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Scottish Water SUDS Retrofit Research Project

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1 Executive Summary

The Bathing Waters Directive has prompted the Water Industry to invest significant capital sums to ensure that owned assets achieve compliance with limits set for bacterial concentration in identified Bathing Waters. In addition, the Water Framework Directive – which demands that all water bodies across the EU achieve “good” ecological status by the year 2015 – as well as a possible revision of the Bathing Waters Directive, both have the potential to increase the levels of investment required on behalf of the Water Industry, as steps are taken to ensure quality standards are achieved.

Traditional approaches to resolving water quality issues caused by the intermittent discharge from sewerage networks involve construction of sizeable storage tanks, networks of tank sewers, or costly separation of storm flows via conventional pipe systems. These types of solutions are highly capital intensive, in many cases require significant maintenance and operational expenditure, and are, in some circumstances, viewed as being unsustainable in the long term.

In response to the need to identify cost effective and sustainable alternatives to conventional engineering practice, Scottish Water commissioned the SUDS Retrofit Research Project. This project, funded by the Scottish Executive and run in partnership with the Scottish Environment Protection Agency (SEPA), set out to determine the cost and effectiveness of SUDS in comparison with traditional engineering practice.

The project aimed to pilot SUDS techniques to minimise sewer system overflow, which can have a direct influence on Bathing Water quality. Nevertheless, the conclusions will also have a general application to other waters.

Briefly, the objectives of the project were defined as:

- To identify sites suitable for retrofitting SUDS facilities (Refer to Section 4.1);
- Design and construct SUD schemes (discussed in Section 4.2);
- Undertake pre and post construction monitoring (discussed in Section 4.2.4);
- Compare the cost and benefit of the constructed scheme to conventional alternatives (discussed in Sections 4.2.5 and 8);
- Develop methodologies for the adoption of SUDS retrofitting, to assist the incorporation of retrofitting into Water Authorities’ capital investment programmes (as discussed in Section 5);

This study examined the site based issues and circumstances which determine the feasibility of SUDS retrofitting in the urban environment. In this respect, it is the first study of its kind to be undertaken in Scotland.

Available funding for the project was tied to the 2003/04 financial year. This led to considerable pressure on project programme. Due to the time required for land acquisition processes and land owner approvals, no schemes were taken forward to construction during the project, as insufficient time was available to allow decision making processes to reach a conclusion.

However, valuable lessons were learned from the experience gained during the project, which has validated and built upon third party desk based research previously undertaken in relation to SUDS retrofitting. In particular, the key points that can be drawn from the work are:

- SUDS retrofitting can be done most expediently at institutional and commercial premises, where single land owners and large areas of roof and paved surface connected to the foul/combined sewer mean that approval processes can be simplified, and benefits to the sewer system can be maximised.

- Identification of sites suitable for SUDS retrofitting was undertaken using Hydraulic Models of catchment areas within the study envelope. The methodology adopted is discussed in detail in Section 4.1, and in summary involved thematically mapping impervious areas which were modelled as being connected to the foul/combined sewer. “Hot spots” of impervious area could then be highlighted, in which retrofitting of SUDS could be undertaken to reduce flow contribution from runoff. While this approach allowed a rapid identification of potential sites, the success of the site selection phase hinged on the accuracy of the modelled representation of impervious areas, which in some cases was found to be poor. The Site Identification stage of the retrofit process is critical, and must be undertaken independently of modelling assumptions. The methodology employed in this study was necessitated by timescales. Methodologies to undertake site identification without reliance on hydraulic models have been presented for future work (as discussed in Section 5.1).
- The runoff contribution to the foul/combined sewer from residential areas has not been addressed. It was not possible to investigate the feasibility of retrofitting SUDS facilities in these locations due to available project timescales. As reported in the Retrofitting SUDS – Dunfermline Case Study Report (Hyder Consulting, 2004), roof connections from residential areas contribute the overwhelming majority of runoff from catchments served by combined sewerage systems. In order to achieve appreciable reduction in sewer flow, and subsequently in discharge volumes from sewer overflow points, runoff contribution from residential areas needs to be effectively dealt with.
- It was not possible to quantify the benefits which can be achieved by undertaking retrofitting on the basis of pre and post construction field measurement because no schemes were taken forward to construction. However, modelling results indicate that retrofitting in isolated areas across a given catchment area is unlikely to achieve flow reductions in the sewer of sufficient magnitude to significantly reduce the frequency and volume of sewage discharges to receiving waters, and is therefore unlikely to result in any appreciable improvement to receiving water quality.
- The benefits of SUDS retrofitting in isolated properties across a given catchment area are therefore related to improving the overall performance of the sewerage network; reducing pumping and treatment costs, minimising flood risk, and providing additional capacity for future development. In addition, the normal benefits of SUDS can be realised, such as provision of amenity and potential educational resource, water re-use and enhancement of habitat. Depending on the number of sites retrofitted in a particular catchment, water quality improvements may be realised over time. Further research would be required in order to quantify the benefits which can be expected by retrofitting SUD systems on this basis.

Because only two schemes were advanced to the detailed design stage, and no solutions were constructed, the data set is not of sufficient size to conclusively determine whether SUDS retrofitting is any more cost effective than conventional engineering.

However, what has been seen from the work conducted is that SUDS may be retrofitted for similar costs to those estimated for conventional solutions. Where the capital costs associated with SUDS have been estimated as being more expensive than conventional solutions, it has been demonstrated that the SUDS solution has offered benefits in addition to the potential for water quality improvement, which have not been provided by conventional engineering options. These benefits include reduction in operational costs and enhanced flood protection in localised drainage networks, where new conveyance systems have been required in SUDS installation.

Percentage improvements in operational cost reductions have been shown to be significant (in the order of 10-35%), although the savings in absolute terms – at sites investigated in this study – were relatively minor, and unlikely to justify capital cost in the absence of demonstrable improvements to Bathing Water quality. However, depending on the size of pumping stations, percentages of this magnitude can translate to substantial cost savings over the design life of the scheme.

Overall, comparison of estimated cost for maintenance of SUDS and conventional options suggests that retrofit SUDS can offer longer term benefits in comparison to conventional practice, through reduced maintenance and operational expenditure.

This result implies that although projected capital costs of SUDS and conventional options are similar, SUDS will be preferable in some circumstances, due to the lower long term operational costs. However, it must also be stressed that the sample group studied in this project is not big enough from which to draw firm conclusions.

To give confidence to the Water Industry that retrofitting offers a viable cost benefit ratio, improvements in water quality improvements must be demonstrated. The economic value of water quality improvements must also be determined, in order to undertake proper cost benefit analyses. Most importantly, a wider data set must be examined in order to draw reliable conclusions from cost analyses.

Frameworks to aid the decision making process during site selection and feasibility have been developed during this study, targeted toward retrofitting of SUDS in urban environments at commercial and institutional premises. To enable the Water Industry to incorporate SUDS retrofitting into capital works programmes and to have confidence in the benefit of implemented schemes, a number of issues must still be resolved. Specifically, these issues are the capital and operational costs of retrofit SUDS, and the actual benefits which can be achieved through retrofitting – particularly where improvements to water quality are sought.

It is therefore recommended that a further programme of research is undertaken, involving two potential research streams: one investigating the actual construction and maintenance costs of schemes, where SUDS retrofit is undertaken on an opportunistic basis wherever site conditions permit; the second examining low cost, non-disruptive SUDS techniques (eg Water-butts) which could be deployed in residential areas. In both cases, a proper determination of cost and benefit should be undertaken. Both programmes of research should allow sufficient time for progression of planning and consultation procedures, and should allow time for a detailed base line and post-construction bacterial sampling programme in order to properly quantify benefits achieved through SUDS retrofitting.

In the meantime, it is recommended that steps are taken to actively encourage retrofit SUDS appraisal in all future works, in order to realise the improvements in network operation which can be achieved. Particular recommendations to this effect are:

- Incorporation of SUDS retrofit analysis into Local Authority Planning procedures, to augment current focus on new build SUDS;
- Incorporation of retrofit SUDS appraisal into Water Industry strategy planning to assist in the reduction of flooding incidence and volume and frequency discharge from intermittent sewage discharge locations;
- Incorporation of SUDS retrofit feasibility assessment into technical specifications for Drainage Area Planning;
- Preparation of best practice guidance for SUDS retrofitting, to complement existing guidance for “new build” SUDS and to assist Engineers during design and option appraisal;
- Encouraging the investigation of SUDS retrofitting during the progression of new development.

2 Introduction

On the 1 August 2003, Scottish Water commissioned Atkins to undertake a pilot research project, investigating the real cost and practicality of retrofitting sustainable drainage systems (SUDS) in urban areas. The project, entitled the Scottish Water Retrofit SUDS Research Project, was run in partnership with the Scottish Environment Protection Agency (SEPA), and was funded by the Scottish Executive.

The benefits provided by SUDS facilities in a “new build” context are well understood, and include enhancement of habitat and creation of amenity areas, in addition to the reduction of peak runoff and some treatment offered by SUDS facilities. It is also recognised that the overall cost of new-build SUDS schemes is in general less than or similar to their conventional counterparts. This economic factor, combined with the ancillary benefits offered by SUDS, makes SUDS an attractive alternative to conventional engineering in new build scenarios. For these reasons, SEPA, the Scottish Executive and local councils are now actively promoting the incorporation of SUDS into all new development within Scotland.

However, relatively little is known regarding the practicalities entailed in retrofitting SUDS. The retrofit process seeks to implement SUDS to provide a new storm water drainage and treatment system in areas where there was no separate storm system previously. In the absence of a dedicated storm drainage system, all connections of impervious surfaces within a given site are usually made to the foul or combined sewerage system. This arrangement leads to potential over loading of sewer systems during rainfall, and subsequent discharge of raw sewage to local water courses and coastal waters via Combined Sewer Overflows (CSOs).

The underlying intention of the retrofit concept is to remove storm water flow from the combined sewer system, thereby:

- Potentially reducing discharge from CSOs within the catchment and therefore improving water quality as the frequency and volume of sewage discharges are reduced;
- Improving the quality of the stormwater discharged from the SUDS facility to the receiving environment through treatment processes that form part of the SUDS process;
- Reducing the risk of flooding by attenuating the discharge from the SUDS to the undeveloped greenfield runoff rate;
- Providing enhanced habitat and amenity areas;
- Achieving reductions in pumping and other treatment costs.

One of the key drivers underpinning this research is Scottish Water's requirement to achieve compliance with the mandatory and guideline standards for bacterial concentrations in bathing waters, as specified in the Bathing Waters Directive. Studies to quantify the impact of Scottish Water assets on Bathing Water quality are currently ongoing, and preliminary results from hydraulic modelling studies indicate that significant capital investment will be required to adhere to legislative guidelines for water quality. Therefore, the research into SUDS retrofitting stems from the need to identify cost effective and sustainable alternatives to traditional engineering practice.

Misconceptions regarding the suitability of SUDS in a retrofit context present a potential barrier to their investigation and incorporation into Water Industry investment strategies. The Water Industry is coming under increasing pressure in the drive to improve Bathing Water quality, due to EU legislation and increasing public concern regarding the environment. Discharges from sewerage networks are often perceived as being responsible for significant detrimental impact on Bathing Water quality. Costs to limit impact using conventional engineering are estimated to be considerable, and arguably, unsustainable in the long term.

Hence there is potentially a benefit in diversifying the approach taken to limit environmental impact, by incorporating alternative technologies such as SUDS in the development of capital works programmes. Scottish Water, SEPA and the Scottish Executive have recognised this and commissioned the study to investigate, for the first time, under what circumstances SUDS retrofitting can be achieved, how effective retrofit schemes actually are, and what the real cost of their implementation is in comparison to conventional practice.

This study can also be seen in the context of the Water Framework Directive which has recently been enshrined in UK legislation. This requires 'good ecological status' to be achieved for watercourses by 2015, with river basin management plans completed by 2009 and programmes of measures implemented by 2012. The retrofit of SUDS in selected areas may be one option for helping to improve the quality of watercourses.

2.1 Objectives

The study is run in partnership with SEPA, and at the time of writing was the first study of its kind in Scotland to investigate the practicalities of SUDS retrofitting. While the overall objectives of the study have been outlined above, the particular objectives associated with the project are described below:

- Develop a methodology to identify sites for SUDS Retrofitting, in the context of achieving improvements to Bathing Water quality;
- Progress selected sites to detailed design and full construction;
- Undertake monitoring prior to, and following construction to determine the effectiveness of the constructed scheme;
- Undertake detailed costing of constructed scheme, including maintenance costs to establish the overall cost of constructed schemes;
- Investigate the costs of a comparable conventional option, and compare with final SUDS outturn cost;
- Report and disseminate project findings.

The ultimate objective of the study was to identify methodologies for SUDS retrofitting which could be used by Scottish Water in the development of their Capital Works programme to alleviate Bathing Water impact.

2.2 Project Constraints

The progression toward achieving project objectives was constrained by two key factors, the first of which was available timescale. The project was funded by the Scottish Executive and £3.5 million was made available for the construction of pilot SUDS schemes. However the funding was tied to the 2003/04 financial year. Timescale was a critical factor and affected the methodologies adopted with regard to site selection and decisions made regarding progression to site, as will be discussed later.

Secondly, because the project was investigating the effect of SUDS on Bathing Waters, the methodology developed to identify sites was tailored towards this objective. Consequently, the search area for prospective retrofit sites was initially limited to proximity to CSOs which were known to impact on Bathing Water quality.

An additional constraint is that the study area was restricted to the Ayrshire region of Scotland. Investigation into other areas may have provided additional scope for location of sites suited to SUDS retrofitting.

2.3 Study Area

The study was conducted in the Ayrshire Region of Scotland, with the study envelope extending from Saltcoats and Kilwinning in the North, to Girvan in the South, to Darvel in the East, as shown in Figure 1 – Map of Study Area below.

Ayrshire is located in the West of Scotland, approximately 30 miles west of Glasgow, and is managed by three regional councils – East, South and North Ayrshire. There is a major conurbation of towns comprising Kilmarnock, Irvine, Prestwick, and Ayr in addition to several smaller villages, which all discharge to the Meadowhead Wastewater Treatment Works (WwTW). Each of the towns which ultimately discharge to the Meadowhead WwTW contains CSOs which discharge to local burns, watercourses, or directly to coastal waters. There are several designated Bathing Waters situated along the Ayrshire Coastline, as shown in Figure 2 – Bathing Waters Within Study Area below.

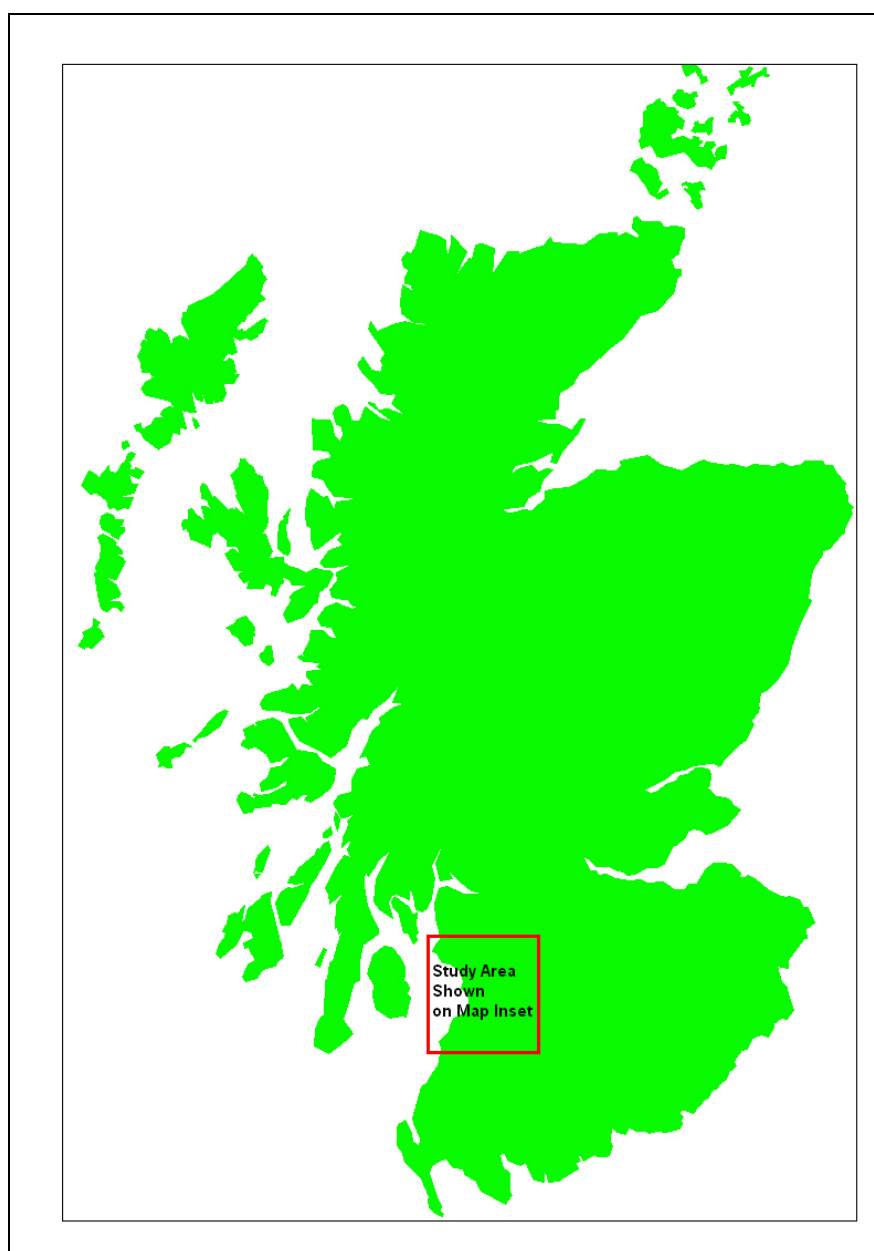


Figure 1 – Map of Study Area

Studies undertaken in the past (David Kay et al, 1999) have confirmed that the Ayrshire coast receives bacterial loading from a variety of sources, including industrial discharges, WwTW effluent, overflow from CSOs, as well as diffuse sources originating from agricultural areas and the heavy, peaty soils which dominate much of the Ayrshire region. Given the variety of potential sources for bacterial loading, the Ayrshire region provides the equivalent of a research laboratory for the investigation of contributors to Bathing Water failure, and is seen as a high priority for investment by Scottish Water and SEPA.

