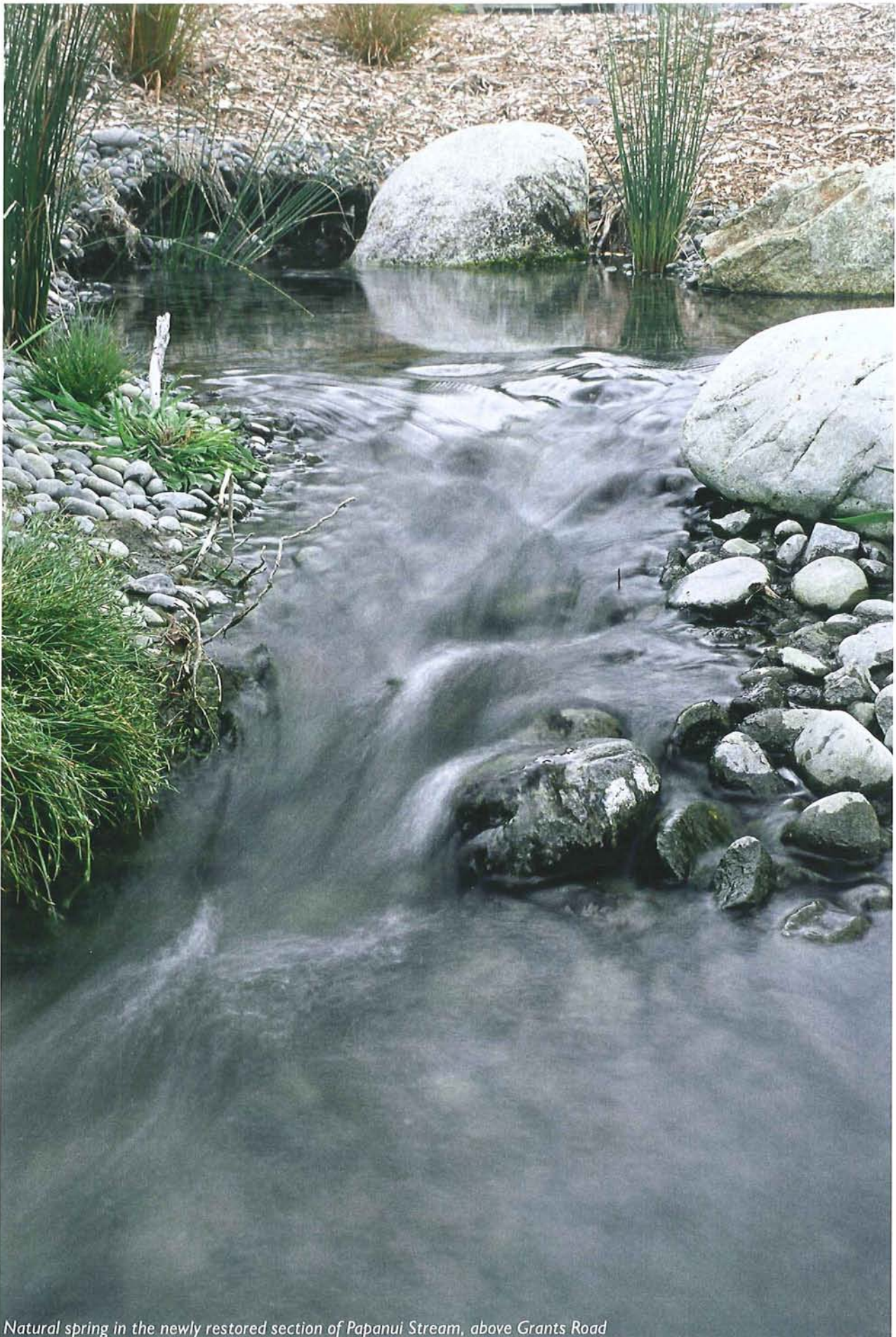


5

Surface Water and Groundwater Interception

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Natural spring in the newly restored section of Papanui Stream, above Grants Road

5.1 Introduction

The interception of surface flow generally occurs at the upstream end of the land drainage system. Surface water interception includes:

- overland flow surfaces that discharge directly into sumps, silt traps, kerb and channel systems, open channels, and swales
- small diameter pipe systems from individual properties, which generally drain roofs and other impervious areas
- public pipe drainage systems that collect water from the above primary collectors and transport it to the river systems or soakage systems
- overland flow paths, which transport discharge directly into waterways.

