winter 118 days only to supply the deficit)
- An average figure which represents average winter and summer abstraction, taken as mathematical average of the first two scenarios

The scenarios above reflect the maximum demand scenarios for each pumping station and the infrastructure have to be sized to meet the worst case scenario. At this stage it would most likely mean that the infrastructure should be sized to meet worst case scenario and that operating rules be adapted to suit specific seasonal requirements.

6.5.2 Yearly operational and maintenance costs

The yearly running costs will include provision for electricity supply and usage, maintenance on pump stations and other infrastructure as well as provision for costs for the operation of the pump stations and associated works.

The annual operational and maintenance costs for pump stations and associated infrastructure are, based on experience, in the region of 7.5% of the outlay capital costs. The annual operational and maintenance costs for canal and storage reservoirs are much less, mainly due to energy and infrastructure type. In general a figure of £18,000/km/annual [A]

is used for maintenance on canals. This figure could obviously be influenced by various factors and the choice of liner, traffic and flow regime in the canal will have an influence on the total cost for each pound.

At this stage only an operation and maintenance costs figure for the maximum demand scenario for the pump stations and associated infrastructure as described above has been prepared. The expected annual costs per pound is reflected in Table 12 above.

In addition to capital and operation and maintenance costs mentioned above there will be a charge for abstraction. These charges are determined by the EA and are based on the annual volume, the season of abstraction, the type of source to be abstracted from and the loss. The charges, based on the EA 2006-07 charging scheme (http://publications.environment-agency.gov.uk/pdf/GEH00406BKNP-e-e.pdf?lang=_e) are given in Table 13 for a total loss of 20mm/d and 100 lock operations per year.

It is assumed that a canal would be treated as a high loss by the EA and the source is unsupported. The standard unit rate for Thames Region for 2006/07 is £12.39/1000m$^{3.}$

Scenario	Summer Volume (m^3)	Winter Volume (m^3)	Annual charge (£)
Winter only	0	281,000	557
Dry summer	13,000	268,000	789
Average summer	55,000	226,000	1,538
Wet summer	90,000	191,000	2,163

Table 13 – Summary of Abstraction Charges

Even with a summer factor of 10 times the winter factor the cost of summer abstractions is still significantly less than the capital cost of storage.

[A] Wilts and Berks Ganal Trust,THE WILTS AND BERKS CANAL ALIGNMENT AT MELKSHAM, Engineering Study Report July 2002 – Halcrow Group

6.6 List of Assumptions

The following general assumptions have been made during the optioneering of engineering solutions and estimation of costs;

- Topographical Levels are assumed based on the information available in the 1:50,000 OS map for the area.
- Leakage assumptions have been made based on best guidance obtained from British Waterways in February 2007. This has been concluded to be 20mm/day plus an allowance for 100 boat movements.
- Estimates of water storage volumes have been based on assumptions relating to days of abstraction during the summer;
  - Dry Summer (17 days of abstraction)
  - Average Summer (72 days of abstraction)
  - Wet Summer (117 days of abstraction)
- The optioneering of engineering solutions is a desktop analysis and can be considered outline for the purposes of getting indicative cost associated with various options.
- The below ground water storage is assumed to be rectangular in section.
- The water storage volumes make no allowance for sedimentation.
- The cost estimates make no allowance at present for security fencing or access roads associated with the water storage locations.
- The costs for each Pumping Stations are based on an assumed kW rating and will be subject to confirmation during any detailed design.
- The costs for the Electricity supply are an estimate and could vary significantly from those given. Confirmation will be required from the local power company.
- The costs make no allowance for a lining material in the storage reservoirs and assume that the in situ clay material is suitable for use as a liner where required.
- The loss factor is assumed to be high for abstraction charges
- The source is unsupported for the abstraction charging scheme
- The 2006/07 abstraction charging scheme is a reasonable basis for future costs
- Operation and maintenance costs are based on typical industry averages and could vary drastically depending on scenario used and seasonal changes in operation rules.
- Typical design life for all infrastructure (pumpstations, pipelines, mechanical and electrical equipment) has been taken as 25 years. No provision for refurbishment or replacement has been made.

7 ENVIRONMENTAL RISKS AND OPPORTUNITIES

7.1 Introduction

The supply of water to the restored canal will have a number of potential environmental consequences which need to be taken into consideration. The water resources study for the North Wilts Canal section will feed into a larger project submission for the CCW, which is being subjected to an Environmental Impact Assessment (EIA). The scope of the EIA includes consideration of the environmental impacts associated with the construction and operation of the canal and therefore to avoid duplication of effort, the environmental issues discussed in this Interim Report are largely confined to those associated with the actual provision of water to the canal in the first instance and then to the maintenance of supplies once the canal is operational.

7.2 Method

The scope of this commission does not include a detailed investigation and assessment of environmental impacts associated with the provision of water resources for the North Wilts Canal. The study has therefore focused on the key environmental risks facing the scheme and also the potential opportunities for environmental benefit that may be derived.

The approach to the assessment has essentially been via desk study work together with site visits, interaction with the project hydrologists and through consultation with key stakeholders (Environment Agency, Natural England, Wilts & Berks Canal Trust and North Wiltshire District Council). Discussion has also taken place with the consultants working on the CCW environmental assessment. The latter was particularly important as they were undertaking environmental field surveys and had considerable useful background information.

7.3 Establishing the Environmental Baseline

The environmental baseline along the canal route has been established mainly through a review of available literature and data searches including the following sources:

- MAGIC website: www.magic.gov.uk
- Landmark Envirocheck Report (PBA)
- Scott Wilson report[5]
- Environment Agency website: www.environment-agency.gov.uk

As noted in Section 8 consultation has also taken place with key stakeholders. Site visits to look at key areas of the canal route and potential locations for winter storage reservoirs and water supply points were undertaken on 14th December 2006 and 6th February 2007.

Broadly speaking, the environment along the route of the canal from Mouldon Hill to Cricklade is predominantly rural in nature with arable farmland and open fields being the main land use (Figure 2). At the Mouldon Hill end of the canal it becomes a little more urban although this is really only at the point where the canal passes under Purton Road. Some of the meadows are within the floodplains of the River Ray and River Key and are subject to periodic inundation during periods of heavy rain.

Figure 2 - River Ray at Mouldon Hill, west of the country park

There are no statutory designated nature conservation sites within the canal route corridor. Table 14 below lists the statutory sites located within 2km of the canal and their key features.

