Catchment hydraulics

Calculating run-off

The catchment run-off must be accurately calculated to determine the correct size of the trench drain.

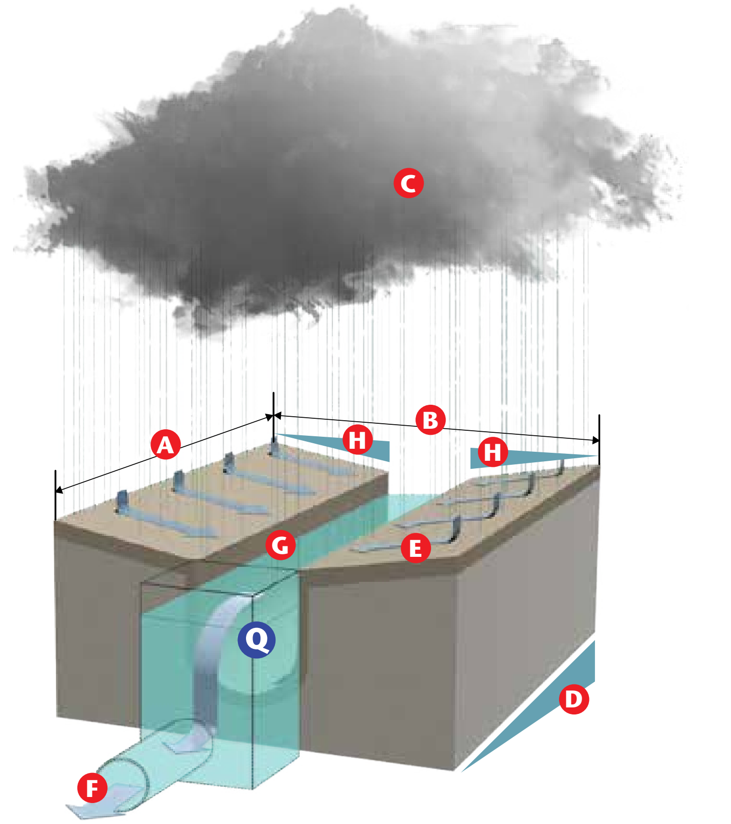
- Pavement length **(A)** x width **(B)** = Catchment area (m²)
- Rainfall intensity **(C)** (mm/hr)

Once catchment run-off **(Q)** is calculated, other inflows can be added.

Factors that affect trench drain hydraulics:

- Ground fall **(D)**
- Pavement material as some materials absorb liquids such as brick pavers **(E)**
- Position and size of outlet pipe **(F)**
- The roughness of the surface of the trench material. For Manning's roughness coefficient, see page 111 **(G)**
- Crossfall to the trench drain can affect grate hydraulics. For example steep slopes may cause bypass in ramp applications **(H)**

$$Q\ (L/s) = \frac{\text{Area (AxB) x Rainfall intensity (C)}}{\text{60 (minutes) x 60 (seconds)}}$$



Non-uniform flow

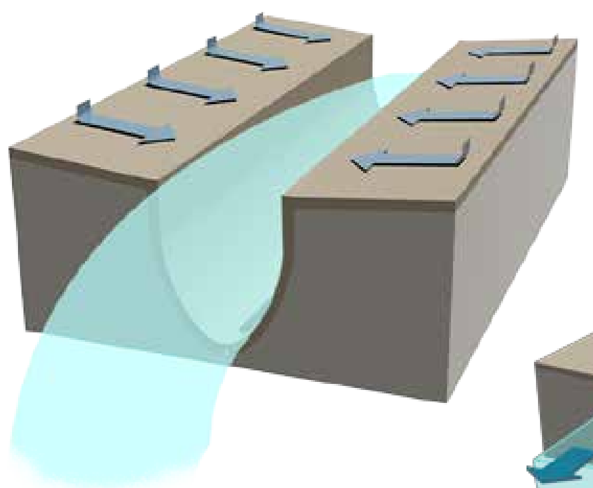
Non-uniform flow accounts for liquid being carried in a trench plus the constant addition of liquid collected through the grates (lateral intake) along the trench run. This resulting buildup of liquid means that a trench's run length will influence its hydraulic capacity.

