Glasgow Strategic Drainage Plan Stage 1– Overview & Case Study

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1 Overview

In July 2002 the City of Glasgow suffered severe flooding due to rainfall, estimated as a 1 in 100-year storm event. This resulted in flooding of numerous properties with sewage and floodwater, with consequent misery for the occupants, and claims for compensation. Although Glasgow was known to be flood-prone, the extent of flooding and damage experienced was a setback for the City and its plans for extensive redevelopment. Both Scottish Water and Glasgow City Council found themselves under considerable pressure from residents, planners, councillors and politicians to identify solutions to this major threat to the City.

In June 2003, Hyder Consulting was appointed as Lead Consultant to undertake masterplanning of the sewerage and drainage infrastructure of Glasgow City through the Glasgow Strategic Drainage Plan (GSDP). The GSDP encompasses the catchment areas served by the Dalmuir, Dalmarnock, Daldowie and Shieldhall Waste Water Treatment Works. Between them, these catchments serve over a million people and include all of Glasgow City plus parts of West Dunbartonshire, East Dunbartonshire, North Lanarkshire, South Lanarkshire and East Renfrewshire.

Responsibilities for stormwater management in Scotland are divided between numerous parties. Since the 2002 flooding event, it was recognised that a joint strategy was required to address the drainage problems in Glasgow and the needs of all stakeholders. The GDSP is thus being promoted and guided by a Steering Group comprising Scottish Water, Glasgow City Council (GCC), the Scottish Environment Protection Agency (SEPA) and Scottish Enterprise Glasgow. The key objectives of the GSDP are as follows:

- Flood risk reduction: the flood risk from both sewers and watercourses is unacceptable in many areas;
- Removal of development constraints: lack of capacity and other deficiencies with the drainage infrastructure is now hampering regeneration efforts and much needed economic development;
- Water quality improvement: many of Glasgow's urban watercourses have been heavily modified over the years with culverts replacing open channels. Whilst the performance of the sewerage system is dependent on the safe operation of numerous CSOs discharging surplus stormwater to watercourses, existing water quality is unacceptable and needs to be improved to meet increasingly stringent legislative requirements;
- Habitat Improvement: urban regeneration should provide opportunities for improving the environment and open watercourses should be considered in this regard;
- Integrated investment planning: the likely level of investment required to address development constraints, flooding and water quality needs to be understood.

Implementation of the Plan will achieve The Vision: *Sustainable Urban Drainage for Glasgow.*

Stage 1 of the GSDP has investigated overall drainage and flooding issues affecting the whole of Glasgow, while at the same time concentrating in particular on the Dalmarnock catchment, which suffered worst from flooding, with over four hundred properties affected. Stage 2 of the GSDP will focus on developing initial strategic options and defining investment requirements for the wider GSDP area. It is important that the potential for cross catchment strategic solutions are assessed in order to meet the long term objectives for the whole of Glasgow and detailed water quality modelling of the River Clyde and Estuary will be essential to facilitate this process.

Stage 1 was completed in April 2004 and identified initial strategic options to realise the long-term objectives for the Dalmarnock catchment requiring investment of some £120m. A simplified integrated InfoWorks macro model, which includes both trunk sewers and watercourses, was used to develop the options. Use of an integrated model permits a better understanding of the hydraulic processes within the catchment, and means that integrated options can be identified. The model was developed by Montgomery Watson Harza (MWH) on behalf of Glasgow City Council. Detailed refinement of the model is ongoing.

In addition to the more traditional 'hard' engineering solutions, the potential for 'soft' engineering solutions such as SUDS retrofit and watercourse de-culverting has also been assessed.

It is important that the correct and most cost-effective balance is achieved between 'hard' and 'soft' engineering solutions, and the issues were demonstrated to the GSDP Steering Group by means of a case study of one of the main watercourses flowing though the Dalmarnock East End Catchment. The Light Burn is typical of the 'corridors of opportunity' that exist to help achieve the vision of a Sustainable Urban Drainage Solution. This case study is reproduced below.

2 Case Study Introduction

The Light Burn area is a good characteristic example of the typical drainage issues affecting the East End area of Glasgow. This particular case study area has been selected in that it best illustrates the interactions between the two drainage systems, and also suffers from typical drainage issues of flooding, poor water quality, development constraints and habitat/amenity losses.

This case study also highlights how an integrated approach can be adopted to alleviate deficiencies on both the sewerage and watercourse systems.

The Light Burn case study area can best be described as including all areas draining to the Light Burn as well as the Eastern Sewer No. 3 trunk sewer. A small area downstream of the Light Burn and in the vicinity of the Camlachie Burn at Shettleston Road, is also included in this case study area. The catchment includes the areas of Queenslie, Ruchazie and Cranhill. Major roads/motorways in this study area include the M8 Motorway, Edinburgh Road, Cardowan Road and Shettleston Road.