Site Name	Location	Status	Habitat
North Meadow Cricklade	SU 094946 1km north of Cricklade	NNR, SAC, SSSI	**Species-rich lowland hay meadow**
Elmlea Meadows	SU 068937 1.5km NW of Cricklade	SSSI	**Species-rich lowland meadow**
Upper Waterhay Meadow	SU068937 2.5km west of Cricklade	SSSI	**Species-rich lowland meadow**
Stoke Common Meadows	SU 064904 2km west of Purton on Stoke	SSSI	**Species-rich lowland meadow**
Haydon Meadow	**SU 120890** **1km north of Mouldon Hill**	**SSSI**	**Species-rich lowland meadow**

Table 14 – Statutory nature conservation sites within 2km of North Wilts Canal

The main watercourse in the study area is the River Ray which flows south to north through Swindon up to its confluence with the River Thames to the east of Cricklade. At the southern end the river flows close to and in places, immediately adjacent to the old canal route. The Environment Agency monitors water quality (chemistry and biology) at several locations along this river including the Haydon Wick pound near Mouldon Hill Country Park. The latest data obtained from the Agency's website (2005) indicates that for both chemical and biological quality, the river is Grade B, Good.

The smaller River Key is located towards the Cricklade end of the canal.

Within Mouldon Hill Country Park there is a small lake which is understood to be fed by groundwater (Figure 3). It is a managed waterbody and is used for recreation including angling.

Figure 3 - Mouldon Lake looking south east towards Swindon

At the time of writing no Phase 1 habitat surveys had been carried out for the CCW therefore there is little detailed ecological information available. It is understood however, that a number of protected species such as great crested newts, bats and badgers are known to inhabit the area.

7.4 Environmental Constraints and Possible Mitigation Measures

Providing a sustainable supply of water to the canal, both to fill it after completion of the restoration work, and subsequently to maintain sufficient water to allow navigation, comes with a number of potential environmental risks. As noted in Section 3, there are several potential options for supplying the canal. At this stage, the environmental considerations have been kept to a generic level focusing on potential risk.

The primary source of water for the canal will be the River Ray. Groundwater may also be used for topping up although this is considered unlikely to be a significant source of water for the canal. The main risks are considered to be:

- Abstraction from ground or surface water resources which may affect protected sites (statutory and non-statutory) such as flood meadows, wet woodland and wetlands.
- Creation of new reservoirs or storage channels in adjacent habitats may affect protected terrestrial species of flora and fauna, such as badgers, reptiles, grassland plants.
- Restoration of currently dry sections of the canal may similarly impact terrestrial species using the old channel.
- Linking currently wet sections may adversely affect wildlife already present, potentially including great crested newt, water vole, important aquatic insects such as water beetles, dragonflies etc.
- All construction work has potential to negatively affect species and habitats. Widespread surveys for bats, badgers, newts, reptiles etc are likely to be required.

There will inevitably be impacts on habitats and species that have established along the line of the canal and within the sections that have already been subject to some restoration work. The latter have, in most cases, started to become overgrown. Where there is water within the canal basin, new aquatic and fringe habitats have established (Figure 4) leading to potential for protected species such as great crested newts to be present. Such species are subject to statutory protection and therefore future restoration work will need to be done in accordance with relevant nature conservation legislation and regulations such as the Wildlife and Countryside Act 1981, as amended. Mitigation to offset the loss of, or damage to these habitats and species will almost certainly be required. However, the loss of habitat must be viewed in the context of the overall canal restoration project which will result in a substantial amount of new aquatic and fringing habitat being created.

Figure 4 - Restored section near Mouldon Hill. Note the spread of vegetation into the main channel.

Some of the more specific risks are discussed below.

7.4.1 Abstraction from River Ray and River Key

It is proposed that the River Ray will be the primary source of water for the canal. As discussed in Section 5 abstraction will be carried out during the winter months when flows in the river are above the QN50 threshold. In and of itself, this should not result in any adverse impacts to the biological communities within the river. It will be important to ensure that water taken from the river is of a suitable quality for introduction to the canal and storage reservoirs. Any abstraction of base flow volume would have potentially more serious effects on in channel and riparian species although the Environmental Agency would generally not allow abstraction to take place under low flow conditions.

Once operational there would be a need to ‘top up’ the canal on a regular basis, particularly during the summer months when water losses through evaporation, seepage and from boat traffic would be greatest. The storage reservoirs would need to be designed and managed in order to maintain an acceptable level of water quality and minimising the risk of algal blooms establishing. Transfer of water to the canal is likely to be subject to licensing by the Environment Agency.

Even in the early stages when the canal is not connected at either end, the Wilts & Berks Canal Trust plans to operate a small number of cruises for visitors to enjoy the canal. Water will move down the canal towards Cricklade as boats go through the locks. At the bottom of the navigation water will require to be discharged, stored or back-pumped. At this time it has been assumed that a storage reservoir will be constructed into which water can be directed with the option of backpumping this water further up the canal (see Section 6.1). Alternatively, water may be discharged into the River Thames. Whichever option is pursued, there will be a need for a discharge licence which will impose water quality limits. Once fully operational with boats regularly navigating along the canal, the water will become turbid caused by propeller action and boat wash. This is a normal situation in canals as a result of the generally shallow water and relatively deep draught of narrowboats. During particularly dry periods water levels within the canal may fall significantly which would exacerbate the turbidity problem.

If the storage reservoir option is developed, there is potential for reed beds to be included to provide a natural treatment for the water including settling out mud and silt. Similar schemes could be incorporated in to the storage reservoirs elsewhere along the canal. Discharges at other locations could incorporate silt traps prior to release into watercourses or to land drains.

Construction of storage reservoirs will have adverse environmental impacts, primarily through the direct loss of terrestrial habitat. Most likely this will be meadow and pasture land. It will be important to ensure that the location of reservoirs does not impact on the fen meadows located along the canal route. The inclusion of reed beds as mentioned above will provide both new (compensatory) habitat and a means of maintaining reasonable water quality within the reservoirs.

7.5 Opportunities for Environmental Gain

As with any development, there are often opportunities to achieve environmental benefits. In the case of the North Wilts Canal the key opportunities are:

- Primary habitat creation – canal, inner and outer margins may benefit wildlife, such as water vole and dragonflies, assuming water quality and vegetation structure are good.
- Secondary habitat creation – storage reservoirs and transfer channels in adjacent areas may represent ecological improvements on the existing situation. Most of the land along the canal is farmland which generally has low biodiversity.
- Related ecological gain – if well vegetated margins of canal area are created, with ecoton[B] between the canal and surrounding farmland, a continuous movement corridor for species such as bats, reptiles, amphibians will be created, assisting dispersal and foraging activities of these groups.

7.6 Conclusion

The key environmental impacts associated with providing water for the canal are related to water quality, both in terms of the sources feeding the canal and discharges from the canal into storage reservoirs or watercourses. All abstractions and discharges will be subject to consent by the Environment Agency with associated limits on water quality parameters.

