PERSONNEL GRATE STUDY FOR STORMWATER PIPES

BY

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ABSTRACT

Safety grates for stormwater pipes are studied at the request of the State of Delaware, Department of Transportation (DelDOT). Various publications related to safety grates were reviewed because safety grates have been studied only sporadically and existing guidelines are not really based on scientific studies. First, trash racks for hydroelectric power plants, wastewater treatment plants and culverts are discussed because trash racks have been studied much longer and more extensively. Trash racks are similar to safety grates except that trash racks are placed to prevent debris from entering a facility instead of the prevention of child entry. Safety grates are more recent and have been installed at the entrance of relatively large culverts and pipes in urbanized areas. Second, debris and clogging problems are examined because safety grates accumulate debris like trash racks. The debris size and type are classified and the problems of debris accumulation on safety grates and sedimentation in stormwater pipes are discussed. Third, available prototype experiments on the tumbling and slipping of a person in flowing water are presented. Existing hydraulic model studies for safety grates are summarized where these studies improved the safety grate geometry for child safety. Fifth, the increase of the headwater depth due to the presence of a safety grate is investigated. Available formulas for the prediction of head loss due to a safety grate were examined critically. These formulas, developed originally for trash racks more than 50 years ago, may not be applicable directly to safety grates. More recent laboratory experiments are presented to assess the present state of the art.

Seven safety grates installed in Delaware are presented as examples to show the diversity of site conditions. A field trial conduced by DelDOT is depicted to discuss the effects of the orientation of the safety grate bars on the accumulation of debris. The design guidelines presented at the end of this report are intended to assist a competent engineer in designing a grate for personnel safety based on site conditions. The need for a comprehensive approach is emphasized because accidents can be minimized if adults and children know the danger of playing in water in the vicinity of stormwater pipes.

The recommendations for a personnel safety grate are summarized as follows:

- A personnel safety grate should be placed beyond the area of flow acceleration upstream of a pipe inlet, slanted at 3H:1V or flatter, and at zero angle of incidence so that the safety grate will cause the least disturbance to the flow.
- The area occupied by bars of a safety grate relative to the open area between bars should be kept as small as the site permits.
- The bar spacing of a safety grate needs to be selected in such a way that a child will not pass between the bars but light-floating debris will pass between the bars. Horizontal bars will block sticks less than slanted bars.

ACKNOWLEDGEMENTS

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SECTION 1. INTRODUCTION

In spring 2004, the State of Delaware, Department of Transportation (DelDOT) requested the Center for Applied Coastal Research (CACR), Department of Civil and Environmental Engineering, University of Delaware to study safety grates for stormwater pipes. The project entitled "Safety Grate Design for Stormwater Pipes" began on July 1, 2004 and completed on June 30, 2005. The hydraulic effects, safety and maintenance considerations were investigated in this project with the objective of the establishment of design guidelines for safety grates for DelDOT.

The specific tasks were as follows:

- Assemble various publications related to safety grates for stormwater pipes.
- Quantify the effects of grates on culvert and pipe hydraulics including the type of grate materials, the grate orientation relative to the flow direction, and the shape of grate bars.
- Assess the effectiveness of grates for child safety under various headwater and flow conditions.
- Assess the effects of grates on debris and leaves where debris clogging depends on the safety grate design but also the stormwater pipe size relative to the size and type of debris.
- Write a technical report on safety grate design for new installations and retrofitting existing installations.
- Finalize the report with input from DelDOT.

The literature search in this study has revealed that available publications are indeed limited and scattered. Consequently, this project report is valuable to DelDOT, other agencies and local communities.

1.1 Background

Hurricane Floyd caused more than 8 inches of rain in New Castle County, Delaware on September 16, 1999. Three girls playing in a drainage ditch in the Caravel Hunt development were swept into a 48-inch diameter stormwater pipe and two of the three girls were drowned (The News Journal, 1999). As a result of this tragic accident, Governor Carper ordered a review of existing stormwater laws and regulations as well as identifying potentially hazardous conditions related to stormwater or drainage (Storm Water Hazard Review Team, 2000). The Review Team identified the following items as potential safety hazards:

- Storm pond outlet structures and appurtenances.
- Stormwater pipes that have a diameter equal to or greater than 18 inches, do not have visible daylight from the other end, and are open ended (no safety grating or catch basins attached).
- Open drainage channels that have a side slope of 2H:1V or steeper and have 2 feet or more of water depth on a frequent basis.
- Areas that are known to be attractive to children.
- Groundwater recharge facilities that use open basins as a means of recharge.

It may be noted that the comprehensive manual, Hydraulic Design of Highway Culverts (2001), published by the U.S. Department of Transportation, Federal Highway Administration minimally addresses child safety. The primary safety considerations in the design and construction of a culvert are its structural and hydraulic adequacy. Safety grates are described very briefly in relation to traffic safety and child safety. Safety grates increase energy loss and promote debris buildup, resulting in reduced hydraulic performance. Furthermore, a child could be pinned against safety grates instead of being pushed through a stormwater pipe. In short, there are no design guidelines for safety grates.

On July 13, 2004, a 7-year-old boy at Pine Valley Farms was sucked into a 12-inch stormwater pipe, being pushed by rushing rainwater 90 degrees into another pipe and landing 175 feet from the giant puddle across the street where he had been playing with his sister and cousin (The News Journal, 2004). The boy suffered some scrapes and bumps but survived. On July 14, 2004, The News Journal (2004) reported that safety grates would be added to about a dozen open stormwater pipes. A similar accident was reported by The Denver Post (2004). On July 30, 2004, a mother, son and dog were sucked into a 30-inch-wide, 120-foot-long concrete stormwater pipe and were flushed out the pipe to the pond at the other end. The three survived, although the mother broke her foot. The literature search in this study has indicated that this kind of stormwater accident may be common.

1.2 Outline of Report

This report are arranged as follows: First, examples of trash racks and safety grates are presented together because the hydraulic design of safety grates is based on earlier knowledge of the hydraulics of trash racks used in hydroelectric power plants and wastewater treatment plants. Second, the clogging problems associated with trash racks and safety grates are discussed because a clogged safety grate will increase the water level upstream of a stormwater pipe. Third, hydraulic factors related to child safety are reviewed on the basis of available experimental studies. Fourth, the hydraulic design of a stormwater pipe with a safety grate is presented to assess the degree of the water level increase due to the safety grate. Finally, design guidelines for safety grates are discussed by summarizing the findings of this study.

SECTION 2. TRASH RACKS AND SAFETY GRATES

2.1 Trash Racks for Hydroelectric Power Plants

The hydraulic characteristics of trash racks were investigated first for hydroelectric power plants (Lyndon, 1916; Creager and Justin, 1950; Davis, 1952; Mosonyi, 1957). Figure 2.1 shows a trash rack of an intake structure in a hydroelectric power plant. The racks are needed to keep out debris that might damage operating equipment including turbines. The trash rack consists of vertical or slightly inclined steel bars placed parallel to each other and spaced uniformly to permit the use of rakes to remove debris and leaves.

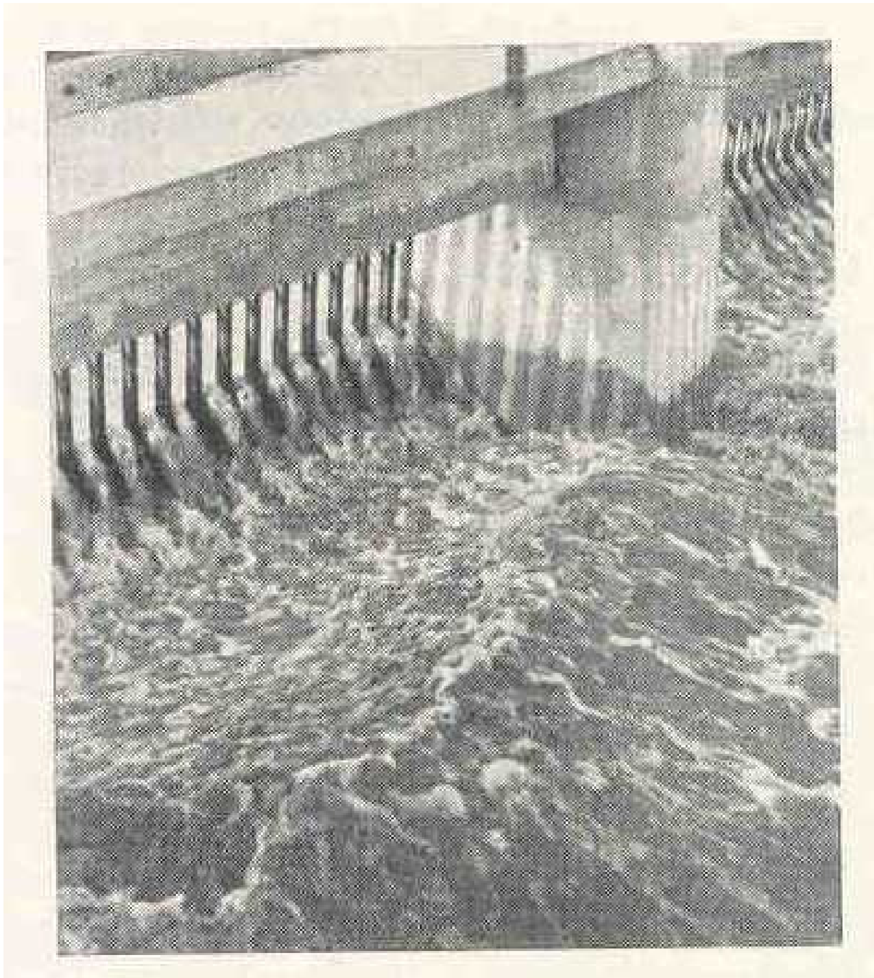


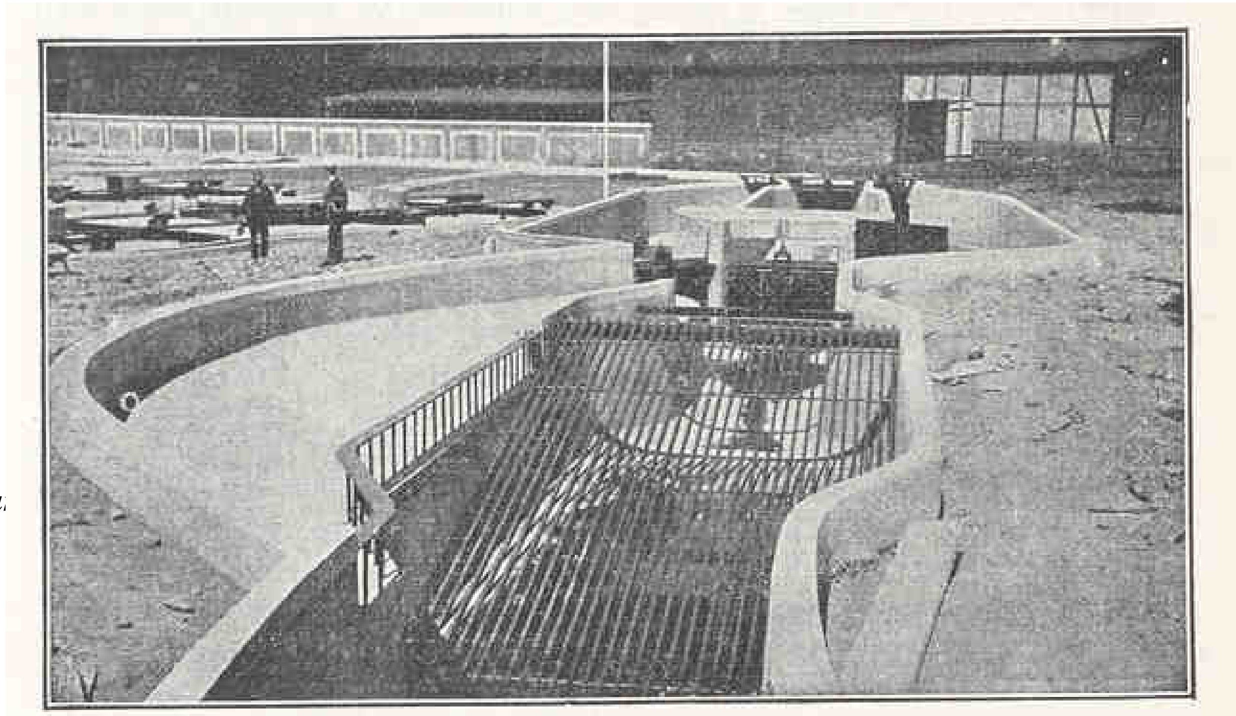
Figure 2.1 *Trash rack of an intake structure (Mosonyi, 1957).*

The spacing of rack bars depends on the allowable size of debris but 5-inch spacing may be regarded as the maximum limit to prevent the entrance of timbers. The maximum length of rack bars between lateral structural supports is limited by vibration characteristics related to bar thickness and water velocity. The loss of energy of water flowing through racks is an important factor for trash rack design. The approach velocity of water may be in the range of 2.5 – 5 ft per second, resulting in head loss (water energy per unit weight of water) in the range of 0.1 – 0.5 ft (Creager and Justin, 1950).

2.2 Trash Racks for Wastewater Treatment Plants

Trash racks are also used in wastewater treatment plants to screen materials in sewage (Metcalf and Eddy, 1930; Böhnke et al., 1989; Crites and Tchobanoglous, 1998). Figure 2.2 shows an example of such trash racks. The size of the bar spacing depends on the purpose to be accomplished by screening. Coarse and fine screenings consist of materials that are retained on screens with openings less than 2.0 and 0.5 inches, respectively. Trash racks need to be cleaned manually or mechanically.

The head loss formula used for these trash racks is simpler than that used for trash racks for hydroelectric power plants as will be discussed in Section 5. The approach velocity of water may be of the order of 2 ft per second. The head loss depends on the degree of clogging due to accumulated coarse solids and may vary in the range of 0.1 – 1.0 ft (Crites and Tchobanoglous, 1998).



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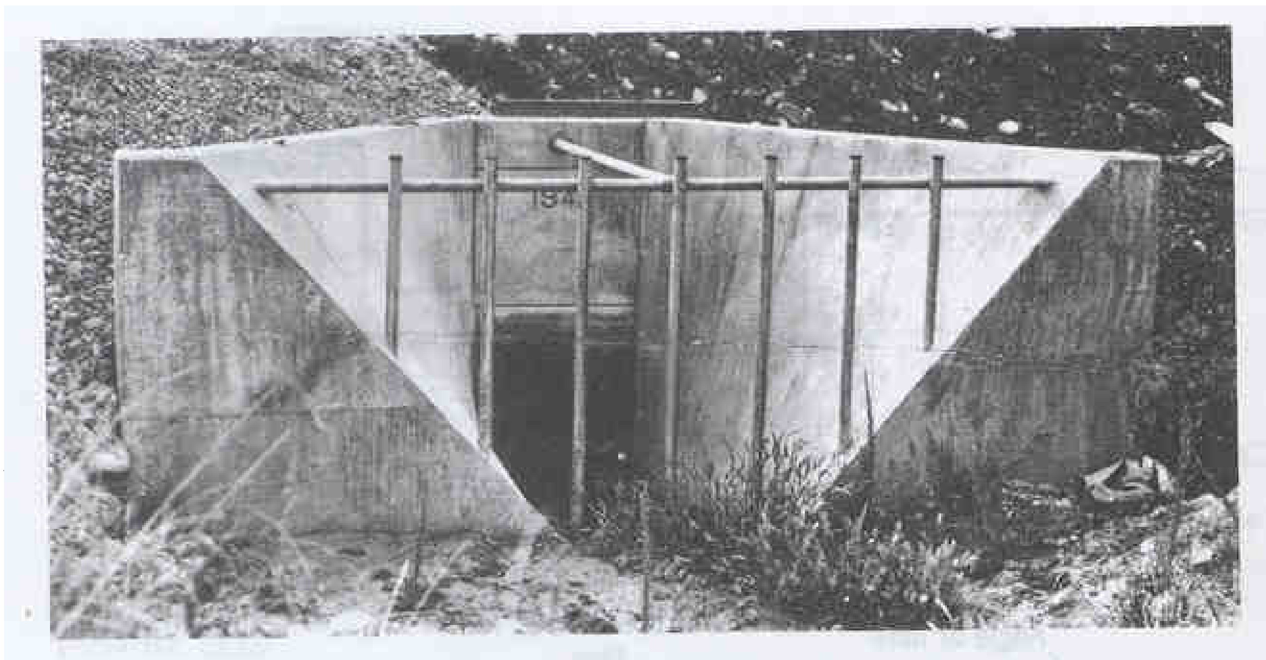
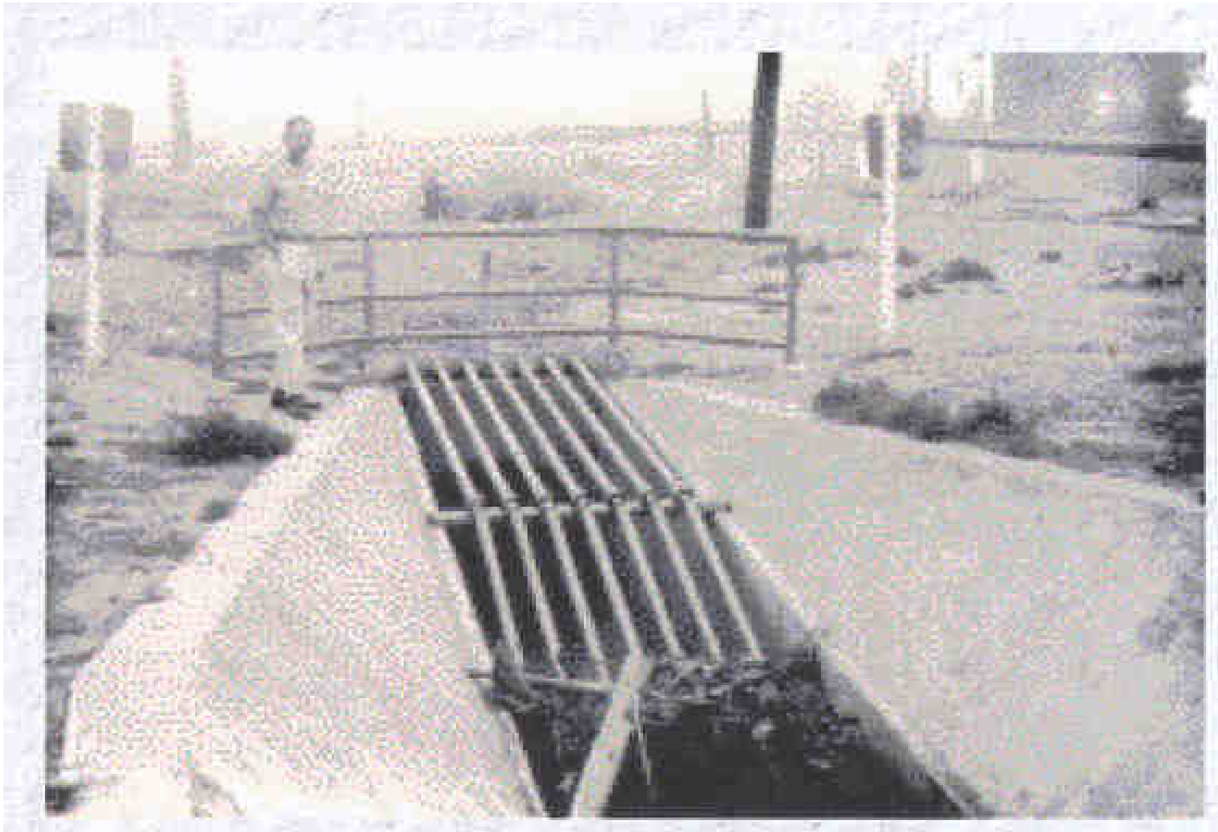
remove once it has entered the drainage system. Armitage and Rooseboom (2000) presented potential trapping structures for urban litter because there is a need for an inexpensive, effective trapping structure that has no moving parts, is vandal-proof, is easy to clean (preferably self-cleaning) and does not increase flood levels in the vicinity of the structure. Their study is not directly applicable to safety grates of stormwater pipes but points out the importance of flow velocity, velocity gradient and gravity for a successful litter trap design.

