

HAVANT BOROUGH  
COUNCIL

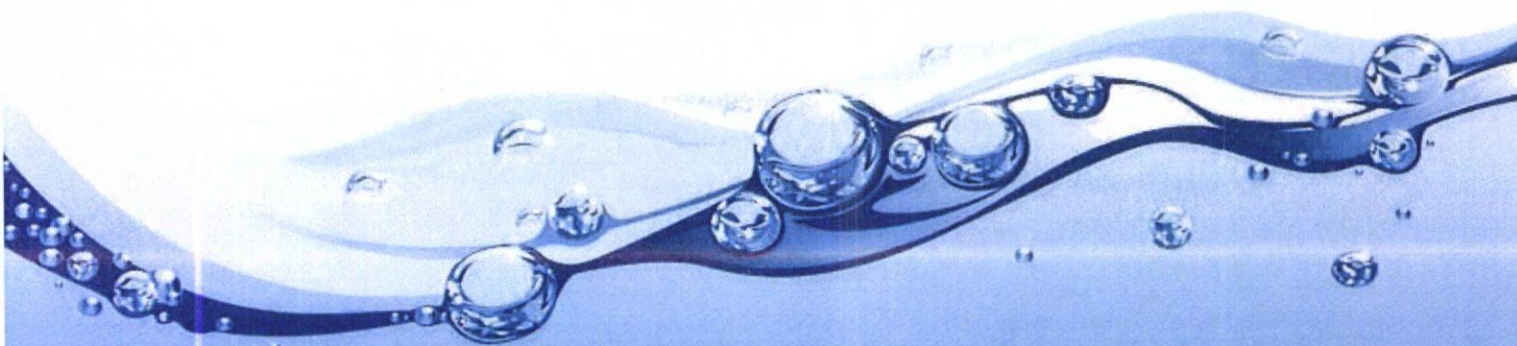
07 JUN 2013

RECEIVED

**Portsmouth Golf Course**  
**Crookhorne Lane, Portsmouth**

**Drainage Strategy**

**May 2013**



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## INFORMATION AND VERIFICATION RECORD

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### CLIENT

Glendale Golf Ltd

### SCHEME DESCRIPTION AND LOCATION

Drainage Strategy for course improvements at Portsmouth Golf Course, Crookhorne Lane, Waterloooville, Portsmouth, PO7 5QL

### INSTRUCTION:

Received from Mr Charles Robinson of Parkwood Consultancy Services.

### REPORT FORMAT:

This report has been prepared to address current and on-going drainage problems. This report is supported by surface water modelling which has been carried out to understand overland flow regimes.

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Prepared by                      Aled Williams BSc (Hons)

Reviewed by                     Andrew Russell BEng (Hons)

Technical Review by         Chris Lewis MEng (Hons)

Approved by                    Paul Hodgkiss

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Document Reference Number..... w3084-130501-Drainage Strategy

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## 1 Overview

- 1.1 This Drainage Strategy has been prepared in support of course improvement works at Portsmouth Golf Course, Crookhorne Lane, Waterloooville, Portsmouth, PO7 5QL.
- 1.2 A location plan and an aerial image are included in Appendix A. An indicative Master Plan of the proposed course improvements is included in Appendix B. As shown on the indicative Master Plan the proposed course improvements include the re-profiling of holes 6, 7, 17 and 18 as well as the provision of a new practice area. The main aim of the re-profiling work is to improve the playability of the course.
- 1.3 The site is divided into an east and west side by Crookfield Lane. Holes 6, 7 and the proposed practice area are located on the east side of the course. Holes 17 & 18 are located on the (north) west side of the course.
- 1.4 The site covers an area of approximately 55.3Ha, with the landscaping works covering an area of approximately 6.2Ha.
- 1.5 The western side of the site generally slopes in a north-westerly direction, from around 90m AOD to 65m AOD. The eastern side of the site generally slopes in an easterly direction from around 65m AOD to 30m AOD. Man-made, localised flat spots and pits occur throughout the course in the form of greens, tees, bunkers and water features such as ponds and ditches.
- 1.6 This report is supported by surface water modelling which has been carried out to understand existing surface water run-off mechanisms. A site visit was also carried out on 15/04/2013 to inform this Drainage Strategy.

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## 2 Ground Conditions

- 2.1 A review of the British Geological Survey (BGS) Geology of Britain Map showed that the site is underlain by clay, silt and sandy soils. Exposed clay was witnessed on parts of the site during the site visit, in particular on the 6<sup>th</sup> and 7<sup>th</sup> holes. Clay soils have poor infiltration characteristics and become damp during periods of heavy / prolonged rainfall.

## 3 Surface Water Modelling

- 3.1 A 2-Dimensional (2D) hydraulic model has been developed to establish the current surface water run-off mechanism at Portsmouth Golf Course and quantify the existing surface water issues on the site.
- 3.2 Detailed coarse and fine scale 2D digital terrain models (DTM) of the existing golf course and surrounding land have been developed from a detailed topographical survey and 2m LIDAR data. A series of extreme rainfall events were then applied onto the DTM areas to establish the predicted flow paths of the run-off, and areas susceptible to ponding / flooding.
- 3.3 The outputs from the surface water run-off modelling of the *existing* site, along with anecdotal evidence, will then be used to support the design of proposed course alterations; the objective of which is to alleviate surface water issues whilst improving the playability of the course.
- 3.4 The following section documents the methodology adopted to carry out the surface water modelling and simulation results that were produced.

### Direct Rainfall Method

- 3.5 The 'Direct Rainfall' method, as described in the 'Surface Water Management Plan Technical Guidance' (DEFRA, March 2010) has been chosen as the most appropriate methodology for simulating design events at the site.
- 3.6 Direct rainfall methods apply rainfall events (of known probability) directly to a model built using DTM data. This method computes run-off volumes and routes flow across the surface identifying pathways and areas where ponding and flooding would occur in low points. This is vital to determine existing surface water issues on site and off site.

- 3.7 The rainfall hyetographs used in the hydraulic models were developed using the Revitalised Flood Hydrograph (ReFH) methodology and associated spreadsheet. Details on the rainfall calculations are included in Appendix C.

#### Initial Coarse Scale Hydraulic Modelling

- 3.8 To identify the key areas of interest where surface water flooding is currently an issue an initial coarse scale model (5m grid resolution DTM) was developed of the whole golf course and surrounding area. The model covers an area of approximately 180 hectares.
- 3.9 The 33.3% (1 in 30) and 1% (1 in 100) annual exceedence probability (or AEP) rainfall events were simulated. Simulation results taken from the coarse scale model identified the general surface water run-off routes across the site and show areas where surface water ponding occurs during an extreme event; results are included in Appendix D. These initial results show potential surface water flooding issues on/near the:
- Clubhouse car park
  - 6<sup>th</sup> fairway and area adjacent to the green
  - 16<sup>th</sup> green
  - 17<sup>th</sup> fairway
  - 18<sup>th</sup> tee
  - Ditch running through the eastern region of golf course
  - Underpass linking eastern and western parts of the course

- 3.10 These results were presented to the client at a site meeting on 15/4/2013. The findings were confirmed as being accurate by the course manager and course designer.

#### Fine Scale Hydraulic Modelling

- 3.11 Following the evaluation of the coarse scale model results, fine scale 2D modelling (2m grid resolution DTM) was undertaken of the specific site areas which have high potential for significant surface water run-off flow and ponding. Fine scale modelling enables more accurate simulation of flow paths across a DTM and enables accurate representation of watercourses and ponds.
- 3.12 The golf course is divided into two separate catchment areas by Crookhorn Lane which runs north to south. As such two fine scale models have been developed to represent these separate catchments. For the purpose of this report they are referred to as the *West Model* and *East Model*. The coverage of the two fine scale models is presented in Figure 3.1 overleaf. The extreme south-west

(Ports Down) and south-east areas of the golf course have been excluded from the 2m models as no significant surface water issues were identified in either the coarse scale modelling or the site visit.