The Light Burn originates in the vicinity of Junction 11 of the M8 and runs parallel to Cardowan Rd before joining the Camlachie Burn near Carntyne Station. Drainage from the M8 motorway is a significant contributor to the Burn. The Light Burn is culverted for 95% of its length. The catchment areas draining into the Burn are almost completely urbanised.

The Eastern Sewer No. 3 trunk sewer follows the route of the Light Burn and collects flow from the Gartsheugh Sewer and other branch sewers and discharges them into the Parkhead Sewer at Carntynehall Road. Approximately 70 % of the contributing areas to the sewer system is combined i.e. both surface water and wastewater. Figure 1 below shows the case study area.

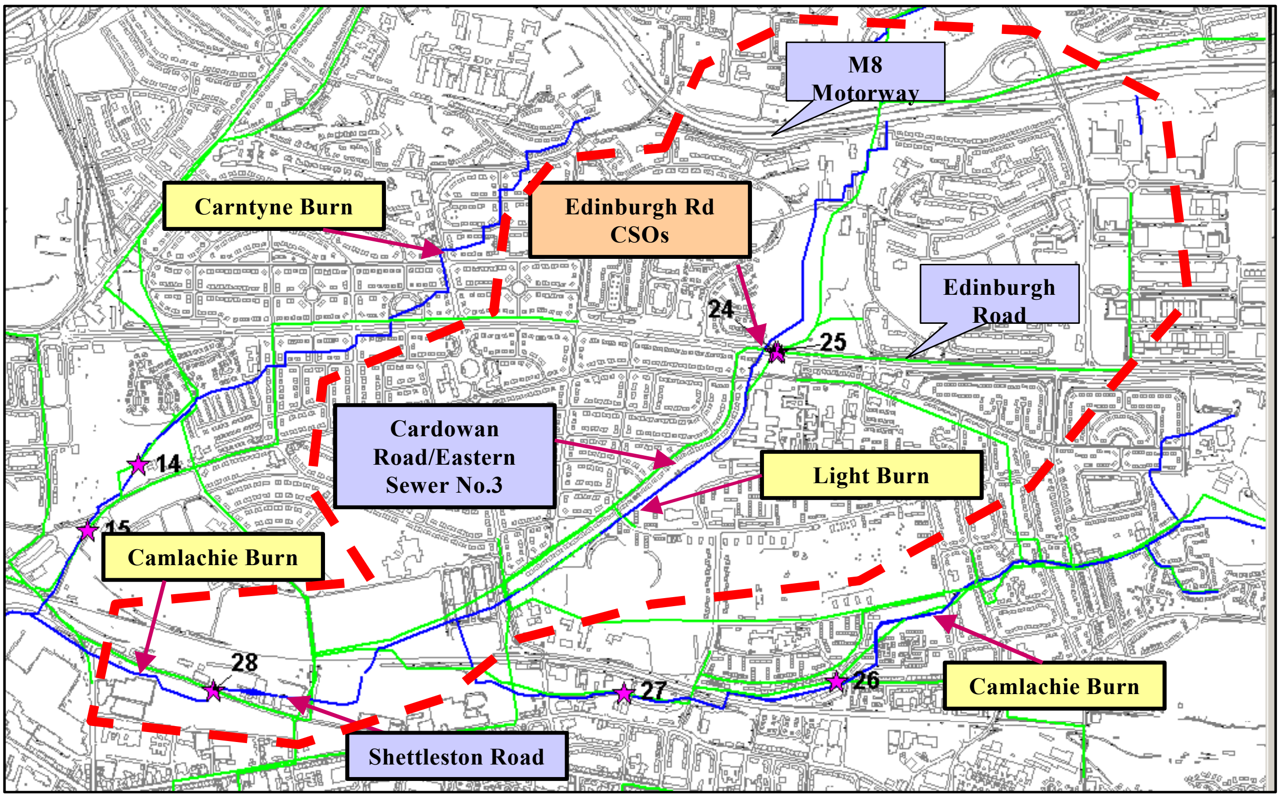

Figure 1 – Light Burn Case Study Area

2.1 Problems/Needs

There are five main problems or needs associated with this study area. These are: -

- *Flooding at Cardowan Road and Shettleston Road.*
- *CSO Impacts at Edinburgh Road and Shettleston Road (Water quality and quantity).*
- *Development Constraints.*
- *Culverted Light Burn (habitat and amenity loss).*
- *Climate Change.*

2.2 Flooding

2.2.1 Cardowan Road

Local authority records show that this area has suffered repeated flooding of roads, houses and industrial properties for at least 40 years. There is an open stretch of the Light Burn at the bottom of Cardowan Road, with a trash screen at the entrance to the culvert under the road.

A digital terrain model (DTM) plot, shown in Figure 2 below clearly shows this area as a low spot, with the overland flood route downstream cut off by rising ground levels to the west. Hence this area acts as first relief point during periods of heavy rainfall, making it difficult for flood water to disperse.
The integrated hydraulic macro model used for this study predicts both sewer flooding and watercourse flooding at this location.

