Dunoon Surface Water Management Plan - Options Appraisal Alexander Street

Final Report

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Revision history

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P01 09/08/19	-	Grant Whyte
P02 31/10/19	ABC Comments	Grant Whyte

Contract

This report describes work commissioned by Grant Whyte on behalf of Argyll & Bute Council by Purchase Order number AB315359. Argyll & Bute Council's representative for the contract was Grant Whyte. Steven Thomson of JBA Consulting carried out this work.

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Purpose

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Contents

1 Introduction

1.1 Site location

The hillside immediately above (west of) Alexander Street consists of open ground covered by small trees, bushes and scrub vegetation. Surface water is intercepted by a number of drainage channels which discharge into culverts before flowing under the urban area of Dunoon. The area above this open hillside consists of recently felled commercial forestry. The primary flood risk relates to the performance of two key headwalls at the top of John Street which are prone to blockages and are under capacity resulting in out of bank flows. The secondary flood risk relates to the sewer network's capacity to deal with the inflows from the catchment which may result in issues further downstream in the network.

1.2 Objectives of the study

The objective of this options appraisal study is to:

- Understand the flooding mechanism of the existing drainage network.
- Undertake a hydrological assessment of the contributing catchments to determine the volume of water entering the combined sewer network during storm events.
- Analyse the impact of the proposed housing development and suggest improvements to the existing drainage network.

2 Existing conditions

2.1 Site visit

On Tuesday 30th January 2018 Steven Thomson and Rene Dobson of JBA Consulting undertook site walkover surveys of 3 surface water flooding hotspots in the Dunoon area and 1 in Kilcreggan. The sites that were visited are those that had been highlighted in the Dunoon and Kilcreggan 2019 SWMPs as high priority (Dunoon SWMP 2019, JBA).

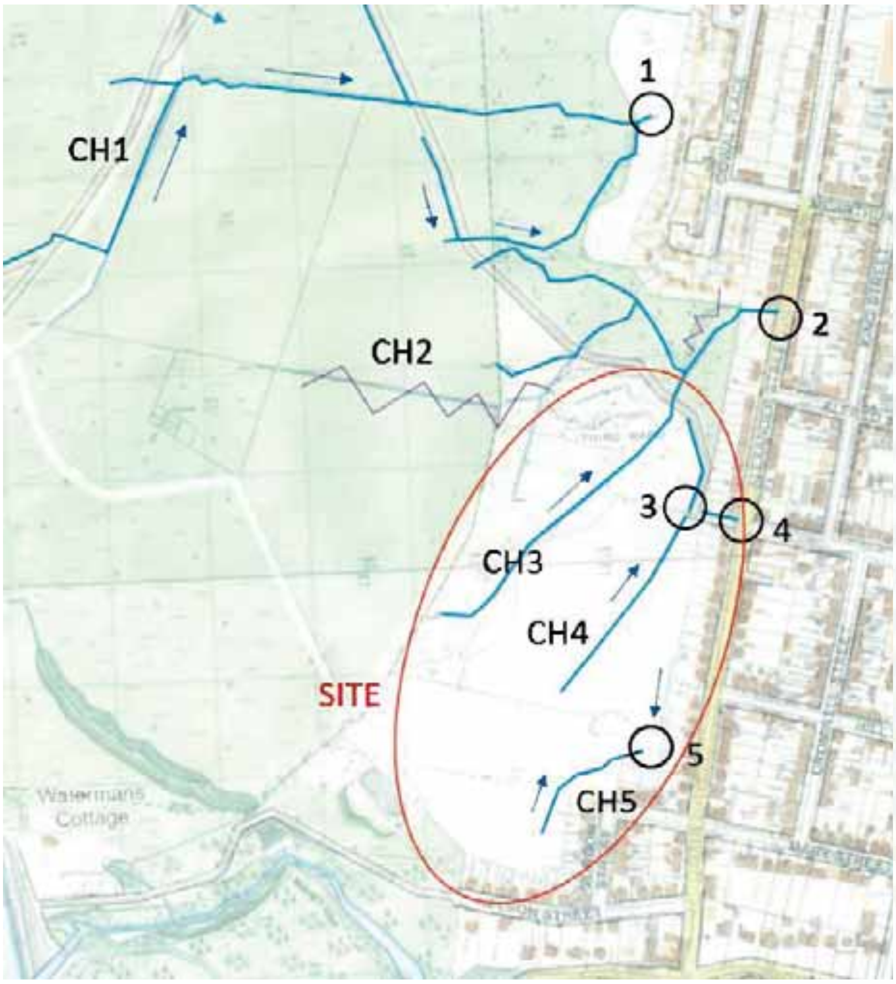
Upon arrival at Alexander Street Argyll and Bute Council (ABC) provided a map recently produced by Kaya Consulting as part of an FRA which was underway for a proposed housing development (19/01456/PP). The proposed development is identified in the Local Development Plan (LDP) and is to consist of approximately 100 affordable homes. The proposed development encompasses the majority of the catchment which discharges to the headwall at John Street.

As well as the channels listed in figure 2-1 below, runoff was observed seeping into the combined sewer via road gullies from gardens and driveways despite dry weather at the time of the walkover. This confirms the presence of rural contributions to the combined sewer in this area out-with the known channels.

2.2 Drainage Channel Walkover

Channels 2,3,4 and 5 were assessed during the walkover. Following a review of Scottish Water data made available post SWMP it is evident that Outfalls 4 and 5 connect to the combined sewer.

