SOUTH EAST WALES COASTAL STRATEGY - A CASE STUDY

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Introduction

The South East Wales Coastal Strategy was developed during the 1990s by Hyder Consulting Limited (HCL) for Dwr Cymru Welsh Water (DCWW) to meet the requirements of the EU Urban Waste Water Treatment Directive (UWWTD). The strategy provided a sewage disposal solution for four towns and twenty-four villages along a 30 km stretch of the Severn Estuary between Chepstow and Newport (Figure 1). The solution is a major transfer scheme involving the abandonment of four existing Waste Water Treatment Works (WWTW) and eight crude outfalls. A series of new pumping stations and rising mains will transfer flows to an extended WWTW at Newport.

This paper describes how drainage area planning and simplified Urban Pollution Management (UPM) techniques were used to develop integrated solutions and to optimise design of the transfer scheme. An important aspect of the approach was to ensure that the Environment Agency (EA) was contacted at the earliest stage and kept informed of all developments.

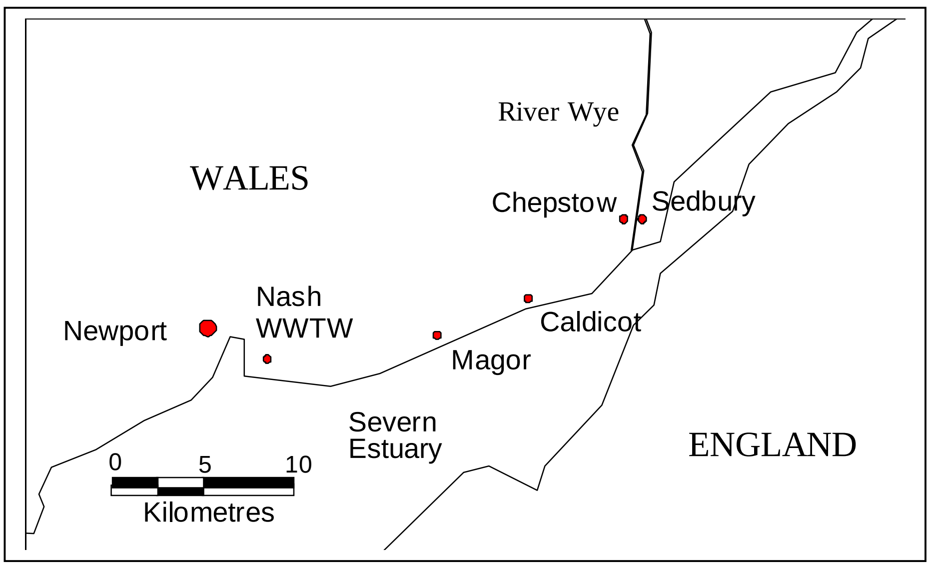

Figure 1 - Location Plan

Background

The principal driver for the strategy was the UWWTD, which included the requirement for provision of secondary treatment at Chepstow by December 2000. Sewage from the northern half of Chepstow is currently discharged untreated via two crude outfalls to the River Wye, whilst that from the southern half receives only preliminary treatment. Existing WWTWs at Sedbury, Caldicot and Magor also require significant improvements and extensions by 2005 to meet stricter UWWTD discharge consent standards.

Rather than consider each town in isolation, DCWW chose to take a broader view. HCL was commissioned in 1995 to undertake a feasibility study to identify the most cost effective sewage disposal strategy. The study considered options such as treatment at individual WWTWs or combining flows for treatment at one or more of the existing sites. In conjunction with a comprehensive study of sludge disposal options for the region, the preferred solution emerged: abandonment of the existing treatment facilities with pumped transfer of all flows to an extended WWTW at Nash near Newport. This solution formed part of a general policy to concentrate treatment at a small number of major sites along the South Wales coast.

