12.00 Safety aspects

12.01 General

Urban waterways and stormwater drainage systems can represent a significant safety risk during storms and times of flood. These risks may be associated with a person deliberately entering a drain or waterway, or as a result of an accidental slip or fall.

Undesirable interaction with stormwater structures can cause various physical and psychological injuries, including:

- Cuts and bruises
- Psychological trauma
- Permanent bodily injuries
- Fatal injuries

These injuries may result from:

- physical harm caused by a person being swept into, or against, a solid object, including a safety screen;
- short or long-term psychological trauma caused by a stormwater-related event; or
- drowning.

The risks associated with stormwater structures can be managed satisfactorily through the use of appropriate management techniques, including:

(i) Designing stormwater flow conditions so that the waters do not represent a risk of injury or death (first priority).

(ii) Designing or shaping the land and environments in and around a stormwater structure in a manner that minimises the risk of a person accidentally falling or slipping into a stormwater system (high priority).

(iii) Designing or shaping the land and environments in and around a stormwater structure in a manner that discourages a person/child from wishing to enter or play in the water during a storm or flood event (high priority).

(iv) Designing stormwater systems to allow a person to readily exit a drain or waterway before being swept into a pipe inlet, culvert or other unsafe waters.

(v) Designing long culverts to maximise those flow conditions where flood waters pass as *free surface flow* through the culverts (i.e. adequate head room exists to reduce the risk of drowning).

(vi) Erecting warning signs to alert people of potential danger (seeking advice from the local government is recommended).

(vii) Erecting external barriers (e.g. fencing) to limit the entry of people into stormwater structures.

(viii) Erecting inlet screens to prevent entry of people into a pipe or culvert.

(ix) Public education programs.

Point (v) above refers only to “long culverts”. Unless otherwise agreed, a long culvert may be taken as a culvert with a flow travel time in excess of 10 seconds. There is no recognised design criteria for the provision of “adequate head room”; however, 300mm freeboard between the water surface and the culvert obvert may be considered a minimum. Whether this freeboard should exist during the design Minor Storm, Major Storm, or an intermediate flow rate, will depend on the assessed safety risk. It should be noted that such design criteria would not render a culvert “safe”, but would at best just reduce the potential safety risk.

12.02 Risk assessment

In circumstances where a local government or stormwater designer considers it necessary to develop a risk assessment profile or develop a risk management strategy, reference should be made to Australian Standard AS 4360. An example of how AS 4360 could be applied to stormwater systems is presented below.

The main elements of the risk management process may be summarised as:

(a) Communicate and consult

- Identify the current asset manager.
- Identify those sections/departments of the community and local government that need to be consulted as part of the risk assessment and risk management process.
- Communicate with the local community about the risks and the adopted management procedures. This communication may include the use of warning signs adjacent high-risk stormwater systems.

(b) Establish the context

- Define the parameters within which risks must be managed. Where possible, relate the risk management objectives to the overall stormwater and organisational objectives. Also define the criteria against which these risks are to be evaluated.

(c) Identify risks

- Identify where, when, why and how stormwater related risks may occur.
- Define what risks are under the control of the organisation and/or asset manager.
- Identify existing processes, devices and practices used to manage the risks and assess their strengths and weaknesses.
- Identify current best management practice options.
- Identify the consequences and likelihood of an event (refer to *Glossary* for definition of terms).

Tables 12.02.1 and 12.02.2 provide examples of possible stormwater related likelihood and consequence scales.

Table 12.02.1 Example of "likelihood" scale

Level	Descriptor	Description
A	Almost certain	The event will occur on an annual basis
B	Likely	The event has occurred several times in recorded history
C	Possible	The event is likely to occur once in 50 years
D	Unlikely	The event has occurred once before
E	Rare	The event has not occurred locally, but has occurred elsewhere
F	Very rare	Never known to have occurred
G	Almost incredible	Theoretically possible, but not expected to occur

Table 12.02.2 Example of "consequences" scale

Level	Descriptor	Description
I	Major	Fatal injuries
II	Significant	Permanent injury or psychological trauma
III	Moderate	Broken bone or open flesh wound
IV	Minor	Cuts and bruises
V	Very minor	Wet clothes or mild scare or mild trauma

(d) Analyse risks

Identify and evaluate existing controls. Determine consequences and likelihood. Develop an appropriate risk assessment table, such as the example shown in Table 12.02.3

Table 12.02.3 Example of a risk assessment matrix

Likelihood Scale	Consequence Scale				
	I	**II**	**III**	**IV**	**V**
A	Medium	High	High	Very High	Very High
B	Medium	Medium	High	High	Very High
C	Low	Medium	High	High	High
D	Low	Low	Medium	Medium	High
E	Low	Low	Medium	Medium	High

(e) Evaluate risks

Compare the level of risk with the established assessment criteria and identify risks that require a change in management/operational procedures.

(f) Treat risks

Identify options for managing the risks. Consider the potential benefits and adverse outcomes of proposed risk management options.

Develop an *Action Plan.* Identify the appropriate asset manager and how the action plan should integrate into the operational procedures of the asset manager.

The adopted risk management measures should be determined from an assessment of all relevant issues including, the likelihood of an incident, the consequences of an incident, cost, aesthetics, legal risk to the utility owner, and community expectations. Consideration must also be given to potential risks to maintenance and rescue/emergency personnel.

