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# DESIGN GUIDANCE FOR COANDA-EFFECT SCREENS

July 2003

U.S. DEPARTMENT OF THE INTERIOR
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Coanda-effect screens address the growing need for screening of small debris and aquatic organisms from water diversions. These screens have large flow capacities and are hydraulically self-cleaning without moving parts, so they require minimal maintenance. Coanda-effect screens have been commercially available for many years in a limited number of configurations. Information needed to develop custom designs has previously been limited. This report reviews laboratory testing performed during the past 10 years that has led to the development of a numerical model that computes flow profiles and hydraulic capacities of Coanda-effect screens. Computer software to perform the calculations is publicly available through the Bureau of Reclamation web site, and its use is described here. The computer model is used to develop hydraulic rating curves defining the performance of several reference screen designs that are typical of existing installations. The model is also used to examine the sensitivity of screen capacity to several individual design parameters varied over typical application ranges. Graphical design aids are produced from this analysis, and design guidance is provided for project planners and screen designers. An appendix provides an extensive list of existing screen installations with narrative accounts of operating and maintenance experience at several projects.

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# DESIGN GUIDANCE FOR COANDA-EFFECT SCREENS

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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# GLOSSARY OF SYMBOLS

| | |
|---|---|
| $C$ | Discharge coefficient |
| $H$ | Head on weir crest |
| $H_a$ | Vertical drop of accelerator plate, measured from weir crest to top of screen |
| $H_s$ | Head measured from upstream pool level to top of screen |
| $L$ | Length of weir crest |
| $p$ | Screen porosity |
| $Q$ | Discharge, volume per unit time |
| $q_{bypass}$ | Unit discharge overflowing screen panel, volume per unit time per foot of width |
| $q_{inflow}$ | Unit discharge approaching screen structure |
| $q_{screen}$ | Unit discharge through screen panel, volume per unit time per foot of width |
| $r$ | Radius of curvature of circular arc screens |
| $\mathrm{Re}$ | Reynolds number |
| $s$ | Slot width |
| $V$ | Flow velocity |
| $w$ | Wire width |
| $\theta_0$ | Incline angle at top edge of screen |
| $\theta_s$ | Included angle of circular arc screens |
| $\nu$ | Kinematic viscosity |
| $\phi$ | Wire tilt angle |

## INTRODUCTION

There is a growing need on water resources projects to screen water to remove and salvage fine debris and small aquatic organisms. This presents significant challenges for traditional screen technologies. As the target of the screening effort is reduced in size, screen openings generally must also be reduced and screen areas increased to obtain suitably low flow velocities through the screen. In most cases, maintenance effort required to keep screens clean is dramatically increased when finer material must be screened, even if velocities are kept low.

One screen design that offers potential for economically screening fine materials with a minimum of clogging and cleaning maintenance is the Coanda-effect screen (fig. 1), also known as the static inclined screen. This self-cleaning screen with no moving parts has been successfully used for debris and fish exclusion at several prototype sites (Ott et al. 1987). The screen is typically installed in the downstream face of an overflow weir. Screening capacities of 0.09-0.14 $m^3$/s per meter of weir length (1.0-1.5 $ft^3$/s/ft) have been reported. Coanda-effect screens have been commercially available for many years, but only in a limited number of configurations, and design information available to hydraulic engineers has previously been limited.

Wahl (2001) conducted extensive laboratory tests and developed a numerical model that can be used to predict Coanda-effect screen capacity and analyze the influence of design parameters. This testing included prototype-size Coanda-effect screen structures (fig. 2) and small screen “coupons” tested in a special flume to determine the discharge coefficients of tilted-wire screen materials

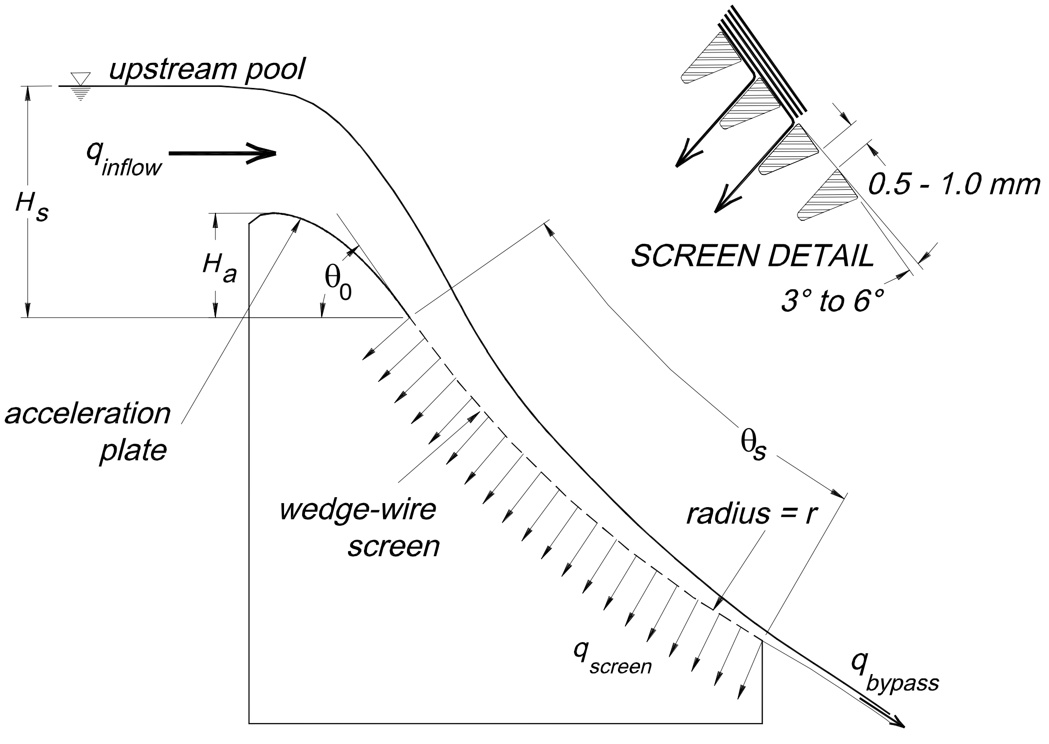


Figure 1. Features, typical arrangement, and design parameters for Coanda-effect screens.

Figure 2. A prototype-size Coanda-effect screen structure tested in the hydraulic laboratory.

(fig. 3). A computer program implementing this model is available from the Bureau of Reclamation at <www.usbr.gov/pmts/hydraulics_lab>

This research report presents the results of a study that used this computer program to model a variety of screen configurations to provide planners and designers with quantitative information about screen capacities and the effects of varying the many available design parameters.

## BACKGROUND

The concept of delivering water across an inclined screen to separate liquids and solids and promote transport of solids toward the downstream end of the screen has been applied for many years in a variety of screen designs used in the mining and wastewater treatment industries. Most of these screens utilize standard wedge-wire screen panels in which the top surface of each wire is parallel to the plane of the complete screen. Coanda-effect screens are an evolution of this screen design utilizing a tilted-wire screen panel, and in recent years have been applied to problems of debris and fish screening at irrigation diversions and small hydropower intakes. One specific Coanda-effect screen configuration has been marketed under the trade name Aqua Shear Static Intake Screen by Aquadyne, Inc., Healdsburg, CA. Some aspects of this screen design are described in U.S. Patent 4,415,462 (Finch and Strong 1983).

The primary features of a Coanda-effect screen installation are illustrated in figure 1. The screen is installed on the downstream face of an overflow weir. Flow passes over the crest of the weir, across a solid acceleration plate, and then across the screen panel, which is constructed of wedge-wire with the wires oriented horizontally,

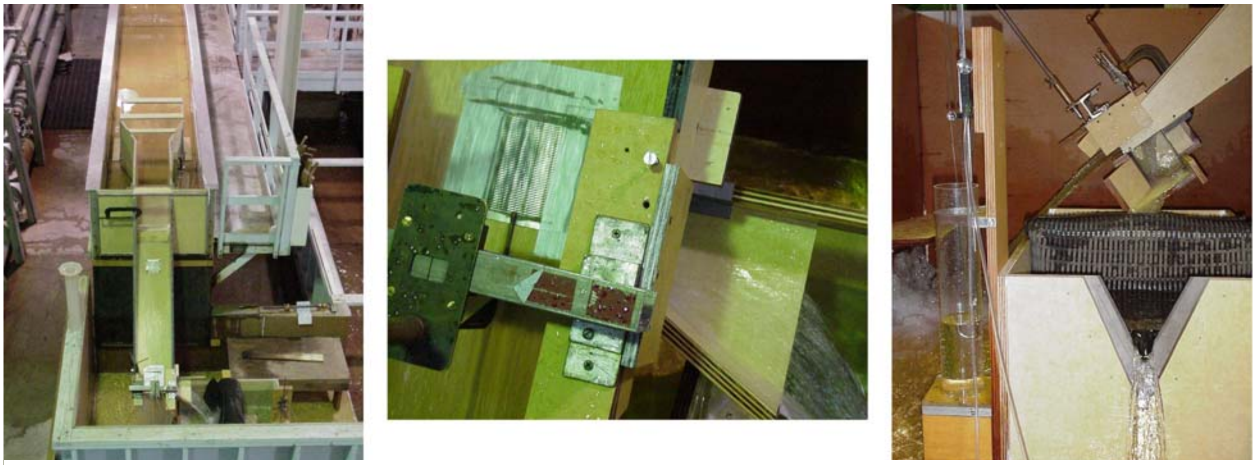


Figure 3. Flume testing of samples of tilted-wire screen panels. A pitot tube (center photo) measures the velocity across the screen surface, and a V-notch weir measures the flow passed through the sample screen.

perpendicular to the flow across the screen. Typically, the screen panel is a concave arc with a radius of curvature of approximately 3 m, although a planar screen panel can also be used. The crest of the weir and acceleration plate can be either an ogee-shaped profile or a simple circular arc; the primary objective is to provide a smooth acceleration of the flow as it drops over the crest, and to deliver the flow tangent to the screen surface at its upstream edge. Flow passing through the screen is collected in a conveyance channel below the screen, while overflow, debris, and fish pass off the downstream end of the screen. Flow velocities across the face of the screen are relatively large, on the order of 2 to 3 m/s in typical configurations, varying as a function of the drop height from the upstream pool to the start of the screen. Coanda-effect screens of this typical design have been applied at a number of field sites for debris removal upstream of small hydropower projects (Strong and Ott 1988), and for exclusion of unwanted fish and other organisms from wetlands (Strong 1989). Coanda-effect screens are also beginning to be applied as fish screens in situations where fish survival is the objective. Due to the dramatic differences in flow regimes for Coanda-effect screens as compared to typical fish screen designs (e.g., drum screens, flat-plate screens), biological testing is still needed to demonstrate fish survival and evaluate side-effects of fish passage over the screen (e.g., injury, disorientation, delayed passage, etc.). Buell (2000) has evaluated passage of juvenile salmonids over a prototype screen installed at the Coleman National Fish Hatchery, Anderson, California. Bestgen et al. (2001) evaluated the passage of fathead minnows over laboratory screens.