In parallel with a need to progress the treatment strategy, there was mounting pressure to address sewerage-related issues within the catchments, such as unsatisfactory CSOs and DG5 property flooding. Increasing development, due principally to the proximity of the M4 motorway, was also placing a strain on the existing sewerage infrastructure. It was clear that an integrated catchment planning approach would provide solutions for these problems as well as the essential data and tools needed for designing the transfer scheme. In May 1997, HCL were appointed to undertake a drainage area study covering all the catchments affected by the proposed scheme.

Initial planning

The initial planning phase was essentially a scoping exercise with the following aims:

- to confirm the scheme envelope and identify all existing discharges, flooding and operational problems within the catchment area;
- to establish the environmental standards required of the receiving waters;
- to review existing data and model coverage and assess requirements for further data collection and modelling to meet the objectives of the study, and;
- to define costs and programme for completion of the study.

The towns of Magor, Caldicot, Chepstow and Sedbury account for approximately 32,000 out of the total catchment population of 41,500. A large number of smaller, outlying villages house the remainder. The M4 motorway divides the catchment - the area north of the motorway is characterised by low hills and agricultural land whilst that to the south is very low lying and drained by reen systems (the Gwent levels).

Discharges from the existing crude outfalls, WWTWs and the majority of the CSOs are to either the River Wye at Chepstow or the Severn Estuary. Theses discharges do not affect any bathing beaches or shellfisheries but the waters are used for recreational purposes and thus subject to either Moderate or High Amenity classifications. The Wye is also classed as an SSSI and as a Special Protection Area. It is worth noting that the Severn Estuary has the second largest tidal range in the world, with a range of some 12m at Chepstow on spring tides. CSOs in the outlying rural areas spill to small streams or reens. These are either Moderate or Low Amenity waters and only one, the Mounton Brook to the west of Chepstow, is subject to target water quality standards (River Ecosystem Class 2).

During the initial planning phase, a comprehensive discharge list was produced in consultation with the EA, DCWW and local Sewerage Management Contractors. The list included crude discharges, WWTW final effluent and settled storm, CSOs and pumping station emergency overflows.

The existing sewerage model coverage was found to be variable. To obtain tools that were fit for purpose, construction and verification of new models was recommended, to be achieved using the results of a selective STC25 manhole survey and a short term flow survey. This work, together with that required to complete the study, was then costed, programmed and presented to DCWW in an Initial Planning Report.

Model construction and verification

Models were constructed and verified using the HydroWorks PM+ package. Base data was obtained from new surveys of assets including 600 manholes, 19 pumping stations and 8 CSOs. Information from existing WALLRUS models and STC25 databases was used to supplement the new survey data and all WALLRUS data was converted and validated to ensure compatibility with HydroWorks. Between them, the models had a combined total of 1400 nodes. During this stage, data for the Chepstow catchment was also used for beta testing of InfoWorks in conjunction with Wallingford Software.

Model predictions were verified using both historical records and the results obtained from a short-term flow measurement survey. A total of 74 flow monitors and 12 raingauges were in place for 12 weeks between February and April 1998. The survey revealed significant infiltration in the rural parts of the catchment. These areas typically consist of small villages connected by long lengths of gravity sewer, often running parallel to natural watercourses. The reactive, or wet weather, infiltration is marked in these areas and causes both flooding problems and premature operation of overflows (Figure 2).

