East Renfrewshire Council

Maidenhill/Malletsheugh
Hydrological Scoping Study

October 2013

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1 INTRODUCTION

1.1 Terms of Reference

EnviroCentre was commissioned by East Renfrewshire Council (ERC) to undertake a hydrological scoping study for the Maidenhill/Malletsheugh development area. The development area is a large scale greenfield release site to the south-west of Newton Mearns and will ultimately accommodate around 1,060 housing units. ERC will prepare a Development Framework that will prescribe the key strategic requirements across the site to ensure that all developers are clear from the outset what will be expected of them. One of the key requirements is for a strongly integrated Green Network including Integrated Green Infrastructure (IGI), informed by the hydrological, ecological and other environmental characteristics of the site.

1.2 Scope of Report

The aim of this study is to provide ERC with the necessary hydrological understanding of the site to assist in the development of the sustainable water management component of the Development Framework. Key aspects of a sustainable water management are drainage, flood risk and water quality following the principles of Sustainable Drainage Systems (SuDS).

1.3 Methodology

The following methodology has been adopted for this study:

1. Collection of hydrological data including open and culverted watercourse alignment, terrain elevation, land use, in-bank structures and flooding history;
2. Consultation with ERC flood team to identify flood history and drainage requirements;
3. Site walkover survey to verify desk-based analyses, identify runoff and drainage mechanisms, and to identify flood risk “pinch points”;
4. Review of flood risk issues within the site and downstream of the site;
5. Identification of constraints and opportunities for future drainage and alignment with IGI principles and preparation of drainage options;
6. Provide support to ERC in preparing relevant sections of the Development Framework; and
7. Preparation of a project final report.

2 BASELINE HYDROLOGICAL CHARACTERISTICS

2.1 Site Description

The Maidenhill/Malletsheugh site is located to the south-west of Newton Mearns, East Renfrewhire (Figure 2.1). The site's surface area is approximately 85 ha. The site is bounded by the M77 motorway to the west, by the A726 Glasgow Southern Orbital (GSO) road to the south and by the existing urban extent of Newton Mearns to the east and north.

The majority of the site currently consists of agricultural land and buildings. From north to south, the three main properties within the site are Malletsheugh Farm complex, Faside House and Maidenhill Farm. The A77 Ayr Road crosses the site in a west-east direction and the Malletsheugh Inn restaurant is located at the junction where Ayr Road turns in a southerly direction. Existing properties are to be retained as part of the development of the area.

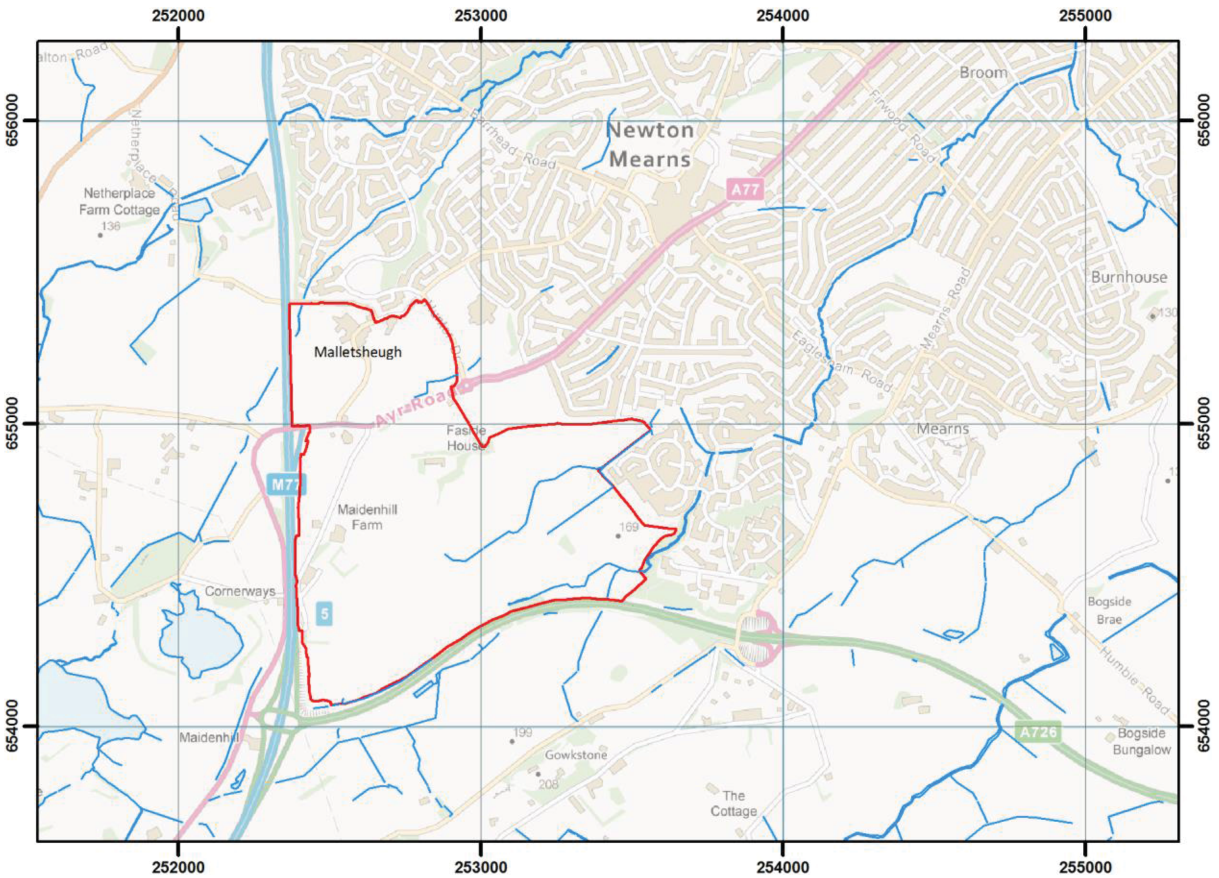

Figure 2.1: Site location plan

2.2 Climate

Annual precipitation at the site is estimated as 1,430 mm based on Flood Estimation Handbook (FEH) data (CEH, 2009).

Data from the UK Climate Projections programme suggest that annual total precipitation is likely to remain constant up to the 2080s (Defra, 2010). However, precipitation during the winter season and extreme storm events may increase as part of long-term climatic changes. For example, the median estimate of the increase in precipitation during the wettest day in winter compared with the present-day climate is estimated as 17% for a "high" carbon emissions scenario (Defra, 2010).

2.3 Rivers

The site is located within the River Clyde and Loch Lomond catchment. The site is drained through four small and unnamed burns, here referred to as Burn A, B, C and D (Figure 2.2).

Burns A and B are located to the north of the A77 road and flow in a north-easterly direction towards the Capelrig Burn via a mix of open and culverted watercourses through Newton Mearns. The Capelrig Burn becomes the Auldhouse Burn, a tributary of the White Cart Water, which in turn is a tributary of the River Clyde.

Burns C and D also flow in a north-easterly direction and confluence at a location approximately 370 m to the east of the site to form a tributary of the Broom Burn. This watercourse is also a mix of open channels and culverts. The Broom Burn flows in a northerly direction and discharges into the Auldhouse Burn.

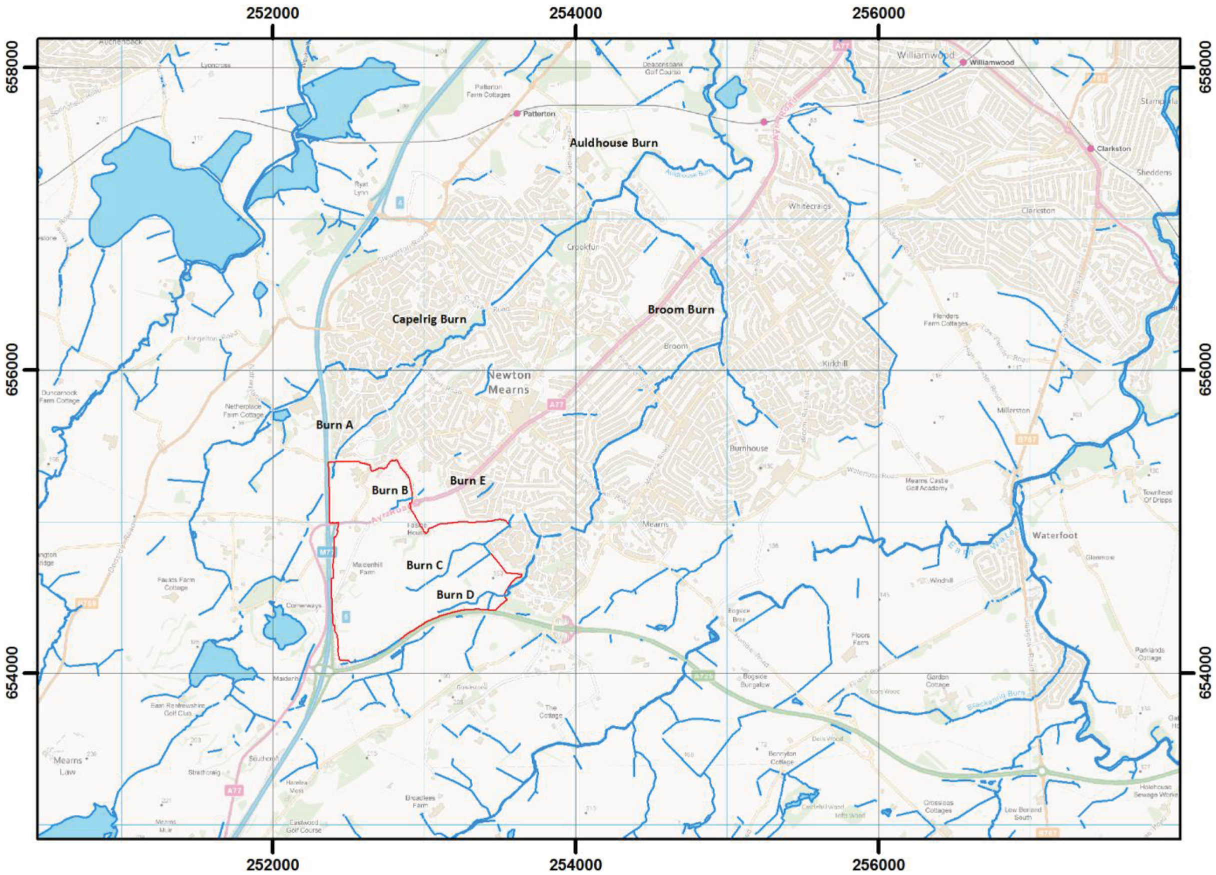

Figure 2.2: Main rivers

2.4 Runoff Directions

To understand the hydrological regime at the site in detail, an assessment has been made of the runoff or drainage directions and the associated drainage areas.

