Integrated Urban Drainage in City Catchments

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1 Introduction

Interest in integrated urban drainage has been increasing in recent years with the growing realisation that the most cost-effective solutions to water quality and flooding problems lie in jointly considering both sewerage and drainage systems, above and below ground. An important part of the cost-effectiveness lies with 'soft' engineering solutions, perhaps replacing, or more likely operating in conjunction with traditional 'hard' engineering schemes. The reality of climate change in increasing rainfall intensity and water levels is further limiting the long-term effectiveness of 'hard' engineering schemes.

In reality most drainage and environmental engineers have probably suspected that integration would be an effective approach to addressing their problems. However we have perhaps lacked the tools and technology to develop the necessary techniques for integrated urban drainage.

This paper illustrates the road that Hyder and Irish and Scottish stakeholders have taken in recent years in developing integrated urban drainage techniques for large city catchments, through the master plans created for the Dublin Region and Glasgow City. The Greater Dublin Strategic Drainage Plan (GDSDS) spanned the years 2001 to 2005, while the Glasgow Strategic Drainage Plan (GSDP) started in 2003 and is completing in its first major phase of implementation in the Clyde Gateway Integrated Water Plan (CGIWP).

2 The Greater Dublin Strategic Drainage Study

The economic success of the Greater Dublin Region since the 1990s had led to a very significant growth in Dublin city and the surrounding counties. The foul and stormwater drainage infrastructure was stretched to keep pace with the increased demand for new serviced land for housing, commercial developments and industry. Overloading of the existing systems was evident from marked deterioration in water quality, increased risks of flooding and concerns that the drainage system and treatment plants have insufficient capacity to cater for future development

The GDSDS was therefore commissioned in June 2001 to carry out a strategic analysis of the existing foul and surface water systems in the local authority areas of Dublin City, Fingal, South Dublin, Dun Laoghaire-Rathdown and the adjacent catchments in Counties Meath, Kildare and Wicklow.

The GDSDS area is shown in Figure 1.

Figure 1 The GDSDS Study Area

The Study objectives were:

- To develop an environmentally sustainable drainage strategy for the Region consistent with the EU Water Framework Directive. This strategy should outline the requirements for foul and stormwater drainage capable of meeting the demands of the Region in the context of current Development Plans, the Regional Planning Guidelines and the longer term development potential of the region;
- To provide a consistent policy framework and standards which will apply throughout the Region, and promote the requirements of environmental legislation and the recommendations of the GDSDS itself;
- To develop tools for the effective management of the drainage systems including Geographical Information Systems (GIS), network models and digital mapping; and
- To develop the optimum drainage solution from a range of alternative scenarios having regard to whole-life cost and environmental performance, the solution to be broken down into a set of implementation projects which can be prioritised and put in place.

In essence the GDSDS was to use the latest hydraulic modelling techniques and databases and thinking on sustainability to produce a completed integrated drainage management system for the use of the seven Councils of the Dublin Region.

2.1 Drainage of the Dublin Region

The history of Dublin's formal sewerage goes back to 1800, with the construction of sewers in the principal streets to drain rainwater into the River Liffey. Major system construction started in 1881 serving the Rathmines and Pembroke areas. The Centre City Main Drainage Scheme followed around 1900 with the City Quays sewers, being interceptor sewers laid either side of the River Liffey, gravitating flows eastwards to the Main Pumping Station and Primary Treatment Works at Ringsend in Dublin Bay. The North Dublin system followed in the late 1950's to serve the then rapidly developing area north of the City. Again this system directed sewage in an easterly direction to a sea outfall off the Nose of Howth.

The southern suburbs were serviced by the Dodder Valley sewer in the early 1970's, still directing sewage eastwards to the Ringsend Treatment Works via a submarine pipeline. The Dun Laoghaire catchment was connected to Ringsend in the early 1990's by a submarine pipeline.

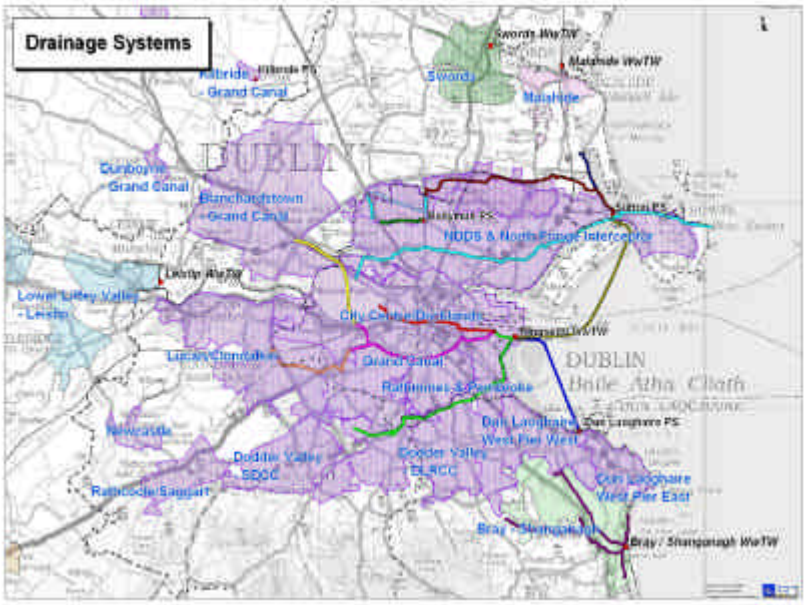

Figure 2 Dublin Existing Drainage Systems

The Grand Canal system was built in the 1980's to serve the new industrial development areas to the west of the City, and relieve the overloaded south city sewers. Through the City, the Grand Canal system comprises a two-compartment tunnel, passing both foul and storm flows. The foul flows gravitate to the Main Lift Pumping Station, which lifts flows into Ringsend Treatment Plant, while the storm flows gravitate to Dublin Bay.

The Ringsend Wastewater Treatment Works and Main Lift Pumping Station were upgraded in late 2003, from a treatment capacity of 0.95m p.e. to 1.64m p.e. with sewage flows from North Dublin also transferred to the Works via the Dublin Bay submarine pipeline, from Sutton to Ringsend.

Stormwater systems are sparse in the older central areas, such as City Centre, Docklands and Dun Laoghaire, which are served by foul/combined or partially separate sewerage. Most stormwater systems have been constructed as part of the separate systems serving post 1960's developments. The Study included all the major rivers, except for the Liffey and Dodder, with their associated surface water systems.

2.2 Methodology for the GDSDS

The Study used a phased approach of initial planning, followed by hydraulic modelling, and optioneering, all leading to the overall strategy output, as shown in the flow chart in Figure 3.