2.3 Trash Racks for Culverts

Trash or debris racks are installed upstream of culverts to prevent the entrance of material that might clog culverts (Linsley et al., 1992). The bars in the rack should be spaced wide enough to allow small material to pass through the bars and to avoid clogging with debris. A bar spacing of one-half to one-third of the least culvert dimension is usually satisfactory (Linsley et al., 1992). The rack must not be placed directly over the culvert entrance where an accumulation of debris may block the culvert. Figure 2.3 shows a V-shaped trash rack upstream of the wingwalls of a concrete box culvert where the rack can be overtopped if it is blocked by debris.



structures including debris racks in the report called HEC9 Debris Control Structures. Figures 2.4, 2.5, 2.6 and 2.7 show four examples out of the 14 debris racks presented by them. These debris racks are similar to safety grates. For the trash rack in an urban area shown in Figure 2.7, it is stated that the bar spacing of the rack should be a maximum of six inches to prevent entrance of children with a gap of about six inches below the rack to permit some debris to pass under the rack during low flows.



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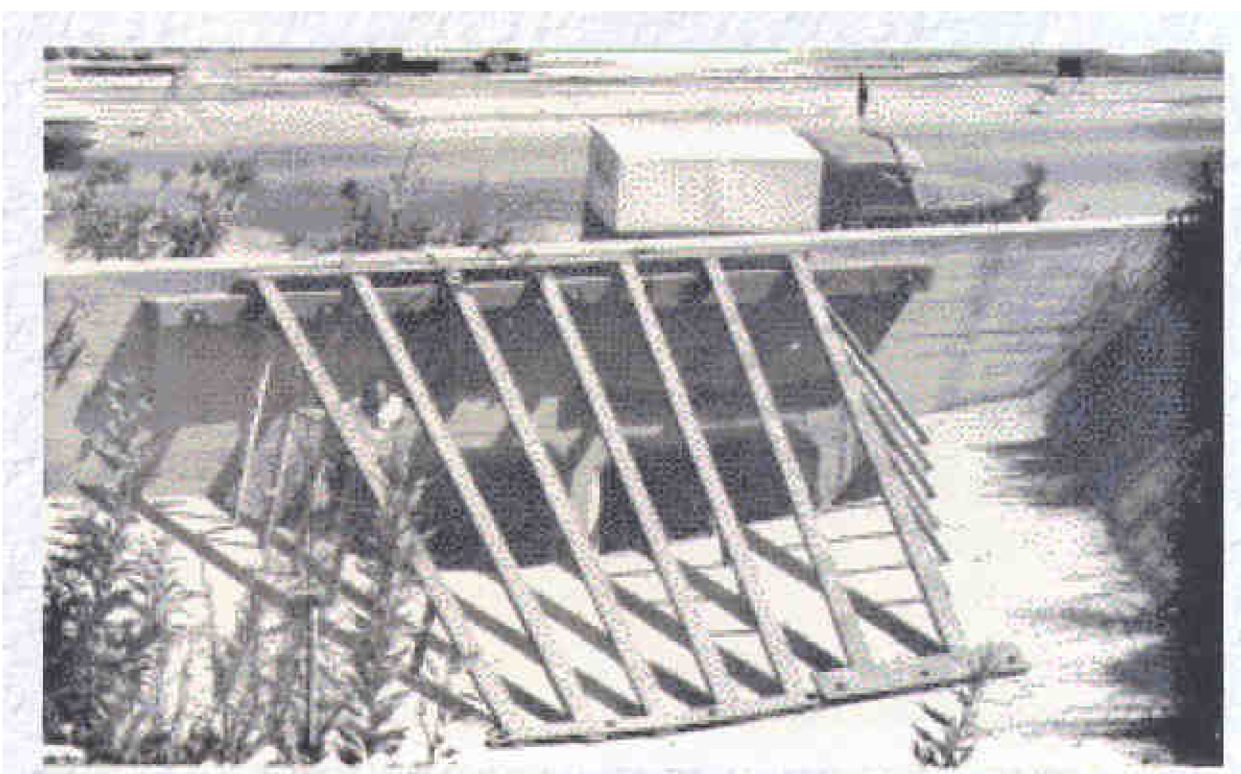


Figure 2.5 *Steel frill debris rack with provision for cleanout afforded by concrete paved area in foreground (Reihsen and Harrison, 1971).*

Figure 2.6 *Debris rack whose design dimensions were given in the HEC9 report (Reihsen and Harrison, 1971).*

Figure 2.7 *Hinged steel debris rack in urban area where, due to nature of debris and possible entry by children, bar spacing is close (Reihsen and Harrison, 1971).*

The other debris control structures described in HEC9 and Culvert Repair Practices Manual (1995) include debris deflectors, debris risers, debris cribs, debris fins, debris dams and basins, and floating drift boom. These structures may be needed for culverts located in mountains and steep regions with heavy volumes of debris.

2.4 Safety Grates for Small Canals and Culverts

Aisenbrey et al. (1978) presented safety racks or grates placed across inlets to small canal structures such as pipe chutes and drops in order to prevent a person from being drawn into the structure and provide a means for the person to climb out of the canal. Figure 2.8 shows the safety grate on a warped transition. These safety grates are generally used in small canals if the canal is relatively free from weeds and debris.

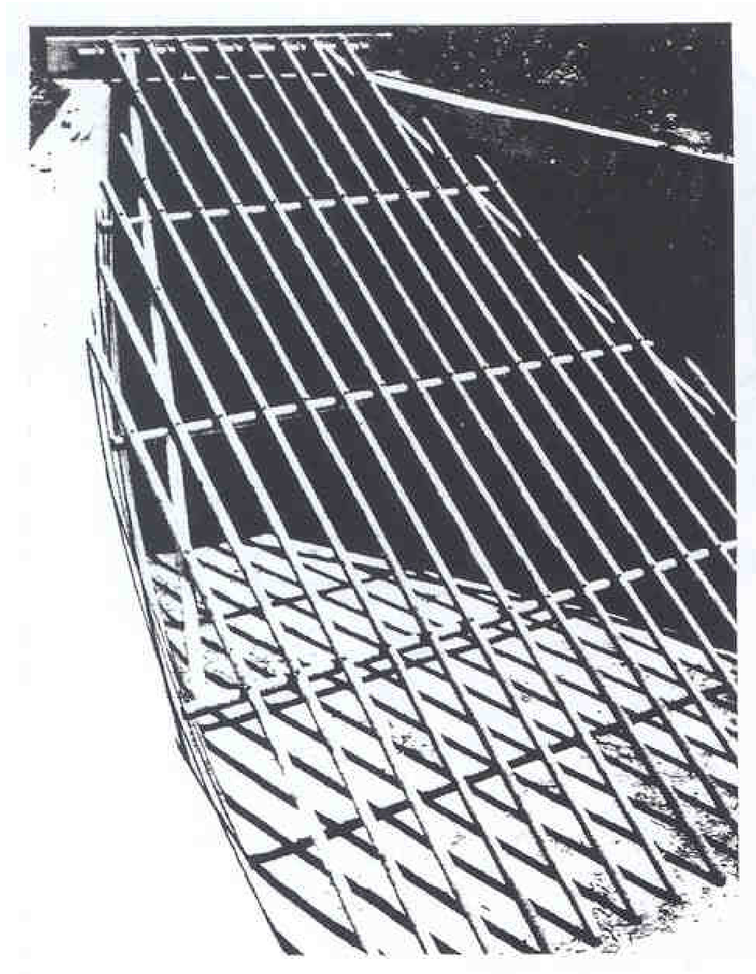


Figure 2.8 *Safety grate on inlet transition in a small canal (Aisenbrey et al., 1978).*

According to Aisenbrey et al. (1978), safety grates are generally made from standard steel galvanized pipe, bolted and welded together to form a grille that is attached to the headwall of an inlet transition. The sloping steel pipes are usually 1-1/2 inches in diameter with 9 inches of clear spacing between pipes. The welded frame, on which the sloping pipes are bolted, may be 2-inch pipe or larger depending on the span of the safety grate. The horizontal pipes give the rack rigidity and provide steps for aiding a person to escape; however, these pipes do catch weeds and make cleaning the rack difficult. Safety grates should be placed on a 3H:1V slope or flatter to facilitate the escape of a person.

These guidelines were given in 1978 to the Bureau of Reclamation, U.S. Department of the Interior.

The City of Winnipeg, Canada published its Culvert and Drainage Inlet/Outlet Safety Guidelines (1998). Inlet grating protection is mandatory for all ditch inlets to closed conduit drainage systems or systems where the point of egress is restricted or undesirable. Figures 2.9 and 2.10 show conceptual representations of typical inclined grates on the flared entrance of a pipe with diameters in the range of 20 – 47 in (50 – 120 cm) and parabolic grates on an inlet structure larger than 79 in (200 cm) in height, width or diameter, respectively. The parabolic grates in Figure 2.10 are based on the hydraulic model study by Engel and Lau (1981) and will be discussed in more detail in Section 4.

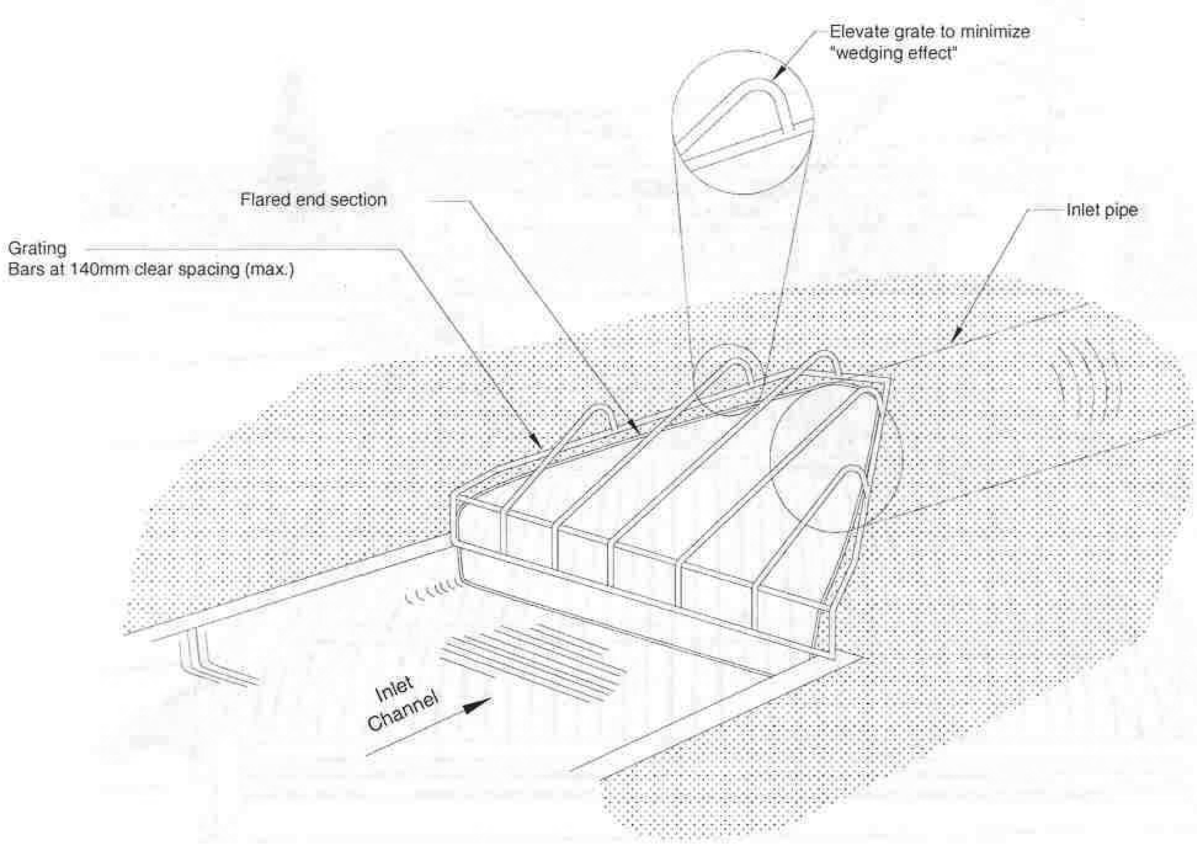
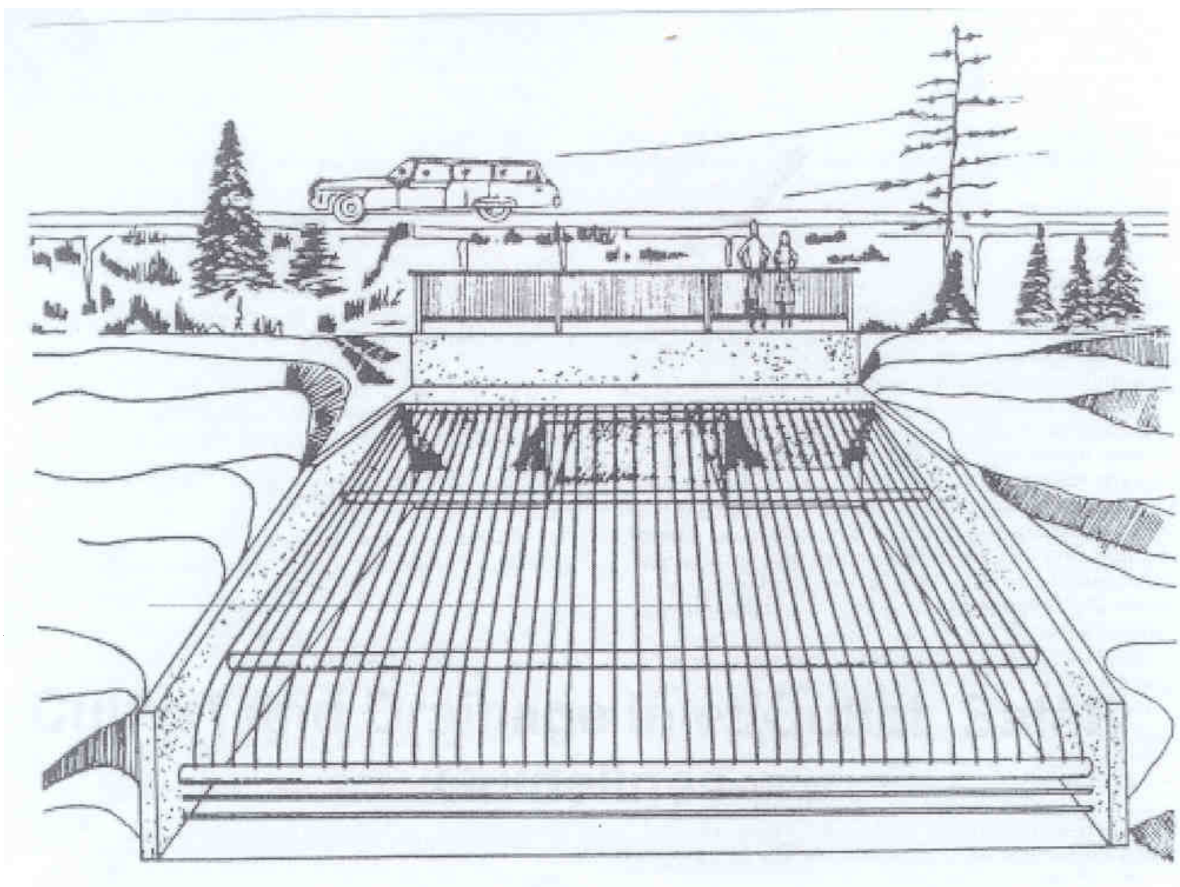


Figure 2.9 *Typical inclined grate on flared entrance into a 50 – 120 cm diameter pipe (City of Winnipeg, Canada, Culvert and Drainage Inlet/Outlet Safety Guidelines, 1998).*



The guidelines by the City of Winnipeg recommend parallel inclined bars for safety and to facilitate ease of maintenance, with no exposed lateral bars. If lateral bars are required as a structural support, it is suggested to recess the bars from the surface of the grate to facilitate the escape of a person from the grating. This guideline does not appear to be consistent with the hydraulic model study of Engel and Lau (1981). The maximum clear space between the longitudinal bars is recommended to be 5.5 in (14 cm) as a safety consideration for children.

For the debris/safety grates on a pipe whose diameter is 35 in (90 cm) and larger, the above guidelines (1998) recommend a removable feature to permit access to the pipe for cleaning and a grate slope of 3H:1V to 5H:1V to permit debris to ride up as the water level rises and to facilitate egress from the grate surface. The net open surface area of the debris/safety grates is recommended to be at least four times the cross sectional area of the pipe to ensure that water velocities will be low enough [less than 3.3 ft/s (1 m/s)] that a person will be able to lift himself or herself off the grating.

For drainage courses and structures adjacent to schools and recreational areas, such as playgrounds, subject to frequent visits by children, all pipes with diameters of 16 in (40 cm) and larger are recommended in the above guidelines (1998) to be provided with inlet and outlet protection devices to prevent children from accessing the drainage system. Grates placed at the downstream end are controversial. The Urban Storm Drainage Criteria Manual published by Wright-McLaughlin Engineers (2001) for the Denver Regional Council of Governments recommends against the installation of trash racks at culvert outlets because debris or persons carried into the culvert will impinge against the rack. No hydraulic testing for the outlet grating appears to have been conducted so far.

Fabricated safety grates and trash racks are marketed commercially. This report does not endorse any commercial product. The brochures of Haala Industries (2004) are attached in Appendix for the sake of comparisons of types, materials and costs. Safety grates and trash racks are generally constructed of steel pipes, round bars and plates.

SECTION 3. DEBRIS AND POSSIBLE CLOGGING PROBLEMS

Drainage facilities, including stormwater pipes and culverts, are necessary in highway or land development projects to relieve drainage from the natural phenomenon of runoff to the highway or developed land (Hydraulic Design Manual, 2004). An accumulation of debris at inlets of stormwater pipes and culverts may result in flooding of the roadway and neighboring area. Consequently, debris is an important factor for the design and maintenance of stormwater pipes and culverts.

Debris can be controlled by three methods: (1) intercepting the debris at or upstream of the inlet; (2) deflecting the debris for detention near the inlet; or (3) passing the debris through the pipe or culvert (Reihsen and Harrison, 1971). The choice of method depends upon the size, type and quantity of debris. When debris from the drainage basin can be passed through the pipe or culvert without clogging, no debris-control structure will be necessary. This is the common case with open stormwater pipes in Delaware. But when grates are installed for personnel safety, debris clogging would be a major concern. Possible clogging problems associated with safety grates will be assessed on the basis of experiences of trash racks.

3.1 Debris Size and Type

The debris classification system developed by the California Division of Highways is used in HEC9 (Reihsen and Harrison, 1971) and separates debris into the following classifications:

1. Very light floating debris or no debris.
2. Light floating debris (small limbs or sticks, and refuse).
3. Medium floating debris (limbs or large sticks).
4. Heavy floating debris (logs or trees).
5. Flowing debris (heterogeneous fluid mass of clay, silt, sand, gravel, rock, refuse or sticks).
6. Fine detritus (fairly uniform bedload of silt, sand, and gravel devoid of floating debris, tending to deposit as water velocity decreases.
7. Coarse detritus (coarse gravel or rock fragments).
8. Boulders (large boulders and large rock fragments carried as a bedload at flood stage).

The debris-control structures described in HEC9 include debris deflectors, racks, risers, cribs, fins, dams and floating drift boom. Debris racks are suitable for light and medium floating debris. In other words, limbs, sticks and refuse will be caught by debris racks. Furthermore, heavy floating debris, coarse detritus and boulders are too large for debris racks. Flowing debris and fine detritus are not blocked by debris racks. Since Delaware is relatively flat, large debris, coarse detritus and boulders are very rare and may be neglected. The accumulation of light and medium floating debris on safety grates and the sedimentation in stormwater pipes are examined in the following sections.

3.2 Debris Accumulation on Safety Grates

Light and medium floating debris may pass through an open stormwater pipe or clog the pipe. If a safety grate is installed at the inlet of an open pipe, the same debris may accumulate on the safety grate or pass through the safety grate and the pipe. As a result, the grate installed for personnel safety will be beneficial for maintenance and safety if the existing open pipe suffers from a clogging problem. On the other hand, an accumulation of debris on the safety grate can become a maintenance problem if the safety grate is installed at the inlet of an open pipe with no clogging problem. Presently, it is not possible to predict how floating debris flows through the pipe with and without a safety grate and quantify the effects of the safety grate on debris movement.

According to Wright-McLaughlin Engineers (2001), the use of safety grates at inlets to culverts and long pipes should be considered on a case-by-case basis because safety grates often become clogged during heavy runoff. Their general rule of thumb is that a safety grate will not be needed if one can clearly "see daylight" from one side of the culvert or pipe to the other, if the culvert is of sufficient size to pass a 48-inch diameter object and if the outlet is not likely to trap or injure a person. They use Figure 3.1 as an example of a safety grate or trash rack that is too small and will increase the risk of entrance clogging. This example is consistent with the more comprehensive guidelines described in Section 2.4.

