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# A Cost Comparison of Traditional Drainage and SUDS in Scotland

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**Abstract** The Dunfermline Eastern Expansion (DEX) is a 350 ha mixed development which commenced in 1996. Downstream water quality and flooding issues necessitated a holistic approach to drainage planning and the site has become a European showcase for the application of Sustainable Urban Drainage Systems (SUDS). However, there is minimal data available regarding the real costs of operating and maintaining SUDS to ensure they continue to perform as per their design function. This remains one of the primary barriers to the uptake and adoption of SUDS. This paper reports on what is understood to be the only study in the UK where actual costs of constructing and maintaining SUDS have been compared to an equivalent traditional drainage solution. To compare SUDS costs with traditional drainage, capital and maintenance costs of underground storage chambers of analogous storage volumes were estimated. A whole life costing methodology was then applied to data gathered. The main objective was to produce a reliable and robust cost comparison between SUDS and traditional drainage.
The cost analysis is supportive of SUDS and indicates that well designed and maintained SUDS are more cost effective to construct, and cost less to maintain than traditional drainage solutions which are unable to meet the environmental requirements of current legislation.
**Key Words** Capital Costs; Operation and Maintenance Costs; Traditional Drainage; SUDS; Whole Life Costs.

## Introduction

DEX is a 50 ha development of residential, retail, commercial, industrial, leisure and public open space which commenced construction in 1996 on a Greenfield site on the eastern periphery of the ancient Scottish city of Dunfermline. The lead developer is Taylor Wimpey (formerly Taylor Woodrow). An holistic approach to the surface water drainage design and planning was necessary because of limitations of the receiving watercourses and flooding issues identified downstream (Maxwell 1997, D'Arcy 1997). DEX is a European showcase for the application of SUDS on a regional scale. On completion in 2012 the development will comprise around 3,500 residential units, a retail centre, schools and community facilities, an 18 hectare leisure park, 59 hectares of parkland and 30 hectares of industrial/ commercial land.
The development relies on retention ponds as the regional treatment component and the systems investigated include four ponds and a constructed wetland. The lead developer commissioned the Universities of Abertay and Edinburgh to undertake a five-year study to determine the perfprmance of the SUDS and compile and review detailed records of maintenance activities and associated costs.
At the design stage restrictions were placed on discharges as the development was expected to double the rate of surface water runoff and impact on the existing drainage system and downstream watercourses. The lead developer liaised with the statutory authorities including

the Scottish Environment Protection Agency (SEPA), East of Scotland Water (now Scottish Water, (SW)) and Fife Council, to develop an integrated stormwater master plan for the development based on SUDS in order to mitigate downstream flooding and ensure water quality targets are met. (Maxwell 1997, Roesner 2001)
Capital and maintenance costs of the SUDS installed at DEX were compared with estimated costs to implement equivalent traditional drainage incorporating underground storage chambers. Within each sub catchment of the development, traditional separate sewer piped systems are implemented upstream of the SUDS, enabling comparisons which were independent of the contributing pipe network to be valid.

## Determining Costs

### Determining Construction Costs

It was necessary to overcome a number of issues for the construction cost comparison study to be viable. The costs of the hypothetical traditional drainage options were calculated on the basis of 2005 competitively tendered rates (the year of the study) while the construction costs of the SUDS were based on 1998 rates. It was therefore inappropriate to use simple linear projection and relationships were therefore based on analysis of the original rates for one of the retention ponds (Pond 7, see figure 1 below) projected forward to 2005 rates. This accounted for changes in the construction industry such as:

- The introduction of new landfill and aggregate taxes
- Increases in fuel taxes over and above the rate of inflation
- The implementation of new health and safety regulations
- Labour, plant and material costs

For example, two major cost differences between 1998 and 2005 were:

- Disposal of excavated rock had increased by around 75% as a result of aggregate tax
- Disposal of unsuitable material had increased by around 85%

Sample relationships for Pond 7 were applied to cost data for the other four SUDS to project construction costs to 2005. Table 1 below illustrates the difference in construction costs between SUDS and traditional drainage for 2 storm return periods. In all cases the SUDS are less expensive to construct than the hypothetical traditional underground chambers.