It is acknowledged that safety risks are unlikely to be eliminated from all stormwater systems; however, all reasonable and practicable measures should be taken to minimise identified risks.

(g) Monitor and review

Monitor the implementation of the action plan. Develop incident reporting procedures. Where appropriate, photograph the stormwater system during runoff/flood conditions. Review the risks, adopted action plan, and the management procedures as necessary.

Local governments can also use the Risk Assessment Matrix presented in Table 12.02.3 to identify those areas of a stormwater network that warrant highest priority for a safety review. The "likelihood" of contact has traditionally been based on a *Contact Class* system (e.g. U.S. Bureau of Reclamation, 1987). An example of such a system is presented in Table 12.04.1. Local governments may choose to adopt an alternative Contact Classification based on conditions more relevant to their local area.

12.03 Safety fencing

Safety fencing may be divided into the following three categories:

(i) *Childproof fencing:* used to prevent access by children that are not old enough to properly assess the safety risks.

(ii) *Exclusion fencing:* used to exclude people (children and adults) from an area.

(iii) *Barrier fencing:* used to minimise the risk of a person accidentally falling onto a hard surface or into dangerous waters.

It is not considered to be in the general interest of the community to design urban drainage channels in a manner that will require the need for safety fencing. The first preference should always be to design stormwater channels with gentle grassed slopes or heavily vegetated banks that will minimise the risk of a person accidentally *falling* into dangerous waters, and allow a child or injured person easy egress.

As a general rule, urban waterways, wetlands and lakes are not fenced unless there is an edging treatment (e.g. high, steep, slippery bank) that could result in a person accidentally falling into dangerous waters, or falling more than 1500mm onto a hard surface.

(a) Childproof fencing

The need for childproof fencing needs to be assessed on a case-by-case basis based on a risk assessment analysis.

Examples of stormwater systems likely to represent reasonably foreseeable danger are presented in Table 12.03.1

Table 12.03.1 Stormwater systems likely to represent a reasonably foreseeable danger

Systems Likely to Represent a Reasonably Foreseeable Danger	Systems not Likely to Represent a Reasonably Foreseeable Danger
• Stormwater systems not clearly visible. • Overland flow paths. • Temporary sedimentation basin associated with a construction activity. • Small stormwater treatment systems, wetlands or ponds not directly associated with a watercourse and as such their existence may not be obvious to a visitor to the area. • Deep-chamber gross pollutant traps installed within a stormwater pipe system. • Stormwater pipes or culverts discharging to a high-risk energy dissipater.	• Vegetated drainage channels or waterways. • Large wetlands or lakes likely to be well known to residents (i.e. clearly visible). • Stormwater systems located within the road reserve of a busy arterial road that would itself represent an obvious safety risk to children. • Most stormwater detention/retention basins.

(b) Exclusion fencing

Even if the risks are considered reasonably foreseeable by the general public, if a stormwater drain, inlet, culvert or other structure is considered to represent a significant safety risk, then all reasonable and practicable measures should be taken to minimise or otherwise manage these risks. In cases where the safety risks exist for both adults and children, then the use of exclusion fencing may be required.

Unfortunately, most exclusion fencing can be scaled, crossed or damaged by a determined person; therefore, the type and height of fencing used should be appropriate to the expected risks and the desired functions of the fence.

(c) Barrier fencing

Barrier fencing is not primarily designed to exclude access by a person. Rather its focus is on providing a visual warning of danger and preventing accidental falls.

If the edge treatment of a stormwater device represents a risk of a person falling more than 1000mm, then appropriate barrier fencing may be required. Such fencing should be designed to sustain the imposed actions specified in AS 1170.1.

12.04 Inlet and outlet screens

12.04.1 General

Risk assessment for the application of inlet and outlet screens has traditionally been based on a *Contact Class* (refer to U.S. Bureau of Reclamation, 1987) as represent in Table 12.04.1. Local governments may choose to adopt an alternative Contact Classification based on conditions more relevant to their local area.

Table 12.04.1 Contact classification

Contact Class	Location Description
Class A	Within or immediately adjacent to a school or childcare centre including the adjoining road reserve.
Class B	Within 100 metres of an existing or future urban residential area or public gathering area such as a park, shopping centre, entertainment or sporting facility.
Class C	More than 100 metres from a school, park, childcare centre, or existing or future urban residential area.
Class D	Within an area surrounded by heavily trafficked arterial roads, childproof fencing or is otherwise considered inaccessible (legally or illegally) to the general public.

General recommendations on the use on inlet and outlet safety screens are provided below for the above Contact Classes. These recommendations need to be reviewed for relevance and practicality on a case-by-case basis on conditions relevant to the local area.

Contact class A:

Within a Class A location, serious consideration should be given to the placement of inlet screens and/or external barriers in the following circumstances:

(i) All culverts and stormwater inlets with a minimum dimension equal to or greater than 375mm and a conduit length greater than 3 metres.

(ii) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm and a conduit containing a potential impact structure (eg. split flow chamber, impact type energy dissipater or drop pit with a drop greater than half the pipe diameter).

(iii) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm and a conduit containing an accessible enclosed deepwater chamber (eg. gross pollutant trap).

(iv) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm that discharge to waters that are either inaccessible to a potential rescuer, or have no suitable egress.

(v) Any culvert or stormwater inlet where the assessed safety risk is considered unacceptable.

