The Welsh Water Capital Alliance 'Virtual Design House'

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Introduction

"Rethinking Construction identified the separation of design from the rest of the project process as a fundamental weakness within the construction industry." (*Extract from the Egan Report)*.

The work in delivering a sewerage improvement programme in South East Wales for D r Cymru Welsh Water (DCWW) has shown that integration of design into the project process has technical and environmental, as well as commercial, benefits. AMEC Group Ltd is working on behalf of DCWW as a member of the Welsh Water Capital Alliance, a group of strategic partners delivering over 60% of DCWW's capital investment programme during the Asset Management Plan 3 (AMP3) for the period 2000-2005. AMEC has a notional budget of £130 million to deliver 282 CSO's in Years 1 to 5 (and a further 61 indicated for Year 6), as well as solutions to many incidents of flooding. This paper examines the innovative mechanisms being used to deliver the programme in South East Wales and some of the benefits that have already been delivered.

Early Stages of the Virtual Design House

The sewerage networks in SE Wales tend to follow the topography of the valleys to 3 main WwTW (Wastewater Treatment Works) at Cardiff (East), Cog Moors (Cardiff West and Barry) and Nash (Newport), all of which were all built during in the AMP2 programme. Fig.1 shows the principal trunk sewers. Nearly all WwTW's in the area are based on 'standard' (i.e. 3DWF) designs. The programme of work in Years 1 to 3 of AMP3 has largely aimed at the improvement of uCSOs within the upper valley areas of these catchments, upstream of the parts of the systems already improved within AMP2. This meant that solutions for these valleys could be considered in 'isolation', although care was required to ensure that flows passed on downstream did not have unacceptable consequences for the parts of the scheme that had already been completed.

Fig.1 SE Wales Trunk Sewer Network

Four consultants with local offices have been used for design purposes in order to ensure that local resource was employed, This means that locations can be visited at any time during the design process, which improves understanding of the system. The consultants are Binnie Black and Veatch (BBV), Hyder Consulting Ltd (HCL), Ove Arup and Partners Ltd and Montgomery Watson Harza (MWH). Co-location was considered but due to the nature of the programme this was not deemed to be cost effective. Each company was given particular catchments to resolve.

Three initial goals were identified, a focus on final outturn cost, common standards and common reporting. To achieve common standards and specifications, the teams worked together to produce new specifications with D r Cymru, as well as standard details and reporting systems. Formal and informal meetings were held, to understand and enhance systems and techniques. Fee targets were agreed as Key Performance Indicators (KPI's) rather than ceilings, and emphasis was placed on total scheme cost. Innovative IT and document control systems were set up to service the team. The mechanisms and close working techniques coalesced the four consultants into an initial form of what has been termed the 'Virtual Design House' (VDH). The 'Virtual Design House' is a concept developed and promoted by AMEC and DCWW whereby design services could be procured from any of the contracted consultants with the expectation of achieving the same results in terms of outputs and service provided. The aim is 'one design process, one "designer"'.

These processes have already began to have 'spin-off' benefits. On certain catchments, the techniques have demonstrated both environmental and cost benefit (ref, *Western Valleys CSO's*, Ian Clifforde and others, WaPUG Spring 2002 Conference). The principles behind these solutions were quickly disseminated to other consultants in the VDH. The latest designs are showing improved environmental performance whilst reducing cost against the original budgets, in some cases significantly. Fig.2 shows the results achieved to-date and illustrates the benefits of the system, in programme and environmental outcome, as well as bettering cost targets.

Year	Designated uCSOs Required	Designated uCSOs Delivered	Additional CSOs Delivered	DG5 (ARR) Properties Resolved	DG5 (HO) Properties Resolved
1	7	9	1	55	1
2	55	74	5	15	7
3	66	*70** (30 complete)	*4** (1 complete)	*81** (26 complete)	*83** (55 complete)

**Projected*
Overall costs to date are circa 6% below AMP3 target (set as 20% less than AMP2 costs).

<u>Fig. 2 Outputs to date</u>

A key principle of the approach has been the early, and full, involvement of Environment Agency (Wales) (EAW). Whilst being mindful of their role as a regulator, and hence their need to ensure independence, EAW has been very helpful in assessing the environmental impacts of various solutions during the options phase of schemes. The design teams have been able to assist in this process by using the EA's SPIRIT software to test the effects of their proposals on the local environs where appropriate.