LiDAR (LIght Detection And Ranging, a remote sensing technique) terrain elevation data, supplied by ERC, was used to create a flow direction layer within a Geographic Information System (GIS). In this process, the flow direction is assigned by following the direction of the steepest slope on a grid cell by grid cell basis. This analysis therefore represents the theoretical runoff directions assuming there is no infiltration of precipitation into the soils. The LiDAR Digital Terrain Model (DTM) provides highly accurate terrain elevation data with a grid cell size of 1 m by 1 m. The DTM was first processed to include flow routes for the locations of known culverts, before undertaking the flow direction analysis in GIS.

Based on the flow direction layer, two GIS layers were created with streamlines, or runoff pathways, draining areas greater than 0.1 ha and areas greater than 1 ha. The results of the analysis are included in a series of maps in Appendix D.

Superimposed on the maps in Appendix D is a layer showing the alignment of open and culverted watercourses within the site and the wider area. As expected, the runoff pathways coincide with the actual watercourse. However, runoff pathways are also shown in areas away from watercourses. This can be explained by (a combination of) the following:

- Runoff pathways could simply represent overland runoff directions. No actual watercourse needs to exist, in particular for the finer grained (0.1 ha) pathways. For example, the south-west corner of the site shows a number of pathways which indicate a high degree of wetness and runoff flowing through the area;
- Infiltration may occur, reducing overland flows, and an actual watercourse may therefore not have formed. Shallow surface water could still follow a similar flow direction as indicated by the pathways, in particular in areas with shallow bedrock;
- Small scale topographic features not represented by the LiDAR DTM could affect runoff pathways. In such cases, indicated pathways may be inaccurate; and
- Urban drainage system not shown on the maps could capture and divert runoff. This is visible to the north of Malletsheugh farm where significant runoff pathways are shown over existing roads. Historic maps show an open watercourse in this area which is likely to have been culverted as part of the road construction and urban development.

Generally, flow pathways are a useful indicator for the natural drainage regime and drainage directions. The alignment of the pathways can be used to identify areas of high wetness, areas where runoff may be obstructed, areas at risk of overland flooding, etc.

2.5 Drainage areas

Based on the flow pathway information, drainage areas were delineated using the GIS. The drainage areas or catchments indicate the surface area that drains through a specified point. Here, a number of such drainage area outlet points was chosen along Burns A to D and a number of smaller streams downstream of the site boundary. Appendix D includes maps showing the extent of each drainage area and Table 2.1 describes the drainage areas.

Table 2.1: Description of drainage area (ranked by surface area, descending)

Watercourse	Outlet location	Surface area (ha)		Description
		Total	Within site	
Burn D	Kirklands Road culvert inlet	131	22	Largest watercourse flowing through the site. Watercourse springs to the south-west of the site.
Burn A	Hunter Drive culvert inlet	117	8	Catchment originates upstream of the site, to the west of the M77 motorway. Only a minor part of the site is drained through this area.
Burn C	Culvert inlet behind Newton Court	40	39	Drainage areas entirely contained within the site boundary. Drains the majority of the southern half of the site.
Burn B	Culvert inlet at Mearns Primary School sports fields	25	24	Drains the areas adjacent to the A77 road and Ayr Road. It is assumed that runoff from areas to the south of Ayr Road are conveyed to the north through culverts below the road.
Burn D (south-west site corner)	Culvert under A726 road	15	11	A sub-drainage area of Burn D draining the south-west corner of the site.
Burn A (Malletsheugh drainage area)	Hunter Drive culvert inlet	12	7	This drainage is shown to discharge to Burn A via Hunter Drive. Historically, an open watercourse was present in this area and currently runoff is discharged via a culvert with an inlet at the Traquair Gardens roundabout to Burn A.
Burn E	Culvert inlet behind Cheviot Drive	11	3	Drains predominantly an area to be developed to the east of the site and only a small area within the site. The drainage area is thought to be larger than shown on the maps in Appendix D due to the presence of a culvert outlet on the western drainage area boundary. This culvert is likely to drain land near Faside House.

2.6 Relevant Water Features

As part of this study, a comprehensive walkover survey was undertaken throughout the site in July 2013. The purpose of the survey was to identify any relevant water management and drainage features, including:

- Verification of theoretical flows paths;
- Identification of soil conditions;
- Identification and visual assessment of culvert inlets and outlets;
- Assessment of stream channel and floodplain geomorphology; and
- Identification of other features and structures which may affect the hydrological regime.

A photographic record and description of all features is included in Appendix A for reference purposes.

2.7 Water Quality

Water quality data, published by SEPA (n.d.), is available for the Capelrig Burn/Auldhouse Burn. The overall status of this watercourse as well as the ecological and hydromorphological statuses were “poor” in 2011. Key pressures include morphological alterations and point and diffuse source pollution due to sewage disposal. Environmental objectives set by SEPA are to have a “moderate” status by 2015 with respect to morphological alterations and a “good” overall status by 2027.

Although the water quality information of the Capelrig Burn/Auldhouse Burn may not be representative of the small streams within the site, it does indicate any pressures on downstream water quality. This information can be used to identify opportunities within the site to improve water quality within and downstream of the site.

ERC noted that improvement works to unsatisfactory combined sewer overflows (UCSO) within the Auldhouse Burn catchment are planned by Scottish Water for the near future. This is likely to have a positive impact on water quality.

3 FLOOD RISK

3.1 Regulatory Framework

Government planning policy on flooding is provided by Scottish Planning Policy (SPP) (2010) (Paragraphs 196 to 211). Flood management policy in SPP is based on the following principles:

- Developers and planning authorities must give consideration to the possibility of flooding from all potential sources including from rivers, coastal waters, overland flow, groundwater, reservoirs and drainage systems;
- New development should be free from significant flood risk from any sources;
- In areas characterised as "medium to high" flood risk for watercourses and coastal flooding, new development should be focused on built up areas and all development must be safeguarded from the risk of flooding;
- The storage capacity of functional flood plains should be safeguarded from further development. The functional flood plains comprise areas generally subject to an annual exceedance probability (AEP) of flooding of 0.5% or greater;
- Drainage is a material consideration and the means of draining a development should be assessed. Any drainage measures proposed should have a neutral or better effect on the risk of flooding both on and off the site.

SPP includes a Risk Framework approach which identifies flood risk in three main categories:

- **Little or no risk area** (0.1% AEP or less). No constraints to development due to flood risk.
- **Low to medium risk area** (between 0.1% AEP and 0.5% AEP). Usually suitable for most developments.
- **Medium to high risk area** (0.5% AEP or greater). Generally not suitable for essential civil infrastructure such as hospitals, fire stations, emergency depots, schools, care homes and ground-based electrical telecommunications equipment unless subject to an appropriate long term flood risk management strategy.

Note that SPP does not provide a quantified risk framework for flood sources other than rivers and coastal waters. In practice, other sources are typically addressed on a qualitative basis following other guidance, for example as issued by the planning authority, and industry best practices. Overland and groundwater flood risk is typically reduced by adopting a suitable drainage system. ERC requires that all drainage systems within the site should be adopted by Scottish Water where possible.

The following guidance documents should be taken into account during the planning and design stages of the development:

- Dicker, S., McKay, G., Ions, L., & Shaffer, P. (2010). *Planning for SuDS – making it happen*. London: CIRIA.
- Scottish Water. (2007). *Sewers for Scotland 2nd Edition*. Swindon: WRc.
- SEPA. (2010). *Technical flood risk guidance for stakeholders*.
- SUDS Working Party. (2005). *Drainage assessment; A guide for Scotland*.
- SUDS Working Party. (2010). *SuDS for roads*.
- Woods Ballard, B. (2007). *The SUDS Manual*. London: CIRIA.

3.2 Watercourse Flooding

3.2.1 Channel Conveyance Capacity

Flooding may occur along open watercourses within the development area during periods of heavy rainfall whereby flow rates exceed the conveyance capacity of the channel. Open watercourses within the site include Burn B along the northern side of the A77 road, Burn C through the centre of the site and Burn D near the southern site boundary.

The channels of Burns B and C are typically no more than 2 m wide and the topography suggests floodplains associated with these streams are constrained to a narrow strip of land either side of the river. Floodplains along burn C are generally well defined by a low lying area adjacent to the river before the land rises at either side (Figure 3.1).

Burn D is somewhat larger than Burn C and the topography suggests that floodwaters could potentially inundate a wider area near the eastern site boundary (Figure 3.1).

Figure 3.1: Burn C (left) and Burn D (right)

3.2.2 Culvert Blockage

Flood levels along all watercourses within and downstream of the site could be affected by a partial or complete blockage of culverts. If a blockage occurs, flood waters could back up and cause flooding at the culvert inlet or further upstream. Blockage could occur at an inlet if debris (brush, tree logs, household waste) obstructs flows entering the culvert. Additionally, blockage could occur within a culvert, for example, due to a (partial) collapse of the culvert or trapped debris.

Consultation with ERC's Roads and Transportation Service highlighted that the structural conditions of the culverts are unknown. CCTV and topographic surveys would be required in the first instance to document the culvert dimensions, connectivity and structural conditions. This information could then be used to make an assessment of flow capacity and determine the need for remedial works.

As part of this project, a high level assessment of culvert capacity and potential flood risk due to the culvert has been made based on observations recorded during the walkover survey and desk based assessments. Appendix A includes qualitative information on flow capacity and blockage risk. Based on this information, a relative ranking from high risk to low risk culverts has been made as shown in Table 3.1 below. Note that this assessment primarily considers the most upstream culvert in each watercourse. Many other culverts exist further downstream and these could all contribute to flood risk.