Contact class B:

Within a Class B location, serious consideration should be given to the placement of inlet screens and/or external barriers in the following circumstances:

(i) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm, and an expected pipe-full flow travel time greater than 10 seconds.

(ii) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm and a conduit containing a potential impact structure (eg. split flow chamber, impact type energy dissipater or drop pit with a drop greater than half the pipe diameter).

(iii) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm and a conduit containing an accessible, enclosed, deepwater chamber (eg. gross pollutant trap).

(iv) All culverts and stormwater inlets with a minimum inlet dimension greater than 375mm that discharge to waters that are either inaccessible to a potential rescuer, or have no suitable egress.

(v) All culverts or stormwater inlets where the assessed safety risk is considered unacceptable.

Contact class C:

Within a Class C location, serious consideration should be given to the placement of inlet screens and/or external barriers in the following circumstances:

(i) All stormwater inlets with a minimum inlet dimension equal to or greater than 600mm and an expected pipe-full flow travel time greater than 20 seconds.

(ii) All culverts and stormwater inlets with a minimum inlet dimension equal to or greater than 600mm and a conduit containing a potential impact structure (eg. split flow chamber, impact type energy dissipater or drop pit with a drop greater than half the pipe diameter).

(iii) All culverts and stormwater inlets with a minimum inlet dimension equal to or greater than 600mm and a conduit containing an accessible, enclosed, deepwater chamber (eg. gross pollutant trap).

(iv) All culverts and stormwater inlets with a minimum inlet dimension equal to or greater than 600mm that discharge to waters that are either inaccessible to a potential rescuer, or have no suitable egress.

(v) Any culvert or stormwater inlet where the assessed safety risk is considered unacceptable.

Contact class D:

Within a Class D location, consideration should be given to the placement of inlet screens and/or external barriers on any culvert or stormwater inlet where the assessed safety risk is considered unacceptable.

12.04.2 Use of outlet screens

Outlet screens should not be used in circumstances where an unauthorised person could enter, or be swept into, the upstream pipe network during a period of pipe flow.

In appropriate circumstances, consideration should be given to the placement of outlet screens on stormwater pipes of 600mm diameter or greater that contain an accessible, enclosed, deepwater chamber (e.g. gross pollutant trap) in Contact Class zones A, B and C (refer to Table 12.04.1).

Grates should only be installed on the stormwater outlets provided:

(i) Possible debris loadings from upstream catchment are adequately assessed.

(ii) The consequences of system failure (e.g. property damages and safety hazards) resulting from debris blockage of the screen have been investigated and addressed to the satisfaction of the local government.

(iii) All upstream inlets and access chambers are secured against unauthorised entry.

12.04.3 Site conditions where barrier fencing or inlet/outlet screens may not be appropriate

Site conditions where the installation of barrier fencing or inlet/outlet screens may not be appropriate include the following examples:

(i) Where the over-all risk to human life as a result of the installation is judged to be greater than if the device was not installed.

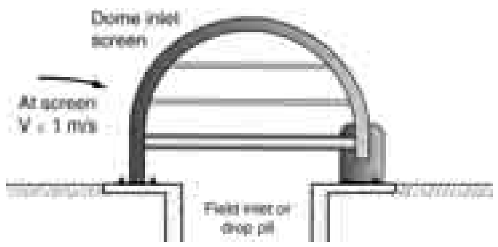
(ii) Where there is an unacceptable risk of trapping wildlife (aquatic or terrestrial) or causing disruption to an essential wildlife corridor.

(iii) Where debris blockage of the fence or screen will cause or increase floor level flooding. The degree of blockage must be commensurate with the existing and likely future catchment conditions.

Each site must be assessed on a case-by-case basis.

12.04.4 Inlet screen arrangements

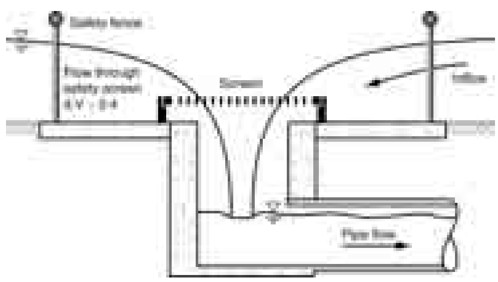
Figures 12.01 to 12.06 provide examples of possible inlet screen arrangements. These examples have been provided for the purpose of assisting designers in developing design concepts. The screen design should not necessarily be limited to the examples provided, for example various tower inlets chambers (not shown) have been used within detention basins.



Design requirements:

- Maximum flow velocity through the screen at zero blockage to be less than or equal to 1 m/s.
- Scour protection lip extends beyond base of dome screen.
- Lockable dome screen hinged to allow maintenance access into pit.

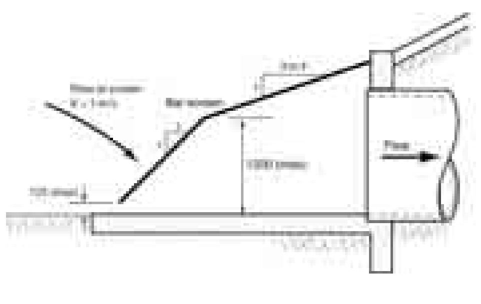
Figure 12.01 – Dome inlet screen



Design requirements:

- Depth-velocity product through the safety barrier fence at zero blockage to be less than or equal to 0.4 m^2/s.
- Lockable maintenance access gate installed in barrier fence.
- Separate lockable debris screen over inlet.