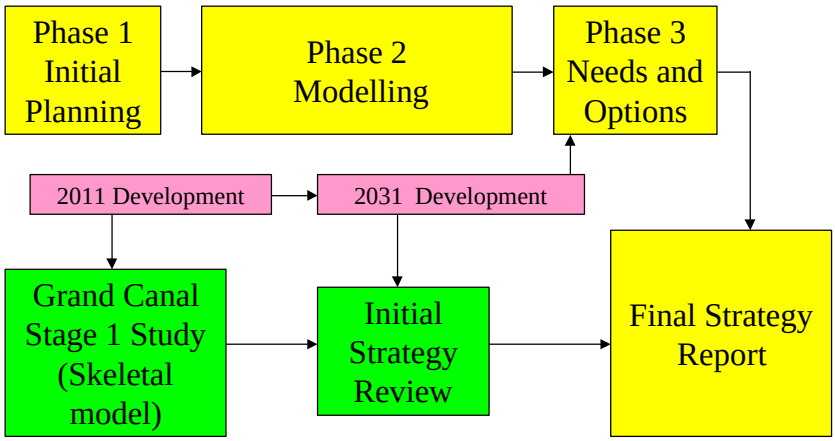

Figure 3 Flow Diagram for Overall Methodology for the GDSDS

Reflecting the importance of development as a driver for the Study, a short-term initial study of the pivotal Grand Canal system was carried out, to obtain an initial review of capacity availability for this main system serving the ongoing development areas to the west and northwest of the City. This study was completed in September 2002, and confirmed that the existing system was performing adequately, but that both trunk sewers were suffering from significant inflow and infiltration. The overall system would be at capacity around the future timeframe of 2011, and hence this initial study used the interim development scenario of 2011. The full study used the overall development scenario of 2031.

The Consultants initiated the concept of an Initial Strategy Review, bringing together the members' widespread knowledge of the sewerage and treatment systems with the results of the initial Grand Canal study. This initial review of possible strategy options was issued in April 2003, and provoked many useful comments and concepts, which were followed up by the later optioneering for the overall master plan

2.3 Integrated Modelling

The Study area comprised foul and storm catchments, varying from dense city centre development to rural streams and rivers. As in most cities, foul drainage is a mixture of separate and combined systems with overflows to watercourses. The storm systems included separate drains, watercourses and major rivers. Foul, combined and storm systems were all represented by InfoWorks models, the detail of the models depending on the availability of asset information and their importance to future development.

The hydraulic models were built from existing SUS25 databases, with further assets being digitised from record drawings, mostly carried out in-house. Asset surveys by specialist contractors provided information on ancillary structures and pumping stations. Information on the main rivers was provided by topographical surveys of the channels, combined with LIDAR aerial survey of the flood plains.

The Consultancy arranged and supervised site surveys to the value of €3.5 million, involving 12 contracts. The specialist surveys included installation of over 480 flow monitors and 270 rain gauges, survey of over 4100 assets and topographical survey of some 74 km of rivers and streams.

All modelling and survey information was held in the Study Geographical Information System (GIS), incorporating digital mapping, ortho-rectified aerial photography, digital terrain mapping, and system information. Reporting and drawing production was also based on the GIS using MapInfo software.

The Consultant's JV team of Hyder, PH McCarthy, RPS/MCOS and HR Wallingford therefore adopted the overall integrated approach of:

- Hydraulic modelling of the entire sewerage and drainage infrastructure of the region, comprising 18 foul/combined catchments, 27 storm water catchments and 7 river catchments;
- Setting up a study Geographical Information System (GIS) of all sewerage, drainage and river systems, by merging existing SUS25 data, digitised paper records and survey results;
- Using a uniform modelling system across both sewerage, drainage and river systems, comprising data capture and processing, asset databases, model build, verification and optioneering;
- Integrated hydraulic modelling and GIS, based on InfoWorks CS to ensure conformity between sewerage and drainage models;
- Phased management of surveys to ensure that data collection (flow surveys, assets surveys, CCTV, etc) is carried out concurrently in corresponding sewerage and drainage catchments;
- Integration of hydraulic modelling parameters between the hydraulic models and the Regional Drainage Policies, including allowances for SUDS in new developments, climate change, etc.

Catchment modelling was managed through the conventional approach of sequential Phase 1, 2 and 3 reporting. Since the JV team comprised over 40 sewerage and river modellers, we produced templates and manuals to ensure that modelling work and reporting was carried to uniform standards, using the same approaches and parameters.
Modelling of the stormwater and river systems proved particularly challenging, as in 2002, there was limited practical experience of modelling watercourses in InfoWorks CS. The stormwater and river catchments were more extensive that the sewerage systems, with much less available information. In order to limit the scope of modelling and survey work to manageable levels, we agreed to prioritise the stormwater drainage models into:

- Type 1 models consisting of a fully integrated model of the river and urban piped stormwater drainage system. Data from a short-term flow survey was used to verify the major piped systems. Long-term river flow data (where available) and short-term flow survey data were also used to calibrate the river flows and depths. References were also made to any available records of historic flooding from both the piped network and the river to verify the model results
- Type 2 models consisting of the urban piped stormwater drainage system. If useful, a nominal representation of the river system was also included, but this was only used to join the piped system together. Data from a short-term flow survey was used to calibrate the major piped systems. Reference was also made to any available records of historic flooding from the piped network. The flows in the river were not considered.
- Type 3 models consisting of the urban piped stormwater drainage system only and no verification of the model was carried out.

2.4 Integrated Wastewater Treatment

The wastewater treatment works were also vital to the drainage strategy, especially Ringsend WwTW, which was receiving most of the foul flows from the City. With populations due to rise from 1.225 million in 2002, to 2.054 million in 2031, substantial additional treatment capacity was needed. The Ringsend site had limited available space for expansion, and the Works discharges into Dublin Bay, with limited assimilative capacity. One of the strategy priorities was therefore to locate a new WwTW, preferably on the Irish Sea coast, since the inland rivers had insufficient flows to accept any discharges, other than of the strictest standard.

The Consultants therefore constructed a coastal water quality model to assess the impacts of discharges from both existing and potential wastewater treatment works, including Ringsend, Shanganagh Bray to the south of Dublin and Malahide, Swords, Portrane and Balbriggan to the north of Dublin.

The modelling software used by the Centre for Water Resources Research, at University College Dublin to simulate flows was TELEMAC. WQFLOW-2D was used in association with the hydrodynamic results to simulate mass transport decay and interaction with water quality variables and defined pollutants.
The modelling confirmed that the existing inland Works would be constraints on major future development, as would the available capacity in the River Liffey and Liffey Estuary. Therefore the most sustainable solution would a new wastewater treatment works discharging directly to the Irish Sea.

2.5 Drainage Strategy for the Dublin Region

The overall drainage strategy for the Dublin Region, at an estimated NPV of €2,585million is to maximise treatment capacity of existing WwTWs and upgrade sewerage locally for conveyance. Ultimately a new Regional Wastewater Treatment Works will be needed in North Dublin, with development of an orbital sewer to serve the Northern and Western environs of the city and with pumped connections from South Dublin, Leixlip and Meath to suit their development demands. Stormwater and river systems need to be upgraded locally to address flood risk.

Implementation of the GDSDS is in progress with expansion of the Ringsend and Bray Shangannagh WwTWs, and upgrading of the Blachardstown and Rathmines and Pembroke sewerage. Regional drainage policies are being rigorously enforced to ensure that sewerage and drainage capacity and flood risk is enshrined in the planning process. Inclusion of SUDS in new developments and improvement in construction quality are high priorities for the Dublin Councils.