Figure 2-1: Map of drainage channels produced by Kaya Consulting

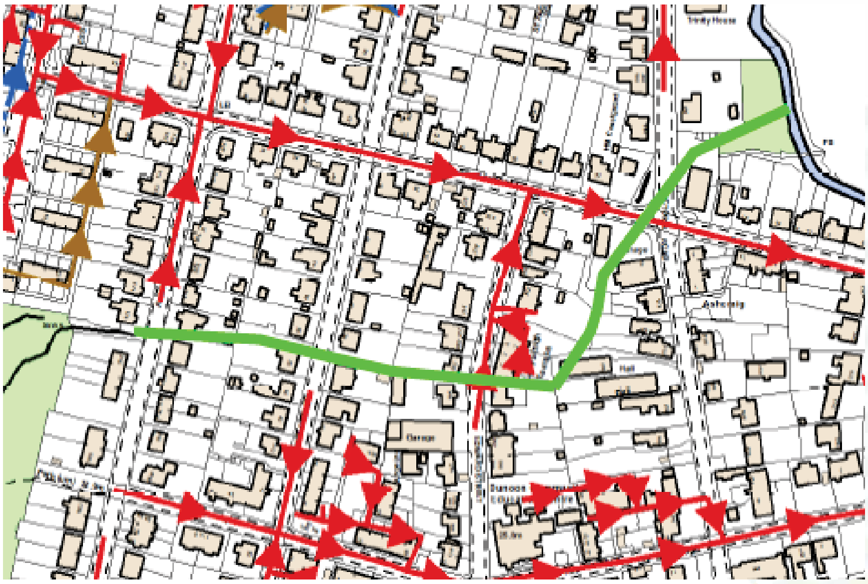


2.2.1 Channel 2:

Channel 2 intercepts Channel 3 before flowing through a large headwall structure on the boundary of the woodland. From here the channel flows in a masonry U-shaped channel to the culvert headwall at Alexander Street (point No.2). The large debris (sofa) was noted in the channel upstream of the trash screen. Scottish Water mapping shows that this watercourse is culverted to an outfall on the Milton Burn.

Figure 2-2: Debris upstream of trash screen (Channel 2)

Figure 2-3: Scottish Water map extract of culverted watercourse (green line – surface water only)



2.2.2 Channel 3:

Channel 3 is one of the larger watercourses on the hillside with flows greater than that of Channel 4 on the day of the site walkover. Under normal conditions the channel passes east of a quarry and through a 300mm ∅ culvert under an access road. At the time of inspection, the culvert was heavily silted, operating at approximately 70% capacity. Following intense rainfall or further blockages at the culvert the watercourse will overtop to the south and flow into the upstream extent of Channel 4.

Figure 2-4: Upstream face of culvert (Channel 3)

Figure 2-5: Point of overflow into Channel 4 north from over topping headwall of Channel 3

2.2.3 Channel 4 upper reaches:

Channel 4 is effectively split in two sections; a short trackside drain to the north and a more substantial drainage channel to the south. The larger drainage channel drains a significant area of hillside and at the time of the site visit was flowing with little sediment and clear of silt and debris blockages. Both drains connect at a headwall before flowing under the access track into a short section of open channel upstream of the headwall and connection to the combined sewer at John Street.

The headwall where the north and south channels join consists of a 450mm ∅ pipe which was submerged due to flows during the site assessment. This is known to overtop and flow down the access track onto Alexander Street. This is the primary flood risk to the properties on John Street and Alexander Street. Road gullies at the base of the access track (western extent of John Street) are blocked by sediment causing flood waters to flow east down John Street or South on Alexander Street. Historically flood water which flows along Alexander Street enters a low-lying property causing interior and exterior damage.

Figure 2-6: Channel 4 north section (also conveys flows from overtopping Channel 3)

Figure 2-7: Channel 4 north and south branch confluence at headwall

Figure 2-8: Channel 4 flooding mechanism at headwall due to under capacity / blocked culvert

Figure 2-9: Channel 4 overflow down access track from confluence headwall

Figure 2-10: Sediment/washout from access track blocks Alexander Street road gullies in flood conditions

2.2.4 Channel 4 lower reach to Alexander Street headwall:

The sediment load in channel consists of gravel and cobbles and is actively eroding the channel bed and banks. The erosive power of the water can be attributed to the relatively steep gradient of the channel which also features small drops (boulders/culvert inlet). Sediment transport is known to be an issue as there is visual evidence of sediment build up at the headwall inlet. This can decrease the capacity of the headwall inlet which then overtops sending further sediment onto the road which in turn blocks road gullies as well as likely contributing to the sediment load in the combined sewer.

Both banks are heavily vegetated by Japanese knotweed although it had been recently cleared at the time of inspections. Informal drains have been constructed by residents which intercept runoff from rear gardens and directs it into the watercourse. It was also apparent that some sediment removal had also been undertaken and placed on the right bank of the watercourse.

The headwall itself is narrow and could easily be blocked by vegetation particularly if the knotweed regrows. Based on site observations due to the increase in height of the right bank (sediment removal works) over topping water may be directed to the left of the headwall and into the front garden of a private property before spilling on Alexander Street. The information available from Scottish Water suggests that this reach discharges directly into the combined sewer.

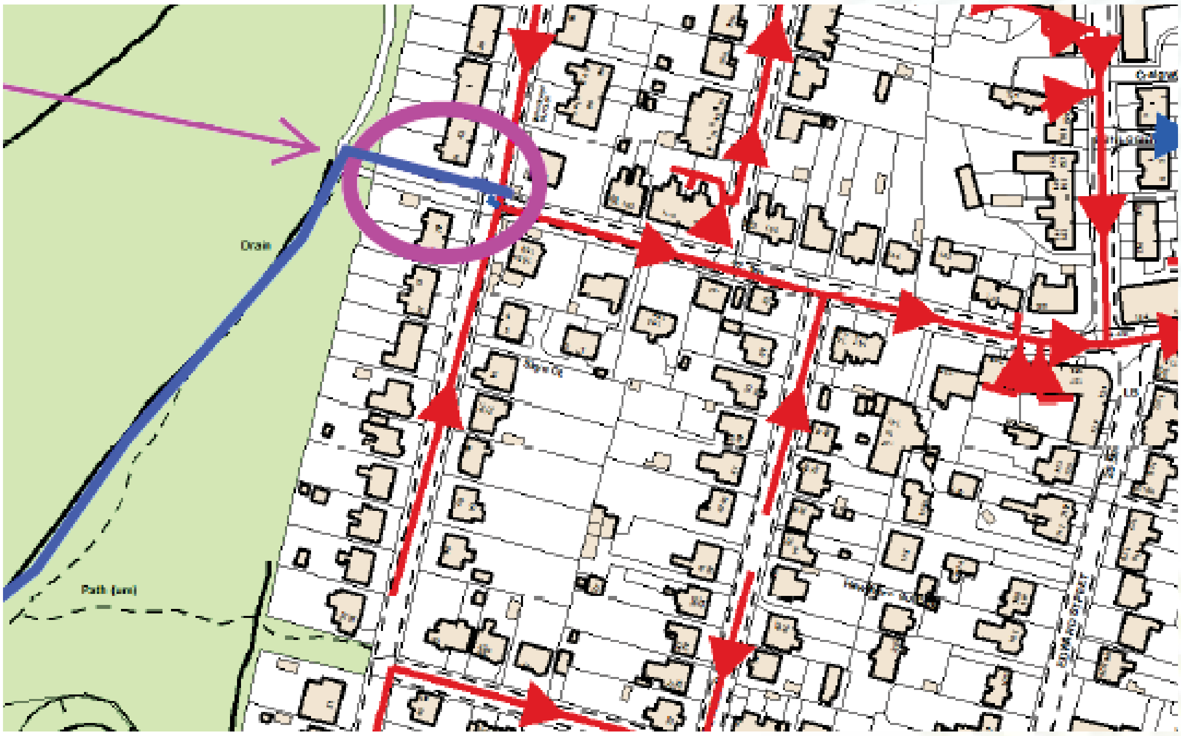
Large quantities of gravel - (washout from access track/sediment from overtopping) could be seen at the base of the access track adjacent to two road gullies on Alexander Street. The gullies are known to have blocked in the past leading to flood damage of residential properties on Alexander Street.