Once the preferred combination of water sources and storage facilities is determined, it is recommended that further detailed studies be undertaken to establish water quality and the appropriate design parameters for treatment systems such as reed beds etc. This will enable the optimum operating conditions for the canal to be established and incorporated in to the engineering design for the future restoration works.

[B] Transitional/buffer zone between habitat types

8 STAKEHOLDER CONSULTATION

The project has progressed through liaison with the Project Steering Group and liaison with individual stakeholders as required. As well as the Project Steering Group the stakeholders who have been contacted to date are given in Table 15 below.

Stakeholder	**Issue**
W&BCT	Background information, reference documents, design standards, local information.
North Wiltshire Council	Maps of the CCW, to approve data requests to the Environment Agency
Environment Agency	Data requests, water resource regulation and conservation issues
British Waterways	Standards for restored canal, typical values for restored canals, guidance on method.
Swindon Borough Council	Information on Coate Water Reservoir
Natural England	Information on Coate Water Reservoir and comments on proposed solution.

Table 15 – Stakeholder Liaison

A stakeholder meeting was held on 2 February at the offices of North Wiltshire Council at which the proposed solution using river abstraction and winter storage was presented.

9 CONCLUSIONS AND RECOMMENDATIONS

The water balance analysis carried out in this study indicates that there are sufficient water resources available from the Rivers Ray and Key to meet the demands of the restored canal. During a dry winter when the opportunity to abstract is reduced there is sufficient water available such that the abstractions do not exceed 11% of the QN50.

The approach taken has been precautionary. For example, a HOF of the QN50 has been assumed in summer and winter, winter top-up from rainfall and runoff has been excluded and a loss rate of 20 mmd-1 has been assumed year-round (even though losses during the winter would be expected to fall well below this rate). Hence, there is high confidence in the availability of sufficient water.

The engineering options considered include lining the canal and providing winter storage to meet summer demand. The possibility of summer abstraction was considered in order to assess the impact on the winter storage volume required and hence the indicative costs.

The indicative capital costs for the preferred option is £2,127,180 for lining and £4,466,000 for storage. The annual abstraction licence would be £1,538 (in an average summer).

The costs presented in this study are indicative and exclude any way-leave costs such as land purchase and planning application fees. The engineering costs are most sensitive to excavation costs and hence raising the reservoirs above ground (all or in part) would have a significant impact on costs.

The environmental scoping study has established that the link between water resources and water quality would need to be better understood in order to assess the impacts of a specific water resource solution and would indicate that a more detailed impact assessment would be required to assess any local HOF constraints and the impacts of any engineering options.

This has been primarily a desk-based assessment of the water resources and engineering options and as such it is recommended that these options are progressed to a more detailed site-specific assessment and feasibility study. This should include a site survey to assess the feasibility of individual sites.

The costs have been based on an assumption that there will be one abstraction point per reservoir, however, there is merit in considering using the canal to convey water from an upstream abstraction point to downstream reservoirs. This particularly applies to reservoir sites R004 and R006. However, as the number of storages will remain constant and total pump capacity will remain unchanged this option has not been looked at in detail for this study given the inherent uncertainties in the costs.

Back-pumping would permit the circulation of water and reduce losses once the canal is fully restored. However, for the purposes of this section of the canal back-pumping will lead to only very small efficiency gains due to the low lockage. It has not therefore been include in the engineering options for this phase of he study.

It should be noted that while 125.9Ml storage is required to meet the demand for an average summer providing less than this is a viable option. For example, providing 89Ml would meet the demand during a wet summer. It is recognised that the approach taken in the water balance assessment has been precautionary and it is therefore very likely that once local HOF conditions have been established and site investigations have been carried out to better assess typical canal losses the winter storage volume required will decrease.

It is therefore recommended that Cricklade Country Way Project considers carrying out a feasibility study to assess the technical and economic viability of the proposed solution. The feasibility study will improve confidence in the engineering solution and the water resource analysis. Hydro-ecological studies would also be required to refine the local HOF conditions. We would recommend that hydrological monitoring observation be included in this study as it will assist in refining the water balance and assessing the high risk sources such as agricultural runoff and urban drainage. Moreover, The EA will require local flow measurement before authorising abstraction

10 REFERENCES

1 - Association of Inland Navigation Authorities (2005). Managing Water Resources: A Good Practice Giude to Navigation Authorities.

2- Environment Agency (2006). The Vale of While Horse Catchment Abstraction Management Strategy.

3 - Environment Agency (2004). The Thames Corridor Catchment Abstraction Management Strategy.

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11 GLOSSARY

AINA = Association of Inland Navigation Authority

BGS = British Geological Survey

BW = British Waterways

B&WCT = Berk & Wilts Canal Trust

CAMS = Catchment Abstraction Management Strategy

CCW = Cricklade Country Way

EA = Environment Agency

EIA = Environmental Impact Assessment

HOF = Hands of Flow

LF2K = Low Flow 2000 UK

MORECS = Met Office Rainfall and Evaporation Calculation System

PE = Potential Evaporation

PET = Potential Evapotranspiration (as used in MORECS)

QN50 = The Natural Flow that is exceeded on average 50% of the time

SUDS = Sustainable Urban Drainage Systems

UKTAG = UK Technical Advisory Group

UPVC = Unplasticed Polyvinylchoride

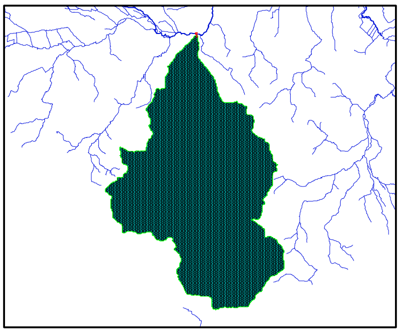
VWHCAMS = Valey of White Horse Catchment Abstraction Management Stategy