3 The Glasgow Strategic Drainage Plan

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 over 500 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 (SW) and Glasgow City Council (GCC) found themselves under considerable pressure from residents, planners, councillors and politicians to identify solutions to this major threat to the city. Glasgow's success in securing the 2014 Commonwealth Games has brought further focus to the problems.

There are also serious water quality problems associated with the River Clyde and its tributaries with classifications of mainly 'poor' and 'seriously polluted'. Existing water quality is also a major constraint to redevelopment. Current water quality is generally well below the Scottish Environment Protection Agency (SEPA) existing and future Water Framework Directive (WFD) target classifications. The WFD requires all water bodies to achieve 'good ecological status' by 2015.

In addition, the latest global warning research predicts that Glasgow is particularly vulnerable to climate change which will further increase flooding risk and water quality problems.

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 Glasgow Strategic Drainage Plan (GSDP) was thus promoted and guided by a Steering Group comprising Scottish Water (SW), Glasgow City Council (GCC), Scottish Environment Protection Agency (SEPA) and Scottish Enterprise Glasgow (SEG).

The GSDP encompasses the catchment areas served by the Dalmuir, Dalmarnock, Daldowie and Shieldhall Waste Water Treatment Works (WwTWs). 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. The four wastewater treatment catchments making up the GSDP drainage systems are shown in Figure 4:

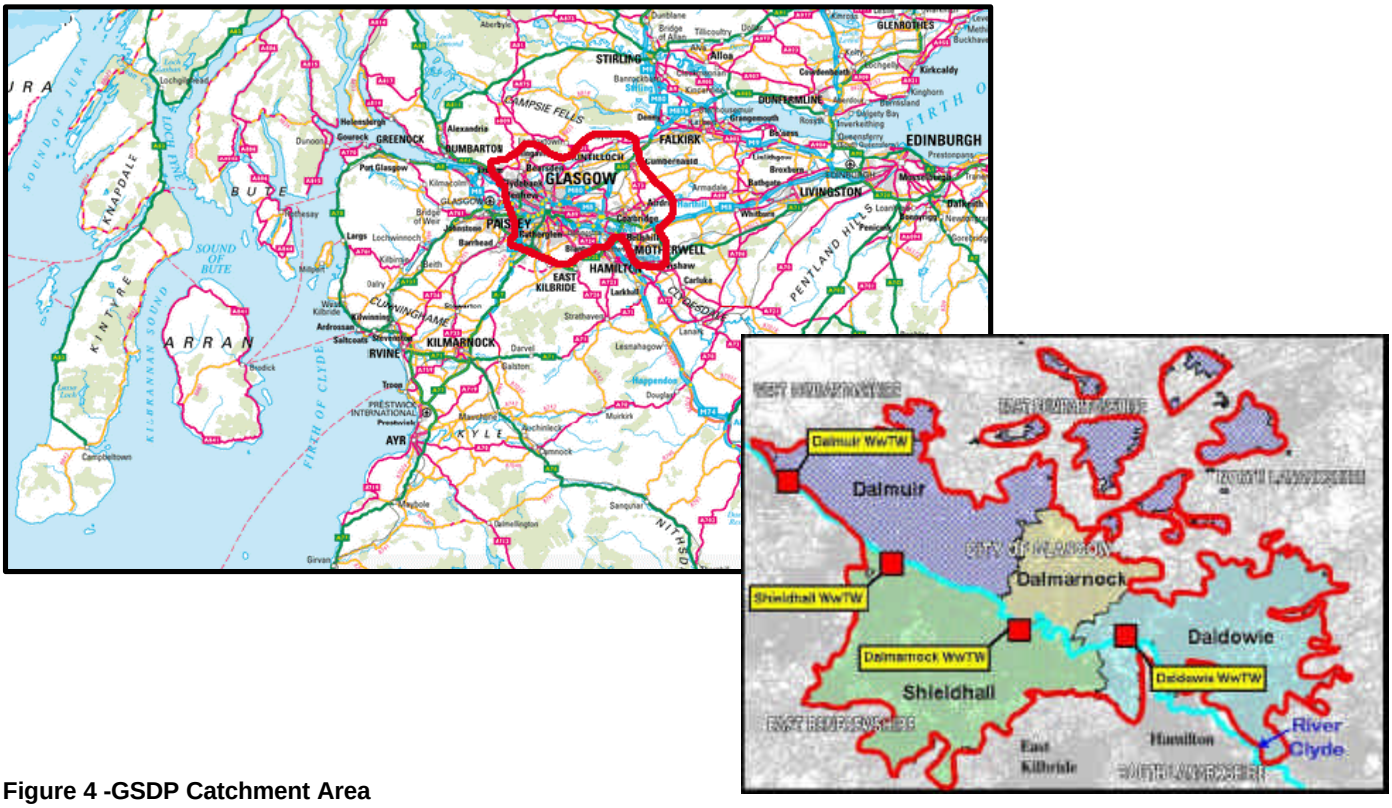

Figure 4 -GSDP Catchment Area

The key objectives of the GSDP are:

- **Flood Risk Reduction:** the flood risk from both sewers and watercourses is unacceptable in many areas. The flood event of 30 July 2002 affected hundreds of families and businesses and caused damage estimated at £100m. Climate change will increase the frequency of such events.
- **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 hydraulic relief provided by numerous Combined Sewer Overflows (CSOs) discharging surplus stormwater to watercourses, existing water quality is unacceptable and needs to be improved to meet increasingly stringent legislative requirements.
- **Removal of Development Constraints:** the lack of capacity and other deficiencies with the drainage infrastructure is now hampering regeneration efforts and much needed economic development. The benefits of other major infrastructure investment, such as the M74 extension and the East End Regeneration Route, will not be realised if development is restricted.
- **Habitat Improvement:** urban regeneration should provide opportunities for improving the environment and open watercourses should be considered in this regard. A further objective is therefore to explore the possible opportunities for "de-culverting" of watercourses. Along with other measures such as provision of attenuation ponds, this could provide valuable habitat and amenity enhancement in an area where it is much needed.
- **Integrated Investment Planning:** the likely level of investment required to address development constraints, flooding and water quality needs to be understood. A business case needs to be made to allow each stakeholder to secure the necessary funding support.

Such is the extent of the legacy position of the sewerage and drainage infrastructure, it was clear that major rehabilitation and investment would be required to address the problems. Although numerous drainage area studies were ongoing at a local catchment level, it is was evident that a more integrated approach was required to cost-effectively address this legacy position and define a blue-print for the long term needs of Glasgow's sewerage and drainage infrastructure.

3.1 Integrated Approach to Glasgow's Drainage

Due to the scale of the legacy flooding and water quality problems in Glasgow, local catchment drainage area planning was increasingly recognised as a too narrow an approach as this only reviews and defines local catchment requirements and solutions. Numerous local solutions may perhaps be individually robust, but are unlikely to be sustainable collectively, particularly in addressing overall water quality requirements.

The lowest cost local solutions are often attenuation based, and even if they could collectively address the strategic hydraulic and environmental requirements, the total storage involved would be impracticable. Local individual solutions also may result in the transfer of hydraulic and environmental problems to another point in the WwTW network. In addition, local drainage area plans are also normally based on fairly short term local development plans.