Figure 2-11: Headwall area at Alexander Street and John Street junction

Figure 2-12: Typical condition of Channel 4 lower reach upstream of the Alexander Street headwall with informal drainage ditch from adjacent private garden

Figure 2-13: Sediment immediately upstream of headwall at Channel 4

Figure 2-14: Scottish Water plan showing connection to the combined sewer



2.2.5 Channel 5 lower reach to Alexander Street headwall:

Channel 5 is a short watercourse which drains an area of bog and hillside toward the south of Alexander Street. The information available from Scottish Water suggests that this discharges directly into the combined sewer. The culvert which connects the headwall to the combined sewer appears to have been recently upgraded from 2No. 6-inch diameter clay pipes to a single 300mm ∅ twinwall pipe. The original headwall appears to have been retained with rudimentary screens providing limited protection from blockage.

Figure 2-15: Channel 5 typical profile

Figure 2-16: Channel 5 current headwall, screen and culvert arrangement

Figure 2-17: Previous headwall arrangement with 2No. clay pipes

Figure 2-18: Scottish Water plan showing connection to the combined sewer

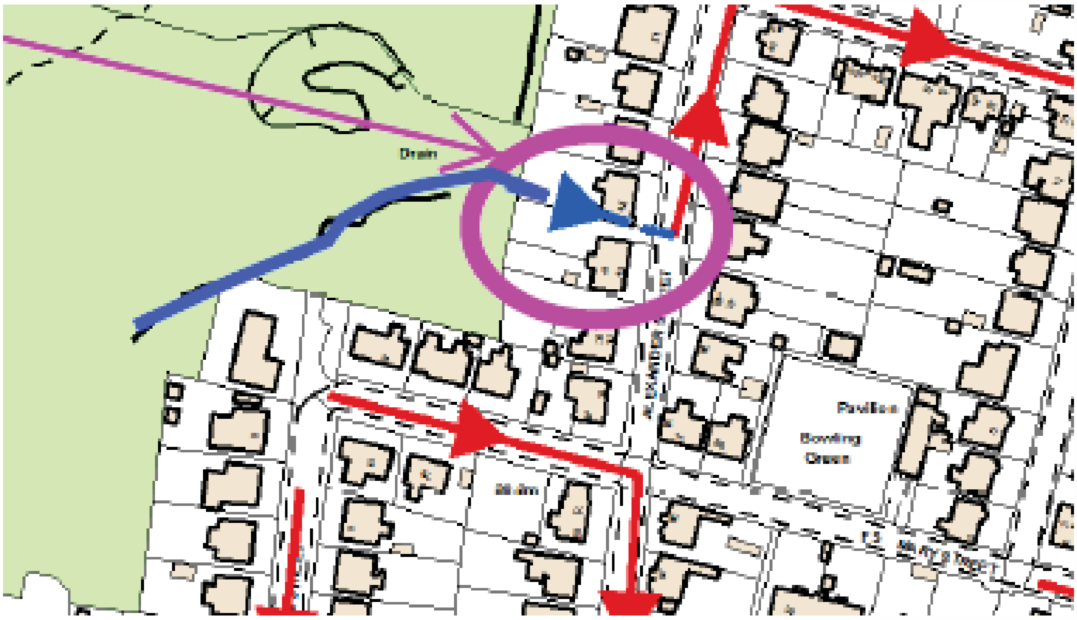


Figure 2-19: Gap in houses facilitating continuous baseflows in to the combined sewer