Table 3.1: Ranking of culverts by potential flood impact

Relative risk	Watercourse	Culvert location	Trash screen present	Potential impact aspects
Higher	Burn C	Behind Newton Court	Yes	• Small culvert dimensions; • Culvert directly located behind many properties.
	Burn D	Kirklands Road	Yes	• Wider culvert than at Burn C; • Watercourse has also largest catchment of all watercourses; • Culvert located within built-up area; • Road levels relatively low above culvert; • Road is only access road to Kirklands Drive estate; • Burn joins Burn C and flood risk along the downstream reach is therefore identical.
	Burn B	Mearns Primary School sports fields	Yes	• Relative small drainage area; • Blockage may cause flooding of sports fields; • Blockage of culvert under Hunter Drive could potentially cause flooding of this road.
Lower	Burn A	Netherplace Road	Unknown	• Blockage would not affect existing developments; • Downstream watercourse is less culverted compared with other watercourses.

All drainage areas within the site discharge to culverted watercourses as shown in Appendix D. It is therefore essential that the risk of culvert blockage is assessed in further detail during the planning and design stage of the development.

3.3 Greenfield Runoff

The principal method to ensure that the development of the site does not increase downstream flood risk, is to reduce or limit the runoff rate from the site. Such runoff rates are not specified by SPP and are therefore typically imposed by the planning authority. ERC policy is to require runoff from the site to be limited to the runoff rate during 50% AEP storm condition for the site prior to development (greenfield). This would apply for storms up to 3.3% AEP conditions. Precipitation under more extreme conditions (up to the 0.5% AEP 2080s climate conditions) should be conveyed and discharged in a controlled manner, for example by ponding of surface water in parks or car parks etc.

The 50% AEP greenfield runoff rate has been assessed using the Institute of Hydrology Report 124 Flood Estimation for Small Catchment method (Marshall & Bayliss, 1994), also known as the IH 124 method. Full details of the calculations are included in Appendix B. Depending on the soil infiltration capacity parameters adopted, the 50% AEP runoff rate is between 6.0 and 7.1 l/s/ha approximately. Consistent with other developments in the wider area, ERC requires that runoff rates from the site are limited to 6.5 l/s/ha.

3.4 Stormwater Attenuation

To reduce the flow rates at the outfalls of the stormwater drainage system for the development, temporary storage of the precipitation is required within the SuDS during heavy rainfall. Storage could take place throughout the drainage system including within the piped network, ditches, swales, infiltration trenches, attenuation ponds, etc.

It is essential that developers from the outset allow for sufficient space in the layout of the development to provide stormwater attenuation. An indicative "space allowance" has therefore been calculated based on the difference between the 60 minute 3.3% AEP precipitation volume and the volume that can be discharged at 6.5 l/s/ha for the same duration. The volume is then divided by a typical average storage depth to obtain a storage area allowance. The results are also affected by the percentage of the site area that will be roofs, hardstandings and other impermeable areas. Two scenarios, 75% and 100% impermeability, have therefore been considered. The results are summarised in Table 3.2 below and full calculation details are provided in Appendix C.

Table 3.2: Assessment of indicative stormwater storage allowance

Impermeable development area (%)	Precipitation Volume (m^3/ha)		Stormwater storage allowance		
	50% AEP greenfield	3.3% post-development	(m^3/ha)	(m^2/ha) [1]	(area-%) [1]
75	23	228	205	410	4.1
100	23	261	238	475	4.8

Notes
1. Assumes an average storage depth of 0.5 m.

The results in Table 3.2 indicate that between 4 and 5% of surface area may be required to provide stormwater attenuation SuDS. The actual space required depends on the percentage of impermeable areas and the type of SuDS adopted.

4 DEVELOPMENT WATER MANAGEMENT PRINCIPLES

4.1 Purpose

The Maidenhill/Malletsheugh greenfield release site will be developed in several phases by various developers. It is therefore essential that a strategic and coherent approach is taken in relation to water management due to the hydrologically inter-linked nature of individual development areas within the site. Additionally, ERC requires a strong green network to be incorporated throughout the area following the principles of IGI. It is considered that the framework of the Green Network and design of IGI should be aligned with the hydrological (and other environmental) characteristics of the site.

The key aim of this report and the Development Framework prepared by ERC is therefore to identify the overall water management requirements and principles that should be adhered to. This information will be beneficial to developers as it provides the constraints and opportunities to be considered during the design of individual development plots. The water management approach presented in this report should not be interpreted as being prescriptive but aims to provide the high level principles that should be considered.

4.2 High-Level Drainage Options

The key principle with regards to urban drainage is that it should following SuDS principles (see for example Dicker, McKay, Ions, & Shaffer, 2010; Woods Ballard, 2007). These principles are widely understood and incorporated into the design of new developments and do not require further explanation in this report. In summary, the following overarching principles apply:

1. Drainage systems should follow the natural hydrological and drainage regime where possible;
2. Stormwater should be buffered within the site to reduce downstream flood risk; and
3. Water quality treatment should be provided to maintain or enhance downstream water quality.

As part of this project, the first two principles have been considered and translated into two high-level drainage options. These drainage options include a delineation of drainage areas, based on the natural drainage area and a consideration of the extent of individual development plots. Option 1 follows the natural drainage areas to the greatest degree whereas option 2 includes a modified delineation of drainage areas in the southern part of the site as may be required by the development layout. In either option, drainage area boundaries are indicative only and may need to be adjusted taking into environmental and development constraints.

In addition to the drainage area boundaries, indicative internal stormwater conveyance directions are indicated as well as potential outfall locations into the Burns A, B, C and D. Furthermore, the stormwater attenuation space allowance is shown by circles with a surface area of 4.5% (Section 3.4) of the relevant drainage area. Although the schematic representation in Appendix E suggests an “end of pipe” attenuation solution as could, for example, be implemented using a SuDS pond structure, attenuation may take place in a distributed manner throughout the SuDS within each drainage area.

Table 4.1 and provides the rationale for each development drainage area (A to G).

Table 4.1: High-level development drainage areas (see also Appendix E)

Drainage area	Option	Potential outfall location	Rationale and comments
A	1 and 2	Burn A upstream of Netherplace Road	Drainage area defined by adjacent existing roads. Incorporates small area currently draining towards Burn B. This is not considered critical as Burn A largely consists of open channels.
B	1 and 2	Burn B upstream of Hunter Drive culvert	Drainage area defined by adjacent existing roads. Most of this area naturally drains towards Burn B.
C	1 and 2	Upstream extent of Burn B	Drainage area defined by adjacent existing roads. Natural drainage is towards Burn B. The drainage outfall would require conveyance of stormwater through drainage area B. Options for an open ditch along Ayr Road/A77 road be may considered. Alternatively an outfall through drainage area A towards Burn A may be considered.
D	1 and 2	Upstream extent of Burn B	Drainage area defined by existing road to the north and natural watershed to the south. Most of this area may not be developed due to topographic and geological constraints. Outfall would require a culvert crossing below the A77 road.
E	1	Two locations along Burn C	Drainage area coincides approximately with natural drainage areas of Burn C. Outfalls anywhere along Burn C could be considered.
	2	Burn C upstream of footpath culvert	Reduction of drainage area under option 1 to include only area north of Burn C.
F	1	Burn D upstream of A726 road culvert	Drainage area defined by watershed to the north and existing roads to the south and west. South-western corner of area may not be suitable for development due to poor soil conditions and presence of peat.
	2		Slight increase in drainage area to incorporate parts of drainage areas E and G.
G	1	Burn D near south-eastern site boundary	Drainage areas defined by watershed to the north and existing road the south. Outfall anywhere along Burn D could be considered.
	2		Increase in drainage area to incorporate area south of Burn C. This increase in drainage area would not increase flood risk as Burn C and D confluence approximately 500 m downstream of the site. Additionally, culverts along Burn D, upstream of the confluence are estimated to be larger than along Burn C. This may therefore be beneficial for flood risk management.

4.3 Development Design Principles

The following water management principles to be considered during the planning and design stage of individual development areas within the Maidenhill/Malletsheugh site have been developed in consultation with ERC:

Flood risk

1. Development should not take place within areas at medium to high risk of flooding from watercourses. This may include areas adjacent to Burn C and D. Detailed flood risk assessment should be undertaken to demonstrate the extent of the floodplain in these areas and compliance with SPP.

2. A minimum freeboard above 0.5% AEP flood levels of 500 mm should be adopted for road and property levels. Additionally, freeboard may be required for high risk areas including schools, public buildings, near culvert inlets etc.
3. The impact of culverts becoming blocked should be assessed in line with the "Culvert Design and Operation Guide" (Balkham, Fosbeary, Kitchen, & Rickard, 2010).
4. Flood risk assessments should be checked and signed off by a qualified professional.

Drainage

5. The design of the drainage system should follow the principles of SuDS (e.g. Dicker et al., 2010; SUDS Working Party, 2010; Woods Ballard, 2007) and should be aligned with the natural drainage and hydrological regime where possible.
6. Two levels of treatment should be provided for roads and residential areas in line with the above guidance documents on SuDS.
7. Runoff should be limited to 6.5 l/s/ha for storms up to 3.3% AEP conditions. This rate should be adjusted where the drainage area at the drainage system outlet is significantly larger than the natural drainage area.
8. Precipitation under extreme storm conditions (up to the 0.5% AEP 2080s climate conditions) should be conveyed and discharged in a controlled manner without causing flooding to properties.
9. No drainage system should be connected with Burn E near Cheviot Drive or culverts connecting with this burn.
10. All SuDS should be designed to adoptable standards. Consultation with SW is recommended to maximise opportunities to integrate SuDS with a Green Network.
11. The conditions of receiving culverted watercourses should be assessed by ways of a CCTV survey.
12. Drainage assessments should be checked and signed off by a qualified professional.
13. The constructed SuDS should be audited and signed off by a suitably qualified professional to confirm the construction complies with relevant guidance.
14. All foul drainage should be connected to the public sewer system.
15. A suitable buffer zone should be left around the watercourses, and opportunities for habitat enhancement investigated and implemented.

Water Environment and Integrated Green Infrastructure

16. Culverting of watercourses should be avoided in line with SEPA policy (SEPA, 2006).
17. Open watercourses such as ditches or swales are preferred to underground stormwater conveyance and storage systems.
18. A suitable buffer zone should be left around all watercourses and opportunities for habitat enhancement should be explored and implemented where possible.
19. Principles of IGI should be considered as part of the development layout design and opportunities for alignment with hydrological features should be exploited, for example by creating a green network (access network, open space provision, etc.) around open watercourses or wetland habitats.
20. Development of areas consisting of peat and Groundwater Dependent Terrestrial Ecosystems (GWDTE) should be avoided where possible.