The debris accumulation on safety grates during heavy runoff is a major concern because it is practically impossible to remove the accumulated debris during heavy runoff. To reduce the debris accumulation, the safety grate should be placed outside of the region of flow acceleration upstream of the pipe inlet. The bar spacing of the safety grate should be large enough to reduce obstruction of the water flow but small enough to prevent the entry of children. The recommended guidelines will be presented in Section 7 after all the factors for safety grate design are discussed.

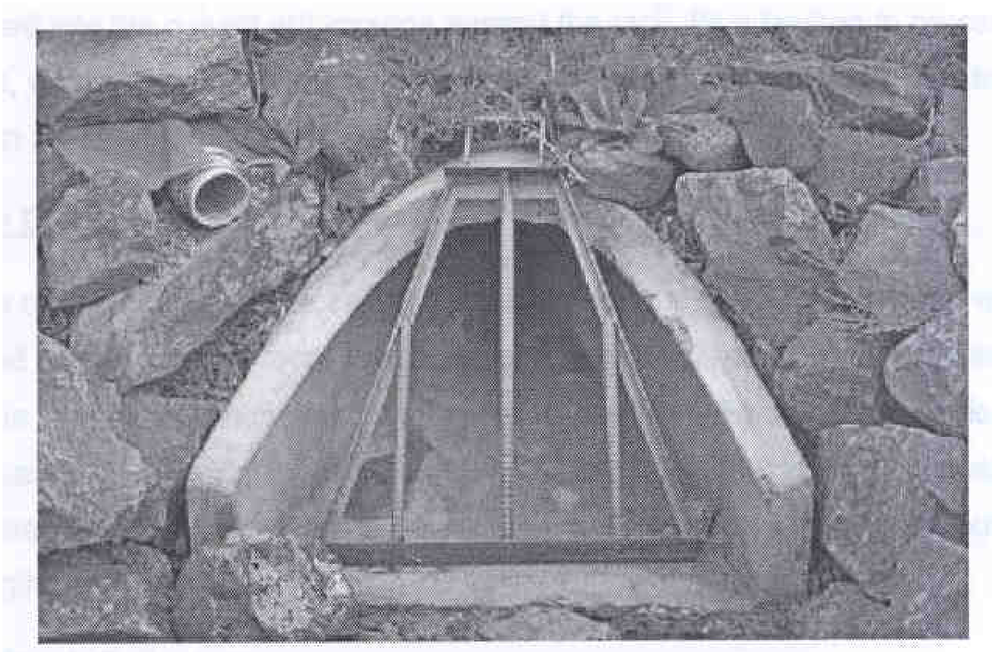


Figure 3.1 *An example of a safety grate or trash rack that is too small and will increase the risk of entrance clogging (Wright-McLaughlin Engineers, 2001).*

3.3 Sedimentation in Stormwater Pipes

Sediment will deposit at the inlet or inside of a stormwater pipe if the water flow in the pipe is not capable of carrying all the sediment transported to the pipe inlet.

Potential sedimentation problems may be assessed using the Model Drainage Manual (2000) but the effect of a safety grate on the sedimentation is not discussed. The procedures of sediment and debris removal are described in the Culvert Repair Practices Manual (1995).

The safety grate causes the head loss of water flowing into the stormwater pipe as will be discussed in Section 5. This head loss will lead to increase in headwater depth if the discharge of water in the stormwater pipe remains the same as the discharge for the case of no safety grate. If the discharge does not change, the safety grate will not reduce the sediment transport capacity in the stormwater pipe. Furthermore, the safety grate will intercept some of the floating debris and reduce clogging problem inside the stormwater pipe. In short, the safety grate will not worsen a sedimentation problem in a stormwater pipe if such a problem exists before the installation of the safety grate.

SECTION 4. PERSONNEL SAFETY

The primary safety considerations in the design and construction of a culvert or stormwater pipe are its structural and hydraulic adequacy, whereas supplementary safety considerations include traffic and child safety (Hydraulic Design of Highway Culverts, 2001). Hydraulic model studies conducted for child safety are summarized in the following sections.

4.1 Tumbling and Slipping of a Person in Flowing Water

Public access to the crest of a breakwater is usually prohibited in Japan due to safety reasons but people enter the prohibited area for recreational purposes. The Japanese Ministry of Transport (JMOT) recently constructed a promenade breakwater to provide the public a recreational area on the crest of the breakwater. Before the construction of this breakwater, a comprehensive study of human safety by the JMOT was conducted using hydraulic and numerical models (Takahashi et al., 1992, 1994; Endoh and Takahashi, 1994). They conducted prototype experiments to quantify the critical hydraulic conditions for a person tumbling and slipping in flowing water.

Figure 4.1 shows the tumbling and slipping conditions for a person standing in flowing water as depicted by Endoh and Takahashi (1994). The current velocity $\overline{U}$ is assumed constant vertically and the water depth is denoted by η . The current causes the drag force $f(z)$ per unit leg length and the total horizontal force F against the two legs which is resisted by the friction force between the legs and the ground. The frictional force is estimated as $\mu_s W_0$ where μ_s is the friction coefficient depending on the types of the shoes and ground and W_0 is the weight of a person standing in water. If the drag force F exceeds the frictional force $\mu_s W_0$, the person would slip because the legs would be swept downstream. The current drag force also causes the overturning moment Fh_G about the heel (point S in Figure 4.1) which is counteracted by the stabilizing moment $W_0 \ell_G$ due to the body weight. If the overturning moment exceeds the stabilizing moment, the person would tumble backward.

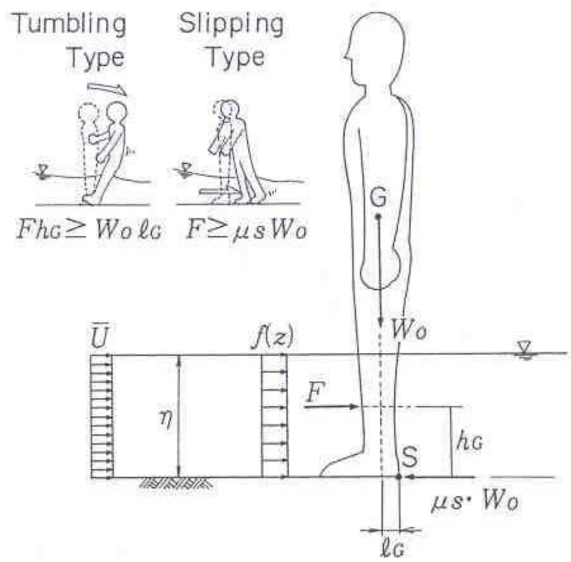


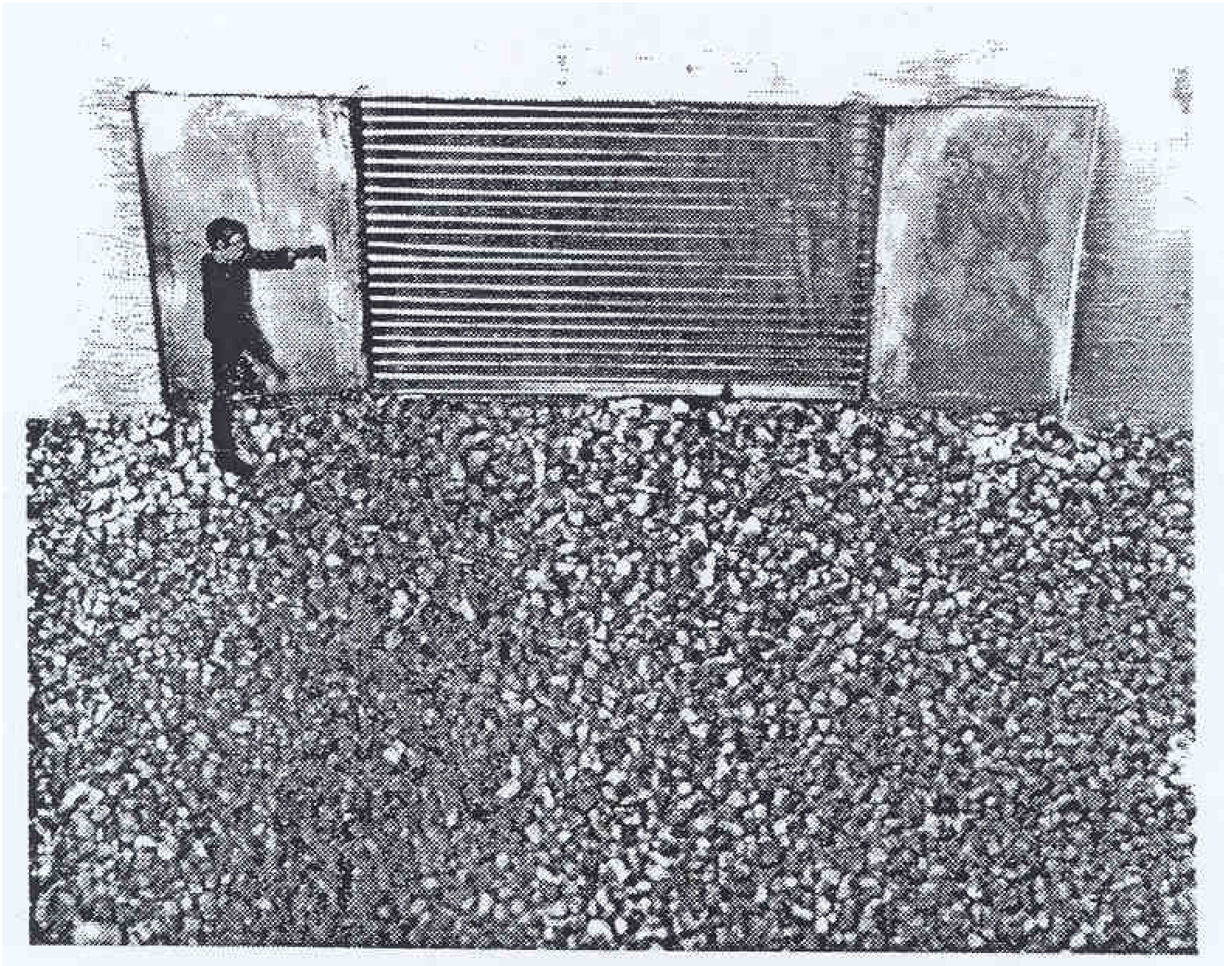
Figure 4.1 *Tumbling and slipping of a person standing in flowing water (Endoh and Takahashi, 1994).*

Experiments using actual persons supported by harnesses were conducted in a large current basin that was 50-m long and 20-m wide. The variables in the experiments included the water depth, current speed, body orientation relative to the current direction, feet spacing, clothes and shoes. Their simple model and experiments indicated that a person would slip in flowing water if the current velocity exceeds 3 – 5 ft/s in water depth of 1.5 – 3 ft. Critical current velocity decreases as water depth increases. Since a child playing in water may fall accidentally, the critical current speed may simply be assumed to be approximately 3 ft/s. The water depth will need to be deep enough for the current to carry a child downstream. The critical water depth may be assumed to be approximately 1.5 ft. In short, a child playing in flowing water with velocity exceeding 3 ft/s and depth exceeding 1.5 ft may possibly slip and be carried downstream.

The comprehensive study by the JMOT examined the danger of a fallen person transported over the breakwater crest due to overflowing water and the effectiveness of various handrails in preventing the person being carried over the handrail into the sea. A 3.6-ft-high fence-type handrail with an opening ratio of 0.7 was found to be very effective in reducing the risk of being carried out into the sea. But this handrail design guideline is not directly applicable to safety grates because the flow due to overtopping waves is highly unsteady and lasts for a short duration on the order of 10 seconds.

4.2 Hydraulic Model Studies of Safety Grates

The drainage of storm runoff in some channels within the boundaries of Metropolitan Toronto requires the use of large culverts with safety grates. The primary purpose of such grates is to prevent persons who may fall into the channel from being swept through the culvert. The experience of Metropolitan Toronto, Canada (Storm Sewer Inlet Grating Design, 1981) indicated that at high flow rates, the forces generated by the flow could be large enough to pin a person against the grate, resulting in serious injury and drowning. The Hydraulics Division at the National Water Research Institute was asked to develop a better grate design and compare different grate configurations using hydraulic model tests. This hydraulic model study by Engel and Lau (1981) is relevant because the concern of a person being pinned against the grate appears to have been initiated because of the accident in Metropolitan Toronto.



person in Figure 4.2 corresponded to a person about 5 ft (1.5 m) tall whose buoyancy characteristics were similar to a real human body. The horizontal bars of the model represented 3/4″ (19 mm) bars with 4″ (102 mm) spacing in the prototype.

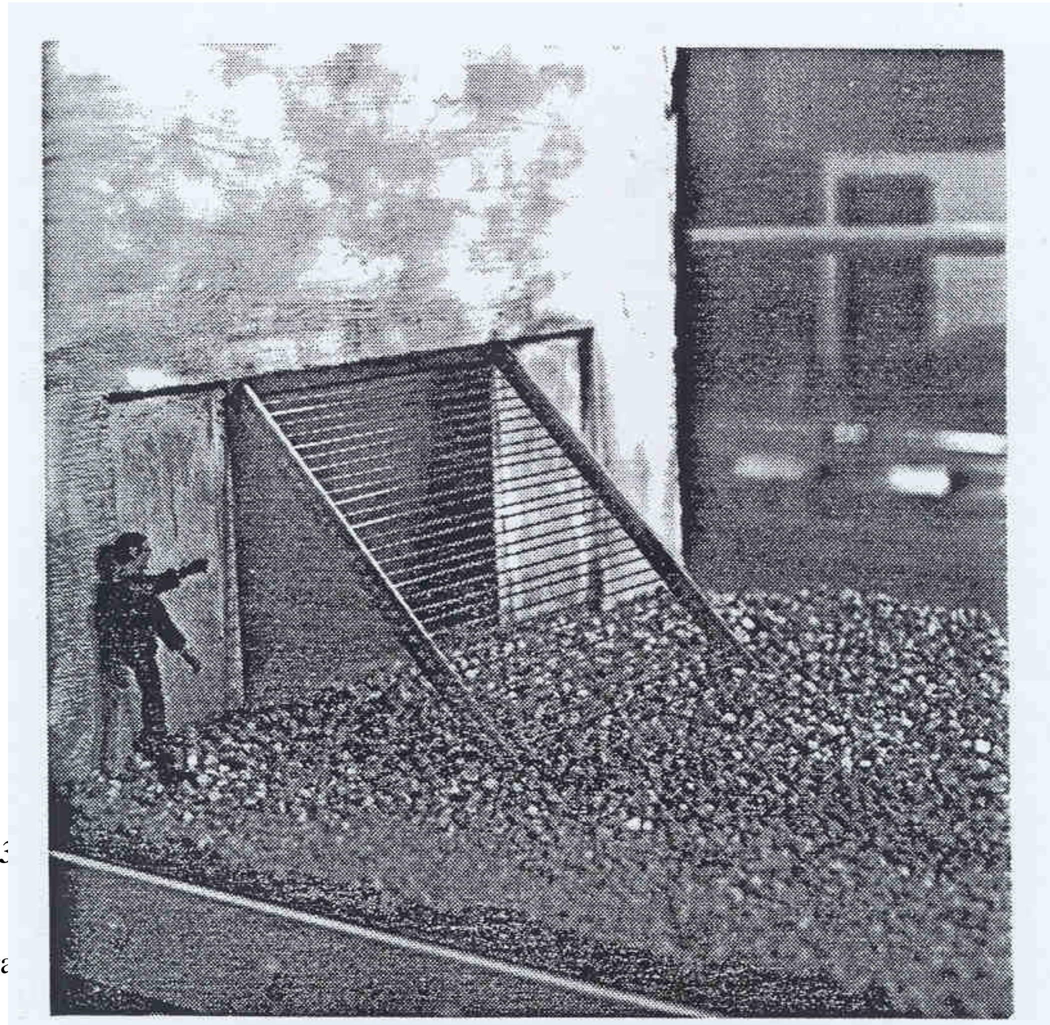


Figure 4.3

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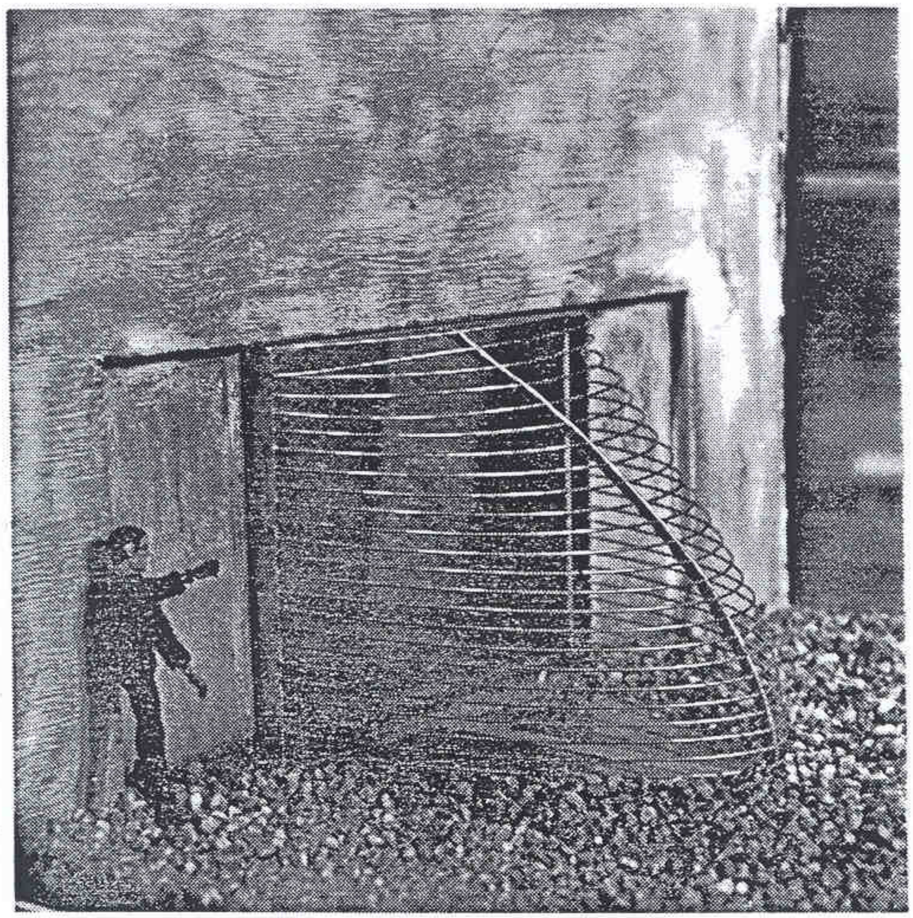
which is approximately horizontal. For the vertical grate, the drag force on the body acts normal to the grate and pins the body against the wall. For a slanted grate such as the grate inclined at an angle of 45° shown in Figure 4.3, the horizontal drag force has a reduced force component normal to the grate (a reduced pinning force) and an upward force component along the grate that would assist a conscious person to climb up the

Figure 4.4



grate. If the friction coefficient between the body and the grate is unity, the angle of 45° corresponds to the situation where the upward force along the grate equals the frictional force associated with the pinning force.

Engel and Lau (1981) also examined parabolic shaped grates to decrease the grate inclination from 90° (vertical) at the base to a smaller angle such as 45° at the top so that a floating body would be subjected to a flatter grating as the flow becomes deeper and faster. Figure 4.4 shows the preliminary parabolic grate whose height is of the same height as the culvert entrance. Each horizontal bar was represented by a different parabola in such a way that its width was the same as the width of the culvert entrance.

This horizontal curvature would assist the lateral movement of a floating body along the grate.

For the vertical, slanted and parabolic grates shown in Figures 4.2, 4.3 and 4.4, 49 tests were conducted for different flow rates and two culvert entrance conditions without and with wingwalls. The actual force pinning a body could not be measured. Instead, a linen bag (15 cm long, 6.5 cm wide and 2.5 m deep) filled with granular polyethylene was used. The upward pulling force along the grate for the initiation of the upward movement of this neutrally buoyant bag was measured in each test. For the culvert entrance with no wingwall, the critical pulling force relative to vertical grates for the initiation of bag movement was reduced by about 30% and 60% for the slanted and parabolic grates, respectively. For the culvert entrance with wingwalls, the reduction was about 70% and 80% for the slanted and parabolic grates, respectively.

Engel and Lau (1981) improved the preliminary parabolic grate shown in Figure 4.4 by extending the parabolic grate outward so as to intercept the flow prior to the onset of flow contraction (or acceleration) toward the culvert entrance both in the upstream and lateral directions. Figures 4.5 and 4.6 show the extended parabolic grate proposed by Engel and Lau (1981) where a person could climb on to the top of the grate.