An integrated approach to both the sewerage and drainage infrastructure was also recommended with the aim to develop cost effective integrated solutions with the right balance between conventional 'hard' engineering solutions and 'soft' solutions such as watercourse improvements and Sustainable Urban Drainage Systems (SUDS). The resulting master plan defines the total catchment solution and enables overall costs, benefits and investment requirements to be understood by the stakeholders. Within the overall master plan, solutions and schemes can then be broken down and prioritised for phased implementation.

The GSDP Steering Group agreed the benefits of the integrated approach on the basis that:

- Flooding is occurring from both sewers and watercourses. Where this occurs together, it is necessary to understand the hydraulic performance and interaction of both systems.
- There can be considerable physical interaction between combined sewer systems and watercourses, e.g. via combined sewer overflows. Assessing both systems together permits a full understanding of the performance of both systems under potential loading conditions.
- Sewer systems, watercourses and treatment works, and the continuous and intermittent discharges there from, are subject to constantly changing loading due to urban development and regeneration. An assessment of population and land use will provide an understanding of short, medium and long term loads.
- Assessment of wastewater treatment capacities, together with an understanding of the assimilative capacity of receiving waters, will allow consideration of potential transfer / treatment options.
- A review of drainage policy will allow appropriate design criteria to be identified and consistently applied in order to provide an acceptable level of service.

It was agreed that the actions described above would permit development of best value strategic drainage options to address the backlog of investment and deliver the Vision of Sustainable Urban Drainage for Glasgow.

The GSDP started in July 2002 with the staged approach shown in Figure 5:

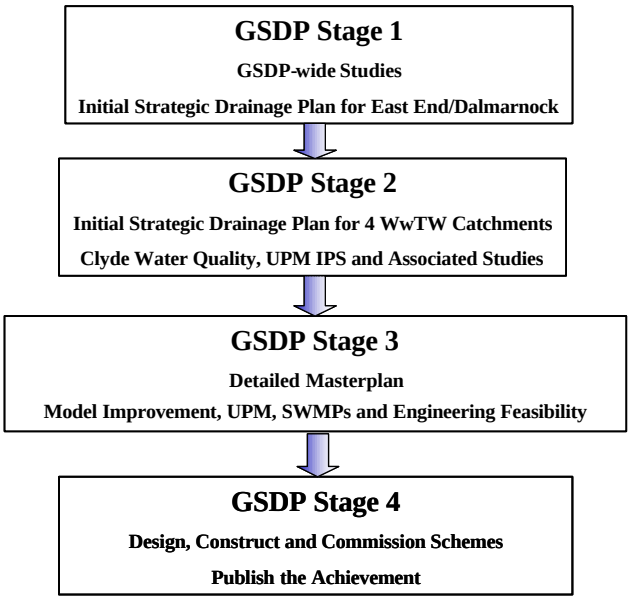

Figure 4 –The 4 Stages of the GSDP

In broad terms, Stage 1 comprised the studies to get an initial understanding of the drainage systems and the Glasgow catchments, with the emphasis on producing schemes to address the flooding that occurred in the East End in 2002. Stage 2 was to a produce the drainage and wastewater treatment strategy across the City, while at the same producing the tools to promote integrated solutions, such as water quality models of the Clyde, surface water management and overland flow routing. Stage 3 was to be finalising of the feasibility studies, with Stage 4 being implementation of resulting schemes.

3.2 GSDP Stage 1

Stage 1 of the study initially investigated overall drainage and catchment issues across Glasgow, while concentrating on the Dalmarnock catchment, which suffered worst from the July 2002 flooding. The primary objective of Stage 1 was to provide the stakeholders with an initial assessment of Glasgow's water quality and flooding problems and further facilitate debate as to how to best address the situation. Stage 1 was completed in April 2004.

The following reports were produced:

- Catchment Hydrology Report.
- Wastewater Treatment Works Assessment Report.
- Land Use and Development Report.
- The Initial Strategic Drainage Plan (ISDP) for the East End/Dalmarnock

These full area studies provided the context for development of the overall Strategic Drainage Plan for Glasgow.

The Initial Strategic Drainage Plan (ISDP) for the East End/Dalmarnock catchment utilised an integrated hydraulic model of both the sewerage and drainage systems to identify the scope of conventional engineering solutions to address the deficiencies identified. The integrated model was developed by Montgomery Watson Harza (MWH) and although not verified at the time, it was sufficient to broadly replicate the existing system performance and identify the nature and scale of initial solutions.

In addition to the more traditional 'hard' engineering solutions, the potential for 'soft' engineering solutions such as SUDS retrofit and watercourse solutions were also initially assessed, showing the beginnings of the surface water management techniques that were to develop in later Stages.

3.3 GSDP Stage 2

Although the stakeholders suspected the potential magnitude of the challenge and investment ahead, this needed to be more refined in terms of scope, complexity, costs and programme. It was important that the stakeholders had something more tangible to engage debate as early as possible, balanced against the need for sufficient accuracy to inform their business plans.

The basic philosophy of Stage 2 was to make best use of all existing information to define an initial understanding of the potential scope and cost effectiveness of a strategic masterplan to achieve the GSDP objectives, prior to defining and embarking on more costly and time-consuming detailed studies. Although existing model coverage and understanding was incomplete, it was considered that there was sufficient information to support an initial masterplan. The initial masterplan would allow future work to define the detailed feasibility studies to be more cost effectively understood and targeted. Stage 2 was completed in August 2005.

The catchment wide studies in Stage 1 had confirmed the importance of understanding the water quality of the River Clyde system, from the urban burns and watercourses, down to the freshwater length of the Clyde above the tidal weir and the tidal length out through the City to the Firth of Clyde. We therefore undertook an initial study, early in Stage 2, to scope the level of UPM/water quality analysis that would be appropriate to the Clyde's tributaries to understand both existing and future target water quality compliance. Indeed, one overriding consideration was fundamentally whether future target water compliance would be achievable both in the tidal and non-tidal waters. The tangible cost benefit of potential water quality improvements needed to be balanced against the other GSDP drivers such as flood risk reduction and the removal of development constraint.

Mindful of the scale of the water course system (some 340km in length with over 600 CSOs) and restricted costs and programme, we adopted a simplified water quality approach whereby CSO discharges were based on minimum Formula A standards, with more rigorous and conservative 'surrogate' standards for many of the receiving watercourses, mainly the minor burns with obvious low flows and hence lack of available dilution. The Clyde River/Estuary model was built to integrate the land based drainage outputs with the flow processes on a major tidal river. This model enabled us to understand the effects of continuous WwTW discharges, intermittent CSO spills and background diffuse pollution on the receiving watercourses, and also to simulate the benefits, or lack of benefits of reductions in such discharges, on a city-wide scale.