5 CONCLUSIONS

This study evaluated the hydrological and drainage characteristics of the Maidenhill/Malletsheugh site to inform the development of a sustainable water management component of a Development Framework document to be prepared by ERC.

The site predominantly consist of agricultural land drained by four unnamed small watercourses, in this study referred to as Burns A, B, C and D. The burns flow in a north-easterly direction towards the existing Newton Mearns built-up area before discharging in the Capelrig Burn and Auldhouse Burn. The watercourses within Newton Mearns are culverted over substantial distances.

Within the urban area, flooding could occur if flow rates exceed the culvert capacity or if blockages occur by debris becoming trapped at culvert inlets or within the culverts. To manage this risk, ERC inspects and maintains these culverts as and when required. An assessment of the capacity and condition of downstream culverts is required as part of the drainage system design to ensure there is no increase in downstream flood risk.

In consultation with ERC, a number of principles should be considered by developers during the design and planning stage of individual development areas. High-level drainage options have also been prepared including the extent of drainage, principal internal stormwater conveyance routes and potential outfall locations. These options demonstrate that a drainage scheme aligned with the natural hydrological regime is feasible for the entire site.

Flood risk within the site should be minimised by developing outwith the functional floodplain and adopting suitable freeboards above flood levels.

SuDS should be incorporated throughout the development to prevent flooding within the site, to reduce downstream flood risk and to maintain or enhance the water quality of the runoff and the receiving surface water.

Information presented in this report should also be used to inform the design of the development layout following the principles of IGI. The surface and groundwater management systems adopted should wherever possible be in alignment with and inform the framework for the Green Network throughout the site and links to existing communities. For example, an access network and open space could be created along open watercourses or near wetland habitats.

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APPENDICES

A Relevant Water Features

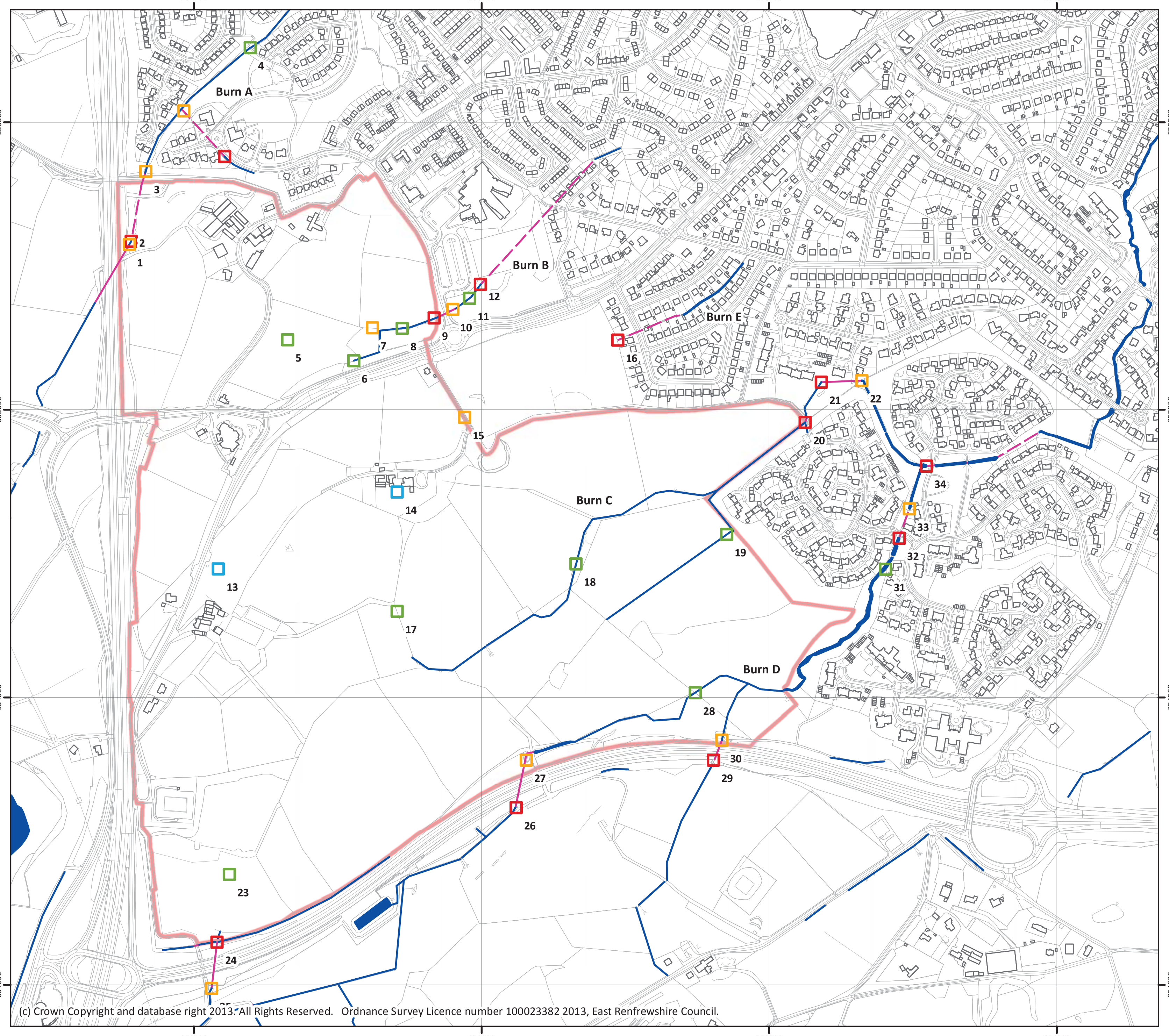
B Greenfield Runoff Estimation

C Attenuation Volume Estimation

D Existing Drainage and Runoff characteristics

E High-Level Development Drainage Options

A RELEVANT WATER FEATURES



Legend

Water Features

- Other
- Culvert inlet
- Culvert outlet
- Well
- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Site boundary

Do not scale this map

Client	East Renfrewshire Council
Project	Maidenhill/Malletsheugh Hydrological Study
Title	Hydrological Features
Status	DRAFT
Drawing No.	164324-008
Revision	
Scale	1:6,500
Size	A3
Date	31 July 2013
Drawn	JS
Checked	FH
Approved	FH

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Feature 1

Culvert outlet

Burn A downstream of M77 motorway

Feature 2

Culvert inlet

Burn A downstream of M77 motorway

Circular pipe, no trash screen installed. This inlet is approximately 5 m downstream of Feature 1. Downstream of this inlet is shown as an open channel on OS maps. This reach has possibly recently been culverted.

Feature 3

Culvert outlet

Burn A at Netherplace Road

Feature 4

River channel

Burn A

Feature 5

Other feature

Assumed disused peripheral ditch around disused industrial site

Feature 6

Other feature

Possible location of outlet of culvert under A77 road

Feature 7

Culvert outlet

Field drain outlet

Feature 8

River channel

Burn B near Hunter Drive

Feature 9

Culvert inlet

Burn B upstream Hunter Drive

Circular pipe, no trash screen installed.

Feature 10

Culvert outlet

Burn B downstream of Hunter Drive

Culvert outlet appears drowned under low flow conditions.

Feature 11

River channel

Burn B near Mearns Primary School

Channel in topographic low area. Fully overgrown during summer season.

Feature 12

Culvert inlet

Burn B upstream of Mearns Primary School sports fields

Inlet fitted with trash screen appears relatively new and in good condition.

Feature 13

Well

Location of well near Maidenhill Farm indicated on OS maps.

No photograph available.

Feature 14

Well

Location of well near Faside House indicated on OS maps.

No photograph available.

Feature 15

Culvert outlet

Approximate location of culvert outlet. Exact drainage area not known. Likely to drain an area at or near Faside House.

No photograph available.

Feature 16

Culvert inlet

Burn E at Cheviot Drive

No drainage systems from the Maidenhill/Malletsheugh site to be connected to this culvert as this may otherwise increase downstream flood risk.

No photograph available.

Feature 17

Other feature

Marshy area south of Faside House. Runoff collects in this area before forming Burn C.

Feature 18

River channel

Burn B near the centre of the site

Narrow watercourse and floodplain at either side of the channel.

Feature 19

Other feature

Ditch south of Burn C

Intercepts runoff predominantly from the south and west.

Feature 20

Culvert inlet

Burn C, culvert under footpath behind Newton Court

Shown on photo is river channel downstream of culvert. Culvert itself is a relatively short culvert under footpath only.

Feature 21

Culvert inlet

Burn C behind Newton Court

Culvert appears relatively new and in good condition with trash screen fitted.

Feature 22

Culvert outlet

No photograph available.

Feature 23

Other feature

Marshy area at southwest corner of site

Runoff collects in this area and drains towards culvert under A726 road (Feature 24). Peat of moderate to shallow depth likely to be present in area.

Feature 24

Culvert inlet

Burn D at A726 road

Culvert constructed as part of A726 between 2003 and 2005. Culvert appears in good condition. No trash screen fitted however, fencing around inlet area reduces blockage risk.

Feature 25

Culvert outlet

No photograph available.

Feature 26

Culvert inlet

No photograph available.

Feature 27

Culvert outlet

No photograph available.

Feature 28

River channel

Burn D near southern site boundary.

Narrow channel with low river banks, slightly meandering. Floodplain may be relatively wide along this reach.

Feature 29

Culvert inlet

No photograph available.

Feature 30

Culvert outlet

No photograph available.

Feature 31

River channel

Burn D near Kirklands Road

Burn flows through deep valley as along the edge of the existing built-up area of Newton Mearns. River banks become lower as it approaches Kirklands Road culvert (Feature 32).

Feature 32

Culvert inlet

Burn D at Kirklands Road

Culvert appears in good condition and substantial trash screen is likely to reduce risk of blockages.

