# The Development of SUDS Whole Life Cost Models for UKWIR/WERF Research and their Application for Scottish Water

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**Abstract**

Following a change in the approach to dealing with surface water drainage and the increasing use of SUDS, the UK water industry identified a need for research into the Whole Life Costs and performance of SUDS.

As part of the collaborative UKWIR/WERF/AwwaRF project 'Post Project Monitoring of BMPs/SUDS to Determine Performance and Whole Life Costs' cost models for five SUDS components have been developed which allow SUDS solutions to be constructed and the expected whole life cost calculated.

Scottish Water required a method of quantifying the costs of meeting any obligations to provide and maintain SUDS during their next investment period. Obligations included that of existing and future SUDS required to serve housing, together with the provision of retrofit "end of pipe" solutions for controlling the pollution discharged to waters from separately drained industrial sites.

The paper presents the outcomes of the UKWIR/WERF project and provides an example of how Scottish Water has used the Whole Life Costing tool in its business planning.

## INTRODUCTION

The policy to promote Sustainable Urban Drainage Systems (SUDS) was originally introduced to the East of Scotland by the Forth River Purification Board in 1995. After the Scottish local government reorganisation of 1996 and the formation of the Scottish Environment Protection Agency (SEPA) this policy was adopted and extended to the whole of Scotland.

Over the last nine years SUDS have been installed for new developments in Scotland, but implementation has been hampered by the fact that the relevant legislation did not use the term SUDS (or an equivalent) when referring to surface water drainage systems. This led to confusion over which authority should be responsible for SUDS both in respect of capital expenditure and operational costs.

Following a meeting with all the major stakeholders, the Sustainable Urban Drainage Scottish Working Party (SUDSWP) was formed in October 1997. The main objective of the working party was to act as a partnership and share the responsibility for protecting the aquatic environment. One of the main outputs of the working party was the development of a Pilot Legal Agreement between West Lothian Council and East of Scotland Water. In 2002, the SUDSWP group changed its approach due to an opportunity for legislative change, and the pilot legal agreement was never implemented.

In Scotland, as part of the enabling legislation relating to the Water Framework Directive, the term 'sewer', has now been redefined to include SUDS components. Through this Scottish Water (SW) was made responsible for the future maintenance and capital replacement of shared public SUD systems and these changes were brought in under Stage 3 of the Water Environment and Water Services (Scotland) Bill (WEWS).

Part 2 of the WEWS Act, by amendment to the Sewerage (Scotland) Act 1968, provides for the Scottish Ministers to make regulations dealing with SUDS. The regulations will establish the construction standards and vesting conditions that SW will apply to all SUDS for which it is to assume responsibility. The Executive will consult publicly on a draft of the regulations ahead of a definitive version being brought into force. Subject to Ministerial approval, the projected date for the regulations to be brought into force is summer 2006.

'Sewers For Scotland' defines the acceptable design and construction standards for SW's sewerage network, but it currently does not cover SUDS. The copyright for this document is held by WRc, and HR Wallingford are recognised as national experts in SUDS, therefore SW commissioned both these parties to work in partnership to produce a second edition of the Sewers for Scotland Manual.

The outputs from the collaborative UKWIR/WERF project have allowed SW to better understand the risks in terms of SUDS performance and cost of maintenance and identify those systems that should initially be included in the design and construction standards;

- Retention ponds;
- Detention basins;
- Underground storage.

SUDSWP and the key stakeholders in Scotland have been consulted throughout the process and this commissioned document will form the basis of the Regulations described above.

England and Wales, are also looking at managing surface water drainage through SUD systems and a National group has been set up to facilitate this transition. The working group published an Interim Code of Practice in 2004 which provides a strategic approach to the allocation of maintenance for SUD systems in England and Wales. This document advocates the best way of securing a long-term maintenance agreement through the Town and Country Planning Act, Section 106. This provides for the developer to make a one off payment to secure long-term operation and maintenance, and in return the local authority agrees to adopt.