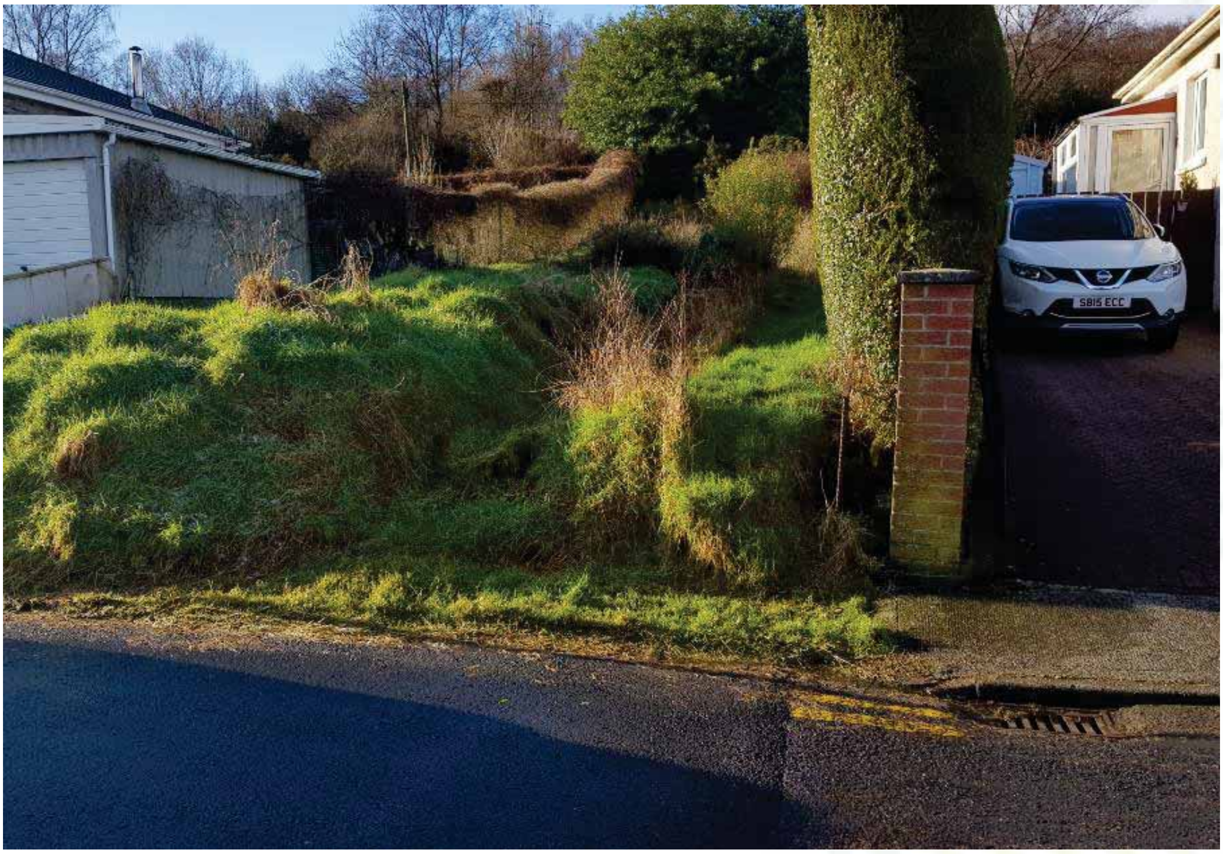


Figure 2-20: Ground water seepage emerging from gardens and driveways typical of properties along Alexander Street

2.3 Site surveys (Topography, drainage etc)

Walk over studies have been undertaken over the years by various parties. However, no formal studies have been undertaken. A flood risk assessment and drainage impact assessment are known to be underway for the proposed housing development.

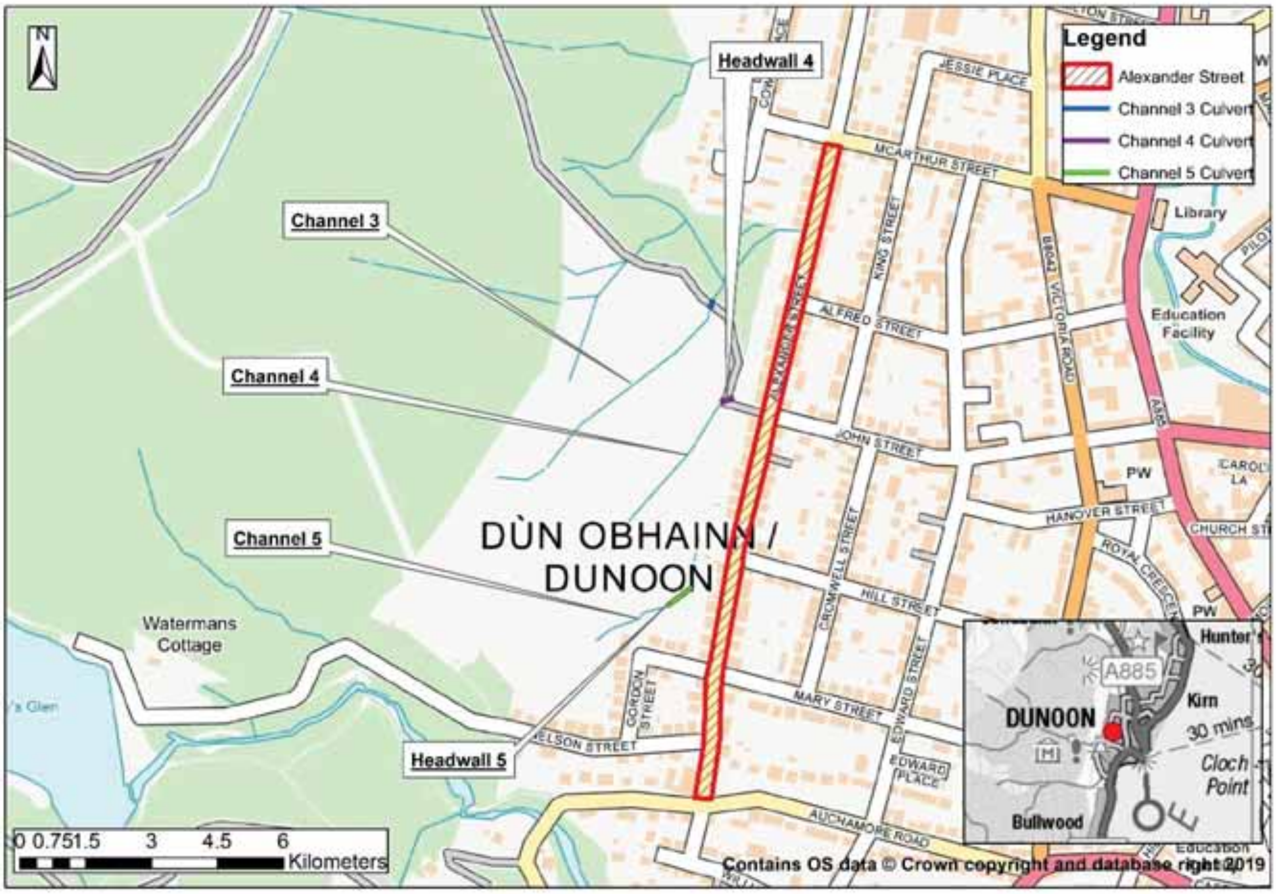
3 Hydrology

3.1 Background and scope

The primary mechanism of flooding at Alexander Street is overland surface water flow to the street, originating from the west (draining from an open hillside which consist of recently felled commercial forestry which comprising of small trees, bushes and scrub vegetation). Flows from the west are intercepted by several drainage channels which intercept pluvial flow for discharge via culverts underneath the urban area of Dunoon into watercourses or the combined sewer network. The surface water flood risk relates to the performance of two key headwalls, located west of John Street underneath an access track (90m and 180m west of Alexander Street) which are prone to either blockage or are under capacity. This results in out of bank flows which erodes an access track, blocking road gullies before flowing towards low-lying residential properties.

The purpose of this study is to assess the overland flow paths that reach the houses and inlets on Alexander Street, Dunoon using an appropriate 2D hydraulic modelling. The return periods required are the 1-in-2 year, 1-in-5 year, 1-in-10 year, 1-in-30 year, 1-in-50 year, 1-in-100 year, 1-in-200 year and 1-in-200 year + CC (climate change) events. In the context of this review climate change uplifts have been applied at 20% in accordance with SEPA's Technical Flood Risk Guidance for Stakeholders, Version 12, 2019.