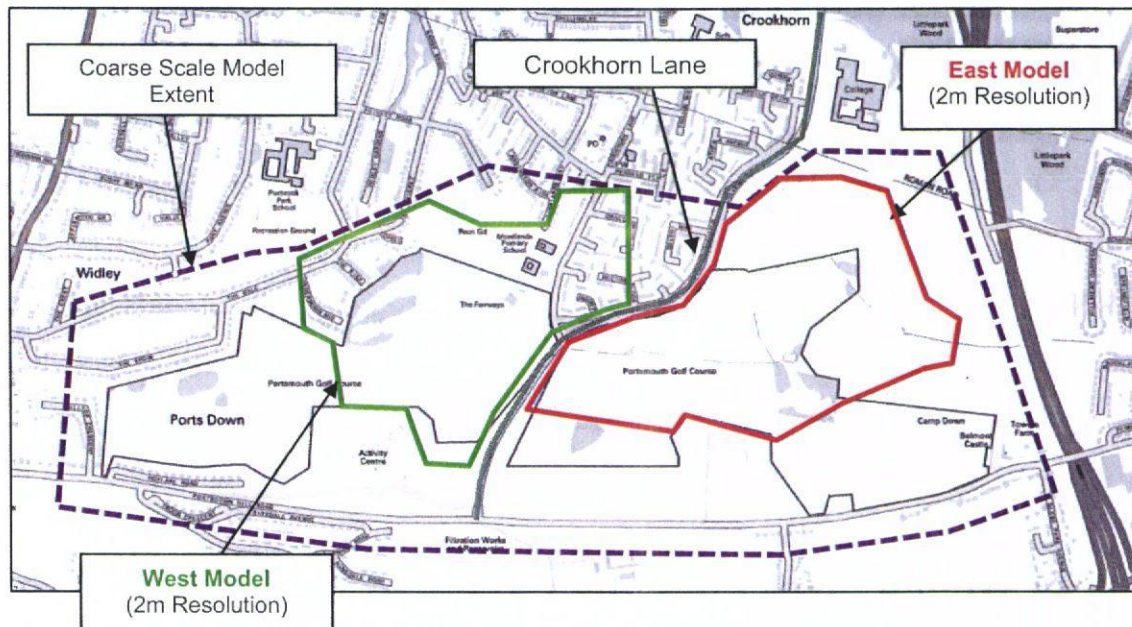


Figure 3.1 - 2D Hydraulic Model Extents

- 3.13 The *West Model* covers an area of approximately 32 hectares located near the Clubhouse and the 18<sup>th</sup> tee. The *East Model* covers an area of approximately 32 hectares in the north-east region of the golf course.
- 3.14 There are a number of small manmade ditches and ponds across the golf course; these have been represented in the 2m DTM. Following the site visit, culverts diverting flow beneath the fairways / 16<sup>th</sup> green have been included in the model.
- 3.15 The 1% AEP rainfall event has been simulated using both the West and East models. In accordance with best practice, a scenario investigating future climate change allowance (CCA) has also been simulated i.e. 1% AEP + CCA event. This was achieved by increasing rainfall intensity by 30%.
- 3.16 Maximum water depth plots extracted from the 2m models are given in Appendix E.

#### 4 Summary of Current Site Drainage and Fine Scale Modelling

- 4.1 A site walkover was carried out on 15/04/2013 to verify the initial surface water modelling and highlight any structures such as culverts, to be incorporated into the fine scale (2m DTM) model

##### Eastern Extent (Holes 6, 7 and Practice Area)

- 4.2 The majority of the eastern part of the course is drained via a drainage ditch which flows from west to east.
- 4.3 This ditch flows within a number of culverted channels. The culverts vary in size with pipe diameters ranging from 100mm to 300mm. The ditch also varies in size along its route and flows into two ponds, one at the upstream end, and one at the downstream end (near to the eastern site boundary). This is shown on the surface water modelling extract (Figure 4.1) below:

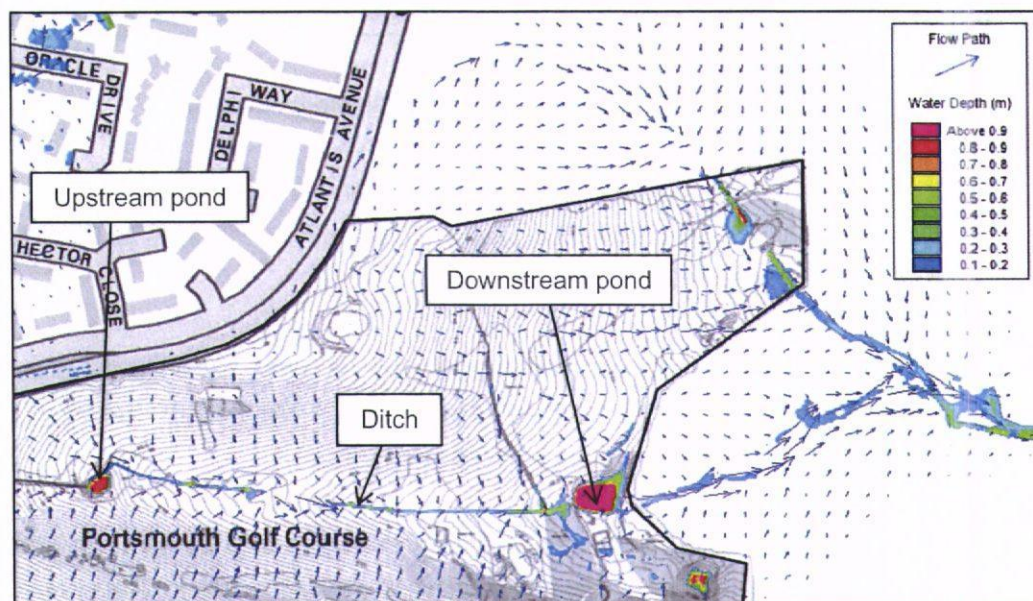


Figure 4.1

- 4.4 A number of pipes feed into the ditch along its route. The origin of these pipes is unknown however it is assumed that these are perforated drainage pipes which drain the surrounding course. The flow from these pipes is accounted for in the model.

- 4.5 Figure 4.2 shows the pond at the downstream (eastern) end of the site. The ditch drains into this pond before discharging into the neighbouring field (shown in Figure 4.3).



Figure 4.2

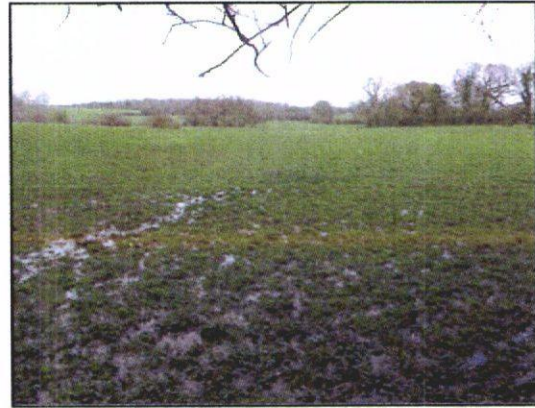


Figure 4.3

- 4.6 The surface water modelling results (Appendix E) show that during the 1% AEP event, run-off discharging into the adjacent field flows east before joining a formal ditch approximately 275m east of the site. This ditch flows in a culverted channel through Bedhamton and joins the Hermitage Stream approximately 1.6km south-east of the site.
- 4.7 The north eastern extent of the site drains via a separate drainage channel as shown in Figure 4.4 below. This channel drains agricultural land to the north of the site and becomes culverted underneath the 6<sup>th</sup> green (Figure 4.5). The surface water modelling shows that during the 1% AEP event, flow backs up behind the 6<sup>th</sup> green culvert inlet (Figure 4.5) and causes shallow depth flooding (100mm – 400mm deep) between the green and the 7<sup>th</sup> fairway.



Figure 4.4



Figure 4.5

- 4.8 Areas of saturated, waterlogged ground (not of sufficient depth to show in the surface water modelling results) were encountered on the 6<sup>th</sup> and 7<sup>th</sup> fairways.

#### **Western Extent (Holes 16, 17 & 18)**

- 4.9 Figure 4.6 below shows the locations of the key drainage features and overland flow regimes at the western extent of the site.