The Department for Environment Food and Rural Affairs (DEFRA) published a consultation in July 2004 "Making space for water". This document set out the concept of integrated urban drainage management and the Government has just published a response which commits it to supporting this concept and funding pilot projects to test different approaches to integrated management.

## THE UKWIR/WERF PROJECT 'POST-PROJECT MONITORING OF BMPS/SUDS TO DETERMINE PERFORMANCE AND WHOLE LIFE COSTS'

In 2001, the UK water industry identified the need for a comprehensive review of performance, risks and costs associated with a SUDS approach to drainage. It was recognised that the United States had significant experience in the implementation, operation and maintenance of such systems (known there as Best Management Practices, or BMPs) so to facilitate effective knowledge sharing, a joint UK Water Industry Research (UKWIR)/US Water Environment Research Foundation (WERF)/American Waterworks Association Research Foundation (AwwaRF) research project was initiated. The 4 year contract was won by Black & Veatch in collaboration with HR Wallingford and the University of Abertay in the UK, and University of Texas and Glenrose Engineering in the US.

The overarching objectives of the project were to document the water quality performance and whole life costs of stormwater management practices implemented in the US and UK to reduce the impact of urbanisation. Phase 1 of the project comprised an extensive literature review of all aspects of BMPs/SUDS design, construction, maintenance, performance and cost together with a survey of organisations across the US and UK to determine the availability of detailed datasets. The report also makes generic and component-specific recommendations regarding future research areas. Through Phase 2, water quality performance datasets were reviewed in detail to examine relationships between performance and design parameters, and relative hydraulic performance was studied using proprietary software. An extensive survey of organisations was conducted to document differences in cost and maintenance requirements as a function of design, climate, philosophy and other factors. This was supplemented with site visits to seven US cities and many sites across England and Scotland to record differences in design elements, maintenance regimes and to provide a visual interpretation of performance levels.

Whole life cost models were then developed by HR Wallingford in a spreadsheet framework for five SUDS components (retention pond, detention basin, swale, filter/infiltration trench and permeable pavement) to allow calculation of the expected lifetime cost of a facility based on design criteria, construction options, maintenance levels and operating regimes.

**Comparing and Contrasting the Costs and Benefits of Conventional and Sustainable Drainage Solutions**

The costs of conventional sewerage systems are determined primarily in terms of initial capital expenditure, with long-term maintenance costs being absorbed by sewerage undertakers responsible for maintaining the infrastructure as part of their "asset base". SUDS generally incorporate surface components and may be primarily dependent on landscaping techniques, both for construction and long-term operational requirements. Costs tend to be less well-understood and are less easily predicted, due to the large number of influencing variables and the lack of experience within the industry in their implementation and future management.

A schematic of a typical expenditure profile for a SUDS scheme is shown in Figure 1.

