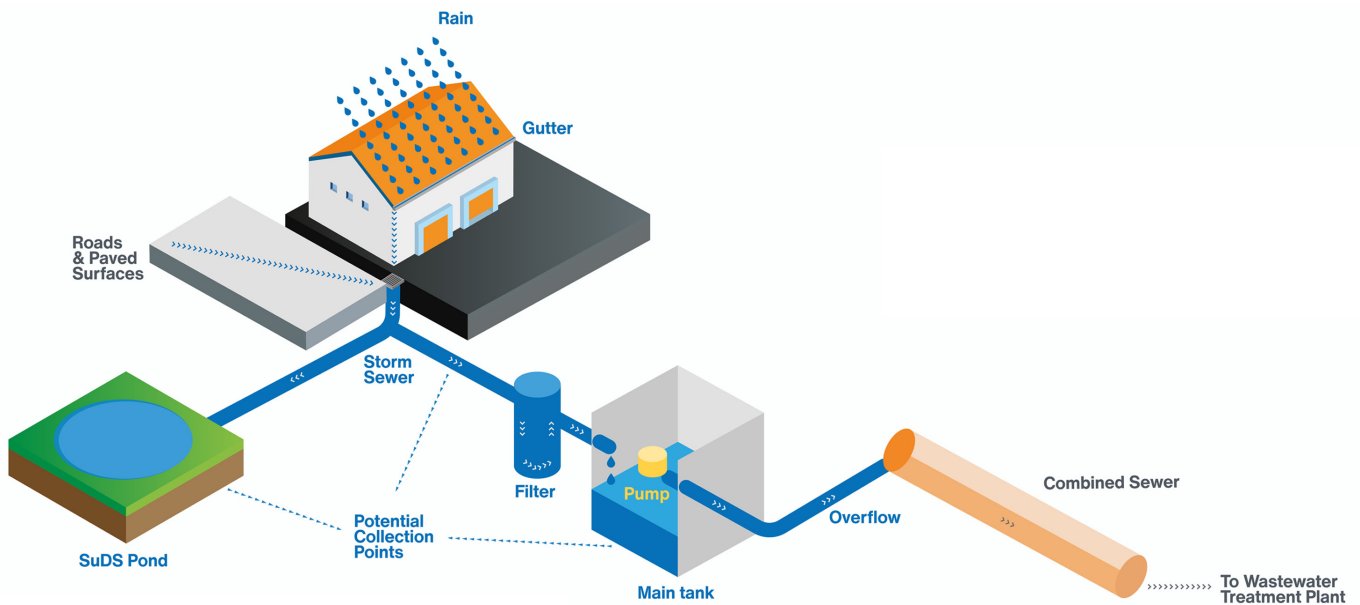


Transitioning Surface Water Collection to Surface Water Reuse Systems

Annex E. Surface Water Reuse Case Study Scenarios

Cuthbertson A., Wade R., Black A., Duffy A., Hendry S., Leask F., Ralph E., Sezen E., Varghese A., Ward K.



POTENTIAL REUSES



WIDER BENEFITS



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E1. Introduction

A number of case study scenarios have been considered at selected sites across the Dundee City area to assess the potential for surface water reuse for a range of different land use types (i.e. residential areas; commercial and industrial sites; schools, universities and hospitals), surface water sources and collection points (i.e. building roofs, paved areas, roads), abstraction/storage types (i.e. rainwater harvesting, surface runoff collection/storage/abstraction) and infrastructure (e.g. water butts, surface water sewers, storage tanks, SUDs), and potential water reuse options and users

(i.e. domestic/property & community levels, public services, commercial & industrial purposes) (see Table E1.1).

These case study scenarios are also considered for a range of different scales of surface water reuse from individual buildings and campuses to large scale industrial/commercial sites and residential areas. The specific details of the different case studies are highlighted in Table E1.1, while their locations within Dundee are shown in Figure E1.1.

Table E1.1: Summary information on different case study scenarios considered for surface water reuse in Dundee City area (part of Hatton wastewater catchment).

Case study area/site (Annex section no.)	Land use(s)	Surface water source	Abstraction type/ infrastructure	Potential water reuse options and users
Michelin Scotland Innovation Parc (MSIP) [E3]	Industry, innovation	Roof area, roads, paved areas	Collection of runoff in on-site storage tank	Baldovie EfW facility (energy generation)
University of Dundee City Campus [E4]	University campus	University building roof area	Collection of runoff in storage tank(s)	Green space watering, road cleaning, campus maintenance.
Ninewells Hospital [E5]	Hospital	Main car parks and bus terminal	Collection of runoff in storage tank	Technology park, data centre cooling
Kingsway West Retail Park (KWRP) [E6]	Commercial/leisure	Commercial premises roof area	Collection/on-site storage in tank	Commercial car wash, industry
Ballumbie (Baldovie North) [E7]	Residential	All surface water runoff entering stormwater sewer	Direct abstraction from stormwater sewer	Baldovie EfW facility, local authority, other industry
St Mary's [E8]	Residential, Primary schools	School building roof area	RWH and on-site storage tanks	Community garden, outdoor education
Ardler [E9]	Residential	Property roofs	RWH/water-butts	Domestic/gardens
Blackness [E10]	Mixed (industry, commercial & residential)	Building roofs, roads, paved areas	Collection/storage of runoff in historic cooling ponds	Industry/commercial, local authority, fire services

E2. Surface Water Reuse Analysis

Within all case studies, rainfall records from Mylnfield rainfall gauge in Dundee for a particularly dry year (i.e. 2003) and particularly wet year (i.e. 2015) were used to generate annual time series of runoff volumes from different surface types (i.e. building roofs, paved areas, permeable areas), as well as the overall total runoff volume. These runoff time series were obtained directly from Scottish Water (Dom McBennett) for all relevant drainage areas defined within Scottish Water's InfoWorks model for assessing surface and subsurface flow interactions within each of the case study area considered. These datasets were

supplied as .csv files and were imported into MS Excel for analysis. In general, the different surface water sources, defined for each water reuse scenario or study area in Table E1.1, were used to determine which runoff datasets from which surfaces would be used in each scenario.

In a number of case study scenarios, the surface water runoff is assumed to be collected and stored temporarily within storage tanks (or SUDs ponds) with varying dimensions and storage capacities, depending on the overall magnitude of the runoff volumes. In such scenarios, when the capacity of the storage tank is exceeded it is assumed that the

excess runoff spills into the adjacent sewer system as an overflow. Surface water volumes collected in these storage tanks can be abstracted at different rates (litres/hour) and for different durations or seasons depending on the particular water reuse options and end-users (see Table E1.1).

E2.1 Level-pool Routing Method

In order to route the surface water runoff through any storage tank or SUDS pond, the “level-pool” routing method¹ is applied to determine the balance between flow input (i.e. surface water runoff), water abstraction (i.e. for surface water reuse), tank/pond storage volume, and overflow spill into the sewer system, via solution of the continuity (mass conservation) equation:

$$Q_{in} - Q_{out} - Q_{abs} = \Delta S / \Delta t \quad (E2.1)$$

where Q_{in} is the surface water runoff volume influx (m³/s) into the storage tank, Q_{abs} (is the flow abstraction rate (m³/s) for reuse purposes, $\Delta S / \Delta t$ is the change in storage volume within the tank over time interval Δt , and Q_{out} is the outflow discharge or spill from the storage tank to the sewer system, estimated by a standard weir equation:

$$Q_{out} = kb_{crest} (H - h_{crest})^{3/2} \quad (E2.2)$$

where k = weir coefficient (= 1.7, assumed), H = water depth in tank, h_{crest} and b_{crest} = height and

width of weir crest, respectively. Eq. E2.1 is solved via a finite difference approximation over the full duration of runoff rainfall-runoff data (i.e. 2003 and 2015) to obtain a time series of spill Q_{out} into the sewer system.

E2.2 Depression Storage and Surface Water Runoff (SCALGO Flash Flood Analysis)

Within some of the larger case study sites (i.e. MSIP, UoD campus, Ninewells Hospital), the online SCALGO platform was used to generate surface water runoff and depression storage maps for a single high-magnitude rainfall event that took place on 17 July 2015, where 25.8 mm of rainfall fell at Mylnfield rain gauge over a four hour period between 03:45 and 07:45. This analysis was undertaken at these sites with both the flash flood map/depression map and depression-free analyses within the SCALGO platform to estimate (i) the total surface water volume stored within each site from this rainfall event due to natural topographic depressions, and (ii) corresponding total surface water runoff volumes from each site. This analysis also provided information on vulnerable sub-watershed areas within each sites that were susceptible to flash flooding, as well as details on the main surface water runoff pathways from these sub-watersheds related to their topography.

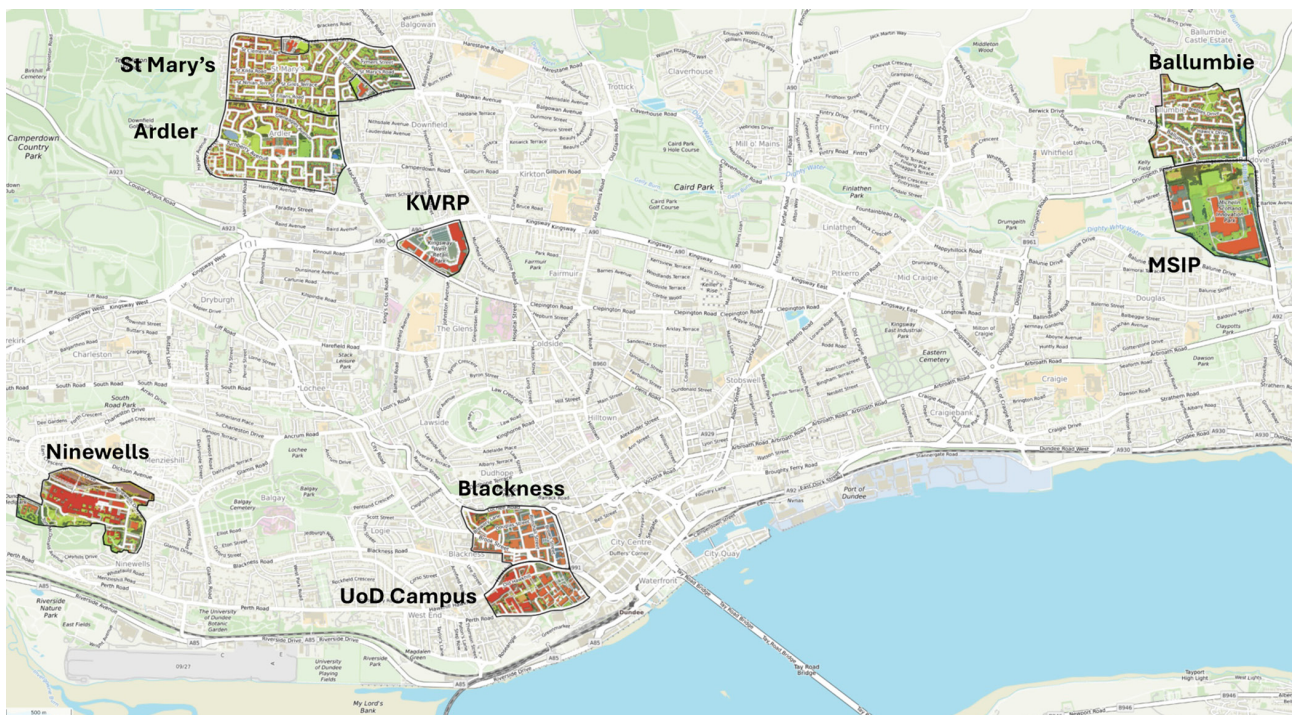


Figure E2.1: Map of Dundee showing locations of case study sites for surface water reuse scenarios considered (see Table E1.1 for details). Map generated using Scalgo Live. © Scalgo

¹<https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/modeling-reservoirs/reservoir-routing-concepts-and-equations>. (HEC-HMS Technical Reference Manual, US Army Corps of Engineers)

Note: the SCALGO flash flood analysis sets all land cover types to impermeable (i.e. a “glass sheet” model) by default, where no ground infiltration of surface water is accounted for. The model runoff analysis also does not explicitly account for surface

water drainage into sub-surface stormwater and combined sewer systems within the site, although surface water storage in SUDS ponds is accounted for (i.e. as depression storage).

E3. Michelin Scotland Innovation Parc (MSIP)

Michelin Scotland Innovation Parc (MSIP) is a joint venture between Michelin, Dundee City Council and Scottish Enterprise to develop Scotland’s hub for sustainable innovation in Dundee at the site of the old Michelin tyre factory that closed during 2020. MSIP was created to generate economic growth in Scotland and support business in the just transition to a net zero economy. A site map for MSIP is shown in Figure E3.1. The Michelin site has the second largest roof area in Dundee (after Ninewells Hospital), making it an ideal case study for surface water collection and reuse.

E3.1 Land use and infrastructure assessment

The MSIP site is bordered on the south-west and east boundaries by the Dighty and Fithie burns, respectively. Stormwater sewers cross the site in a north-south orientation, discharging into the Dighty burn. The site is also bounded by combined sewers at the north, south and east boundaries of the site, although these do not appear to be connected



Figure E3.1: Site map for the MSIP site (Map generated using Scalgo Live. © Scalgo).

directly to the MSIP site (see Figure E3.2). Existing SUDS ponds are also shown at MSIP and adjacent areas.

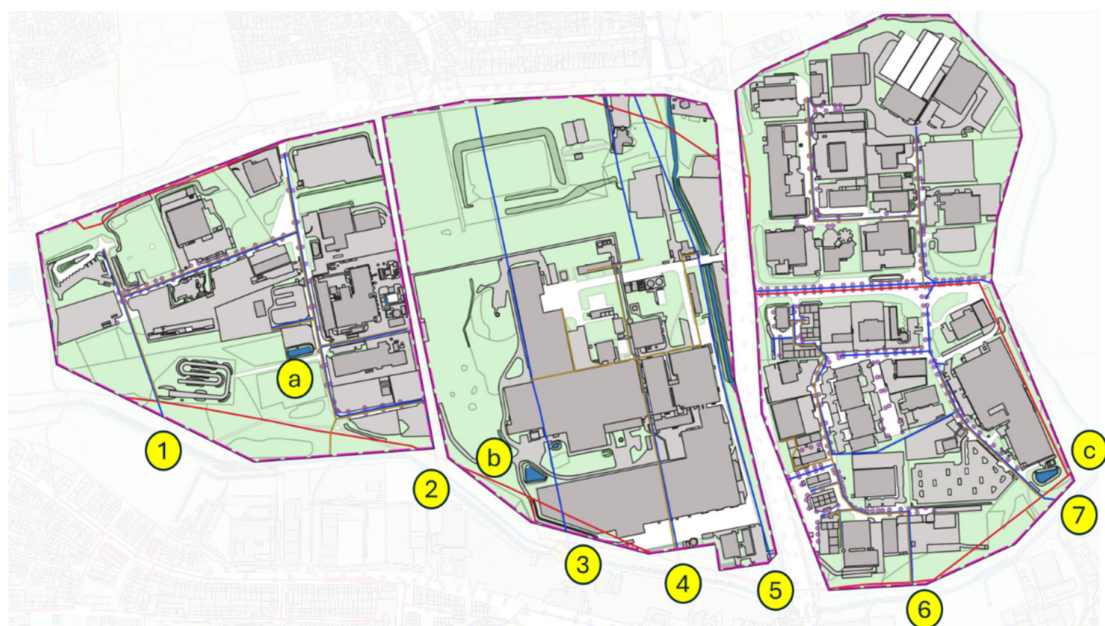


Figure E3.2: GIS map showing main MSIP site infrastructure and in adjacent areas east and west. Combined sewers shown in red, storm sewers shown in blue. Labels 1 – 7 indicate storm sewer discharges to Dighty burn, a - c indicate existing SUDS ponds.

Table E3.1: Description of potential surface water access points at MSIP site and adjacent areas.		
Surface water access point	Ref. on map	Notes
Roofs	–	Good potential for rainwater collection across large industrial roof area, organisational level RWH possible at MSIP site
Paved surfaces	–	Roads and car parks areas appear to drain into stormwater sewer, easier to collect from there
Storm sewer	1 – 7	Stormwater sewers discharge into Dighty and Fithie burns rather than combined sewer
SUDS	a – c	There are SUDS ponds at various site locations, not clear whether these are linked as part of a SUDS treatment train

In terms of land use/cover at MSIP site (total site area = 0.485 km²), this is obtained directly from SCALGO, as shown Figure E3.3. The largest land cover type present at the MSIP site is shallow vegetation, which accounts for 31% of the total area (see Figure E3.3). Of the impervious surfaces that are most likely to generate surface water runoff suitable for reuse purposes, buildings (roofs), other paved areas, and roads account for 19%, 20% and 2% of the MSIP site area, respectively.

E3.2 Description of surface water reuse scenario

MVV Environmental Ltd. operate the Baldovie Energy from Waste (EfW) facility, adjacent to the MSIP site, that incinerates all non-recyclable waste from Dundee City and Angus Council areas. This facility produces approximately 20MW of electricity over two Energy from Waste (EfW) plants, which is currently exported to the National Grid. In the production of energy, the EfW facility utilises over

230,000 m³ of water/year, of which approximately 66,000 m³ is supplied from mains water².

The surface water reuse scenario considered here is whether part of this mains water demand could be replaced by surface water runoff from the MSIP site, based on assessment of runoff volumes generated from annual rainfall records collected at Mylnfield raingauge station that are representative of a very dry year (i.e. 2003) and a very wet year (i.e. 2015). The surface runoff data for the MSIP site for these two annual rainfall data sets were obtained from model simulations of the surface water volumes entering the sewer system, conducted by Scottish Water (Hatton catchment team). Within this analysis, the MSIP site is split up into separate drainage areas, as shown in Figure E3.4, from which the total runoff from building roofs, other paved areas and roads is calculated and summed for all areas (excluding DB Upper_1A and 252, Figure E3.4).

²MVV Environment Baldovie Ltd (2022). Annual Performance Report 2022.