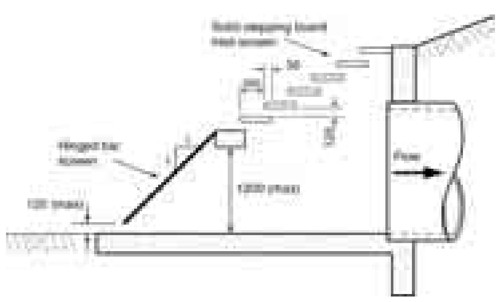
Figure 12.02 – Major inlet structure



Design requirements:

- Maximum flow velocity through the screen at zero blockage to be less than or equal to 1 m/s.
- Lockable, hinged screen to allow maintenance access.

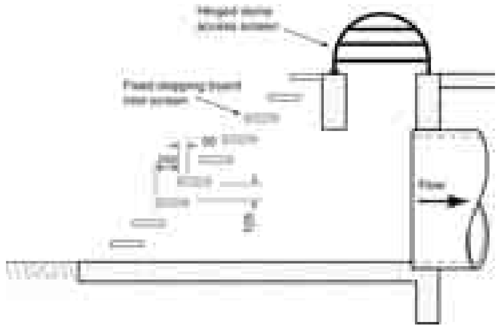
Figure 12.03 – Hinged inlet bar screen



Design requirements:

- Maximum flow velocity through both bar and stepped inlet screens at zero blockage to be less than or equal to 1m/s.
- Lockable, hinged lower bar screen to allow maintenance access.
- Fixed upper stepping board screen.

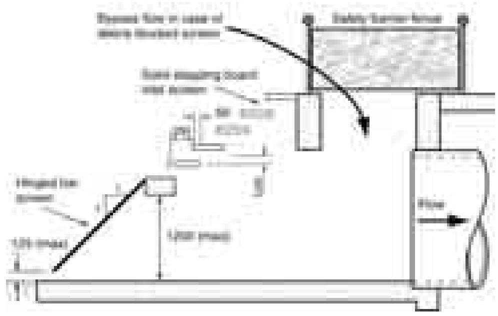
Figure 12.04 – Bar screen with upper stepping board inlet screen



Design requirements:

- Maximum flow velocity through stepped inlet screen at zero blockage to be less than or equal to 1 m/s.
- Lockable, hinged dome inlet screen to allow maintenance access and minor bypass flows.
- Fixed stepping board screen.

Figure 12.05 – Fixed stepping board inlet screen



Design requirements:

- Maximum flow velocity through both bar and stepped inlet screens at zero blockage to be less than or equal to 1m/s.
- Lockable, hinged lower bar screen to allow maintenance access.
- Fixed upper stepping board screen.
- Depth-velocity product through the upper safety barrier fence at zero blockage to be less than or equal to 0.4 m^2/s.

Figure 12.06 – Alternative major inlet structure

12.04.5 Design guidelines for inlet and outlet screens

The following guidelines apply to the design of inlet and outlet screens.

(i) Any culvert or pipeline provided with outlet protection shall be provided with inlet protection.

(ii) Maximum "clear" spacing of vertical bars is provided in Table 12.04.2.

Table 12.04.2 Maximum 'clear' spacing of vertical bars

Location	Maximum "Clear" Spacing of Vertical Bars
Child-proof barrier fencing	100 mm
Inlet safety screens	125 mm
Outlet screens	150 mm

(iii) Maximum clear spacing of the screen above ground level is 125mm and 150mm for inlet and outlet screens respectively.

(iv) Maximum inclined spacing of horizontal support bars is 600mm. This maximum bar spacing aims to allow a trapped person to climb up the screen to safety. Note: a minimum spacing of 1 metre applies to safety fencing (not inlet/outlet screens) to *prevent* a child climbing over the fence.

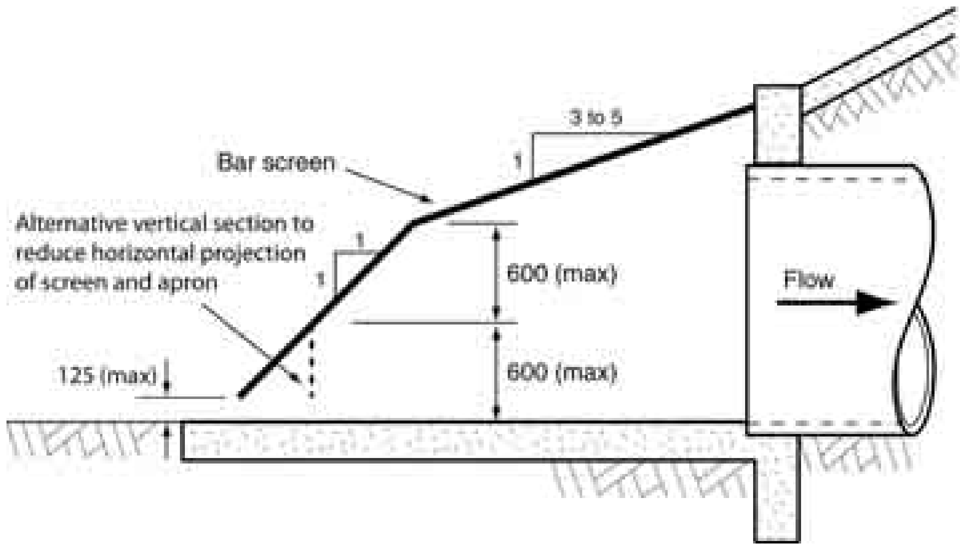
(v) In waterways containing permanent water, either still or flowing, aquatic passage requirements must be considered.