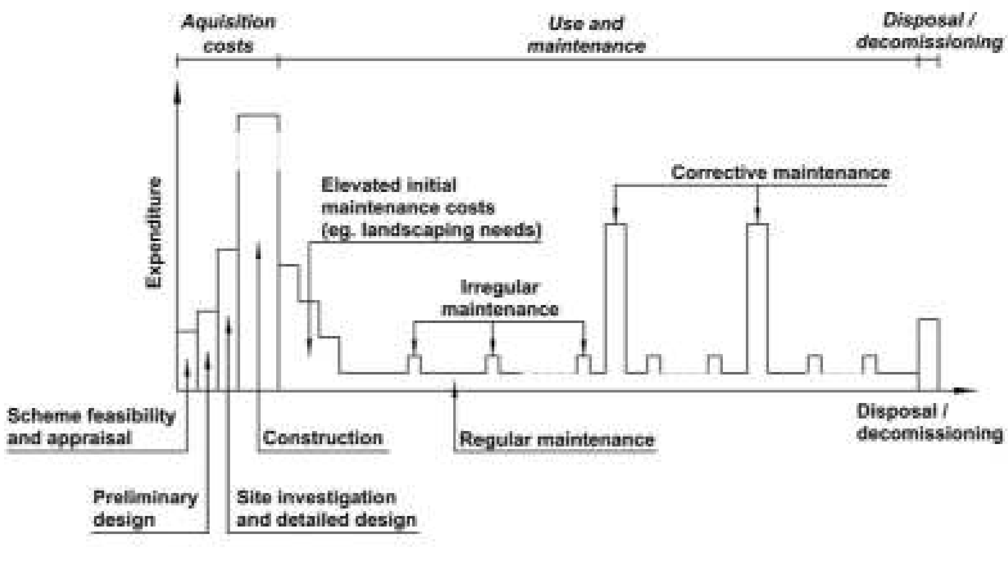


**Figure 1 Typical SUDS Expenditure Profile**

When comparing sustainable drainage with more conventional alternatives, it is important that the engineering options meet the same drainage objectives. Implementation of the Water Framework Directive will require consideration of the water quality of all surface water discharges, so in the future treatment components are likely to be required for all solutions to the management of rainfall runoff from urban surfaces. Equivalent attenuation measures will also be required although these are financial costs that may be met by others, such as the sewerage undertaker rather than the developer, so may not be evident in an assessment restricted to on-site cost elements.

In addition to a direct comparison of drainage infrastructure costs, issues such as the absence of conventional kerbs and gullies, the reduced need for pipes and manholes, the absence of deep trench excavations and subsurface storage tanks, leading to reduced excavation and construction costs; and the use of simpler construction techniques can also be considered.

There are a range of environmental benefits that may accrue from implementing SUDS, including amenity and recreation opportunities, biodiversity and ecological enhancement, aquifer and base flow augmentation, water quality improvements and net flood risk reductions. Although it is possible to identify where benefits may occur, it is less easy to estimate the economic values. The whole life cost models recognise that the consideration of both costs and benefits is an important part of decision making and therefore provides the user with the option of entering quantified benefits where these are available, or else adopting a relative ranking of expected environmental benefits for a range of options.

**The Benefits of Adopting a Whole Life Costing Approach**

Whole life costing involves estimating the present day value of the total costs of a system throughout its entire life. The benefits of undertaking such an appraisal for SUDS systems include:

- Improved understanding of long-term investment requirements, in addition to capital costs;
- More sustainable project choices at project appraisal stage;
- Explicit assessment and management of long term risk through the encouragement of a planned monitoring and maintenance program;
- Reduced uncertainties associated with the development of appropriate adoption agreements and/or commuted sum contributions.

**The Whole Life Cost Models**

The UKWIR/WERF Whole Life Cost models provide a framework for automating a whole life costing approach, allowing users to systematically and consistently identify and combine capital costs and ongoing expenditures in order to estimate whole life costs for individual components. It allows the model user to estimate generic costs for a drainage network through the application of default model assumptions and unit costs, or to combine user-entry, site-specific costs to develop detailed design costings. It allows the user to specify different design approaches (e.g. changes to size of the permanent volume 1Vt – 4Vt) and/or select a range of operating regimes and maintenance levels, and facilitates the appraisal of different options.

A description of each of the model sheets in given in the following table:

**Table 1 Summary of Whole Life Cost Model Spreadsheets**

| Sheet | Sheet Title | Sheet Description |
|---|---|---|
| 1 | Design & Maintenance Options | This requires inputs for:<br>• Catchment characteristics and land allocation<br>• Hydraulic, water quality, planting and geometric design criteria<br>• Number and type of inlets / outlets<br>• Construction works design<br>• Maintenance options<br>• Discount rate<br>A few of these inputs are essential user-entry. For others, model default values are available, but should be over-ridden with site-specific data wherever possible. |