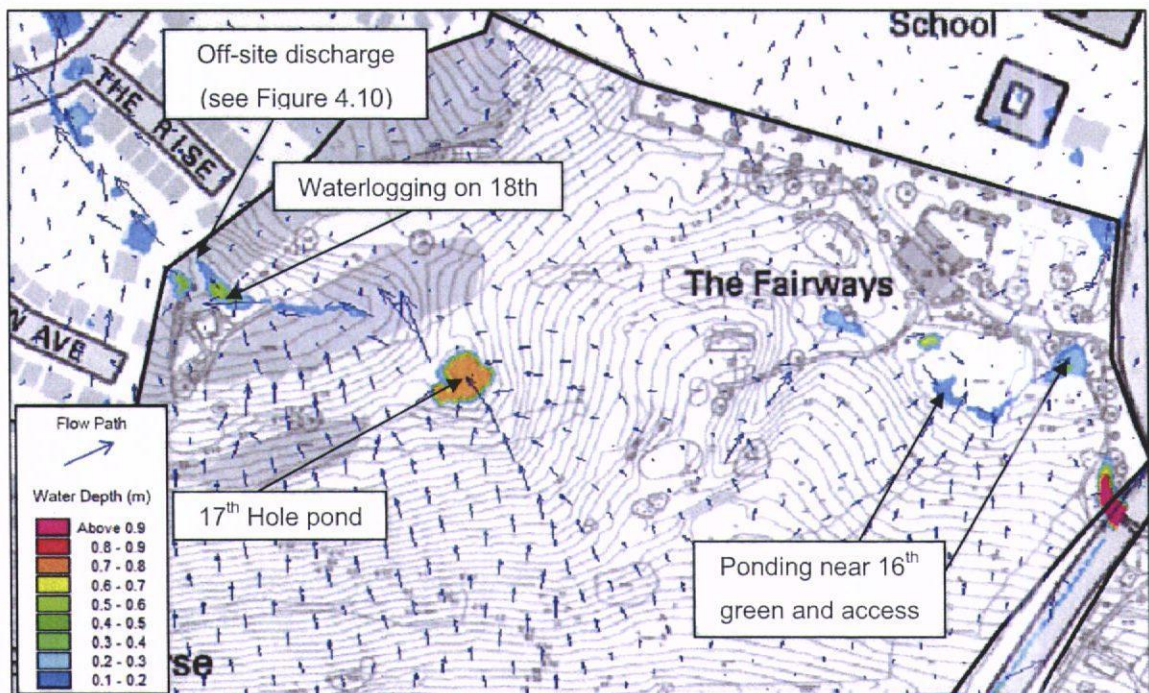


Figure 4.6

- 4.10 Run-off from the western extent of the site drains via ditches, pipes and culverts. The topography generally falls from south-east to north-west with waterlogging occurring at topographic low points adjacent to the 18<sup>th</sup> tee area and 16<sup>th</sup> green.
- 4.11 The majority of run-off from the higher ground to the southern extent of the site drains naturally into a pond on the 17<sup>th</sup> fairway (as shown in Figure 4.7 overleaf) which partially attenuates flows. Run-off is also directed into a small channel in a woodland area which separates the 17<sup>th</sup> and 18<sup>th</sup> holes. As shown in the modelling results (in Figure 4.6 above and in Appendix E) this channel directs run-off towards the 18<sup>th</sup> tee and causes waterlogging (shown in Figure 4.8) and shallow depth flooding of up to 300mm during the 1% AEP + CCA event.



Figure 4.7



Figure 4.8

- 4.12 A formal channel appears in the woodland area to the north (downstream) of the waterlogged area at the 18<sup>th</sup> tee (see Figure 4.9). The source of this channel is unknown, however it is likely to originate from perforated drainage pipes. This channel flows into a 225mm piped culvert (see Figure 4.10) where surface water is discharged off-site. This culvert likely joins the public sewer system. It is assumed that the surface water sewers (highway drains) serving the residential areas immediately north of the site drain into a small stream located adjacent to Widley Gardens (road) approximately 240m north of culvert shown in figure 4.10.



Figure 4.9



Figure 4.10

- 4.13 Off-site flooding has occurred in garden areas of properties immediately downstream of the culvert shown in Figure 4.10. This flooding was likely caused as a result of a blockage of the culvert inlet. The modelling results (Appendix E) show a flow route through neighbouring gardens.

- 4.14 Other drainage features on the western part of the course include a ditch running alongside the 18<sup>th</sup> fairway. This ditch was dry at the time of the site visit and does not show as a flow receptor in the surface water modelling.
- 4.15 Waterlogged areas were also encountered around the 16<sup>th</sup> green (near to the site access). As shown in the modelling results (Appendix E) surface water collects in hollows adjacent to the green. The modelling also shows shallow depth surface water ponding occurs near to the access road and in the car park area. The course manager confirmed that flooding occurs at the site access.
- 4.16 No above ground drainage channels are present near to the 16<sup>th</sup> green. However drain covers were found in this area which indicates a system of underground drains. These drains likely discharge off-site and into the sewer network in the adjacent roads.

## 5 Course Improvements & Drainage Solutions

- 5.1 As shown on the Master Plan in Appendix B and as discussed in the site meeting, the proposed course improvements include:

### Eastern extent

- Re-profiling land to create a new practice area
- Safety mounding between the practice area and College Road
- Re-profiling the 6<sup>th</sup> hole to improve drainage of the fairway
- Re-profiling and de-silting the pond on the 6<sup>th</sup> hole
- Re-profiling sections of the 7<sup>th</sup> fairway
- Placement of a new pond along the drainage channel on the eastern part of the site

### Western extent

- Re profiling of the 17<sup>th</sup> fairway and re-location of the pond
- Re profiling of the 18<sup>th</sup> fairway to improve drainage
- Placement of a new pond / water feature near the 18<sup>th</sup> tee

- 5.2 The proposed re-profiling will improve the drainage of the fairways and practice area through directing surface water run-off to ditches. The introduction of imported material (soils) will improve the infiltration rate on site and reduce the waterlogging problem.

- 5.3 There are three ponds on the existing site which play a key role in providing attenuation and reducing run-off leaving the site. These ponds are identified as Pond 1 (17<sup>th</sup> fairway), Pond 2 (adjacent to 9<sup>th</sup> hole) and Pond 3 (6<sup>th</sup> hole) in Figure 5.1 below.

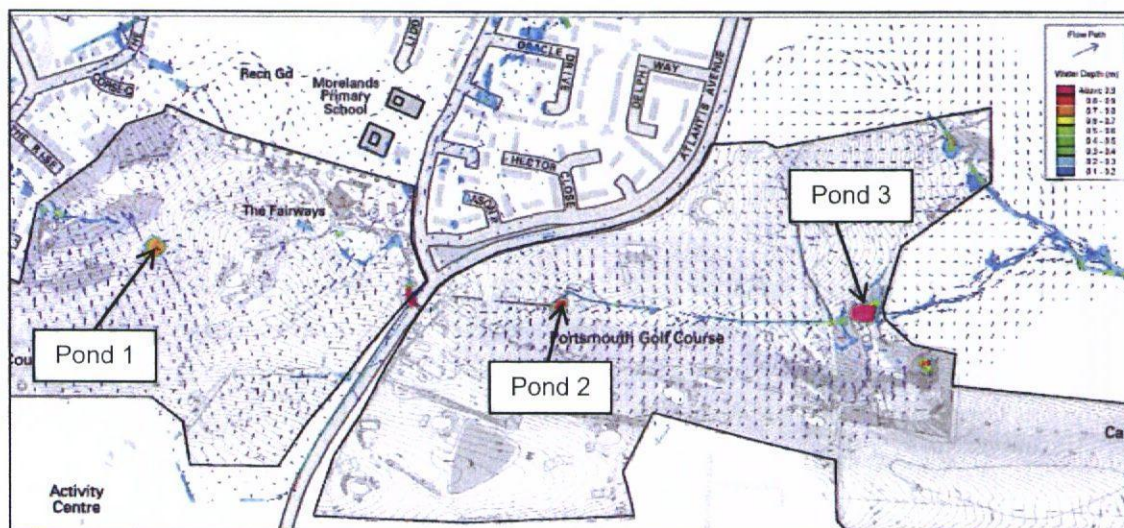


Figure 5.1

- 5.4 An assessment of the pond volumes has been carried out as part of the surface water modelling study. Approximate pond volumes during the 1% AEP + CCA event are included below:

|                                         | <b>Pond 1</b><br>17th Hole | <b>Pond 2</b><br>9th Hole | <b>Pond 3</b><br>Hole 6 |
|-----------------------------------------|----------------------------|---------------------------|-------------------------|
| Assumed Depth (mm)                      | 300                        | 500                       | 500                     |
| Assumed Bed Level (m AOD)               | 63                         | 55.79                     | 39.8                    |
| Surveyed WL (m AOD)                     | 63.3                       | 56.29                     | 40.3                    |
| 1% AEP Water Level (m AOD)              | 63.73                      | 56.61                     | 41.26                   |
| 1% AEP + CCA Water Level (m AOD)        | 63.75                      | 56.66                     | 41.3                    |
| Approx. Pond Volume (m <sup>3</sup> ) * | <b>393.56</b>              | <b>154.77</b>             | <b>1025.09</b>          |

\* Approximate pond volume assuming uniform depth as stated. No pond bathymetry data available

- 5.5 It is proposed to relocate Pond 1 to the side of the fairway. This is to improve the playability of the 17<sup>th</sup>. The pond volume of 393.56m<sup>3</sup> should be retained and if possible increased to provide betterment in terms of attenuation storage.

