PERMCON

HOW PERMEABLE CONCRETE SYSTEMS CAN IMPROVE WATER QUALITY IN RECEIVING WATERWAYS

RESEARCH SUMMARY

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PART 1

INTRODUCTION

Urban development changes the way rainwater moves through the land. As cities grow, more surfaces become sealed – like roads, driveways and footpaths – rapidly channelling polluted runoff into stormwater networks and local rivers and streams. This document summarises research into how permeable concrete can help reduce the environmental impacts of increased stormwater runoff.

Pavement surfaces – defined here as hard, paved areas used for vehicle or pedestrian traffic, such as roads, footpaths and parking areas – make up around 25% of impervious urban land (Dr J.T. Kevern et al, 2016). Yet, as UN-Habitat's Dr Joan Clos noted in 2015, cities with less than 30% of land dedicated to street networks are fundamentally imbalanced (Scruggs, 2015). The result? Larger volumes of stormwater, moving faster, with less opportunity to soak into the ground. This creates serious downstream impacts:

- More frequent and intense flooding.
- Degradation of natural waterways.
- Reduced groundwater recharge (Leopold, 1968).

But the damage isn't just about volume. Impervious surfaces also accumulate pollutants from vehicles, infrastructure and urban activity. During rain events, these contaminants are flushed directly into receiving waterways. As natural land is replaced by buildings and roads, the rain that once soaked into the soil or evaporated now runs off hardened surfaces. This leads to:

- Erosion of stream channels.
- Loss of aquatic habitats.
- Decreased water quality.

Runoff from roads and parking areas often contains:

- Tyre and brake dust.
- Oil, grease and lubricants.
- Asphalt particles from road wear.

Even residential driveways contribute. Oils, car wash products and cleaners are regularly washed into stormwater systems – adding to the degradation of local streams and rivers.

HOW IT WORKS. WATCH OUR PERMCON PERMEABLE CONCRETE EXPLAINER VIDEO HERE.

INTRODUCTION (CONT.)

The Toronto and Region Conservation Authority identified in a 2008 report the following typical contaminants.

TABLE 1. TYPICAL CONTAMINANTS IN STORMWATER RUN-OFF

Contaminants	Source
Particulates	Pavement wear, vehicles, atmosphere, road maintenance
Nitrogen, Phosphorus	Atmosphere, roadside fertiliser application
Lead	Tyre wear (lead oxide, filter material, lubricating oil and grease, bearing wear), metal deterioration
Zinc	Tyre wear (filter materials), motor oil (stabilising additive), grease, metal deterioration
Iron	Auto body rust, steel highway structures (barriers, guard rails etc), moving engine parts, metal deterioration
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides, metal deterioration
Cadmium	Tyre wear (filler material), insecticide application, metal wear
Chromium	Metal plating, moving engine parts, break lining wear, metal deterioration
Nickel	Diesel fuel and petrol (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving, metal deterioration
Manganese	Moving engine parts
Cyanide	Anti-cake compound (used to keep de-icing salts granular)
Sodium, Chloride	De-icing salts
Sulphate	Roadway beds, fuels, de-icing salts
Petroleum, oil and grease	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate, fuel and oil spills and leaks
PAH's (polycyclic aromatic hydrocarbons)	Asphalt, fuel and oil spills and leaks
Suspended solids	Sanding in winter, tyre wear, tyre tread deposits

INTRODUCTION (CONT.)

Pollutant levels vary by land use – as this table demonstrates, showing figures gathered from extensive research by the United States Environmental Protection Agency (EPA).

In their *Stormwater Effects Handbook* (2001), researchers Burton and Pitt reference these EPA findings and seek to demonstrate the benefits of permeable concrete on improving water quality.

