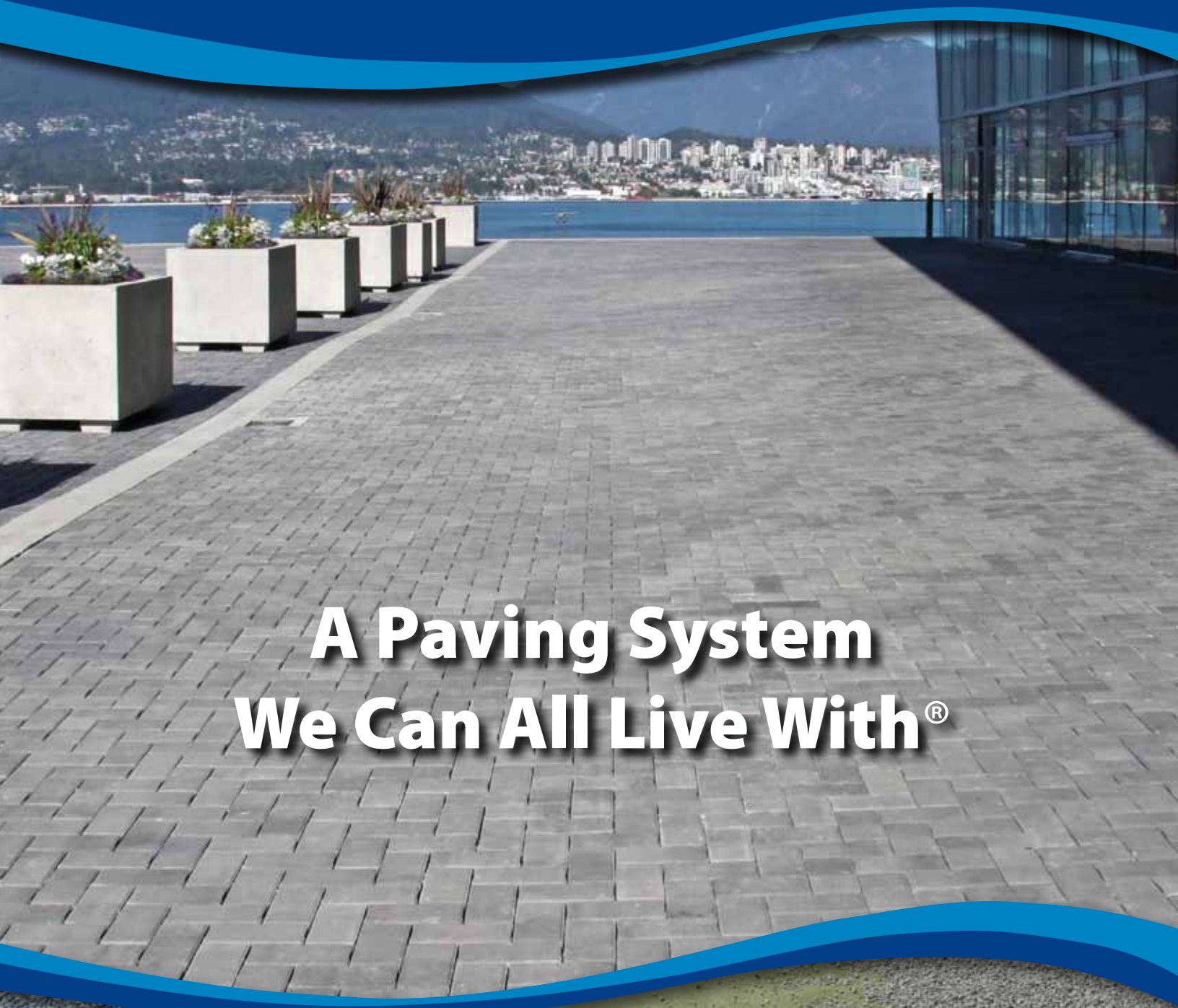
AQUAPave®

Permeable On-Site Stormwater Source Control System



A Paving System We Can All Live With®

Hanson
HEIDELBERGCEMENT Group
Hanson Hardscapes

A Paving System We Can All Live With®

- **Lower Construction & Life Cycle Costs**
- **Pedestrian Friendly**
  AquaPave® provides a flat smooth surface with narrow voids that is free of loose aggregates
- **Disability Friendly**
  Meets design guidelines recommended by the Americans with Disabilities Act (ADA)
- **Eliminates Surface Runoff**
- **Reduces Pollutants in the Environment**
- **Water Harvesting**
- **Traffic Calming**
- **Geothermal Systems**
- **Earn Up To 12 LEED® Points**

AQUAPave®

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The Problem

Increasing urbanization generates excess stormwater runoff from impervious surfaces. What were once farmers' fields or native forests are now subdivisions, shopping malls and roadways. This strains stormwater drainage systems, overloading them during periods of heavy rain. As a result, downstream areas are encountering more frequent and intense flooding. In addition, groundwater elevations are dropping and streams are experiencing increased bank erosion and sedimentation.

With respect to water quality, heavy metals, hydrocarbons, nutrients, rubber, dust and sediment collect on impervious surfaces during dry weather. These accumulations are flushed away during the next rainstorm and enter downstream watercourses. The "first flush" is the initial period of a rainstorm where pollutant concentrations are highest. These pollutants enter streams, lakes and bays affecting the quality of receiving waters for drinking, recreation and fishing. Treasured fish species such as salmon and other eco-systems are negatively impacted by these events.

The Solution - AquaPave® Permeable On-Site Stormwater Source Control System

Regulatory agencies have responded to the problem by requiring developers to utilize Best Management Practices (BMPs) to deal with stormwater on site; in short, no impacts are to be imposed on downstream receptors. The U.S. Environmental Protection Agency has recognized permeable pavements as a BMP suitable for improving stormwater management.

The **AquaPave®** Permeable On-Site Stormwater Source Control System is an important first effort to reduce excess stormwater runoff quantities and improve water quality. The **AquaPave®** system allows commonly recurring rainstorms to infiltrate through a permeable concrete paving stone surface into a clear crushed open-graded aggregate base before being released into storm sewers or watercourses. Known as permeable interlocking concrete pavement, the system acts as an infiltration facility for the storage, treatment, and improvement of released water.

All **AquaPave®** pavers provide drainage through vertical channels and allow water through the surface at a rate of approximately 9000 mm/hr (354 in/hr). This is regulated to 4500 mm/hr (177 in/hr) by a layer of geotextile. If the soil subgrade and underlying geology are suitable, some or all of the water can infiltrate directly into the subgrade, thereby substantially reducing outflow rates. Alternately, the surface water can be temporarily stored in the sub-base before being slowly released into the receiving water system. The **AquaPave®** system helps to clean and improve the quality of runoff water by filtration through the base and microbial action. In many instances, the outflow can be re-used for irrigation of domestic and commercial landscapes.

Applications

Consisting of permeable interlocking concrete pavers and a clear crushed open-graded aggregate base, the **AquaPave®** Permeable On-Site Stormwater Source Control System is suitable for parking lots, residential driveways, commercial entrances, overflow parking areas, boat ramps, sidewalks, plazas, and low-speed residential roads.

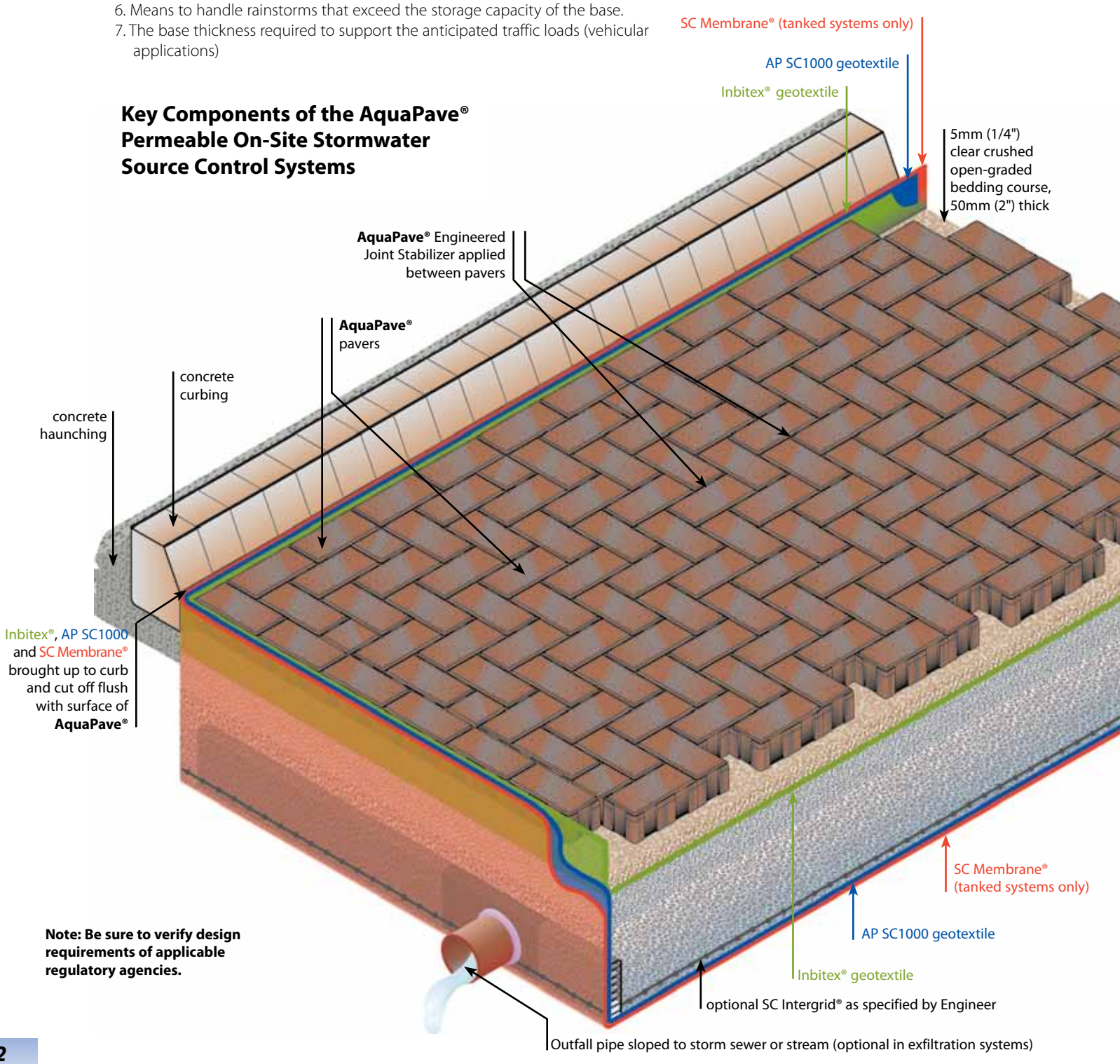
Most municipalities strive to manage runoff from a range of storms with the intent of reducing runoff volumes and peak flows to those from pre-development conditions. In addition, many U.S. cities must obtain permits from the National Pollutant Discharge Elimination System (NPDES) administered by state and federal agencies. The applications for permits must include post-construction BMPs for the reduction of runoff and pollutants. As an effective BMP, the **AquaPave®** Permeable On-Site Stormwater Source Control System can be part of a municipality's stormwater management plan and help achieve compliance with the NPDES regulations.

Photos at right demonstrate the drainage capability of a typical AquaPave® installation over a two minute period.

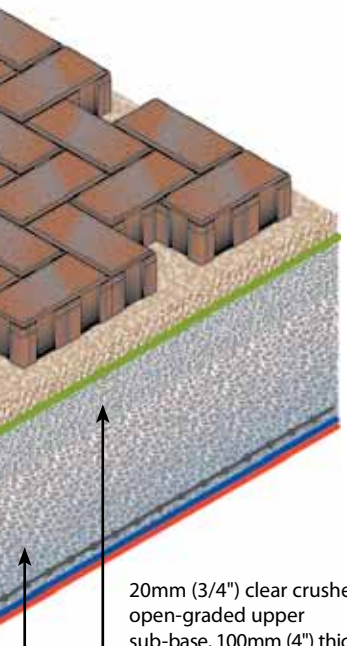
When designing an AquaPave® system, the following conditions need to be determined by a qualified design professional:

1. The range of design storms and antecedent moisture conditions that will be managed by the system. These are commonly recurring rain storms.
2. The total area contributing to the AquaPave® system. Typically this is no greater than a 5:1 ratio based on the standard design as shown below.
3. The amount of water that will enter the system and be stored in the base, treated, filtrated, and/or released over a specific time, typically between 24 and 72 hours.
4. The long-term infiltration capacity of the soil subgrade.
5. Exfiltration options for the base, as guided by the determinations in conditions 1 through 4.
   Exfiltration options include:
   - Full Exfiltration into the soil subgrade with no underlying drain pipes.
   - Partial Exfiltration, i.e., some infiltration into the soil subgrade and some detention with drainage through underlying pipes.
   - No Exfiltration where an impermeable liner captures the stored runoff and prevents its infiltration to the soil. This is a detention facility with drainage through underlying pipes.
6. Means to handle rainstorms that exceed the storage capacity of the base.
7. The base thickness required to support the anticipated traffic loads (vehicular applications)

Key Components of the AquaPave® Permeable On-Site Stormwater Source Control Systems



Note: Be sure to verify design requirements of applicable regulatory agencies.



AquaPave® Interlocking Concrete Paver

The unique features of the patented **AquaPave®** interlocking concrete pavers are the vertical channels and other design characteristics that allow surface water to infiltrate through to the sub-base. These unique characteristics can be applied to any paver shape, providing an unlimited number of possibilities. Our stock paver size, thickness and colours are shown on page 5 – for specialty colours, shapes or sizes, call Hanson Hardscapes at 800 265 6496.

