**SIIOP NAME** **EASTERN EDINBURGH**

**SIIOP REFERENCE** **ED03**

## CONTENTS

# 1. MODEL BUILD AND VERIFICATION AUDIT REPORT CONTENTS

## 1.1 Summary

This report describes the findings of the Eastern Edinburgh model build and verification audit performed n June 2000 by BGP-Reid Crowther.

Montgomery Watson developed the Type II model of Eastern Edinburgh drainage area, completing the model in March 2000. The model covers an area of approximately 2500 hectares and a population of approximately 170 000. The model was verified against a short flow survey data. The model building process was to a generally good standard.

The model is generally well built and verified. The documentation is also generally of a good standard. However there are some areas that need to be improved.

A few discrepancies have been found in the system data and the representation of ancillaries, these should be corrected.

The representation of permeable surface runoff does not follow best practice. The normal runoff should be left at the default runoff speed and additional dummy areas added to represent slow response runoff. However this does not invalidate the model as the verification generally shows good results.

The verification does not attempt to represent the true detail of the downstream restriction at the treatment works or the pump failure at Eastfield PS. These should be done. The verification also did not review pipe roughness values to give good matches on depth and velocity as well as on flow.

The items described in this report as requiring attention should be addressed. A full review of the audit will not be required but a statement should be submitted on the changes made to the model to address each of the issues.

The lack of verification against historic flooding is an important issue and should be investigated further.

## 1.2 Introduction

The Eastern Edinburgh model represents the eastern drainage area of the City of Edinburgh and contains residential, commercial and industrial urban areas. The total catchment area included in the latest version of the model is 3 161 ha, of which 1 054 ha (34%) is modelled as impervious. The catchment is predominantly combined, with only 10% of the sub-catchments designated as being separately drained. The population of the catchment was estimated by Montgomery Watson (MW) as approximately 170 000.

A macro model of the entire Edinburgh catchment was originally built by MW in 1994 to assist in the design of the Almond Valley Interceptor sewer (AVIS).

Detailed models of the Edinburgh system were required for more accurate analysis of local sewers, and so the Eastern Edinburgh model was built. The purpose of this model audit is to assess the suitability of the Eastern Edinburgh model to meet its intended purpose.

## 1.3 Information Received

A summary of the information received is given in document 1.1.

*Check 1 results: Pass.*

## 1.4 Model Description

The Draft Verification Report states that MODASSET version 3.1 was used to build the model. The modelling software used was HydroWorks version 5.0. This modelling software is considered suitable by the auditor for use on the project.

The HydroWorks model received for the audit is called E12NEW.dsd. It has a file date of 26/05/00 and a file size of 1037 KB. This is the model that is put forward as best representing the operation of the sewerage network at the time of the flow survey.

### *Model files*

A summary of the model files received is given in document 1.2.

*Check 2 results: Pass.*

### *Model purpose and type*

The purpose of the model submitted for audit is to identify the needs of the Eastern Edinburgh catchment and for solution modelling. The model consists of 2546 nodes (15 nodes per 1000 population), with 1052 hydrological nodes (6 nodes per 1000 population). The modelled level of detail is appropriate for a Type II model (6 to 20 nodes per 1000 population).

*Check 3 results: Pass.*

***Modelled boundary***

To check the extents of the model, the network was overlaid onto the MapInfo digital sewer records. It appears to extend sufficiently far upstream and downstream. The model terminates at the WwTW, although the treatment works is not included in the model.

The model has inflow hydrographs at 2 locations (nodes 32737007 and 32737104), both just upstream of the Eastfield CSO and PS. The inflow hydrographs represent flow from the East Lothian catchment (not modelled). The use of inflow hydrographs is satisfactory but should be stated in the model building report.

There are possible locations of interaction between the Eastern Edinburgh catchment and the Western Edinburgh catchment. One has been modelled as allowing spill from the Eastern catchment into the Western catchment, outfalling at node 24727801. It is possible that reverse flow may occur at this location that would not be represented by this form of modelling. The macro model should be used to check that this does not occur and this limitation should be mentioned in the model building report.

A second bifurcation has not been modelled (NT27758506.2 via NT27757616.1), which if modelled may improve predicted results at monitor site 30.

Another location of interaction is at the Seafield siphons where the EIS and the WIS combine before entering the WwTW. This is described below.

***Modelled downstream conditions***

The DWF outfall of the model is located at the head of the inverted siphon at Seafield WwTW. The siphon receives flow from the Eastern Interceptor catchment and also from the Water of Leith and Western Interceptor catchments, which are not modelled. The incoming flows are controlled by three penstocks which exert a hydraulic influence on the incoming sewers.