- 
- 5.6 Pond 2 is to be retained, however it is recommended that this pond is de-silted to improve its attenuation capacity. The inflow and outflow channels to / from the pond should be cleared of any overgrown vegetation or debris.
- 5.7 It is proposed to re-profile and de-silt Pond 3. The volume of the pond (1025m<sup>3</sup>) should be retained and if possible increased to minimize off site run-off. Run-off discharging from this pond (off-site) could be controlled by an outflow orifice or hydro-brake. Provision should be made for an overflow structure to enable discharge (not to exceed existing) from the pond during extreme rainfall events i.e. the 0.1% AEP (1 in 1000 year) event.
- 5.8 It is proposed to introduce 2 new ponds on site; one between Ponds 2 and 3 and one near the 8<sup>th</sup> tee which was waterlogged during the site visit. The storage volume of these ponds is to be determined by the client. The provision of new attenuation ponds will provide an increase in attenuation storage and will provide betterment in terms of a reducing run-off leaving the site.
- 5.9 A new pond near the 18<sup>th</sup> tee will provide further surface water attenuation storage. An attenuation pond in this location would reduce the likelihood of flooding to the gardens of nearby properties. Run-off discharging from this pond (off-site) could be controlled by an outflow orifice or hydro-brake. This will reduce the rate and volume of run-off entering the culvert (public sewer system) to the north of the site.

Further Recommendations / Considerations

- 5.10 A maintenance routine should be established to clear any ditches, ponds and culvert inlets / outlets of vegetation and debris.
- 5.11 The screen on the culvert as shown in Figure 4.10 should be regularly checked for blockage.
- 5.12 The source of the channel shown in Figure 4.9 should be investigated further. Perforated drainage pipes may be present in the location of the proposed pond near the 18<sup>th</sup> tee.
- 5.13 The developer should consider creating a pond adjacent to the 16<sup>th</sup> tee. This pond would provide attenuation storage. The outfall from this pond could be controlled by an outflow orifice or hydro-brake and should be connected to the existing (underground) drains which run near to the 16<sup>th</sup> green. The provision of a pond and flow control could potentially alleviate the current flooding problems at the site access.

- 5.14 The surface water modelling results (Appendix E) shows that significant ponding, with potential depths greater than 0.9m, occurs in the underpass which links the eastern and western sides of the course. This underpass, shown in Figure 5.2 below, is drained by drainage grates which link to the highway drainage. These grates should be regularly cleared of debris (mud) to reduce the likelihood of blockage and resulting surface water ponding.



Figure 5.2

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## 6 Summary and Conclusions

- 6.1 This Drainage Strategy has been prepared in support of course improvement works at Portsmouth Golf Course, Crookhorne Lane, Waterloo, Portsmouth.
- 6.2 Initial coarse scale surface water modelling has been carried out to identify the key areas of interest where surface water flooding is currently an issue.
- 6.3 Following an evaluation of the coarse scale model results and site visit, fine scale 2D modelling was undertaken of specific site areas which have high potential for significant surface water run-off flow and ponding.
- 6.4 The surface water modelling highlighted potential surface water flooding issues on/near the:
- Clubhouse car park
  - 6<sup>th</sup> fairway and area adjacent to the green
  - 16<sup>th</sup> green
  - 17<sup>th</sup> fairway
  - 18<sup>th</sup> tee
  - Ditch running through the eastern region of golf course
  - Underpass linking eastern and western parts of the course
- 6.5 Proposed course improvement works include the re-profiling of land; introduction of new attenuation ponds; and the re-profiling, de-silting and relocation of existing ponds. The proposed course improvements will enhance the playability of the course and improve the course drainage.
- 6.6 The course improvement works allow the opportunity to reduce the surface water run-off rates leaving the site by controlling discharge from the attenuation ponds through the use of outflow orifices or hydro-brakes.
- 6.7 Existing off site flooding problems to the north of the 18<sup>th</sup> hole could be alleviated through establishing a maintenance schedule to ensure culvert inlets (and outlets) are regularly checked for blockage and debris is cleared.
- 6.8 The provision of a pond and flow control near the 18<sup>th</sup> tee and 16<sup>th</sup> green would reduce the surface water run-off rates and volumes leaving the western part of the site during storm events. This would reduce the severity of any off site flooding or flooding on the sites access.

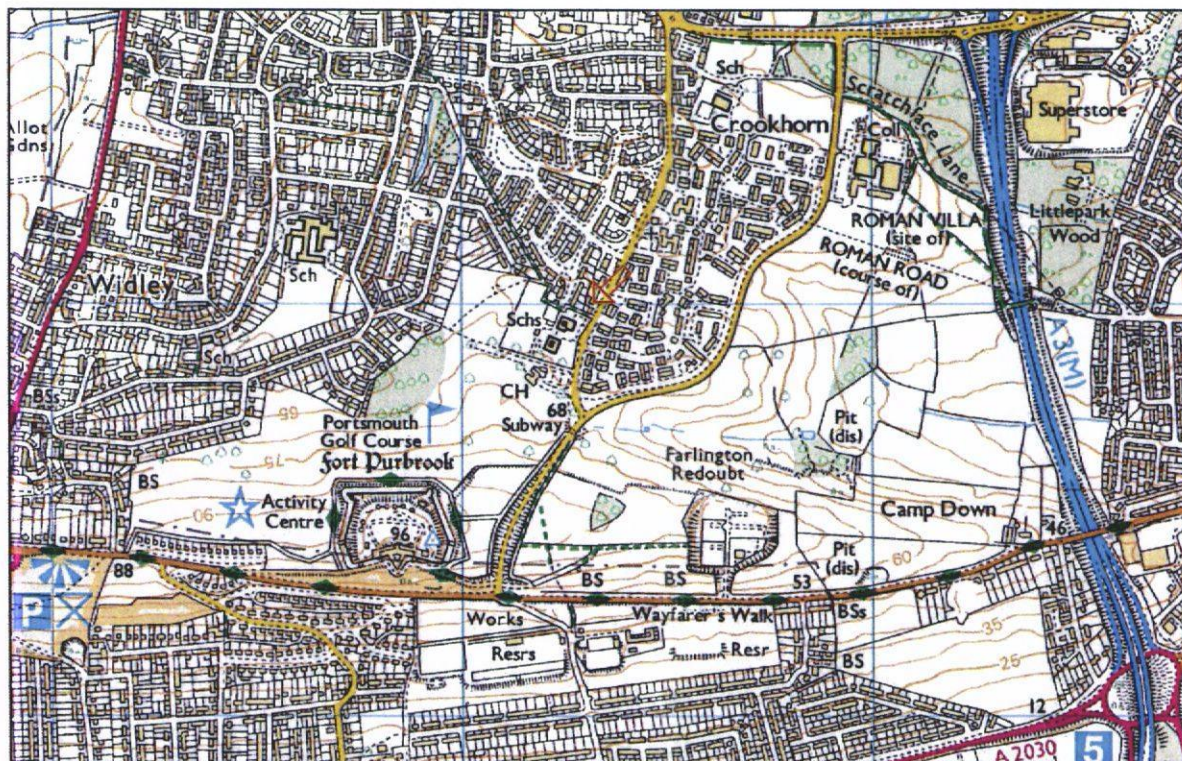
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- 6.9 The existing pond on the 6<sup>th</sup> fairway is to be de-silted and re-profiled. Run-off discharging from this pond (off-site) could be controlled by an outflow orifice or hydro-brake. This would reduce surface water run-off rates leaving the eastern part of the course during storm events.
- 6.10 The re-profiling of the practice area and the 6<sup>th</sup>, 7<sup>th</sup>, 17<sup>th</sup> and 18<sup>th</sup> holes using inert material (imported soil) will improve the infiltration rates and natural drainage. This will reduce any waterlogging experienced on the fairways.

## **7 Recommendations**

- 7.1 To fully quantify the effects of the proposed course re-profiling the proposed site layout should be modelled.
- 7.2 The environmental / ecological impact of any de-silting of the ponds should be investigated further.