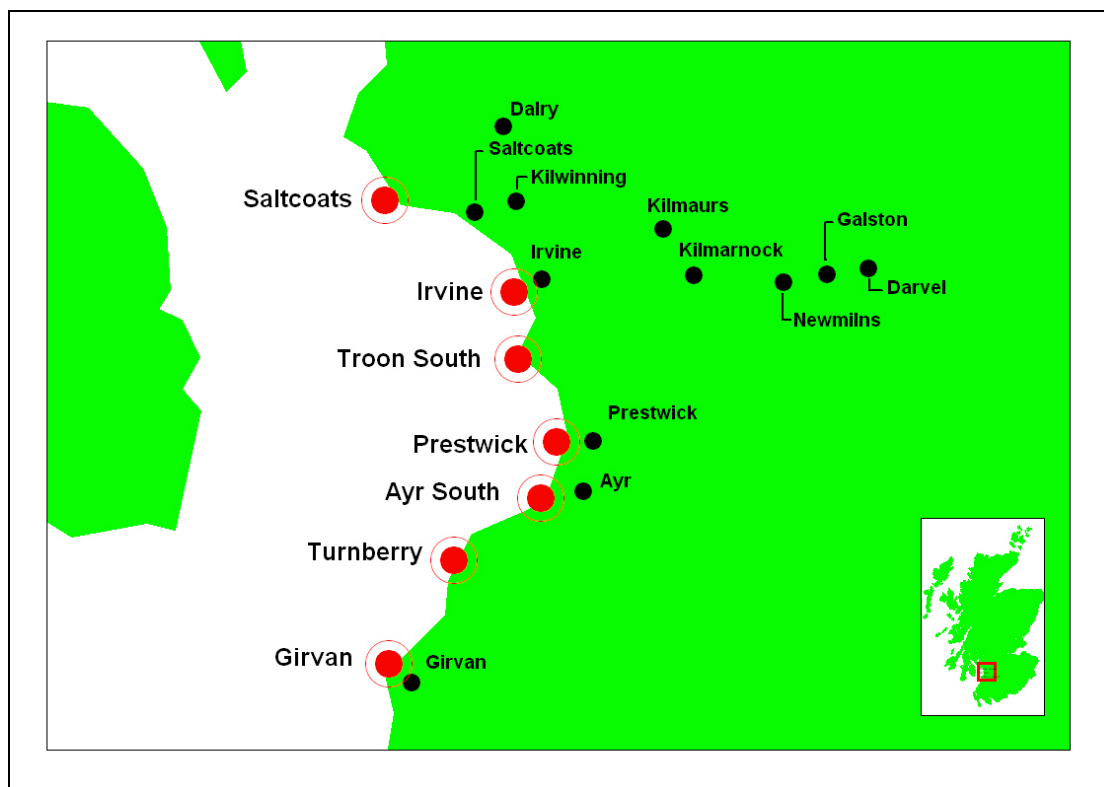


Figure 2 – Bathing Waters Within Study Area

Bathing Water quality at Ayrshire Bathing Beaches has been shown to improve since 2002, following implementation of a number of sewerage schemes and the construction and refurbishment of WwTW at various locations, including, most significantly, a new works at Meadowhead. However, concerns still exist regarding diffuse pollution and the potential for pollution originating from urban sewers.

Scottish Water have commissioned modelling studies to investigate the impact of Scottish Water owned assets on receiving water quality, including the Kilmarnock UPM Study and the Ayrshire Coast Macro Modelling study.

SEPA and the Scottish Executive are also responsible for leading ongoing research work to investigate how the impact of diffuse pollution can be either managed, or mitigated. Deeper analysis into the application of SUDS measures is one of the key facets of this wider programme of research, and the SUDS Retrofit Research Project comprises one aspect on the ongoing SUDS research.

The Ayrshire region, with its long sinuous coastline, existence of aging sewerage systems and multitude of CSOs, provided the ideal environment in which to investigate the suitability and effectiveness of SUDS retrofitting, in the context of providing improvements to bathing water quality.

3 Review of Works Completed by Other Parties

This section of the report summarises the other work carried out to date which has investigated SUDS retrofitting. This provides both the context for this project and demonstrates how the study has sought to further the existing body of knowledge which currently exists within the industry.

A brief summary of work undertaken in relation to SUDS and SUDS retrofitting is provided in Appendix H. Table 1 – Summary of Work Completed by Other Parties below summarises the work reported in the Appendix:

Research Title	Author(s)	Comment
Retrofitting SUDS Systems – Dunfermline Case Study	Hyder Consulting	Desk study into SUDS retrofit feasibility
Decision Support Framework for design of retrofit SUDS	University of Sheffield	Desk study providing guidance on SUDS site & option selection for retrofitting
Study of Residence Times in Pond and Wetland Systems	Atkins	A review of factors affecting the re-mobilisation of pollutants within pond and wetland treatment systems and recommendations for further research.
Identification of measures to control diffuse pollution to support implementation of the WFD	Institute for European Environmental Policy	A European wide study for the Environment Agency which assesses the requirements of the WFD and measures taken by other EU Member States to control pollution.
Urban Diffuse Pollution – Key Issues	Middlesex University	Desk study assessing the different sources of diffuse urban runoff and key issues related to the Water Framework Directive.
Bourne Stream Rehabilitation	Bourne Stream Partnership (Borough of Poole Leisure Services, EA)	Retrofitting SUDS into urban watercourses to achieve environmental improvement, and bathing water improvement
The Road to Retrofit	Shropshire County Council	Retrofitting SUDS for highways drainage in rural areas
SUDS in Schools	Bob Bray Associates	Retrofitting SUDS in schools to improve drainage

Table 1 – Summary of Work Completed by Other Parties

This section shows that some work investigating retrofitting of SUDS, together with the wider policy issues associated with diffuse pollution, has been undertaken. However, the work conducted has not focussed directly on all of the issues associated with SUDS retrofitting, and although some work has been undertaken on a practical basis the following issues still require attention:

- Under what circumstances can SUDS be effectively retrofitted into urban environments?
- What are the issues that should be investigated when assessing site suitability within urban areas?
- What is the overall capital cost and maintenance requirement for SUDS retrofit in an urban setting?

- How effective are retrofit systems, and can the benefits of SUDS in a retrofit context be utilised to effect improvements in bathing water quality?
- Can SUDS contend with traditional engineering on a cost basis when retrofitting?

The missing link of all current work is the concentrated examination of the practical, site based issues encountered during SUDS retrofitting. The circumstances which define the viability of SUDS retrofitting on a practical basis have not been conclusively identified to date, nor have detailed methodologies been devised to deal with identified issues. Where SUDS can be shown to provide a viable alternative to conventional engineering, generic methodologies for implementation of retrofit SUDS need to be developed, in order that SUDS retrofitting can be effectively considered within capital investment programmes.

It has been the intention of this project to advance industry understanding of the practical site based issues encountered when considering SUDS retrofitting, and how these issues can be effectively dealt with. The study has focussed attention on retrofitting in an urban setting, with the objective of effecting improvements in Bathing Water quality.

4 Project Methodology

SUDS can be retrofitted to achieve several objectives. The focus of this study has been on achieving improvements in Bathing Water quality by reducing surface water discharges to the foul sewer and hence limiting spills from CSOs. The project has been carried out in two separate phases; the first entailing site selection, and the second involving progression to construction.

Both phases are discussed in turn in the sections below. It has been necessary to adopt particular approaches in both project phases in order to best meet project objectives in the timescale available. Recommendations regarding potential improvements to methodologies developed during this project, as well as key lessons learned from the experience gained are outlined in Section 5. It should be noted that specific sites and options resulting from the methodology adopted are discussed in later sections of this report.

4.1 Phase 1 – Site Identification

Phase 1 of the project was concerned with identifying sites suitable for SUDS retrofitting, in the context of achieving water quality improvements in Bathing Waters. The following tasks were undertaken:

- Site identification
- Feasibility assessment of sites deemed most suitable for SUDS retrofitting
- Workshop with project stakeholders to agree sites to take forward to detailed design and construction

The crux of Phase 1, and arguably of the project itself, was the selection of appropriate sites at which improvements to Bathing Water quality could be demonstrated, and where the practical implementation of the SUDS retrofit scheme would be permitted. This study has utilised a combination of desk and practical, site based, analyses in the identification of potential sites. Work completed has built upon current knowledge with regard to the complexities of retrofitting in an urban context.

4.1.1 Establishing Site Selection Criteria

As stated above, the methodology for site identification was developed under two main constraints, which influenced the site identification process significantly:

- The need to identify sites which would provide improvements to CSO performance in proximity to Ayrshire Bathing waters;
- Available timescales.

The first constraint affected the search area for site selection, while the second affected the detail of the identification process, as will become apparent in Section 4.1.2, which provides discussion regarding the site selection methodology. It should be stressed that the methodology developed has been specifically tailored to meet the objectives of the project, subject to the two constraints above, and therefore has inherent limitations. The criteria developed for the initial desktop review were as follows;

1. Improvements in CSO performance

Initial site selection criteria related to improvements in CSO performance was based on the following information which could be assessed at a desktop level;

- Surface water drainage connected to the combined system;
- Impermeable area upstream of a CSO.

This allowed sites to be identified where the retrofitting of SUDS could be beneficial.

2. Available timescales

Achieving the project objectives within the proposed timescales was a critical issue. Therefore, the site selection methodology required to be weighted toward finding sites which could be progressed toward construction as quickly as possible.

Factors which were considered to influence project programme during the short-listing of initial sites are displayed below in Table 2 - Risk Weighting for Site Specific Time Considerations. Each is given a particular weighting in order that sites with the most time-based risk could be screened out. Sites with high scores were dropped at the desk top level. Sites with lower scores were taken forward for further investigation prior to feasibility assessment.

Time-Based Risk Factor		Risk Ranking
Land Owner Agreement	Residential	3
	Industrial/Commercial	2
	Council/SW Owned	0
Consent Processes		1
Planning Permission Requirements		1
Land Procurement Procedures	Residential	3
	Industrial/Commercial	2
	Council/SW Owned	0
Disclosure Scotland Checks (for working in Schools)		3
Public Participation		3

Table 2 - Risk Weighting for Site Specific Time Considerations

The table above allowed the development of risk assessment criteria used as part of the desk top study. This focused the study on car parks and large institutional roofs, connected to the combined sewer and close to CSOs. Residential areas were largely eliminated from the process, together with any complications caused by multiple land owners or a requirement for public participation.

The criteria utilised for site selection therefore showed a hierarchy of surfaces for retrofit shown in Table 3 - Site Preferences for SUDS Retrofitting. This clearly shows that to progress the project within the proposed timescales, sites such as institutional roofs and car parks should be targeted.

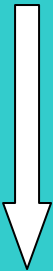
Ranked Preference (to least preferred)	Area Type	Comment
	Institutional Roofs	One land owner, hence fewer complexities in obtaining agreement. Large contributing area, hence demonstration of benefit may be clearer. Available land area for construction of solutions likely
	Car Parking	One land owner. Large contributing area, hence demonstration of impact is easier. Available land area for construction of solutions
	Residential Roofs	Several land owners. Lengthy consenting requirements. High complexity in achieving redirection of existing drainage. Disruptive.
	Highways	Involves detailed knowledge of illegal connection to foul/combined sewer. Too search intensive for purposes of study

Table 3 - Site Preferences for SUDS Retrofitting

It is necessary to stress that the remit of this study was to retrofit to limit CSO spills, and hence discharge to water courses via storm water culverts and highway drainage (unconnected to the foul/combined network) was not investigated.

4.1.2 Site Selection Methodology

Once the outline criteria for selection of sites had been formulated and agreed with project partners, site selection was progressed as discussed in the sections below.

4.1.2.1 Stage 1 – Desk Top Analysis

It was important that the site selection methodology was able to process a large number of sites in as short a time as possible, and that as wide a search area as possible was covered. The overall methodology followed in initial site screening is presented in the form of a flowchart in Figure 5 – Site Selection Methodology, Stage 1 overleaf.

The impact of retrofitting SUDS was required to affect the operation of CSOs downstream of the site. This selection criterion was used, as the emphasis of this study was to assess the impact of SUDS retrofitting on Bathing Water quality, and hence the operation of CSOs had to be demonstrably improved.

Hydraulic models were utilised as the primary tool for identifying impervious roof and road areas which were known to be connected to the foul sewer. Modelled contributing areas were mapped thematically using the GIS package MapInfo, to produce plans of catchment areas which clearly identified where significant proportions of impervious area were connected to the foul/combined sewer. Modelled sewers could be overlaid on the thematic map to determine the proximity of CSOs to localised “hot spots” of impervious area, as illustrated in Figure 3 –Thematic Mapping of Modelled Impervious Area and Figure 4 – Overlaying Aerial Photography at Potential Sites below.

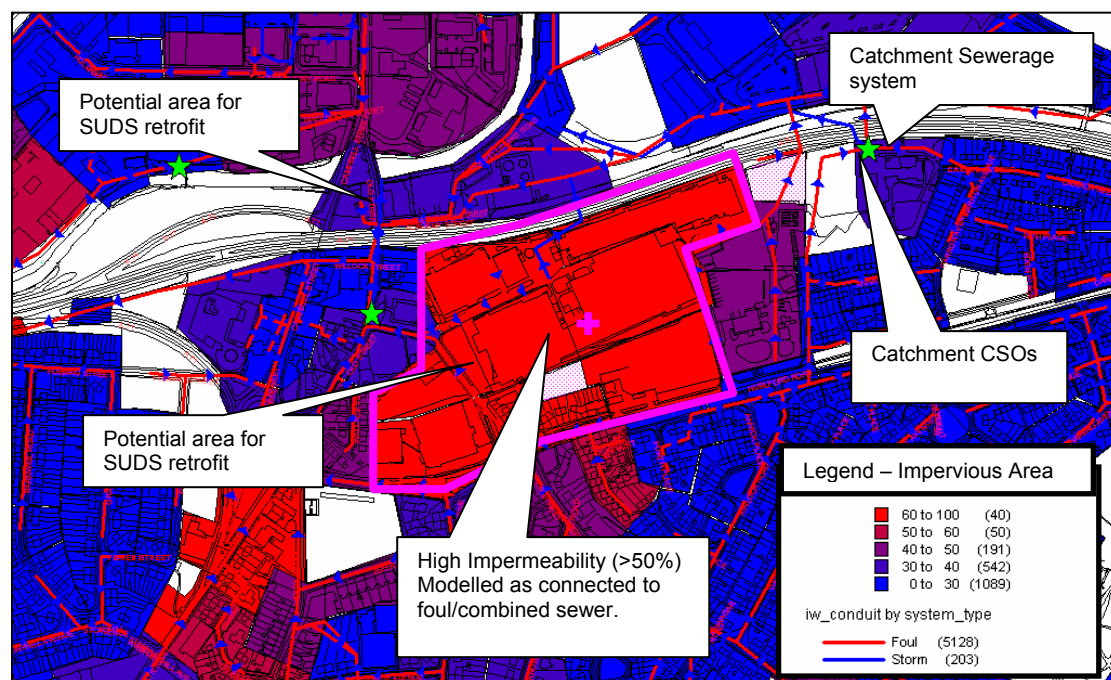


Figure 3 –Thematic Mapping of Modelled Impervious Area

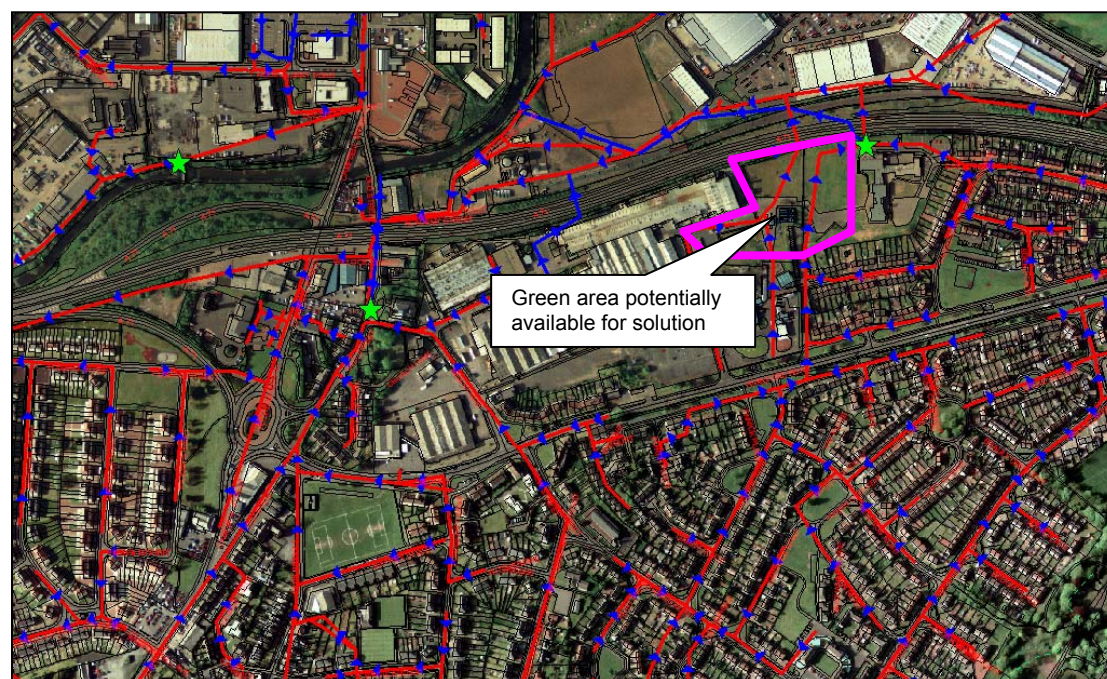


Figure 4 – Overlaying Aerial Photography at Potential Sites

The area indicated in purple above can be considered as potential sites, due to their high area contribution and proximity to downstream CSOs. Aerial photos were then overlaid to determine surrounding land use and land area which may be available for solutions, as can be seen in Figure 4 – Overlaying Aerial Photography at Potential Sites.

It should be noted that sites also required sewers with diameters suitable for effective flow monitoring, in order that any constructed scheme could be properly monitored before and following construction. Therefore this criterion was also introduced during initial short listing of sites.

Project stakeholders were also contacted at the inception of the project to make use of their local knowledge in the identification of potential retrofit sites.

Finally, the risk score discussed earlier was also used during short listing of sites, in order to arrive at a final list of sites which could be rapidly progressed toward construction in the time available.

The overall process followed is described in the flow chart below.