The macro model shows that the flooding is caused by a lack of capacity in the trunk sewer and Light Burn downstream, causing significant backing up and ultimately, flooding.

It should be noted that it was reported that flooding of the Light Burn in July 2002 event was exacerbated by flows from the flooded M8 Motorway.

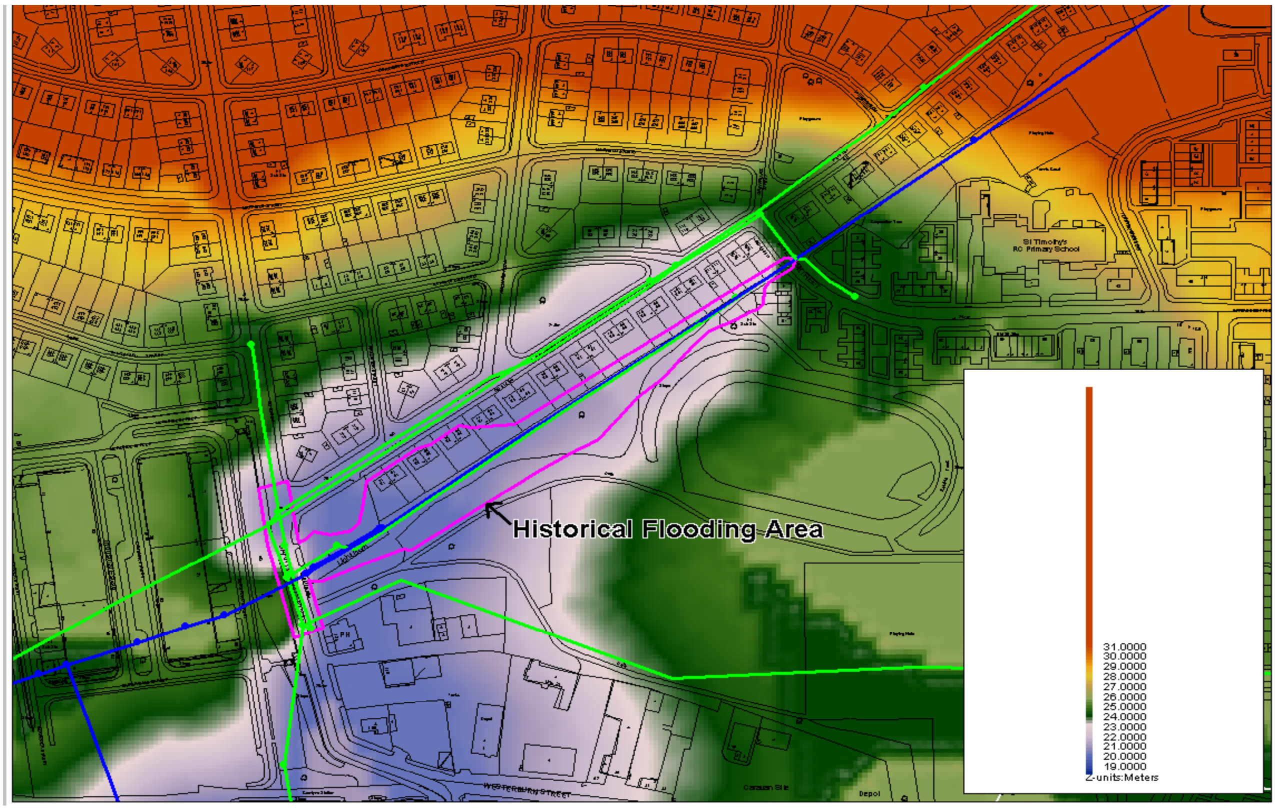

Figure 2 – Elevation Plan showing low-lying Cardowan Road area (Cardowan Road 15m AOD, surrounding areas 35m AOD).

2.2.2 Shettleston Road

Scottish Water and Local authority records show that this area has suffered repeated flooding of roads, houses and industrial properties for a number of years. The Camlachie Burn is culverted here for the most part, with only a short open section.

A DTM plot of the area showed it to be a low spot area with the overland flood route downstream cut off by rising ground levels to the west of the Forge Shopping Centre.

Where the culverted burn crosses Shettleston Road there is a CSO, but this operates in reverse and the sewer acts as a relief to the burn. The hydraulic model shows that the flooding is caused by caused by lack of capacity in the Camlachie burn downstream, causing significant backing up and ultimately, flooding. Recent surveys have found silt and debris in the burn along this stretch which will obviously reduce the actual hydraulic capacity.

2.3 CSO Impacts – Water Quality and Quantity

Three CSOs are known to exist in this case study area. Two of them are located at Edinburgh Road and discharge to the Light Burn. The other overflow, located at Shettleston Road, actually operates in reverse, in that flow is over-spilled from the watercourse (Camlachie Burn) to the sewer system, rather than vice-versa.