The Rhymney Valley is an example where the benefits of this approach were clearly demonstrated. This catchment had been assessed during AMP2 and a solution proposed based on achieving CSO performance equivalent to Formula (SOC) 'A' involving significant sewer duplications and storage. As the flows passing forward to treatment had already been effectively limited to 3DWF by AMP2 works at the bottom of the catchment, any solution had to be a balance between spilling and storing. As a matter of principle, EAW prefer any CSO spills to be spread throughout a catchment (to minimise local impacts whilst ensuring compliance with their 'no deterioration' policy). When the team analysed the environmental impacts for various options at the uCSO's, one uCSO in particular was shown to have a major impact (circa 550,000m^3 spillage per annum). It was found that, by a limited amount of trunk sewer upgrading, the existing network could be used to attenuate the flows, and spills at the next downstream CSO were only at 5% of that of the existing uCSO. Fig.3 shows the results of the SPIRIT analysis of various options, Option A being the one agreed for implementation: note that the two tables formed part of the actual submission to EAW. Option C gave marginally better environmental results but, as this would have added circa £400,000 to cost, it was accepted that this additional expenditure was not justified. A key point to note however is that a quality based approach does not always reduce works, and hence cost, but it does deliver outputs more focussed on the local environmental needs.

Table 1: Options for Improving Dwr Cymru-Welsh Water Assett No: 52220/AMEC Scheme E33/Unique Identifier DC 110 2314

Option	Description of Works	Spills/Year	Spill Time/ Year (%)	Annual spill volume (m^3)	Pass forward flow- (3DWF) (l/s)	Formula A (l/s)	Notes
Existing solution	• No new works, CSO E33 operating at existing settings	100	16	573,885	238 (603)	1056	• Distance to fish farm **3.70 km** (4.69 km) (3)
A	• Decommission CSO E33 • Provide replacement CSO E34 with 6mm screen.	44	1.3	26,427	850 (810)	1325	• Distance from E33 **2.45 km** (2.91 km) (3) • Distance to fish farm **1.25 km** (1.78 km) (3)
B	• Decommission CSO E33 • Decommission CSO E34 • Provide new CSO with 6mm screen upstream of scheme E38(1)	48	2.1	91,806	480 (627)	1086	• Distance from E33 **1.70 km** (1.87 km) (3) (1) Distance to fish farm **2.00 km** (2.82 km)(3)
C	• Decommission CSO E33 • Decommission CSO E34 • Provide new CSO with 6mm screen upstream scheme E38(1)	21	0.6	19,975	630 (627)	1086	• Distance from E33 **1.7 km** (1.87 km)(3) • Distance to fish farm **2.00 km** (2.82 km)(3) • This solution requires works further near Scheme E28(2); these comprise 710m of 750mm pipe with a high level overflow at E28(2). If this overflow is not consented, then an additional 450m of 750mm pipe will also be required. • CSO E28(2) would be maintained as a high level overflow for 5 and 10 year return period storms with a maximum spill of $500m^3$ in the 10 year storm.
D	• Decommission CSO E33 • CSO E34 retained as a high level overflow • Provide new CSO with 6mm screen downstream scheme E27(1) .	51	1.8	49,038	510 (609)	1062	• Distance from E33 **0.70 km** (0.70 km) (3) • Distance to fish farm **3.00 km** (3.99km) (3) • This solution requires works further near Scheme E28(2); these comprise 710m of 750mm pipe with a high level overflow at E28(2). If this overflow is not consented, then an additional 450m of 750mm pipe will also be required. • CSO E28(2) would be maintained as a high level overflow for 5 and 10 year return period storms with a maximum spill of $500m^3$ in the 10 year storm. • The existing overflow located at CSO E34 will activate on the 5 and 10 years return period storms with a maximum spill of $750m^3$ in the 10 year storm. Note: This is likely to include a requirement for pumping into the river which would need to be confirmed by a topographic survey.