Figure E3.3: GIS map showing different land cover types at MSIP site infrastructure and adjacent area at Baldovie EfW facility. The equivalent areas for each land cover type at MSIP are tabulated (Table E3.2). Map generated using Scalgo Live. © Scalgo.

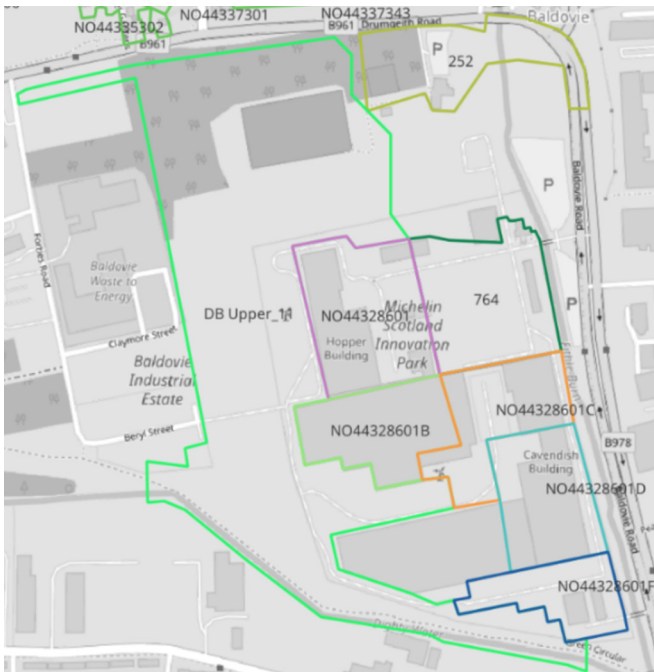


Figure E3.4: Map of the MSIP site showing main drainage areas modelled for surface water runoff estimation.

Within the surface water reuse scenario for MSIP site, it is assumed that the surface water runoff volumes from the different modelled drainage areas can be collected, combined and stored temporarily within a storage tank prior to abstraction for use at the Baldovie EfW facility, with any residual runoff discharged into the sewer system. As such, the potential impact that this surface water reuse scenario could have on reducing runoff entering the sewer system from the MSIP site is also assessed.

In this context, the scenario proposes construction of a large, online surface water storage tank at the MSIP site, sized to provide a continuous surface water supply to Baldovie EfW facility throughout the two years of rainfall records assessed. The assumed storage tank dimensions are given in Table E3.3 below to account for the variability in surface water runoff volumes between particularly dry (i.e. 2003) and wet (i.e. 2015) years.

Tank length (m)	Tank width (m)	Weir height (m)	Weir width (m)	Volume full (m ³)
30	25	1.0	0.5	750

E3.3 Surface runoff, abstraction and spill for 2003 and 2015 rainfall data

For the two years of rainfall data under investigation (i.e. 2003 and 2015), analysis to the total surface water runoff from the MSIP site (including buildings, paved areas and roads) indicates considerable variability in the surface water volume fluxes generated at the site during dry and wet years [i.e. as indicated by the blue time series in Figures E3.5(a) and E3.6(a), respectively]. The corresponding residual outflow spill volumes from the storage tank into the sewer system are estimated via the “level-pool” routing method for different water abstraction rates Q_{abs} from the storage tank to supply the Baldovie EfW facility.

The temporal change in the surface water volume within the storage tank can also be assessed over the two years of runoff data, with Figs. E3.5(b) and E3.6(b) showing how the water surface level within the storage tank varies as a result of the balance between inflow Q_{in} , abstraction Q_{out} and spill Q_{abs} volume fluxes. As the MSIP site surface water reuse scenario assumes a continuous supply of surface water to Baldovie EfW facility, the analysis also accounts for the potential need for different surface water abstraction rates, based on the difference in total surface runoff volume availability during dry (e.g. 2003) and wet (e.g. 2015) years. For this reason, the abstraction rates are varied between $Q_{abs} = 150, 300$ and 500 l/hr for both the 2003 and 2015 rainfall-runoff data (see Table E3.4).

Based on this approach, the overall annual volume of surface runoff from the MSIP site, surface water abstraction volume for the Baldovie EfW facility, and the residual spill volume to the stormwater sewer system can be calculated for the entirety of the 2003 and 2015 records. These overall annual water volumes are summarised in Table E3.4. It is interesting to note that, with continuous abstraction rates $Q_{abs} = 150, 300$ and 500 l/hr, the total surface water reuse volumes based on 2003

rainfall records are ~46%, ~93% and 100% of the total runoff volume from the MSIP site within that year. [Note: the total surface water reuse volume calculated for a constant abstraction rate $Q_{abs} = 500$ l/hr exceeds the total runoff volume available for the MSIP site for the 2003 rainfall records and, hence, this maximum abstraction volume must be set equal to the total runoff volume, Table E3.4]. The corresponding residual spill from the storage tank to the stormwater sewer therefore corresponds to ~54%, ~7% and 0% of the total runoff volume, respectively, for $Q_{abs} = 150, 300$ and 500 l/hr. This is highlighted by the reduced number of spill periods observed throughout the year [i.e. yellow → orange → red data series in Fig. E3.5(a)]. By contrast, for a similar analysis based on the 2015 rainfall data, with the same continuous abstraction rates $Q_{abs} = 150, 300$ and 500 l/hr, the total surface water reuse volumes correspond to ~20%, ~41% and ~68% of the total runoff available from MSIP (i.e. with ~80%, ~59% and ~32% residual spill to the stormwater sewer, Table E3.4). This is highlighted by the considerably increased number of residual spill periods to the storm sewer system, particularly during the second half of the 2015 runoff records [i.e. yellow, orange and red data series, Figure E3.6(a)].

The temporal variation in the water surface elevation within the storage tank is also shown to be affected by the abstraction rate Q_{abs} [see Figures E3.5(b) and E3.6(b)]. For the 2003 rainfall data, the maximum abstraction rate of $Q_{abs} = 500$ l/hr results in the storage tank emptying completely for long periods of time throughout the year, whereas with lower abstraction rates the water surface elevation within the storage tank remains above a minimum level of ~0.3 m (i.e. for $Q_{abs} \leq 300$ l/hr). For the 2015 rainfall data, the surface water elevation in the storage tank remains above a minimum level of ~0.3 m for all abstraction rates tested ($Q_{abs} = 150, 300$ and 500 l/hr), thus ensuring a continuous reuse water supply to Baldovie EfW facility.

Table E3.4: Summary of total run-off volume from MSIP site, abstraction rates and re-use volumes, and spill into sewer system during 2003 and 2015.

Year	Total runoff volume (m ³)	Abstraction rate (l/hr)*	Total re-use volume (m ³)	Re-use (%)	Total spill volume (m ³)+	Spill (%)
2003	2,726.34	150	1,263.8	46.4	1,462.5	53.6
		300	2,527.7	92.7	198.69	7.3
		500	2,726.3	100.0	0.0	0.0
2015	6,200.68	150	1,263.8	20.4	4,936.2	79.6
		300	2,527.7	40.8	3,673.0	59.2
		500	4,212.8	67.9	1987.9	32.1

* Based on constant abstraction from storage tank throughout year, maintaining water level in tank throughout.

+ Calculated from weir equation (Eq. E3.1)

In terms of reducing the overall annual mains water demand from the Baldovie EfW facility, the potential reuse of surface water from the MSIP site, based on the 2003 and 2015 rainfall records, corresponds to savings of approximately 1.9 – 4.1%* and 1.9 – 6.4% (up to 9.4%*), respectively [* based on reuse of 100% of total surface water runoff from MSIP site]. Importantly, the reuse of surface water from MSIP also reduces the runoff volume directly entering the storm sewer system at MSIP by 46 – 100% and 20 – 68%, based on 2003 and 2015 rainfall records, respectively. These potential benefits are summarised in Table E3.5 below.

E3.4 Depression storage and surface runoff from MSIP site (SCALGO flash flood analysis)

Depression storage and surface water runoff volumes were also obtained at the MSIP site from SCALGO flash flood analysis for a single high-magnitude rainfall event occurring on 17 July 2015,

where 25.8 mm of rainfall fell at MyInfield rain gauge over a four hour period between 03:45 and 07:45. This analysis was undertaken with the flash flood map/depression map and depression-free analyses within the SCALGO platform. Figure E3.7 shows the map of flooded areas and depression-free surface flow paths at the MSIP site for this event. This indicates that significant surface water accumulation can occur in areas of depression at the MSIP site, while surface water runoff pathways also indicate drainage of the site to adjacent watercourses (i.e. Dighty and Fithie burns). Overall, the estimated surface water volume in depression storage within the MSIP site is 10,076 m³ (79%), while the surface runoff volume is estimated to be 2,681 m³ (21%) for the 26 mm: 4 hour rainfall event. From SCALGO, the total estimated land area for the MSIP site (i.e. for all land cover types combined) was 484,578 m² (Table E3.2) and, hence, the total volume of rainwater falling on the MSIP site would be 484,578 × 0.026 = 12,599 m³ (i.e. within 1.25% of the estimated surface depression storage and runoff water combined).

Year	Abstraction rate (l/hr)*	Change in mains water demand (%)	Change in runoff volume entering sewer system (%)
2003	150	-1.9	-46.4
	300	-3.8	-92.7
	500	-4.1	-100.0
2015	150	-1.9	-20.4
	300	-3.8	-40.8
	500	-6.4 (up to -9.4*)	-67.9

*Based on 100% reuse of runoff from MSIP site

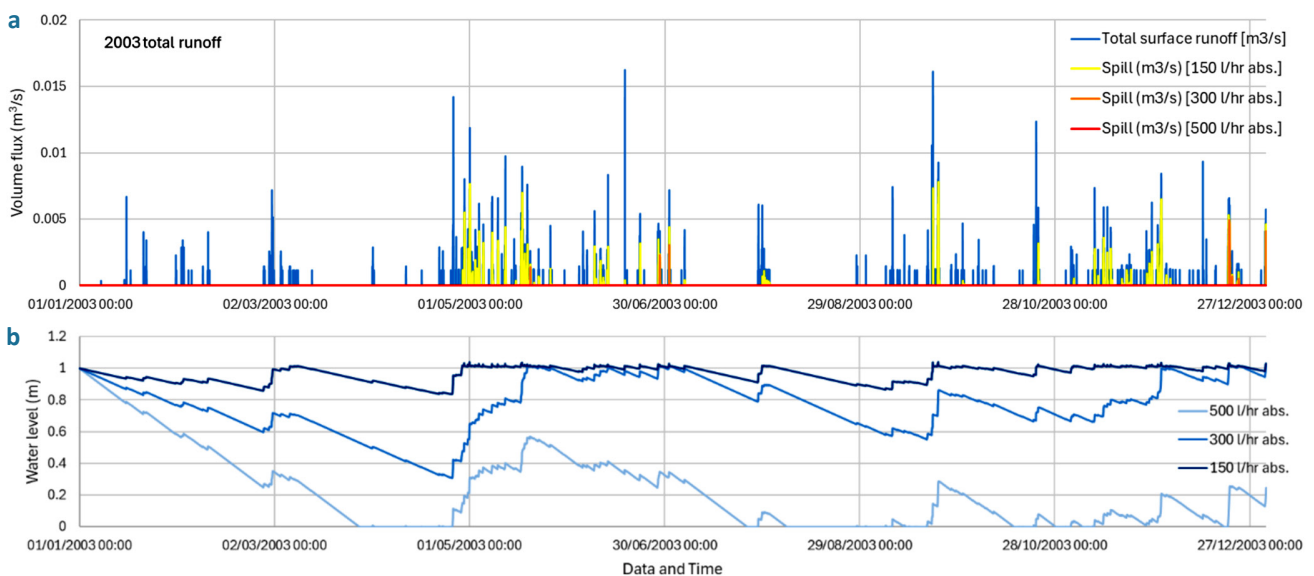


Figure E3.5: (a) 2003 time series of volume flux (m³/s) for MSIP site total runoff and resulting spill into sewer system from storage tank (based on tank dimensions in Table E3.1), (b) corresponding variation in water surface elevation within storage tank for constant abstraction rate of 300 l/hr (for re-use in Baldovie EfW facility).

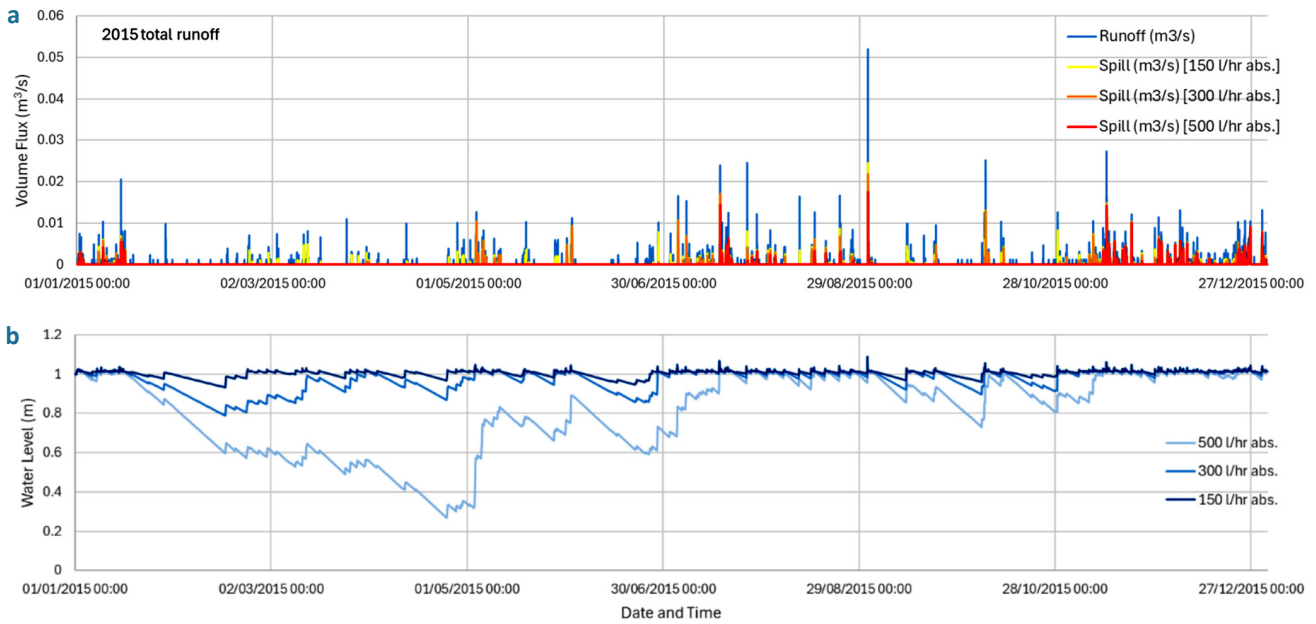


Figure E3.6: (a) 2015 time series of volume flux (m^3/s) for MSIP site total runoff and resulting spill into sewer system from storage tank (based on tank dimensions in Table E3.1), (b) corresponding variation in water surface elevation within storage tank for constant abstraction rate of 500 l/hr (for re-use in Baldovie EfW facility).

E3.5 Reuse summary and other considerations

The MSIP site has considerable potential to provide surface water for reuse purposes at the adjacent Baldovie EfW facility, which in turn provides steam for heating at MSIP. This surface water reuse can both reduce mains water demand at Baldovie (by up to ~9% for the annual rainfall data considered) and reduce runoff volume inputs into the stormwater sewer system at the site (by up to 100%), which

discharges directly into the Dighty burn. The MSIP site already collects surface water in depression storage areas during periods of high rainfall and so these areas could be adapted to provide designed surface water storage for Baldovie EfW plant, for example, through the provision of a storage tank or SUDS ponds. Being a post-industrial site, careful consideration would also be required for the level of on-site water treatment needed to ensure that any legacy contaminants (e.g. hydrocarbons) are removed prior to surface water reuse.



Figure E3.7: Map showing flash flood analysis at MSIP for a 26 mm rainfall event over a four hour duration, indicating areas/depths of depression storage and main depression free runoff pathways from the site. Map generated using Scalgo Live. © Scalgo.

E4. University of Dundee City Campus

The University of Dundee's main city campus sits to the west of Dundee City centre. It is bounded to the north by Hawkhill and south by Perth Road. It consists of a number of University buildings, student residences, roads, car parks, other paved areas and green spaces. A site map of the University of Dundee campus is shown in Figure E4.1.

E4.1 Land use and Infrastructure assessment

The University of Dundee (UoD) has a series of combined sewers across the campus (see Figure E4.2) that generally run down the main internal roads within the campus (e.g. Old Hawkhill, Balfour Street, Park Wynd, Small's Wynd and Park Place) with no separate storm sewer system. These combined sewers generally drain into larger combined sewers running along Hawkhill (generally



Figure E4.1 Site map of the University of Dundee campus (Map generated using Scalgo Live. © Scalgo).

to the north of the campus) and Perth Road (to the south of the campus). There are no existing SUDS infrastructure within the campus or adjacent areas.



Figure E4.2: GIS map showing main University of Dundee campus. Combined sewers shown in red typically drain to Hawkhill (NW, N and NE of campus) and Perth Road (S and SE of campus). There are no stormwater sewers or SUDS infrastructure within the campus.

Table E4.1: Description of potential surface water access points at UoD campus.		
Surface water access point	Ref. on map	Notes
Roofs	–	Significant roof area across campus buildings from which rainwater could be harvested
Paved surfaces	–	Some paved areas could be redirected but would require significant adjustments to existing infrastructure
Storm sewer	–	No stormwater sewer provision within the university campus. Runoff discharges directly into combined sewers
SUDS	–	No SUDS infrastructure within the university campus

The total site area of the University of Dundee campus (shown in Figure E4.3) is 0.225km² (obtained from SCALGO). It is also interesting to note the general reduction in elevation from west to east in the site. The largest land cover types are other paved areas (38%) and buildings (34%), while dense and shallow vegetation combined make up about 22% of the total land cover area within the campus.