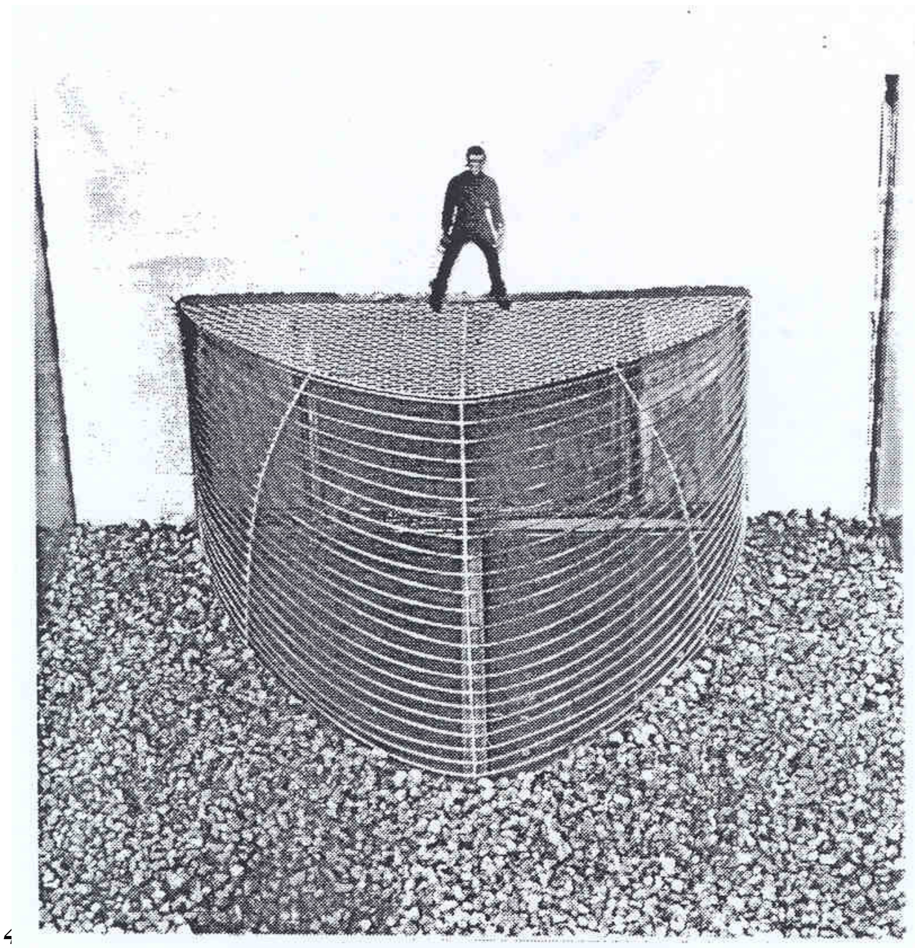


Figure 4

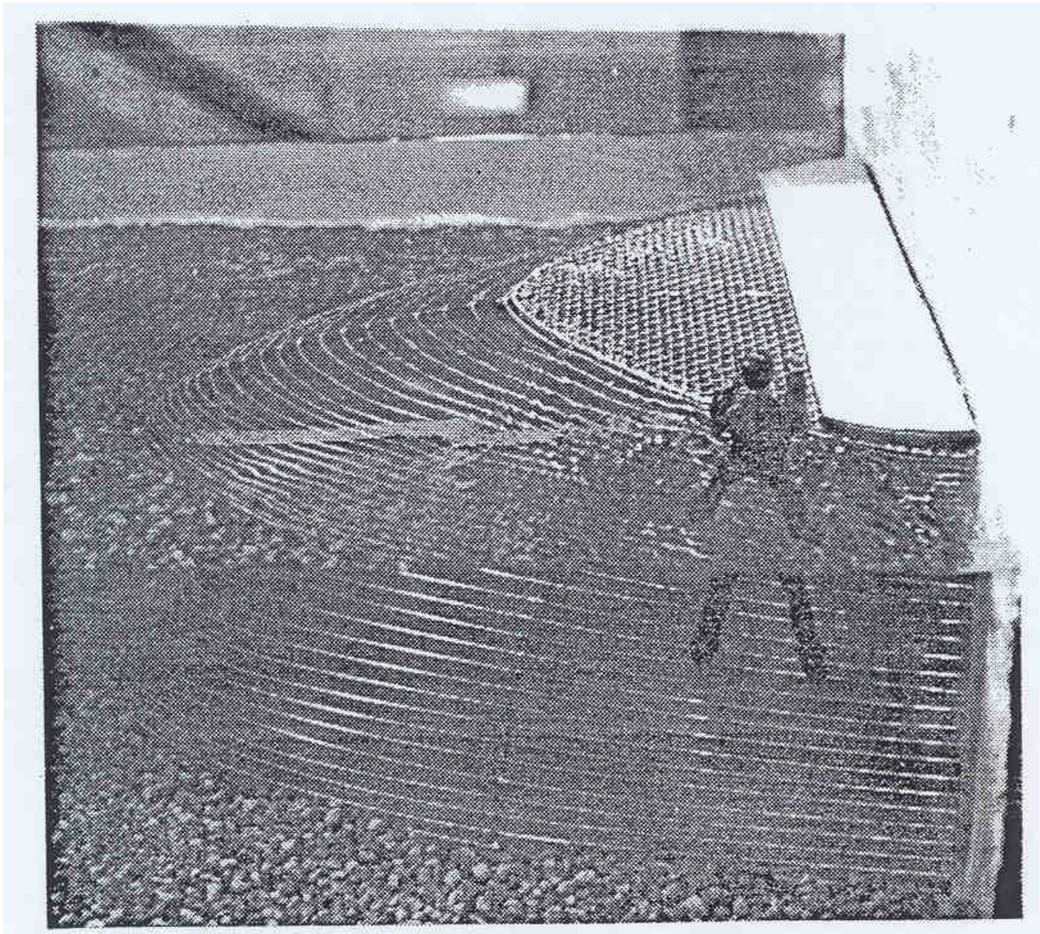


Figure 4.6

Weisman (1989) conducted a similar hydraulic model study of safety grating for a culvert in Allentown, Pennsylvania. The culvert was 850 ft long, 15 ft wide and approximately 5.3 ft high. The safety grate tested in his study was parabolic only in the vertical plane because of fabrication problems. The laboratory experiment was conducted using a 1/10 scale model. The size and spacing of the bars corresponded to 1.1 in (2.8 cm) and 3.75 in (9.5 cm) in the prototype. The prototype discharge was in the range of 300 – 1,000 ft^3/s. The tests with and without the grate were conducted to obtain the headwater elevation increase due to the presence of the grate which was in the range of 0.10 – 0.53 ft in the prototype. Almost neutrally buoyant human-shaped objects were placed in the channel. Upon reaching the grate, the object rotated and turned on its side resting on the grate. The object was then pushed up the inclined grate. The issue of debris was not addressed by Weisman (1989) who stated that debris could be a maintenance problem as well as a flood hazard problem.

In summary, both hydraulic model studies have shown that the slanted and parabolic grates will prevent human-scale objects being carried into the culvert and reduce the pinning force on such objects significantly. The safety grate will not increase the headwater elevation noticeably (below 1 ft) but the accumulation of debris may cause problems.

SECTION 5. SAFETY GRATE HYDRAULICS

The hydraulic design of a stormwater pipe (or culvert) for a specified discharge is described in detail in Hydraulic Design of Highway Culverts (2001) and Stormwater Conveyance Modeling and Design (2003). The flow analysis for a straight, uniformly-shaped pipe is separated into inlet control and outlet control to simplify the analysis for various flow conditions. For inlet control, empirical formulas are used to estimate the headwater depth for the specified discharge and given entrance and pipe characteristics. These empirical formulas were based on experiments for the entrance with no safety grate. Additional experiments would be necessary to include the safety grate effect in these formulas. For outlet control, the headwater depth is predicted using the energy equation for steady flow from the headwater at the inlet to the tailwater at the outlet. The safety grate effect may be included in the energy equation as an additional head loss at the entrance.

The head loss due to the safety grate is estimated using available empirical formulas and the increase in the headwater is assumed to be approximately the same as the estimated head loss. This assumption is appropriate for outlet control and may be acceptable for inlet control if the safety grate does not modify the entrance flow appreciably. The experiment by Weisman (1989) discussed in Section 4.2 indicated that the safety grate would increase the headwater depth only slightly in the absence of debris clogging. Hydraulic Design of Highway Culverts (2001) recommends an open area between bars of 1.5 and 3.0 times the area of the pipe (or culvert) entrance depending on the anticipated volume and size of debris.

5.1 Head Loss due to Safety Grate

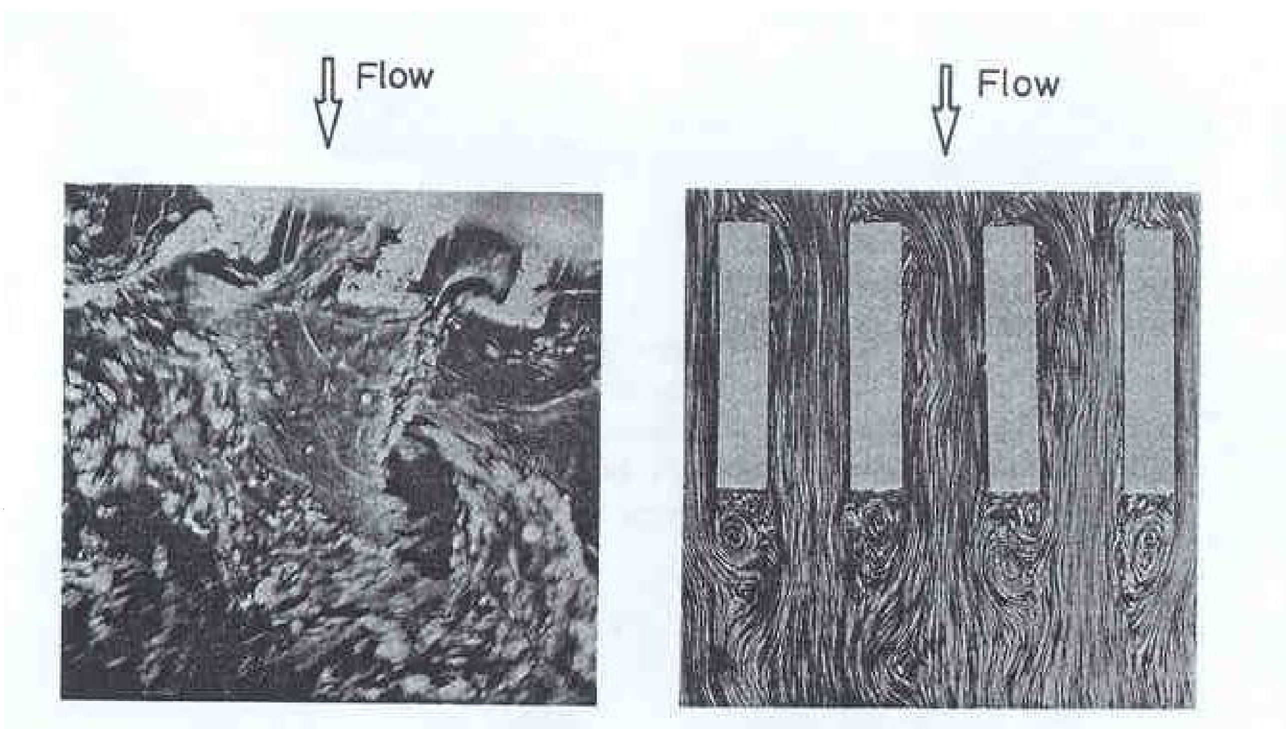
Hydraulic Design of Highway Culverts (2001) presented two formulas for the head loss due to a bar grate from Handbook for Applied Hydraulics by Davis (1952) and Wastewater Engineering (1972). These formulas were developed for trash racks explained in Sections 2.1 and 2.2. The origins of these two formulas have turned out to be earlier as explained in the following. These formulas may not have been verified for safety grates.

Figure 5.1 shows typical flows near trash racks at a high angle of incidence and at an approximately zero angle of incidence (Nguyen and Naudascher 1991). The head loss is caused mostly by energy dissipation in swirls and vortices. The angle of flow incidence clearly affects the flow pattern and vortex generation. The shape and spacing of trash rack bars determined for the prevention of debris entry may be noticeably different from the shape and spacing of safety grate bars for the prevention of child entry.

Metcalf and Eddy (1930) and Crites and Tchobanoglous (1998) estimated the head loss H_g due to a trash rack for a wastewater treatment plant using the following formula

$$H_g = \frac{1}{0.7}\left(\frac{V_g^2 - V_u^2}{2g}\right) \tag{5.1}$$

where H_g = head loss (ft); V_g = water velocity between the bars (ft/s); V_u = approach velocity (ft/s), which may be taken as the velocity in the absence of the rack; and g = gravitational acceleration (32.2 ft/s^2). For steady flow, the discharge of the approach flow is the same as the discharge between the bars. Consequently, V_g in the reduced area between the bars is larger than the approach velocity V_u. The head loss H_g decreases with the decrease of V_g resulting from the increase of the area between the bars. It may be noted that 1/0.7 in Eq. (5.1) is replaced by 1.5 in Hydraulic Design of Highway Culverts (2001).



laboratory experiment near zero angle of incidence (Nguyen and Naudascher, 1991).

Creager and Justin (1950), Stahre and Urbonas (1989), and Allred-Coonrod (1994) used a different formula shown below:

$$H_g = \left[1.45 - 0.45\left(\frac{A_g}{A_u}\right) - \left(\frac{A_g}{A_u}\right)^2\right]\frac{V_u^2}{2g} \tag{5.2}$$

where A_g = open area between the bars (ft^2); A_u = total area of the rack and supports (ft^2); and V_u = water velocity in the total rack area which may be regarded to be the same as V_u in Eq. (5.1). It is noted that Eq. (5.2) was not included in Hydraulic Design of Highway Culverts (2001).

To compare Eqs. (5.1) and (5.2), use is made of the parameter $a = (A_u - A_g)/A_g$ which is the ratio of the area of the bars to the open area between the bars. For the grate of child safety, the parameter a is expected to be of the order of 0.2 where a = 0.2 approximately corresponds to bars of 1.0 in diameter spaced at an open distance of 5.0 in. The velocities V_g and V_u in Eq. (5.1) are related by $V_g A_g = V_u A_u$, assuming that the discharge is the same with and without the safety grate. Substituting $V_g/V_u = A_u/A_g = (1+a)$ into Eq. (5.1) and assuming $a \ll 1$, Eq. (5.1) is simplified as

$$H_g = \frac{2a}{0.7}\frac{V_u^2}{2g} = 2.86a\frac{V_u^2}{2g} \tag{5.3}$$

Substituting $A_g/A_u = (1 + a)^{-1}$, Eq. (5.2) is approximated as

$$H_g = 2.45a\frac{V_u^2}{2g} \tag{5/4}$$

The difference between Eqs. (5.3) and (5.4) is less than 20%, probably within the error or uncertainty of the empirical equations (5.1) and (5.2) which do not account for the grate inclination and bar shape.

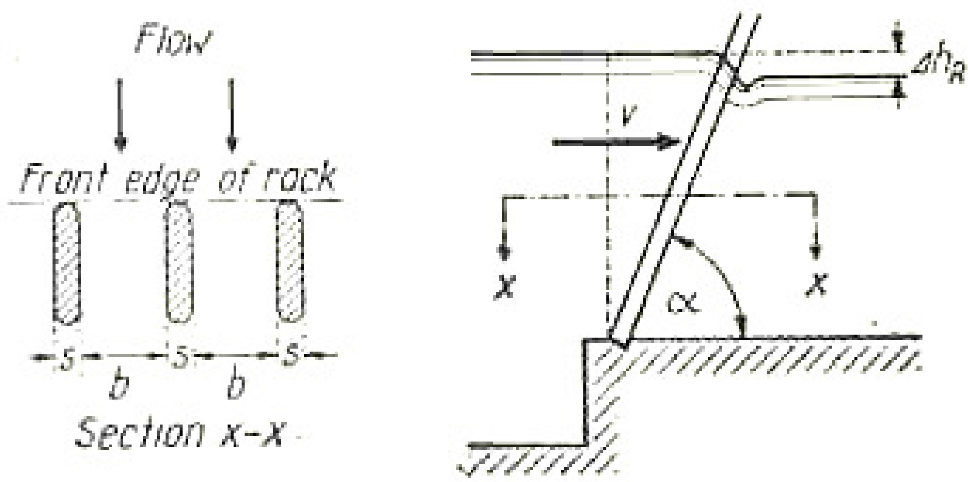
The formula by Kirschmer (1926) is the most comprehensive and has been used by Davis (1952), Mosonyi (1957), Idelchik (1986), and Böhnke et al. (1989). In the following, use is made of Mosonyi (1957) who gave detailed explanations of the formula of Kirschmer (1926) published in German. The head loss for the flow at a zero angle of incidence is expressed as

$$H_g = K_g \sin(\alpha)\left(\frac{s}{b}\right)^{4/3}\frac{V_u^2}{2g} \tag{5.5}$$

where K_g = dimensionless bar shape factor; α = angle in degrees of the grate with respect to the horizontal; s = maximum cross-sectional width of the bar facing the flow (ft); and b = minimum clear spacing between the bars (ft). Figure 5.2 sketches the definitions of s, b, α and $V=V_u$ where V_u is used in Eq. (5.5) to be consistent with Eqs. (5.1) and (5.2). The Hydraulic Design of Highway Culverts (2001) included Eq. (5.5) without the power (*4/3*) of (*s/b*), which is a typographical error. The shape factor K_g for the different bar shapes is shown in Table 1. Comparing Eq. (5.5) with Eqs. (5.3) and (5.4) where $a = (s/b)$, Eqs. (5.1) and (5.2) may have been developed for vertical grates with α =90°. Eq. (5.5) with $\sin(\alpha) = 1$ is not very different from Eqs. (5.3) and (5.4) except for $a = (s/b)$ in comparison with $a^{4/3}$ where $(0.2)^{1/3}$ = 0.58. For circular bars with K_g = 1.79 and $\sin(\alpha) = 1$, Eq. (5.5) yields $H_g = aV_u^2/(2g)$ for $a = 0.2$, which is about 40%

of H_g based on Eqs. (5.3) and (5.4). This difference decreases with the increase of a from 0.2 where trash racks tend to have larger values of a to prevent the entry of debris.

Eq. (5.5) was developed for flow at a zero angle of incidence as depicted in Figures 5.2 and 5.3. Figure 5.1 shows that the angle of flow incidence modifies the flow pattern and resulting energy dissipation. Mosonyi (1957) introduced the coefficient β for oblique flow with an angle δ of incidence as shown in Figure 5.4. The head loss H_g calculated by Eq. (5.5) was multiplied by this coefficient β tabulated in Table 5.2 only for rectangular bars (bar shape a in Figure 5.3). The coefficient β increases with the increase of the angle δ and the decrease of s/b for the rectangular bar (5 cm by 1 cm) used in the experiments. For the circular bar shape g in Figure 5.3, the value of β may not increase much from unity but no data is available.



