3 Pollution control

Improving water quality in permeable pavements

The Water Framework Directive (WFD) is European legislation that is incorporated into UK law by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 and the Water Environment (Water Framework Directive) (Northumbria River Basin District) Regulations 2003. Northumbria requires separate legislation as the WFD is based on river catchments and in this area the catchments span between England and Scotland.

It was incorporated in Scotland in the Water Environment and Water Services (Scotland) Bill which was enacted at the beginning of 2003 and makes the use of SUDS mandatory in Scotland.

The objective of the WFD is to introduce a co-ordinated approach to water management based on river catchments and specifically to:

- Protect aquatic ecosystems, including groundwater
- Promote sustainable water use
- Reduce pollution (including that from surface water drainage)
- Help reduce floods and droughts

The Environment Agency are aiming to publish River Basin Management Plans by the end of 2008. The use of the SUDS approach is ideal to meet the WFD objectives and the Environment Agency is likely to use these as a key tool to reduce diffuse pollution entering watercourses.

Dealing with pollution at source

Permeable surfaces are an excellent means of removing pollution from urban run-off. The main reason for this is that the pollution is dealt with at source before it becomes concentrated, entrained and emulsified within the run-off, which can occur in conventional piped systems.

Pollution removal mechanisms

The systems are also robust because there are a number of different pollution removal mechanisms occurring within the pavement. These include in order of significance:

1 Filtration of sediment particles either by geotextiles or by aggregate materials

2 Biodegradation of organic pollution such as oil

3 Adsorption of pollutants onto aggregates

4 Settlement of sediment within the aggregate or cellular subbase

Pollution removal performance

The pollution removal performance of a wide range of pervious surfaces has been measured on installed pavements both in the UK and worldwide. The results show their effectiveness in removing metals and hydrocarbons as well as the beneficial effect on the concentrations of phosphorous and nitrogen in run-off.

A summary of the design removal efficiency from CIRIA Report C697 is provided in Table 4, which applies to all types of permeable surface including porous asphalt and permeable concrete block paving. Also provided for comparison are the values for oil separators. Permeable pavements are easily able to remove pollution to the levels required in Pollution Prevention Guideline No. 3 for oil separators.

Pervious pavements provide such efficient pollution removal because there are a number of mechanisms at work within the pavement:

- Filtration to remove silt or suspended solids (with associated pollutants)
- Biodegradation of hydrocarbons and other organic pollutants
- Adsorption
- Volatilisation
- Precipitation

The majority of pollution in rainfall run-off occurs in either frequently occurring storms or in the first part of the flows from less frequent but more intense events (known as the first flush). It has been recognised that if 90% of the average annual rainfall is captured and treated, then most pollution will be dealt with. This can easily be achieved by permeable pavements.

Table 4: Pollution removal efficiencies for pervious surfaces (CIRIA, 2004)

Technique	Percentage removal of pollutants of concern					
	Total suspended solids	Hydrocarbons	Total Phosphorous	Total Nitrogen	Faecal Coli forms	Heavy metals
Pervious pavements	60-95	70-90	50-80	65-80	–	60-95
Oil separator	0-40	40-100	0-5	0-5	–	–

Aggregate Industries' systems for pollution removal

The Permafilter system provides three options for the control and removal of pollution:

- Permachannel and Permaceptor
- Permavoid Biomat
- Permafilter Geotextile

These products can be used separately or in conjunction with one another to suit project requirements.

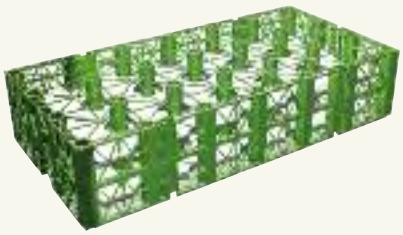
All products are made from recycled materials and stringent quality control measures are enforced to ensure that the production process is of the highest standard.