**Figure 1** Pond 7, top left

### SUDS Maintenance Costs and Design Detail and Specifications

Information regarding maintenance activities and costs for the SUDS was methodically collected from 1999 to 2004. This included a review of actual Contractors invoices for the maintenance works and the associated activity timesheets. Regular visual inspections of the SUDS were also undertaken by the authors to verify that these activities were undertaken to the required standards.

The developer desired ponds with a high visual profile to increase the marketability of the development. This contributed to both the aesthetic design and to the specification and scope of the structural landscaping around the ponds. Strict planning constraints were also applied in order to address (perceived) safety issues - this included planting extensive barrier vegetation which subsequently added to the maintenance burden.

The drainage networks leading to the SUDS were designed as traditional systems with, for example, standard upstream carrier pipes and road gullies. This meant that a comparison with the traditional drainage option was relatively straightforward.

**The Stormwater Treatment Train and Traditional Systems**

The analysis presented here compares the cost of constructing and maintaining a stormwater drainage system based on SUDS against traditional underground storage chambers. Hypothetical designs for the chambers were costed on the basis that they would attenuate 50 and 100 year storm events. The SUDS were designed to attenuate the 100 year event.

**Figure 2** Cascades Pond Treatment Train, detention basin on the left, at the head of the pond

In reality, this comparison is invalid for DEX as traditional drainage would not treat stormwater as per SEPA requirements. To ensure water quality objectives were met SEPA policy required that treatment ponds were implemented at the outlet of each sub catchment in addition to the required flood attenuation storage. Receiving watercourses, although small, are not classified as sensitive and were not in need of enhanced protection.

In order for the storage chambers to achieve the required water quality, their discharge would require downstream treatment. This would have increased the complexity of the cost study therefore this extension of the hypothetical scenario was not developed. As a result, the costs of SUDS, which provide treatment and attenuation of surface water runoff, are compared with storage chambers which provide flow attenuation with minimal treatment.

**Maintenance Frequencies and Tasks**

Recent research (Lampe et al, 2005) has shown that maintenance tasks for SUDS are required at a frequency which is, at a strategic level, governed by the requirements of the owner. Specific tasks undertaken are either routine or irregular depending on the location and type of facility. The following overall levels of maintenance apply;

- Low/Minimum is the basic level of maintenance required to maintain the design function. If maintenance of vegetation is not undertaken on a regular basis, then outlets are susceptible to blockages which will subsequently impact on performance.
- Medium is the level of maintenance required to maintain desired function and appearance.
- High is an enhanced maintenance regime which is driven by appearance and amenity. In addition to grass cutting and litter picking, inspections will be frequent and minor defects

remediated. As a result, activities which are required to maintain functionality will be undertaken as part of amenity maintenance.

When the maintenance level has been decided, tasks are either routine and / or corrective;

- Routine tasks are carried out by Contractors without specific intervention by a supervisor.
- Irregular tasks are normally required to correct defects, are much less frequent, and are necessary to address a specific issue which might affect operation or safety.

The SUDS at DEX benefit from an extremely organised and intensive maintenance regime when compared with other SUDS maintenance regimes in existence in the UK as reported in parallel studies (Lampe et al 2005).

## Results for the Structures as Implemented

### Construction Costs

Table 1 details construction costs for the five regional SUDS for which there are wide variations as a result of the different catchment sizes and site specific construction details. For example; Halbeath Pond is the only structure with an impermeable liner and the Cascades are a series of three separate ponds and the only location where excavation of rock was required. In all cases there is a significant difference between the traditional and SUDS solution, the latter always being less. On average, the construction cost of SUDS compared to traditional is around 70% less.