B GREENFIELD RUNOFF ESTIMATION

Greenfield Runoff Calculation, utilising a WRAP value of 0.37

Institute of Hydrology Report No.124 - Flood Estimation for Small Catchments (IH124)

Flow Calculation

(blue)	User Defined
(yellow)	Calculated

Project No.	164324
Project Title	Maidenhill
Version No.	1

Calculation by:	JS	**Date:**	25/07/2013
Checked by:	FH	**Date:**	25/07/2013

Flow Summary:

Return Period (years)	Flow (m^3/s)	Flow (l/s)	Flow (Ml/d)
2	0.01	6.0	0.52
5	0.01	7.4	0.64
10	0.01	9.4	0.81
25	0.01	12.0	1.04
50	0.01	14.4	1.24
100	0.02	17.4	1.51
200	0.02	19.9	1.72
200+cc	0.02	23.9	2.06

Development size	Method
0 – 50 ha	The Institute of Hydrology Report 124 *Flood estimation for small catchments* (Marshall & Bayliss, 1994) is to be used to determine peak greenfield runoff rates for QBAR. Where developments are smaller than 50 ha, the analysis for determining greenfield discharge rate should use 50 ha in the formula but linearly interpolate the flow rate value based on the ratio of the size of the development to 50 ha. FSSR 14 (IH, 1993) regional growth curve factors should be used to calculate greenfield peak flow rates for 1-, 30- and 100-year return periods.
50-200 ha	IH Report 124 should be used to calculate greenfield peak flow rates. Regional growth factors to be applied.
Above 200 ha	IH Report 124 can be used for catchments that are much larger than 200 ha. However, for schemes of this size it is recommended that the Flood Estimation Handbook (FEH) (IH, 1999) should be applied. Both the statistical approach and the unit hydrograph approach should be used to calculate peak flow rates. However, where FEH is not considered appropriate for the calculation of greenfield runoff for the development site, for whatever reasons, IH 124 should be used.

OS Grid Ref: NS 52812, 54723

AREA: 1 Ha — Catchment area.
0.01 km^2

SAAR: 1430 mm — From FEH CD-ROM / literature.
NB If catchment not defined in FEH, assume SAAR from neighbouring FEH-defined catchments

SOIL: 0.37 — SOIL = 0.15 x (WRAP1) + 0.30 x (WRAP2) + 0.40 x (WRAP3) + 0.45 x (WRAP4) + 0.50 x (WRAP5)
(See Winter Rain Acceptance Potential Map)

WRAP Class	1	2	3	4	5
Factor	0.15	0.3	0.37	0.45	0.5
Fraction	0	0	1		0

$QBAR_{rural}$

$QBAR_{rural}$: 0.33 m^3/s — $QBAR = 0.00108*AREA^{0.89}*SAAR^{1.17}*SOIL^{2.17}$ (IH124 7.1)

if site is <50ha — Area Reductio 0.02 (ratio of size of site to 50ha)
$QBAR_{rural\ (adjusted)}$: 0.01 m^3/s — Applicable if area is < 50 ha

$QBAR_{urban}$

CWI: 123.93 — Catchment Wetness Index

SAAR	<835	>=835
CWI	=0.1745*SAAR-23.238	=0.0024*SAAR+120.5

CIND: 37.59 — Catchment Index — CIND = 102.4*SOIL+0.28*(CWI-125) (IH124 7.2)

NC: 0.58 — Rainfall Continentality Factor — NC = 0.92-0.00024*SAAR (for 500≤SAAR≤1100mm); NC = 0.74-0.000082*SAAR (for 1100≤SAAR≤3000mm) (IH124 7.3) — NC: 0.5768 / 0.62274

URBAN: 0 — Fraction of catchment under urban land use

$QBAR_{urban}/QBAR_{rural}$: 1.00 — $QBAR_{urban}/QBAR_{rural}$ = [1+URBAN]^2NC*[1+URBAN{(21/CIND)-0.3}] (IH124 7.4)

$QBAR_{urban}$: 0.01 m^3/s

For conservative design, choose higher of $QBAR_{urban}$ and $QBAR_{rural}$

QBAR: 0.01 m^3/s

Hydrometric Area: 2 — See map opposite for hydrometric areas within Scotland

Growth Curve Factors

Region	Hydrometric Area	Return Period 2	5	10	25	50	100	200	500
N Scotland	1	0.9	1.2	1.45	1.81	2.12	2.48	2.8	3.25
S Scotland	2	0.91	1.11	1.42	1.81	2.17	2.63	3	3.45
	$Q_{return\ period}$ (m^3/s)	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02

(Growth factors and hydrometric areas taken from CIRIA SUDS Manual C697)

Greenfield Runoff Calculation, utilising a WRAP value of 0.4

Institute of Hydrology Report No.124 - Flood Estimation for Small Catchments (IH124)

Flow Calculation

(blue)	User Defined
(yellow)	Calculated

Project No.	164324		
Project Title	Maidenhill		
Version No.	1		
Calculation by:	JS	**Date:**	25/07/2013
Checked by:	FH	**Date:**	25/07/2013

Flow Summary:

Return Period (years)	Flow (m^3/s)	Flow (l/s)	Flow (Ml/d)
2	0.01	7.1	0.62
5	0.01	8.7	0.75
10	0.01	11.1	0.96
25	0.01	14.2	1.23
50	0.02	17.0	1.47
100	0.02	20.6	1.78
200	0.02	23.5	2.03
200+cc	0.03	28.3	2.44

Development size	Method
0 – 50 ha	The Institute of Hydrology Report 124 *Flood estimation for small catchments* (Marshall & Bayliss, 1994) is to be used to determine peak greenfield runoff rates for QBAR. Where developments are smaller than 50 ha, the analysis for determining greenfield discharge rate should use 50 ha in the formula but linearly interpolate the flow rate value based on the ratio of the size of the development to 50 ha. FSSR 14 (IH, 1993) regional growth curve factors should be used to calculate greenfield peak flow rates for 1-, 30- and 100-year return periods.
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OS Grid Ref: NS 52812, 54723

AREA: 1 Ha — Catchment area.
0.01 km^2

SAAR: 1430 mm — From FEH CD-ROM / literature.
NB If catchment not defined in FEH, assume SAAR from neighbouring FEH-defined catchments

SOIL: 0.40 — SOIL = 0.15 x (WRAP1) + 0.30 x (WRAP2) + 0.40 x (WRAP3) + 0.45 x (WRAP4) + 0.50 x (WRAP5)
(See Winter Rain Acceptance Potential Map)

WRAP Class	1	2	3	4	5
Factor	0.15	0.3	0.4	0.45	0.5
Fraction	0	0	1		0

$QBAR_{rural}$

$QBAR_{rural}$: 0.39 m^3/s — $QBAR = 0.00108*AREA^{0.89}*SAAR^{1.17}*SOIL^{2.17}$ (IH124 7.1)

if site is <50ha — Area Reduction: 0.02 (ratio of size of site to 50ha)
$QBAR_{rural\ (adjusted)}$: 0.01 m^3/s — Applicable if area is < 50 ha

$QBAR_{urban}$

CWI: 123.93 — Catchment Wetness Index

SAAR	<835	>=835
CWI	=0.1745*SAAR-23.238	=0.0024*SAAR+120.5

CIND: 40.66 — Catchment Index — CIND = 102.4*SOIL+0.28*(CWI-125) (IH124 7.2)

NC: 0.58 — Rainfall Continentality Factor — NC = 0.92-0.00024*SAAR (for 500≤SAAR≤1100mm); NC = 0.74-0.000082*SAAR (for 1100≤SAAR≤3000mm) (IH124 7.3)

NC	
	0.5768
	0.62274

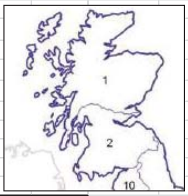
URBAN: 0 — Fraction of catchment under urban land use

$QBAR_{urban}/QBAR_{rural}$: 1.00 — $QBAR_{urban}/QBAR_{rural}$ = [1+URBAN]^2NC*[1+URBAN{(21/CIND)-0.3}] (IH124 7.4)

$QBAR_{urban}$: 0.01 m^3/s

For conservative design, choose higher of $QBAR_{urban}$ and $QBAR_{rural}$
QBAR: 0.01 m^3/s

Hydrometric Area: 2 — See map opposite for hydrometric areas within Scotland



Growth Curve Factors

Region	Hydrometric Area	2	5	10	25	50	100	200	500
		Return Period							
N Scotland	1	0.9	1.2	1.45	1.81	2.12	2.48	2.8	3.25
S Scotland	2	0.91	1.11	1.42	1.81	2.17	2.63	3	3.45
	$Q_{return\ period}$ (m^3/s)	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03

(Growth factors and hydrometric areas taken from CIRIA SUDS Manual C697)

