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APPENDIX ES18.2

SURFACE WATER MANAGEMENT PLAN FOR THE PROPOSED EXTENDED EAST NORTHANTS RESOURCE MANAGEMENT FACILITY (REPORT REFERENCE AU/KCW/JRC/20032/01SWMP DATED JULY 2021)

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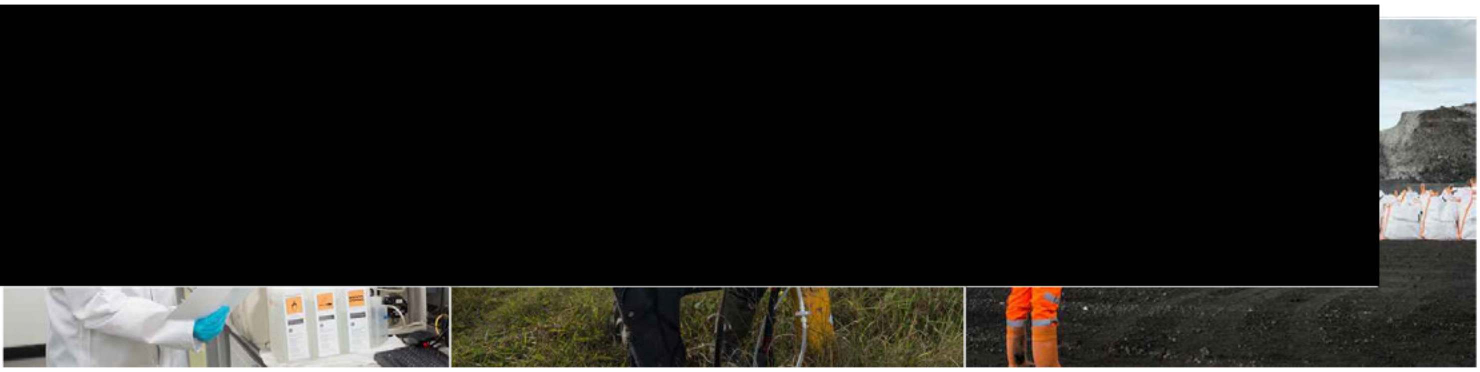

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1. Introduction

1.1 MJCA is commissioned by Augean South Limited (Augean) to prepare a Surface Water Management Plan for the restored East Northants Resource Management Facility (ENRMF) to include the proposed western extension to the site. The western extension to the site and alterations to the existing ENRMF are the subject of an application for a Development Consent Order (DCO) with PINS project reference WS010005. This Surface Water Management Plan comprises an update to the current approved surface water management plan for the site dated May 2007 (2007 SWMP). A copy of the 2007 SWMP is provided at Appendix A to this report. This Surface Water Management Plan (2021 SWMP) has been prepared in support of the application for the DCO. The purpose of the 2021 SWMP is to demonstrate that surface water can be managed as part of the restored site such that there is no significant change in drainage or increase in flood risk downstream of the site.

1.2 Operational surface water management is regulated by the Environment Agency through Environmental Permit reference EPR TP3430GW for the site. The principles of the operational surface water management are presented in this surface water management plan.

1.3 The 2021 SWMP is based on the agreed 2007 SWMP and relies on information presented in the 2007 SWMP hence no amendments to the calculations or design works presented in the 2007 SWMP have been carried out as part of this surface water management plan. Consistent with guidance calculations have been carried out to demonstrate that surface water runoff from a 1 in 100 year rainfall event with an allowance for climate change can be managed on site with discharge at the pre-development greenfield runoff rate or 2l/s/ha whichever is greater or at the permitted discharge rate.

1.4 Schematic plans of the proposed surface water drainage ditchcourses are presented in this report. The principles for the detailed designs of the ditchcourses presented in the 2007 SWMP will be used when the final designs are prepared prior to restoration of each phase of the site. It is concluded that surface water runoff from a 1 in 100 year rainfall event with an allowance for climate change can be managed on site. It is anticipated that the precise locations of the ditches and surface water attenuation basins or detention basins presented in this report may change following further investigations in the central area of the site where a proposed ditchcourse will convey water from west to east across the site to discharge into a swallow hole consistent with current routes of surface water flow. Any changes will be subject to final design and approval from the relevant planning authority as part of the final detailed designs prepared prior to restoration of each phase of the site.

2. Principles of surface water management in the operational areas of the site

2.1 As there will be continuity of operation between the existing ENRMF site and the proposed western extension area the scheme for managing surface water during the operational period in the western extension is based generally on the current surface water management practices at the site. The management of surface water in the operational areas of the site is the subject of specific Augean site management procedures implemented through Augean's Environmental Management Systems and regulated by the Environment Agency through the Environmental Permit. The general principles of the operational surface water management procedures are explained in this report.

2.2 Surface water runoff from the restored areas in the existing ENRMF site is managed by a system of drains and ponds broadly in accordance with the existing 2007 SWMP. Part of the current surface water management systems on the site comprises a series of drainage channels (cut off ditches) which are located across the landfill and round the site boundary generally. The water from the channels discharges to a series of ponds which are located strategically at points near the boundary to manage flow.

2.3 The status of each area on the site changes over time as the site operations progress, for the purposes of operational surface water management the operational site at any given time is spilt into the following conceptual catchment areas and surface water management systems:

- **Excavation and landfill cell construction areas -** Incident rainfall and runoff to these areas either infiltrates into the ground, evaporates, or is contained within the excavation which is then dewatered to allow the cell construction works to progress.
- **Operational landfill cells** - Incident rainfall and runoff to these areas is collected in the cell and absorbed into the waste mass and becomes part of the waste and leachate within the cell.

- **Uncapped or uncovered areas of completed cells with waste exposed at the surface** - These areas are limited to the small area of the most recently completed landfill cell and rainfall and runoff is managed as for operational landfill cells. Given the availability of site derived low permeability clays these areas are temporarily capped quickly with capping and restoration to follow.
- **Capped and restored areas, including temporarily capped and areas with clean stockpiled materials (site derived overburden and clays)** - Once temporarily capped, or capped and restored, a ditch system is developed following the principles of the 2007 SWMP to allow the separate collection of clean surface water runoff so that it can be directed to clean surface water ponds for discharge from site. These areas continue to change due to stockpiling needs and the principles of the 2007 SWMP are progressively implemented. The ongoing development of the site will allow further capped and restored areas to be completed and allow connection of the surface water systems to the permitted discharge point in the south east of the site.
- **Soil treatment plant (STP)** - The STP comprises a sealed surface area. Specific design calculations for the STP show that the storage volume in the tanks and on the soil processing pad area is capable of providing sufficient surface water storage for a 1 in 100 year event. The surface water runoff control procedures and requirements of the STP are monitored and reviewed and where necessary updated to reflect future changes. The site development assumes that in the operational life of the site the STP will be removed and the area will be excavated and developed as a landfill cell and then restored following the principles of the 2007 SWMP.
- **Dredging waste lagoon** - Incident rainfall and runoff to this area is collected within the dredging waste lagoon and the collected water is used in the STP processes. The site development assumes that in the operational life of the site the dredging waste lagoon will be removed and the area excavated and developed as a landfill cell and then restored following the principles of the 2007 SWMP.
- **Haul roads** - Incident rainfall and runoff to the haul roads is collected within the ditches constructed adjacent to the haul roads and directed to dedicated

surface water lagoons or collection points. Given the potential for waste residues to accumulate on the haul roads, the collection of surface water runoff from the haul roads within the same ditches, lagoons and ponds as clean water is avoided. Potentially 'dirty' water runoff from haul roads is used in dust suppression, in wheel washes and managed through the STP surface water system.

- **Ditches and ponds** – The ditch and pond system is being developed as areas of the site are restored following the principles of the 2007 SWMP to allow the separate collection of clean surface water runoff so that it can be directed to clean surface water ponds or discharged from site.

2.4 In summary the collection of clean water runoff from capped and restored areas is separate from the collection of runoff from haul roads comprising potentially contaminated water. The generation of potentially contaminated water is reduced by constructing separate bunded ditches along haul roads with separate dedicated clean and potentially polluted surface water collection lagoons.

2.5 The principles of the operational surface water management procedures will continue in the proposed western extension with the installation of a system of drains and attenuation basins following the principles of the 2007 SWMP and the restoration proposals presented in this report.

3. Current site catchments

3.1 The hydrology at and in the vicinity of the site is described in detail in the Environmental Statement submitted in support of the DCO application. The site is located in the catchment of the River Nene which flows generally eastwards and is located approximately 6km east south east of the existing ENRMF site at the closest point.

3.2 Information on the surface water catchments at the site on the Environment Agency catchment data explorer website indicates that the proposed western extension is partially within the catchment of the Wittering Brook and is partially within the catchment of the Willow Brook consistent with the existing ENRMF site. The catchments of the Wittering Brook and the Willow Brook are shown on Figure 1.

3.3 A drainage ditch runs along the western and southern boundaries of Collyweston Great Wood to the east of the proposed western extension and north of the existing ENRMF site. It is understood that the drainage ditch continues eastwards from the site joining a tributary of the Wittering Brook where it issues approximately 2.0km north east of the existing ENRMF site. The Wittering Brook joins the River Nene approximately 7.5km east of the existing ENRMF site.

3.4 The ditch to which site runoff is discharged via the permitted discharge point in the south east of the existing ENRMF site flows generally to the south and joins a drainage ditch running west to east on the west side of Stamford Road approximately 450m south south east of the existing ENRMF site. The west to east drainage ditch runs along the northern boundary of Little Wood approximately 50m south of the western extension and continues eastwards to the east of Stamford Road and then south eastwards to where it joins a tributary of Willow Brook. The tributary outfalls to the Willow Brook approximately 2.5km south of the existing ENRMF site. The Willow Brook joins the River Nene approximately 9km south east of the existing ENRMF site.

Permitted ENRMF site

3.5 The existing ENRMF site comprises a northern and a southern catchment area. The details of the catchment areas and the currently approved surface water management scheme for these areas is presented in the 2007 SWMP (Appendix A).

Proposed western extension

3.6 Consistent with the existing ENRMF site, the proposed western extension is on a surface water divide. The north eastern half of the northern area of the proposed western extension drains to the east to the drainage ditch which runs along the western and southern boundaries of Collyweston Great Wood eventually joining a tributary of the Wittering Brook. The remainder of the northern section and the central area of the proposed western extension to the landfill drains via field drains and drainage ditches to a swallow hole located approximately 10m to the north of the north western corner of the existing ENRMF site boundary. Surface water entering the swallow hole at the site enters groundwater beneath the site which it is likely feeds tributaries of the Willow Brook and the Willow Brook to the south. The southern section of the proposed western extension area drains to the south and south east to the drainage ditch that runs from west to east approximately 50m south of the site and continues eastwards to the east of Stamford Road and then south eastwards to where it joins a tributary of Willow Brook.

3.7 The current catchments at the site have been determined from the available Light Detection and Ranging (LIDAR) data at and in the vicinity of the site from the Environment Agency National LIDAR Programme digital terrain model (DTM). The topography at and in the vicinity of the site comprising the available LIDAR data are shown on Figure 2. A topographical survey of the proposed western extension is presented at Appendix B. The LIDAR data is consistent with the topographical survey of the site as can be seen from a comparison of the survey (Appendix B) and the LIDAR data (Figure 2). The site catchments have been delineated based on the LIDAR data and the catchments are presented on Figure 3. The approximate areas of the pre-development catchment areas across the western extension are presented in Table 1.

Surface water entering the site from upstream

3.8 A number of drainage ditches from land to the west of the extension area drain into the perimeter drainage ditches round the proposed western extension area with a drainage ditch from the south culverted under the central part of the extension area towards the swallow hole. A second culvert approximately 175m north of the southern culvert is located under the central part of the extension area draining from the west towards the swallow hole. The entrance to the southern culvert was partially filled with soil debris during a site visit in June 2021 with the exit in the southern valley feature near the swallow hole buried. Surface water from the perimeter ditch was observed entering a clay pipe close to the culvert entrance. The pipe was orientated along the boundary between the northern and southern part of the proposed western extension. The outfall of the pipe could not be located. It is known that drainage along this boundary is routed to flow towards the swallow hole entering the swallow hole from the south.

3.9 Based on the available LIDAR data for topography to the west of the site, areas to the north west of the site drain towards the northern part of the northern area of the site and towards the south of the northern area as well as to the central area of the site. Areas to the south west of the site drain towards the central area of the site. There are areas to the north west, west and south west of the site that drain towards depressions located to the west of the central area of the site. Based on observations made during site visits in February and June 2021 these comprise dolines with water draining into the depressions infiltrating the ground in the base of the depressions. At the time of the site visits there was little evidence of surface water flowing from these depressions onto the site or entering the culverts under the central part of the extension area.

3.10 A small area to the west of the south western corner of the site will drain to the southern area of the site. The upstream catchments in the vicinity of the site are shown on Figure 3.

3.11 The approximate areas of the upstream catchments draining to the western extension are presented in Table 2.

Flood risk

3.12 Flood risk at and in the vicinity of the site is described in detail in the Environmental Statement submitted in support of the DCO application. The site is located in Flood Zone 1 comprising land having a less than 1 in 1,000 annual probability of river or sea flooding. Hazardous waste landfill sites comprise '*more vulnerable development*' as defined in the National Planning Policy Framework (NPPF) technical guidance on flood risk (reference 1) and they are considered appropriate development in Flood Zone 1. The flood risk maps show that the majority of the site is shown as at very low to low risk of flooding from surface water with limited areas of medium to high risk in the central area of the proposed western extension at the extremities of the culverts and in the vicinity of the swallow hole.

4. Principles of the surface water management plan

4.1 The Wittering Brook and the tributary of the Willow Brook to which the drainage ditches collecting runoff from the site discharge are ordinary watercourses. Lead local flood authorities, district councils and internal drainage boards carry out flood risk management work on ordinary watercourses. North Northamptonshire Council is the Lead local Flood Authority (LLFA) for the ordinary watercourses in the vicinity of the site and is a statutory consultee to the planning process to assess the surface water drainage implications of proposed developments.

4.2 LLFA guidance (reference 2 and 3), Department for Environment, Food and Rural Affairs (DEFRA), Sustainable Drainage Systems guidance (reference 4) and Industry Code of Practice guidance on surface water management systems at landfill sites (reference 5) has been used together with guidance presented on the Environment Agency website (reference 6) and included in the technical guidance to the NPPF in respect of flood risk (reference 1) to inform the 2021 SWMP.

4.3 The proposed restoration concept scheme for the whole of the ENRMF site including the existing ENRMF site and the proposed western extension area is presented on the plan presented at Appendix C. The restoration topographic contours together with the indicative surface water features that will be present at the site following restoration are shown on Figure 4. The proposed restoration does not include any areas of hardstanding and comprises a domed restoration profile compared with the relatively flat pre-development topography. Soil stripped during excavations at the site will be retained on site and used in the restoration. The restoration soils will comprise clay loam and clay soils.

4.4 The 2021 SWMP is based on sustainable drainage principles consistent with guidance. Sustainable drainage systems typically control runoff rates and volumes hence reduce the risk of downstream flooding, encourage infiltration rather than direct conveyance of surface water where possible, reduce concentrations of suspended solids in runoff and where possible provide habitat for wildlife and enhanced aesthetic and amenity value. As the surface water management plan has been developed to be consistent with the principles of sustainable drainage the components of the scheme form part of a system of integrated water management features which will contribute to the sustainable management of surface water at the restored ENRMF by controlling runoff as close to the source where feasible and managing water on a site wide basis taking into consideration the potential for impacts on surface water flows and quality locally and in the wider hydrological environment.

4.5 The design principles on which the 2021 SWMP is based are summarised below:

- A series of surface water attenuation basins or detention basins will be created in the restored areas of the site.
- Shallow ditches will direct runoff to the basins and ditches will convey water between the basins and the point of discharge from the site where discharge is not directly from the basins.
- The rate at which water can leave each attenuation basin will be controlled so that during extreme rainfall events a proportion of runoff will be held back to attenuate the runoff peak.
- The function of the basins is for surface water attenuation only. Should the basins be developed such that water is maintained in the basins for other purposes such as ecology a freeboard will be maintained to accommodate the necessary surface water attenuation.
- The current outlet for the discharge of water from the surface water management system will be maintained so that water can drain by gravity and in a controlled manner to the permitted discharge point at the southern east corner of the existing ENRMF site. Suitable outlets for the discharge

of water from the surface water management system will be created so that water can drain by gravity and in a controlled manner to the swallow hole, to the eastern drainage ditch round Collyweston Great Wood which joins a tributary of the Wittering Brook and to the southern drainage ditch which joins a tributary of the Willow Brook.

- The rate at which water will leave the surface water management system will be constrained to a rate equivalent to the greenfield runoff rate or 2l/s/ha, whichever is larger, consistent with guidance so the risk of flooding downstream is minimised.

- The design rainfall event assumed for the purpose of the calculations presented in this report is the 1 in 30 year rainfall event plus a 20% allowance for climate change. The 20% central allowance for climate change is the potential increase in peak rainfall intensity specified in Environment Agency guidance for design allowances (reference 6) resulting from anticipated climate change during the period 2085 to 2115. The extreme rainfall event assumed for the purpose of the calculations presented in this report is the 1 in 100 year rainfall event plus a 40% allowance for climate change. The 40% upper end allowance for climate change is the potential increase in peak rainfall intensity specified in Environment Agency guidance for design allowances (reference 6) resulting from anticipated climate change during the period 2085 to 2115.

- A portion of the surface water discharge from the restored landform will be routed to the swallow hole consistent with pre-development conditions at the site. It is assumed that further infiltration based approaches for surface water attenuation in other areas of the site generally will not be appropriate following restoration due to the significant thickness of low permeability strata above the underlying aquifer.

4.6 Further information on the parameters and assumptions affecting the operation of the surface water management system are presented in Section 5. The results of calculations to estimate the attenuation capacities necessary in the individual basins is presented in Section 6. The results of calculations of the dimensions of perimeter ditches which will need to convey water from discharge points from the detention basins to the west to east crossing are presented in Section 7.

5. Restored site catchments and drainage constraints

5.1 The proposed restored site has been divided into seven catchments delineated based on the topographic restoration contours and the surface water drainage ditches draining the restored land to basins at the low point in each catchment as shown on Figure 4. The seven catchments are shown on Figure 5. The point of discharge of each of the seven catchments in summarised in the table below. The approximate areas of the catchments are presented in Table 1.

Catchments	
Catchment 1	Drains to basin C1 in the south east discharging to the permitted discharge point
Catchment 2	Drains to basin C2 in the north west of the existing ENRMF site discharging to the swallow hole
Catchment 3	Drains to basin C3 in the west discharging to the western drainage ditch which in turn discharges to the swallow hole via the west to east crossing
Catchment 4	Drains to basin C4 in the west discharging to the western drainage ditch which in turn discharges to the swallow hole via the west to east crossing
Catchment 5	Drains to basin C5 in the south west discharging to the drainage ditch to the south of the site
Catchment 6	Drains to basin C6 in the north discharging to the drainage ditch to the east of the site
Catchment 7	Drains to basin C7 in the west discharging to the swallow hole via the west to east crossing

5.2 The design of the proposed ditchcourse which will convey water from west to east across the proposed western extension to discharge into the swallow hole at the north western corner of the existing ENRMF site will be the subject of the results of further investigation. The ditchcourse will be constructed and will be designed to convey flows at the greenfield runoff rate for a 1 in 100 year event with an allowance for climate change as a minimum. The detail of the watercourse design will be agreed with the relevant planning authority following confirmation of the design of the crossing from the results of further investigation.

Pre-development greenfield runoff rates

5.3 The indicative surface water catchment of the site including areas which are external to the site and which may drain to the site has been delineated based on available topographical information as presented in Section 3. Calculations to determine the current greenfield surface water runoff rate from the catchments in the western extension have been carried out using the method presented in The Institute of Hydrology (IOH) document entitled “Flood estimation for small catchments” report number 124 dated 1994 (reference 7, the IOH 124 method). Consistent with guidance the Flood Estimation Handbook (FEH) rainfall intensity data has been used in the calculations. The greenfield surface water runoff rate for the mean annual flood (Qbar) has been calculated with a growth factor applied to calculated the 1 in 30year and the 1 in 100year greenfield runoff rates. The calculations are presented at Appendix D. The greenfield run off rates for the existing ENRMF are presented in the 2007 SWMP.

5.4 The calculated Qbar using the IOH 124 method are all less than 2l/s/ha. For the purpose of the calculations a discharge limit of 2l/s/ha is assumed. Qbar calculations using the FEH statistical method have been carried out using the UKSUDS online tool for comparison with the IOH 124 results and the 2l/s/ha limit assumed. A HOST class number of 22 (Till, compacted head) has been selected for the site in the calculations. The results of the IOH 124 method and the FEH statistical method for the Qbar calculations using the UKSUDS online tool are presented at Appendix D together with a summary table of the results (Table D4). The 2l/s/ha limit has been selected as a conservative assumption given the known limitations of both the IOH 124 method and the FEH statistical method in respect of small catchments.

Permitted discharge

5.5 The permitted discharge from the site is an outfall from the south east pond (2007 SWMP) comprising a 225mm diameter pipe which discharges to the upstream point of a road culvert. It is calculated in the 2007 SWMP that with no orifice control an outflow rate from the site for the critical 1 in 100 year return period storm would be approximately 110l/s. It is calculated in the 2007 SWMP that the downstream highway culvert would have the capacity to receive a discharge rate of over 500l/s from the site without being at risk of flooding. This is significantly greater than the 1 in 100 year return period storm outflow rate with no orifice control reported in the 2007 SWMP with a 40% upper end allowance for climate change of approximately 150l/s. The design of the permitted discharge point in the 2007 SWMP is such that the permitted discharge rate from the site is 50l/s.

Comparison of pre-development and restored catchments

5.6 As can be seen from the comparison in Table 1 similar areas of the pre-development catchments and restored catchments discharge to the permitted discharge point, the eastern ditch, the swallow hole and the southern ditch.

6. Attenuation storage

6.1 The discharges from the restored catchment areas will be controlled at the pre-development greenfield runoff rates or at 2l/s/ha, whichever is larger, consistent with guidance or at the permitted discharge rates such that there will be no increased flood risk downstream of the site as a result of the proposed development. The basins at the low point in each of the restored site catchments have been sized such that the capacity of the basins can store the amount of water it is necessary to attenuate so that the discharge from the basins is managed to the pre-development discharge rates or at the permitted discharge rate. Consistent with guidance FEH rainfall intensity data has been used in the calculations. Calculations to estimate the attenuation storage that will be created as a result of the construction of the attenuation basins as part of the restoration are presented at Appendix E.

6.2 The detention basins have been sized to accommodate the calculated 1 in 30 year return period storm with a 20% allowance for climate change with an additional 300mm freeboard based on the permitted discharge rate from catchment 1 and the 2l/s/ha discharge rate from all other catchments. The indicative capacity of the detention basins are presented on Figure 5. The detail of the detention basins in each area will be designed and agreed with the relevant planning authority before the development of each phase of the landfill. The calculated maximum attenuation storage needed in each catchment for a 1 in 100 year return period storm with a 40% allowance for climate change is presented in Table E15 at Appendix E. It is proposed that low bunding is formed round the attenuation basins such that the additional attenuation storage needed for the 1 in 100 year return period storm with a 40% allowance for climate change can be accommodated. The indicative bund round attenuation basin C1 is shown on Figure 5. The indicative height of the perimeter bunds needed round the attenuation basins is presented in Table E15 at Appendix E.

7. Calculation of the capacity of the proposed ditches for the conveyance of surface water

7.1 Consistent with the 2007 SWMP surface water ditches will be excavated into the restoration soils of the landfill to direct runoff to the attenuation basins with the indicative ditch section profile presented on Drawing 1621.SWM.10 of the 2007 SWMP (Appendix A). Intermediate ditches will be provided on the batter slopes to intercept and slow the rate of run off to reduce ravelling and the risk of erosion of the restoration soils and underlying cap.

7.2 It is proposed that surface water from detention basin C1 will discharge to the permitted discharge location in the south east of the site at the permitted discharge rate. It is proposed that surface water from detention basin C2 will discharge to the swallow hole at the 2l/s/ha discharge rate. It is proposed that surface water from detention basins C3 and C4 will discharge to the perimeter ditch at the 2l/s/ha discharge rate. Water in the perimeter ditch will convey water northwards to the west to east crossing in the central area of the site where it will eventually discharge to the swallow hole. It is proposed that surface water from detention basin C5 will discharge to the perimeter ditch at the 2l/s/ha discharge rate. Water in the perimeter ditch will convey water southwards and will discharge to the drainage ditch to the south of the site. It is proposed that surface water from detention basin C6 will discharge from the site to the drainage ditch along the eastern boundary of the western extension at the 2l/s/ha discharge rate. It is proposed that surface water from detention basin C7 will discharge at the 2l/s/ha discharge rate to the west to east crossing in the central area of the site where it will discharge to the swallow hole. The discharge from each of the catchment areas will be controlled in a similar manner to that set out in the 2007 SWMP with suitable flow control apparatus such as discharge pipes of an appropriate diameter at the outlet from the attenuation basins such that the rate at which water leaves the basins does not exceed the flow rate assumed in the calculations.

7.3 The western perimeter ditch which currently conveys water from off site to the southern culvert across the central area of the proposed extension and then to the swallow hole will also convey water from catchments 3 and 4 following restoration to the proposed watercourse crossing the site from west to east to discharge to the swallow hole. Prior to any development at the site these areas of the site drained directly to the area of the swallow hole from the site via field drains or drainage ditches internal to the existing ENRMF site as well as the western extension site. The western perimeter ditch which conveys water from off site to the southern drainage ditch will also convey water from catchment 5 following restoration to the southern drainage ditch. Pre-development these areas of the site drain directly to the southern drainage ditch from the site via field drains. Indicative calculations of the capacity of the western perimeter ditch to convey water to the west to east crossing and to the southern drainage ditch are presented at Appendix F and are described in this section. All other perimeter drainage ditches will convey water from similar drainage routes and at similar rates pre and post development.

7.4 The capacity of a drain to convey surface water has been calculated based on Manning's resistance equation which takes into account the dimensions, geometry and other characteristics of the drain. For the purposes of the calculations it is assumed that the drain will comprise an open ditch generally. Calculations of the flow capacity in the drain using Manning's resistance equations are presented in Table F1 at Appendix F. The calculation of the relevant Manning's roughness coefficient is presented in Table F2 at Appendix F.

7.5 Based on the calculations presented at Appendix F the perimeter ditch will have a flow capacity sufficient to convey the necessary quantity of surface water during the 1 in 100 year rainfall event plus a 40% allowance for climate change to the west to east crossing and to convey the necessary quantity of surface water during the 1 in 100 year rainfall event plus a 40% allowance for climate change to the southern drainage ditch. Suitable flow control apparatus will be constructed at the outlets from the detention basins in the restored catchment areas such that the rate at which water enters the receiving drainage ditches from the site during the design storm event does not exceed the flow rates assumed in the calculations. It is anticipated that the locations of the ditches and surface water attenuation basins or detention basins may be refined following further investigations in the central area of the site where a proposed watercourse will convey water from west to east across the site to discharge into the swallow hole consistent with current routes of surface water flow.

7.6 The western perimeter drain discharges to a culvert beneath the southern track thence into the southern drain. The culvert comprises a 200mm diameter plastic pipe. Making assumptions about the fall of the pipe across the track based on the topographical survey and observations during a surface water features survey of the site in October 2019, the pipe has the capacity to convey at least twice the necessary quantity of surface water during the 1 in 100 year rainfall event plus a 40% allowance for climate change.

8. The maintenance and management of the surface water drainage system

8.1 Consistent with the LLFA guidance the drainage system in the restored areas shall be subject to regular maintenance to secure its efficient operation and the effective management of water.

8.2 During the operational period of the site including restoration operations Augean will maintain and manage the drainage system in the areas of the site where the operations being carried out affect the drainage system. In the parts of the extension area where landfill development has not yet commenced and where agricultural activities continue the responsibility for maintenance and management of the surface water drainage system will remain with the farmer until the landfill development commences and normal agricultural activities no longer are practicable.

8.3 Following restoration an agreed aftercare scheme will be in place which will include the maintenance and management of the surface water drainage system for an agreed period.

8.4 The principles on which maintenance and management will be based are set out below:

- Regular inspections of the surface water drainage system will be undertaken. The purpose of the inspections will be to confirm the adequate performance of the drainage system, to identify operational problems and to facilitate planning of maintenance actions as necessary.
- Insofar as it is practicable inspections of the surface water drainage system will be carried out in a range of weather conditions including during rainfall events.
- Maintenance actions will be planned and implemented as necessary to facilitate the proper functioning of the drainage system.

- The planning and implementation of maintenance actions will take into account the protection of habitats and ecosystems as necessary.

8.5 Specific maintenance and management actions are likely to include but may not be limited to:

- Removal of litter and debris from attenuation basins and ditches at the site as necessary.
- Sediment management such as the removal of accumulated sediment in attenuation basins and the ditches as necessary.
- Inspection and remedial maintenance of the flow control structures at the outlet of attenuation basins as necessary.
- Grass cutting and other vegetation management such as pruning as necessary.
- Control of weeds and invasive plants as necessary.
- Repairing damage to ditches caused by erosion or other processes.

Management in support of the wider nature conservation objectives of the restored site are included in the ecological assessments presented in the Environmental Statement and associated schemes submitted in support of the DCO application.

8.6 The management regime will be updated as necessary as the operations and restoration works the subject of the approved aftercare scheme progress.

9. Conclusions

9.1 The post restoration 2021 SWMP is designed based on the principle that there will be no significant increase in surface water discharges from the site compared with the pre-development situation, hence no increased flood risk downstream of the site following restoration including during a 1 in 100 year rainfall event when a potential 40% increase in rainfall intensity as a result of climate change is taken into account.

9.2 The proposed restoration design incorporates areas designed to function as attenuation basins. The rate at which water will leave the attenuation basins will be controlled so that during extreme rainfall events a significant proportion of runoff will be retained to attenuate the runoff peak. On this basis the surface water attenuation function of the 2021 SWMP will be accomplished primarily by allowing water to accumulate in the basin areas temporarily during storm events and to be released from the basin areas in a controlled manner.

9.3 It is demonstrated in the 2021 SWMP that surface water can be managed on site without increased flood risk downstream of the site. The final details of the design of the drainage ditches and associated surface water attenuation basins will be agreed with the relevant planning authority prior to development of each landfill area.

9.4 The management and maintenance of the 2021 SWMP and the plan's capacity to facilitate water quality improvements is generally consistent with the existing surface water management plan.

10. References

1. https://www.gov.uk/guidance/flood-risk-and-coastal-change

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TABLES

Table 1

Surface water catchment areas

Catchment	Area draining to eastern drainage ditch[1] (m²)	Area draining to the swallow hole (m²)	Area draining to southern drainage ditch[2] (m²)	Area draining to permitted discharge point (m²)
Predevelopment catchment				
Western extension				
North and eastern margin of the northern area	49,650			
South and western margin of the northern area and the central area		155,100		
Southern area			64,100	
Permitted ENRMF[3]				
Northern catchment		67,000		
Southern catchment				257,200
TOTAL	**49,650**	**222,100**	**64,100**	**257,200**
Restored site				
Catchment 1				201,970
Catchment 2		60,945		
Catchment 3		82,230		
Catchment 4		27,750		
Catchment 5			59,080	
Catchment 6	41,075			
Catchment 7		32,930		
Additional areas[4]	3,400	42,715	3,035	24,180
TOTAL	**44,475**	**249,055**	**62,115**	**226,150**

1 Eastern drainage ditch round Collyweston Great Wood draining eastwards joining a tributary of the Wittering Brook.

2 Southern drainage ditch draining eastwards and then south eastwards joining a tributary of Willow Brook

3 Permitted ENRMF areas are taken from 2007 SWMP giving a total area of the existing ENRMF site of 324,200m². The updated area for the permitted ENRMF site is 317,600m² hence the slight discrepancy between the predevelopment and restored site catchments.

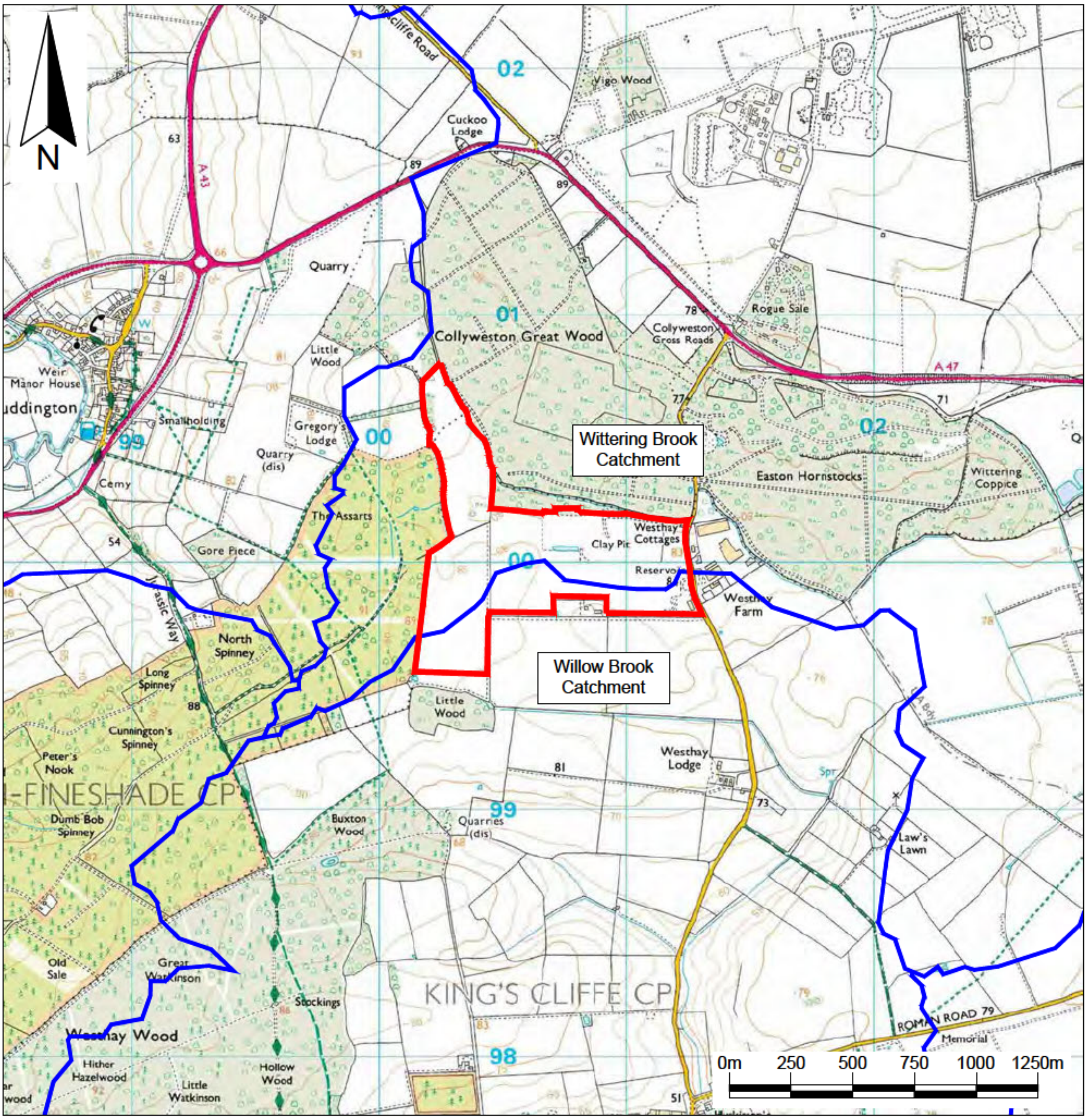
4 Restored site additional areas comprise managed grassland standoff areas round the perimeter of the site and in the pipeline corridors and perimeter boundary areas. In general, these areas are at shallow topographical gradients with drainage ditches upgradient from these areas collecting the majority of surface water runoff from the site.