WRMU = Water Resource Management Unit

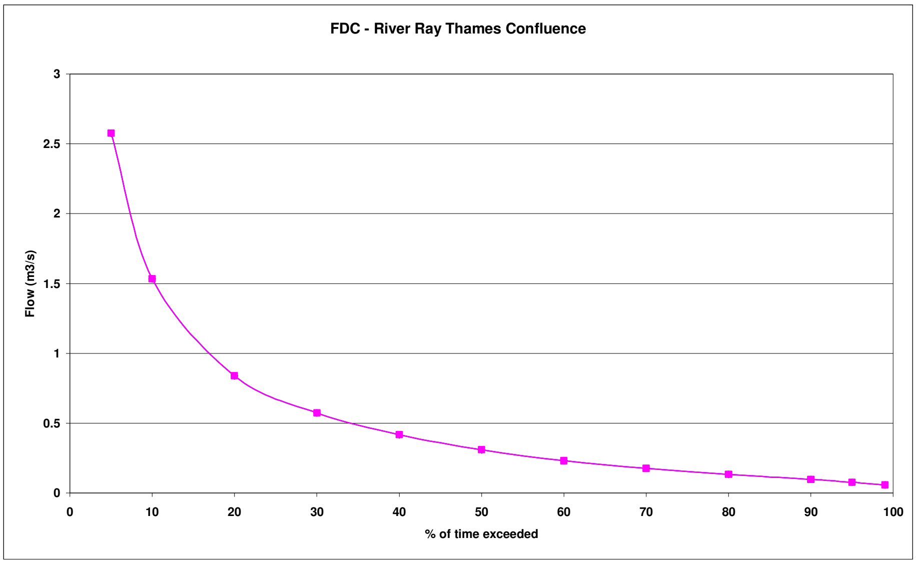
APPENDIX 1 – FLOW DURATION CURVES

FLOW DURATION CURVES

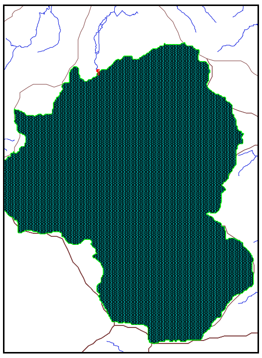
1. River Ray at Thames Confluence (Water Eaton)



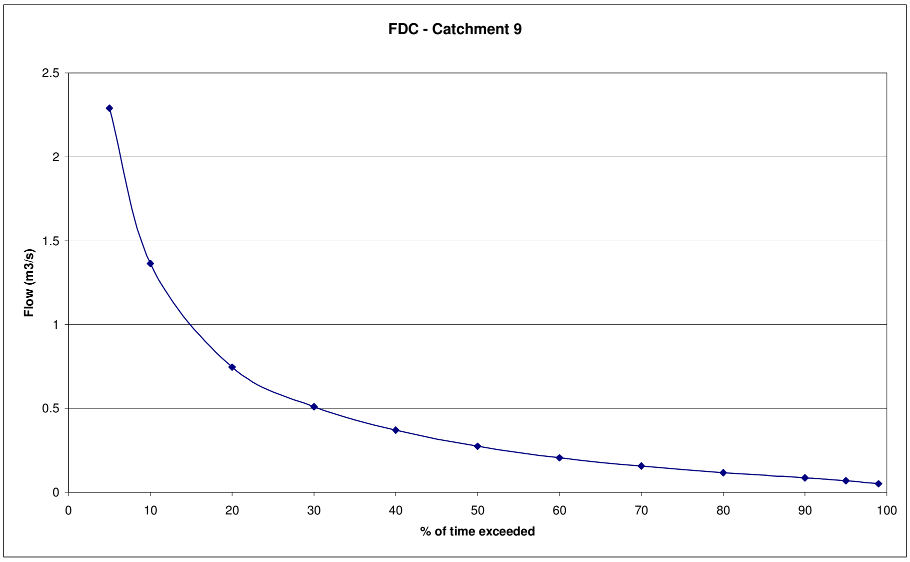
	P (%)	Q (m³/s)	Q (Ml/d)	Average (Ml/d)	Available	
					10%	Volume (Ml/yr)
	0	3.62	312.77			
1	5	2.577	222.65	2.25	0.23	82.23
2	10	1.534	132.54	9.01	0.90	328.92
3	20	0.839	72.49	18.02	1.80	657.68
4	30	0.573	49.51	23.76	2.38	867.40
5	40	0.417	36.03	28.48	2.85	1039.58
6	50	0.309	26.70	32.68	3.27	1192.85
7	60	0.23	19.87	36.43	3.64	1329.87
8	70	0.176	15.21	39.47	3.95	1440.56
9	80	0.132	11.40	42.32	4.23	1544.63
10	90	0.097	8.38	44.89	4.49	1638.45
11	95	0.077	6.65	46.49	4.65	1696.79
12	99	0.057	4.92	48.16	4.82	1757.97



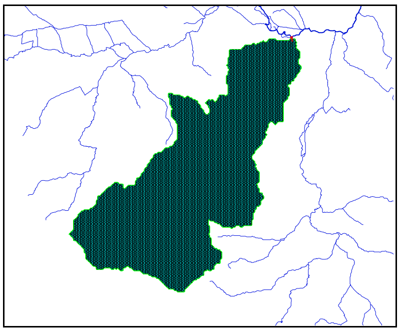
2. Catchment 9 (Nr Purton Road Bridge)



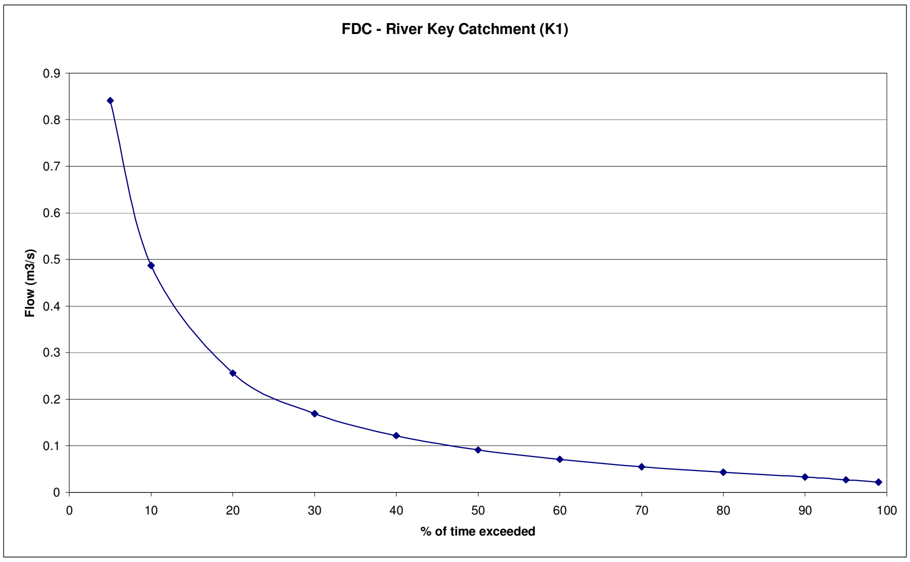
	P (%)	Q (m³/s)	Q (Ml/d)	Average (Ml/d)	Available	
					10%	Volume (Ml/yr)
1	5	2.289	197.77			
2	10	1.363	117.76	6.00	0.60	219.02
3	20	0.746	64.45	14.00	1.40	510.88
4	30	0.51	44.06	19.09	1.91	696.95
5	40	0.371	32.05	23.30	2.33	850.37
6	50	0.274	23.67	27.07	2.71	988.02
7	60	0.205	17.71	30.35	3.03	1107.70
8	70	0.156	13.48	33.10	3.31	1208.14
9	80	0.117	10.11	35.63	3.56	1300.39
10	90	0.087	7.52	37.83	3.78	1380.80
11	95	0.069	5.96	39.27	3.93	1433.31
12	99	0.051	4.41	40.78	4.08	1488.37