Coanda-effect screens make use of a unique type of wedge-wire screen panel in which the individual wires are tilted a few degrees downstream during manufacture to produce shearing offsets into the flow above the screen. The typical tilt angle is 5°, but angles of 3° to 6° are available from most screen manufacturers, and tilt angles can be controlled during manufacturing to ± 0.25° (personal communication, James Strong, Aquadyne, Inc.). Wires are typically spaced to produce 1 mm or smaller openings. The detail in figure 1 illustrates the wire tilt and its interaction with the flow. If wires are not tilted, the flow would simply skip from the trailing edge of one wire to the leading edge of the next, and the only flow that would pass through the screen would be due to gravity deflecting the jet slightly downward as it crosses the opening between the wires. At typical velocities and screen openings, this deflection is very slight. However, with tilted wires, the offset produced at each wire is able to shear a layer of flow of significant thickness off the bottom of the water column and direct it out the bottom side of the screen. This shearing action is enhanced by the fact that the flow remains attached to the top surface of each wire and is thus directed into the offset created at the next downstream wire. This attachment of the flow to the top surface of each wire is an example of the Coanda effect, the tendency of a fluid jet to remain attached to a solid flow boundary.

The Coanda effect is familiar to most hydraulicians, although perhaps not by name. The effect was first observed in 1910 by Henri-Marie Coanda, in connection with exhaust flow from an experimental jet engine (Stine 1989). When a jet is discharged along a solid boundary, flow entrainment into the jet is inhibited on the surface side. For the jet to separate from the surface there must be flow entrainment into the jet on the surface side beginning at the separation point. However, the close proximity of the surface limits the supply of fluid needed to feed such entrainment. Thus, the jet tends to remain attached to the surface. If the surface deviates sharply away from the jet, separation will occur, but if the surface curves gradually away, the flow may remain attached for long distances. Primary applications of the Coanda effect have been in aeronautics; wings and engines using the effect have achieved increased lift and thrust. Reba (1966) describes experimental work on propulsion systems using the Coanda effect, including hydrofoils, jet engines, and a levitating vehicle. The Coanda effect has also proved useful in the design of improved nozzles for combustion applications, ventilators for medical use, and a variety of other industrial applications.

## DESIGN PARAMETERS

A number of design parameters affect the capacity of a Coanda-effect screen structure. Some of these parameters are primarily related to the structure:

- Drop height from upstream pool to start of screen (or from upstream weir crest to start of screen)
- Screen slope
- Curvature (arc radius) of screen
- Length of screen

Others are properties of the screen material:

- Slot width
- Wire width
- Wire tilt angle

Finally, the hydraulic operating conditions affect the flow through the screen:

- Bypass flow
- Backpressure beneath the screen surface
- Tailwater depth against screen

This report determines the capacity curves for a number of reference screens and then analyzes the influence of the structure and screen design parameters. The influence of bypass flow is incorporated into the reference screen capacity curves, and the sensitivity of screen capacities to changes in bypass flow conditions is considered in the analysis of several of the design parameters. The modeling described in this report assumes that there is no backpressure beneath the screen surface and that the tailwater depth is lower than the downstream toe of the screen.

## SCREEN CAPACITY – BASIC CONCEPTS

Coanda-effect screen capacity is expressed as the discharge (volume / time) passing through the screen surface per unit width of screen or crest, or the *unit discharge*. There are three unit discharges of interest, the inflow to the screen (flow over the crest), the flow through the screen, and the bypass flow over the screen that is discharged off the downstream toe. At very low inflow rates, all flow passes through the screen and there is no bypass flow; a portion of the downstream end of the screen is dry. As inflow increases, the wetted length of the screen increases until the screen is fully wetted, at which point bypass flow begins. As the inflow is further increased, the flow through the screen and the bypass flow both increase (bypass flow increasing faster), as the depth of flow over the screen increases.

Flow passes through the screen by a combination of two mechanisms. First, the tilted wires shear off thin layers of the flow from the bottom of the water column and direct them through the screen. Second, the pressure of the water against the screen causes flow to pass through the slots as though they were simple orifices. Both phenomena act simultaneously in varying degrees, depending on the properties of the screen surface and the characteristics of the flow over the screen. The shearing action is primarily related to the amount of wire tilt and the velocity of the flow across the screen. As the velocity is increased, the shearing action becomes more dominant. The orifice behavior is primarily related to the porosity, or percentage of open screen area (i.e., the slot width relative to the wire thickness), and the pressure against the screen surface, which is proportional to the flow depth. For curved screens, the pressure is also increased by the radial force exerted on the flow to cause it to follow the curved surface (assuming a concave screen). This radial force is proportional to the depth of flow, the square of the flow velocity, and the degree of curvature. Other factors also have a minor influence on the screen capacity (e.g., Reynolds number effects). Important dimensionless parameters describing the relative influence of the shearing and orifice components are the ratios $\mathsf{F}^2/(2+\mathsf{F}^2)$ and $2/(2+\mathsf{F}^2)$, respectively, where $\mathsf{F}$ is the Froude number of the flow (Wahl 2001).

It will be valuable to keep in mind the concept of the flow through the screen being made up of two parts, a shearing component and an orifice-flow component. As we examine the influence of different design parameters, this concept will repeatedly be illustrated and will help to explain the changing sensitivity of screen capacity to different design parameters as flow conditions vary.

## RELATION BETWEEN SCREEN INCLINE AND DROP HEIGHT

As described earlier, the accelerator plate provides a smooth transition between the tranquil flow condition upstream from the structure and the rapid flow across the screen face. The flow should accelerate smoothly and be delivered tangent to the screen surface for best performance. The ideal accelerator plate profile is an ogee shape—the trajectory of a free-falling jet passing over a weir under the influence of gravity. This shape fully supports the flow as it passes over the weir. The ideal ogee shape is different for each unit discharge and also varies slightly depending on the flow depth and velocity in the upstream pool. The ogee shape is described by a power equation so that the slope of the freely falling jet increases continuously in the downstream direction. If a specific screen incline angle is desired, one must determine the point along the ogee-shaped curve at which that slope occurs, and install the screen at that point so that it is tangent to the ogee shape. Thus, for a given discharge and screen angle, the drop height will be determined by the ogee shape for that discharge. Similarly, if a specific vertical drop height is desired, that will determine the slope of the screen. If a specific combination of drop height and screen slope is desired, it can only be obtained at a single unit discharge; for larger unit discharges the ogee shape will produce a flatter screen at the same drop height, and for smaller unit discharges the ogee shape will be steeper at the same drop height (figure 4).

Figure 4. Ogee crest profile shapes for different design discharges.

At a specific site, the accelerator plate must have one definite shape, i.e., the shape is selected to match the ogee profile for a specific design discharge. For smaller discharges, the shape will support the flow somewhat (thereby reducing the discharge coefficient of the crest), and for larger discharges the shape will be steeper than the theoretical jet trajectory. In this latter case, the result will be negative pressures on the face of the crest, or possible separation of the flow from the ogee surface. Either condition will cause a reduction in flow through the screen, with actual flow separation being the most severe problem. To avoid this problem, the crest shape should be designed for the maximum discharge likely to occur over the structure; for all lower discharges the flow will be supported by the crest and will be delivered tangent to the screen surface with a positive pressure against the screen. This is a conservative design philosophy, since testing of ogee-shaped spillway crests has shown that flow separation in ideal cases will not occur until the actual head far exceeds the design head (in some cases up to 6 or 7 times the design head).

Accelerator plates need not have a perfect ogee shape, and in fact on most commercially available screens they have been constructed as circular arcs for simplicity. The *Coanda* computer program, as described later, can determine the ogee shape for a given discharge and then determine the corresponding possible combinations of drop heights and screen incline angles. Alternatively, the program can determine the design discharge of an ogee shape having a specific slope (incline angle) at a given vertical drop height. This feature can be used to estimate the allowable discharge over a non-ogee shaped accelerator plate. A non-ogee shaped accelerator plate will of course experience some localized negative pressures at this design discharge, but should not experience flow separation as long as the shape is smooth without offsets or other flow disruptions.