Notes:
(1) See Drawing E34/3000
(4) Spill analyses are based on the 100 SGR storms

Table 2: Cost/Benefit Analysis of Options for Improving Dwr Cymru-Welsh Water Assett No. 52220/ AMEC Scheme E33/Unique Identifier DC 110 2314

Option	Description of Works	Capital Cost Ratio	Construction Difficulty	Benefit Analysis (Benefit Ranking Scores shown in brackets – highest figure is best): River Water Quality (from SPIRIT Analyses): Location	BOD (mg/l)	NH_4^+ (mg/l)	RE Class	Other Environmental Factors: Construction Area	Access Arrangements	Impact on Community	Ecological	Benefit Ranking Score (Sum of Individual Ranking Scores from preceding columns)
Existing Situation	None; existing situation at CSO at E33 (DC 110 2314)	0%	N/A	E33 E34	53.05 6.16	6.99 0.43	>5 2	N/A	N/A	Present outfall is unsatisfactory		
A	1. Decommission CSO at E33 (DC 110 2314) 2. Construct new powered CSO and outfall at E34 (DC 110 2320) and decommission old CSO and outfall at E34	100%	No difficult operations; the new CSO replaces an existing CSO and will be an improve-ment with 6mm screens	E33 E34 E38	Decommissioned 3.20 2.82 (1)	0.20 0.15	1 1	Approx. $200m^2$ of ground to be cleared to construct new CSO (to replace existing E34) and new outfall (2)	From car park adjacent to greyhound track (2)	Minimal if construction avoids dates of dog meets (2)	Japanese Knotweed present; special measures required to control spread. No other significant constraints (2)	9
C	1. Decommission CSO at E33 (DC 110 2314) 2. Decommission CSO at E34 (DC 110 2320) 3. Construct new powered CSO upstream of E38 (DC 110 2337) 4. Maintain emergency overflow at E28 (DC 110 1337) 5. Construct 710m of 750mm concrete pipe in Llanbradach alongside existing sewer	260%	Constructing the new 750mm concrete pipes is likely to involve some disruption to householders in Llanbradach.	E33 E34 E38	Decommissioned Decommissioned 2.77 (2)	0.15	1	As for Solution B plus approx. $12,000m^2$ of land requires stripping for construction of pipeline (1)	Access possible from highway; other temporary access will be part of clearance for laying pipeline (1)	Could affect some gardens to properties in Llanbradoch (1)	Moderate ecological constraint in riparian corridor; need to limit working hours to safeguard otters (1)	6

Fig.3 Environmental impacts (derived from SPIRIT) of options for Rhymney Valley uCSO's

The Fully Developed Virtual Design House

The Barry and Cardiff catchments present a complex problem which has to be addressed in AMP3. Not only do the specific local environment issues related to numerous uCSO discharges need to be resolved, but all of the outputs, together with several continuous discharges and many other polluting inputs in the area, have the potential to affect the compliance standards at the Barry bathing beaches, which is a critical local issue. Because of the technical complexity and the potential high cost of the solution to these issues, the Barry/Cardiff catchment has been selected as the vehicle for implementation of the 'Virtual Design House' concept in its complete form.

In total, there are 94 designated uCSOs in this area, 58 of which are scheduled for Year 6. Most outputs have nominal U16 and Bath13 environmental drivers. The usual approach for such outputs is to ensure less than 3 spills per bathing season on average over 10 years and on aggregate across the catchment affecting the bathing beaches. However due to the size and complexity of the networks, it was quickly recognised that such effects would be difficult to predict. A key concern was assessing and modelling rainfall across the catchments. Accurately predicting aggregate spills across the catchment was thus deemed unlikely to be successfully achievable and would, in any event, lead to very high solution costs.

It has therefore been agreed that a quality based approach should be adopted both to ensure compliance of the Barry bathing waters with the target BWD Guideline Standards and for planning the improvements to the many uCSOs. To this end, the VDH was commissioned to build a 2-Dimensional computer model of the Severn Estuary from Chepstow to Porthcawl. In order to successfully predict the quality effects, input from all of the members of the VDH design team was required to quantify the discharges from the many of the catchments that might impact on the Barry bathing waters. Fig.4 shows the impact of the various key sewerage outfalls in a 1 in 1 year storm, prior to the new Cardiff WwTW being commissioned: Fig.5 shows the same after commissioning of the WwTW.