Table 2

Upstream catchment areas

Catchment upstream of the western extension	Area (m^2)	Location to which the catchment area drains
Area to the north west drains to the northern part of the northern area	43,900	To the eastern drainage ditch
Area to the north west drains to south of the northern area and the central area	41,000	To the swallow hole
Area to the south west drains to the central area	207,050	To the swallow hole
Areas to the north west, west and south west drains to the west of the site	233,200	Drains to dolines to the west of site
Area to the south west drains to southern area	7,750	To southern drainage ditch

FIGURES



Key / Notes

Approximate boundary of the area the subject of the application for the Development Consent Order

Catchments defined on Environment Agency Catchment Data Explorer website

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	26/07/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Documented surface water catchments

Figure 1

Scale
1:25,000@A4

Drawing Ref
AU/KCW/03-21/22297

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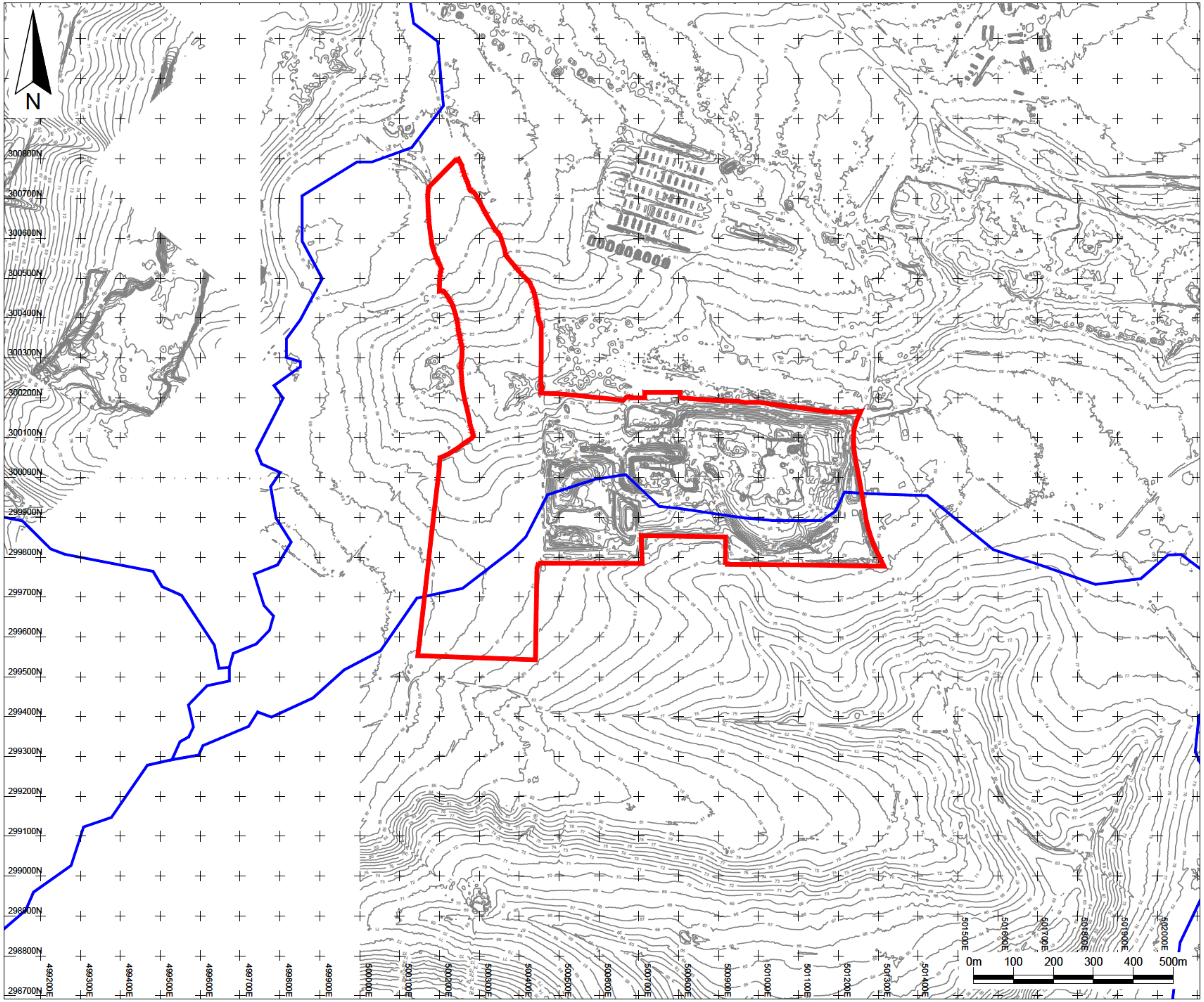

Key / Notes

- Approximate boundary of the area the subject of the application for the Development Consent Order
- Catchments defined on Environment Agency Catchment Data Explorer website
- 75 — LIDAR contours in metres above Ordnance Datum (mAOD)

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	26/07/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Topographical LiDAR data

Figure 2

Scale
1:10,000@A3

Drawing Ref
AU/KCW/03-21/22319

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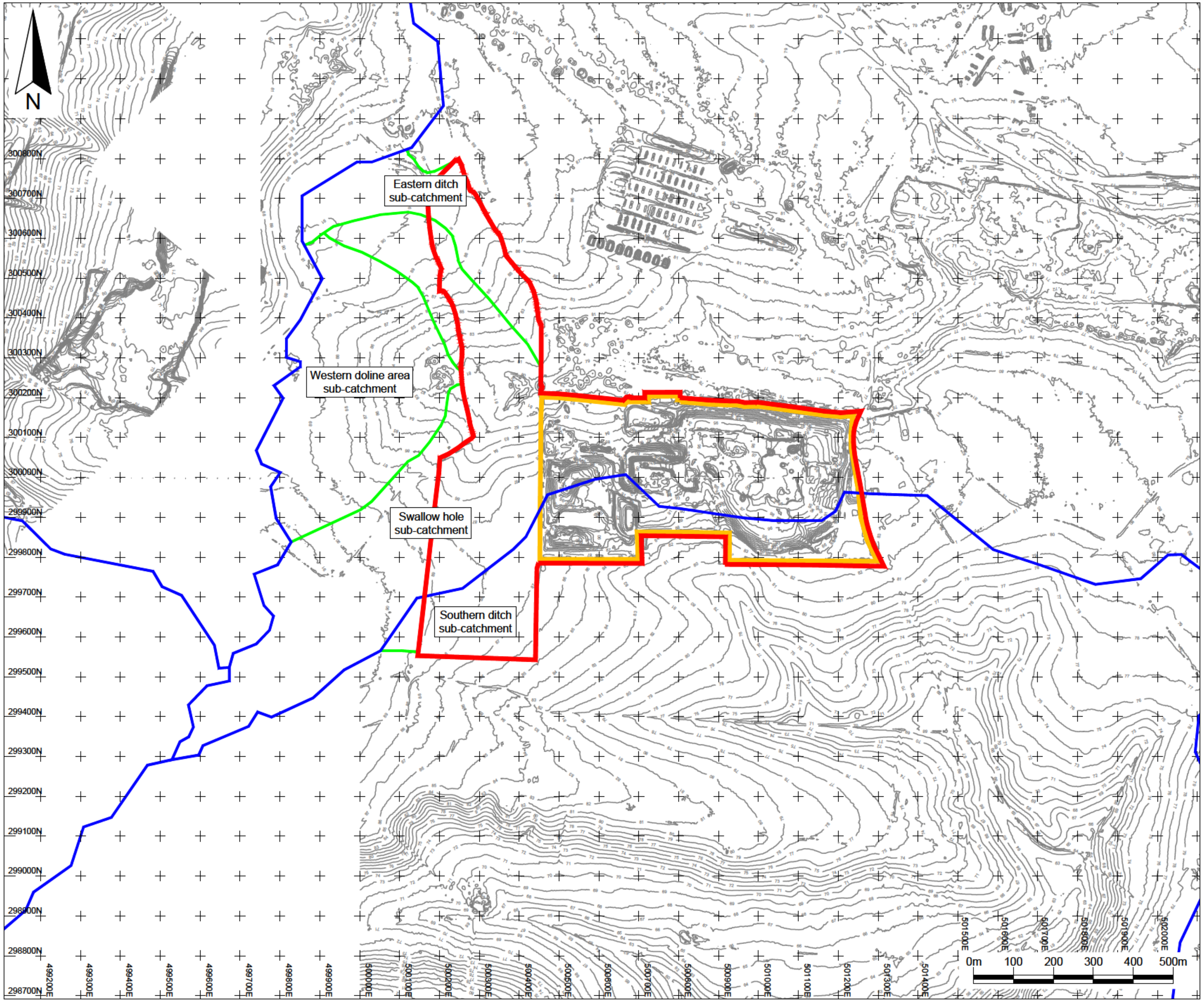

Key / Notes

- Approximate boundary of the area the subject of the application for the Development Consent Order (red)
- Current ENRMF site (orange)
- Catchments defined on Environment Agency Catchment Data Explorer website (blue)
- Sub-catchments interpolated from the LIDAR data (green)
- —75— LIDAR contours in metres above Ordnance Datum (mAOD)

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	26/07/21

Site: EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client: Augean SOUTH LTD

Title: Sub-catchments at and in the vicinity of the site

Figure 3

Scale: 1:10,000@A3

Drawing Ref: AU/KCW/03-21/22354

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Key / Notes

- Approximate boundary of the area the subject of the application for the Development Consent Order
- Indicative surface water drainage ditches
- Proposed restoration contours (at 1m intervals)
- Proposed locally native broadleaved woodland
- Proposed scrub/natural regeneration broadleaved woodland within grassland areas
- Proposed individual tree or small tree group
- Existing hedgerow reinforced with trees/shrubs
- Proposed hedgerow
- Proposed hedgerow with trees
- Existing agricultural land to remain as undisturbed standoff, to provide a number of ecological functions
- Existing species-rich neutral/ calcareous grassland to be retained
- Proposed neutral/calcareous grassland (depending on soil type)
- Existing pond to be retained
- Basin C4 — Proposed attenuation feature (lowest areas to act as ephemeral ponds to enhance biodiversity)
- Approx. 0.5m high bund around attenuation pond 1 to contain 1 in 100 year event. bund to be planted with scrubby species
- Public car park area accessed from existing main site entrance.

Note:
Based on file reference 210520_008.006_ENORTH25_Final Rest Plan_Dft5.dwg dated May 2021

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	26/07/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Indicative surface water drainage ditches

Figure 4

Scale
1:5,000@A3

Drawing Ref
AU/KCW/05-21/22467

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Key / Notes

- Approximate boundary of the area the subject of the application for the Development Consent Order
- Proposed restoration contours (at 1m intervals)
- Proposed locally native broadleaved woodland
- Proposed scrub/natural regeneration broadleaved woodland within grassland areas
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- Proposed attenuation feature (lowest areas to act as ephemeral ponds to enhance biodiversity)
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- Public car park area accessed from existing main site entrance.

Note:
Based on file reference 210520_008.006_ENORTH25_Final Rest Plan_Dft5.dwg dated May 2021

Rev	Status	Drn	App	Chk	Date
	Final	KR	JRC	LH	26/07/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
Restored surface water catchments

Figure 5

Scale
1:5,000@A3

Drawing Ref
AU/KCW/05-21/22466

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APPENDICES

APPENDIX A

SURFACE WATER MANAGEMENT PLAN DATED MAY 2007

Augean plc

Augean plc

Kings Cliffe Landfill

SURFACE WATER MANAGEMENT PLAN

May 2007

egniol

Client :	Augean plc
Project Title :	Surface Water Management Plan
Site:	Kings Cliffe LFS
Project No.	1621
Project Director:	John Marshall
Project Manager:	John Marshall

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	Environment Agency	

CONTENTS

APPENDICES

1.0 INTRODUCTION

1.1. Egniol Limited was commissioned by Wastego, now part of Augean plc, to prepare a surface water management (SWM) design and risk assessment for the Kings Cliffe Landfill Site (*the Site*). The site is licenced under the Pollution Prevention and Control (England and Wales) Regulations 2000 for co disposal of waste in Cells 1 and 2 and hazardous waste in Cells 3, 4 and 5. This report supports a variation notice application to the Environment Agency (EA).

1.2 The purpose of the assessment is to determine whether the site restoration proposals and surface water management design pose an unacceptable risk to surface and groundwater and whether proposed mitigation measures are sufficiently robust to reduce/control those risks to an acceptable level.

1.3 The report will review the present situation and assess the risks based on the progressive site development. The risk will be in the context of the source, pathway, receptor style of approach with appropriate engineering design to address it. Consideration is then given as to how the engineering measures are controlled and monitored for performance to ensure that they continue to meet site operations and environmental need.

1.4 Subsurface flow within the site, if any, has been ignored since this assessment deals purely with surface water runoff. The hydrogeological aspect of the site development is covered by Environmental Simulations International Ltd in a separate risk assessment.

1.5 Proposed discharge rates of runoff to off site are expressed in terms of "Greenfield" rates. There are calculations in Appendix A to identify how this rate has been computed as well as a prediction of the percentage runoff (PR) for the restored site.

The particle settlement calculations for the efficiency of the north and south ponds are also given in Appendix A.

1.6 Calculations for the predicted performance of the ditches and attenuation ponds have been produced using the Flood Studies Report in the MicroDrainage software. The calculations are included in Appendix B and C.

2.0 PRESENT SITUATION

2.1 There is little active management of surface water runoff beyond the fence boundary at present. What is in place is a passive system of embankments along the whole of the eastern and part of the southern elevations and these jointly serve as visibility bunds to obscure site operations. Active landfilling operations are confined well within the site and road sweeping is carried out both on the public highway and the site access roads and weighbridge area.

2.2 The intermittent perimeter bund, nominally two metres high, on the southern and eastern boundaries from the wheelwash eastwards to the site entrance entraps surface runoff from the access road and the MRF area. There is a pond on the southern boundary that does not have an overflow but is monitored for level and has 600mm nominal freeboard to the southern boundary. The pond is used as a source for watering for dust suppression.

2.3 It is expected that the present system of surface water management for the southern catchment will be changed when the construction of the new lagoon to the south east corner replaces the present one on the southern boundary. The new lagoon will then be able to receive runoff from the rolling programme of restoration when this commences.

2.4 The eastern perimeter bund extends northwards from the site entrance and stands nominally 2 - 4 metres high above normal ground level and becomes part of the batter to Cell 2 at the north east corner of the site. Surface runoff along the eastern boundary is prevented from leaving the site by the bund. On the northern batter, proposals are in hand and discussed below, to entrap surface runoff before it reaches the site perimeter. This runoff will be directed westwards to the proposed settlement / attenuation pond to be constructed under the surface water management proposals.

2.5 There is no identified runoff from the western and south western horizons of the site as this is undeveloped.

2.6 At present surface water collecting within unlined cells is encouraged via grips to fall into a collection lagoon/sump located at the lowest point within this area. This provides initial storage capacity and settlement of suspended solids. A pump is used to pump water to the settlement pond on the southern boundary.

2.7 To minimise surface run off from the side-slopes into active landfill areas, temporary cut-off trenches can be provided as required to intercept the flow and route it to the perimeter cut-off ditches and thence to the above pond for settlement.

3.0 SOURCES OF POLLUTION

3.1 The main sources of potential contamination are from the waste, site engineering/development, the drum storage / skip / lorry park area and the materials recycling facility (MRF). The surface water runoff from these areas is designed to be captured within the on-site drainage system.

3.2 The skip / lorry park / drum storage area presently consists of imported stone overlying compacted clay. There is no formal sub surface drainage system but ground levels trend northwards towards the centre of the site.

3.3 The general level of the limestone aquifer under the skip / drum storage area is 72mAOD and the ground level 83.5mAOD. The natural clay has a permeability of 1×10^{-5} m/s so a thickness of 11m or so provides a good level of protection to the limestone.

3.4 The northern catchment of the site comprises Cells 1 and 2 and has a steep batter on the northern site boundary. This potentially could shed polluted runoff off site. There are no receiving waters on this boundary and runoff tends to form localised pond areas. On the eastern horizon the cell batter runoff is contained by the visibility bund which is some 3 - 4 metres high at this point.

4.0 PATHWAYS AND RECEPTORS

4.1 The main receptors for any potential contamination are groundwater via the swallow hole to the north, the northern off site boundary along Cells 1 and 2 and the receiving watercourse in the valley to the south of the site.

Swallow Hole

4.2 The swallow hole lies in woodland some 20m north (NGR 500470, 300240) of the north west corner of the site and provides a natural sink for pre development site runoff to issue directly to groundwater. Runoff from surrounding agricultural land already gravitates to the swallow hole via a system of field ditches.

4.3 The other pathway which could pose a risk to groundwater contamination here is from discrete seepage from peripheral ditches installed as part of the proposed surface water management scheme or overland flow from a proposed pond.

Northern Boundary – Cells 1 and 2

4.4 Runoff from the northern batter of Cells 1 and 2 is free to issue off site and could percolate into groundwater if the overburden soils of the aquifer are conducive to it.

Unnamed Watercourse, South of the Site

4.5 There is no direct connection with the watercourse and the site at present as the two are remote. It is proposed, however, under the surface water management plan to issue site runoff to it.

4.6 The watercourse issues to a road culvert and the capacity of this has been checked to confirm that flooding does not result under design operating conditions.

5.0 PROPOSED SURFACE WATER MANAGEMENT

5.1 The proposed surface water management system is shown on drawing 1621.SWM.10 in Appendix G. The site restored slopes will be configured into north and south catchment areas. These are referred to as such in the discussion below.

5.2 The system will be progressively installed on completion of each cell. The progression of cell construction and filling is shown on drawing 1621.SWM.24 in Appendix J. Surface water ditches will be excavated into the restoration soils to direct run-off into the main perimeter cut-off ditch. The ditch section profile is indicated on drawing 1621.SWM.10 in Appendix G and is integrated with the capping materials.

5.3 Site restoration will generally consist of 1metre restoration soils overlying a geomembrane/ clay liner. On the northern batter slopes, a drainage geocomposite with 1mm textured geomembrane clay liner is specified below the restoration soils.

Northern Site Catchment

5.4 The northern catchment will issue into a pond in the north-west corner of the site. The selected location of the proposed pond is ideal as regards its remoteness from working areas as this minimises the probability of accidental contamination. It is in close proximity to road access for service vehicles for the pumping station and overhead power supplies for the pump units. The pond elevation is also conducive to collecting runoff by offering a westerly outfall route from the restored slopes on Cells 1 and 2. An outfall to the east is not readily available. In contrast to these attributes there is the likelihood that the pond may, during its operation, contain contaminated water and this will be stored for assessment prior to licenced disposal. Since the pond will be lined with engineered clay, overtopping and overland routing of water to the swallow hole is the only available pathway of escape to groundwater. Given the worst case scenario where the pumps fail during the critical 100 year return period storm, it is predicted that there would still be a 46 hour time lapse between failure of the pumps and overtopping of the lagoon. It is considered that this would be ample time to commission tankers onto site to draw down the water levels, restore power supplies or repair/reset stalled pumps. The risk of groundwater contamination via this pathway is therefore considered negligible.

5.5 The pumping station will be subject to an annual maintenance agreement with a competent M&E Contractor and this will run for the life of the station. The agreement will stipulate the frequency of non reactive service inspections and the response times for reactive ones. A telemetry outstation will be provided in the pumping station kiosk and this will respond to a landline telephone designated by Augean. In the first instance, this will report faults to the maintenance contractor. The outstation will also have a dial up facility to enable interrogation of the stations' operational status by authorised parties.

5.6 Inlet ditches to the pond will be lined with engineered clay and constructed to CQA site standards, as will the ponds. Overtopping will occur at the pond before the ditch and this risk has been discussed and discounted earlier. The risk of contamination of groundwater is therefore considered to be negligible from this source.

5.7 A pumped outfall from the pond to the proposed south east pond and then to watercourse south of the landfill site will offer less contamination risk than an outfall to groundwater via the swallow hole to the north. The pumped outfall option has thus been selected for preference but both options have been reviewed for risk.

5.8 In the pumped outfall scenario, to achieve a self-cleansing velocity in the rising main commensurate with a pipe diameter to resist blockage, it will be necessary for the outflow from the pond to exceed Greenfield Run-off. MicroDrainage calculations in Appendix E show that even for the critical 1 in 100 year return period storm, this increased rate of pumping will not cause flooding downstream at the road culvert. The pond has therefore been sized on this rate. The north west pond and pumping station is shown on drawing 1621.SWM.11 in Appendix H.

5.9 The proposed pond will have a side slope no steeper than 1 in 3, a width to length ratio of 1 to 3 (recommended for optimum suspended sediment settlement) and a minimum freeboard of 600mm above design top water level. It will incorporate sufficient storage capacity to contain the inflow from the critical long duration storm of 1440minutes assuming that pump failure endures up to 24 hours.

5.10 The additional storage capacity provided as a safeguard against overtopping following pump failure, will also allow inflows to be safely contained within the pond so that the water quality can be monitored if pollution is suspected. If the water quality complies with the discharge consent, the pumps can then be re-activated to draw the water level back down and release it at a controlled rate to the south east pond. In normal operation, the pumping station would respond automatically to inflow from rainfall.

5.11 In the unlikely event that water sampling reveals substances outside prescribed limits, the water will be treated as leachate and processed at a licenced facility off site.

5.12 The inflow ditches to the pond will be lined with clay and dressed in topsoil with ryegrass seed to form a swale. When established, the grass will provide natural filtration and further attenuation. Stone pitching will be provided at the inlets and down the banking to avoid erosion and allow escape. The pond will be fenced and signs erected to warn of deep water.

Southern Site Catchment

5.13 The southern catchment will issue to the proposed south east pond see drawing 1621.SWM.14 in Appendix 1. It is sized to cater for a 1 in 100 year (1% probability) rainfall event and pass forward a controlled discharge to the upstream point of the road culvert. Calculations are included in the report to show that flooding of the culvert for events up to 1 in 100 years is avoided (see Appendix D and E).

5.14 The calculations further demonstrate that even without attenuation on site the highway culvert will not flood for the critical 1 in 100 year return period event. However, for the purpose of monitoring and controlling discharges from site a pond has been included in the surface water management of the site.

5.15 The outfall will comprise a 225mm diameter pipe laid under Licence in the highway verge to the receiving watercourse, where it will issue at NGR 501480 299360. With *no* orifice control over the 225mm diameter outfall pipe, there would be an outflow rate for the critical 1 in 100 year return period storm of approximately 11 x Greenfield Run-off (ie 11 x 10l/s). It has been calculated that the downstream highway would have the capacity to receive a discharge rate of greater than 50 x Greenfield Run-off from this pond without being at risk from flooding.

5.16 The size of the south east pond will be limited by the presence of the MRF building, the haul road and the minimum easement width for the water mains. Given that the discharge is increased to 5 x 'Greenfield Run-off', it will be possible to design the pond with 1 in 3 side slopes, however the restrictions on space mean that it will not be possible to design the pond to the recommended width to length ratio of 1 to 3.

5.17 Details for the rating curve of the orifice outlet and outflow rate are included in Appendix A as Calculation 4.

5.18 The capacity of the south east pond is 1506m3 between incoming invert level and top of bank. The volume used by the 1 in 100 year event is 954m3 so the volume available as freeboard is 552m3. The percentage available volume available for climate change and dilapidation is therefore 552/954 = 57%, ignoring the silt storage volume of 367m3. Silt will be removed for the base of the pond as part of the programmed maintenance regime under the surface water management plan.

5.19 Following a request from the EA, the performance of the south east pond has been verified to accommodate 80% of the surface water runoff volume produced by a 1in 10 year storm of the critical duration 24hrs after it has been filled to design level. The pond is actually predicted to be empty after 960mins (16 hours) from the 100year event. This means that full capacity is available within 24hrs to cater for further events.

5.20 In the scenario of a more extreme event than 1 in 100 years, the runoff would back up the incoming ditches utilising available storage within them with a similar rise in the pond level. Out of bank flows will occur in the local ditches to the pond and the pond itself. If the event occurs while the site is still operational it is expected that flow routing will be towards the centre of the site. Should overtopping occur when the site is closed and fully restored, then flood routing will be confined to the south east corner of the site providing the visibility bund is retained.

Northern Slope at Cells 1 and 2

5.21 The northern batter slope is programmed to undergo reprofiling as part of the overall restoration. Under the SWM plan, a collector ditch will be incorporated into the reprofiled batter to prevent off site runoff and issue runoff to the proposed north west pond.

Technical Aspects of the SWM Design

5.22 The ditch sections in the SWM design are chosen to provide a minimum level of service of no flooding during a 1 in 10 year event. To reduce ravelling, and the risk of eroding the capping / liner, intermediate ditches will be provided on the batter slope. As the landform settles, ditches may need to be realigned to maintain gradient.

5.23 Design calculations in support of the proposed Surface Water Management Scheme are included in the Appendices. The settlement ponds have been designed in accordance with "Design of Flood Storage Reservoirs" published by CIRIA and discharge rates determined by use of the Flood Studies Report / Flood Estimation Handbook.

5.24 Construction of surface water management infrastructure will be subject to Construction Quality Assurance supervision to ensure that the Works are built in accordance with the Drawings

6.0 MONITORING

Baseline Monitoring at Existing Receptors

6.1 Baseline monitoring has been carried out by recovering samples of water from the two obvious inlet points to the swallow hole and the reception point at the southern watercourse. The results are tabulated in Appendix F.

6.2 For both the present northern and southern issues into the swallow hole (sample location reference SW SWALL N and SW SWALL S), measured levels of 0.4mg/l Ammoniacal Nitrogen exceed DWS levels of 0.35mg/l. Samples recovered after implementation of the surface water management scheme from the proposed pond on the northern catchment will be compared against the baseline results for the issue into the swallow hole from the south.

6.3 The outfall for the southern and northern catchments is at the confluence of the watercourse as it leaves arable land and a roadside ditch accepting direct runoff from the carriageway (sample location reference SW Field RO and SW Road RO). Baseline sampling from the arable land reach of the watercourse has been undertaken on the 8th February and the 2nd and 24th March 2005. Samples of road runoff were recovered on the 14th and 19th October 2005.

6.4 Comparison has been made against Drinking Water Standards (DWS) in accordance with the Water Supply (Water Quality) Regulations 2000.

Arable Land Runoff

6.5 Conductivity is recorded (2 March 2005) as 2770µs/cm which is >1500µs/cm DWS. Cadmium is 0.001mg/l which is >0.1µg/l MRV but <0.005mg/l DWS (24 March 2005). Ammoniacal Nitrogen of 0.5mg/l is > DWS of 0.35mg/l (24 March

2005). Mecoprop of 0.186µg/l is > 0.04µg/l MRV and the 0.1µg/l DWS (24 March 2005). All of the above determinations are in low concentrations.

Road Runoff

6.6 Baseline monitoring was undertaken in October 2005 when sufficient rainfall was evident to provide a sample. The results are included in Appendix F.

6.7 Ammoniacal Nitrogen is 0.5mg/l and <0.3mg/l which is close to DWS of 0.35mg/l. Mecoprop of <0.04µg/l is similar to the MRV of 0.04µg/l. All of the above determinations are low concentrations.

Future Monitoring

6.8 The ponds offer the opportunity to analyse stored water for potential contamination and it is proposed that sampling be undertaken on an initial two weekly basis to establish the quality of the first inflows. After this period a monthly programme can be initiated. This will allow the operator to classify whether the water lies within EA agreed threshold limits for its controlled disposal. Testing will be carried out in accordance with the Environmental Monitoring Plan.

6.9 As an additional safeguard, routine walk over inspections will continue to be to alert to irregularities in the landform which could indicate the capping membrane to have ripped and any unusual discolourations on the landform which could indicate the presence of a contaminant. If a potential contamination hazard is identified, water samples will be recovered for testing in accordance with the Environmental Monitoring Plan.

6.10 The decision to pump runoff from the northern catchment does not offer an ideal, sustainable solution to dispose of rainfall since power usage is dictated by the vagaries of the weather. The choice of this option should, however, be viewed in the context of the risk to groundwater against the capital and revenue cost of the station. To estimate the station cost, it is necessary to attempt a forecast of the likelihood that polluted flows may issue to it in the years to come against the residual risk when the station is decommissioned and flow is diverted to the swallow hole.

6.11 The purpose of the pumping station at the north western corner of the site is to effect control over potentially contaminated surface water drainage from the landfill. There is a potential for contamination of surface water during the operational period and in the period following capping and restoration due to contamination of run off, perched leachate and erosion. As leachate collecting in the base of the cell is managed at a level several metres below ground level it does not present a risk to the surface water system. The installation of the landfill cap, placement of soils and the establishment of a vegetated surface will provide a barrier to contaminants and prevent erosion. The most active stage of biodegradation and settlement hence disturbance of the landfill surface occurs in the first five years after landfilling. It is anticipated that the landfill surface will become increasingly stable and the risk of significant contamination of surface water run-off will progressively reduce. Surface water draining from the northern part of the site will continue to be pumped to the south eastern lagoon until the quality of the drainage is consistently acceptable. At this time, subject to the agreement of the Environment Agency, the discharge from the north western pond will be diverted to the swallow hole.

7.0 CONCLUSION

7.1 This risk assessment examines the potential impact of contaminated surface water runoff from the site on the surrounding environment. It discusses the source, severity of the risk, the likelihood of it occurring and the protocol provided to contain it. Providing the routing of surface runoff and the containment of it is maintained then the sampling regime should adequately monitor the site generated flows.

7.2 The storage ponds represent an opportunity for intercepting potentially contaminated flows from escaping to the environment. In designing the ponds, careful consideration has been given to ensure that they are both adequate to afford protection against downstream flooding and sufficiently sized to allow a response to a pollution incident. The ponds also incorporate protective fencing and means of escape via hard paved inflow channels set at manageable gradients.

7.3 The ponds have penstock controls incorporated at the outlet. The flow control on the south east pond is a simple orifice plate which regulates discharge to prescribed limits. This can be removed by unbolting in the event of blockage. If desilting of the ponds is required, the penstock can be closed to prevent onward passage of silts to the outfall.

7.4 Settling of solids is a primary function of both the ponds and the geometry has been carefully configured to dissipate energy from incoming turbulent flow during storm events. The ponds are both to have at least one metre of water below the outlet level which will provide inertia to reduce inlet velocity. Sumps have been incorporated into the base to collect solids and aid removal.

7.5 Freeboard of 600mm for the 1 in 100 year event is provided to contain flows and safeguard against offsite flood routing.

7.6 Outflow through the northern pond will be controlled by a pumping station which will regulate the discharge to that required for self cleansing of the rising main. If desilting of the pond is required, the pump can be simply turned off and the silt withdrawn by a portable sludge pump into a bowser for licenced disposal. A similar procedure will be adopted for the south east pond once the outlet penstock is closed. Calculations are included in the Appendices to show that the receiving watercourse is adequate to accept the flow

7.9 Flood routing and the passage of contaminated water within final paved areas will be effectively curtailed by the use of ground profiles in the form of kerbs and highway ramps.

7.10 Testing of contained water in the surface water lagoons will be undertaken in accordance with the Environmental Monitoring Plan. Records of sampling data shall be available for scrutiny by the Environment Agency at all reasonable times to offer assurance that compliance to agreed discharge criteria is being adhered to. Sampling data will be sent the EA on a quarterly basis and non conformances sent immediately via a Schedule 1.

APPENDIX A

CALCULATIONS

CALCULATIONS 1 - ESTIMATION OF ACCEPTABLE RUN OFF FROM SITE

Northern Catchment

Determine Q (mean annual flood) using FSR for each catchment

From FSR Supplementary Report No 6,

$Q = 0.00066 \times AREA^{0.92} \times SAAR^{1.22} \times SOIL^2$

Total contributing AREA = 6.7 ha = $0.067\ km^2$

Kings Cliffe National Grid Ref – 500500E 300500N

From Fig II 3.1 (S) » SAAR = 580mm

From Fig I 4.18 (S) » $S_1 = 100\%$

$$SOIL = \frac{0.15S_1 + 0.3S_2 + 0.45\,S_3 + 0.45\,S_4 + 0.5\,S_5}{S_1 + S_2 + S_3 + S_4 + S_5}$$

SOIL = 0.15

Therfore $Q = 0.00066 \times 0.067^{0.92} \times 580^{1.22} \times 0.15^2$

$Q_{NORTH} = 2.91$ l/s

Southern Catchment

From FSR Supplementary Report No 6,

$Q = 0.00066 \times AREA^{0.92} \times SAAR^{1.22} \times SOIL^2$

AREA = $0.2572\ km^2$

SAAR = 580mm

SOIL = 0.15

Therefore $Q = 0.00066 \times 0.2572^{0.92} \times 580^{1.22} \times 0.15^2$

Using the southern catchment area, Qsouth = 10 l/s

CALCULATIONS 2 - PERCENTAGE RUN OFF CALCULATIONS

Calculate the predicted percentage run off for the restored site

From "Design of Flood Storage Reservoirs" (CIRIA)

$PR_{RURAL} = SPR + DPR_{CWI} + DPR_{RAIN}$

Where $SPR = 10\ S_1 + 30\ S_2 + 37S_3 + 47\ S_4 + 53\ S_5$

Restoration soils will be approximately 800mm deep over HDPE membrane or engineered clay cap.

T 4.5 (FSR Vol 1)

Drainage Group = 1 (Rarely waterlogged within 60cm)
Depth to impermeable layer > 80cm
Permeability Group above Imp layer = Medium
Slope > 8^0

Therefore Soil Class = 2 so S2 = 100%

SPR = 30.1 = 30

$DPR_{CWI} = 0.25 (CWI - 125)$

Kings Cliffe Grid Ref 500500E 300500N

From FSR Fig II 3.1 (S) SAAR = 580mm
FSR Fig I 6.62 CWI = 47

Therefore $DPR_{CWI} = 0.25 (47 - 125) = -19.5$

$DPR_{CWI} = - 19.5$

$DPR_{RAIN} = 0.45 (P - 40)^{0.7}$

Where P = Rainfall(in mm) for the design event
For Kings Cliffe M5 - 60 = 20mm
R = 0.42

Critical Duration = Time of Entry + Time of Flow

Maximum length of ditch to outfall = 500m
Assume flow velocity in ditch of 0.4m/s
Assume overland flow velocity of 0.1m/s

$$\text{So Te} = \frac{\text{Distance from catchment boundary to furthest ditch}}{\text{Overland flow velocity}}$$

$$= \frac{135\text{m}}{0.1 \times 60}$$

Te = 22.5mins

Tc = Te + Tf

$$\text{So Tc} = 22.5 + \frac{500}{0.4 \times 60} = 43 \text{ mins}$$

Critical Duration = 43 mins

Z	M100 - 30	M100 - 60	M100 -120
Z1	0.8	1	1.6
Z2	1.99	2.03	1.95

Therfore

M100 – 30 = 20 .0.8.1.99 = 32 So P_{30} = 32 mm
M100 – 60 = 20 1.0.2.03 = 40.6 So P_{60} = 40 mm
M100 – 120 = 20 .1.6 1.95 = 62.4 So P_{120} = 62mm

So $DPR_{RAIN} = 0.45 \,(P - 40)^{0.7}$

For Tc = 60mins, $DPR_{RAIN} = 0.45 \,(41 - 40)$

$DPR_{RAIN} = 0.45$

Therefore $PR_{60} = 30 + (-19.75) + 0.45$

<u>$PR_{60} = 10.7\%$</u>

For Tc = 30 mins, $DPR_{RAIN} = 0$ ($P<40$)

So $PR_{30} = 30 + (-19.5) + 0$

<u>$PR_{30} = 10.5\%$</u>

For Tc = 60 mins, $DPR_{RAIN} = 0.45 \,(40 - 40)^{0.7}$

$DPR_{RAIN} = 0$

So $PR_{60} = 10.5\%$

For Tc = 120 mins, $DPR_{RAIN} = 0.45\ (62 - 40)^{0.7}$

$DPR_{RAIN} = 3.91$

So $PR_{120} = 30 - 19.5 + 3.91$

$\underline{PR_{120} = 14.41\%}$

say

Percentage Runoff for the restored site = 12.5%

CALCULATIONS 3 - DETERMINING PARTICLE SETTLING VELOCITIES

Assess terminal velocity of settlement of fluvial deposits in balancing pond using "Design of Flood Storage Reservoirs" by CIRIA.

From para 6.5.1

The settlement velocity of a sphere of given diameter, d, is derived from the drag force, Cd and Reynolds Number, Re, expressed in two dimensional groups:-

$$\frac{Cd}{Re} = \frac{4}{3} \frac{((\rho_p - \rho) g\mu)}{\rho^2 - \upsilon_s^2} \qquad \text{Equation 6.2}$$

$$Cd. Re^2 = \frac{4}{3} \left(\frac{\rho(\rho_p - \rho) gd^2}{\mu^2} \right) \qquad \text{Equation 6.3}$$

Where g = gravitational acceleration 9.81m/s^2

μ= absolute viscosity of the fluid (Ns/m^2)

ρ_p = particle density (kg/m^3)

ρ = fluid density (kg/m^3)

Assume the particle size will arise from use of the granular restoration soils. Also check the efficiency of the designed ponds to cater for clay content if the restoration soils are taken from soil arising from waste inputs.