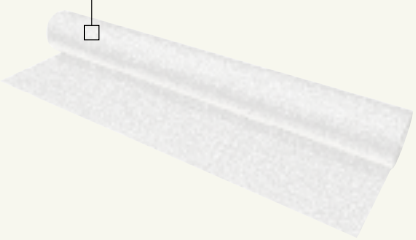
In the development and validation phases, we ensure extensive cooperation and collaboration is undertaken using the opinions of our clients, distributors and universities. Permavoid has enjoyed collaboration with Coventry University and Warwick University (Warwick HRI) for over seven years and Salford University for over six years.

The Charcon Permafilter system

The Permafilter range of products is designed to control and remove hydrocarbon pollution.

The fibres in Permafilter Geotextile exhibit specific hydrophilic and hydrophobic properties.





Permachannel

An innovative channel system with an in-built silt and oil separation mechanism to provide combined source control surface water collection and treatment drainage for predominantly impervious surfaces. The channel is designed for use on new developments or for retro-fitting to existing developments.

Permavoid Biomat

Permavoid Biomat is designed especially for use with underground Permavoid attenuation and infiltration systems. The use of the Permavoid Biomat provides additional oil retention and water treatment capability to an underground water storage system and can be tailored to site-specific risk requirements.

Permafilter Geotextile

Permafilter Geotextile is a non-woven, dimpled, needle punched geotextile that has been specifically designed for hydrocarbon pollution treatment in civil engineering applications (such as filtration separation, drainage, protection and reinforcement). The entrapped hydrocarbons can be biodegraded by naturally occurring micro-organisms providing a self-cleansing mechanism.

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Charcon Permachannel

Permachannel is a versatile drainage system that can provide source control and pollution treatment in a wide variety of locations and applications.

Performance

Permachannel is not used to convey water large distances like conventional channel drainage, instead it is used to trap silts and oils. The outlet incorporated in the channel is a baffle and weir system that captures any silt or free floating hydrocarbons and retains them in the channel.

The performance of the Permachannel system has been assessed by laboratory testing of full-scale prototypes.

The results show that the Permachannel alone will outperform conventional Class 2 oil separators and so will meet the design requirements of the Environment Agency's Pollution Prevention Guideline PPG3.

The performance can be improved by providing a sand or geotextile filter as a further stage of treatment after the Charcon Permachannel which will ensure the whole treatment train meets the requirements of a Class 1 oil separator.

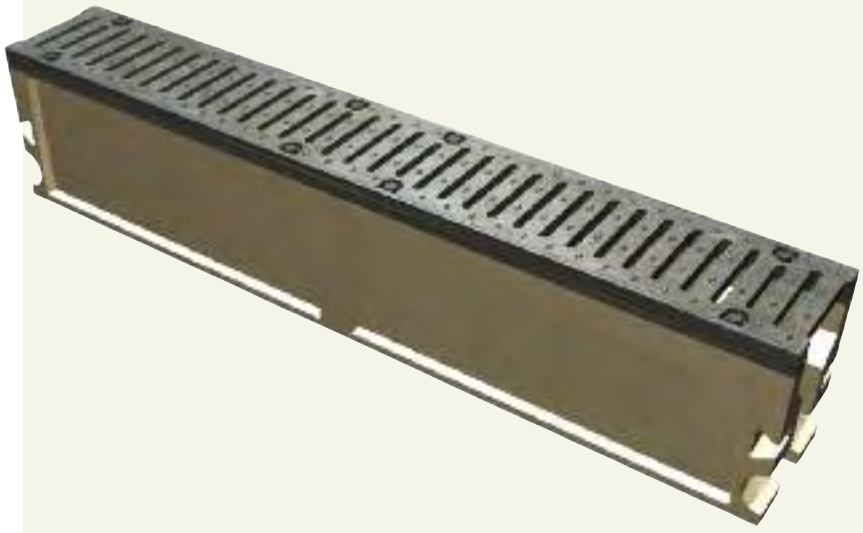
Permachannel performs several key functions in relation to controlling pollution in run-off, including stilling the sheet flow to encourage controlled deposition of silt and effluent, interception and separation at source.

The system has been installed in, and is monitored on, several sites. On one large site, the first annual maintenance inspection reported that the drainage system was operating effectively with silt and effluent controlled within the channels and the development manager reported no problems with the system, which is routinely monitored and maintained.