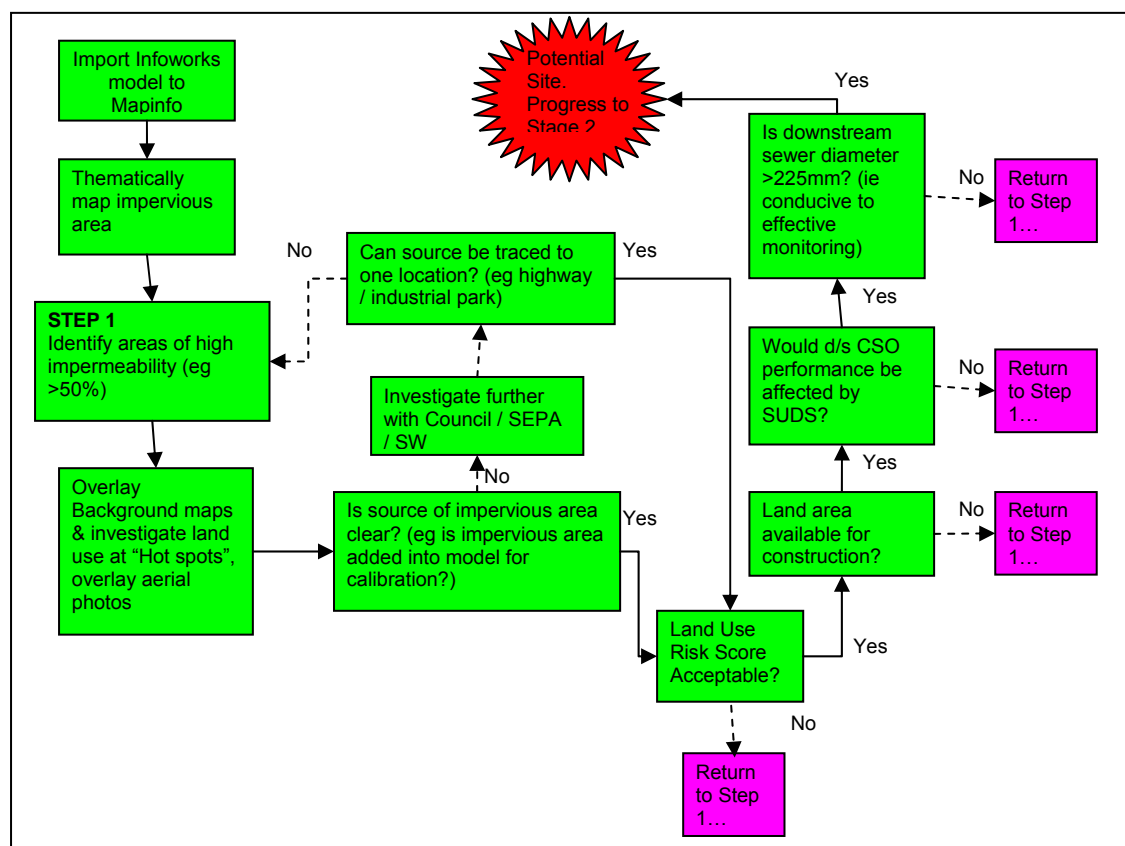


Figure 5 – Site Selection Methodology, Stage 1

Following completion of the desk-based site assessment, a list of sites was drawn up from the catchment areas studied.

There are a number of limitations inherent in the use of hydraulic models for site identification, however as stated earlier it was necessary to progress site identification as rapidly as possible in order to allow time in the programme for scheme construction. Hydraulic models provided a platform from which a reasonable assessment of site suitability could be developed, and the methodology used is considered to represent a “fast track” option. More detailed discussion regarding the limitations of the site selection methodology is given in Section 5 of this report.

The overall study area covered in this project has been described earlier in Section 2.3. For the purposes of site assessment, catchment areas which were situated in close proximity to coastal waters, or receiving waters perceived to have an impact on coastal waters, were selected for screening. Additionally, catchments for which hydraulic models were available were investigated in order to use the fast track site identification methodology outlined above.

Subsequently, the following catchments were assessed as part of the Stage 1 site identification process:

East Ayrshire	North Ayrshire	South Ayrshire
Kilmarnock	Kilwinning	Ayr
Darvel	Dalry	Prestwick
Newmilns	Saltcoats	Girvan*
Galston	Ardrossan	
	Irvine	

Table 4 – Catchments Assessed During Stage 1 Site Selection

* No hydraulic model was available for Girvan. Site investigations in this area were undertaken in response to advice from Scottish Water regarding storm sewer connections to the foul system.

4.1.2.2 Stage 2 – Site Inspection

Stage 2 of the site selection process involved a further desk based assessment of site topography, to determine whether the drainage characteristics of the site would be conducive to SUDS implementation. Presence of a suitable receiving water to discharge flow to was also investigated at this stage. The overall process followed was that described in Figure 6 – Site Selection Methodology, Stage 2.

Analysis of soil conditions and land contamination potential were also investigated at this stage. Rough assessment of soil type was undertaken using Wallingford Winter Rainfall Acceptance Potential (WRAP) Maps (Wallingford Procedure, Volume 3). The WRAP maps give soil classifications of 1 to 5 for sandy to clay soils respectively, which was considered a sufficient level of detail to assess infiltration potential at the site investigation stage. Details regarding land contamination were requested from local councils and SEPA.

Once the desk based assessment of site suitability had reached a satisfactory conclusion, site visits were undertaken at each of the short-listed sites. Site visits were considered critical in the determination of site suitability for the following reasons:

- Factors relating to buildability cannot be properly investigated off-site. These factors include details such as access, space available for construction, condition of existing structures, soil conditions, topography, distance and likely fall to outfall location and estimation of likely maximum receiving water levels in adjacent watercourses;
- Digital plans become outdated following new development, and information contained in hydraulic models is not always accurate. Site inspection allows a double check of desk based results;
- Onsite drainage characteristics of the site can be viewed, allowing an appreciation of site conditions and better understanding of what solutions (if any) would be feasible;
- Traffic conditions and other factors affecting potential disruption to residents and/or local businesses, as well as delivery of materials to and from site, can be determined;
- Site visits provided an opportunity to discuss the project with the land owner, and to establish the land owners understanding of site drainage. This allowed an additional check against the understanding of system configuration obtained from desk top studies.

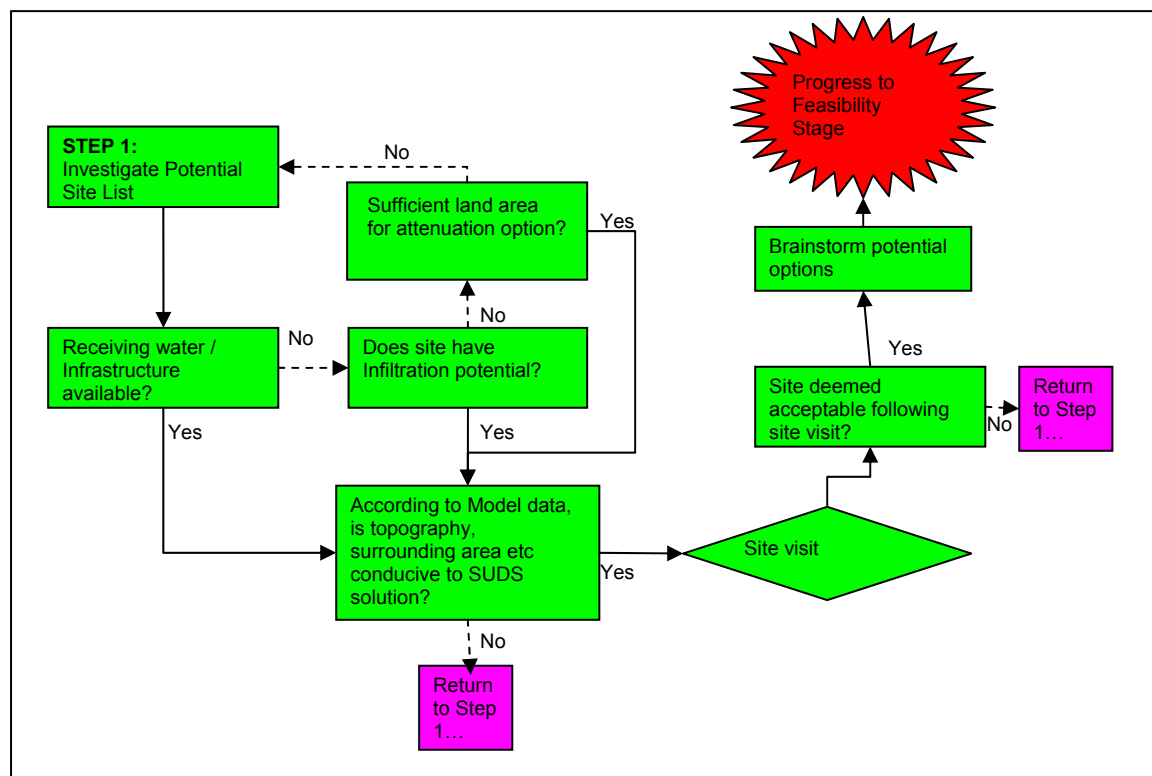


Figure 6 – Site Selection Methodology, Stage 2

Following the screening of sites in the Stage 2 selection process, a final list of sites considered suitable for SUDS Retrofitting was arrived at. Feasibility assessments at each preferred site were then undertaken, as discussed in the following section.

4.1.3 Feasibility Assessments

Once a list of preferred sites had been collated, feasibility assessments for each site were undertaken to determine whether the site was fully viable for construction. Prior to commencing feasibility, an assessment of the most suitable SUDS option had been undertaken, based on the site visit which was carried out in the last stage of Site Selection. Feasibility assessments therefore involved the following tasks:

- Meeting with Scottish Water, SEPA and local councils to agree SUDS design criteria;
- Outline modelling of proposed option to size potential solution, and determine whether sufficient land was available either within or adjacent to the site to accommodate the proposed SUDS option;
- Assessment of the potential SUDS retrofit options
- Outline modelling to determine likely improvements to downstream CSO performance;
- Obtaining all service plans in the area to establish presence and location of underground services;
- Contact with SEPA to determine maximum water levels in any adjacent receiving waters;
- Discussion with Land Owners to determine existing drainage connections, and assess their willingness to become involved in the project;
- Discussion with SEPA regarding the acceptability of the proposed SUDS scheme;

It is worth noting that cost estimates were not prepared as part of feasibility assessment. Although there is a lack of comprehensive costing information which is available for SUDS schemes, outline cost estimates were not undertaken during feasibility due to the absence of specific information required to prepare reliable cost estimates. In addition, it was agreed that the decision regarding whether to progress a site toward construction would not be made solely on cost, but on the probability of concluding construction works within the project time scales, and of producing a benefit to Bathing Water quality.

4.1.4 Workshop

Following completion of feasibility assessments, a workshop was convened, attended by all key project stakeholders. The purpose of the workshop was to present the methodology employed during site selection, discuss the findings of feasibility assessments, and agree sites to take forward to detailed design and construction.

Convening the workshop at the conclusion of the feasibility stage allowed all stakeholders an opportunity to contribute to the decision making process, highlight their own concerns and understanding of risk associated with each site, and was an effective means of information and knowledge transfer at a key point in the retrofit process. In addition, the workshop was consistent with the ethos of partnering, which should underpin any planning processes in which implementation of SUDS is concerned.

The outcome of the workshop was the agreement between all stakeholders of which sites would be taken forward to detailed design and construction. Also agreed was that additional efforts would be undertaken on behalf of Councils, Scottish Water Operations staff and SEPA, to apply their local knowledge to identify further sites suitable for SUDS retrofitting. Conclusion of the workshop marked the end of Phase 1 of the project, and Phase 2 commenced.

4.2 Phase 2 – Detailed Design & Construction

Following the Phase 1 workshop, selected sites were to be taken forward to detail design and construction. Pre and post construction monitoring was to be undertaken to assess the benefit of the retrofit scheme in terms of improvement to Bathing Water quality, and finally, cost-benefit analyses were to be carried out to determine how effective SUDS retrofit was in comparison to conventional engineering. At project inception, the following tasks were envisaged for Phase 2 of the project:

- Progress detailed design at sites selected for construction;
- Obtain land owner/stakeholder approval and progress planning application/consenting procedures;
- Prepare contract documents and initiate a tendering procedure to enable selection of contractors for scheme construction;
- Undertake pre and post-construction monitoring at sites at which construction was to be progressed;
- Provide Planning Supervision services as required under CDM regulations;
- Provide site supervision as required;
- Prepare and cost conventional engineering solutions in order to compare and contrast costs established for SUDS retrofitting;
- Prepare a final report detailing study findings, for dissemination across appropriate stakeholders.

Key aspects relating to the above tasks are discussed in detail in the following sections.

4.2.1 Land Owner Approval and Consenting Processes

SEPA actively encourages a partnering approach when considering the design of any SUDS system, and it is this ethos that has been adopted throughout this project. Project stakeholders, including Scottish Water, Local Councils and SEPA, were involved from project inception, which led to early agreement of final design, planning requirements and overall efficiency in project programme.

It is worthwhile noting that the benefits of SUDS amongst project stakeholders were well recognised, and that overall the project was met with enthusiasm and interest from prospective land owners and stakeholders alike.

Approaches adopted when determining consent and planning requirements, and when obtaining approval from land owners are discussed in the following sections. More detailed discussion regarding the types of issues encountered during this study when negotiating approval for SUDS retrofitting is presented in Section 4.2.1, with detailed discussion given in Appendix E.

4.2.1.1 Land Owner Approval

Obtaining land owner approval proved to be critical to the success of this project. One of the key lessons which can be drawn from the work conducted – particularly in relation to private land owners – is that there needs to be significant time allowance in the project programme to resolve the range of issues which may arise while seeking land owner approval. While the project was discussed with land owners during site identification stages to gauge their overall willingness to be involved in the project, it was not possible to begin official approval processes until the workshop had been completed at the end of Phase 1.

There is a range of issues which need to be resolved to the mutual satisfaction of all parties before land owner consent can be obtained. Table 2 - Risk Weighting for Site Specific Time Considerations, assigned a risk weighting to each prospective land owner according to likely time requirements necessary in obtaining approval. Risk weightings for land owner categories were assigned in order to favour sites in land owned by local councils or Scottish Water, where land owner approvals were likely to be less complicated.

Particular issues encountered and their relative significance in terms of retrofit programme are discussed in detail in Appendix E of this report.

4.2.1.2 Planning Requirements

SUDS implementation, whether retrofit or new build, is subject to the same planning procedures required of any change to land use. Local Council representatives approached in connection with this study advised that construction of the SUDS solutions proposed could be undertaken as “Permitted development”, as prevention of flooding and treatment of flow in sewers falls under Scottish Water’s remit under Section 3A of the Sewerage (Scotland) Act (1968), and construction was being undertaken by and for Scottish Water. The 1968 Act is revised to encompass provision of SUDS, in the Water Environment and Water Services Act (2003). This act is due to come into force in 2005.

As discussed earlier, this project used a partnering approach, involving both SEPA and Local Councils from project inception. This approach was found to result in early agreement of design criteria, as well as an agreed understanding of project objectives and timescales. This is particularly important for SUDS retrofitting, as it is still a relatively new process and subsequently there is a lack of precedent against which to make planning decisions. Hence early involvement with council planning representatives is essential.

4.2.1.3 SEPA Involvement

SEPA buy-in for outline options was sought prior to commencing detailed design, to ensure that design criteria were agreed and that all environmental considerations had been appropriately accounted for. In addition, SEPA were regularly consulted throughout the detail design process, to discuss certain aspects of construction methodologies and ways of mitigating potential environmental impacts which may have been caused by construction.

SEPA has powers under the Control of Pollution Act 1974 (as amended) to regulate discharges made to coastal waters, lochs, ponds, reservoirs and canals, and groundwaters. However, discharges of surface water run-off i.e. rainwater and mobilised pollutants, do not automatically require consent from SEPA at present.

The Water Framework Directive will require that all discharges liable to cause pollution are subject to some form of prior approval. Until then, SEPA has discretionary powers which it may use. These discretionary powers allow SEPA to issue a “prohibition notice” or “conditional prohibition notice”. It is not the intention to prohibit discharges, but to give SEPA powers to regulate the discharge through a consent, if it is considered necessary in a particular case.

The conditional prohibition notice would specify that final drainage arrangements should be in accordance with the drainage design agreed during pre-application discussions. In addition, SEPA may use these powers during the construction phase to regulate discharges from the construction works.

Therefore the requirement to issue a consent is currently reviewed by SEPA on a case by case basis.

4.2.1.4 Long term maintenance of retrofit SUDS

Longer term maintenance of the system was considered at this stage. It was agreed by Scottish Water that they would be responsible for the long term maintenance of the SUDS retrofit system. Hence issues associated with maintenance were not an obstacle to the development of potential sites.

4.2.2 Scheme Design

For the chosen two sites, SUDS and conventional schemes were designed to assess the potential difference in cost between the two options. The methods used for the design of both options are described below.

4.2.2.1 SUDS Retrofit Design

Guidance with regard to the design criteria for the SUDS retrofit schemes was obtained from 'Drainage Impact Assessment – Guidance for Developers and Regulators' produced on behalf of the North East Scotland Flooding Advisory Group, together with other information such as the Scottish Water targets for protecting properties from flooding. The following design criteria were proposed and agreed with project stakeholders;

- Drainage system to be designed for a 1 in 30 year storm;
- Sensitivity tests to assess the impact and prevent flooding of properties or infrastructure in the event of a 1:100 year storm;
- No allowance was made for climate change.

These design criteria were considered to provide an appropriate balance between providing adequate flood protection, and occupying the smallest possible site footprint in the retrofit context. Final sizing of options during the detailed design process was undertaken using modeling tools, in order to ensure that flow dynamics throughout the entire system, as well as system storage, were optimized. Although no explicit allowance was made for climate change, attenuation was provided up to the 1:100 year storm and allowances made for safe exceedance of the drainage system in the event of a storm with a return period greater than 1:100 years.

Design of schemes was undertaken with reference to the following documents:

- "Sustainable Urban Drainage Systems – design manual for Scotland and Northern Ireland" (CIRIA, 2000);
- SUDS Advice Note – Brownfield Sites (SEPA, June 2003);
- Planning Advice Note (PAN) 61, "Planning and Sustainable Urban Drainage Systems", (Scottish Executive);
- "Design and analysis of urban storm drainage, Volume 4, The modified rational method" (HR Wallingford, October 1981).

4.2.2.2 Conventional Scheme Design

Design of more conventional engineering options was undertaken following successful completion of pre-construction flow monitoring. Data returned following conclusion of the monitoring period was used in the local re-verification of available hydraulic models, around the site of the proposed SUDS system.

For the schemes designed in connection with this project, provision of off line gravity or pumped storage was considered be the most likely alternative to SUDS systems. For an appropriate comparison between SUDS and conventional engineering, it was important to ensure that both systems were capable of delivering the same improvements in system performance, as demonstrated by flow surveying downstream of the development.

However, because no schemes were constructed, post construction flow surveying was not undertaken. For simplicity, it was therefore assumed that the implemented SUDS scheme

would have been 100% successful in removing all surface water from the site. Conventional options for storage were then sized based on this assumption, using available hydraulic models as a design tool.

Following localized re-verification of measured pre-construction flows, the 30 year design storm was simulated to determine CSO spill volumes downstream of the SUDS site. In order to simulate the SUDS scenario, modeled impervious area at the SUDS site was then removed from the model and spill volumes were assessed again, to determine the reduction in volume that had been achieved through SUDS implementation.

Storage was then defined based on the difference between pre-and post SUDS CSO spill volume. For clarity, the methodology used to assess storage tank volume is described in the figure below. Costing of solutions is described in Section 4.2.5.