For drainage area purposes, a CSO can be described as deficient if it fails to pass a minimum conveyance standard, often referred to as Formula A, operates in dry weather, adversely affects water quality of the receiving water body when spills occur, or fails to meet consented operational standards. SEPA can also categorise a CSO as unsatisfactory if its discharge causes visual or aesthetic impact on the receiving water body. Whether or not a Formula A setting is sufficient to protect water quality is dependent on the relative sizes of the sewer and watercourse. A large sewer spilling to a small watercourse (in this case the Light Burn) may have a significant impact despite passing Formula A. The East End watercourses are relatively small compared to the combined trunk sewers which discharge into them at CSOs.

In order to illustrate the hydraulic impact of the CSO spills on the watercourses, the macro model was simulated with a 5 year return period 2-hour duration design storm event. Flow volumes passed in the watercourses upstream and downstream of each CSO were abstracted and processed in a spreadsheet.

Figure 3 shows a cumulative build-up of volume down the Light Burn. For each column pair: the left hand column represents the cumulative volume of flow contributed to the burn via CSOs upstream of that point; the right hand column represents the total cumulative volume of flow passed down the burn. As can be seen these CSOs account for over 75% of the volume in the burn.

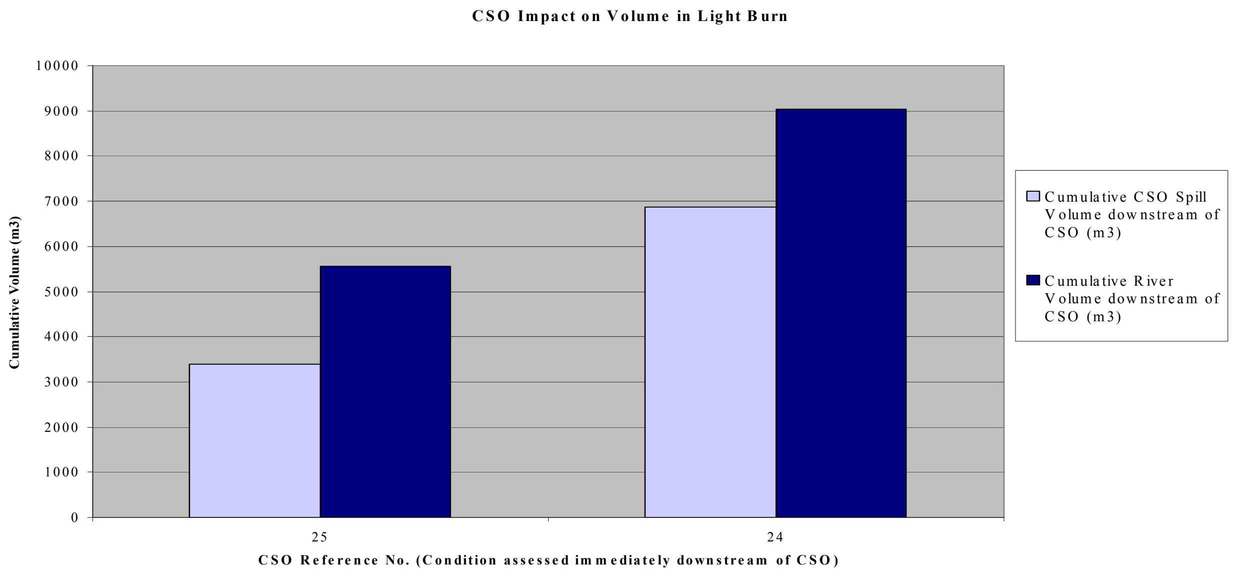

Figure 3 – CSO Impact on the Light Burn

As the Light Burn is almost fully urbanised, with most hard surfaces intercepted by the combined sewer system, improvement of these CSOs is seen as a primary step in improving the water quality. Base flow in the Light Burn is very low in dry weather and the capacity to assimilate spills from the relatively large trunk sewers needs to be considered.

To summarise, it is quite clear that the CSOs in this area have a significant impact in reducing the water quality of the Light Burn as well as considerably increasing the flood risk associated with this watercourse.

2.4 Development Constraints

A primary objective of the GSDP is the removal of development constraints. GCC have identified a number of major developments upstream of this case study area. These include the proposed development of 790 residential homes at Gartloch Road.

The state of the drainage infrastructure is now hampering efforts to regenerate the East End area. GCC have estimated that £1.5billion worth of development is affected by drainage constraints in the overall catchment area.

Failure to address the development constraints will have severe consequences (economic, social, environmental), and the benefits of other investment, such as the east end regeneration route and the M74 extension, will not be fully realised. Removal of these development constraints is a therefore a key driver for investment in the drainage system. Strategic solutions identified by the Initial Strategic Drainage Plan are sized to account for development to the year 2020 horizon.