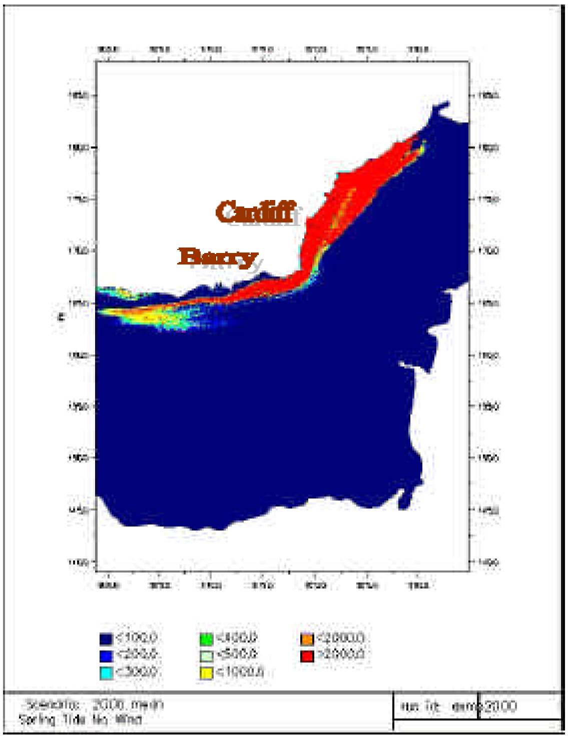

Fig.4 FC/ 100ml prior to Cardiff WwTW

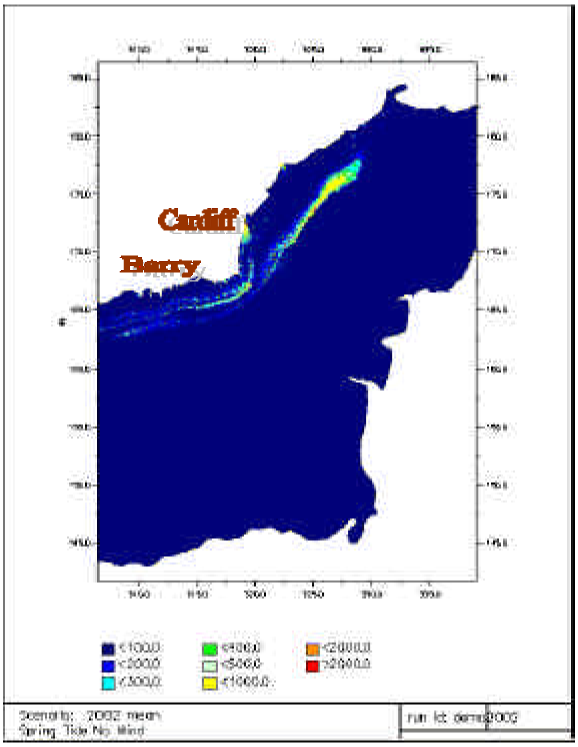

Fig.5 FC/ 100ml post Cardiff WwTW

A quality based approach implies the need to integrate the various sewer models, river models and the coastal model to verify current effects and test potential solutions. Using traditional consultant agreements for the many parties involved in obtaining such output would have been costly and complex. The VDH approach greatly simplified this process. Meetings were held between DCWW, AMEC and key senior staff from the four consultants' members of the VDH. The principle of joint working and shared resource was agreed, based on the current target fee system, thus truly creating a 'Virtual Design House' (VDH). The four consultants then jointly agreed a fee and programme proposal for the works, split into five stages (Preliminary, Strategy, Outline Design, Detailed Design and Construction), that is being used for monitoring progress and cost via KPI's. The Preliminary stage, now completed, was for all the team to fully understand the issues and ensure the various models would be suitable. The VDH is able to call on resources from all of the component companies and allocates work packages according to resource skill and availability. The programme has been set up so that the VDH team jointly develops solutions during the first three stages and then teams from each individual consultant will be allocated individual schemes, by the VDH, to design in detail; in this way many of the issues of Professional Indemnity are being resolved. An early issue was verification of models produced by one consultant and used at a later stage by another. This is a particular issue with the coastal model, as few people have the necessary skills to undertake construction and validation of such models. The VDH team was concerned that simply to engage another consultant may not have resolved key issues. The solution was thus to appoint 'panel engineers', i.e. individual experts in the particular field. All the mechanisms and resources are generally agreed between the VDH members, with AMEC and DCWW supporting as required. Operating contractors are also included in the development of solutions, so that their issues can be included.