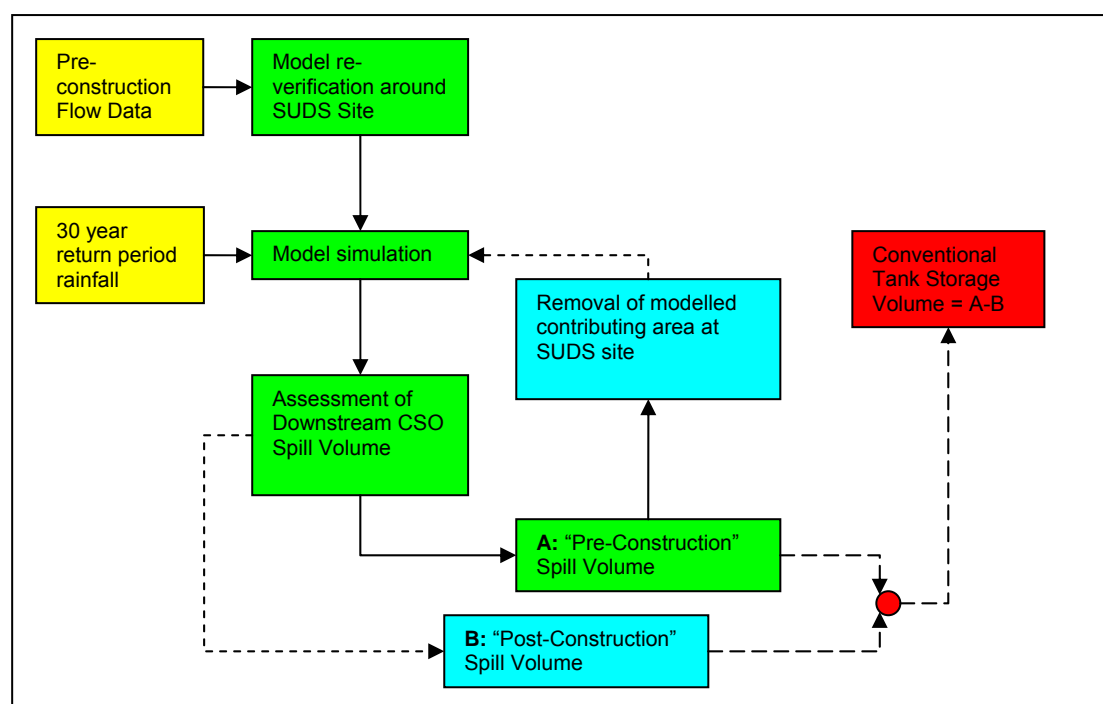


Figure 7 – Assessment of Conventional Option (Storage Tank)

4.2.3 Appointment of Contractors

Framework contractors were utilised, sourced from Scottish Water Solutions (SWS), the arm of Scottish Water responsible for delivery of Scottish Water's capital works programme. SWS operated a framework comprising a number of Joint Venture (JV) contractors, which could be assigned to work undertaken in connection with the SUDS project under a clause in their contract with SWS.

The ability to liaise continually with contractors throughout the design stage was invaluable, and permitted the development of a partnering relationship between Atkins, Scottish Water and the Contractor, leading to many efficiencies at later stages of the project, as discussed in further detail in Section 5.

4.2.4 Pre and Post Construction Monitoring

Monitoring was to be undertaken as part of the Phase 2 process, in order to gauge the effectiveness of constructed SUDS schemes. Because the intention of retrofitting SUDS was

to facilitate improvements to Bathing Waters, employing a bacteriological sampling programme before and after construction was initially considered as a means of gauging scheme effectiveness. However, because of the short project timescale and likely changeable seasonal periods across which sampling would be undertaken, it was considered that a sampling programme would likely prove to be inconclusive due to external influences which could affect recorded results.

Therefore, it was agreed that scheme performance would be gauged using flow monitors, situated immediately downstream of the site of the proposed SUDS scheme. Hydraulic modelling would then be undertaken to determine the impacts of reduced flow rates downstream of the development site. Localised model re-verification would be undertaken based on recorded flows. Any corresponding reduction in CSO spill frequency and volume could then be predicted by the model and coarsely related to improvements to Bathing Water quality.

It is preferable that a biological sampling programme is undertaken in addition to in-sewer flow monitoring, in order to properly quantify the benefits achieved by SUDS retrofitting to Bathing Water quality. It would be recommended that any future studies allow sufficient time for baseline and post-construction biological sampling. However, the approach adopted in this study was necessary because of time constraints imposed by project funding. It is worth noting at this point that there is relatively little information available within the industry at present regarding the removal efficiencies of SUDS schemes, particularly in respect of pollutants such as bacteria. Unfortunately it was not possible to determine this aspect of SUDS performance, due to the short term nature of the project.

4.2.5 Costing of SUDS and Conventional Solutions

The ultimate objective of the research conducted in this study was to compare the cost of Retrofitting SUDS against more conventional engineering solutions. As will be discussed in detail in later sections of this report, no schemes were progressed to construction, and hence it has not been possible to fully and accurately determine the final outturn cost of retrofit solutions defined within this project.

Scheme costs for proposed SUDS solutions were determined by the contractor based on the detailed design drawings prepared by Atkins' Design team. Due to the level of involvement construction contractors had during the design process, there is a high degree of confidence in prepared cost estimates, particularly for SUDS schemes. Confidence in costing estimates arises from the following points:

- The final design is appropriate for construction purposes, and is underpinned by significant site investigation and survey work.
- The contractor has walked the site with Atkins on several occasions, all likely construction issues have been discussed at length and resolved to the mutual agreement of all parties,
- Because of the site survey work and understanding of potential risks that has been developed between the contractor and the Design team, there has not been any need to make simplifying assumptions in the assignation of cost to aspects of construction.

Despite the amount of survey works undertaken during the build up to detailed design, it should be noted that the costing of work does account for some elements of risk, based on a percentage of the overall estimated construction cost. This would be expected in any construction project, as not all construction risk can be controlled by the contractor.

Due to the presence of a performance related contract with SWS, the contractor's future workload from SWS is dependent on a record of cost related performance – if the contractor exceeds their budget targets their future workload is diminished, and vice versa. It is therefore in their best interest to complete work under budget, and hence there is some confidence that final outturn cost would not exceed targets. It should also be stressed that all submitted target

costs were checked independently by SWS and Atkins to ensure that prepared cost targets were reasonable.

In conclusion, costs prepared for SUDS retrofitting are considered to be as accurate as practicably possible, short of physical construction of works.

4.3 Summary of discussion regarding project methodology

It has been the intention of this section to highlight the methodologies that were developed during this project to meet the unique objectives required of the study. Discussion relating to how the constraints of the project have influenced methodologies has been provided.

Section 55 provides a review of the methodologies developed, and identifies particular advantages and disadvantages associated with what are perceived to be the key stages in the retrofit process. It should be noted that any comment made regarding the potential success of retrofitting is related to observations made in connection with this study, and comments are not intended to be made in relation to the case for retrofitting in general.

5 Review of Methodology

It has been the intention of this study to investigate the practicalities of retrofitting SUDS and to examine, in detail, the cost and benefit of SUDS retrofitting in comparison to more conventional engineering options.

Methodologies employed in the identification of sites suitable for SUDS retrofitting have confirmed the validity of previous desk based approaches. However, the study has also found that there are many practical issues which need to be overcome, which follow from the selection of site and have influence on whether the site can indeed be considered acceptable for SUDS retrofitting.

The work undertaken in this project has identified that site selection and the manner in which land owners are approached is critical to the success of the retrofit process. This section seeks to identify what lessons can be drawn from the methodologies discussed above in these two areas. Finally, improvements for future work are recommended.

A wider review of the opportunities for SUDS retrofit within the context of improving Bathing Water quality and reducing flooding is made in Section 10.

5.1 General Discussion

5.1.1 Site Selection

This methodology was devised to identify suitable sites for SUDS retrofit under difficult programme constraints and the need to show benefit to Bathing Waters. Because of time constraints, a “fast track” methodology was developed which utilised hydraulic models to identify areas of high impermeability within catchment areas.

While this is, in principle, an effective method of screening an entire catchment area within a short time frame, the methodology is underpinned by one critical assumption: that the modelled representation of impervious area connections to the foul/combined sewer is correct. Where Impervious Area Surveys (IAS) were undertaken, model representation of connected impervious area may be considered reliable. However, where no IAS was carried out, the confidence in how impervious area has been allocated to the modelled network is reduced considerably.

This uncertainty was taken into account in the site based stage of the methodology, which involved discussion with the land owner and inspection of on site drainage, and later during feasibility stages when dye testing was undertaken to conclusively confirm the extent of impervious area connection to the foul sewer.

However, it was found at many sites that even land owner understanding of their own drainage system can be unreliable, and that therefore inspection of service plans and subsequent dye testing should be incorporated into the Site Identification methodology, in order to properly screen out unsuitable sites before progressing to feasibility stage.

One further limitation inherent in the methodology adopted for site selection was the need to demonstrate improvement to Bathing Water quality through SUDS implementation. Prior to project commencement it was acknowledged by all parties that SUDS retrofitting would be unlikely to provide benefits of sufficient significance to provide an outright alternative to traditional engineering. As site identification progressed, it was apparent that the circumstances in which retrofitting was feasible were quite rare. Therefore in using Bathing Water improvement as a criteria in the selection process, opportunities in which retrofitting

could be progressed were being eliminated. The decision was then made to select sites based on the ease with which the site could be progressed to construction.

5.1.2 Land Owner Approval

As stated earlier in Section 4.2.1.1, obtaining land owner approval for construction of SUDS schemes, particularly when dealing with private land, will ultimately determine the success of the retrofit scheme. As mentioned earlier, time related risk is reduced in instances where land belongs to either Local Authorities or Water Industry bodies, however there remains a high likelihood that retrofit schemes will require some form of land agreement with private land owners before schemes can progress to construction.

It is therefore important to allow sufficient time for the land owner to make a decision. Again, because of time constraints construction was not possible during this project, as particular land owners felt they were unable to make an affirmative decision in the time available within project programme. However, despite this disappointing result, there are useful lessons which can be drawn from the experience gained during the process.

Detailed discussion on particular issues which should be considered when seeking approval for scheme progression from land owners is provided in Appendix E. Relative impacts of each issue on project programme are also highlighted.

5.2 *Potential Improvements to Project Methodology*

The impetus to demonstrate Bathing Water improvements from SUDS retrofitting stems from a need to devise more sustainable, economic alternatives to those provided by traditional engineering. The trend from contemporary SUDS research indicates that the feasibility of retrofitting is isolated to a few select properties at which a variety of rarely attainable criteria are combined. Retrofitting in select, isolated instances will not achieve flow reductions radical enough to result in significant water quality improvements.

The work conducted in this study has shown that retrofitting can be more simply undertaken in areas with single land owners – schools, commercial premises, car parking facilities, and industrial and institutional premises. However – with some exceptions – undertaking retrofitting in these isolated locations is unlikely to achieve flow reductions of enough significance to result in appreciable improvements to CSO performance, and subsequently improvements in receiving water quality are also likely to be limited. However, the collective reduction in flow volume across an entire catchment area may be significant where a number of retrofit cases is possible.

If one were to consider actual runoff contribution to the foul/combined sewer on a catchment-wide volumetric basis, residential roofs would be placed as the primary contributor. Hyder Consulting undertook an investigation of area contribution to the foul/combined sewer in their Dumfermline SUDS report. Using GIS mapping, it could clearly be shown that residential areas comprise the highest contribution of roof and road area on a catchment wide basis. This analysis is supported in the investigations undertaken in this study.

In order to achieve the kind of flow reduction necessary to improve the environmental performance of catchment sewerage systems, the flow contribution from residential areas must be addressed.

There is a current perception that retrofitting in residential areas is likely to be disruptive, complex, costly, and that any proposal would meet strong public resistance. While this is probably true of schemes involving separation of foul and surface water drainage, there are instances in which application of SUDS principles could prove to be cost effective, involve

minimal intrusion on residents in installation and could operate effectively with minimal maintenance – for example in the application of water-butts.

However, it was considered that likely processes involving consenting, public participation and eventual agreement would prove to be too lengthy to make any solution in residential locations possible within the project timescales. Therefore no investigation into this avenue has been possible as part of this study.

Further research should be undertaken to determine whether cost effective and low maintenance SUDS measures such as water-butts can be successfully deployed in residential areas. Flow from residential areas contributes the most significant volumetric input to sewer flow rates on a catchment wide basis. The discovery of successful retrofit SUDS techniques for residential areas served by combined sewerage systems, could conceivably lead to significant water quality improvements at key CSOs, and potential scheme reduction for any conventional solution required to protect receiving water quality.

5.2.1 Retrofitting in Non-Residential Areas

The work conducted has sought to identify the issues which are encountered when retrofitting in non-residential areas within a developed urban setting. The Site Selection phase of this study has shown that retrofitting in this context can only be feasibly achieved at single locations. Furthermore, large isolated premises at which SUDS can be effectively retrofitted to achieve improvements in Bathing Water quality through reduction of CSO spill are rarely available.

Therefore, where the Water Industry is to investigate retrofitting of SUDS in foul/combined sewerage systems, the driver for retrofitting is more likely to originate from a requirement to achieve more generalised efficiencies in network operation. In this case, the benefits accrued to the Water Industry through SUDS retrofitting could include the following:

- Reduction in operational costs at Sewer Pumping Stations and WwTW;
- Reduction of flooding risk;
- Freeing up hydraulic capacity for development purposes;
- Provision of public amenity;
- Enhancement of habitat;
- Provision of educational resources.

Site selection under these circumstances needs to be methodical, and undertaken over a time period which allows an exhaustive catchment by catchment screening process. Accurate utility plans for Water and Sewerage, depicting the location of all sewerage assets owned by the affected Water Industry body should be utilised from the outset, combined with an overall selection strategy that targets commercial and institutional properties first. An improved site selection methodology could therefore incorporate the following factors:

- The philosophy underpinning site selection should be based on an opportunistic approach, in that selection will be entirely dependent on whether site conditions permit construction.
- Site searches should be undertaken on a catchment by catchment basis, and should seek to retrofit SUDS wherever conditions allow. The collective reduction in in-sewer flow on a catchment wide basis may be significant enough to achieve improvement to local water quality, however the benefits of retrofitting are most likely to be those listed above;
- Local knowledge from Councils, Water Industry Operations staff, and Environmental Regulators should be fully exploited and thoroughly investigated, to maximise site potential;

- Utilising aerial photos and GIS mapping, commercial and institutional premises should be investigated methodically, to assess site suitability on a case by case basis. Full listings of all properties should be obtained from Local Councils and from Water Industry trade waste records;
- Where potential sites are identified, site visits should be undertaken combined with dye testing to confirm all connections to the foul sewer, and to assess buildability issues.

Prospective land owners should be engaged at a senior level as soon as is practically possible. Certainly, preliminary involvement should commence during site selection. If possible, contractors for works construction should be appointed at project inception, and should be present at all site inspections during the selection process, and should be responsible for the dye testing undertaken during Phase 2 of site selection. A potential process flow for a SUDS retrofit exercise could therefore follow that presented in the figure below:

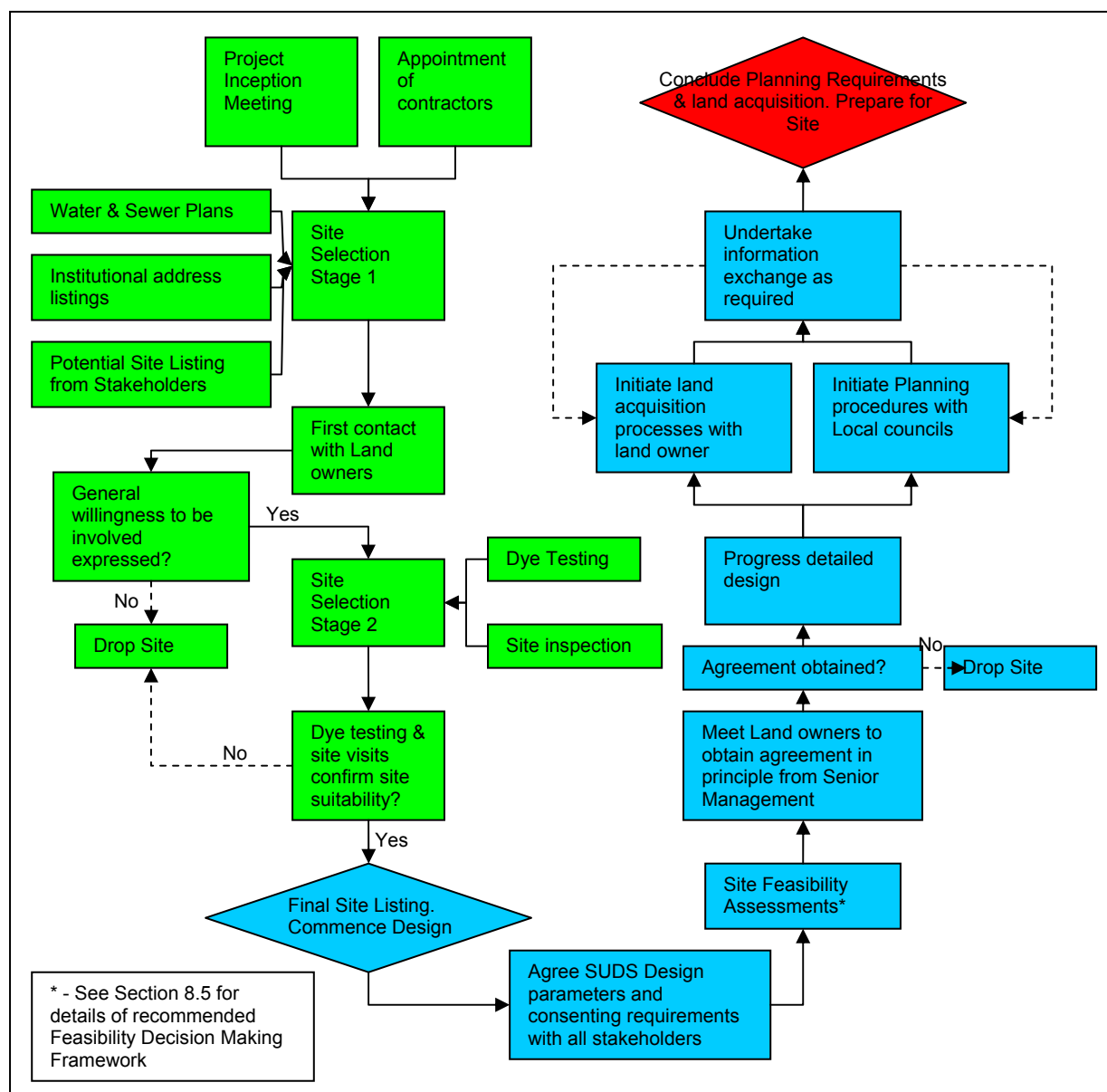


Figure 8 – Proposed SUDS Retrofit Process Diagram

6 Feasibility Results

The methodology for Site Selection and progression of sites toward feasibility assessment has been described in Section 4. The intention of this Section is to record particular sites investigated during feasibility assessments, and report the factors which made the site favourable for retrofitting in the context of the project brief (i.e to achieve improvements to Bathing Water quality).

It is worth noting that two Site Selection passes were undertaken, as the results of the feasibility studies conducted during the first pass showed that opportunities for construction were limited.

6.1 First Pass Site Selection

Table 5 – First Pass Site Selection – Feasibility Results below summarises each site which was identified and taken forward to feasibility stage following the first pass site selection.