Key features and discharges of the Clyde River/Estuary model are shown in Figure 5:

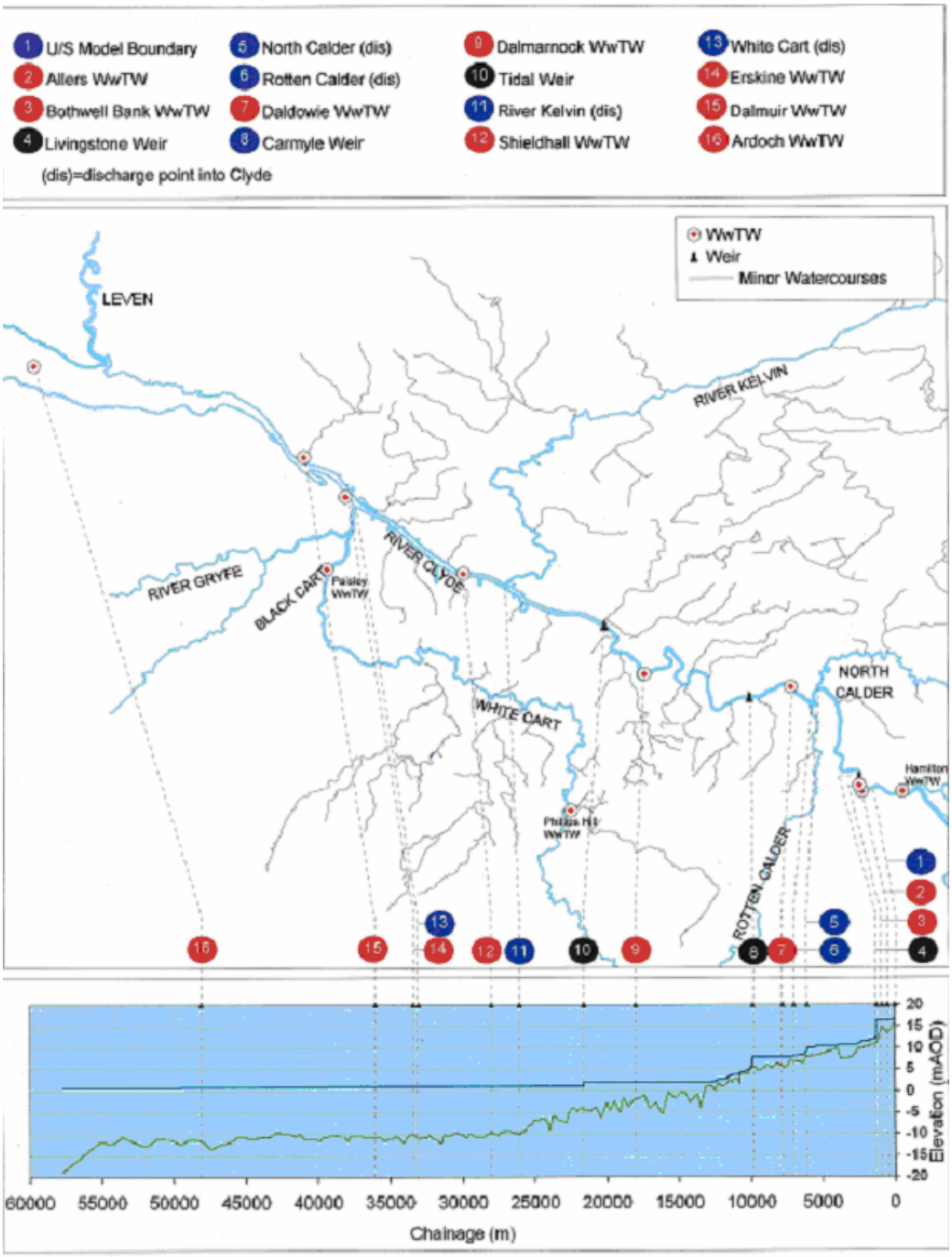

Figure 5 River Clyde Water Quality Model

A fully integrated sewerage and drainage approach had already been adopted for the Dalmarnock catchment with associated integrated modelling. Hyder amalgamated existing models for the other three WwTW catchments of Dalmuir, Shieldhall and Daldowie as shown in Figure 6.

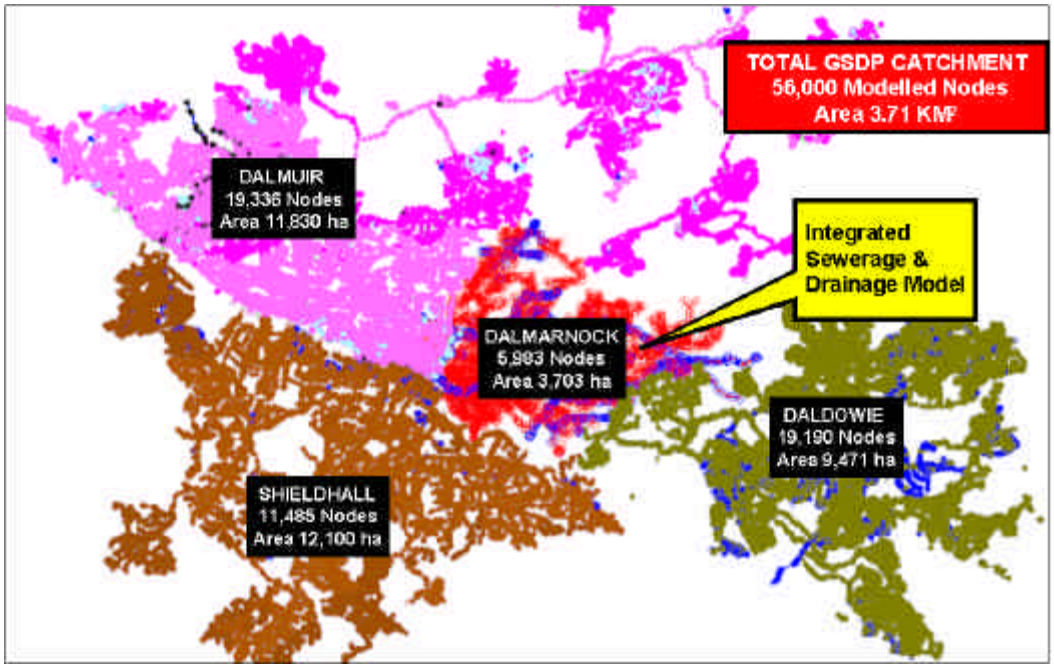

Figure 6 The GSDP Hydraulic Models

We were thus able to understand whether the integrated approach was applicable and justifiable to the wider GSDP catchment area. The requirements for integrated modelling needed to be considered at two levels: to enhance the analysis and delivery of a sewerage masterplan and/or; to facilitate a combined sewerage/drainage masterplan via the mechanism of Surface Water Management Plans (SWMP's). Rather than embarking on wholesale integrated modelling, it was considered that an initial assessment would define the need for only targeted catchment areas. Catchment wide integrated modelling would have significant implications on future GSDP costs and programme and therefore compromise the shorter term definition and removal of development constraint.

Results from existing and future model runs were then used to define and test strategic engineering options at WwTW catchment level and to understand potential 'cross catchment' solutions. The river and estuary models were used to assess the water quality impact of the potential solutions against baseline conditions and future water quality objectives.

Both 'strategic' and 'local' solutions were developed. 'Local' solutions are defined as schemes that address catchment deficiencies that are more cost effectively remedied at a local level rather than at a strategic level. Although, the main focus of Stage 2 was the development of strategic solutions, it was necessary to define outline solutions to local needs so as to ensure that the downstream strategic options accounted for any increase in pass forward flows from these local solutions. The scope of 'local' solutions was also needed to understand overall costs.
The resulting strategic and local schemes are illustrated in Figures 7 and 8.