**Table 1** Construction Costs – Storage Chambers and Regional SUDS

| | Catchment Area (Ha) | Storage Volume ($m^3$) | | Capital Cost (£) | | | |
|---|---|---|---|---|---|---|---|
| | | 50 Year | 100 Year | Storage Chamber | | SUDS | |
| Pond Name | | | | 50 Yr | 100 Yr | 1995 | 2005 |
| Halbeath Pond | 13.5 | 1.797 | 2.145 | 238.520 | 281.875 | 101.193 | 159.950 |
| Linburn Pond | 67.5 | 8.987 | 10.723 | 1.116.646 | 1.350.676 | 174.388 | 312.470 |
| Wetland | 58.1 | 7.735 | 9.230 | 978.383 | 1.164.653 | 65.841 | 115.037 |
| Pond 7 | 16.5 | 2.197 | 2.621 | 288.359 | 341.186 | 35.281 | 106.524 |
| Cascades | 16.8 | 2.230 | 2.661 | 292.469 | 346.170 | 149.951 | 251.174 |
| Total | 172 | 22.946 | 27.380 | 2.914.377 | 3.484.560 | 526.654 | 945.155 |
| Average | 34 | 4.590 | 5.480 | 582.900 | 696.900 | 105.300 | 189.000 |

### Maintenance Activities and Costs

Maintenance intensity is dependant upon basic functionality and other requirements such as visual aesthetics, amenity and biodiversity potential. Table 2 details both routine and irregular maintenance activities which are required. Table 3 details anticipated maintenance data for the storage chambers on the assumption that land take will be maintained as mown grass.

**Table 2** Maintenance activities and frequencies for DEX ponds

| Activity | Frequency |
|---|---|
| Inspection | Monthly (from year 3) |
| Litter Picking | Monthly |
| Grass Cutting | 3 per year |
| Weeding | 1 per year |
| Prune / Trim | 1 every 3 years |
| Algae Removal | Seasonal in first 3-5 years |
| Silt Removal | Regularly during construction. Intermittently once construction complete. Frequency depends on catchment conditions (soil type etc) |
| Aquatic Plant Aftercare | Seasonal in first 2 years |
| Fence/ Sign Maintenance | Seasonal – winter danger signs. Reactionary – usually related to vandalism |
| In/ Outlet Maintenance | Reactionary – clearing blockages |
| Filter Drain Maintenance | Reactionary – if structure becomes overwhelmed from overland runoff |

Average maintenance costs over the five year period are detailed in table 4 and are based on the recorded data for the SUDS together with estimated maintenance costs for traditional drainage. It will be noted that Halbeath pond has a greater cost than traditional drainage due to the extensive amenity and barrier vegetation planted in order to provide additional amenity and safety benefits. On average, the annual cost of maintaining SUDS is less than for the equivalent traditional approach.

**Table 3** Assumed maintenance activities and frequencies for storage chambers

| Item Description | Frequency |
|---|---|
| **Routine** | |
| Grass cutting (rate allows for 8 cuts per year) | 8 per year |
| Litter removal (rate allows for 8 visits per year) | 8 per year |
| Engineers inspection of structures | 2 per year |
| Desilt inlet / outlet structures | 1 per year |
| Controlled disposal / haulage of silt | 1 per year |
| **Irregular** | |
| Blockages | Every 10 years |
| Jetting | Every 10 years |
| Repair Broken Components | Every 10 years |

**Table 4** Average Annual Maintenance Costs of Storage Chambers and SUDS

| | Catchment Area (Ha) | Maintenance Cost (average annual) (£) | | | % Difference | |
|---|---|---|---|---|---|---|
| | | Storage Chamber | | | 50 Year | 100 Year |
| Pond Name | | 50 Year | 100 Year | SUDS | 100 Yr | 1995 |
| Halbeath Pond | 13.5 | 3.454 | 3.584 | 4.981 | 31 | 28 |
| Linburn Pond | 67.5 | 6.150 | 6.801 | 3.383 | 55 | 50 |
| Wetland | 58.1 | 5.681 | 6.241 | 2.321 | 41 | 37 |
| Pond 7 | 16.5 | 3.604 | 3.763 | 2.700 | 75 | 72 |
| Cascades | 16.8 | 3.616 | 3.778 | 2.000 | 55 | 53 |
| Total | 172 | 22.505 | 24.167 | 15.385 | | |
| Average | 34 | 3.760 | 4.045 | 2.564 | 51 | 48 |

Note – reverse black and white indicates SUDS more expensive

## Above Ground and Below Ground Maintenance

It is anticipated that above ground maintenance of SUDS will be the responsibility of different organisations from those responsible for below ground maintenance (SW 2005). To assess this division in maintenance costs, the different activities in table 4 were separated into above and below ground activities and the resulting cost breakdown are provided in table 5. There is a decrease in above ground maintenance costs for the larger SUDS; those with larger catchments having lower maintenance costs (economies of scale). A substantial increase is observed again at Halbeath Pond due to the extensive barrier / amenity vegetation.