Water treatment design

The design of the Permachannel systems should ensure sufficient pollution removal and storage capacity. As a basic rule of thumb, a maximum of 30 m^2 of impermeable area should drain to each 1 m length of Permachannel. The volume of the silt trap within the channel or kerb is required to provide sufficient silt and floating oil storage capacity. The spacing of the Permaceptor outlets also ensures that flow velocities are not excessive.

See also Appendix 2, Design details, pages 78-87.



Example silt and oil loading calculation

Calculate required silt and oil storage volumes in accordance with Environment Agency's Pollution Prevention Guideline 3.

Silt trap capacity

Volume of silt trap in Permachannel = 0.0045 m^3/m

Sediment load in catchment = 865 kg/ha/yr

Catchment area = 6800 m^2

Total sediment load from catchment = 588 kg/yr

Assume density of unconsolidated sediment in base of silt trap is 1200 kg/m^3 (typical value for dock silt) then volume of sediment per year from whole car park = 0.5 m^3.

Channel length is 700 m

Volume of silt trap in channel in total for the site = 3.2 m^3

So, time to fill this with silt is approximately 6 years (assuming no maintenance is undertaken).

Oil trap capacity

The amount of oil that can be retained is the difference in height between the baffle and weir in the separator.

Height difference = 40 mm

So, volume that can be accommodated = 0.003 m^3/m

Total volume for site = 2.2 m^3

Required capacity from PPG 3

Nominal size of separator = NSB = site area x 0.0018

NSB = 0.0018 x 6800 = 12.2

Required silt storage = NSB x 100 = 1220 l = 1.2 m^3

Actual storage = 3.2 m^3 which is acceptable

Oil storage required

= NSB x 15 = 184 l = 0.18 m^3

Actual is 2.2 m^3 which is acceptable.

Charcon Permavoid Biomat

The Permavoid Biomat system has been specifically designed to remove hydrocarbon pollutants from the surface run-off water. The system comprises a buoyant geocomposite located inside a Permavoid unit. The composite interacts with oil deposits, allowing formation of a 'biofilm' on its solid surface and providing the opportunity for nutrient recycling which would allow active biofilm development. The system provides an environment which encourages oil-degrading micro organisms as moisture, oil and oxygen from the atmosphere are all present supplied with a large surface area for oil adsorption and biofilm attachment.

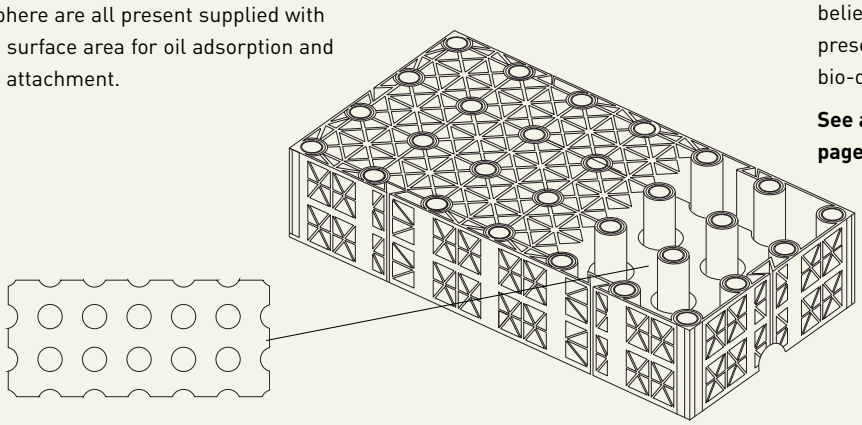
The Permavoid Biomat system has been extensively researched in partnership with Coventry University.

The experiments included studies of the oil retention, the biofilm formation and the mineralisation of the entrapped hydrocarbons. Model systems were used for the study comprising a full pavement cross-section. The models were subjected to an oil loading of 1.2 l/m^2 and a weekly rainfall of 20 mm.