So for restoration soils:-

µ metres	% Passing
20	65
60	100

Where < 2 µm is clay
2 -6 µm is fine silt
6 -20 µm is medium size silt
20 – 60 µm is coarse silt
60 – 200 µm fine sand

Determine the particle settling velocity for 20μm particles settling in water at 20^0 C. Assume a specific gravity of 2.4.

Check υ_s for 20μm size particles;-

$$Cd.\ Re^2 = \frac{4}{3}\left(\frac{\rho(\rho_p - \rho)\,gd^2}{\mu^2}\right)$$ Equation 6.3

= 0.076

From Fig 6.7 Re = 0.04

As Reynolds Number is < 1, Stokes Law is valid and settlement is in the laminar range.

So from Cd. Re^2 = 0.076

Cd = 47.5

And υ_s = 2.6mm/s (20μm particle)

Similarly, υ_s for 60μm gives Re = 0.23 (laminar) and Cd = 38.94

and υ_s = 4.98mm/s (60μm particle)

Determine the trap efficiency of the North West Pond

From Design of Flood Storage Reservoirs Para 6.5.3

$$\text{Trap efficiency} = \eta = \frac{\upsilon_s\, t_R}{d_1}$$

where υ_s = Settling velocity
t_R = Mean hydraulic residence time
d_1 = Flowing layer mean depth of flood basin

Check η for 20μm and 60μm particles

For 20μm, Volume = L x B x H
Size of pond at Bottom Water Level (BWL) is 161.38m^2 and at Top Water Level (TWL) 305m^2. Average surface area is (305 + 161) 0.5 = 233 m^2 . The Pond has 1 in 3 side slopes.

Depth of pond for a 1 in 100 year event = TWL – BWL = 79.02 – 78.25 = 0.77m

At the 1 in 100 year event the pond is technically full plus the 1000mm freeboard.

Size of the pond at mid depth = 233m2

So volume = 233x 0.77 = $179m^3$

Mean hydraulic residence time $t_R = \frac{Vol}{Q}$

Where Q = steady state inflow / outflow. This is not feasible for attenuation ponds where inflow / outflow ratios will change, so use outflow rate.

So $t_R = \frac{179}{0.0147}$ = 12,176s = 3.38 hours

Mean through flow velocity $V = \frac{L}{t_R} = \frac{20m}{12,176}$

$= 1.64 \times 10^{-3}$ m/s

for 20µm particles, where υ_s = 2.66mm/s

$$\eta = \frac{\upsilon s \times t_R}{d_l} = \frac{2.66 \times 10^{-3} \times 12176}{0.77}$$

$\eta = 42$ Satisfactory

Therefore all of the remaining 20µm particles would be trapped in 1/42 the length of the ponds. The Erosamat lining and grass within the outfall ditches would entrap fluvial fine silts also.

CALCULATION 4 – RATING FOR THE ORIFICE ON KINGS CLIFFE SOUTH EAST POND

Rating Curve for Orifice on Kings Cliffe South East Pond

Q = Cd A (2gH)*0.5

Cd	A	2g	H	Qm3/s
0.6	0.0172034	19.62	0.2	0.020
0.6	0.0172034	19.62	0.4	0.029
0.6	0.0172034	19.62	0.6	0.035
0.6	0.0172034	19.62	0.8	0.041
0.6	0.0172034	19.62	1	0.046
0.6	0.0172034	19.62	1.2	0.050
0.6	0.0172034	19.62	1.4	0.054

The south east pond will operate as the table below. The 240min duration Winter event is the critical event for the catchment:

Rainfall Return Period and Orifice Outflow Rate - South East Pond

Return Period	1	5	10	30	50	100
Critical Storm	240 Winter	240 Winter	240Winter	240 Winter	240Winter	240Winter
Outflow (l/s)	33	39	42	46	47	50
Top Water Level (m)	83.094	83.312	83.42	83.61	83.7706	83.845
Freeboard (mm)	1256	1038	930	739	644	505
On Site Flooding	None	None	None	None	None	None

The predicted top water level is 83.845mAOD and top of bank level 84.35mAOD

APPENDIX B

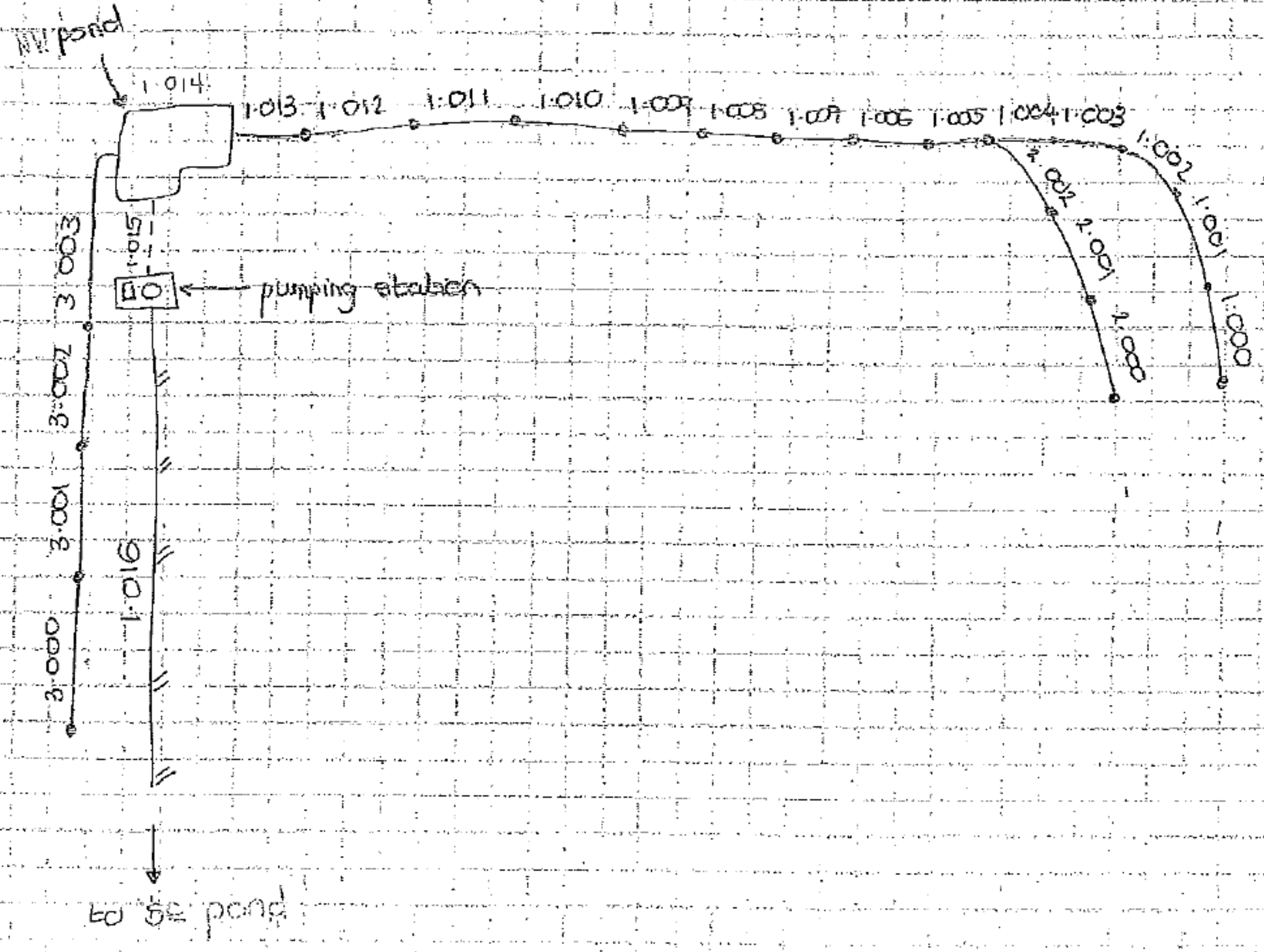
MICRODRAINAGE OUTPUT – NORTHERN CATCHMENT

Calculation Sheet

egniol

Client: Augean	Job No: 1621	Project: Kings Cliffe SWM.		
Made by: Jenny Mills	Date: Jun 05	[redacted]	Date:	Sheet No: B Rev A

Northern Catchment



Network Details

* - Indicates pipe has been modified outside of WinDes's Storm/Foul & Schedules

PN	Length (m)	Fall (m)	Slope (1:x)	Area (ha)	T.E. (mins)	Rain Pro	k (mm)	Hyd Sect	Dia (mm)
1.000	130.00	5.510	23.6	0.133	18.00	1	300.000	\/	32
1.001	50.00	0.120	416.7	0.016	0.00	1	300.000	\/	32
1.002	50.00	0.130	384.6	0.024	0.00	1	300.000	\/	32
1.003	50.00	0.120	416.7	0.013	0.00	1	300.000	\/	32
1.004	50.00	0.130	384.6	0.004	0.00	1	300.000	\/	32
2.000	126.50	0.720	175.7	0.098	16.00	1	300.000	\/	32
2.001	50.00	1.890	26.5	0.026	0.00	1	300.000	\/	32
2.002	50.00	5.040	9.9	0.021	0.00	1	300.000	\/	32
1.005	50.00	0.130	384.6	0.023	0.00	1	300.000	\/	32
1.006	50.00	0.120	416.7	0.023	0.00	1	300.000	\/	32
1.007	50.00	0.130	384.6	0.021	0.00	1	300.000	\/	32
1.008	50.00	0.120	416.7	0.023	0.00	1	300.000	\/	32
1.009	50.00	0.160	312.5	0.022	0.00	1	300.000	\/	32
1.010	56.00	0.180	311.1	0.022	0.00	1	300.000	\/	32
1.011	101.00	0.320	315.6	0.056	0.00	1	300.000	\/	32
1.012	108.00	0.340	317.7	0.090	0.00	1	300.000	\/	32
1.013	50.00	0.160	312.5	0.075	0.00	1	300.000	\/	32
3.000	65.00	0.200	325.0	0.024	5.00	1	300.000	\/	32
3.001	75.00	0.600	125.0	0.022	0.00	1	300.000	\/	32
3.002	70.00	2.200	31.8	0.033	0.00	1	300.000	\/	32
3.003	90.00	5.000	18.0	0.071	0.00	1	300.000	\/	32

PN	USMH No.	US/CL (m)	US/IL (m)	US/Dep (m)	DS/CL (m)	DS/IL (m)	DS/Dep (m)	Ctrl No.	US/MH (mm)
1.000	1	87.670	87.170	0.005	82.160	81.660	0.005		3000
1.001	2	82.160	81.660	0.005	82.040	81.540	0.005	3	3000
1.002	3	82.040	81.540	0.005	81.910	81.410	0.005	3	3000
1.003	4	81.910	81.410	0.005	81.790	81.290	0.005	3	3000
1.004	5	81.790	81.290	0.005	81.660	81.160	0.005	3	3000
2.000	6	89.310	88.810	0.005	88.590	88.090	0.005		3000
2.001	6	88.590	88.090	0.005	86.700	86.200	0.005	3	3000
2.002	6	86.700	86.200	0.005	81.660	81.160	0.005	3	3000
1.005	6	81.660	81.160	0.005	81.530	81.030	0.005	3	3000
1.006	7	81.530	81.030	0.005	81.410	80.910	0.005	3	3000
1.007	8	81.410	80.910	0.005	81.280	80.780	0.005	3	3000
1.008	23	81.280	80.780	0.005	81.160	80.660	0.005	3	3000
1.009	23	81.160	80.660	0.005	81.000	80.500	0.005	3	3000
1.010	23	81.000	80.500	0.005	80.820	80.320	0.005	3	3000
1.011	23	80.820	80.320	0.005	80.500	80.000	0.005	3	3000
1.012	23	80.500	80.000	0.005	80.160	79.660	0.005	3	3000
1.013	23	80.160	79.660	0.005	80.000	79.500	0.005	3	3000
3.000	23	88.000	87.500	0.005	87.800	87.300	0.005		3000
3.001	23	87.800	87.300	0.005	87.200	86.700	0.005	3	3000
3.002	23	87.200	86.700	0.005	85.000	84.500	0.005	3	3000
3.003	23	85.000	84.500	0.005	80.000	79.500	0.005	3	3000

Network Details

PN	Length (m)	Fall (m)	Slope (1:x)	Area (ha)	T.E. (mins)	Rain Pro	k (mm)	Hyd Sect	Dia (mm)
1.014	10.00	1.250	8.0	0.000	0.00	1	300.000	\/	32
1.015	1.00	0.000	30000.0	0.000	0.00	1	0.006	o	225
1.016	760.00	7.325	103.8	0.000	0.00	1	0.006	o	150

PN	USMH No.	US/CL (m)	US/IL (m)	US/Dep (m)	DS/CL (m)	DS/IL (m)	DS/Dep (m)	Ctrl No.	US/MH (mm)
1.014	23	80.000	79.500	0.005	80.000	78.250	1.255	3	3000
1.015		80.000	78.250	1.525	80.000	78.250	1.525	3	1200
1.016	23	80.000	77.300	2.550	87.525	69.975	17.400	5	1800

On-Line Controls (Non Return Valve)

US/PN	Volume (m³)	Ctrl MH Name	US/PN	Volume (m³)	Ctrl MH Name	US/PN	Volume (m³)	Ctrl MH Name
1.000	65.532	2	1.005	24.252	7	1.013	24.252	23
1.001	24.252	3	1.006	24.252	8	3.000	31.992	23
1.002	24.252	4	1.007	24.252	23	3.001	37.152	23
1.003	24.252	5	1.008	24.252	23	3.002	34.572	23
1.004	24.252	6	1.009	24.252	23	3.003	44.892	23
2.000	63.726	6	1.010	27.348	23	1.014	4.076	
2.001	24.252	6	1.011	50.568	23			
2.002	24.252	6	1.012	54.180	23			

On-Line Controls (Pump)

US/PN	Volume (m³)	Ctrl MH Name	Invert (m)	Headloss (m)	Flow (m³/s)
1.015	0.040	23	77.300	0.20	0.0168
				0.40	0.0176
				0.60	0.0184
				0.80	0.0192
				1.00	0.0200
				1.40	0.0217
				1.80	0.0233
				2.20	0.0247
				2.60	0.0260
				3.00	0.0270

Storage Pond at pipe 1.015 USMH

Storage Pond Invert Level (m) 78.250

Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.0	147.0	2.4	658.6	4.8	658.6	7.2	658.6	9.6	658.6
0.4	227.0	2.8	658.6	5.2	658.6	7.6	658.6	10.0	658.6
0.8	327.4	3.2	658.6	5.6	658.6	8.0	658.6		
1.2	426.2	3.6	658.6	6.0	658.6	8.4	658.6		
1.6	536.6	4.0	658.6	6.4	658.6	8.8	658.6		
2.0	658.6	4.4	658.6	6.8	658.6	9.2	658.6		

APPENDIX C

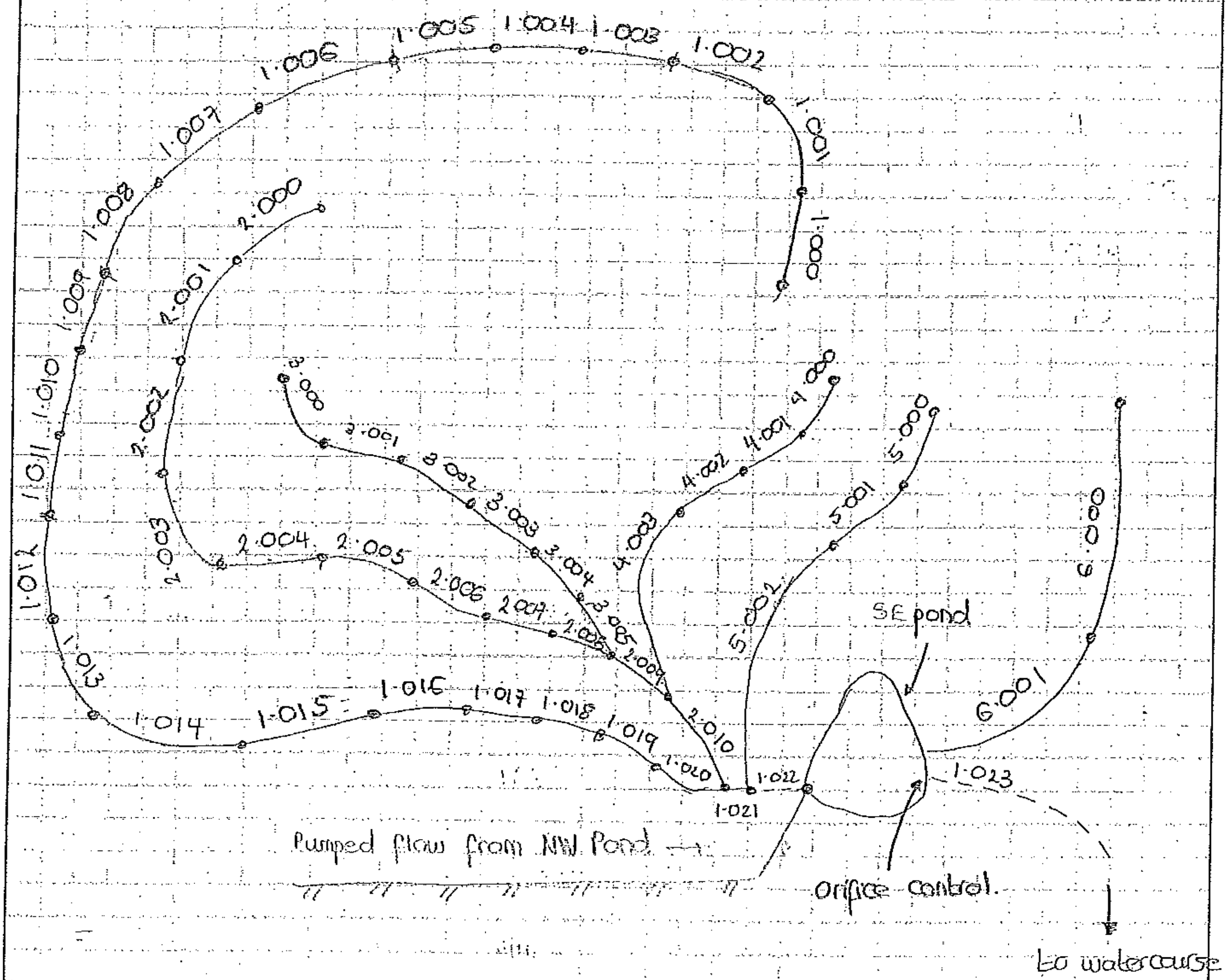
MICRODRAINAGE OUTPUT – SOUTHERN CATCHMENT

Calculation Sheet

Client:	Job No:	Project:
Augean	1621	Kings Cliffe SWM.

Made by:	Date:	Checked by:	Date:	Sheet No:
Jenny Mills	Jun 05.			D Rev A

Southern Catchment



Network Details

* - Indicates pipe has been modified outside of WinDes's Storm/Foul & Schedules

PN	Length (m)	Fall (m)	Slope (1:x)	Area (ha)	T.E. (mins)	Rain Pro	k (mm)	Hyd Sect	Dia (mm)
1.000	68.00	0.230	295.6	0.028	12.00	1	300.000	\/	32
1.001	50.00	0.170	294.1	0.021	0.00	1	300.000	\/	32
1.002	50.00	0.500	100.0	0.030	0.00	1	300.000	\/	32
1.003	50.00	0.300	166.7	0.028	0.00	1	300.000	\/	32
1.004	50.00	0.700	71.4	0.025	0.00	1	300.000	\/	32
1.005	50.00	0.150	333.3	0.026	0.00	1	300.000	\/	32
1.006	43.00	0.110	390.9	0.028	0.00	1	300.000	\/	32
1.007	58.00	0.150	386.7	0.041	0.00	1	300.000	\/	32
1.008	100.00	0.250	400.0	0.125	0.00	1	300.000	\/	32
1.009	101.00	0.260	388.4	0.048	0.00	1	300.000	\/	32
1.010	102.00	0.250	408.0	0.058	0.00	1	300.000	\/	32
1.011	100.00	0.350	285.7	0.076	0.00	1	300.000	\/	32
1.012	140.00	0.320	437.5	0.112	0.00	1	300.000	\/	32
1.013	127.00	0.860	147.7	0.135	0.00	1	300.000	\/	32
1.014	90.00	0.300	300.0	0.057	0.00	1	300.000	\/	32
1.015	80.00	1.000	80.0	0.049	0.00	1	300.000	\/	32
1.016	70.00	0.500	140.0	0.060	0.00	1	300.000	\/	32
1.017	100.00	0.250	400.0	0.078	0.00	1	300.000	\/	32
1.018	100.00	0.250	400.0	0.064	0.00	1	300.000	\/	32
1.019	100.00	0.250	400.0	0.037	0.00	1	300.000	\/	32
1.020	25.00	0.062	403.2	0.006	0.00	1	0.060	o	300
2.000	73.00	0.200	365.0	0.037	10.00	1	300.000	\/	32
2.001	51.00	0.130	392.3	0.029	0.00	1	300.000	\/	32
2.002	100.00	0.370	270.3	0.050	0.00	1	300.000	\/	32

PN	USMH No.	US/CL (m)	US/IL (m)	US/Dep (m)	DS/CL (m)	DS/IL (m)	DS/Dep (m)	Ctrl No.	US/MH (mm)
1.000	1	90.900	90.400	0.005	90.670	90.170	0.005		3000
1.001	4	90.670	90.170	0.005	90.500	90.000	0.005		3000
1.002	4	90.500	90.000	0.005	90.000	89.500	0.005		3000
1.003	4	90.000	89.500	0.005	89.700	89.200	0.005		3000
1.004	4	89.700	89.200	0.005	89.000	88.500	0.005		3000
1.005	4	89.000	88.500	0.005	88.850	88.350	0.005		3000
1.006	4	88.850	88.350	0.005	88.740	88.240	0.005		3000
1.007	4	88.740	88.240	0.005	88.590	88.090	0.005		3000
1.008	4	88.590	88.090	0.005	88.340	87.840	0.005		3000
1.009	4	88.340	87.840	0.005	88.080	87.580	0.005		3000
1.010	4	88.080	87.580	0.005	87.830	87.330	0.005		3000
1.011	4	87.830	87.330	0.005	87.480	86.980	0.005		3000
1.012	4	87.480	86.980	0.005	87.160	86.660	0.005		3000
1.013	4	87.160	86.660	0.005	86.300	85.800	0.005		3000
1.014	4	86.300	85.800	0.005	86.000	85.500	0.005		3000
1.015	4	86.000	85.500	0.005	85.000	84.500	0.005		3000
1.016	4	85.000	84.500	0.005	84.500	84.000	0.005		3000
1.017	4	84.500	84.000	0.005	84.300	83.750	0.055		3000
1.018	5	84.300	83.750	0.055	84.300	83.500	0.305		3000
1.019	6	84.300	83.500	0.305	84.500	83.250	0.755		3000
1.020	7	84.500	83.250	0.950	84.350	83.188	0.862		3000
2.000	8	90.700	90.200	0.005	90.500	90.000	0.005		3000
2.001	11	90.500	90.000	0.005	90.370	89.870	0.005		3000
2.002	11	90.370	89.870	0.005	90.000	89.500	0.005		3000

Network Details

PN	Length (m)	Fall (m)	Slope (1:x)	Area (ha)	T.E. (mins)	Rain Pro	k (mm)	Hyd Sect	Dia (mm)
2.003	70.00	0.600	116.7	0.045	0.00	1	300.000	\/	32
2.004	60.00	0.400	150.0	0.042	0.00	1	300.000	\/	32
2.005	93.00	1.500	62.0	0.048	0.00	1	300.000	\/	32
2.006	90.00	1.200	75.0	0.066	0.00	1	300.000	\/	32
2.007	115.00	0.200	575.0	0.059	0.00	1	300.000	\/	32
2.008	105.00	0.400	262.5	0.020	0.00	1	300.000	\/	32
3.000	62.00	0.500	124.0	0.028	9.50	1	300.000	\/	32
3.001	73.00	1.000	73.0	0.050	0.00	1	300.000	\/	32
3.002	81.00	0.700	115.7	0.068	0.00	1	300.000	\/	32
3.003	55.00	0.400	137.5	0.118	0.00	1	300.000	\/	32
3.004	105.00	1.100	95.5	0.201	0.00	1	300.000	\/	32
3.005	120.00	2.100	57.1	0.158	0.00	1	300.000	\/	32
2.009	80.00	0.400	200.0	0.055	0.00	1	300.000	\/	32
4.000	25.00	0.100	250.0	0.010	18.00	1	300.000	\/	32
4.001	15.00	0.050	300.0	0.009	0.00	1	300.000	\/	32
4.002	25.00	0.100	250.0	0.010	0.00	1	300.000	\/	32
4.003	120.00	3.300	36.4	0.015	0.00	1	300.000	\/	32
2.010	80.00	1.612	49.6	0.022	0.00	1	0.060	o	300
1.021	12.00	0.030	399.9	0.005	0.00	1	300.000	\/	32
5.000	50.00	0.300	166.7	0.028	18.00	1	300.000	\/	32

PN	USMH No.	US/CL (m)	US/IL (m)	US/Dep (m)	DS/CL (m)	DS/IL (m)	DS/Dep (m)	Ctrl No.	US/MH (mm)
2.003	11	90.000	89.500	0.005	89.400	88.900	0.005		3000
2.004	11	89.400	88.900	0.005	89.000	88.500	0.005		3000
2.005	11	89.000	88.500	0.005	87.500	87.000	0.005		3000
2.006	11	87.500	87.000	0.005	86.800	85.800	0.505		3000
2.007	11	86.800	85.800	0.505	86.600	85.600	0.505		3000
2.008	12	86.600	85.600	0.505	86.200	85.200	0.505		3000
3.000	13	91.500	91.000	0.005	91.000	90.500	0.005		3000
3.001	16	91.000	90.500	0.005	90.000	89.500	0.005		3000
3.002	16	90.000	89.500	0.005	89.300	88.800	0.005		3000
3.003	16	89.300	88.800	0.005	88.900	88.400	0.005		3000
3.004	16	88.900	88.400	0.005	87.800	87.300	0.005		3000
3.005	16	87.800	87.300	0.005	86.200	85.200	0.505		3000
2.009	17	86.200	85.200	0.505	85.800	84.800	0.505		3000
4.000	18	88.850	88.350	0.005	88.750	88.250	0.005		3000
4.001	19	88.750	88.250	0.005	88.700	88.200	0.005		3000
4.002	20	88.700	88.200	0.005	88.600	88.100	0.005		3000
4.003	21	88.600	88.100	0.005	85.800	84.800	0.505		3000
2.010	22	85.800	84.800	0.700	84.350	83.188	0.862		3000
1.021	23	84.350	83.188	0.667	84.350	83.158	0.697		3000
5.000	24	87.700	87.200	0.005	87.400	86.900	0.005		3000

Network Details

PN	Length (m)	Fall (m)	Slope (1:x)	Area (ha)	T.E. (mins)	Rain Pro	k (mm)	Hyd Sect	Dia (mm)
5.001	35.00	0.150	233.3	0.015	0.00	1	300.000	\/	32
5.002	125.00	3.592	34.8	0.018	0.00	1	0.060	o	300
1.022	12.00	0.030	400.0	0.099	0.00	1	0.060	o	300
6.000	70.00	0.200	350.0	0.034	18.00	1	300.000	\/	32
6.001	100.00	0.250	400.0	0.260	0.00	1	300.000	\/	32
1.023	10.00	0.105	95.2	0.000	0.00	1	0.060	o	225
1.024	200.00	7.000	28.6	0.000	0.00	1	0.060	o	225
1.025	250.00	8.750	28.6	0.000	0.00	1	0.060	o	225

PN	USMH No.	US/CL (m)	US/IL (m)	US/Dep (m)	DS/CL (m)	DS/IL (m)	DS/Dep (m)	Ctrl No.	US/MH (mm)
5.001	25	87.400	86.900	0.005	87.250	86.750	0.005		3000
5.002	26	87.250	86.750	0.200	84.350	83.158	0.892		3000
1.022	27	84.350	83.158	0.892	84.350	83.128	0.922		3000
6.000	28	84.800	84.300	0.005	84.600	84.100	0.005		3000
6.001	29	84.600	84.100	0.005	84.350	83.850	0.005		3000
1.023	30	84.350	82.500	1.625	84.000	82.395	1.380	1	3000
1.024	31	84.000	82.395	1.380	77.600	75.395	1.980		3000
1.025	32	77.600	75.395	1.980	84.000	66.645	17.130		1500

On-Line Controls (Orifice)

US/PN	Volume (m^3)	Ctrl MH Name	Invert (m)	Dia (m)	Coef of Contraction
1.022	0.636	30	82.500	0.148	0.600
6.001	50.052	30	82.500	0.148	0.600

Storage Pond at pipe 1.023 USMH 30

Storage Pond Invert Level (m) 82.500

Depth (m)	Area (m^2)	Depth (m)	Area (m^2)	Depth (m)	Area (m^2)	Depth (m)	Area (m^2)	Depth (m)	Area (m^2)
0.0	469.6	2.4	1225.4	4.8	1225.4	7.2	1225.4	9.6	1225.4
0.4	598.4	2.8	1225.4	5.2	1225.4	7.6	1225.4	10.0	1225.4
0.8	740.3	3.2	1225.4	5.6	1225.4	8.0	1225.4		
1.2	892.6	3.6	1225.4	6.0	1225.4	8.4	1225.4		
1.6	1054.3	4.0	1225.4	6.4	1225.4	8.8	1225.4		
2.0	1225.4	4.4	1225.4	6.8	1225.4	9.2	1225.4		

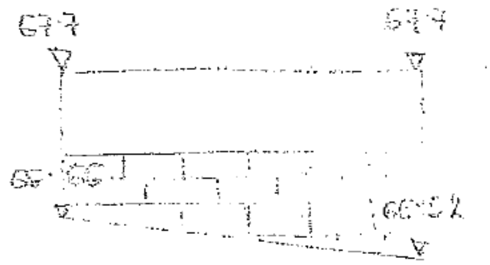
APPENDIX D

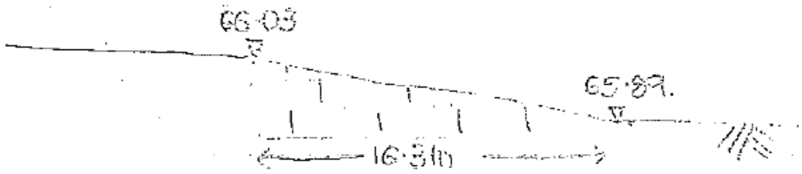
FLOOD ANALYSIS OF HIGHWAY CULVERT

Calculation Sheet

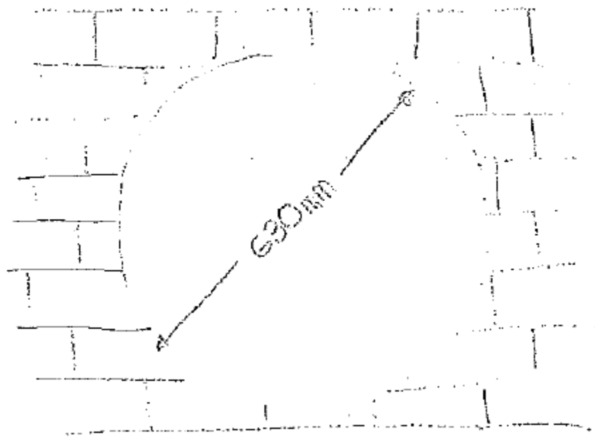
Client:	Job No:	Project:			
Augean	1621	Kings [illegible]			
Made by:	**Date:**	[redacted]		**Date:**	**Sheet No:**
[illegible]	15/08/05				F-1

<u>Highway culvert</u>





S = (66.03 - 65.89) / 16.3 = 0.0086



Levels taken from Dwg No. 1621 SHT 14

Client: Augean
Job: King's Cliffe SWM
Title: Table 1 - Hydraulic Analysis of Highway culvert

Manning's equation, $Q = A/n\ R^{2/3}\ S^{1/2}$

Condition of Highway culvert	d m	A m^2	P m	R	S	k_s mm	n	Q m^3/s	% blocked	Q max m^3/s	Q max l/s
well pointed brickwork (good), 0 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	1.5	0.0127	0.6627	0	0.6627	663
well pointed brickwork (normal), 0 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	3.0	0.0145	0.5826	0	0.5826	583
well pointed brickwork (poor), 0 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	6.0	0.0161	0.5229	0	0.5229	523
old, in need of pointing (normal), 0 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	15.0	0.0178	0.4727	0	0.4727	473
old, in need of pointing (poor), 0 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	30.0	0.0207	0.4076	0	0.4076	408
well pointed brickwork (good), 25 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	1.5	0.0127	0.6627	25	0.4970	497
well pointed brickwork (normal), 25 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	3.0	0.0145	0.5826	25	0.4370	437
well pointed brickwork (poor), 25 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	6.0	0.0161	0.5229	25	0.3922	392
old, in need of pointing (normal), 25 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	15.0	0.0178	0.4727	25	0.3546	355
old, in need of pointing (poor), 25 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	30.0	0.0207	0.4076	25	0.3057	306
well pointed brickwork (good), 50 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	1.5	0.0127	0.6627	50	0.3313	331
well pointed brickwork (normal), 50 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	3.0	0.0145	0.5826	50	0.2913	291
well pointed brickwork (poor), 50 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	6.0	0.0161	0.5229	50	0.2614	261
old, in need of pointing (normal), 50 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	15.0	0.0178	0.4727	50	0.2364	236
old, in need of pointing (poor), 50 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	30.0	0.0207	0.4076	50	0.2038	204
well pointed brickwork (good),75 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	1.5	0.0127	0.6627	75	0.1657	166
well pointed brickwork (normal), 75 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	3.0	0.0145	0.5826	75	0.1457	146
well pointed brickwork (poor), 75 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	6.0	0.0161	0.5229	75	0.1307	131
old, in need of pointing (normal), 75 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	15.0	0.0178	0.4727	75	0.1182	118
old, in need of pointing (poor), 75 % blocked	0.63	0.3117	1.9792	0.1575	0.0086	30.0	0.0207	0.4076	75	0.1019	102

d diameter
A cross sectional area
P wetted perimeter
R hydraulic radius
S slope
ks Nikuradse equivalent sand rougness size
n Manning's roughness coefficient

Client: Augean

Job: King's Cliffe SWM

Title: Table 2 - Unit Hydrograph at Highway culvert – Flow from field

Unit Hydrograph Calculator

Unit Hydrograph | **FSR Input** | FEH Input | Results Graph

FSR - Method

Region	England and Wales	Main Channel Length (m)	1038.000	CWI	82.600
M5-60	20.000	H(85%) (m)	79.500	Urban	0.000
Ratio R	0.420	H(10%) (m)	69.000	SPR	10.000
		Area (ha)	79.000	LAG (hrs)	0.000
Areal Reduction Factor	1.000	SAAR (mm)	580		

Map

Calculate

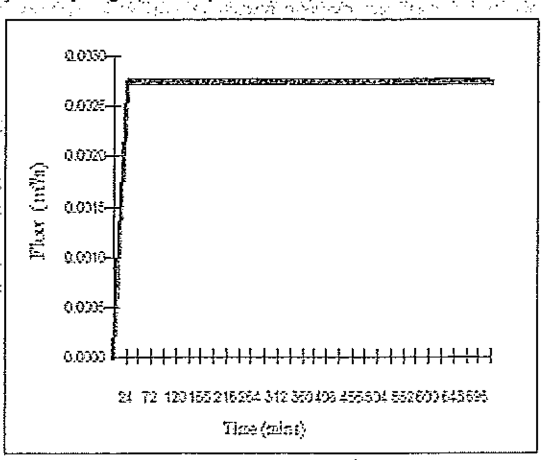
Unit Hydrograph Calculator

Unit Hydrograph | FSR Input | FEH Input | **Results Graph**

Results

TP0 (mins)	234
T (mins)	24
TPt (mins)	246
QP (m3/s 10mm)	0.425
TB (mins)	619
Base Flow (m3/s)	0.003
PR (%)	0.000
S1085 (m/km)	13.487