Figure 5 can be used to determine the drop height, screen inclination, or design discharge of an ogee crest accelerator plate when any two of these three parameters is known. The curves were developed by application of the design equations and curves for ogee crest spillways contained in *Design of Small Dams*, 3rd edition (Reclamation 1987). For example, if an incline angle of 45° is desired and the design

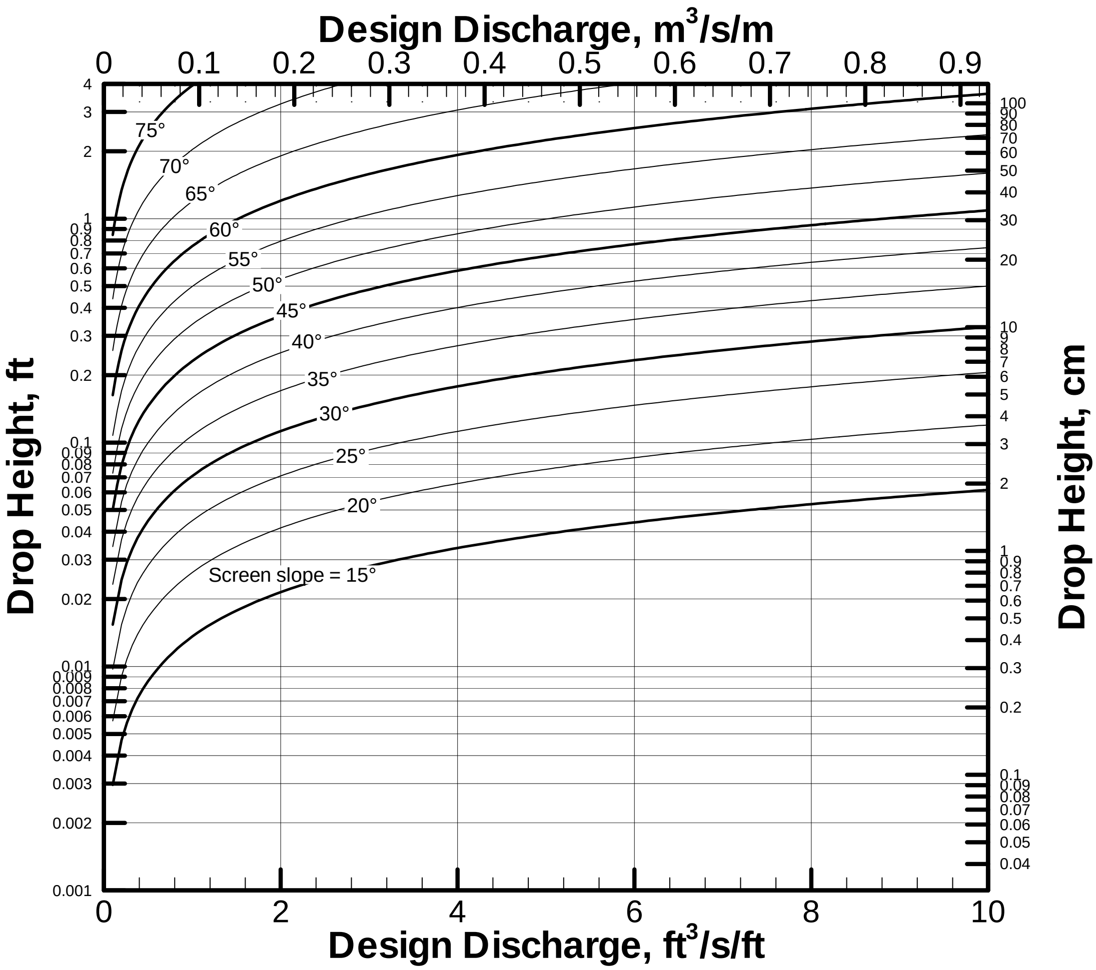


Figure 5.  Design parameters for ogee crest accelerator plates.

discharge is 1 $ft^3/s/ft$, Figure 5 shows that the drop height would be about 0.23 ft.

Similarly, if the design discharge is 1.2 $ft^3/s/ft$ and a drop height of 0.5 ft is desired, the screen angle would be about 53º. Finally, if a drop height of 0.5 ft and a screen angle of 40º are desired, the design discharge is about 5.6 $ft^3/s/ft$.

## REFERENCE SCREENS

To provide a starting point for the selection and sizing of Coanda-effect screens, detailed capacity curves are presented for several reference screens. The capacities of these reference screens can be adjusted to account for other design variations using the information presented later in the section titled Effect of Design Parameters. The reference screens utilize typical screen materials and structure dimensions, and are provided in both metric and English units.

The reference screen capacity curves show the wetted length of screen and the flow rate through the screen as a function of the inflow rate. The percentage of bypass flow and screened flow are also shown. The sensitivity analysis in the next section shows how the zero-bypass capacity of screens varies as a function of various design parameters. For some design parameters, the 20%-bypass capacity is also analyzed.

### English Reference Screens

Capacity curves for the English reference screens are given in figures 6 through 10. Figure 6 is for a concave screen starting at an incline angle of 60° and bending through 25° of arc. All of the other reference screens are planar, with variation of the screen slope and/or slot width. The planar screens are appropriate for sites where limited head (i.e., 0.75 to 2.5 ft) might be available, while the concave screen is similar to the commercial Aquadyne screen and requires about 4 to 5 ft of head.

### Metric Reference Screens

Capacity curves for the metric reference screens are given in figures 11 through 15. Figure 11 is for a concave screen that requires about 1.25 to 1.5 m of head for operation. The other reference screens are planar and require head drops of about 0.25 to 0.75 m.

## EFFECT OF DESIGN PARAMETERS

The information in this section can be used to adjust the capacities of the reference screens for planning purposes, and also provides the designer with an understanding of the relative influence of changing the various design parameters. Knowing which parameters most strongly affect screen capacity will allow designers to efficiently consider important design variations and avoid analysis of unimportant alternatives. Adjustments to the reference screen capacities should be considered as estimates only; for accurate determination of the capacity of a specific design, the computer model should be used (see <www.usbr.gov/pmts/hydraulics_lab>).

Unless otherwise noted, the base screen structure for all of the following analyses is a 1-m long screen with a 0.1-m vertical drop across the accelerator plate. The screen panel uses 0.060” (1.524 mm) thick wires with a slot opening of 1 mm and a wire tilt angle of $\phi$=5°. Also unless noted, all capacities were determined at a zero-bypass flow condition with the screen length fully wetted.

### Accelerator Drop Height

Figure 16 shows the effect of changing the vertical drop across the accelerator plate, for the base screen installed at 3 different incline angles. The details of the accelerator plate shape are not important, as long as the plate delivers the flow smoothly tangent to the top of the screen. For the screen installed at a 10° incline the capacity increases significantly as the drop height is reduced. For steeper incline angles, this effect is reduced, and an incline angle of 60° causes the screen capacity to reach a minimum at a drop height of about 0.1 m and increase slightly for higher drop heights.

The reason for these differences is that the flatter screens have a larger component of orifice flow and a smaller component of shearing flow. Orifice flow is further increased when the accelerator drop height is reduced, since this increases the depth of flow above the screens. By contrast, for the steeper screen, shearing flow is more dominant, and shearing flow is increased when the drop height increases, since this increases the velocity across the screen.

One might conclude from this that the accelerator plate and its associated drop should be eliminated entirely. However, an important consideration when selecting the drop height is the effect it has on the velocity at the top edge of the screen. Fontein (1965) suggested that the Reynolds number of the flow across the screen surface

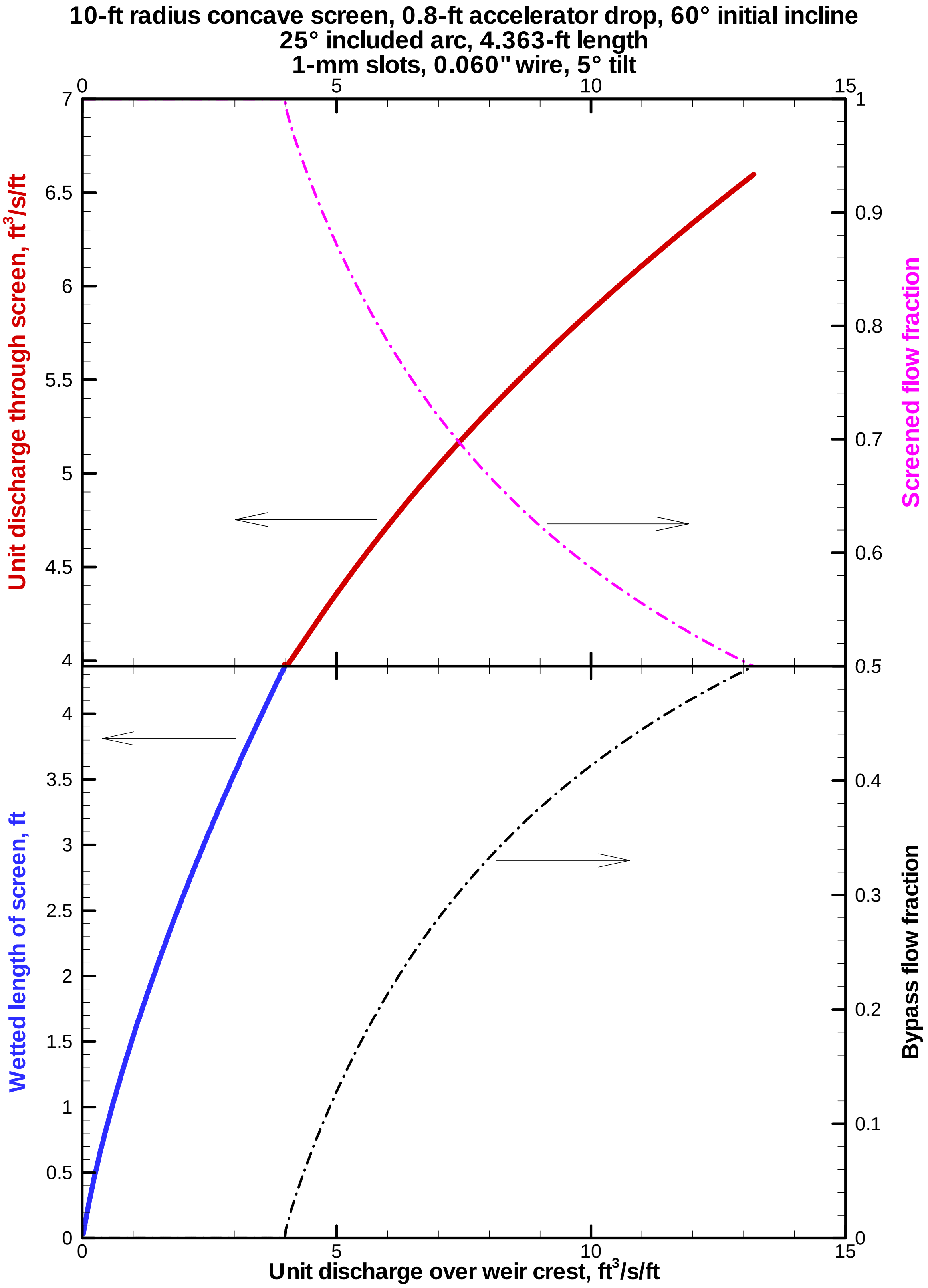


Figure 6. Concave reference screen in English units.