2.5 Habitat/Amenity

The Light Burn and the Camlachie Burn are recognised as notorious examples of the detrimental effects that past urban practices have had on the habitat and amenity value of a watercourse. The burns are extensively culverted (95% of the Light Burn is culverted) and many of the remaining open sections have been straightened in steep sided channels of concrete or masonry. In many locations, high fences bar public access.

Urban watercourses should be considered as assets that will add value to an urban environment and improve the quality of life. Culverted watercourses pass through numerous green spaces (e.g. Cranhill Park) within this case study area. In some of these areas, there may be potential for de-culverting or creation of ponds. Such measures would require careful design.

SEPA's 'Culverting – An Agenda for Action' states:
"As a result of the water quality impacts, flooding and habitat loss caused by culverts, SEPA wishes to encourage a shift from tacit acceptance of culverting to a presumption against it….SEPA would also like to see reviews being undertaken of existing culverted streams, particularly where flooding is an issue and, where appropriate and cost effective, to encourage de-culverting and habitat restoration proposals."

Aside from the watercourses, the use of SUDS in both new developments and retrofit sites can provide additional habitat and amenity value. The presence of 'blue space' in urban areas can also add value to surrounding properties.

As a driver for investment, the improvement of habitat and amenity is perhaps not as high profile as the flooding or development issues. Nor is it as strongly influenced by legislation as the water quality requirements. However, in an area of regeneration and change, opportunities for improving on the current poor condition should be positively encouraged.

2.6 Climate Change

The potential affects of climate change are an important consideration. Drainage engineers commonly use 'design' rainfall events to assess the performance of drainage systems under extreme conditions. A practical means of generating design events for future rainfall is therefore needed. The UK Water Industry Research (UKWIR) project 'Climate Change and the Hydraulic Design of Sewerage Systems' has addressed this requirement and it was recommended that use be made of the outputs from this recent research for drainage planning in Glasgow. A design horizon up to the year 2080 was adopted for long term strategic planning.

The UKWIR research produced uplift factors and these were applied to current FEH design rainfall to generate 2080 design storms. Following impact assessments undertaken on the existing macro model, it was concluded that applying the rainfall ‘uplift’ factors could greatly increase solution costs to deal with existing deficiencies.

Following a GSDP Steering Group/Technical Group workshop, it was agreed that the degree of certainty with regard to future hydrological change is acknowledged as being quite low, particularly for the extreme events that are critical for drainage design. It was therefore agreed that all improvement solutions would be developed based on the 2020 development model and existing design rainfall. However, the impact of the 2080 rainfall on the solution model was tested once full options had been developed. Although no specific options were looked at to combat the effects of climate change, the effect on the catchment (e.g. additional storage/flooding required at main flooding areas) was tested and reported.

3 Solutions – ‘Hard’ Engineering

Three different ‘hard’ engineering solutions were proposed and assessed using the macro model in order to resolve the above-mentioned deficiencies in this case study area. These included:

a) An interceptor tunnel (move flow)

b) An Offline Storage tank (attenuate flow)

c) Separation of storm and foul flows (reduce flows)

3.1 Interceptor Tunnel Solution

This scheme comprises of the construction of a 1500mm diameter relief tunnel, 1 km long, from Edinburgh Road to Carntynehall Road. Intermediate connections to the existing sewer system will allow flow to be diverted into the proposed tunnel.

This relief tunnel scheme allows for the abandonment of the two Edinburgh Road CSOs which discharge into the Light Burn, as well as Shettleston Road CSO, which experiences reverse flow from the watercourse to the sewer system. The proposed scheme is shown in Figure 4 below.