A characteristic of non-uniform flow is the change of liquid velocity and height at successive cross-sections along the trench. Differential calculus and computer modelling is required to simulate this. **'Hydro'** is a purpose written hydraulic design program modelled on differential calculus for non-uniform flow in open channels.

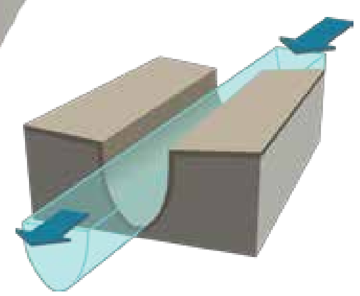
The program has been calibrated by empirical data from a series of experiments, modelling lateral intake into trenches. Analysis on the effect of slope, run length and trench cross section profiles are included in the program. It can also model complex scenarios and optimum outlet positions along trench runs.

For more information, see page 117.

$$\frac{dy}{dx} = \frac{S_0 - S_1 - 2\alpha Qq / gA^2}{1 - \alpha Q / gA^2 D}$$



Non-uniform flow



Steady uniform flow

ACO Technical Services – Modelling channel hydraulics

To generate results from the **'Hydro'** program, the following information is required:

- Length of trench run (metres).
- Length and width of catchment area (metres).
- Surrounding pavement material, for example concrete, asphalt or pavers.
- Rainfall intensity (mm/hr).
- Ground fall along the trench run (%).
- Crossfall perpendicular to the trench run (%).
- Preferred position of outlets along trench drain and any outlet size restrictions.
- Any slab depth restrictions.

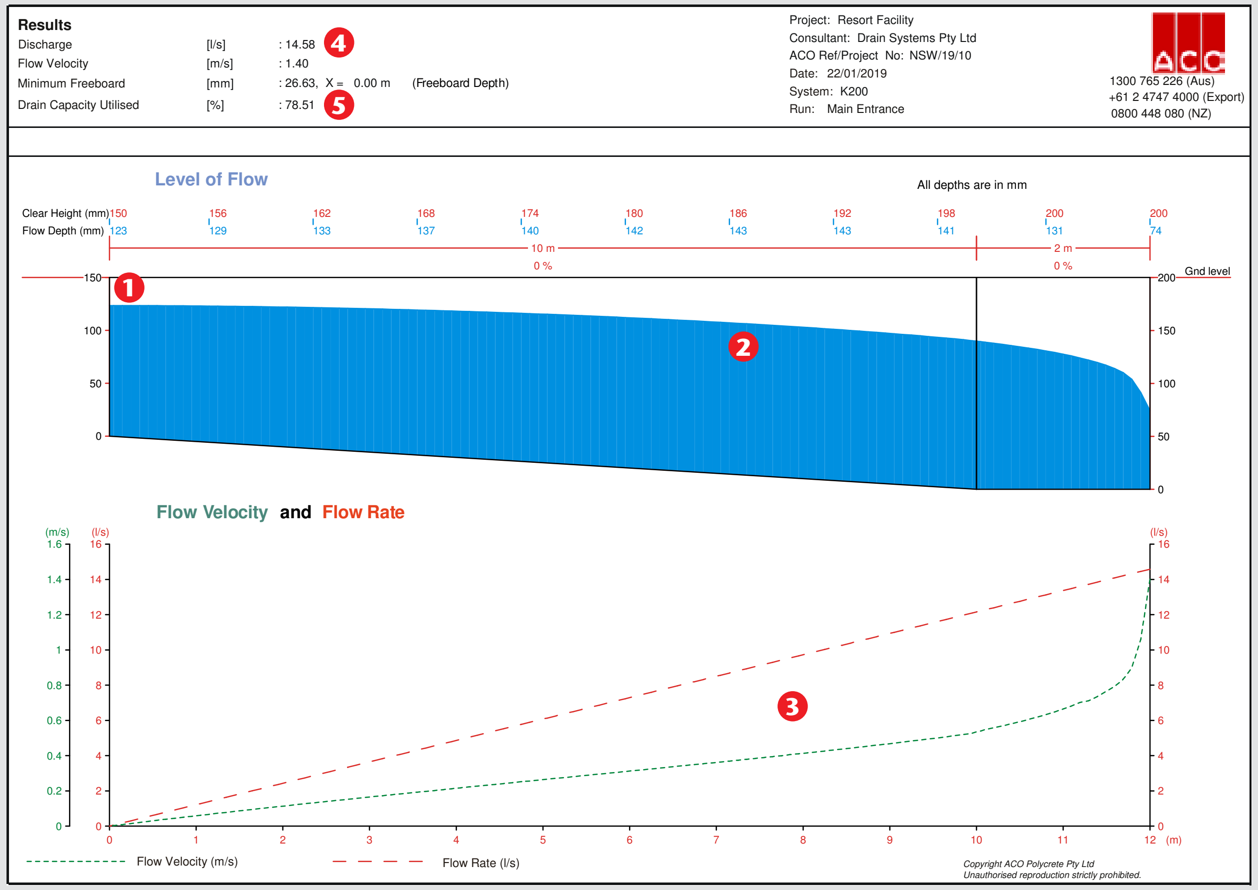
The electronic request form can be found at **www.acodrain.com.au/technical-support.htm**
Results are provided either electronically or as a printout.