TABLE 2. POLLUTANT YIELD IN TYPICAL STORMWATER RUN-OFF

Land Use	Commercial	Parking Lot	High Density Residential	Medium Density Residential	Low Density Residential	Freeways	Industrial	Parks	Shopping Centres
Total Solids	2100	1300	670	450	65	1700	670	n/a	720
Suspended Solids	100	400	420	250	10	880	500	3	440
Chloride	420	300	54	30	30	470	25	n/a	36
Total Phosphorus	1.5	0.7	1	0.3	0.04	0.9	1.3	0.03	0.5
TKN	6.7	5.1	4.2	2.5	0.3	7.9	3.4	n/a	3.1
NH3	1.9	2	0.8	0.5	0.02	1.5	0.2	n/a	0.5
NO3 + NO2	3.1	2.9	2	1.4	0.1	4.2	1.3	n/a	1.7
BOD5	62	47	27	13	1	n/a	n/a	n/a	n/a
COD	420	270	170	50	7	n/a	200	n/a	n/a
Lead	2.7	0.8	0.8	0.05	0.01	4.5	0.2	0.005	1.1
Zinc	2.1	0.8	0.7	0.1	0.04	2.1	0.4	n/a	0.6
Chromium	0.15	n/a	n/a	0.02	0.002	0.09	0.6	n/a	0.04
Copper	0.4	0.06	0.03	0.03	0.01	0.37	0.1	n/a	0.09
Cadmium	0.03	0.01	0.01	0.01	0.001	0.02	0.05	n/a	0.01
Arsenic	0.02	n/a	n/a	0.01	0.001	0.02	0.04	n/a	0.02

PART 2

HOW PERMEABLE CONCRETE SUPPORTS WATERWAY HEALTH

The core principle of permeable concrete is to manage stormwater at the source – reducing flood risk and limiting the transfer of pollutants through the stormwater network, while still providing a durable surface for light traffic use.

Unlike conventional concrete, which channels stormwater directly into the drainage system, permeable concrete allows water to filter through the surface into an underlying basecourse, where it is temporarily stored and released slowly over time.

This process:

- **Reduces peak flows** during severe weather events.
- **Improves water quality** by trapping contaminants.
- **Supports natural hydrology** by recharging the soil.

In contrast, runoff from conventional hard surfaces carries pollutants – such as oils, sediments and debris – rapidly into local streams and rivers. This increases the risk of flooding when stormwater systems are overwhelmed or waterway levels rise.

In dense urban areas, underground attenuation tanks are sometimes used to manage flooding – but these systems don't deliver the additional environmental benefits of permeable concrete.

ADDED SOIL AND ECOLOGICAL BENEFITS

Because permeable concrete lets water, air and nutrients pass through to the subsoil, it supports soil health by enabling:

- Aerobic microbial respiration.
- Nutrient cycling.
- Microbial necromass accumulation – a key contributor to stable soil carbon.

These processes are vital for sustaining healthy, functioning landscapes – particularly in urbanised environments.

SUPPORTING WATERWAY HEALTH (CONT.)

SYSTEM TYPES

Permeable concrete can be designed in three main configurations, as defined in Interpave's *Design and Construction of Concrete Block Permeable Pavements* (Dec. 2018):

- **Total infiltration** – all water infiltrates the soil below.
- **Partial infiltration** – some infiltration, with overflow to stormwater system.
- **No infiltration** – no soil infiltration; water is temporarily stored and drained.

TOTAL INFILTRATION

This is used where the sub grade easily allows the passage of water into the aquifers. The system allows all water falling onto the surface to pass through the joints in the paving, then through the permeable base layers beneath it and into the sub grade. Temporary retention in the base course may occur as the water infiltrates the sub grade.

PARTIAL INFILTRATION

This is used where the existing sub grade may only be capable of absorbing some of the water passing through the structure. Typically, this would occur in a larger storm event. In these instances, an underdrain is used to collect water that has filled the permeable base to a measured point, which is then conveyed to the next part of the stormwater management system. This is an effective way of reducing the volume and frequency of runoff in a storm event.