Results

The research has demonstrated that the system is capable of retaining and bio-degrading the hydrocarbon pollutants from the surface waters. The system is capable of retaining 56 g of oil per Charcon Permavoid Biomat. The entrapped hydrocarbons become part of a complex biofilm, which utilises the oil pollutants as a nutrient source (mineralisation).
The system also demonstrated that both unused and used lubricating oil can be degraded. This experiment produced an unexpectedly beneficial result, as it was believed previously that substances present in used oil may inhibit the bio-degrading organisms responsible.

See also Appendix 2, Design details, pages 78-87.



Charcon Permafilter Geotextile

Permafilter Geotextile has been specially designed to retain hydrocarbon pollutants. Permafilter Geotextile comprises non-woven, needle punched geotextile made from a proprietary blend of modified polyester fibres. The textile has a weight of 300g/m^2.

The entrapped pollutants are either removed or reduced to levels suitable for discharge into controlled waters.

Working principle

The proprietary blend of fibres in Permafilter Geotextile exhibit specific hydrophilic and hydrophobic properties and these, combined with the dimpled structure, work together to form multiple layers with inherent oil retention properties.

The hydrophobic (repelling) material receives and retains the hydrocarbon pollutants, whilst the hydrophilic (water-attracting) elements simultaneously facilitate water retention resulting in a long-term stable biofilm, which subsequently degrades the entrapped pollutants.

Applications

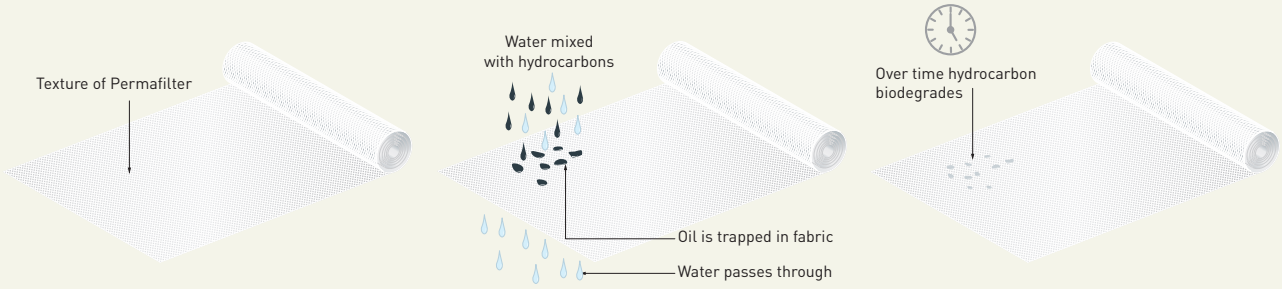
The range of applications for the Permafilter Geotextile is virtually unlimited in traditional geotextile applications, where enhanced hydrocarbon treatment can be achieved. Furthermore, it is applicable in many 'new' applications where the superior hydrocarbon retention is an indispensable requirement.

Examples for applications using Permafilter® geotextile:

- Pollution barriers
- Permeable pavements
- Impervious pavements
- Infiltration systems
- Attenuation systems

Experimental results

Permafilter Geotextile demonstrated retention of up to 6 l of oil per 10 m^2. The effluent monitoring showed a maximum discharge of 4.5 ppm* during the first flush and during consecutive rain events only an average concentration of 1.5 ppm.



*ppm = parts per million

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The treatment train system with Charcon Permavoid, Permachannel and Permaceptor

Benefits of the complete system

- Effluent loading under normal conditions treated and degraded at source
- Accidental and catastrophic spills recoverable at source
- Outperforms Class I and II separators as defined by PPG3
- Low velocity water flow throughout, minimising emulsification and sediment mobilisation
- Routine maintenance easily achieved at source
- Safe system, no large access points, no deep storage, minimal velocities

Stage 1 treatment: At source – Charcon Permachannel

Phase 1 primary treatment at source of silt and oil.