The downstream conditions for the EIS model have been represented by a LEV file hydrograph generated using the Edinburgh macro model, run with penstock openings taken from the diary notes at the WwTW. The penstocks are assumed to be fully open during design events as this is the proposed regime. For events D and F the levels are lower than the 1 year design level of 8.9 m AOD (provided in file 1yrMax.lev). During event B, a peak level of nearly 9.7 m AOD is given in the associated LEV file. The WwTW diary states the penstocks were manually throttled to between 20% and 33%, when the flow exceeded 15 $m^3$/s. The Macro model has all penstocks modelled throttled to 33% throughout the simulation. A more accurate representation of the operation of the penstocks and their effect on the models would require the use of the RTC option in the macro model.

The impact of the downstream condition will depend on the flows coming from the catchments and if there are significant changes proposed in any of the catchments, for example major new sewers or attenuation storage then it will be necessary to represent this in the macro model to get revised level hydrograph files for the downstream condition. An alternative method of representing this would be to extend the Eastern model to the penstocks and represent the flows from the other catchments as inflow hydrographs determined from the macro model.

All inspected CSO outfalls have at least one length of overflow pipe included in model to represent any outfall restrictions. Large culverts receiving spill from a number of CSOs are also modelled. However, no flap valves were modelled even when Section 6.1 of the model build report stated that they exist (e.g. Blackford Ave CSO and Comiston Road CSO). If the modelled culverts were predicted to surcharge, reverse flow into the foul system would be predicted that would not occur in reality.

*Check 4 results: The model is fit for purpose on this check but the following minor items should be addressed.*

*It would be better practice to model flap valves where they exist, even if they are unlikely to affect the operation of the system.*

*The report should describe the use of QIN files to represent flow from the East Lothian catchment.*

*The report should describe the need to re-derive LEV files to represent the downstream boundary if there are significant changes in the catchment.*

*The need to model the bifurcation at (NT27758506.2 via NT27757616.1) should be reviewed.*

## 1.5 Manhole Survey Information

The original STC25 database of the catchment contained little data, so a selective manhole survey was performed. MW internally surveyed 2068 manholes out of the 2699 attempted. Printed manhole cards were provided for the audit that contained the typed in survey data. The hand written survey cards were generally not available for the audit, so the data entered into the revised STC25 database could not be checked. Also, the STC database that was provided was from a version of the software that was not compatible with the auditors version, so this could not be compared to the printed manhole cards.

The survey data was available for some CSO and bifurcation structures, so 27 manholes were checked as part of the audit.

Generally, the modelled data matched the STC data, but discrepancies include:

24683503 The depth of the outgoing X pipe appears to have been incorrectly defined as 2.9 m, instead of 1.9 m. This is supported by the paper sewer records, photographic evidence and the long section. The source of error could be the mis-typing of the site data into STC or from the site survey itself.

24700210 The assumed ground level may be too low. IL is correctly interpolated.

24700210 The assumed ground level may be too low (it is modelled lower than the node in the adjacent watercourse, which was raised in the model during verification). IL is correctly interpolated.

24703201, 3203 Model appears to be correct, but there is confusion in the STC manhole number references.

24728808, 8806, 8905 Generally the inverts have been modelled 2m lower than the data on the STC cards. Changes have been hand written on model cards, except for 24728808 which has not been revised.

25717004 Slight discrepancy in the pipe height (1140 mm, 1440 mm or 1540 mm as modelled). Levels taken from the old survey, but note on MH card says data was assumed[1].

29728002 STC database contains the wrong incoming pipe size (900 x 260 circular pipe). Model correctly contains the data from old survey.

Note 1. Manhole cards were duplicated for ancillaries, with copies of the Sewer Records contained in the Ancillaries folder. The latter were generally superseded by the former, and should be updated.

*Check 5 results: Pass, but minor discrepancies should be addressed and STC card data for the ancillaries should be updated.*

## 1.6 Interpolated Manhole Data

The MapInfo tool Vertical Mapper had been used to interpolate the missing ground levels based on known cover levels and spot heights. These were corrected around rivers as appropriate, as documented in the manhole record files. The depth data included in the STC25 database was then used to calculate the missing invert levels. The report also states that Modasset was used to interpolate the remaining missing invert levels. There are also about 50 hand calculations of interpolated manhole data provided in the manhole record files.

The MW node database detailed 541 modelled manholes in which the levels were interpolated. 30 were randomly selected and checked as part of this audit by visually inspecting long sections. The interpolation was normally carried out correctly, with the following exceptions:

NT26673207 The STC data contained depths, but no cover level. MW correctly assumed a CL of 126.0, based on the adjacent manhole. MW interpolated the inverts without considering the 2 m step in invert as detailed in the STC database. Based on extrapolation of the downstream sewer, it appears the u/s link of 26673207.1 should be at a level of about 121.55 m not 123.974 m as modelled. This also affects a bifurcation modelled at this point. This bifurcation may not exist, but the auditors could not resolve this due to limited data.

NT25733802 This node is the start of a modelled pipe branch, with no upstream level data. The ground and invert levels were therefore assumed by MW. The long section shows that the pipe and ground slope is very flat.