NO INFILTRATION

In this design, rainwater is captured in the permeable basecourse – but infiltration is prevented by an impermeable layer at the interface of the basecourse and sub grade.

Water is held in the permeable base and released into the stormwater network in a measured fashion via underdrains. This system can be used where the underlying soil conditions are such that the ingress of water is to be avoided – eg, contaminated sites or where there are structural concerns with the soil strength.

PART 3

WATER QUALITY

As we have already touched upon, permeable pavements do more than manage runoff – they actively help clean it. The surface layer filters out sediment and pollutants through the joints, while the aggregate layers encourage sedimentation. As water moves through the basecourse, it can also be treated by absorption, biological breakdown and chemical changes (Pratt et al, 1999).

TACKLING HYDROCARBONS WITH MICROBES

Runoff often contains oil, petrol, grease and other hydrocarbons from vehicles. These are a major concern for water quality in receiving environments.

Research has shown that permeable pavements support microbial communities that feed on these hydrocarbons. These bacteria, in turn, attract protozoa and metazoan – larger organisms that help keep the base layer free-draining and support the growth of oil-degrading microbes (Newman et al, 2006).

In their research, Newman et al found that:

- Microbial communities were well established just six months after installation.
- Bacteria, fungi, protozoa and metazoa thrived without added nutrients.
- Standard pavement materials supported a diverse, effective oil-degrading ecosystem.

RELEVANCE TO AUCKLAND'S CLAY SOILS

A 2018 study by Braswell, Winston and Hunt into looked at permeable pavements in Durham, North Carolina, which has similar soil challenges to Auckland.

While some parts of Auckland have well-draining subgrades, others – especially those with clay – struggle with infiltration.

While the focus of the study was on infiltration into clay soils, it also analysed 29 storm events for water quality. Importantly, across 74 monitored storms, permeable pavements reduced runoff volume by an average of 22% compared to the control – even with low-permeability clay underneath.

CONCLUSION

From filtering out sediment to supporting microbial communities that break down hydrocarbons, permeable concrete systems bring real environmental benefits, even in challenging clay soils.

PART 3

WATER QUALITY (CONT.)

Numerous studies of permeable concrete systems have documented significant reductions in pollutant concentrations of:

- Suspended solids (Legret and Colandini, 1996; Fassman and Blackbourn, 2012; Roseen et al, 2012; Drake et al, 2013).
- Phosphorus (Bean et al, 2007; Roseen et al, 2012; Drake et al, 2014).
- Metals (Legret and Colandini, 1999; Fassman and Blackbourn, 2012; Roseen et al, 2012; Drake et al, 2013).

The Braswell et al study had similar results, summarised in Table 3. Stormwater was monitored from an impervious area (the control) and compared with effluent from the underdrain of a permeable pavement.

TABLE 3. SUMMARY OF POLLUTANT REDUCTIONS IN STORMWATER RUNOFF (BRASWELL ET AL)

	TKN (mg/l)		TKN (mg/l)		TKN (mg/l)	
	Control	Effluent	Control	Effluent	Control	Effluent
Average	1.91447	0.21391	0.12897	0.43695	0.1253	0.07999
Median	1.56934	0.1354	0.10664	0.33968	0.11724	0.03001
	TN (mg/l)		TP (mg/l)		SRP (mg/l)	
	Control	Effluent	Control	Effluent	Control	Effluent
Average	2.04344	0.65086	0.50005	0.02633	0.00333	0.00333
Median	1.65122	0.52168	0.44186	0.01566	0.00251	0.00251
	TSS (mg/l)		Cu (ug/l)		Pb (ug/l)	
	Control	Effluent	Control	Effluent	Control	Effluent
Average	703.17	14.74	15.3	3.2*	13.5	1.0*
Median	568.34	6.99	11	2.3*	12	1.0*
	Zn (ug/l)					
	Control	Effluent				
Average	51.3	5.3*				
Median	41	5.0*				

*When reported values were below the minimum detection limit, half the minimum detection limit was used for storm-by-storm comparison and computation of the mean and median

PART 3

WATER QUALITY (CONT.)