| Sheet | Sheet Title | Sheet Description |
|---|---|---|
| 2 | Design Parameter Calculations | This is a model calculation sheet. The spreadsheet computes all relevant geometries, and presents a simple figure showing the dimensions of the proposed scheme. |
| 3 | Capital Costing | This calculates the cost of all system infrastructure including excavation, liners, planting, inlets & outlets, silt management and erosion control systems. Default quantities are calculated from Sheet (2), but can be overridden by the model user. Unit costs can be entered by the user – otherwise default 2002 unit cost values are assumed (generally an average of costs collected as part of the project). |
| 4 | Associated Capital Costs | This covers:<br>• planning and design costs (a 15 % overhead is assumed as default)<br>• construction overheads (a 15 % overhead is assumed as default)<br>• land costs (actual land costs can be factored by areas computed from Sheet (2), otherwise the model user can enter total figures)<br>• additional flood risk management costs (user entry) |
| 5 | Environmental Benefits | This covers an assessment of environmental benefits likely to be associated with the system (e.g. hydraulic, water quality, amenity, ecology). The user can select a simple ranking approach, or full economic appraisal where data is available. |
| 6 | Damage Costs | Where the system owner / operator is liable for any damage resulting from exceedance of or pollution from the system, the probability and financial consequences can be entered in this sheet. |
| 7 | Operation and Maintenance | This calculates the ongoing costs associated with the operation of the system. Regular monitoring and maintenance, post-construction inspection and rehabilitation, corrective maintenance (i.e. rehabilitation works) and irregular maintenance (i.e. sediment management) are all included. |
| 8 | Costs and Benefits Summary | This sheet provides a full summary of the costs and benefits entered into the model. Each of the costs / benefits to be included within the WLC calculation can be flagged, to facilitate sensitivity analyses / scenario-testing. |
| 9 | Whole Life Costs | This presents a time series of the costs expended on the system, and computes the net present value of these costs. |
| 10 | Net Present Value Graphs | The Net Present Value of cost with time is graphed, together with a cumulative Net Present Value cost curve. |
| 11 | Hydraulic Calculation Tables (UK only) | For the UK, the model includes a very simple hydraulic appraisal routine that allows an estimate of attenuation volume to be made. These tables are required as part of the calculation tool for this process. |

## EXAMPLE OF APPLICATION OF THE WHOLE LIFE COST MODELS

As part of SW's investment planning process, MWH were commissioned to develop auditable costings to meet any obligations to provide and maintain SUDS during the period 2006 to 2014. Obligations included maintaining new SUDS to serve housing established during the investment period, and maintaining SUDS in place at the start and/or vested during that period. Obligations also include the provision of retro-fit "end of pipe" SUDS solutions to treat run-off from separately drained industrial sites, highlighted by SEPA as polluting their receiving waters.

The UKWIR/WERF cost models were successfully used, out with the UKWIR/WERF project, to generate auditable cost estimates to cover the obligations described.

### Method of Approach to Costing Scottish Waters Future Obligations associated with SUDS

The initial challenge was in predicting how future housing developments and subsequently SUDS solutions and costs would differ from that of existing housing. Any likely changes to the layout and density of future housing developments had to be allowed for so that SUDS solutions could be developed and costed accordingly. As future housing densities are likely to vary depending on government planning policy, it was decided to develop SUDS solutions and costs for a sample of housing developments carefully chosen with an even split between standard density and high density housing. In this way the relative differences could be explored.

The costing approach was based on a unit cost per dwelling on the basis that unit costs could then be translated into total network capital and operational costs by utilising data relating to future housing numbers and that of existing SUDS to be vested. Drainage and layout plans for a sample of eight housing developments were obtained from a selection of housing developers. Information on the type and number of dwellings and any available topographic data was also obtained.

Using the outputs from the draft Sewers for Scotland Edition 2 document, retention ponds were the only SUDS option considered for the future costs estimation. Retention pond solutions include for a permanent pool plus an attenuation volume. In this way runoff will be treated before discharging to the receiving waters, as likely to be required by the Water Framework Directive. Also surface water will be attenuated before entering the existing drainage systems thus reducing the negative impact of development on the sewerage network and receiving waters. The retention pond cost model was employed as the base tool to develop SUDS solutions and whole life costs for each of the housing developments therefore.