The Barry and Cardiff catchment has been split into seven urban drainage models, Cardiff East and Cardiff Central, terminating at Cardiff WwTW, and Cardiff West, Penarth, Barry East, Barry West and Dinas Powys, all being served by Cog Moors WwTW (which is situated between Penarth and Barry). In addition to this, Cardiff WwTW is also the terminal works for the Ystradyfodwg and Pontypridd, Rhondda, Western and Rhymney Valley systems, which have their own models. Most of the sewer models are constructed in Infoworks, although the WinDAP programme has also been used. Several new river models, generally MIKE11, have been implemented, including the Cadoxton river. The coastal model itself uses Delft3D software and comprises over 100,000 grid squares. The coastal model team has developed bespoke application software for their model (called a 'toolkit') which is based on the well proven unit hydrograph/pollutograph approach. This will enable options to be quickly tested without the need for full model runs, although of course final options will be passed through the actual coastal model for verification. The technical aspects of these models, and their integration, may be the subject of future papers.

The current Strategy stage is key, where the principles of the model integration are agreed and tested, and the 'macro' solution developed. At present, the coastal model, backed up by observed data, is showing that BWD Guideline Standards are close to being achieved. Indeed two of the three designated bathing beaches actually achieved Guideline Standards this year, although EAW has rated this summer as 'very dry', so hopes of a 'no build' solution are perhaps rather optimistic! EAW has agreed in principle to the quality based approach, although of course such agreement is subject to technical verification. The sewerage models for the Barry areas are already verified for winter conditions and are currently being enhanced for summer conditions with additional surveys, such as impermeable areas, and the new UK runoff model now being used. The Cardiff East model is currently being audited by EAW, and Cardiff Central and West models are due for completion in early 2003.

A notable feature of the VDH's work to-date has been the way specialists from the different consultants have been freely sharing information and data, and also assisting their peers in resolving technical difficulties. The strategic aim during solution development will be generally to avoid large storage wherever possible as, not only does this greatly increase cost and local disruption, it also can lead to overall environmental detriment. (Paper, "*Is combined sewer overflow spill frequency/ volume a good indicator of receiving water quality impact?*", David

Butler, James Lau and Manfred Schûtze, Hilton Bristol Conference October 2001). Another aim is to base pass forward flows on environmental need, rather than fixed parameters such as Formula 'A' . Other issues, such as telemetry, are being challenged, and the effectiveness of earlier designs is being tested by joint revisits to CSO's with the operating contractors (a report of these inspections has been prepared for internal use: this may be published at a later date). Another key benefit has been the ability to assess problems 'globally', so that other issues such as flooding can be incorporated were feasible, or outline solutions put forward as possible future works (AMP4 onwards).

Conclusion

The 'Virtual Design House' has been established without the need for complex contractual agreements and yet operates, in almost all cases, as a single entity. This has been due both to the simple, yet effective, commercial arrangements within the Welsh Water Capital Alliance[1] and the spirit of co-operation between all parties. There has already been significant benefit to all stakeholders:

- DCWW and AMEC have sufficient skilled local resource to deliver the programme, whilst gaining access to a wide range of technical experts, and a greater consistency of approach and standards.
- Environment Agency Wales gain a consistency of approach and early involvement in schemes, whilst retaining control of the environmental parameters.
- The consultants gain a share of the total work and greater control of the overall solution, whilst minimising their commercial risk and enhancing their opportunities with DCWW.

All these benefits are a result of the unique mechanisms of the Welsh Water Capital Alliance that have enabled the 'Virtual Design House' concept to develop and flourish. As the VDH method of working becomes more established, it is anticipated that these benefits will be confirmed and reinforced.

References

"*Western Valleys CSO's*", Ian Clifforde and others, WaPUG Spring 2002 Conference.

"Is combined sewer overflow spill frequency/ volume a good indicator of receiving water quality impact?", David Butler, James Lau and Manfred Schûtze, Hilton Bristol Conference October 2001.

"*Rhymney Valley Trunk Sewer – Design of CSO Improvements For Trunk Area 2*", Ove Arup and Partners Ltd.

"*Sewer Leakage, detection and cures*." Mike Jones, published on 'The Sewer List' (University of Texas) Web Site (via http://www.swopnet.com/engr/jones/leaksewer.html).

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[1] The basis of this is 6.7% of total savings on Alliance budget (£650m), a fixed fee on area budget (£130m), and pain/gain on individual scheme target costs and on Alliance budget, pain capped at total fixed fee. Designers paid fees incurred, monitored (using KPI's) against original fee proposal.