AquaPave® Engineered Joint Stabilizer

AquaPave® Engineered Joint Stabilizer is placed in the spaces (joints) between the pavers to help ensure the interlock, therein creating a more stable and secure surface. Since gradation, texture and durability are critical to the long-term performance of the Engineered Joint Stabilizer and in turn the entire system, Hanson Hardscapes supplies pre-bagged **AquaPave®** Engineered Joint Stabilizer for your convenience. Contact Hanson Hardscapes for more information on available package sizing.

Bedding Course

The bedding course provides four main functions: it beds the pavers during installation; it helps initialize interlock among the pavers; it provides a structural component for the system; and it facilitates drainage of water that infiltrates through the joints. To ensure proper performance, the bedding course material needs to be a 5mm (1/4") clear crushed open-graded aggregate. This aggregate must be manufactured to ensure proper performance; natural rounded material is not permitted. The source material must be of sufficient durability as to withstand the expected traffic loading.

Inbitex® Geotextile

Inbitex® is a thermally bonded non-woven geotextile that was specifically developed to work within the **AquaPave®** system to optimize the cleaning of water entering the sub-base. The various characteristics have been combined to create a unique geotextile that not only provides separation between the bedding course and sub-base, but also aids in the development of naturally occurring microbes. These microbes are vital to the bio-degradation of captured pollutants and overall cleansing of the water. Inbitex® also provides these microbes refuge during periods of drought.

For optimal performance, Inbitex® is to be laid out horizontally immediately below the bedding course. Along the perimeter, the geotextile is to be brought up vertically with the curb and cut off flush with the surface of the **AquaPave®** pavers. Contact Hanson Hardscapes for available roll sizes of Inbitex®.

Sub-base and SC Intergrid® Geogrid

The sub-base has two main functions: it provides the structural foundation upon which the pavers rest; and it provides sub-base storage capacity. Specifications for the upper and lower sub-base materials are included on Page 21 – Tables 2 and 3 respectively. Where additional structural support is required, the Design Professional may select to augment the sub-base with one or more layers of SC Intergrid® Geogrid.

AP SC1000 Woven Geotextile

The purpose of the AP SC1000 is to prevent mixing of the imported sub-base material with the native subgrade which could weaken the sub-base. To prevent native material from migrating into the sub-base from the sides of the excavation and reducing void capacity storage, the AP SC1000 needs to be brought up and cut off flush with the **AquaPave®** pavers.

SC Membrane®

For "No Exfiltration Systems" (see page 4 for details), it is necessary to install an HDPE (high density polyethylene) or EPDM (ethylene propylene diene monomer) membrane to prevent the migration of water into the existing subgrade. As with the woven geotextile, the SC Membrane® must encapsulate the entire system.

Although the SC Membrane® is subject to selection by the Design Professional, the material must be, at a minimum, inert to biological degradation and must resist naturally encountered chemicals, alkalis and acids.

Typical Systems and Exfiltration Options *(Modify to site conditions)*

The following is intended to serve as a reference guide only for designing an AquaPave® system, and is not intended to replace an actual site specific design as prepared by the Design Professional.

Step 1 – Evaluate Existing Conditions

1. Determine the hydraulic conductivity and structural strength of the subgrade soils. Reference ICPI Tech Spec 4 for assistance.

Step 2 – Conduct a Water Balance

1. Identify the total area contributing to the **AquaPave®** system, including the paved area and the surrounding run-on area. When using our standard design specifications, the run-on area should not be greater than five times the paved area.
2. Select the intensity and duration of the design storm to be used, and calculate the resulting antecedent moisture conditions (for each applicable soil type within the contributing area) that will be managed by the system.
3. Calculate the infiltration rate and total amount of water entering the system.
4. Compare the infiltration rate to the hydraulic conductivity of the soil subgrade. Determine the resulting storage requirements of the sub-base (if any).

Step 3 – Sub-base Design

1. Calculate the structural design thickness of the sub-base subject to the subgrade strength, anticipated loading, and design life.
2. Compare the previous to the design thickness based on storage capacity of the base (approximately 30% of the base volume).
3. Select the greater of the two. In the case of the structural design being greater, consider re-evaluating design using SC Intergrid®.

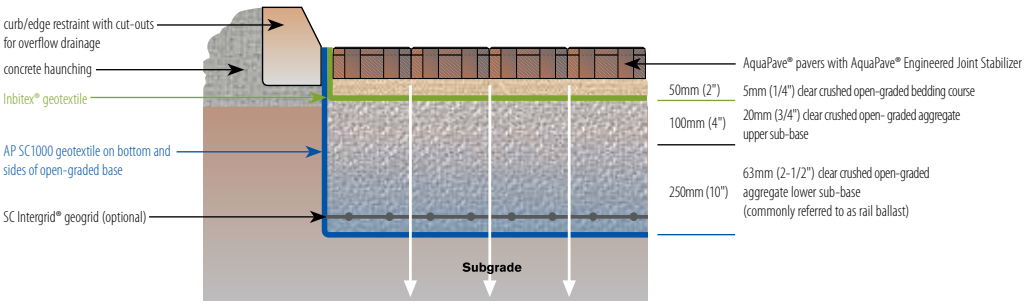
Step 4 – Verify Overflow Drainage

1. Verify the location and elevation of the available storm drain(s) or watercourse(s).
2. Compare these to the proposed elevation of the outfall pipe.

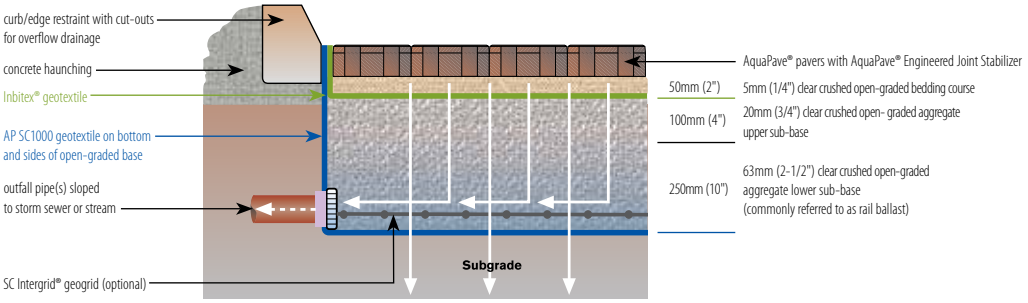
If the infiltration rate of the soil subgrade, with or without the allowable storage volume within the base material, exceeds the infiltration rate of the system, then a "Full Exfiltration System" can be used. (Note: Full Exfiltration System refers to exfiltration from the system itself).

For permeable soils in which the infiltration rate of the soil subgrade is lower than the infiltration rate of the system, even after allowing for storage within the base material, a "Partial Exfiltration System" can be used. Where a tanked system is desired, a "No Exfiltration System" can be used.

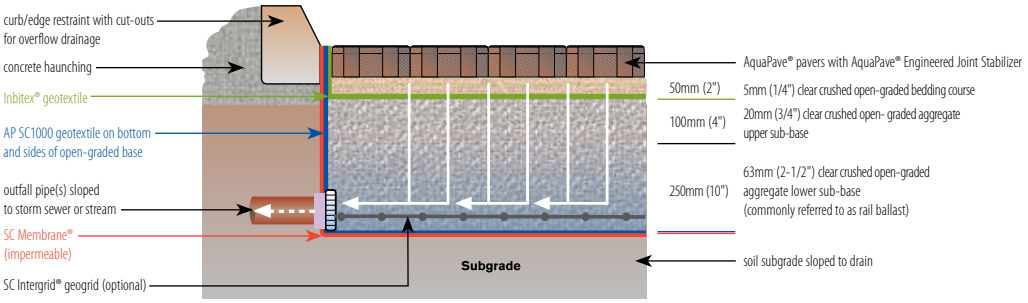
Full Exfiltration System



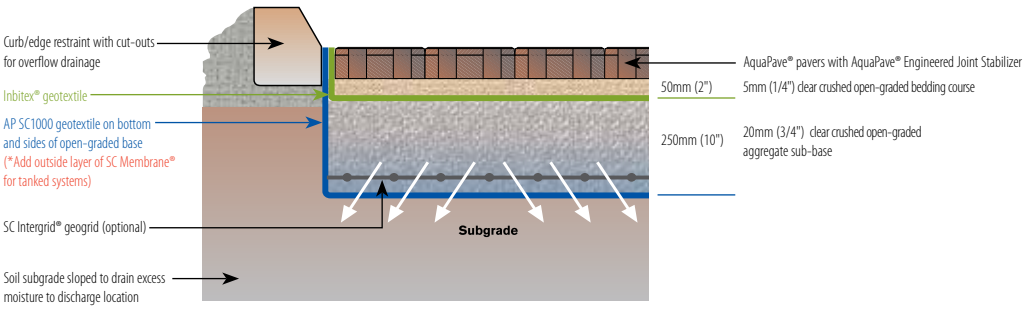
Partial Exfiltration System



No Exfiltration System



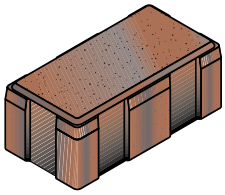
Typical Residential Driveway/Sidewalk Construction



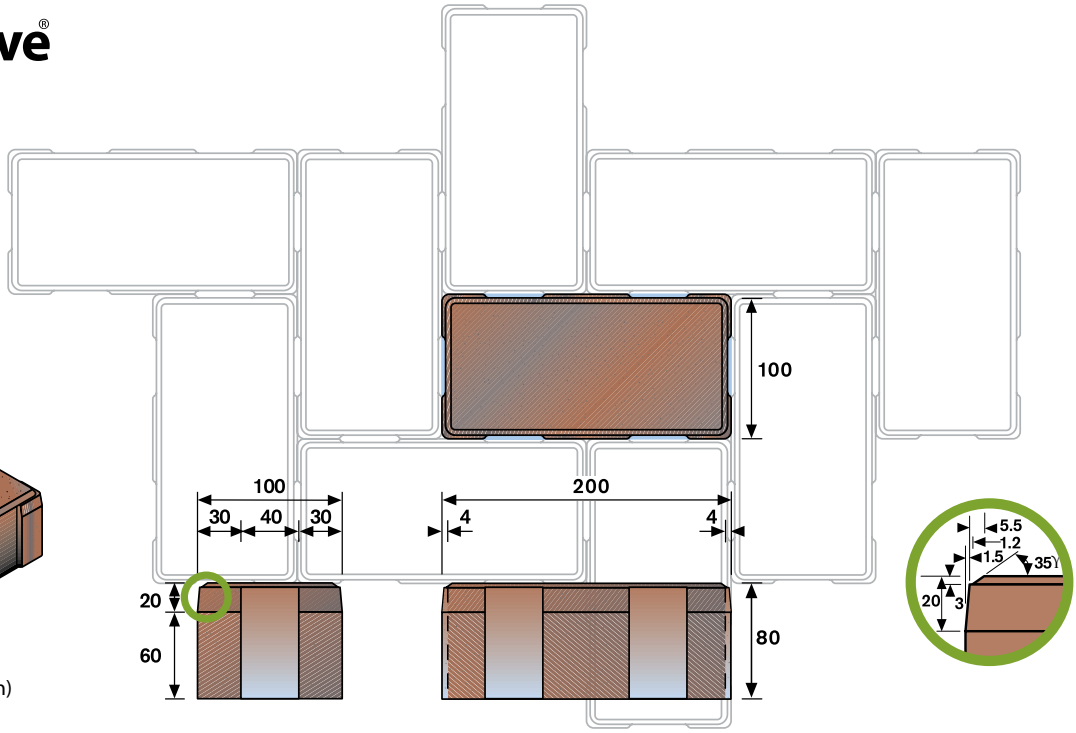
On all designs:
- Open-graded base thickness varies depending on water management and/or structural requirements.
- For pedestrian sidewalks or residential driveway applications, only the 20mm (3/4") clear crushed open-graded aggregate, upper sub-base is required. Base depth varies depending on application but should be a minimum of 150mm (6") thick.

AQUAPave®

Niagara™
80mm



198 x 98 x 80 mm
(7.80 x 3.86 x 3.15 in)



AquaPave® Niagara™ Colours

Conestoga Buff Blend
Buff/Medium Brown

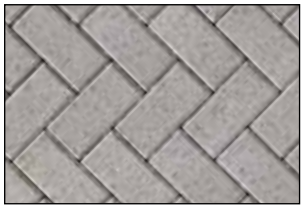
Granite Blend
Natural Grey/Black

Riverbed Blend
Salmon/Buff/Black

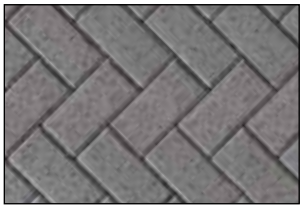
Smoke Blend
Light Buff/Black

Terra Cotta Blend
Salmon/Brown/Black

Walnut Blend
Brown/Black



Natural
Natural Grey



Charcoal
Black

Custom colours are available as a special order. Please call Hanson Hardscapes at 800 265 6496 for details. *While the colours shown here are represented as accurately as possible, they should only be used as a guide. Actual samples should be viewed before making final colour selection. For best results, pavers should be installed from several pallets at once, removing them from pallets in stacks rather than in layers.*

Hanson Hardscapes offers **AquaPave®** Niagara as its standard use shape. **AquaPave®** Niagara 80mm is intended for areas subject to constant vehicle traffic such as parking lots and low speed roads. It is also suitable for residential driveways and pedestrian areas. **AquaPave®** Niagara pavers should be laid in a 90º or 45º herringbone pattern. To accommodate machine lay installations, pavers are packaged in a 90º herringbone pattern.