NT29755002 Inverts have been correctly interpolated, but produce shallow depths. Perhaps extrapolation of the downstream pipe may be more appropriate.

*Check 6 results: Generally OK, but the items described above should be checked.*

*The method of interpolation should be reviewed to see if it will always fail to deal with steps in invert levels, as at NT26673207, and if so further checks should be carried out.*

## 1.7 Contributing Areas and Flooding Representation

There are 1052 contributing areas in the Eastern Edinburgh model. These were manually defined by MW on 1:2500 scale plans. Once digitised, the MW software MODASSET was used to calculate the roof areas. The road areas were based on the length of road and an assumed road with. Car parks and other features were manually added to the model by MW.

Due to the automated process that Montgomery Watson used, it was felt that only a 2.5% check was likely to be necessary and this could be extended to 5% if errors were found. 26 areas were selected from a plan drawing for the initial check. This ensured that samples were taken from throughout the model and for catchments of reasonable size. The results of this 2.5% checks were good, see below, and so no further checks of imperviousness were performed.

***Area definition***

The total contributing areas were correctly defined, using property boundaries as appropriate. Large grassed areas were correctly excluded from the contributing areas.

The average modelled total contributing area was 3.0 ha, with the smallest being 0.15 ha. The MW report states that as a general rule that contributing areas should be kept to a maximum of 4 ha. However there are 73 nodes with areas between 4 ha and 5 ha, 27 nodes with areas between 5 ha and 9 ha, 4 nodes with areas between 10 ha and 25 ha and 10 nodes with areas between 25 and 150 ha. The ten nodes with contributing area greater than 25 ha appear to be dummy areas, and are discussed in the permeable area section below.

The areas were calculated using MapInfo, and had been entered into the model correctly.

*Check 7 results: Pass.*

***Impermeabilities***

The contributing permeable and impermeable areas depend on the drainage system type as well as the amount of roof and paved surfaces.

**<u>Drainage type</u>**

The links database provided by MW shows that most of the sewers are combined, with several areas on the outskirts of the catchment served by separate systems. Of the 26 audited sub-catchments, only 2 were separate. MW reduced the impermeable area in these sub-catchments (27685809 and 23685001) to 0 % and 6% respectively. Due to presence of illegal cross-connections a lower limit of 6 % is probably acceptable for older developments, although 0% for new developments is thought to be low, with 4% more commonly used.

**<u>Impermeable areas</u>**

The auditors checked the modelled roof and paved areas against the OS background data for the sample 26 sub-catchments. The results compared well, with the percentage impervious errors generally within 5%, with the auditors estimate normally lower than modelled.

There were 2 areas where the discrepancy was more than 10%. The first sub-catchment (25738404) was modelled as 100% impervious. The auditors calculation of 80% impervious made the assumption that the grounds of cathedral was grassed. The second sub-catchment (28698404) was modelled as 45 % impervious. The auditors calculated 33 % as being impervious. The reason for this could be that MW correctly allowed for a car park that is located just outside the defined catchment boundary.

**Permeable areas**

The permeable areas are generally blank in the DSD file, resulting in non-impervious areas being modelled as pervious. The exceptions are 27 nodes that have zero areas defined. These nodes drain to foul sewers presumably located in separately drained areas. The average model PIMP is 34%.

MW included 10 large dummy areas in the model to increase predicted slow runoff. Section 9.3.2 of the MW report states that dummy areas were used on sewers running alongside rivers to obtain the increase in flow recorded by the flow monitoring. These were generally assigned as very slow runoff, using the New UK model. A more appropriate method of modelling this slow response may be to use the Infiltration model now available in Infoworks.

The MW report also states that in some cases a small impermeable value was also required in these large dummy areas. The table below lists the dummy nodes, and their area characteristics. Node 28696907 has 12 hectares of paved area assigned. This has been defined as areas type 1, which is defined in the RPF file to contribute 100% runoff (see check 16). This large impervious area may generate inappropriate runoff during design events.

These nodes are detailed in document 1.3.

The DSD file does not contain comments describing the purpose of the above dummy nodes.

*Check 8 results: Pass, although some very large 'dummy' areas may not be appropriate for design events. Dummy nodes should be commented in DSD file, or given distinct names.*

***Flooding representation***

Manholes that could not be lifted during the manhole survey appear to have been defined as flood type 0 (sealed). This would not be appropriate if the sewer had other gully or house connections that would allow the escape of flood water. The foul sewers in separately drained areas were correctly assigned flood type 2 (water lost). All other nodes were correctly assigned flood type 1 (water retained). The model contains 76 nodes with flood type 0, 695 nodes with flood type 1 and 281 nodes with flood type 2 defined.

Consideration of flood water has correctly been applied following the SIIOP model build specification (both dummy contributing areas and flood storage shapes).