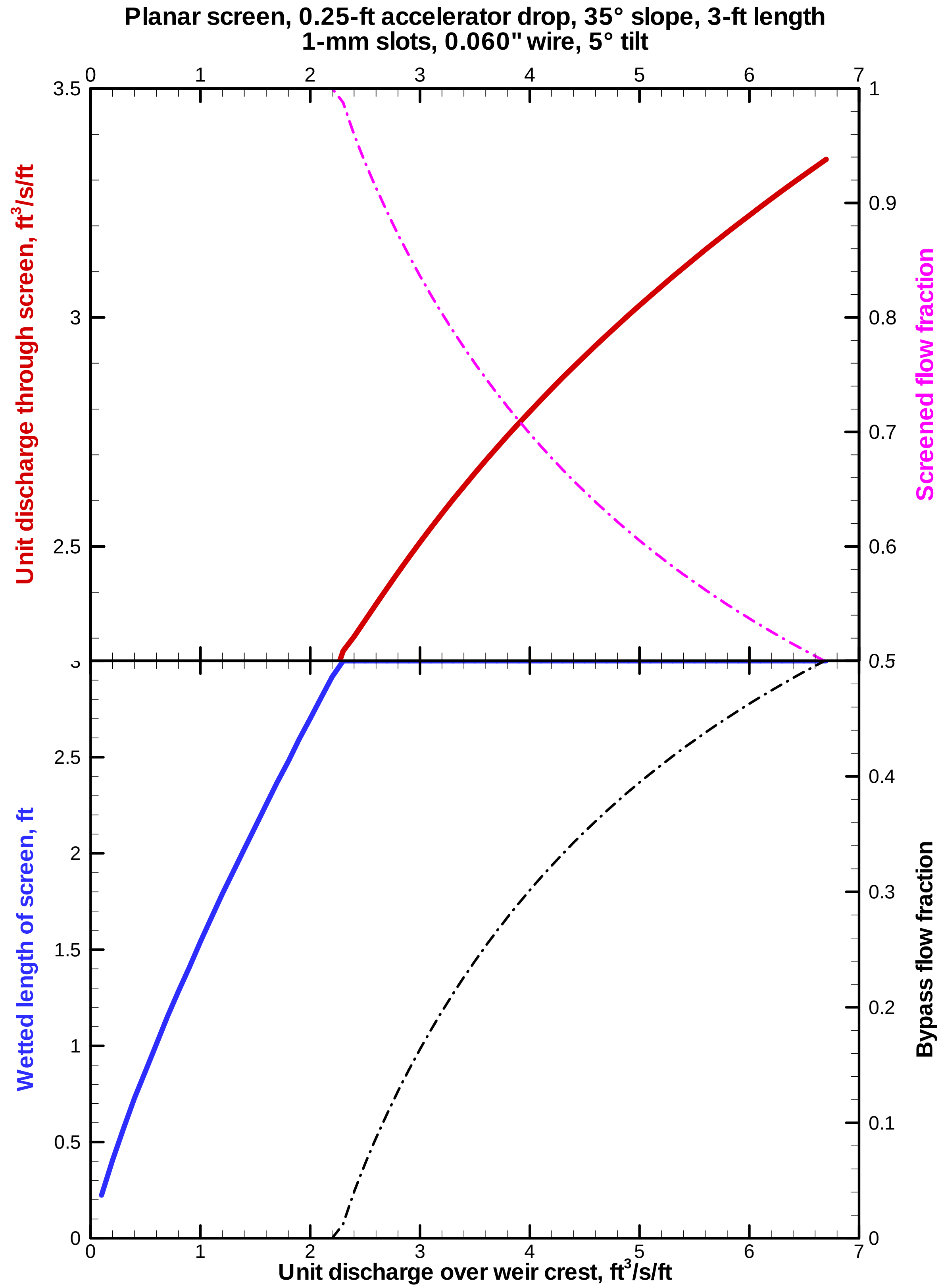


Figure 7. Planar reference screen, English units, 35° incline.

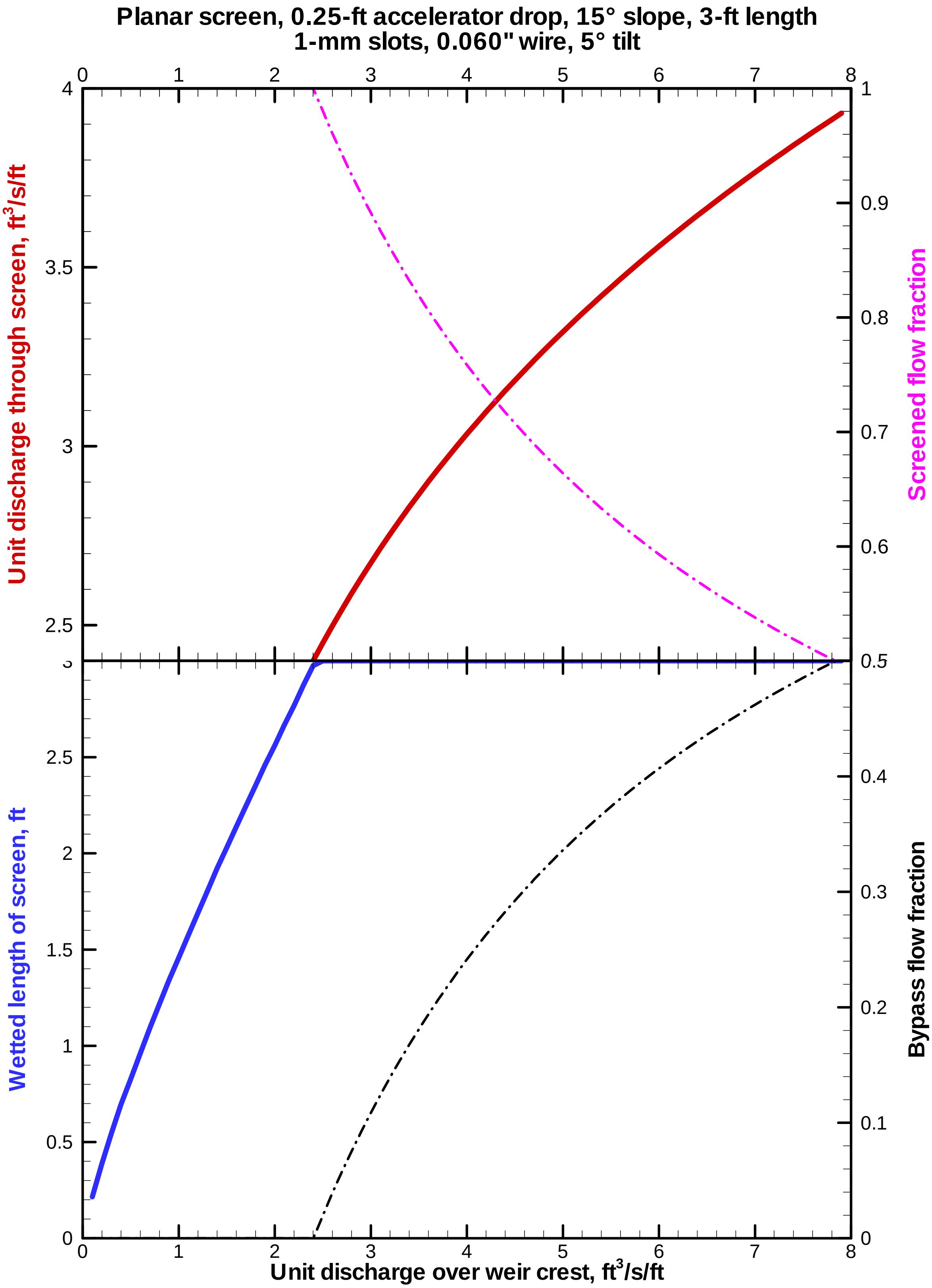


Figure 8. Planar reference screen, English units, 15˚ incline.

