

A Drainage System

FIELD OF THE INVENTION

5 The invention is directed to the management of surface water including rainfall runoff, flooding and direct high intensity rain. In particular, the invention is directed to draining such surface water so as to reduce peak discharge rates during high surface water flows.

BACKGROUND

Surface water is defined as including but not limited to rainfall runoff resulting from heavy rain within the relevant catchment, flood water (either natural or man-induced) or high intensity rainfall directly onto the system.

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Large parts of urban areas are paved. Rainfall on paved areas results almost instantly into runoff to the urban drainage system. During severe rainstorm events, large peak flows are generated. Normally urban drainage systems are designed to cope with most of these peak flows, resulting in large drainage canals
20 or pipes. Most of the time, however, these drainage systems are almost empty which, in the case of canals, detracts from the aesthetics of the urban landscape. Low Impact Development (LID) solutions that are used to change the urban runoff, like green roofs, swales and porous pavement, show an improved result on a long term average basis.

However, the effectiveness of these LID-solutions and/or retention capacity of these systems for extreme rainstorm events are often negligible.

5 SUMMARY OF THE INVENTION

In a first aspect the invention provides a drainage system comprising a permeable layer having a surface for receiving water; a storage layer for receiving water from the permeable layer; said storage layer having an outlet, and; a
10 permeable drainage block along the said outlet, and arranged such that water draining from said storage layer passes through said permeable drainage block.

Accordingly, the invention provides a means for diverting runoff through a permeable layer to a storage layer which may have a high porosity. The storage
15 layer may be large enough to provide a buffer for high intensity rainfall so as to maintain runoff discharge within a manageable range. The water level, and rate of discharge, is then maintained by ensuring the storage layer drains through a permeable drainage block.

20 This arrangement may allow significant flexibility in design parameters to be usable within a wide range of applications. For instance, the relationship between the permeability of the permeable layer and the drainage block is essential a control parameter from the rate of water ingress into the system and water egress into the stormwater infrastructure. By varying this relationship, associated

culverts, drains, open channels can be designed accordingly so as to optimise capacity of this infrastructure. The cost savings of such an arrangement avoid expensive over-design.

- 5 A further parameter includes the storage capacity of the storage layer. For instance, in catchments which experiences short term high intensity rainfall, reducing peak flow in urban runoff may require a high permeability for the permeable layer and a storage area sufficient to hold most of the incoming water. To optimise stormwater infrastructure, it may be necessary to reduce the
- 10 corresponding permeability of the drainage block. For the drainage system to act as a buffer, the storage layer must therefore have a storage capacity to accommodate the differential discharge rates of the permeable layer and drainage block.
- 15 In general terms the invention relates to a drainage block having a porous medium substantially restricting the outlet flow of a drainage system, which may also act as a water harvesting system. In some applications this may have the advantage(s) that (i) both large reduction of peak flow and large delay of runoff and thus a large runoff spread (over time) for moderate as well as for extreme
- 20 rainstorm events, (ii) large flexibility in delaying capacities, (iii) simple concept, (iv) low in maintenance, (v) applicability for water purification techniques and/or (vi) more time to treat, filter or modify the water before it is passed into subsequent systems.

The drainage system according to the present invention may be used for roof runoff, runoff from roads, parking lots, pavements, and in small canals. It may also be used for porous pavements.

5 These features may make the drainage system very applicable in a modular system. Simultaneous application of a wide range of delaying capacities of the drainage system in a modular system may extend the runoff spreading even more. This may be applicable both as different drainage system in a single area, and as similar drainage systems on different areas that runoff to the same
10 drainage system.

The drainage systems may also be applied to improve water harvesting, and to create a much larger base flow that is required for beautification and naturalization of urban canals.

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In one embodiment, the storage layer includes a high porosity cell. To act as a storage layer, a high porosity so as to maximise capacity may be useful. Such a high porosity cell may be achieved using aggregate wrapped in geotextile, hollow section and polymer drainage cell. Whilst a contained aggregate may have
20 advantages to prevent crushing in high load applications (car parks etc.), hollow section, and a drainage cell may provide more compact and higher capacity containment.

The permeable layer may be a layer of coarse-grained soil/sand, particularly if a higher permeability is required, including coarse sand or aggregate. Alternatively, the permeability layer may be a permeable pavement, which may be an assembly of porous pavement blocks.

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The drainage system may also include a gutter arranged to receive water from the drainage block. Such a gutter may be used as a final buffer prior to discharging water to the stormwater infrastructure. Alternatively, the gutter may facilitate connection of the drainage system to the stormwater infrastructure.