To allow flooding results to be shown at all nodes in the HydroWorks model, dummy contributing areas were correctly assigned to nodes that did not have actual areas assigned to them. A contributing area of 1.0 ha was assigned to these internal nodes, with the HydroWorks areas correctly set to zero percentages to prevent any runoff.

The land use file has also been set up correctly so it does not produce additional populations or infiltration from these dummy areas.

The 6 known locations of flooding, see below and Section 1.18 were generally modelled in sufficient detail. The auditors were not provided with full details of house addresses that flooded, so this check was not performed. The roads that flooded contain the following degree of representation in the model:

- Christiemiller Avenue - bottom 3 manholes are modelled, top 3 are not modelled
- Holyrood Park (rear of Scotsman Office) - auditors could not locate
- Liberton Brae - fully modelled
- Mountcastle Drive south - northern part is modelled, southern part is not modelled
- Oxgangs Avenue Rise - fully modelled
- Prestonfield Avenue - most of road modelled (top 2 nodes are not)

*Check 9 results: Pass, but sealed manholes should not be used if there is an alternative route for flood water to escape.*

## 1.8 Foul Flow

Foul flow has been represented in the model by assigning a population to each sub-catchment which is factored by a diurnal profile provided in the WWG file.

***Population figures***

The population figures entered in the model were based on address point data, and an assumed occupancy rate of 2.75 per property. The report states that the population is 170 664. However, the sum of the populations with land use 1 (residential) has been calculated by the auditors as being 189 659, suggesting an occupancy rate of 3 was used. This discrepancy of nearly 19 000 should be checked.

This total population figure could not be checked as census data was not available. Montgomery Watson confirmed in an email dated 28 June 2000 that no census data was available during the study.

***Per capita flow***

When requested, details of the derivation of a per capita flow value of 188 l/s were provided. The workings show the per capita flow was calculated and averaged for 5 flow monitor sites located on the extremities of the catchment. These sites are probably not ideal as the flows are below the monitoring equipment limitations and further checks would be useful.

***Land use and wastewater generator files***

The WWG file, EASTED.wwg has been checked and suitable weekday and weekend diurnal profiles are included. There are also profiles included for the various trade flow daily patterns. A consumption figure of 190 l/d per capita flow is used for the domestic flows and 1000 l/day per capita flow is used for trade flows.

The WWG file, E12Flat.wwg is identical to Easted.wwg, except the domestic diurnal pattern for weekday and weekend is constant at 1.0. For design storms and time series analysis, a higher DWF multiplier may be more conservative, but this is out of the scope of this audit.

The LUD file supplied is named EastEd.lud and the parameters have been defined correctly.

*Check 10 results: Fail. Discrepancy in total population should be checked .*

## 1.9 Infiltration

The calculated infiltration flows were entered into the DSD file as fixed point values assigned to each node based on a pro-rata basis conforming to the SIIOP process. A total of 762 l/s is applied to modelled nodes with contributing areas. A further 98 l/s infiltration is applied to nodes with no contributing areas.

***Infiltration calculations***

Minimum flows were correctly taken off each flow monitor for each of the three selected DWF days. Dubious data, data drop outs and pumped flow regimes were considered in calculating the average minimum flow at each site. The minimum flows were then factored from 90% to 99% to account for small quantities of domestic flow. It is not clear how the factors were calculated for each monitor site. The infiltration flow at each site was then pro-rated into the upstream sub-catchments correctly.

The table on page 15 of the MW report contains a few discrepancies.

***Observed infiltration***

The DWF hydrographs comparing the predicted and observed flow at all monitor sites, were provided in Appendix A of the MW report. It is not clear if these plots were produced using the originally developed domestic diurnal profile (EASTED.WWG file) or the flatter diurnal profile (EDFALT.WWG). This change in domestic diurnal profile will affect the base flows slightly.

Visual inspection of the plots confirmed that a good match was achieved in the base flow at most sites. The only comments are:

- Monitor sites 103, 47, 8 and 31 generally show an over-prediction in base flow of about 50 l/s.
- Monitor site 57 generally was inconsistent in base flow and population generated flow, possible due to poor hydraulics at this site. This is not a key site and the low flow discrepancies do not affect the model fitness for purpose.

*Check 11 results: Pass.*

## 1.10 Trade Flows

A spreadsheet list of traders was provided for the audit. This list contains 1995 and 1999 consented and actual discharge figures for selected traders. All the 16 trades listed are represented in the model.

The trade flows were represented in the model by including equivalent populations and applying a time-varying multiplier. The time varying multipliers were defined in the waste water file and were applied by assigning appropriate land use to the modelled nodes. A per capita flow of 1000 l/day was applied, resulting in the modelled populations matching the consented / actual daily flow.

Generally the consent values were modelled, as they are normally higher than the actual flow values. Exceptions are:

- ESW Fairmileghead filters. The 1999 actual value (1722 $m^3$/d) was used. To be conservative, the consented value of 2000 $m^3$/d should be used. Also see comment below regarding QIN representation.