E4.2 Description of surface water reuse scenario

The most likely surface water reuse scenario for the University of Dundee campus is associated with collection and reuse of rainwater falling onto university building roofs for non-potable purposes associated with campus maintenance (e.g. watering of green spaces, cleaning paved areas and roads, and washing university vehicles) that would otherwise utilise mains water. It is proposed to demonstrate this potential by considering the runoff volumes that could be collected from the roof of a single university building complex (the Wellcome Trust/Discovery/Sir James Black buildings to the

west of the campus, which combined is the largest building on campus) again for 2003 (“dry” year) and 2015 (“wet” year) rainfall records. This building is largely contained within the Scottish Water model area 39293902 (see Figure E4.4), which drains to a combined sewer running down Hawkhill Place to Perth Road (see Figure E4.2). The surface water reuse scenario will then consider the additional water volumes available from other rainwater harvesting from other university buildings and associated drainage areas. The main potential impacts from this reuse scenario are therefore to reduce main water demand on the campus for non-potable purposes and the potential reduction of surface water run-off entering the combined sewer system.

For this purpose, a surface water storage tank will be utilised to collect and store temporarily water collected from university buildings. The assumed tank dimensions are dependent on the number of university buildings from which rainwater is collected and utilised (see Table E4.3). Furthermore, the demand for surface water will vary throughout the year (e.g. seasonal demand) based on potential use (see Table E4.4).

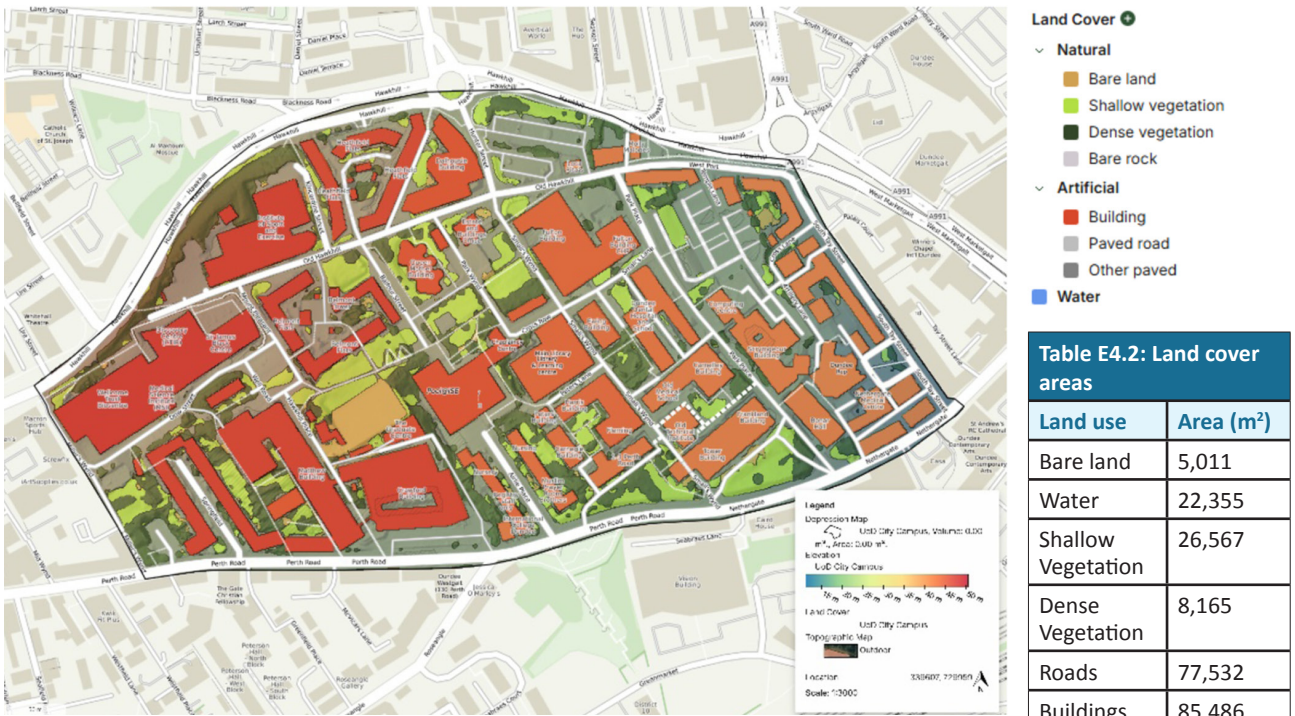


Figure E4.3: GIS map showing different land cover types at University of Dundee city campus. The equivalent areas for each land cover type are tabulated in Table E4.2. Map generated using Scalgo Live. © Scalgo.

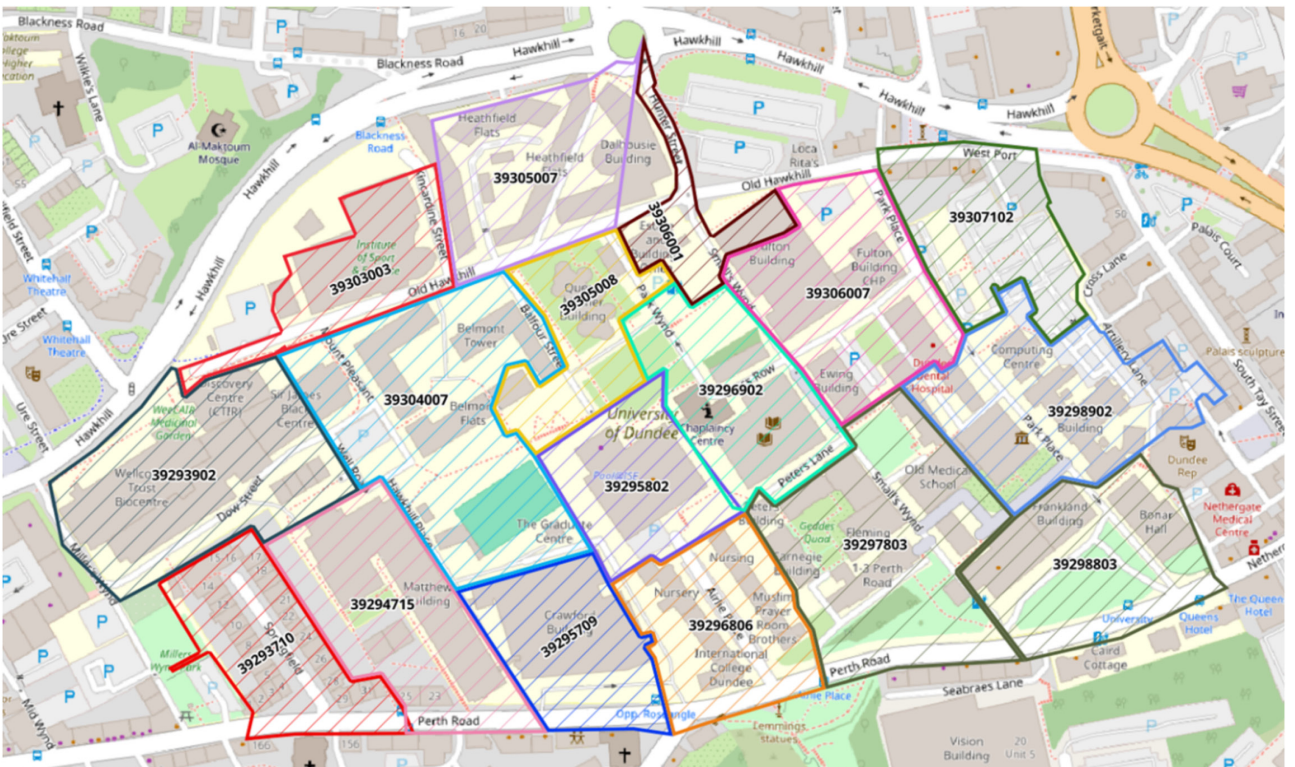


Figure E4.4: Map of the University of Dundee campus showing main drainage areas modelled for surface water runoff estimation. Note: this reuse scenario only considers runoff from university building roofs.

Building(s)	Tank length (m)	Tank width (m)	Weir height (m)	Weir width (m)	Volume full (m ³)
Wellcome Trust ³	8	4	0.5	0.5	16
Wider campus ⁴	20	8	1.0	1.0	160

³Wellcome Trust consists of Wellcome Trust Biocentre, Discovery Centre and Sir James Black Centre.
⁴Wider campus consists of ³ above, Institute for Sport and Exercise, Dalhousie Building, Belmont residences, Queen Mother Building, University Library, and Fulton Building.

E4.3 Surface run-off, abstraction and spill for 2003 and 2015 rainfall data

The total surface water runoff volumes from the roofs of the Wellcome Trust buildings and wider campus buildings were calculated for the 2003 and 2015 rainfall records (Table E4.4). Abstraction volumes for surface water reuse were based on typical values from literature, based on likely reuse purposes on campus (i.e. green space watering, pressure cleaning of paved areas, road sweeping, washing campus vehicles). These estimated volumes are detailed in Table E4.5.

For simplicity, it is assumed that watering of green spaces on the campus takes place on a daily basis throughout the months of May – August, while other cleaning tasks that may be able to utilise surface water collection from university buildings

are combined together and spread out uniformly throughout the year. The total area of shallow vegetation (e.g. lawned/grassed areas) on campus is approximately 2.2 hectares (see Figure 4.3), although it is highly unlikely that this whole area would be watered/irrigated. It is therefore assumed, firstly, that the rainfall collection from the Wellcome Trust buildings alone will be utilised to water the University Green (area ~2,400 m²), which is irrigated regularly over the summer months, as well as providing sufficient additional water volume for the other campus cleaning tasks, as detailed in Table 4.5. However, this required surface water reuse volume of 186 m³ is shown to be only 6.8% and 3.2% of the total rainfall runoff volume from the Wellcome Trust building roofs during 2003 and 2015 rainfall years, respectively (see Table E4.4).

Year	Building(s)	Roof runoff volume (m ³)	Total re-use volume (m ³)	Re-use (%)	Total spill volume (m ³)	Spill (%)
2003	Wellcome Trust ¹	2,721	186*	6.8	2,535	93.2
	Wider campus ²	10,801	3,327+	30.8	7,474	69.2
2015	Wellcome Trust ¹	5,900	186*	3.2	5,714	96.8
	Wider campus ²	23,423	3,327+	14.2	20,096	85.8

* Total reuse scenario based on watering of University Green only (May – Aug) + road/paved areas/vehicle cleaning
+ Total reuse scenario based on watering of 1 hectare of university grounds (May – Aug) + road/paved areas/vehicle cleaning

Surface water reuse purpose	Estimated volume rate	Frequency	Total estimated annual water volumes (litres)
Watering of all green spaces [University Green only]	26,820 l/day/hectare ¹ [644 litres/day]	Daily ¹	3,218,400 (per hectare) [77,280]
Cleaning paved areas (high pressure cleaning)	600 litres/hour ²	Annually	18,000
Road/street cleaning (conventional sweeper)	100 litres/hour ³	Monthly	7,200
Washing campus vehicles (power washing)	160 litres/vehicle ⁴	Fortnightly	83,280

¹ Assuming daily watering between May – August between 10:00 and 16:00 (18°C average daytime temp; 5.9 hours average sunshine per day) [Irrigation Water Requirement Calculator | Calculate Water Usage Easily](#)
² Assuming high pressure washing of other paved areas for one week on an annual basis. [Demystifying Discharge Capacity/Flow Rates: Understanding The Flow Rate Of Pressure Washers - Idropower](#)
³ Assuming conventional street sweep/cleaning for one day per calendar month. [What is the water consumption of a road sweeper with a dust suppression system? - Blog](#)
⁴ Assuming 20 university vehicles cleaned on a fortnightly basis. [Car Wash Water Management | Castle Water](#)

Table E4.6: Summary of potential benefits provided by reuse of surface water from UoD campus building roofs

Year	Total reuse volume (m ³)*	Change in runoff volume entering sewer system (%)
2003	186 3,327	-6.8 ⁽¹⁾ -30.8 ⁽²⁾
2015	186 3,327	-3.2 ⁽¹⁾ -14.2 ⁽²⁾

* Based on the lower and higher surface water reuse scenarios
⁽¹⁾ Based on surface water reduction from Wellcome Trust buildings only
⁽²⁾ Based on surface water reduction from wider campus buildings.

As such, there is considerable scope to increase surface water reuse for irrigation and/or cleaning activities on the campus. Indeed, when considering the surface water volume requirement for watering of a larger 1 hectare green space area spread across the campus, in addition to the campus cleaning tasks previously highlighted, the total required surface water reuse volume of 3,327 m³ exceeds the total rainfall volume collected from Wellcome buildings alone (based on 2003 rainfall data, Table E4.4). If the larger number of university building roofs are also included in rainwater harvesting, then this additional water demand would be easily met (i.e. 30.8% and 14.2% of the total roof runoff in the wider campus² for 2003 and 2015 rainfall records).

It is also important to note that the relatively small volumes of surface water reuse on campus, especially for the lower total reuse volume scenario (i.e. seasonal watering of University Green only + campus cleaning activities), will have a negligible impact on the overall surface water spill volume entering the combined sewer system (Table E4.4). In order to have a more pronounced impact on reducing spill volumes into the combined sewer system, a significantly larger volume of the total surface water runoff from the campus would have to be collected (e.g. in stormwater drains), temporarily stored (e.g. in tanks and/or SUDS infrastructure) and potentially reused. The costs associated with this infrastructure upgrade are likely to be prohibitive in relation to any savings made on water supply costs.

However, as indicated in Figure E4.3 and Table E4.2, with 78% of the campus land cover consisting of impermeable surfaces (i.e. buildings, paved areas, roads and bare land), any potential reduction in surface water runoff through storage and reuse will have potential benefits in reducing flood risk, particularly during high magnitude rainfall events.

E4.4 Depression storage and surface runoff from UoD campus (SCALGO flash flood analysis)

Depression storage and surface runoff volumes were obtained for the UoD campus from SCALGO flash flood analysis for the 25.8 mm:4 hour rainfall event that occurred on 17 July 2015. Figure E4.5 shows the map of the main areas of surface water accumulation on campus, as well as the main surface runoff pathways for depression-free flow. This indicates that there are a number of areas within the campus where surface water can accumulate in areas adjacent to main university buildings, while the main surface run-off pathways are again towards Perth Road and Nethergate in the southeast of the campus and Hawkhill Road to the north of the campus. Overall, the estimated surface water volume in depression storage within the University of Dundee campus for the 26 mm: 4 hour rainfall event is 1,321 m³ (23%), while the equivalent total surface runoff volume is 4,360 m³ (77%) for all land cover types combined. Given the total land area for the campus (from SCALGO) is estimated to be 225,096 m² (Figure E4.3), the total rainfall volume from the 26 mm: 4 hour event would be 5,852 m³ (i.e. within 2.9% of the estimated surface water storage and runoff volumes combined). This discrepancy is due to a number of small watershed areas around the campus that are not included in the overall assessment of storage and runoff volumes from SCALGO. Considering that the surface water reuse scenario for the University of Dundee campus has been from building roofs only, the maximum water volume available for reuse from the 26 mm: 4 hour rainfall event would be $77,532 \times 0.026 = 2,016 \text{ m}^3$.

E4.5: Reuse summary and other considerations

While rainwater harvesting scenarios from the roofs of university buildings in the City Campus can provide a viable surface water reuse resource for campus activities such as watering green spaces and cleaning operations, the reuse volumes involved are relatively low in comparison to the total water volume falling onto the campus (based on analysis of 2003 and 2015 rainfall records). This reuse would therefore be expected to have a limited impact on reducing surface runoff volumes entering the combined sewer system and, hence, on local urban flood risk. This is particularly evident during higher magnitude rainfall events, where

significant gradients (West-East and North-South, Figure E4.5) often lead to rapid rainfall run-off, especially with vast majority of the campus land cover being impermeable surfaces. The potential to collect, store and reuse rainwater harvested from university building roofs for non-potable purposes does, however, present opportunities to reduce overall reliance on drinking water supplies to undertake these tasks, in accord with the University’s sustainability and net-zero ambitions ([Sustainability | University of Dundee, UK](https://www.dundee.ac.uk/sustainability)). In addition, collection of rainwater from university building roofs would reduce the need for pre-treatment, especially if the surface water was used primarily for campus watering and irrigation purposes.

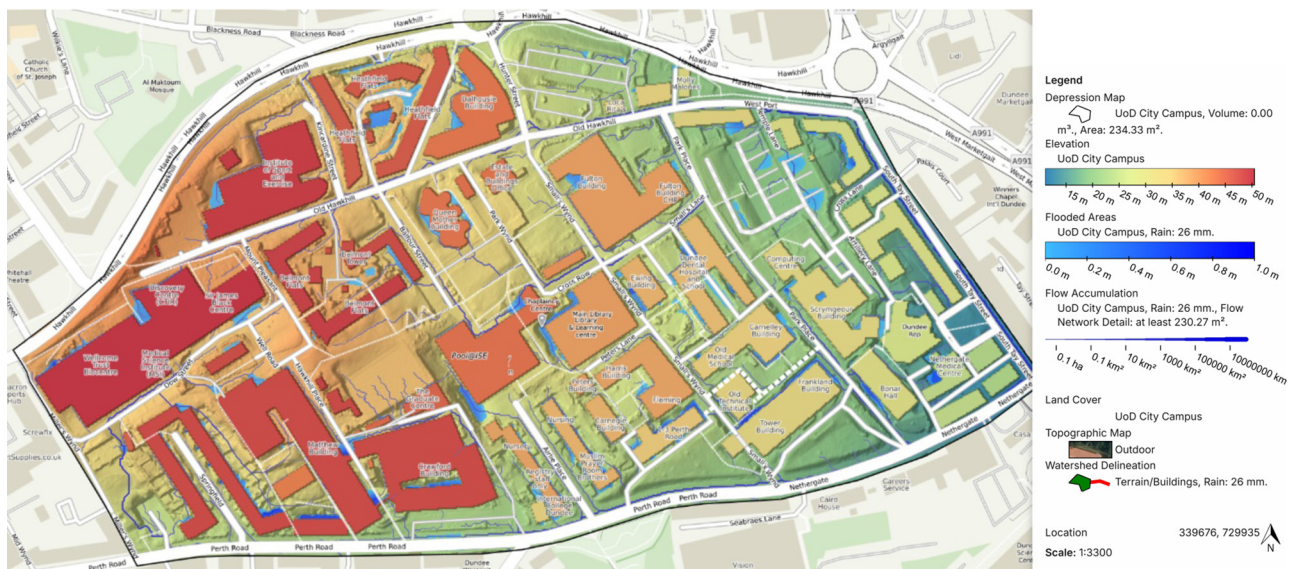


Figure E4.5: Map showing flash flood analysis at UoD City Campus for a 26 mm rainfall event over a four hour duration, indicating areas/depths of depression storage and main depression free runoff pathways from the site. Map generated using Scalgo Live. © Scalgo.