C ATTENUATION VOLUME ESTIMATION

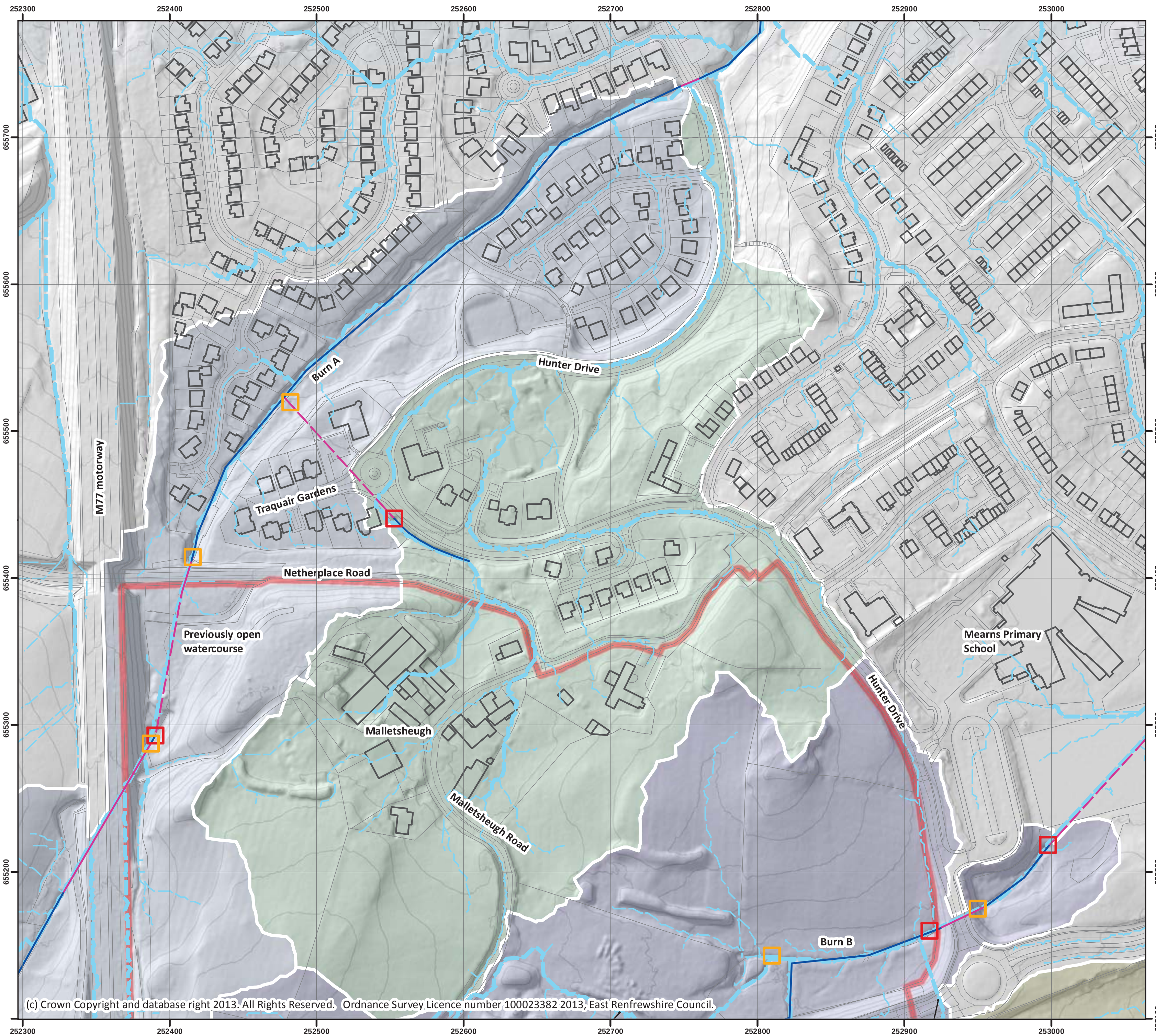
Attenuation Volume Calculation, 75% Impermeable

	Impermeable	Permeable
Pre-development	0%	100%
Post-development	75%	25%
Runoff coefficient	1	0.5
Greenfield runoff rate 50% AEP	6.5	l/s/ha
Storm duration	60	min
Greenfield runoff volume	23	m3/ha
3.3%AEP rainfall depth	26.1	mm
Development runoff volume	228	m3/ha
Attenuation requirement	205	m3/ha
Average attenuation depth	0.5	m
Attenuation land take	410	m2/ha
	4.1	%

Attenuation Volume Calculation, 100% Impermeable

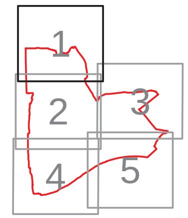
	Impermeable	Permeable
Pre-development	0%	100%
Post-development	100%	0%
Runoff coefficient	1	0.5
Greenfield runoff rate 50% AEP	6.5	l/s/ha
Storm duration	60	min
Greenfield runoff volume	23	m3/ha
3.3%AEP rainfall depth	26.1	mm
Development runoff volume	261	m3/ha
Attenuation requirement	238	m3/ha
Average attenuation depth	0.5	m
Attenuation land take	475	m2/ha
	4.8	%

D EXISTING DRAINAGE AND RUNOFF CHARACTERISTICS



Legend

- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Runoff pathway (draining > 0.1 ha)
- Runoff pathway (draining > 1 ha)
- Site boundary
- Terrain contour (2m)
- Culvert inlet
- Culvert outlet
- Well



Do not scale this map

Client	East Renfrewshire Council
Project	Maidenhill/Malletsheugh Hydrological Study
Title	Existing drainage and runoff characteristics (1 of 5)
Status	DRAFT
Drawing No.	164324-001
Revision	A
Scale	1:2,500
Size	A3
Date	9 July 2013
Drawn	JS
Checked	NG
Approved	NG

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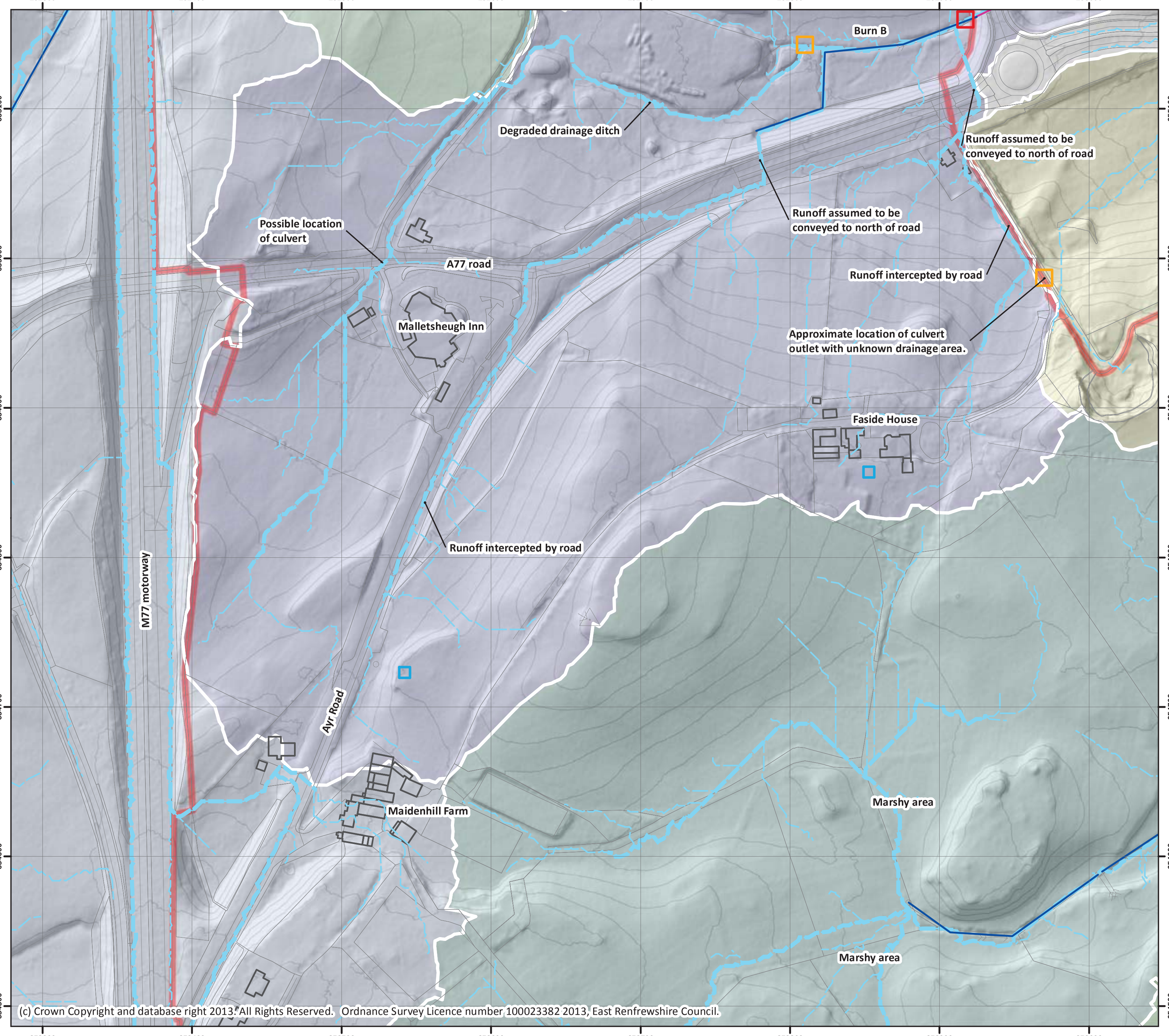
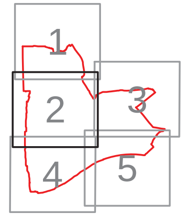
Fax: 0141 341 5045



Legend

- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Runoff pathway (draining > 0.1 ha)
- Runoff pathway (draining > 1 ha)
- Site boundary
- Terrain contour (2m)
- Culvert inlet
- Culvert outlet
- Well



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Client: East Renfrewshire Council

Project: Maidenhill/Malletsheugh Hydrological Study

Title: Existing drainage and runoff characteristics (2 of 5)