Key component benefits

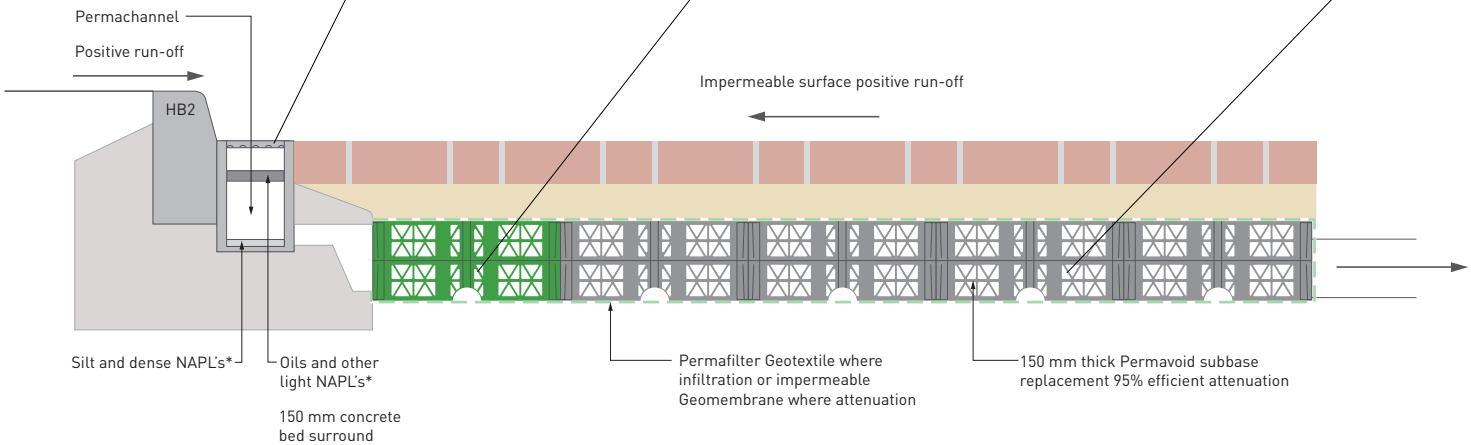
- Prescribed micro-catchment with proportional effluent and silt loading
- Gravity separation of oils and silts at source
- Stilling of flows for controlled silt deposition and emulsification prevention
- Trapped effluent naturally treated by aerobic digestion

Stage 2 treatment: Charcon Permavoid Biomat

Phase 2 secondary treatment for potential residual hydrocarbon (potential emulsification) Permavoid Biomat.

Key component benefits

- Floating medium maintained at air-water interface for optimum conditions for aerobic degradation
- Self-maintaining ecosystem with micro-organisms digesting the hydrocarbons



* Non-aqueous petroleum liquids

Stage 3 treatment: Charcon Permavoid attenuation

Phase 3 tertiary treatment, attenuation and dilution.

Key component benefits

- Permavoid is made from recycled materials and is easily recoverable and reusable
- Shallow system avoids excavation in soils (potentially contaminated) and reduces quantities of imported quarried material

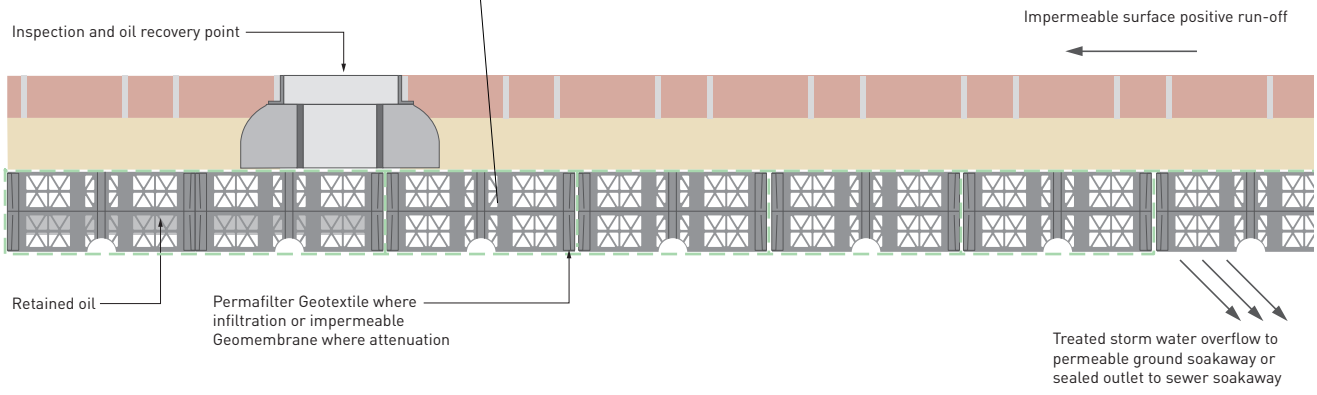
Stage 4 treatment: Charcon Permaceptor

Phase 4 final treatment, catastrophic event oil separation.