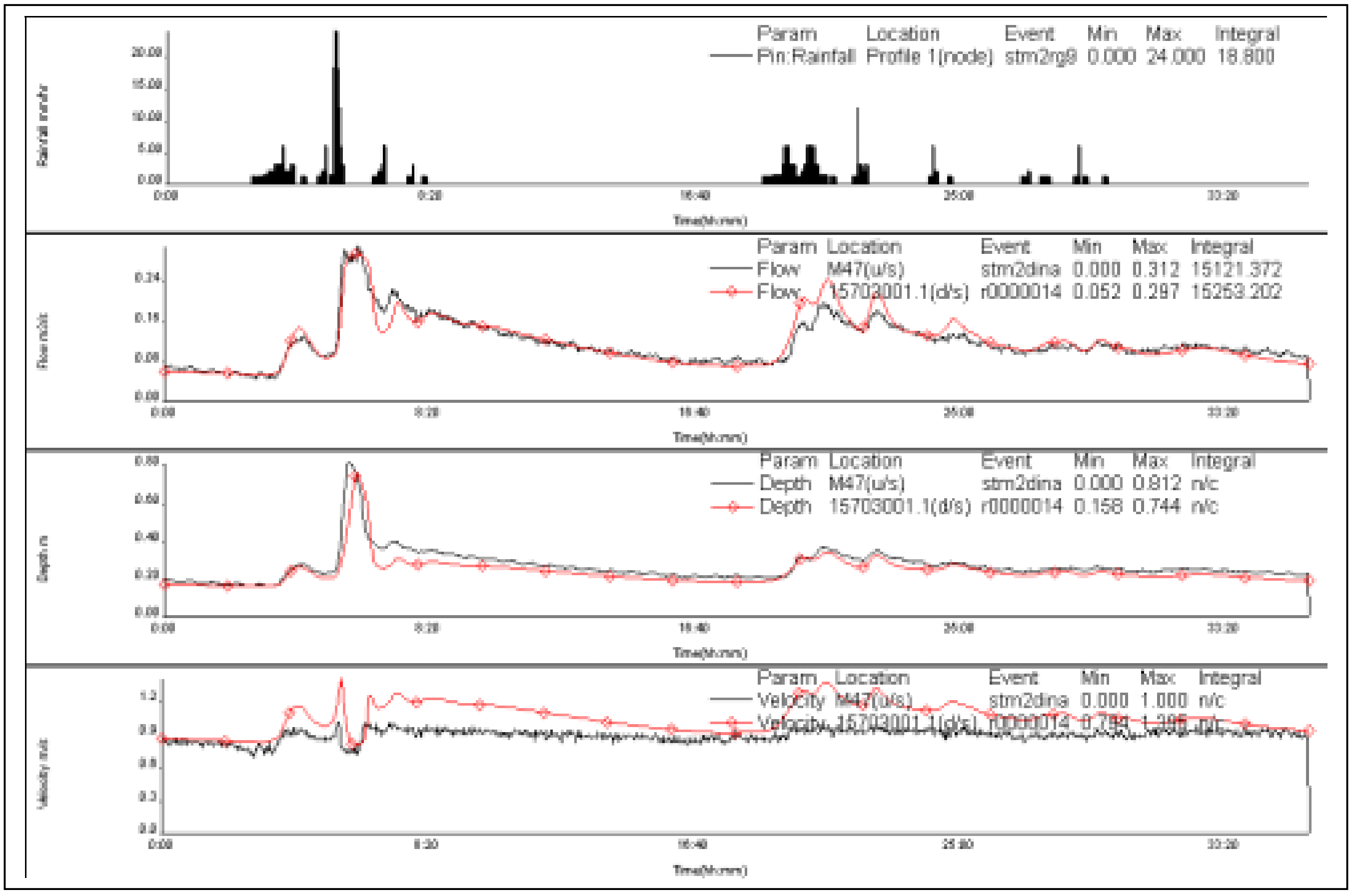

Figure 2- Model verification plot showing wet weather infiltration

As the models were going to be used for transfer scheme design, particular emphasis was placed on understanding and representing base dry weather flows and reactive infiltration. The effort invested at this stage proved worthwhile as the quality of the verification achieved gave the EA confidence that the models could be used for refinement of the transfer scheme flow regime.

Hydraulic and environmental assessment

Using the verified models, hydraulic assessment of the sewerage systems was carried out for both existing (1998) and future (2011) scenarios. Details of future developments were obtained from recently completed Unitary Development Plans. Similarly, for all existing CSO discharges, a spill frequency assessment was undertaken using historical time series rainfall data. A 'typical year' was selected from an appropriate 11 year historical data set and all events (174) were run to provide an indication of average annual CSO performance.