Hydraulic results

The **'Hydro'** program calculates the following information:

Key

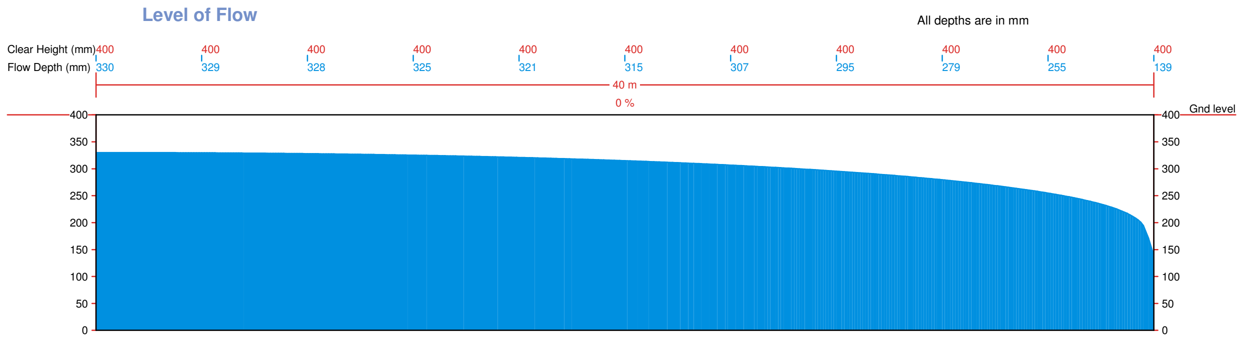
1. Position and size of minimum freeboard (gap between underside of grate and top of liquid in trench).
2. Hydraulic profile of liquid.
3. Flow velocity and flow rate at all points along the trench.
4. Maximum discharge capacity of trench run.
5. The percentage (%) of the hydraulic utilisation of the trench drain. If the hydraulic utilisation is over 100%, ponding occurs. The example below shows a hydraulic utilisation of 78.51%.

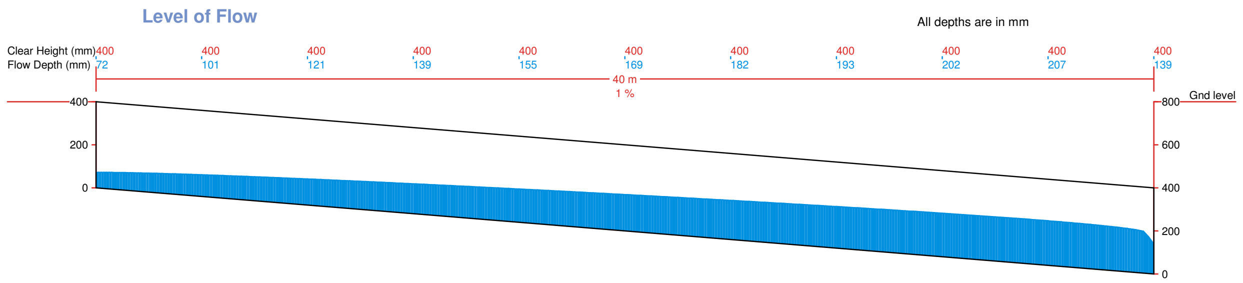


Effect of slope on trench drain hydraulics

Hydraulic capacity

Slope increases the hydraulic capacity of the trench drain because flow velocity is increased. This increase in capacity may result in larger areas being drained, outlets spaced further apart or a narrower and/or shallower trench system being specified that will result in product and installation cost savings.The drawings below highlight the water profile in the trench. The channel and flows are the same in both examples except the lower image has a 1% slope added. Note the difference in flow depth.