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The drainage system may be well suited to a modular construction, such as for new car park construction or other highly repetitive or large scale installation. To this end, the drainage system may include a housing to which the permeable layer, storage layer and drainage block are mounted.

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In one embodiment, the drainage block may include a porous medium encased within a water permeable material, such as sand wrapped within a geotextile or the sand may be cast into a finite shape using some cementing material. Alternatively, and possibly of benefit to modular construction, the drainage block
20 may be a solid porous medium, such as a permeable pavement block.

In one embodiment the drainage system may be placed within a drain with storm water runoff directed at least partially to the drainage system. Consequently, the initial peak intensity rainfall may be directed to the drainage system rather than

directly to the drain. Thus, peak flow within the main portion of the drain may be reduced with the base flow within the drain being a combination of the slow drainage from the drainage system and the subsequent low intensity rainfall and runoff during and directly after the storm.

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In a further embodiment the drainage system within a drain may be arranged such that when the drainage system reaches capacity overflow is directed into the main drain. Further, whilst in one embodiment a portion of the runoff is directed to the drainage system, in an alternative arrangement all of the runoff is
10 directed to the drainage system such that runoff is only directed to the drain once capacity of the drainage system has been reached.

In one embodiment the drainage system may incorporate a permeable pavement layer. In this case, a high porosity pavement used for a road surface percolate the
15 runoff into the storage layer which subsequently releases water to the gutter/drain of the road system at a substantially lower flow rate.

In a further embodiment, the drainage system may be used in association with a "blue roof". A "blue roof" is defined as a roof used for the storage of rainfall falling
20 directly onto the roof. A roof having a drainage system according to the present invention may temporarily store the rainfall whilst slowly releasing water through the drainage block. Thus, a "blue roof" according to one embodiment of the present invention may not have permanent water storage but temporary water storage. If the intention is to harvest water from the drainage system the stored

water may be covered so as to prevent excessive volumes of detritus clogging the permeable layer.

5 BRIEF DESCRIPTION OF THE DRAWINGS

It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention.

Other arrangements of the invention are possible and consequently, the
10 particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

Figure 1 is a schematic view of the drainage system according to one embodiment of the present invention;

15 Figures 2A to 2F are sequential views of the construction of a drainage system according to a further embodiment of the present invention;

Figure 3 is a schematic view of a drainage system according to a further embodiment of the present invention;

Figure 4 is a schematic view of a drainage system according to a further
20 embodiment of the present invention;

Figure 5 is a graph of storage water level versus time for a drainage system according to a further embodiment of the present invention;

Figure 6 is a graph of discharge versus time for a drainage system according to a further embodiment of the present invention;

Figure 7A is a comparative graph of discharge versus time for various prior art systems and the drainage system according to a further embodiment of the present invention;

Figures 7B to 7D are comparative examples used for the graph of Figure 7A.

5 Figures 8A to 8C are elevation views of the drainage system within a drain according to various embodiments of the present invention;

Figure 9 is an elevation view of a road system incorporating the drainage system according to a further embodiment of the present invention;

Figure 10 is an isometric view of the drainage system according to a further
10 embodiment of the present invention;

DETAILED DESCRIPTION

The Drainage system may be a rectangular block of some sort of porous medium that is placed (and held) between the drainage layer of the storage medium (such
15 as roof, parking lots, porous pavements, etc) and the outflow gutter. Both block dimensions and material of the porous medium may be flexible. When placed in the drainage layer, the height of the block may be limited to the height of the drainage layer. However, it may also be applied in a separate block between the storage medium and the gutter. The width and the permeability of the block
20 together with the porosity of the drainage layer may determine the additional retention capacities of the Drainage system. The main retention capacities of the Drainage system are strong reduction of the peak flow, and major delay of the runoff.

Driving force for the flow through the Drainage Block is the difference in water level between the inner (h_i) and outer (h_o) side of the block. The flow velocity is determined by this driving force, and by the width (d_b) and permeability (k_b) of the block.

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For proper functioning of the Drainage system the storage capacity of the drainage layer may be adapted to the design rainstorm event. For instance if the storage medium is designed to handle an intense shower of 40 mm of rainfall in a short period of time, the required thickness of the drainage layer multiplied by its porosity is 40 mm. A porosity of 50 % will then lead to a thickness of 8 cm.

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The higher the porosity of the drainage layer, the lower the water level at the inner side of the Drainage system, and subsequently the lower the flow velocity through the Drainage system will be.

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The flow velocity of water percolating out through the Drainage system is independent of the length (L) of the drainage system. However even a visibly flat system will have a small slope. A slope of 1 % implies that the storage capacity of the system reduced by 1 cm for each meter further before the Drainage system.