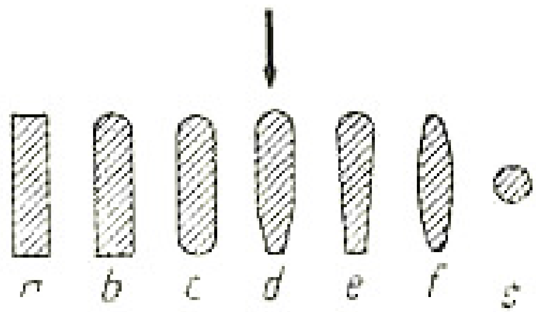


Figure 5.3 *Bar shapes a – g used for dimensionless bar shape factor K_g (listed below) in Kirschmer's formula (Mosonyi, 1957).*

Table 5.1 *Shape factor for bar shapes a – g.*

Bar Shape	a	b	c	d	e	f	g
K_g	2.42	1.83	1.67	1.03	0.92	0.76	1.79

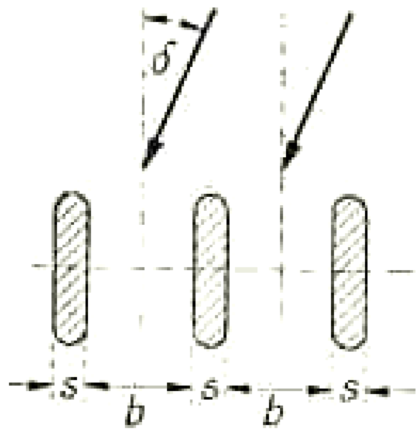


Figure 5.4 *Flow at angle δ of incidence (Mosonyi, 1957).*

Table 5.2 *Coefficient β for oblique flow.*

s/b	δ in degrees	0	10	20	30	40
0.2	β	1.00	1.50	2.25	3.60	5.70
0.3	β	1.00	1.14	1.43	1.90	2.56
0.4	β	1.00	1.12	1.31	1.64	2.10

Mosonyi (1957) discussed the prototype-scale experiments conducted by W. Fellenius in 1923 with trash racks inclined at α = 45°, 60°, 75° and 90° and with the velocity V_u in the range of 1.6 – 4.9 ft/s (0.5 – 1.5 m/s). It is noted that safety grates are normally inclined more (α < 45°). Figure 5.5 shows the trash rack bars tested by W. Fellenius. Mosonyi (1957) expressed the results of these experiments in the following formula

$$H_g = k\frac{s}{s+b}\frac{V_u^2}{2g} \tag{5.6}$$

where the values of k for bars A – G in Figure 5.5 were tabulated for α = 45° - 90°. The tabulated values can be approximated as $k = k_{90}\sin(\alpha)$ where k_{90} is the value of k for α = 90° and is similar to K_g in Eq. (5.5). As a result, Eq. (5.6) is practically the same as Eq. (5.5) except that $(s/b)^{4/3}$ is replaced by $s/(s+b)$. The values of $(s/b)^{4/3}$ and $s/(s+b)$ are compared in Table 5.3. Mosonyi (1957) did not specify the experimental range of s/b but the difference is not very large for s/b =0.3 – 0.5.

Table 5.3 *Values of (s/b)$^{4/3}$ and s/(s+b) for s/b = 0.2 – 0.7.*

s/b	0.2	0.3	0.4	0.5	0.6	0.7
$(s/b)^{4/3}$	0.12	0.20	0.29	0.40	0.51	0.62
s/(s+b)	0.17	0.23	0.29	0.33	0.38	0.41

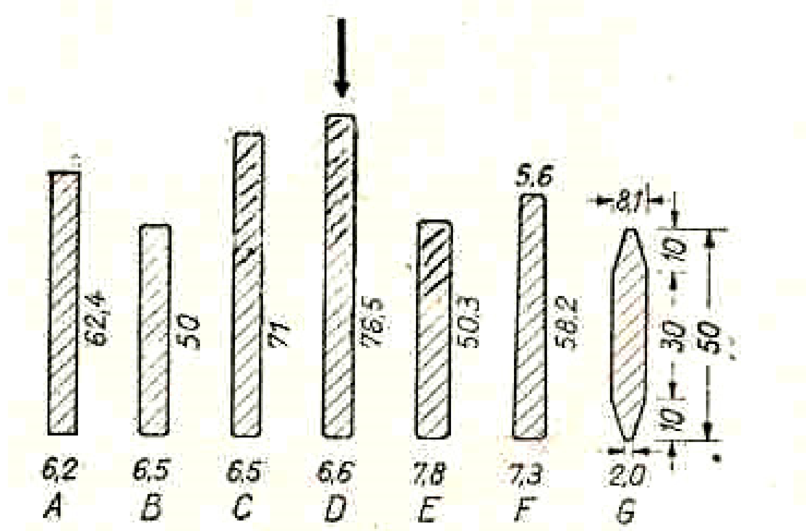


Figure 5.5 *Trash rack bars (all dimensions in mm) used in prototype-scale experiments by W. Fellenius (Mosonyi, 1957).*

Mosonyi (1957) also described the experiments conducted by L. Escande using rectangular bars. Figure 5.6 shows the flow patterns around the short and long rectangular bars where the head loss H_g increases with the decrease of the contraction coefficient μ defined in this figure. Figure 5.7 shows the measured values of μ as a function of *b/s* for the seven different bar profiles tested by L. Escande. The measured values of μ were close to unity for the streamlined profile 6 and increased with the increase of *b/s* for the other profiles. For the circular bar, the value of μ might be between those for profile 6 and the other profiles. Figure 5.7 also indicates the typical range of $b/s = 1 - 3$, that is, $a = (s/b) = 0.3 - 1.0$ for trash racks in comparison with $a = 0.2$ or less for safety grates. This suggests that Eqs. (5.1) – (5.6) developed for trash racks may not be very accurate when they are applied to safety grates.

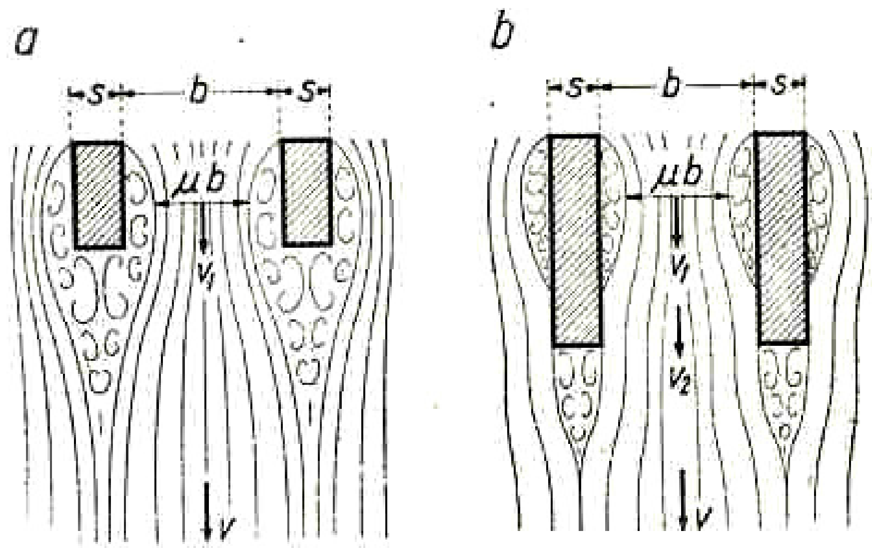
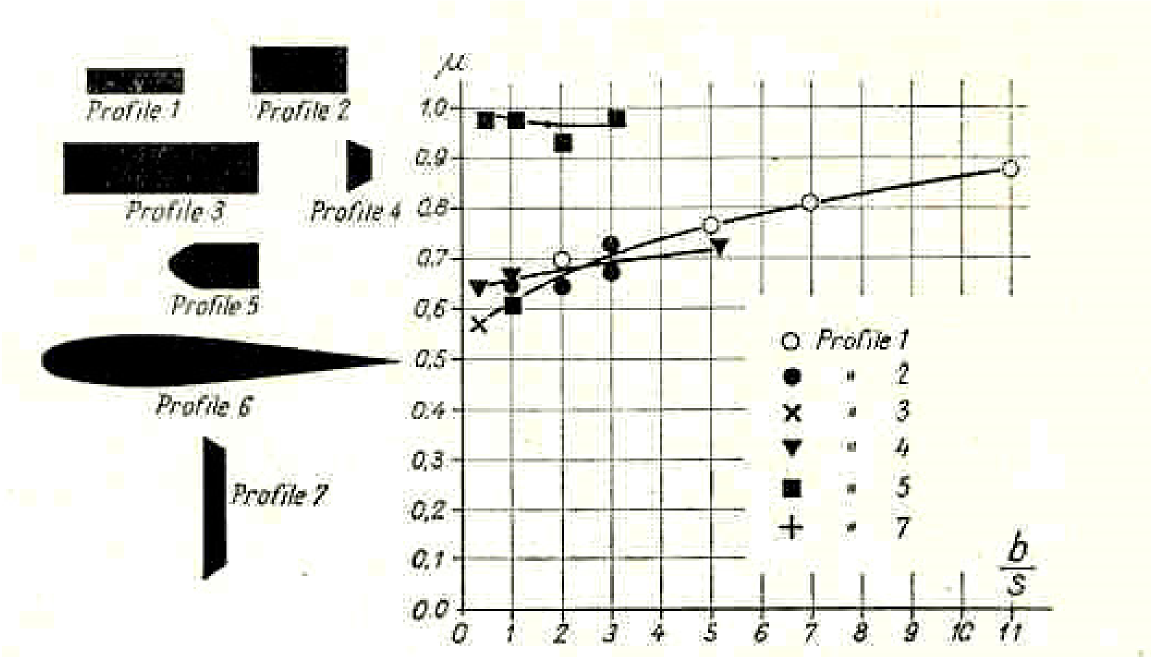


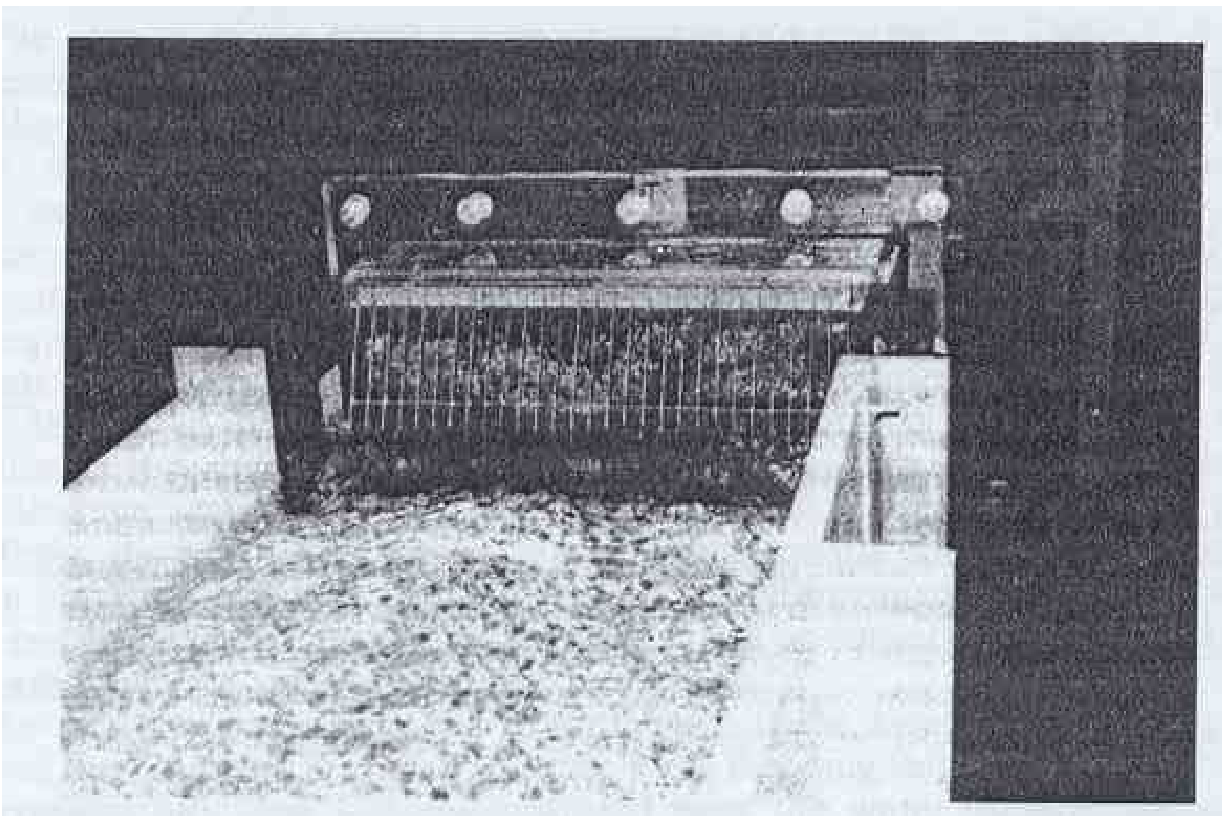
Figure 5.6



The three formulas given by Eqs. (5.1), (5.2) and (5.5) have been used in recent publications as discussed in Section 5.1 but these formulas were developed using the experimental data for trash racks obtained more than 50 years ago. Recent experiments included those conducted by Engel and Lau (1981) and Weisman (1989) for safety grates at specific sites as explained in Section 4.2. More recent experiments are summarized in the following.

Nguyen and Naudascher (1991) examined the vortex-induced vibrations of trash racks in parallel and inclined flows analytically and experimentally. They quoted examples of trash rack failures for the operation of conventional and pumped-storage hydroelectric power plants. Unlike the trash racks exposed to flow continuously, safety grates are subjected to large flow velocities only during major storms. In any event, a safety grate must be securely connected to a solid structure so that a person cannot open it by hand. Furthermore, the safety grate can be inspected in connection with the maintenance work of a stormwater pipe.

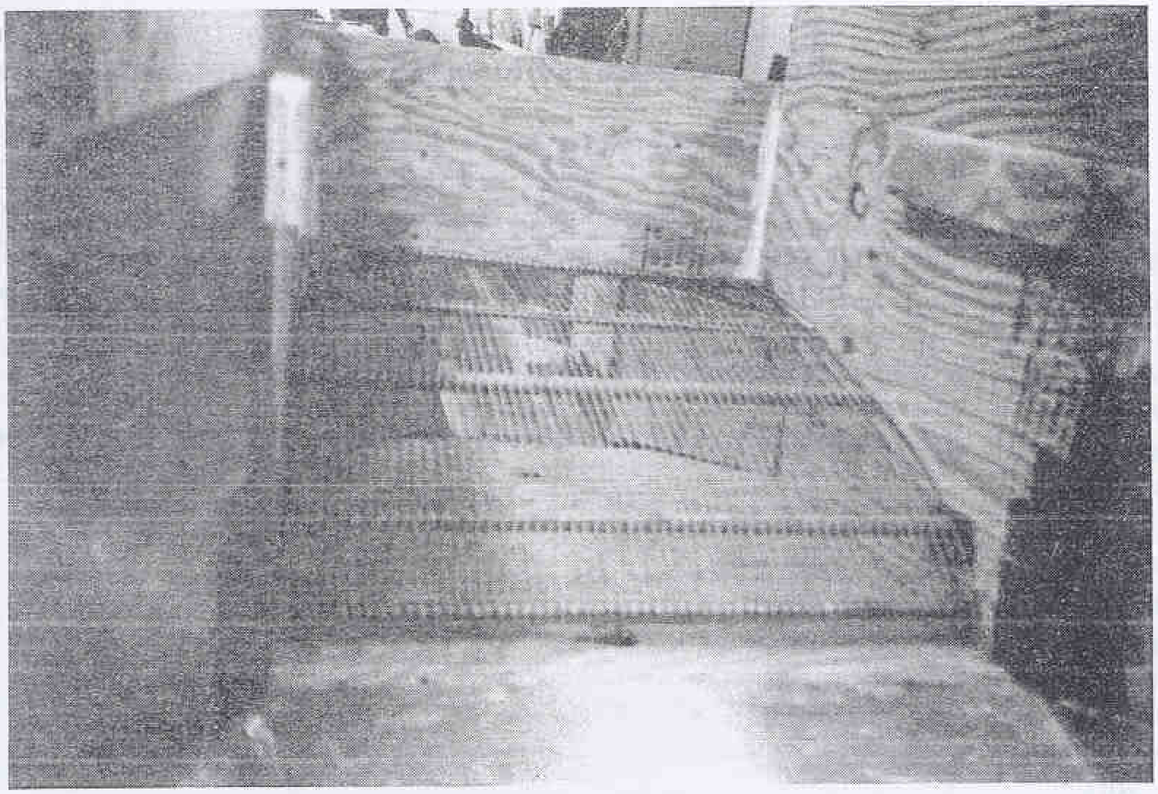
Abt et al. (1992) conducted a 1/15 (model/prototype) Froude scale model of a portion of an urbanized drainage basin in Colorado. Figure 5.8 shows their experimental setup where the slope of the trash rack was 1H:2V in this figure. 100-year recurrence supercritical flows with prototype velocities of approximately 17 ft/s were simulated in their experiment. It is noted that the velocity of 17 ft/s is very high in this steep channel in Colorado. Debris was simulated using wood lathe (floating) and plastics (nonfloating). The simulated debris (floating and nonfloating) was trapped firmly against



The slope of the trash rack was flattened to 3H:1V in order to reduce the blockage problem. The flattened-bar inclination and the momentum of the floating debris forced the debris up the rack and stored it out of the flow area. The nonfloating debris was firmly trapped at the toe of the 3H:1V trash rack. Abt et al. (1992) examined the effects of different debris conditions for the 3H:1V trash rack by placing the debris on the trash rack artificially. Nonfloating debris was found to cause localized flooding with less blockage than floating debris in supercritical flow conditions. Their study suggested that the traditional procedure for evaluating the hydraulic performance of the trash rack by assuming 50% blockage would need to be revised to 40% blockage in supercritical flow. It is not clear why they tested only the longitudinal bars shown in Figure 5.8. Horizontal bars might have reduced the clogging caused by nonfloating and floating debris. For their study, the trash rack prevented debris from clogging an inlet drop structure. As a result, the functions of trash racks and safety grates are different.

Allred-Coonrod (1994) conducted a 1/18 Froude scale model of a parabolic safety grate in supercritical flow for a flood-control system in Albuquerque, New Mexico. The hydraulic model studies by Engel and Lau (1981) and Weisman (1989) were conducted in subcritical flow with significantly lower velocities. Allred-Coonrad (1994) stated that no dead raccoons had been found on the parabolic-shaped grates which was installed in Toronto after two separate drownings in 1980.

Figure 5.9 shows the parabolic safety grate tested in the experiment by Allred-Coonrad (1994). The grate bars were longitudinal unlike the horizontal bars shown in Figures 4.3 – 4.6. The prototype bar spacing was 4.75 in (12 cm) to prevent the heads of small children ranging from age 3 to 5 years from passing through the grate. Bars made of 2-in (5-cm) diameter pipe were considered for the prototype conditions with high velocities. Toy figures representing children were swept up the grate out of the flow of water. Sticks, stones and leaves thrown in the laboratory channel were also swept up the safety grate. The water surface profile was measured with and without the grate in place. The measured head loss due to the safety grate was in the range of 9 – 13 in (23 – 33 cm) in the prototype. This head loss was relatively small in spite of the relatively large values of $s/b = 5/12 = 0.42$ in the flow velocity of 10.2 ft/s (3.1 m/s) in the square box culvert whose width was 14 ft (4.3 m). The velocity through the grate was estimated to be



SECTION 6. PERSONNEL SAFETY GRATES IN DELAWARE

Before safety grate design guidelines are discussed on the basis of the findings in Sections 2 – 5, examples of safety grates in Delaware are presented to show the diversity of site conditions. These safety grates were installed by different companies and agencies before Fall, 2004 without the benefit of this report but are evaluated in light of the findings in Sections 2 – 5.

6.1 Safety Grates Installed in Delaware

Table 6.1 lists the locations of seven safety grates SG 1 – 7 depicted in this report. Figures 6.1 – 6.5 show their locations and Figures 6.6 – 6.12 show photographs of these grates. These photographs indicate that their design was based on the characteristics of each site.

Table 6.1 *Locations of seven safety grates SG1 – SG7.*

Safety Grate	**Location**
SG1	In front of Wilmington Friends School on Alapocas Rd. (Installer unknown).
SG2	Bedford Rd. (Off from Weldin Rd. in Forest Hills Park) installed by New Castle Conservation District
SG3	Near intersection of Rt. 141 and Rt. 202 installed by Astra Zeneca
SG4	East of Rt. 72 and near Rachel Ct. and Westover Woods installed by DelDOT
SG5	Rt. 273 north side of road, east of Churchmans Rd. installed by DelDOT
SG6	72 Clifton Dr. in Hickory Woods, south of Porter Rd. and west of Rt. 72 installed by New Castle Conservation District.
SG7	Tidal ditch at Kitts-Hummock, the end of Kitts Hummock Rd. (Southeast of Dover Air Force Base), the south end of the lane along the beach just west of the roadway (Installer unknown).