(vi) The net open surface area of the inlet rack should be at least three times the cross sectional area of the pipe/culvert inlet.

(vii) Recommended slope of "inlet" safety screens is provided in Table 12.04.3. A variable slope inlet screen may be developed as shown in Figure 12.07.

Table 12.04.3 Recommended slope of inlet safety screens

Height of Screen	Maximum Recommended Slope to the Horizontal
Less than or equal to 375 mm with an approach velocity no greater than 1 m/s	Vertical
Greater than 375 but less than 1200 mm with an approach velocity no greater than 1 m/s	Slope of 1:1 (45°)
Less than or equal to 600 mm with an approach velocity greater than 1 m/s	Slope of 1:1 (45°)
Greater than 600 but less than 1200 mm with an approach velocity greater than 1 m/s	Slope of 3:1 to 5:1 (H:V)
Greater than 1200 mm	Slope of 3:1 to 5:1 (H:V)



Design requirements for inlet screens
Figure 12.07

(viii) Where practical, inlet screens should be located and designed such that flow velocities through the "clean" screen will be low enough (typically equal to or less than 1 m/s) to allow a person to egress from the structure.

(ix) If the inlet consists of a transition that significantly contracts stormwater flow into the pipe or culvert, then where practical, the screen should be located upstream of the resulting drop in water surface profile.

(x) Where practical, the vertical downward component of water velocity at an inlet grate should be minimised.

(xi) Appropriate access must be provided to the screen for dry weather maintenance including the removal of debris.

(xii) All screens should be appropriately designed to allow cleaning even when fully blocked.

(xiii) Inlet screens/racks should have a removable feature to permit access for cleaning inside the pipe/culvert.

(xiv) Outlet screens shall not be used in circumstances where an unauthorised person could either enter, or be swept into, the upstream pipe network.

(xv) Outlet screens on pipe/box units up to 1800mm in width should be designed such that the full width of the outfall pipe/box can be accessed for periodic maintenance.

(xvi) All screens should be secured with tamper-proof bolts or a locking device.

(xvii) Outlet screens should be structurally designed to break away under the conditions of 50% blockage (or lower if needed to prevent undesirable backwater flooding) during the pipe's design storm event.

(xviii) Local governments may consider allowing the use of top hinged outlet screens installed at an angle of say, 10 degrees to the vertical, to restrict unauthorised entry, but allow the passage of water during significant debris blockage. No guidance on the design of such screens is provided in this Manual.

12.04.6 Hydraulics of inlet screens

Hydraulic analysis of screened inlets should consider the following:

(i) Upstream flood levels should ideally be based on 100% blockage of the screen during the designated "major storm", but only if 100% blockage is considered likely.

(ii) The designated "minor storm" should be analysed assuming at least 50% debris blockage of any inlet screen, unless such blockage is considered unlikely to occur.

Case A:

Head loss through a clean or partially blocked screen that is located well upstream of the pipe/culvert inlet (i.e. not bolted directly to the face of the headwall, or inside the pipe) may be assessed based on Equation 12.01. In such cases, pipe entry losses need to be considered separately.

$$\Delta H = K_t^* (V_n^2/2g) \quad (12.01)$$

where:

$$K_t^* = 2.45A_r - A_r^2 \quad (12.02)$$

Technical Note 12.04.1:
Equation 12.02 has been developed from the original recommendations of US Bureau of Reclamation (1987). The coefficients are generally higher than those recommended by Miller (1990), but are considered to be more realistic for heavily blocked screens. The coefficients provided by Equation 12.02 for a "clean" screen (say $A_r < 0.2$) are comparable with those recommended by Miller.

Case B:

If the screen is bolted directly to the face of the inlet headwall, or where flow immediately downstream of the screen is confined within a conduit with a cross sectional area approximately equal to the gross area of the screen, then the head loss for the screen may be determined from Equation 12.03. In such cases, the pipe entry loss cannot be considered separately, and thus the head loss of the screened pipe inlet must be taken as the greater of the screen loss or the pipe entry loss.

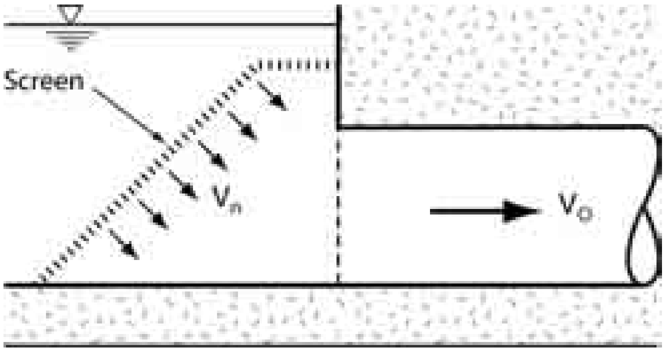
$$\Delta H = K_t (V_o^2/2g) \quad (12.03)$$

where:

$$K_t = (2.45A_r - A_r^2)/(1 - A_r)^2 \quad (12.04)$$

Case A:
Screen upstream of pipe/culvert inlet (Figure 12.08)

Energy loss (ΔH) consists of screen loss plus pipe entry loss.