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To minimize these limitations a modular application may be useful. Modular application has some major advantages. It creates the possibility to use small prefabricated units that are easy to transport, handle, replace and come with the economic benefits of mass production. Modular application also creates the

possibility to use different materials in the Drainage system, thus further enlarging the runoff spread.

In situations that the delay of the runoff is preferred over the reduction of the runoff, the Drainage system may be applied in a so-called Water Harvest system. Function of this system is only to delay the runoff, and not to reduce it, which may be applied on the roof systems. Therefore, the green roof with Drainage system may be adapted accordingly. The plants and the growing medium may be replaced by a larger drainage/storage layer with a small layer of pebbles on top, which functions are to maximize the percolation of rainfall into the drainage layer, and at the same time minimize the evaporation. Enlarging the drainage layer will enlarge the delaying capacity of the system.

Figure 4 illustrates an experimental setup of such a system. Figures 5 and 6 show some actual results for this specific setup, both theoretically calculated and measured.

The Drainage system may be applicable for flat roofs. However, the principle may also be applied at roads, parking lots, storm water storage facilities, etc.

The Drainage system may be suited for modular application. Since the Drainage system may be applied on flat structures, such as roofs, both existing (load permitting) and new, this system may be suitable for mass production.

In one embodiment, the system may include a regulated control system that automatically closes the drainage layer when a large rainstorm event is approaching. The system then can release the runoff water again when the receiving drainage system is capable of handling this runoff again.

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With reference to the figures, Figure 1 shows a schematic cross section of the Drainage system 5. This figure illustrates the basic principle of the Drainage system 20. The rain falls on the permeable layer (soil or plants, not drawn, or permeable pavement or parking lot). The water that is not captured by the plants,
10 or used to saturate the soil or porous pavement, percolates 12 into the storage layer 15. The thicker the storage layer 15 and the higher its porosity, the better the performance. The water 30 in the storage layer is slowed before it runs off into the gutter. The block 20 includes a porous medium (like fine sand), through which the stored water 30 can only flow out slowly. The higher the water level, the
15 higher the flow. A higher porosity results in a lower storage water level, and thus a slower outflow. After the rain is stopped the storage layer empties itself slowly through the Drainage system, more slowly as the water level lowers further, at the same moment creating new storage room for the next rainstorm event.

Figures 2A to 2F show sequential construction steps for constructing a green roof
20 with a Drainage Block according to one embodiment of the present invention. This figure illustrates the stepwise construction of the experimental setup that was used to test the functionality of the Drainage Block in a green roof. First, a storage layer is built in. With drainage material 70 inserted within the storage layer. Along the gutter, some space is reserved for the Drainage Block 75.

Secondly, the Drainage Block 75 is applied. In the experiment, fine sand was wrapped in a water permeable fabric 80. Subsequently the drainage layer is covered with the fabric 80, and an extra mat 85 for stability and root resistance. Finally, permeable growing medium for the plants (potting soil) 90 is applied
5 forming the permeable layer

Figure 3 is a schematic cross section of the water harvest roof 92. Compared to the green roof with Drainage Block the storage layer 105 is much larger, and a thin layer of pebbles 95 replaces the soil of the permeable layer. The function of the pebbles 95 is to maximize the rainwater infiltration to the storage layer 105,
10 and to minimize the evaporation. On top of the Drainage Block 115, a waterproof foil 110 is applied to prevent water from flowing in from this side.

Figure 4 shows a photograph of a working water harvest roof 120. The photo shows that the Drainage system 150 has a wet 145 and a dry part 140. On the
15 right the green roof with Drainage Block 150.

Figure 5 shows a graph of calculated 170 and measured 175 accumulated runoff from the water harvest roof. The graph illustrates the runoff caused by four rain events during three consecutive days in March 2010 as shown in Table #1. The
20 calculations are carried out with a simple spreadsheet model. Also in the graph is the calculated water level 160 at the inner side of the Drainage Block.

Event	Duration (h)	Rainfall (mm)
1	6	8.1
2	0.7	47.2
3	1.5	6.4
4	0.5	1

Table #1

Figure 6 shows a graph of calculated 180 and measured 185 flow rates from the
5 water harvest roof. The graph illustrates for the same events as in Figure 5 and
Table #1.

The effectiveness of water-harvest roof using the drainage system is
demonstrated in Figures 7A to D using a real rainfall event, where peak flow from
10 the roof is greatly reduced and base flow is extended. The green roof with a
similar drainage system as the water harvest roof would lead to an almost similar
runoff.