Figure 6.1 *Map for safety grates SG 1 – 3.*

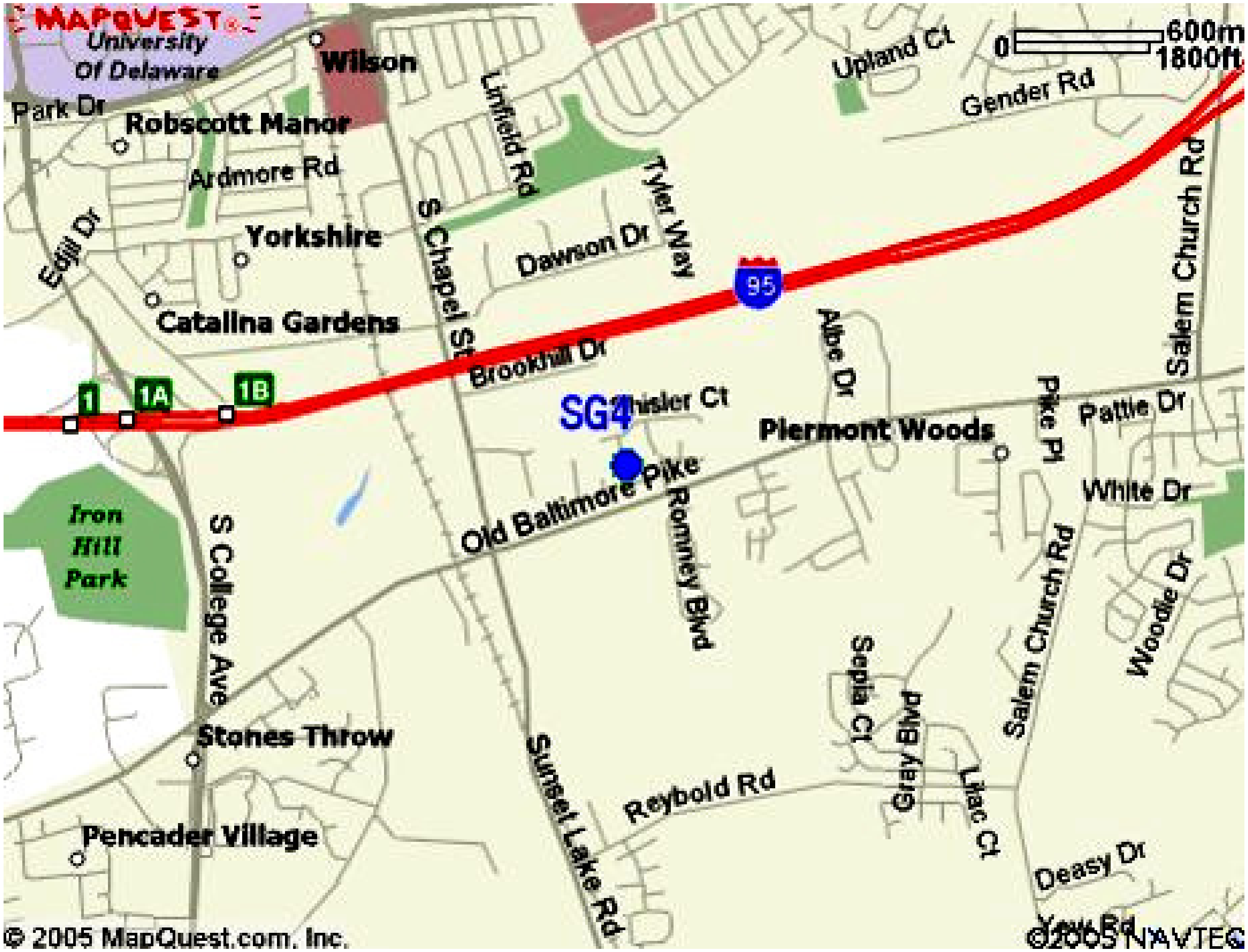


Figure 6.2 *Map for safety grate SG4.*

Figure 6.3 *Map for safety grate SG5.*

Figure 6.4 Map for safety grate SG6.

Figure 6.5 Map for safety grate SG7.

Figure 6.6 *Safety grate SG1 and surrounding area.*

Safety grate SG1 in Figure 6.6 looks similar to the safety grate shown in Figure 3.1 which was used as a bad example by Wright-McLaughlin Engineers (2001). According to their rule of thumb, this safety grate may be too small and increase the risk of entrance clogging. Nevertheless, Figure 6.6 indicates that SG1 is located in an area of very light floating debris or no debris on the basis of the debris classification in Section 3.1. The concern at this site may be the growth of vegetation and reduced entrance area.

Safety grate SG2 in Figure 6.7 is located in an area of light floating debris and placed on the flared entrance in a manner similar to that shown in Figure 2.9. If this grate had been installed inside the flared entrance like safety grate SG1, the clogging problem would be worse. The accumulated debris will need to be removed before the entire grate is covered with the debris. The bars of SG2 are slanted as in Figure 2.9. The slanted bars appear to be effective in trapping sticks that rest horizontally across the bars. This is the reason why the bars of the trash rack are slanted. If the purpose of the safety grate is solely the prevention of personnel entry, horizontal bars may reduce the accumulation of debris at the grate entrance. This alternative assumes that the debris passing through the horizontal bars will not accumulate inside the stormwater pipe. If the debris accumulation inside the pipe did not occur before the installation of the safety grate, the bars of the safety grate should be designed to minimize the accumulation of debris on the safety grate.

Safety grate SG3 in Figure 6.8 was installed on the entrance walls of the stormwater pipe for security of the facilities of Astra Zeneca. The slope of the safety grate may be somewhat steep in view of the reduction of the pinning force due to flowing water discussed in relation to Figure 4.3. However, the water depth during heavy runoff

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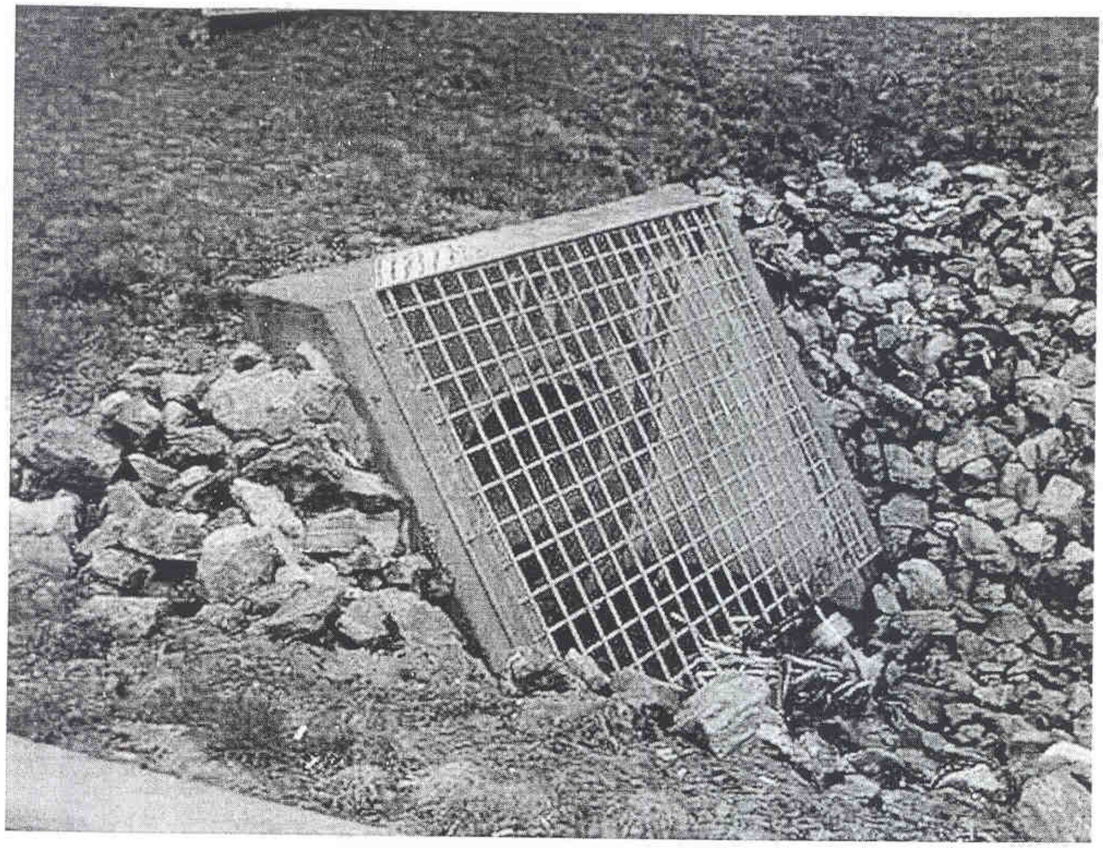

at this site is expected to be much less than the water depth in front of the large culvert in Figure 4.3.

Safety grate SG4 in Figure 6.9 is installed on the flared entrance like SG2 but in an area of less debris. The vegetation at the entrance might cause a head loss as much as the safety grate but no data is available presently.

Safety grate SG5 in Figure 6.10 is placed parallel to the surface of the side walls and embankment. This is the largest of the seven safety grates. The pipe diameter is approximately 5 ft and the bar length is about 23 ft. The bar diameter and spacing are approximately 0.4 and 1.0 ft, respectively, corresponding to $a = (s/b) = 0.4$ in Eq. (5.5) where the slope $\sin(\alpha) = 1/4$ and K_g =1.79 for circular bars. The horizontal support for the grate is neglected for simplicity. Consequently, Eq. (5.5) yields $H_g = 0.13 H_v$ where the velocity head $H_v = V_u^2/(2g)$. On the other hand, Eqs. (5.1) and (5.2) with $a = 0.4$ predict $H_g = 1.37 H_v$ and $0.62 H_v$, respectively. The major difference is the slope effect $\sin(\alpha)$ in Eq. (5.5) which may have been developed for $\alpha > 45°$ and may not be accurate for $\sin(\alpha) = 1/4$.

In contrast, Eqs. (5.1) and (5.2) may have been developed originally for vertical grates with $\alpha = 90°$. A reasonably conservative estimate may be $H_g = 0.5 H_v$. If V_u = 8 ft/s, the velocity head H_v = 1.0 ft and the grate head loss H_g = 0.5 ft which appears to be consistent with the recent experimental results by Weisman (1989) and Allred-Coonrod (1994). It is noted that the bar spacing of 1.0 ft is larger than the spacing of

***Figure 6.9** Safety grate SG4 and surrounding area.*

Figure 6.10 *Safety grate SG5 installed parallel to surface of side walls.*

4.75 in recommended by Allred-Coonrad (1994) to prevent the heads of small children (3 – 5 yrs old) from passing through the grate.

Safety grate SG6 in Figure 6.11 is installed within the side walls and appears to satisfy the requirement of the open surface area of the safety grate being at least four times the cross sectional area of the pipe as discussed in relation to Figure 2.9. This requirement ensures the reduction of the water velocity at the safety grate in comparison with the velocity inside the pipe and will reduce the percentage of the surface area blocked by debris if any debris occurs. The bar spacing of SG6 is smaller than that of SG5 probably because this grate is located in a residential area.

Safety grate SG7 in Figure 6.12 is blocked by sediment accumulated near the entrance. This grate is located in a tidal ditch along Delaware Bay. This sedimentation problem is not discussed in any of the references quoted in this report because this is regarded as a coastal engineering problem instead of a hydraulic engineering problem. To identify the cause of the sedimentation problem, it will be necessary to examine the sediment transport pattern in the tidal ditch and along the bay caused by tidal currents and wind waves. The Center for Applied Coastal Research has capabilities to perform such a study if requested.

Figure 6.11 *Safety grate SG6 installed within side walls.*

Figure 6.12 *Safety grate SG7 and sedimentation problem.*

6.2 Uncontrolled Exploration on Debris Clogging

Common debris in Delaware is lightly floating debris such as leaves, grass and small sticks. No data is available to determine the orientation of bars which will reduce the accumulation of such debris on the safety grate with bars. DelDOT conducted a field trial on debris clogging in 2004.

Figure 6.13 shows a safety grate slanted at an angle of 45° ($\alpha = 45°$ in Figure 5.2) and at a zero angle of flow incidence ($\delta = 0°$ in Figure 5.4). The bars were horizontal in this clogging test. The flow velocity was about 0.6 ft/s. Leaves tend to accumulate at the intersection of the longitudinal support and the horizontal bar especially when the bar is located on the water surface which would rise and fall during a storm.

Figure 6.14 shows a safety grate with a 3H:1V slope ($\tan\alpha = 1/3$) with horizontal bars at a zero angle of flow incidence as well as an improvised safety grate with vertical bars. The experiment by Abt et al. (1992) discussed in Section 5.2 indicated the reduction of debris blockage due to the flattening of the slope from 1H:2V to 3H:1V. Their experiment was a trash rack with longitudinal bars. The safety grate with horizontal bars shows a tendency of self-cleaning (trapped debris tends to be swept away eventually). The safety grate with vertical bars is essentially the same as the trash rack with vertical bars which is used to capture sticks. An elongated floating object tends to rotate and turn on its side resting on the vertical bars in light of the experiment by Weisman (1989) discussed in Section 4.2.

Figure 6.13 *Clogging test for safety grate slanted at 45° with horizontal bars placed at a zero angle of flow incidence where the flow velocity was about 0.6 ft/s.*

Figure 6.14 *Clogging test for safety grate with 3H:1V slope (top photo) and with vertical bars (bottom photo).*

Figure 6.15 *Clogging test for safety grate with inclined bars at an angle of flow incidence.*

Figure 6.15 shows a safety grate with a 3H:1V slope at an angle of flow incidence ($\delta > 0°$ in Figure 5.4) where the horizontal bars were slightly off-horizontal and the entire horizontal bar was not on the free surface. Floating debris tended to accumulate at the intersection of the bar and the longitudinal support.

SECTION 7. SUMMARY AND RECOMMENDATIONS

Various publications related to safety grates for stormwater pipes were reviewed and presented in Sections 2 through 5. Culvert and Drainage Inlet/Outlet Safety Guidelines (1998) by the City of Winnipeg, Canada discussed in Section 2.4 may be the most specific and rigid perhaps because the city environment is well established and densely populated. The seven safety grates in Delaware presented in Section 6.1 indicate the diverse site-specific conditions and rigid guidelines are not appropriate in Delaware. Furthermore, some of the guidelines by the City of Winnipeg are not consistent with the other guidelines. As a result, the guidelines recommended in this report are less rigid but intended to assist a competent engineer in designing a personnel safety grate with minimum adverse effect on the hydraulic performance of the stormwater pipe. The design engineer must read the entire report to understand the complexities caused by competing objectives – the need of a grate to prevent persons from being carried by stormwater into the pipe yet the pipe must be open to carry stormwater as efficiently as possible during storm events and to prevent flooding upstream of the pipe.

There are several major factors to consider in designing a safety grate upstream of a stormwater pipe that is determined to be hazardous. These are placement of the grate in relation to the pipe inlet, orientation and inclination of the grate; and orientation and spacing of the bars of the grate as illustrated in Figure 7.1.

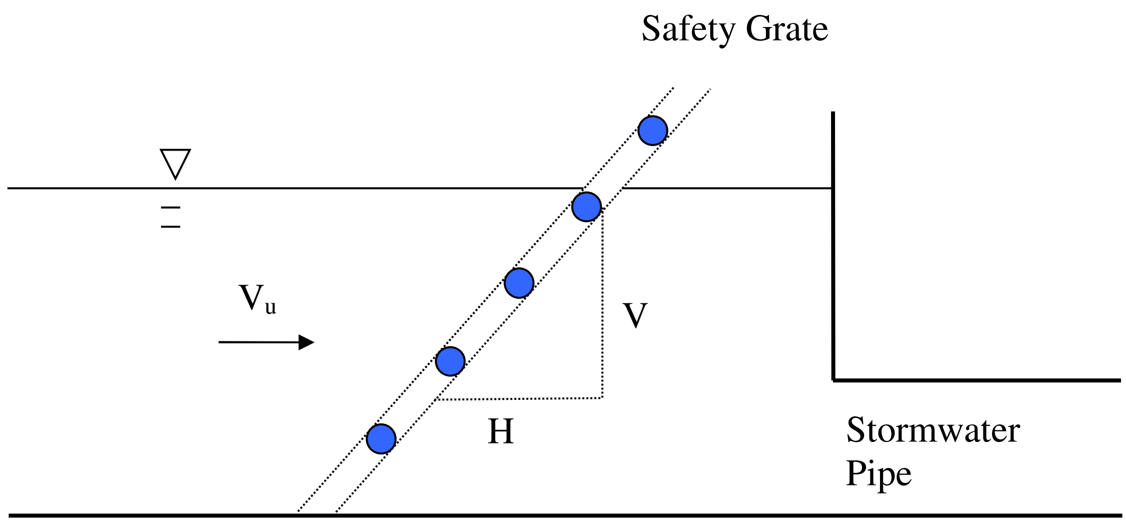

Figure 7.1 *Definition sketch for safety grate upstream of stormwater pipe.*

Placement, Orientation and Inclination of the Grate

Placement of the grate in relation to the pipe inlet is important as it directly affects the velocity upstream and through the grate. These velocities, in turn, have direct bearing on the pinning force against the grate, the headwater loss, and the potential for debris accumulation on the grate. Tempered with site and cost constraints, the grate should be placed beyond the area of flow acceleration upstream of the pipe inlet, slanted at 3H:1V or flatter, and at zero angle of incidence. The drag force acting on a person is proportional to V_u^2 and can be decreased considerably by reducing the approach velocity V_u to the safety grate. The City of Winnepeg Guidelines (1998) recommended that the net surface area through the grate be at least four times the area of the pipe to ensure that the flow velocity is low enough for an adult to climb off the grate.

The model study by Engel and Lau (1981) showed that the pinning force on a slanted grate is reduced markedly relative to a vertical grate. This result is supported by other studies. Also lower inclination angle lowers the head loss H_g according to Eq. (5.5). An increase in the headwater depth due to the installed grate will occur and may be assumed to be approximately the same as the head loss H_g due to a trash rack.

The head loss H_g will increase with the angle of flow incidence (δ) as shown in Figure 5.4. Consequently, the safety grate should be installed at a zero angle of incidence $(\delta = 0°)$ so that the safety grate will cause the least disturbance to the flow. The head loss H_g for the case of $\delta = 0°$ may be estimated using Eqs. (5.1), (5.2) and (5.5) even though these formulas were developed for trash racks more than 50 years ago and may not directly apply to safety grates. Eqs. (5.1) and (5.2) are likely to result in too high a value of H_g for the safety grate shown in Figure 6.10, SG5.

If the ratio a between the bar area and the open area between the bars is less than 0.4 and the grate inclination is flatter than 3H: 1V, the head loss H_g will be less than 0.5 ft if the approach velocity V_u is less than 8 ft/s. To minimize the increase in headwater depth, the ratio a and the approach velocity V_u must be kept as small as the site permits. The minimum value of a depends on the required structural strength of the grate.

The potential for debris accumulation is reduced by proper placement and inclination as described above. But orientation and spacing of the bars of the grate, as discussed below, also have a large effect on this potential problem.

<u>Bars Orientation and Spacing</u>

The bar spacing of a safety grate needs to be selected in such a way that a child will not pass between the bars but light-floating debris will pass between the bars. The clear space between the bars quoted in Sections 3 thru 5 is in the range of 4 thru 9 inches. The bar spacing should depend on the size of children who may be attracted to the area surrounding the specific safety grate. The range of 5 thru 6 inches appears to be typical for the prevention of entry by small children. Wider bar spacing is less prone to clogging with leaves and grass.

Horizontal bars will block sticks less than slanted bars because sticks tend to rotate and align their longest length normal to the flow at the safety grate. However, the quantity and type of debris vary from one site to another as shown in Figures 6.6 thru 6.12. Each site should be examined carefully, especially for significant sediment transport such as that shown in Figure 6.12. Placing the bottom bar at least 5 to 6 inches from the bottom of the stream helps reduce sediment accumulation at the grate.

Holistic Approach

Finally, a holistic approach should be adopted with the participation of various agencies, civic groups and media. Accidents can be minimized if children and adults know the danger of playing in water in the vicinity of stormwater pipes. Active participation of the public through stream clean up and eliminating household litter in backyards and roads all help reduce debris clogging on grates. Public education, such as public service announcements in local radio and television programs at the beginning and during the hurricane season, should be part of the overall efforts in promoting safety near stormwater pipes.

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APPENDIX

Haala Industries in Minnesota (www.haala.com) markets fabricated safety grates. This report does not endorse any commercial product but presents the brochures of the following products for the sake of comparisons of types, materials, and costs:

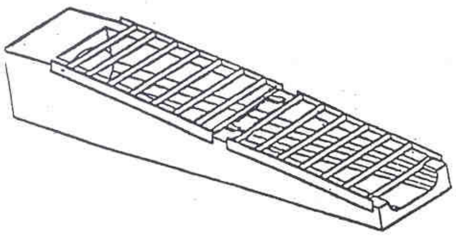
- Safety grate for precast concrete aprons: 1/4 slope.
- Safety grate for precast concrete aprons: 1/6 slope.
- Safety apron grates: MN DOT Std. Plate 3128G for metal pipe.
- Pipe grates: 1/4 precast concrete aprons.
- Vehicle safety grate for centerline concrete culverts: galvanized pipe.
- Concrete pipe: Galvanized trash guards.
- Steel pipe safety grates.
- Culvert locator rod.
- Iowa-style galvanized trash guards.
- Trash guard: bull nose style for inlet apron.
- Pipe reinforcement: galvanized beveled rebar.
- Apron endwall pipe grates.
- Illinois style galvanized trash guard.
- Galvanized pond skimmer grates.
- Cone grate trashrack.