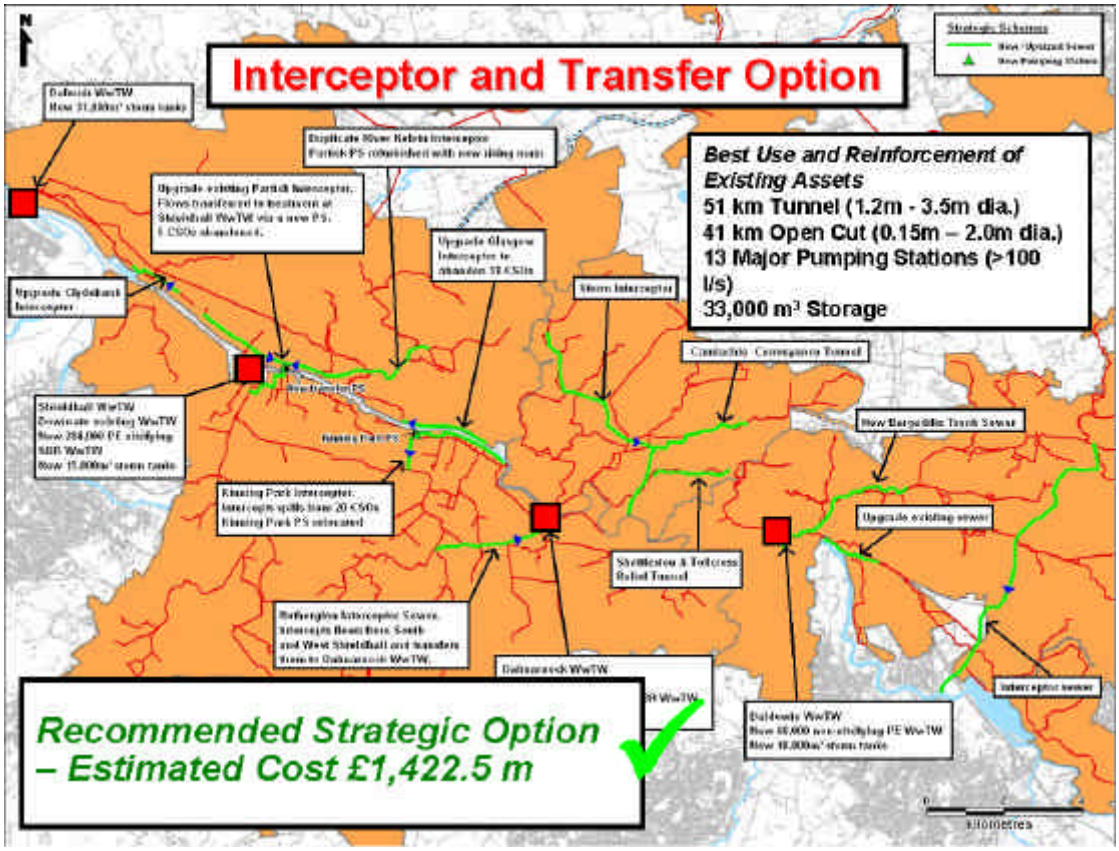

Figure 7 Interceptor and Transfer Strategy

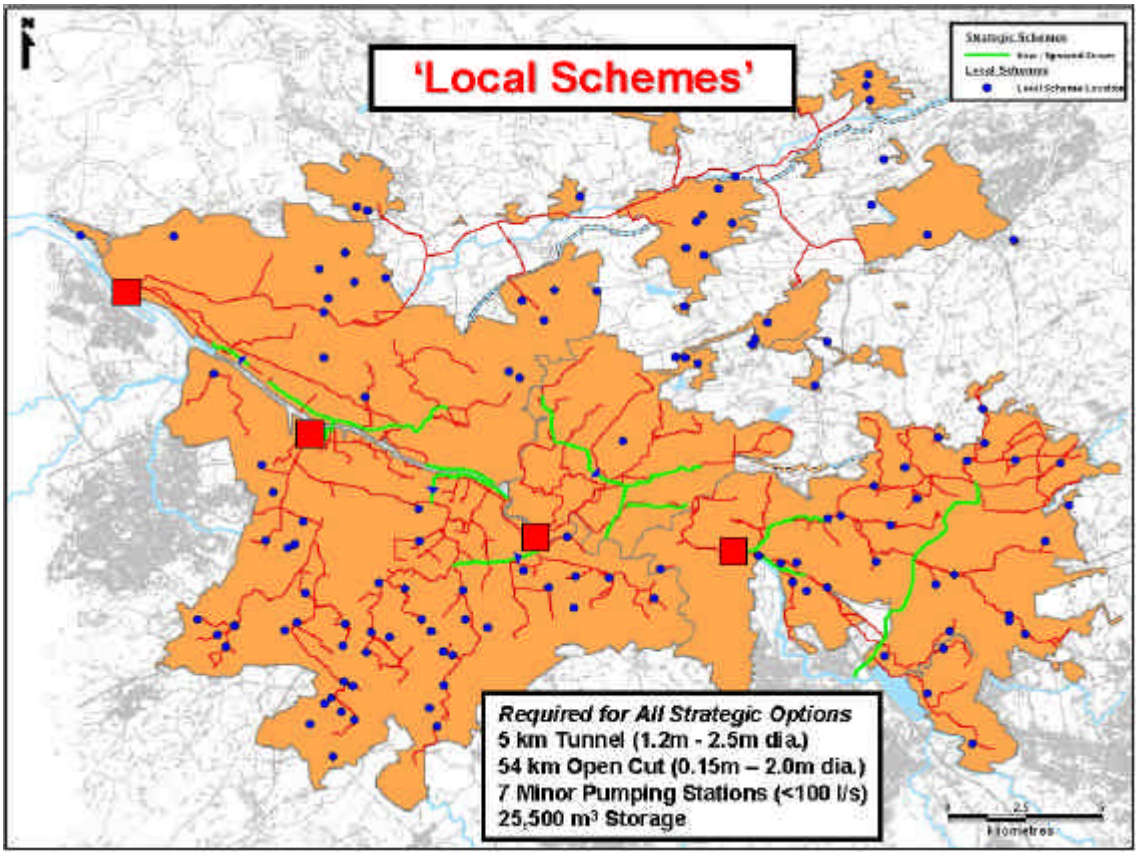

Figure 8 Local Schemes

The GSDP Toolbox was created to integrate the many disparate sources of information, models, databases, and techniques derived and promoted under Stages 1 and 2. The intention was that the Toolbox should continue to be used for the following stages of the GSDP, and for other external investigations and operational issues. Toolbox contents include:

- Amalgamated sewerage models of Dalmuir, Daldowie and Shieldhall catchments.
- Integrated sewerage and watercourse model of Dalmarnock catchment.
- Future models of all WwTW catchments, including Q&S2 upgrading works.
- Process assessment of existing and future potential for Glasgow WwTWs.
- Water quality model of River Clyde integrated with WwTWs and catchment models.
- UPM Initial Planning Study for River Clyde tributaries.
- Infiltration mapping and “hot spots” for reduction strategy.
- Stormwater Management Plan based on Cardowan case study.
- Overland flood routing techniques based on case study.
- Catchment Hydrology and design and time series rainfall.
- Watercourse assessment for future improvement.
- Sites for potential future SUDS retrofit.
- Population and Land Use Maps and GIS databases of existing and future development.
- Review of drainage policy.