E5. Ninewells Hospital

Ninewells Hospital on the western outskirts of Dundee is a large teaching hospital providing various medical services for Tayside and North Fife. It has the largest roof area of any building in Dundee, extending to approximately 58,000 m² for the main hospital building. The site sits in an elevated position overlooking the Tay estuary. It also has a significant paved area associated with car parking, a bus terminal and connecting roads and a large area of lawn adjacent to the Maggie Cancer Centre and helipad. Figure E5.1 shows a site map of the main hospital complex (from SCALGO).



Figure E5.1: Site map of Ninewells hospital complex (Map generated using Scalgo Live. © Scalgo).

E5.1 Land use and Infrastructure assessment

Ninewells hospital has very limited information on the sewer infrastructure within the main site, with two main combined sewers running approximately west-east to the north and south of the main building complex. Due to the hillside topography of the site, largely sloping downhill from north to south, it is assumed that surface water runoff from

the main car parks and bus terminal (numbered 4 in Figure E5.2) enter the combined sewer north of the building complex, while the run-off from the building itself enters the combined sewer to the south of the hospital.



Figure E5.2: GIS map showing main Ninewells Hospital complex. Combined sewers are shown in red. There are no significant stormwater sewers or SUDS infrastructure shown within the site.

Table E5.1: Description of potential surface water access points at Ninewells hospital (with map reference to Figure 5.2).		
Surface water access point	Ref. on map	Notes
Roofs	3	Large roof area (approx. 58,000 m ²) on main hospital but it is a complex shape and likely to be difficult to collect together. Sewer information for the site is sparse.
Paved surfaces	4	Potential collection from the car parking areas, particularly given the topography of the site. However, lack of information on how drainage is currently collected.
Stormwater sewer	1, 2	Some very short lengths of stormwater sewer at (1) and (2). Likely too small to be of significant use.
SUDS	–	No SUDS noted within the Ninewells case study area

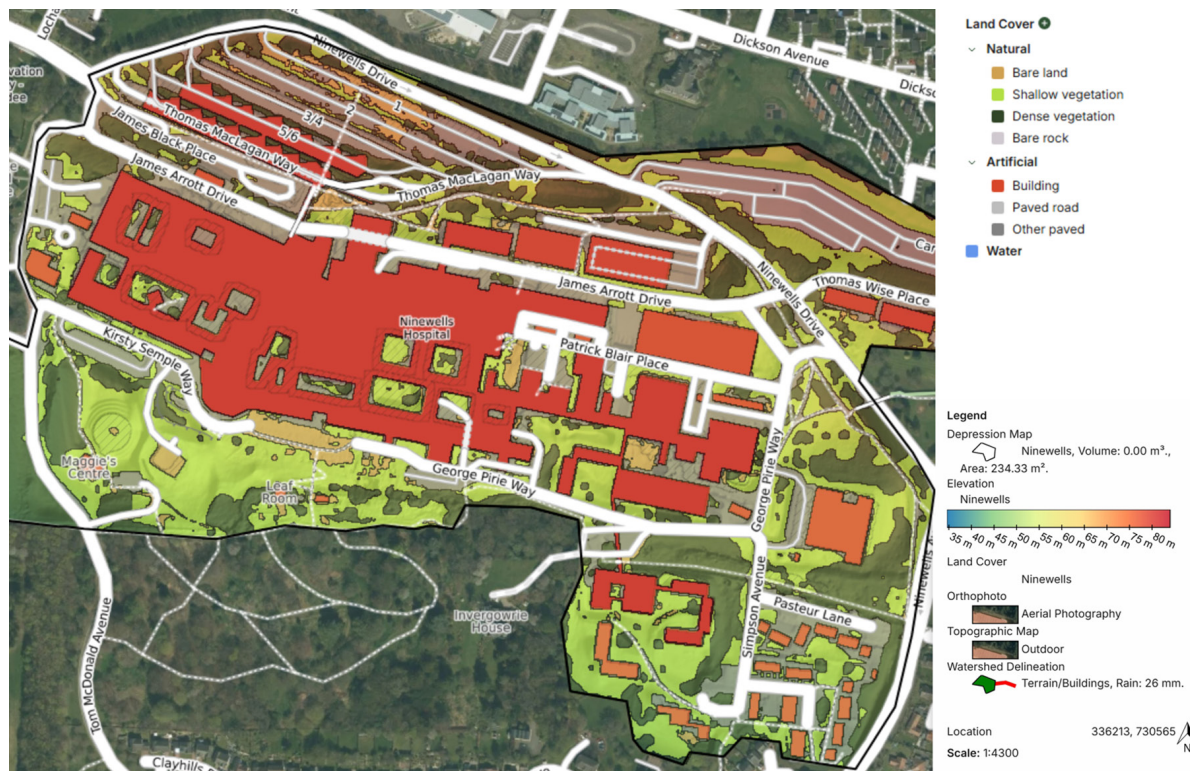


Figure E5.3: GIS map showing land cover map for the main Ninewells Hospital site. Map generated using Scalgo Live. © Scalgo.

The 0.38 km² site is dominated by the main hospital buildings, although it is assumed that the complexity of the main hospital building, extending to a total roof area of about 58,000 m², means that rainwater harvesting from the building itself would be very difficult. Furthermore, there are very few stormwater sewers and no SUDS infrastructure noted at the site.

E5.2 Description of surface water reuse scenario

The surface water reuse scenario considered here is the collection, storage and reuse of surface runoff from the car park areas on the north side of the Ninewells Hospital site (see Figure 5.3) for industrial cooling purposes at the adjacent technology park (i.e. Brightsolid data centre). It is known that the majority of the 16 data centres

currently operational in Scotland run on “open-loop” systems requiring a constant supply of mains water⁵. In 2025, the volume of water used to run these data centres reached a combined total of approximately 18 million litres⁵. Therefore, for the purposes of this reuse scenario, it is assumed that the mains water demand at the Brightsolid data centre in Dundee will be $18,000,000 \div 16 = 1,125,000$ litres of mains water per year. This corresponds to a continuous mains water supply of approximately 130 litres/hour.

It is considered here what proportion of this mains water demand can be replaced by the reuse of surface water runoff from the Ninewells Hospital site, again based on rainfall records for 2003 (“dry” year) and 2015 (“wet” year). In this analysis, the surface runoff volume from paved areas and roads (i.e. main hospital car parks and bus terminal) was calculated from the Scottish Water drainage model (i.e. areas NO36300702, NO36302703 and NO35308802 combined, Figure E5.4).

⁵<https://www.bbc.co.uk/news/articles/c77zxx43x4vo>.

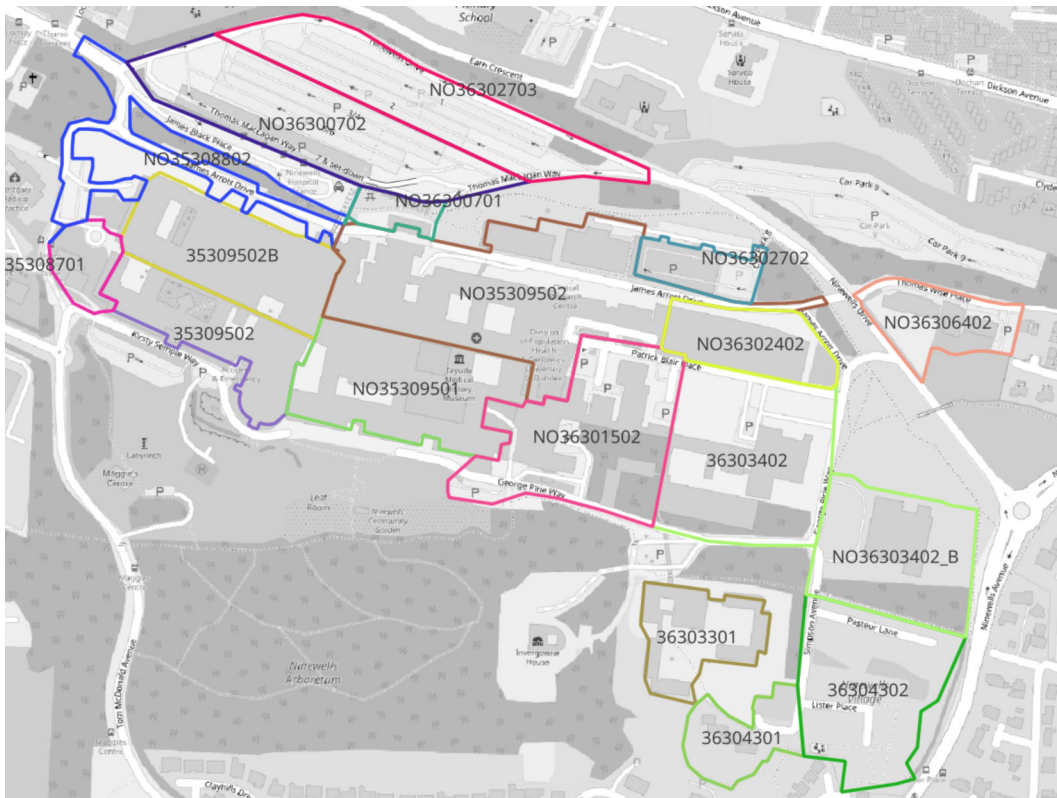


Figure E5.4: Map of the Ninewells Hospital site showing drainage areas modelled for surface water runoff estimation.

It is also assumed that the collected surface water for these areas can be collected, combined and stored within an adjacent storage tank from which water can be abstracted to supply the data centre, with residual runoff discharged into the combined sewer system. The potential reduction in surface water runoff entering the sewer system from the site is therefore also assessed. The assumed storage tank dimensions are detailed in Table E5.2 below, sized to cope with the variability in surface water runoff during particularly dry (i.e. 2003) and wet (i.e. 2015) years.

Table E5.2: Dimensions of surface water storage tank for surface runoff from Ninewells Hospital main car parks				
Tank length (m)	Tank width (m)	Weir height (m)	Weir width (m)	Volume full (m ³)
12	6	1.0	0.5	72

E5.3 Surface runoff, abstraction and spill for 2003 and 2015 rainfall data

The total surface water runoff volumes from the main car park and bus terminal areas at Ninewells Hospital were calculated for the 2003 and 2015 rainfall records (Table E5.3). The total reuse volume was calculated based on the annual mains water demand from the adjacent data centre (i.e. continuous supply of 130 litres/hour). Figures E5.5(a) and (c) show the temporal variations in surface runoff and spill to the combined sewer from the storage tank for 2003 and 2015 rainfall records, respectively, while Figures E5.5(b) and (d) indicate the variability in the storage tank water level over the duration of these records. The spill volumes from the storage tank into the combined sewer system, along with the tank water level, are estimated using the “level-pool” routing method through solution of the continuity equation.

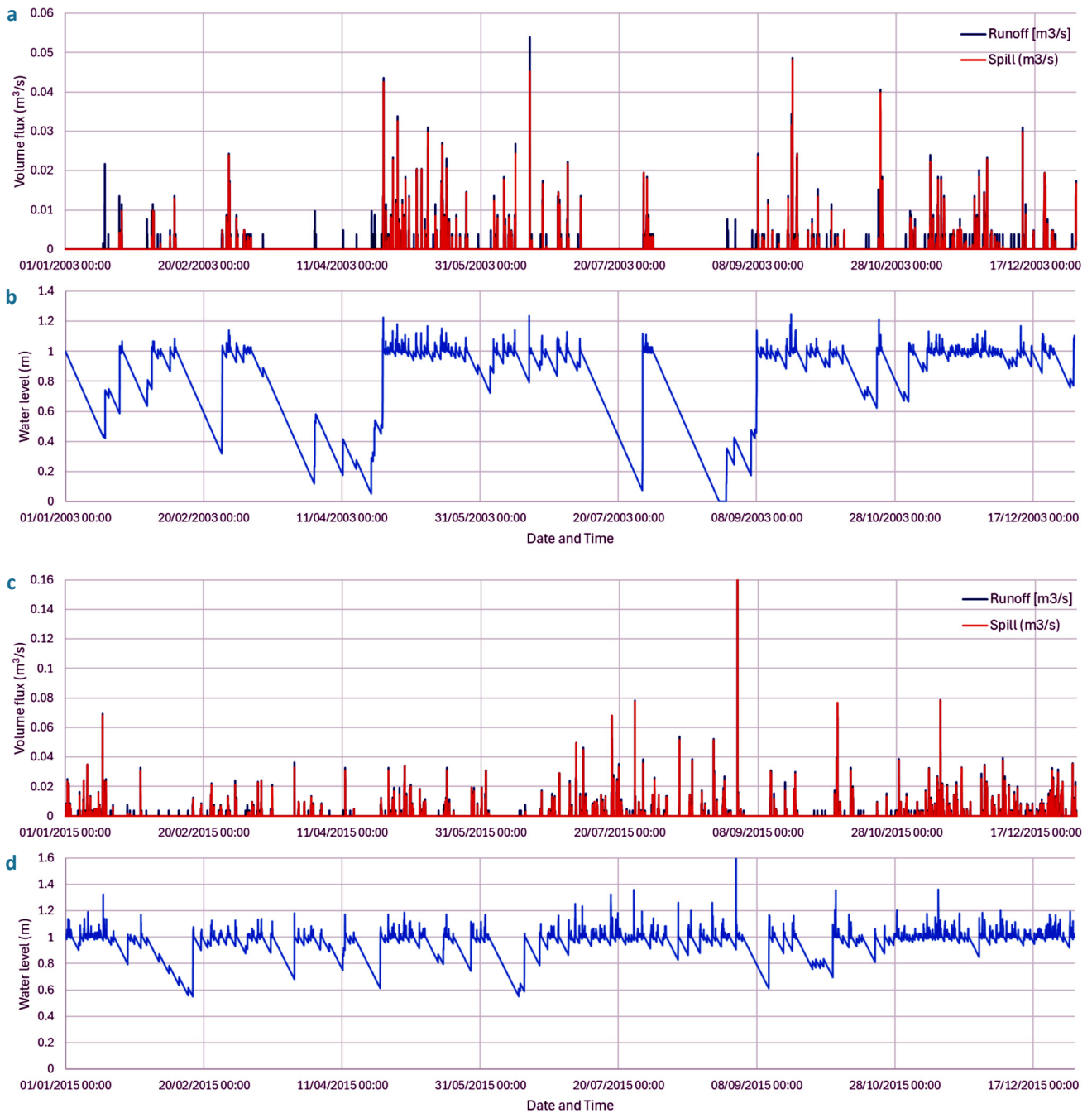


Figure E5.5: (a) and (c) 2003 and 2015 time series of volume flux (m^3/s) for runoff from Ninewells Hospital main car parks and resulting spill into combined sewer system from storage tank (based on tank dimensions in Table E5.2), (b) and (d) corresponding variations in water surface elevation within storage tank during 2003 and 2015 for constant water abstraction rate of 130 l/hr (for reuse in data centre cooling).

It is interesting to note that, for the trial storage tank size selected, the tank is shown to empty for a short period of time based on the 2003 rainfall records between 25-27 August 2003 (Figure E5.5b) following a significant period with no rainfall runoff (from 31 July 2003) (Figure E5.5a). During this short period, mains water would clearly be required to replace the lack of stored surface water. Other periods during 2003 where the tank is shown to nearly empty are on 31 March 2003, 21 April 2003, and 28 July 2003, following particularly dry periods with little or no surface runoff collected

(Figures E5.5a,b). For the 2015 rainfall records, the trial storage tank is shown to remain well filled throughout the year with water levels generally greater than ~ 0.6 m (Figures. E5.5c,d).

In terms of reducing the overall mains water demand from the Brightsolid data centre, there is the potential to collect virtually all of required annual water volume from surface water runoff at the Ninewells Hospital site, based on the 2003 and 2015 rainfall records. It is shown in Table E5.3 that this corresponds to approximately 13% and

6% of the total runoff generated from the hospital main car parks during the dry (i.e. 2003) and wet (i.e. 2015) years. The reuse of surface waters from Ninewells Hospital car parks also reduces the runoff volume directly spilling to the combined sewer system at the site. However, these flow reductions are relatively modest and unlikely to significantly

affect inflow volumes into the combined sewer system from the Ninewells site, particularly when considering total runoff volumes (i.e. from buildings and paved areas) generated across the site. These potential benefits are summarised in Table E5.4 below.

Table E5.3: Summary of main car park surface runoff volume from Ninewells Hospital, abstraction rates and re-use volumes, and spill into combined sewer system, based on 2003 and 2015 rainfall records.

Year	Total runoff volume (m ³)	Abstraction rate (l/hr)*	Total re-use volume (m ³)	Re-use (%)	Total spill volume (m ³)	Spill (%)
2003	8,319.51	130	1,087.8	13.1	7,228.4	86.9
2015	18,051.62	130	1,095.3	6.1	16,956.2	93.9

* Based on constant abstraction from storage tank throughout year, maintaining water level in tank throughout.

Table E5.4: Summary of potential benefits provided by reuse of surface water from Ninewells Hospital main car parks for cooling waters at Brightsolid data centre.

