Draft Rainwater Harvesting Report

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SPECTRUM CENTRE – GUILDFORD

DRAFT FEASIBILITY REPORT ON RAINWATER HARVESTING
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1. **INTRODUCTION/ INSTRUCTION**

1.1 The building achieved practical completion on 19 January 1993, and as a result of various defects associated with the building it has been recommended by APWCL, in a feasibility report dated March 2014 (as instructed by Guildford Borough Council (GBC)), to re-roof the building as well as carry out other associated works to address these other defects (e.g. improve the air handling to the swimming pool areas).

1.2 The roof drainage system, was originally designed as a siphonic system incorporating valley gutters and the outlets were all piped to the outside perimeter of the building.

1.3 This system was designed for a return period of storm of once in one year, for this area giving a flow rate of 0.021L/s.m², which means that it could not cope with flows greater than this.

1.4 Modern systems, incorporating valley gutters which if they overflowed could do so inside the building are designed in accordance with BS EN 12056-3:2000, where for this particular type of building and location a flow rate of 0.052L/s.m², which is a storm of return period of once in 45 years.

1.5 In order to deal with the gutter leaks into the building, caused in part by inadequate roof drainage, and also to deal with the risk of a 1 in 45 year return period storm occurring and flooding the building, works were carried out in 2008 and 2010 to provide a gravity overflow system to discharge the overflow balance of 0.031L/s.m² from the building to the outside.

1.6 The ground drainage, to deal with the rainwater, was not designed to cope with a flow rate of 0.052L/s.m² and because of topography and services etc it was not possible to incorporate all of this additional flow into soakaways.

1.7 A complete upgrade of the system, i.e. increasing existing pipe diameters, falls of pipes and manhole sizes and depths was not practicable and neither was it acceptable within budgetary constraints, and as such a compromise solution was adopted whereby a soakaway was introduced on the south side of the building to deal with a part of this additional flow, as well as taking some of the
overflow into a manhole on the west side of the building, however this meant that the balance of the overflow would discharge eventually into the River Wey.

1.8 In the March 2014 report, it was recommended that as a new roof was to be installed, the roof drainage scheme should also be renewed to cope with a design flow rate of 0.052L/s.m², with improvements to the existing ground rainwater drainage system as well as introducing further soakaways in order to try and ensure that the under designed existing ground rainwater system along with these measures could cope with a more realistic design flow rate and not impose a further burden on the River Wey in the event of a storm.

1.9 Since the March 2014 report, GBC have instructed APWCL to produce a feasibility report on a Rainwater Harvesting System (RWH).
2. STATEMENT OF TRUTH

I confirm that in so far as the facts stated in my report are within my own knowledge I have made clear which they are and I believe them to be true, and that opinions I have expressed represent my true and complete professional opinion.

Signed:

A P Williamson
Date: 30.01.2015
3. **QUALIFICATIONS OF WRITER**

3.1 The writer of this report, Mr. A. P. Williamson B.Sc. (Hons), C.Eng. M.I.C.E., M.I.Struct.E., F.I.O.R. has been employed in the Construction Industry for the last 47 years.

3.2 The work experience has varied from working for Civil Engineering Contractors on various projects such as motorways and airports, working for a Local Authority on Highway designs, working for a firm of Consultant Engineers on various Structural designs, working for a Transport Authority on the design and installation of various railway structures and maintenance of properties, and for the last 28 years being involved specifically in the Roofing and Cladding Industry.

3.3 Experience in the Roofing and Cladding Industry was with a Roofing and Cladding Contractor for a period of 16 years, involved in Design and Build contracting for many varied Clients such as Railway Authorities, Housing Authorities, Banks, Main Contractors, Developers, School Authorities, Health Authorities and many others.

3.4 Experience of roofing and cladding works has been gained in the design and installation of Industrial Roofing and cladding, from renovation to new build, using many varied systems ranging from self supporting pierce fixed constructions to standing seam constructions, and various materials have been used such as asbestos cement and fibre cement roof sheets, plastisol coated steel, stainless steel and colour coated aluminium.