STRONG RESULTS FOR POLLUTANT REMOVAL

In one study, 29 paired storm events were sampled. The results showed that the permeable pavement system significantly reduced key pollutants compared to the control site. The median removal rates were:

- **Total suspended solids (TSS):** 98.8%
- **Total nitrogen (TN):** 68.4%
- **Total phosphorus (TP):** 96.5%

These results exceeded the removal efficiencies reported in earlier studies, although the influent concentrations of TSS, TN and TP at this site were relatively high.

WHAT ABOUT DISSOLVED POLLUTANTS?

Some studies (Bean et al, 2007; Collins et al, 2010; Roseen et al, 2012) have found that removing dissolved pollutants such as nitrate/nitrite-nitrogen and orthophosphate isn't always guaranteed. However, a 2008 report from the Toronto and Region Conservation Authority 'Performance evaluation of Permeable Pavement and a Bioretention Swale' took a broader look at both water and soil quality. It monitored 56 rain events and found:

- Only one event produced runoff from the permeable pavement – at just 10% the volume of the control.
- Median concentrations of oil, grease, TSS, TP and zinc were all significantly lower than those from the impermeable roadway.

This supports the idea that permeable systems provide strong stormwater management benefits and help maintain natural infiltration processes.

SOIL QUALITY STAYS INTACT

To check for long-term soil impact, the researchers sampled the soil beneath the pavement at the start and end of the study. They found no significant change in the chemical makeup of the subgrade.

This suggests that most contaminants, whether suspended or dissolved, get trapped in the basecourse, not the underlying soil.

These findings align with work by Legret et al (1996), who reported that water infiltrating into the subgrade didn't contain measurable pollutants.

PART 3

WATER QUALITY (CONT.)

PERMEABLE SYSTEMS AS POLLUTION SINKS

A 2013 report on permeable shoulders by the American Association of State Highway and Transportation Officials reached a similar conclusion. It found that permeable concrete can act as a pollution sink, with the geotextile layer at the base playing a key role in preventing fine particles from migrating upward and pollutants from reaching the subgrade.

Finally, the Braswell et al (2018) study concludes that permeable pavements built over low-infiltration clay soils can deliver significant improvements in water quality and provide moderate hydrologic benefits.

LONG-TERM RESULTS FROM A PARKING LOT

In 2004, Brattebo & Booth published a report titled Long-term Stormwater Quantity and Quality Performance of Permeable Pavement Systems. It examined how four types of permeable pavement performed after six years of daily parking use.

They evaluated each system for durability, infiltration, and water quality and found the following results:

- **No structural issues** were observed across any of the four systems.
- **Almost all rainfall infiltrated** through the pavements, with very little surface runoff.
- **Lower copper and zinc levels** were recorded in the infiltrated water than in runoff from a standard asphalt surface.
- **No motor oil** was found in the permeable concrete samples – whereas it was detected in 89% of asphalt runoff samples.
- **No lead or diesel** was detected in the permeable concrete samples.

The study concluded that the infiltrated stormwater was significantly cleaner than the asphalt runoff. Most samples had undetectable or safe levels of copper and zinc, while the asphalt runoff regularly showed toxic concentrations. The difference in oil levels was particularly striking and lead and diesel were entirely absent from all infiltrate samples.

BROADER EVIDENCE FROM MULTIPLE SYSTEMS

- A 2015 summary report from the National Centre for Sustainable Transportation in the US supported these findings. *The Application of Permeable Pavement with Emphasis on Successful Design, Water Quality Benefits and Identification of Knowledge and Data Gaps* reviewed 18 studies focused on water quality:

PART 3

WATER QUALITY (CONT.)

- Eight papers studied permeable pavers.
- Others looked at porous asphalt and pervious concrete.
- Two focused specifically on the role of geotextiles.