3. River Key Catchment at Confluence with the River Ray



	P (%)	Q (m³/s)	Q (Ml/d)	Average (Ml/d)	Available	
					10%	Volume (Ml/yr)
1	5	0.841	72.66			
2	10	0.487	42.08	2.29	0.23	83.73
3	20	0.256	22.12	5.29	0.53	193.00
4	30	0.169	14.60	7.17	0.72	261.59
5	40	0.122	10.54	8.59	0.86	313.47
6	50	0.091	7.86	9.79	0.98	357.46
7	60	0.071	6.13	10.74	1.07	392.15
8	70	0.055	4.75	11.64	1.16	424.95
9	80	0.043	3.72	12.42	1.24	453.33
10	90	0.033	2.85	13.15	1.32	480.14
11	95	0.027	2.33	13.63	1.36	497.64
12	99	0.022	1.90	14.05	1.41	512.93



APPENDIX 2 - WATER RESOURCES REGULATIONS

WATER RESOURCES REGULATIONS

The North Wiltshire Canal (NWC) crosses the catchments of the Rivers Ray and Key. In its lower reaches it crosses the floodplain of the River Thames. The Rivers Ray and Key are covered by the Vale of White Horse Catchment Abstraction Management Strategy (VWHCAMS) while the upper reaches of the River Thames lie within the Thames Corridor Catchment Abstraction Management Strategy (TCCAMS).

The resource availability of the Ray, Cole, Ock and Ginge Brook returned a low flow resource availability status of “water available”. However, this has been overridden to protect the status of the lower Thames and has been assigned a status of “no water available.”

The VWHCAMS reports that both the fully licensed and recent actual scenarios are above the ecological flow objective for 100% of the 365 days of the year for the rivers Ray, Ock and Cole.

The VWHCAMS reports a surplus of 34.1 Ml/d and 31.8 Ml/d for the River Ray under the recent actual scenario and under the full licensed scenario at the 95 percentile flow (Q95). The flow exceeds the ecological flow objectives for 100% of the 365 indicating that surplus flow is available all year round.

However, as all the VWHCAMS rivers are tributaries of the Thames allowance had to be made for the status of the lower Thames. Consumptive abstraction from VWHCAMS rivers would lead to further reduction in the flows in the Thames causing the lower Thames to become further over-abstracted. Therefore a Hands-Off-Flow (HOF) constraint of the Q50 at Kingston Weir on the Thames will be applied to all new licenses as well as a local HOF condition.

The TCCAMS gives the following policies on new abstractions:

Consumptive Abstractions from Inland Waters (Rivers, Streams, Lakes, Ponds etc)	
Policy G1	No licences will be granted allowing the abstraction of water in the summer months (April to October) for a consumptive use from an inland water except in cases which can be continuously monitored and with a condition prohibiting abstraction at times when river flows are below a prescribed flow.
Policy G2	Winter abstractions from an inland water will normally be allowed but will also contain a prescribed flow condition.
Non-consumptive Abstractions	
Policy G6	Where a very high proportion (95% or more) of the water taken is returned to the source of supply upstream of or immediately downstream of the point of abstraction a licence will normally be granted provided that any by-passed stretch of channel is adequately protected against low flows.
Very Small abstractions "De minimus"	

Consumptive Abstractions from Inland Waters (Rivers, Streams, Lakes, Ponds etc)	
Policy G7	Very small abstractions for general agricultural, private water undertaking and occasionally other uses, may be allowed without the constraint of a prescribed flow, a prescribed level or a time limit. The cut-off limits for an individual abstraction for these concessions will normally be 5000 cubic metres (1.1 million gallons) per year and 20 cubic metres (4,400 gallons) per day.
Spray Irrigation	
Policy G8	Spray irrigation abstractions from rivers will not be permitted in summer (April to October) but will normally be permitted in Winter with a prescribed flow constraint to protect low winter flows.
Abstractions from the Tideway of the River Thames	
Policy G11	Abstraction from the tideway of the River Thames will normally be permitted providing there is no conflict with water quality and fisheries

New Licences

i) Abstractions must cease when flow at Kingston Weir falls below Q50.
ii) The rights of any existing licence holders will be protected.
iii) No new consumptive licenses at low flows
iv) Licenses will be time limited (end date of 2013 and 21 year review)
v) Abstractions for the canal will be considered as consumptive
vi) Consumptive licences for groundwater can be considered where there is no hydraulic connectivity

The local HOF allowance will depend on factors such as:

i) Existing licenses and HOF conditions
ii) Designated areas (SSSI, SAC) sensitive to water resources
iii) Non-designated areas
iv) Sensitive species/habitats

There areno surface water abstractions in the Ray catchment so there are no existing HOF to be considered.

There are 3 STW discharging into the Ray. Swindon STW discharge is the largest with a dry weather flow (DWF) consent of 41Ml/d.

All future licence applications are considered by the EA against the requirements of the Water Resources Act 1991 and Water Act 2003. CAMS do not negate the need for a local impact assessment for a licence application. **The EA will always assess the impacts of a proposed abstraction on the local environment and existing licence holders through a local impact assessment. This assessment may override the resource availability status as defined through the resource assessment**. Even if the strategy indicates that water may be available, the local assessment may prevent a licence from being issued.

A large licence held by Thames Water Utilities Ltd dominates authorised abstraction from the River Thames Corridor. The licence allows the company to abstract water from the Lower Thames to supply London. It accounts for 64% of the Thames Corridor CAMS authorised public water supply abstraction. An operating agreement between the Environment Agency and Thames Water Utilities Limited controls actual abstraction rates authorised by this licence. The agreement uses a control diagram that relates storage in the London reservoirs and the time of year to hands-off flow conditions at Kingston gauging station (this gauging station records the flow over Teddington weir). As the volume of water stored in the London reservoirs reduces, the HOF is reduced in three steps from 800 Ml/d to 300 Ml/d. The current policy of no consumptive abstraction in the summer months in Thames Region is designed, in part, to protect the conditions of this licence.

Thames Water Utilities Ltd holds a single licence that dominates authorised abstraction from the Upper Thames WRMU. The licence allows the company to abstract water from the River Thames to fill Farmoor reservoir which is used to supply Oxford, Swindon and Banbury. It is the only public water supply licence in the Upper Thames WRMU and accounts for virtually 100% of the total authorised abstraction in the Upper Thames WRMU. The licence authorises a maximum daily abstraction of 300 Ml but it is constrained by a licence condition relating to the flow at Farmoor gauging station. This constraint reduces the amount permitted to be abstracted during low flow periods.