The interception of groundwater occurs below the ground surface. Groundwater interception systems include the following:

- open drains
- subsoil drains.

Understanding natural drainage systems, including the boundaries of water catchments, is fundamental to providing sustainable drainage systems. In many instances, some monitoring will be required prior to design and implementation. When undergoing land use change from rural to urban, existing drainage systems need to be re-evaluated. For example, in some parts of Christchurch the low groundwater levels are maintained by pumping systems or deep open waterways. This method of groundwater control is costly and may not be sustainable in the long term. In these circumstances the design of any new development should reflect natural drainage patterns and may need to assume higher future groundwater levels.

Water interception can provide opportunities for water conservation practices, for example, storage of roof water for garden irrigation. Seek further advice from staff in the Christchurch City Council's Parks and Waterways Unit.

5.2 Surface Water Interception

The primary function of surface water interception and drainage systems is to remove surface runoff from streets, footpaths, parking areas, and the roofs of buildings. These systems are also designed to provide immediate and long-term drainage for yards and gardens, public parks, and rural land: areas where surface water runoff is considered an inconvenience.

Design standards for private collection systems are set out in the Approved Document for the New Zealand Building Code, Surface Water Clause E1 (Building Industry Authority 2002). For public systems refer to:

- *Chapter 20: Inundation Design Performance Standards*, for level of service requirements.
- *Chapter 21: Rainfall and Runoff*, for determining flow rates and quantities.
- *Chapter 22: Hydraulics*, for sizing of water conveyance systems.
- *Chapter 14: Pipeline Structures*, for details of component assembly.

Some level of ponding is acceptable during frequent storm events, so there is some scope for flexibility when designing the capacity of an interception system. However, always allow for the possibility of blockages to the system, and for storm events that may cause the system to exceed its capacity.

Consider providing vegetated swales and vegetative filters, which not only provide some water quality and quantity control benefit but also enhance the streetscape. Roading design, which incorporates green spaces outside the carriageway, can likewise enhance the streetscape or environment and provide space for shade trees and birds.

5.2.1 Roadside Drainage

Road runoff is a major non-point source of pollution of Christchurch's waterways. The designer must aim to minimise pollution of downstream waterways by attempting to limit the entry of litter and other contaminants into the primary stormwater system.

Interception and control of roadside drainage can be achieved by vegetated swales, or by kerb and channel systems. The use of vegetated swales instead of pipes will help improve water quality by trapping suspended sediment, and can also assist with storm flow attenuation.



Figure 5-1A: Grassed swales primarily convey stormwater, but have significant water quality and quantity benefits. Grassed swale alongside QEII Drive.

Figure 5-1B: Vegetated swales are a useful means of capturing stormwater in areas of high imperviousness, such as in carparks. They may also reduce the total volume of runoff through infiltration loss. Vegetated swales in the rugby league carpark, Hinton Drive, Addington.

5.2.1.1 Vegetated Swales

Vegetated swales are primarily channels used to convey stormwater. They are usually located adjacent to a roadside (Figure 5-1A), in a highway median, in a parking lot (Figure 5-1B), or alongside residential properties. Swales also help to slow stormwater flows, capture some contaminants, and may reduce the total volume of runoff through infiltration loss. Therefore, while their function is primarily to convey water, vegetated swales also have significant water quality and quantity benefits.

Swales affect stormwater flows in two ways. Firstly, conveyance in a vegetated channel causes a decrease in water velocity due to flow resistance. The increased resident time of stormwater within the swale system can reduce the severity of flood peaks on receiving waters and surrounding environments. As a result, habitat destruction and bank erosion often caused by peak flows from small storm events is reduced. Some flow may infiltrate the soil, depending on existing soil saturation and permeability.