Figure 3-1: Study Location and significant features



3.2 Methodology

3.2.1 Hydraulic modelling

To assess the flood risk and the overland flow paths to Alexander Street, a surface water hydraulic model was constructed in Infoworks Integrated Catchment Model (ICM) to assess flood risk from pluvial sources within the catchment both to and from the site. ICM allows for a single model that can incorporate urban and river catchments and enables the hydraulics of both to be assessed in a single model. It is considered the most suitable software where flood risk to a site may arise from multiple sources. The inputs to the ICM model in order to assess surface water flood risk are a Digital Terrain Model (DTM) and a design rainfall event.

Two scenarios were considered within the hydraulic model:

- Scenario 1 - Baseline Scenario to represent the overland flow paths and flood risk to Alexander Street with the drainage system working to full efficiency.
- Scenario 2 - Blockage Scenario to represent the overland flow paths and flood risk to Alexander Street where flows from Channel 3 are diverted into Channel 4, caused by a blocked culvert (See Figure 1-1).

As well as assessing pluvial flood risk to risk Alexander Street, an assessment will also be undertaken for the headwalls of Channel 4 and Channel 5 for both scenarios to determine the potential impact that a blockage scenario of the culvert along Channel 3 would have on the flows reaching the headwall in Channel 4.

3.2.2 Digital Terrain Model and 2D mesh

To assess surface water flood risk, the contributing catchment must be included in the model, to determine flow entering the site. Therefore, a DTM was created by combining freely available elevation based data and LiDAR data, obtained from the Scottish Remote Sensing Portal (SRSP). ICM builds a mesh of triangular elements with varying cell size base on the terrain which allows for flat areas to be modelled with large elements and undulating areas to be represented with small elements. The mesh parameters were set so that the minimum element size and maximum mesh triangle area set to $1m^2$ for the whole of the study area. Boundary Points were set to Normal Condition and the Rainfall Percentage value was changed from the default of 100% to 75% to represent the surface water which will be soaked up by permeable ground.

Built structures utilised for this study were derived by using OS Open Map Local data to create a shapefile of buildings located within the 2D mesh zone. Buildings were imported into the model as porous polygons with a height of 300mm and a porosity of 30%. The roads were exported as roughness zones and were given a roughness co-efficient of 0.005. Both DTM scenarios included culverts which flow underneath an access track to the west of Alexander Street and Johns Road to represent normal flow through these culverts into the combined sewer.

A second mesh zone was created to simulate the blockage scenario. For Scenario 2, the culvert in Channel 3 was modified to simulate a blockage scenario by removing the culvert from the 2D Mesh Zone as the culvert located on Channel 3 has been identified as a structure which could be susceptible to blockage within the model extent. On inspection of the culvert at Channel 3, it was noted that it was heavily silted and was operating at around 70% capacity. Intense rainfall or further blockages at this culvert would cause the watercourse to overtop and flow into Channel 4.

3.2.3 Design Rainfall Events

Rainfall estimates were generated using the Flood Estimation Handbook (FEH) with Depth-Duration-Frequency (DDF) modelling used to generate a baseline rainfall. Catchment Descriptors were obtained for the site from the FEH Web Service in February 2019. 1 km² DDF parameters are included within the FEH Web Service catchment descriptors and were used to inform the InfoWorks FEH rainfall generator available within the ICM software (DDF parameters are provided in Table 3-1). To simulate surface water flooding across the area of interest, the hydraulic model uses a Direct Rainfall approach which consists of applying a rainfall hyetograph representative of a storm event to every individual element within the 2D surface model (across the 2D zone). The design events modelled are listed in Section 3.1.

The base model was run for a number of storm durations to determine the critical storm duration by determining which storm event achieved the highest peak water level at the headwalls, and thereby the greatest volume. Following a review of the peak flows, it was established that the 30 minute duration event is the critical storm duration for the storage area (Table 3-2). The model simulation time was set to 5 hours to show the extent of each return period and to allow water in high topographical areas to flow throughout the model, giving more accurate results of the extent of flooding.

Table 3-1: 1 km² DDF parameters

DDF Parameter	Value
C(1km)	-0.019
D1(1km)	0.502
D2(1km)	0.402
D3(1km)	0.466
E(1km)	0.259
F(1km)	2.413

Table 3-2: Critical Storm Duration Results

200-Year Return Period		
Scenario	Duration (min)	Depth (m)
Base	30	0.116
Base	60	0.114
Base	90	0.108
Base	120	0.104
Base	180	0.098
Base	240	0.093
Base	300	0.091
Base	360	0.089
Base	420	0.089
Base	480	0.088
Base	540	0.088
Base	600	0.088
Base	720	0.088
Base	840	0.087

200-Year Return Period		
Base	960	0.087
Base	1080	0.086
Base	1200	0.086
Base	1320	0.085
Base	1440	0.085