The TCCAMS states that the EA encourage the use of storage reservoirs to store water for use during periods of scarcity. The use of storage reservoirs will help to alleviate the restrictions of no consumptive abstractions being allowed during the summer months (April to October inclusive). Before a reservoir can be filled during the abstraction period, river flows will need to be either at, or above, the prescribed flow level.

There are many options for off-stream reservoirs, so no explicit rules for determination are given. The Regional Water Resources Strategy supports the development of winter storage in the CAMS area.

The TCCAMS states that the HOF condition at Kingston gauging station is equivalent to the gauged Q50 (1780 Ml/d). This HOF value was approved by the National Water Resources Policy Manager and was outlined in the Thames Corridor CAMS Consultation Document. The HOF was selected primarily to prohibit consumptive summer surface water abstraction, which thereby mimics the previous licensing policy. The Q50 HOF offers the same level of protection to existing abstractors, navigation, water quality and the tideway as the previous licensing policy. In the Thames Corridor it was proposed to maintain the ban on consumptive summer surface water abstraction, so the new HOF will only operate in winter months. In a normal year the HOF will not be enforced, as flows should be high enough for winter abstraction. The HOF will only be enforced in a dry winter and therefore protects the Thames against deterioration of winter low flows.

Tributary CAMS do not have the seasonal ban on consumptive summer surface water abstraction like the Thames Corridor. However, by applying the Thames HOF to new and varied tributary licences all year round, means that in a normal year the HOF will be enforced in the summer to prohibit consumptive surface water summer abstraction. However if it is a wet summer abstraction may be allowed, conversely if it is a dry winter abstraction may be prohibited.

Summary of the sustainability appraisal results for the Thames Corridor CAMS

The table below summarises the current and target resource availability status for each water resource management unit and the preferred management options where a Tier 2 appraisal was undertaken.

WRMU	**Current resource availability status**	**Target - resource availability status**	**Preferred management option(s)**
WRMU1 – Upper Thames	Over abstracted	Over abstracted	• Maintain current presumption against summer abstraction • Investigate feasibility of changing to year-round constrained abstraction • Investigate flow requirements of Oxford watercourses • Encourage licence holders to voluntarily reduce abstraction
WRMU2 – Middle Thames	No water available	No water available	No tier 2 appraisal required
WRMU3 – Lower Thames(freshwater sections only)	Over abstracted	Over abstracted	• Maintain current presumption against summer abstraction • Investigate feasibility of changing to year-round constrained abstraction • Investigate flow requirements of Lower Thames and Tideway • Encourage licence holders to voluntarily reduce abstraction

For the purpose of this study the following assumptions have been adopted:

i) Abstraction only permitted from the Ray and Key between October to March inclusive with a HOF constraint of Q50 (1780 Ml/d) at Teddington
ii) Local HOF constraint of natural Q50 as applied at VWHCAMS AP5 on the Ray
iii) Consumptive abstractions of less than 20m^3 will not be licensed.

APPENDIX 3 - CANAL DEMAND ANALYSIS

1. Losses

POUND DETAILS							LOSSES		
Pound Ref.	Pound Description	Pond Length (m)	Volume in Pound (m^3)	No. of Lock	Volume in Lock (m^3)	Total Volume	Seepage Losses	Lockage Losses	TOTAL Losses (Ml/day)
001	Purton Bd. Bdg. to Pry Lock	1,787	**17,166**	1	68	**17,234**			0.447
002	Pry Lock to Cross Lanes	1,342	**12,892**	1	68	**12,960**			0.336
003	Crosslanes Lock to Hayes Knoll	987	**9,483**	1	68	**9,551**			0.247
004	Hayes Knoll Lock to River Key	1,802	**17,310**	1	68	**17,378**			0.451
005	River Key Aqueduct to End	1,547	**14,861**	1	68	**14,929**			0.387
								CANAL TOTAL =	**1.87**

Table A 3.1: Losses Assuming NO LINING (LOW LOSS 1.75Ml/week) (Ml/d)

POUND DETAILS							LOSSES		
Pound Ref.	Pound Description	Pond Length (m)	Volume in Pound (m^3)	No. of Lock	Volume in Lock (m^3)	Total Volume	Losses (Ml/day)	Lockage	TOTAL Losses (Ml/day)
001	Purton Bd. Bdg. to Pry Lock	1,787	**17,166**	1	68	**17,234**	0.076	0.022	0.098
002	Pry Lock to Cross Lanes	1,342	**12,892**	1	68	**12,960**	0.057	0.022	0.079
003	Crosslanes Lock to Hayes Knoll	987	**9,483**	1	68	**9,551**	0.042	0.022	0.064
004	Hayes Knoll Lock to River Key	1,802	**17,310**	1	68	**17,378**	0.077	0.022	0.099
005	River Key Aqueduct to End	1,547	**14,861**	1	68	**14,929**	0.066	0.022	0.088
								CANAL TOTAL =	**0.430**

Table A 3.2: Losses Assuming 100 Boat Movements going upstream & (SEEPAGE of 10mm/day) (Ml/d)

POUND DETAILS							LOSSES		
Pound Ref.	Pound Description	Pond Length (m)	Volume in Pound (m^3)	No. of Lock	Volume in Lock (m^3)	Total Volume	Losses (Ml/day)	Lockage	TOTAL Losses (Ml/day)
001	Purton Bd. Bdg. to Pry Lock	1,787	**17,166**	1	68	**17,234**	0.153	0.022	0.175
002	Pry Lock to Cross Lanes	1,342	**12,892**	1	68	**12,960**	0.115	0.022	0.137
003	Crosslanes Lock to Hayes Knoll	987	**9,483**	1	68	**9,551**	0.084	0.022	0.106
004	Hayes Knoll Lock to River Key	1,802	**17,310**	1	68	**17,378**	0.154	0.022	0.176
005	River Key Aqueduct to End	1,547	**14,861**	1	68	**14,929**	0.132	0.022	0.154
								CANAL TOTAL =	**0.748**

Table A 3.3: Losses Assuming 100 Boat Movements going upstream & (SEEPAGE of 20mm/day) (Ml/d)

Note: Lockage losses estimated as:
E.g. Purton Road Bridge to Pry Lock
No. of lock = 1
Boat movement = 100 boat/year = 0.274 boat/day
Volume of water transferred = 0.0808Ml
Total = 1lock x 0.274 boat/day x 0.0808 Ml = 0.022 Ml/d