Two of the CSO discharges, in a rural subcatchment to the west of Chepstow, affected the Mounton Brook (RE Class 2). For these, spill hydrographs were supplied to the EA, who carried out a QUALSIM analysis to check compliance with target 99 percentile criteria for BOD and total ammonia. Spills at these CSOs are common during the winter months due to heavy infiltration related to high groundwater and river levels. Predicted spill frequency was found to be highly dependent on the level of infiltration assigned in the model. For the QUALSIM assessment, it was agreed that basing the infiltration on the average level observed during the 12 week winter flow survey would be a reasonable approach.

A substantial amount of data on structural deficiencies in the sewerage systems had been obtained as part of DCWW's Asset Management Plan in 1992/3. This information was updated after consultation with the local Sewerage Management Contractors. Plans were produced detailing all the identified hydraulic, environmental and structural deficiencies. These were submitted in a report (Phase 2) issued to all parties for comment prior to development of the catchment plan.

Development of the catchment plan

Having identified all deficiencies, it was possible to apply an integrated approach to the development of improvement options. Whilst this process was generally progressed on an individual catchment basis, the proposed transfer scheme affected decisions in a number of areas. For example:

- In Chepstow town centre, a bifurcation divides flow between two crude outfalls to the River Wye, some 4km apart. Improvement options to address flooding problems considered altering the division of flow at this bifurcation. As the transfer scheme proposes to intercept the crude outfalls with pumping stations, the long-term advantages of diverting more flow by gravity to the downstream transfer station had to be taken into account.
- An overflow into the Mounton Brook at Mathern Pumping Station was found to have a current setting of less than Formula A, the restriction being the capacity of the pumping station and rising main. In addition, the pumps had been observed to operate at full capacity for long periods during the winter due to major infiltration. Increasing the setting to Formula A would have required new pumps and replacement of several kilometres of rising main at considerable cost. There would also have been cost implications at the downstream transfer station in terms of storage provision and pump running costs. Rather than transfer additional infiltration for long distances, the existing setting has been retained.

All improvement options were assessed and preferred solutions identified. Solutions were then allocated a priority rating. The highest priority was assigned to solutions that had to be implemented as part of the transfer scheme, i.e. by December 2000. Distinction was made between solutions for historic flooding locations and those for areas where problems had not been reported. Models were produced to represent the fully implemented catchment plan and these were subsequently used for design of the transfer scheme. The estimated total cost of implementing the catchment plan was £8.5m.

Development of the transfer scheme

Whilst the catchment plan had been based on the Unitary Development Plan horizon of 2011, a much longer design life was required for the major pipelines needed for the transfer scheme. Meetings were held with Planning Directors from Forest of Dean District Council, Monmouthshire County Council and Newport County Borough Council to obtain details of general growth rates and any potentially significant individual developments beyond 2011.

A spreadsheet was developed to derive Dry Weather Flow (DWF), Flow to Full Treatment (FFT) and Formula A values at each of the proposed transfer stations for 1998, 2011 and 2060. Account was taken of seasonal differences in the number of tourists and day visitors but variations in infiltration were found to be much more significant, particularly in the rural catchments. Calculations were based on three levels of infiltration (as observed during the 12-week winter flow survey):

- Maximum reactive infiltration – the level of infiltration still present 1 day after rainfall;
- Maximum base infiltration – the level of infiltration still present 7 days after rainfall, and;
- Minimum base infiltration – the minimum observed at any time.

Peak DWF factors were calculated based on flow survey data and used to derive reduced FFT figures. The factors ranged from 1.9 to 2.5 across the five catchments. Preliminary pipe sizes were also identified, based on all infiltration scenarios and the full design range from 1999 to 2060. Flow to full treatment was agreed on this basis assuming maximum reactive infiltration. This gave a total flow of 350 l/s to be passed forward for treatment at Nash WWTW, compared with the 3DWF figure of 460 l/s.

Implementation of the transfer scheme will create new CSOs at the existing outfall locations. The basic requirement for such CSOs is for a pass forward flow of Formula A. With reduced FFTs, storage must be provided to ensure equivalent performance in terms of annual spill volume. In this case, the proposed discharges are to tidal waters that are remote from Bathing Waters and Shellfish Waters, and as such do not have quality objectives. The potential therefore existed at some of the locations to explore the possibility of alternative storage volumes (such as 2 hours at Formula A less FFT).