Year	Abstraction rate (l/hr)	Change in mains water demand (%)	Change in runoff volume entering sewer system (%)
2003	130	-100*	-13.1
2015	130	-100*	-6.1

* Based on complete replacement of mains water demand with surface water reuse from Ninewells

E5.4 Depression storage and surface runoff (SCALGO flash flood analysis)

Depression storage and surface runoff volumes were obtained for the Ninewells Hospital site from SCALGO flash flood analysis for the 25.8 mm: 4 hour rainfall event that occurred on 17 July 2015. Figure E5.6 shows the map of the main areas of surface water accumulation on site, as well as the main surface runoff pathways for depression-free flow. The total water storage on the site was estimated to be 5,876m³, while the total runoff volume was estimated at 3,904m³. This is in good agreement with the overall rainfall volume onto the site during the event (i.e. area × rainfall depth = 380,695 m² × 0.026 m = 9,898 m³), which is only 1.2% larger than the combined storage and runoff volumes calculated from SCALGO (= 9,780m³). These storage and runoff volumes thus correspond to about 60% and 40% of the total rainfall volume to the site. Figure E5.5 indicates that the majority of this depression storage is shown to accumulate around the main building complex, while the main outflow pathways from the site flow predominantly in a north to south direction, following the general south-facing topographic downslope at the site.

E5.5 Reuse summary and other considerations

The reuse of surface waters for industrial cooling has the potential to significantly reduce mains water demand associated with the rapid expansion of new data centres across Scotland, especially with many of these centres currently operating on an “open-loop” water system. It has been shown within this scenario that sufficient surface water volume can be collected and stored from the main car park and bus terminal areas at Ninewells Hospital to largely replace the mains water demand from one such data centre, Brightsolid (situated in the adjacent Dundee Technology Park), the exception possibly being during any extended periods of dry weather in particularly dry years, such as occurred in 2003. For this scenario, a suitable sized storage tank (or potentially SUDs infrastructure) would need to be constructed on-site from which water could be abstracted at the required rate (estimated to be ~130 litres/hr). As this surface water is collected from the main car parks and bus terminal at Ninewells, careful consideration of the pollutants (i.e. hydrocarbons, heavy metals, micro-nano particulates) likely to be present within the surface water resource, and thus the level of pre-treatment required for the water to be suitable for use in cooling applications, would need to be fully established. This water quality may be significantly enhanced through passage of the surface water through a well-designed SUDs treatment train.

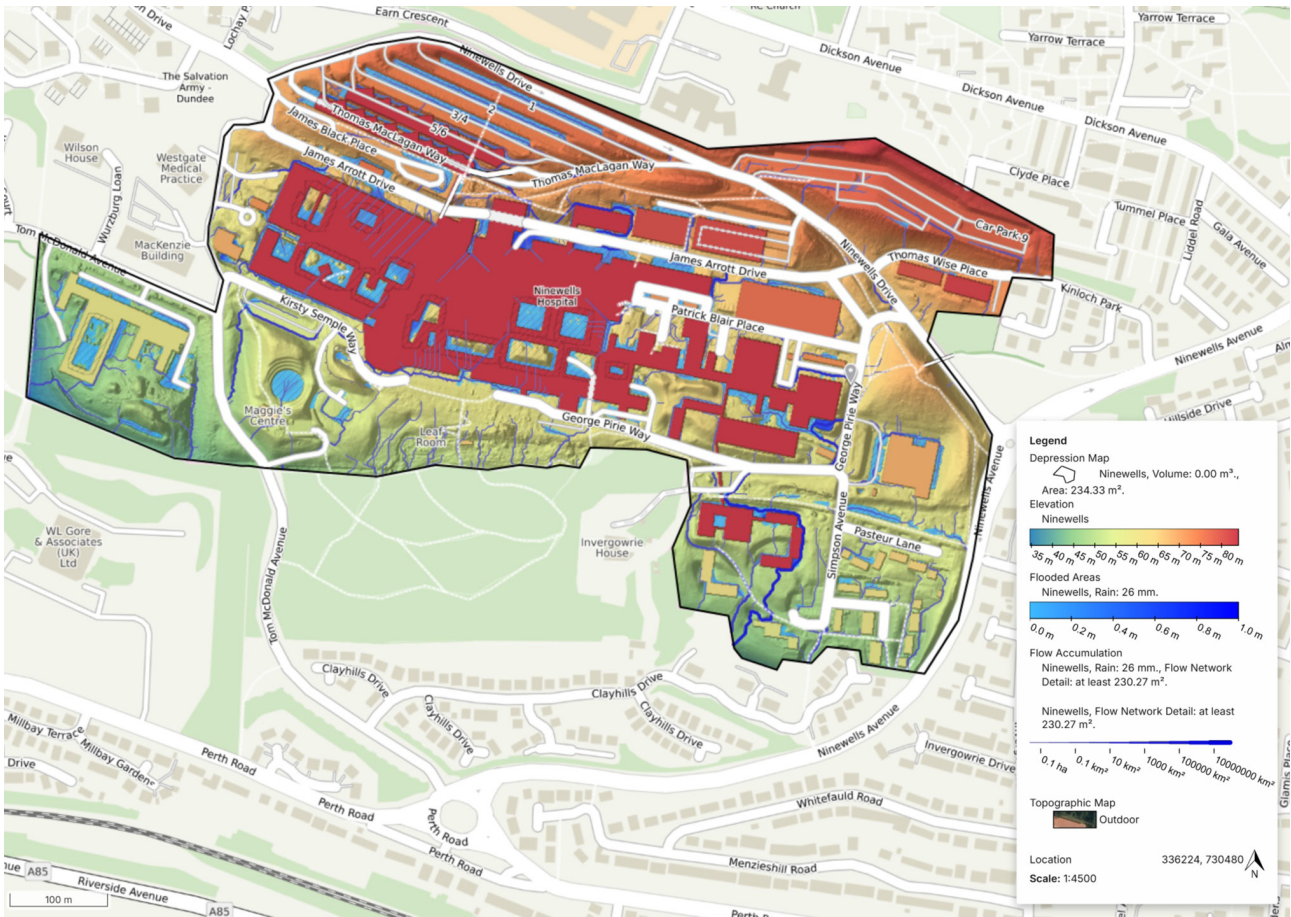


Figure E5.6: Map showing flash flood analysis at Ninewells Hospital for a 26 mm rainfall event over a four hour duration, indicating areas/depths of depression storage and main depression free runoff pathways from the site. Map generated using Scalgo Live. © Scalgo.

E6. Kingsway West Retail Park

Kingsway West Retail Park (KWRP) in Dundee is a major retail outlet bounded by Kingsway West (A90) and Cleppington Road. It has a number of large retail stores and leisure facilities covering approximately 28,000 m² (with an equivalent roof area) on two sides around a large car park for up to 1,200 vehicles. Access roads are to/from Kingsway West and Cleppington Road (see Figure E6.1). The overall site is approximately 0.15 km² in area.

E6.1 Land use and infrastructure assessment

As shown in Figure E6.2, the retail park is largely made up of impermeable land cover types (i.e. buildings, paved roads) with only small areas of shallow/dense vegetation along the northern Kingsway West site boundary and internally within the site. There is very little information on the sewer network at the site, except for a combined sewer running north-west along Cleppington Road from just before the access road into the retail park to the roundabout with Kingsway West.



Figure E6.1: Site map of Kingsway West Retail Park (Map generated using Scalgo Live. © Scalgo).

A second combined sewer crosses the retail park in a northeast direction between Halfords and Tapi Carpets, joining a combined sewer along Kingsway West. There is also a water feature in the retail park, but no information on whether this is designed as a surface water retention pond.

E6.2 Description of surface water reuse scenario and calculated volumes

As indicated in Table E6.1, the surface water reuse scenario considered here is the collection of rainfall from the significant roof area within the retail park through rainwater harvesting, collection and off-line storage. By contrast, the potential to collect significant volumes of water from paved roads and car parks in the retail park is less favoured for two main reasons, (i) the apparent absence of stormwater sewers/SUDs onsite, and (ii) the likely reduction in water quality due to road pollution, compared with higher water quality obtained from roof collection. In terms of specific users of this surface water, there are a number of industrial units in the vicinity of the retail park, including two commercial car washing premises (IMO, Tesco). Estimated volumes of water usage for commercial

car washes vary depending on the type of car wash⁶. Both car wash businesses in the vicinity of Kingsway West Retail Park are commercial tunnel washes, which typically use about 30 gallons per wash⁶ (~140 litres). If it is assumed that both car washes wash an average of 100 cars per day, the total water use over a year would be approximately $2 \times 100 \times 365 \times 140 = 10,220,000$ litres (or 10,220 m³/year).

Within this scenario, the total runoff from all building roofs contained within the SW modelled drainage areas for the retail park (shown in Figure E6.3) are combined to estimate the maximum water volume potentially available for reuse within these local commercial car washes. It is assumed that this volume will be stored locally in off-line rainwater tanks.



Figure E6.2: GIS map showing land cover for the Kingsway West Retail Park, Dundee. Map generated using Scalgo Live. © Scalgo.

⁶<https://engineerfix.com/how-much-water-does-a-car-wash-use/>

Table E6.1: Description of potential surface water access points at Kingsway West Retail Park, Dundee.		
Surface water access point	Ref. on map	Notes
Roofs	–	Large roof area associated with retail outlets (~28,000 m ²) seems to be most straightforward option for surface water collection (i.e. rainwater harvesting) and reuse
Paved surfaces	–	Significant area of paved roads and car parks may offer options to collect surface water runoff.
Stormwater sewer	–	There does not appear to be any separate stormwater sewers in the retail park area or near vicinity.
SUDS	–	No SUDS features are noted within the case study area. Water feature may act as surface water runoff storage pond.

Based on the rainfall records for 2003 (i.e. dry year) and 2015 (i.e. wet year), the total annual volume of surface water runoff collected from rainwater harvesting from the roofs of all commercial retail units in the Kingsway West Retail Park is given in Table E6.2 below.

It is noted that utilising the maximum surface water reuse volume (10,220 m³/year) for the continued operation of the two commercial car washes could hypothetically reduce the mains water demand at both premises to virtually zero (i.e. if an appropriate volume of surface water was consistently available throughout any given year). However, this scenario does not account specifically for variability in rainwater totals throughout the dry and wet years under consideration (i.e. 2003 and 2015), and particularly the effect of prolonged dry spells where rainwater harvesting from the retail park roofs will not be possible. It is therefore more realistic

to consider that a smaller fraction of the total roof runoff volumes will be able to be harvested and utilised at the car washes. In both cases, however, this reuse should still have a significant impact on both the mains water demand from the car washes and the surface water overflow volumes entering the combined sewer system. For example, if we attempt to abstract water from an initially full 128 m³ rainwater storage tank at a continuous rate of 1,167 litres/hr (i.e. ~10,220,000 litres/year), the maximum achievable surface water reuse volumes for 2003 (i.e. dry year) and 2015 (i.e. wet year) will be 5,778 m³ (i.e. 57% of mains water demand) and 8,154 m³ (i.e. 80% of mains water demand), respectively (see Table E6.2). The corresponding outflow volumes to the combined sewer would therefore be 7,569 m³ (i.e. 57% of total roof runoff for 2003 records) and 23,100 m³ (i.e. 76% of the total roof runoff for 2015 records).

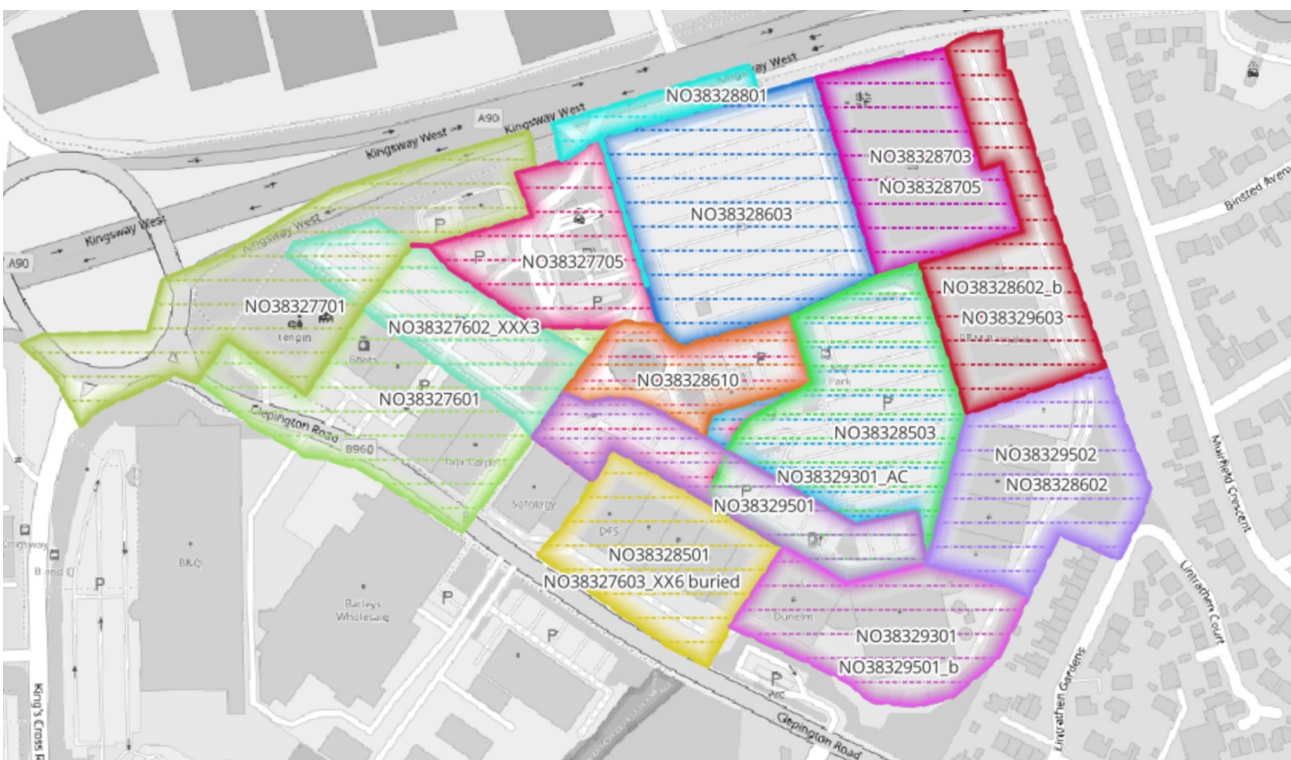


Figure E6.3: Map of the main drainage areas in Kingsway West Retail Park, modelled by Scottish Water to provide a total surface water runoff volume from the roofs of all retail units combined.

Table E6.2: Summary of total surface run-off volume from Kingsway West Retail Park (KWRP), assuming maximum surface water reuse volume generated for 2003 and 2015 rainfall records matches annual water demand from car washes. Residual overflow volume of excess surface water to combined sewer also shown.

Year	Roof runoff volume (m ³)	Maximum re-use volume (m ³)*	Reuse (%)	Residual overflow to sewer (m ³)	Spill (%)
2003	13,353	5,778	43.3	7,569	56.7
2015	31,248	8,154	26.1	23,100	75.9

*Assuming proportion of annual water demand from car washes is replaced by surface water from KWRP

E6.3 Reuse summary and other considerations

Rainwater harvesting from the extensive commercial roof area in the Kingsway West Retail Park can provide a significant water resource that could be reused at local commercial car washes, replacing some of the existing mains water demand for these businesses. Although there is hypothetically enough surface runoff volume from the roofs to completely cover the expected water demand, it is not realistic to remove completely this mains water demand, particularly during extended periods of dry weather with minimal rainfall totals

(as observed during April, July and August 2013). Water quality issues associated with rainwater harvesting from the roofs of the commercial retail park premises should be significantly reduced compared to surface water runoff from paved roads and car parks. However, problems may still exist with microbial/bacterial contaminants from bird faeces (e.g. E. coli), and the potential presence of heavy metals (e.g. copper, lead), nutrients (e.g. nitrites, nitrates, phosphorus), etc. It is therefore likely that some level of pre-treatment of surface water would be required before reuse in the commercial car washes.

E7. Ballumbie (Baldovie North)

Ballumbie is a residential area that is situated in Baldovie directly north of the Michelin Scotland Innovation Parc (MSIP) and Baldovie EfW facility. It is bounded by Drumgeith Road on the south and the Fithie burn on the east (Figure E7.1). The residential area has a significant network of stormwater sewers that collect surface runoff prior to discharging either into the Fithie burn or combined sewer network.

E7.1 Land use and infrastructure assessment

As shown in Fig. E7.2, Ballumbie has an existing network of separate stormwater sewers that either discharge into combined sewers running along adjacent main roads [i.e. (1) and (2), Figure E7.2] or directly into the Fithie Burn [i.e. (3) in Figure E7.2]. As indicated in the SCALGO land cover map (Figure E7.3), the largely residential area consists mainly of individual properties (i.e. buildings), gardens and green spaces (i.e. shallow vegetation), paved roads and other paved areas.



Figure E7.1: Site map of Ballumbie residential area (Map generated using Scalgo Live. © Scalgo).

