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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 performance 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

Pond Name	Catchment Area (Ha)	Storage Volume (m ³)		Capital Cost (£)			
		50 Year	100 Year	Storage Chamber		SUDS	
				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

Pond Name	Catchment Area (Ha)	Maintenance Cost (average annual) (£)			% Difference	
		Storage Chamber		SUDS	50 Year	100 Year
		50 Year	100 Year		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

Pond Name	Catchment Area (Ha)	Average Annual Maintenance Costs (£)					
		Above Ground Maintenance Costs			Below Ground Maintenance Costs		
		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	Catchment 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 Pond 7	58.1	7.735	9.230	1.087.983	1.288.238	181.065	83	86
Cascades	16.5	2.197	2.621	346.156	402.948	137.147	60	66
	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.

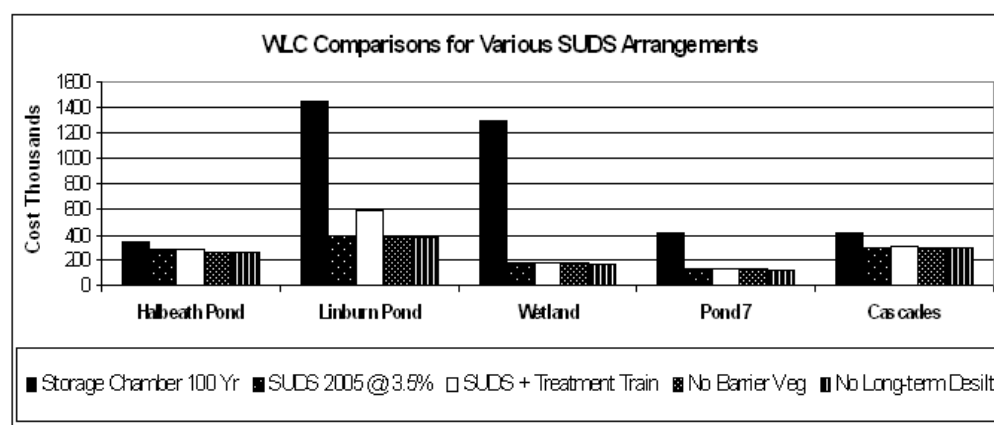


Figure 3 Variations of different SUDS scenarios

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 (£)			Capital Cost / Ha (£/Ha)		
		Chamber	Chamber	SUDS	Chamber	Chamber	SUDS
		50Y ear	100 Year		50Y ear	100 Year	
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 (£)			Maintenance Cost / Ha (£/Ha)		
		Chamber	Chamber	SUDS	Chamber	Chamber	SUDS
		50Y ear	100 Year		50Y ear	100 Year	
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 (£)			Whole Life Cost / Ha (£/Ha)		
		Chamber	Chamber	SUDS	Chamber	Chamber	SUDS
		50Y ear	100 Year		50 Y ear	100 Year	
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 oversized 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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References

- Center for Watershed Protection (CWP). (1998). *Costs and Benefits of Storm Water BMP's: Final Report 9/14/98*. Center for Watershed Protection, Ellicott City, MD.
- CIRIA. (2007). *The SUDS Manual (C697)*. CIRIA, London. ISBN:978-0-86017-697-8
- Clift, M. and Bourke, K. (1999). *Study on Whole Life Costing*. BRE.
- D'Arcy B.J. and Roesner L.A. (1997). *Scottish Experiences with Stormwater Management in New Developments*. Engineering Foundation Conference, Sustaining Urban Water Resources in the 21st Century. 8-12 September 1997, Malmo, Sweden.
- DTI. (2002). *Position Paper on Whole Life Issues*.
<http://www.dti.gov.uk/construction/consult/pro001/wlc.htm>
- HR Wallingford. (2003). *Sustainable Drainage: A Whole Life Cost Approach to Financing*. Draft Report EX 4793
- Jefferies C. (Ed). (2004). *SUDS in Scotland – The Monitoring Programme of the Scottish Universities SUDS Monitoring Group*. Scotland & Northern Ireland Forum For Environmental Research (SNIFFER) Report No SR (02) 51. ISBN: 1844321797 February 2004.
- Lampe LK et al (2005). *Post-Project Monitoring of BMP's/SUDS to Determine Performance and Whole-Life Costs*. WERF Report (Project 01-CTS-21T)
- Maxwell J. (1997). *Scotland's First Best Management Practice Surface Water Treatment - The Developers Perspective*. Engineering Foundation Conference, Sustaining Urban Water Resources in the 21st Century, Malmo, Sweden. 8-12 September 1997. pp420-433
- Roesner L, et al. (2001). *Master Planning Stormwater Management Facilities for the Dunfermline, Scotland Expansion Project*. Novatech 4th International Conference on Innovative Technologies in Urban Storm Drainage. Lyon France. 25-27 June 2001
- Scottish Water. (2005) *Sewers for Scotland 2nd Edition*. Draft including regulations for SUDS.