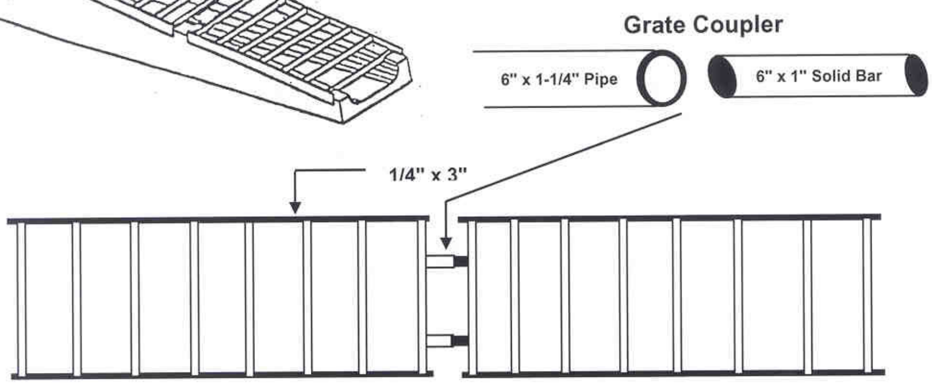
HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

SAFETY GRATE

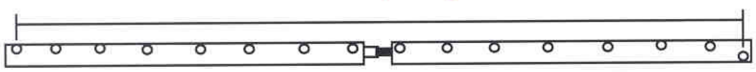
For Precast Concrete Aprons

4:1 Slope





NOTE: Spacing between cross bars depends on the diameter of the cross bars.
6" Center to Center Spacing between 1-1/4" Cross Bars
12" Center to Center Spacing between 1-1/2" Cross Bars



Section A-A

NOTES:

Galvanize per spec. 3394 after fabrication.

Safety Apron shall be constructed of structural steel per spec. 3306.

All Cross bars shall be welded all around to steel plate frame.

IMPORTANT: Please specify rod dia. & spacing when ordering.

2004 Prices

Specify rod dia. & spacing when ordering

Apron Size	Slope	12"CC 1-1/2"	6"CC 1-1/4"
24"	4:1	$185.00	$215.00
30"	4:1	$225.00	$260.00
36"	4:1	$340.00	$390.00
42"	4:1	$390.00	$450.00
48"	4:1	$570.00	$650.00
54"	4:1	$760.00	$875.00
60"	4:1	$1,170.00	$1,345.00
66"	4:1	$1,400.00	$1,610.00
72"	4:1	$1,540.00	$1,770.00

NOTE: Prices reflect minumum order of 10 for sizes 24-48"
For orders of less than 10 Grates add 10%.

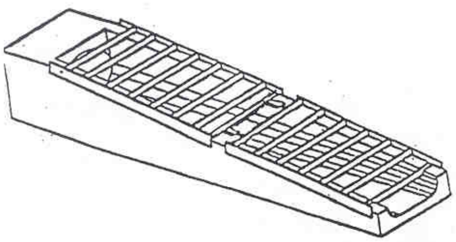
04-20

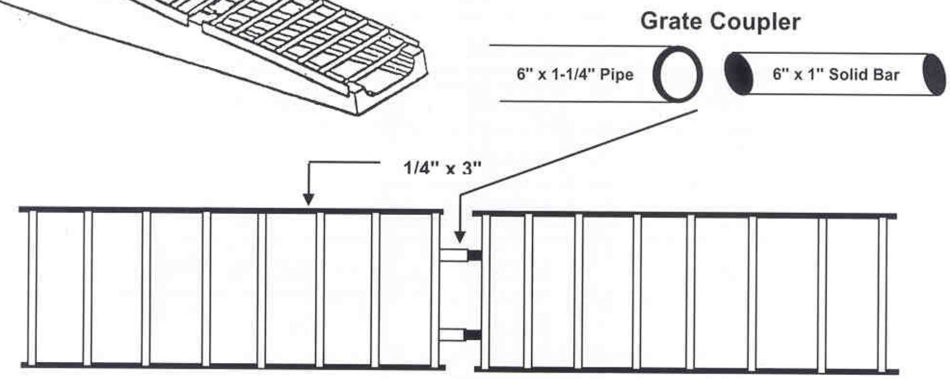
HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

SAFETY GRATE

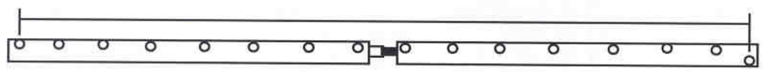
For Precast Concrete Aprons

6:1 Slope





NOTE: Spacing between cross bars depends on the diameter of the cross bars.
6" Center to Center Spacing between 1-1/4" Cross Bars
12" Center to Center Spacing between 1-1/2" Cross Bars



Section A-A

NOTES:
Galvanize per spec. 3394 after fabrication. Safety Apron shall be constructed of structural steel per spec. 3306. All Cross bars shall be welded all around to steel plate frame. Please specify rod diameter and spacing when ordering.

specify rod dia. & spacing when ordering

NOTE: Prices reflect minimum order of 10. For orders of 1-9 please add 10% to listed price.

2004 Prices

Apron Size	Slope	12"CC 1-1/2"	6"CC 1-1/4"
12"	6:1	$180.00	$206.00
15"	6:1	$180.00	$206.00
18"	6:1	$180.00	$206.00
24"	6:1	$265.00	$305.00

04-21

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Safety Apron Grates

MN DOT Std. Plate 3128G
(for Metal Pipe)

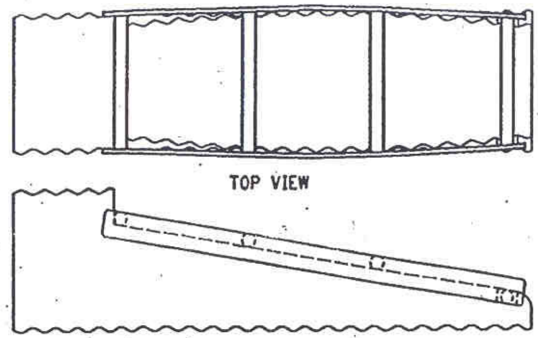
Wt.	Diameter of Pipe	2004 Price Galvanized 4:1 Slope	6:1 Slope	10:1 Slope
30	12"	$38.00	$40.00	$47.00
55	15"	$57.00	$60.00	$66.00
75	18"	$84.00	$88.00	$92.00
145	21"	$157.00	$159.00	$174.00
165	24"	$172.00	$182.00	$202.00
245	30"	$255.00	$265.00	$293.00
325	36"	$340.00	$352.00	$394.00
410	42"	$396.00	$396.00	$455.00
514	48"	$498.00	$498.00	$562.00
36	15" Arch (18x12)	$41.00	$43.00	$48.00
52	18" Arch (21X15)		$59.00	$79.00
85	21" Arch (24X18)		$93.00	$100.00
120	24" Arch (28X20)		$131.00	$147.00
155	30" Arch (35X24)		$170.00	$200.00
195	36" Arch (42X29)		$214.00	$236.00
240	42" Arch (49x33)	$261.00	$268.00	$302.00

* See Page 04-23 for Detail

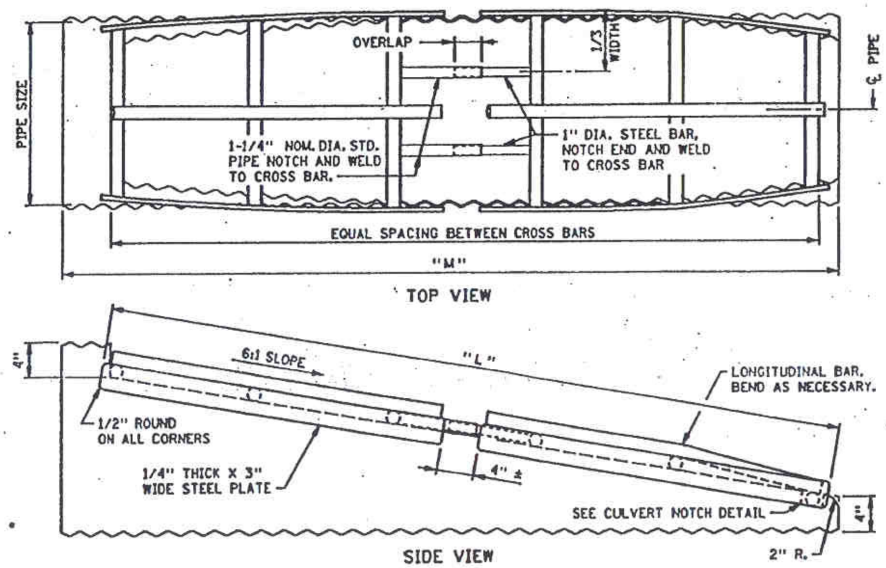
Prices reflect minimum order of 10.
For orders of less than 10 add 10%.

PIPE SIZE AND TYPE	GAGE	NUMBER OF LONGITUDINAL BARS	NUMBER OF CROSS BARS	"L" LENGTH OF GRATE	NO. OF PIECES TO GRATE (1)	TOTAL WEIGHT OF PIECES (APPROX.)	"M" LENGTH OF PIPE
18" ROUND	12	0	5	5'7"	1	75 LBS.	6'9"
21" ROUND	12	1	6	7'1"	2	145 LBS.	7'6"
24" ROUND	12	1	6	8'7"	2	165 LBS.	9'3"
30" ROUND	10	1	8	11'8"	4	245 LBS.	12'9"
36" ROUND	10	1	10	14'8"	5	325 LBS.	15'3"
(2) 21" CMP-A	12	1	4	4'1"	1	85 LBS.	5'0"
(2) 24" CMP-A	12	1	5	5'7"	2	120 LBS.	6'9"
(2) 28" CMP-A	12	1	6	6'7"	2	155 LBS.	7'3"
(2) 35" CMP-A	10	1	6	8'7"	3	195 LBS.	9'3"

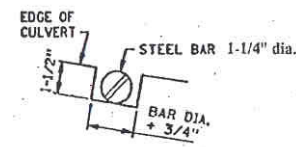
(1) EACH SECTION SHOULD BE OF EQUAL LENGTH FOR SPLIT GRATE WHEN POSSIBLE.
(2) SPAN DIMENSIONS.



TYPICAL SINGLE PIECE GRATE



TYPICAL SPLIT GRATE
(MITERED PIPE SHOWN)



CULVERT NOTCH DETAIL

NOTES:

GALVANIZE PER SPEC. 3394 AFTER FABRICATION.

SAFETY APRON SHALL BE CONSTRUCTED OF STRUCTURAL STEEL PER SPEC. 3306.

ALL CROSS BARS SHALL BE WELDED ALL AROUND TO STEEL PLATE FRAME.

THE APRON SHALL BE FASTENED TO THE CULVERT WITH A STANDARD COUPLING BAND. SEE STANDARD PLATE 3221. SEE SHEET 2 OF 2 FOR CONNECTION TO CONCRETE CULVERTS.

ALL CROSS BARS AND CENTER LONGITUDINAL BARS SHALL BE 1-1/2" DIAMETER.

APPROVED SEPT. 23, 1999 Delbert W. Sandas STATE DESIGN ENGINEER	STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION **APRON GRATE** FOR USE ON APPROPRIATE CULVERT ENDS WITHIN REQUIRED CLEAR ZONE	SPECIFICATION REFERENCE 2501	STANDARD PLATE NO. **3128G** 1 OF 2

See Page 04-22 for Prices

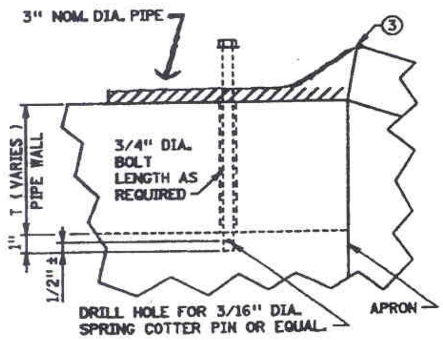
HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Pipe Grates

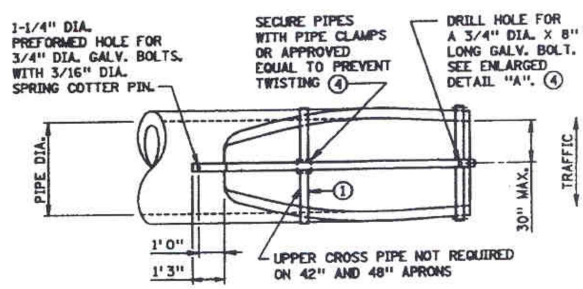
4:1 Precast Concrete Aprons

Standard Plate NO. 3132A

Apron Size	Approx. Pipe Lengths Long.	Approx. Pipe Lengths Trans.	Cross Pipes Req'd	2004 Price
12"				$ 115.00
15"				$ 125.00
18"				$ 140.00
24"				$ 190.00
30"	9'	25-3/4"	1	$ 252.00
36"	9'4"	29-1/4"	1	$ 290.00
42"	11'8"	46"	1	$ 363.00
48"	13'8"	52"	1	$ 424.00
54"	15'10"	58"	2	$ 582.00
60"	17'11"	64"	2	$ 657.00
72"	22'0"	76"	2	$ 807.00



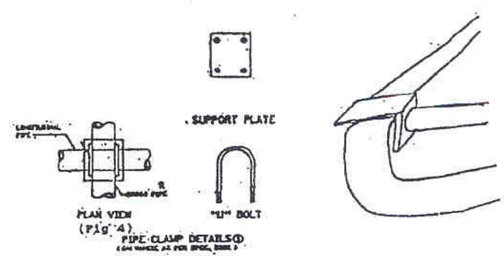
ENLARGED DETAIL "A"



TOP VIEW
(54" OR 60" CONCRETE APRON SHOWN)

NOTES: All pipe is schedule 40 galvanized pipe as per spec. 3362. 3" Nominal dia. 7.58 lbs. Per FT. Galvanize after fabrication as per spec. 2471.3L. Galvanize fasteners as per spec. 3392. See standard plate 3022 (3 of 3) for aprons.

1.) Upper cross pipe to have firm contact with apron and longitudinal pipe.
2.) Two longitudinal pipes equally spaced required on 72" dia. apron.
3.) Bend or cut and weld pipe as shown.
4.) Welding as per spec. 2471 may be used at all pipe connections



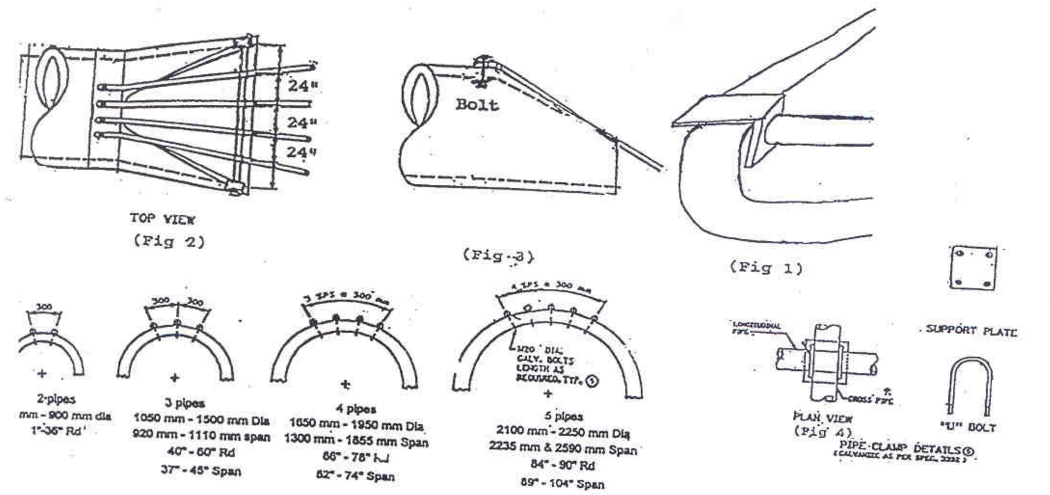
APPROVED DEC. 18, 1996 Gerald J. Rohrbach STATE DESIGN ENGINEER	STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION GRATE FOR 4:1 PRECAST CONCRETE APRONS FOR CROSS DRAINS WITH 42" TO 72" DIA. PIPE	SPECIFICATION REFERENCE 3406 2471 REVISED 6-26-97	STANDARD PLATE NO. 3132A

04-24

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Veh. Safety Grate

For Centerline Conc. Culverts (Galv. Pipe)



1.) EQUAL SPACING - NOT TO EXCEED 600mm. All 75mm. Pipe - SPEC. 3362
2.) SEE STANDARD PLATE 3022, 3100, 3110.
3.) WELD ALL ABUTTING SURFACES.

Note:
SAFETY GRATE SHALL BE CONSTRUCTED OF 75mm. STEEL PIPE (SPEC. 3362)

Rd.	Span	2004 Prices
18"	22"	$290.00
24"	29"	$310.00
30"	36"	$324.00
36"	44"	$338.00
42"	51"	$402.00
48"	59"	$425.00
54"	65"	$496.00
60"	73"	$550.00
72"	88"	$588.00
78"		$675.00
84"		$712.00
90"		$820.00

04-25

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Plate Style


Round Bar Style

Arch Apron

NOTE: Due to variations in forms & arch design, prices for arch apron guards may vary. Please send detail specs when ordering Ach Apron Guards.

Concrete Pipe - 2004 Prices

Trash Guards - Galvanized

Prices reflect minimum order of 10 guards. For orders of less than 10 guards add 10%. For orders of 25 or more guards deduct 10%.

	Size	Standard	Heavy
ROUND APRONS	12"	$78.00	$89.00
	15"	$95.00	$108.00
	18"	$111.00	$127.00
	21"	$128.00	$192.00
	24"	$156.00	$224.00
	27"	$196.00	$274.00
	30"	$262.00	$331.00
	33"	$331.00	$417.00
	36"	$358.00	$565.00
	42"	$410.00	$816.00
	48"	$475.00	$933.00
	54"	$735.00	$1,152.00
	60"	$901.00	$1,386.00
	66"	$1,014.00	$1,689.00
	72"	$1,135.00	$1,760.00
	84"	$1,380.00	$2,142.00
	90"	$1,535.00	$2,420.00
ARCH APRONS	18"-22"	$130.00	$160.00
	24"-28"	$180.00	$235.00
	30"-36"	$330.00	$382.00
	36"-43"	$352.00	$586.00
	44"- 51"	$368.00	$661.00
	48"-59"	$378.00	$682.00
	54"-65"	$464.00	$847.00
	60"-73"	$747.00	$1,159.00
	72"-88"	$1,252.00	$1,853.00
	84"-102"	$1,397.00	$1,873.00

PRICES REFLECT F.O.B. SLEEPY EYE * DELIVERY AVAILABLE

STANDARD DETAILS FLARED END SECTION AND TRASHGUARD	Revisions	Plate No. 1-28

04-26

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Steel Pipe Safety Grates

2004 Prices			
Size:	Plain	Painted	Galv.
12"	$34.00	$38.00	$40.00
15"	$39.00	$44.00	$48.00
18"	$62.00	$69.00	$74.00
Call for more sizes - not yet available at time of printing			

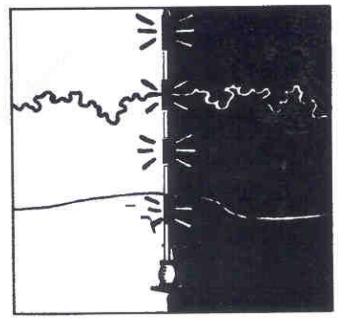
Prices reflect minimum order of 10 guards. For orders of less than 10 guards add 10%. For orders of 25 or more guards deduct 10%.

Plate style guard design is more durable and allows for quick and easy one man install (cordless drill and vice-grip is all that is needed for either pre-install or on the job site install). Grates also have pipe size marking for easy pipe to grate coordination.

04-27

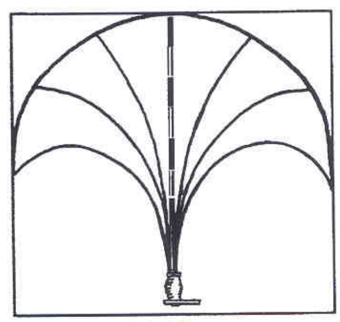
HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Culvert Locator Rod



HIGH DAY/NIGHT VISIBILITY

The 6" wide **highly reflective** red stripping tape on the white Locator Rod fiberglass shaft affords instant day & night visual loacation of the culvert. The high-visibility Locator Rod quickly locates culverts barried in snow or covered with seasonal vegetation overgrowth.