For projects in Canada and the United States, paving units are manufactured to meet or exceed *CSA A231.2-06, Precast Concrete Pavers* and *ASTM C936-09, Standard Specification for Solid Concrete Interlocking Paving Units*.

Specialty Shapes

As mentioned previously, the unique design of the patented **AquaPave®** interlocking concrete pavers are the vertical channels and other design characteristics that allow surface water to infiltrate through to the sub-base. These unique characteristics can be applied to any paver shape, providing an unlimited number of possibilities.

For sufficiently large-sized projects, it is possible to manufacture a specialty shape upon request. However, please note that at least 6 months notice would be required to allow for the mould to be ordered and obtained.

Benefits

Lower Construction Costs

In conventional drainage design, infiltration and detention facilities are separate from impervious parking lots and pedestrian areas. **AquaPave®** On-Site Stormwater Source Control System combines the parking, infiltration and detention facilities into one location, allowing more space on the site for income-generating buildings. With the water detention facilities located below ground, we eliminate public safety concerns associated with the accidental drownings of children. This also eliminates the breeding areas for insect born diseases such as West Nile Virus.

Experience has shown that total construction costs are lower in most **AquaPave®** systems than conventionally drained surfaces. For some designs there will be cost savings through the reduction or elimination of typical stormwater management infrastructure, including collection works, water retention ponds, treatment systems (e.g. oil/water separators), and associated appurtenances.

Considering the ever increasing cost of oil, **AquaPave®** is becoming comparable in unit price to other traditional paving systems. Couple this with the increased design life equivalent and you have a superior, more aesthetically pleasing surface at a lower cost. With its flat continuous surface, **AquaPave®** accepts pavement marking materials such as paint and thermal plastic tapes.

Reduction of Runoff

With an open surface area of about 2%, the openings can infiltrate as much as 9000 mm/hr (354 in/hr). The infiltration rate of the clear crushed open-graded aggregate used for the bedding and base is similar. For design purposes, a conservative 90% reduction in efficiency is generally assumed for infiltration facility design, due to the build-up of sediment over years of service. When considering a 90% reduction of initial infiltration as a typical design assumption, the **AquaPave®** On-Site Stormwater Source Control System will still capture, treat, infiltrate and filter rainstorms over 900 mm/hr (35.4 in/hr). This includes the commonly recurring storms, which generate the most pollution.

Recharging the Groundwater Table

Approximately 30% of water entering the system is lost through evaporation and does not leave in the form of exit water. With "Full Exfiltration" and "Partial Exfiltration" systems, some if not all of the rain water that falls on the paved area is allowed to infiltrate into the ground and recharge the local groundwater table. Groundwater is not only a primary source of drinking water, but it also maintains the base flow characteristics of our watercourses between precipitation events.

Roof Water Management

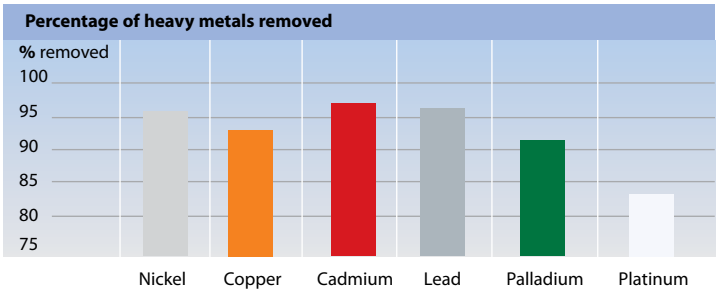
Roof water can be discharged into the sub-base. With gravity fed drainage it is recommended that the water is introduced into the sub-base by means of a sump with a manhole cover adjacent to the paved area. Any debris can be easily caught and cleared. The water is then dispersed within the system via a permavoid distribution tank or perforated outlet pipe. With siphonic drainage, a special chamber is used to disperse the water within the sub-base.

Pollutant Category Source	Solids	Nutrients	Bacteria	Dissolved oxygen demands	Metals	Oils (PAHs)* SOCs*
Soil erosion	•	•		•	•	
Cleared vegetation	•	•		•		
Fertilizers		•				
Human waste	•	•	•	•		
Animal waste	•	•	•	•		
Vehicle fuels & fluids	•			•	•	•
Fuel combustion		•			•	
Vehicle wear	•			•	•	
Industrial/household chemicals	•	•	•	•	•	•
Industrial processes	•	•	•	•	•	•
Paints & preservatives				•	•	•
Pesticides				•	•	

Common sources of pollution in urban stormwater runoff
PAHs = polynuclear aromatic hydrocarbons
SOCs = synthetic organic compounds
ref. 1

Pollutant	0.5 in (13mm) of Runoff per Impervious Acre	1.0 in (25mm) of Runoff per Impervious Acre	2-year Design Storm Treatment
Total suspended solids	60-80	80-100	80-100
Total phosphorous	40-60	40-60	60-80
Total nitrogen	40-60	40-60	60-80
Biological oxygen demand	60-80	60-80	80-100
Bacteria	60-80	60-80	80-100
Metals	60-80	60-80	80-100

Projected average annual pollutant removal capability of infiltration areas in percent
Note: These rates are not based on actual data since monitoring what enters and leaves any infiltration facility is difficult to measure. This data is based on land application of pollutants and their treatment through soils.
ref. 2



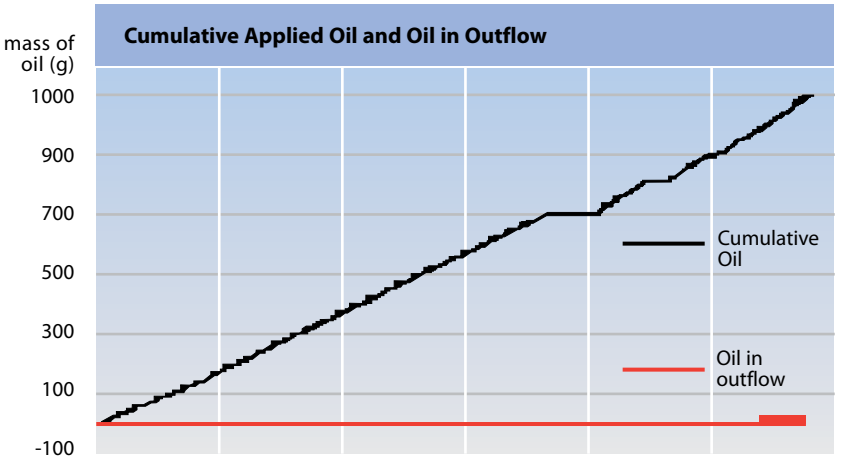
Data provided by the kind permission of Dr. Chris Jefferies and Fiona Napier. Urban Water Technology Centre, University of Albertay, Dundee.
ref. 3

Management of Oil Contaminates

"The runoff from parking lots represents the biggest single source of tonnages of oil going into the ocean" – *Brian Giroux, Port Hardy Forum on the Development of Off-shore Oil Exploration & Drilling.*

Oil drippings and related hydrocarbons are typically digested within the base through filtering and microbial action. Research by Coventry University, England on microbial action has shown that the **AquaPave®** system is capable of bioremediation at the rate of 400 grams (0.88 lbs) of oil per square metre (approx. 11ft^2) per year. Severe hydrocarbon contamination can be dealt with by feeding the affected areas with slow release fertilizer.

An additional advantage is that water exiting the system has a pH of approximately 7.5. *(In most urban areas, rainfall has a pH of approximately 4.5.)*



Courtesy of Stephen Coup, Coventry University *ref. 4*

Filtering and Treatment of Pollutants

Studies of permeable interlocking concrete pavement have shown substantial reduction of non-point source pollutants in runoff. The clear crushed open-graded aggregate base has a storage volume of at least 30%. This storage capacity enables a decrease in peak flows and treatment of pollutants, especially nutrients and total suspended solids prior to drainage of the water from the base through drain pipes.

Substantial reductions of metals can occur in full or partial exfiltration designs where the water enters silt and clay soils.

Analysis of exit water from the system has shown it to be as clean as the water discharged from a modern sewage treatment facility.

Westbrooke Shopping Centre

Pedestrian Friendly

The **AquaPave®** patented design was created to accommodate all types of pedestrian traffic. Unlike other permeable pavements, the **AquaPave®** system does not incorporate loose aggregates on its surface, making it safer and more comfortable to walk on, even with high heels. The result is a flat, smooth walking surface for customers and employees, completely free of water build up. **AquaPave®** is ideal for high foot traffic areas like building entrances, parking lots, inspection areas and bike paths.

LEED® Green Building Rating System

The Leadership in Energy and Environmental Design (LEED®) rating system uses a point system to recognize environmentally conscious site and building designs. LEED® is a design guideline used by some agencies for certification. It is a voluntary, consensus-based rating system to encourage sustainable construction sites and buildings. In Canada it is administered by the Canadian Green Build Council (www.cagbc.org) and in the U.S.A. by the U.S. Green Building Council (www.usgbc.org). More information can also be obtained in ICPI Tech Spec 16 (Achieving LEED® Credits with Segmental Concrete Pavements).

The **AquaPave®** Permeable On-Site Stormwater Source Control System can be eligible for earning points under LEED®. For example, SS Credit 6.1 offers 1 point for stormwater management on building sites where the existing impervious surface is greater than 50%. The LEED® requirement is that runoff rate and quantity be reduced by at least 25%. The **AquaPave®** system can reduce runoff rates and quantities from common storms by as much as 100%.

Another opportunity is MR Credit 5.1 (1 to 2 points) that requires a minimum of 20% of building materials manufactured within a radius of 800 km (500 miles). MR Credit 5.2 earns an additional point if 50% of the regionally manufactured materials are extracted, harvested or recovered within this same radius. Most **AquaPave®** projects will be within this distance from the manufacturer's plant, earning these credits.

There is also SS Credit 6.2 (1 point), Stormwater Management Treatment. (Additional LEED® points are available, see page 16 under Water Harvesting.)

Marine Way Shopping Centre

Access for People With Disabilities

AquaPave® paving units have gaps less than 13 mm wide, which meet the recommendations of the Americans with Disabilities Act Accessibility Guidelines *(ADAAG)*. Since **AquaPave®** does not need to be sloped to drain, access for the disabled can be made easier. **AquaPave®** provides a safe, smooth surface free of loose aggregates ensuring a reliable footing for the elderly or disabled using canes, crutches, walkers, or wheelchairs.

Slip and Skid Resistance

The ADAAG recommends that the slip resistance, expressed as a minimum coefficient of friction, be 0.6 for accessible routes and 0.8 for ramps. Testing conducted on behalf of the ICPI has verified that pavers, with the exception of pavers with polished surfaces, meet these guidelines. Vehicular skid resistance tests have demonstrated that stopping distances are shorter at speeds up to 64 km/hr (40 MPH) than either asphalt or typical concrete surfaces. Since the surface of the **AquaPave®** system consists of concrete pavers, the same resistance to skidding and shorter stopping distances can be expected. Couple this with the rapid infiltration of water, and the result is a reduction in accidents and increased safety.

Performance

Sun Micro Systems

Design Life

AquaPave® has a design life equivalent to that of conventional interlocking concrete pavers, typically 30 to 40 years. Should the pavers become damaged or cracked, they can be removed and replaced with new ones. The infiltration rate, storage capacity, and pollution reduction performance of the base depends on the amount of sediment that enters it. Therefore, control of sediment entering the system during and after construction is vital to continuing infiltration performance. When outside sources of sediment are kept from the pavement, a minimum of 25 to 30 year life can be expected. When the rate of outflow is significantly diminished, the **AquaPave®** pavers are removed, the clear crushed open-graded bedding and the Inbitex® geotextile are replaced, and the **AquaPave®** pavers reinstated.

Infiltration facilities and permeable interlocking concrete pavements such as **AquaPave®** are conservatively designed with the assumption of a 90% reduction in the infiltration rate. Using this as a worst case scenario, 10% of the initial infiltration rate of 9000 mm (354 in) per hour would be 900 mm (35.4 in) per hour. This infiltration rate would still be 18 times greater than the 50 mm (2 in) per hour system infiltration rate typical to many designs.

Professor John Argue of the Urban Water Resources Centre at the University of South Australia in Adelaide has conducted extensive research on the siltation of the pavers and bedding layer. His research assumed rainfall of 580 mm (22.8 in) per year with a loading of 200 parts per million of silts. This is a sediment loading similar to what would be found in an established urban catchment. His conclusion was that even after a thirty year life, the permeability of the surface was only reduced by 25%. *(For a copy of this research, please contact us.)*

Design Considerations & Maintenance

All pavement systems require regular maintenance. With the **AquaPave®** system, sediment that collects in the surface openings should be removed by vacuuming a minimum of two times per year. It is recommended that this take place in the early spring and late fall during a dry period. In most cases, this operation is already part of a regular maintenance program.

AquaPave® surfaces can be cleaned by pressure washing without risking damage to its components or dislodging and spreading loose aggregates like in other permeable paver systems. This makes it ideal for high foot traffic areas such as mall entrances and sidewalks.


BC Cancer Agency

Although there is a sizable factor of safety in terms of infiltration capabilities through the pavers, there is always the chance that sheeted ice or packed snow between plowing events could plug the system; should this occur, some surface water runoff would be expected. Every project should therefore have one or more separate spillways cut into the concrete curbs to allow for these conditions.