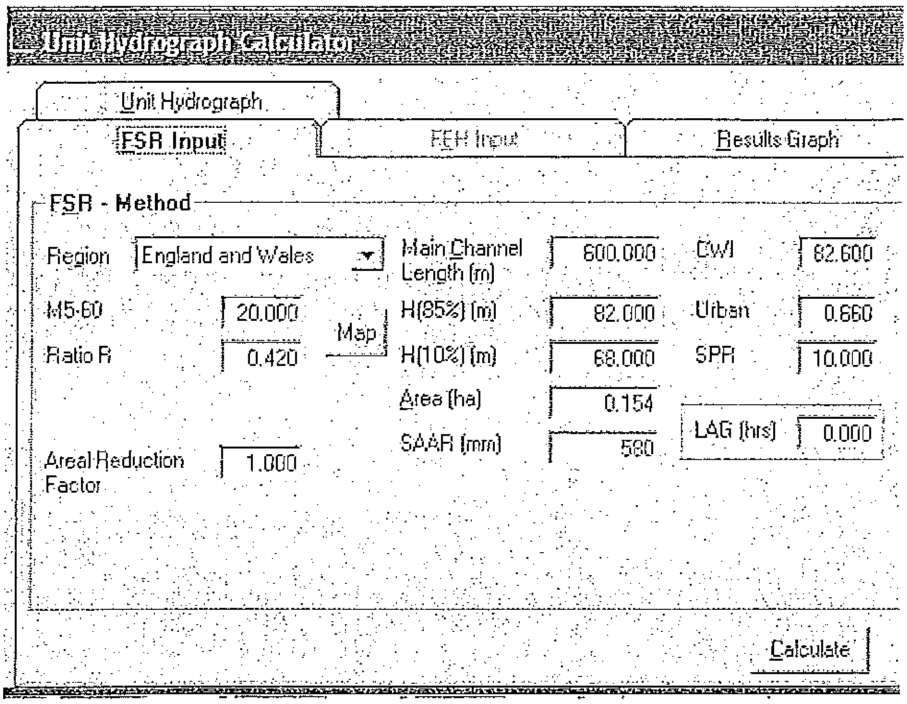
Unit Hydrograph for 1 year return period 120 minutes storm

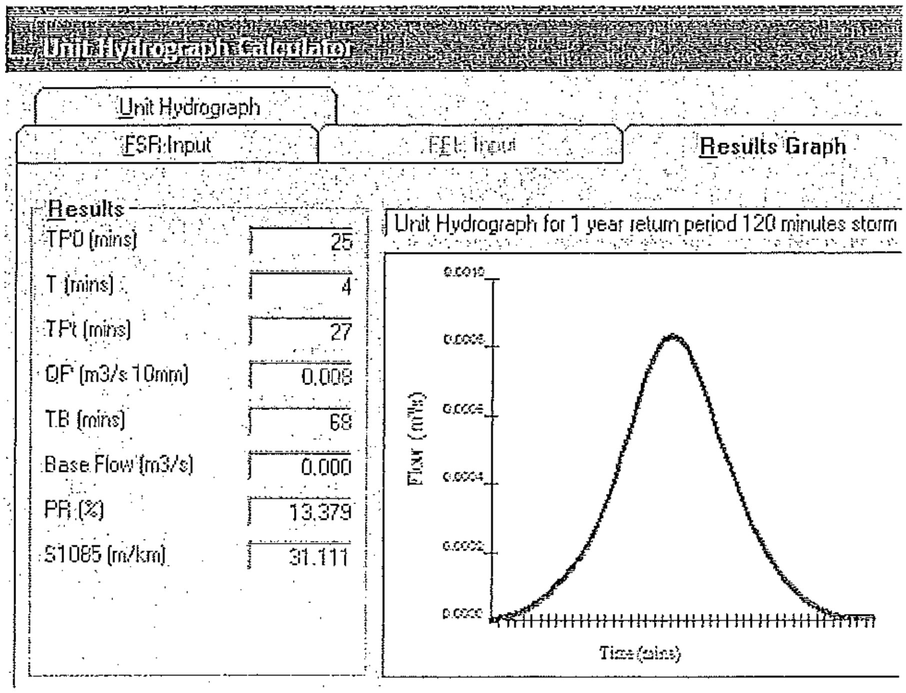


Client: Augean

Job: King's Cliffe SWM

Title: Table 3 - Unit Hydrograph at Highway culvert – Flow from Highway to North

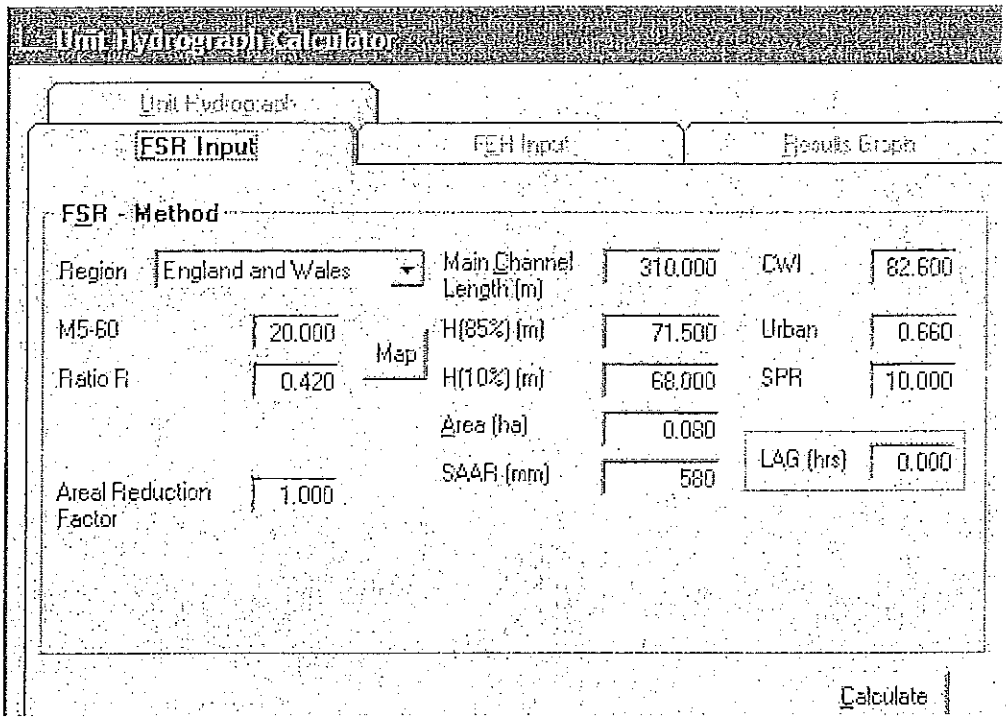


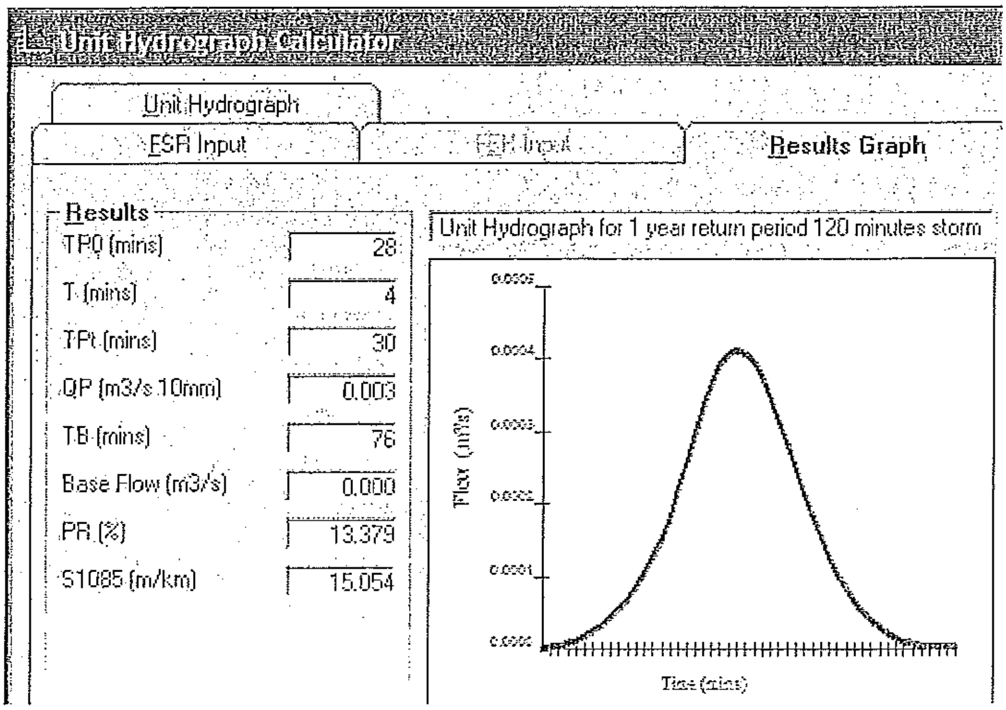


Client: Augean

Job: King's Cliffe SWM

Title: Table 4 - Unit Hydrograph at Highway culvert – Flow from Highway to South





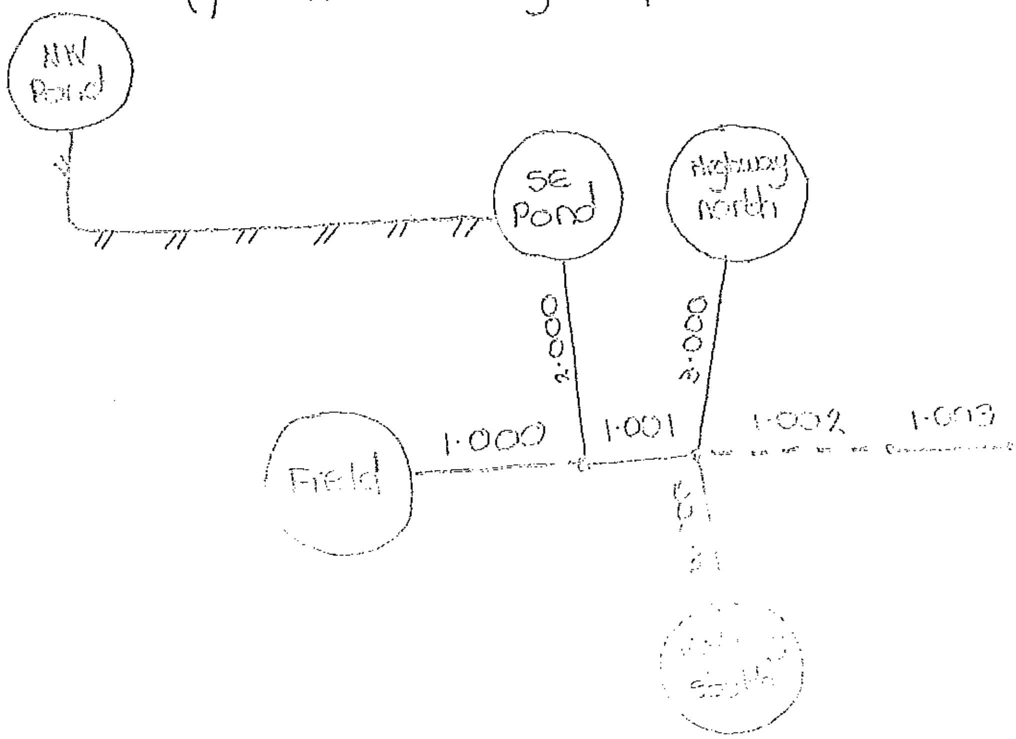
Client: Augean	Job No: 1521	Project: Kings Cliffe SWM		
Made by: J. Hills	**Date:** 9/01/06	**Checked by:**	**Date:**	**Sheet No:** H1 RevA

Assessment of the most significant area contributing to highway culvert flow

SE Discharge consent = 5 x GFR = 50 l/s.

Return Period		1	5	10	30	50	100
Max. outflow	SE pond (2.000)	33 240 Win.	39 240 Win	42 240 Win	46 240 Win	47 240 Win	50 240 Win
	Field (1.000)	3 15 Sum	8 1440 Sum	21 1440 Sum	49 1440 Sum	66 1440 Sum	94 1440 Sum
	Highway (3.000 + 4.000)	1 60 Sum	3 60 Sum	3 60 Sum	3 60 Sum	4 60 Sum	5 60 Sum
Critical area.		SE pond	SE pond	SE pond	Field	Field	Field
Highway culvert (1.002)	Critical storm.	240 Win	240 Win	240 Win	1440 Sum	1440 Sum	1440 Sum.
	Max. outflow.	34	42	45	86	105	138

( ) = MicroDrainage Reference No



APPENDIX E

MICRODRAINAGE OUTPUT

- FLOOD ANALYSIS OF HIGHWAY CULVERT

Summary of Results

Return Period (year)	1	Analysis Time Step	Fine
Storm Duration (mins)	240	DVD Status	OFF
Profile Type	Winter	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m³)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.052	-0.443	0.000	0.00	0	3	O K
2.000	67.631	-0.154	0.000	0.22	0	31	O K
1.001	66.651	-0.404	0.000	0.03	0	34	O K
3.000	66.290	-0.485	0.000	0.00	0	1	O K
4.000	66.726	-0.489	0.000	0.00	0	0	O K
1.002	66.127	-0.533	0.000	0.08	0	34	O K

Summary of Results

Return Period (years)	5	Analysis Time Step	Fine
Storm Duration (mins)	240	DVD Status	OFF
Profile Type	Winter	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m^3)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.052	-0.443	0.000	0.00	0	3	O K
2.000	67.640	-0.145	0.000	0.28	0	39	O K
1.001	66.660	-0.395	0.000	0.03	0	42	O K
3.000	66.295	-0.480	0.000	0.00	0	1	O K
4.000	66.730	-0.485	0.000	0.00	0	0	O K
1.002	66.138	-0.522	0.000	0.10	0	42	O K

Summary of Results

Return Period (years)	10	Analysis Time Step	Fine
Storm Duration (mins)	240	DVD Status	OFF
Profile Type	Winter	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m³)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.052	-0.443	0.000	0.00	0	3	O K
2.000	67.644	-0.141	0.000	0.30	0	42	O K
1.001	66.663	-0.392	0.000	0.03	0	45	O K
3.000	66.297	-0.478	0.000	0.00	0	1	O K
4.000	66.731	-0.484	0.000	0.00	0	1	O K
1.002	66.142	-0.518	0.000	0.11	0	45	O K

The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow in culvert	Micro Drainage
Date Jan-06 File 10.01.06, 30 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

Summary of Results

Return Period (years)	30	Analysis Time Step	Fine
Storm Duration (mins)	1440	DVD Status	OFF
Profile Type	Summer	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m^3)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.171	-0.324	0.000	0.08	0	49	O K
2.000	67.640	-0.145	0.000	0.28	0	39	O K
1.001	66.707	-0.348	0.000	0.06	0	86	O K
3.000	66.290	-0.485	0.000	0.00	0	1	O K
4.000	66.727	-0.488	0.000	0.00	0	0	O K
1.002	66.191	-0.469	0.000	0.21	0	86	O K

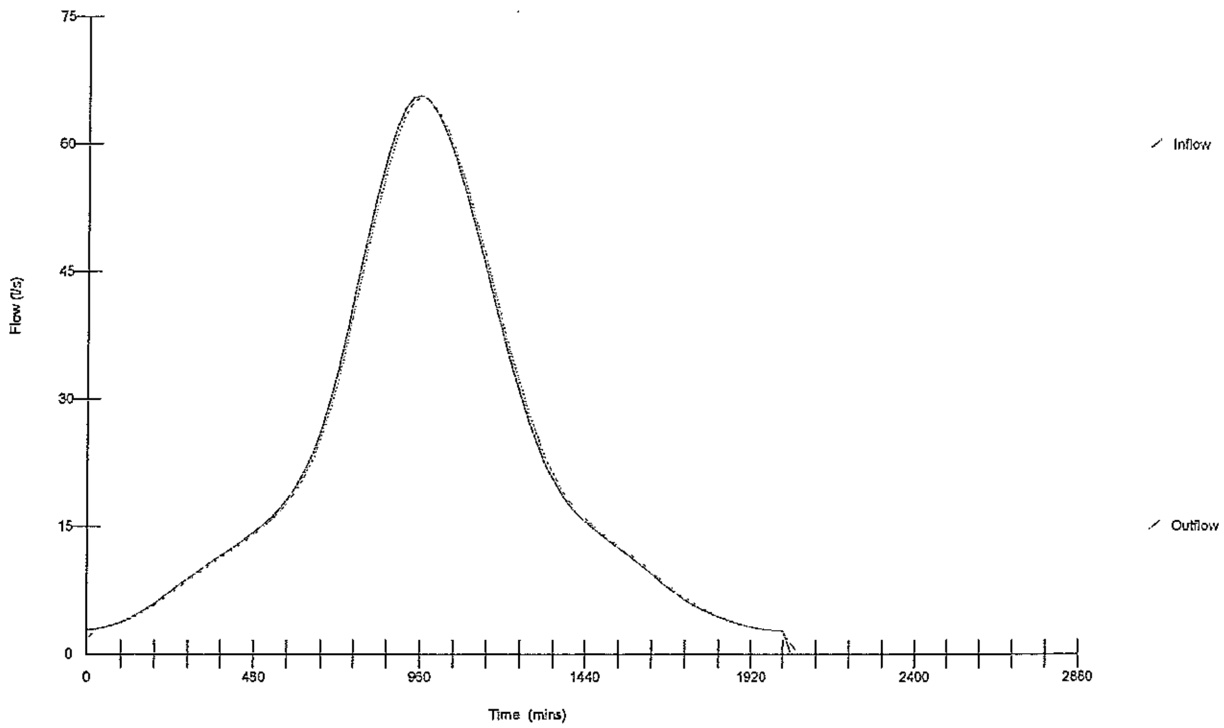
Summary of Results

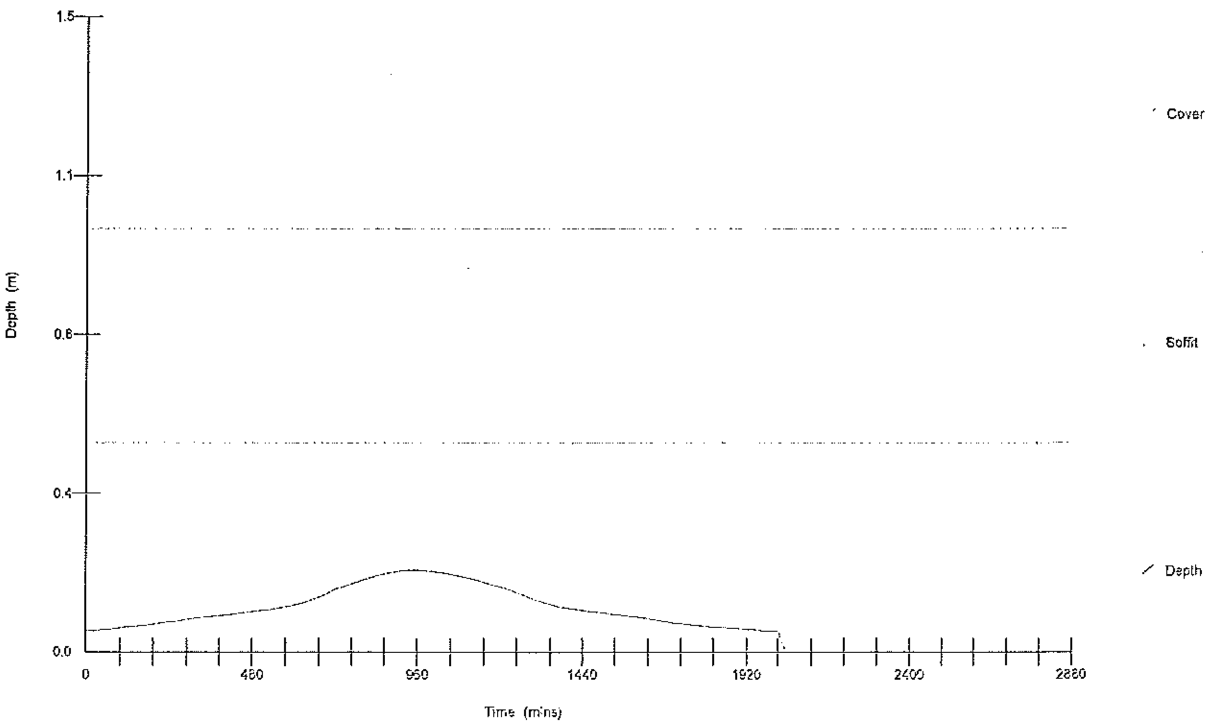
Return Period (years)	50	Analysis Time Step	Fine
Storm Duration (mins)	1440	DVD Status	OFF
Profile Type	Summer	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m³)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.194	-0.301	0.000	0.11	0	66	O K
2.000	67.642	-0.143	0.000	0.29	0	41	O K
1.001	66.719	-0.336	0.000	0.08	0	105	O K
3.000	66.292	-0.483	0.000	0.00	0	1	O K
4.000	66.728	-0.487	0.000	0.00	0	0	O K
1.002	66.214	-0.446	0.000	0.25	0	105	O K

Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from field	Micro Drainage
Date Jan-06 File 10.01.06, 50 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

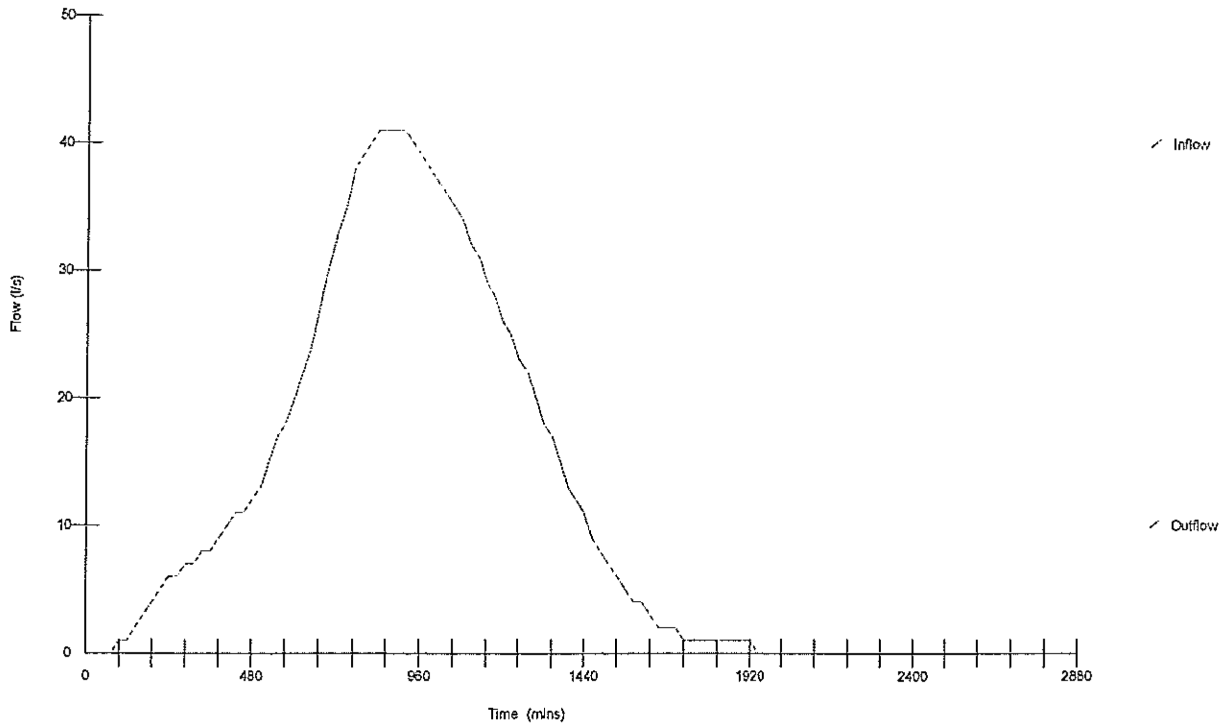
Graphs for Pipe 1.000 USMH Number 2
Storm Duration 1440 mins (Summer) Return Period 50 years
Status : OK

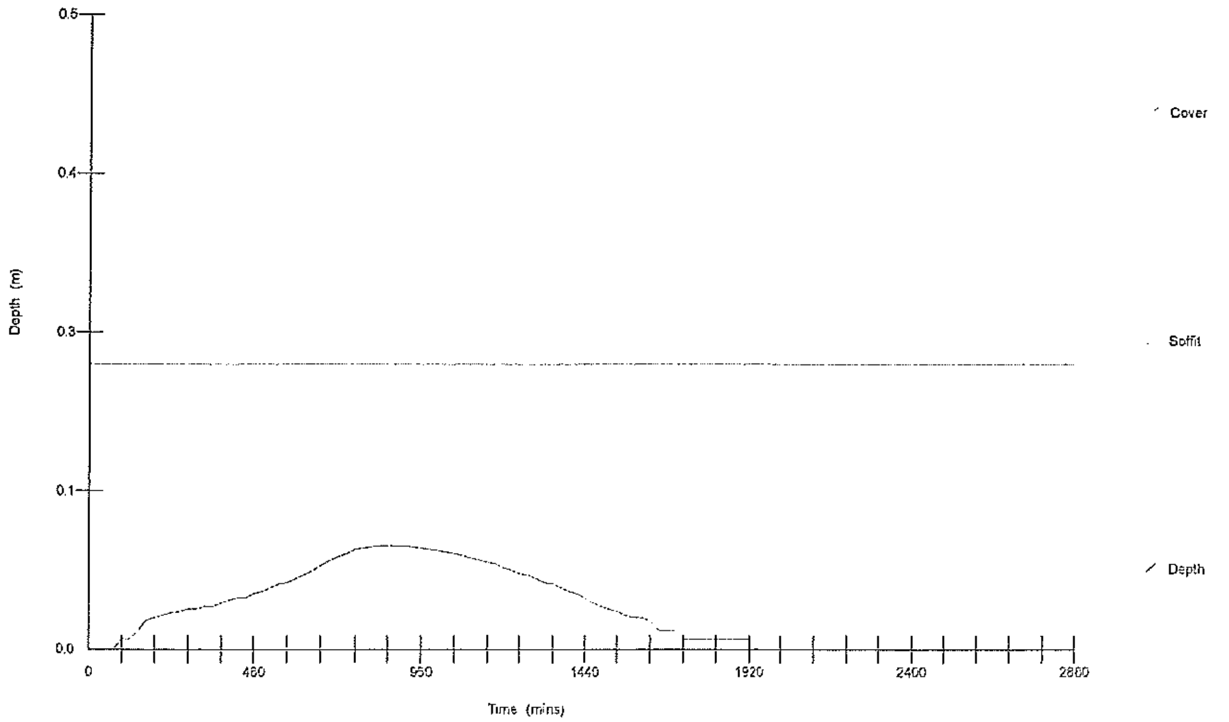




Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from SE pond	Micro Drainage
Date Jan-06 File 10.01.06, 50 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

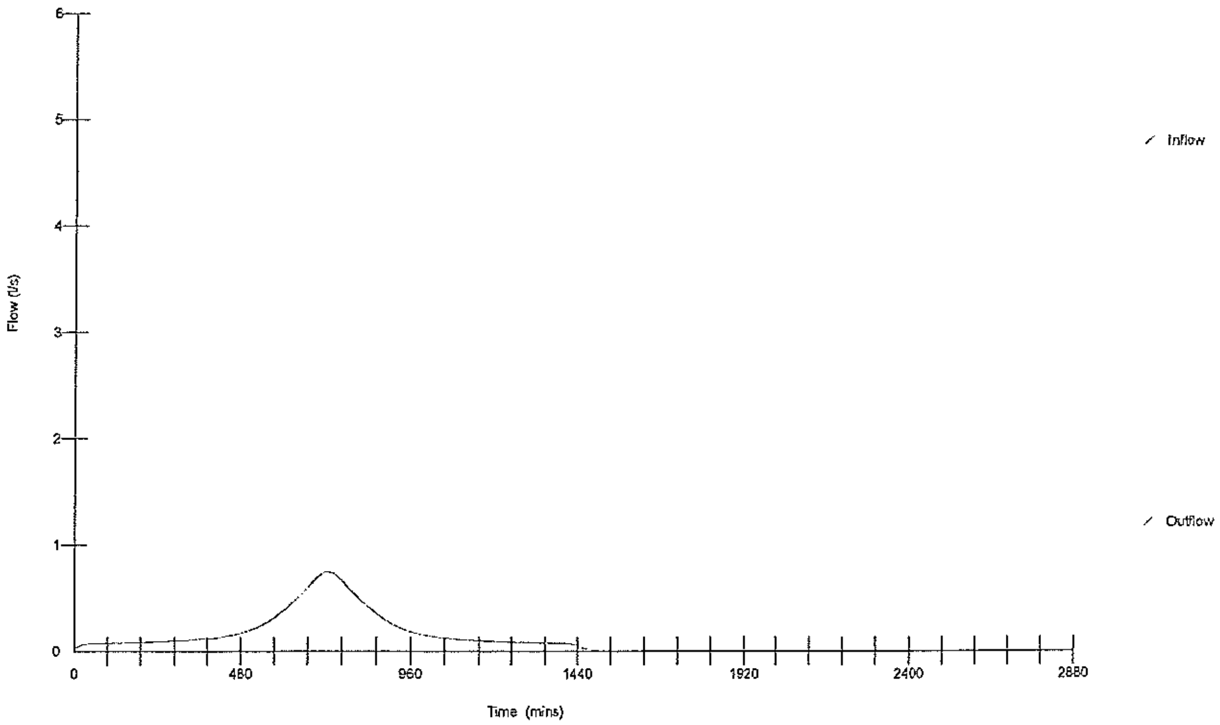
Graphs for Pipe 2.000 USMH Number
Storm Duration 1440 mins (Summer) Return Period 50 years
Status : OK

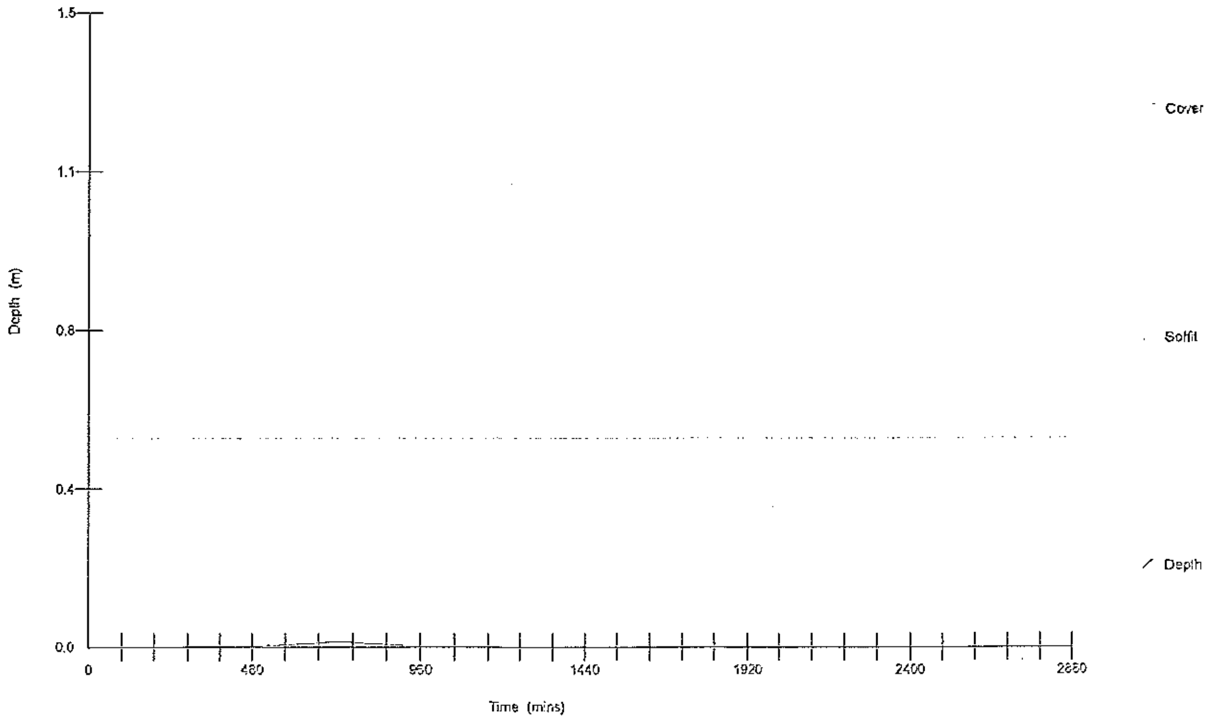




Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from road N	Micro Drainage
Date Jan-06 File 10.01.06, 50 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

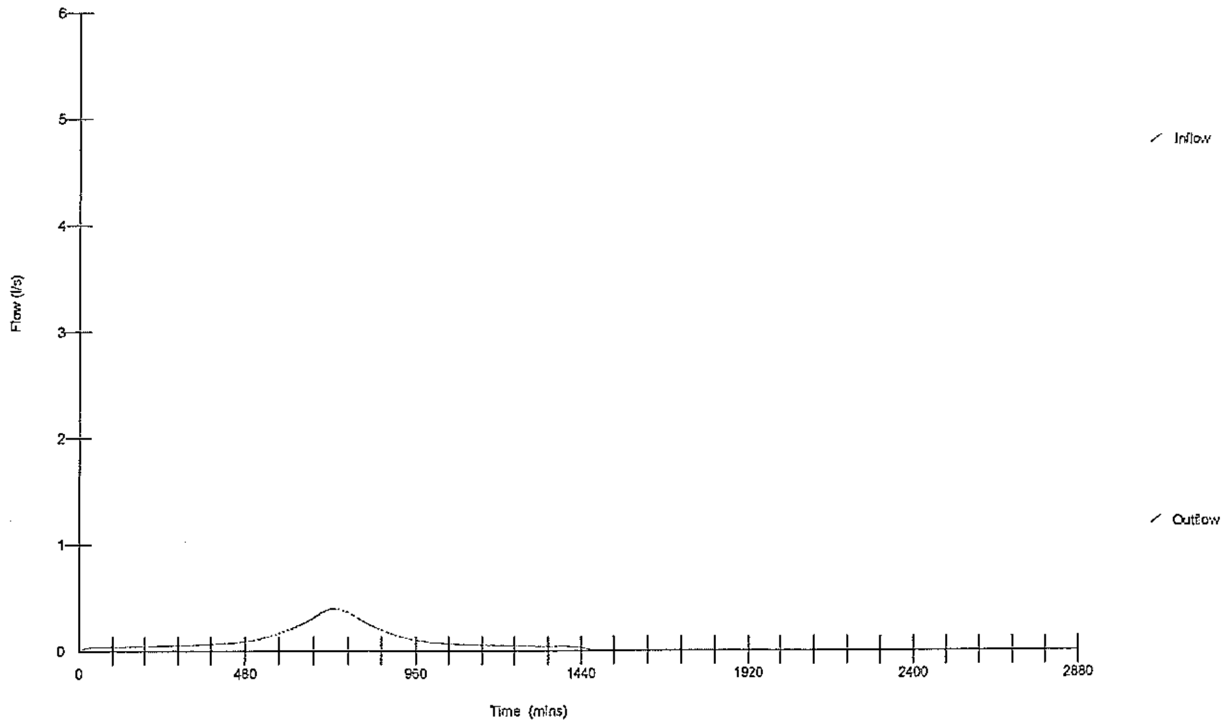
Graphs for Pipe 3.000 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 50 years
Status : OK