Secondly, the passage of stormwater through the vegetated swale can help improve water quality by reducing contaminant loadings. A decreased flow velocity facilitates the settling of some sediments, while vegetation will trap additional suspended sediment, and can directly absorb nutrients and use them for growth.

For Christchurch there is currently no data available on the performance of swale systems in general, and only limited data is available for elsewhere. However, despite a lack of local data, the EPA NSW report (Environmental Protection Authority New South Wales 1997) states that grass swales have a high pollutant trapping efficiency for sediment, oil and grease, and bacteria. Swales are most effective as a stormwater treatment device when there is adequate residence time, water velocities are low, and there is dense grass growth.

There are many factors affecting the performance of swales in removing contaminants. Factors that can increase swale pollution trap efficiency include:

- check dams that reduce flow velocities
- flat slopes (less than 2%)
- permeable soils
- dense grass cover
- long contact time of flow with vegetation
- combination of swales with other practices such as infiltration basins
- longer swale lengths (greater than 60 metres).

Factors that can decrease swale efficiency include:

- compacted soils
- short contact time of runoff with vegetation
- large storm events
- short grass height (less than 50 mm)
- steep slopes (greater than 2%)
- high runoff velocities (greater than 0.1 m/sec)
- semi-permanent wetness, that concentrates flows and prevents grass growth.

The cost of constructing a vegetated swale is generally less than the cost of constructing kerbing, inlets, and conveyance piping of conventional stormwater systems. A swale may also be cheaper to maintain.

Maintenance

The primary maintenance objectives are to keep a dense mat of vegetation growing and to keep the swale free of obstructions such as leaf litter and significant deposits of sediment. Periodic mowing and inspection can achieve these objectives. Adjacent residents should be discouraged from cutting the grass too short (Figure 5-2). It may occasionally be necessary to reseed areas that become bare. Note that different plant species are being considered to assess their effectiveness.

Detailed Design

For detailed design of vegetated filter strips, see the Auckland Regional Council's (ARC) Stormwater Treatment Devices Design Guideline Manual (Auckland Regional Council 1992).

5.2.1.2 Kerb and Channel

Design Water Level

At design flow, water levels should not exceed kerb level at sump positions (allowing for losses through sump gratings). Alternatively, if losses through sump gratings are not allowed for, then design water level of the pipe system to which the kerb and channel discharges should be no higher than the channel invert level.

Kerb Profiles Adjacent to Waterways

Where hard standing areas (e.g. roads, footpaths, and car parks) are adjacent to waterways or extensive lower-lying berm areas that are grassed or landscaped, consider cutting down kerb height and providing slots, or have no edging at all. These measures will make use of non-point disposal of stormwater to surface waters or to ground.

Refer to *Chapter 22.10.1: Side Channel Flow Capacity*, for design specifications.

5.2.2 Hillside Interception Channels

Historically, the Christchurch City Council has required that substantial interception channels be installed on the uphill boundaries of newly subdivided land. However, in addition to increasing peak flows, these channels have been difficult to maintain. Frequent blockages caused by the progressive accumulation of sediment and debris, or storm related slips across the channels can direct storm flows through buildings, resulting in substantial damage.

Consider using separate interception channels for each section, rather than continuous channels for an entire subdivision, to assist with maintenance of the channel. This will place maintenance responsibility with each individual owner and remove reliance on downstream maintenance by others.



Figure 5-2: Cutting the grass too short in vegetated swales, such as illustrated above, will reduce the efficiency of the swale. For peak efficiency the swale needs a dense mat of vegetation. Lower Styx Road, Brooklands.

5.3 Groundwater Interception

Winter rainfall on the Canterbury Plains, combined with underground flows from the Waimakariri River, produce the groundwater in the aquifers that underlie Christchurch. Near the coast and the Port Hills, fine-grained soil-confining layers usually prevent the upward leakage of groundwater from the deep aquifers.

Springs can act as relief valves for the groundwater system. Generally, groundwater emerges in the tributaries of some of Christchurch's main river systems, providing year-round base flows to these streams. Spring and stream flows will vary with groundwater levels, which themselves depend on antecedent rainfall, groundwater extraction, and groundwater recharge rates.