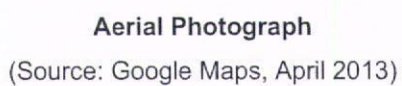
## Appendix

### A – Location Plan and Aerial Image



Site Location Plan

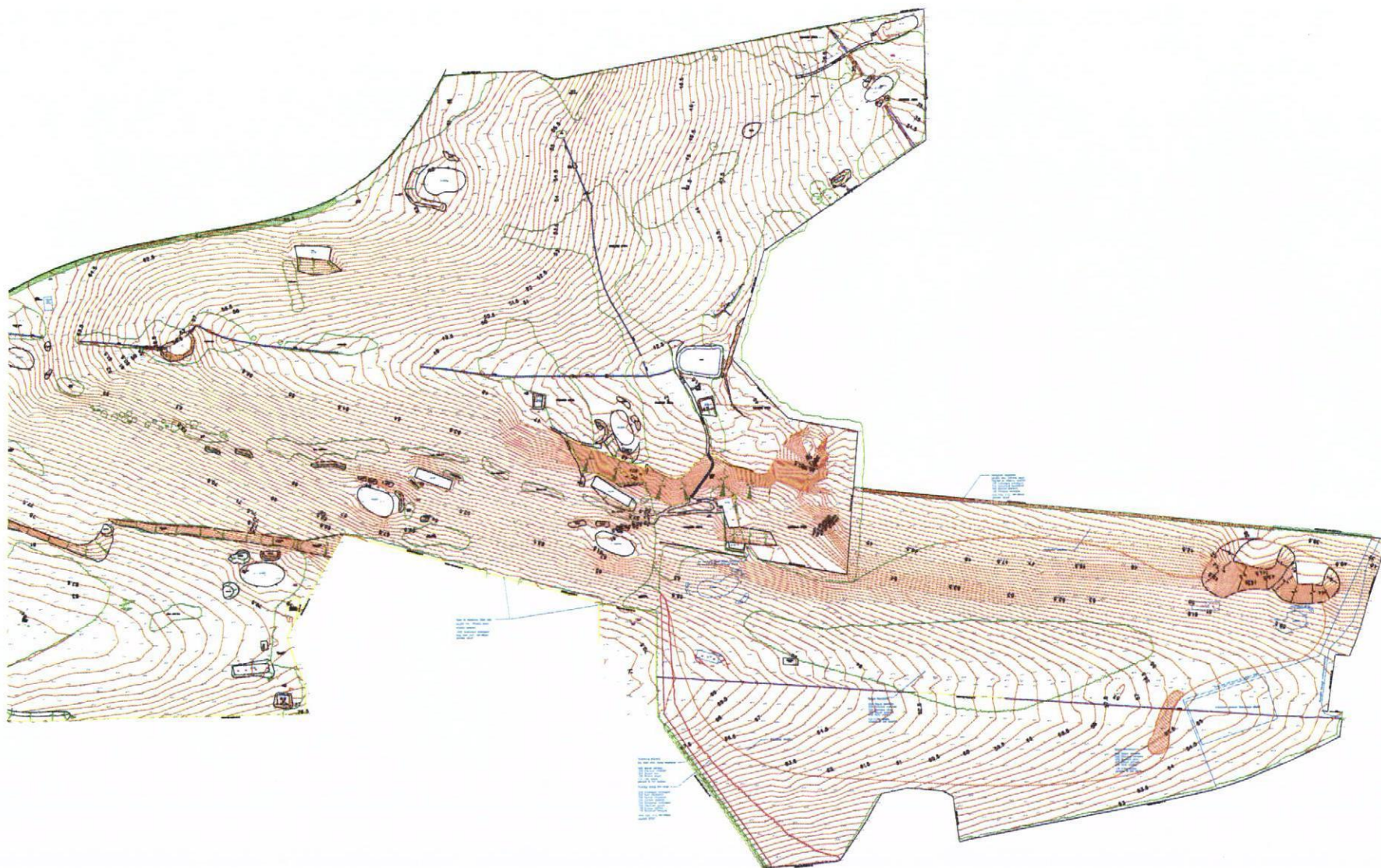
(Source: Streetmap, April 2013)



## Appendix

### B – Topographic Survey and Master Plan

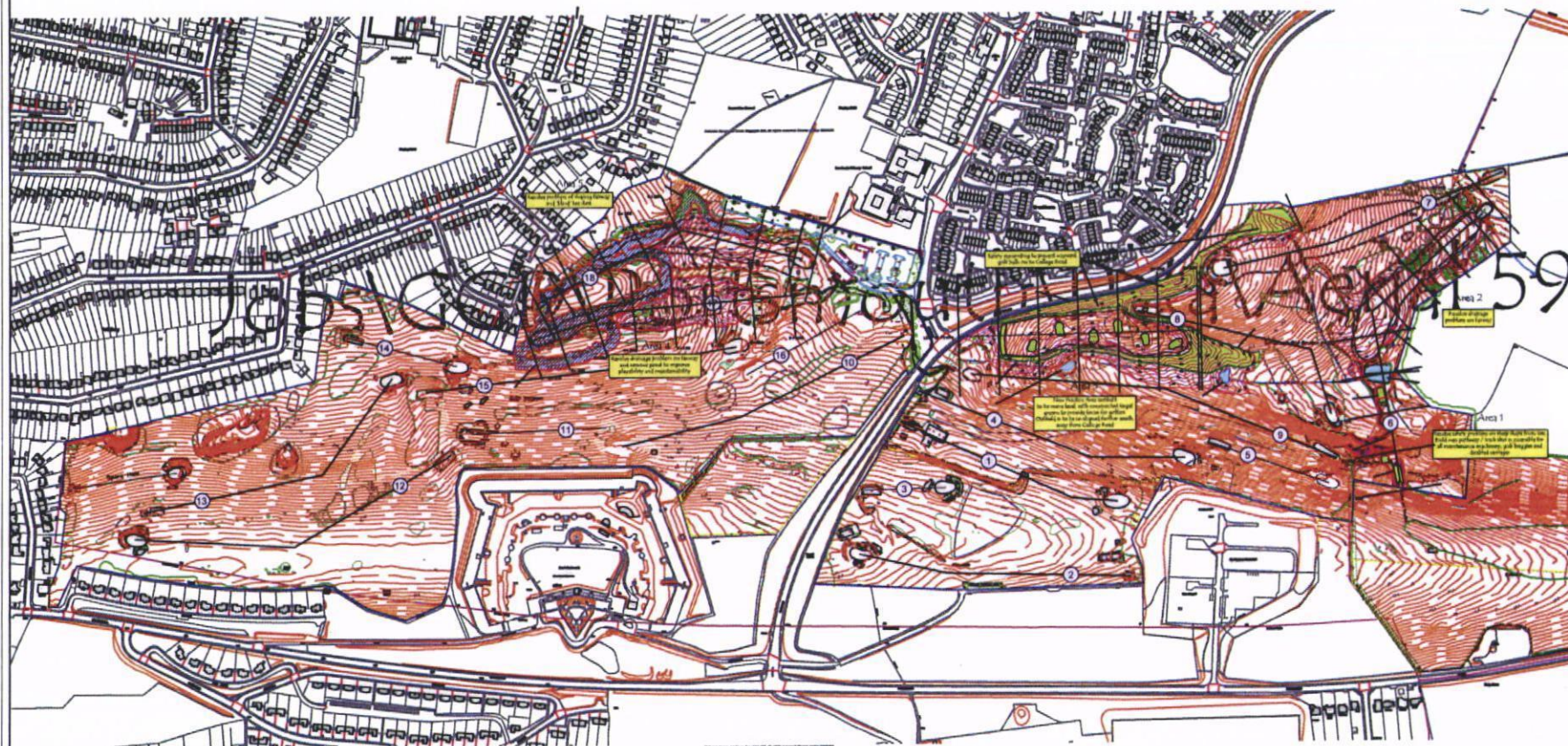






LOGO:Glenale Golf.jpg

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| Revision History |
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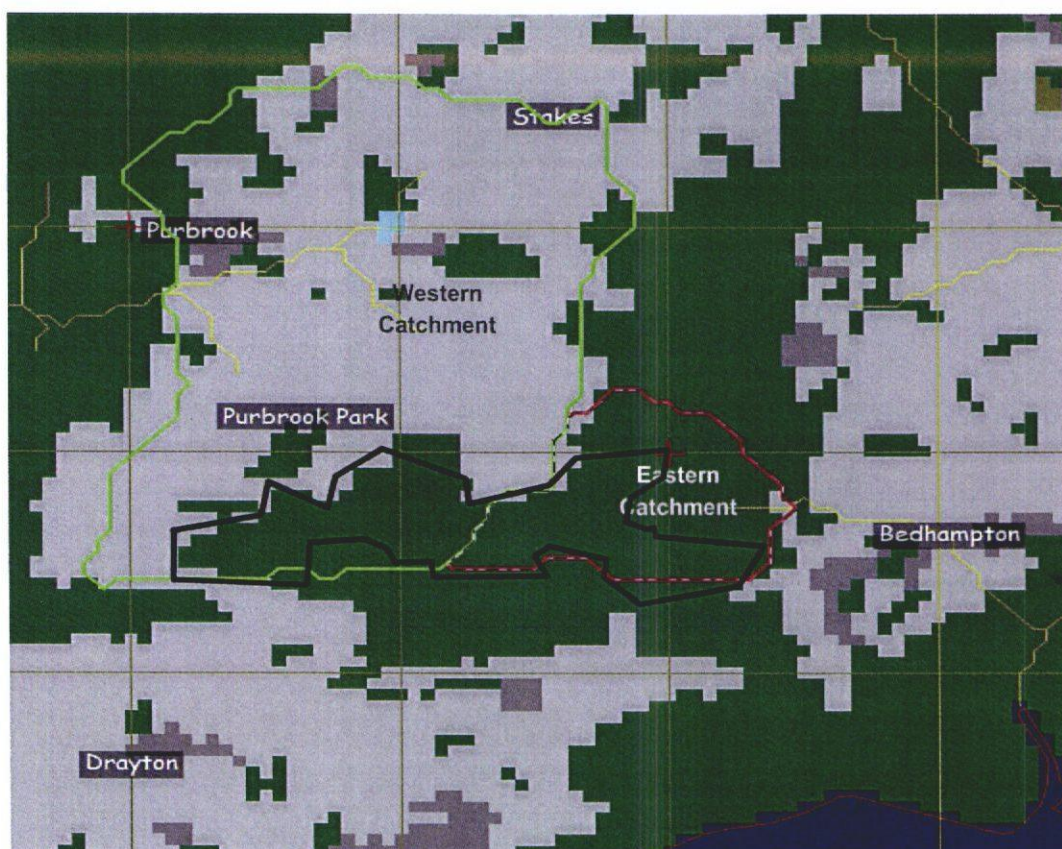
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|-------------|----------------------|
| Client:     | Portsmouth Golf Club |
| Project:    | Course Improvements  |
| Drawing:    | Master Plan          |
| Drawn By:   | J.C.C.               |
| Check:      | 07/09/10 J.C.C.      |
| Drawn Date: | 07/09/10             |
| Check Date: | 07/09/10             |
| Drawn No:   | 001-001-010          |
| Revision:   | 1 of 1               |