- The City Hospital. The 1999 actual flow (634 $m^3$/d) was greater than the consented flow (500 $m^3$/d). The latter was modelled. To be conservative the higher value should be modelled.

- GNER. The 35 $m^3$/d flow is for surface water disposal, and so is not applicable to DWF. It may be more appropriate to model the train depot's contributing area with a limiting discharge of 0.4 l/s.

The time varying flows considered the discharge regimes of the traders, with some traders discharging 7 days per week, some 5 days per week and some based on shift working hours. Discrepancies identified include:

- ESW Fairmileghead filters (profile 7). Discharges every 2 hours, not every 3 hours as detailed in the spreadsheet provided.

- The profile for land uses 4 and 5 are not correctly normalised and 12% of flow is lost from the GNER trader and 25% extra flow is generated from the SNBTS Ellens Glens trader. However, the volumes generated / lost by these discrepancies are insignificant.

The MW report states that the ESW Fairmileghead filters flow was represented using a QIN file due to its unusual nature. The QIN files provided for the audit did not include this trade flow, and the model contains an effective population (1722 pe), so presumably the report requires updating.

*Check 12 results: Pass (minor discrepancies should be fixed).*

## 1.11 Manhole Headlosses

The MW software Modasset includes a routine to incorporate the manhole headlosses due to bends in the sewerage system. This assigns headloss coefficients and uses normal headloss index.

The upstream headloss coefficients have been correctly represented in the model by assigning suitable values to the outgoing pipes. No downstream headlosses were defined and is a minor deficiency in the model.

*Check 13 results: Pass, but downstream headloss coefficients should be included.*

## 1.12 Storage Compensation

The Modasset software also includes a routine to incorporate the storage compensation to allow for un-modelled pipes and connections. This also takes the Priessman slot into account.

To check the modelled values, the auditors used their in-house software to calculate the storage compensation using the data provided in the model. This routine is also based on the WaPUG User Note 15 and considers the Priessman slot. The shaft areas calculated for non-hydrological nodes were identical, but the shaft areas for hydrological nodes varied considerably. The sum of the shaft areas calculated by the auditors was 15% higher than modelled, when excluding the nodes with large dummy areas. 12 hydrological nodes were selected and checked in detail. Half of these have differences in shaft area of greater than 10 $m^2$, and are listed below:

| **Node** | **Modelled Shaft Area (m2)** | **Auditor's Estimated Shaft Area (m2)** |
|---|---|---|
| 23706610 | 2.9 | 60.1 |
| 26715201 | 58.4 | 19.5 |
| 28681803 | 18.3 | 28.7 |
| 29732201 | 12.7 | 1.0 |
| 29733403 | 30.5 | 8.3 |
| 29747801 | 1.8 | 39.5 |

The above discrepancies suggest that nodes at the head of a branch do not have enough modelled storage, and nodes with large populations have too much modelled storage. The actual reasons for these discrepancies could not be determined by the auditor due to lack of access to the Modasset routine.

*Check 14 results: Unsatisfactory on individual nodes and should be re-calculated although as errors are both plus and minus it may have little impact on overall results.*

## 1.13 Runoff Modelling and Slow Response Runoff

***Selection of runoff model***

The model uses the New UK percentage runoff equation (NR equation) with the normal flow routing model. These are considered to be the appropriate models for this application.

The model build and verification report (9.3.3) refers to the use of fixed runoff for the foul systems. This is confusing and should be removed.

*Check 15 result: Pass.*

***Application of runoff model***

It is difficult to audit the application of the runoff model because the Runoff Parameter (RPF) file includes a large number of definitions, most of which are not used in this model. It would be less confusing to model users if only those definitions being used in the model were included.

**Paved**

The model build report states that two definitions of paved surface are used. For combined systems, type 10, which is the default for the NR equation, giving a minimum runoff of 70%. For separate foul systems, type 1 giving a minimum runoff of 100%.

The impermeable surface represented on separate foul systems is an arbitrary figure to represent mis-connections. Although there is no real justification for this to have 100% runoff, this figure is probably as good as any. One node on the combined system (28684911) is incorrectly assigned surface type 1. This is not a significant error.

**Roof**

All roof areas use surface type 20 which is the default for the NR equation. This gives a minimum runoff of 70%. This is satisfactory although a slightly higher value is used by many modellers.

**Permeable**

Permeable runoff was generated using the NR equation with the default 200 mm of storage. Three surface types are used with different values of runoff routing factor. Types 18 and 21 use an absolute value of 75. Surface type 17 uses an absolute value of 150. None of the surfaces use the default of a relative value of 4. Two types are used with the same value to distinguish combined and separate systems. However type 18 appears to be used on some combined areas.

40 nodes are defined as having runoff type 17. 140 nodes are defined as having runoff type 18. 872 nodes use type 21.

Good practice is to use the default value for real contributing areas and to add additional dummy areas to provide additional slow runoff to represent interflow and rainfall infiltration. Some dummy areas are included for this purpose.