Catchment Area	Site Name	Comment
Ayr	-	No space available for construction within available timescales
Prestwick	-	No space available for construction within available timescales
Annick	-	No scope
Kilmarnock	K1 – Shopping precinct	Water level and available topography prohibits discharge to receiving water during high flow events. Potential for infiltration limited due to soil type, high groundwater table and potential for contamination.
	K2 – Industrial Premises	Contaminated land and potentially contaminated runoff, plus no receiving water available - agreed at workshop to abandon site due to risk.
	K3 - Residential area,	Retrofitting in residential areas considered too difficult within available timescales
Hurlford	K4 - Industrial Premises	Owners confirmed new separate storm sewerage had recently been installed
Newmilns	K5 - Industrial Premises	Site progressed following workshop. However, dye testing showed majority of storm drainage discharges to river and site was subsequently dropped due to no reduction in sewer flows.
Irvine	I1 - Industrial Premises	Site dropped as no benefit to downstream CSO performance. Also problems with potential contamination within the site area.
	I2 - Industrial Premises	Dye testing and plans confirmed all stormwater discharges to separate sewers.

Table continued over page ►

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Catchment Area	Site Name	Comment
(Irvine cont...)	I3 – Shopping precinct	Site dropped as no benefit to downstream CSO performance.
	I4 – Industrial Premises	Site progressed following workshop.
	I5 – Hotel Facilities	Site dropped as no benefit to downstream CSO performance.

Table 5 – First Pass Site Selection – Feasibility Results

It can be seen that a number of sites were dropped as no benefit to CSO performance downstream of the site could be demonstrated by SUDS implementation, based on the results of sewer modelling. During the first pass site selection, sites were dropped on this basis. It is worth noting that retrofitting of SUDS may still be physically possible at these locations, but that retrofitting may not necessarily result directly in improvements to Bathing Water quality due to reduced spills from CSOs. Rather, retrofitting is more likely to contribute to other benefits (including reductions in sewer flows) in keeping with the ethos of sustainability which underlies the SUDS approach.

For example, retrofit schemes at certain identified industrial premises were investigated to incorporate the use of rainwater in industrial processes. This would have reduced the cost of operation for both industries and reduced abstraction of potable water resources in these areas. However, site were subsequently dropped because storm sewers were found to discharge to the adjacent receiving water, rather than the foul sewer as was indicated by available hydraulic models. Alternatively, sites were dropped as modelling showed no improvement to downstream CSOs.

In some occasions, retrofit SUDS would have resulted in the reduction of storm water input to the foul sewer, thereby providing localised capacity within the sewer system for residential or commercial development, which may have provided local socio-economic benefits. In addition, systems comprising features such as wetlands to treat runoff from particular sites have the potential for habitat enhancement, and may be used as an educational resource by local schools and the general public. However, because hydraulic modelling indicated no benefit to the spill performance at downstream CSOs, site were not progressed.

Of course, in some instances retrofitting of SUDS is simply not feasible. For example, issues such as high water levels in available receiving waters during high flow events, the potential for contaminated land and high groundwater levels can preclude SUDS installation. In some instances land area was available but SEPA and Environmental Health officers within the Local Councils reported heavy contamination within site boundaries. Where high contamination had been recorded, Local Councils and SEPA considered that the risk of contaminants being remobilised as a result of SUDS retrofitting too great to permit scheme progression.

Site feasibility in some townships was found to be limited, based on the methodology used for site selection. Detailed inspection of sites in the manner described in Section 5.2.1 may provide a better indication of the potential for retrofit in these areas, as selection of sites would be independent of hydraulic modelling assumptions.

Additionally, further conversation with land owners and inspection of detailed service plans revealed that modelled representation of areas connected to the foul sewer was incorrect at some locations. Again, removing hydraulic modelling assumptions from the selection process may result in more sites being identified.

6.2 Second Pass Site Selection

The list presented in Table 5 – First Pass Site Selection – Feasibility Results was discussed at the workshop with SEPA and Local Councils. It was agreed at the workshop that two sites would be taken forward to detailed design at Irvine and Newmilns. As discussed earlier, the latter site was dropped when dye testing showed that the majority of roof and paved connections discharged to the River Irvine. In order to have more data from which to draw reliable conclusions in relation to cost and performance, an additional site selection pass was undertaken. Criteria for site selection were relaxed, based on reduction in sewer flows and construction in available time scales rather than necessarily demonstrating a reduction in spills from CSOs.

Information from Scottish Water Operations, SEPA and Local Councils regarding potential sites was sought in both site selection passes, in addition to the assessment of impervious areas within hydraulic models. Additional information from stakeholders was more forthcoming in the second pass assessment, as respective organisations had had more time to investigate potential sites at that stage in the project process. The table presented below summarises feasibility results for the second pass Site Selection:

Catchment Area	Site Name	Comment
Kilwinning	KW1 - Industrial Premises	Several site owners. Not progressed due to the lack of available information.
	KW2 - Car sales yard	Discussion with owner confirmed separate sewerage installed, not shown in hydraulic model
	KW3 - Residential area	No space available for construction, time constraints associated with separation in a residential area.
Saltcoats	SC1 - Industrial Premises	Discussion with site owners revealed plans showing separate sewers (not shown in hydraulic model).
	SC2 – Education Facility	Progressed, however dye testing showed all connections to storm sewer (not shown in hydraulic model).
	SC3 – Industrial Premises	Progressed, however potential for contamination posed too great a risk to progress to construction
	SC4 – Public Facility	Progressed, however dye testing showed all connections to storm sewer (not shown in hydraulic model).
Kilmarnock	K6 – Industrial Premises	No available land for construction
Other*	Kilmaurs - Industrial Premises	Small industrial units close to river. No space available for retrofitting.
	Galston	Old industrial buildings. Unclear what is connected to the foul sewer. No space for SUDS.
	Girvan – Residential Area	Separate foul and surface water systems. Storm sewer connects to foul. Site progressed to detail design.

Table 6 – Second Pass Site Selection – Feasibility Results

* - Indicates site passed to Project Team by Scottish Water Operations.

As can be seen from Table 6 – Second Pass Site Selection – Feasibility Results, the use of hydraulic models to identify potential sites resulted in similar problems as were experienced during the first pass site selection. However, the same selection methodology was employed due to the time constraints discussed earlier in this report.

The second pass site selection investigated several sites provided by Scottish Water Operations, as indicated in the table above. At the majority of these sites, SUDS retrofitting was considered infeasible due to limited access ways and lack of land area available for solutions. However, the site at Girvan was found to be suitable and was progressed to detail design. Details relating specifically to this site are provided in the Section 9.

7 Summary of Issues Affecting Site Feasibility

Detailed discussion regarding the issues which were found to affect site feasibility is provided in Appendix F. This section is intended to briefly summarise the issues encountered in order to highlight the key factors which require consideration when considering SUDS retrofitting in developed urban areas.

It is highlighted that the issue of cost is an important consideration in any feasibility assessment. However, due to the timescales involved in this study, progression to construction was made on the basis of conditions permitting construction, and cost benefit analyses were not undertaken during the feasibility stage.

One of the desired outputs of this study was the preparation of cost models to describe potential capital and operation costs associated with retrofit SUDS schemes. Detailed discussion regarding cost estimation for feasibility purposes is provided in Section 8 below. Therefore this section seeks to summarise issues which impact scheme feasibility in relation to site conditions and design, as detailed in the bullet points below:

- Contaminated land. An issue with large industrial sites which are connected to the combined sewer (ie old sites) which restricts the use of efficient / cheap SUDS retrofit solutions;
- Topography of the site and existence of sloped or embanked areas;
- Protected areas, such as SSSI sites, sites of historical significance;
- Proximity to available receiving waters, ground water levels, receiving water levels;
- The condition of existing buildings on site can affect construction feasibility, particularly for older sites where access is constrained and construction close to existing buildings is required;
- Nature of existing drainage - how much foul / surface separation is required and how difficult will this be? In some cases, the potential for on-site contamination from industrial processes may preclude scheme progression. It may only be possible to separate part of the site – in these instances, the benefit which can realistically be achieved downstream must be weighed up;
- Landowner willingness to be involved. See Appendix E for details regarding likely issues which may arise when seeking land owner approval, and their relative impact on project programme;
- Return periods used during design – where the impact of climate change is considered, the size of potential solutions can result in greater land take. For retrofitting SUDS, where space is already a premium, this can have implications on the progression of schemes. It may be possible to design smaller solutions that work for a range of return periods, then overflow for the really big events. While discussions should be held with project stakeholders to agree design criteria at the earliest opportunity, it may be necessary to revise flood protection measures depending on land availability.

8 Assessment of Retrofit Cost

No form of cost comparison was undertaken at feasibility stage during this study, for the following reasons:

- No costing information was available;
- As project funding for pilot schemes had been secured, cost assessment was not a critical factor in determining scheme feasibility;
- Criteria for progression to construction was based on demonstration of bathing water quality improvement, and ease with which construction could be progressed within available time scales, rather than purely cost.

It is recognised that for future work, assessment of costs associated with SUDS retrofitting will require to be undertaken during feasibility. Where the Water Industry is to be undertaking the retrofit exercise, some form of standardised costing database, covering a range of potential SUDS facilities, may be required to assist in the efficient estimation of retrofit costs, particularly in the event that SUDS retrofitting is to be integrated into capital investment programmes and budgetary costings are required.

There are two components to scheme cost which must be considered during assessment of scheme feasibility, the first is the capital cost, and the second is operational and maintenance expense necessary to ensure the system operates optimally throughout its life cycle, in addition to any part replacement costs.

8.1 Estimation of Capital Cost

The TR61 Cost Estimating Manual (WRc Plc) is an example of the type of information required for adequate, standardised cost estimation. This manual is used for capital cost estimation, comparative performance assessments, asset valuation and investment planning in water and wastewater construction. It contains data from more than 1000 contracts and is kept up to date by applying various inflation indices. The proportion of costs in different asset types (e.g. M&E, civil) is also presented.

It should be noted that the TR61 is more accurate when applied to large scale capital works, and hence is not particularly useful for estimation of cost for the smaller scale works required of typical SUDS retrofit schemes. However, it is recommended that a database of retrofit costs is compiled and maintained by the Water Industry or nominated party, in a similar manner. The intention of the database would be to present a series of cost models, in order to provide indicative costs on a volumetric or linear basis for differing SUDS options. This database should ideally be based on as varied a series of retrofit applications as possible, to increase the level of confidence which can be placed in the cost models presented.

The information developed and presented in this report can be utilised in the development of the costing database. As discussed in Section 4.2.5, detailed cost estimates have been prepared in connection with this study. These are discussed further in Section 9, and are presented in Appendix A and B, for SUDS and conventional engineering alternatives respectively.

In addition, some information has been received from other parties who have been involved in retrofitting SUDS in schools (Bob Bray Associates). Costing data has been provided in terms of unit rates for typical SUDS solutions such as swales and stilling ponds. The information provided has been included in Appendix D.

In the absence of costing databases, costs for SUDS retrofit works must be estimated by Quantity Surveyors or suitable Contractors. While reasonable costs may be output from this

kind of exercise, using actual data gathered from real applications provides additional confidence in cost estimates, and will provide a standard costing model suitable for use in any given retrofit application.

8.2 Estimation of Maintenance Cost

Very little information regarding the maintenance costs associated with SUDS systems is available in the industry at the present time. The University of Abertay has undertaken a study investigating maintenance requirements associated with certain SUDS systems. Unfortunately the results of the study were not available in time to be used for the work conducted in this project. Some research has also been undertaken by HR Wallingford in the investigation of SUDS long term maintenance costs. Although this report is only at a draft stage at present, some of the data has been used to provide estimates for maintenance costs associated with this study. However, due to the lack of information, some costs associated with time, plant and materials have been estimated for the purposes of this project.

The following aspects have been investigated during the generation of maintenance cost:

- Maintenance tasks required for SUDS and Conventional options;
- Costs covering provision of staff, materials and plant in executing maintenance tasks;
- Costs associated with operation of SUDS & Conventional systems. Where SUDS reduces operational requirements (such as pumping), this benefit has been included;
- Costs associated with part replacement of SUDS and Conventional options as required.

Estimation of maintenance time and cost has therefore been undertaken with a degree of subjectivity, and certain assumptions have been necessary in order to determine approximate costs. All assumptions made during estimation of maintenance requirements have been detailed in Section 09.

Assumptions were necessary when considering the long term periodic part replacement within proposed SUDS schemes, as installations of certain technologies (for example cellular storage systems) are relatively recent and within the project design life, and therefore the actual design life and replacement needs of certain systems has not been adequately tested in the field. In addition, the SUDS approach is relatively new in the UK, with most installations having occurred within the last decade, and hence periodic replacement needs (based on available data) are yet to be confirmed for the majority of cases.

Estimated maintenance costs associated with each scheme developed to the detail design stage are presented in Section 9 of this report. Estimated maintenance costs – in addition to estimated reductions in maintenance and operational costs imparted by SUDS systems – have been used during NPV calculations, in order to compare the differences in maintenance requirements between SUDS and conventional options.

8.3 Estimating the Value of SUDS Benefits

The benefit of retrofitting SUDS in urban areas can be broadly separated into three separate areas, as indicated in the diagram below:

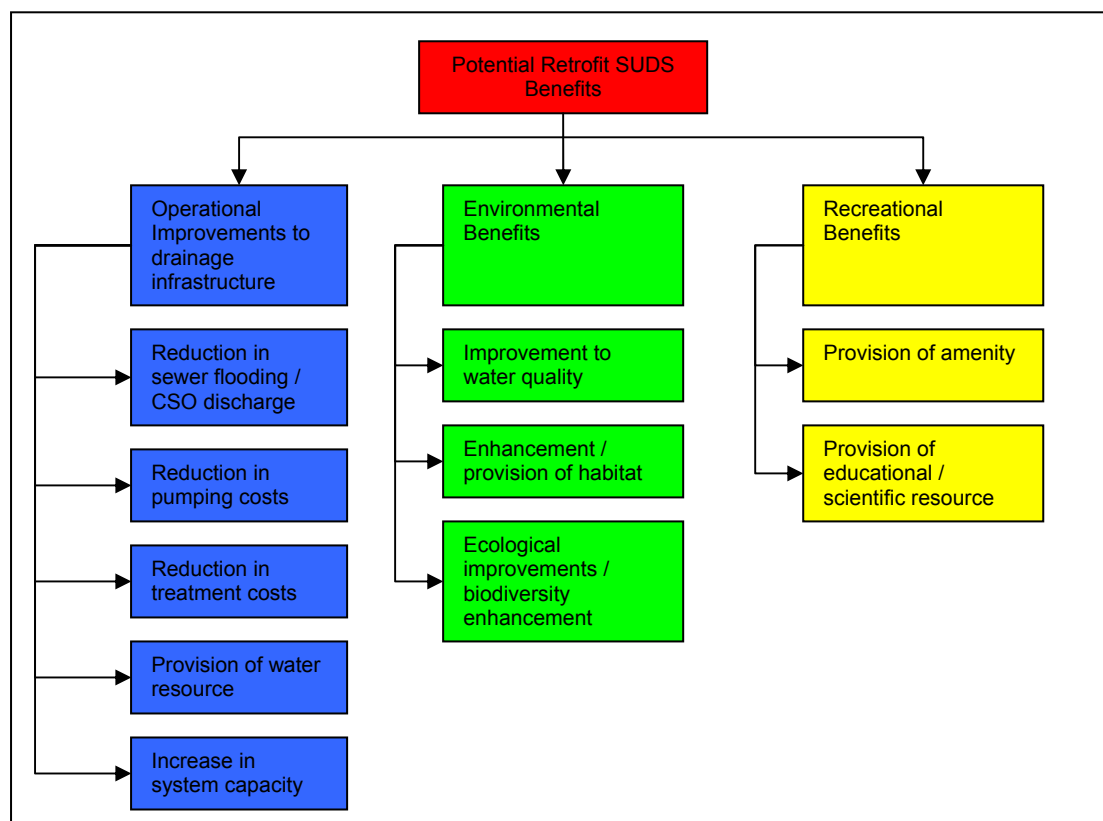


Figure 9 – Potential Benefits of SUDS Retrofitting in Urban Areas

Clearly, not all SUDS retrofit schemes will be capable of achieving all of the benefits listed above. However, it is necessary to assign a value to each benefit if an adequate cost/benefit assessment is to be undertaken.

8.3.1 Operational Benefits

8.3.1.1 Costing Improvements in Operational Efficiency

Costing of Operational benefit in terms of improvements to operational efficiencies, such as reduced pumping and treatment costs, are relatively straightforward for the majority of cases. An estimate of the volume of flow removed from the system over a typical year can be utilised to determine likely reductions in treatment and pumping costs. Similarly, where water re-use is being investigated, the cost saving through utilisation of SUDS can be determined and offset against annual mains charges.

8.3.1.2 Assigning Economic Value to Reduction in Sewer Flooding

Assigning cost to reduction in sewer flooding becomes slightly more complex. The economic value assigned to flooding from the combined sewer is a function of the severity and frequency of the flooding. For properties more vulnerable to flooding, such as hospitals or schools, the economic cost which could be assigned to flooding is likely to be higher.

Determining the benefit of reduced flooding could be achieved by combining the following approaches:

- Examination of property prices;

- Calculating the cost of clean up operations required following flooding incidence (ie, an assessment of required maintenance);
- Assessing peoples "Willingness to Pay" (WTP) for reductions in flood incidence;
- Undertaking an assessment of the health benefits of reducing flooding.

At present, limited work has been undertaken in assessing the cost related benefits of resolving sewer flooding. However, it is highly likely that work in this area is ongoing and it is anticipated that attention to risk based assessments of flood occurrence will be more prevalent in the future, as water authorities seek to prioritise their investment in this area.

It is recommended that assessments of benefits achieved by SUDS in terms of flood reduction are determined once more information becomes available. In the absence of detailed information, this element of economic value provided by SUDS has not been accounted for in this study.

8.3.2 Environmental Benefits

Considering cost values for enhancement of habitat and water quality improvement becomes increasingly more complicated. An assessment of peoples "Willingness to Pay" (WTP) in relation to Bathing Water improvements can be undertaken, using the results of various studies which have examined populations visiting Scottish Bathing Beaches, and assigning a cost to Bathing Water improvements based on values extracted from studies which have determined WTP values for percentage reductions in bacterial concentrations in Bathing Waters.

Appendix G provides more detailed discussion on this complex issue, and assigns an economic value to achieving 1-2% improvements to Bathing Water quality for Irvine Beach, where the proposed SUDS scheme in Irvine may have been shown to effect some reduction in bacterial loading at Irvine Beach.

However, the value provided in Appendix G should be viewed as being indicative of the range of benefits which could be ultimately achieved in improving Bathing Water quality. Because it has not been possible to quantify improvements in Bathing Water quality which can be achieved through SUDS retrofitting, assigning a cost to benefits such as improvements to water quality cannot be undertaken with any degree of confidence until Bathing Water improvements can be adequately quantified. Once this is done, observed reductions in baseline bacterial loading (expressed in percentage terms) may be used to provide an estimate of the economic value of achieved water quality improvements.