The catchment plan models were used with 'typical year' rainfall data to predict spills at the proposed transfer stations for the two alternative storage scenarios. A summary is shown in Figure 3.

2011 Design horizon		Sedbury	Chepstow North The Back	Chepstow North Fairfield	Chepstow South	Caldicot	Magor
Flow to Full Treatment (FFT)	l/s	45	16	12	99	75	104
Formula A flow	l/s	80	48	37	183	147	142
Formula A Equivalence Volume	m^3	525	525	325	1750	1500	425
Annual Spill Frequency		20	35	69	13	2	0
2 hours @ Formula A - FFT	m^3	251	228	178	605	515	274
Annual Spill Frequency		54	93	112	60	27	2

Figure 3- Storage volumes and spill frequencies

At Chepstow (The Back) and Sedbury, full Formula A equivalent storage was considered appropriate. However, due to land issues and site constraints, it was found to be more cost effective to pass forward Formula A flows from The Back and Fairfield across the river to Sedbury, where more land was available for storage (Figure 4). Again, the models were used to determine spill frequencies and volumes. At Sedbury, a 1400m3 storage tank was assessed as being sufficient to limit spills to the required volume. The models were also used to optimise the hydraulic design of screens to meet aesthetic control standards (6mm mechanically raked screens were proposed at each transfer station, with screenings retained in the flow passed forward for treatment).

Cost savings

Where improvements are needed in a sewerage system, the economic sense of using hydraulic modelling to understand the performance of the system and develop a drainage area plan is well understood. In this case, where a major £13m transfer scheme will collect flows from four existing WWTW catchments, the cost savings are even more significant.

Due to the considerable transfer distances, the biggest benefit was achieved by carefully assessing the required flow to full treatment from each transfer station. This resulted in significant capital savings in pumping stations and rising mains. The sewerage modelling, and in particular the thorough assessment of infiltration and representation of dry weather flows, has been crucial in demonstrating the optimum values of flow to full treatment.

Analysis of hydraulic performance and demonstration of acceptable spill frequencies and volumes was also an essential part of the process. At Magor, the analysis showed that an acceptable spill frequency was achievable with storage even below the 2 hours at Formula A less FFT figure.