The artificial drainage network that is constructed as part of the city's infrastructure (i.e. subsoil drains, utility waterways, and stormwater pipelines) controls groundwater levels in the shallow surface aquifer. This conventional drainage infrastructure has lowered shallow groundwater levels, resulting in a reduction in the year-round base flows of Christchurch's tributary streams and waterways, and in some areas the drying-up of upstream reaches. Additionally, penetration, interception, and diversion of confined aquifers can negatively impact on natural springs downstream, with similar results.

5.3.1 Groundwater Drainage

Groundwater drainage systems are often installed to lower and control seasonally high groundwater levels, which can adversely affect the surface land use. Groundwater drainage systems include open drains and subsoil drains.

Groundwater drainage must be considered carefully, as inadequate design can cause a number of adverse effects to surrounding waterways, wetlands, properties, and pipelines, including:

- shrinkage of peat soils
- drying of wetland areas
- failure to allow for infrequent high groundwater levels in wet seasons
- flotation of pipe systems, tanks, etc
- flooding of basements
- rise of groundwater levels following the piping of a wet area or drain with sealed pipes
- iron precipitate and/or iron-reducing bacteria sludge deposits.

5.3.1.1 New Groundwater Drainage Philosophy

Open waterways are generally a more effective means of groundwater control than piped subsoil drains. Subsoil drains should only be used to remedy the surface water logging problems in an existing developed area such as older low-lying suburbs.

The appropriate philosophy is to design for the groundwater regime in a way that avoids adverse effects and that takes opportunities to protect or restore wetland areas. For example:

- New subdivisions could be filled to increase ground height to deal with high groundwater levels, instead of using subsoil drainage systems.
- Particularly wet, low-lying areas should be protected and restored as wetlands, instead of being developed. Refer to *Chapter 10: Restoring Wetlands*, for further information.
- Restoring naturally saturated soils to wetlands, as well as integrating soakage systems (swales, soil absorption basins, soakage chambers) and constructed wetlands into the catchment's stormwater system will contribute to retaining groundwater levels and natural springs.
- Springs are also important natural features of the waterways and wetlands of Christchurch, and as such, every opportunity should be taken to protect and restore them. Good examples of spring-fed waterways include Thistledown Reserve, off Portman Street in Woolston, and Papanui Stream, above Grants Road.

Greenfields Development

The need for groundwater drainage in new urban areas can be avoided by:

- Restoring wetlands in natural ponding areas and areas saturated during winter. These areas can become valuable components of the public open space for the neighbourhood.
- Providing an effective network of swales and open waterways.

Stormwater disposal by soakage to groundwater has been recently encouraged in new urban growth areas to the south and west of the city. Increased use of such systems will help to slow the decline of stream base flows. Environment Canterbury has granted the Christchurch City Council a comprehensive consent for stormwater disposal by soakage through an approved soakage basin.

Integrated Swale and Subsoil Drainage Systems

An innovative surface stormwater drainage system based on subsoil drains underlying roadside swales has been installed at Brooklands and Spencerville. Roof runoff is piped to a soakage chamber located near the street frontage of each residential lot. The sandy soil provides temporary stormwater detention storage that is drained slowly by a subsoil drain network in the road reserve.

Given sandy soil conditions, low site coverage and generous road reserve widths this is a cost-effective alternative stormwater drainage system, which can result in an attractive quasi-rural living environment.

Refer to *Chapter 6.5: Soakage Systems*, for information on the types and design of soakage systems.

5.3.1.2 Subsoil Drains

Subsoil drains are usually installed to intercept and lower groundwater levels, and sometimes to intercept surface water. Use of subsoil drains to intercept surface water should generally be avoided where prolonged periods of ponding are not acceptable.

It is often necessary to make special provision for groundwater control when an existing open drain is piped. This may require a dual line of a sealed pipe and a perforated subsoil pipe. Where subsoil drains are likely to be running all year round, it is important to try to ensure complete submergence of the line to limit algal growth, which is known to significantly reduce the useful life of subsoil drains.