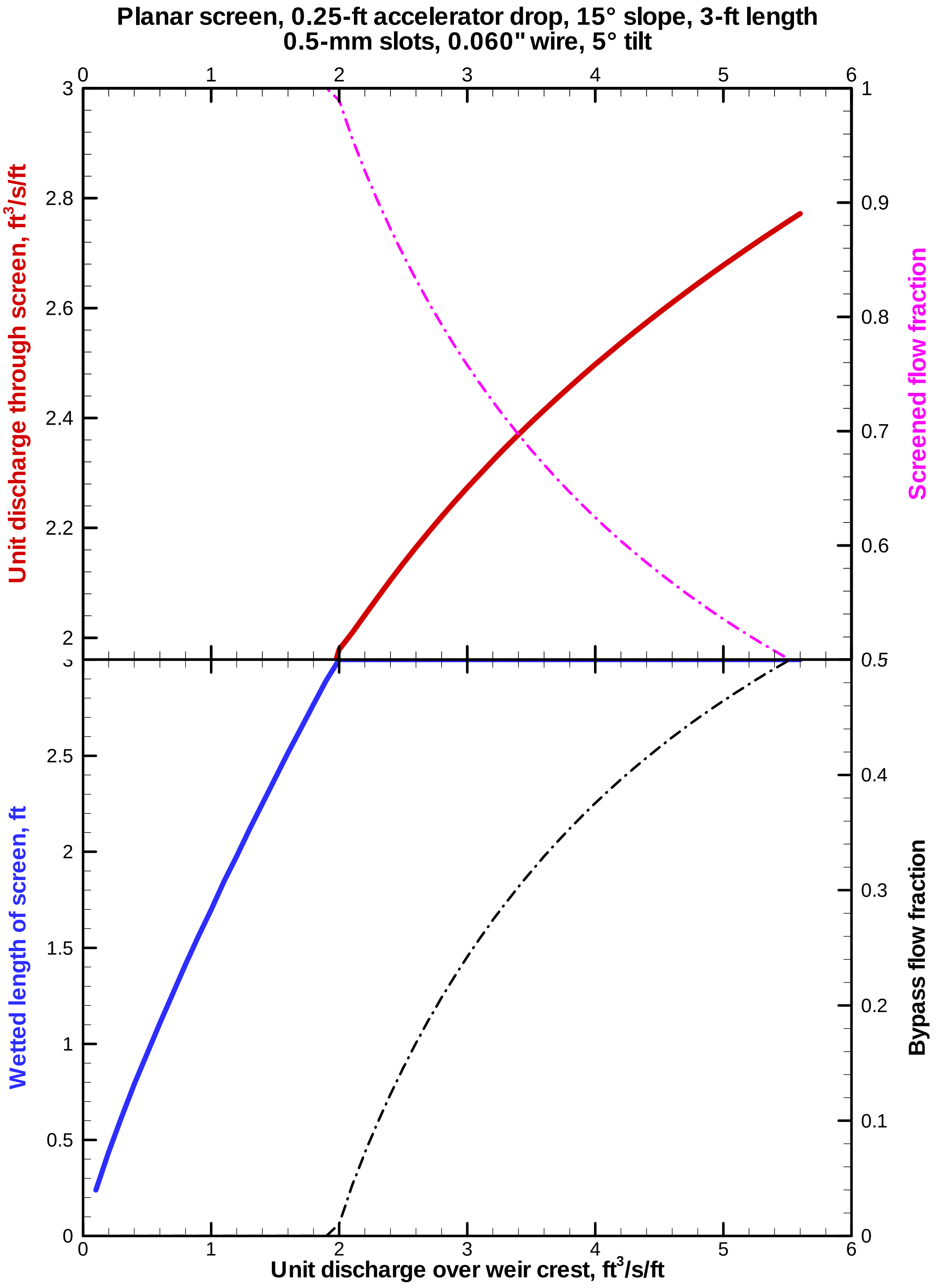


Figure 9. Planar reference screen, English units, 15° incline, 0.5-millimeter slots.

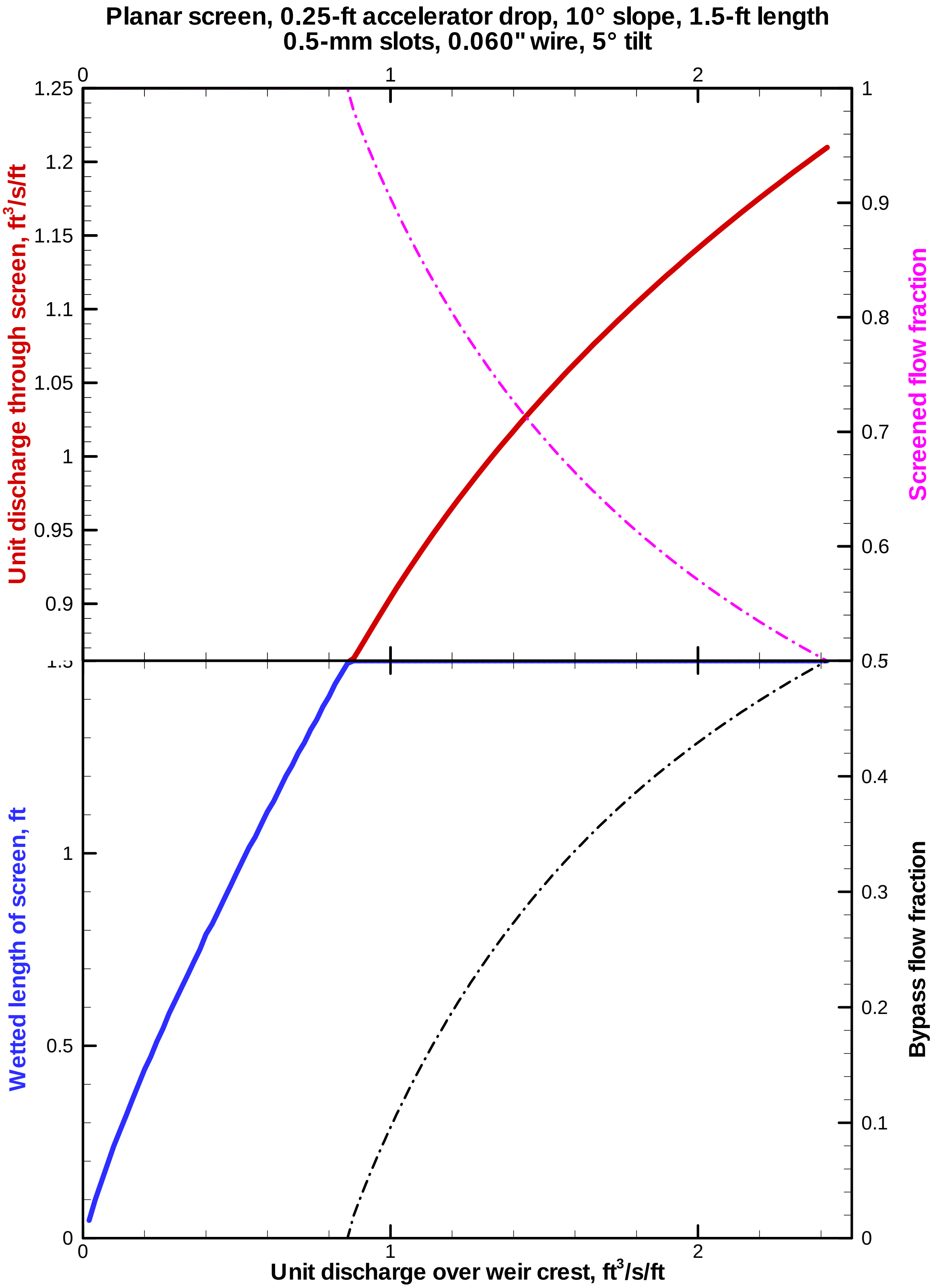


Figure 10. Planar reference screen for low-head applications. English units, 10˚ incline, 0.5-millimeter slots, 1.5-foot length.

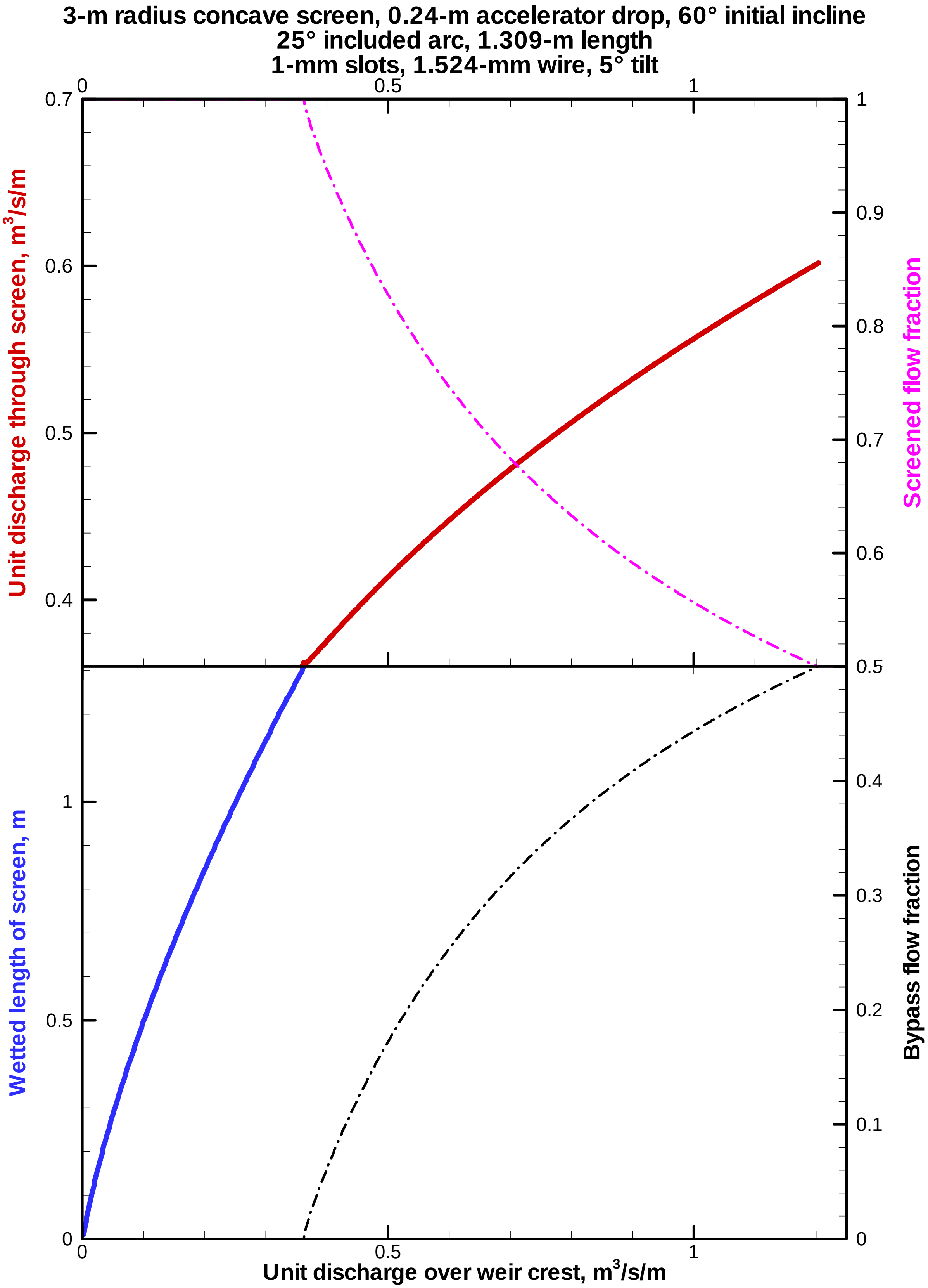


Figure 11. Concave reference screen in metric units.