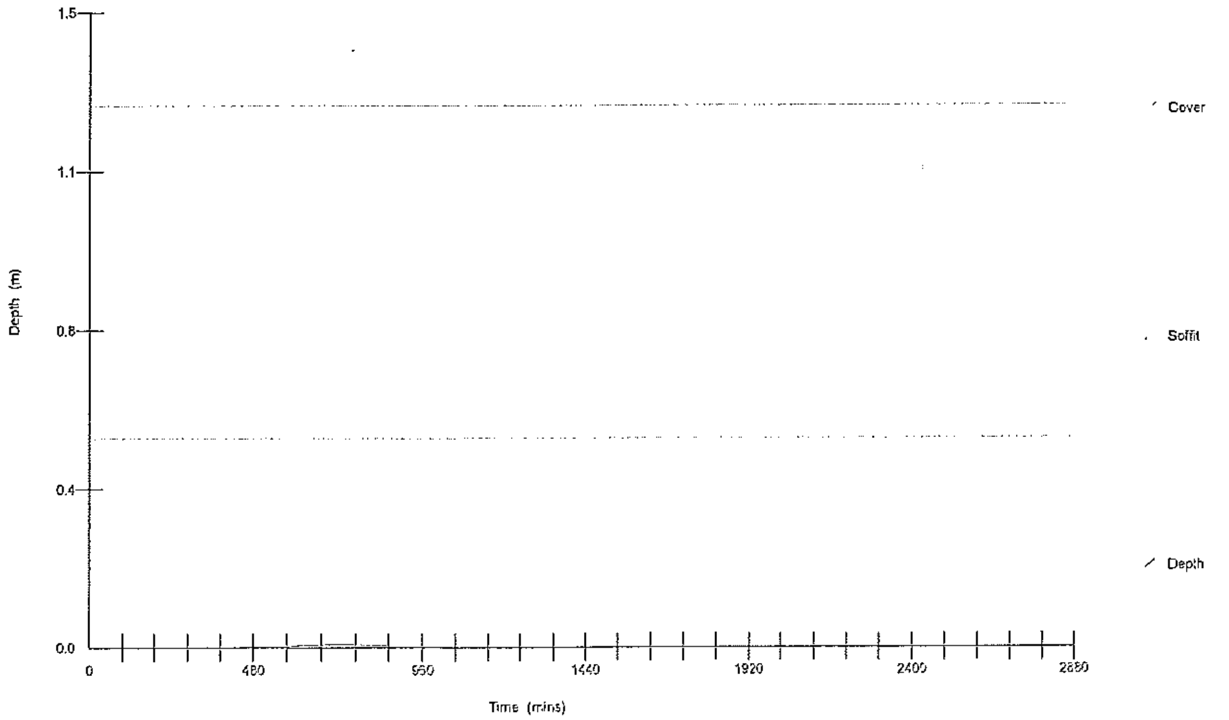




Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from road S	Micro Drainage
Date Jan-06 File 10.01.06, 50 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

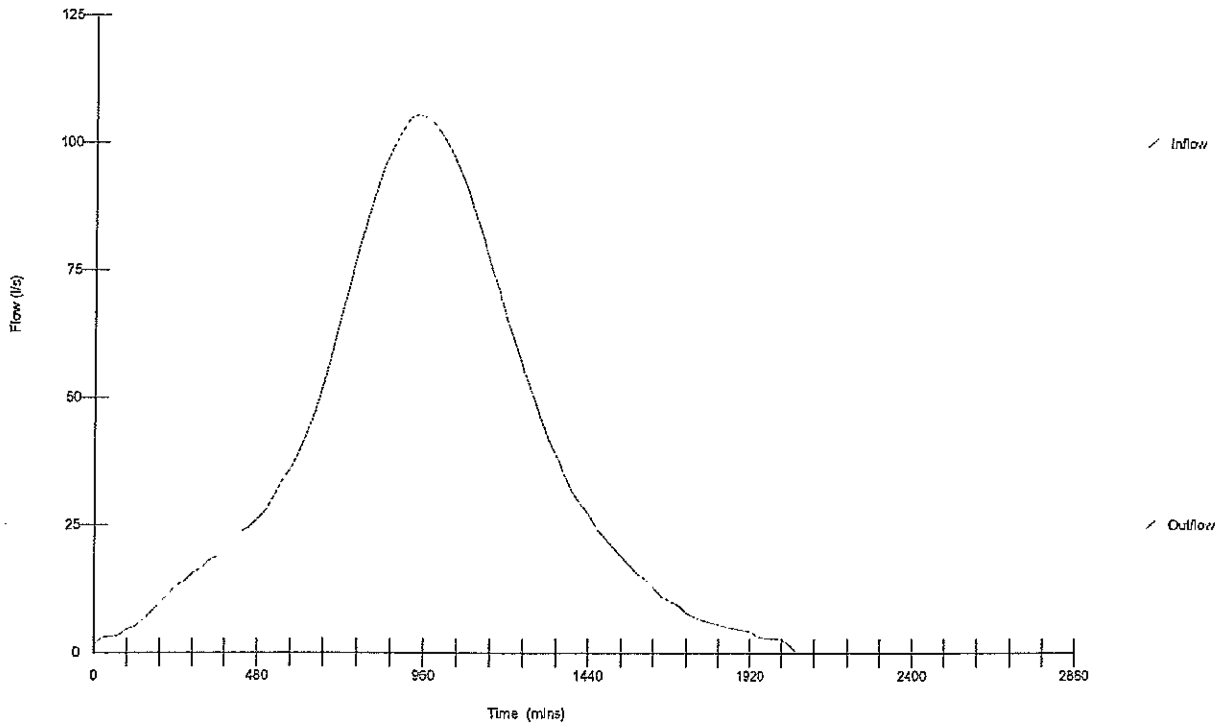
Graphs for Pipe 4.000 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 50 years
Status : OK

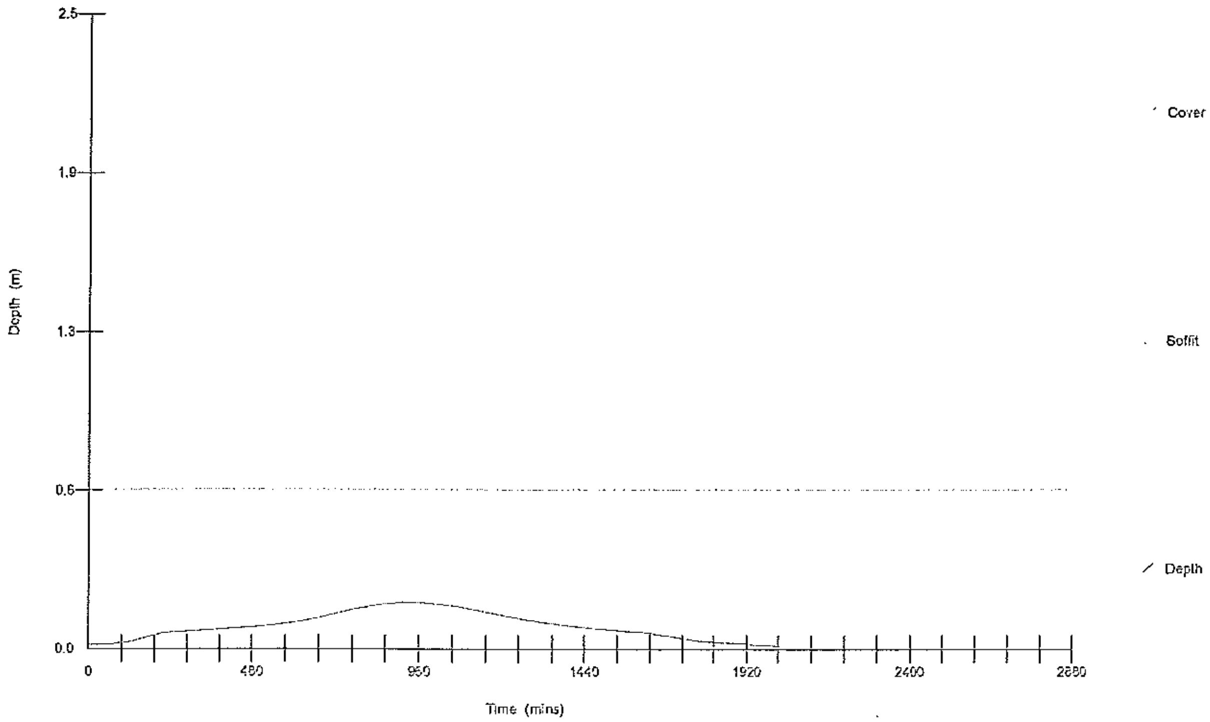




Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow in culvert	Micro Drainage
Date Jan-06 File 10.01.06, 50 yr RP, 14...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

Graphs for Pipe 1.002 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 50 years
Status : OK





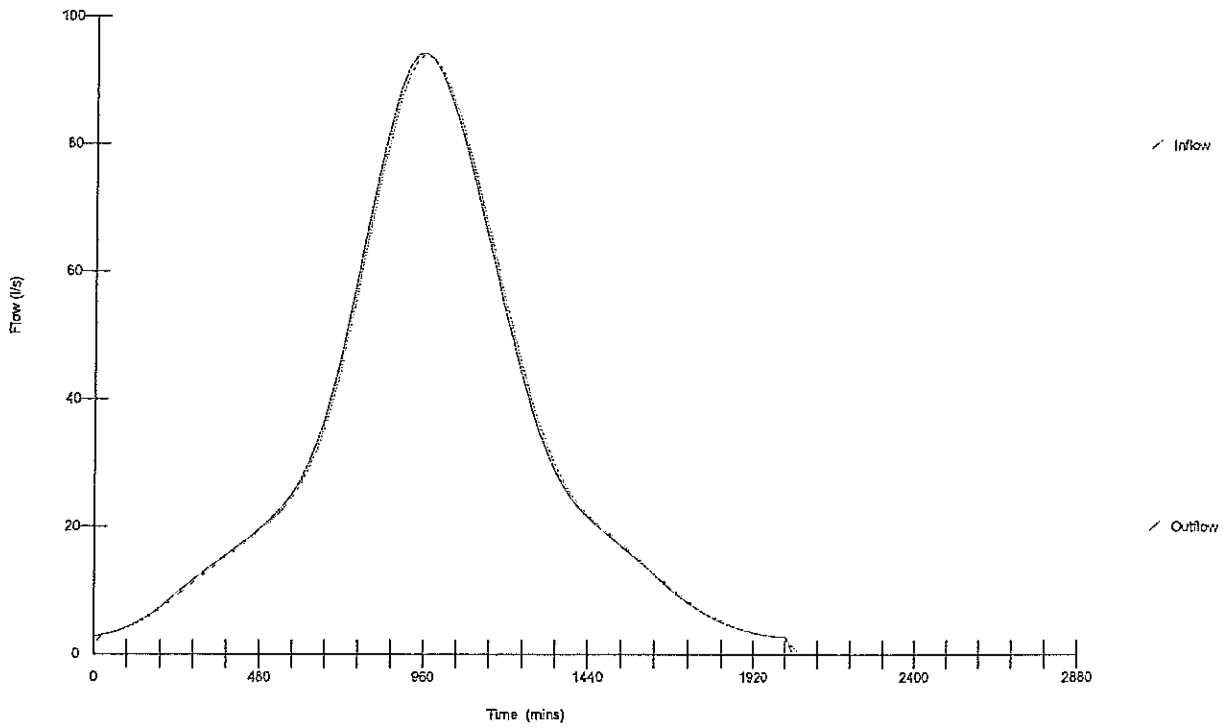
Summary of Results

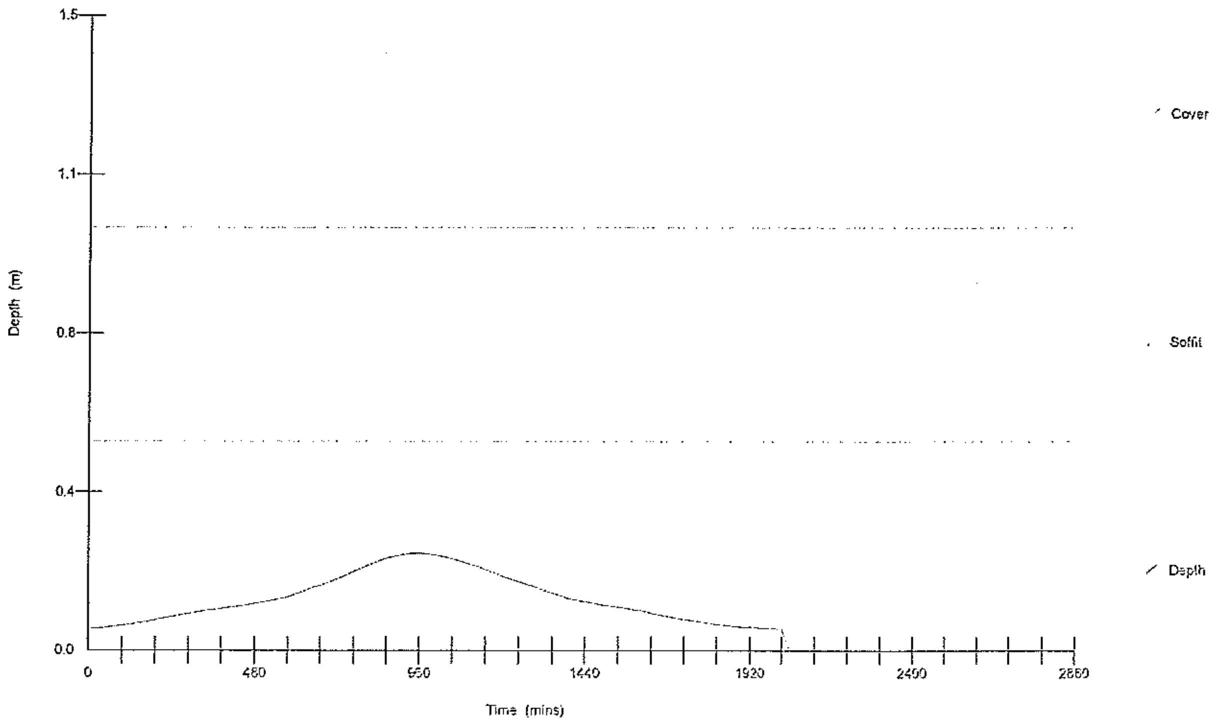
Return Period (years)	100	Analysis Time Step	Fine
Storm Duration (mins)	1440	DVD Status	OFF
Profile Type	Summer	Inertia Status	OFF
Margin for Flood Risk warning (mm)	200		

PN	Water Lev. (m)	Surcharged Depth (m)	Flooded Vol (m^3)	Flow/ Capacity	Overflow (l/s)	Pipe Flow (l/s)	Status
1.000	74.230	-0.265	0.000	0.16	0	94	O K
2.000	67.646	-0.139	0.000	0.31	0	44	O K
1.001	66.737	-0.318	0.000	0.10	0	137	O K
3.000	66.294	-0.481	0.000	0.00	0	1	O K
4.000	66.729	-0.486	0.000	0.00	0	0	O K
1.002	66.243	-0.417	0.000	0.33	0	138	O K

Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from field	Micro Drainage
Date Jan-06 File 10.01.06, 100 yr RP, 1...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

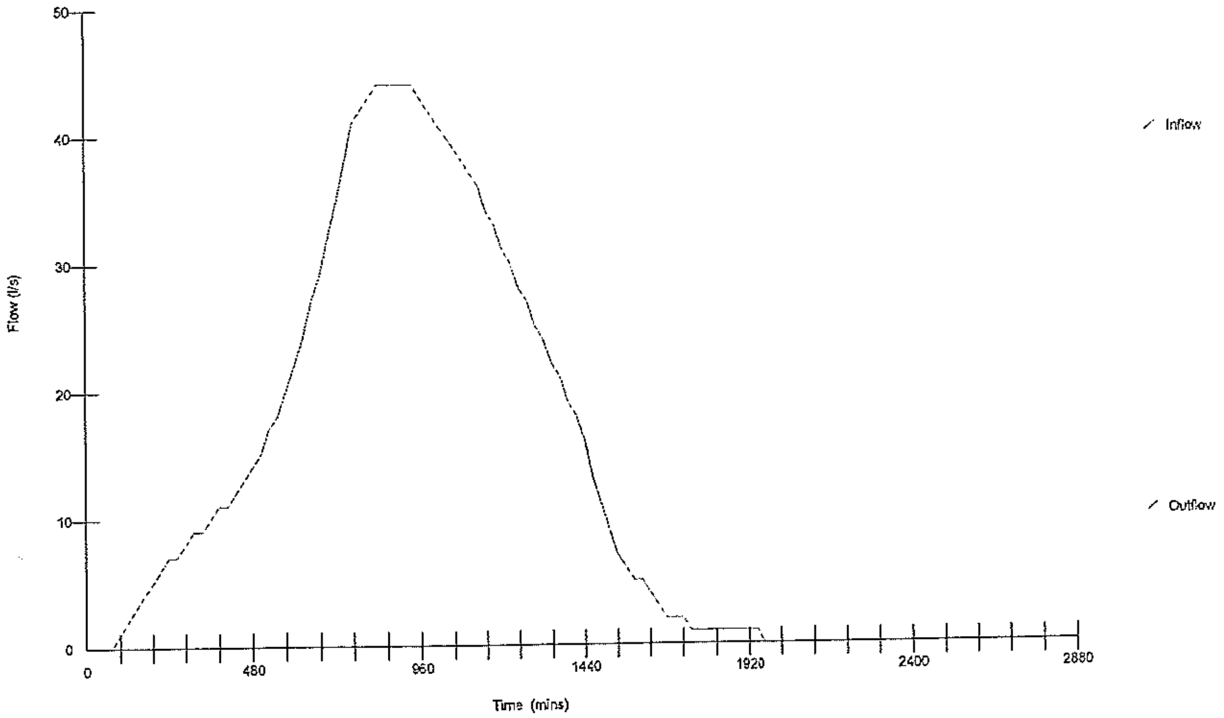
Graphs for Pipe 1.000 USMH Number 2
Storm Duration 1440 mins (Summer) Return Period 100 years
Status : OK

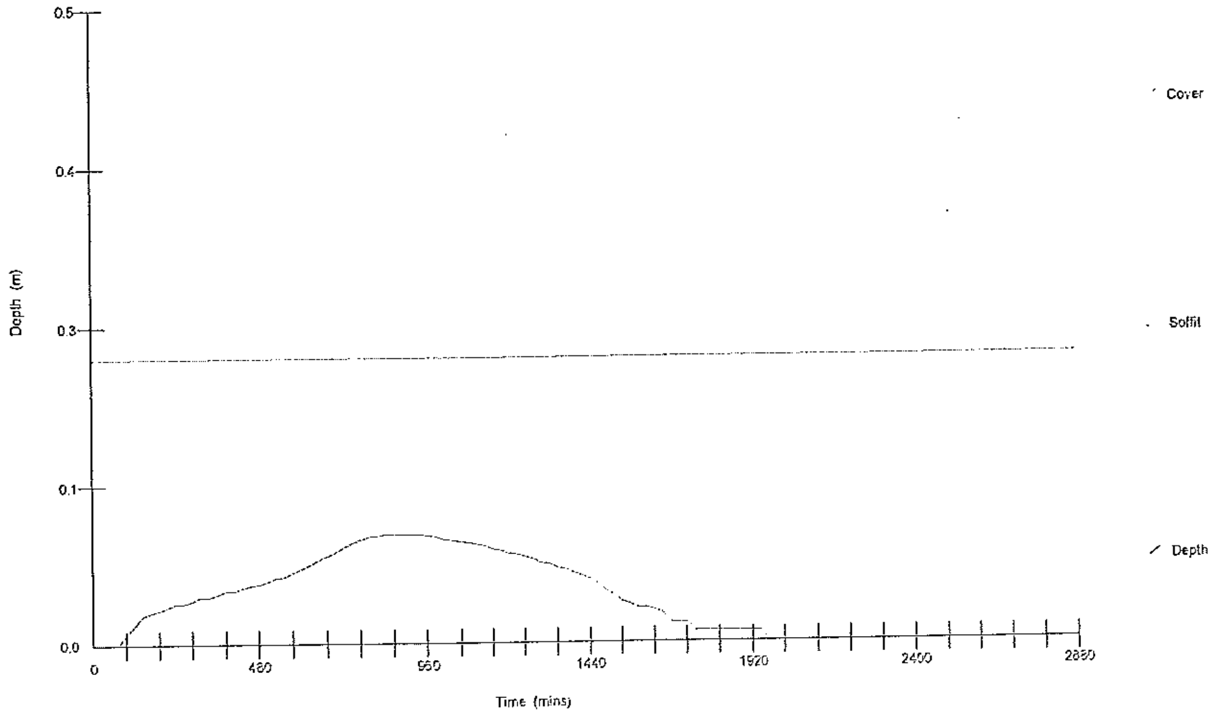




Egniol Limited		
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from SE pond	Micro Drainage
Date Jan-06 File 10.01.06, 100 yr RP, 1...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

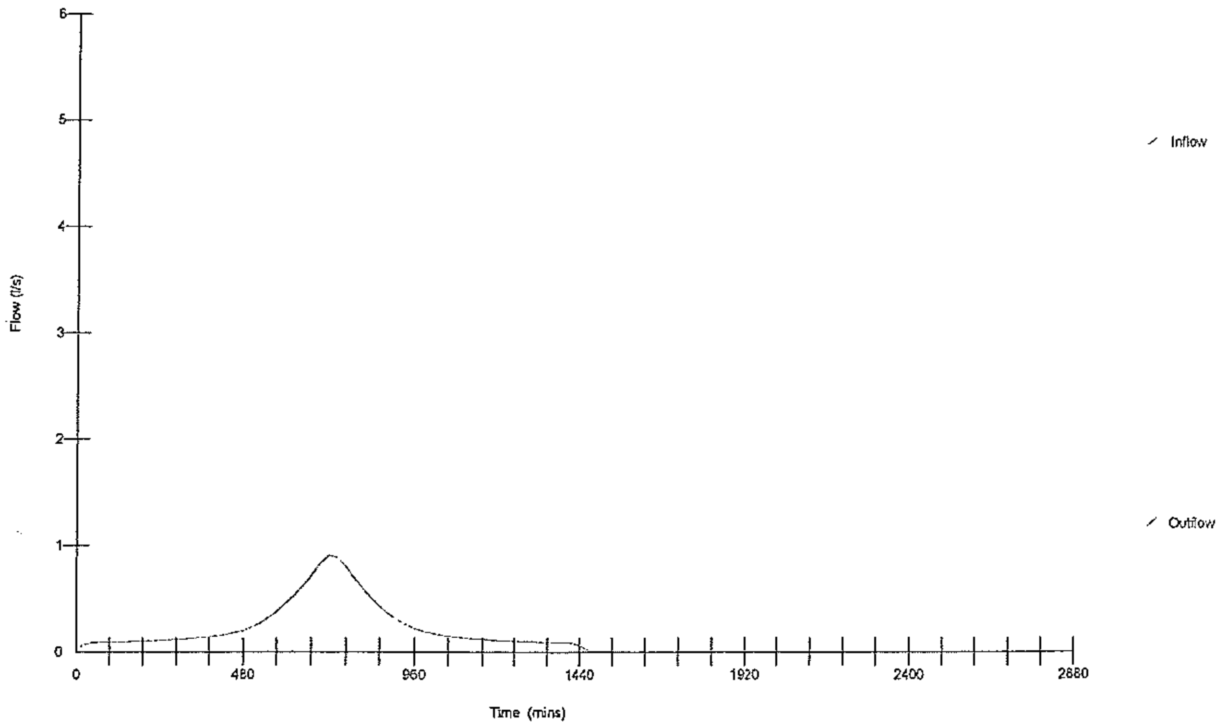
Graphs for Pipe 2.000 USMH Number
Storm Duration 1440 mins (Summer) Return Period 100 years
Status : OK

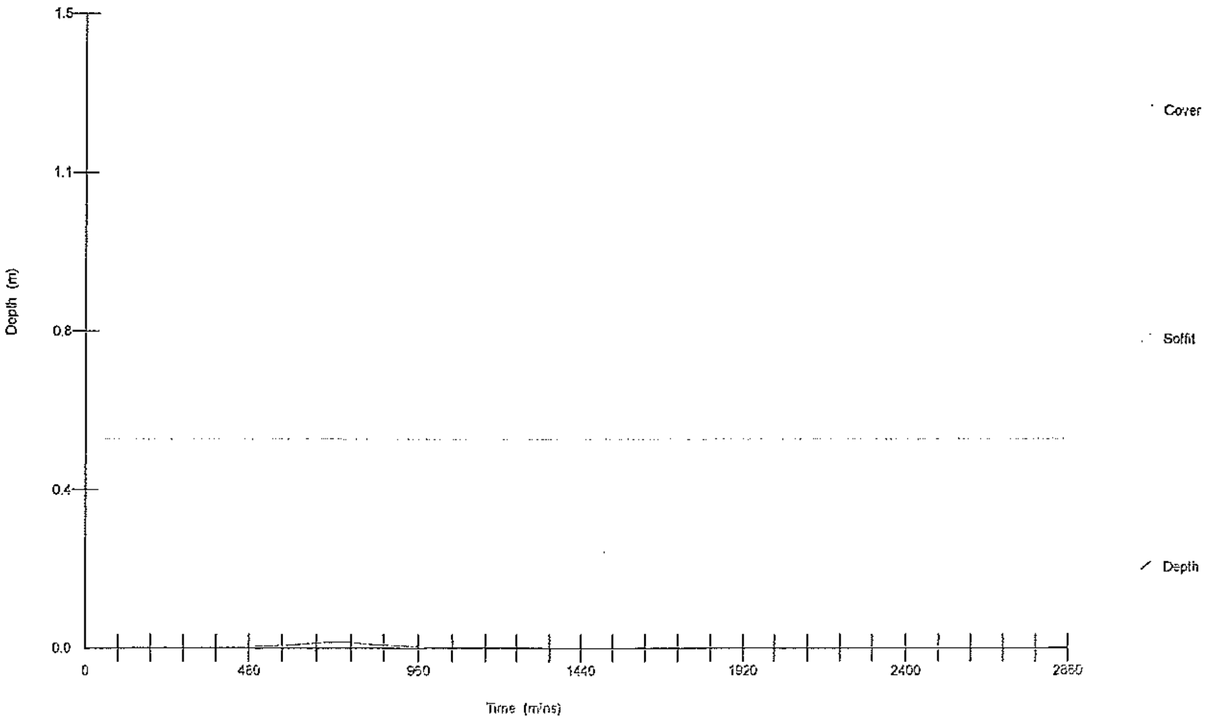




Egniol Limited		Page 1
The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from road N	Micro Drainage
Date Jan-06 File 10.01.06, 100 yr RP, 1...	Designed By JLM Checked By	
Micro Drainage	Simulation W.9.5	

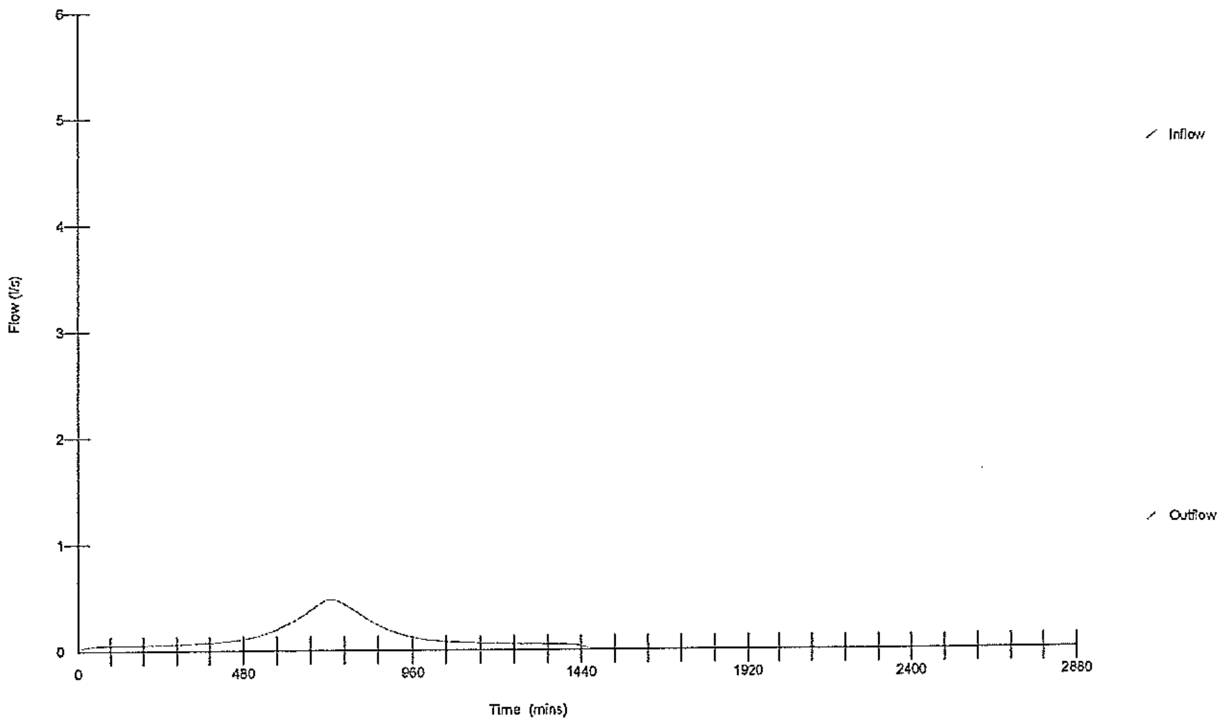
Graphs for Pipe 3.000 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 100 years
Status : OK

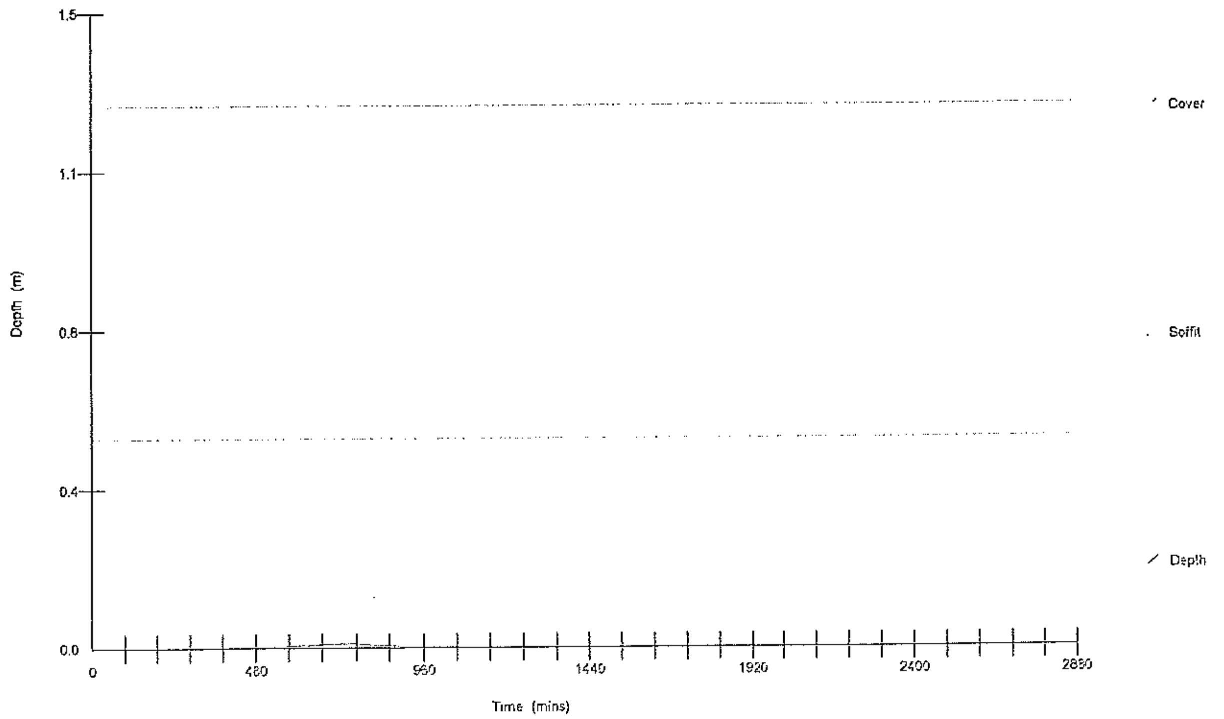




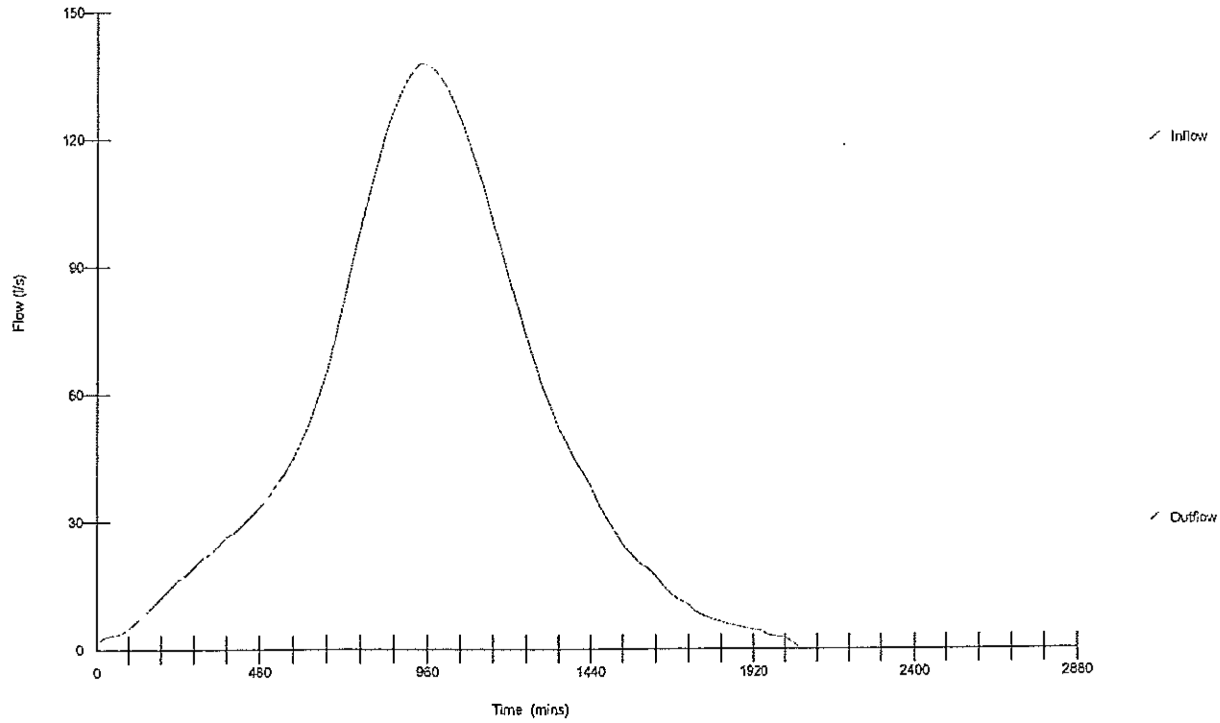
Egniol Limited The Felin Bangor LL57 4LH	Client: Augean Job: King's Cliffe SWM Title: Flow from road S	Page 1
Date Jan-06 File 10.01.06, 100 yr RP, 1...	Designed By JLM Checked By	Micro Drainage
Micro Drainage	Simulation W.9.5	

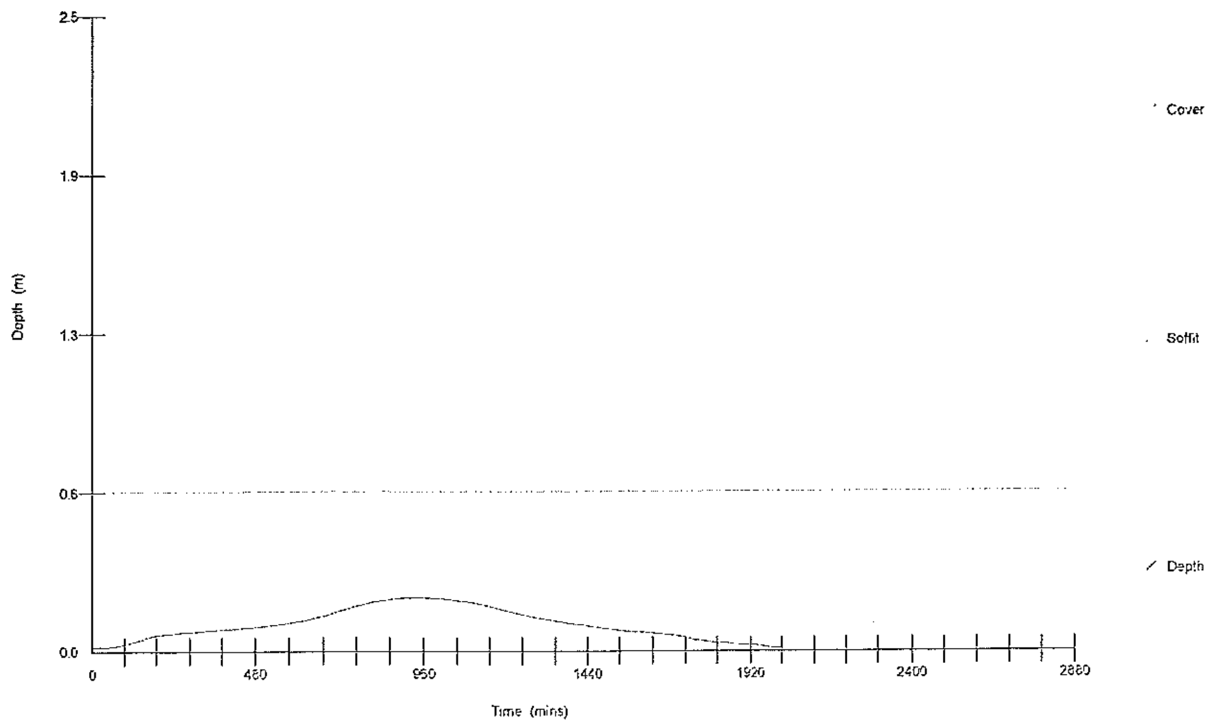
Graphs for Pipe 4.000 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 100 years
Status : OK