The effectiveness of subsoil drain systems in the long-term is limited by:

- susceptibility to blockage by iron bacteria deposits and roots
- maintenance difficulties including inspection, clearing and repair
- expensive replacement costs
- impeded drainage through surrounding soil due to compaction, and low permeability strata of inadequate filter medium surrounding the pipe.

Design Considerations

The main considerations for subsoil drainage pipes are flow, depth, pipe size, cleaning access, tree roots, and appropriate bedding.

Design Flow:

- In the absence of any more appropriate criteria, a design flow of 1 mm/hour (2.78 l/s/ha) has been assumed for subsoil drainage systems. This has been established through historical experience.

Depth is usually governed by:

- the level of which groundwater levels should be reduced
- the depth of probable soil cultivation
- loading from traffic
- depth of the outfall.

Pipe Size:

- Perforated pipes with a smooth internal surface are preferable to facilitate better cleaning operations.
- Subsoil drains installed in road reserves are to be a minimum of 150 mm diameter, and are to be solid walled with a smooth internal bore (e.g. DN150 PVC drilled, as shown on standard detail SD377, in Christchurch City Council 2002a), with access points at the upstream end.
- Lightweight perforated corrugated pipes are unsuitable for Council maintained systems.

Cleaning Access:

- The location and spacing of access points should be considered, as should the diameter appropriate to the expected flow rate and grade. Access for cleaning should be through a standard inspection chamber, or 'rodding chamber', typically not more than 100 m apart.
- The designer must take note that field drains are prone to blockage by root intrusion and are costly to maintain and replace.
- In some areas it is important to try to ensure complete submergence of the subsoil drainage line to limit filamentous bacterial growth, which is known to significantly reduce the useful life of subsoil drains.

Bedding and Backfill:

- Bedding and backfill around a subsoil drain pipe must be more free-draining than the native soil.
- If filter fabrics are used, the designer should be aware that clogging could considerably reduce the through flow.
- Past experience indicates that good results can be obtained using a reasonably open, coarse grained filter media, such as concrete premix with slotted pipe, or pipe perforated with holes up to 8 mm in diameter.
- Where a filter fabric is used the designer should refer to manufacturer's literature for data on filter fabrics and technical text for information on filter design, as well as soil filter material criteria given below.
- Typical subsoil drainage details are shown on standard detail SD377.

Soil Filter Material Criteria

Filter material is used to allow water to flow more easily from the surrounding soil through openings in the pipelines, without carrying unwanted fine soil particles. The optimum filter material will depend on the characteristics of the surrounding soil. A larger interface area between filter media and soils of low permeability can increase flows.

The following criteria may help in choice of filter material of suitable particle size distribution.

- 1) To prevent the movement of particles in the protected soil:

$$\frac{15\% \text{ size of filter material}}{95\% \text{ size of protected soil}} < 5 \quad \text{Eqn (5-1a)}$$

- 2) Permeability Ratio: To permit free water to reach a subsoil drain:

$$5 < \frac{15\% \text{ size of filter material}}{85\% \text{ size of protected soil}} < 40 \quad \text{Eqn (5-1b)}$$

- 3) Uniformity ratio: To prevent clogging of a subsoil pipe with small particles infiltrating through openings:

$$\frac{50\% \text{ size of filter material}}{50\% \text{ size of protected soil}} < 25 \quad \text{Eqn (5-1c)}$$

- 4) To prevent the fines of the filter material blocking the perforations of the subsoil pipe:

$$\frac{85\% \text{ size of filter material}}{\text{Width of perforation}} < 1 \quad \text{Eqn (5-1d)}$$

To satisfy all the above criteria a series of filter layers may be required, but this is usually expensive to implement. This can often be avoided in the case of silts if observations confirm that the silt has sufficient cohesion to withstand slow flow velocities.

Crushed content of a filter will generally improve performance. It has been found that 19 mm concrete premix performs well as a free draining filter for many of the finer soils in Christchurch, but the designers should satisfy him/herself that this is the case for a particular application. Where the 19 mm stone content is undesirable, then Type 2A sand can be quite useful as an alternative. See CSS Part 1: General (Christchurch City Council 2002b).