8.3.3 Recreational Benefits

Again, determining the economic value of recreational improvements is a complex issue. Few studies have been undertaken to assess the economic benefit which can be assigned to changes in land use and improvement of amenity. The economic benefit which can be assigned to amenity will be dependent on the number of users. For sites such as the Industrial area in Irvine, where the amenity is situated within private land and is therefore available to site staff for limited periods of time and visitors only, the economic value of the amenity is further diminished.

Appendix G summarises the findings of one particular study which has examined a WTP figure for public visits to publicly owned Woodlands. Clearly, transferring WTP values related to public Woodlands to a landscaped pond feature in private industrial land is not valid, but has been undertaken in relation to the Irvine site in order to provide an indication of the likely economic value which can be assigned to amenity. Results are reported in Appendix G, but should be taken as being generally indicative. It is stressed that further work is required to obtain values for economic benefit which can be translated to the types of amenity provided by SUDS with more confidence.

8.4 Comparison of Retrofit SUDS against Conventional Engineering

In light of information presented in the Sections above, no value has been assigned to the benefits offered by SUDS such as environmental or aesthetic improvements, during comparison of SUDS and Conventional options costs. Additionally, these “softer” benefits are not strictly within Scottish Water’s remit, and therefore fall outside the focus of this study.

Attempts have been made to determine cost savings to be achieved in reduction of operational costs at existing pumping stations, where appropriate. This approach has been adopted as reductions in Water Industry operational expenditure achieved through SUDS retrofitting is more relevant to the study remit, and may be more clearly demonstrated.

Operational and capital costs can be determined for SUDS and comparative conventional options using Net Present Value (NPV) calculations.

NPV costs account for estimated capital expenditure as well as routine maintenance and part replacement, across the expected life time of the asset. The values for maintenance and operational cost for each year are discounted at a defined rate, to determine the value of the required investment in present day terms. Accrued income can also be offset against cost, to determine whether a return can be made on the investment.

An assessment of NPV cost for the proposed SUDS system can be compared to NPV costs for conventional systems in the assessment of SUDS feasibility. Estimated scheme benefits can be costed and offset against NPV cost for both schemes. Determination of where SUDS is feasible can then be made using the simple formulae below:

$$NPV_{\text{SUDS}} - NPV(\text{BENEFIT})_{\text{SUDS}} = A$$

$$NPV_{\text{Conventional}} - NPV(\text{BENEFIT})_{\text{Conventional}} = B$$

Where $A > B$, Conventional Engineering is more cost effective

Where $A < B$, SUDS Retrofitting is more cost effective.

8.5 Recommended Approach for Assessment of Site Feasibility

This study has investigated retrofitting SUDS from the perspective of the Water Industry. Although it has not been possible to demonstrate that retrofitting is capable of achieving direct improvements in bathing water quality, there are potentially many operational benefits to be achieved through SUDS retrofitting.

In the event that the Water Industry sector is seeking to integrate SUDS retrofitting into a wider capital investment programme, detailed methodologies are required to aid the decision making process and highlight likely capital investment requirements. The flow chart presented in Section 5.2.1 lays out a potential retrofit methodology. Entailed within the methodology presented is the feasibility assessment of potential sites.

The particular issues which should be considered during feasibility assessments (when retrofitting in urban areas) have been described in the sections above. The following flow chart has been developed in order to aid the decision making process when assessing site feasibility.

It should be noted that an integral part of site feasibility assessment is the determination of scheme costs. Therefore it is recommended that cost models as discussed in Section 8 are prepared in order to increase the efficiency of the cost assessment element of the feasibility stage.

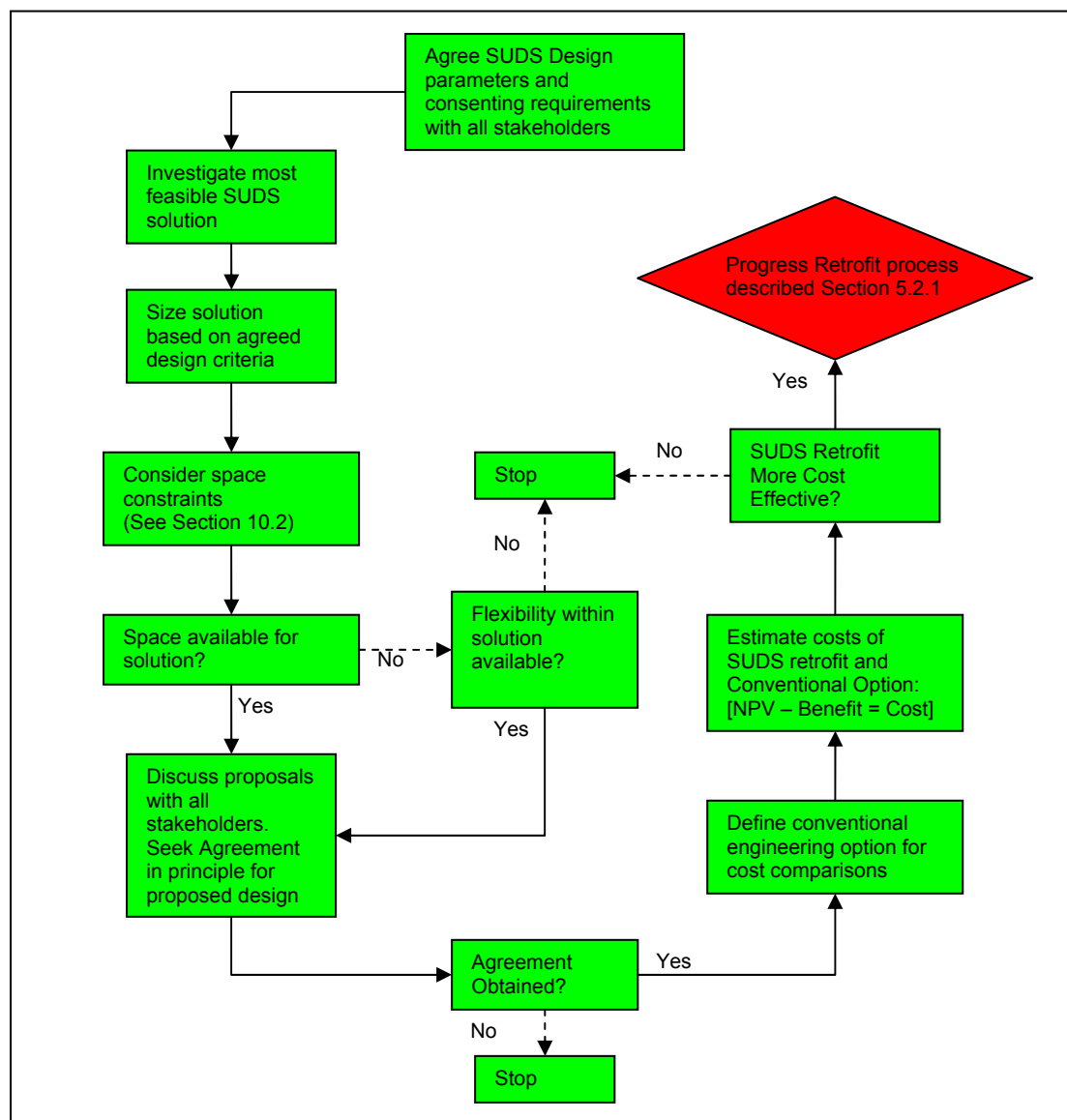


Figure 10 – Proposed Decision Making Framework for Feasibility Assessment

9 Schemes taken forward to Detail Design

Progression toward detail design was made following consensus between all project stakeholders, achieved at the workshop discussed earlier. As discussed in earlier sections of this report, progression to detail design was made at a total of two locations, as follows:

Site Name	Comment
Irvine Industrial Premises	Site progressed to detail design. No construction undertaken as land owner was unable to commit to project in required time scales
Girvan – Residential Area	Site progressed to detail design. No construction possible due to project timescales

Table 7 – Sites progressed to Detailed Design

As discussed in Section 4.2.5, costings for both SUDS and conventional options was undertaken by the Contractor.

Specific details related to the design of each site, perceived benefits and comparative cost/benefit analyses are presented in the following sections.

9.1 Industrial Premises, Irvine

The site at Irvine was selected in the first pass site selection exercise, as most of the criteria used to identify preferred sites were met at this location.

9.1.1 Site Background

The Irvine site was identified as having significant areas of roof and paved surface connected to the foul sewer. This was later confirmed by checking land owner understanding of the drainage network, and by subsequent dye testing results. In addition, the site is situated adjacent to a designated bathing beach and immediately upstream of a small pumping station (PS). Model predictions indicated that spills would occur from the PS emergency overflow (EO) during a one in five year return period event. It was considered that retrofitting of SUDS upstream of this location would reduce risk to the bathing beach, as well as reducing operational costs at downstream pumping stations and treatment works.

Initial contact with the land owner was made at a local level, although it was later discovered that the company was a multinational with its main head quarters in the United States. Following initial meetings with local site management staff, the project was greeted with enthusiasm and a willingness to be involved was expressed.

9.1.2 Proposed Solution

The existing site drainage in the Irvine site splits in two directions, with flows draining north and south (toward the intermittent discharge location) of the site. The retrofit proposal involved reconnection of all roof and surface drainage, and redirection of all flows toward a balancing pond situated in the area of disused ground at the rear of the site. A generalised schematic of the system is presented below:

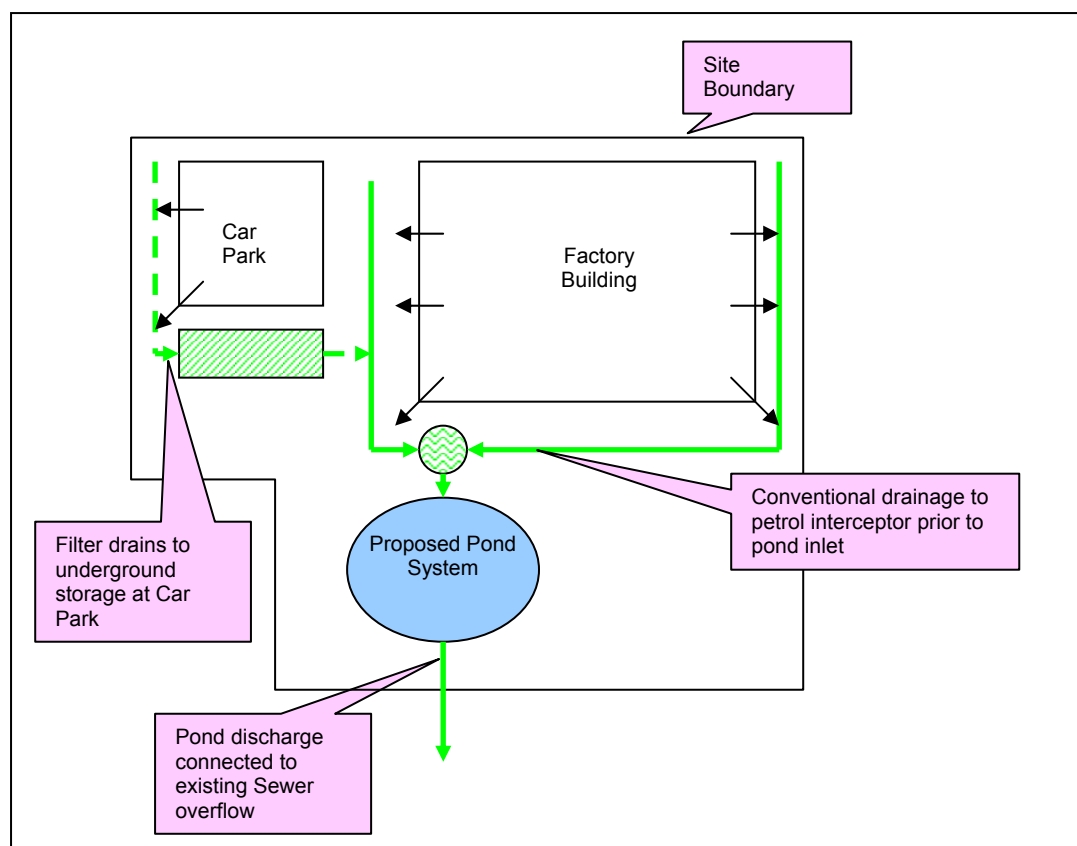


Figure 11 – Schematic of Proposed SUDS Scheme, Irvine

As can be seen from the figure above, the proposed retrofit system comprised three main components:

- SUDS system to treat runoff from car park;
- Conventional drainage to redirect storm water connections from foul/combined sewer to proposed attenuation system;
- Pond system to treat and attenuate site runoff.

The following paragraphs provide some discussion in relation to each component of the SUDS system.

9.1.2.1 Car Park System

In an effort to reduce the size of the required pond system, a separate SUDS facility to deal with flows from the car park within the site was proposed. This system was to consist of filter drains around the car park perimeter together with some road gullies, draining to a below ground attenuation system before eventual discharge into the main drainage network. The network of filter drains around the perimeter of the car parking area also provides some attenuation and treatment prior to discharge to proposed below-ground storage tanks. The storage was to be provided by cellular storage systems which are available from a number of suppliers. The advantage of this type of system is the high void volume ratios, which serve to reduce the size of the storage area, and the robustness of the system, which can withstand vehicle loading and is therefore ideally suited to car park application.

The benefit of the proposed system is that the greenfield runoff rate for the car park can be achieved within the drainage system. This must be balanced against the additional cost of this system and the additional maintenance requirements. The incorporation of silt traps and

other devices upstream of the below-ground storage tanks should minimise the ingress of silt to the tank system.

9.1.2.2 Conventional Drainage to Balancing Pond

Due to previous contamination of the site and space constraints it was decided that the most suitable drainage option for the site is a conventional drainage scheme leading to a balancing pond.

As part of the feasibility assessment of the site, the existing drainage was identified. This showed approximately 7 ha of impermeable area (hardstanding and roof area). There are foul connections to the combined network on site from the cafeteria and several toilet blocks around the site. Otherwise, the majority of connections to the network are made up of stormwater.

Redirection of all storm flow was to be made upstream of connections to the existing system. A conventional piped system was then proposed to convey stormwater to the balancing pond. The system was designed with oversized pipes laid at a shallow gradient in order to minimise flow velocities to the balancing pond within accepted design limits. Petrol interceptors and silt traps were included in the design to reduce the risk of pollution from day to day use of the site.

Important issues considered during the design of the system were;

- Maintaining the foul network during construction
- Ensuring adequate stormwater drainage during construction
- Design of the proposed gravity system around existing services and other obstructions
- Maintaining landowner access to the site for deliveries and other operational purposes

9.1.2.3 Pond System

All discharge of runoff from the site was to be directed to a balancing pond, located in an area of disused ground to the rear of the site. The pond was to provide attenuation of storm flows, and was sized in order to discharge runoff from the site at a rate equivalent to the estimated runoff rate for the undeveloped site (ie Greenfield), as per the methodology discussed in Section 4.2.2.1. Water is discharged from the balancing pond to the existing overflow from the pumping station, and from there to sea.

The volume of water to be balanced by the pond was approximately 2500 m³, based on the 100 year return period design storm. A simple schematic of the proposed pond is shown in Figure 12 – Operating Levels of Proposed Pond. During events up to and including the 1:1 year event, the water level would rise to the level of the path. For events greater than this, the path would be flooded and would rise up the bank. In a 1:100 year storm, the water level would reach the level of the overflow. If the top water level of the pond were exceeded, water would overflow back to the combined sewer. Thus the proposed drainage and balancing pond system would provide attenuation of flow and some treatment.

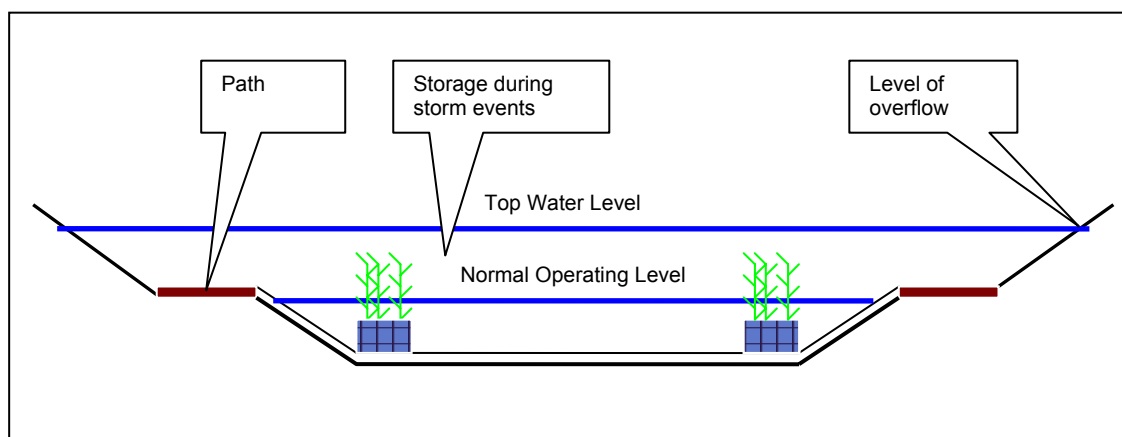


Figure 12 – Operating Levels of Proposed Pond

As at the pond inlet, an emergency penstock and overflow was fitted to the pond outlet, to be operated in the event that hazardous materials entered the pond network during accidental spill within the site. Once the penstock is shut down, the pond system discharges via an overflow connected to the existing foul combined sewer or any pollution could be pumped to the foul network.

9.1.3 Site Constraints

9.1.3.1 Land Contamination

During initial feasibility assessments contact with the North Ayrshire Council and SEPA had revealed that the land surrounding the Irvine site was classified as being contaminated. Site Investigation (SI) surveys were undertaken, comprising borehole and trial pit samples in the vicinity of the proposed pond. These identified slightly elevated levels of arsenic.

During construction any soils transported off site therefore required to be treated as hazardous waste. In order to limit cost, it was proposed that soil excavated from the pond area would be retained on site and landscaped.

It was proposed that the balancing pond be lined with an impervious geosynthetic membrane, in order to prevent exfiltration of water which may re-mobilise contaminants. In addition, the liner would prevent infiltration of potentially contaminated groundwater to the pond.

9.1.3.2 Groundwater

No ingress of groundwater levels to boreholes or trial pits was noted during SI works. However, subsequent inspection of boreholes identified groundwater levels approximately 2m below existing ground level. The minimum potential groundwater depth was unknown as it was not possible to monitor levels over a period of time.

In order to resist uplift pressures on the liner, a layer of overburden was to be added above the base of the pond. The worst case situation would be high groundwater levels at a time when the pond was emptied during maintenance. In order to minimise this risk, a requirement to assess groundwater levels before draining down the pond was included.

9.1.3.3 Design to Minimise Impact During Construction

The route of redirected surface water systems needed to be considered carefully in order to allow daily operations within the site to continue with the minimum of disruption. Meetings

were held with Site Management to determine the required access, any potential pinch points during construction and potential H&S risks to construction crew and site staff. The contractor attended all meetings to ensure that any design changes were effectively communicated and agreed by all parties.