The use of absolute values for runoff routing is questionable. The meaning, and even the units, of the absolute values is doubtful and there is no immediate way of knowing whether a factor of 75 is faster or slower than the default value. The use of absolute values also means that the runoff attenuation and delay does not vary with ground slope or catchment area. The use of relative values is therefore recommended.

The soil type is defined as Type 4 throughout and this agrees with the value shown on the Wallingford Procedure map.

*Check 16 result: Not best practice. Runoff routing for permeable surfaces should be reviewed.*

## 1.14 Ancillaries

Roof levels have not been defined in the DSD file. The only nodes that have defined chamber floors are the 3 pumping stations.

The key ancillaries reviewed are detailed in document 1.4.

The following discrepancies were identified. Most of these are minor and unlikely to have significant effect on the results of the model. They should however be corrected.

***Key CSOs***

***Comiston Road / Braid Hills Road CSO (NT24692801) – MW no.1***

Conduit 24692802.1, which connects to the CSO node is not shown on one of the CSO manhole cards and is shown as disused on another. Node 24692802 has 1.212 ha contributing (48% imp.). ESW sewer records do show the pipe.

There is some confusion as to whether the CSO continuation pipe is a 300 mm or 375 mm. It is modelled as 375 mm although comments suggest that a flow monitor was in the d/s end which was measured as 300 mm. The error / discrepancy is not significant.

The chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. The error / discrepancy is not significant.

***Glenisla Gardens CSO (NT25717004) – MW no. 3***

The incoming and continuation pipes are modelled as 970 x 1540 egg sewers, but the manhole cards show 970 x 1440 egg. Error / discrepancy is not significant. Flow survey data may confirm dimensions if monitor was placed here.

The chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. The error / discrepancy is not significant.

***Blackford Avenue CSO (NT25719107) – MW no. 5***

The 3 high level pipes (sizes unknown) are not modelled, but the weir coefficient is low (0.5) considering there are no screens or scum boards. The low coefficient probably accounts for any throttling effects of the pipes, although calculations to justify the coefficient were not provided.

***Vetnor Terrace CSO (NT27710513) – MW no. 10***

Description in report (page 7) says the weir is 1800 mm long but the model and manhole card show 490 mm.

***Craigentinny CSO (NT28748801) – MW no. 16***

The value for the weir coefficient seems a bit low at 0.45.

We are unable to reconcile the modelled weir level of 10.95 m with other data. This should be checked.

Chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. Error / discrepancy could be significant if chamber becomes drowned (area = 124 $m^2$).

***Niddrie / Seafield CSO (NT28749305) – MW no. 17***

Chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. Error / discrepancy could be significant if the chamber becomes drowned (area = 25 $m^2$). Also the shaft area should be greater as the manhole is 7 m dia (38 $m^2$).

The value for the weir coefficient seems a bit low at 0.45.

***Duddington Rd / Milton Rd West CSO (NT29731007) – MW no. 19***

The value for the weir coefficient seems a bit low at 0.5.

Chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. Error / discrepancy is not significant.

***Mountcastle Drive CSO (NT29735601) – MW no. 20***

This could be a low-sided weir but the actual weir dimensions have been modelled as if it was a high-sided weir. Calculations should be provided by the consultant to justify this.

***Nantwich Drive CSO (NT29744806) – MW no. 22***

The invert level of penstock appears 0.5 m too low.

The invert level of the incoming sewer and weir have been raised by 0.5 m to match the flow survey data (monitor 010).

Chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. Error / discrepancy is not significant.

***Key bifurcations***

***Fishwives Causeway bifurcation (NT29748001) – MW no. 6***

The manhole card shows continuation pipe as 300 mm dia, but it is modelled as a 375 mm.

***Stanley Street bifurcation (NT30737203) – MW no. 10***

This could be a low-sided weir but the actual weir dimensions have been modelled as if it was a high-sided weir. Calculations should be provided by the consultant to justify this.

Chamber area in model should extend higher – i.e. roof level (manhole level 1) should be higher. Error / discrepancy not significant. Also chamber and shaft area should be greater as manhole is 3.07 x 1.81 m (5.6 $m^2$) and the model show 1.5 and 1.0 $m^2$ respectively.

***Key pumping stations***

***Fillyside P.S (NT29750409) – MW no. 1***

The pump rates in model do not match those in the Model Build report but are similar to those in the ancillary data file. This is assumed to be due to typing errors.

***Eastfield P.S (NT32737007) – MW no. 3***

The overflow from County Sewer is not modelled, although the emergency overflow in the pumping station is modelled. The two overflows may be at the same level but no justification is provided.

Pump rate of 1046 l/s is ok but report says 1026 l/s. This is probably a typing error in the report.

***Key siphons***

The only key siphons in the system are those at the entrance to the treatment works. See section 1.4 for a discussion of these.