Although the Initial Masterplan of late 2005 represented a huge body of knowledge, the stakeholders were faced with the implementation of this blueprint. The Masterplan also confirmed the worth of the integrated approach, bringing mutual benefits to sewerage and watercourse flooding and for balancing water quality against CSO and WwTW discharges.

The main implementation challenge was the cost and disruptions of such major works across the City. Even allowing for the twenty-year programme, annual funding would exceed current availability of finances.

4 The Clyde Gateway Integrated Water Plan

Although the GSDP addressed problems across Glasgow, the priority area for drainage improvement still remained as the East End, which had suffered such severe flooding in 2002. Although some drainage improvements were underway and Scottish Water was addressing unsatisfactory CSOs through its Q&S programme, the flood risk remained. The priority of the East End was confirmed in February 2006, with the publication of the Scottish Executive Regeneration Policy Statement ‘People and Place’ which identified the Clyde Gateway as the ‘national regeneration priority for Scotland’. The location of the Commonwealth Games Village within the Gateway added further impetus.

An estimated £2 billion investment in the Gateway over 25 years will aim to deliver 10,000 new homes, together with 20,000 new jobs and 400,000m^2 of business and industrial floor space. From previous GSDP findings, water infrastructure was seen as a significant constraint to redevelopment, and therefore stakeholders needed to fully understand the water infrastructure needs of the Clyde Gateway. The Water Infrastructure Plan therefore covers sewerage, drainage, wastewater treatment and water supply for the existing and future development of the Clyde Gateway.

The earlier Cardowan and overland flow case studies had demonstrated the potential of Surface Water Management to benefit flooding from sewerage and watercourse systems, as well as reducing CSO spills, and hence became an important element of the Plan.

The boundary of the Gateway spans the Clyde and its boundary is shown in Figure 9, overlaying the sewerage networks of Dalmarnock and Shieldhall.

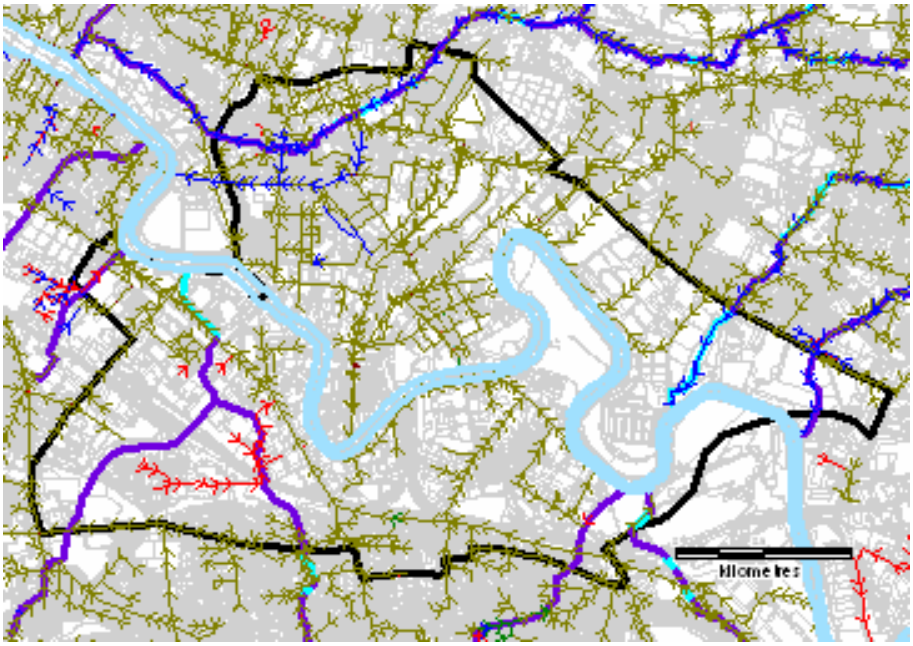

Figure 9 Location of the Clyde Gateway

4.1 Integrated Approach to Development and Land Use

As would be expected with such a major regeneration area, planning studies were on-going during (and after) the Integrated Water Plan. Although populations were not totally certain, we recognised that the Surface Water Management Plan would potentially require significant land areas. We therefore concentrated on liaison with the planners to ensure that they understood the importance of community and regional SUDS facilities, and that land had to be allocated within their land use proposals. The SWMP has fed knowledge into these planning studies but has had to be considerably adapted to provide the flexibility required to accommodate ongoing uncertainties in planning and land use.

This integrated approach proved successful, and is continuing within Glasgow City and South Lanarkshire Councils, who are currently involving their planners and urban designers in designing SUDS facilities within city landscapes, building on the outline SUDS and flow conveyance arrangements defined in the Surface Water management Plan.

4.2 Integrated Approach to Surface Water Management

Surface Water Management Planning (SWMP) was applied the Clyde Gateway because:

- Recent drainage legislation in Scotland requires new developments to be drained separately using Sustainable Urban Drainage Systems (SUDS).
- The Gateway contains multiple development sites and an overall management plan brings major advantages compared with a site-by-site approach.
- Regeneration on this large scale provides a precious opportunity to manage surface water effectively and sustainably, avoiding the problems experienced in existing urban areas such as flooding and pollution.
- Parts of the Clyde Gateway are at risk of flooding from the Clyde. Some parts are already protected by flood walls and embankments and these measures are likely to be adopted elsewhere in the Gateway as new sites are developed. In these circumstances, management of surface water in extreme events requires particular attention.

In line with the recommendations of the SWMP and guidance in Sewers for Scotland, 2nd Edition it is assumed that all future developments in the Gateway will be separately sewered. As such, surface water flows from these areas do not contribute to trunk combined sewers, other than a small allowance for

misconnections. Were all new developments required to use separate drainage, then the division of system type would be as indicated in Figure 10, which quantifies the differences between baseline and future based on the assumed distribution.

Scenario	Area (ha)			
	Separate	Combined	Separate to Combined	Unknown
Baseline	88	420	1	17
Future	467	197	1	11

Figure 10 Contributing Area Breakdown

In total, regeneration of the Clyde Gateway will increase the developed area by 150ha but reduce the area contributing to the combined system by 223 ha. Delivery of this transformation, via new sustainable drainage networks, will be a major achievement in this high-density urban setting, with contaminated land and tidal/river flood risk giving additional challenges. The benefits, however, will be significant. One advantage will be the local reduction in stormwater loading on the existing combined sewer network due to the removal of over 220 ha of contributing area. This permits the relatively minor additional foul flows from new developments to be accepted without detriment to hydraulic performance.