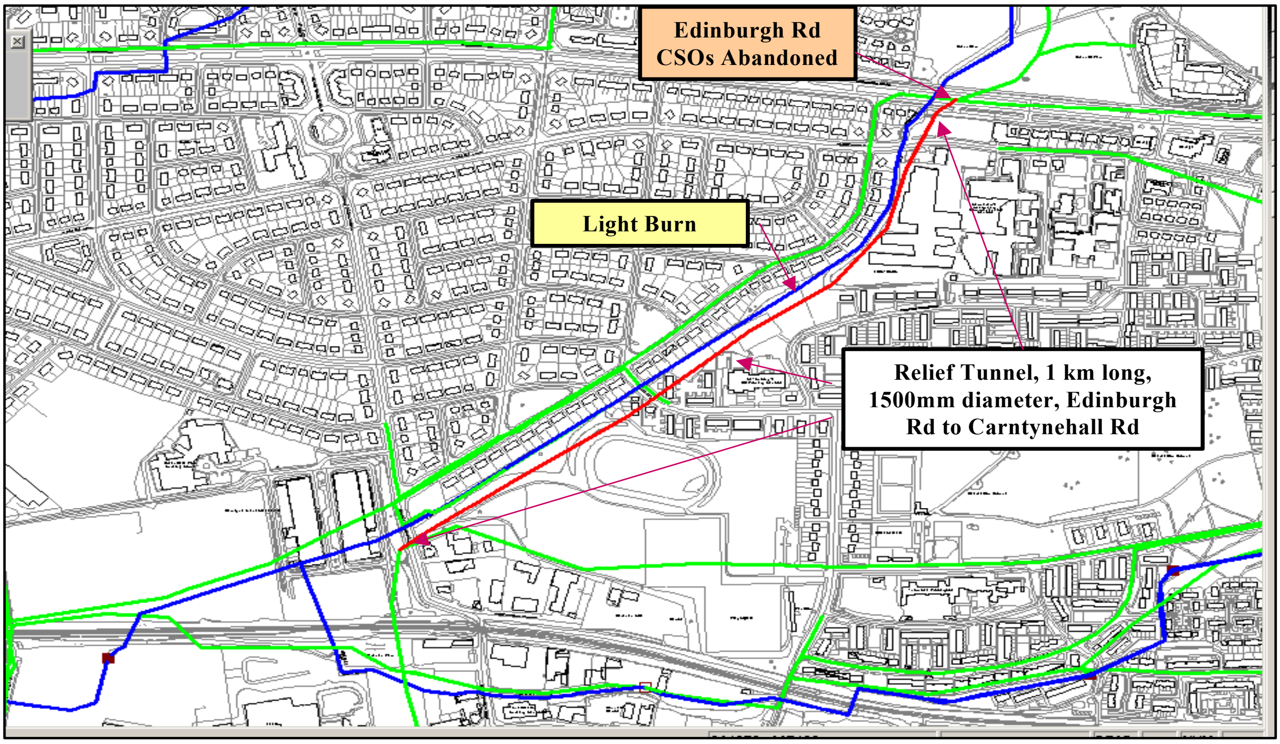

Figure 4 – Interceptor Tunnel Scheme

With this option, the macro model predicts no sewer flooding up to the 1 in 30 year return period long-term standard, and no watercourse flooding up to the 1 in 100 year return period. Taking into consideration the significant impact that the CSOs have on the watercourse, their abandonment should result in a considerable improvement in the water quality of the Burns, as well as further reduce flood risk.

It should be noted that this scheme results in more flow being passed forward to the existing trunk sewer downstream. Although this results in increased surcharge levels in the downstream trunk sewer, the macro model predicts no flooding. Preliminary cost estimates indicated that this scheme would cost approximately £4.2m to construct.

3.2 Off-line Storage Tank Solution

This scheme involves the construction of an off-line storage tank adjacent to the Edinburgh Road CSOs. The storage is sized in order to alleviate the flooding at Cardowan Road and Shettleston Road and effectively allow for the abandonment of the Edinburgh Road CSO spills to the Light Burn.

The capacity of storage required to achieve the long-term level of performance is 21,500 m^3 to give both the 1 in 30 yr return period sewer flooding and the 1 in 100 yr return period watercourse flooding protection.

This scheme allows for the avoidance of passing more flows forward to the trunk sewer downstream. However there are numerous concerns with the implementation of this scheme, and these include land availability, size of storage required, high cost and maintenance issues, as well as tank emptying issues. Preliminary cost estimates indicated that this scheme would cost approximately £21.5m to construct.

3.3 Storm/Foul Flow Separation Solution

This option involves undertaking a separation scheme upstream of Edinburgh Road. The scheme therefore involves removing storm water from the combined system and routing the flows via SUDS schemes to the Light Burn.

It may be possible to separate storm and foul flow due to the close proximity of the Light Burn and the fact that parts of the catchment area upstream of Edinburgh Road are already separate. It is expected that this scheme will involve the duplication of some 12.7km of the existing foul/combined system.

This scheme effectively allows for the Edinburgh Road CSOs to be effectively abandoned, as the model predicts no spill of the overflows up to a 1 in 30 yr return period event. This scheme will also result in the reduction of flows in the trunk sewer downstream. Water quality and amenity benefits of implementing SUDS will also be realised. There are however obvious concerns with regards to the feasibility, cost, and complexity of this scheme. Preliminary cost estimates indicated that this scheme would cost approximately £13.6m to construct.

3.4 Hard Engineering Solutions Assessment

The three conventional engineering options proposed above all resolve the flooding reported in this area in the long term. Abandoning the CSOs will obviously enhance the water quality of the burns.

As expected, the storage and separation options are much more expensive and may be difficult to implement. The size of the off-line detention tank required is immense and will create maintenance and tank emptying problems. Although the separation option provides extra advantages in reducing pass forward flow, and improving water quality and amenity, it will be very disruptive to local residents and might be complex to construct.

For these reasons the interceptor tunnel is the preferred option as it costs significantly less, is feasible to construct, and does cater for the long-term requirements of this area.

A tunnel interceptor solution will remove the significant wet weather discharges into the burn resulting in extremely low summer flows. This could be mitigated by piping water from the Monklands Canal (which runs parallel to the M8 motorway) to provide a more sustainable solution for the burn.