Position of outlet

Trench drains connect to underground pipes and the outlet position can dramatically affect the size and length of the trench drain required.

End outlet

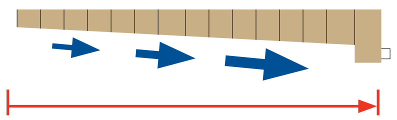
With a single end outlet, water may build up along the trench and cause ponding before reaching the outlet.

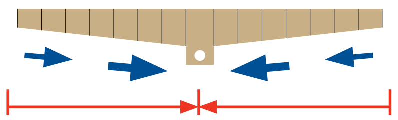
Central outlet – two directions

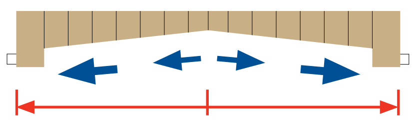
A central outlet enables a smaller trench drain as the central outlet reduces the build up of water, reducing the risk of ponding.

Double end outlet – two directions

An outlet at either end of the trench run enables a smaller trench drain but requires more outlets and additional pipework.







Size and type of outlet

Designers need to ensure the outlet and pipe infrastructure is not undersized restricting the outflow of the trench drain.

Horizontal end outlet

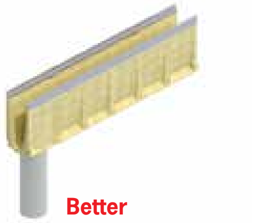
A pipe is connected horizontally at the end of the trench. This minimises excavation but offers the lowest outlet capacity.

Vertical end outlet

A pipe is connected vertically at the bottom of the trench. This option improves the outlet capacity due to gravity.

In-line pit

The pit is the same width as the trench, but deeper. It offers superior outlet capacity as large pipes can be connected and the increased depth gives increased head of water pressure.



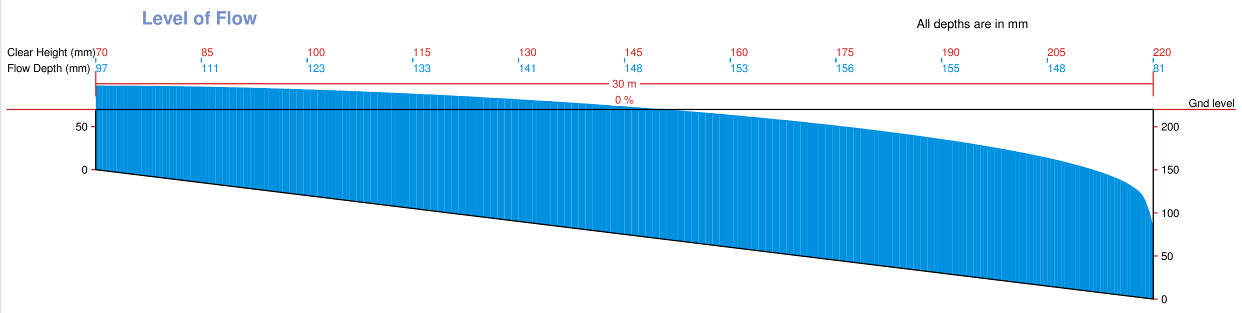
ACO Technical Services – Modelling catchment hydraulics

Temporary ponding refers to a brief flood situation that is acceptable with an undersized trench drain to enable a more cost effective drainage solution. The drain is designed to work effectively under average weather conditions, but will be slightly undersized during heavy storms.

Temporary ponding should only be considered where buildings and property are not in close proximity to the drainage system to minimise risk of damage. It is an ideal option for outer areas such as large car parks and distribution yards. A risk analysis should be carried out when temporary ponding is considered.

In order to produce a ponding analysis map, the following information is required:

- The same information required for the **'Hydro'** program, see page 117.
- Plan of site showing elevations.
- Location of buildings near the drain.