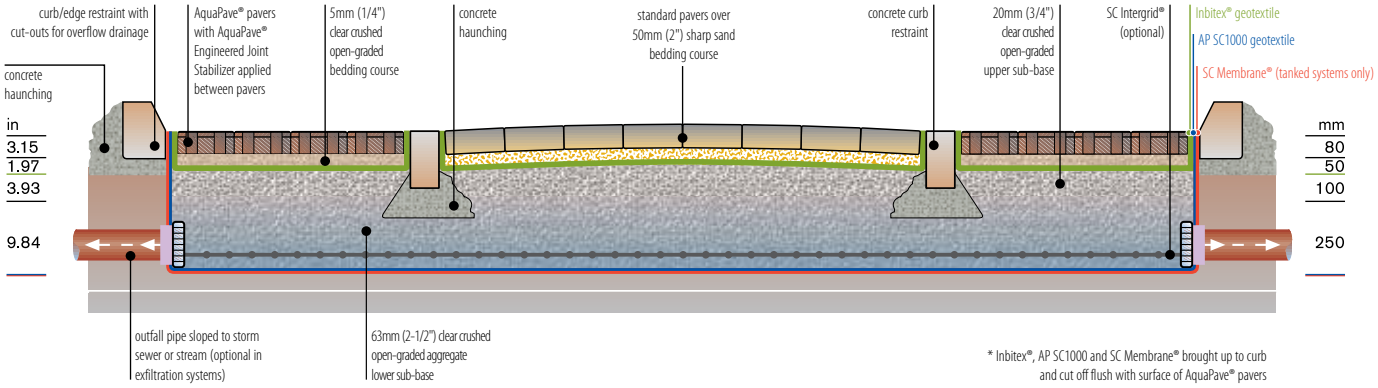
Design consideration should also be given to ensuring that soft landscaping is retained to prevent migration of softscape materials (e.g. topsoil) into the **AquaPave®** surface. Doing so will significantly help to maintain the integrity of the system.

AquaPave® doesn't incorporate loose aggregates or turf as an integral component of its system, therefore, mechanical snow removal methods are very effective on its flat continuous surface. Other types of permeable pavements may have to rely on chemical de-icing due to their shaped top surface. This may be counter to the water handling portion of the installation.

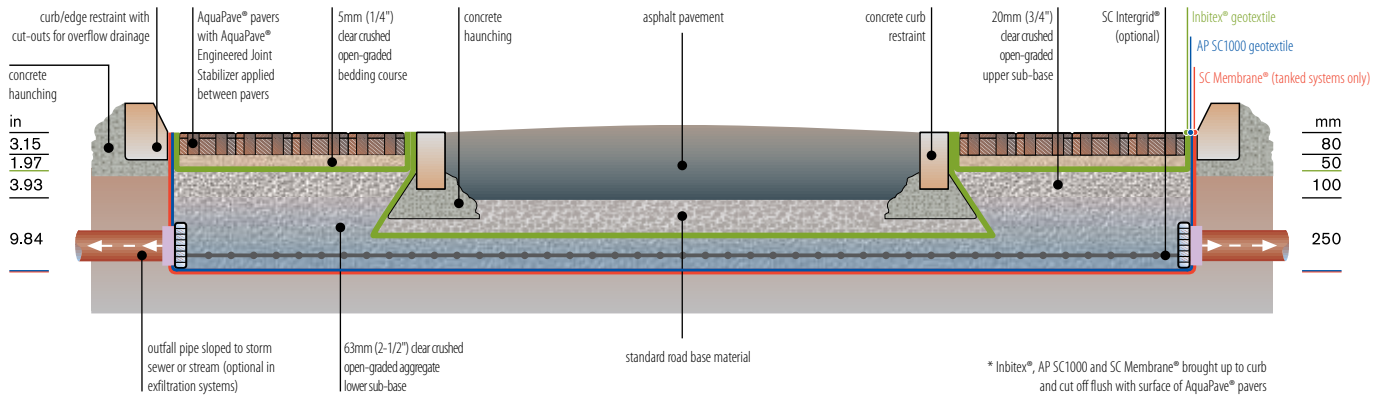
Settlement up to 25 mm (1 in) in the surface, as in all segmental interlocking systems, can be easily corrected. First, remove the area of pavers affected, then fill and compact the clear crushed open-graded aggregate used under the paving units. **AquaPave®** can then be reinstated and compacted with a plate compactor. Likewise, broken pavers can simply be removed, replaced and compacted. Unlike other paving systems, **AquaPave®** can be immediately reopened for use.
Heaving from freezing water in the crushed stone base is generally not a concern. There is typically sufficient void space within the aggregate to accommodate the 10% expansion in the volume of water when it freezes.

An observation well is recommended in all installations of the **AquaPave®** Permeable On-Site Stormwater Source Control System. The well is typically a 150 mm (6 in) diameter perforated pipe, placed near the lowest elevation of the pavement, out of the way of vehicular traffic. The top of the well can be under the pavers, hidden from view and covered with a secure lid. The well enables monitoring of outflow and sedimentation after storms, as well as an opportunity to sample and test water quality. Outflow should be monitored at least once a year after a large storm. Every project should have separate overflow drains or spillways to accommodate the saturation conditions that occur in high intensity and/or long duration rain storms.

AquaPave® In Conjunction With Conventional Interlocking Concrete Pavers

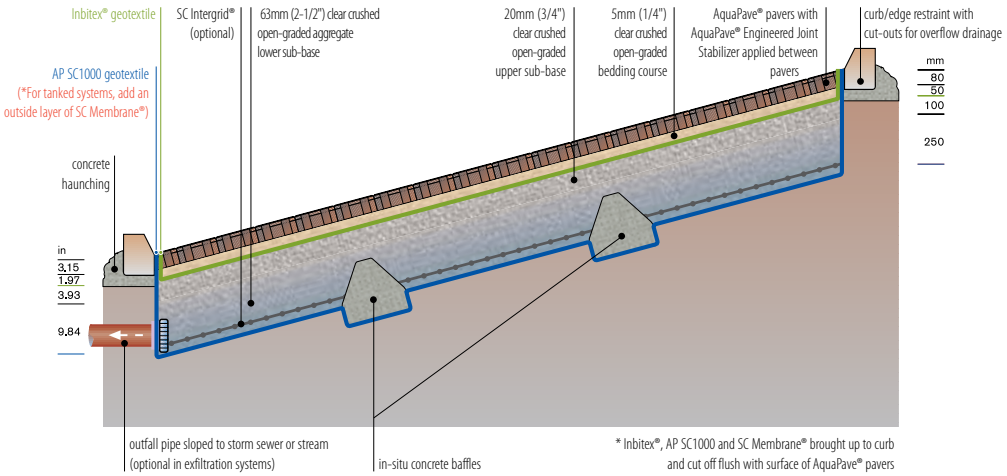


AquaPave® In Conjunction With Asphalt Pavement



All conversions from Metric to Imperial are approximate. Illustrations are not to scale.

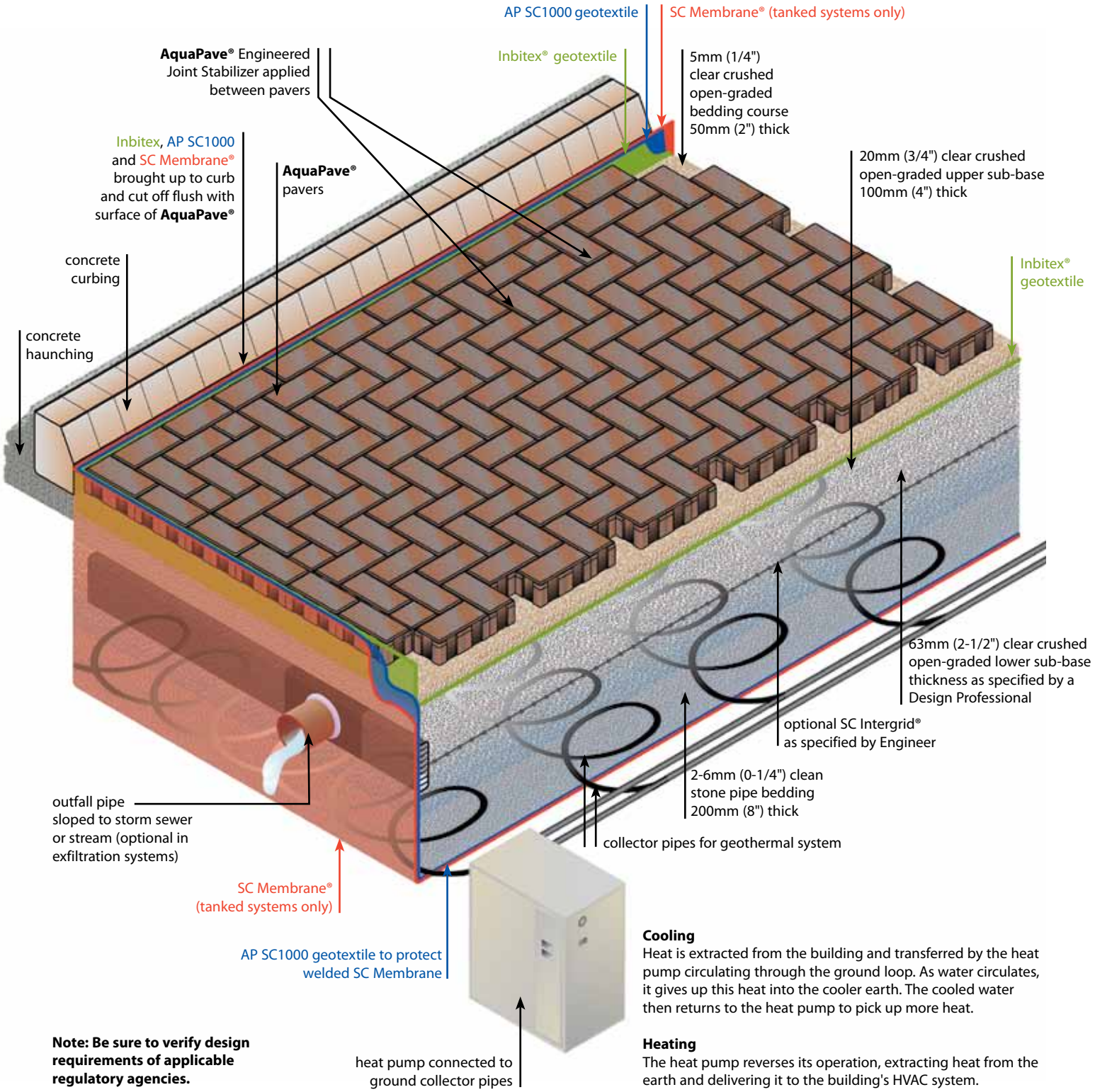
AquaPave® With Exfiltration System on a Slope



AquaPave® Geothermal System

The AquaPave® Geothermal System is capable of reducing a building's reliance on gas and/or electricity for heating and cooling by up to 50%. The patented system for heat capture from stored water can be used to generate 6 kilowatts of energy from approximately 100sq metres (1100 sq feet) of AquaPave® for indoor climate control.

A heat pump moves the heated or cooled water through either underfloor heating or radiators.



Cooling
Heat is extracted from the building and transferred by the heat pump circulating through the ground loop. As water circulates, it gives up this heat into the cooler earth. The cooled water then returns to the heat pump to pick up more heat.

Heating
The heat pump reverses its operation, extracting heat from the earth and delivering it to the building's HVAC system.

Note: Be sure to verify design requirements of applicable regulatory agencies.

AquaPave® Geothermal System

In one hour the sun imparts sufficient solar power to earth to support its total energy needs for one year.

In most places in the world, the temperature of the ground from 1 metre (3 ft) to 100 metres (330 ft) deep is approximately 10°C (50°F), every day of the year.

The **AquaPave®** Geothermal System is capable of reducing a building's reliance on gas or electricity for heating and cooling. This system combines the technology of the permeable pavement with geothermal technology using a patented sub-base and ground source heat pump (GSHP). The heat pump moves heated water through either underfloor heating, enlarged radiators or by fan coils to heat the building. Cooling is simply achieved by reversing this cycle.

The typical payback period on a standard system when balanced and operated correctly is approximately 6 years, after which, other than the cost of running the heat pump, heating and cooling costs are completely removed. There is no requirement for the burning of fossil fuels in this system as it uses 'environmentally friendly' and sustainable methods. This can reduce Carbon Dioxide emissions by over 50% and can show a reduction of up to 50% on energy bills.

As with our other **AquaPave®** systems, the **AquaPave®** Geothermal System also combines parking, infiltration and detention facilities into one location, allowing more space on the site for income-generating buildings.

The **AquaPave®** Geothermal system works by utilizing the voided sub-base to generate sufficient energy to allow the exchange of heat into buildings during cold periods and out of the building in the summer months. This is achieved by the pump using the constant temperature of the ground surrounding the installation which is typically used in summer months as a heat sink, and then in colder times as a source of heat.

There is an ambient temperature in the subgrade of 10°C (50°F) and it is the temperature differential between the loop and the ground that creates the energy produced within the refrigerant that affects the heat exchanger (GSHP). The ground source heat pump acts in a similar manner to a refrigerator, a series of collector loops are set horizontally within the sub-base. It is the refrigerant in the loop that passes the heat to the pump, this then goes through a compressor that channels the heat into the building via under floor heating, radiators or fan coils.

Although the pump is powered by electricity, this use of electricity is mitigated by a performance coefficient in excess of 4:1 i.e. you will get four units of energy for every one you put in, therefore reducing the overall use of non-sustainable energy.

6,500 m² (70,000 ft²) of our geothermal system supply 580kW of heating and 200kW of cooling to this 2,700m² (29,000 ft²) office building

1. Install welded membrane

2. Lay and compact 2-6 mm (0-1/4") clean bedding stone

3. Install the geothermal horizontal collector pipes

Geothermal heat recovery pipes are shown here, being installed by certified personnel. As the addition of these pipes represents the only difference in pavement design from a standard AquaPave® tanked system, the extra cost is minimal.