Old marine sands, often encountered as running sand where it occurs below the water table, can require special attention to keep under control. Table 5-1 gives gradings for typical Christchurch marine sands.

Private Subsoil Drains

Generally, private property owners are responsible for the surface water control of stormwater falling on their own properties and should provide and maintain their own field drains as necessary for groundwater control. For private subsoil drains the Council will nominate or provide an outfall.

Subsoil drains that are on private property are highly susceptible to blockage by roots from trees and shrubs. The Council's landscape architects can advise on suitable plant species and location to minimise the risk of blockage by roots.

The past procedure of having a long Council field tile line crossing several properties parallel to the larger Council stormwater main is to be discontinued, mainly because of future foreseeable maintenance difficulties. Where damp properties require a field tile line to assist subsoil drainage it is current Council policy that any necessary field tile lines and sumps are the responsibility of the individual property owner. The Council has no objections to neighbours sharing sumps, but recommends appropriate private easements be arranged. The Council will continue to maintain and be responsible for the larger sealed stormwater line.

Individual private property subsoil drains connecting to the public stormwater main through a sump is the recommended practice (Figure 5-3, opposite page). Alternatively, a shared subsoil drain between two properties along or near their common boundary is also acceptable. Connection of more than two properties to the one subsoil drain is discouraged because of the high risk of root blockage.

Subsoil Drains in Areas Affected by Iron Precipitate

Iron deposits are a problem where there are high concentrations of iron in the groundwater, such as in eastern parts of Christchurch. Deposits appear when groundwater containing soluble ferrous ions reaches the interface between the anaerobic aquifer and an aerated surface, such as a pipe or aerated surface water. Iron precipitates or by-products from iron-reducing bacteria or fungi can cause blockages

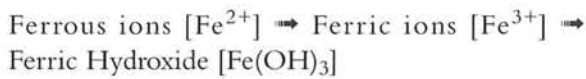
Table 5-1: Christchurch marine sand grading.

Sieve Size (mm)	% Finer
0.300	98.0
0.150	20.0
0.075	1.5

in pipes, perforations, backfill, and drainage media, which can severely reduce the effectiveness of the drainage system.

Deposition does not occur chemically under acid conditions or in groundwater that is naturally low in oxygen. However, a precipitation reaction occurs and is catalysed or accelerated by specialised bacteria such as *Thiobacillus ferro-oxidaans* or *Leptospirillum ferro-oxidaans*.

Changes in oxidation conditions cause ferrous ions to oxidise to ferric ions, which then form ferric hydroxide from available hydroxide (OH⁻) ions in the groundwater. The deposit is due to the formation of Ferric Hydroxide:



Alternatively, the bacterium *Thiobacillus ferro-oxidaans* may be responsible for producing dense filamentous threads when ferrous ions chelate with substances in the bacterial cell (Figure 5-4A). This results in iron encrustations on the cell sheath. The formation of threads, spirals, or capsules indicates the type of bacteria responsible for the contamination.

As the energy obtained from this reaction is small, the bacteria must process large amounts of iron, thus accounting for the large sludge deposits that are sometimes seen. Deposition rates vary, but in one instance a 250 mm diameter perforated main became one-third blocked within only six months after installation (Figure 5-4B).



Figure 5-4A: The iron reducing bacterium *Thiobacillus ferro-oxidaans* can form filamentous threads.

Figure 5-4B: This pipe has become blocked with sludge deposits produced by iron reducing bacteria.