The **'Hydro'** result above indicates that flooding and ponding will occur and the situation requires a re-evaluation of the drainage size (width, depth, run length) or if temporary ponding can be tolerated, a ponding analysis, see below.

Ponding analysis results

The ponding analysis map shows the size and location of the ponding.

Key

1. Run-off scenario.
2. Catchment geometry showing width and depth of temporary ponding.
3. Visual map of worst ponding scenario.
4. Trench drain length an length of temporary ponding.
5. Project notes.

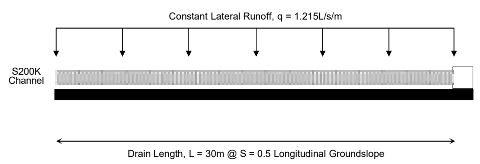
Ponding Analysis

Based on the results from ACO's 'Hydro' hydraulic design program

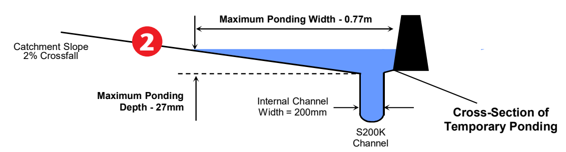
PROJECT: Resort Facility
Contact: James Smith
Company: JBD Constructions

Tel. No: 04011315527
Fax No:
email: James.Smith@JBDConstructions.com

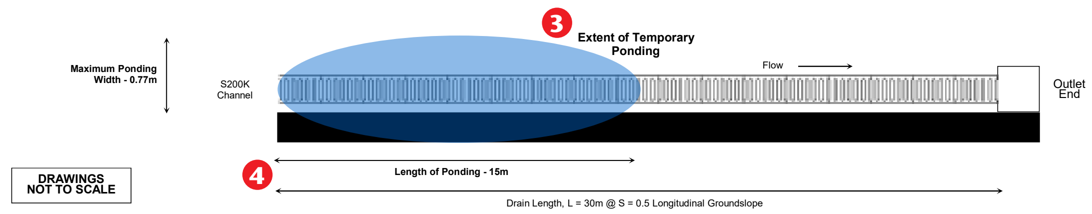
Runoff Scenario 1



Catchment Geometry (Cross Section)



Ponding Map



General Information

Date: 22/01/19 **ACO Contact:** Jarred Taylor **Ref. No:** NSW/19/10

Note: 5
1. The hydraulics of the ACO Drain System were calculated based on the assumed Runoff Scenario above.
2. The extent of ponding, depth and width, were determined from the Catchment Geometry (Cross-Section).

ACO Pty Ltd

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ACO

Grate hydraulics

In typical conditions, a trench drain reaches hydraulic capacity before the grate. When there are concentrated flows running down a steep slope for example, the grate may not be capable of capturing all the flow, even if the trench is correctly sized.

Correctly located drains position grates in the direct path of surface runoff. A grate has a finite capacity to capture the surface run-off from the catchment area. When the grate's hydraulic capacity has exceeded, bypass occurs.

A grate's hydraulic performance can be greatly influenced by subtle changes in the design of the grate and catchment characteristics.

When liquid moves over a grate, the following two scenarios may occur:

- **Weir** occurs when liquid depths are minimal and the speed of liquid is high.
- **Drowned orifice** occurs when there is an accumulation of liquid above the grate.

Drains positioned in sag or valley locations allow for more liquid to accumulate. This gives rise to higher flow rates due to the increased pressure of the liquid depth being pushed through the grate openings.

Hydraulic performance is affected by the characteristics of the grate and catchment.

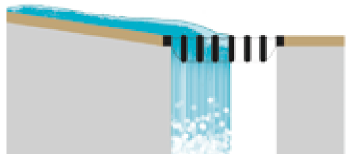
1. Grate characteristics

- Intake area.
- Width of grate.
- Design features such as the direction of bars, slots and slip resistance features.

2. Catchment characteristics

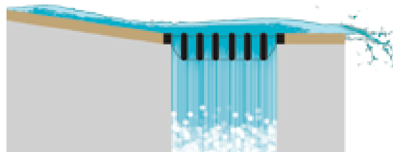
- Catchment slope determines the liquid velocity.
- Catchment roughness determines the liquid velocity and head of liquid.
- Flow direction – one direction requires a barrier drain, two or more directions requires a sag or valley drain.
- Type of liquid.
- Debris within the liquid.