4. Pressurize and system check

5. Install and compact the graded sub-base stone

6. Compact for laying course

Benefits of the AquaPave® Geothermal System:

- **Save up to 50% on fuel bills - presenting a payback within the first 5-6 years.**
- **Low maintenance**
- **Low noise**
- **Reduces CO^2 emissions up to 50%**
- **Cuts water bills by an average of 50% - water stored underground can provide a supply for re-use within the home, i.e. toilets, car washing and irrigation.**

7. Install the AquaPave® pavers

8. Trim Inbitex®, AP SC1000 and SC Membrane® at finished grade

9. Final compaction and sweep in the AP Engineered Joint Stabilizer

Water Harvesting

The **AquaPave®** Permeable On-Site Stormwater Source Control System collects water from all impermeable surfaces, roofs, sidewalks and parking facilities.

All water entering the system through the paved surface is treated and cleaned by the Inbitex® geotextile layer before storage *(see page 6 & 7)*.

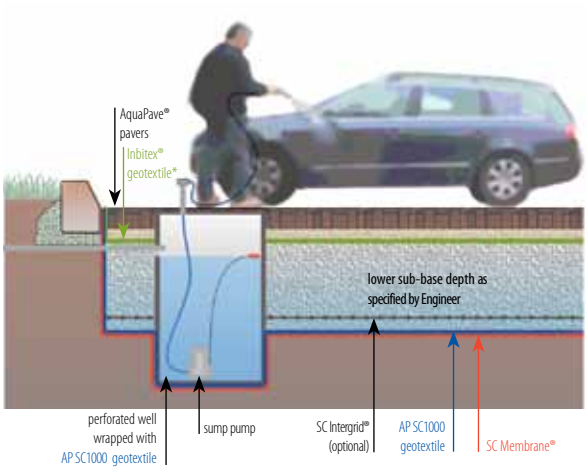
The filtered and treated water exiting the **AquaPave®** system can be re-used for non-potable uses such as domestic or commercial irrigation. In fact, some schools and youth hostels are currently using this non-potable water for the flushing of lavatories. This conserves and economizes on water usage and charges in some localities. (*Water quality has been tested at Edinburgh and Coventry Universities and independently verified by Severn Trent Water Authority - see page 23.)*

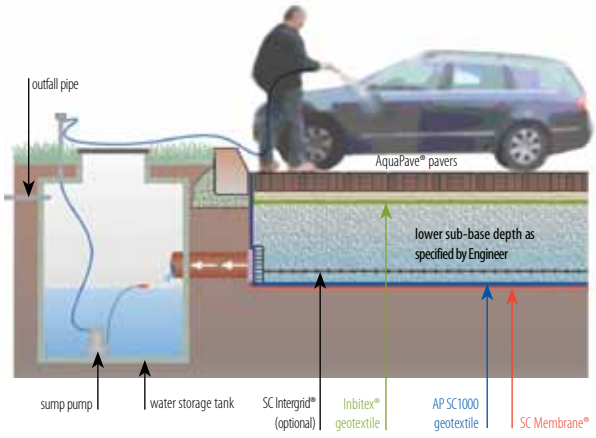
These practises may also qualify for additional LEED® points under Water Efficiency:

- 1 point WE credit 1.1
- 1 point WE credit 1.2
- 1 point WE credit 2
- 1 point WE credit 3.1
- 1 point WE credit 3.2

This nursery offers an example of using reclaimed water from a tanked system to provide plant irrigation.

Harvested treated water can be used in the washing of vehicles and then re-enter the permeable surface to be recycled.





* Inbitex®, AP SC1000 and SC Membrane® brought up to curb and cut off flush with surface of AquaPave® pavers

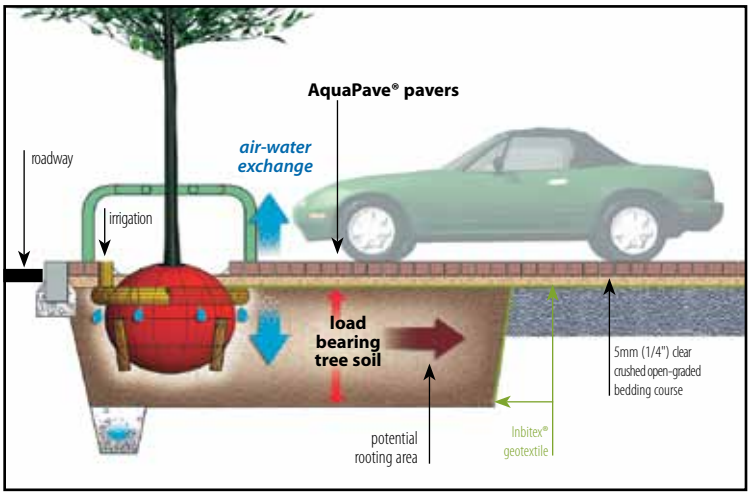
Vancouver Convention Centre
Home of the 2010 Olympic Torch

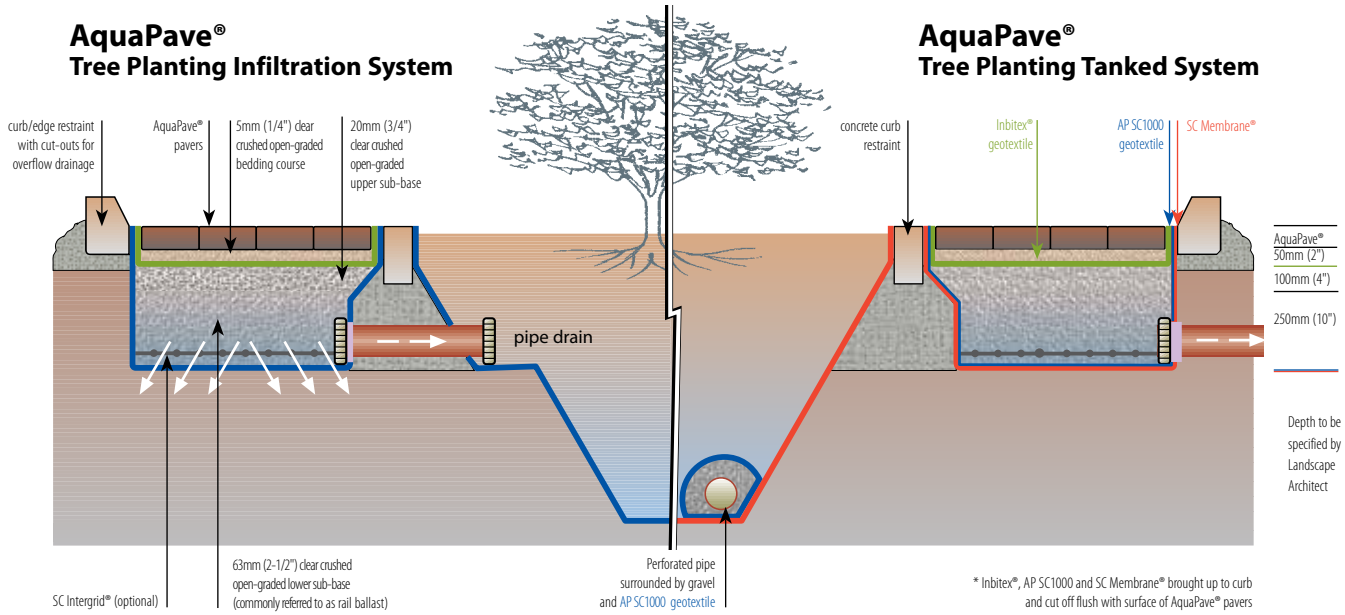
Root System Maintenance

Availability of air and water to the root systems of existing or newly planted vegetation, particularly trees, is key to their survival and growth. When building near trees, the previous BMPs were to install a grate around the perimeter of the tree to allow for direct infiltration, or to install a subgrade irrigation system.

It has been proven that the **AquaPave®** system can be used successfully with load bearing tree soils. This allows the pavers to be installed right up to the border of the tree pit, which increases the available parking area, while still allowing air and water to reach the root structure. This practise is not possible with conventional paving.

In applications where additional water is desired within the root system, it is possible to divert the overflow from a "Partial Exfiltration" or "No Exfiltration" system to the root zone (see below, left side), or even create an artificial tanked system (see below, right side).





All conversions from Metric to Imperial are approximate. Illustrations are not to scale.

Typical AquaPave® Installation

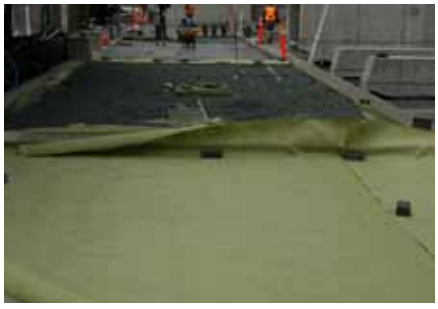
1. Place the AP SC1000 woven geotextile with the specified overlap.

2. Place and spread the clear crushed open-graded lower sub-base aggregate without wrinkling or folding the geotextile.

3. Compact the lower sub-base.

4. Place and spread the clear crushed open-graded upper sub-base.

5. Compact the clear crushed open-graded upper sub-base.



6. Place the Inbitex® geotextile.

7. Place and spread the clear crushed open-graded bedding material.

8. Compact the clear crushed open-graded bedding material.

9. Loose screed the clear crushed open-graded bedding course.

10. Place the AquaPave® pavers.

11. Compact the AquaPave® pavers.

12. Spread and sweep in the AquaPave® Engineered Joint Stabilizer.

13. Close-up view of the joints with AP Engineered Joint Stabilizer applied before final compaction.

14. Final compaction of the AquaPave® pavers.

15. Close-up view of the joints with AP Engineered Joint Stabilizer applied after final compaction.

AquaPave® Installation Using Mechanical Laying Equipment

1. Excavate subgrade, removing any organic material.

2. AP SC1000 geotextile is rolled out and fastened to subgrade .

3. Clear crushed open-graded aggregate lower sub-base is placed, followed by grading and compaction.

4. Paver restraints are placed.

5. Clear crushed open-graded aggregate upper sub-base is placed.

6. Upper sub-base is graded to elevation and compacted.

7. Inbitex® is placed followed by the 5mm clear crushed open-graded bedding course .

8. AquaPave® pavers are delivered to site, prearranged on pallets .

9. AquaPave® is placed using mechanical laying equipment [can increase production to 745-930 m^2 (8,000-10,000 ft^2) per day with a standard crew].

10. All cuts must be made with a masonry saw.

11. AP Engineered Joint Stabilizer is applied and swept into place.

12. After final compaction the paved area is available for immediate use.

GUIDE SPECIFICATIONS FOR CONSTRUCTION OF THE AQUAPAVE® PERMEABLE ON-SITE STORMWATER SOURCE CONTROL SYSTEM

SECTION 32 14 13.19
AquaPave® Permeable Interlocking Concrete Pavement

Note: This guide specification is for the construction of an AquaPave® permeable interlocking concrete paver system which is designed to allow for the infiltration, detention and release of stormwater from a permeable, open-graded base. Components covered under this specification include AP SC1000 Woven Geotextile, permeable clear crushed open-graded sub-base, Inbitex® Geotextile, Bedding Layer, AquaPave® Pavers and AquaPave® Engineered Joint Stabilizer, which are generic to all AquaPave® Systems. Additional specifications are required where drain pipes, SC Membrane® and SC Intergrid® are used. The text below must be edited to suit specific project requirements. It will require review by a qualified civil or geotechnical engineer, or landscape architect familiar with the site conditions and local materials. Edit this specification as necessary to identify the design professional in the General Conditions of the Contract. This guide specification is intended for use in the U.S. or Canada and should be edited to fit terms and standards appropriate to each region.

PART 1 GENERAL

1.01 SUMMARY
A. Section Includes
1. AquaPave® Permeable Concrete Pavers.
2. AquaPave® Engineered Joint Stabilizer.
3. Clear crushed open-graded aggregate Bedding Course.
4. Inbitex® Geotextile.
5. Clear crush open-graded sub-base materials.
6. [SC Intergrid® - Base reinforcement grid].
7. AP SC1000 Woven Geotextile.
8. [SC Membrane® - Impermeable liner].

Note: Curbs will typically be precast or cast-in-place concrete. Plastic edging with steel spikes can be used if the spikes are driven into substantial soils and are not driven into any of the open-graded drain rock or pierce any portion of the water containment system. Plastic edging should not be used where wheel loads are within 2.5 feet of the restrained edge. In areas of severe freeze-thaw cycles plastic edge restraints are not recommended.

1.02 RELATED SECTIONS
A. Section [-]: Curbs.
B. Section [-]: Stabilized aggregate base.
C. Section [-]: [PVC] Drainage pipes.
D. Section [-]: Impermeable liner.
E. Section [-]: Edge restraints.
F. Section [-]: Drainage pipes and appurtenances.
G. Section [-]: Earthworks/excavation/soil compaction.

1.03 REFERENCES
A. American Society of Testing Materials (ASTM)
1. C 131, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
2. C 136, Method for Sieve Analysis for Fine and Coarse Aggregate.
3. C 936-09, Standard Specification for Solid Interlocking Concrete Pavers.
4. C 979, Specification for Pigments for Integrally Coloured Concrete.
5. D 448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
6. D 698, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 5.5-lb (2.49 kg) Rammer and 12 in (305 mm) drop.
7. D 1557, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 10-lb (4.54 kg) Rammer and 18 in (457 mm) drop.
8. D 1883, Test Method for California Bearing Ratio of Laboratory-Compacted Soils.
9. D 2488, Description and Identification of Soils (Visual/Manual Procedure).
10. D 2922, Standard Test Methods for Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth).
11. D 4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.
12. D 4873, Guide for Identification, Storage and Handling of Geotextiles.
13. D 6928, Standard Test Method for Resistance of Coarse Aggregates to Degradation by Abrasion in the Micro-Deval Apparatus.