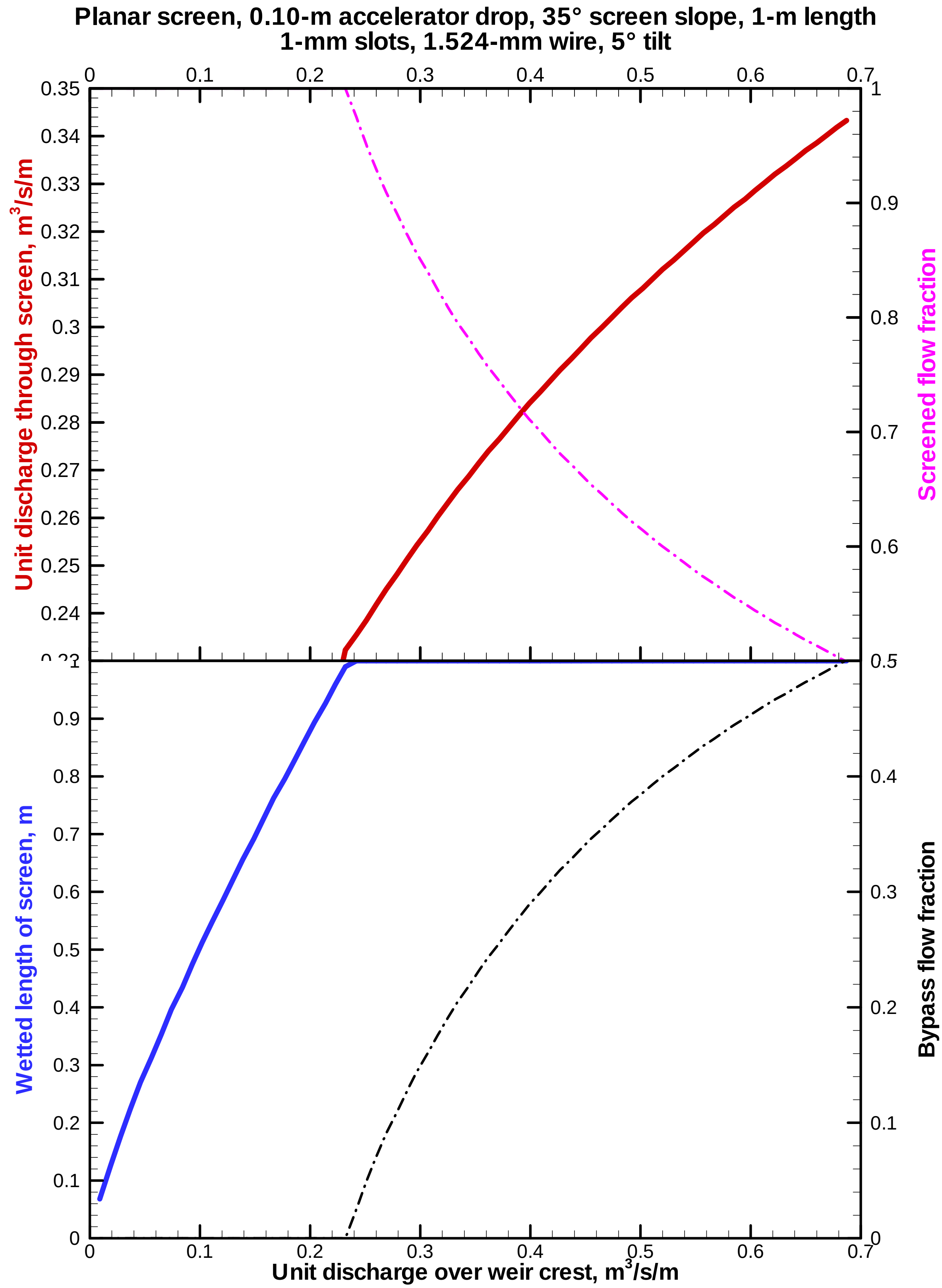


Figure 12. Planar reference screen, metric units, 35˚ incline.

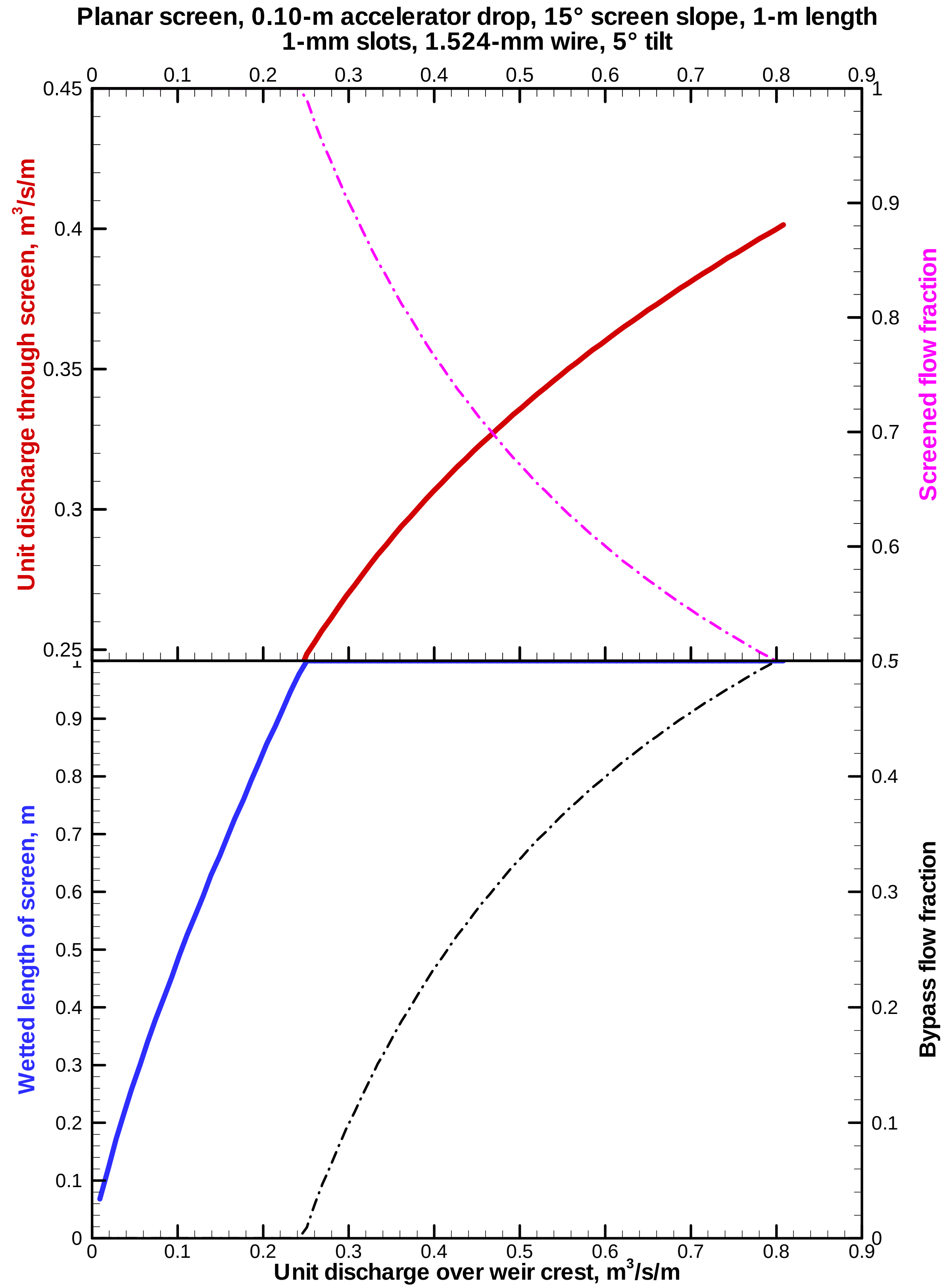


Figure 13. Planar reference screen, metric units, 15°incline.