**Appendix**  
C – Rainfall Calculations

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                        |                                                 |              |                                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|---------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>             |
| Client :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br>1 of 7 |
| Scheme :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Portsmouth Golf Course |                                                 |              | revision<br>A                   |
| Section :                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Rainfall Analysis      |                                                 |              |                                 |
| prepared by: Laura Howe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                        | date:                                           |              | 15/04/2013                      |
| checked by: Chris Lewis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                        | date:                                           |              | 15/04/2013                      |
| approved by: Paul Hodgkiss                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                        | date:                                           |              | 15/04/2013                      |
| <b>Project Description</b> <div style="border: 1px solid black; padding: 10px; margin-top: 10px;"> <p>2D surface water runoff model used to model proposed reprofiling of Portsmouth Golf Course.</p> <p>Rainfall analysis required to determine peak rainfall rates, event duration and event hyetograph. Events to be considered include the 1 in 30 and the 1 in 100 return periods.</p> <p>Portsmouth golf course is located across 2 catchments in the FEH CD-ROM 3 (referred to as Eastern and Western catchments).</p> <p>Both Wallingford and ReFH methods are to be used. The highest peak calculated will be used as an input to the 2D model; this is considered to be conservative.</p> </div> |                        |                                                 |              |                                 |

|                                                                                   |                        |                                                 |              |                                        |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|----------------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>                    |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br><b>2 of 7</b> |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |              | revision                               |
| Section :                                                                         | Rainfall Analysis      |                                                 |              | <b>A</b>                               |

**FEH Catchments (Taken from FEH CD-ROM 3)**



Approximate Site Boundary shown in Black

Note: Golf course crosses 2 catchments (50:50) - Both catchments have been reviewed.

|                                                                                   |                        |                                                 |              |                                     |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|-------------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>                 |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br><br>3 of 7 |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |              |                                     |
| Section :                                                                         | Rainfall Analysis      |                                                 |              | revision<br><br>A                   |

## FEH Catchment Descriptors

### Western Catchment:

FEH CD-ROM 3 - Catchment Descriptors

Subject Site Location : 467150 107700 [SU 67150 07700]  
Catchment centroid : 467858 107558 [SU 67858 07558]

Catchment Descriptors

|                             |                     |
|-----------------------------|---------------------|
| AREA : 3.35 km <sup>2</sup> | RMED-1H : 8.9 mm    |
| ALTBAR : 53 m               | RMED-1D : 34.7 mm   |
| ASPBAR : 341 degrees        | RMED-2D : 43.5 mm   |
| ASPVAR : 0.30               | SAAR : 768 mm       |
| BFDHOST : 0.394             | SAAR-1170 : 773 mm  |
| DPLBAR : 1.38 km            | SPRHOST : 39.2      |
| DPSBAR : 36.7 m/km          | URBCONC1990 : 0.682 |
| FARL : 0.977                | URBEXT1990 : 0.3011 |
| LDP : 2.67 km               | URBLOC1990 : 0.979  |
| PROPWET : 0.34              | URBCONC2000 : 0.920 |
| FPEXT : 0.1000              | URBEXT2000 : 0.3851 |
| FPLOC : 0.674               | URBLOC2000 : 0.950  |
| FPOBAR : 0.69 cm            |                     |

Catchment average DOF values

|            |            |
|------------|------------|
| C : -0.028 | D3 : 0.378 |
| D1 : 0.457 | E : 0.306  |
| D2 : 0.288 | F : 2.242  |

1 km point DOF values for 467000 108000 [SU 67000 08000]

|                  |                  |
|------------------|------------------|
| C(1 km) : -0.027 | D3(1 km) : 0.376 |
| D1(1 km) : 0.459 | E(1 km) : 0.304  |
| D2(1 km) : 0.288 | F(1 km) : 2.243  |

Export... Cancel

### Eastern Catchment:

FEH CD-ROM 3 - Catchment Descriptors

Subject Site Location : 469450 106750 [SU 69450 06750]  
Catchment centroid : 468993 106784 [SU 68993 06784]

Catchment Descriptors

|                             |                     |
|-----------------------------|---------------------|
| AREA : 0.68 km <sup>2</sup> | RMED-1H : 8.9 mm    |
| ALTBAR : 50 m               | RMED-1D : 34.7 mm   |
| ASPBAR : 85 degrees         | RMED-2D : 43.6 mm   |
| ASPVAR : 0.49               | SAAR : 755 mm       |
| BFDHOST : 0.469             | SAAR-1170 : 757 mm  |
| DPLBAR : 0.67 km            | SPRHOST : 35.2      |
| DPSBAR : 72.8 m/km          | URBCONC1990 : 0.000 |
| FARL : 1.000                | URBEXT1990 : 0.0055 |
| LDP : 1.39 km               | URBLOC1990 : 0.547  |
| PROPWET : 0.34              | URBCONC2000 : 0.500 |
| FPEXT : 0.0294              | URBEXT2000 : 0.0276 |
| FPLOC : 0.331               | URBLOC2000 : 1.220  |
| FPOBAR : 0.17 cm            |                     |

Catchment average DOF values

|            |            |
|------------|------------|
| C : -0.029 | D3 : 0.379 |
| D1 : 0.457 | E : 0.309  |
| D2 : 0.294 | F : 2.238  |

1 km point DOF values for 469000 107000 [SU 69000 07000]

|                  |                  |
|------------------|------------------|
| C(1 km) : -0.029 | D3(1 km) : 0.379 |
| D1(1 km) : 0.456 | E(1 km) : 0.310  |
| D2(1 km) : 0.298 | F(1 km) : 2.242  |

Export... Cancel

|                                                                                   |                        |                                                 |              |                                 |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|---------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>             |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br>4 of 7 |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |              | revision                        |
| Section :                                                                         | Rainfall Analysis      |                                                 |              | A                               |

### Method 1 - ReFH (Revitalised Flood Hydrograph Method)

The golf course crosses 2 catchments in the FEH CD-ROM 3 (50% in each). As such, both are reviewed below.

ReFH spreadsheet (v1.4) has been used for each catchment. Recommended storm durations and time steps were used. Peaks rainfall rates are detailed below for both catchments:

*Note: Golf course crosses 2 catchments (50:50) - Both catchments are reviewed below.*

Western catchment                      3.35 km<sup>2</sup>

Eastern catchment                      0.68 km<sup>2</sup>

#### Western Catchment

| Return Period<br>(yr) | Time Step<br>(hr) | Storm Duration<br>(hr) | Infall Intensity<br>(mm/ts)   (mm/hr) |             |
|-----------------------|-------------------|------------------------|---------------------------------------|-------------|
| 30                    | 0.1               | 1.5                    | 3.1                                   | 31.0        |
| 100                   | 0.1               | 1.5                    | 4.4                                   | <b>44.0</b> |

#### Eastern Catchment

| Return Period<br>(yr) | Time Step<br>(hr) | Storm Duration<br>(hr) | Infall Intensity<br>(mm/ts)   (mm/hr) |             |
|-----------------------|-------------------|------------------------|---------------------------------------|-------------|
| 30                    | 0.1               | 2.1                    | 3.7                                   | 26.4        |
| 100                   | 0.1               | 2.1                    | 5.3                                   | <b>37.9</b> |

|                                                                                   |                        |                                                 |              |                                        |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|----------------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>                    |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br><b>5 of 7</b> |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |              |                                        |
| Section :                                                                         | Rainfall Analysis      |                                                 |              | revision<br><b>A</b>                   |