The Permaceptor has been developed to provide the benefits of a multi-stage treatment system at the source of surface run-off where a conventional road gully is used.

Key component benefits

- High effluent capacity for catastrophic events
- Treatment occurs after attenuation, therefore low flows (typically greenfield run-off) low velocity = improved treatment
- Oil recovery and inspection access



Use of Geotextiles and Geomembranes

Geotextiles

Geotextiles may be used in two locations in concrete block permeable pavements:

1 Between the laying course and the subbase (upper geotextile).

2 At the bottom of the subbase, either as a separator from the subgrade or to protect the impermeable geomembrane (lower geotextile).

Upper geotextile

The upper geotextile is used to prevent migration of the finer laying course material into the coarser subbase material.

Tests have shown that water quality will improve when it flows through a concrete block permeable pavement, and there is evidence that the use of geotextile between the laying course and the subbase, may assist in enhancing pollution removal and biodegrading of pollutants.

The decision to use a geotextile between the laying course and the subbase is a balance between durability and structural performance of the pavement and possible improvements in water quality. For non-woven geotextiles in contact with open graded aggregate durability has been shown to increase as the weight of the textile increases.

Geotextiles such as those specified by Aggregate Industries are heavier weight materials (300g/m^2) that are more durable than thin light weight materials.

In applications where there will be frequent trafficking by HGV's, buses, etc, or the pavement is subjected to a large number of breaking and accelerating forces, the upper geotextile should be omitted and the grading of the laying course and subbase designed to avoid migration of materials.

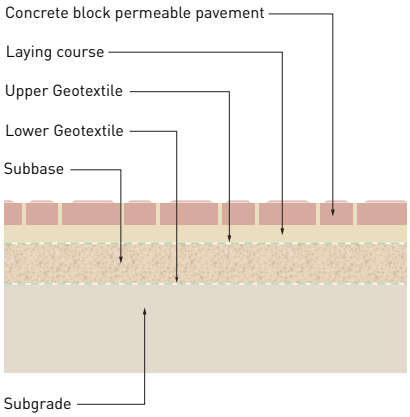
Lower geotextile

Geotextiles are used in this location to act as a separator to prevent the subbase punching into the subgrade soils and causing clogging of the sub base. Where water infiltrates to the ground this geotextile will also act as a filter and support biodegradation.

Where the geotextile is to be used to protect an impermeable membrane, the use of a reinforced geotextile is recommended by Aggregate Industries.

Other uses

Charcon's Permafilter Geotextile can also be used to protect against oil ingress below swales, infiltration basins and other similar SUDS components where additional protection is required.



Geomembranes

Geomembranes are impermeable liners used in Aggregate Industries' SUDS components to form water tight tanks. The membrane used depends on a risk assessment of the site and the ground and groundwater conditions.

The use of a polypropylene membrane that is robust and resistant to puncture is recommended. The membrane has welded joints and should be installed by a qualified sub contractor under a quality assurance scheme that includes testing of the joints.

Permeable pavements on sloping sites

If a pervious pavement is built on a sloping site, it must be designed to prevent all the water in the subbase running to the bottom of the slope and exiting the surface. The slope also reduces the available storage in the subbase.

For sloping sites where the subgrade gradient exceeds about 5%, terraced areas of permeable pavements, separated below the surface by compartment walls, are particularly effective. Here, flow rates between compartments can be controlled enabling optimal treatment of the water for maximum pollutant removal within the pavement. Terraces of interconnected permeable pavements can be used in isolation or with just a final SUDS stage, such as a pond, to effectively treat run-off from paving and roofs.