4 Solutions – Soft Engineering

In order to attain the long-term vision of a sustainable urban drainage solution, ‘soft’ engineering solutions also need to be identified. It is accepted that the implementation of these soft engineering solutions alone may not wholly resolve all the identified deficiencies such as flooding and CSO spills.

However, it is expected that in addition to the obvious advantages of habitat improvement, water quality improvement and area regeneration that the soft engineering solutions will provide, other advantages including further reducing flood risk, mitigating the scale of hard engineering solutions, and offsetting the negative impacts of climate change, can be realised.

The soft engineering solutions can be grouped into two categories; Retrofit SUDS and Watercourse Improvement Solutions.

4.1 Retrofit SUDS Solutions

The Light Burn Case Study area (and in fact the East End of Glasgow) has significant areas of green space and brownfield sites which could be used to accommodate SUDS. The following explains the methodology behind the hierarchical approach to selection of potential SUDS sites:

- ***Separately sewered areas*** (in relatively new developments) were assessed to generate an understanding of whether they discharge into the combined sewer network or to watercourses;
- ***Large properties*** were identified and categorised into: Institutional, Commercial and Industrial (based upon a decision framework developed by Stovin and Swan). This allowed identification of properties where SUDS retrofitting was potentially feasible;
- ***Motorway drainage*** produced significant amounts of runoff, which discharged into combined sewers and watercourses. An assessment of various asset databases identified the destination of this runoff.

A number of potentials retrofit SUDS areas upstream of the flooding locations were identified. These sites include a section of the M8 motorway draining into the Light Burn as well as Queenslie industrial estate at Cardowan Road. Impact assessments undertaken using the hydraulic macro model demonstrated that implementing these retrofit SUDS could result in considerable reductions in predicted flooding (approximately 30%) and CSO spills.

4.2 Watercourse Solutions

The case study has identified opportunities to address capacity problems in the Light Burn. The use of on-line and off-line attenuation ponds has been considered along with de-culverting of buried watercourse. These measures provide the additional benefit of providing amenity and habitat improvements and can increase the value of adjacent properties and brownfield sites.

Two areas at Cranhill Park and Carntyne Industrial Estate have been identified where attenuation ponds could be potentially sited. In addition, a 1 km stretch of potential de-culverting of the Light Burn has been identified. It is important to recognise that these on-line and off-line ponds are not SUDS and would only be used to attenuate flows in watercourses. These facilities would not be used to attenuate or treat urban runoff directly, but they are a component in the overall stormwater masterplan.

Due to a lack of a detailed hydraulic model, as well as time limitations, the impact of the potential watercourse solutions has not been hydraulically quantified as yet. However, it is certain that the implementation of these schemes will further reduce flood risk as well improve the habitat of the area.

5 Conclusions

The Glasgow Strategic Drainage Plan represents an innovative planning approach to dealing with the complexity of issues surrounding the management of urban drainage. The multi-agency approach has allowed all parties to work together to find the best solutions. Ultimately, this benefits both the agencies involved, the environment and the people affected by drainage related problems.

The physical interactions between the sewers and watercourses in the East End of Glasgow required an integrated analysis of both systems. The macro model has allowed the full extent of the interaction to be quantified for the first time. In addition, a much better understanding of the true causes of flooding has been achieved.

The strategic planning approach has also permitted a good appreciation to be gained of the potential for using softer engineering techniques to address the identified deficiencies. Knowledge of areas with potential for SUDS retrofit or watercourse de-culverting/attenuation broadens the range of possibilities when integrated improvement options are being developed. Whilst the habitat and amenity advantages of these options are understood, integrated modelling has allowed the full hydraulic benefits to be properly measured.

The case study highlights the benefits of a holistic approach to identify conventional and soft engineering solutions in order to achieve the desired objective of a Sustainable Urban Drainage Solution for Glasgow. Whilst the desire to reduce flooding risk may be a primary desire for this study, the methodology adopted will also address development constraints, water quality and the desire for habitat enhancement in an area much in need of regeneration.

For the Light Burn Case Study area, it is quite clear that the transfer tunnel option offers the best conventional engineering solution to the area's needs in terms of cost and feasibility. The implementation of the watercourse restoration/Retrofit SUDS measures will further reduce flood risk, offset the negative impacts of climate change, mitigate the scale of the hard engineering solution, and improve water quality and habitat.

Figure 5 shows the recommended transfer tunnel solution identified for this area. The potential watercourse restoration and retrofit SUDS areas identified are also shown on this drawing.