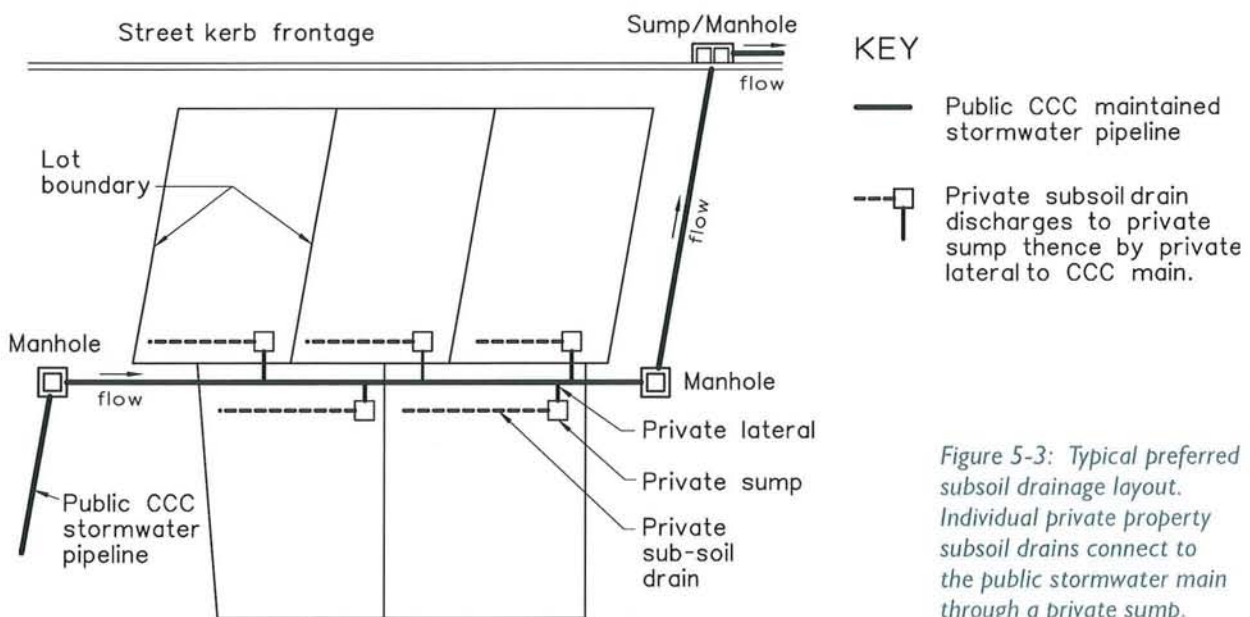


Figure 5-3: Typical preferred subsoil drainage layout. Individual private property subsoil drains connect to the public stormwater main through a private sump.

Check whether iron bacteria could be a problem by observing the existing subsoil drain outlets, and by enquiry. If so, the drain should be designed to prevent iron-related build-up by excluding air from the pipeline, backfill, etc. Methods of air exclusion include the following:

- water table control by weirs in either sumps or manholes
- installing the pipeline beneath the permanent groundwater level (below seasonal fluctuations)
- installing inverted siphons on the main and laterals.

Two means of achieving air exclusion are shown in Figure 5-5.

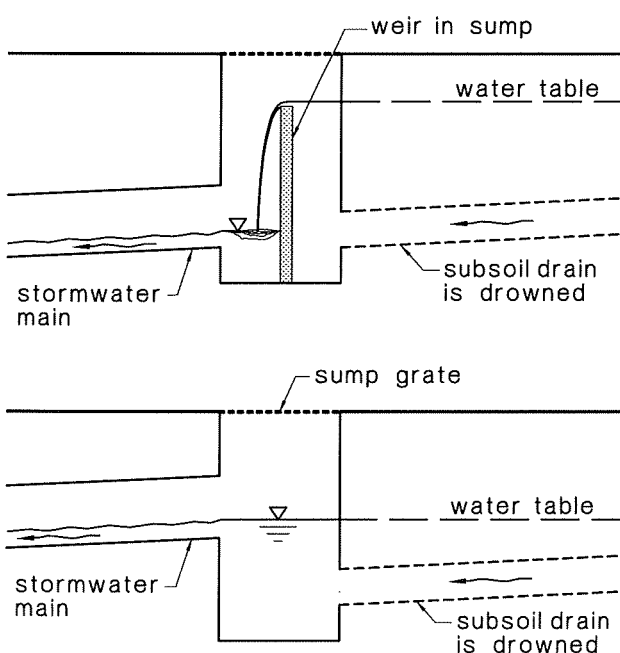


Figure 5-5: Two methods of achieving air exclusion, with a weir (top), and without a weir (above).

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