There are four potential solutions to this issue:

1 Install dams within the subbase with flow controls to ensure the water does not flow to the lowest level and come out of the surface. There are various ways of achieving this including bunds formed in concrete, membrane or blockwork.

2 Terrace the site to give flat areas of permeable paving that have separated subbase storage areas.

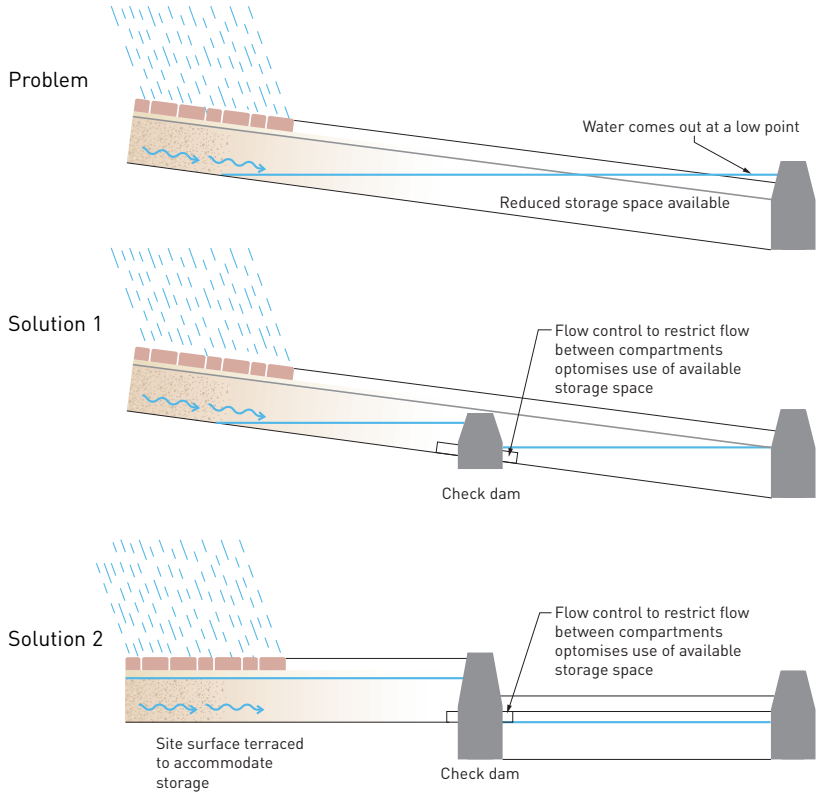
3 Use Permavoid units at the lower end of the site to increase storage capacity.

4 The subbase thickness can be increased to allow for the reduced storage capacity in the subbase at the top of the slope.

These precautions are required wherever the subbase is used for water storage on sloping sites (including any infiltration systems). In all cases, careful analysis and detailing is required to ensure that the water flows within the pavement are as predicted and that unexpected 'spring lines' do not occur in the pavement. The exact design will depend on the site area, discharge limits, etc.

If the pavement area slopes towards a building then, as a precaution, a channel drain or surface channel should be provided to drain the water away to a suitable outfall and prevent it ponding up against the building.

Solutions for sloping sites



Charcon Permachannel and Permavoid on sloping sites

Permachannel is not designed to allow the conveyance of water along the length of a channel run. It is designed to collect water and convey it to a Permavoid system which will sit parallel to the channel run and as such, Permachannel is normally installed to a zero gradient (i.e. level). The levels of the area being drained must be designed to accommodate this. If this is not possible and it is used on a sloping site, it must have an adjacent conduit (Permavoid) that is sized to carry the discharge to a Permavoid attenuation facility.

Permachannels can be installed on a 'hit and miss' basis with outlets spaced at given centres as dictated by the size of the catchment area and quantity of water being collected by the channel. This may be appropriate on sites where there is a longitudinal gradient to overcome.

Permavoid is designed to be installed level or with a nominal 1 in 500 fall to outlet if used as an attenuation system. Permavoid may be placed on a gradient if it is used as a conveyance device.