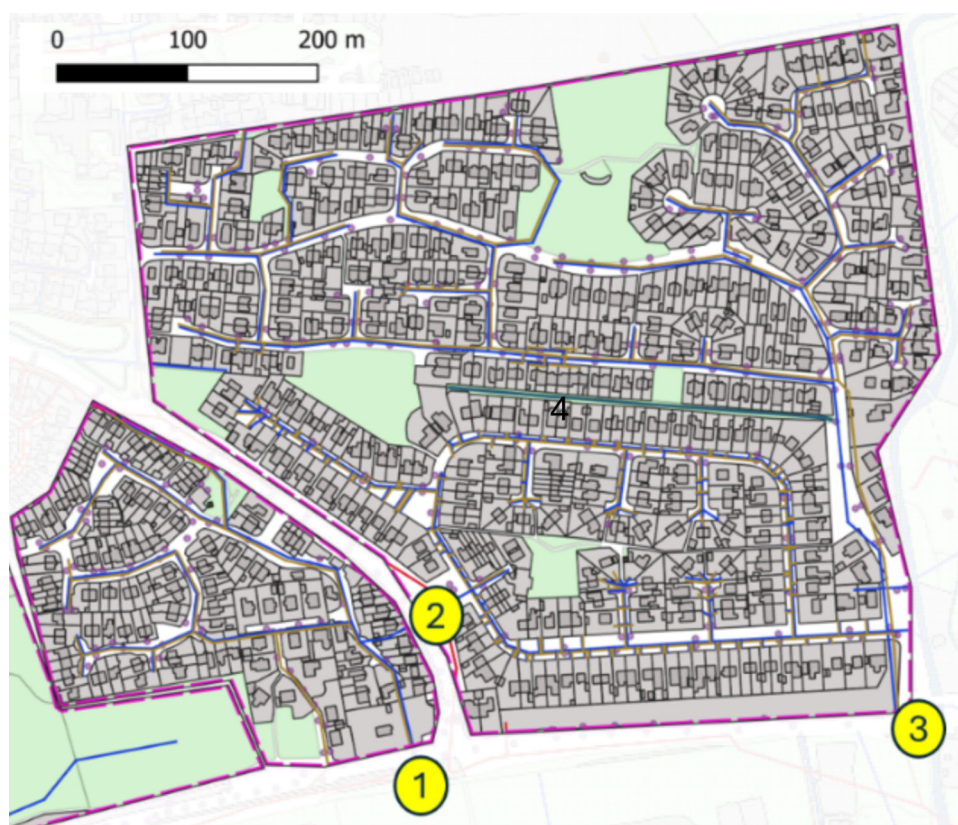


Figure E7.2: GIS map showing Ballumbie residential area in Baldovie North. The network of stormwater sewers within the area shown in blue. There are no significant combined sewers or SUDS infrastructure shown within the site.

Surface water access point	Ref. on map	Notes
Roofs	4	Large percentage of domestic properties in area. Simple rainwater harvesting butts or tanks could be installed at property level to reduce runoff to stormwater sewer.
Paved surfaces	–	Roads throughout the residential area are drained to the separate stormwater sewer network. Collected rainwater may be easier to abstract from the storm sewer.
Stormwater sewer	1	Earlston Avenue area (west of Ballumbie Road) is drained by a stormwater sewer that discharges into a combined sewer along Drumgeith Road.
	2, 3	Hawick Drive (east of Ballumbie Road) is drained by storm-water sewers, some discharging to Fithie burn (3), others discharging to a combined sewer on Ballumbie Road (2).
SUDS	–	No SUDS features are noted within the case study area.

E7.2 Description of surface water reuse scenario and calculated volumes

The surface water reuse scenario considered here is the collection of surface water runoff directly from the separate stormwater sewer before it discharges into the combined sewer. For this scenario, we consider only the residential area to the west of Ballumbie Road (Earlston Avenue area) that currently discharges into the combined sewer on Drumgeith Road. This is the closest discharge point [see (1) on Figure E7.2] to the Michelin Scotland Innovation Parc (MSIP) and Baldovie

EfW facility (see Annex E3 for the MSIP surface water reuse scenario). As stated in Annex E3, the mains water demand for the Baldovie EfW plant is approximately 66,000 m³/year or 66 million litres. As such, abstraction and reuse of surface water runoff volumed from the adjacent stormwater sewer, prior to its discharge into the combined sewer, may provide some degree of offset against this mains water demand. This is again analysed for the annual rainfall records collected at Mylnfield raingauge during 2003 (i.e. dry year) and 2015 (i.e. wet year).

Table E7.2: Summary of total surface run-off volume from residential area to west of Ballumbie Road, assuming 100% is collected directly from the stormwater sewer flows generated for 2003 and 2015 rainfall records.

Year	Total runoff volume (m ³)	Max. available reuse volume (m ³)*	Reuse (%)	Total volume entering combined sewer (m ³)	Spill (%)
2003	6,040.5	6,040.5	100	0	0
2015	14,466.4	14,466.4	100	0	0

*Based on continuous 100% abstraction from stormwater sewer throughout year (no spill to combined sewer)

It is noted from Table E7.2 that utilisation of the maximum available surface water volumes for reuse at the Baldovie EfW facility would result in a reduction in the mains water demand by approximately 9.2% and 21.9%, respectively, based on the 2003 and 2015 rainfall records. Clearly the assumption of continuous 100% abstraction of surface water volumes entering the stormwater sewer for reuse may be unrealistic due to losses throughout the sewer network. Even a stormwater collection efficiency of 50% or even 25% would still have a significant impact on reducing the mains water demand from Baldovie EfW facility by 4.6% or 2.3% for the 2003 rainfall records (i.e. dry year) and by 11% or 5.5% for the 2015 rainfall records (i.e. wet year). This would also continue to have beneficial effects on reducing surface water discharges into the combined sewer system.

E7.3 Reuse summary and other considerations

Direct abstraction of surface water runoff from the separate stormwater sewer system within the Ballumbie residential area, immediately to the north of the Michelin Scotland Innovation Parc (MSIP), can provide a potentially viable water resource for reuse at the Baldovie Energy from Waste (EfW)

facility that currently has a high annual mains water demand. For the residential area considered in the scenario (to the west of Ballumbie Road), the total annual surface water runoff volume, based on rainfall records for particularly dry and wet years (2003 and 2015), equates to between approximately 9% and 22% of this annual mains water demand. These mains water savings are further increased when this is combined with the potential surface water volumes available for reuse from within MSIP itself (see Annex E3). Collection and non-potable reuse of water abstracted directly from stormwater sewers is not without risks from cross-contamination of stormwater with combined sewer waters (e.g. through misaligned sewer connections). In addition, surface runoff entering the stormwater sewer system from paved roads may contain a number of hazardous contaminants and pollutants (e.g. hydrocarbons, oil/grease, heavy metals, micro-nano particulates, debris and sediments) that can significantly affect the quality of surface waters abstracted from stormwater sewers for reuse purposes. This is therefore likely to require a level of pre-treatment for the surface water (e.g. filtration, sedimentation) before the water would be suitable for reuse (potentially through a SUDS treatment train).

E8. St Mary's (Craigowl and St Andrews Primary Schools)

St Mary's is a large residential area in the north of Dundee, bounded by Ardlar to the south and Downfield to the south and east. The total area of St Mary's is approximately 0.66 km². The focus of this surface water reuse scenario within the St Mary's area will be two primary schools: [(1) Craigowl Primary School and (2) St Andrews Primary School, see Figure E8.1).

E8.1 Land use and infrastructure assessment

As shown in Figure E8.2, the vast majority of the sewer system in the St Mary's residential area is combined sewers. There are only limited areas with separate stormwater sewers around the two primary schools in the area: Craigowl [i.e. point (1) in Figure E8.2] and St Andrews [i.e. point (2) in Figure E8.2], and for two small residential areas adjacent to St Andrews [i.e. points (3) and (4) in Figure E8.2].



Figure E8.1: Aerial site map of St Mary's residential area showing two primary schools as focus of surface water reuse scenario (Craigowl to north-west and St Andrews to south-east). Map generated using Scalgo Live. © Scalgo.

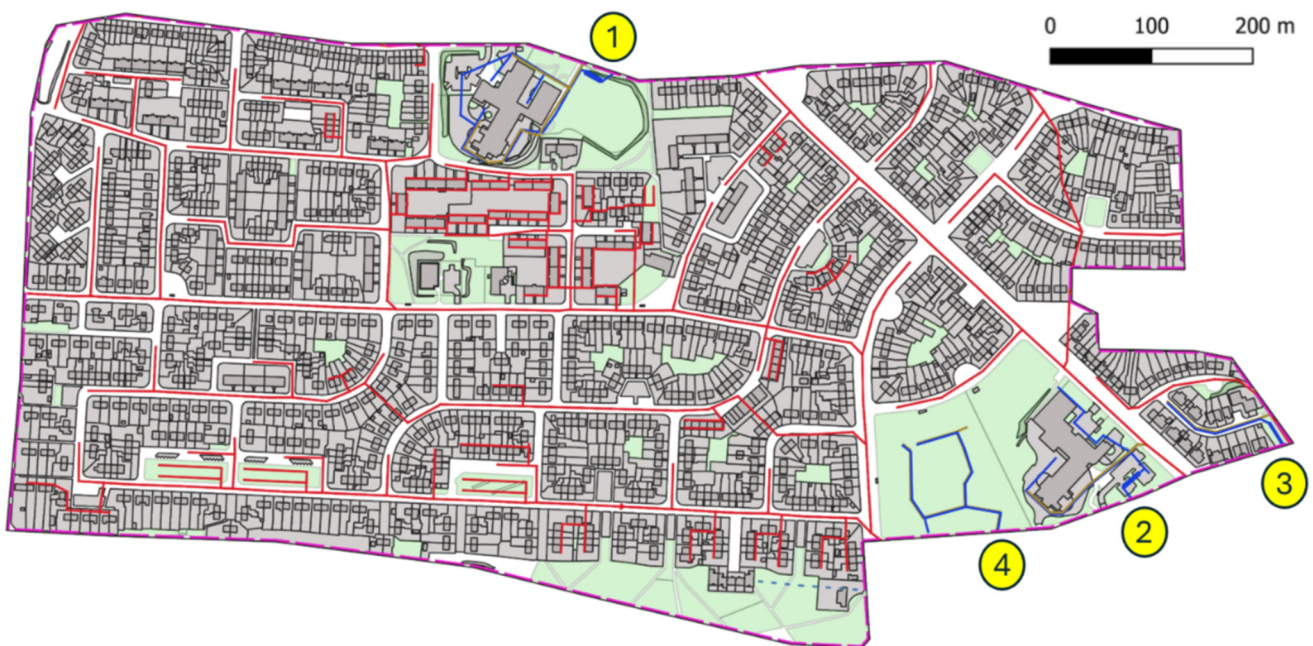


Figure E8.2: GIS map showing sewer system in the St Mary's residential area of Dundee. Combined sewers are shown in red, while separate stormwater sewers are shown in blue.

There is considerable potential for rainwater harvesting at property level within the St Mary’s area, where rainfall runoff from property roofs could be intercepted and collected by water butts before it discharges into the combined sewer system. Note: a pilot community level water butt scheme, supported by Scottish Water and Dundee City Council, is currently ongoing in the area as part of the Water Resilient Dundee St Mary’s Drainage Strategy⁷. However, for the purposes of the current surface water reuse scenario, the focus is on surface water collection and reuse from the two primary schools in the area. Assessment of the potential surface water access points is given in Table E8.1 below with reference to Figure E8.2.

As shown in Figure E8.3, the land cover at both Craigowl and St Andrews Primary Schools in St Mary’s is largely split between the school buildings, paved areas (i.e. car parks and playground), and vegetated areas (i.e. playing

fields). The overall site areas from Craigowl and St Andrews are 2.60 and 2.25 hectares, respectively.

E8.2 Description of surface water reuse scenario and calculated volumes

With the focus of this scenario being on surface water collected from two primary schools in the St Mary’s residential area of Dundee, potentially from roof buildings and paved surfaces. It is anticipated that this water could either be stored in water butts/tanks (when collected directly from the building roofs) or abstracted from the separate stormwater sewer on site, prior to discharge into the adjacent combined sewer system. Potential uses for this surface water resource could be in the irrigation/watering of community gardens, rain gardens or planters within school grounds, or outdoor education through development of SUDS and/or vegetable and fruit growing spaces.

Table E8.1: Description of potential surface water access points in St Mary’s residential area, Dundee.		
Surface water access point	Ref. on map	Notes
Roofs	1, 2	Large percentage of domestic properties in case study area – simple rainwater harvesting butts or tanks could be installed at property level. There are some larger buildings - two primary schools (1) and (2) could be used to collect surface water. These areas are also covered by stormwater sewer collection.
Paved surfaces	–	Surface water collection from roads in the area would be difficult as these typically drain directly to combined sewers. Significant sewer upgrade work would be required to separate stormwater runoff from roads/paved surfaces.
Stormwater sewer	1 - 4	Separate stormwater sewers exist at two primary schools (1) and (2) and small residential areas to east of St Mary’s (3) and (4). (1) – (3) discharge into the combined sewer system.
SUDS	4	The stormwater sewer discharge from (4) discharges to a SUDS pond/attenuation basin. Discharge/overflow from the SUDS pond appears to be to the combined sewer.



Figure E8.3: GIS map showing land cover for the (a) Craigowl Primary School and (b) St Andrews Primary School, St Mary’s, Dundee. Map generated using Scalgo Live. © Scalgo.

⁷<https://waterresilientdundee.co.uk/st-marys-drainage-strategy/>

As a very simple example, it can be assumed that the water demand for these irrigation/watering activities and fruit/vegetable cultivation is 60 litres/hr (between 09:00 – 17:00 each day) = 480 litres/day or 175,200 litres/year at each school. During periods when this surface water is not required for irrigation/watering, it is assumed to drain directly to an on-site rain garden or another small SUDs measure introduced at each school.

Within this scenario, the roof and paved area surface water runoff from the two schools will be assessed separately through analysis of their associated Scottish Water modelled drainage

areas (i.e. NO3747209 for Craigowl PS and NO38332708/801 for St Andrews PS, see Figure E8.4). Again, for simplicity, it can be assumed that rainfall runoff from the school building roofs is collected and stored in 12.5 m³ tanks sited at each school, while surface water runoff from the paved surfaces can be collected, if required, directly from the stormwater sewer system at each site.

Based on the rainfall records for 2003 (i.e. dry year) and 2015 (i.e. wet year), the total annual volume of surface runoff from Craigowl and St Andrews Primary School building roofs and paved areas is shown in Table E8.2 below.

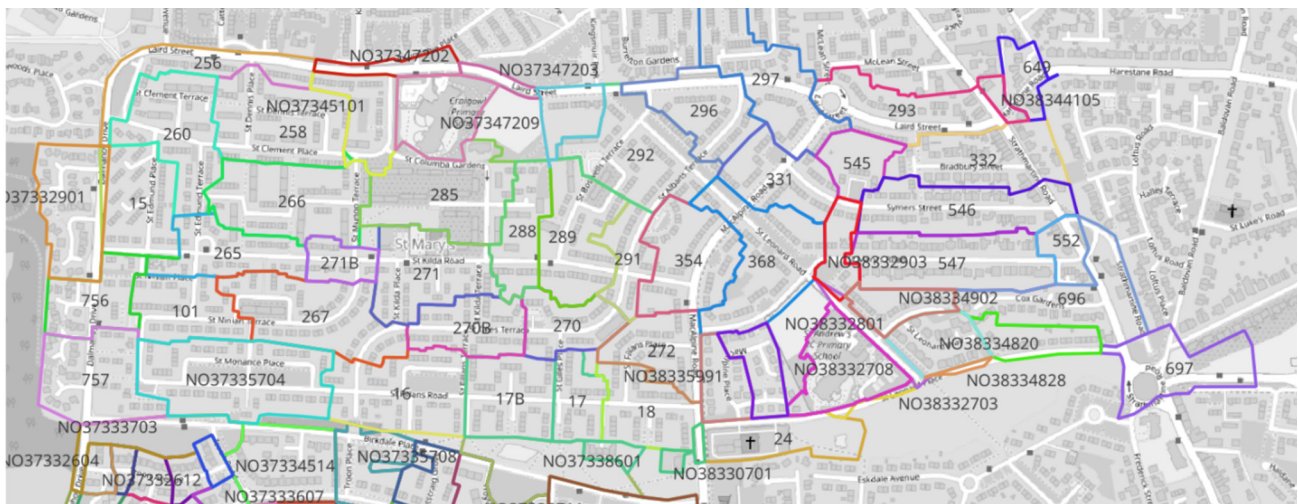


Figure E8.4: Map of the main drainage areas in the St Mary's residential area of Dundee. The drainage areas associated with Craigowl and St Andrews Primary Schools are NO3747209 and NO38332708/801, respectively.

Table E8.2: Summary of total surface run-off volume from Craigowl and St Andrews Primary Schools, St Mary's, Dundee based on surface water volume generated from 2003 and 2015 rainfall records. Estimated roof run-off reuse volumes based on on-site use for irrigation/watering, rain gardens and other small SUDs measures. Residual overflow volume of excess surface water to combined sewer also shown.

Year	Site	Total runoff volume (m ³)	Estimated re-use volume (m ³)*	Reuse (%)	Residual overflow to sewer (m ³) ⁺	Spill (%)
2003	Craigowl:	1,176.7	175.2	14.9	1,001.5	85.1
	Building roof	1,466.9	–	–	1,466.9	100
	Paved areas					
	St Andrews:	1,223.3	175.2	14.3	1,048.1	85.7
2015	Craigowl:	2,551.2	175.2	6.9	2,376.0	93.1
	Building roof	3,180.9	–	–	3,180.9	100
	Paved areas					
	St Andrews:	2,652.6	175.2	6.6	2,477.4	93.4
	Building roof	3,296.2	–	–	3,296.2	100
	Paved areas					

* Assuming daily water "reuse" of 480 litres spread evenly throughout year
⁺ Assuming all surface water volumes not "reused" on-site will discharge via stormwater sewer to combined sewer.

Based on the surface water reuse volumes estimated for irrigation/watering, outdoor education, and cultivation purposes at each school, as shown in Table E8.2, the reuse from of rainwater harvested from school buildings alone would be sufficient to provide this water resource, being 14.3 – 14.9% and 6.6 – 6.9% of the total roof run-off generated from the 2003 and 2015 rainfall records, respectively. As such, this small on-site water demand would only slightly reduce the surface water volumes entering the stormwater sewers at each site, subsequently discharging into the adjacent combined sewer system (equating to about 93% and 97% of the total runoff from the sites for 2003 and 2015 rainfall records, respectively).