3.3 Hydraulic Model results.

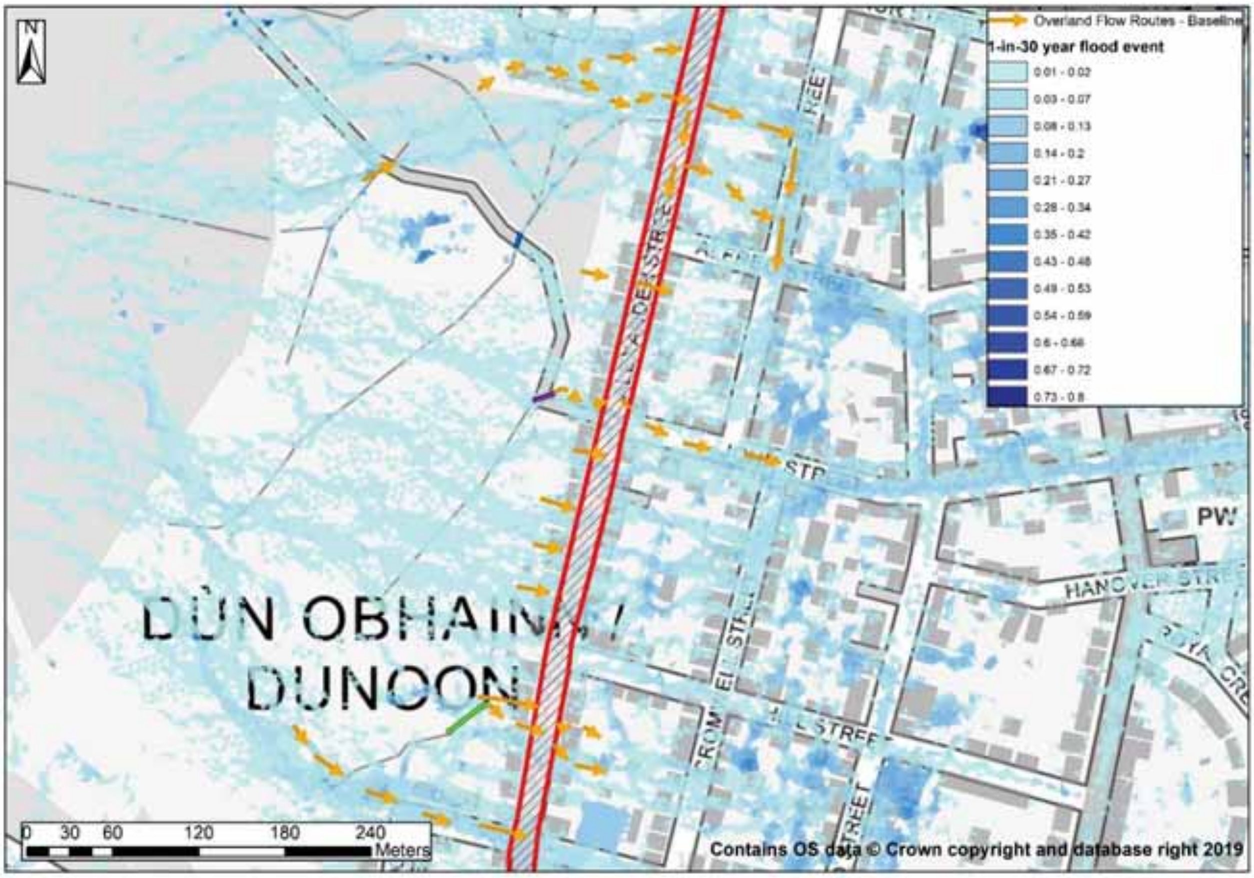
3.3.1 Flood Outlines

Modelled flood depths were capped to a minimum depth of 0.01m, as flood depths modelled below this level are considered insignificant and unlikely to result in any significant damage within the area. Flood depths and extents for each return period were imported into ArcGIS to visually show how pluvial flooding of each design event could impact the site.

3.3.2 Baseline Scenario

Infoworks ICM v8.5 mapping indicates the primary location of overland flow to Alexander Street does originate from the west from the existing drainage channels. Modelling indicates that a large number properties at Alexander Street could be impacted during a 1-in-30 year flood event however modelling also indicated that, if the drainage system to the west is working at optimal capacity, pluvial flood depths expected at the properties of Alexander Street during this event would be less than 0.08 m above ground levels. This is due to the steep hillside which is generally falling west to east preventing water from ponding instead the flood water is shallow but widespread.

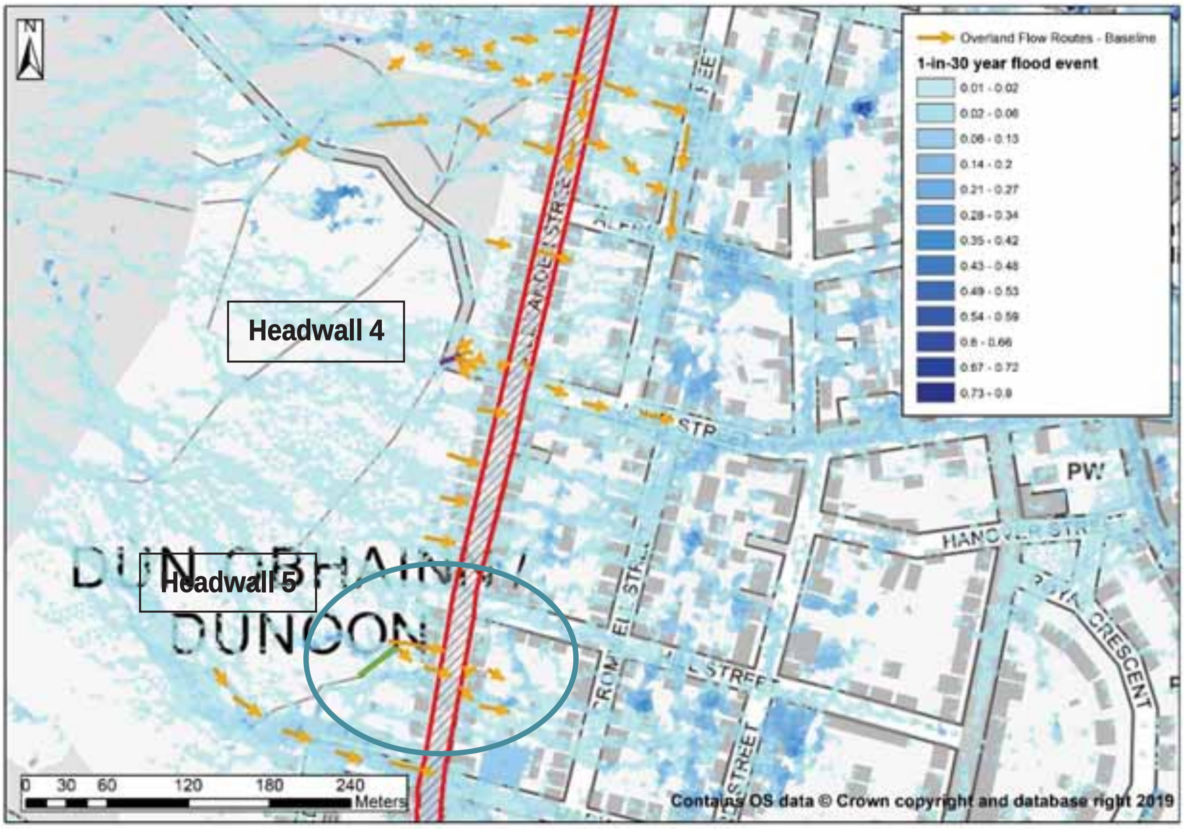
Figure 3-2: Surface water flood depths for the 1-in-30 year flood event – existing scenario.



3.3.3 Blockage Scenario and Headwall Analysis

The flow paths identified during the baseline scenario do not change during the blockage scenario (Figure 3-3) however, modelling suggests that the velocity of flood waters discharging from the Channel 4 culvert and water located along the access track from the culvert to Alexander Street/John Street does increase during a scenario where Channel 3 is blocked, indicating more water is entering and leaving the culvert during a flood event.