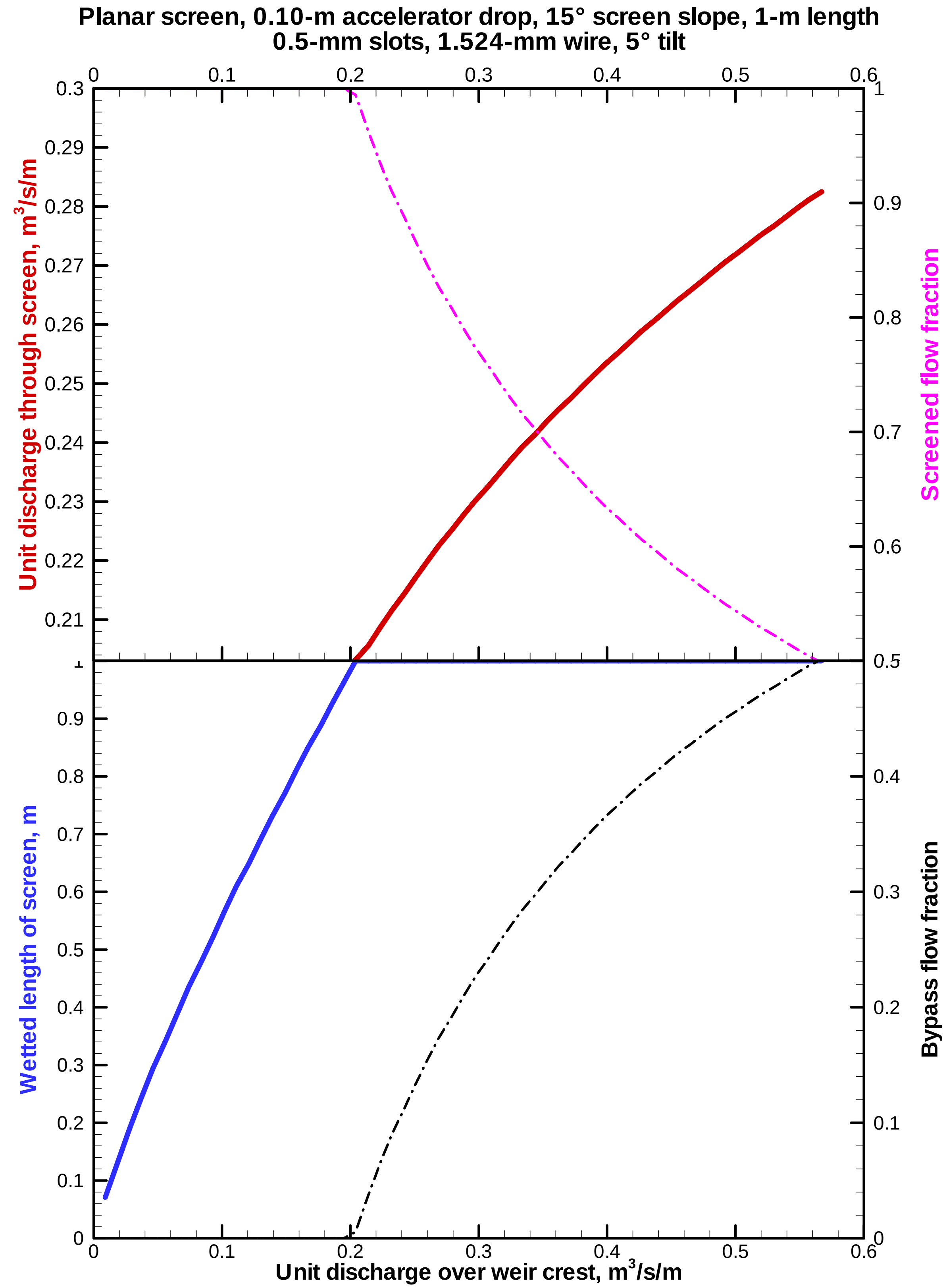


Figure 14. Planar reference screen, metric units, 15°incline, 0.5-millimeter slots.

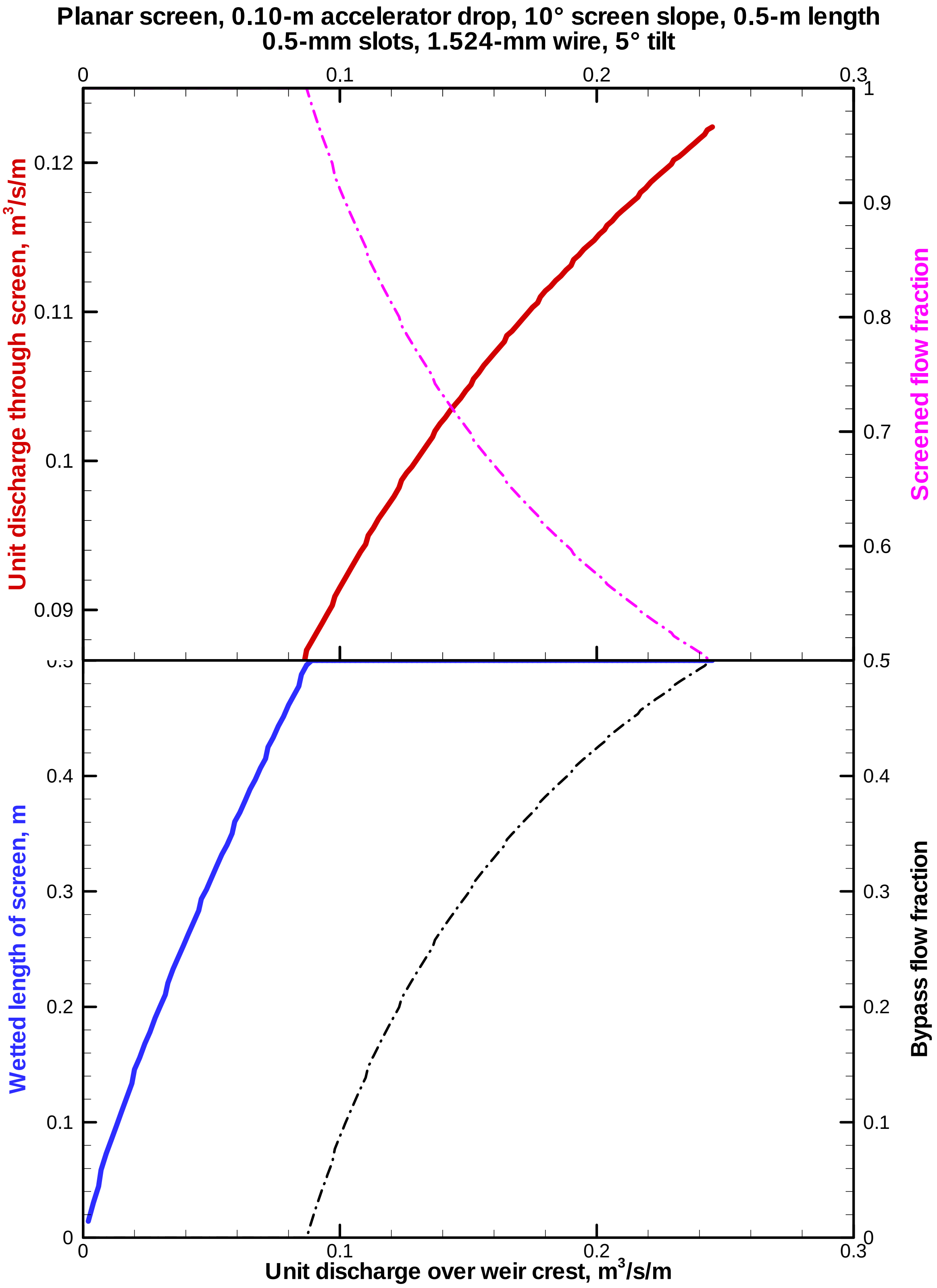


Figure 15. Planar reference screen for low-head applications, metric units, 10˚ incline, 0.5-millimeter slots, 0.5-meter length.

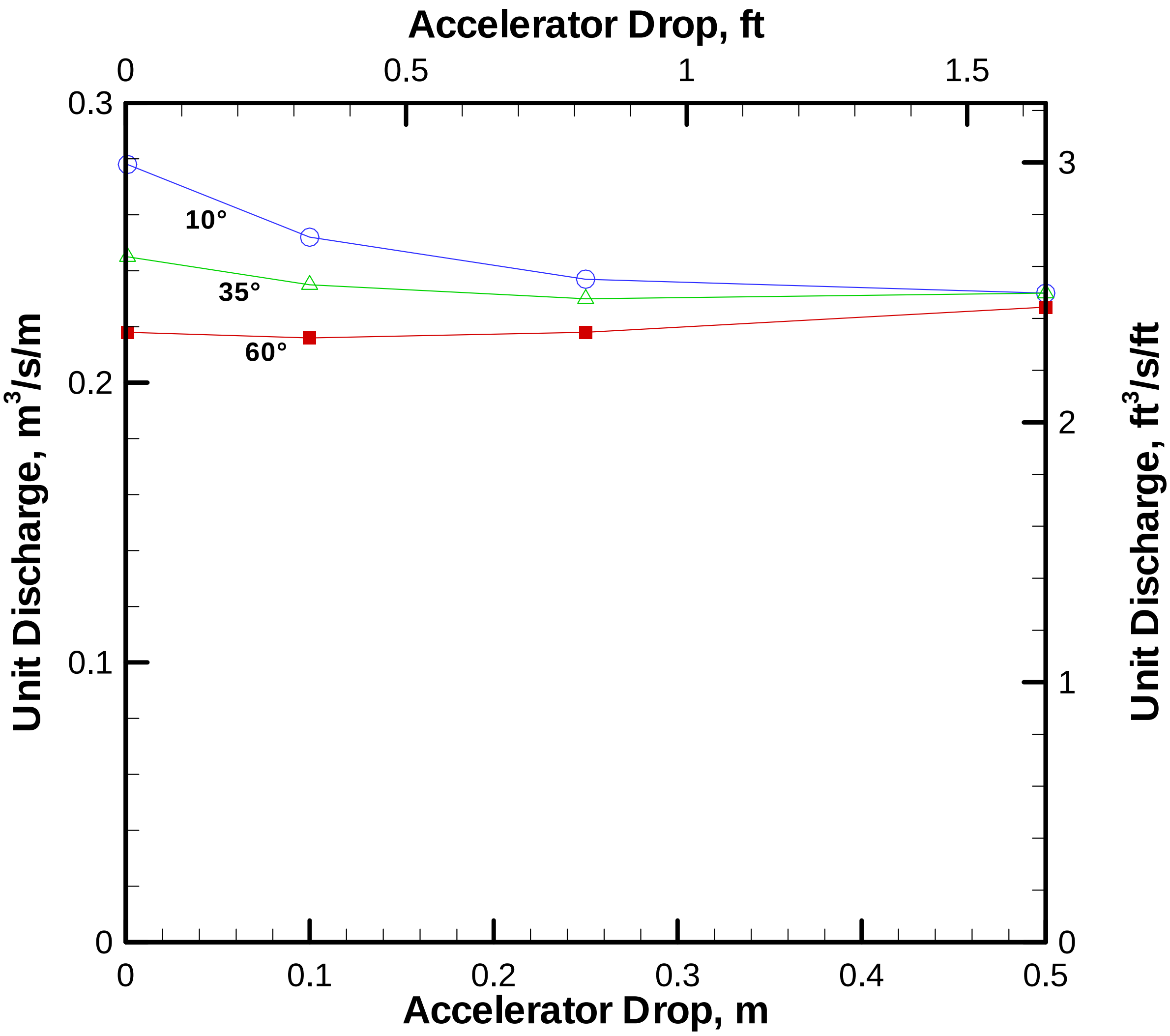


Figure 16. Effect of accelerator plate drop height on unit discharge through screen.

should be kept above 1000 to ensure adequate self-cleaning of the screen (Re=*Vs*/ν, where *V* is the velocity, *s* is the slot width, and *v* is the kinematic viscosity). For a slot width of 0.5 mm this corresponds to a velocity of about 2.1 m/s (6.9 ft/s), and for a slot width of 1.0 mm the required velocity is 1.05 m/s (3.45 ft/s). Providing at least a small amount of vertical drop ensures that this velocity can be achieved at the leading edge of the screen, and the accelerator plate helps to align the flow smoothly tangent to the beginning of the screen.