No bypass



100% Capture
All the liquid flows through the grate opening.

Bypass



Less than 100% Capture
Bypass occurs when not all of the liquid flows through the grate openings.
Reasons for bypass include:

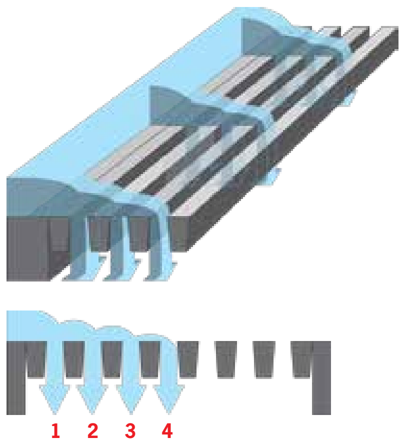
- Not enough grate open area.
- Too much runoff.
- Too much slope perpendicular to grate.

Types of inlet grates

Grate with longitudinal openings

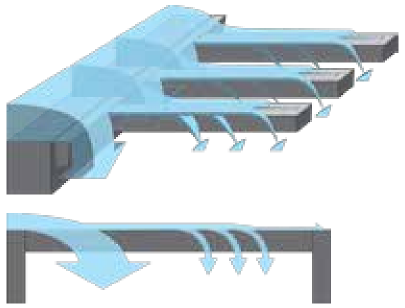
When comparing grates of equal intake area and width, grates with longitudinal openings offer the highest water intake and the maximum flow evacuation. See image below.

- Four bars interrupt and slow down the flow before a weir is produced.
- Slots 1, 2 and 3 are drowned orifices.
- Slot 4 acts as a weir.



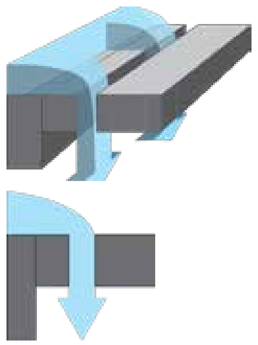
Grate with transverse openings

When comparing grates of equal intake area and width, grates with transverse openings offer moderate water intake. The bars create a bridge across both sides of the drain with minimal flow interruption, this can result in early (low volume) bypass.



Grate with a slot opening

When comparing grates of equal intake area and width, grates with slot openings provide minimal flow interruption as a weir is produced. The water intake is the lowest and the minimal depth above the slot will have negligible drowned orifice effect.



Note: Designers need to be aware of the trade-off between small inlets for heel safety and large inlets for optimum grate hydraulics. For more information, see page 115.

ACO Technical Services – Modelling grate hydraulics

Grate intake experiments

Due to the complex nature of fluids in relation to grate inlet hydraulics, testing is the only way to accurately predict how a grate will intercept surface water run-off.

ACO commissioned the UNSW Water Research Laboratory to research and test grate hydraulics. Three studies were carried out in 1998, 2004 and 2016 to investigate the water intake performance of ACO grates.

The tests were carried out under varying flow rates and catchment approach slopes. Each grate was tested until bypass occurred, which is the point where liquids pass across the grate.