9.1.3.4 Planned Expansion within the Irvine Site

Discussion with site management staff revealed that there were no plans for expansion of operations into the site of the proposed pond. Indeed, operations within the site were due to be scaled down over forthcoming months, and the project team were informed that any expansion in the future would be most likely to occur to available land at the west of the site.

9.1.3.5 Potential Pollution Issues

Transport and storage of hazardous materials on site posed a potential risk to the receiving environment, in the event of accidental spill of materials on site. In order to minimise this risk, the following measures were incorporated into the conveyance system upstream of the pond:

- Relocation of road gullies around oil storage areas to minimum distance requirements (none within 10m of oil storage facility);
- Penstock at inlet chamber to pond, to allow shut down of flow during accidental spill events;
- Provision of emergency overflow from pond inlet chamber to existing foul sewer, to act as a bypass to prevent flooding in the event that penstock requires closure during prolonged rainfall.

Likewise, a penstock and overflow was fitted to the pond outlet. This would allow containment of any hazardous material within the pond following an accidental spill within the site which was not adequately contained within the drainage system.

9.1.4 Stakeholder Issues

Discussion with project stakeholders was held during the feasibility and detailed design process, in order to ensure that the needs of all parties were met. Discussions with SEPA during the design process revealed that there is a degree of subjectivity in the approach taken to resolving certain issues pertinent to certain types of SUD system. However, this is to be expected due to the lack of comprehensive guidance within industry currently. In addition, the relative recency of SUDS technologies means there is a lack of available data against which precedents may be set and confident decisions made. It is anticipated that regulatory approaches will become more standardised and objective with the increased implementation of SUDS. Primary issues encountered, and how these were resolved, are summarised below:

9.1.4.1 Health and Safety Concerns

The issue of Health & Safety associated with an open water body was raised by stakeholders. However, the potential for drowning in the proposed pond is similar to the risk posed by the River Irvine or Irvine coastline. The following design measures were adopted to minimise health and safety risks;

- Limiting access to the area to employees only;
- Educating site staff about the hazards associated with the pond;
- Minimising the depth of the pond to 0.75m and providing shallow slopes to facilitate safe egress;

- The inclusion of a reed bed around the fringe of the pond to discourage entry.

9.1.4.2 Long term maintenance of the proposed system

The allocation of operation and maintenance responsibilities is an important element of any drainage system. This is particularly true for SUDS, where different types of maintenance will be required. During the detailed design process it was agreed that the site owners would be responsible for maintenance of the drainage network and petrol interceptors, as they are at present. Scottish Water Operations agreed to take over maintenance of the balancing pond and outfall from the pond to the sea.

9.1.4.3 Size of Pond and Required Land Take

The size of the pond in relation to currently disused land was of primary concern to the landowner. Due to the size of the impermeable area at the site, the pond system was required to be of significant size in order to accommodate the volume of rainfall calculated for the design rainfall event. The site footprint of the pond was therefore substantial, and would have occupied a significant proportion of land area at the rear of the site.

While this was not a particular concern to resident Environmental Management staff, other members of senior management on site were cautious about agreeing to the scheme, as the pond system would effectively sterilise a significant proportion of site area for any future development. Although industrial operations were due to contract in the future, rather than expand, none of the senior management felt comfortable with affirming commitment to the project on behalf of the organisation, due to potential repercussions in the event that the prevailing market conditions changed and expansion was necessary at the Irvine site.

Site management therefore sought approvals from the organisation head quarters in the United States. While the project team was in continual contact with local Environmental Management in efforts to keep programme on track, there was no direct control over communications within the landowner organisation. Bottlenecks in information transfer occurred, resulting in significant and uncontrollable delays. Delays then affected programming of the necessary plant, materials and resources required for construction, pushing likely construction dates beyond the limits of the project funding.

It was not possible to delay construction indefinitely due to the time based nature of project funding. Eventually, the Scottish Executive considered that the lack of confirmed commitment from the landowner placed too great a risk on the construction phase of the project, and the decision was therefore made to withdraw funding.

9.1.4.4 Concern regarding the potential to increase pollution to bathing waters due to bird fouling:

Very little information regarding the efficiency of pond systems in the removal of influent bacterial loading is available. Therefore, sampling of the roof system was undertaken during a number of rainfall events, to determine base loading of bacterial concentration likely to enter the pond system.

This work was undertaken by Barbara Barbarito of Scottish Water, the results of which may be viewed under Appendix C. In summary, analysis of the results obtained from samples collected on site, examples from the literature and the characteristic of the pond design suggested that the discharge from this system will not cause a problem in terms of FIO (Faecal Indicator Organism) input to the bathing waters of Irvine Bay. Additional monitoring was recommended once the structure had been completed in place.

It was generally accepted that risk of pollution from bacteria originating from bird fouling would be effectively managed through the following:

- The shallow depth of the pond facilitating penetration of sunlight, therefore increasing bacterial decay rates;
- The use of gravel as overburden rather than soil;
- Limiting the input of sediment to the pond through silt traps and petrol interceptors;
- The treatment of water from the proposed reed bed;
- The design of the pond to have an average retention period of 5 days.

It was agreed with SEPA that following construction, bacterial sampling at the inlet and outlet of the pond would be undertaken, in order to assess the bacterial reductions achieved.

9.1.5 Cost Estimates

Cost estimates were prepared for proposed SUDS and Conventional Engineering Schemes. The conventional engineering option consisted of a storage tank at the pumping station, designed in the manner described earlier in Section 4.2.2.2.

Cost estimates for both SUDS and Conventional options have been built up based on an estimated programme of works, and include for the following:

- Supervision
- Site establishment
- General Items
- Civils construction (Materials, staff, plant utilised during construction)
- Pipework and pumping stations
- Outfalls
- Mechanical, Electrical, Instrumentation, Control and Automation (MEICA)
- Insurances (as percentage of capital cost)
- Risk (as percentage of capital cost)

Cost estimates developed for SUDS and Conventional options are summarised in Appendices A and B respectively.

9.1.6 Cost/Benefit Comparisons

9.1.6.1 Capital Cost Estimation

The following table summarises calculated figures for capital cost, operation and maintenance for the proposed SUDS and conventional alternatives:

Cost	SUDS Option	Conventional Option
Capital Cost (£k)	956.6	702.6
Maintenance NPV Cost (£k)	38.9	65.2
Total	995.5	767.8

Table 8 – Cost Comparisons: Irvine

As can be seen from the table above, estimated capital cost for the SUDS option is higher than the proposed conventional option by approximately 30%. This is a significant difference, and can be attributed to the differing systems proposed in both options.

An integral part of the proposed SUDS option was the construction of a new pipe system to collect and transfer storm water runoff from the foul sewer to the proposed pond. The new surface water system was to be built to provide flood protection to the 30 year design return period, with no flooding at the 100 year return period, thereby representing a significant improvement on the existing drainage network, which was known to flood with approximate yearly frequency. This aspect of the proposed SUD system represents a significant improvement on the existing situation – a benefit which has not been incorporated into the conventional storage option – and would have provided significant operational savings to the landowner, as factory closure was forced during flood incidence at considerable cost to the company.

The cost estimated for the new surface water collection and transfer system accounts for almost 50% of the total capital cost (see Appendix A) of the SUD scheme. While this aspect of the SUD system proposed for the Irvine site was an essential component of the overall scheme, the same is not true of the conventional option.

The driver for retrofitting at the Irvine site was to achieve improvements in Bathing Water quality, therefore the requirement of both conventional and SUDS options was to reduce spill at the pumping station. In order to meet this objective in the Conventional option, additional storage could be provided at the PS without undertaking any amendment of drainage infrastructure within the landowner property, thereby resulting in a lower overall capital outlay.

Where the driver for retrofitting is to reduce water quality impact only, in this instance the conventional option is preferable in cost terms, despite the higher maintenance requirement. However, it should also be stressed that the proposed SUDS option provided considerable improvements to local drainage infrastructure which would have benefited local industry, and (as discussed in the following section) some savings in operational costs could be achieved at the existing pumping station, due to the removal of storm flow from the foul network.

It is also useful to note that cheaper SUDS alternatives (such as swales and infiltration type solutions) were not feasible at the Irvine site due to ground contamination and the potential for accident during transport of hazardous materials within the site area. Providing a solution to minimize risk of contamination has therefore necessitated a higher overall system cost. The issue of ground contamination in industrial and brown field sites is likely to be commonly encountered during the retrofit process. Hence it is considered likely that retrofitting in

industrial premises is more likely to involve a higher level of capital investment, although further work would be necessary to confirm this conclusion.

9.1.6.2 Maintenance & Operational Costs

NPV costs for estimated maintenance and operational costs have been summarised in Table 8 – Cost Comparisons: Irvine above. Further detail regarding costs associated with maintenance and operation of the respective schemes is provided in the table below. All cost estimates and assumptions used in determining maintenance and operational costs have been listed in Appendices A and B.

Maintenance Cost	SUDS Option	Conventional Option
Maintenance (£k/yr)	1.70	3.00
Operating Cost (£k/yr)	0	0.03
Economic Benefit (£k/yr)	0.19	0
Total Annual Cost (£k/yr)	1.51	3.30

Table 9 – Comparison of Estimated Maintenance Costs: Irvine

It should be noted that maintenance costs for Scottish Water only have been included in the above estimation, as this study has sought to investigate SUDS retrofit costs borne by the Water Industry. Subsequently, maintenance of the SUDS option includes an allowance for maintaining the pond system, outfall, and surrounding landscaped area. The pipe network upstream of the pond was to be maintained by the landowner as the conveyance system was within their site boundary. Scottish Water liability in the event of a pollution incident (eg accidental spillage of hazardous material) occurring on site could also be diminished with this arrangement.

The cost burden associated with maintaining and operating the pond network is estimated as being approximately 50% of the cost required to maintain pumped storage. It is stressed that the figures listed above are indicative only, and are underpinned by the assumptions detailed in Appendices A and B. However, the indication that SUDS (in this instance) is cheaper to maintain than pumped storage is intuitively accurate, as the pond system operates by gravity and therefore has much lower operational requirements, and mechanical maintenance needs.

The SUD system removes significant quantities of storm water from the foul sewer, which is currently contributed by connected paved and roof area within the Irvine site. This serves to reduce the inflow received by the existing pumping station, resulting in some savings to current operational costs, as detailed in the Appendices. Conversely, an additional operational cost is incurred with the conventional option, due to the new pumping arrangement.

Estimated operational costs and savings are presented in Appendix A for the SUDS option. As can be seen, it is estimated that approximately £180 per annum can be saved, which amounts to £11,160 over a projected 60 year design life. Sufficient information to accurately calculate total operational expense per year was not available for this study, however operational savings which could potentially be achieved in percentage terms have been estimated, as recorded in Appendix A.

Calculations indicate that approximately 35% reductions in operational cost could be achieved at the Irvine site. However, considering the minimal estimated annual savings, it is unlikely that the Water Industry would consider it economic to progress a scheme based on the figures presented above. If, however, improvements to Bathing Waters could be demonstrated – something which has not been possible to assess in this study for reasons discussed earlier – the decision in favour of progressing a scheme may be altered.

9.2 Residential Area, Girvan

Details in relation to the residential area in Girvan were passed to Atkins by Scottish Water Operations, during the second pass Site Selection phase.

9.2.1 Site Background

The residential area examined in this study is served by a separate storm and foul sewer system with dual manholes. Scottish Water plans and operational reports indicate that the separate system connects to a foul sewer downstream of the development. Flow is then conveyed to a foul pumping station and is passed forward for treatment.

Due to the absence of a hydraulic model for Girvan, no information was available regarding the frequency of overflow at the pumping station downstream of the development site. However, Scottish Water was keen to progress a scheme at this location in order to remove storm flow from the foul sewer and reduce operational costs for downstream pumping and treatment. In addition, Scottish Water investigations had shown that land and roads drainage upstream of the development site was connected to the foul sewer. Additional storm flow from these connections had caused hydraulic overloading of the storm sewer, resulting in external property flooding at a property within the development site. The SUDS system was therefore also required to intercept road and land drainage, and convey flows to a suitable discharge point.

Land for potential solutions was available at several public open spaces within the development and in nearby park areas, adjacent to the coastline. Discussions with the South Ayrshire Council revealed that there were no plans to develop the available areas, and that no contamination issues were known to exist.

9.2.2 Proposed Solution

A SUDS scheme was proposed to retrofit an 'end of pipe' solution to the stormwater sewer, removing the storm connection to the foul sewer. Site Investigation works were undertaken to prove the infiltrative potential of the soils in the Girvan area. This showed a sandy soil with high infiltration potential. No evidence of land contamination was identified.

In order to deal with the overall runoff issues from the site, two independent SUDS systems were required: the first dealing with flows transferred from the previously connected storm sewer system, and the second to intercept flows from connected land drainage and road gullies.

9.2.2.1 Transferring Connected Storm Flows

The results of the SI survey showed that an infiltration type system would be feasible. The proposed solution intercepts storm flows from the development site and infiltrates the water to ground. Note that prior to construction of this system, monitoring of groundwater levels would need to be carried out during the winter period.

A system of underground infiltration tanks were proposed for the infiltration system. These provide higher void volumes (95% voids) than traditional soakaways, therefore reducing land take. The infiltration tanks were sized in accordance with the design criteria detailed in Section 4.2.2.1. An overflow from the tank system was provided, to allow spill to the foul sewer during extreme events.

It should be noted that Scottish Water Operations have reported the presence of dual manholes within the development site. In addition, there is a high likelihood that there are illegal connections from the foul to the storm sewer within the development area. In order to eliminate the risk of pollution at the Girvan bathing beach, these issues would need to be resolved to ensure that no foul flow element is carried downstream to the SUDS system. Further discussion in relation to this particular issue is provided in Section 09.2.5 below.

9.2.2.2 Intercepting Land and Road Drainage

In addition to the infiltration tanks described above, it is necessary to intercept land and road drainage connections which were entering the storm sewer. To do this, it is proposed that filter drains are installed adjacent to the existing road. Road drainage connections to the existing storm sewer should be redirected to the newly constructed filter drains.

New filter drain systems could discharge to existing road drainage adjacent to the development, which, following site visits, was found to discharge to the coast through the gravel beach at Girvan. Information regarding the capacity and layout of existing road drainage is unknown. Therefore, this aspect of the design requires finalisation pending receipt of data from the SAC Roads Department.

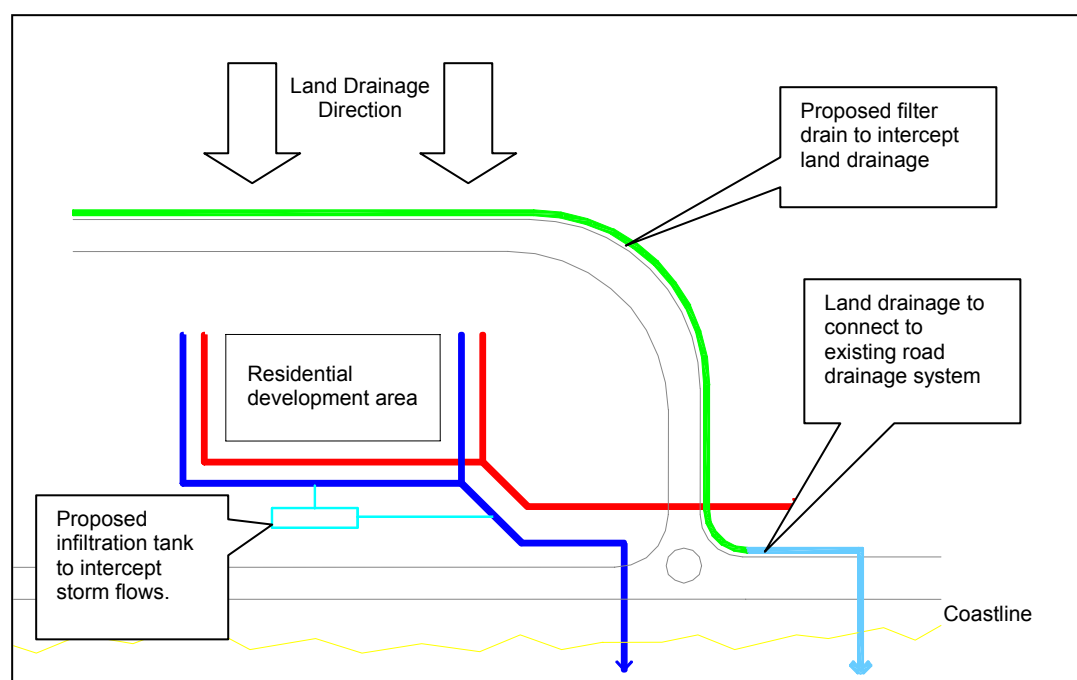


Figure 13 – Schematic of Proposed SUDS Scheme – Girvan

9.2.3 Site Constraints

There were three main areas identified as useable land within the development site in Girvan. Two sites situated inland were selected for the proposed infiltration schemes. These areas were preferred due to lower groundwater levels and a less public aspect.

No land contamination issues were raised during discussion with the South Ayrshire Council (SAC). Similarly, no evidence of contamination was recorded during Site Investigation surveys. Groundwater levels were not observed during SI works, hence the likely maximum level of ground water in the area has not been ascertained. Groundwater levels will probably rise due to rainfall events and tide levels and would need to be carefully monitored prior to construction of any system.

Following discussion with SAC, it was highlighted that there were no plans to develop any of the areas identified for siting of potential SUDS schemes.

Constraints on developing SUDS schemes in this location is therefore related to the presence of services within the site, access, and standard construction buildability issues.

9.2.4 Stakeholder Issues

Issues which arose in relation to the proposed SUDS scheme at Girvan were confined to the potential environmental impact caused by dual manholes and from illegal cross connections to the surface water sewer within the residential area.

During construction of this scheme, all dual manholes should be separated to prevent cross-contamination during storm events. Also, a method for removing illegal foul connections to the storm sewer would be required to redirect any foul connections to the foul network. There are a number of methodologies which could be used to achieve this objective.

Achieving complete separation of storm and foul flows across the development area will limit the potential for pollution from the SUDS system, and is essential to enable construction of the proposed system to proceed. This is the key part of any retrofit SUDS system where there is a separate system in place where the stormwater discharges to the foul network.