Surface water management was carried out in three Phases, each with their own report for stakeholders and other Gateway studies, principally planning:

- Phase 1 established the baseline scenario (in terms of land use, topography, drainage, hydrology, water quality, flood risk, environment and constraints) and set out how these aspects may change - or be protected from change – under the future development scenario. Phase 1 also put forward a proposed approach for development of options in Phase 2, defined a set of drainage groups within the Clyde Gateway and listed some preliminary ideas for regional SUDS facilities in each group.

- Phase 2 built on the foundations laid down in Phase 1 by developing regional SUDS schemes in appropriate areas. These schemes were tested by detailed hydraulic modelling so that the component sizes required for compliance with design criteria could be determined. Cost estimates were prepared and constraints identified. This phase highlighted the need to resolve specific drainage issues in Dalmarnock, Shawfield and Farme Cross to enable the SWMP to be progressed further. These areas are now all subject to detailed planning studies.

- Phase 3 responded to the uncertainties surrounding land use planning by both capturing relevant knowledge across the whole Gateway and by defining a practical means of progressing to detailed design in specific surface water drainage 'scheme areas' as shown in Figure 11. Technical data sheets were provided for each area and included details on aspects such as flood risk from all sources, existing drainage, ground conditions and historical land use.

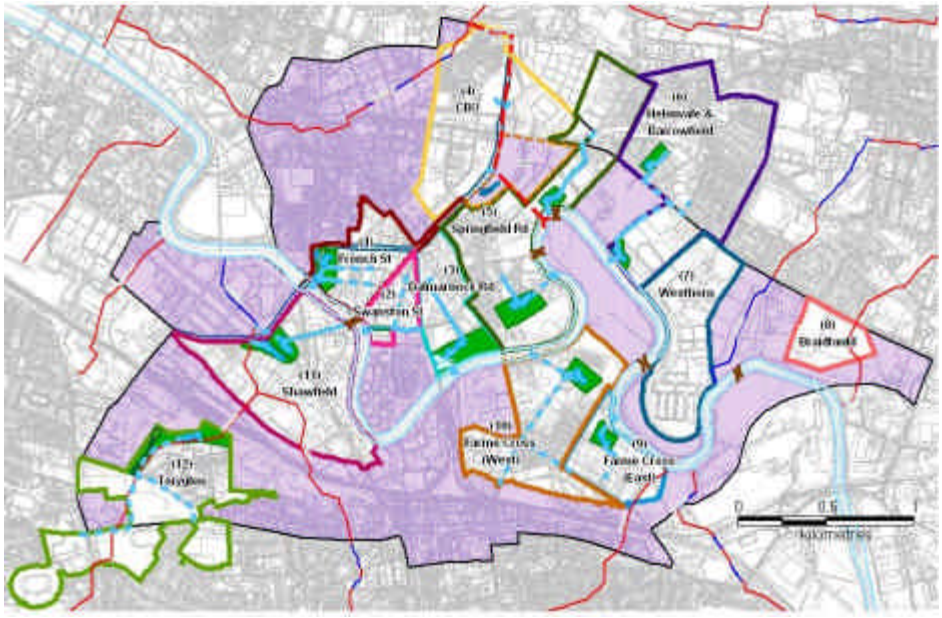

Figure 11 SWMP Areas in the Clyde Gateway

A key point of surface water management planning is the need for full integration of urban design and surface water drainage design. This requires a change in thinking and approach from that perhaps envisaged at the outset of the project. The best overall drainage solution will be obtained when there is sufficient development knowledge to design the full system from source to outfall. In these circumstances, there will be maximum flexibility over distribution of surface water treatment between source, site and regional controls, and hence maximum flexibility of land use.

The general recommendations from the SWMP are:

- Legal requirements for SUDS require a new approach to land use planning when large, multiple-site regions like the Clyde Gateway are being developed. As preferred land use scenarios are developed into detailed area plans, the indicative drainage schemes outlined in the Surface Water Management Plan should be advanced into detailed designs as an integral part of the planning and urban design process.

- The Surface Water Management Plan should be used to inform detailed design of schemes and assist those responsible for undertaking and reviewing formal assessments - such as Flood Risk Assessments, Drainage Assessments and Development Impact Assessments – for individual sites.

- Regeneration of the Clyde Gateway will bring physical changes to infrastructure, land form and flood defences, and major sewerage changes will be required to deliver water quality improvements. The models used to assess flood risk will need to be regularly updated to reflect these changes.

- A policy decision should be made on whether new, regional surface water drainage schemes should be sized to allow for sewer separation in those areas where existing housing is due to be retained.

- The scale of the Clyde Gateway and the likely nature of the proposed regional drainage schemes are such that agreements between stakeholders will be required. Dialogue between stakeholders regarding funding, ownership, adoption and maintenance of regional drainage infrastructure should continue.

- The Commonwealth Village Site has become high profile now that Glasgow's bid for the 2014 Games has proved successful. This should be seen as an opportunity to consider some more forward-thinking ideas concerning the water cycle, including: green roofs, rainwater harvesting, greywater re-use, stormwater re-use and perhaps a more visible and creative use of surface water in the development.

5 Integration of Stakeholders

Integrated drainage planning in large city catchments is an ongoing process shared by the consultant team, the client and stakeholders. Although the most detailed briefs and technical proposals may be prepared, there will inevitably be changes, and it is therefore vital that all major stakeholders maintain close technical and managerial involvement throughout the project.

For Dublin this was done by Dublin City Council having a small counterpart team working closely with the consultants on technical and project management issues. The Dublin City Council Team then liaised with the other six client Councils, and fed back into the Study. There were also monthly Steering Group Meetings attended by the County Managers to maintain the high-level liaison, and ensure that any policy or political issues were addressed.

The Steering Group for Glasgow and Gateway projects has a similar role and includes external stakeholders, such as Scottish Enterprise Glasgow and the Clyde Gateway Initiative. The Technical Group is responsible for technical delivery, but includes members of the Steering Group to maintain communications and feedback between the two Groups. The Metropolitan Glasgow Strategic Drainage Partnership (MGSDP) was set up in 2007 to address implementation of the upgrading of Glasgow's sewerage, drainage and watercourse systems.

In January 2008, the Scottish Government in its 'National Planning Framework for Scotland 2' designated the GSDP and the Commonwealth Games Facilities and Infrastructure/Clyde Gateway Regeneration as 'National Developments – Statements of Need'. The profile of the MGSDP is being raised to integrate with the local and national bodies responsible for these nation-wide projects,

6 Conclusions

The overall messages from these large city-based drainage projects would be to:

- Understand the catchment first, before launching into an integrated approach. It may be that some areas could not benefit;
- Use appropriate modelling tools and target suitable areas of need. Integrated hydraulic modelling is an expensive and time-consuming process;
- Use appropriate modelling tools, preferably with industry standard software, databases and GIS;
- Consider both 'hard' and 'soft' engineering solutions, to compliment each potential benefit;
- Appreciate that plans are living documents and deserve periodic review as circumstances change;
- Employ integration between drainage and planning policy and plans;
- Maintain client and stakeholder liaison throughout, to encourage the 'no surprises' culture;
- Introduce prioritising and implementation aspects as early as possible, to get stakeholders used to these issues that will become so important to them
- Maintain the integrated view of the project and its objectives, and avoid obsession with modelling

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