**Method 2 - Wallingford**

Using rainfall intensity tables taken from Wallingford Procedure (1981) the following rainfall intensities were calculated:

M5-60 min =                      19

M5-60/M5-2day =                0.4

| Return Period (yr) | Storm Duration (hr) | Rainfall Intensity (mm/hr) |
|--------------------|---------------------|----------------------------|
| 30                 | 1                   | 29.8                       |
| 30                 | 2                   | 18.0                       |
| 100                | 1                   | <b>38.4</b>                |
| 100                | 2                   | <b>23.2</b>                |

|                                                                                   |                        |                                                 |              |                                 |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|--------------|---------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 | Calculations | ref<br><b>w3084</b>             |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |              | no of pages attached:<br>6 of 7 |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |              |                                 |
| Section :                                                                         | Rainfall Analysis      |                                                 |              | revision<br>A                   |

**Final peaks for ReFH & Wallingford methods during the 1% AEP event**

| Method (yr) | Catchment | Storm Duration (hr) | Rainfall Intensity (mm/hr) |
|-------------|-----------|---------------------|----------------------------|
| Wallingford | -         | 1                   | 38.4                       |
|             |           | 2                   | 23.2                       |
| ReFH        | WC        | 1.5                 | 44                         |
|             | EC        | 2.1                 | 37.9                       |

**Final peak chosen - ReFH method (Western Catchment)**

ReFH method takes into account more catchment descriptors than the Wallingford method and so was favoured in this case. It also presents a 'worst case' result.

The Western catchment was chosen over the Eastern catchment as the peak rainfall is higher; this is considered conservative.

Hyetographs have been taken directly from the ReFH calculations and are presented on page 7. They have then been converted from mm/6mins to mm/day for import into the MIKE21 Surface Water model.

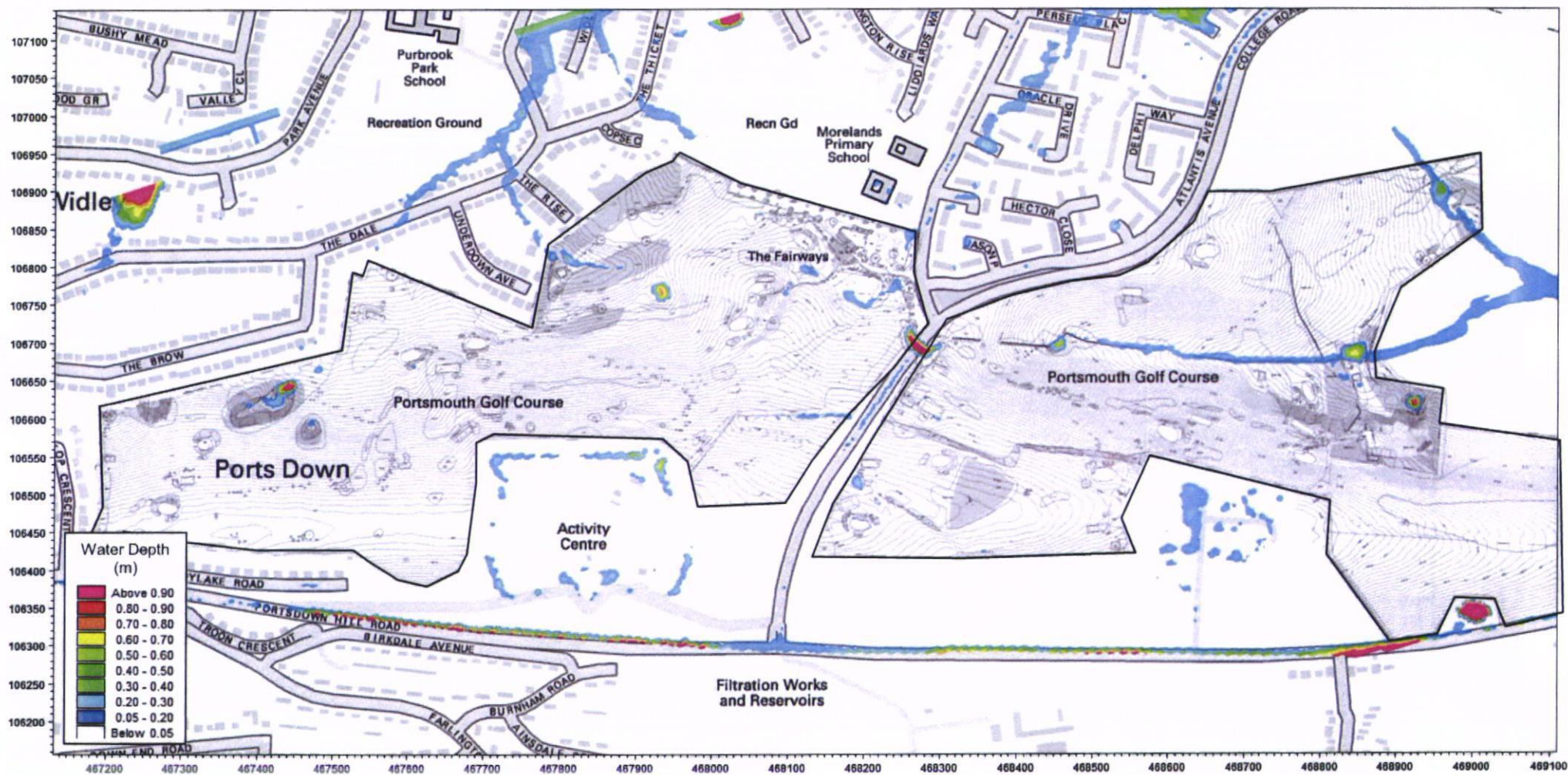
|                                                                                   |                        |                                                 |                                                                   |              |                                      |                                                              |
|-----------------------------------------------------------------------------------|------------------------|-------------------------------------------------|-------------------------------------------------------------------|--------------|--------------------------------------|--------------------------------------------------------------|
|  |                        | Eden Court, Lon Parcwr,<br>Ruthin, 01824 702220 |                                                                   | Calculations |                                      | ref<br><b>w3084</b>                                          |
| Client :                                                                          | Glendale Golf Ltd      |                                                 |                                                                   |              |                                      | no of pages attached:<br><br>7 of 7<br><br>revision<br><br>A |
| Scheme :                                                                          | Portsmouth Golf Course |                                                 |                                                                   |              |                                      |                                                              |
| Section :                                                                         | Rainfall Analysis      |                                                 |                                                                   |              |                                      |                                                              |
| <b>Western Catchment Hyetograph</b>                                               |                        |                                                 |                                                                   |              |                                      |                                                              |
|                                                                                   | As per ReFH SS         |                                                 | Rate converted to /hr (i.e. x10<br>- number of time steps in 1hr) |              | Rate converted to /day<br>(i.e. x24) |                                                              |
| Time                                                                              | 3.33%                  | 1%                                              | 3.33%                                                             | 1%           | 3.33%                                | 1%                                                           |
| hr                                                                                | mm/6mins               | mm/6mins                                        | mm/hr                                                             | mm/hr        | mm/day                               | mm/day                                                       |
| 0                                                                                 | 0.3                    | 0.4                                             | 2.682441                                                          | 3.837397     | 64.37858                             | 92.09753                                                     |
| 0.1                                                                               | 0.4                    | 0.6                                             | 3.919911                                                          | 5.607675     | 94.07787                             | 134.5842                                                     |
| 0.2                                                                               | 0.6                    | 0.8                                             | 5.714391                                                          | 8.174789     | 137.1454                             | 196.1949                                                     |
| 0.3                                                                               | 0.8                    | 1.2                                             | 8.304592                                                          | 11.88023     | 199.3102                             | 285.1256                                                     |
| 0.4                                                                               | 1.2                    | 1.7                                             | 12.01767                                                          | 17.19201     | 288.424                              | 412.6083                                                     |
| 0.5                                                                               | 1.7                    | 2.5                                             | 17.27624                                                          | 24.71472     | 414.6297                             | 593.1534                                                     |
| 0.6                                                                               | 2.4                    | 3.5                                             | 24.49613                                                          | 35.04322     | 587.9071                             | 841.0374                                                     |
| 0.7                                                                               | 3.1                    | 4.4                                             | 30.61574                                                          | 43.79771     | 734.7778                             | 1051.145                                                     |
| 0.8                                                                               | 2.4                    | 3.5                                             | 24.49613                                                          | 35.04322     | 587.9071                             | 841.0374                                                     |
| 0.9                                                                               | 1.7                    | 2.5                                             | 17.27624                                                          | 24.71472     | 414.6297                             | 593.1534                                                     |
| 1                                                                                 | 1.2                    | 1.7                                             | 12.01767                                                          | 17.19201     | 288.424                              | 412.6083                                                     |
| 1.1                                                                               | 0.8                    | 1.2                                             | 8.304592                                                          | 11.88023     | 199.3102                             | 285.1256                                                     |
| 1.2                                                                               | 0.6                    | 0.8                                             | 5.714391                                                          | 8.174789     | 137.1454                             | 196.1949                                                     |
| 1.3                                                                               | 0.4                    | 0.6                                             | 3.919911                                                          | 5.607675     | 94.07787                             | 134.5842                                                     |
| 1.4                                                                               | 0.3                    | 0.4                                             | 2.682441                                                          | 3.837397     | 64.37858                             | 92.09753                                                     |
| 1.5                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 1.6                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 1.7                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 1.8                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 1.9                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2                                                                                 | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.1                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.2                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.3                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.4                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.5                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.6                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.7                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.8                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 2.9                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3                                                                                 | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.1                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.2                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.3                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.4                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.5                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.6                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.7                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.8                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 3.9                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4                                                                                 | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.1                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.2                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.3                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.4                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.5                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.6                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.7                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |
| 4.8                                                                               | 0.0                    | 0.0                                             | 0                                                                 | 0            | 0                                    | 0                                                            |