POUND DETAILS							LOSSES		
Pound Ref.	Pound Description	Pond Length (m)	Volume in Pound (m^3)	No. of Lock	Volume in Lock (m^3)	Total Volume	Losses (Ml/day)	Lockage	TOTAL Losses (Ml/day)
001	Purton Bd. Bdg. to Pry Lock	1,787	**17,166**	1	68	**17,234**	0.076	0.111	0.187
002	Pry Lock to Cross Lanes	1,342	**12,892**	1	68	**12,960**	0.057	0.111	0.168
003	Crosslanes Lock to Hayes Knoll	987	**9,483**	1	68	**9,551**	0.042	0.111	0.153
004	Hayes Knoll Lock to River Key	1,802	**17,310**	1	68	**17,378**	0.077	0.111	0.188
005	River Key Aqueduct to End	1,547	**14,861**	1	68	**14,929**	0.066	0.111	0.177
								CANAL TOTAL =	**0.872**

Table A 3.4: Losses Assuming 500 Boat Movements going upstream & (SEEPAGE of 10mm/day) (Ml/d)

POUND DETAILS							LOSSES		
Pound Ref.	Pound Description	Pond Length (m)	Volume in Pound (m^3)	No. of Lock	Volume in Lock (m^3)	Total Volume	Seepage Losses	Leakage Losses	TOTAL Losses (Ml/day)
001	Purton Bd. Bdg. to Pry Lock	1,787	**17,166**	1	68	**17,234**	0.153	0.111	0.263
002	Pry Lock to Cross Lanes	1,342	**12,892**	1	68	**12,960**	0.115	0.111	0.225
003	Crosslanes Lock to Hayes Knoll	987	**9,483**	1	68	**9,551**	0.084	0.111	0.195
004	Hayes Knoll Lock to River Key	1,802	**17,310**	1	68	**17,378**	0.154	0.111	0.265
005	River Key Aqueduct to End	1,547	**14,861**	1	68	**14,929**	0.132	0.111	0.243
								CANAL TOTAL =	**1.191**

Table A 3.5: Losses Assuming 500 Boat Movements going upstream & (SEEPAGE of 20mm/day) (Ml/d)

Assumption	No boat Movement	100 Boats/year			500 Boats/year			1000 Boats/year		
		Downstream	Upstream	50% share	Downstream	Upstream	50% share	Downstream	Upstream	50% share
No seepage		0.022	0.111	0.011	0.111	0.553	0.055	0.221	1.107	0.111
NO LINING (LOW LOSS 1.75Ml/Week)	1.867									
NO LINING (MEDIUM LOSS 3Ml/Week)	3.200									
NO LINING (HIGH LOSS 5Ml/Week)	5.334									
% of Drift in each Canal Reach is Puddle Clay LINED	3.067									
100% of Canal is CONCRETE LINED	0.000									
50% of Each Canal Reach is BENTONITE LINED	4.898									
100% of Canal is BENTONITE LINED	0.000									
10mm/day	0.319	0.341	0.430	0.330	0.430	0.872	0.374	0.540	0.540	0.430
20mm/day	0.638	0.660	0.748	0.649	0.748	1.191	0.693	0.859	1.744	0.748
30mm/day	1.020	0.979	1.067	0.968	1.067	1.510	1.012	1.178	2.063	1.067

Table A 3.6: Total Losses [Ml/day]

2. Water Balance

2.1 Av Summer (72 Days)

Pound 001 - Purton Rd Bridge to Pry Lock

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.447	0	0.572	0.538	1.110	32.81	3.4%
Summer	0.447	0.447	0.447	0	0.447		1.4%
Annual	0.447	0.262	0.273	0.174	0.447		

Pound 002 - Pry Lock to Cross Lanes

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.336	0	0.429	0.404	0.833	31.70	2.6%
Summer	0.336	0.336	0.336	0	0.336		1.1%
Annual	0.336	0.197	0.205	0.131	0.336		

Pound 003 - Crosslanes Lock to Hayes Knoll Lock

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.247	0	0.316	0.297	0.613	30.87	2.0%
Summer	0.247	0.247	0.247	0	0.247		0.8%
Annual	0.247	0.145	0.151	0.096	0.247		

Pound 004 - Hayes Knoll Lock to River Key

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.451	0	0.577	0.542	1.119	30.25	3.7%
Summer	0.451	0.451	0.451	0	0.451		1.5%
Annual	0.451	0.264	0.275	0.224	0.727		

Pound 005 - River Key Aqueduct to End

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch K2	
		Storage	key			QN50	%QN50
Winter	0.387	0	0.495	0.466	0.961	9.46	10.2%
Summer	0.387	0.387	0.387	0	0.387		4.1%
Annual	0.387	0.227	0.236	0.151	0.387		

Total[1] - Purton Rd Bridge to End

	Net loss	Feed from		Into Storage	Total Abs
		Storage	Ray		
Winter	1.867	0	2.389	2.246	4.635
Summer	1.867	1.867	1.867	0	1.867
Annual	1.867	1.094	1.141	0.726	1.867

[1] - %QN50 is not given in the Total because abstractions are taken from the Rivers Ray and Key and single %QN50 is not apporpiated

Table A 3.7: Water Balance [Ml/d] Assuming Av. Summer (72days) and NO LINING (LOW LOSS 1.75Ml/Week/KM)

2.2 Av Winter (118 Days)

Pound 001 - Purton Rd Bridge to Pry Lock

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.447	0	0.572	0.810	1.382	32.81	4.2%
Summer	0.447	0.447	0.000	0	0.000		0.0%
Annual	0.447	0.262	0.185	0.262	0.447		

Pound 002 - Pry Lock to Cross Lanes

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.336	0	0.429	0.609	1.038	31.43	3.3%
Summer	0.336	0.336	0.000	0	0.000		0.0%
Annual	0.336	0.197	0.139	0.197	0.336		

Pound 003 - Crosslanes Lock to Hayes Knoll Lock

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.247	0	0.316	0.448	0.764	30.39	2.5%
Summer	0.247	0.247	0.000	0	0.000		0.0%
Annual	0.247	0.145	0.102	0.145	0.247		

Pound 004 - Hayes Knoll Lock to River Key

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch 9	
		Storage	Ray			QN50	%QN50
Winter	0.451	0	0.577	0.817	1.394	29.63	4.7%
Summer	0.451	0.451	0.000	0	0.000		0.0%
Annual	0.451	0.264	0.186	0.338	0.577		

Pound 005 - River Key Aqueduct to End

	Net loss	Feed from		Into Storage	Total Abs	Supply Catch K2	
		Storage	Key			QN50	%QN50
Winter	0.387	0	0.495	0.702	1.197	9.46	12.6%
Summer	0.387	0.387	0.000	0	0.000		0.0%
Annual	0.387	0.227	0.160	0.227	0.387		