3.5 The roofing works have incorporated other elements such as various types of glazing systems, including patent glazing and glazed curtain walling systems and also various forms of roof drainage, ventilation systems, roof access and safety systems and associated elements such as secondary steel supports. Experience was also gained in other systems such as built – up felt, single ply membranes, slating and tiling, and also the decking supports to many of these coverings.

3.6 Experience of cladding works involved the design and installation of, for example, twin skin metal constructions, with both over and under rail lining,
composite panels laid both vertically and horizontally, twin skin construction using a variety of different board materials, curtain walling and various types of glazing systems, acoustic sound attenuation louver screens, and other similar constructions including insulated render systems.

3.7 These cladding works have also included integrated window systems and also curtain walling.

3.8 I have also had experience in fully supported standing seam stainless steel roofing, and have aided in the design of various elements of its construction, such as eaves and verge details.

3.9 These works have been carried out on both new build and renovation projects using various forms of contract in many different environments such as green field sites and occupied premises and the value of the largest roofing and cladding contract undertaken was £5m, which included over-roofing using a standing seam pitched roof with cold rolled galvanised steel section truss support over a flat roof to a Railway Depot.

3.10 I was a member of the B.S.I representing the National Federation of Roofing Contractors on various Technical Code Drafting committees such as the revision to BS 5247, and various CEN committees, and was a committee member of the London and Southern Counties region of the N.F.R.C. and sat on the drafting committee of the 3rd Edition of the Guide to Good Practise being specifically responsible for the roof drainage section, and was the chairman of the N.F.R.C. Technical Sheeting and Cladding Committee, and represented the N.F.R.C. on a number of training committees with the C.I.T.B. involving N.V.Q. qualifications and also safety related matters.

3.11 I was also a Technical Committee member of the ZELRO (zero leaks in roofing) group established by leading developers and clients in conjunction with the then Building Research Establishment to produce a good practise code to be used with projects that were associated with the client group.

3.12 I was also a Board member of the Institute of Roofing and have act as a judge at the National Federation of Roofing Contractors Roofing awards.
Apart from carrying out forensic inspections for many varied clients, as a Consultant, I also carry out designs for gutters, secondary steelwork, various cladding elements and curtain walling, and have acted as a Consultant for a major manufacturer of roofing products.

I have also acted as an Expert Witness in cases involving disputes associated with many of the above-mentioned disciplines.
4. **INFORMATION SOURCES**

4.1. Information provided by GBC regarding water usage with regards to urinals and WC’s.


4.4. DEFRA Briefing Note BNWAT06 – Domestic water used in new and existing buildings – Supplementary briefing note.


4.7. UK Rainwater Harvesting Association Briefing Paper – An introductory guide to rainwater harvesting systems.


4.9. Building Regulations Part H3


4.11. BRE Digest 365 - Soakaways
5. **EXECUTIVE SUMMARY**

5.1. Rainwater harvesting has to be designed to BS 8151:2009 and this requires a certain ratio between yield (the amount of yearly runoff from the roofs) and demand, i.e. the use of non-potable water (i.e. mainly used for toilet and urinal flushing).

5.2. The main reason for this ratio is to ensure that there is sufficient storage capacity during storm conditions.

5.3. The yield from the entire roof area and the total demand for non-potable water use would meet this ratio but the amount of storage required (circa 740m$^3$) would not be practicable, particularly as it is preferable to store underground.

5.4. Also given that the rainwater drainage systems are located on the outside perimeter of the building means that distribution to the toilets, which are inside the building, would not always be practicable.

5.5. However, it is possible to meet the requirements of BS 8151:2009 and also keep within reasonable practicable limits by utilising RWH from some of the roof areas to serve the Arena toilets resulting in a saving of some 1188m$^3$ of water per annum.

5.6. This will have the added bonus of reducing an overloaded rainwater drainage system.

5.7. However the cost of water is such that the savings are relatively modest compared to the relatively large capital cost of installation and would require a payback period of some 40 years.
6. DISCUSSION ON SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS) & RAINWATER HARVESTING (RWH)

6.1. Government, for a number of years, has been stressing the need to reduce mains water consumption and, in particular, reducing waste and using water efficient devices and, at the same time, not increasing local or downstream flood risks, particularly as a result of extreme weather events as have recently occurred.