Inlet screen mounted away from the inlet
Figure 12.08

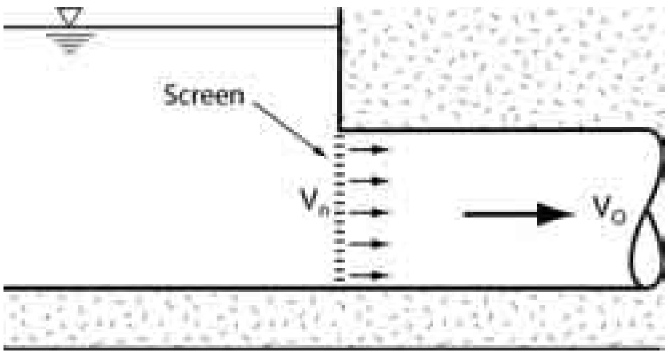
$$\Delta H = K_t^* .(V_n^2/2g) + K_e .(V_o^2/2g) \quad (12.05)$$

where:

K_e is typically 0.5 for square edged inlet, and K_t^* is determined from Equation 12.02.

Case B:
Screen located at pipe/culvert inlet (Figure 12.09)

Energy loss (ΔH) is the greater of the "screen loss" and the "pipe entry loss".



Inlet screen mounted close to the inlet
Figure 12.09

ΔH = the greater of:

(i) $K_t .(V_o^2/2g)$ or, (12.06)

(ii) $K_e .(V_o^2/2g)$ (12.07)

where:

K_e is typically 0.5 for square edged inlet, and K_t is determined from Equation 12.04. It is noted that in this case $K_t .(V_o^2/2g) = K_t^*.(V_n^2/2g)$.

where:

- ΔH = Head (energy) loss (m)
- K_t^* = head loss coefficient based on velocity through screen
- K_t = head loss coefficient based on downstream flow velocity
- A_r = Area ratio = A_b/A = $1 - A_n/A$
- A_b = Blockage surface area of the screen bars (including debris blockage where applicable) (m^2)

A_n = Net flow area through screen (i.e. excluding bars and debris)

A = Gross flow area at the screen, $A = A_b + A_n$ (m^2)

V_n = flow velocity through the partially blocked screen (m/s)

V_o = flow velocity downstream of screen (m/s)

g = acceleration due to gravity ($9.79\ m/s^2$)

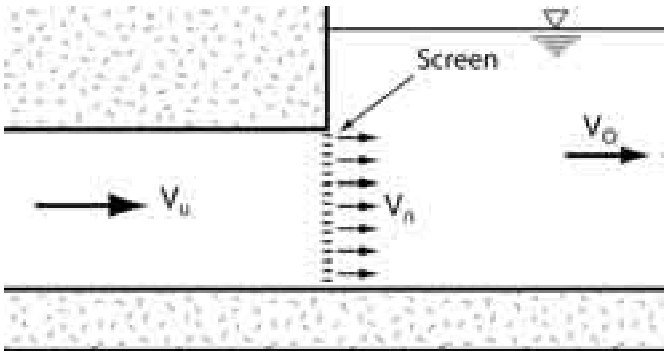
12.04.7 Hydraulics of outlet screens

Head loss through a fixed outlet screen that is located downstream of a pipe/culvert outlet headwall may be estimated using the procedures presented for Cases C to E below.

If partial debris blockage of the screen is considered possible, then an appropriate adjustment should be made to the assumed "net" area through the screen.

Case C:
"Clean" screen, i.e. (A_r < 0.2) located at pipe/culvert outlet (Figure 12.10)

Energy loss (ΔH) consists of screen loss (based on drag force equation) plus normal exit loss.



Outlet screen with minimal blockage
Figure 12.10

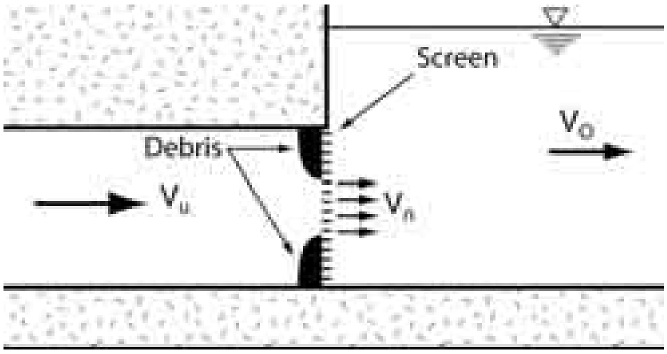
$$\Delta H = C_d.A_r.(V_u^2/2g) + K_{exit}[(V_u^2/2g) - (V_o^2/2g)] \qquad (12.08)$$

Where the drag coefficient "C_d" is typically 1.5 for round bars and 1.9 for rectangular bars.

Exit loss coefficient, K_{exit} may be determined from Section 5.16.9 based on side wall conditions at the exit, typically K_{exit} = 0.7 in such cases due to the effects of a flush channel bed in expansion of the outlet jet.