The collective evidence reinforces that, when designed well, permeable pavements consistently deliver strong water quality outcomes over time – even under frequent use, such as in parking areas.

OTHER KEY FINDINGS FROM THE RESEARCH

In addition to the studies already covered, several others reinforce the water quality benefits of permeable pavements.

HYDROCARBON REDUCTION

A full-scale lab study by Pratt et al (1999) tested a permeable pavement system under long-term, low-level hydrocarbon loading – similar to what you'd find on urban roads or in parking lots. It found:

- Petroleum contamination in the effluent was just 2.4% of the applied load.
- From 900 g/m^2 of hydrocarbon applied, only 22 g/m^2 was present in the runoff.

Note: These results reflect ideal laboratory conditions.

NUTRIENT REMOVAL AND PH BALANCE

Collins et al (2010) monitored four permeable pavements and one asphalt surface over seven months. They found:

- Higher pH levels from the permeable pavements.
- Lower concentrations of ammonium and total Kjeldahl nitrogen (TKN).*
- All four pavements performed similarly with respect to nitrogen removal, with efficiency similar to a sand filter treatment.

** TKN is a measure of nitrogen in the form of organic nitrogen and ammonia.*

WATER QUALITY (CONT.)

Drake et al (2012) also reported reduced concentrations across a wide range of pollutants, including:

- Suspended solids, oil, grease.
- Ammonia, ammonium, nitrate.
- Phosphorus, chloride, calcium, iron, manganese, zinc.
- Average pH of 8.3.

HEAVY METALS AND SOLIDS

Huang et al (2012) focused on suspended solids, nutrients and metals. They found the following average removal rates in permeable concrete filtrate:

- 91% for suspended solids.
- 78% for total phosphorus.
- 68% for copper.
- 65% for lead.
- 55% for zinc.
- 6% for total nitrogen.

SOIL PROTECTION AND POLLUTANT RETENTION

Drake et al (2013) confirmed that permeable pavements retain suspended solids, metals and hydrocarbons within the system. Key findings:

- Oils and grease were often below detection limits.
- Stormwater pollutants rarely reached the underlying soils.
- Most studies found little to no evidence of groundwater contamination.
- Infiltrated water typically had a pH between 8 and 9.5 – suggesting the system helps neutralise acidic runoff.

THERMAL PERFORMANCE

Wardynski et al (2013) monitored a permeable pavement car park over 12 months. Results showed:

- Effluent temperatures never exceeded the 21°C target.
- The pavement buffered high summer runoff temperatures.
- Subsurface soils stayed above freezing during winter.

PART 4

POLLUTION MITIGATION AND DESIGN STANDARDS

In 2015, the UK's Construction Industry Research and Information Association (CIRIA) published the SuDS Manual – a detailed guide for designing and maintaining sustainable drainage systems. CIRIA is a respected, not-for-profit organisation that produces practical, evidence-based guidance on sustainable construction.

The manual introduced two key tools for assessing and managing pollution risk:

- **Pollution Hazard Index**, which rates land uses by pollution risk.
- **Mitigation Index**, which scores how well SuDS features, such as permeable pavements, treat pollutants.

CIRIA recognises permeable pavements as suitable for medium hazard sites, including urban roads and commercial car parks with frequent vehicle turnover (eg, retail, hospitals). In New Zealand, these are typically designed for lower hazard levels, placing our standard practice well within CIRIA's validated performance range and supporting both local application and international alignment.