6.2. As a response to this requirement to regulate surface water, sustainable urban drainage systems (SUDS) have been employed relying on surface water attenuation systems.

6.3. However, RWH provides a solution to SUDS in that it assists in surface water management (by storing rainwater run-off) and also reduces the need for mains water consumption, as the surface water run-off is stored and filtered for non-potable uses (such as toilet flushing, which consumes relatively large amounts of potable water).

6.4. An RWH system comprises of a method of collection (in this case the roofs of the Spectrum Centre), a means of storage (such as tanks) and a delivery facility (e.g. pipework). See Appendix C for a visual representation of a typical system.

6.5. The rainwater that falls on the roof (and in this case, roof glazing as well) is channelled into valley gutters that are connected to a roof drainage system (which is proposed as being entirely Siphonic, rather than the current hybrid main Siphonic system with a secondary gravity overflow system) that discharges to the outside of the building (where the drains are located and not inside the building).

6.6. Rather than the water then partly passing into the drains and proposed soakaways it passes through a mesh filter (for the removal of leaves and debris) and then enters into a storage tank via a calmed inlet which is designed to smoothly introduce the fresh and highly oxygenated rainwater into the bottom of the tank. The reason for this is to avoid stagnation at the lowest level and it assists maintenance of stored water in the tank.

6.7. The storage tanks, located at the outside perimeter of the building, can either be located at ground level, below ground, or in the roof space, which in this case is not practicable due to the size and weight required and the fact that the location...
of a rainwater tank (i.e. in the middle of the building in the plant room area under
the ‘street’ is not compatible with the rainwater drainage discharge which is taken
to the perimeter).

6.8. It is possible, however, to locate storage tanks at the perimeter and then pump
water to an intermediate cistern(s) in the roof area, albeit again there are
problems regarding weight and size particularly as the existing plant rooms above
the ‘street’ are very congested, and other problems, which will be discussed later
in this report.

6.9. As a result of demand for non-potable water uses (such as toilet and urinal
flushing) this stored water is then pumped and piped back into the building. This
demand is sensed, either by a control unit or by the pump itself and activates the
pump to meet the demand. When the demand is met sensors stop pumping.

6.10. During periods of prolonged rain, the storage tank becomes full and overflows
into either soakaways or the main drainage system is made via pipework
connecting the tank to these systems using a back-flow prevention valve if
connected to a sewer.

6.11. The whole of the tank volume cannot be utilised because it may be full during
heavy downpour conditions, hence the need to allow for overflow.

6.12. However, in dry spells the stored water in the tank may fall to very low levels and
to ensure that there is no risk of running dry, mains water is allowed to enter the
system, controlled electronically using Class – AA air-gaps to prevent any direct
contact between the potable and non-potable water.

6.13. The ratio of non-potable water use from the Millennium Dome study compared to
that of a typical office in the year 2000 shows that the Millennium Dome use was
55% of all water demand use and that of an office was 63%. So it is possible that
considerable savings of water for non-potable use can be made, if circumstances
permit.

6.14. The design of RWH systems is covered by BS8515: 2009, which deals with a
simplified approach for residential situations (i.e. houses with upto 5 occupants)
where there is a consistent daily demand for non-potable water. It also contains
an intermediate approach for a more accurate estimation of storage capacity and
there is a detailed approach for non-standard systems where there is a variable demand through the year.

6.15. Preliminary calculations have been carried out, using the detailed approach as Note 3 of clause 4.1.2.1 states ‘For larger rainwater harvesting systems, the size of the system may benefit from using the detailed approach to ensure a cost-effective solution is developed’.

6.16. The method of calculating the yield is as that based on the recommendations of Clause A.5.1 of BS8115: 2009, however there is not a prescriptive calculation for the demand for this type of building and so recourse was made to factual data provided by the Leisure Centre with regards to the number of visits to each part of the Leisure Centre, based on paying customers.