B. Canadian Standards Association (CSA)
1. A231.2-06, Precast Concrete Pavers.
2. A23.2A, Sieve Analysis of Fine and Coarse Aggregates.

1.04 SUBMITTALS
A. In accordance with Conditions of the Contract and Submittal Procedures Section.
B. Site Plan - indicate the following: area of AquaPave® Paver installation; perimeter conditions; stormwater run-on area; and, layout, patterns and colour arrangements.
C. Installation details – provide details for each of the following: junction with other materials; expansion and control joints; layout pattern, and relationship of paving joints to fixtures; panel layouts and installation drawings at appurtenances and curbs, for each of the applicable: Inbitex® geotextile, AP SC1000 woven geotextile, SC Membrane®, SC Intergrid®, and project formed details.
D. AquaPave® Engineered Joint Stabilizer, Bedding Course and Sub-base (upper and lower):
1. Sieve analysis of aggregates per [ASTM C 136] [CSA A23.2A].
2. Durability of aggregates using Micro-Deval Degradation per [ASTM D 6928] [CSA A23.2A].
3. Percentage of angular and sub-angular particles per [ASTM D 2488].
4. Minimum 3 lb (2kg) samples of sub-base, base and bedding aggregate materials.
E. Site soils report including: in-situ density test reports; soil classification(s); infiltration rate(s) measured on site under compacted conditions; saturated bearing capacity calculations and recommendations on suitability of native soils for the intended project.
F. Erosion and sediment control plan including details on how to prevent contamination of the AquaPave® permeable system during and after construction.
G. Stormwater management (quality and quantity) calculations.
H. Permeable concrete pavers:
1. Manufacturer's product catalog sheets with specifications.
2. [Four] representative full-size samples of each paver type, thickness, colour, and finish. Submit samples indicating the extremes of colour expected in the finished installation. Note that accepted samples become the standard of acceptance for the work of this Section.
3. Laboratory test reports certifying compliance of the concrete pavers with [ASTM C 936-09] [CSA A231.2-06].
4. Copy of ICPI Certified Manufacturer Certificate.
5. Manufacturer's material safety data sheets for the safe handling of the specified materials and products.
I. Geotextiles:
1. Manufacturer's product catalog sheet with specifications.
2. One 0.5 x 0.5 m (18 x 18 in) panel of each: Inbitex®, AP SC1000 geotextile, SC Intergrid® geogrid and/or SC Membrane® for inspection and testing. The sample panels shall be uniformly rolled and shall be wrapped in plastic to protect the material from moisture and damage during shipment. Samples shall be externally tagged for easy identification. External identification shall include: name of manufacturer; product type; product grade; lot number; and physical dimensions.
J. Paver Installation Subcontractor:
1. Statement of Installer Qualifications: Submit list of comparable projects completed by installer. Include list of completed projects with project names, addresses, names of Architect/Engineer and Owners with contact information, and dates of construction.
2. Copy of current 'ICPI Concrete Paver Installer Certification Program' Level I Certificate, or Level II Certificate if project is to be mechanically installed, for site supervising personnel.
3. A letter of assurance or copy of Certificate from the manufacturer stating that the site supervising personnel is an AquaPave® Approved Installer.
4. Written Method Statement and Quality Control Plan that describes material staging and flow, paving direction and installation procedures, including representative reporting forms that ensure conformance to the project specifications.

1.05 QUALITY ASSURANCE
A. Installer Qualifications: Engage an experienced, certified installer who has successfully completed permeable pavement installations similar in design, material, and extent indicated for this project.
B. Review paver installation subcontractor's Method Statement and Quality Control Plan with a pre-construction meeting of representatives from the manufacturer, paver installation subcontractor, general contractor, engineer and/or owner's representative.

C. Field-constructed Mock-up:
   1. Install 3 x 3 m (10 x 10 ft) area with Geotextiles, Sub-base, Bedding Course, AquaPave® Engineered Joint Stabilizer and AquaPave®.
   2. Use area to determine surcharge of the bedding layer, joint sizes, lines, laying pattern(s), colour(s), and texture of the job.
   3. Use the area as the standard to judge the remaining work.
   4. Subject to acceptance by the owner, mock-up may be retained as part of the finished work.
   5. If mock-up is not retained, remove and dispose of mock-up.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Concrete Pavers:
   1. Comply with manufacturer's ordering instructions and lead-time requirements to avoid construction delays.
   2. Coordinate delivery of paving stones to minimize interference with onsite works, and normal use of buildings, roads and structures adjacent to works.
   3. Deliver concrete pavers to the site palletized for transfer by forklift or clamp lift. Maintain manufacturer's original, unopened, undamaged packaging with identification labels intact.
   4. Unload pavers at job site in the location designated by the Installation Contractor and in such a manner that no damage occurs to the product or existing construction.
   5. Where the pallets are numbered, they should be stored so that they can be accessed in the order specified by the manufacturer.

B. Imported Soils and Aggregates:
   1. Handle and transport material to avoid segregation, contamination and degradation.
   2. Keep different materials sufficiently separated as to prevent mixing. Do not dump or store one material on top of another unless it is part of the installation process.
   3. Cover material with waterproof covering if needed to prevent exposure to rainfall or removal by wind. Secure the covering in place.

C. Geotextiles:
   1. Geotextiles shall be delivered, stored and handled in accordance with [ASTM D 4873].
   2. Maintain manufacturer's original, unopened, undamaged packaging with identification labels intact.
   3. The geotextiles shall be kept dry and wrapped in waterproof wrapping such that it is protected from UV light and the elements during delivery and storage.

D. The Installer shall check all materials delivered to the site to ensure that the correct materials have been received and are in good condition prior to signing off on the manufacturer's packing slip.

1.07 ENVIRONMENTAL REQUIREMENTS

A. Do not install in heavy rain or snow.
B. Do not install frozen Bedding Course, AquaPave® Engineered Joint Stabilizer or Sub-base materials.
C. Do not install on frozen soil subgrade.

1.08 MAINTENANCE

A. Extra materials: Provide [Specify area] [Specify percentage] additional material for use by owner for maintenance and repair.

PART 2 PRODUCTS

A. Manufactured by Hanson Hardscapes
   Phone: 800 265 6496 Fax: 800 276 3091
   AquaPave® Niagara: [Colour]
   200 mm x 100 mm x 60 mm thick
   200 mm x 100 mm x 80 mm thick

B. Meet [ASTM C 936-09] [CSA A231.2-06]. Freeze-thaw requirements may be waived in applications with no freeze-thaw conditions.
   1. When testing 3-1/8 in (80 mm) thick units for conformance to [ASTM C 936-09], compressive strength tests shall be corrected by multiplying the results by 1.18 to equate the results to that from 2-3/8 in (60 mm) thick pavers.

C. Manufactured in a plant where paving products are certified by ICPI as having passed manufacturer designated [ASTM] [CSA] requirements.
D. Colour(s): [Specify from selection in Hanson Hardscapes literature or custom colour as required].

2.02 CLEAR CRUSHED OPEN-GRADED BEDDING COURSE AND SUB-BASE MATERIALS

Note: The bedding and sub-base materials are an integral part of the AquaPave® system design. When designing an AquaPave® system, compliance with the following points must be strictly observed.

A. Aggregates to be clean, non-plastic, and free from deleterious or foreign matter.
B. Micro-Deval Degradation of less than 8%. Soft Aggregates such as Limestone cannot be used as they will lead to total system failure.
C. Percentage of angular and sub-angular particles greater than 90%. Do not use rounded river gravel. Base and bedding materials must be clear crushed open-graded aggregates.
D. Gradation criteria.

Note: Dx is the particle diameter size at which x percent of the particles are finer. For example, D15 is the particle size of the aggregate for which 15% of the particles are smaller and 85% are larger.

   1. D15 upper sub-base stone/D50 bedding stone < 5.
   2. D15 lower subbase stone/D50 upper subbase stone < 5.
   3. D50 upper sub-base stone/D50 bedding stone > 2.
   4. D50 lower subbase stone/D50 upper subbase stone > 2.

E. LA Abrasion <40, minimum CBR of 80%.

Local guidance note: For low volume roads, parking lots, driveways and residential roads in Southern Ontario, the exclusion of limestone materials is not necessarily required. For these types of pavement, if the aggregates meet the following physical requirements, they should perform in a satisfactory manner over the typical design life of the pavement:

Micro-Deval degradation, % maximum loss	**15**
Absorption, % maximum	**2.0**

Note: The following gradations in Tables 1, 2 and 3 can be used for the clear crushed open-graded bedding course and sub-bases. Check gradations against the above criteria.

Table 1
Grading Requirements for Clear Crushed Bedding Course (ASTM D 448 No. 8)

Sieve Size	Percent Passing
12.5 mm (1/2 in)	100
9.5 mm (3/8 in)	85 to 100
4.75 mm (No. 4)	10 to 30
2.36 mm (No. 8)	0 to 10
1.16 mm (No. 16)	0 to 5

Table 2
Grading Requirements for Clear Crushed Upper Sub-base (ASTM D 448 No. 56)

Sieve Size	Percent Passing
37.5 mm (1-1/2 in)	100
25 mm (1 in)	90 to 100
19 mm (3/4)	40 to 85
12.5 mm (1/2 in)	10 to 40
9.5mm (3/8 in)	0 to 15
4.75mm (No. 4)	0 to 5

Note: ASTM D 448 No. 57 is also an acceptable alternative for the upper sub-base material, as determined by the consulting engineer.

Table 3
Grading Requirements for Clear Crushed Lower Sub-Base (ASTM D 448 No. 2)

Sieve Size	Percent Passing
75 mm (3 in)	100
63 mm (2-1/2 in)	90 to 100
50 mm (2 in)	35 to 70
37.5 mm (1-1/2 in)	0 to 15
19 mm (3/4 in)	0 to 5

2.03 GEOTEXTILES

A. AP SC1000 and Inbitex® Geotextiles and SC Intergrid® as supplied by:
   Hanson Hardscapes Phone: 800 265 6496

2.04 AquaPave® ENGINEERED JOINT STABILIZER

A. Pre-bagged AquaPave® Engineered Joint Stabilizer as supplied by:
   Hanson Hardscapes Phone: 800 265 6496

PART 3 EXECUTION

3.01 ACCEPTABLE INSTALLERS

A. [Specify acceptable paver installation subcontractors.].

3.02 EXAMINATION

Note: The elevations and surface tolerance of the soil subgrade determine the final surface elevations of concrete pavers. The paver installation contractor cannot correct deficiencies in excavation or grading of the soil subgrade with the addition of bedding materials. Therefore, the surface elevations of the soil subgrade should be checked and accepted by the General Contractor or designated party, with written certification presented to the paver installation subcontractor prior to starting work.

A. Acceptance of Site Verification of Conditions:
   1. General Contractor shall inspect, accept and certify in writing to the paver installation subcontractor that site conditions meet specifications for the following items prior to installation of interlocking concrete pavers.

Note: Compaction of the soil subgrade may be necessary to achieve stability under vehicle loads. Compaction, however, will reduce the permeability of soils. In such cases, laboratory and on-site testing for density and soil permeability should be conducted. These can help establish a relationship between compacted density and anticipated design permeability after compaction. An experienced civil or geotechnical engineer familiar with local soil conditions should be consulted for determining project standards for the percentage of soil Proctor density and test methods for permeability. When soil compaction is required, standard Proctor density per ASTM D 698 for pedestrian and driveway areas is recommended. Modified Proctor density per ASTM D 1557 is recommended for vehicular areas. Density and moisture should be checked in the field with a nuclear density gauge or other test methods for compliance to specifications. Stabilization of the soil and/or base material may be necessary with weak or continually saturated soils, or when subject to high wheel loads. These conditions may require the use of drain pipes within open-graded bases. Compaction on the "open aggregate base" for pedestrian and residential driveway areas, a minimum 97% standard Proctor density per ASTM D 698 is recommended. For vehicle and high traffic areas, a minimum 97% modified Proctor density per ASTM D 1557 is recommended.

      a. Verify that subgrade preparation, compacted density and elevations conform to specified requirements, particularly where backup drains are to be located.
      b. Provide written density test results for soil subgrade to the Owner, General Contractor and paver installation subcontractor.
      c. Verify location, type, and elevations of edge restraints, [concrete collars around] utility structures, and drainage pipes and inlets.
   2. Do not proceed with installation of bedding and interlocking concrete pavers until subgrade soil conditions are corrected by the General Contractor or designated subcontractor.

3.03 PREPARATION

Note: The minimum slope of the soil subgrade is typically 0.5%. Actual slope of soil subgrade will depend on the drainage design and exfiltration type.

A. Verify that subgrade surface, base and sub-base materials are free from standing water, uniform, even, free of any organic material or sediment, debris, are ready for installation, prior to installation of AP SC1000 geotextile or SC Membrane®.
B. Edge Restraints:
   1. Verify location, type, installation and elevations of edge restraints around the perimeter to be paved. Ensure the side of the edge restraint adjacent to the paver is perpendicular to the bedding course. This will ensure proper interlock eliminating possibility of creep, or a potential trip hazard.
C. Beginning of installation means acceptance of subgrade and edge restraints.