Status: DRAFT

Drawing No.	Revision
164324-003	A

Scale		Date
1:2,500	A3	9 July 2013

Drawn	Checked	Approved
JS	NG	NG

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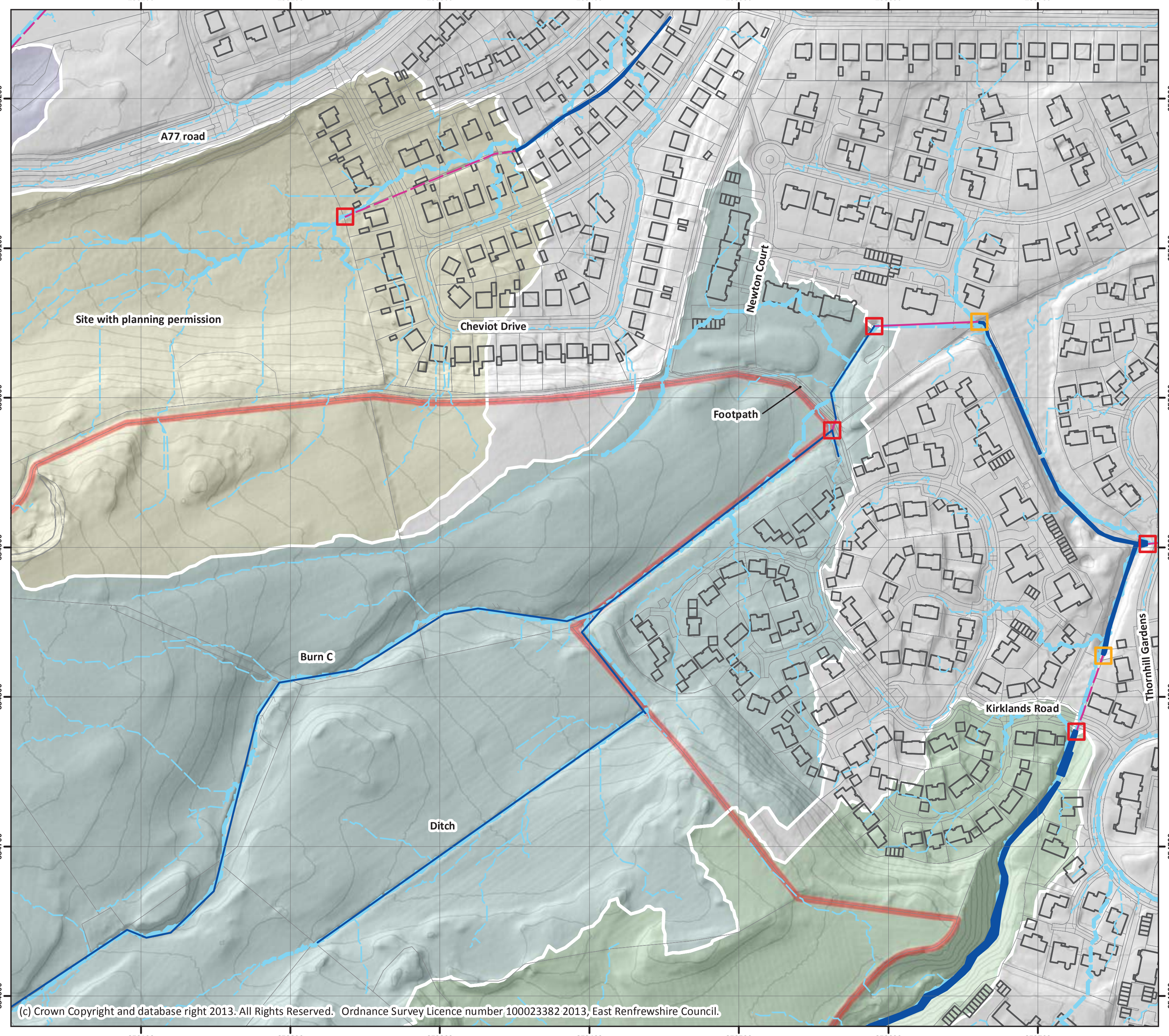
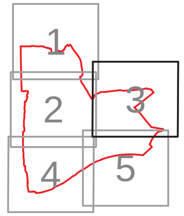


Legend

- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Runoff pathway (draining > 0.1 ha)
- Runoff pathway (draining > 1 ha)
- Site boundary
- Terrain contour (2m)
- Culvert inlet
- Culvert outlet
- Well



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Client	East Renfrewshire Council
Project	Maidenhill/Malletsheugh Hydrological Study
Title	Existing drainage and runoff characteristics (3 of 5)
Status	DRAFT
Drawing No.	164324-002
Revision	A
Scale	1:2,500
Size	A3
Date	9 July 2013
Drawn	JS
Checked	NG
Approved	NG

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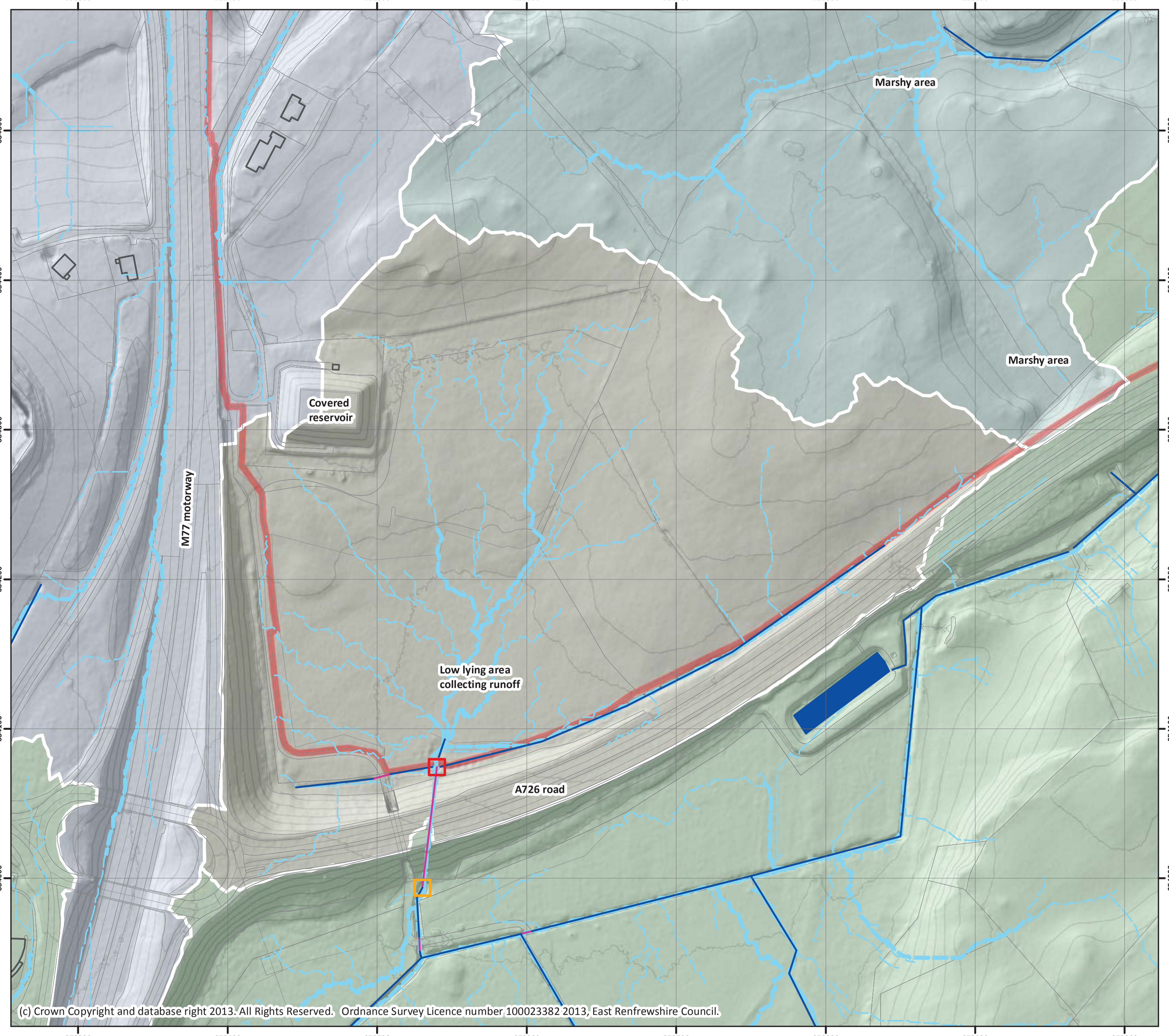
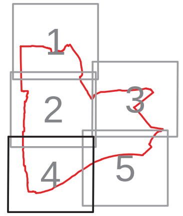
Fax: 0141 341 5045



Legend

- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Runoff pathway (draining > 0.1 ha)
- Runoff pathway (draining > 1 ha)
- Site boundary
- Terrain contour (2m)
- Culvert inlet
- Culvert outlet
- Well



Do not scale this map

Client
East Renfrewshire Council

Project
Maidenhill/Malletsheugh Hydrological Study

Title
Existing drainage and runoff characteristics
(4 of 5)

Status
DRAFT

Drawing No.	Revision
164324-004	A

Scale		Date
1:2,500	A3	9 July 2013

Drawn	Checked	Approved
JS	NG	NG

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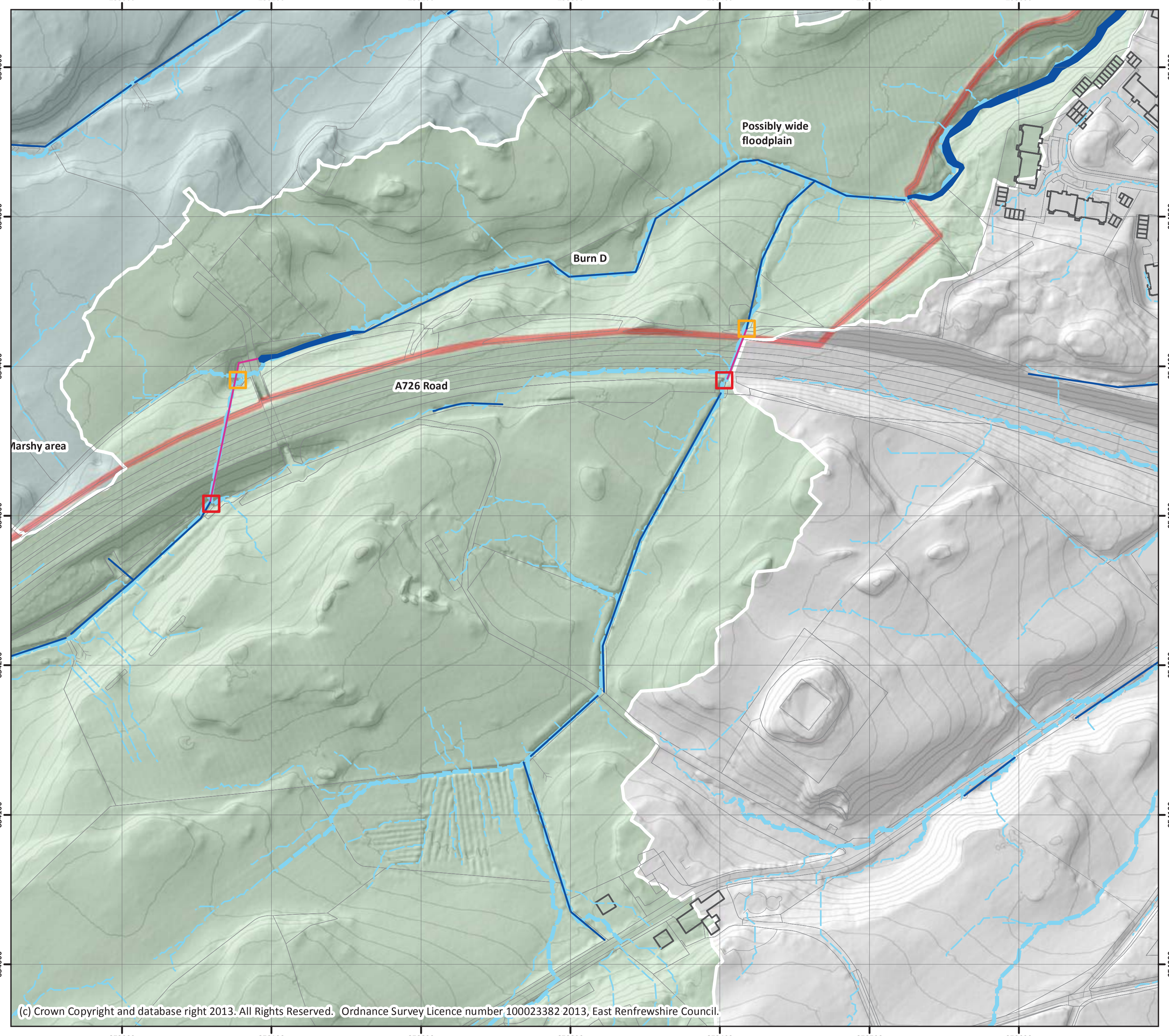
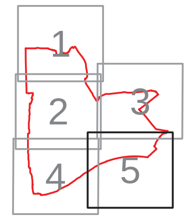