*Check 17 results: Pass, but discrepancies should be corrected..*

## 1.15 System Capacity and Silt

The model was given a global roughness of 3.0 which is considered appropriate for the age of the system. Silt was modelled at locations recorded during the CCTV and flow survey inspections.

The auditors checked about 10% of the modelled silt depths, and found them to match well with the occurrence of debris, encrustations and other obstructions recorded in the Examiner CCTV data. The sewers in which silt was modelled have their roughnesses appropriately increased to 50 mm for the bottom third of the pipe.

The summary of modelled silt provided by MW, clearly states which values were altered during the verification process. The Examiner data showed that mass roots was the reason for the need to reduce the sewer capacity.

***Comparison of predicted depths with observed***

The verification plots indicate several flow monitor sites where the model under-predicts the depth of flow and over-predicts the velocity. This indicates that the modelled pipe roughness is slightly too low. The effect is not always consistent between events which may indicate sediment movement. Sites where roughness probably needs to be increased include: 10, 11,18, 24, 27, 28, 47, 53, 54, 58, 60, 70, 78, 94, 104, 106, 109, 111, 117, 119.

There are also a few monitors showing the opposite effect where roughness may need to be reduced. These include: 21, 112, 113, 114, 115, 118.

*Check 18 results: Pass, but pipe roughnesses should be reviewed to give better match with measured depths and velocities.*

## 1.16 Rainfall Data

22 raingauges were installed as part of the short term flow survey (STFS). Data from 6 long-term gauges was also available. The number of gauges is sufficient for the 25 $km^2$ catchment. The rainfall profiles were correctly assigned to the modelled nodes.

***Event selection***

The 7 week STFS was extended by 4 weeks in order to obtain a sufficient number of suitable rainfall events.

Three verification events have been used as shown in the table in document 1.5. All three storms are long duration events, although storm D consists of many individual peaks over the 30 hour duration.

The next table (document 1.6) shows a detailed assessment of whether each raingauge meets the WaPUG criteria for each event.

Events B and F are marginal on the peak intensity test but should be satisfactory.

***Catchment wetness***

The model build and verification report provides details of the calculation of both UCWI and API30. The UCWI values are not used in the final model and this should be made clear in the report or this section could even be omitted. The UCWI and API30 values have all been calculated correctly.

***RED files***

The rainfall data has been entered correctly into the RED files.

***DSD file and profile assignment***

The allocation of raingauges to contributing areas appears appropriate.

*Check 19 results: Pass.*

## 1.17 Observations on Individual Flow Sites

***Suitability of flow data***

All monitor sites except those in overflow pipes show an adequate response to rainfall in all three events. All overflow monitors show measured and modelled responses in at least one event. The only exception to this is site 105 where the sewer is now disused due to recent changes to the sewerage system. This sewer shows no flow at any time during the survey.

Several flow monitors show timing errors of 1/2, 1, 2 or 4 hours - presumably due to incorrect setting of the monitor clocks. These have not been corrected in the verification plots.

The pump logger data has not been used for verification and is not presented as part of the verification report.

Several sites are in steep pipes and give poor monitoring results because of low depths and high velocities.

The following monitor faults are not identified in the verification report.

ADS monitor 45 gives erratic results for both depth and flow in storm conditions and should be ignored.

ADS monitor 54 is only recording depths by ultrasonic and does not show surcharge.

Overall there is adequate data to verify the model.

The schematic of the system showing monitor locations that is provided in the flow survey report is incorrect in several significant areas and should be marked as superseded.

*Check 20 result: Pass.*

***DWF verification***

Monitor 43 indicates a different pattern of flow from Joppa pumping station. This could indicate an error in the pump capacity or wet well area.

Overall the results are good within the range of accuracy of the flow data that is available.

*Check 21 result: Pass.*

***Storm verification***

The following comments on individual sites need to be reviewed.

***8, 14***

The flows are held back significantly in event F by the penstocks at the WwTW. Some effort should be made to represent this in the model so as to confirm the operation of the bottom part of the catchment.

***15***

In event B there is a large drop in flow for about 6 hours. This appears to be due to a failure at the Eastfield pumping station as it is also shown at other monitor sites. Some effort should be made to represent this in the model so as to identify changed interactions with other flows.

***23***

Significant under-prediction of peak flows. If there are local flooding problems the model should be improved, although the error is not significant for the overall catchment performance.

***30***

Significant under-prediction of peak flows. The audit of ancillaries identified errors in this area of the model. The model should be corrected and the verification re-viewed.

***35, 36, 37, 38***

The model is showing significantly higher peak depths than are monitored. The roughness and diameter of the sewers in this area should be reviewed and the verification improved.

***41, 43***

There are significant differences in surcharge levels and the duration of surcharge for these sewers. (The measured depths appear to be incorrect for event F at monitor 43.) The differences may be due to errors in modelling of Joppa pumping station. This should be reviewed as the differences are locally significant.