TABLE 4. POLLUTION HAZARD INDEX (CIRIA)

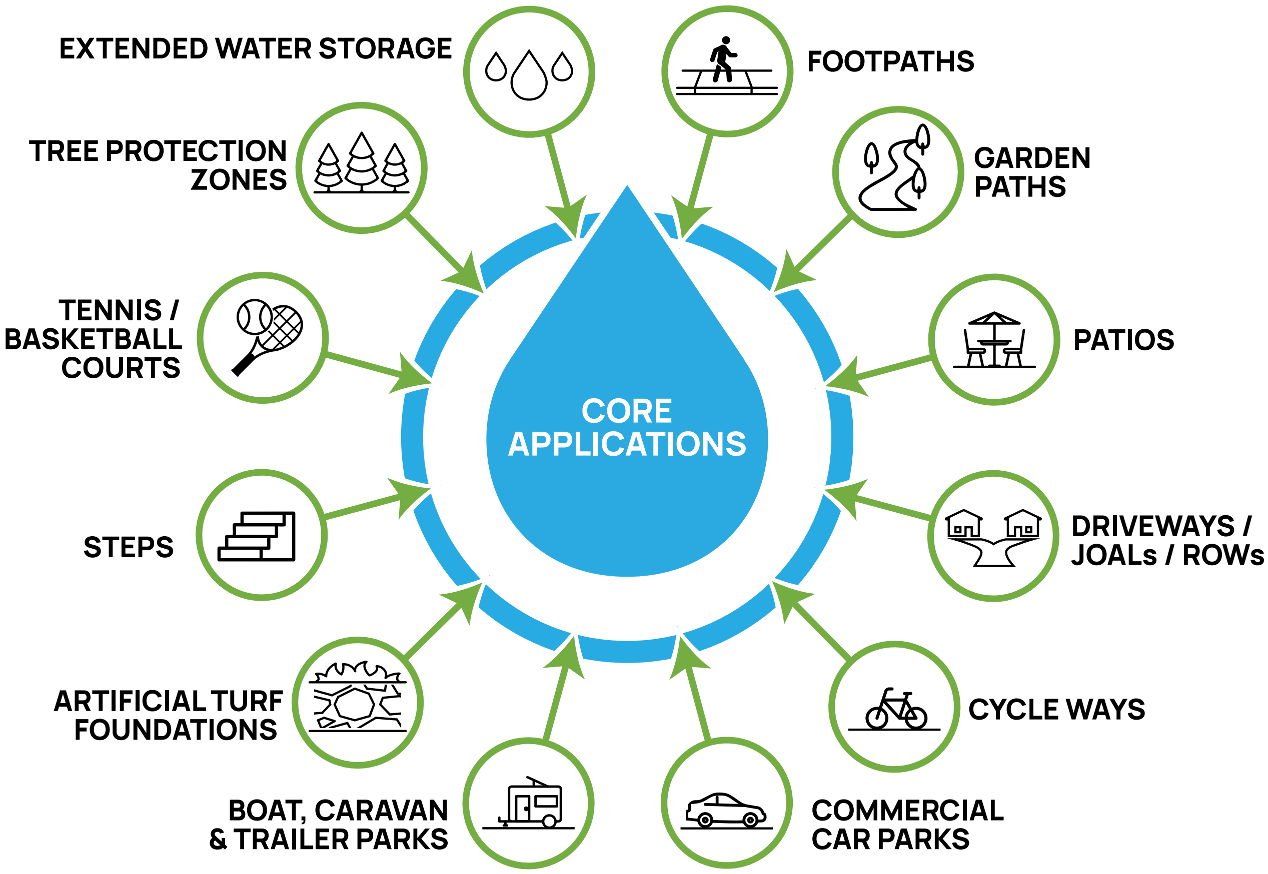
Land use	Pollution hazard level	Total suspended solids (TSS)	Metals	Hydrocarbons
Residential roofs	Very low	0.2	0.2	0.05
Other roofs (typically commercial industrial roofs)	Low	0.3	0.2 (up to 0.8 where there is potential for metals to leach from the roof)	0.05
Individual property driveways residential car parks, low traffic roads (eg, cul de sacs, home zones and general access roads) and non-residential car parking with infrequent change (eg, schools, offices) ie, less than 300 traffic movements per day	Low	0.5	0.4	0.4
Commercial yard and delivery areas, non-residential car parking with frequent change (eg, hospitals, retail), all roads except low-traffic roads and trunk roads/motorways	Medium	0.7	0.6	0.7
Sites with heavy pollution (eg, haulage yards, lorry parks, highly frequented lorry approaches to industrial estates, waste sites), sites where chemicals and fuels (other than domestic fuel oil) are to be delivered, handled, stored, used or manufactured; industrial sites; truck roads and motorways	High	0.8[2]	0.8[2]	0.9[2]