Here the comparative effect of the invention is shown with Figure 7D showing a
15 drainage system 220 according to one embodiment of the present invention
compared to a conventional roof 200 shown in Figure 7B and a green (sedum)
roof 210 arranged to allow some infiltration of the rainfall rather than
instantaneous runoff as is the case for the roof of Figure 7B.

20 The graph of Figure 7A indicates the rainfall 190 compared to the discharge
intensity for each of the example roofs 200, 210, 220. Interestingly, the reference
roof 200 and the green roof 210 yield similar results 195, 205 and in comparison

with the rainfall, little benefit in preventing runoff as compared to the graph for the drainage system 215 according to the present invention. As can be seen in Figure 7A the discharge rate was considerably less than that of the comparative roofs 200, 210, with the discharge from the drainage system remaining at a low level
5 presumably well beyond one hour after the peak rainfall intensity. Accordingly, this shows the result of the intended benefit of the invention in that peak flow is reduced, with base flow increasing and extending over time.

Figures 8A to 8C show various embodiments whereby the drainage system 225, 260, 290 has been placed within a larger drain 235, 270, 300. For Figure 8A the
10 drainage system 225 includes the permeable layer 245 which receives runoff 230, 255 entering the drain 235. As the runoff is directed to the drainage system 225, a portion of the runoff percolates into the storage layer 246 which subsequently passes through the drainage block 250 into the drain at a rate much lower than that of the peak intensity. Accordingly, peak load from the runoff 230,
15 255 is reduced and the water draining from the drainage system 225 enters the drain 235 at a much slower rate. Runoff 240 from the drainage system 225 then enters the drain directly.

Whereas the drain of Figures 8A is completely open, Figure 8B includes a
20 partially enclosed drain 270 whereby the drainage system 260 lies protected from direct rainfall and subsequent detritus. Runoff 265 is still directed to the drainage system 260 and again the drainage system incorporates a permeable layer 280, storage layer 281 and drainage block 285. Runoff 275 from the drainage system 260 is then directed to the main drain 270.

In a further embodiment, Figure 8C shows a drain 300 having a drainage system 290. Again the drain 300 is partially open with runoff 295 directed to the drainage system 290. The permeable layer 310, storage layer 311 and drainage block 315
5 then act to direct water into the main drain with runoff 305 from the drainage system directed into the main drain 300.

Figure 9 shows an embodiment of the present invention whereby the permeable layer 321 is a porous road pavement. Water directed to the road pavement 321
10 either runs off 330 into a drain 335 or percolates 325 into the storage layer 340 and subsequently drains through drainage blocks 346 into the drain 335.

Figure 10 shows a further embodiment whereby the storage layer 355 is partitioned 360 with each partitioned storage layer draining through a drainage
15 block 355 into a main drain 350. This may provide several advantages including isolating individual storage layers in case one partitioned storage layer is clogged and no longer serviceable, and so ensuring the remaining system is not compromised. Alternatively, it allows for certain parts of the drainage system to accommodate higher peak loads and thereof larger storage areas compared to
20 other areas receiving less runoff and so having less need for a high volume storage layer.

Claims:

1. A drainage system comprising
 - 5 a permeable layer having a surface for receiving water;
a storage layer for receiving water from the permeable layer;
said storage layer having an outlet drain;
a permeable drainage block along the said outlet, and arranged such that
water draining from said storage layer passes through said permeable
10 drainage block,
wherein the permeability constant of the drainage block is lower than the
permeability constant of the storage layer.
2. The drainage system according to claim 1, wherein the storage layer
 - 15 includes a high porosity cell.
3. The drainage system according to claim 2, wherein the high porosity cell
includes any one or a combination of: aggregate wrapped in geotextile,
hollow section and polymer drainage cell.
- 20 4. The drainage system according to any one of claims 1 to 3, wherein the
permeable layer includes a layer of coarse-grained soil or porous
pavement.

5. The drainage system according to any one of claims 1 to 5, further including a gutter arranged to receive water from the drainage block.
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6. The drainage system according to any one of claims 1 to 6, further including a housing to which the permeable layer, storage layer and drainage block are mounted.
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7. The drainage system according to any one of claims 1 to 7, wherein the drainage block includes a porous medium encased within a water permeable material.
8. The drainage system according to claim 8, wherein the water permeable material includes a geotextile material.
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9. The drainage system according to any one of claims 1 to 9, wherein the permeable layer is arranged vertically above the storage layer.
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10. The drainage system according to any one of claims 1 to 10, wherein the permeable layer is a permeable road pavement.

11. The drainage system according to any one of claims 1 to 11, wherein the drainage system is located within a drain, and positioned so as to direct at least a portion of a runoff flow entering the drain to the permeable layer, and further such that water passing through said drainage block enters the drain.
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