Case D:
Partially blocked screen, i.e. (A_r > 0.2) located at pipe/culvert outlet (Figure 12.11)

Energy loss (ΔH) consists of screen loss (heavily blocked screen) plus an exit loss component.

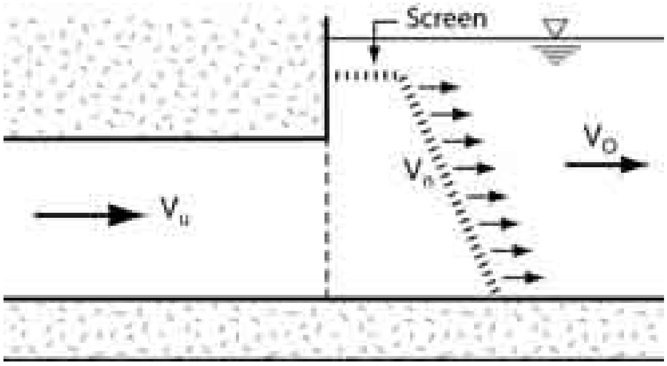


Partially blocked outlet screen
Figure 12.11

$\Delta H = K_t^*.(V_n^2/2g) + [(V_u^2/2g) - (V_o^2/2g)]$ (12.09)

Case E:
Screen located well downstream of pipe/culvert outlet (Figure 12.12)

Energy loss (ΔH) consists of pipe/culvert exit loss plus screen loss.



Outlet screen mounted away from the outlet
Figure 12.12

$\Delta H = K_t^* .(V_n^2/2g) + K_{exit} [(V_u^2/2g) - (V_o^2/2g)]$ (12.10)

Exit loss coefficient, K_{exit} may be determined from Section 5.16.9 based on side wall conditions at the exit, typically K_{exit} = 0.7 in such cases due to the effects of a flush channel bed in expansion of the outlet jet.

where:

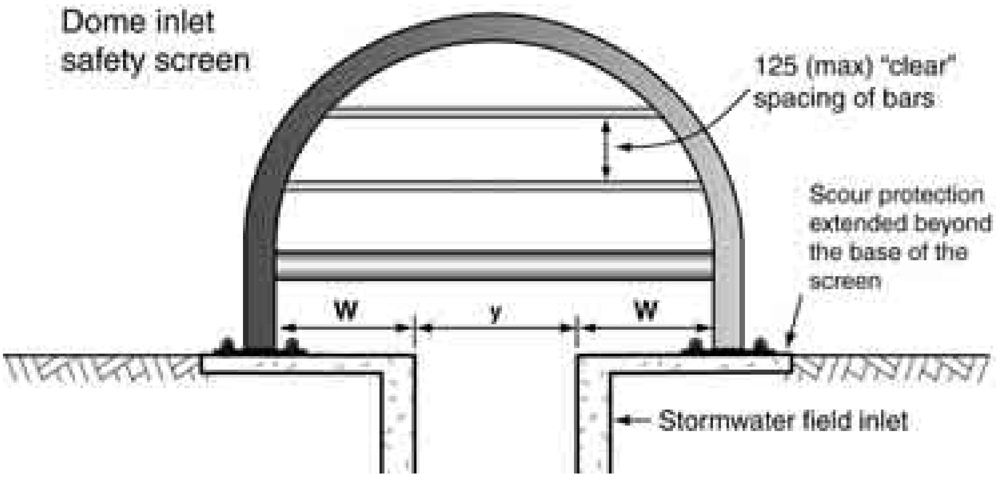
V_u	=	Average flow velocity upstream of outlet (m/s)
C_d	=	Drag coefficient
K_e	=	Entry loss coefficient
K_{entry}	=	Exit loss coefficient

12.04.8 Dome field inlet safety screens

There are two critical dimensions on a domed inlet screen constructed over a horizontal field inlet:

(i) Maximum clear bar spacing of 125mm (Figure 12.13).

(ii) Minimum screen width to achieve a screen through-velocity of 1 m/s.



Minimum width requirements of dome safety inlet screen
Figure 12.13

The minimum dome inlet screen width to achieve an approach velocity of 1m/s (as defined in Figure 12.13) may be determined from Table 12.04.4.

Table 12.04.4 Standard dimensions of dome inlet safety screen

Total Angle of Approaching Flow (Figure 12.14)	Minimum Dimension of " W "	
	All Inlets	Square Inlets Operating under Orifice Flow
90°	2.5 H^*	0.98 y
180° to 360°	2 H^*	0.78 y

where:

W = width of screen extending beyond the edge of the field inlet (m)

y = inside dimension of inlet (only relevant for square inlets) (m)

H^* = the <u>minimum</u> of the following:

(i) maximum expected upstream water depth relative to the inlet crest;

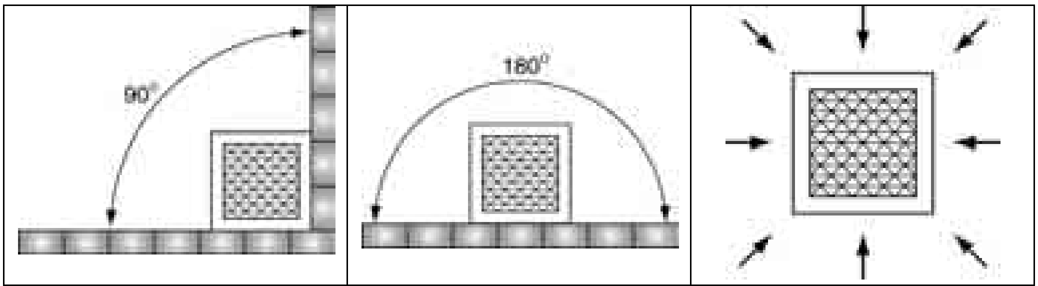
(ii) maximum upstream head (H^*) prior to "orifice" flow conditions as presented in Equation 12.11.