9.2.5 Recommended Phasing of Construction

In order to optimise construction of the proposed SUDS system at Girvan, the following phasing of works is recommended:

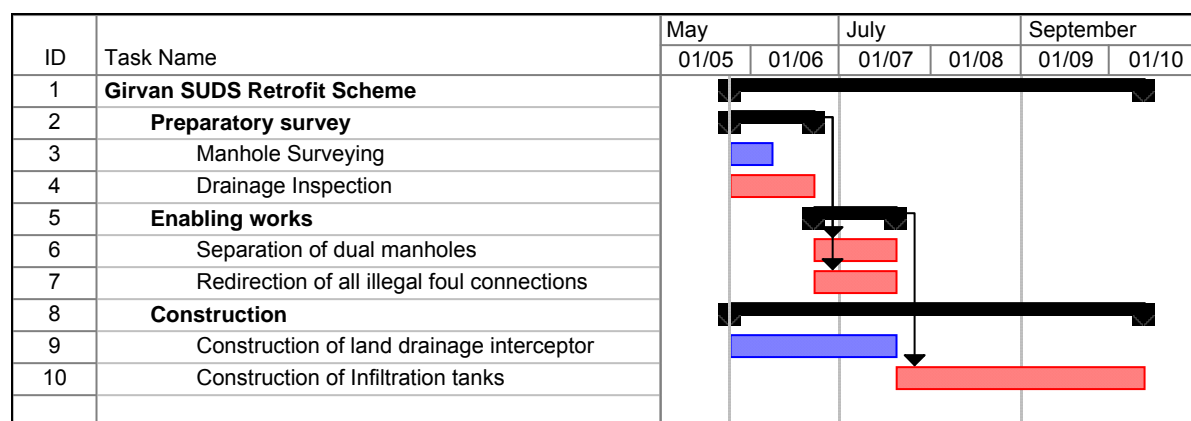


Figure 14 – Proposed Phasing of Construction for Girvan SUDS Retrofit

It is stressed that the above programme is to indicate phasing of works only. Actual construction start dates and times will require to be established with contractors prior to commencement of work.

However, it can be seen from the figure above that construction of the land drainage interceptor could be phased to commence at the same time as survey works within the development area. Separation of dual manholes and redirection of all illegal connections must be undertaken prior to construction of the proposed infiltration tanks.

9.2.6 Cost Estimates

Cost estimates were prepared for proposed SUDS and Conventional Engineering Schemes. The conventional engineering option consisted of a storage tank at the site of proposed below ground infiltration. Sizing of the proposed storage was undertaken on the same design basis as that for the SUD system, to ensure like for like comparisons could be undertaken during cost assessment.

Cost estimation was undertaken in the same manner as for the Irvine site, as discussed in Section 9.1.5.

9.2.7 Cost/Benefit Comparisons

9.2.7.1 Capital Cost Estimation

The following table summarises calculated figures for capital cost, operation and maintenance for the proposed SUDS and conventional alternatives at Girvan:

Cost	SUDS Option	Conventional Option
Capital Cost (£k)	838.08	826.3
Maintenance NPV Cost (£k)	26.64	34.26
Total	864.72	860.56

Table 10 – Cost Comparisons: Girvan

As can be seen from the table above, total estimated capital cost for the SUDS and conventional options are very close. The difference (less than 1%) is considered to be within the margin of error expected during a typical cost estimation exercise of the type undertaken in this study.

As noted at the Irvine site, the major difference in the two schemes originates from the differing maintenance requirements, as discussed in further detail in the Section below.

9.2.7.2 Maintenance & Operational Costs

NPV costs for estimated maintenance and operational costs have been summarised in Table 10 – Cost Comparisons: Girvan above. Further detail regarding costs associated with maintenance and operation of the respective schemes is provided in the table below. All cost estimates and assumptions used in determining maintenance and operational costs have been listed in Appendices A and B.

Maintenance Cost	SUDS Option	Conventional Option
Maintenance (£k/yr)	1.1	2.0
Operating Cost (£k/yr)	0	0
Economic Benefit (£k/yr)	0.18	0
Total Annual Cost (£k/yr)	0.92	2.0

Table 11 – Comparison of Estimated Maintenance Costs: Girvan

As per the Irvine site, maintenance costs for Scottish Water only have been included in the above estimation. The calculated figures show that operation and maintenance of the SUD system is approximately 50% of the cost estimated for the storage tank system. However, the

overall NPV values (Table 10 – Cost Comparisons: Girvan) between the SUDS and Conventional options differ by 30%.

The difference in maintenance costs reflects the more onerous cleaning requirement inherent in the conventional option, which would require regular cleaning to avoid siltation and ensure smooth operation. Conversely, the SUDS facility is by and large self maintaining, with requirements to remove deposited sediments from silt traps upstream of the infiltration storage only.

It should also be noted that the SUDS options removes storm flow from the foul sewer, thereby reducing pump running costs at the Pumping station in Girvan which lifts flow to the WWTW. It is estimated that reductions in operating costs achieved through the separation of storm flow offered by SUDS could be as much as 12%, by examining the contributing area removed by the SUD scheme and comparing this with the current size of the pump catchment area. Coarse calculations for the Girvan site estimate that reductions in pump cost could be in the region of £330 per year, in comparison with a total estimated cost for the whole catchment of approximately £2,900 per year. This equates to an overall saving of £19,800 over the projected 60 year design life of the scheme.

The closer difference in overall NPV reflects estimated part replacement costs for the cellular storage system which was to be used in the infiltration solution proposed in the SUD system. The design life of such systems, the extent to which sediment can accumulate within the storage units, and the subsequent requirements and costs for periodic replacement are currently unknown. At present, an estimated figure has been allocated in the NPV calculation to allow for excavation, replacement and cleaning of units, and reinstatement. It has been estimated that this exercise will occur with a frequency of once every 30 years, in accordance with manufacturer guidelines.

The frequency and cost of part replacement in the SUDS option at Girvan is based on unproven assumptions, and can potentially have significant effects on overall NPV costs. It is therefore recommended that more detailed information is sought once the currently ongoing research (mentioned in Section 8.2) is completed. No such costs are required in the proposed conventional option, where proposed storage tanks are gravity fed and therefore require no mechanical and electrical M&E componentry.

10 Project Summary

The work reported in this document has focused on retrofitting SUDS in urban areas, in order to achieve improvements in bathing water quality. The issues which require to be overcome when investigating SUDS retrofitting in this context have been examined from a practical, site based perspective. This is the first study of its kind to be undertaken in Scotland. The experience gained from the work undertaken has been used to develop decision making frameworks for site selection and feasibility assessment to aid the incorporation of SUDS retrofitting into Water Industry capital works programmes.

The project has validated some of the approaches to SUDS retrofitting recommended in previous desk based research, and has identified new areas in which further research would be beneficial, as outlined in the following sections.

10.1 Drivers for Retrofitting SUDS – The Water Industry Perspective

In order to realise the potential benefits offered by SUDS retrofitting in Scotland, a clear policy direction from the Scottish Executive would be beneficial. This will then cascade down a series of responsibilities and required actions to regulatory bodies, councils and Scottish Water to ensure that SUDS are implemented in a pragmatic, targeted approach which is conscious of environmental and economic sustainability.

One of the key investment drivers for the Scottish Executive and Scottish Water (and the Water Industry throughout the European Union) is the Water Framework Directive, and the need to achieve “good ecological status” in all receiving water bodies. Changes to the Bathing Water Directive may also result in more stringent bacterial standards in the future, placing further emphasis on the need to improve the environmental performance of waste water networks. There are a number of diffuse and point source pollution sources which have an effect on water quality – this study has only sought to investigate the impact of retrofit SUDS on CSO performance.

This study has not been able to fully assess the feasibility of retrofitting SUDS to achieve bathing water improvements, as no schemes have been taken forward to construction. In addition, it has not been possible to investigate the feasibility of retrofitting SUDS in residential areas served by combined sewerage systems, where it is known that most flow contribution to the combined sewer originates.

However, the work undertaken has supported previous assessments of land type suitability, as determined by Swan and Stovin (2002). This study has therefore examined the feasibility and effect of retrofitting SUDS in industrial or commercial premises, and institutional roofs.

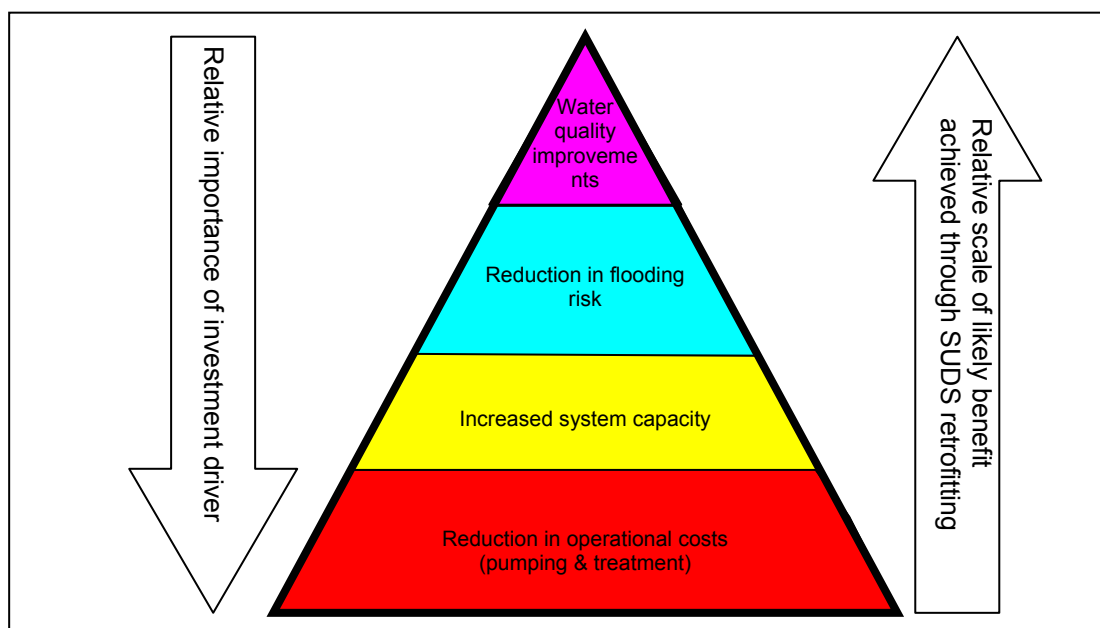


Figure 15 – Relationship Foundation behind SUDS Benefits

The benefits of SUDS retrofitting in the manner investigated in this study are most likely to be related to improvements in the operational performance of sewer networks rather than in direct improvements to bathing water quality. The relative likelihood of benefit in relation to SUDS drivers can be described as shown above in Figure 15 – Relationship Foundation behind SUDS Benefits. The figure is intended to show that the benefits achieved through separating storm flow from the combined sewer – whether through SUDS or conventional means – at isolated areas within a catchment are inversely related to catchment drivers.

However, targeting retrofit at commercial and industrial premises can still achieve worthwhile benefits. Improving the operational performance of sewer systems can be optimised by approaching retrofitting on a catchment wide basis, selecting and progressing as many sites as possible within a given catchment where conditions permit. The overall flow reduction across the catchment may be sufficient to achieve reduction in sewage spill volume from the network, and it may be possible to realise improvements in Bathing Water quality over time.

If tangible improvements to receiving water quality are desired, methods to reduce storm flow from residential areas must be identified. Alternatively, further work could be targeted at the following areas:

- Effectiveness of retrofitting SUDS in urban storm water systems;
- Examining retrofit SUDS in resolving diffuse pollutions issues (particularly in agricultural land);
- Examination of urban watercourse regeneration should be considered, utilising the types of systems used in SUDS such as wetland systems (as per the Bourne Stream discussed in Section 3).

10.2 Critical Issues Affecting SUDS Retrofitting

This study has shown that there is potential for retrofitting of SUDS in commercial or institutional premises, but that significant time investment is required in order to identify appropriate sites, and take the project through land acquisition issues with land owners. Methodologies have been developed as a result of the work completed, to assist in these critical stages of the retrofit process.

10.2.1 Site Selection

The site selection process requires a methodical analysis of detailed plans, in combination with catchment knowledge from local Councils, Regulatory bodies, and Water Industry Operations staff. Dye testing of all areas should be undertaken during the site selection phase, to confirm suspected roof and paved surface connections to the foul/combined sewer.

10.2.2 Feasibility Assessment

Accurate costing of potential schemes requires to be undertaken to properly determine scheme feasibility, particularly if SUDS retrofitting is to be seriously considered by the Water Industry as an alternative to conventional practice. Therefore, costing models require development, using real costs incurred in constructed schemes. A costing database similar to TR61 should be developed over time to improve the accuracy of cost estimates for feasibility purposes.

Also required are models to assess the whole life costs of retrofit SUDS systems. Therefore the development of a database containing actual maintenance costs should be considered. Standardised approaches to the determination of CAPEX and OPEX costs will be essential in the efficient determination of likely budgetary requirements, and in the identification of retrofit feasibility over conventional engineering.

10.2.3 Land Owner Approvals

Adequate time allowance must be provided in the project programme for decision making processes to take place where land acquisition involves private land owners. This is of particular importance for commercial and industrial premises, and it is recommended that management at the most senior level is engaged from the first contact, to speed decision making processes where industrial or commercial premises are targeted for retrofit.

11 Conclusions and Recommendations

The review of work completed by other parties (summarised in Section 3) has investigated SUDS retrofitting in a variety of different circumstances, and to achieve differing ends. The work conducted in this project has attempted to pull together key findings of completed research, and apply that learning in practical terms to further the body of knowledge that exists within the industry, specifically in relation to retrofitting in urban areas.

The key driver behind the research conducted was to investigate SUDS retrofitting from the Water Industry perspective in relation to Bathing Waters, in an effort to determine methodologies which would enable the incorporation of SUDS retrofitting into capital investment programmes. The work conducted in this project has gone part of the way toward meeting this objective. However there remain several issues which will need to be addressed in order to conclusively demonstrate the effectiveness of SUDS retrofitting, in the context examined in this study.

11.1 Outstanding Issues

This study has furthered the understanding of issues encountered during site selection, feasibility, detailed design, obtaining land owner approvals, and in the build up towards construction, for the retrofit of SUDS in urban areas. Methodologies to address the issues encountered have been proposed based on the experiences gained during the project process. However, there remain issues associated with SUDS retrofitting which this project has been unable to address. Issues likely to be critical to the Water Industry are as follows:

- Adequate determination of retrofit cost compared to conventional engineering. Because only two sites have been costed, neither of which has been progressed to construction, it has not been possible to draw reliable conclusions from the work completed. It is also not possible to confidently predict likely capital cost associated with retrofit schemes, due to the lack of information available within the field at present.
- Cost of maintenance associated with SUDS retrofitting. While some information has been gathered from other sources, it is recommended that more information is gathered from other research programmes, or parties who have successfully undertaken retrofitting, in order to confidently predict likely maintenance costs associated with retrofit systems.
- Quantification of benefits achieved by SUDS in terms of key investment drivers which determine Water Industry investment strategies (eg bathing water improvement, flood risk reduction). Because no schemes were constructed during this study, a proper assessment of flow reduction, monitored assessment of water quality improvements, and accurate determination of scheme benefit in “real” terms has not been possible.
- Assessment of retrofit feasibility in residential areas. Residential areas contribute the overwhelming majority of flow to the combined sewer during rainfall events. Achieving substantial improvements in water quality through reduction in CSO spill volume will require that flow from residential areas is addressed. Further work into investigating feasible SUDS options for implementation in residential areas is recommended.

11.2 Potential Research Programmes

In order to provide answers to the issues outlined in the section above, it would be necessary to construct and monitor constructed schemes. Ideally, two research streams would be progressed, as follows:

- The first research stream would investigate the development of retrofitting in the manner proposed within this document, undertaking detailed bacterial monitoring before and after scheme construction. Focus would be on gathering information to quantify the benefit of respective schemes, and costing information to be compiled into the costing databases. Project timescales would be over one to two years, to allow for sufficient time for identification and construction of sites, as well as adequate assessment of baseline bacterial loadings before and after construction.
- The second research stream would investigate piloting low cost SUDS techniques in selected residential areas. Again, detailed pre and post construction monitoring would be required in order to properly determine scheme benefit. The focus of this research would be to determine the feasibility of retrofitting in residential areas, and an assessment of the circumstances which need to be met in order to make one option favourable over another. Project timescales would be over one to two years, to allow enough time for likely consultation and planning processes, and for adequate assessment of baseline bacterial loadings before and after construction.

11.3 Potential Means of Encouraging SUDS Retrofit

It is recommended that steps are taken to formalise the assessment of retrofitting during option appraisal, and encourage the development of SUDS retrofit wherever possible. The Water Industry, regulator and councils all have a part to play, as does (for the Scottish case) the Scottish Executive.

Encouraging SUDS retrofitting in urban areas could be achieved through a variety of means, as discussed below:

- The use of retrofit SUDS could be written into Water Industry specifications for the option appraisal phase of Drainage Area Planning studies. This will force the engineer to consider retrofit feasibility when determining options to resolve flooding issues and reduce spill frequency at catchment CSOs.
- Increasingly, the Water Industry, environmental regulators and local councils are requesting that SUDS are incorporated into any proposed development site. Where new development is connecting to existing combined sewerage, it is recommended that (where practical) new build SUDS incorporate an element of retrofit to accommodate road and roof drainage surrounding the development site. This will free up capacity downstream of the development, by removing an amount of runoff equivalent to or greater than the foul flow contribution from the development. This will then minimise the impact of future development on existing network performance. The change in size of the new build SUDS scheme will often be minor, as the retrofit element is only required to militate against the foul flow contribution entering the combined network from the development.
- Councils could incorporate an examination of the potential for SUDS retrofitting in their assessment of land area deemed suitable for SUD schemes. This could be facilitated through discussion within their respective Flood Liaison and Advice Group (FLAG).
- Relevant Water Industry parties can investigate premises which are currently paying standard charges for storm water connections, and encourage the owners of these premises to consider retrofitting SUDS to manage site drainage. A further step would be for the Scottish Executive to make funding available for feasibility assessments at such premises, and potentially to secure funding for payment of construction (eg a grant scheme). Financial incentives to reduce standing charges for premises operating SUDS systems could also be considered. However, it is acknowledged that such policy mechanisms may be difficult to manage effectively, and costly to implement.

- The issues encountered during retrofitting SUDS are substantially different to those encountered during a new build scenario. In order to provide definitive guidance to engineer responsible for retrofit appraisal, it is recommended that a best practice guidance document is developed, specifically tailored toward SUDS retrofitting. This could incorporate contributions from a wide range of stakeholders and research bodies, in a similar manner to the preparation of the SUDS Design Manual.
- When the Planning Advice Note (PAN) 61 is reviewed, consideration should be given to advice on the contribution which the planning system could make to retrofitting sustainable drainage.

APPENDIX A –COST ESTIMATES FOR SUDS SCHEMES

APPENDIX B –COST ESTIMATES FOR CONVENTIONAL OPTIONS

APPENDIX C – MONITORING REPORT FOR INDUSTRIAL ROOFS, IRVINE

APPENDIX D – CASE STUDY FOR RETROFITTING IN SCHOOLS

APPENDIX E –DISCUSSION REGARDING LAND OWNER APPROVAL ISSUES

APPENDIX F –DISCUSSION REGARDING FACTORS AFFECTING SITE FEASIBILITY

APPENDIX G – DISCUSSION REGARDING ECONOMIC BENEFIT OF SUDS

APPENDIX H – SUMMARY OF WORK COMPLETED BY OTHER PARTIES

APPENDIX I – REFERENCES

Atkins is one of the world's leading providers of professional, technology based consultancy and support services. In recent years, it has expanded from its historical base in traditional engineering, management consultancy and property services into related technological consultancy and the management of outsourced facilities. With over 14,000 staff worldwide, Atkins has enormous expertise, providing both breadth and depth of knowledge in an extremely diverse range of disciplines.

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