3.04 INSTALLATION

Note: AP SC1000 geotextile is placed on the soil subgrade [or SC Membrane®] on bottom and sides of the excavation with overlapped joints a minimum of 30cm (12 in) Overlap is a function of CBR, 30 to 45cm (12 to 18in) for CBR 3.0 and above, 60 to 90cm (24 to 36 in) for CBR 1.0 to 3.0, for CBR values below 1.0 they should be sewn. Please consult manufacturers' specifications and your Geotechnical Engineer. Overlaps should follow down slope with drainage. All drainpipes, observation wells, overflow pipes, and SC Membrane® impermeable liner (if applicable) should be in place per the drawings either prior to or during placement of the base, depending on their location. The open-graded base is typically compacted in 10 to 15 cm (4 to 6 in) thick lifts with a minimum 10 T (10 ton) static roller. Care must be taken not to damage drainpipes during compaction and paving. There should be at least 4 passes with no visible movement in the base material when compaction is complete. Absolutely no mud or sediment can be left on the base or bedding aggregates. If they are contaminated, they must be removed and replaced with clean materials.

A. Keep area where pavement is to be constructed free from sediment during entire job. Geotextiles, sub-bases and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
B. Place geotextile on the bottom and sides of the excavated area with a minimum down slope overlap of 30cm (12 in).
   Allow for enough geotextile to exceed the final elevation of the AquaPave® surface. Do not use spikes or similar items where the SC Membrane® is used. After final compaction the excess geotextiles should be cut flush with the finished surface.
C. Place and spread the clear crushed open-graded lower sub-base without wrinkling or folding the geotextile. To prevent damage to the geotextile, track vehicles must not be used to spread the initial base course.
D. Do not damage SC Membrane®, drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation.
E. Spread, moisten and compact clear crushed open-graded lower and upper sub-bases in 10 to 15 cm (4 to 6 in) lifts with a minimum 10 T (10 ton) vibratory roller.
F. For each lift, make at least two passes in the vibratory mode then at least two in the static mode until there is no visible movement of the material. Do not crush aggregate with the roller.
G. The elevation of the final surface of the clear crushed lower sub-base should not deviate more than ±65 mm (± 2-1/2 in) over a 3 m (10 ft) straightedge. The upper sub-base should not deviate more than ±25 mm (± 1 in) over a 3 m (10 ft) straightedge.
H. Place the Inbitex® geotextile over the clear crushed open-graded upper sub-base following the panel installation drawings. Ensure a minimum down slope overlap of 30cm (12 in), allowing for enough Inbitex® to exceed the final elevation of the AquaPave® surface.
I. Spread, moisten and lightly compact the bedding material course. Use a Plate Compactor on this course. No visible movement should occur in base material when compaction is complete.
J. Loose screed the Bedding Course. The elevation of the bedding layer shall not deviate more than ±10 mm (±3/8 in) over a 3 m (10 ft) long straightedge.
K. Lay the AquaPave® in the pattern(s) shown on the drawings. Maintain straight pattern lines.
L. Fill gaps at the edges of the paved area with cut units, ensuring no cut unit is less than one third its original size.
M. The use of Guillotine or Paver Splitters is not acceptable. Cut pavers with a masonry saw only. Do not allow slurry from the cuts to adhere to the surface of the pavers.
N. Compact and seat the pavers into the bedding material using a low amplitude, 75-90 Hz plate compactor capable of at least 5,200 lbs. (23 kN) centrifugal compaction force. After the first pass with the vibrating plate compactor, remove and replace any damaged pavers.
O. Apply a dressing of AquaPave® Engineered Joint Stabilizer to the surface and sweep into the joints. Approximately 3kg/m^2 (6.6lbs/10 ft^2) will be required. Fill joints and sweep off excess material before continuing compaction. Two or three more passes with the compactor will be required.
P. Do not compact within 1 m (3 ft) of the unrestrained edges of paving units.
Q. Remove excess aggregate by sweeping pavers clean.
R. All pavers outside of the 1 m (3 ft) laying face must be left fully compacted at the completion of each day.
S. The final surface elevations shall not deviate more than ±10 mm (±3/8 in) under a 3 m (10 ft) long straightedge.
T. The surface elevation of pavers shall be 13 mm (1/2 in) above adjacent drainage inlets, concrete collars, or channels to allow for future settlement.

3.05 FIELD QUALITY CONTROL

A. After sweeping the surface clean, check final elevations for conformance to the drawings.
B. The top surface of the pavers shall extend 13 mm (1/2 in) above the final elevations after compaction to compensate for possible minor settling. (see 3.04 T)
C. Lippage: No greater than 3 mm (1/8 in) difference in height between adjacent pavers.
D. Remove excess Inbitex® and AP SC1000 geotextile from the top edge of AquaPave® Permeable concrete pavers.

3.06 PROTECTION

A. After work in this Section is complete, the General Contractor shall be responsible for protecting the work from damage and sediment due to subsequent construction activity on the site.
B. Design consideration must be taken to ensure that soft landscaping is retained to prevent migration of softscape materials on to the AquaPave® surface. This will significantly help to maintain the integrity of the system.

End of section

Many water quality variables have been examined in **AquaPave®** paving, most produced during independent research by UK and overseas universities funded by Hanson Formpave. This data is vital in determining the safety of the rainwater. The table shows the main chemical and microbiological contaminants that have been screened for in **AquaPave®** water.

Also present is information on the authority producing the data and information on when it was produced.

AquaPave® water quality has been intensively analyzed by third party organizations. Although the water quality variables do not all meet drinking water standards, all are in line with surface water discharge standards. The results were also derived using only a geotextile in the upper layers of paving, with no further treatment.

To use the water in washing machines or for other domestic purposes, in line treatment such as filtration is recommended to remove suspended particles and some secondary water treatment such as UV sterilization.

Research Authority	Contaminant	Concentration	Analysis method
	Metals		
Coventry University 2008	Aluminium	0.100 mg/l	ICP-OES
	Arsenic	0.002 mg/l	ICP-OES
	Boron	Not detected	ICP-OES
	Cadmium	Not detected	ICP-OES
	Calcium	26.01 mg/l	ICP-OES
	Copper	0.007 mg/l	ICP-OES
	Iron	0.072 mg/l	ICP-OES
	Lead	0.001 mg/l	ICP-OES
	Lithium	0.008 mg/l	ICP-OES
	Magnesium	1.720 mg/l	ICP-OES
	Molybdenum	0.004 mg/l	ICP-OES
	Nickel	0.002 mg/l	ICP-OES
	Potassium	6.210 mg/l	ICP-OES
	Sodium	26.01 mg/l	ICP-OES
	Vanadium	0.013 mg/l	ICP-OES
	Zinc	0.007 mg/l	ICP-OES
	Organics, nutrients and others		
Edinburgh University 2007	Ammonia	≤1.0 mg/l	Palintest kit
Severn Trent Laboratories 2008	Benzene	Undetectable	HPLC
Edinburgh University 2007	BOD	0.4-1.0 mg/l	BOD reactor
	Dissolved oxygen	7.5-7.8 mg/l	O2 meter
Coventry University 2008	Electrical conductivity	≤350µS	EC meter
Severn Trent Laboratories 2008	Ethylbenzene	Undetectable	HPLC
Edinburgh University 2007	Nitrate	≤5.50 mg/l	Palintest kit
	Nitrate and Nitrite	≤10 mg/l	Palintest kit
Coventry University 2008	Oil and grease	≤1.0 mg/l	Solvent extraction
	pH	6.3-8.4	pH meter
Edinburgh University 2007	Phosphates	≤0.42 mg/l	Palintest kit
Coventry University 2008	Sulphates	≤ 5.0 mg/l	Titration
Edinburgh University 2007	Suspended solids	≤100 mg/l	Filtration
Severn Trent Laboratories 2008	Toluene	Undetectable	HPLC
Coventry University 2008	Total dissolved solids	≤200 mg/l	Filtration evaporation
Severn Trent Laboratories 2008	Xylene	Undetectable	HPLC
	Microbes	Concentration *(organisms per ml of pavement water)*	
Coventry University 2006/08	Acanthamoeba	0-5 /ml	Microscopy
	E. coli	< 1 /ml	Selective media
Edinburgh University 2007	Enterococci	< 1 /ml	Selective media
	Heterotrophs	78 /ml	Selective media
Severn Trent Laboratories 2007	Legionellae *3 key species*	Undetectable	Selective media
Edinburgh University 2007	Salmonellae & Shigellae	< 1 /ml	Selective media

Glossary of Terms

Antecedent A preceding occurrence or cause or event.

Bioremediation Use of living organisms to clean up oil spills or remove other pollutants from soil, water, or wastewater.

CBR California Bearing Ratio. An empirical test used for estimating the bearing value of highway sub-bases and subgrades.

Detention An enforced delay.

Detention Pond A pond that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system.

Eco-system A system made up of a community of animals, plants and bacteria and the physical and chemical environment with which it is interrelated.

Exfiltration A gradual escape of fluid.

LEED® Leadership in Energy & Environmental Design. It is a voluntary rating system that is used to evaluate a project in relation to its use of "green building" technology.

Impervious Incapable of being passed through or penetrated.

Inbitex® Inbitex® is a thermally bonded nonwoven geotextile. Inbitex® has been specifically developed to optimize the cleansing of water entering the system. The various characteristics have been combined to create a unique geotextile that aids in the development of naturally occurring microbes and offers them refuge during periods of drought.

Infiltrate To pass, or cause (a fluid) to pass, through small gaps or openings; filter.

Infiltration Rate The rate, usually expressed in inches per hour, at which water percolates or moves down through the soil profile.

In-situ To treat in place.

Non-Point Pollution Source Pollution that enters any waters from any dispersed land-based or water-based activities and does not result from discernible, confined or discrete conveyances. Collectively, this is the largest source of stormwater pollution.

Observation Well A perforated pipe inserted vertically into an open-graded base used to monitor its infiltration rate.

One Hundred Year Storm A very unusual rainfall event that occurs once every 100 years and has a 1% chance of occurring in a given year.

One Year Storm A rainfall event that occurs once a year or has a 100% chance of occurring in a given year.

Outfall Point of water disposal to a stream, river, lake, tidewater or artificial drain.

Peak The maximum instantaneous rate of flow during a storm; Discharge usually in reference to a specific design storm event.

Permeable Open to passage or penetration, especially by fluids.

PICP Permeable Interlocking Concrete Pavements.

Pretreatment The removal of materials such as solids, grit, grease and scum from flows prior to physical, biological or physical processes to improve treatability.

PSC Permanent Stormwater Control Plan. A plan which includes permanent BMP's for the control of pollution from stormwater runoff after construction and/or land distributing activity has been completed.

Retention Pond A pond that is either designed to hold water for a considerable length of time and then release it by evaporation, plant transpiration and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Void Ratio Ratio of the volume of void space to the volume of solid particles in a given mass.

References:

1. Northern Virginia Planning District Commission, Nonstructural Urban BMP Handbook, Annandale, Virginia, December, 1999, p. 1- 4
2. Debo, T. N. and Reese, A. J, Municipal Storm Water Management, Lewis Publishers, CBC Press, Boca Raton, Florida, 1995
3. Smith, D. R., Permeable Interlocking Concrete Pavement, Interlocking Concrete Pavement Institute, Washington, DC, 2001
4. Dr. Chris Jefferies and Fiona Napier. Urban Water Technology Centre, University of Albertay, Dundee.
5. Stephen Coup, Coventry University
6. John Argue of the Urban Water Resources Centre at the University of South Australia
7. Severn Trent Laboratories
8. Edinburgh University

Patents:

The system and products described in this brochure are covered by patents issued or pending in the following countries:
Australia, Canada, European Patent Convention, Great Britain, New Zealand, Singapore, South Africa and the United States of America.

QUALITY CONTROL CHECK LIST FOR THE AQUAPAVE® PERMEABLE ON-SITE STORMWATER SOURCE CONTROL SYSTEM

This form is provided to assist in the construction of the AquaPave® On-site Stormwater Source Control System and provides a list of the important elements to be checked at each stage of the construction process.

PART 1 OF THE FORM RELATES TO THE CONSTRUCTION OF THE SUB-BASE
PART 2 RELATES TO THE LAYING OF THE PAVING SURFACE

PROJECT OWNER _____

NAME OF THE GENERAL CONTRACTOR _____

NAME OF THE GC SITE SUPERINTENDENT _____

NAME OF APPROVED AQUAPAVE® INSTALLER _____

SITE ADDRESS _____

_____

SITE TELEPHONE NUMBER _____

NAME OF ENGINEER RESPONSIBLE FOR THE PROJECT _____

_____

PART 1

1.0 SUB-GRADE

1.1 HAS THE SUB-GRADE BEEN EXCAVATED TO THE APPROPRIATE DEPTH AND SLOPE AS INDICATED ON THE DRAWING? ❑ YES ❑ NO

1.2 WERE THERE ANY VARIABLES IN THE SUB-GRADE SUCH AS SOFT SPOTS, EXISTING DRAINS OR CABLES? ❑ YES ❑ NO

IF YES, SPECIFY WHAT WAS DONE TO TREAT THE VARIABLES _____

_____

_____

_____

1.3 WAS THE SUB-GRADE COMPACTED WITH A VIBRATING ROLLER OR VIBRATING PLATE? ❑ YES ❑ NO

1.4 WERE THERE ANY SHARP STONES OR PROTRUSIONS IN THE SUB-GRADE THAT MAY CAUSE DAMAGE TO THE SC MEMBRANE®? *(Not applicable to infiltration systems)* ❑ YES ❑ NO

IF YES, WAS A SAND CAPPING LAYER OR PROTECTIVE BLANKET USED? ❑ YES ❑ NO

2.0 GEOTEXTILE

2.1 WAS THE AP SC1000 AND THE INBITEX® GEOTEXTILE PLACED FLAT AND TIGHT WITH NO FOLDS, WITH THE OVERLAPS FOLLOWING THE DOWN SLOPE WITH DRAINAGE? ❑ YES ❑ NO