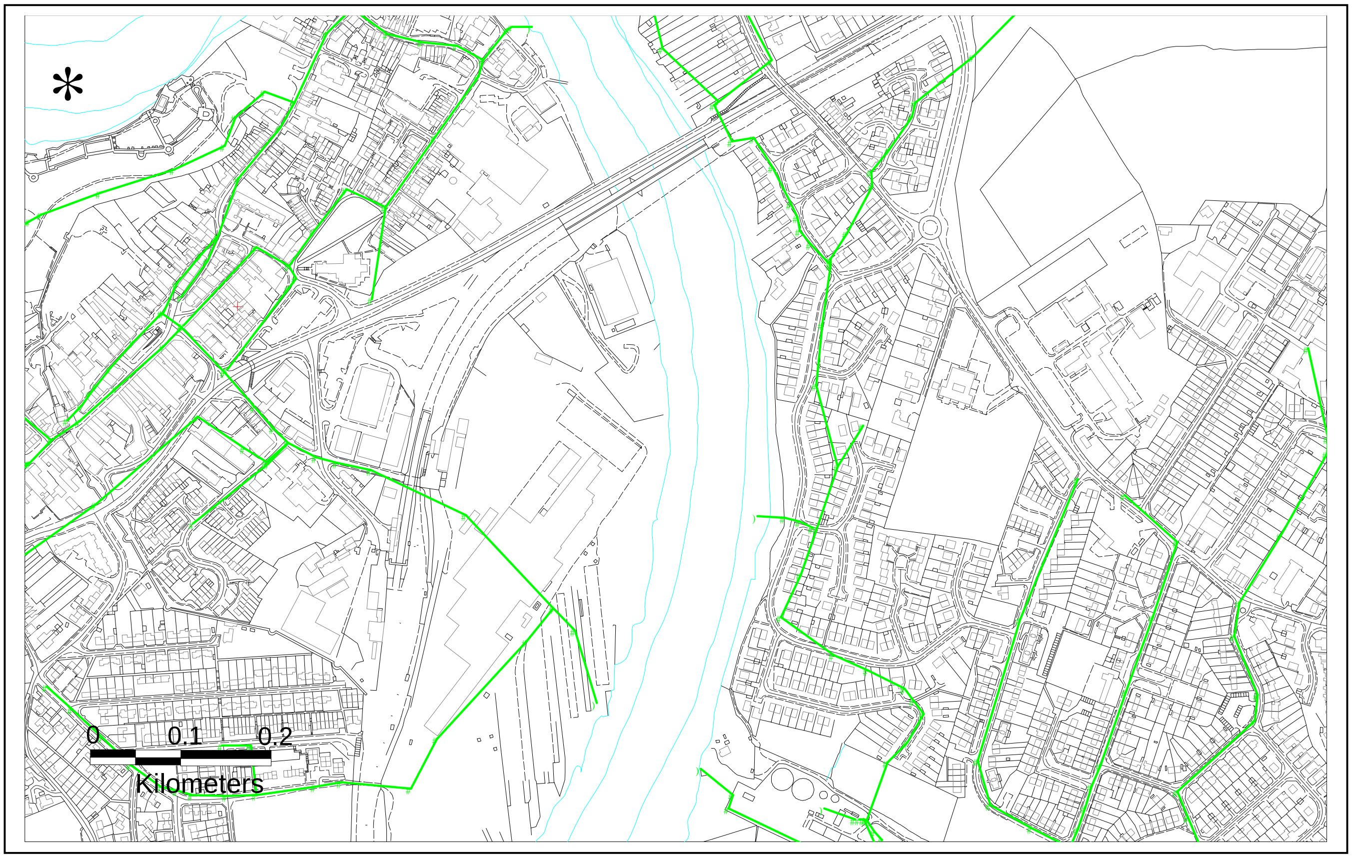

Figure 4- Proposed arrangements at Chepstow North and Sedbury

Within each catchment, the integrated solutions that address structural, hydraulic and CSO deficiencies will undoubtedly result in further savings. In addition, the individual catchment models have been used on three occasions to assess points of adequacy for new sewers to serve housing developments. Against all these benefits, the total study cost amounted to less than 5% of the savings achieved on the transfer scheme alone.

Conclusions

The South East Wales Coastal Strategy was developed as part of a major investment programme to meet the requirements of the UWWTD. In a climate of constant pressure on capital costs and to improve operational efficiency, the need for carefully engineered solutions is more important than ever. Whilst savings can be achieved in many ways and at all phases in a project, the greatest advantages are gained during planning and outline design. This case study provides an example of how such advantages can be realised.

The initial planning identified the data and tools needed to meet the objectives of the study. Sewerage modelling then provided a thorough understanding of the flow regime in each catchment under both dry weather and storm conditions. The models were used firstly to develop an overall catchment plan to an agreed design horizon and secondly to design the main features of the transfer scheme. Demonstration of reduced flows to full treatment and smaller storage tanks was a direct result of the confidence inspired by the high quality model verification that was achieved. The full process, from initial planning to completion of outline design of the transfer scheme, took just under two years but the end result was that the most cost effective solution had been identified.

Discussion

Question **Richard Allitt Richard Allitt Associates**

How did you get such good fits on the verification plots?

Would you have liked to have used the infiltration model that has now become available in InfoWorks?

Answer

The recession effect, caused by slower response to rainfall, was represented by including an additional impermeable area but with a much reduced rate of runoff in the runoff equation. This was calibrated against 3 storm events.

We would be interested in looking at the new model. However these effects are represented, caution is required when extrapolating to design conditions. A good example would be a model verified with a winter flow survey and then used to design a bathing water scheme.