**Table 5** Annual Maintenance - Above and below ground activities

| | Catch-ment Area (Ha) | Average Annual Maintenance Costs (£) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Above Ground Maintenance Costs | | | Below Ground Maintenance Costs | | |
| Pond Name | | Chamber 100 Year | SUDS | SUDS / Chamber | Chamber 100 Year | SUDS | SUDS / Chamber |
| Halbeath Pond | 13.5 | 804 | 2.966 | 73 % | 1.280 | 188 | 85 % |
| Linburn Pond | 67.5 | 4.021 | 2.100 | 48 % | 1.280 | 188 | 85 % |
| Wetland | 58.1 | 3.461 | 1.354 | 61 % | 1.280 | 189 | 85 % |
| Pond 7 | 16.5 | 983 | 1.952 | 50 % | 1.280 | 195 | 85 % |
| Cascades | 16.8 | 998 | 1.219 | 18 % | 1.280 | 186 | 85 % |
| Total | 172 | 10.267 | 9.590 | | 6.400 | 950 | |
| Average | 34 | 2.050 | 1.920 | 6 % | 1.280 | 189 | 85 % |

Note – reverse black and white indicates SUDS more expensive

## Whole Life Costs

Land take costs are excluded from the WLC analysis due to their inherent variability over time. It may be reasonably assumed that SUDS will be in public open space provided

planning authorities accept the need for SUDS as part of the greater environment as opposed to having only a drainage function. These include various habitat / amenity initiatives for new developments and the reality that in most cases it is not the developer but another party (Local Authority or Factor) which will be responsible for maintenance activities.
The standard accounting procedure used is Present Value (HR Wallingford 2003). The discount rate to adjust future costs to 2005 was 3.5% and the discount period used was 60 years (DTI 2002). The resulting WLC figures detailed in table 6 confirm that SUDS ponds are significantly more cost effective when compared with traditional drainage storage chambers.

**Table 6** Whole life costs calculated at 3.5% discount rate over 60 years

| Pond Name | Catch-ment Area (Ha) | Storage Volume ($m^3$) | | WLC 3.5% (£) | | | Cost Difference SUDS / Chamber (%) | |
|---|---|---|---|---|---|---|---|---|
| | | 50 Year | 100 Year | Chamber 50 Yr | Chamber 100 Yr | SUDS | 50 Yr | 100 Yr |
| Halbeath Pond | 13.5 | 1.797 | 2.145 | 292.575 | 339.185 | 290.092 | 1 | 14 |
| Linburn Pond | 67.5 | 8.987 | 10.723 | 1.237.964 | 1.488.227 | 394.291 | 68 | 74 |
| Wetland | 58.1 | 7.735 | 9.230 | 1.087.983 | 1.288.238 | 181.065 | 83 | 86 |
| Pond 7 | 16.5 | 2.197 | 2.621 | 346.156 | 402.948 | 137.147 | 60 | 66 |
| Cascades | 16.8 | 2.230 | 2.661 | 350.574 | 408.307 | 275.449 | 13 | 25 |
| Total | 172 | 22.946 | 27.380 | 3.315.302 | 3.927.006 | 1.280.049 | | |
| Average | 34 | 2.050 | 5.475 | 663.060 | 785.400 | 256.010 | 61 | 67 |

**Costs for Different Scenarios found in the UK**

The resulting whole life costs must be considered bearing in mind that no allowance has been made for treatment of runoff from the traditionally costed components. Additional treatment costs should be added to the traditional approach for the study to be strictly comparable and this would further accentuate the cost differences highlighted in this study.
Design variations of different scenarios which represent alternative SUDS arrangements found in the UK today were applied to the WLC data (CIRIA 2007). These findings are presented in figure 3 and variations examined include:

- Addition of construction and maintenance costs of upstream SUDS
  a. Linburn Pond has 3 detention basins upstream
  b. The Cascades has one detention basin upstream
- Removal of amenity and barrier planting costs as this is considered excessive at DEX
- Removal of desilting costs – removal in year 30 was used when calculating WLC. Extensive performance monitoring at these ponds indicate that sediment accumulation rates are low and limited to the construction phase (Jefferies 2004), particularly where detention basins have been constructed upstream.