Total[1] - Purton Rd Bridge to End

	Net loss	Feed from		Into Storage	Total Abs
		Storage	Ray		
Winter	1.867	0	2.389	3.385	5.774
Summer	1.867	1.867	0.000	0	0.000
Annual	1.867	1.094	0.772	1.094	1.867

[1] - %QN50 is not given in the Total because abstractions are taken from the Rivers Ray and Key and single %QN50 is not apporpiated

Table A 3.8: Water Balance [Ml/d] Assuming Av. Winter (118days) and NO LINING (LOW LOSS 1.75Ml/Week/KM)

2.3 Calulation Examples

E.g. Purton Rd Bge to Pry Lock

Assuming NO LINING (LOW LOSS 1.75Ml/Week/KM)
Winter Abstraction Only
Daily demand = 0.447Ml/d
Summer demand to be met from storage = 214 x 0.447 = 95.66Ml
15% = 14.35Ml
Total = 110Ml

Assuming the recommended demand scenario of 20mmd-1 and 100 lock operations

Winter Abstraction only:
Daily demand = 0.175Ml/d
Summer demand = 214d x 0.175ml/d = 37.45ML
15% = 5.61Ml
Total = 43.06Ml

Dry Summer:
17days abstraction during summer
Summer demand to be met from storage = (214d – 17d) x 0.175Ml/d = 34.475ML
15% = 5.17Ml
Total = 39.6Ml

APPENDIX 4 - COST ESTIMATES

1. Reservoir 1 for Pound 1.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No. 4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£62,700.00**
2	10m of 0.1m dia Rising Main			**£706.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	40,500.00	£20.75	**£840,375.00**
4	Abstraction Pumps (2 No. 4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£62,700.00**
4	850m of 0.1m dia Rising Main			**£60,427.00**
			TOTAL =	**£1,056,908.00**

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No. 8l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£68,000.00**
2	10m of 0.1m dia Rising Main			**£679.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	23,437.50	£20.75	**£486,328.13**
4	Abstraction Pumps (2 No. 8l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£68,000.00**
4	850m of 0.1m dia Rising Main			**£57,700.00**
			TOTAL =	**£710,707.13**

2. Reservoir 2 for Pound 2.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No. 3l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
2	10m of 0.1m dia Rising Main			**£700.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	32,175.00	£20.75	**£667,631.25**
4	Abstraction Pumps (2 No.3l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
4	700m of 0.1m dia Rising Main			**£48,000.00**
			TOTAL =	**£872,331.25**

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No. 6l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
2	10m of 0.1m dia Rising Main			**£700.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	18,000.00	£20.75	**£373,500.00**
4	Abstraction Pumps (2 No.6l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£66,000.00**
4	700m of 0.1m dia Rising Main			**£48,000.00**
			TOTAL =	**£581,200.00**

3. Reservoir 3 for Pound 3.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.3l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
2	250m of 0.1m dia Rising Main			**£17,000.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	24,750.00	£20.75	**£513,562.50**
4	Abstraction Pumps (2 No.3l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
4	500m of 0.1m dia Rising Main			**£34,000.00**
4				**£0.00**
			TOTAL =	**£720,562.50**

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£64,000.00**
2	250m of 0.1m dia Rising Main			**£17,000.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	14,025.00	£20.75	**£291,018.75**
4	Abstraction Pumps (2 No.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£64,000.00**
4	500m of 0.1m dia Rising Main			**£34,000.00**
4				**£0.00**
			TOTAL =	**£500,018.75**

4. Reservoir 4 for Pound 4.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£63,000.00
2	300m of 0.1m dia Rising Main			£20,000.00
1	POWER SUPPLY			£5,000.00
1	TELEMETRY			£25,000.00
3	Excavation of Material for Potential Storage	40,500.00	£20.75	£840,375.00
4	Abstraction Pumps (2 No. 4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£63,000.00
4	910m of 0.1m dia Rising Main			£62,000.00
4				£0.00
			TOTAL =	£1,078,375.00

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.8l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£39,309.00
2	300m of 0.1m dia Rising Main			£22,787.00
1	POWER SUPPLY			£5,000.00
1	TELEMETRY			£25,000.00
3	Excavation of Material for Potential Storage	23,625.00	£20.75	£490,218.75
3				£0.00
4	Abstraction Pumps (2 No.8l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£39,309.00
4	910m of 0.1m dia Rising Main			£64,429.00
4				£0.00
			TOTAL =	£686,052.75

5. Reservoir 5 for Pound 5.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.1.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 1.5m dia Wet Well			£62,000.00
2	20m of 0.1m dia Rising Main			£1,700.00
1	POWER SUPPLY			£5,000.00
1	TELEMETRY			£25,000.00
3	Excavation of Material for Potential Storage	18,000.00	£20.75	£373,500.00
3				£0.00
3				£0.00
4	Supply Pumps (2 No.1.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 1.5m dia Wet Well			£63,000.00
4	300m of 0.1m dia Rising Main			£21,000.00
4				£0.00
			TOTAL =	£551,200.00

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£63,000.00
2	20m of 0.1m dia Rising Main			£1,700.00
1	POWER SUPPLY			£5,000.00
1	TELEMETRY			£25,000.00
3	Excavation of Material for Potential Storage	10,237.50	£20.75	£212,428.13
3				£0.00
3				£0.00
4	Supply Pumps (2 No.4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			£63,000.00
4	300m of 0.1m dia Rising Main			£21,000.00
4				£0.00
			TOTAL =	£391,128.13

6. Reservoir 6 for Pound 5.

DRY SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.1.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 1.5m dia Wet Well			**£62,000.00**
2	20m of 0.1m dia Rising Main			**£1,700.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	0.00	£20.75	**£0.00**
3				**£0.00**
4	Supply Pumps (2 No.1.5l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 1.5m dia Wet Well			**£63,000.00**
4	300m of 0.1m dia Rising Main			**£21,000.00**
4				**£0.00**
			TOTAL =	**£177,700.00**

WET SUMMER ASSUMED

Engineering Ref.	Item Description	Quantity	Unit Rate	Total Cost
1	Abstraction Pumps (2 No.4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
2	20m of 0.1m dia Rising Main			**£1,700.00**
1	POWER SUPPLY			**£5,000.00**
1	TELEMETRY			**£25,000.00**
3	Excavation of Material for Potential Storage	0.00	£20.75	**£0.00**
3				**£0.00**
4	Supply Pumps (2 No.4l/s pumps assumed) DUTY/STANDBY ARRANGEMENT in 2m dia Wet Well			**£63,000.00**
4	300m of 0.1m dia Rising Main			**£21,000.00**
4				**£0.00**
			TOTAL	**£178,700.00**

APPENDIX 5 – DRAWINGS