Graphs for Pipe 1.002 USMH Number 3
Storm Duration 1440 mins (Summer) Return Period 100 years
Status : OK





APPENDIX F

BASELINE MONITORING RESULTS

Results for 08 February 2005

REF. NO		612164	612165	612166
LOCATION		SW Swall Inl S	SW Swall Inl N	SW Field RO
DATE		08/02/2005	08/02/2005	08/02/2005
Cadmium , Total as Cd	mg/l	<0.0005	<0.0005	<0.0005
Chromium , Total as Cr	mg/l	<0.005	<0.005	<0.005
Lead , Total as Pb	mg/l	<0.005	<0.005	0.020
Mercury , Total as Hg	mg/l	<0.0001	<0.0001	<0.0001
Nickel , Total as Ni	mg/l	<0.005	<0.005	<0.005
Zinc, Total as Zn	mg/l	<0.005	<0.005	0.087
pH		8.0	7.9	7.8
Conductivity- Electrical 20C	uS/cm	655	524	688
Ammoniacal Nitrogen as N	mg/l	1.6	<0.3	<0.3
Chloride as Cl	mg/l	11	7	63
Sulphate as SO4	mg/l	72	20	128
BOD + ATU (5 day)	mg/l	<1	<1	<1
Mecoprop	ug/l	<0.05	<0.05	<0.05
Trichloroethene	ug/l	<1	<1	<1
2 - Chlorophenol	ug/l	<20	<20	<20
2 - Methylphenol	ug/l	<20	<20	<20
2,4 - Dichlorophenol	ug/l	<20	<20	<20
2,4 - Dimethylphenol	ug/l	<20	<20	<20
2,4,6 - Trichlorophenol	ug/l	<20	<20	<20
3,5 Dimethylphenol	ug/l	<20	<20	<20
4-Chlorophenol	ug/l	<20	<20	<20
4-Methylphenol	ug/l	<20	<20	<20
Phenol	ug/l	<20	<20	<20
Toluene	ug/l	<0.4	<0.4	<0.4
Tributyltin	ug/l	<0.02	<0.02	<0.02
Arsenic (FILT) ICPMS	mg/l	<0.001	<0.001	<0.001
Selenium (T) ICPMS	mg/l	0.002	0.001	0.002
Comment				

Results for 02 March 2005

REF. NO		631002	631003	631004	631005
LOCATION		SWSWALLI NLS	SWSWALLI NLN	SW Field RO	SW Road RO
DATE		02/03/2005	02/03/2005	02/03/2005	02/03/2005
Cadmium , Total as Cd	mg/l	<0.0005	<0.0005	<0.0005	
Chromium , Total as Cr	mg/l	<0.005	<0.005	<0.005	
Lead , Total as Pb	mg/l	<0.005	<0.005	0.010	
Mercury , Total as Hg	mg/l	<0.0001	<0.0001	<0.0001	
Nickel , Total as Ni	mg/l	<0.005	<0.005	<0.005	
Zinc, Total as Zn	mg/l	<0.005	<0.005	0.070	
pH		8.2	8.2	8.1	
Conductivity- Electrical 20C	uS/cm	529	555	2770	
Ammoniacal Nitrogen as N	mg/l	2.4	1.5	1.1	
Chloride as Cl	mg/l	12	9	807	
Sulphate as SO4	mg/l	48	21	141	
BOD + ATU (5 day)	mg/l	<1	<1	<1	
Mecoprop	ug/l	<0.04	<0.04	<0.04	
Trichloroethene	ug/l	<1	<1	<1	
2 - Chlorophenol	ug/l	<20	<20	<20	
2 - Methylphenol	ug/l	<20	<20	<20	
2,4 - Dichlorophenol	ug/l	<20	<20	<20	
2,4 - Dimethylphenol	ug/l	<20	<20	<20	
2,4,6 - Trichlorophenol	ug/l	<20	<20	<20	
3,5 Dimethylphenol	ug/l	<20	<20	<20	
4-Chlorophenol	ug/l	<20	<20	<20	
4-Methylphenol	ug/l	<20	<20	<20	
Phenol	ug/l	<20	<20	<20	
Toluene	ug/l	<0.4	<0.4	<0.4	
Tributyltin	ug/l	<0.02	<0.02	<0.02	
Arsenic (FILT) ICPMS	mg/l	<0.001	<0.001	0.003	
Selenium (T) ICPMS	mg/l	0.002	0.002	0.001	
Sample Received					Empty
Comment					

Results for 24 March 2005

REF. NO		651596	651597	651598	651599
LOCATION		SW Swall N	SW Swall S	SW Field RO	SW Road RO
DATE		24/03/2005	24/03/2005	24/03/2005	24/03/2005
Cadmium, Total as Cd	mg/l	<0.0005	<0.0005	0.0010	
Chromium, Total as Cr	mg/l	<0.005	<0.005	<0.005	
Lead, Total as Pb	mg/l	0.009	0.011	0.016	
Mercury, Total as Hg	mg/l	<0.0001	<0.0001	<0.0001	
Nickel, Total as Ni	mg/l	<0.005	<0.005	<0.005	
Zinc, Total as Zn	mg/l	0.012	0.016	0.061	
pH		8.1	8.1	8.2	
Conductivity- Electrical 20C	uS/cm	515	669	805	
Ammoniacal Nitrogen as N	mg/l	0.4	0.4	0.5	
Chloride as Cl	mg/l	9	17	107	
Sulphate as SO4	mg/l	19	86	130	
D.O. concentration	mg/l	Sch`d	Sch`d	Sch`d	
BOD + ATU (5 day)	mg/l	<1	<1	<1	
Mecoprop	ug/l	<0.04	<0.04	0.186	
Trichloroethene	ug/l	<1	<1	<1	
2 - Chlorophenol	ug/l	<20	<20	<20	
2 - Methylphenol	ug/l	<20	<20	<20	
2,4 - Dichlorophenol	ug/l	<20	<20	<20	
2,4 - Dimethylphenol	ug/l	<20	<20	<20	
2,4,6 - Trichlorophenol	ug/l	<20	<20	<20	
3,5 Dimethylphenol	ug/l	<20	<20	<20	
4-Chlorophenol	ug/l	<20	<20	<20	
4-Methylphenol	ug/l	<20	<20	<20	
Phenol	ug/l	<20	<20	<20	
Toluene	ug/l	<0.4	<0.4	<0.4	
Tributyltin	ug/l	<0.02	<0.02	<0.02	
Arsenic (FILT) ICPMS	mg/l	0.005	0.005	0.005	
Selenium (T) ICPMS	mg/l	0.001	0.001	<0.001	
Sample Received					Empty
Comment					

Results from 11 July 2005

REF. NO		769818
LOCATION		SWFIELD
DATE		11/07/2005
Cadmium , Total as Cd	mg/l	0.0010
Chromium , Total as Cr	mg/l	<0.005
Lead , Total as Pb	mg/l	<0.005
Mercury , Total as Hg	mg/l	<0.0001
Nickel , Total as Ni	mg/l	<0.005
Zinc, Total as Zn	mg/l	0.013
pH		7.9
Conductivity- Electrical 20C	uS/cm	534
Ammoniacal Nitrogen as N	mg/l	<0.3
Chloride as Cl	mg/l	9
Sulphate as SO4	mg/l	39
BOD + ATU (5 day)	mg/l	<1
Mecoprop	ug/l	<0.04
2 - Chlorophenol	ug/l	<20
2 - Methylphenol	ug/l	<20
2,4 - Dichlorophenol	ug/l	<20
2,4 - Dimethylphenol	ug/l	<20
2,4,6 - Trichlorophenol	ug/l	<20
3,5 Dimethylphenol	ug/l	<20
4-Chlorophenol	ug/l	<20
4-Methylphenol	ug/l	<20
Phenol	ug/l	<20
Tributyltin	ug/l	<0.05
Arsenic (FILT) ICPMS	mg/l	<0.001
Selenium (T) ICPMS	mg/l	<0.001
Trichloroethene	ug/l	<0.10
Toluene	ug/l	<0.10
Comment		

Results for 25 July 2005

REF. NO		769817
LOCATION		SWFIELD
DATE		25/07/2005
Cadmium , Total as Cd	mg/l	0.0010
Chromium , Total as Cr	mg/l	<0.005
Lead , Total as Pb	mg/l	<0.005
Mercury , Total as Hg	mg/l	<0.0001
Nickel , Total as Ni	mg/l	<0.005
Zinc, Total as Zn	mg/l	0.005
pH		7.9
Conductivity- Electrical 20C	uS/cm	536
Ammoniacal Nitrogen as N	mg/l	<0.3
Chloride as Cl	mg/l	10
Sulphate as SO4	mg/l	38
BOD + ATU (5 day)	mg/l	<1
Mecoprop	ug/l	<0.04
2 - Chlorophenol	ug/l	<20
2 - Methylphenol	ug/l	<20
2,4 - Dichlorophenol	ug/l	<20
2,4 - Dimethylphenol	ug/l	<20
2,4,6 - Trichlorophenol	ug/l	<20
3,5 Dimethylphenol	ug/l	<20
4-Chlorophenol	ug/l	<20
4-Methylphenol	ug/l	<20
Phenol	ug/l	<20
Tributyltin	ug/l	<0.05
Arsenic (FILT) ICPMS	mg/l	<0.001
Selenium (T) ICPMS	mg/l	0.001
Trichloroethene	ug/l	<0.10
Toluene	ug/l	<0.10
Comment		

Results for 14 October 2005

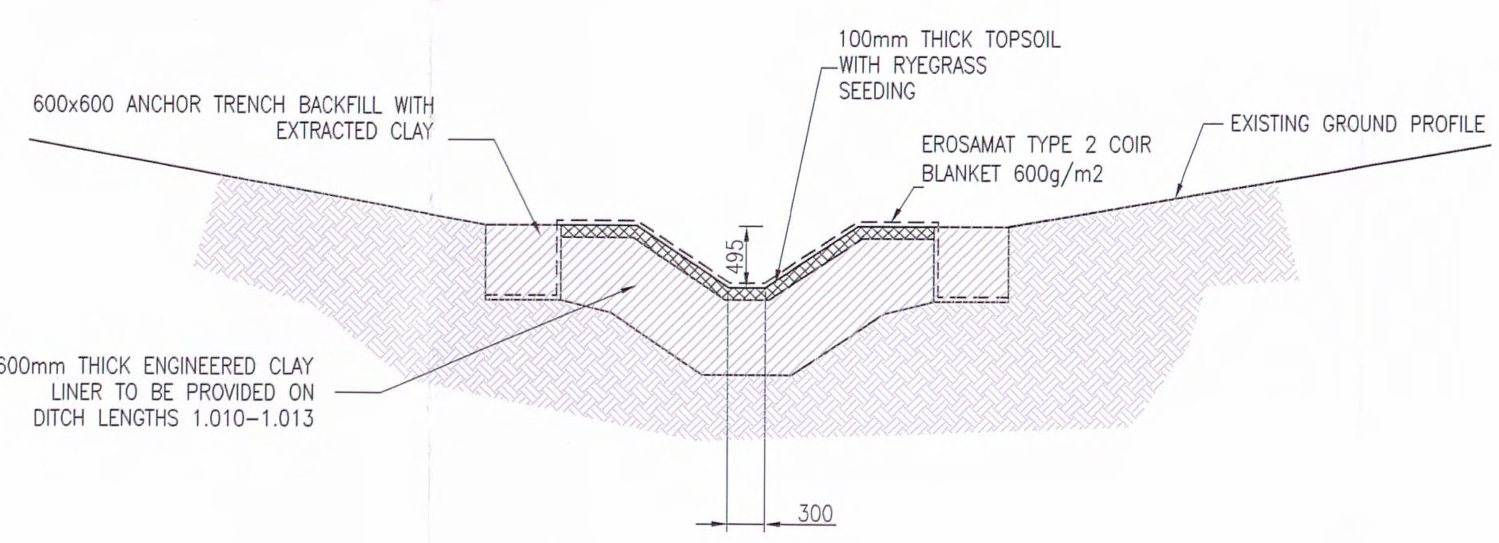
REF. NO		135905
LOCATION		SWROADRO
DATE		14/10/2005
Cadmium , Total as Cd	mg/l	<0.0005
Chromium , Total as Cr	mg/l	<0.005
Lead , Total as Pb	mg/l	0.020
Mercury , Total as Hg	mg/l	0.0001
Nickel , Total as Ni	mg/l	<0.005
Zinc, Total as Zn	mg/l	0.068
pH		6.7
Conductivity- Electrical 20C	uS/cm	150
Ammoniacal Nitrogen as N	mg/l	0.5
Chloride as Cl	mg/l	16
Sulphate as SO4	mg/l	5
BOD + ATU (5 day)	mg/l	4
Mecoprop	ug/l	<0.04
2 - Chlorophenol	ug/l	<20
2 - Methylphenol	ug/l	<20
2,4 - Dichlorophenol	ug/l	<20
2,4 - Dimethylphenol	ug/l	<20
2,4,6 - Trichlorophenol	ug/l	<20
3,5 Dimethylphenol	ug/l	<20
4-Chlorophenol	ug/l	<20
4-Methylphenol	ug/l	<20
Phenol	ug/l	<20
Tributyltin	ug/l	<0.02
Arsenic (FILT) ICPMS	mg/l	<0.001
Selenium, total by ICP-MS	mg/l	<0.001
Trichloroethene	ug/l	<0.10
Toluene	ug/l	<0.10
Comment		

Results for 19 October 2005

REF. NO		135922
LOCATION		SWROADRO
DATE		19/10/2005
Cadmium , Total as Cd	mg/l	<0.0005
Chromium , Total as Cr	mg/l	<0.005
Lead , Total as Pb	mg/l	0.012
Mercury , Total as Hg	mg/l	0.0001
Nickel , Total as Ni	mg/l	<0.005
Zinc, Total as Zn	mg/l	0.045
pH		7.0
Conductivity- Electrical 20C	uS/cm	130
Ammoniacal Nitrogen as N	mg/l	<0.3
Chloride as Cl	mg/l	13
Sulphate as SO4	mg/l	<5
BOD + ATU (5 day)	mg/l	2
Mecoprop	ug/l	<0.04
2 - Chlorophenol	ug/l	<20
2 - Methylphenol	ug/l	<20
2,4 - Dichlorophenol	ug/l	<20
2,4 - Dimethylphenol	ug/l	<20
2,4,6 - Trichlorophenol	ug/l	<20
3,5 Dimethylphenol	ug/l	<20
4-Chlorophenol	ug/l	<20
4-Methylphenol	ug/l	<20
Phenol	ug/l	<20
Tributyltin	ug/l	<0.02
Arsenic (FILT) ICPMS	mg/l	<0.001
Selenium, total by ICP-MS	mg/l	<0.001
Trichloroethene	ug/l	<0.10
Toluene	ug/l	<0.10
Comment		

APPENDIX G

DRAWING 1621.SWM.10



TYPICAL DITCH DETAIL
(BASE WIDTH AND SIDE SLOPE DEPTH MAY VARY)
1:50

NOTES

1. THIS PLAN CONTAINS ORDNANCE SURVEY MAP DATA REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONARY OFFICE, CROWN COPYRIGHT (LICENCE No AL100036676)

2. REINSTATEMENT OF AGRICULTURAL LAND TO BE AGREED WITH THE LANDOWNER

LEGEND

- 2.005 — PROPOSED SURFACE WATER DITCH ALIGNMENT AND REFERENCE
- PROPOSED POST SETTLEMENT CONTOURS
- PROPOSED RISING MAIN
- EXISTING WATER MAIN
- PYLON ON 11KV OVERHEAD POWER LINE

REV	MODIFICATIONS	BY	CH	AP	DATE
E	RE-ROUTE OF RISING MAIN	AS	JM	–	10.1.06

Augean SOUTH LTD

KINGS CLIFFE LANDFILL SURFACE WATER MANAGEMENT

OUTLINE SURFACE WATER DRAINAGE PROPOSALS

DRAWN BY: AK	DATE: 17.08.2005
CHECKED BY: JLM	SCALE @ A1: 1:2000
APPROVED BY: JM	ISSUING OFFICE: PEOVER

DRAWING NUMBER	ISSUE	REVISION
1621.SWM.10	-	E

Egniol Limited
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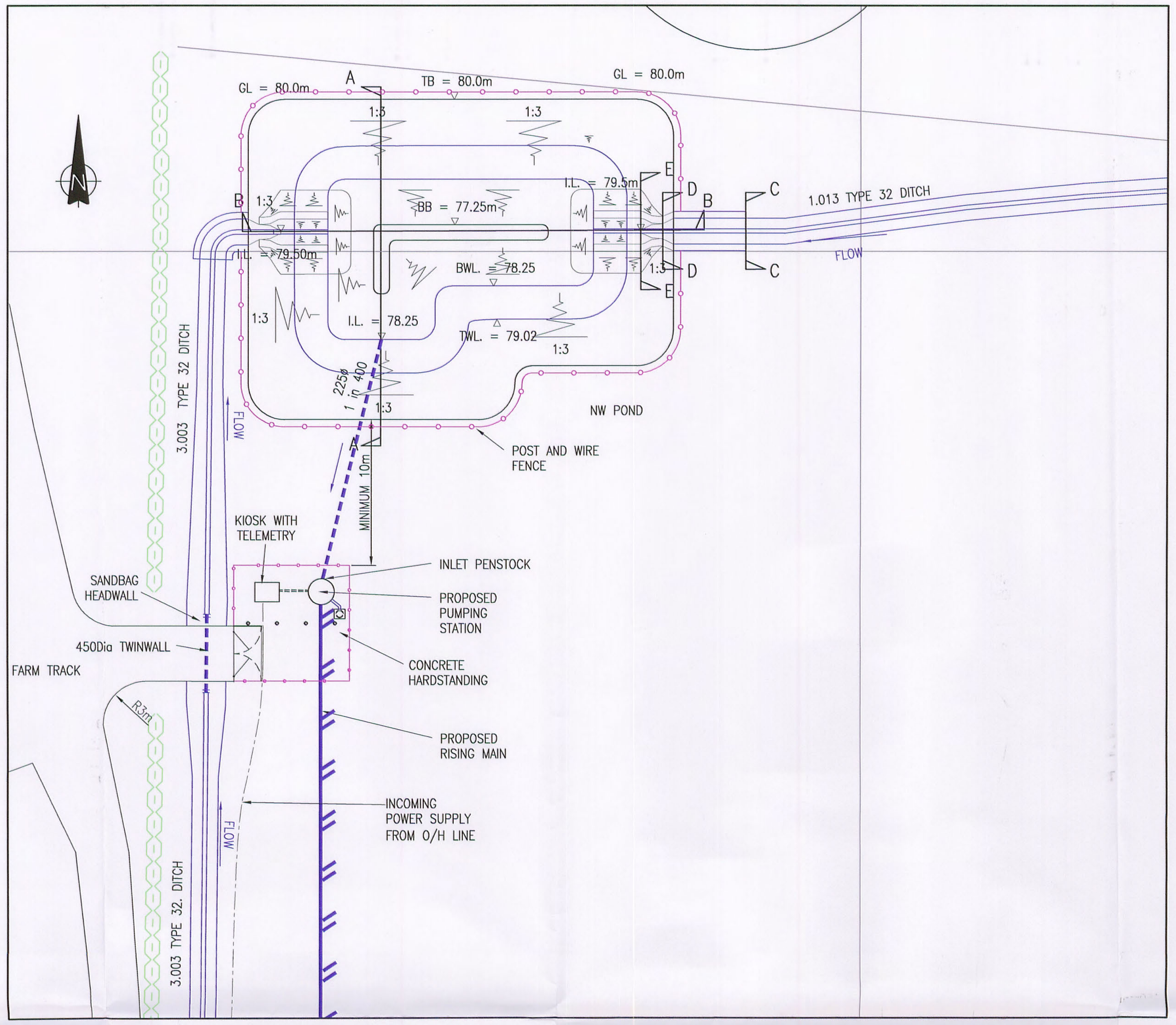
Fax: 01565 723945
Website: www.egniol.co.uk

egniol

CAD FILE REF: 1621.SWM.10.DWG

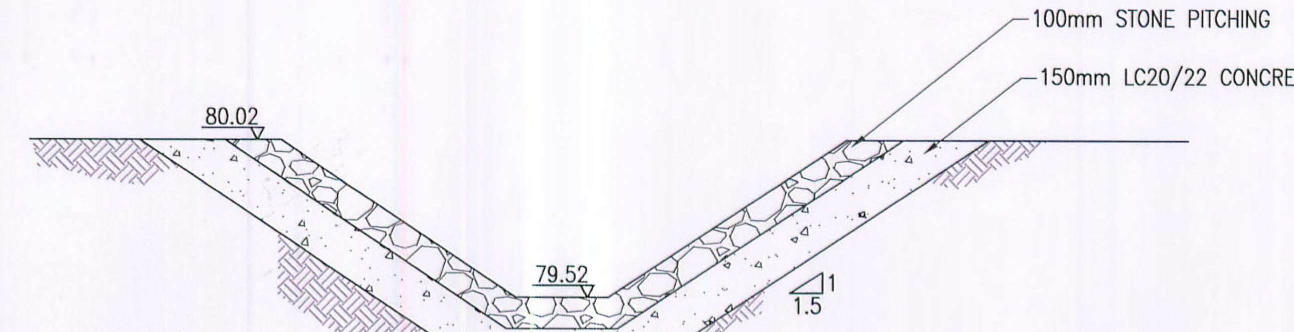
APPENDIX H

DRAWING 1621.SWM.11



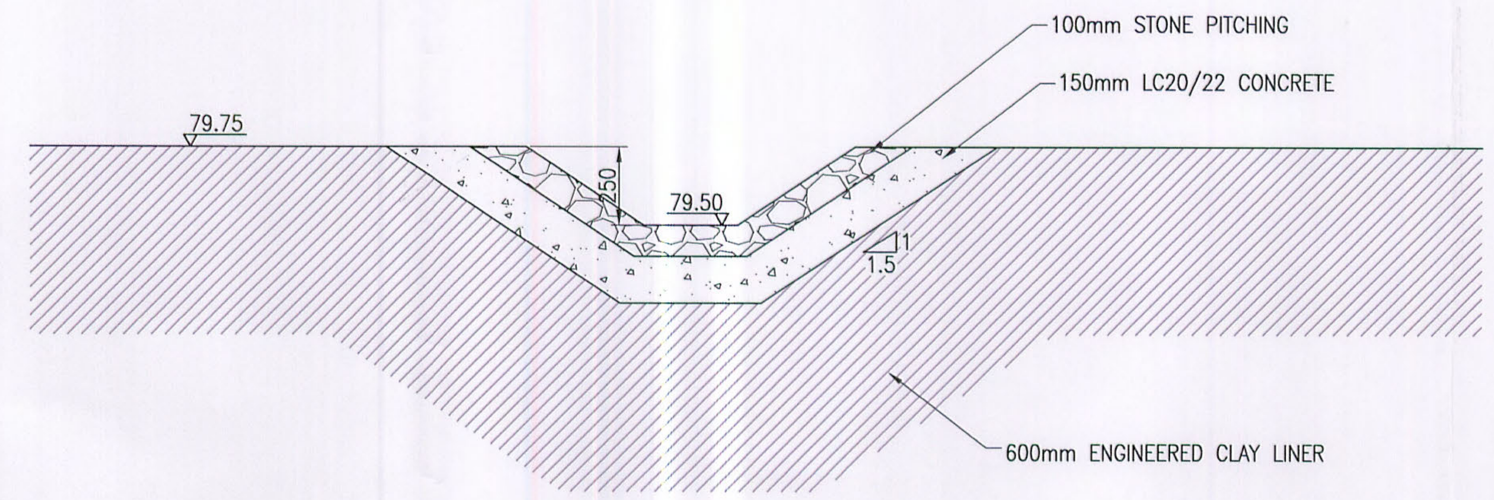
PROPOSED SURFACE WATER SETTLEMENT POND AND PUMPING STATION

SCALE 1:250



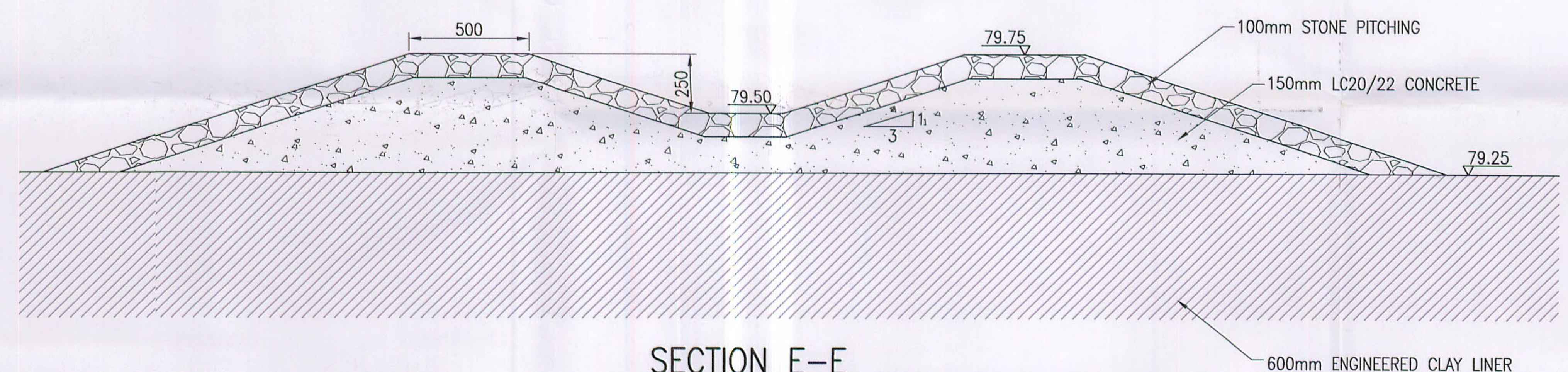
SECTION C–C

SCALE 1:20



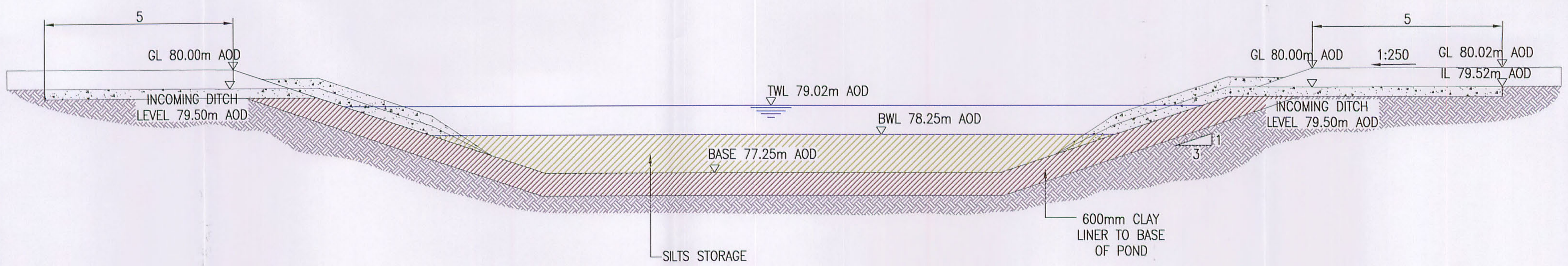
SECTION D–D

SCALE 1:20



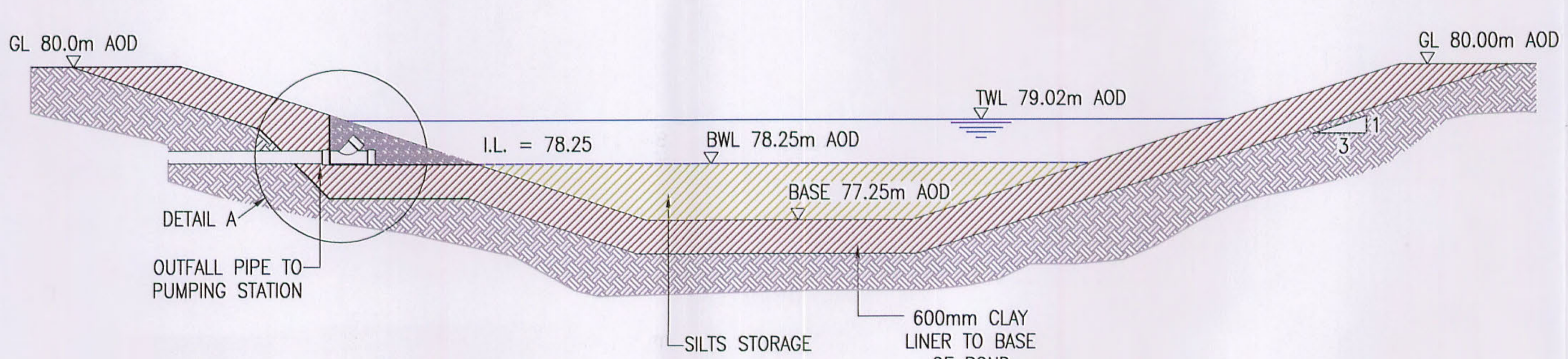
SECTION E–E

SCALE 1:20



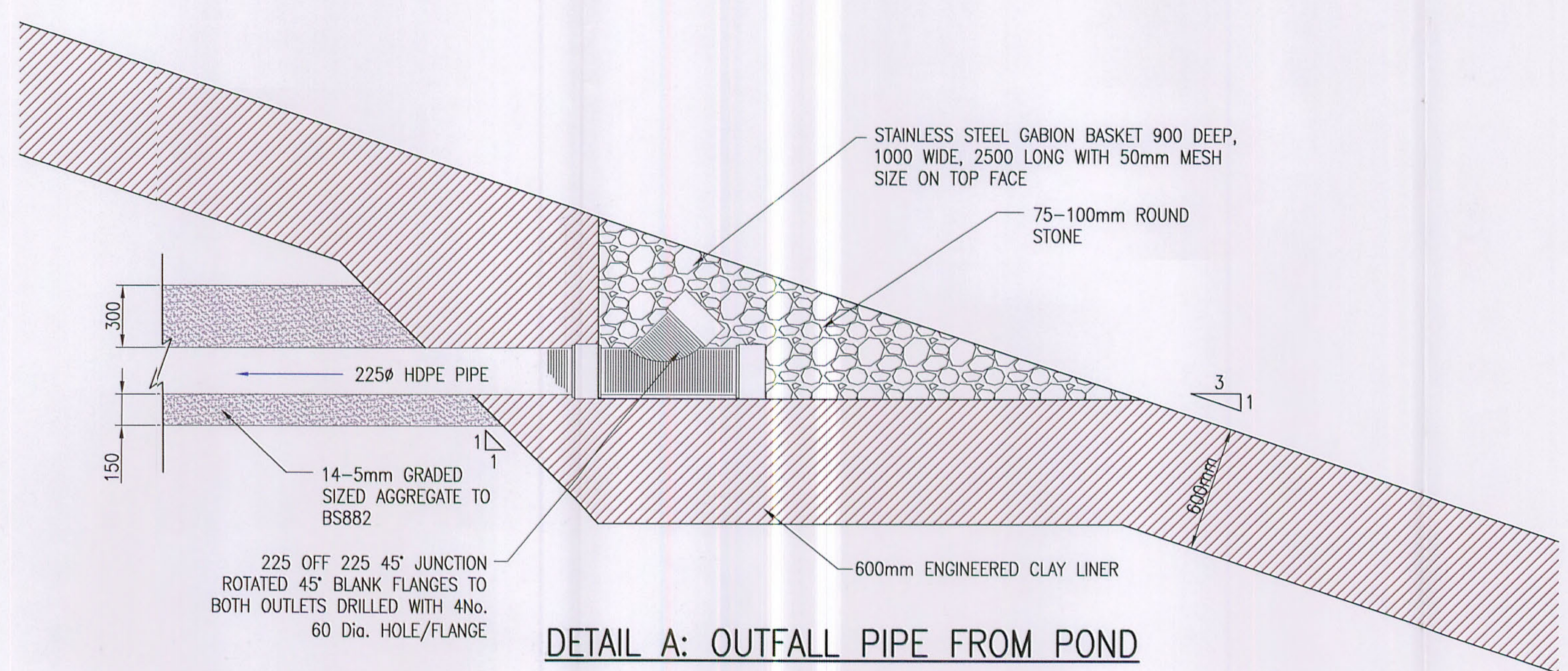
SECTION A–A THROUGH PROPOSED SETTLEMENT POND