In each case the treatment volume was automatically generated within the whole life cost model by adding Flood Studies Report (FSR) data and runoff parameters, electing to provide a treatment volume equivalent to 1 x Vt. In this case it was considered that 1 x Vt would provide the necessary treatment to runoff from housing developments. However the volume of treatment can easily be increased within the cost model, to account for any known pollutants, by entering an increased multiple of Vt.

To assess the attenuation volume required at each development, the amount of expected surface water runoff had to be determined. At the time of the study, the cost model was found not to extend to include all eventualities: however this was overcome by generating rainfall for each of the housing sites for differing durations using FSR data. This allowed the attenuation volume to be established using a 100 year peak rate of run-off determined by the Rational Method with the time of concentration assumed equal to 15 minutes. The trapezoidal flow hydrograph was assumed for the inflow, calculated with the rational formula and the outflow was approximated by a triangular hydrograph with a peak flow of 5 l/s/ha.

The total estimated pond volume was then translated into a land area by dimensioning the ponds and choosing appropriated design parameters, in accordance with the draft Sewers for Scotland, within the costing model. In this way the model was checked at a detailed level against the recommended design parameters. Other land allocation factors such as easement and any additional access required for maintenance are populated within the cost model to arrive at the total land area required to implement each solution.

Sewer invert level data and receiving water level data from existing records along with level data established from interrogation of contoured mapping was utilised to ascertain land availability and propose a pond location. The cost model easily allows the user to choose the appropriate pond infrastructure such as inlet and outlet structures, in building up the total final estimated capital cost.

The required regular and irregular maintenance activities are chosen within the cost model to generate OPEX and Capital Maintenance costs. The cost model default figures can be used or the user can define site-specific operational and maintenance regimes by entering a different frequency of visits. The cost of a regular maintenance activity such as the checking of inlet and outlet structures, grass-cutting and litter collection was generated by assigning estimated yearly visits. Similarly, capital maintenance costs were determined by entering the frequency of visits for any irregular maintenance activities such as pond de-silting.

**Results**

Eight retention pond solutions with whole life CaPEX, OPEX and Capital Maintenance costs were generated and then broken down into two sets of unit costs per dwelling. One set of standard density housing unit costs for the provision of SUDS for existing housing and the other set intended for that of future density housing. Plotting both sets of unit CaPEX costs on the same Figure 2 below displays that there was no evidence to support separating the cost of implementing SUDS at existing and future sites.