VANDAL PROOF

The resilient 3/8" diameter white laminar matrix fiberglass Locator Rod shaft is attached to a heavy duty MIL SPEC chrome plated carbon steel spring mount that allows for 360 deg. **total flexibility.**

* The manufacturer claims no responsibility for any misuse of the Locator Rod beyond its intended and specified function as a high-visibility culvert locating device.

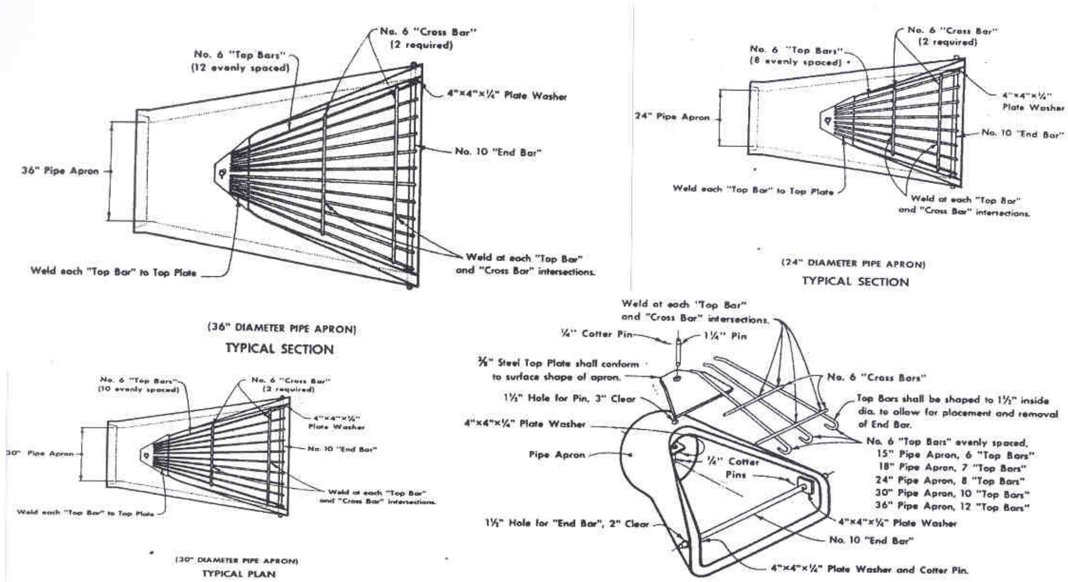
2004 Prices:	Order Quantity		
Item Description	1-249	250-499	500+
5 Ft. Rod (UPM-5) Non-Spring	$9.95	$9.50	$8.95
5 Ft. Rod (UPM-5) w/ Spring	$15.50	$15.00	$14.50
6 Ft. Rod (UPM-6) Non-Spring	$11.45	$11.00	$10.45
6 Ft. Rod (UPM-6) w/ Spring	$17.00	$16.50	$16.00
7 Ft. Rod (UPM-7) Non-Spring	$12.95	$12.95	$11.95
7 Ft. Rod (UPM-7) w/ Spring	$18.50	$18.00	$17.50
Edgelock Bracket (UPM-EDGE) (7 ft. models only - No Spring)	$11.95	$11.50	$10.95
Flat Bracket or "L" Bracket	$1.50	$1.50	$1.50
U-Bolt Mount	$2.50	$2.50	$2.50
Minie Flag	$3.95	$3.95	$3.95

04-28

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Iowa Style Trashguards

Galvanized



GENERAL NOTES:

It is intended that the design for the pipe apron guard detailed hereon provide treatment for the exposed end of pipe culvert, such that an out of control vehicle could pass over the end of the culvert without undue loss of control or damage to the vehicle.

Steel bars used in constuction of the guard shall be ASTM A615, Grade 40, or merchant quality, smooth or deformed steel conforming to the fabrication requirements of section 2404 of current Standard Specifications.

Welding of steel parts shall be as shown and subject to the approval of the engineer. The completed apron guard shall be hot-dip galvanized in accordance with current ASTM A 123 Specifications.

Details indicated are for type 1 Apron as shown on Standard Road Plan RF-3. Appropriate modification of apron guard shown may be made for type 2 Apron.

Alternate details for design of apron guard may be submitted to the engineer for approval.

Priced bid for "Pipe Apron Guard" for the various sizes required shall be considered full compensation for fabrication and installation of the guard detailed hereon, including the fabrication or drilling of neccessary mounting holes in the concrete pipe apron.

SPECIAL NOTE:

When detail project plans require pipe apron guards of sizes other than those shown hereon, the design for such apron guards shall be similar to those indicated, conforming to minimum bar spacing and general requirements shown.

Quantity Discounts Available

Iowa Style Trashguard
2004 Prices

12"	$99.00
15"	$130.00
18"	$152.00
24"	$210.00
27"	$275.00
30"	$335.00
36"	$462.00
42"	$549.00
48"	$622.00
54"	$693.00
60"	$785.00
88"	$1,476.00

Iowa Department of Transportation
Highway Division
STANDARD ROAD PLAN RF-26
RECOMMENDED 8/19/86
APPROVED
PIPE APRON GUARD

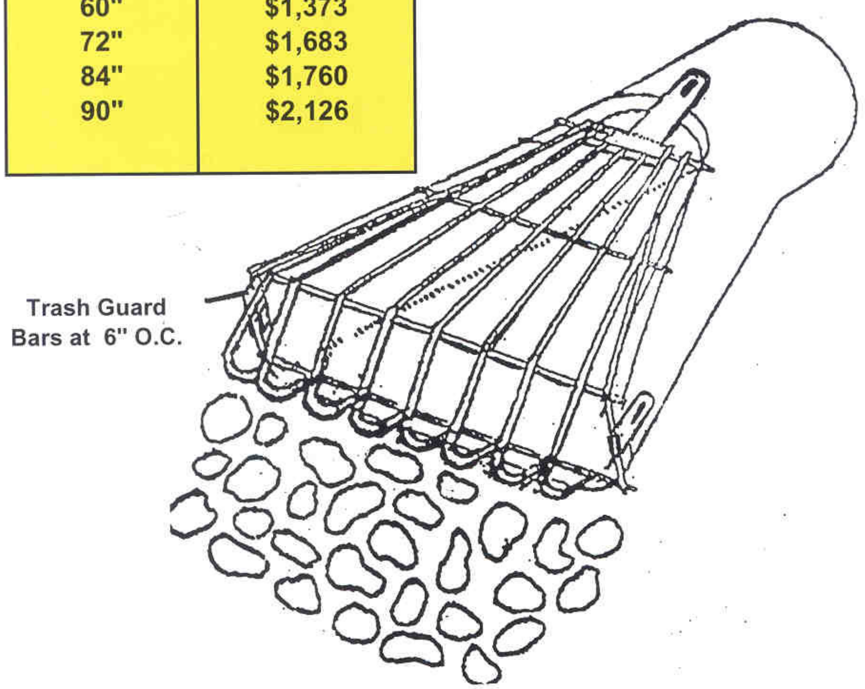
04-29

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Trash Guard
"Bull Nose Style"
(for inlet aprons)

2004 Prices Galvanized	
12"	$143
15"	$174
18"	$206
21"	$241
24"	$294
30"	$350
36"	$569
42"	$812
48"	$930
54"	$1,155
60"	$1,373
72"	$1,683
84"	$1,760
90"	$2,126

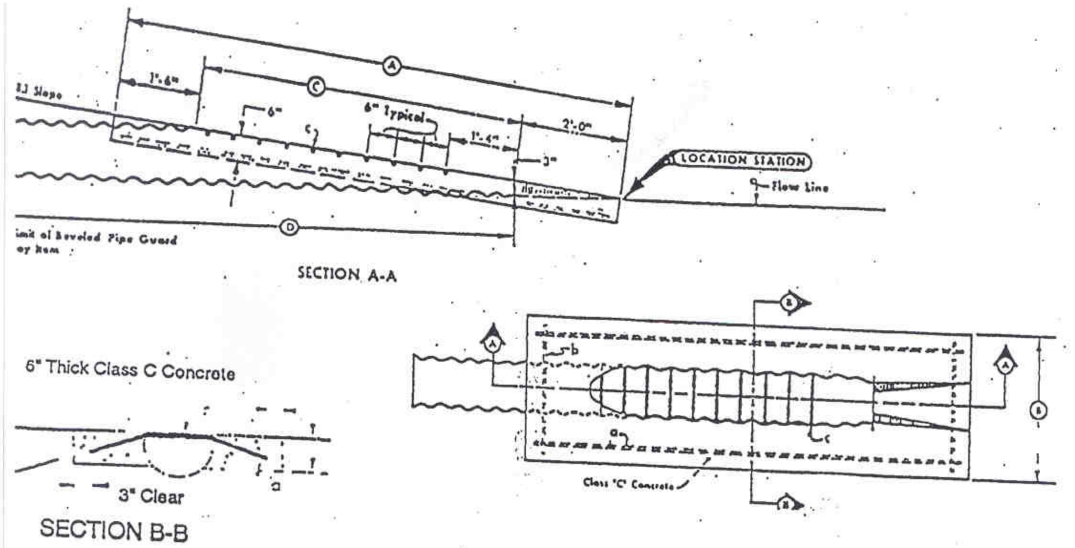
Pipe Size	Bar Size
12" - 18"	5/8"
21" - 48"	3/4"



04-30

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Pipe Reinforcement
(Galv. Beveled Rebar)



General Notes:
Details show herein are for the construction of beveled pipe guard. Alternate desings, methods of construction and materials involved shall conform to current standard specs
Reinforcement steel used in construction of "bevled Pipe & Guard" shall be deformed bars meeting the requirements of Section 4151.003. All steel bars shall be hot dip galvanized in accordance with ASTM A 123 specs.
Concrete used in construction of the beveled pipe & guard shall be class "C" concrete. The corrugated metal pipe shall be cut to fit the 8:1 foreslope. Slots shall be cut into the C.M.P. for placement of the #8 bars. After the foreslope has been placed the #8 bars shall be fitted into the slots cut in the C.M.P. so they will be in proper position when the concrete collar is poured.
Price bid for the "Beveled pipe & guard" each shall be considered full compensation for furnishing all materials & constructing the beveled pipe & guard as detailed herein and as directed by the engineer. SPECIAL NOTE: A silt basin will be required immediately upstream from the inlet of culvert. Refer to Standard Road Plan RL-9 for construction details and basis of payment.

12" Pipe Reinforcing Schedule

Mark	Size	Length	Minn. No. Req.	Iowa No. Req.
a	#5	10' 8"	2	2
b	#5	2' 8"	2	2
c	#8	2' 10"	10	5

15" Pipe Reinforcing Schedule

Mark	Size	Length	Minn. No. Req.	Iowa No. Req.
a	#5	12' 10"	2	2
b	#5	2' 11"	2	2
c	#8	3' 1"	14	7

18" Pipe Reinforcing Schedule

Mark	Size	Length	Minn. No. Req.	Iowa No. Req.
a	#5	15'	2	2
b	#5	3' 2"	2	2
c	#8	3' 4"	16	9

24" Pipe Reinforcing Schedule

Mark	Size	Length	Minn. No. Req.	Iowa No. Req.
a	#5	18' 6"	2	2
b	#5	4'	2	2
c	#8	49-1/2"		13

2004 Prices

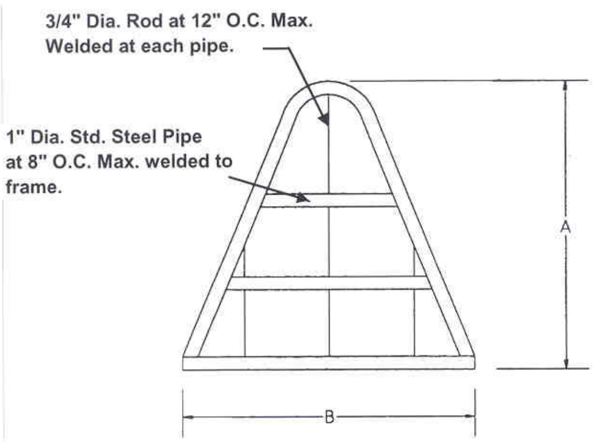
	Minnesota	Iowa
12"	$103.00	$65.00
15"	$151.00	$93.00
18"	$181.00	$120.00
24"	$212.00	$160.00

For orders of less than 10 sets add 10%. For orders over 25 sets deduct 10%

04-31

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

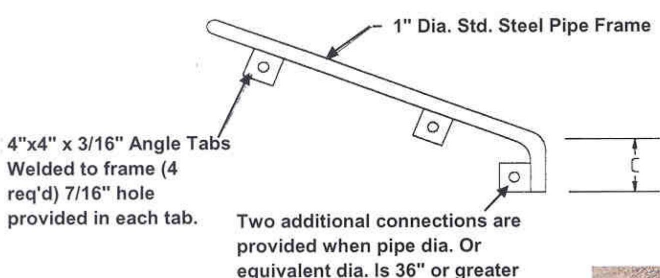
Apron Endwall Pipe Grates



Note: Dimensions are in inches.

DIA.	A.	B.	C.
12"	29	26	
15"	30	32	
18"	29	41	4
21"	38	48	5
24"	46	52	6
27"	52	60	6
30"	57	65	7
36"	68	80	9
42"	68	82	17.5
48"	77	95	20
54"	73	100	20
60"	72	100	19
66"	82	109	22
72"	92	118	24
84"	111	127	18

Round Endwall Gates



NEW PRODUCT:
Complete information not available at time of printing. Please call for additional information.

2004 Prices		
Size:	Price Plain	Price Galv.
12"	$68.50	$75.00
15"		
18"		
21"		
24"		

NOTE: For order quantities of less than 10 add 10%.

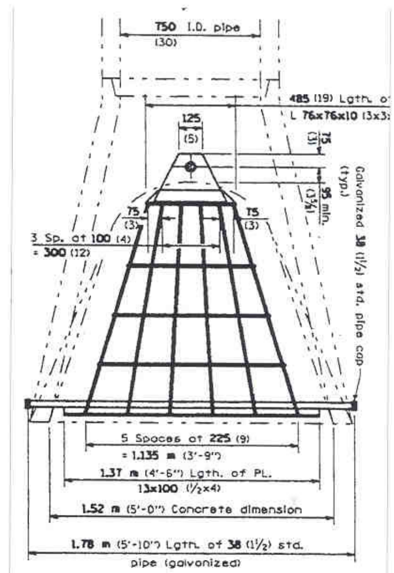
04-32

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

ILLINOIS Style Trashguard
(Galvanized)

2004 Price Galvanized		
Pipe Size	Flat Iron Price	Plate Style Price
12"	$102.00	$102.00
15"	$119.00	$119.00
18"	$125.00	$125.00
21"	$169.00	$169.00
24"	$182.00	$182.00

NOTE:
Prices reflect minimum order of 10 guards. For orders of less than 10 guards add 10%.



DATE	REVISIONS	
1-1-97	Renum. Standard 2364-3 and Standard 2379-2.	GRATING FOR CONCRETE FLARED END SECTION (FOR 600 mm (24") THRU 1350 mm (54") PIPE) (Sheet 1 of 2)
6-15-94	Moved G.N. to Specs. Added Metric.	STANDARD 542311

04-33

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

Galvanized Pond Skimmer Grates

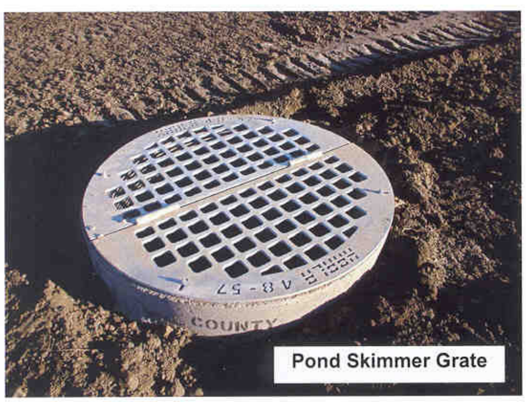
Part #	Pipe Size I.D.	Grate Size O.D.	Price 1-10	Price 11-24	Price 25+
36-43	36"	43"	$230.00	$215.00	$205.00
48-57	48"	57"	$335.00	$305.00	$275.00
54-63	54"	63"	$385.00	$350.00	$315.00
60-70	60"	70"	$475.00	$435.00	$390.00
72-84	72"	84"	$625.00	$565.00	$510.00
84-98	84"	98"	$845.00	$770.00	$690.00
96-112	96"	112"	$1,100.00	$1,000.00	$900.00
2-3	2' x 3'	34-1/2" x 45"	$110.00	$100.00	$90.00

NOTE: Sizes 60-70 & larger have 3/8"x3" bridged support on bottom.

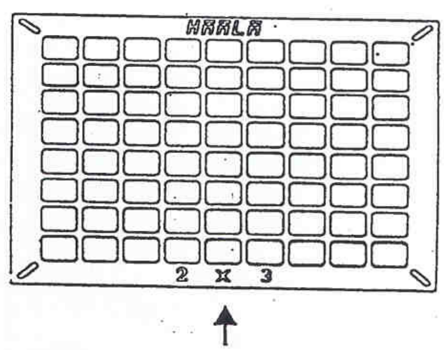
Fastener Package: 4 - 1/2" Anchors $7.65

NOTE: Grates can be made to your specifications.
Hinged & Locked access doors can be added (call for pricing)

** Add 10% to price for Rod Style Pond Skimmer.



Pond Skimmer Grate



Catch Basin Grate

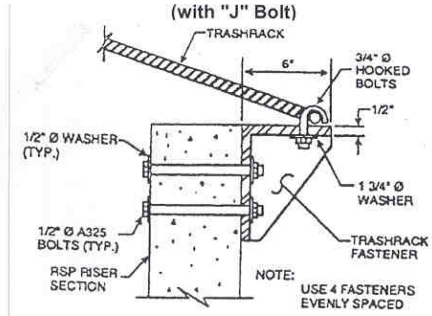
04-34

HAALA INDUSTRIES INC
SLEEPY EYE, MN
507-794-5821
www.haala.com

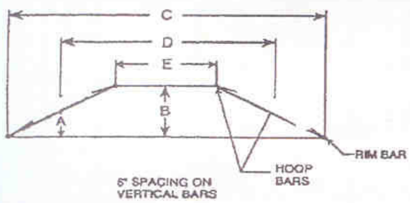
Cone Grate Trashrack

with Angle Brkt. & J-Bolt

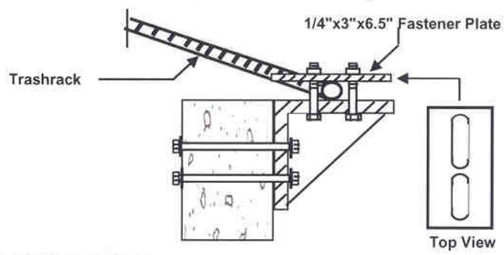
Fastener Detail Style "A"
(with "J" Bolt)

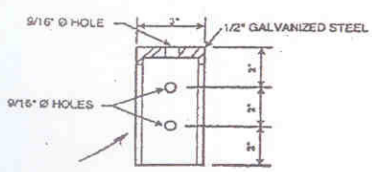


DETAIL: TRASHRACK FASTENER ATTACHMENT
NOT TO SCALE



Fastener Detail Style "B"
(with Fastener Plate)





TRASHRACK DIMENSION TABLE

2004 PRICES - Galvanized

MN/CB Dia.	A	B	C	D	E	Bar Dia.	Rim Bar	Bolt Size	Brkts. # Fast.	Price 1-10	Price 11-24	Price 25+
27"	6"	9"	46"		18"	3/4"	3/4"	1/2"x7"	4	$480.00	$456.00	$432.00
48"	6"	9"	70"	34"	18"	3/4"	3/4"	1/2"x7"	4	$636.00	$604.00	$572.00
60"	9"	12"	84"	39"	18"	3/4"	1"	1/2"x8"	6	$801.00	$761.00	$721.00
72"	9"	12"	98"	44"	18"	3/4"	1"	1/2"x9"	8	$1,016.00	$965.00	$915.00
84"	9"	12"	114"	50"	18"	3/4"	1"	1/2"x10"	8	$1,300.00	$1,235.00	$1,170.00
96"	12"	18"	126"	66"	24"	3/4"	1"	1/2"x11"	8	$1,579.00	$1,500.00	$1,421.00
120"	16"	37"	154"	90"	25"	1"	1"	3/4"x14"	8	$1,985.00	$1,886.00	$1,787.00

04-35