## Appendix

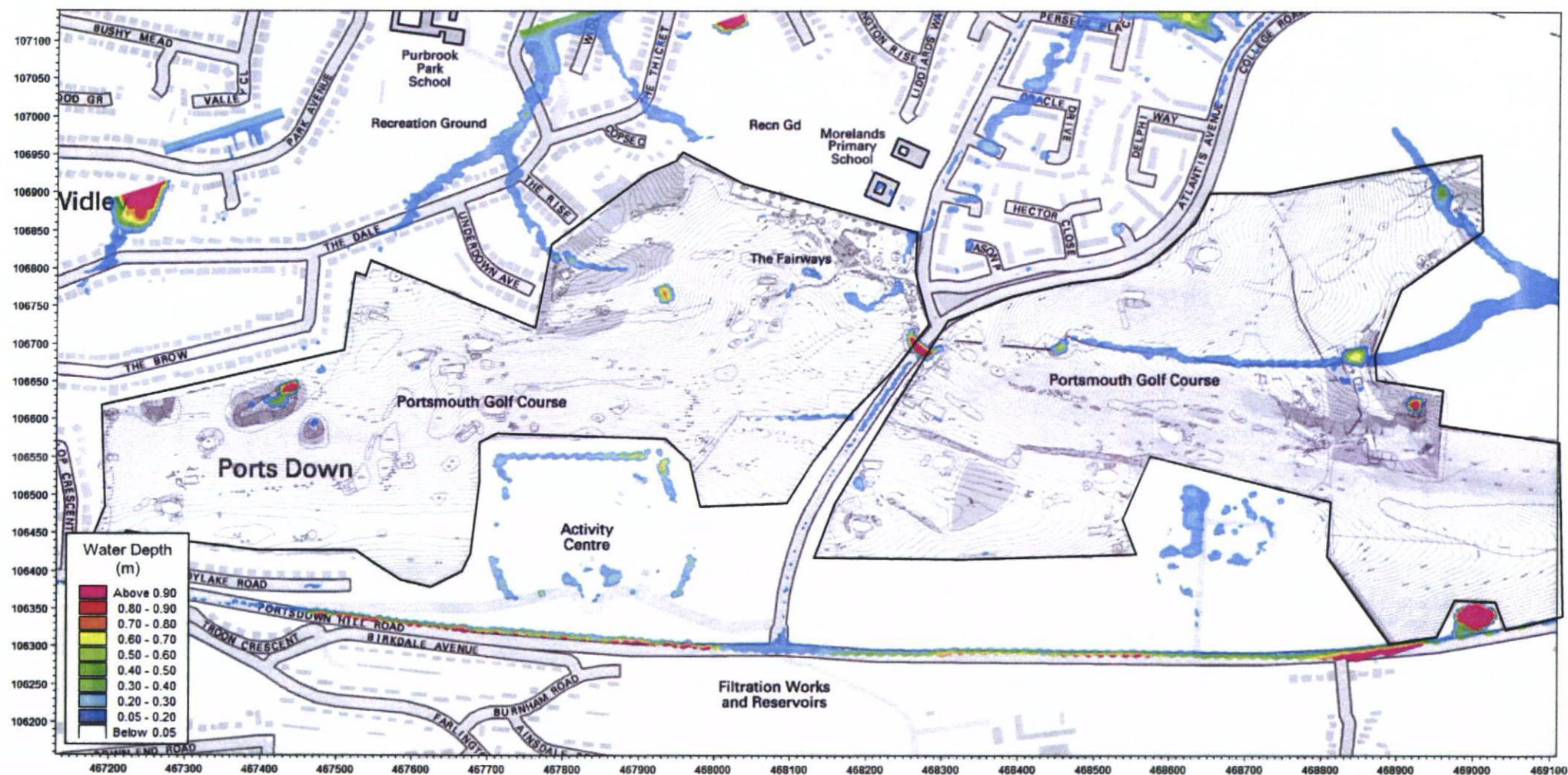
### D – Coarse Scale Model Results

## 5m Grid Model Results

33.3% AEP rainfall event



1% AEP rainfall event



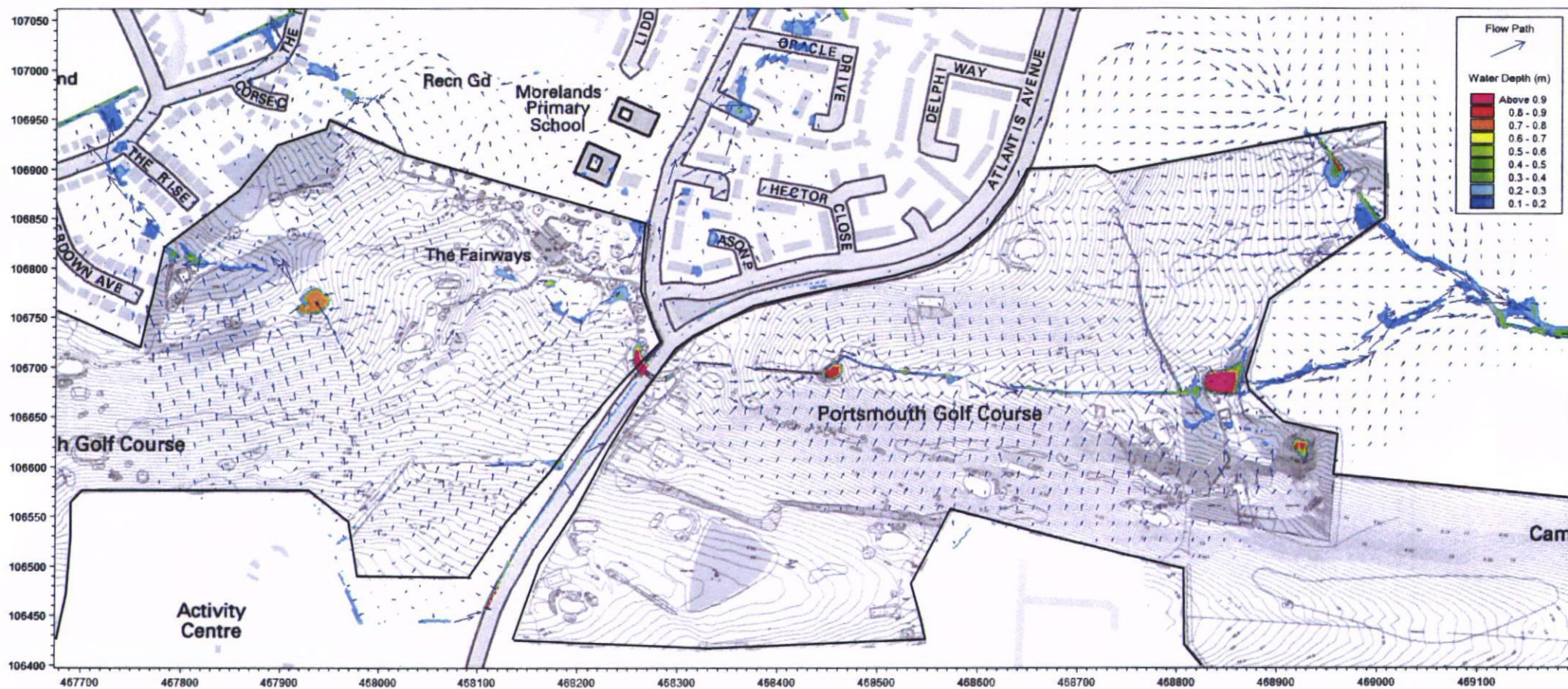


## Appendix

### E – Fine Scale Model Results

## 2m Grid Model Results

1% AEP rainfall event



## 2m Grid Model Results

1% + CCA AEP rainfall event