PART 4

SUMMARY

Permeable pavements offer a range of practical and environmental benefits:

- Reduce flood risk by managing runoff from urban surfaces.
- Provide a strong, load-bearing surface – while allowing rainwater to soak into the basecourse.
- Filter out a wide range of pollutants, improving stormwater quality.
- Recharge groundwater or direct treated water for reuse or further treatment.
- Help cool urban environments through evapotranspiration.
- Suit a variety of applications – residential driveways, footpaths, patios, car parks and more.
- Combine multiple functions in one: structure, storage, filtration and flow control.
- Offer a cost-effective alternative to conventional drainage and paving.



PART 5

CONCLUSION

Research from both the UK and abroad confirms that permeable pavements offer proven water quality benefits. According to CIRIA's SuDS Manual (2015), they are suitable for treating stormwater in areas with a **medium pollution hazard level** — such as:

- Commercial yards and delivery areas.
- Car parks with frequent turnover (eg, retail, hospitals).
- Most urban roads.

CIRIA advises against using permeable pavements in **high hazard areas**, including:

- Industrial sites.
- Locations where fuels or chemicals are stored or handled.
- Trunk roads and motorways.

International organisations such as the **Interlocking Concrete Pavement Institute (ICPI)** and the **American Society of Civil Engineers (ASCE)** also recognise the stormwater treatment potential of permeable pavements.

Local trials – like those conducted at Birkdale Road, Albany by Sam Blackbourne – have shown performance results consistent with international findings, confirming that New Zealand conditions align well with global benchmarks (Table 6).

TABLE 6. SUMMARY OF STORMWATER QUALITY IMPROVEMENTS IN PERMEABLE PAVING

	Contaminant	Pervious Paving	
	ASCE 2015	ICPI 2008 Guideline	Birkdale Rd Trial
Total Suspended Solids (TSS)	Mean 81% Max 96% Min 32%	60 to 90%	58% +/- 15% (included fines from subbase subgrade)
Copper	Mean 67% Max 100% Min 33%	50 to 89%	57% +/- 11%
Zinc	Mean 72% Max 97% Min 36%	62 to 88%	91% +/- 5%

CONCLUSION (CONT.)

New Zealand's approach to freshwater management has changed considerably in recent years. Under the **National Policy Statement for Freshwater Management (NPS-FM 2020)**, regional councils are now legally required to restore and protect water bodies by setting enforceable limits on contaminants, sediment and flow.

Infrastructure choices are no longer just about durability or aesthetics – they now have to meet environmental performance benchmarks.

Regional councils must deliver results on their freshwater plans by 2026. That means they are looking for infrastructure partners, who understand the direction of policy and can deliver solutions that support compliance, performance and community outcomes.

Infrastructure is where policy meets delivery. Permeable concrete provides a tangible, scalable way for councils to manage stormwater runoff at source. It reduces sediment loads, moderates flows and limits the pressure on piped networks. These outcomes directly support Te Mana o te Wai – the NPS-FM's foundational principle – and can help councils meet catchment-level objectives more cost-effectively than retrofitting conventional grey infrastructure.

Contractors who specify and deliver permeable solutions are directly supporting council compliance under the NPS-FM.

For developers, projects that fail to support freshwater goals risk delays, redesign, or rejection.

Bottom line? Permeable pavement is no longer just a sustainability box-tick – it's an essential tool in the ground-level response to New Zealand's evolving freshwater framework. Contractors and developers who understand this shift are already a step ahead.

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