Legend

- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)
- Runoff pathway (draining > 0.1 ha)
- Runoff pathway (draining > 1 ha)
- Site boundary
- Terrain contour (2m)
- Culvert inlet
- Culvert outlet
- Well



Do not scale this map

Client	East Renfrewshire Council
Project	Maidenhill/Malletsheugh Hydrological Study
Title	Existing drainage and runoff characteristics (5 of 5)
Status	DRAFT
Drawing No.	164324-005
Revision	A
Scale	1:2,500
Size	A3
Date	9 July 2013
Drawn	JS
Checked	NG
Approved	NG

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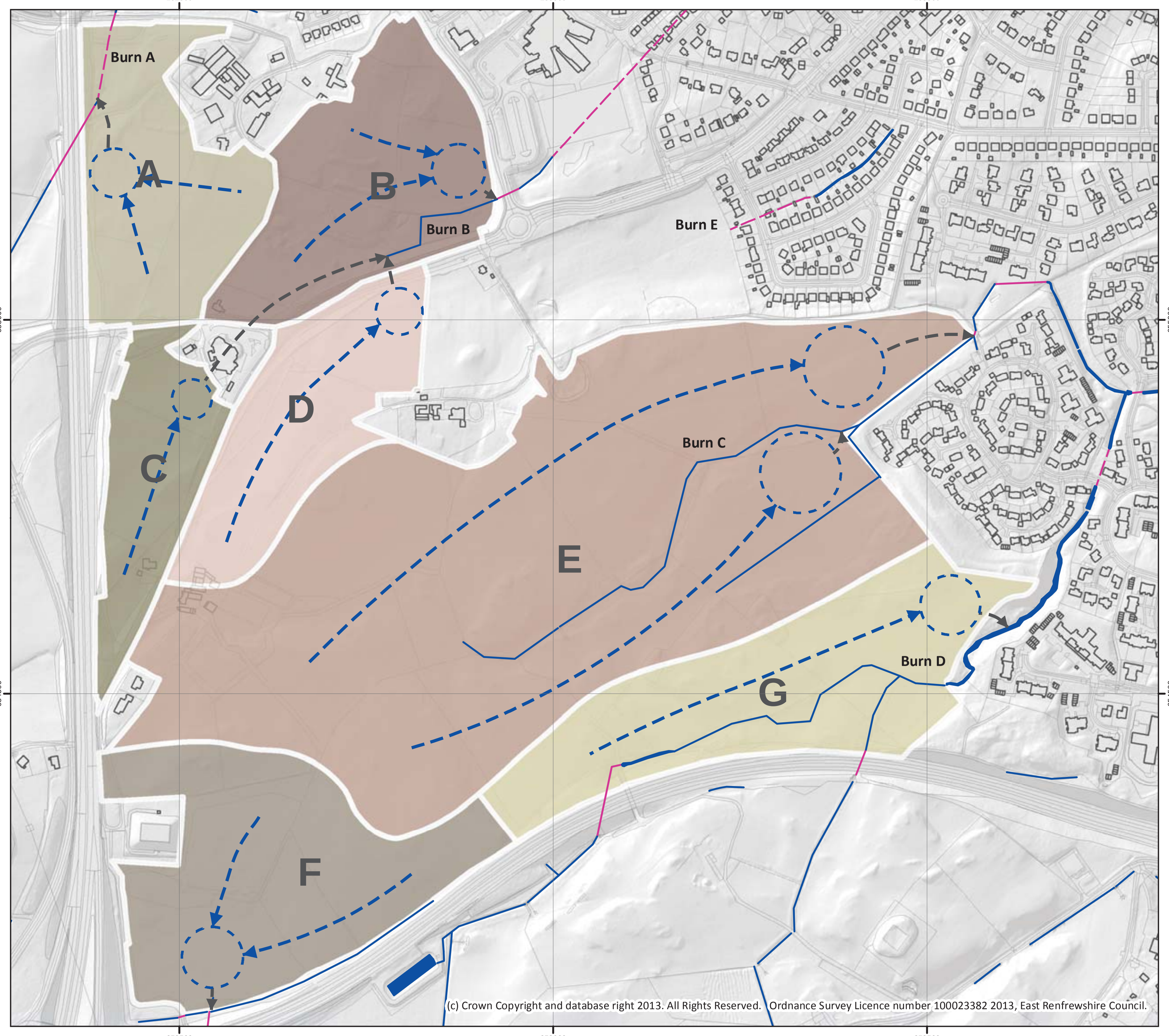
E HIGH-LEVEL DEVELOPMENT DRAINAGE OPTIONS



Legend

- Drainage outfall
- Internal conveyance route
- Development Drainage Attenuation
- Open watercourse
- Culverted watercourse (estimated)
- Culverted watercourse (known)

Do not scale this map

Client	East Renfrewshire Council
Project	Maidenhill/Malletsheugh Hydrological Study
Title	Indicative development drainage (Option 1)
Status	DRAFT
Drawing No.	164324-006
Revision	B
Scale	1:5,000
	A3
Date	18 July 2013
Drawn	FH
Checked	NG
Approved	NG

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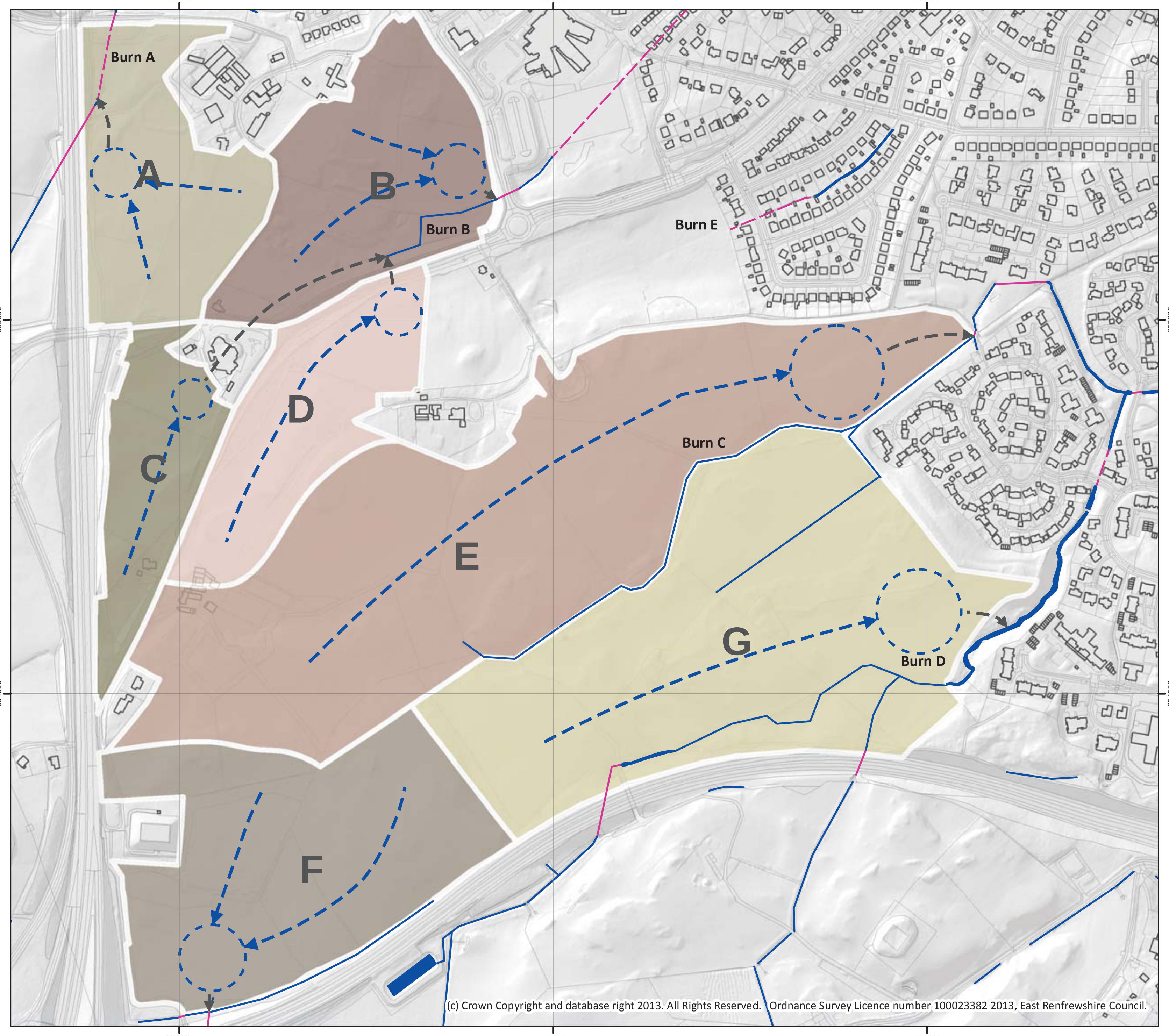
Fax: 0141 341 5045



Do not scale this map

Client	East Renfrewshire Council	
Project	Maidenhill/Malletsheugh Hydrological Study	
Title	Indicative development drainage (Option 2)	
Status	DRAFT	
Drawing No.	164324-007	Revision: B
Scale	1:5,000 A3	Date: 18 July 2013
Drawn: FH	Checked: NG	Approved: NG

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