2.2 WERE ALL JOINTS OVERLAPPED ACCORDING TO THE SPECIFICATIONS? (Minimum 12 in. or 30 cm) ❑ YES ❑ NO

2.3 WAS THE AP SC1000 AND INBITEX® GEOTEXTILE TURNED UP AT ALL RESTRAINING EDGES ALLOWING ENOUGH EXCESS TO BE CUT OFF FLUSH WITH THE FINISHED SURFACE? ❑ YES ❑ NO

3.0 NO EXFILTRATION SYSTEM

3.1 WAS THE SC MEMBRANE® LAID BETWEEN THE SUB-GRADE AND THE AP SC1000 GEOTEXTILE? ❑ YES ❑ NO

3.2 WERE THE JOINTS OVERLAPPED 12 in. (30cm) MINIMUM? ❑ YES ❑ NO

3.3 WERE THE JOINTS SEALED WITH TAPE OR WELDED? ❑ YES ❑ NO

3.4 WAS THE SC MEMBRANE® TURNED UP AT ALL RESTRAINING EDGES ALLOWING ENOUGH EXCESS TO BE CUT OFF FLUSH WITH THE FINISHED SURFACE? ❑ YES ❑ NO

4.0 SUB-BASE

4.1 DID THE AGGREGATE USED FOR THE LOWER AND UPPER SUB-BASE COMPLY WITH THE SPECIFICATIONS DETAILED IN THE CONTRACT DOCUMENTATION? ❑ YES ❑ NO

4.1.1 IS THE MANUFACTURER'S SEIVE ANALYSIS ATTACHED? ❑ YES ❑ NO

IF NO, GIVE DETAILS _____

_____

4.2 WHAT DEPTH OF SUB-BASE WAS USED? LOWER SUB-BASE _____

UPPER SUB-BASE _____

4.3 WAS THE SUB-BASE CONSTRUCTED IN LIFTS OF NOT MORE THAN 4 to 6 in. (10 to 15cm) AND COMPACTED WITH A MINIMUM 10 TON VIBRATORY ROLLER? ❑ YES ❑ NO

4.4 WAS EACH LIFT COMPACTED SEPARATELY? ❑ YES ❑ NO

4.5 STATE THE TYPE OF COMPACTOR USED _____

5.0 GEOGRID

5.1 WAS SC INTERGRID® GEOGRID INCORPORATED WITHIN THE SUB-BASE AGGREGATE? ❑ YES ❑ NO

IF YES, GIVE DETAILS _____

5.2 WERE ALL JOINTS OVERLAPPED 12 in. (30cm) MINIMUM? ❑ YES ❑ NO

5.3 IS IT POSITIONED AT THE INTERFACE BETWEEN THE TWO AGGREGATE LAYERS? ❑ YES ❑ NO

6.0 LAYING COURSE

6.1 DOES THE 1/4 in. (5mm) CLEAR CRUSHED AGGREGATE USED, COMPLY WITH SPECIFICATION DETAILS IN THE CONTRACT DOCUMENTATION? ❑ YES ❑ NO

6.1.1 IS THE MANUFACTURER'S SIEVE ANALYSIS ATTACHED? ❑ YES ❑ NO

IF NO, GIVE DETAILS _____

_____

6.2 WAS THE MATERIAL KEPT IN A CLEAN, UNCONTAMINATED CONDITION PRIOR TO USE, AND DURING THE LAYING OPERATION? ❑ YES ❑ NO

6.3 WAS THE LAYING COURSE MATERIAL LOOSE SCREEDED TO A DEPTH OF 2 in.(5cm)? ❑ YES ❑ NO

PART 2

7.0 AQUAPAVE® PAVING SURFACE

7.1 WERE THE AQUAPAVE® PAVERS JOINTED TIGHTLY TOGETHER IN THE APPROPRIATE PATTERN AS SPECIFIED IN THE DRAWINGS? ❑ YES ❑ NO

7.2 WERE ALL CUT PAVERS TIGHTLY FITTED, WITH NO CUT UNIT BEING LESS THAN ONE THIRD OF ITS ORIGINAL SIZE? ❑ YES ❑ NO

7.3 WAS A MASONRY SAW USED FOR ALL CUTS? ❑ YES ❑ NO

7.4 WAS A LIGHT DRESSING OF 3mm CLEAR CRUSHED AQUAPAVE® ENGINEERED JOINT STABILIZER APPLIED TO THE SURFACE PRIOR TO FINAL COMPACTION AS SPECIFIED IN THE CONTRACT DOCUMENTATION? ❑ YES ❑ NO

8.0 COMPLETION OF WORK

8.1 WAS THE PAVED SURFACE LEFT IN A CLEAN AND TIDY CONDITION UPON COMPLETION? ❑ YES ❑ NO

8.2 HAS ANY HEAVY SOFTSCAPING OR PLANT MATERIAL BEEN MOVED OVER THE COMPLETED PAVED SURFACE? ❑ YES ❑ NO

IF YES, GIVE DETAILS _____

_____

_____

8.2.1 WERE APPROPRIATE MEASURES TAKEN TO PROTECT THE SURFACE? ❑ YES ❑ NO

GIVE DETAILS _____

_____

_____

8.3 HAS ANY LOOSE MATERIAL BEEN STORED ON THE PAVED SURFACE? ❑ YES ❑ NO

IF YES, GIVE DETAILS _____

_____

_____

8.4 HAS THE GC , UPON COMPLETION OF THE PROJECT, BEEN INFORMED TO NOTIFY ALL TRADES STILL WORKING ON THE SITE THAT SPECIAL CONSIDERATION AND CARE MUST BE TAKEN WITH THE AQUAPAVE® SURFACE? ❑ YES ❑ NO

8.5 HAS THE PROJECT OWNER BEEN INFORMED OF THE MAINTENANCE SCHEDULE REQUIRED FOR THEIR NEW AQUAPAVE® ON-SITE STORMWATER CONTROL SYSTEM AND OR IS A COPY OF THE SCHEDULE ATTACHED? ❑ YES ❑ NO

9.0 GENERAL COMMENTS

COMMENT ON ANYTHING UNUSUAL THAT HAS BEEN NOTED DURING THE CONSTRUCTION OF THE PROJECT

_____

_____

_____

_____

_____

continue on back

PROJECT ENGINEER

PRINT NAME: _____

SIGNATURE: _____ DATE: _____

PROJECT OWNER OR REPRESENTATIVE

PRINT NAME: _____

SIGNATURE: _____ DATE: _____

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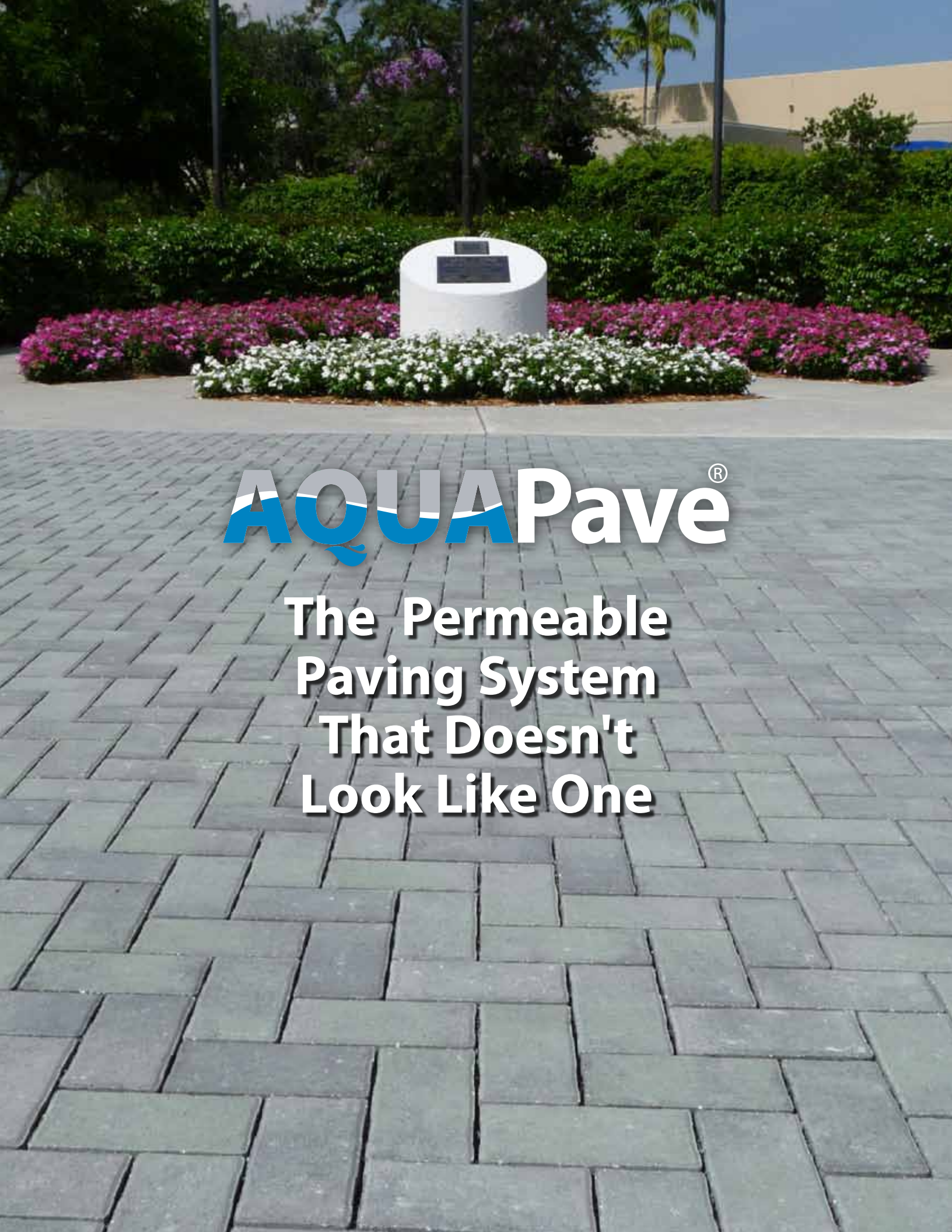

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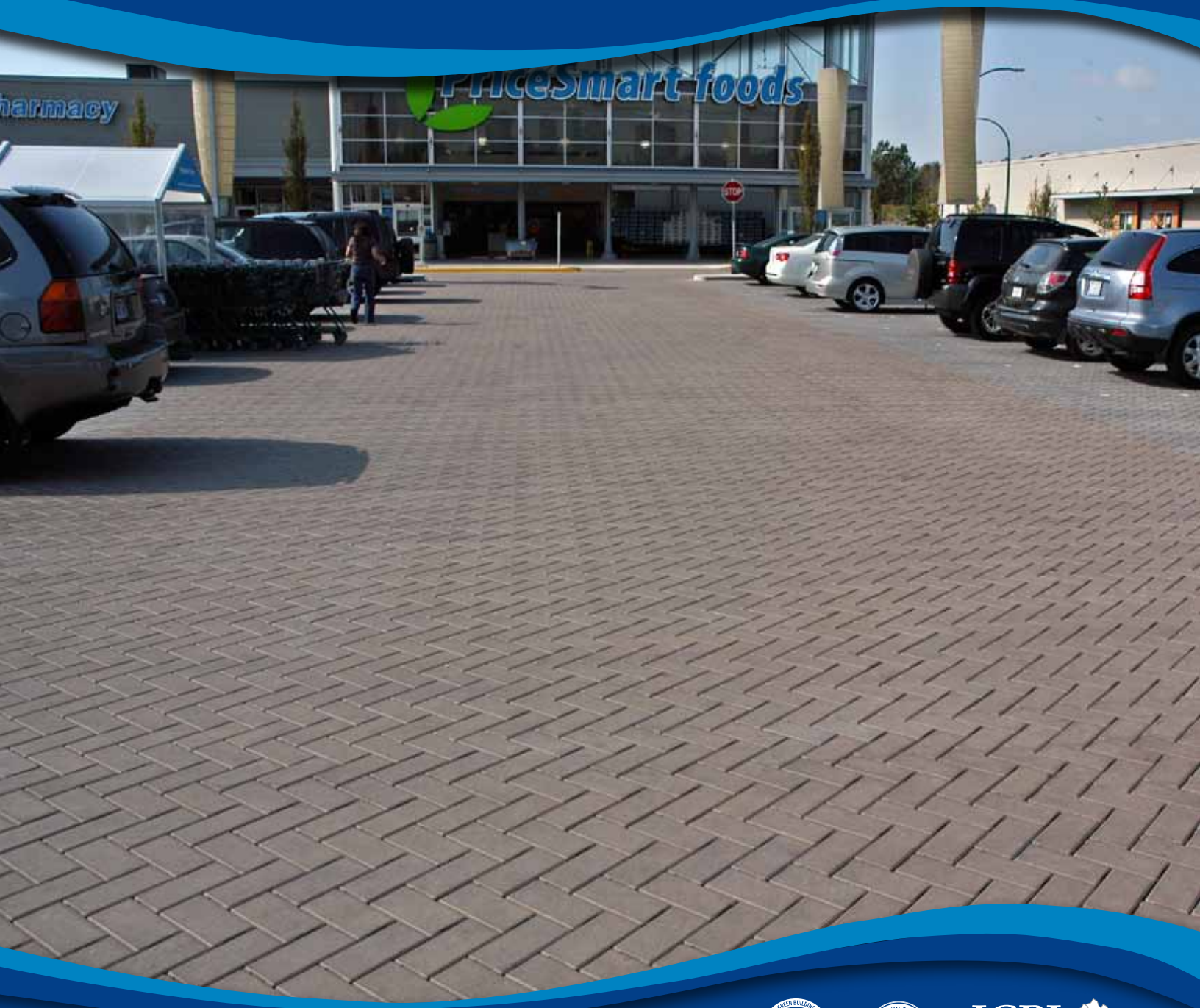

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