6.17. The number of uses of the WC or urinals was then estimated using the recommendations of the DEFRA briefing note – BNWATO6 – Domestic water use in new and existing buildings based on 1 use per visit with a male female visit ratio of 1:1 and multiplying this by the number of visits multiplied by 6L per WC flush (information provided by GBC), with an allowance of an average of 50% additional visits for spectators as well as paying customers.

6.18. The demand has been based on historical data provided by the Spectrum Centre, for the various toilet areas, which are, generally, located towards the centre of the building.

6.19. This demand, for the entire building, is greater than the yield of the entire building, i.e. the rainwater run-off from the roof, the total area of which is in excess of 9000m² produces less water than is used for toilet and urinal flushing. Note 1 of clause 4.1.2.1 of BS 8515: 2009 states that ‘The use of rainwater harvesting for stormwater management (see A.1) may only be applied in situations where the average run-off yield is less than the average non-potable demand. This is because of the low likelihood of significant spare storage in the tank occurring at the time of a large storm when the average yield is greater than the demand’.

6.20. And so RWH catering for both non-potable water use and also for stormwater management is possible for the Leisure Centre, however these preliminary calculations show that storage in excess of some 700m³ (700,000L) is required,
which is considerably excessive when compared to a house with say 4 bedrooms of say 7.8m$^3$ (78000L) and poses a considerable problem with regards to the location of the tanks, which are generally (but not exclusively) located below ground. See Appendix D for examples of sizes and types of RWH storage tanks.

7. **FEASIBILITY OF RETROSPECTIVE INSTALLATION OF AN RWH SYSTEM**

7.1 As previously noted, the shape and layout of these roofs dictate that the rainwater is taken to the perimeter of the building as the design is based on a Siphonic system rather than a gravity system, with the mains drainage being located outside of the building.

7.2 Gravity systems work on the principle that the downpipes are approximately 30% full of water, the rest being air. Siphonic systems work on the basis that the pipes are 100% full of water, and as such smaller pipes and a lesser number of down pipes are used.

7.3 It would not be practicable to locate any of the rainwater systems inside the building, as this would require wholesale excavation of the existing floors, which contain ice rinks as well as gymnasiums and swimming pools, and so the existing format, albeit locally altered to suit the circumstances of not utilising the entire roof areas, has to be retained.

7.4 On the south side of the building there is far more space to locate either ground level or underground storage tanks than there is on the other elevations. Also there are other problems with locating storage systems on the other elevations.

7.5 For example, on the west side there is a paved emergency access route, with external plant buildings and mains sewers, an access road and plant on the north side and an underground car park on part of the east side, albeit there is space on the south side of the main access ramp on the east side.

7.6 If storage for RWH was provided to the south side of the ‘Street’ area for the entire building then it would require in excess of 700m$^3$ of RWH storage and if this was located at ground level, assuming say a 3m height (the height dictates the water pressure and hence stresses on the walls and base of the tank) then the base would require a footprint of some 250m$^2$ or say a square of side some 15m, which is considerable.
7.7 Apart from any visual and actual location concerns of storing harvested rainwater above ground, a serious concern (with above ground storage) is the potential risk of Legionnaires Disease.

7.8 It is not unusual, in the summer, for water in an above ground storage tank to reach 35°C, which is an optimum temperature for Legionnaires Disease to occur.

7.9 Storing harvested rainwater in an underground tank will keep it cooler and hence greatly reduce the risk of Legionnaires Disease.

7.10 The sizes (and materials) of tanks vary, however the maximum size of an underground unit is some 90m³ (90000L) although it is possible to link tanks to increase storage.

7.11 However, even if the quantity of storage was not a problem, there is a problem, because it is an existing building, with distribution of the water back inside the building and then onto the toilets that are located on different levels.

7.12 It is not practicable to take water from the outside of the building, say at the south end (where storage is not so much of a problem) towards the east-west centre line of the building (where most, but not all of the toilets are located) and also where a riser access exists between levels 1 – 3, because this could mean trying to route water pipes up in the roof trusses to avoid the swimming pools or in the case of the north side of the building (where there is considerably less storage area available) trying to avoid excavations through arena floors or the ice rink.