Figure 3-3: Surface water flood depths for the 1-in-30 year flood event – Blockage scenario.



A comparison of the flows reaching Headwall 4 between the baseline and the blockage scenario was undertaken to assess further how a blockage at the culvert along Channel 3 would affect the flows reaching Headwall 4 and the flooding extent it would cause on Alexander Street.

Peak flows were extracted for a range of return periods at Headwall 4 and Headwall 5 for both the baseline and the blockage scenarios (Tables 3-3 and 3-4). Upon further assessment, as no amendments were made in the model to Headwall 5 between the baseline scenario and the blockage scenario, flows extracted at Headwall 5 for both scenarios were exactly the same. The only significant changes observed between the two scenarios was at Headwall 4. Again, the flood map shows widespread shallow flooding due to the steep topography of the area. It is also worth noting that the model does not include interception by road gullies.

Table 3-3: Comparison of flows at Headwall 4

Return Periods	Baseline Scenario (m3/s)	Blockage Scenario (m3/s)	Increase from Baseline Scenario (m3/s)
2	0.012	0.008	-0.004
5	0.021	0.014	-0.007
10	0.031	0.02	-0.011
30	0.052	0.036	-0.016
50	0.067	0.046	-0.021
100	0.093	0.064	-0.029
200	0.126	0.088	-0.038
200+CC	0.198	0.141	-0.057

Table 3-4: Comparison of flows at Headwall 5

Return Periods	Baseline Scenario (m3/s)	Blockage Scenario (m3/s)	Increase from Baseline Scenario (m3/s)
2	0.018	0.018	0
5	0.026	0.026	0
10	0.042	0.042	0
30	0.079	0.079	0
50	0.094	0.094	0
100	0.126	0.126	0
200	0.161	0.161	0
200+CC	0.242	0.242	0

Table 3-3 shows that, during a blockage scenario, flows reaching Headwall 4 have decreased in comparison to flows derived during a baseline scenario. Upon further assessment, the decrease in flows at Headwall 4 is likely due to flood water bypassing the culvert and instead flowing out of bank along the access road which bypasses the headwall. This is supported by a flood depth comparison at points along the access road which connects to St John Street and Alexander Street. At a random point on the access track, located between Channel 3 and Channel 4 and at a higher elevation to Channel 4, modelled flood depth is 0.022m during a baseline scenario and 0.021m during a blockage scenario. At another point on the access track, located between Channel 4 and John Street and at a lower elevation to Channel 4, modelled flood depth is 0.022m during a baseline scenario and 0.024m during a blockage scenario.

3.4 Conclusions and Recommendations

A surface water hydraulic model was constructed in Infoworks ICM to assess pluvial flood risk to Alexander Street, Dunoon for a Baseline Scenario (representative of the risk to Alexander Street with the drainage system working to full efficiency) and a blockage scenario to represent the flood risk to Alexander Street caused by out of bank flows. An assessment was undertaken for the headwalls of two channels to further understand the potential impact that a blockage scenario could have at Alexander Street.

The results from the simulations in the ICM model have highlighted that the blocked culvert could have a substantial influence on the increase of flow reaching the remaining operational culvert and headwall if one were to become blocked. While there would be a decrease in flow reaching the operational culverts, the decrease in flows at Headwall 4 is likely due to flood water bypassing the culvert and instead flowing out of bank on the access track and subsequently Alexander Street. Surface water which is able to flood onto the access track is then able to swiftly flow east and onto Alexander Street and John Street increasing the overall flood risk in this area.

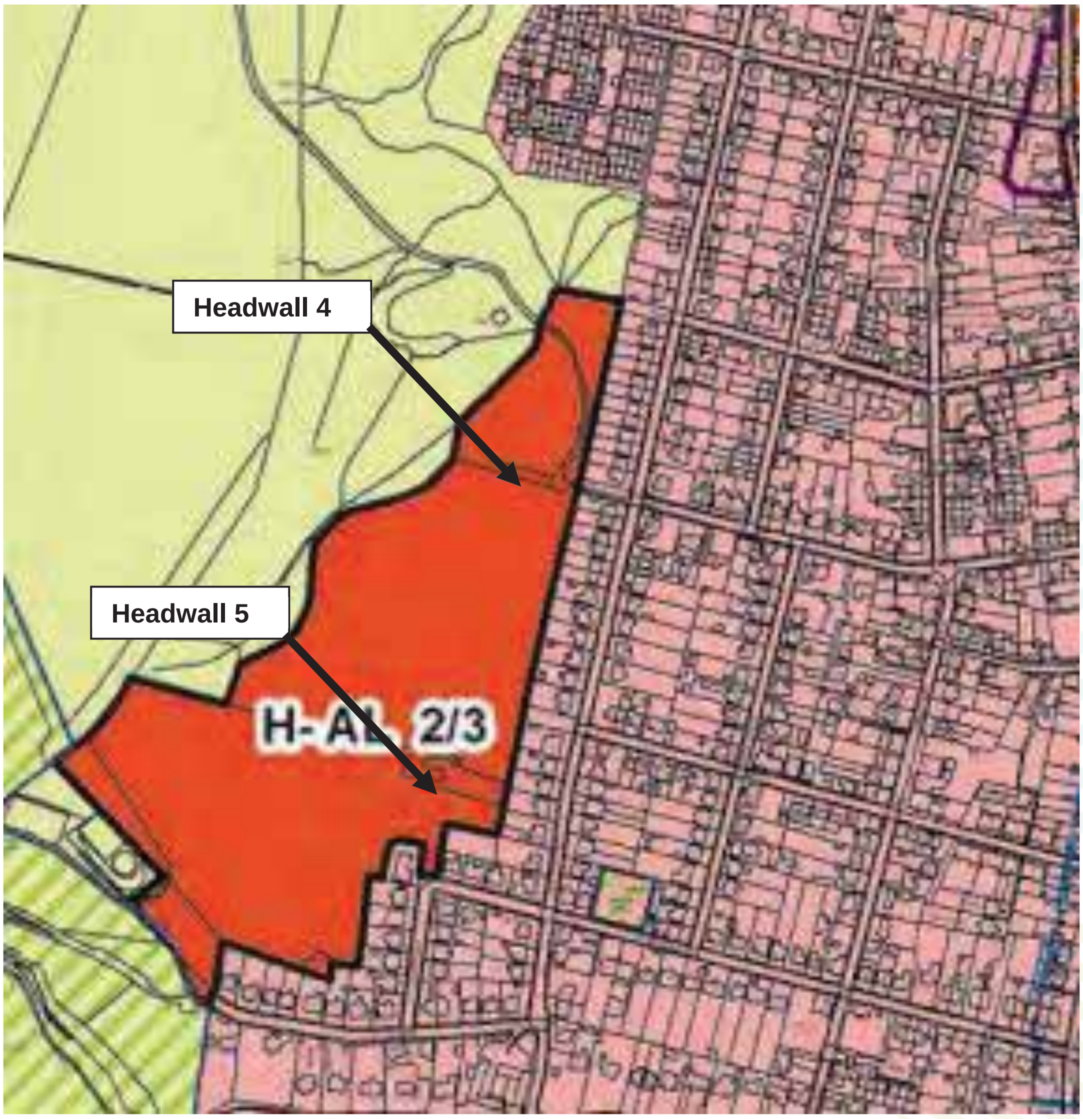
The predicted overland flowpaths shown in Figures 3-2 and 3-3 highlight the volume of surface water runoff that travels down the hillside toward Alexander Street. It should be noted that any overland flow that is not directed into channels is still destined to enter the combined sewer. The overland flow routes via gardens and driveways and gaps between houses then flows or seeps onto the road and into the sewer via road gullies.