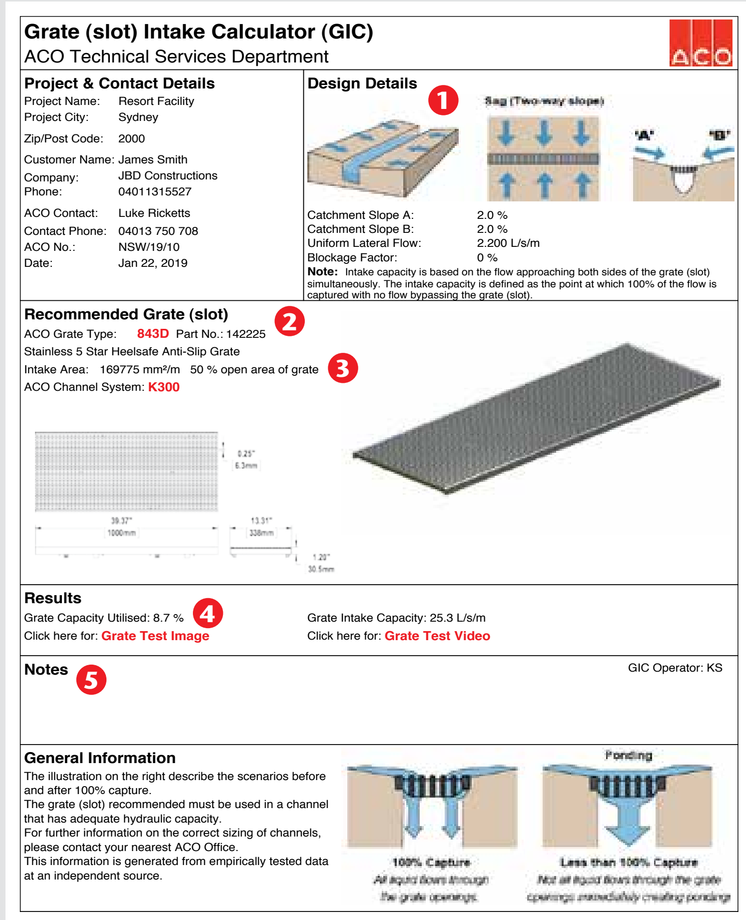
The hydraulic grate test results enable ACO to accurately recommend grates for specific projects based on their catchment hydraulics.

Grate intake calculator

Grate Intake Calculator (GIC) provides valuable information on the performance of a grate during design conditions.

To generate results from the **'GIC'** program the following information is required:

- Preferred grate type.
- Length of grate (metres).
- Length and width of catchment area (metres).
- Position of trench in catchment area.
- Surrounding pavement material for example concrete or asphalt.
- Rainfall intensity in (mm/hr).
- Crossfall perpendicular to the trench drain (%).



Grate (slot) Intake Calculator (GIC)
ACO Technical Services Department

Project & Contact Details
Project Name: Resort Facility
Project City: Sydney
Zip/Post Code: 2000
Customer Name: James Smith
Company: JBD Constructions
Phone: 04011315527
ACO Contact: Luke Ricketts
Contact Phone: 04013 750 708
ACO No.: NSW/19/10
Date: Jan 22, 2019

Design Details 1
Sag (Two-way slope)
'A' 'B'
Catchment Slope A: 2.0 %
Catchment Slope B: 2.0 %
Uniform Lateral Flow: 2.200 L/s/m
Blockage Factor: 0 %
Note: Intake capacity is based on the flow approaching both sides of the grate (slot) simultaneously. The intake capacity is defined as the point at which 100% of the flow is captured with no flow bypassing the grate (slot).

Recommended Grate (slot) 2
ACO Grate Type: 843D Part No.: 142225
Stainless 5 Star Heelsafe Anti-Slip Grate
Intake Area: 169775 mm²/m 50 % open area of grate 3
ACO Channel System: K300
0.25" 6.3mm
39.37" 1000mm
13.31" 338mm
1.20" 30.5mm

Results
Grate Capacity Utilised: 8.7 % 4
Click here for: Grate Test Image
Grate Intake Capacity: 25.3 L/s/m
Click here for: Grate Test Video

Notes 5
GIC Operator: KS

General Information
The illustration on the right describe the scenarios before and after 100% capture.
The grate (slot) recommended must be used in a channel that has adequate hydraulic capacity.
For further information on the correct sizing of channels, please contact your nearest ACO Office.
This information is generated from empirically tested data at an independent source.
Ponding
100% Capture
All liquid flows through the grate openings.
Less than 100% Capture
Not all liquid flows through the grate openings immediately creating ponding

Grate analysis results

ACO's grate analysis program calulates the following information.

Key

1. Catchment design and hydraulics.
2. Recommended grate information.
3. Total intake area per metre of trench run.
4. Hydraulic utilisation of the grate – 100% indicates that all the grate intake capacity is used.
5. Additional notes relating to the grates performance.

For a quick result, an online version of the **'GIC'** program is available.

Grate Intake Calculator (GIC)
Every grate on the ACO Drain website has a link to the **'GIC'** program.
Go to **www.acodrain.com.au**
Click the symbol to go to the **'GIC'** input page.