7.13 A potential solution to the routing of pipework, to convey RWH to toilets, is to locate the storage at the west end of the building (towards the south side where it is all open land) and to run pipework along the top of the walls of the ‘Street’ towards the riser which serves level 1 to 3 which for most of it’s length is hardly trafficked (as it forms an escape route). The water could then be conveyed down to Level 2 Pool WC’s and urinals or to the Arena toilets.

7.14 Because storage is not practicable for the entire area, supply would be made to a specific area, and for the criterion for yield to be < 0.9 times the demand, which is a requirement of Clause A5.1 of BS 8515: 2009, to be met, balancing of the yield area with the demand that produces this ratio is required.
7.15 Various combinations of areas have been looked at with demand and if, for example, the area of roof south of the ‘Street’ were to be considered (where storage is more readily available) then this would not be adequate to meet the demand for non-potable water for the entire centre.

7.16 Another scenario that was considered was the entire roof area to the south side of the ‘Street’ serving the toilets / urinals in the competition and leisure pool areas and although this could be made to work, with regards to satisfying the design criteria, it would still require a RWH storage of some 240m$^3$ (240000L), which is still excessive.

7.17 Another solution was considered whereby some of the roof area to the South side of the ‘Street’ would be rainwater harvested to serve the WC’s and urinals in the competition pool area. The balancing of some of the areas with this demand satisfies the design criteria for RWH and also only requires storage of some 84m$^3$ (84000L), which is more easily accommodated than either 240m$^3$ or in excess of 700m$^3$.

7.18 However, I am advised by GBC, that the Arena toilets are more heavily used than the competition pool toilets and so another solution was considered i.e. using the same area of roof to serve the Arena toilets but using the service riser between levels 1 – 3 and running pipework through the ceiling voids to access the arena toilets. See photograph No. 1 below of service riser.

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Photograph No. 1

View looking up the riser shaft
7.19 This route was initially surveyed with GBC staff on 20.01.2015 and appears to be feasible and I am informed by GBC that similar routing of flexible water pipes has previously been carried out.

7.20 The solution of using slightly more roof area to the south side of the ‘Street’ (than the roof area required for RWH to serve the competition pool toilets) to serve the WC’s and urinals in the Arena area would require storage of some 136m$^3$ (8136000L), which again is more easily accommodated than either 240m$^3$ or in excess of 700m$^3$.

7.21 So, it cab be seen that there are a choice of roof areas for achieving satisfactory RWH but a factor that also has to be taken into account when considering which areas to harvest, is that of the effect on the ground drainage system, which cannot cope with the design rainfall for the roof (which is a different design criteria than that of RWH, as in the case of roof gutter design a storm of 2 minute duration with a return period of once in 45 years is used, which is totally different than a design storm of a 100 year 6 hour event).

7.22 The optimum choice of roof area provides a situation where the RWH storage of some 136m$^3$ on the south side of the rainwater drainage system (which will provide non-potable water to approximately 1/8th of the entire building) reduces the total flow on the south side such that it is compatible with the sizing of the system to cope with the original design flow of 0.021L/s.m$^2$ (instead of the 0.052L/s.m2 which is what it needs to be designed to as per current codes of practice), albeit some local upsizing of some of the underground pipes will be required.

7.23 Because of the limitations on storage for RWH to the North side of the building, it will be necessary to consider soakaways to this side to reduce the flow.

7.24 The design of soakaways, uses another set of design flow criteria that is different for that used on the roof gutter design or for RWH systems, but notwithstanding that it produces smaller volumes of soakaway storage (as water soaks away after a period of time) than is required for RWH, albeit there is still a problem of location on the north side of the building, where a soakaway of some 12m$^3$ would be required.
7.25 This soakaway would again reduce the flow in the underground rainwater drainage system to nearer to the original flow rate for which it was designed (0.021L/s.m\(^2\) compared to 0.052L/s.m\(^2\) the current design rate) albeit some of the existing pipe sizes would have to be slightly enlarged in addition to the soakaway.