SCALE 1:100



SECTION B–B THROUGH PROPOSED SETTLEMENT POND

SCALE 1:100



DETAIL A: OUTFALL PIPE FROM POND

SCALE 1:25

NOTES

1. SPECIFICATION TO BE "CIVIL ENGINEERING SPECIFICATION FOR THE WATER INDUSTRY, 5th EDITION" UNLESS DETAILED OTHERWISE.

2. FOR DETAILS OF PUMPING STATION SEE DRAWING 1621.SWM.12

3. SETTING OUT DETAILS FOR THE POND AND INLETS TO BE PROVIDED IN ELECTRONIC FORM

REV	MODIFICATIONS	BY	CH	AP	DATE

Augean SOUTH LTD

KINGSCLIFFE LANDFILL SITE SURFACE WATER MANAGEMENT

CONSTRUCTION DETAILS FOR NW POND

DRAWN BY AK	DATE 15.11.2005
CHECKED BY JLM	SCALE @ A1 AS SHOWN
APPROVED BY JM	ISSUING OFFICE PEOVER

DRAWING NUMBER	ISSUE	REVISION
1621.SWM.11	Dr	A

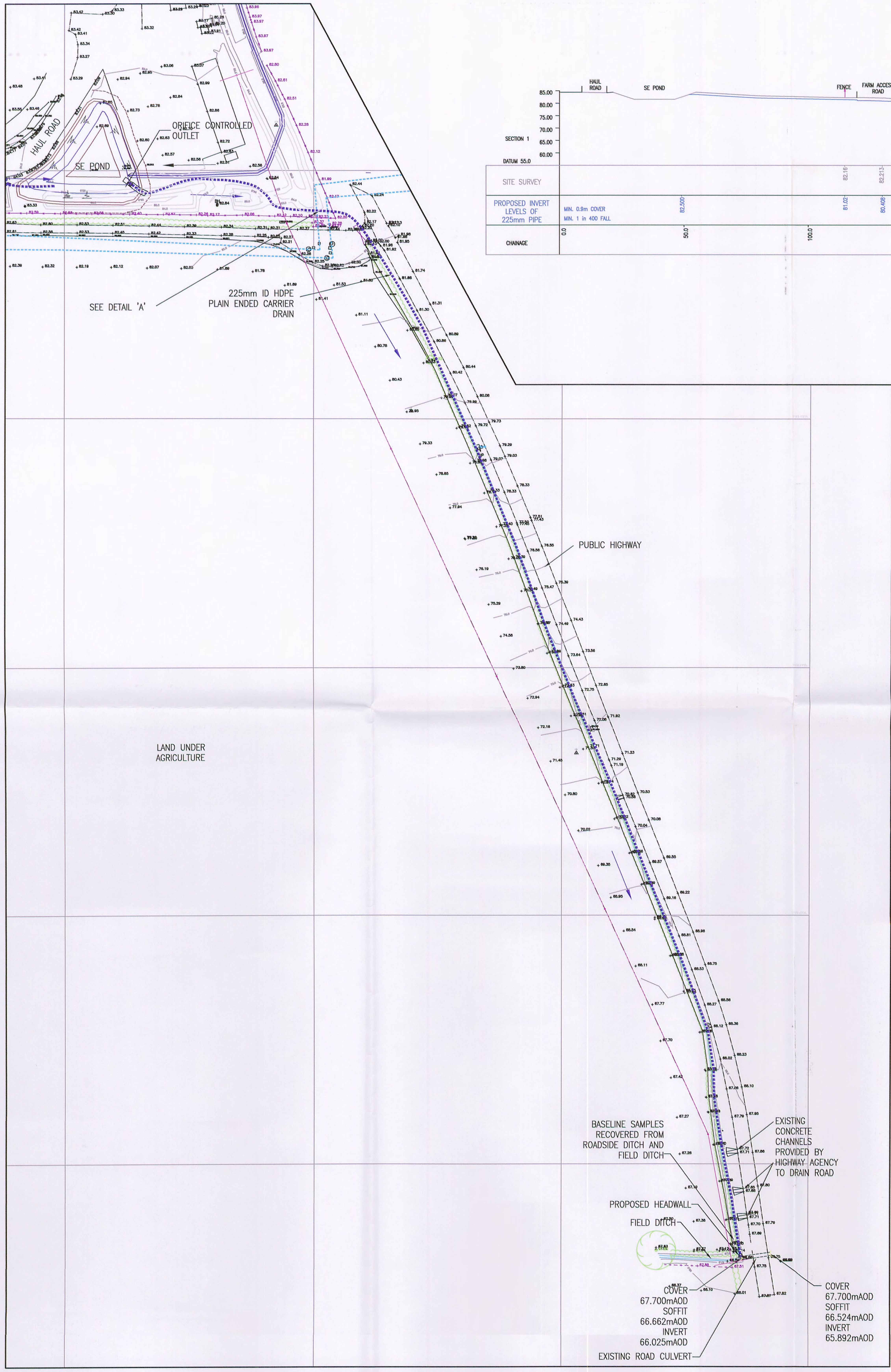
Egniol Limited
Primtec House, Lower Peover,
Nr Knutsford,
WA16 9QQ
Tel: 01565 723618
Fax: 01565 723945
Website: www.egniol.co.uk

egniol

CAD FILE REF: 1621.SWM.11.DWG

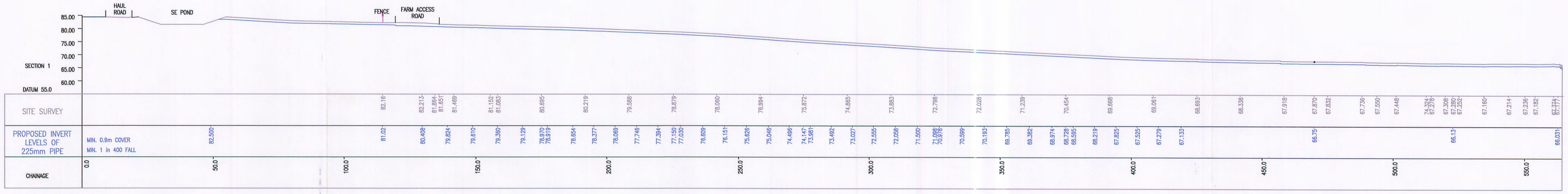
APPENDIX I

DRAWING 1621.SWM.14



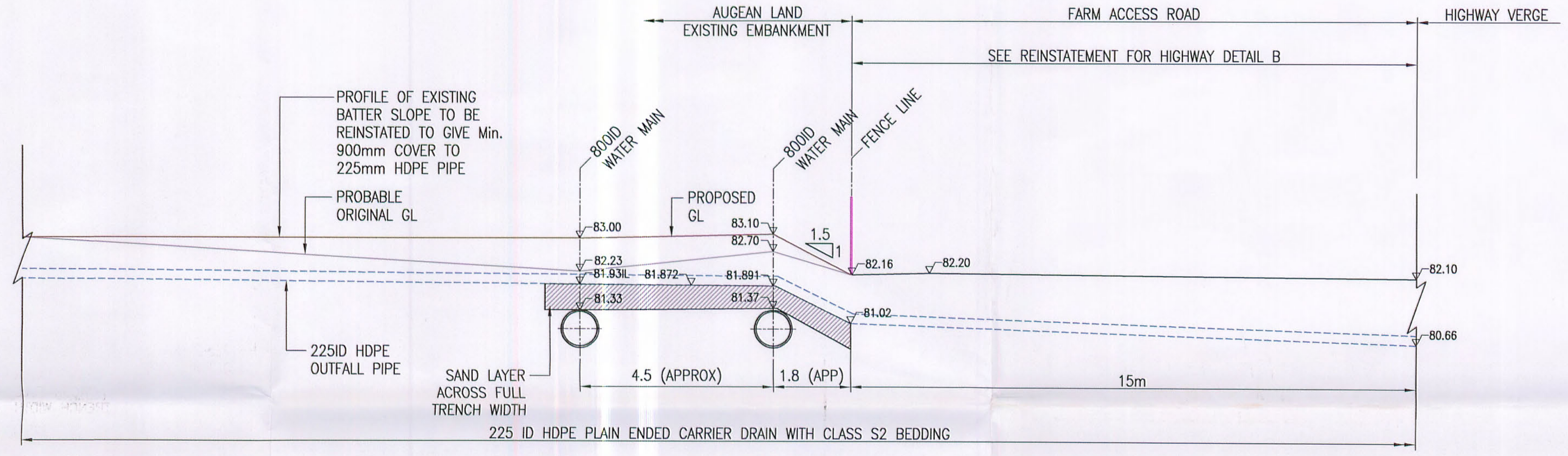
LAYOUT OF SOUTHERN PONDS AND OUTFALL

1:1000



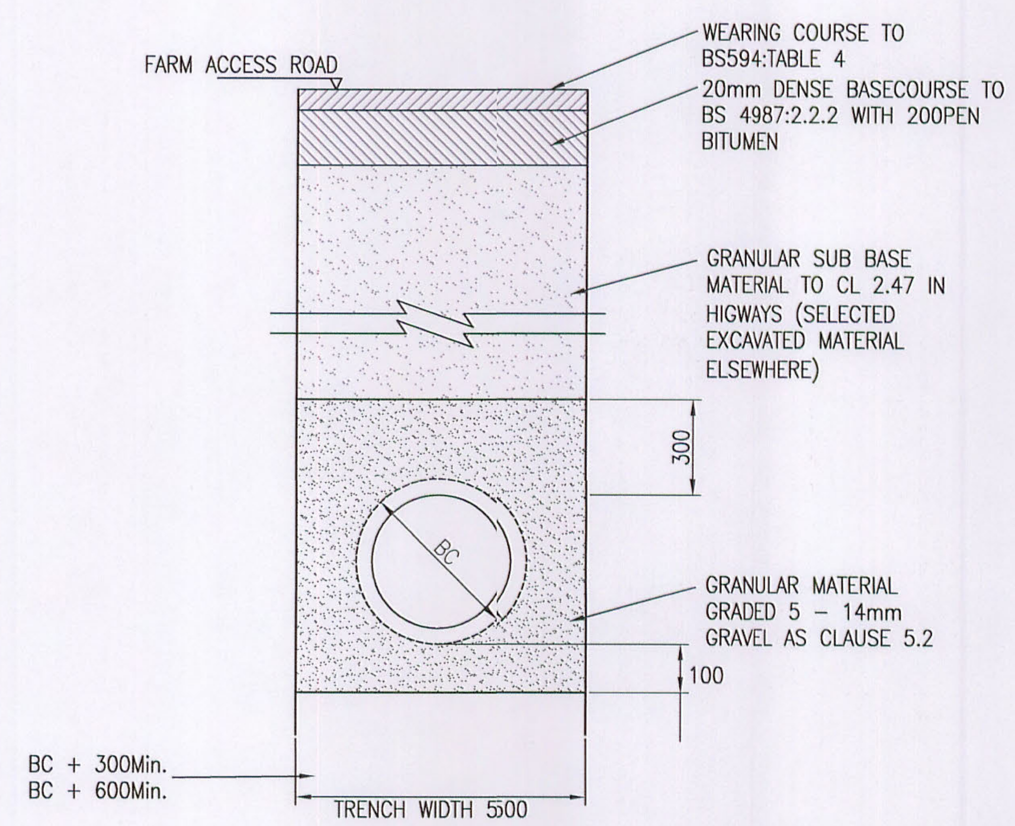
LONG SECTION THROUGH SOUTH EAST POND AND OUTFALL PIPE IN VERGE

1:1000



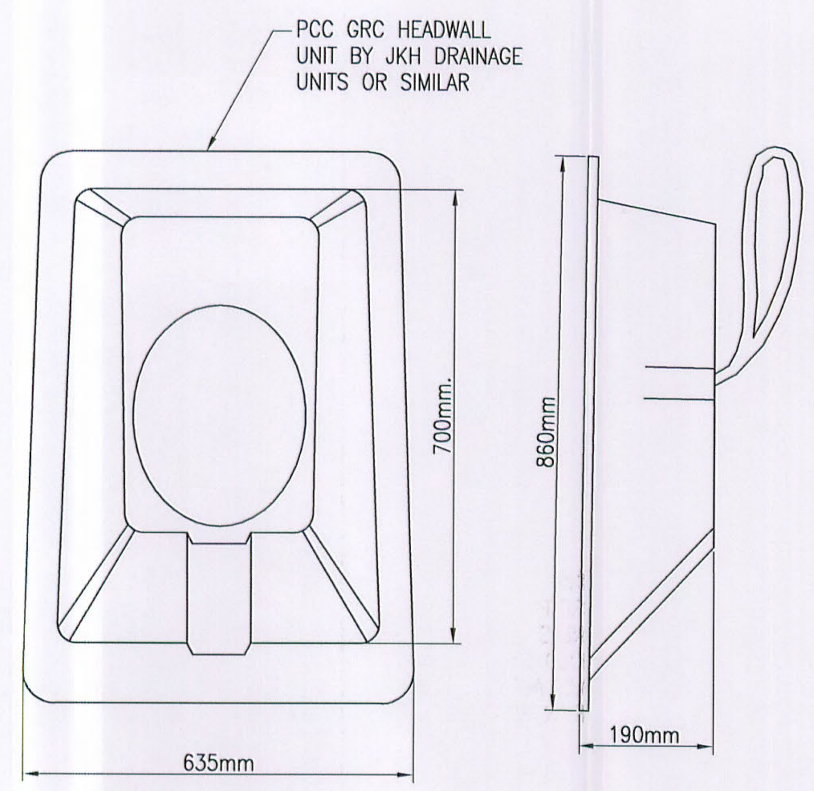
DETAIL A: WATERMAIN CROSSING DETAIL FROM SE POND

1:50



DETAIL B: CLASS "S2" DRAINAGE PIPE AND TRENCH AS BS EN 1295–1: 1998

SCALE 1:20



DETAIL C: OUTFALL DETAIL TO WATERCOURSE

SCALE 1:10

NOTES

1. SPECIFICATION TO BE "CIVIL ENGINEERING SPECIFICATION FOR THE WATER INDUSTRY, 5th EDITION" UNLESS DETAILED OTHERWISE

2. HDPE PIPE TO COMPLY WITH ROAD AND BRIDGE AGREEMENT CERTIFICATE 00/R121

REV	MODIFICATIONS	BY	CH	AP	DATE

Augean SOUTH LTD

KINGSCLIFFE LANDFILL SITE SURFACE WATER MANAGEMENT

OUTFALL DETAILS FOR SE POND

DRAWN BY AK	DATE 17.08.2005
CHECKED BY JLM	SCALE @ A1 AS SHOWN
APPROVED BY JM	ISSUING OFFICE PEOVER

DRAWING NUMBER	ISSUE	REVISION
1621.SWM.14	Dr	-

Egniol Limited
Primtec House, Lower Peover,
Nr Knutsford,
WA16 9QQ
Tel: 01565 723618
Fax: 01565 723945
Website: www.egniol.co.uk

CAD FILE REF: 1621.SWM.14.DWG

APPENDIX J

DRAWING 1621.SWM. 24

1. THIS PLAN CONTAINS ORDNANCE SURVEY MAP DATA REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE, CROWN COPYRIGHT © (LICENSE No AL100036676)

NOTES

- FILLED AREAS
- OPERATIONAL AREAS
- FUTURE LANDFILLING OPERATIONS
- DIRECTION OF LANDFILLING

REV	MODIFICATIONS	BY	CH	AP	DATE

Augean SOUTH LTD

KINGS CLIFFE LANDFILL SITE

PROGRESSIVE WASTE FILL

DRAWN BY AK	DATE 10.01.2006
CHECKED BY MN	SCALE @ A1 1:1250
APPROVED BY MN	ISSUING OFFICE ALFRETON

DRAWING NUMBER	ISSUE	REVISION
1621.SWM.24	Dr	A

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CAD FILE REF: 1621.SWM.24DWG

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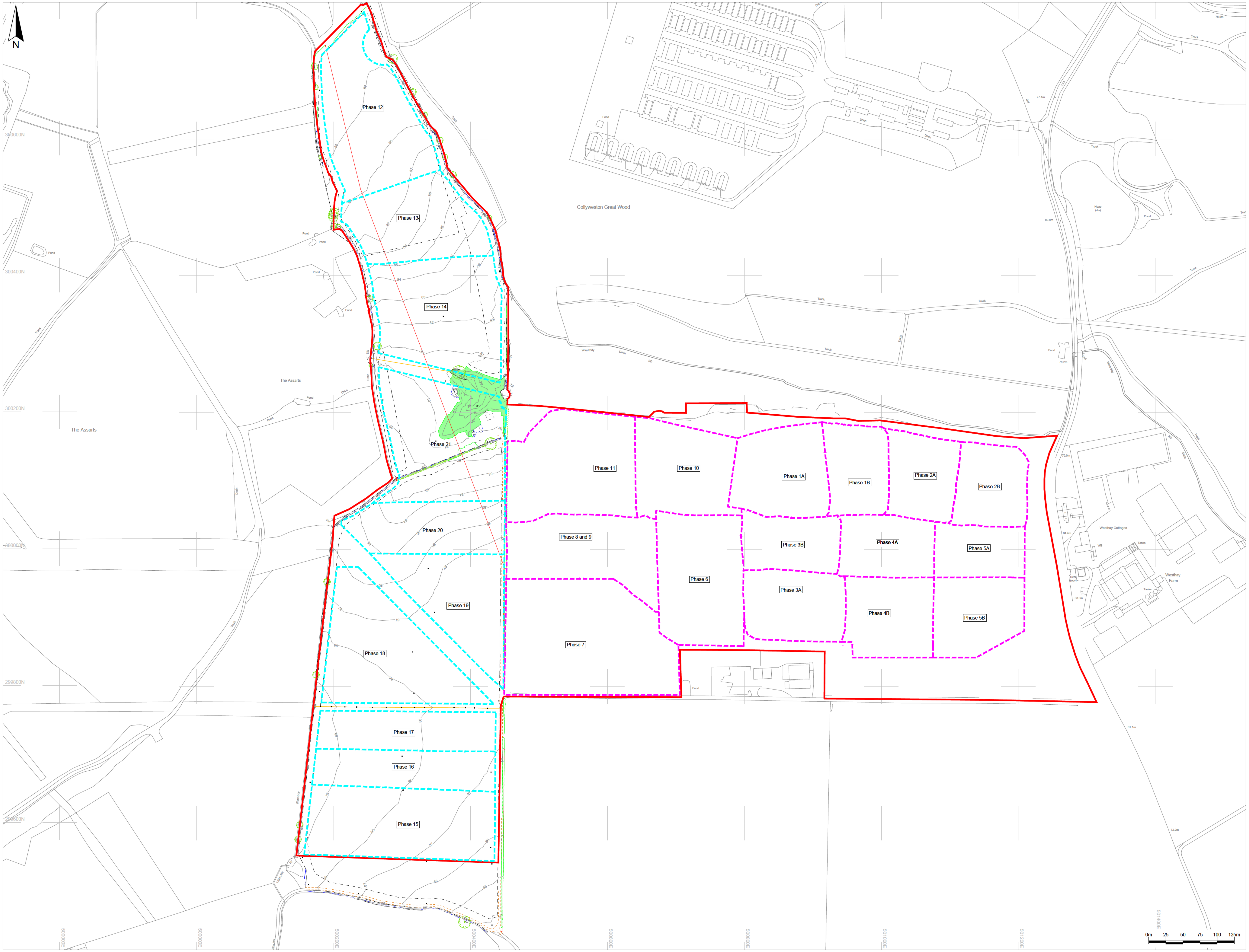
APPENDIX B

TOPOGRAPHICAL SURVEY OF THE PROPOSED WESTERN EXTENSION



Key / Notes

Red solid outline	Approximate boundary of the area the subject of the application for the Development Consent Order
Magenta dashed outline	Approximate phase boundary in the existing ENRMF
Cyan dashed outline	Approximate phase boundary in the proposed western extension
Blue dashed line	Bottom of Bank
Blue dashed line	Bottom of Ditch
Black dashed line	Change of Surface
Green wavy line	Hedge
Orange double line	Pipe
Black long-dashed line	Top of Bank
Black dashed line	Top of Ditch
Orange dashed line	Track
Red line	Overhead electricity cabe (to be diverted)
Grey line labelled 18	Contours (mAOD)
Green filled box	Vegetation area
Green circle	Tree

Notes:
Drawing based on LSS model reference 'AU-US-15845.LSS' and 'FULL SITE SURVEY UPDATE 24.05.2005.lss' provided by Egniol in 2005

The survey data is based on the ENRMF site control 'KINGSCONTROL' created using the co-ordinates of 6 survey points supplied by Augean PLC. The co-ordinate system was established and transformed via a OneStep transformation using a Leica GPS system in February 2007.

Rev	Status	Drn	App	Chk	Date
	Final	KR	HL	LH	26/07/21

Site
EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Client
Augean SOUTH LTD

Title
The current topography at the proposed western extension based on the topographical survey undertaken in January 2021 and the proposed phase boundaries

PINS document reference 5.3.18.1

Figure ES18.1

Scale 1:2,500@A1

Drawing Ref AU/KCW/07-21/22685

MJCA
Technical advisers on environmental issues
Baddesley Colliery Offices,
Main Road, Baxterley, Atherstone,
Warwickshire, CV9 2LE.
Telephone : 01827 717891
Fax : 01827 718507

APPENDIX C

PROPOSED RESTORATION CONCEPT SCHEME

KEY

- APPLICATION BOUNDARY
- PROPOSED RESTORATION CONTOURS (At 1m AOD intervals)
- EXISTING FOOTPATH
- PROPOSED FOOTPATH
- POSSIBLE NEW PATH ROUTE TO LINK WITH EXISTING PUBLIC RIGHT OF WAY, SUBJECT TO DISCUSSION & AGREEMENT
- PROPOSED 4m WIDE TRACK FOR SITE AFTERCARE/MAINTENANCE
- PROPOSED LOCALLY NATIVE BROADLEAVED WOODLAND
- PROPOSED SCRUB/NATURAL REGENERATION BROADLEAVED WOODLAND WITHIN GRASSLAND AREAS
- PROPOSED INDIVIDUAL TREE OR SMALL TREE GROUP
- EXISTING HEDGEROW (TO BE REINFORCED WITH TREES/SHRUBS WHERE CONSIDERED NECESSARY/DESIRABLE)
- PROPOSED NATIVE HEDGEROW
- PROPOSED NATIVE HEDGEROW WITH OCCASIONAL TREES
- FORMER AGRICULTURAL LAND DEVELOPED AS MANAGED GRASSLAND AREA
- EXISTING SPECIES-RICH NEUTRAL/CALCAREOUS GRASSLAND TO BE RETAINED
- PROPOSED NEUTRAL/CALCAREOUS GRASSLAND (Depending on soil type)
- EXISTING POND OUTSIDE THE APPLICATION BOUNDARY
- PROPOSED POND FOR THE PURPOSE OF ENHANCING BIODIVERSITY AND ATTRACTING NEWTS. EXACT LOCATIONS TO BE DETERMINED DURING RESTORATION WORKS
- HIBERNACULA TO BE CONSTRUCTED IN CLOSE PROXIMITY TO PROPOSED PONDS
- PROPOSED ATTENUATION FEATURE
- APPROX. 0.5m HIGH BUND AROUND ATTENUATION BASIN C1 TO CONTAIN 1 IN 100 YEAR EVENT. BUND TO BE PLANTED WITH SCRUBBY SPECIES
- PUBLIC CAR PARK AREA ACCESSED FROM EXISTING MAIN SITE ENTRANCE
- INDICATIVE CROSS SECTIONS (Refer to Drawing No. ENORTH029)

Proposed Tree and Shrub Planting Palette

The proposed planting blocks across the restored site landscape would be planted with a selection of the following tree and shrub species which are characteristic of the surrounding landscape:

Trees:

Ash (Cultivar resistant to dieback) - *Fraxinus excelsior*
Field Maple - *Acer Campestre*
Pedunculate Oak - *Quercus robur*
Silver Birch - *Betula pendula*
Small leaved lime - *Tilia cordata*
Wild Service Tree - *Sorbus torminalis*
Wych elm - *Ulmus glabra*

Shrubs/Scrub/Climbers:

Black bryony - *Tamus communis*
Blackthorn - *Prunus spinosa*
Bramble - *Rubus fruticosus*
Buckthorn - *Rhamnus cathartica*
Dewberry - *Rubus caesius*
Dog-rose - *Rosa canina*
Dogwood - *Cornus sanguinea*
Elder - *Sambucus nigra*
Goat willow - *Salix caprea*
Gorse - *Ulex europaeus*
Grey willow - *Salix cinerea*
Hawthorn - *Crataegus monogyna*
Hazel - *Corylus avellana*
Ivy - *Hedera helix*
Spindle - *Euonymus europaea*
Spurge laurel - *Daphne laureola*
Traveller's joy - *Clematis vitalba*
Wayfaring tree - *Viburnum lantana*
White bryony - *Bryonia dioica*
Wild privet - *Ligustrum vulgare*

0 10 20 30 40 50 60 70 80 90 100 METRES

SCALE 1:2500

Client: Augean SOUTH LTD

Site: EAST NORTHANTS RESOURCE MANAGEMENT FACILITY

Project: PROPOSED WESTERN EXTENSION

Drawing Title: RESTORATION CONCEPT SCHEME

Date	JULY 2021	Drawing No.	ENORTH028
Scale	1:2,500 @ A1		
File Ref	2107_008.006_ENORTH028_Restoration Plan	Revision	0

DB Landscape Consultancy
T: 01344 624 709
M: 07736 083 383
david@dblc.co.uk
www.dblc.co.uk

APPENDIX D

GREENFIELD RUNOFF CALCULATIONS

Table D1

Calculation of the greenfield surface water runoff rate for the catchment draining to the east based on the method presented in The Institute of Hydrology, 1994. Flood estimation for small catchments. Report number 124.

Parameter (units)	Units		Source/Justification
Area of catchment	km²	0.05	Table 1 and as shown on Figure 3.
Area of catchment in SOIL class 1	km²	0.05	Soil type at and in the vicinity of the site prior to extraction based on the soil maps presented in the Flood Studies Report published by the The Institute of Hydrology dated 1993.
Area of catchment in SOIL class 2	km²	0.00	
Area of catchment in SOIL class 3	km²	0.00	
Area of catchment in SOIL class 4	km²	0.00	
Area of catchment in SOIL class 5	km²	0.00	
Soil index (SOIL)	n/a	0.1	Calculated from the weighted sum of the fractions of the surface areas within the catchment which have different soil types
Standard average annual rainfall (SAAR)	mm	575	FEH catchment descriptor
Greenfield surface water run-off rate for 50ha site (Q_{50ha})	m³/s	0.007	
Correction	m³/s	0.0993	
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/s	0.001	Calculated.
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/day	57	Calculated.
1 in 1 year surface water runoff for rainfall	m³/s	0.001	Calculated assuming a 1 year growth curve factor of 0.87. The 1 in 1 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 1 year surface water runoff for rainfall	m³/day	50	Calculated.
1 in 30 year surface water runoff for rainfall	m³/s	0.002	Calculated assuming a 30 year growth curve factor of 2.55. The 1 in 30 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 30 year surface water runoff for rainfall	m³/day	146	Calculated.
1 in 100 year surface water runoff for rainfall	m³/s	0.002	Calculated assuming a 100 year growth curve factor of 3.56. The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall	m³/day	204	Calculated.
1 in 100 year surface water runoff for rainfall plus 40%	m³/s	0.003	Calculated assuming a 100 year growth curve factor of 3.56 and a 40% allowance for increased rainfall intensity as a result of climate change The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall plus 40%	m³/day	285	Calculated.

Table D2

Calculation of the greenfield surface water runoff rate for the catchment draining to the swallow hole based on the method presented in The Institute of Hydrology, 1994. Flood estimation for small catchments. Report number 124.

Parameter (units)	Units		Source/Justification
Area of catchment	km²	0.16	Table 1 and as shown on Figure 3.
Area of catchment in SOIL class 1	km²	0.16	Soil type at and in the vicinity of the site prior to extraction based on the soil maps presented in the Flood Studies Report published by the The Institute of Hydrology dated 1993.
Area of catchment in SOIL class 2	km²	0.00	
Area of catchment in SOIL class 3	km²	0.00	
Area of catchment in SOIL class 4	km²	0.00	
Area of catchment in SOIL class 5	km²	0.00	
Soil index (SOIL)	n/a	0.1	Calculated from the weighted sum of the fractions of the surface areas within the catchment which have different soil types
Standard average annual rainfall (SAAR)	mm	575	FEH catchment descriptor
Greenfield surface water run-off rate for 50ha site (Q_{50ha})	m³/s	0.007	
Correction	m³/s	0.3102	
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/s	0.002	Calculated.
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/day	179	Calculated.
1 in 1 year surface water runoff for rainfall	m³/s	0.002	Calculated assuming a 1 year growth curve factor of 0.87. The 1 in 1 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 1 year surface water runoff for rainfall	m³/day	156	Calculated.
1 in 30 year surface water runoff for rainfall	m³/s	0.005	Calculated assuming a 30 year growth curve factor of 2.55. The 1 in 30 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 30 year surface water runoff for rainfall	m³/day	456	Calculated.
1 in 100 year surface water runoff for rainfall	m³/s	0.007	Calculated assuming a 100 year growth curve factor of 3.56. The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall	m³/day	637	Calculated.
1 in 100 year surface water runoff for rainfall plus 40%	m³/s	0.010	Calculated assuming a 100 year growth curve factor of 3.56 and a 40% allowance for increased rainfall intensity as a result of climate change The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall plus 40%	m³/day	891	Calculated.

Table D3

Calculation of the greenfield surface water runoff rate for the catchment draining to the south based on the method presented in The Institute of Hydrology, 1994. Flood estimation for small catchments. Report number 124.

Parameter (units)	Units		Source/Justification
Area of catchment	km²	0.06	Table 1 and as shown on Figure 3.
Area of catchment in SOIL class 1	km²	0.06	Soil type at and in the vicinity of the site prior to extraction based on the soil maps presented in the Flood Studies Report published by the The Institute of Hydrology dated 1993.
Area of catchment in SOIL class 2	km²	0.00	
Area of catchment in SOIL class 3	km²	0.00	
Area of catchment in SOIL class 4	km²	0.00	
Area of catchment in SOIL class 5	km²	0.00	
Soil index (SOIL)	n/a	0.1	Calculated from the weighted sum of the fractions of the surface areas within the catchment which have different soil types
Standard average annual rainfall (SAAR)	mm	575	FEH catchment descriptor
Greenfield surface water run-off rate for 50ha site (Q_{50ha})	m³/s	0.007	
Correction	m³/s	0.1282	
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/s	0.001	Calculated.
Greenfield surface water run-off rate ($Qbar_{rural}$)	m³/day	74	Calculated.
1 in 1 year surface water runoff for rainfall	m³/s	0.001	Calculated assuming a 1 year growth curve factor of 0.87. The 1 in 1 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 1 year surface water runoff for rainfall	m³/day	64	Calculated.
1 in 30 year surface water runoff for rainfall	m³/s	0.002	Calculated assuming a 30 year growth curve factor of 2.55. The 1 in 30 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 30 year surface water runoff for rainfall	m³/day	188	Calculated.
1 in 100 year surface water runoff for rainfall	m³/s	0.003	Calculated assuming a 100 year growth curve factor of 3.56. The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall	m³/day	263	Calculated.
1 in 100 year surface water runoff for rainfall plus 40%	m³/s	0.004	Calculated assuming a 100 year growth curve factor of 3.56 and a 40% allowance for increased rainfall intensity as a result of climate change. The 1 in 100 year growth curve factor was determined using information obtained using the greenfield runoff estimation tool presented on the UK Sustainable Drainage website (http://www.uksuds.com/greenfieldrunoff_js.htm).
1 in 100 year surface water runoff for rainfall plus 40%	m³/day	368	Calculated.

Table D4

Comparison of Qbar calculations with 2l/s/ha

Catchment	Area (m^2)	Qbar IOH124 (l/s)	Qbar UKSUDS FEH STAT (l/s)	2l/s/ha (l/s)
Catchment draining to the east	49,650	0.66	13.14	**9.93**
Catchment draining to the swallow hole	155,100	2.07	41.06	**31.02**
Catchment draining to the south	64,100	0.86	16.97	**12.82**

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Jo Congo
Site name:	ENRMF W Ext - Wittering
Site location:	Northants

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	52.58852° N
Longitude:	0.51857° W
Reference:	3062305219
Date:	Jul 09 2021 12:15

Runoff estimation approach FEH Statistical

Site characteristics

Total site area (ha): 4.965

Methodology

Q_{MED} estimation method:	Calculate from BFI and SAAR
BFI and SPR method:	Calculate from dominant HOST
HOST class:	22
BFI / BFIHOST:	0.374
Q_{MED} (l/s):	11.69
Q_{BAR} / Q_{MED} factor:	1.12

Hydrological characteristics

	Default	Edited
SAAR (mm):	579	579
Hydrological region:	5	5
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 30 years:	2.45	2.45
Growth curve factor 100 years:	3.56	3.56
Growth curve factor 200 years:	4.21	4.21

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	13.14	13.14
1 in 1 year (l/s):	11.43	11.43
1 in 30 years (l/s):	32.2	32.2
1 in 100 year (l/s):	46.79	46.79
1 in 200 years (l/s):	55.33	55.33

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Jo Congo
Site name:	ENRMF W Ext - Swallow hole
Site location:	Northants

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance “Rainfall runoff management for developments”, SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	52.58852° N
Longitude:	0.51857° W
Reference:	3040132544
Date:	Jul 09 2021 12:19

Runoff estimation approach FEH Statistical

Site characteristics

Total site area (ha):	15.51

Methodology

Q_{MED} estimation method:	Calculate from BFI and SAAR
BFI and SPR method:	Calculate from dominant HOST
HOST class:	22
BFI / BFIHOST:	0.374
Q_{MED} (l/s):	36.53
Q_{BAR} / Q_{MED} factor:	1.12

Hydrological characteristics

	Default	Edited
SAAR (mm):	579	579
Hydrological region:	5	5
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 30 years:	2.45	2.45
Growth curve factor 100 years:	3.56	3.56
Growth curve factor 200 years:	4.21	4.21

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	41.06	41.06
1 in 1 year (l/s):	35.72	35.72
1 in 30 years (l/s):	100.59	100.59
1 in 100 year (l/s):	146.16	146.16
1 in 200 years (l/s):	172.85	172.85

Greenfield runoff rate estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Jo Congo
Site name:	ENRMF W Ext - Willow
Site location:	Northants

This is an estimation of the greenfield runoff rates that are used to meet normal best practice criteria in line with Environment Agency guidance “Rainfall runoff management for developments”, SC030219 (2013) , the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site Details

Latitude:	52.58852° N
Longitude:	0.51857° W
Reference:	3241136926
Date:	Jul 09 2021 12:22

Runoff estimation approach FEH Statistical

Site characteristics

Total site area (ha):	6.41

Methodology

Q_{MED} estimation method:	Calculate from BFI and SAAR
BFI and SPR method:	Calculate from dominant HOST
HOST class:	22
BFI / BFIHOST:	0.374
Q_{MED} (l/s):	15.1
Q_{BAR} / Q_{MED} factor:	1.12

Hydrological characteristics

	Default	Edited
SAAR (mm):	579	579
Hydrological region:	5	5
Growth curve factor 1 year:	0.87	0.87
Growth curve factor 30 years:	2.45	2.45
Growth curve factor 100 years:	3.56	3.56
Growth curve factor 200 years:	4.21	4.21

Notes

(1) Is Q_{BAR} < 2.0 l/s/ha?

When Q_{BAR} is < 2.0 l/s/ha then limiting discharge rates are set at 2.0 l/s/ha.

(2) Are flow rates < 5.0 l/s?

Where flow rates are less than 5.0 l/s consent for discharge is usually set at 5.0 l/s if blockage from vegetation and other materials is possible. Lower consent flow rates may be set where the blockage risk is addressed by using appropriate drainage elements.

(3) Is SPR/SPRHOST ≤ 0.3?

Where groundwater levels are low enough the use of soakaways to avoid discharge offsite would normally be preferred for disposal of surface water runoff.