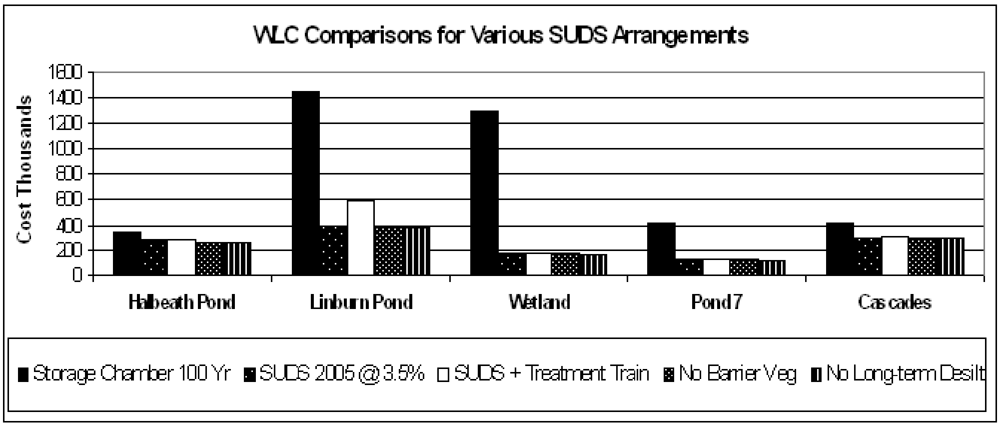


**Figure 3** Variations of different SUDS scenarios

**Catchment Cost Comparisons**

Capital and Maintenance Costs, and WLC were compared with the catchment served by the SUDS and the results, as presented in tables 7 to 9, demonstrate that costs of traditional drainage are greater than those for SUDS and this is summarised as follows:

- Capital costs of traditional drainage are more than double the capital costs of SUDS
- Annual average maintenance costs would be 20 - 25% greater for traditional drainage
- WLC of traditional drainage are around double the costs for SUDS

**Table 7** Capital costs expressed per catchment area

| Pond Name | Catchment Area (Ha) | Capital Cost (£) Chamber 50Y ear | Capital Cost (£) Chamber 100 Year | Capital Cost (£) SUDS | Capital Cost / Ha (£/Ha) Chamber 50Y ear | Capital Cost / Ha (£/Ha) Chamber 100 Year | Capital Cost / Ha (£/Ha) SUDS |
|---|---|---|---|---|---|---|---|
| Halbeath Pond | 13.5 | 238.520 | 281.875 | 159.950 | 17.668 | 20.880 | 11.848 |
| Linburn Pond | 67.5 | 1.116.646 | 1.350.676 | 312.470 | 16.543 | 20.010 | 4.629 |
| Wetland | 58.1 | 978.383 | 1.164.653 | 115.037 | 16.840 | 20.046 | 1.980 |
| Pond 7 | 16.5 | 288.359 | 341.186 | 106.524 | 17.476 | 20.678 | 6.526 |
| Cascades | 16.8 | 292.469 | 346.170 | 251.174 | 17.409 | 20.605 | 14.951 |
| Total | 172 | 2.914.377 | 3.484.560 | 946.318 | 85.936 | 102.219 | 39.935 |
| Average | 34 | 582.875 | 696.912 | 189.264 | 17.187 | 20.444 | 8.000 |