4 Options appraisal

4.1 Option 1: Future development H-AL 2/3

The Local Development Plan 2015 for Dunoon lists much of the catchment west of Alexander Street as a suitable site for housing. During the stakeholder engagement it became apparent that a planning application notice had been approved (18/02005/PAN) for up to 100 units on the site. As part of the planning process drainage impact assessments and flood risk assessments are to be undertaken. This development will substantially affect the existing drainage ditch network. Channels 4 and 5 are likely to be completely removed and remodelled with SUDs. The proposed development presents an opportunity to mitigate flood risk relating to blocked culverts as well as a possible opportunity to remove surface water from the sewer network. Whilst it is up to the developer to submit plans which adequately control surface water on site it may be possible to provide additional advice or apply constraints that require the developer to improve flood risk out with the site boundary. At the time of writing there were no plans or information on the proposed housing development or its drainage strategy as such the proposed options are generalised.

Figure 4-1: Local Development Plan H-AL 2/3



4.1.1 This option will consist of the following actions:

Areas of improvement that maybe delivered through future development:

- Design out Channels 4 and 5 through development.
- The culvert which conveys Channel 4 below the access track should be upsized with a new headwall arrangement to lower the risk of blockage and out of bank flows if they are not completely replaced/removed by the development.
- Install erosion protection measures on the channel upstream of the John Street headwall to limit sediment movement into the sewer and also lower the blockage risk at the headwall itself.
- Implement measures to control the growth of Japanese Knotweed at the culvert headwall at John Street. This will ensure the headwall and screen can be accessed at all times. Concrete Canvas is commonly used as vegetation suppressant by Network Rail.
- Upgrade the headwall and screen at Channel 5 to meet current design standards if the channel remains in use. Also formalise an access route to allow for easy inspection and removal of debris.
- The proposed development area extends across the access track and is approximately bounded to the west by Channel 3 which discharges into a surface water culvert that ultimately flows into the Milton Burn. It would be prudent for the developer improve this channel to direct as much of the surface water from the catchment above the site into the natural watercourse noting the culvert capacity and downstream flood risk. This has the potential to remove a substantial volume of surface water from the combined sewer network as well as limit the flood risk at the proposed development as well as Alexander Street. As this is outside of the development area it may require joint input and funding from Argyll and Bute Council to deliver the improvements.

  As part of the Channel 3 improvements the culvert which conveys flows below the access track should be upsized with a new headwall arrangement to lower the risk of blockage and out of bank flows. This should be done to a 1:200year +cc design scenario.
- New development drainage to intercept surface water and attenuate using SuDS this will reduce the peak flow into critical points in the network. As it won't be practical to reduce the post-development runoff volume, peak flow rates would need to be capped at the 1 in 2 year event green field runoff rate or the capacity of the pipe the SuDS are discharging into, whichever is lower. In order to do this it will require enhanced SuDS that will likely be larger/more complex than the developer may be anticipating to install.
- It will be essential that the new development considers exceedance events as the site is steep this should be assessed based on the most sensitive aspect of the drainage network. It is assumed this will be the interception using gullies.
- It is a requirement of the developer to assess options/improvements which would need to be independently verified.

Figure 4-2: Potential development options

4.2 Option 2: Create new surface water sewer network

The developer may choose to continue to discharge surface water into the combined sewer at the existing location.

Given the flows outlined in this study the Developer may wish to create a separate surface water sewer to remove the flows from Headwalls 4 and 5 from the sewer network (1:2year flow of 30l/s, 1:200year flow of 287l/s).

The most favourable route for a new surface water pipe would intercept the flows from Headwalls 4 and 5 as well as the gullies in the western side of Alexander Street. This would convey flows north to an existing surface water culvert which discharges to the Milton Burn.

Figure 4-3: Potential surface water interceptor pipe

The alternative routes to this would likely involve installing a pipe east down John Street through the centre of Dunoon and discharging into the Clyde Estuary which is likely to be prohibitively expensive and complicated.

5 Conclusion

The analysis undertaken in this options appraisal study has shown how there are two surface water issues effecting the Alexander Street area; flood risk from over overtopping drainage ditches to properties on Alexander Street and John Street, and also substantial volumes of surface water enter the combined sewer network.

There are a number of options available for both scenarios. The flood risk via overtopping can be addressed by the proposed residential development which encompasses much of the contributing catchment. Suggestions have been proposed which include upgrading headwalls and up sizing culverts. It is likely that the proposed development will remediate the existing flooding mechanism as the channels are likely to be removed or substantially altered.

To reduce surface water entering the combined sewer it may be possible for the Developer to install a surface water pipe which would intercept flows from Headwalls 4 and 5 and flow north along Argyll Road before connecting to a culverted watercourse.

There is also an opportunity to improve Channel 3 which is located just above the western boundary of the proposed development. This channel could intercept flows before they reach the site and direct them into a surface water culvert and ultimately the Milton Burn. By using this option only water that has fallen on the site itself would be directed to the existing Headwalls 4 and 5 (the combined sewer).

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