Greenfield runoff rates

	Default	Edited
Q_{BAR} (l/s):	16.97	16.97
1 in 1 year (l/s):	14.76	14.76
1 in 30 years (l/s):	41.57	41.57
1 in 100 year (l/s):	60.41	60.41
1 in 200 years (l/s):	71.44	71.44

APPENDIX E

ATTENUATION STORAGE CALCULATIONS

Table E1

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C1 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	20	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	4320	m^3/day	Permitted discharge limit (2007 SWMP)
Runoff coefficient	0.62	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensi ivity of he design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	5208.98	45.00	5164
0.5	38.79	108.61	6805.54	90.00	6716
0.75	44.39	82.86	7788.03	135.00	7653
1	48.39	67.75	8489.82	180.00	8310
1.5	54.55	50.91	9570.56	270.00	9301
2	59.39	41.57	10419.72	360.00	10060
3	67.22	31.37	11793.46	540.00	11253
4	73.3	25.66	12860.17	720.00	12140
5	78.18	21.89	13716.34	900.00	12816
6	82.2	19.18	14421.63	1080.00	13342
7	85.57	17.11	15012.89	1260.00	13753
8	88.42	15.47	15512.91	1440.00	14073
9	90.88	14.14	15944.50	1620.00	14325
10	93.02	13.02	16319.96	1800.00	14520
15	100.66	9.39	17660.36	2700.00	14960
15.25	100.94	9.27	17709.49	2745.00	14964
15.5	101.22	9.14	17758.61	2790.00	14969
15.75	101.5	9.02	17807.74	2835.00	14973
16	101.76	8.90	17853.35	2880.00	14973
16.25	102.02	8.79	17898.97	2925.00	14974
16.5	102.28	8.68	17944.58	2970.00	14975
16.75	102.52	8.57	17986.69	3015.00	14972
17	102.77	8.46	18030.55	3060.00	14971
18	103.69	8.06	18191.96	3240.00	14952
19	104.52	7.70	18337.58	3420.00	14918
20	105.28	7.37	18470.92	3600.00	14871
24	107.8	6.29	18913.04	4320.00	14593
30	110.48	5.16	19383.24	5400.00	13983
40	113.5	3.97	19913.08	7200.00	12713
50	115.52	3.23	20267.48	9000.00	11267
60	116.92	2.73	20513.11	10800.00	9713
70	118.12	2.36	20723.64	12600.00	8124
80	119.18	2.09	20909.62	14400.00	6510
90	120.15	1.87	21079.80	16200.00	4880
96	120.71	1.76	21178.05	17280.00	3898

Maximum storage volume	**14975**	m^3
Critical Storm Period	**16.5**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels
Denotes parameters which are calculated based on other parameters

Table E2

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C1 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	20	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	4320	m^3/day	Permitted discharge limit (2007 SWMP)
Runoff coefficient	0.62	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on he catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	3311.41	45.00	3266
0.5	28.64	68.74	4306.94	90.00	4217
0.75	32.51	52.02	4888.92	135.00	4754
1	35.48	42.58	5335.55	180.00	5156
1.5	39.85	31.88	5992.72	270.00	5723
2	43.22	25.93	6499.51	360.00	6140
3	48.66	19.46	7317.59	540.00	6778
4	52.92	15.88	7958.22	720.00	7238
5	56.41	13.54	8483.05	900.00	7583
6	59.35	11.87	8925.17	1080.00	7845
7	61.91	10.61	9310.15	1260.00	8050
8	64.12	9.62	9642.49	1440.00	8202
9	66.05	8.81	9932.73	1620.00	8313
10	67.76	8.13	10189.88	1800.00	8390
11	69.28	7.56	10418.47	1980.00	8438
12	70.63	7.06	10621.48	2160.00	8461
12.25	70.95	6.95	10669.60	2205.00	8465
12.5	71.25	6.84	10714.72	2250.00	8465
12.75	71.55	6.73	10759.83	2295.00	8465
13	71.84	6.63	10803.44	2340.00	8463
13.25	72.12	6.53	10845.55	2385.00	8461
13.5	72.39	6.43	10886.15	2430.00	8456
13.75	72.66	6.34	10926.76	2475.00	8452
14	72.92	6.25	10965.86	2520.00	8446
15	73.91	5.91	11114.73	2700.00	8415
20	77.72	4.66	11687.69	3600.00	8088
30	82.24	3.29	12367.42	5400.00	6967
35	83.8	2.87	12602.01	6300.00	6302
40	85.11	2.55	12799.01	7200.00	5599
50	87.23	2.09	13117.82	9000.00	4118
60	88.87	1.78	13364.45	10800.00	2564
70	90.33	1.55	13584.01	12600.00	984
80	91.69	1.38	13788.53	14400.00	-611
85	92.34	1.30	13886.27	15300.00	-1414
86	92.47	1.29	13905.82	15480.00	-1574
87	92.6	1.28	13925.37	15660.00	-1735
87.25	92.63	1.27	13929.88	15705.00	-1775

Maximum storage volume	**8465**	m^3
Critical Storm Period	**12.75**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E3

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C2 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	6	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	1053	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cul ivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	uni less	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensitivity of the design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	1668.60	10.97	1658
0.5	38.79	108.61	2180.03	21.94	2158
0.75	44.39	82.86	2494.75	32.91	2462
1	48.39	67.75	2719.56	43.88	2676
1.5	54.55	50.91	3065.75	65.82	3000
2	59.39	41.57	3337.76	87.76	3250
3	67.22	31.37	3777.82	131.64	3646
4	73.3	25.66	4119.52	175.52	3944
5	78.18	21.89	4393.78	219.40	4174
6	82.2	19.18	4619.70	263.28	4356
7	85.57	17.11	4809.10	307.16	4502
8	88.42	15.47	4969.27	351.04	4618
9	90.88	14.14	5107.53	394.92	4713
10	93.02	13.02	5227.80	438.80	4789
15	100.66	9.39	5657.17	658.21	4999
16	101.76	8.90	5718.99	702.09	5017
17	102.77	8.46	5775.75	745.97	5030
18	103.69	8.06	5827.46	789.85	5038
19	104.52	7.70	5874.10	833.73	5040
19.25	104.71	7.62	5884.78	844.70	5040
19.5	104.9	7.53	5895.46	855.67	5040
19.75	105.09	7.45	5906.14	866.64	5040
20	105.28	7.37	5916.82	877.61	5039
20.25	105.46	7.29	5926.93	888.58	5038
20.5	105.63	7.21	5936.49	899.55	5037
20.75	105.81	7.14	5946.60	910.52	5036
21	105.98	7.07	5956.16	921.49	5035
22	106.63	6.79	5992.69	965.37	5027
23	107.23	6.53	6026.41	1009.25	5017
24	107.8	6.29	6058.44	1053.13	5005
25	108.31	6.07	6087.11	1097.01	4990
30	110.48	5.16	6209.06	1316.41	4893
35	112.15	4.49	6302.92	1535.81	4767
40	113.5	3.97	6378.79	1755.22	4624
50	115.52	3.23	6492.31	2194.02	4298
60	116.92	2.73	6570.99	2632.82	3938
70	118.12	2.36	6638.43	3071.63	3567
80	119.18	2.09	6698.01	3510.43	3188
90	120.15	1.87	6752.52	3949.24	2803
96	120.71	1.76	6783.99	4212.52	2571

Maximum storage volume	**5040**	m^3
Critical Storm Period	**19**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E4

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C2 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	6	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	1053	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	1060.75	10.97	1050
0.5	28.64	68.74	1379.65	21.94	1358
0.75	32.51	52.02	1566.07	32.91	1533
1	35.48	42.58	1709.15	43.88	1665
1.5	39.85	31.88	1919.66	65.82	1854
2	43.22	25.93	2082.00	87.76	1994
3	48.66	19.46	2344.05	131.64	2212
4	52.92	15.88	2549.27	175.52	2374
5	56.41	13.54	2717.39	219.40	2498
6	59.35	11.87	2859.01	263.28	2596
7	61.91	10.61	2982.33	307.16	2675
8	64.12	9.62	3088.79	351.04	2738
9	66.05	8.81	3181.77	394.92	2787
10	67.76	8.13	3264.14	438.80	2825
15	73.91	5.91	3560.40	658.21	2902
15.25	74.14	5.83	3571.48	669.18	2902
15.5	74.37	5.76	3582.56	680.15	2902
15.75	74.59	5.68	3593.16	691.12	2902
16	74.81	5.61	3603.75	702.09	2902
16.25	75.02	5.54	3613.87	713.06	2901
16.5	75.23	5.47	3623.99	724.03	2900
16.75	75.43	5.40	3633.62	735.00	2899
17	75.63	5.34	3643.25	745.97	2897
18	76.39	5.09	3679.87	789.85	2890
19	77.08	4.87	3713.10	833.73	2879
20	77.72	4.66	3743.93	877.61	2866
30	82.24	3.29	3961.67	1316.41	2645
40	85.11	2.55	4099.93	1755.22	2345
50	87.23	2.09	4202.05	2194.02	2008
60	88.87	1.78	4281.05	2632.82	1648
70	90.33	1.55	4351.38	3071.63	1280
80	91.69	1.38	4416.90	3510.43	906
90	92.98	1.24	4479.04	3949.24	530
96	93.73	1.17	4515.17	4212.52	303

Maximum storage volume	**2902**	m^3
Critical Storm Period	**15.5**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E5

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C3 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	8	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	1421	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.64	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensi ivity of he design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	2199.74	14.80	2185
0.5	38.79	108.61	2873.96	29.60	2844
0.75	44.39	82.86	3288.87	44.40	3244
1	48.39	67.75	3585.23	59.21	3526
1.5	54.55	50.91	4041.63	88.81	3953
2	59.39	41.57	4400.22	118.41	4282
3	67.22	31.37	4980.35	177.62	4803
4	73.3	25.66	5430.82	236.82	5194
5	78.18	21.89	5792.38	296.03	5496
6	82.2	19.18	6090.22	355.23	5735
7	85.57	17.11	6339.91	414.44	5925
8	88.42	15.47	6551.06	473.64	6077
9	90.88	14.14	6733.33	532.85	6200
10	93.02	13.02	6891.88	592.06	6300
15	100.66	9.39	7457.93	888.08	6570
16	101.76	8.90	7539.43	947.29	6592
17	102.77	8.46	7614.26	1006.50	6608
18	103.69	8.06	7682.42	1065.70	6617
18.5	104.11	7.88	7713.54	1095.30	6618
19	104.52	7.70	7743.92	1124.91	6619
19.25	104.71	7.62	7758.00	1139.71	6618
19.5	104.9	7.53	7772.07	1154.51	6618
19.75	105.09	7.45	7786.15	1169.31	6617
20	105.28	7.37	7800.23	1184.11	6616
25	108.31	6.07	8024.72	1480.14	6545
30	110.48	5.16	8185.50	1776.17	6409
40	113.5	3.97	8409.25	2368.22	6041
50	115.52	3.23	8558.91	2960.28	5599
60	116.92	2.73	8662.64	3552.34	5110
70	118.12	2.36	8751.55	4144.39	4607
80	119.18	2.09	8830.08	4736.45	4094
90	120.15	1.87	8901.95	5328.50	3573
96	120.71	1.76	8943.44	5683.74	3260

Maximum storage volume	**6619**	m^3
Critical Storm Period	**19**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E6

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C3 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	8	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	1421	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.64	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	1398.40	14.80	1384
0.5	28.64	68.74	1818.81	29.60	1789
0.75	32.51	52.02	2064.58	44.40	2020
1	35.48	42.58	2253.19	59.21	2194
1.5	39.85	31.88	2530.71	88.81	2442
2	43.22	25.93	2744.73	118.41	2626
3	48.66	19.46	3090.20	177.62	2913
4	52.92	15.88	3360.74	236.82	3124
5	56.41	13.54	3582.37	296.03	3286
6	59.35	11.87	3769.08	355.23	3414
7	61.91	10.61	3931.65	414.44	3517
8	64.12	9.62	4072.00	473.64	3598
9	66.05	8.81	4194.57	532.85	3662
10	67.76	8.13	4303.16	592.06	3711
11	69.28	7.56	4399.69	651.26	3748
12	70.63	7.06	4485.43	710.47	3775
13	71.84	6.63	4562.27	769.67	3793
14	72.92	6.25	4630.86	828.88	3802
14.5	73.42	6.08	4662.61	858.48	3804
14.75	73.67	5.99	4678.49	873.28	3805
15	73.91	5.91	4693.73	888.08	3806
15.5	74.37	5.76	4722.94	917.69	3805
16	74.81	5.61	4750.88	947.29	3804
17	75.63	5.34	4802.96	1006.50	3796
18	76.39	5.09	4851.22	1065.70	3786
19	77.08	4.87	4895.04	1124.91	3770
20	77.72	4.66	4935.68	1184.11	3752
30	82.24	3.29	5222.73	1776.17	3447
40	85.11	2.55	5404.99	2368.22	3037
50	87.23	2.09	5539.63	2960.28	2579
60	88.87	1.78	5643.78	3552.34	2091
70	90.33	1.55	5736.49	4144.39	1592
80	91.69	1.38	5822.86	4736.45	1086
90	92.98	1.24	5904.79	5328.50	576
96	93.73	1.17	5952.41	5683.74	269

Maximum storage volume	**3806**	m^3
Critical Storm Period	**15**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E7

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C4 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	3	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	480	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensi ivity of he design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	756.64	5.00	752
0.5	38.79	108.61	988.55	9.99	979
0.75	44.39	82.86	1131.27	14.99	1116
1	48.39	67.75	1233.21	19.98	1213
1.5	54.55	50.91	1390.19	29.97	1360
2	59.39	41.57	1513.54	39.96	1474
3	67.22	31.37	1713.09	59.94	1653
4	73.3	25.66	1868.03	79.92	1788
5	78.18	21.89	1992.40	99.90	1892
6	82.2	19.18	2094.85	119.88	1975
7	85.57	17.11	2180.73	139.86	2041
8	88.42	15.47	2253.36	159.84	2094
9	90.88	14.14	2316.06	179.82	2136
10	93.02	13.02	2370.59	199.80	2171
15	100.66	9.39	2565.30	299.70	2266
16	101.76	8.90	2593.33	319.68	2274
17	102.77	8.46	2619.07	339.66	2279
18	103.69	8.06	2642.52	359.64	2283
18.5	104.11	7.88	2653.22	369.63	2284
19	104.52	7.70	2663.67	379.62	2284
19.5	104.9	7.53	2673.35	389.61	2284
20	105.28	7.37	2683.04	399.60	2283
21	105.98	7.07	2700.88	419.58	2281
22	106.63	6.79	2717.44	439.56	2278
23	107.23	6.53	2732.73	459.54	2273
24	107.8	6.29	2747.26	479.52	2268
25	108.31	6.07	2760.25	499.50	2261
30	110.48	5.16	2815.56	599.40	2216
40	113.5	3.97	2892.52	799.20	2093
50	115.52	3.23	2944.00	999.00	1945
60	116.92	2.73	2979.68	1198.80	1781
70	118.12	2.36	3010.26	1398.60	1612
80	119.18	2.09	3037.27	1598.40	1439
90	120.15	1.87	3061.99	1798.20	1264
96	120.71	1.76	3076.27	1918.08	1158

Maximum storage volume	**2284**	m^3
Critical Storm Period	**19**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E8

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C4 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	3	ha	Derived consistent wi h Sec ion 5 and as shown on Figure 5.
Discharge rate	480	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	481.01	5.00	476
0.5	28.64	68.74	625.61	9.99	616
0.75	32.51	52.02	710.15	14.99	695
1	35.48	42.58	775.03	19.98	755
1.5	39.85	31.88	870.49	29.97	841
2	43.22	25.93	944.10	39.96	904
3	48.66	19.46	1062.93	59.94	1003
4	52.92	15.88	1155.99	79.92	1076
5	56.41	13.54	1232.22	99.90	1132
6	59.35	11.87	1296.45	119.88	1177
7	61.91	10.61	1352.37	139.86	1213
8	64.12	9.62	1400.64	159.84	1241
9	66.05	8.81	1442.80	179.82	1263
10	67.76	8.13	1480.16	199.80	1280
11	69.28	7.56	1513.36	219.78	1294
12	70.63	7.06	1542.85	239.76	1303
13	71.84	6.63	1569.28	259.74	1310
14	72.92	6.25	1592.87	279.72	1313
14.5	73.42	6.08	1603.79	289.71	1314
15	73.91	5.91	1614.50	299.70	1315
15.5	74.37	5.76	1624.54	309.69	1315
16	74.81	5.61	1634.16	319.68	1314
16.5	75.23	5.47	1643.33	329.67	1314
17	75.63	5.34	1652.07	339.66	1312
18	76.39	5.09	1668.67	359.64	1309
19	77.08	4.87	1683.74	379.62	1304
20	77.72	4.66	1697.72	399.60	1298
30	82.24	3.29	1796.46	599.40	1197
40	85.11	2.55	1859.15	799.20	1060
50	87.23	2.09	1905.46	999.00	906
60	88.87	1.78	1941.28	1198.80	742
70	90.33	1.55	1973.18	1398.60	575
80	91.69	1.38	2002.88	1598.40	404
90	92.98	1.24	2031.06	1798.20	233
96	93.73	1.17	2047.45	1918.08	129

Maximum storage volume	**1315**	m^3
Critical Storm Period	**15.5**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restora ion scheme, rainfall data or o her constraints on discharge or water levels
Denotes parameters which are calculated based on other parameters

Table E9

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C5 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	6	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	1021	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.64	unitless	The runoff coefficent has been calculated using he nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensitivity of the design and additional mi igation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	1565.54	10.63	1555
0.5	38.79	108.61	2045.37	21.27	2024
0.75	44.39	82.86	2340.66	31.90	2309
1	48.39	67.75	2551.58	42.54	2509
1.5	54.55	50.91	2876.39	63.81	2813
2	59.39	41.57	3131.60	85.08	3047
3	67.22	31.37	3544.47	127.61	3417
4	73.3	25.66	3865.07	170.15	3695
5	78.18	21.89	4122.39	212.69	3910
6	82.2	19.18	4334.36	255.23	4079
7	85.57	17.11	4512.06	297.76	4214
8	88.42	15.47	4662.34	340.30	4322
9	90.88	14.14	4792.05	382.84	4409
10	93.02	13.02	4904.89	425.38	4480
15	100.66	9.39	5307.75	638.06	4670
16	101.76	8.90	5365.75	680.60	4685
17	102.77	8.46	5419.00	723.14	4696
18	103.69	8.06	5467.52	765.68	4702
19	104.52	7.70	5511.28	808.21	4703
19.25	104.71	7.62	5521.30	818.85	4702
19.5	104.9	7.53	5531.32	829.48	4702
19.75	105.09	7.45	5541.34	840.12	4701
20	105.28	7.37	5551.36	850.75	4701
20.25	105.46	7.29	5560.85	861.39	4699
20.5	105.63	7.21	5569.81	872.02	4698
21	105.98	7.07	5588.27	893.29	4695
21.5	106.31	6.92	5605.67	914.56	4691
22	106.63	6.79	5622.54	935.83	4687
23	107.23	6.53	5654.18	978.36	4676
24	107.8	6.29	5684.23	1020.90	4663
25	108.31	6.07	5711.13	1063.44	4648
30	110.48	5.16	5825.55	1276.13	4549
40	113.5	3.97	5984.79	1701.50	4283
50	115.52	3.23	6091.30	2126.88	3964
60	116.92	2.73	6165.13	2552.26	3613
70	118.12	2.36	6228.40	2977.63	3251
80	119.18	2.09	6284.29	3403.01	2881
90	120.15	1.87	6335.44	3828.38	2507
96	120.71	1.76	6364.97	4083.61	2281

Maximum storage volume	**4703**	m^3
Critical Storm Period	**19**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E10

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C5 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	6	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	1021	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.64	unitless	The runoff coefficent has been calculated using he nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	995.23	10.63	985
0.5	28.64	68.74	1294.43	21.27	1273
0.75	32.51	52.02	1469.34	31.90	1437
1	35.48	42.58	1603.58	42.54	1561
1.5	39.85	31.88	1801.09	63.81	1737
2	43.22	25.93	1953.40	85.08	1868
3	48.66	19.46	2199.27	127.61	2072
4	52.92	15.88	2391.81	170.15	2222
5	56.41	13.54	2549.54	212.69	2337
6	59.35	11.87	2682.42	255.23	2427
7	61.91	10.61	2798.13	297.76	2500
8	64.12	9.62	2898.01	340.30	2558
9	66.05	8.81	2985.24	382.84	2602
10	67.76	8.13	3062.53	425.38	2637
11	69.28	7.56	3131.22	467.91	2663
12	70.63	7.06	3192.24	510.45	2682
13	71.84	6.63	3246.93	552.99	2694
14	72.92	6.25	3295.74	595.53	2700
14.5	73.42	6.08	3318.34	616.80	2702
15	73.91	5.91	3340.49	638.06	2702
15.5	74.37	5.76	3361.28	659.33	2702
15.75	74.59	5.68	3371.22	669.97	2701
16	74.81	5.61	3381.16	680.60	2701
16.25	75.02	5.54	3390.65	691.24	2699
16.5	75.23	5.47	3400.14	701.87	2698
16.75	75.43	5.40	3409.18	712.50	2697
17	75.63	5.34	3418.22	723.14	2695
17.5	76.02	5.21	3435.85	744.41	2691
18	76.39	5.09	3452.57	765.68	2687
19	77.08	4.87	3483.76	808.21	2676
20	77.72	4.66	3512.68	850.75	2662
25	80.33	3.86	3630.65	1063.44	2567
30	82.24	3.29	3716.97	1276.13	2441
40	85.11	2.55	3846.69	1701.50	2145
50	87.23	2.09	3942.50	2126.88	1816
60	88.87	1.78	4016.63	2552.26	1464
70	90.33	1.55	4082.61	2977.63	1105
80	91.69	1.38	4144.08	3403.01	741
90	92.98	1.24	4202.39	3828.38	374
96	93.73	1.17	4236.28	4083.61	153

Maximum storage volume	**2702**	m^3
Critical Storm Period	**15**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E11

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C6 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	4	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	710	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.62	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensitivity of the design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	1052.03	7.39	1045
0.5	38.79	108.61	1374.47	14.79	1360
0.75	44.39	82.86	1572.90	22.18	1551
1	48.39	67.75	1714.63	29.57	1685
1.5	54.55	50.91	1932.91	44.36	1889
2	59.39	41.57	2104.40	59.15	2045
3	67.22	31.37	2381.85	88.72	2293
4	73.3	25.66	2597.29	118.30	2479
5	78.18	21.89	2770.20	147.87	2622
6	82.2	19.18	2912.65	177.44	2735
7	85.57	17.11	3032.06	207.02	2825
8	88.42	15.47	3133.04	236.59	2896
9	90.88	14.14	3220.21	266.17	2954
10	93.02	13.02	3296.04	295.74	3000
15	100.66	9.39	3566.75	443.61	3123
16	101.76	8.90	3605.73	473.18	3133
17	102.77	8.46	3641.52	502.76	3139
17.5	103.24	8.26	3658.17	517.55	3141
18	103.69	8.06	3674.12	532.33	3142
18.5	104.11	7.88	3689.00	547.12	3142
18.75	104.31	7.79	3696.08	554.51	3142
19	104.52	7.70	3703.53	561.91	3142
19.25	104.71	7.62	3710.26	569.30	3141
19.5	104.9	7.53	3716.99	576.69	3140
20	105.28	7.37	3730.46	591.48	3139
21	105.98	7.07	3755.26	621.05	3134
22	106.63	6.79	3778.29	650.63	3128
23	107.23	6.53	3799.55	680.20	3119
24	107.8	6.29	3819.75	709.78	3110
25	108.31	6.07	3837.82	739.35	3098
30	110.48	5.16	3914.71	887.22	3027
35	112.15	4.49	3973.88	1035.09	2939
40	113.5	3.97	4021.72	1182.96	2839
50	115.52	3.23	4093.30	1478.70	2615
60	116.92	2.73	4142.90	1774.44	2368
70	118.12	2.36	4185.42	2070.18	2115
80	119.18	2.09	4222.98	2365.92	1857
90	120.15	1.87	4257.35	2661.66	1596
96	120.71	1.76	4277.20	2839.10	1438

Maximum storage volume	**3142**	m^3
Critical Storm Period	**18.5**	hr

References

Reference 1. Na ional Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.
Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.
Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels
Denotes parameters which are calculated based on other parameters

Table E12

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C6 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	4	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	710	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.62	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	668.78	7.39	661
0.5	28.64	68.74	869.85	14.79	855
0.75	32.51	52.02	987.38	22.18	965
1	35.48	42.58	1077.59	29.57	1048
1.5	39.85	31.88	1210.31	44.36	1166
2	43.22	25.93	1312.67	59.15	1254
3	48.66	19.46	1477.89	88.72	1389
4	52.92	15.88	1607.27	118.30	1489
5	56.41	13.54	1713.27	147.87	1565
6	59.35	11.87	1802.56	177.44	1625
7	61.91	10.61	1880.31	207.02	1673
8	64.12	9.62	1947.43	236.59	1711
9	66.05	8.81	2006.05	266.17	1740
10	67.76	8.13	2057.99	295.74	1762
11	69.28	7.56	2104.15	325.31	1779
12	70.63	7.06	2145.15	354.89	1790
13	71.84	6.63	2181.90	384.46	1797
14	72.92	6.25	2214.70	414.04	1801
14.25	73.18	6.16	2222.60	421.43	1801
14.5	73.42	6.08	2229.89	428.82	1801
14.75	73.67	5.99	2237.48	436.22	1801
15	73.91	5.91	2244.77	443.61	1801
15.5	74.37	5.76	2258.74	458.40	1800
16	74.81	5.61	2272.11	473.18	1799
16.5	75.23	5.47	2284.86	487.97	1797
17	75.63	5.34	2297.01	502.76	1794
18	76.39	5.09	2320.09	532.33	1788
19	77.08	4.87	2341.05	561.91	1779
20	77.72	4.66	2360.49	591.48	1769
25	80.33	3.86	2439.76	739.35	1700
30	82.24	3.29	2497.77	887.22	1611
35	83.8	2.87	2545.15	1035.09	1510
40	85.11	2.55	2584.94	1182.96	1402
50	87.23	2.09	2649.32	1478.70	1171
60	88.87	1.78	2699.13	1774.44	925
70	90.33	1.55	2743.48	2070.18	673
80	91.69	1.38	2784.78	2365.92	419
90	92.98	1.24	2823.96	2661.66	162
91	93.1	1.23	2827.61	2691.23	136
92	93.23	1.22	2831.55	2720.81	111
93	93.36	1.20	2835.50	2750.38	85
94	93.48	1.19	2839.15	2779.96	59
95	93.61	1.18	2843.10	2809.53	34
96	93.73	1.17	2846.74	2839.10	8

Maximum storage volume	**1801**	m^3
Critical Storm Period	**14.75**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E13

Calculation of attentuation storage during a 1 in 100 year storm event plus an allowance for climate change for the attenuation basin C7 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	3	ha	Derived consistent with Sec ion 5 and as shown on Figure 5.
Discharge rate	569	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0.66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving he runoff coefficient a dominant vegeta ion type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	40%	unitless	The recommended upper end increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3) to test the sensitivity of the design and additional mitigation.

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	29.69	166.26	908.01	5.93	902
0.5	38.79	108.61	1186.32	11.85	1174
0.75	44.39	82.86	1357.59	17.78	1340
1	48.39	67.75	1479.92	23.71	1456
1.5	54.55	50.91	1668.31	35.56	1633
2	59.39	41.57	1816.34	47.42	1769
3	67.22	31.37	2055.80	71.13	1985
4	73.3	25.66	2241.75	94.84	2147
5	78.18	21.89	2390.99	118.55	2272
6	82.2	19.18	2513.94	142.26	2372
7	85.57	17.11	2617.00	165.97	2451
8	88.42	15.47	2704.16	189.68	2514
9	90.88	14.14	2779.40	213.39	2566
10	93.02	13.02	2844.85	237.10	2608
15	100.66	9.39	3078.50	355.64	2723
16	101.76	8.90	3112.14	379.35	2733
17	102.77	8.46	3143.03	403.06	2740
18	103.69	8.06	3171.17	426.77	2744
18.25	103.9	7.97	3177.59	432.70	2745
18.5	104.11	7.88	3184.02	438.63	2745
18.75	104.31	7.79	3190.13	444.56	2746
19	104.52	7.70	3196.55	450.48	2746
19.25	104.71	7.62	3202.37	456.41	2746
19.5	104.9	7.53	3208.18	462.34	2746
19.75	105.09	7.45	3213.99	468.26	2746
20	105.28	7.37	3219.80	474.19	2746
20.5	105.63	7.21	3230.50	486.05	2744
21	105.98	7.07	3241.21	497.90	2743
22	106.63	6.79	3261.08	521.61	2739
23	107.23	6.53	3279.43	545.32	2734
24	107.8	6.29	3296.87	569.03	2728
25	108.31	6.07	3312.46	592.74	2720
30	110.48	5.16	3378.83	711.29	2668
35	112.15	4.49	3429.90	829.84	2600
40	113.5	3.97	3471.19	948.38	2523
50	115.52	3.23	3532.97	1185.48	2347
60	116.92	2.73	3575.79	1422.58	2153
70	118.12	2.36	3612.49	1659.67	1953
80	119.18	2.09	3644.90	1896.77	1748
90	120.15	1.87	3674.57	2133.86	1541
96	120.71	1.76	3691.70	2276.12	1416

Maximum storage volume	**2746**	m^3
Critical Storm Period	**19**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on he restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E14

Calculation of attentuation storage during a 1 in 30 year storm event plus an allowance for climate change for the attenuation basin C7 catchment using the Rational Method (reference 1)

Parameter	Value	Units	Reference
Catchment area	3	ha	Derived consistent with Section 5 and as shown on Figure 5.
Discharge rate	569	m^3/day	QBAR (2l/s/ha)
Runoff coefficient	0 66	unitless	The runoff coefficent has been calculated using the nomogram presented on Figure 3 of Reference 1. In deriving the runoff coefficient a dominant vegetation type of cultivated land or short grass has been assumed and dominant soil type of clay/loam has been assumed. The slope is derived based on the catchment.
Climate change factor	20%	unitless	The recommended precautionary increase in rainfall intensity to allow for climate change for 2085 to 2115 (reference 3).

Storm Duration (hr)	Rainfall for the site derived from reference 2 (mm)	Rainfall Intensity corrected for climate change (mm/hr)	Volume of rainfall run off in time period (m^3)	Outflow in time period (m^3)	Storage necessary in time period (m^3)
0.25	22.02	105.70	577.24	5.93	571
0.5	28.64	68.74	750.77	11.85	739
0.75	32.51	52.02	852.22	17.78	834
1	35.48	42.58	930.08	23.71	906
1.5	39.85	31.88	1044.63	35.56	1009
2	43.22	25.93	1132.98	47.42	1086
3	48.66	19.46	1275.58	71.13	1204
4	52.92	15.88	1387.25	94.84	1292
5	56.41	13.54	1478.74	118.55	1360
6	59.35	11.87	1555.81	142.26	1414
7	61.91	10.61	1622.92	165.97	1457
8	64.12	9.62	1680.85	189.68	1491
9	66.05	8.81	1731.45	213.39	1518
10	67.76	8.13	1776.27	237.10	1539
11	69.28	7.56	1816.12	260.81	1555
12	70.63	7.06	1851.51	284.52	1567
13	71.84	6.63	1883.22	308.22	1575
14	72.92	6.25	1911.54	331.93	1580
14.5	73.42	6.08	1924.64	343.79	1581
15	73.91	5.91	1937.49	355.64	1582
15.25	74.14	5.83	1943.52	361.57	1582
15.5	74.37	5.76	1949.55	367.50	1582
15.75	74.59	5.68	1955.31	373.43	1582
16	74.81	5.61	1961.08	379.35	1582
16.25	75.02	5.54	1966.59	385.28	1581
16.5	75.23	5.47	1972.09	391.21	1581
16.75	75.43	5.40	1977.33	397.14	1580
17	75.63	5.34	1982.58	403.06	1580
17.5	76.02	5.21	1992.80	414.92	1578
18	76.39	5.09	2002.50	426.77	1576
18.5	76.74	4.98	2011.67	438.63	1573
19	77.08	4.87	2020.59	450.48	1570
20	77.72	4.66	2037.36	474.19	1563
21	78.32	4.48	2053.09	497.90	1555
22	78.87	4.30	2067.51	521.61	1546
23	79.39	4.14	2081.14	545.32	1536
24	79.88	3.99	2093.99	569.03	1525
25	80.33	3.86	2105.78	592.74	1513
30	82.24	3.29	2155.85	711.29	1445
35	83.8	2.87	2196.75	829.84	1367
40	85.11	2.55	2231.09	948.38	1283
50	87.23	2.09	2286.66	1185.48	1101
60	88 87	1.78	2329.65	1422.58	907
70	90 33	1.55	2367.92	1659.67	708
80	91 69	1.38	2403.58	1896.77	507
90	92 98	1.24	2437.39	2133.86	304
96	93.73	1.17	2457.05	2276.12	181

Maximum storage volume	**1582**	m^3
Critical Storm Period	**15.5**	hr

References

Reference 1. National Coal Board, 1982. Technical Management of Water in the Coal Mining Industry.

Reference 2. The Institute of Hydrology, 1999. Flood Estimation Handbook.

Reference 3. https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances#peak-rainfall-intensity-allowances

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels

Denotes parameters which are calculated based on other parameters

Table E15

Indicative height of the bunds needed round the proposed attenuation basins to accommodate additional storage needed for 1 in 100 year event with 40% allowance for climate change (CC)

Catchment	Storage volume for 1 in 30 year event with 20% CC (m^3)	Storage volume for 1 in 100 year event with 40% CC (m^3)	Area of basin designed to hold storage volume for 1 in 30 year event with 20% CC (m^2)	Additional storage needed for 1 in 100 year event with 40% CC (m^3)	Indicative height of bund needed to accommodate 1 in 100 year event with 40% CC (m)
Catchment 1 – Attenuation basin C1	8,465	14,975	8,900	6,510	0.7
Catchment 2 – Attenuation basin C2	2,902	5,040	3,525	2,138	0.6
Catchment 3 – Attenuation basin C3	3,806	6,619	2,780	2,813	1.0
Catchment 4 – Attenuation basin C4	1,315	2,284	1,575	969	0.6
Catchment 5 – Attenuation basin C5	2,702	4,703	3,310	2,001	0.6
Catchment 6 – Attenuation basin C6	1,801	3,142	1,215	1,341	1.1
Catchment 7 – Attenuation basin C7	1,582	2,746	2,225	1,164	0.5

APPENDIX F

DRAINAGE DITCH CALCULATIONS

Table F1. Calculations of the conveyancing capacity of the western drainage ditch northwards and southwards from the proposed discharge locations using the Manning Resistance Equation

Western perimeter drainage ditch draining to west east crossing from catchments 3 & 4 & from off site

Parameter	Value	Unit	Justification
Flow rate	63	l/s	Greenfield runoff from upstream catchment and catchments 3 & 4 (2l/s/ha)
Flow rate for 100 year flood event plus climate change	316	l/s	The 1 in 100 year plus 40% allowance for climate change rainfall event for upstream catchment and catchments 3 & 4 (based on greenfield runoff rate above)
Elevation of drain bed at upstream end	85.25	mAOD	The elevation of the current topography along western boundary at proposed C3 & C4 discharge locations - 0.75m (depth of ditch from surface water features survey in October 2019)
Elevation of bed at downstream end	82.00	mAOD	The elevation of ground at the southern crossing - 0.75m (depth of ditch from surface water features survey in October 2019)
Length of ditch	163	m	The length of the western perimeter ditch from the area of C3 & C4 discharges to the southern culvert
Manning roughness coefficient	0.12305		Calculated based on Table F2.
Bed width	1	m	Ditch dimension from surface water features survey in October 2019
Depth of flow	0.30	m	The average depth of the channel.
Channel area	0.3	m^2	Calculated.
Wetted perimeter	1.60	m	Calculated.
Hydraulic radius	0.19		Calculated.
Gradient	0.0200		Calculated.
Discharge	0.11	m^3/s	Calculated using the Manning Resistance Equation as presented in Reference 1
Discharge	112.89	l/s	Calculated.
Depth of flow	0.70	m	The average depth of the channel.
Channel area	0.7	m^2	Calculated.
Wetted perimeter	2.40	m	Calculated.
Hydraulic radius	0.29		Calculated.
Gradient	0.0200		Calculated.
Discharge	0.35	m^3/s	Calculated using the Manning Resistance Equation as presented in Reference 1
Discharge	354	l/s	Calculated.

Western perimeter drainage ditch draining to southern ditch from catchment 5 & from off site

Parameter	Value	Unit	Justification
Flow rate	13	l/s	Greenfield runoff from upstream catchment and catchment 5 (2l/s/ha)
Flow rate for 100 year flood event plus climate change	67	l/s	The 1 in 100 year plus 40% allowance for climate change rainfall event for upstream catchment and catchment 5 (based on greenfield runoff rate above)
Elevation of drain bed at upstream end	88.39	mAOD	The elevation of the current topography along western boundary at proposed C5 discharge location - 0.75m (depth of ditch from surface water features survey in October 2019)
Elevation of bed at downstream end	87.35	mAOD	The elevation of ground at the southern track - 0.75m (depth of ditch from surface water features survey in October 2019)
Length of ditch	63	m	The length of the western perimeter ditch from the area of C5 discharge to the southern track
Manning roughness coefficient	0.107		Calculated based on Table F2.
Bed width	0 6	m	Ditch dimension from surface water features survey in October 2019
Depth of flow	0.20	m	The average depth of the channel.
Channel area	0.12	m^2	Calculated.
Wetted perimeter	1.00	m	Calculated.
Hydraulic radius	0.12		Calculated.
Gradient	0 0166		Calculated.
Discharge	0.04	m^3/s	Calculated using the Manning Resistance Equation as presented in Reference 1
Discharge	35.17	l/s	Calculated.
Depth of flow	0.40	m	The average depth of the channel.
Channel area	0.24	m^2	Calculated.
Wetted perimeter	1.40	m	Calculated.
Hydraulic radius	0.17		Calculated.
Gradient	0 0166		Calculated.
Discharge	0.09	m^3/s	Calculated using the Manning Resistance Equation as presented in Reference 1
Discharge	89.24	l/s	Calculated.

References

Reference 1. Highways Agency. February 2004. Drainage of runoff from natural catchments. Design manual for roads and bridges, Volume 4, Section 2, Part 1. Report reference HA 106/04

Denotes parameters which are determined based on the restoration scheme, rainfall data or other constraints on discharge or water levels
Denotes parameters which are calculated based on other parameters
Denotes parmeters which are specified to achieve the necessary flow in the ditch

Table F2. Calculation of Manning's Roughness Coefficient, n

$n = (n_b + n_1 + n_2 + n_3 + n_4)m$

Western ditch draining to north			
Parameter	**Symbol**	**Value**	**Justification**
Base value	n_b	0.032	Upper end of values for straight uniform channel in Firm Soil (ie clay material).
Irregularity of the channel	n_1	0.005	Upper end of minor iregularities.
Cross section	n_2	0.005	Size and shape of channel does not change significantly. This is the upper end of the alternating occasionally category.
Obstructions	n_3	0.015	Upper end of minor obstructions category.
Vegetation	n_4	0.05	Upper end of large category.
Meandering	m	1.15	Appreciable meandering - a bend in the ditch course (~35degrees) & will be followed by a further bend (~20 degrees)
	n	0.12305	

Western ditch draining to south			
Parameter	**Symbol**	**Value**	**Justification**
Base value	n_b	0.032	Upper end of values for straight uniform channel in Firm Soil (ie clay material).
Irregularity of the channel	n_1	0.005	Upper end of minor iregularities.
Cross section	n_2	0.005	Size and shape of channel does not change significantly. This is the upper end of the alternating occasionally category.
Obstructions	n_3	0.015	Upper end of minor obstructions category.
Vegetation	n_4	0.05	Upper end of large category.
Meandering	m	1	No significant meandering
	n	0.107	

References

Reference 1. United States Geological Survey. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Catchments and Floodplains. United States Geological Survey Water-Supply Paper