**Table 8** Maintenance costs expressed per catchment area

| Pond Name | Catchment Area (Ha) | Annual Maintenance Cost (£) Chamber 50Y ear | Annual Maintenance Cost (£) Chamber 100 Year | Annual Maintenance Cost (£) SUDS | Maintenance Cost / Ha (£/Ha) Chamber 50Y ear | Maintenance Cost / Ha (£/Ha) Chamber 100 Year | Maintenance Cost / Ha (£/Ha) SUDS |
|---|---|---|---|---|---|---|---|
| Halbeath Pond | 13.5 | 3.454 | 3.584 | 4.981 | 256 | 266 | 369 |
| Linburn Pond | 67.5 | 6.150 | 6.801 | 3.383 | 91 | 101 | 50 |
| Wetland | 58.1 | 5.681 | 6.241 | 2.321 | 98 | 107 | 40 |
| Pond 7 | 16.5 | 3.604 | 3.763 | 2.700 | 218 | 228 | 164 |
| Cascades | 16.8 | 3.616 | 3.778 | 2.000 | 215 | 225 | 119 |
| Total | 172 | 22.505 | 24.167 | 15.385 | 878 | 927 | 741 |
| Average | 34 | 3.760 | 4.045 | 2.564 | 176 | 185 | 148 |

**Table 9** WLC expressed per catchment area

| Pond Name | Catchment Area (Ha) | Whole Life Cost (£) Chamber 50Y ear | Whole Life Cost (£) Chamber 100 Year | Whole Life Cost (£) SUDS | Whole Life Cost / Ha (£/Ha) Chamber 50 Y ear | Whole Life Cost / Ha (£/Ha) Chamber 100 Year | Whole Life Cost / Ha (£/Ha) SUDS |
|---|---|---|---|---|---|---|---|
| Halbeath Pond | 13.5 | 273.163 | 318.627 | 241.576 | 20.234 | 23.602 | 17.895 |
| Linburn Pond | 67.5 | 1.194.868 | 1.439.415 | 362.868 | 17.702 | 21.625 | 5.376 |
| Wetland | 58.1 | 1.049.013 | 1.244.344 | 153.425 | 18.055 | 21.417 | 2.641 |
| Pond 7 | 16.5 | 325.426 | 380.823 | 107.686 | 19.723 | 23.080 | 6.526 |
| Cascades | 16.8 | 350.574 | 408.307 | 285.483 | 20.868 | 24.304 | 16.993 |
| Total | 172 | 3.193.044 | 3.791.515 | 1.151.038 | 96.582 | 113.728 | 49.431 |
| Average | 34 | 638.609 | 758.303 | 230.208 | 19.316 | 22.746 | 9.886 |

## Conclusions

This report addresses the concern surrounding the lack of available and reliable cost data for SUDS as identified by developers, unitary and regulatory authorities. It is the view of many developers that SUDS will result in a significant increase of both capital and maintenance costs to implement development surface water drainage infrastructure. It is also a concern to the drainage utilities that the costs to maintain and operate SUDS as per design function will be greater than current statutory obligations associated with traditional drainage.

The data presented demonstrates positive cost benefits associated with SUDS as overall, construction and maintenance costs are less than the alternative traditional drainage solution which would be to incorporate underground storage chambers. To realise such cost benefits, regional SUDS should be located in public open space (as has been assumed in this study);

and a competent treatment train should be implemented upstream of the regional SUDS to promote low sedimentation rates.
The high amenity DEX SUDS also increase the aesthetic appeal of the area in addition to their functional benefits of water quality protection and flood control. These SUDS are also over-sized from a water quantity point of view according to revised codes (SW 2005, CIRIA 2006) and they still have lower construction, operation and maintenance costs when compared with the hypothetical alternative of traditional drainage. These findings are very supportive of SUDS which are all the more attractive since the traditional systems hypothesised would not deliver the equivalent water quality improvements required by current legislation.
In addition to watercourse protection, containment of potential pollution, attenuation of runoff rates and reduction in flood risks, SUDS, specifically retention ponds and wetlands, offer environmental benefits in the form of habitat enhancement or creation and biodiversity potential. However these positive environmental impacts (as opposed to negative impacts encountered with traditional drainage systems) on the surrounding environment are extremely hard to quantify in monetary terms to developers and local residents. The fact remains that these additional benefits exist and should be highlighted in association with SUDS. Data presented from this study at DEX confirm that well designed and maintained SUDS are more cost effective than traditional drainage solutions which are unable to meet environmental requirements of current legislation.

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