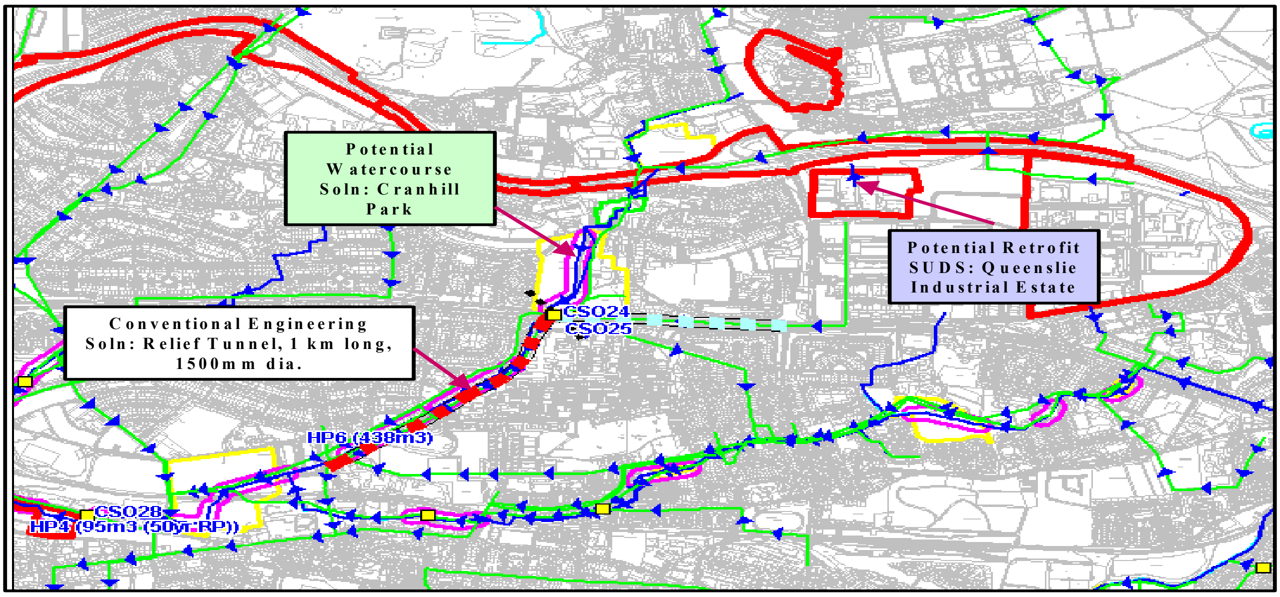

Figure 5 – Potential Solutions for Light Burn Case Study Area

Figure 6 shows how an ultimate target level of service could be achieved for sustainable urban drainage for Glasgow. The figure illustrates that a total drainage target level of service over a design horizon can be achieved by implementing all the engineering techniques (conventional schemes, SUDS retrofitting/watercourse restoration etc) discussed and identified in this paper.

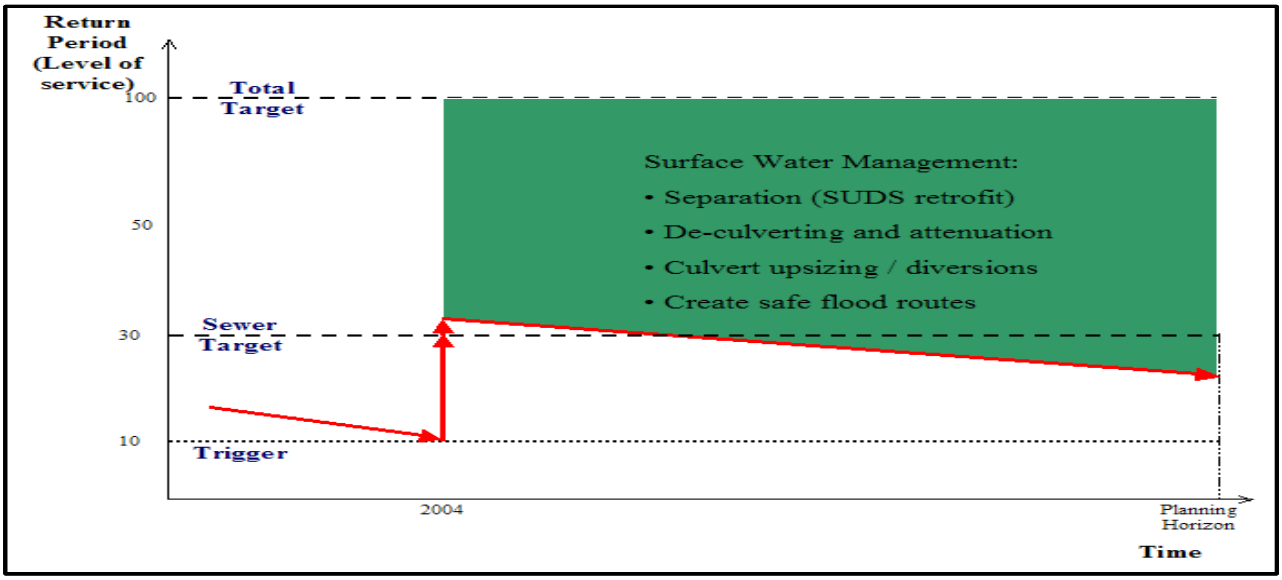

Figure 6 – Total Catchment Level of Service