***54***

The depth monitor is faulty and is not recording depths grater than pipe full. The pipe roughness for low flows is also incorrect. Correcting theses two items should give a good match at this site.

***58, 60***

Significant under-prediction of depths probably because of errors in pipe roughness.

***71, 74***

Additional slow response runoff would improve the verification fit but is probably not significant to the identification of needs and options.

***94***

The verification at this monitor is good, unlike the monitors upstream with some over-predicting and some under-predicting. This could be due to errors in allocation of areas or system connectivity. If there are flooding problems in this area then the model should be improved.

***110, 114, 117, 118***

Additional slow response runoff would improve the verification fit but is probably not significant to the identification of needs and options.

***124***

Significant under-prediction of peak flows. If there are local flooding problems the model should be improved, although the error is not significant for the overall catchment performance.

*Check 22 result: Verification needs to be reviewed, particularly for those issues affecting the main trunk sewers.*

***Model stability***

*Check 23 result: Not done.*

## 1.18 Review of Historical Verification

The MW report states that the SAPS database was searched for historic flooding details and these were confirmed through discussions with operational staff. There were 6 locations of known flooding that are listed in Section 1.7.

The model had been run with 5 year events of a range of durations from 1 to 10 hours to identify the critical duration. The range of durations, profiles and choice of API30 values seems appropriate. The critical duration was identified as 120 minute summer storm and this was run for return periods from 1 to 30 years.

The model showed a much larger number of significant flooding locations than those reported. The draft MW report states that site visits were still being carried out to confirm the large number of flooding locations predicted by the model for frequent events. The review of storage compensation recommended in section 1.12 may help to reduce the unconfirmed flooding.

The verification report states that there is no information on frequency of overflow spill.

*Check 24 result: Fail, due to large number of currently unconfirmed flooding locations.*

## 1.19 Conclusions

The model is generally well built and verified. The documentation is also generally of a good standard. However there are some areas that need to be improved.

A few discrepancies have been found in the system data and the representation of ancillaries, these should be corrected.

The representation of permeable surface runoff does not follow best practice. The normal runoff should be left at the default runoff speed and additional dummy areas added to represent slow response runoff. However this does not invalidate the model as the verification generally shows good results.

The verification does not attempt to represent the true detail of the downstream restriction at the treatment works or the pump failure at Eastfield PS. These should be done. The verification also did not review pipe roughness values to give good matches on depth and velocity as well as on flow.

## 1.20 Recommendations

The items described in this report as requiring attention should be addressed. These are summarised in the next section and described in more detail in the body of the report. A full review of the audit will not be required but a statement should be submitted on the changes made to the model to address each of the issues.

The lack of verification against historic flooding is an important issue and should be investigated further.

## 1.21 Summary of results

*Check 1 results: Pass.*

*Check 2 results: Pass.*

*Check 3 results: Pass.*

*Check 4 results: The model is fit for purpose on this check but the following minor items should be addressed.*

*It would be better practice to model flap valves where they exist, even if they are unlikely to affect the operation of the system.*

*The report should describe the use of QIN files to represent flow from the East Lothian catchment.*

*The report should describe the need to re-derive LEV files to represent the downstream boundary if there are significant changes in the catchment.*

*The need to model the bifurcation at (NT27758506.2 via NT27757616.1) should be reviewed.*

*Check 5 results: Pass, but minor discrepancies should be addressed and STC card data for the ancillaries should be updated.*

*Check 6 results: Generally OK, but the method of interpolation should be reviewed to see if it will always fail to deal with steps in invert levels, as at NT26673207, and if so further checks should be carried out.*

*Check 7 results: Pass.*

*Check 8 results: Pass, although some very large 'dummy' areas may not be appropriate for design events. Dummy nodes should be commented in DSD file, or given distinct names. Consider using infiltration model instead.*

*Check 9 results: Pass, but sealed manholes should not be used if there is an alternative route for flood water to escape.*

*Check 10 results: Fail. Discrepancy in total population needs to be reviewed.*

*Check 11 results: Pass.*

*Check 12 results: Pass (minor discrepancies).*

*Check 13 results: Pass, but downstream headloss coefficients should be included.*

*Check 14 results: Unsatisfactory on individual nodes and should be re-calculated although as errors are both plus and minus it may have little impact on overall results.*

*Check 15 result: Pass.*

*Check 16 result: Not best practice. Runoff routing for permeable surfaces should be reviewed.*

*Check 17 results: Pass but discrepancies should be corrected.*

*Check 18 results: Pass, but pipe roughnesses should be reviewed to give better match with measured depths and velocities.*

*Check 19 results: Pass.*

*Check 20 result: Pass.*

*Check 21 result: Pass*

*Check 22 result: Verification needs to be reviewed, particularly for those issues affecting the main trunk sewers.*

*Check 23 result: Not done.*

*Check 24 result: Fail, due to large number of currently unconfirmed flooding locations.*