$$H^* = 1.56\,(A_e/L) \qquad (12.11)$$

where:

A_e = effective "clear" area of the field inlet opening ($A_e = y^2$ for square inlets) (m^2)

L = total weir length of field inlet opening ($L = 4y$ for square inlets)



(a) Field Inlet with 90° Angle of Approach Flow	(b) Field Inlet with 180° Angle of Approach Flow	(c) Field Inlet with 360° Angle of Approach Flow

Diagrammatic representation of approach flow angle (plan view)
Figure 12.14

12.04.9 Example culvert inlet screen

Figure 12.15 shows an example culvert inlet screen with dimensions (X and Y) provided in Table 12.04.5.

The dimensions presented in Table 12.04.5 have been based on the following requirements and assumptions:

(i) The net open surface area of the inlet screen is at least three times the cross sectional area of the pipe/culvert inlet.

(ii) Flow velocity through an unblocked screen will be one-third the flow velocity through the culvert when the culvert is flowing full. Thus if the culvert velocity is less than 3 m/s then the flow velocity through the screen will be less than 1 m/s when the culvert is flowing full.

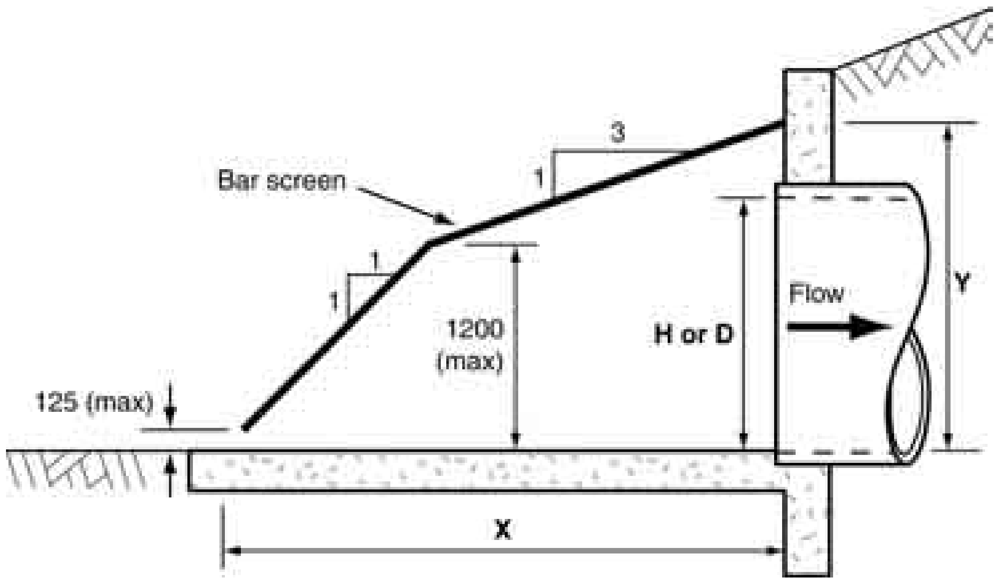
(iii) The total width of the screen bars is assumed to cause a 14% reduction in the effective flow area at the screen.

(iv) Wing walls are straight and parallel with the flow. If angled wing walls are used, then the design is conservative because the effective flow area at the screen is increased.

(v) No allowance has been made for debris blockage.

(vi) Flow velocity approaching the inlet screen is less than 1 m/s.

Where appropriate, a more efficient and thus cost effective design may be achieved through the development of a site-specific design based on a detailed hydraulic analysis. If the maximum average flow velocity within the pipe or culvert is significantly less than 3 m/s, then a site-specific design should significantly reduce the size of the screen.



Standard culvert inlet safety screen
Figure 12.15

Table 12.04.5 Dimensions of example (figure 12.15) culvert inlet screen

Box Culvert			Pipe Culvert		
Height (mm)	**X (m)**	**Y (m)**	**Diameter (mm)**	**X (m)**	**Y (m)**
600	1.77	1.39	**375**	1.01	0.89
750	2.26	1.55	**450**	1.21	1.03
900	2.75	1.72	**525**	1.41	1.17
1200	3.72	2.04	**600**	1.61	1.25
1500	4.69	2.36	**750**	2.01	1.38
1800	5.67	2.69	**900**	2.42	1.51
2100	6.64	3.01	**1050**	2.82	1.63
2400	7.61	3.34	**1200**	3.22	1.76
2700	8.59	3.66	**1350**	3.63	1.89
3000	9.56	3.99	**1500**	4.03	2.02
3300	10.53	4.31	**1800**	4.83	2.27
3600	11.51	4.64	**2100**	5.64	2.53

12.05 References

Miller, D.S. 1990, *Internal Flow Systems*, British Hydrodynamics Research Association, Edition 2.

U.S. Bureau of Reclamation 1987, *Design of Small Dams*, U.S. Department of the Interior, Washington, D.C., U.S.A.