E8.4 Reuse summary and other considerations

Rainwater harvesting from the roofs of school buildings can provide a surface water resource that could be used for outdoor education activities

such as gardening and fruit/vegetable cultivation, and the creation of rain gardens, small wetlands habitats, or other SUDS initiatives. However, the volumes of surface water used within these on-site initiatives may be relatively low compared to the overall surface water runoff volumes generated, particularly when combined with other surface water runoff from impermeable paved areas. As such, the benefits achieved from the reduction in surface water volumes entering combined sewer system may be relatively minor. It is also anticipated that surface water reuse at school sites for these activities will have marginal impacts on mains water demand for these sites. Care must again be taken with water quality of rainwater harvested from building roofs that might become contaminated with bacteria, heavy metals and nutrients. There may therefore need to be some level of pre-treatment of rainwater harvested from school roof buildings, particularly if it is likely to be used for fruit/vegetable cultivation or activities where children may be in direct contact with the surface water.

E9. Ardler

Ardler, a residential area in the Northwest of Dundee, has been the focus of previous regeneration work. It has two housing areas, in the north and south,

arranged around a central area of greenspace and community buildings (see Figure E9.1).

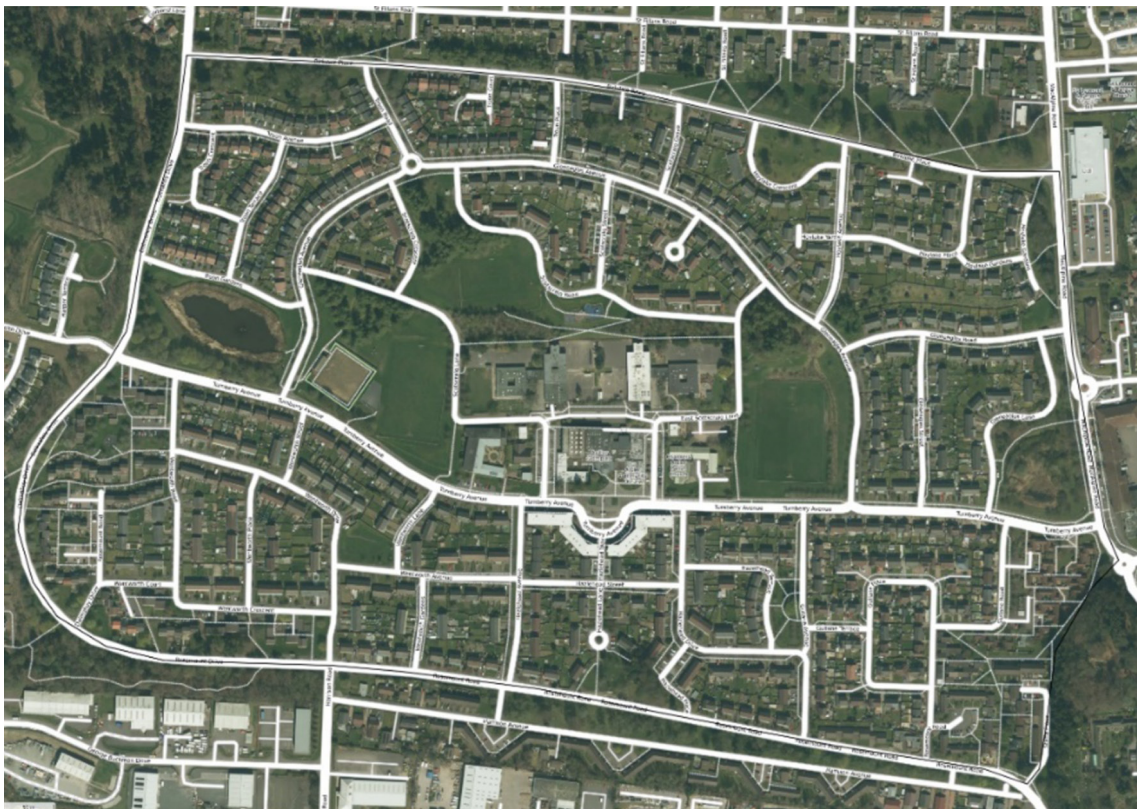


Figure E9.1: Site map for the Ardler residential area (SCALGO). Map generated using Scalgo Live. © Scalgo.

E9.1 Land use and infrastructure assessment

Ardler is bisected by a culverted watercourse connecting two SUDS ponds (Fig. E9.2). To the north of this, domestic properties are drained through separate foul and stormwater sewer systems, although a combined sewer does remain. To the south of the culverted watercourse, the surface water drainage system is mixed, with some areas served by separate storm and foul sewers while others remain on a combined sewer network.

In terms of land use/cover in Ardler (total site area = 0.582km²), this is obtained from the land cover data in SCALGO, as shown Figure E9.3. The largest land cover type present in Ardler is shallow vegetation, which accounts for 30% of the total area (see Figure E9.3). Of the impervious surfaces that are most likely to generate surface water runoff suitable for reuse purposes, buildings (roofs), other paved areas, and roads account for 14%, 26% and 9% of the Ardler area, respectively.

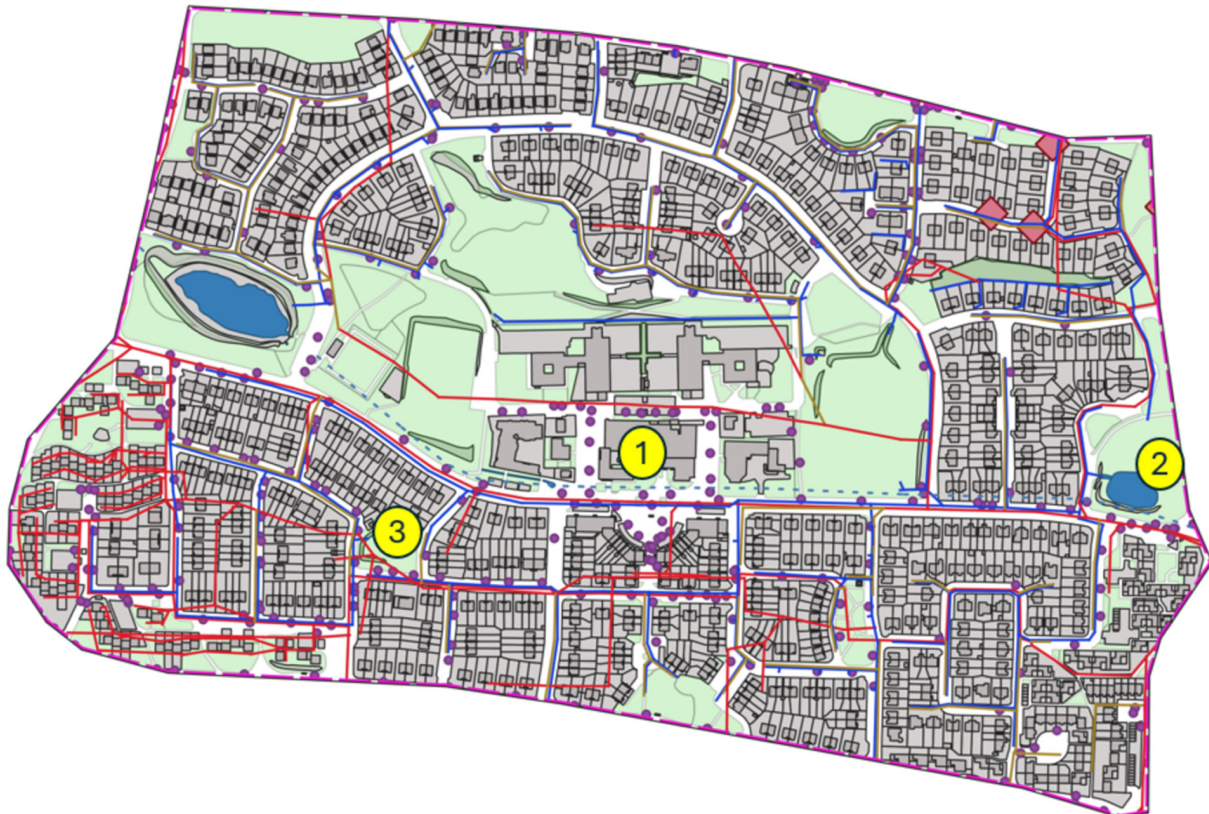


Figure E9.2: GIS map showing Ardler infrastructure. Combined sewers shown in red, storm sewers shown in blue. Label 1 is a potential collection point from non-domestic roofs; labels 2 & 3 are potential extraction points from existing SUDS infrastructure.

E9.2 Description of surface water reuse scenario

For this case study, the impact of domestic rainwater harvesting will be investigated. The area is largely family homes with gardens, so houses with rainwater harvesting have got reasonable opportunity to make use of rainwater collected from roofs.

The surface water reuse scenario considered here is to what extent could rainwater harvesting replace potable water for use in a garden/outdoor use scenario based on assessment of runoff volumes generated from annual rainfall records

collected at Mylnfield raingauge station that are representative of a very dry year (i.e. 2003) and a very wet year (i.e. 2015). The surface runoff data for the Ardler area these two annual rainfall data sets were obtained from model simulations of the surface water volumes entering the sewer system, conducted by Scottish Water (Hatton catchment team). The Scottish Water model simulations split Ardler into drainage areas, for the rainwater harvesting analysis, a single drainage area within Ardler was considered and scaled down to a single household. As shown in Figure E9.4, the data taken from the model was runoff from building roofs in area NO38330531.

Table E9.1: Description of potential surface water access points in Ardler.		
Surface water access point	Ref. on map	Notes
Roofs	1	<p>Widespread opportunity on a domestic scale across the case study site, in the north of the case study area it appears that roof water is collected into stormwater sewers that discharge into SUDS then into a culverted watercourse (Gelly Burn) so RWH in this area could impact potable water use but not peak flow reduction in the combined sewer. In the south of the site the situation is more ambiguous, with both combined and stormwater sewers present. The combined sewer may be superseded/partially superseded, relating to the major change in housing.</p> <p>There are opportunities for roof collection from larger scale buildings, mainly the schools, church and community buildings in the centre of the case study area. These are housed in fairly extensive greenspace, providing a possible use for collected water although given the SUDS in the area, additional irrigation may not be required.</p>
Paved surfaces		<p>Roads are drained into the stormwater sewer and discharged through SUDS, makes more sense to collect from either of these points, rather than require additional infrastructure.</p> <p>Non-roads – the school playgrounds are impermeable hardstanding and could potentially be a collection source. Difficult to assess where these surfaces drain to due to a paucity of data.</p>
Stormwater sewer		Stormwater sewers discharge to SUDS which appear to discharge to a culverted watercourse (emerges as the Gelly Burn). Extraction from this point gives impact 1 (reduce potable water use) but not 2 (reduction in sewer peak flow).
SUDS	2	Two SUDS ponds/attenuation basins that are also providing amenity, overflow might be directed away for use.
	3	Potential to make use of SUDS earlier, point 3 may be an infiltration area.

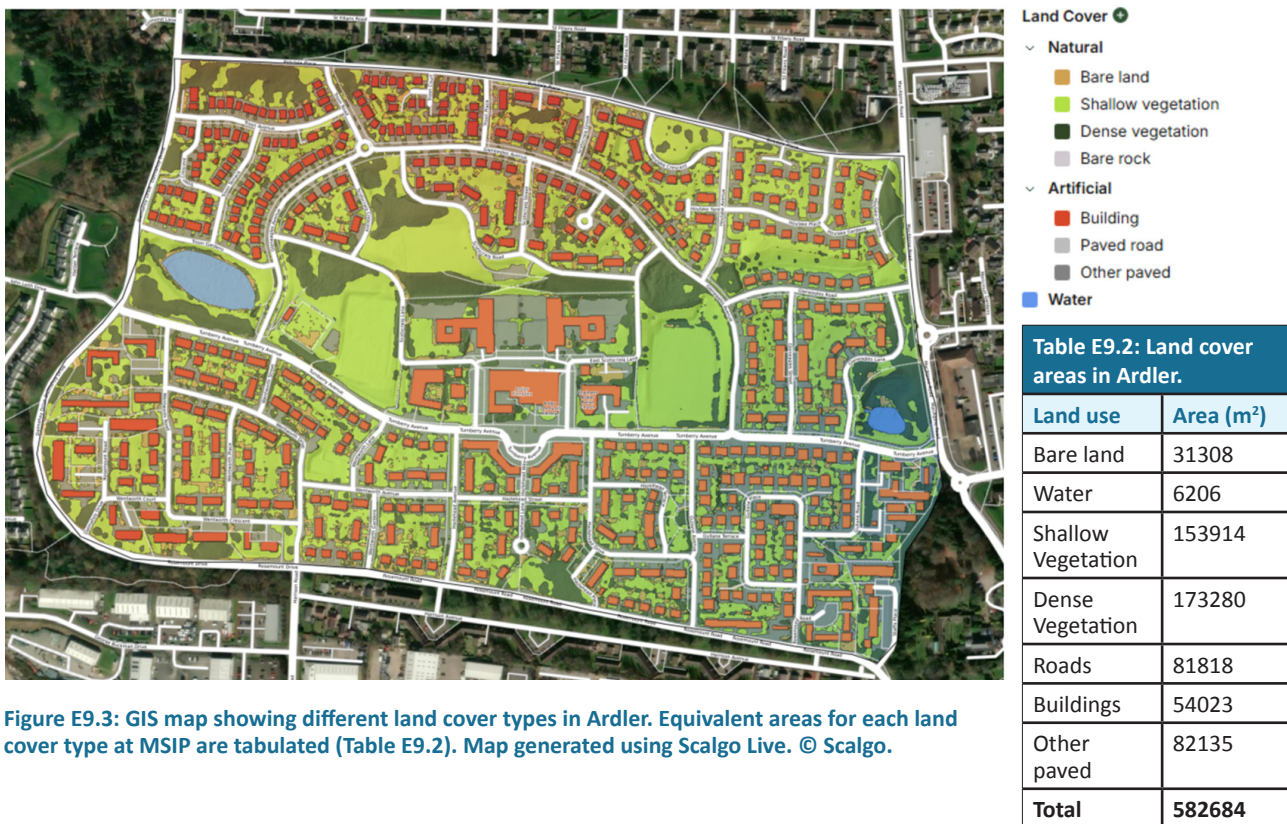


Figure E9.3: GIS map showing different land cover types in Ardler. Equivalent areas for each land cover type at MSIP are tabulated (Table E9.2). Map generated using Scalgo Live. © Scalgo.



Figure E9.4: Map of Ardler showing main drainage areas and highlighting NO38330531 the area modelled for surface water runoff estimation.

Within the surface water reuse scenario for Ardler, it is assumed that the surface water runoff volumes from an individual property roof can be collected and stored temporarily within a storage tank prior to abstraction for use within the individual property, with any residual runoff discharged into the sewer system. As such, the potential impact that this surface water reuse scenario could have on reducing runoff entering the sewer system from the site is also assessed.

In this context, the scenario proposes the connection of a rainwater harvesting tank to the

roof drainage, with tank overflow directed back into the sewer system. A range of typical storage tank sizes – 100, 150 and 200 litres – were considered to assess the impact of storage size on the scenario. Three different use profiles were also considered, each based on manual extraction of water from the tank (reflecting using watering cans to water parts of the garden, rather than a hose/sprinkler set up) and to model behaviour that is responsive to the weather conditions, each use profile is split into dry day use and wet day use. The three use scenarios are shown in Table E9.3. The first two profiles are

Table E9.3: Water use profiles modelled.						
	Minimal summer use		Moderate summer use		Moderate summer use with continual minor drawdown	
	Dry day	Wet day	Dry Day	Wet day	Dry Day	Wet Day
	Litre/day	Litre/day	Litre/day	Litre/day	Litre/day	Litre/day
January	0	0	0	0	2	2
February	0	0	0	0	2	2
March	0	0	0	0	2	2
April	0	0	10	0	10	2
May	0	0	15	0	15	2
June	20	0	20	0	20	2
July	25	0	25	0	25	2
August	20	0	20	0	20	2
September	0	0	10	0	10	2
October	0	0	0	0	2	2
November	0	0	0	0	2	2
December	0	0	0	0	2	2

focused on summer use only, with the minimal use scenario focused only on the peak of the summer months and the moderate use scenario covering a longer growing season from April through to September. The third profile models more use (or loss) from the tank in order to investigate whether leaky or smart drawdown approaches could have a positive impact on attenuation without negatively impacting availability.

E9.3 Surface runoff, abstraction and spill for 2003 and 2015 rainfall

The scenario modelling for Ardler uses a mass-balance approach, with the inflow taken from the surface runoff model and outflow taken from the daily use scenario. Outflow is taken as a single abstraction rather than distributed throughout the day. When there is no or insufficient water available to meet the demand, it is assumed to be fulfilled by potable water instead which enables investigation of the potential savings over the course of a year.

The range of modelling reveals that in all cases, having and using a rainwater harvesting tank reduces potable water use, with the biggest savings occurring with the largest tanks and the highest use.

Rainwater harvesting on this scale does have the potential to replace a proportion of potable water use, although there are some important points to note. As shown in Table E9.4, in dry years – the

2003 scenario – there will be greater demand and therefore the RWH is only able to cover a smaller portion of the demand. In the 2003 scenario there are also lengthy dry spells when the RWH tank sits empty for extended periods – up to 22 days for the 100 l tank and even in the wetter 2015 year there are periods of up to 7 days when no water is available from the RWH system – see Figures E95 and 6. These shortages may have impacts on user behaviour, with the RWH system not considered as reliable. It is notable that the in the scenario with moderate summer use with continual minor drawdown, there is little impact on the performance of the tanks in the summer period but there is a positive impact in the winter months when more attenuation occurs. In 2003 the number of days with no water available increases from 60 to 68 but the driest stretch remains 22 days; across the whole year the number of events where the tank provides some attenuation jumps from 93 (24.7%) to 222 (58.9%) in the continual minor drawdown scenario.

Comparing the moderate summer use with the continual drawdown scenario for the 2015 data, the number of days with no water available increases from 12 to 15 and the driest stretch increases by a day from 7 to 8 days. Considering the capacity to provide attenuation, the number of events where the tank provides some attenuation increases from 111 (20.4%) to 258 (47.5%) in the continual drawdown scenario.