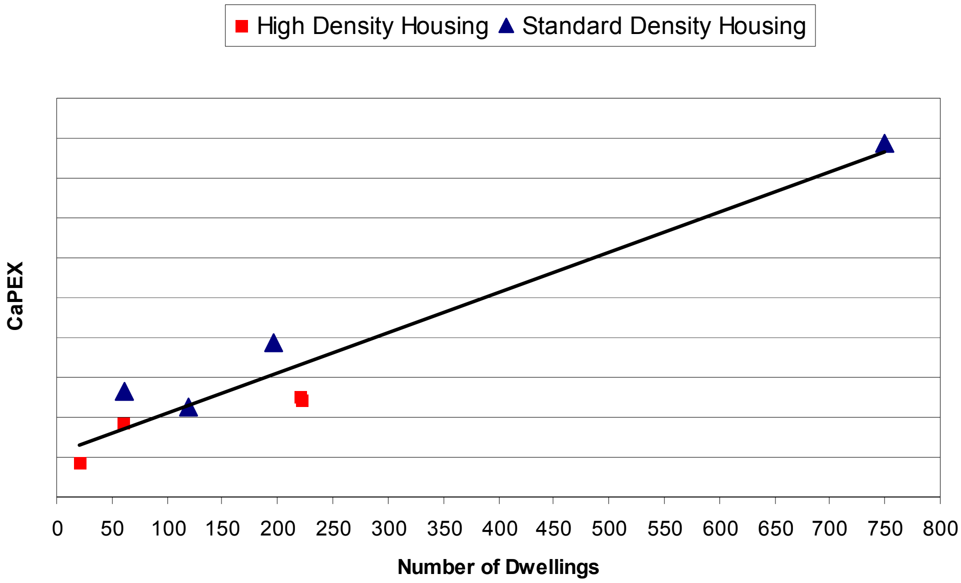


**Figure 2: Unit CaPEX costs.**

Similarly to the CaPEX costs, there was no evidence to support separating unit OPEX or Capital Maintenance costs for existing and that of future housing. Figure 3 displays unit OPEX costs for both.

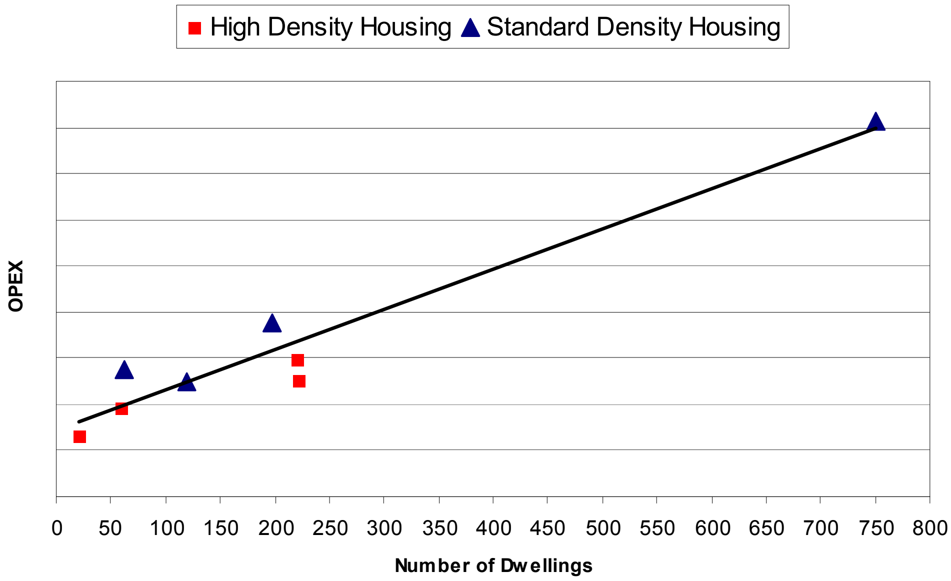


**Figure 3: Unit OPEX cost**

Data on existing housing drained to SUDS and future housing projections was utilised in conjunction with the new unit costs to provide an estimate of the level of investment that is required to meet obligations associated with the implementation of SUDS. These costs were then presented to SW as an assessment of the likely level of funding required to allow the successful implementation of SUDS from the period 2006 to 2014.

## Conclusions

The UKWIR/WERF Whole Life Cost Model has proved to be an extremely valuable tool in assessing the future obligations associated with the implementation of SUDS. An assessment of this detail would not have been possible had the tool not been available. Scottish Water believe that this approach is the best way to develop robust and auditable costings and that in taking steps to comprehensively identify the correct level of funding required, there are likely to be fewer barriers in the path to vesting and regulatory approval.

Scottish Water believes that the whole life costing tool provides a comprehensive framework for planning and implementing SUDS that can evolve and be improved upon into the future. It is based on the most inclusive costing study to date and in its application to Scottish Waters potential future asset base, has been independently examined and evaluated. It is recognised that to improve generic SUDS costings, the model default values and unit costs must be reviewed and updated, once more regional-specific information is available. The model itself provides a means of logging actual construction and maintenance costs, and an appropriate feedback and update route would increase confidence and reduce risks associated with long-term costing predictions.