7.26 The problem with siting a much reduced (in volume) soakaway (compared to a RWH tank), is that it will have to be on the North side of the access road to the North side of the building. This will mean excavating for a pipe run under the access road and negotiating existing services in the road (including a drain run).

7.27 However I am informed by GBC that the only services in the road way adjacent to where a soakaway would be required are drains, which are set at a much lower level and could be accommodated.

7.28 Mains water will still have to be provided to the Toilets to cope with fluctuations and these two types of water supply have to be specially isolated from one another so as to prevent any possible risk of contamination.

7.29 Also, the pipes for the RWH need to be identified as not being potable water.
8. **CONCLUSIONS / RECOMMENDATIONS**

8.1. Given that the Spectrum Centre has large areas of roof and uses large quantities of non-potable water, which has to be paid for and is becoming a more scarce resource it appears to make sense to utilise Rainwater Harvesting.

8.2. If the building were being constructed from scratch, on a Greenfield site (such as this was) then the design of the roof drainage and the RWH systems to serve the toilets could have been carried out in a co-ordinated manner to provide a more cost effective solution.

8.3. However this is not the case with this building it is a case of trying to make a RWH system fit the building, which although possible would be so at prohibitive cost.

8.4. The system has to be designed to BS 8515:2009 and because the demand has to be greater than the yield, (which for the entire building it is) it is not practicable to store the water for all the building (as it would require a storage system of some 744m³).

8.5. For health reasons it is advisable to store the harvested rainwater below the ground which involves considerable excavation and removal costs, which are relatively very expensive. This is apart from the prohibitive costs of distributing all of this water to the various toilet locations in the building.

8.6. However, it is practicable to use certain roof areas to the south side of the ‘Street’ to provide a RWH system to provide non-potable water to some of the toilets in the building such that it complies with BS 8515:2009.

8.7. Below is a table showing the two most reasonable solutions of using various areas of roof to the south side of the ‘Street’ to service toilets in the competition pool or the Arena.

<table>
<thead>
<tr>
<th></th>
<th>Volume saved per annum m³</th>
<th>Budget Cost saving pa £</th>
<th>Budget Cost of installation £</th>
<th>Approximate pay back period years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Roof area 1, 3 &amp; part 11 serving Comp pool toilets</td>
<td>794</td>
<td>£794</td>
<td>£38000</td>
<td>48</td>
</tr>
</tbody>
</table>
2. Roof area 1, 3 & part 11 serving Arena toilets | 1188 | £1187 | £47000 | 40

8.8. It must be noted that all of these particular types of RWH systems require electric pumps and there is no allowance made for the cost of electricity or of maintenance of the system.

8.9. The introduction of either RWH system described above will also have the added benefit of removing a significant amount of rainwater from entering the existing drainage system, on the south side of the building, which is not adequate to cope with a once in 45 year storm event (which is what the building should have been designed for).

8.10. However, in order for the existing system to not surcharge under the design rainfall conditions of a once in 45 year return period storm, it will also be necessary to take some of the flow, on the north side of the building into a soakaway on the north side of the building.

8.11. These proposals for the RWH system are shown on the plan drawing in Appendix A.

8.12. It will also be necessary to increase some of the existing pipe diameters to accommodate the residual flow, i.e. from manhole 4 – 3 and from manhole 2 – 3 from 225mm diameter to 375mm diameter and from manholes 9 – 8 and 8 – 7 from 225mm diameter to 250mm diameter. These are shown on a separate plan in Appendix B, which also includes the new soakaway (of crated size of 13m$^3$ and an overall size of 36m$^3$).

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APPENDIX A – Rainwater harvesting system
Key: Blue solid line shows roof areas piped off to RWH tank
Blue dotted line shows internally run pipes in ceiling void

- RWH tank
- Service Riser
APPENDIX B – Plan of existing surface water drainage layout with proposed pipe changes in blue colour.

New soakaway taking manhole 10 flow
APPENDIX C – Typical RWH Systems
APPENDIX D – Typical RWH Storage Tanks