Table E9.4: Summary showing impact of storage tank volume. Figures are for a single household

Storage size (litres)	2003		2015	
	Volume used from RWH (m ³)	RWH use as % of total	Volume used from RWH (m ³)	RWH use as % of total
Minimal summer use				
100	0.52	36	0.55	76
150	0.62	43	0.60	83
200	0.67	47	0.65	90
Moderate summer use				
100	0.81	45	1.10	86
150	0.96	53	1.15	90
200	1.02	56	1.20	94
Moderate summer use with continual minor drawdown				
100	0.75	41	1.09	86
150	0.90	50	1.14	90
200	1.00	55	1.19	94

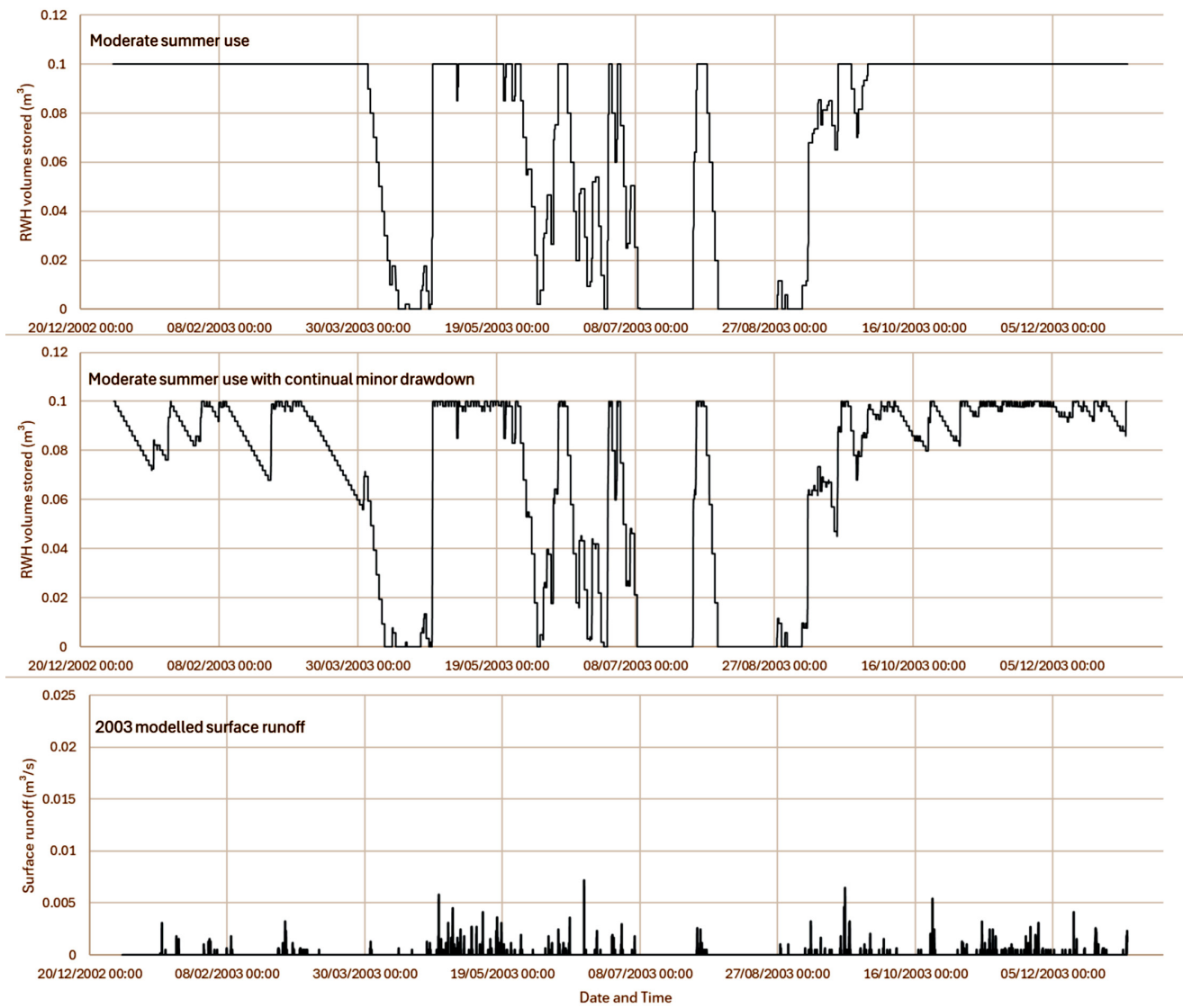


Figure E9.5: Comparing change in storage across 2003 in 100 L rainwater harvesting tank.

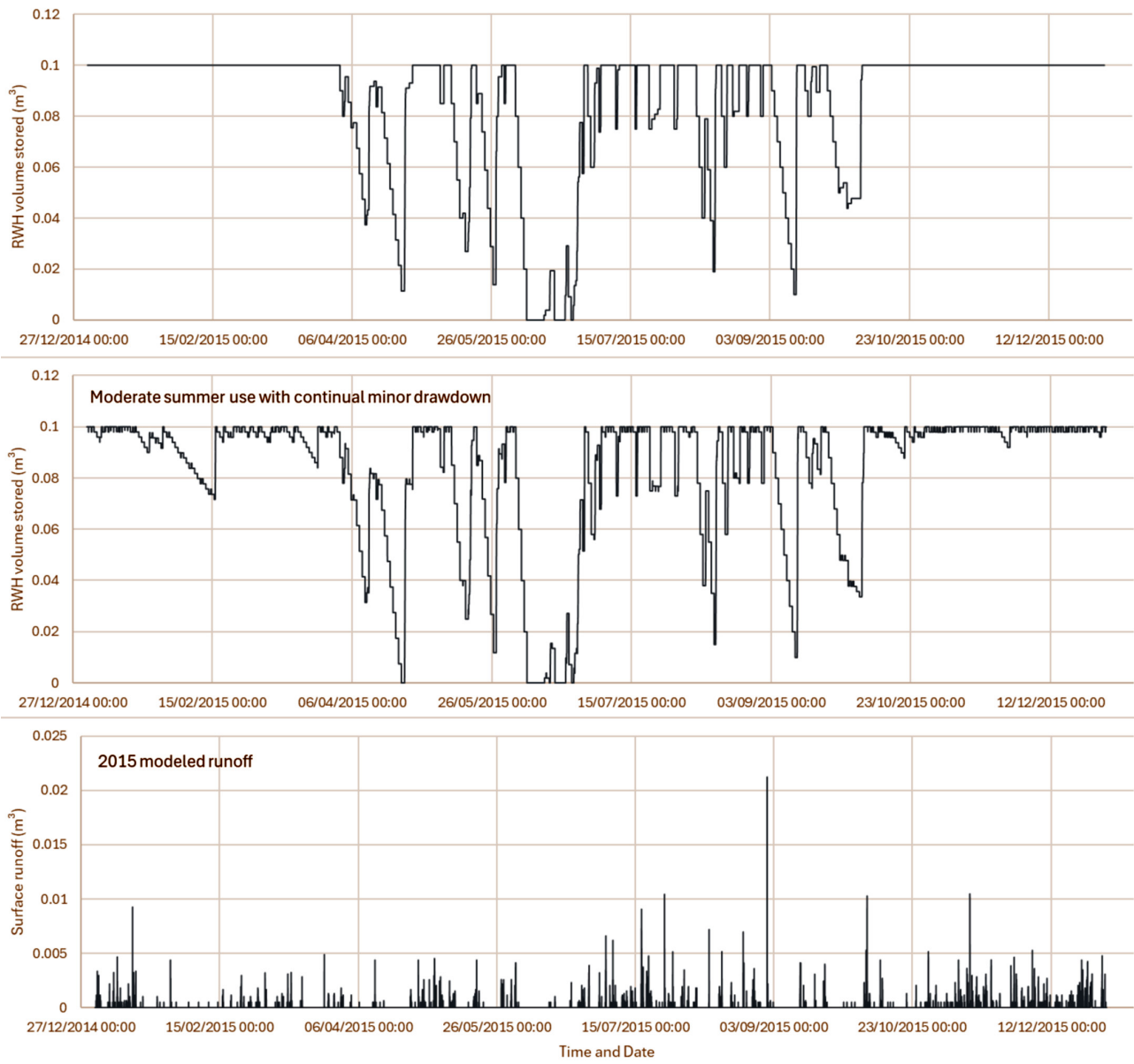


Figure E9.6: Comparing change in storage across 2015 in 100 L rainwater harvesting tank.

E10. Blackness

Historically, Blackness was the prime industrial area in Dundee for jute production during the 19th century, the area having a high density of mills and workers tenement housing closely packed together with a network of narrow cobbled streets (DCC, 2025). Blackness is now a Conservation Area in Dundee and many remaining historic buildings have undergone significant redevelopment with residential conversions, including contemporary student accommodation, as well as a mix of industrial, commercial and leisure uses (DCC, 2025) (Figure E10.1).

E10.1 Land use and infrastructure assessment

As indicated by the historical context of Blackness, the vast majority of the area (0.29 km² in total) is made up of impermeable land cover (i.e. buildings, roads and other paved areas, see Figure E10.2), with only some vegetated areas to the north and east of the area. In terms of sewer infrastructure, a network of combined sewers runs beneath the site, following the main cobbled streets and lanes. The culverted watercourse, the Scouring Burn, also passes through the site in a largely west to east direction, which was crucial to the location of the historic mills in the area.



Figure E10.1: Site map for Blackness area in Dundee Map generated using Scalgo Live. © Scalgo.



Figure E10.2: GIS map showing different land cover types in Blackness. Map generated using Scalgo Live. © Scalgo.

E10.2 Description of surface water reuse scenario

A number of historic cooling ponds associated with these historic mills in the Blackness area could potentially provide viable storage tanks for surface water runoff from the surrounding buildings and paved areas. However, as no specific information is currently available from Scottish Water or Dundee City Council on the current state of these ponds or their potential retrofit to capture and store diverted surface water for reuse purposes, this scenario is largely hypothetical and based on recent assessment of historical cooling pond data (Clements, 2025).

The cooling ponds at site 1 (Brown Street) and site 2 (in vicinity of Brook Street) have estimated combined storage volume of 2,268m³ and 3,585m³, respectively. Rainfall records from 2003 (dry year) and 2015 (wet year) are again used to estimate the surface runoff volumes from adjacent drainage areas to these storage ponds. The drainage areas included at site 1 were NO39307101, NO39307306 and NO39307201 (Figure E10.3), while for site 2 the corresponding drainage areas were NO39302302, NO39301307 and NO39301411 (Figure E10.3). It is anticipated that the potential reuse for this collected and stored surface water runoff could be by local industrial or commercial businesses,

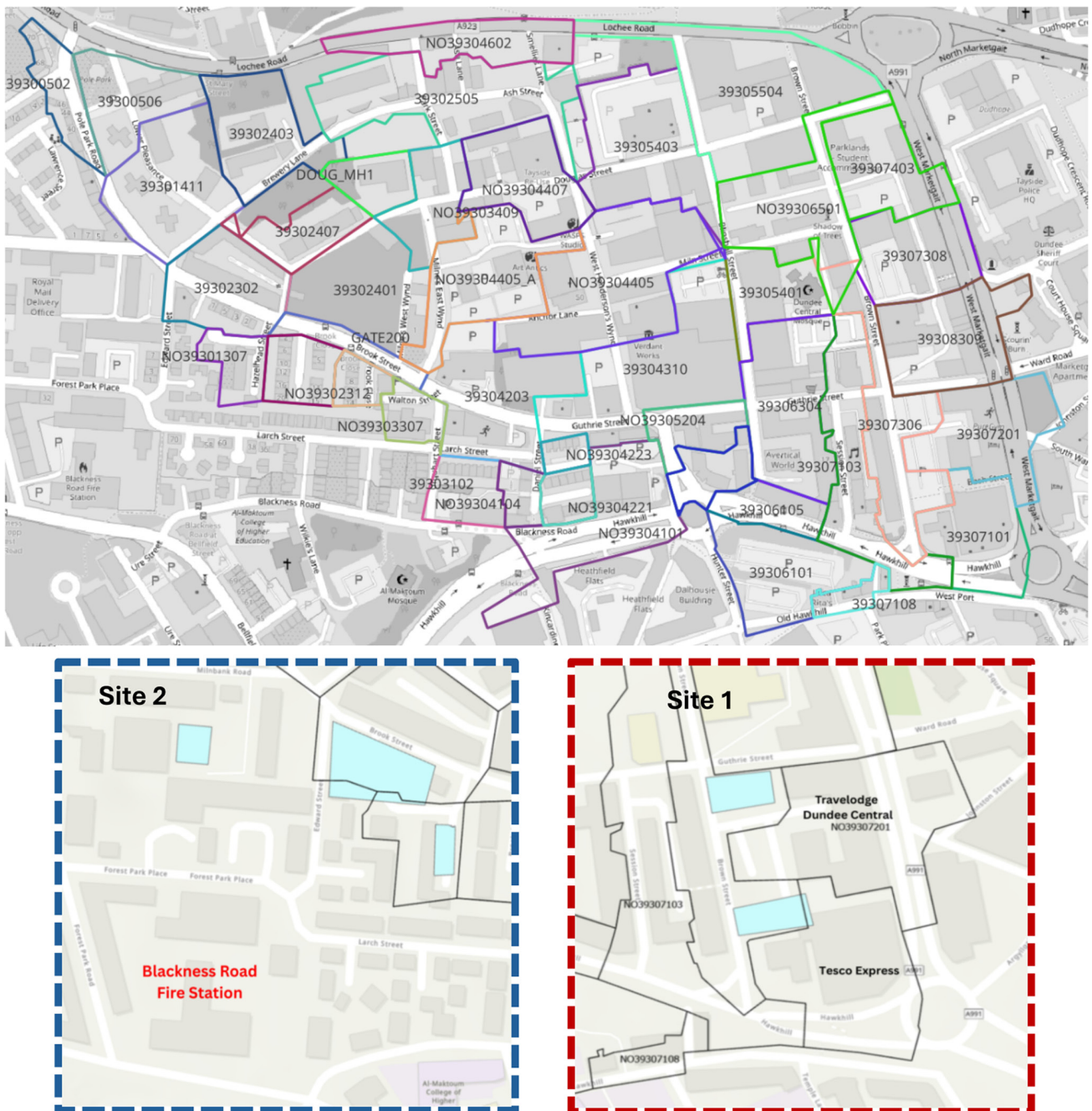


Figure E10.3: Map of Blackness showing main drainage areas from the Scottish Water InfoWorks model. Two areas highlighted to the west (Site 2) and east (Site 1) of Blackness show approximate locations of historic cooling ponds.

local authority services (e.g. green space watering/irrigation, street cleaning) or fire service usage (e.g. at Blackness fire station for fire drills). No specific volume estimates are made for these potential reuse cases, but a constant abstraction and consumption rate of 250 litres/hr is assumed (when possible) from combined cooling tanks at each site for indicative purposes. It is also assumed that these historic cooling ponds are empty at the start of the 2003 and 2015 rainfall records.

E10.3 Surface runoff, abstraction and spill volumes for 2003 and 2015 rainfall

Table E10.1 shows the total surface water runoff from the drainage areas considered at both Blackness sites, based on the 2003 and 2015 rainfall records. These surface water volumes are assumed to be routed into the historic cooling ponds at both locations, with spill to the sewer only possible when these storage tanks are predicted to become full. It is noted that the continuous abstraction rate of 250 litres/hour represents about 19-38% and 27-53% of the total runoff from drainage areas adjacent to Brown Street (site 1) and Brook Street (site 2), respectively. Due to the potential large tank storage capacity of the cooling ponds at both sites, the corresponding spill to the combined sewer network is estimated to be 19-62% and 0-34% of the total runoff volumes at site 1 and 2, respectively, for 2003 and 2015 rainfall records.

E10.4 Reuse summary and other considerations

The potential use of historic cooling ponds as storage for considerable volumes of surface water runoff from surrounding buildings and paved areas could serve to provide both a continual water resource for various non-potable reuse purposes, whilst significantly reducing surface water runoff into the combined sewer system, potentially reducing urban flood risk (e.g. from sewer surcharge) and/or CSO spills. The viability of utilising historic cooling ponds for this storage and reuse purpose would clearly rely on detailed surveys to assess their residual capacity, structural integrity and condition, while ensuring that they are completely disconnected from the combined sewer system. Surface water runoff from post-industrial sites, such as Blackness, would also need careful assessment and monitoring in terms of water quality to identify the potential presence of harmful contaminants (e.g. bacteria, heavy metals). It is envisaged that a level of pre-treatment would be required for these surface waters before the water could be reused in the majority of non-potable uses suggested.

E10.5 References

- Dundee City Council (DCC) (2025). Blackness Conservation Area. <https://www.dundee.gov.uk/service-area/city-development/planning-and-economic-development/development-management/blackness-conservation-area>
- Clements, K. (2025). Modelling the impact of reusing historical infrastructure to reduce surface water flood risk in Dundee, Scotland. BSc dissertation, University of St Andrews.

Table E10.1: Summary of total surface run-off volume from Site 1 (Brown Street) and Site 2 (Brook Street) in Blackness area of Dundee based on surface water volume generated from 2003 and 2015 rainfall records. Estimated abstraction volume for reuse and overflow spill volume to sewer based on storage of runoff in historic cooling ponds at both sites.

Year	Site	Total runoff volume (m ³)	Estimated re-use volume (m ³)*	Reuse (%)	Residual overflow to sewer (m ³)+	Spill (%)
2003	Site 1 (Brown St)	5,315	2,036	38.3	1,012	19.0
	Site 2 (Brook St)	3,614	1,896	52.5	0	0
2015	Site 1 (Brown St)	11,717	2,188	18.7	7,261	62.0
	Site 2 (Brook St)	7,977	2,188	27.4	2,204	36.4

* Assuming continual abstraction and "reuse" of 250 litres/hour throughout year
+ Calculated from the total runoff volume minus sum of estimated reuse volume and tank storage volume.



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