## Effect of Screen Slope

Figure 17 shows the effect of changing the screen slope. The solid line is for the base screen described previously. Discharge through the screen varies linearly with changing screen angle. To examine the secondary effects of screen material properties on the relationship between screen angle and discharge, four other alternatives were analyzed. The two dashed lines show that changing the wire tilt angle increases or decreases the capacity, and this is slightly more pronounced at higher slopes,

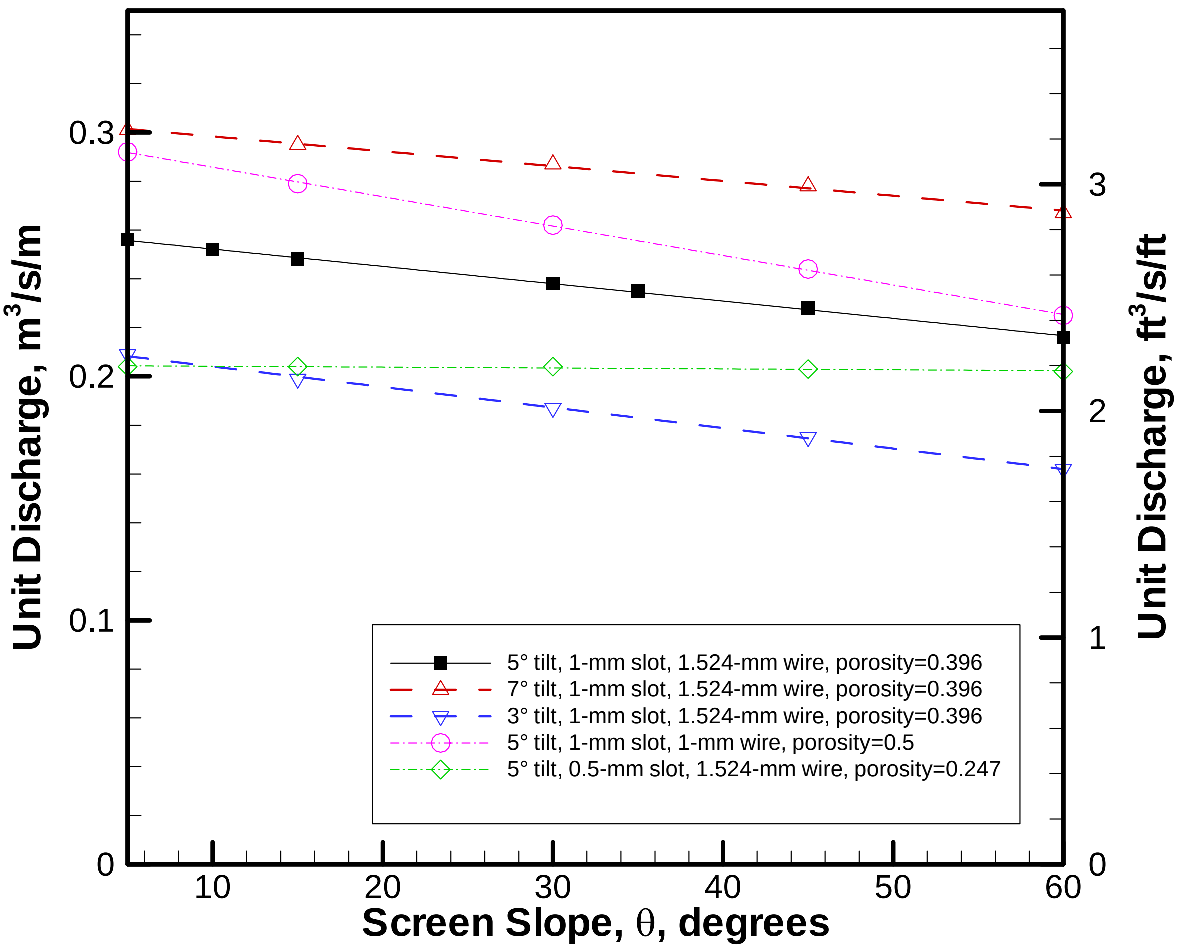


Figure 17. Effect of screen slope on unit discharge through screen.

where shearing flow becomes more dominant. Conversely, the dash-dot lines show the effect of changing the screen porosity, either by changing the slot width or wire width. The effect of changing the porosity is more pronounced at low screen angles, where orifice flow is more important than shearing flow. It should be noted that with a wire tilt of 5° and a porosity of 0.247, the screen slope has almost no effect on capacity. This indicates that for this screen the orifice and shearing flow components are approximately balanced.

### Effect of Screen Length

Screen length obviously has an important influence on total screening capacity. Figure 18 shows that capacity increases nonlinearly with increasing length. For the base screen analyzed here, the screening capacity is proportional to about $L^{1.24}$, where $L$ is the screen length. Changes in the surface properties of the screen (wire tilt angle, slot width, wire width) would be expected to change this relationship to some degree.

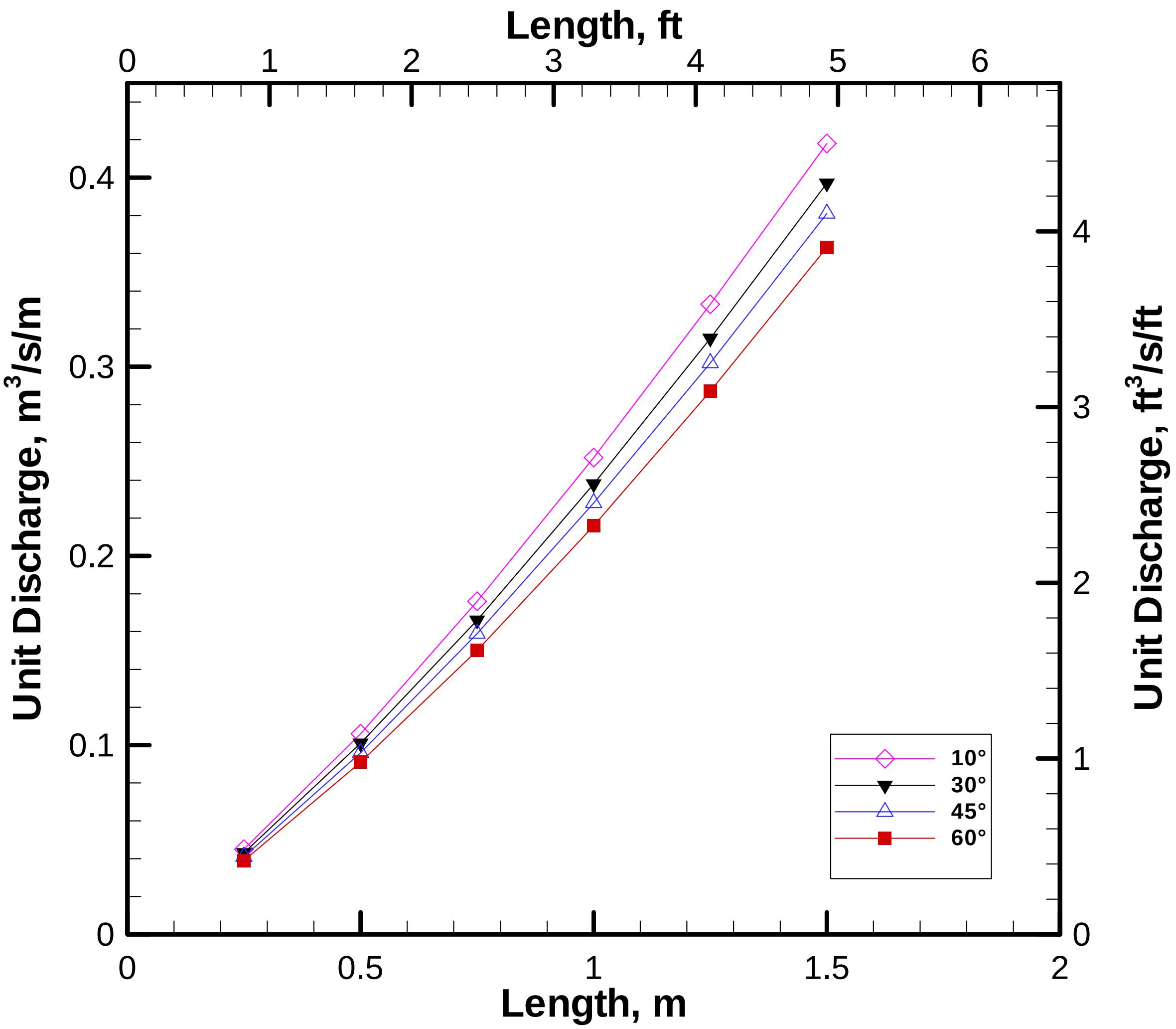


Figure 18. Effect of screen length on unit discharge through screen, at a zero-bypass condition. For all four slopes, the discharge is approximately proportional to $L^{1.24}$, where $L$ is the screen length.

## Effect of Screen Curvature

Commercially available screens have often utilized a concave screen panel. The concave panel allows for a steep slope at the start of the screen with a flatter slope at the toe where bypass flow is discharged downstream. This may help reduce erosion in the downstream channel if it is not otherwise protected. The concave screen panel also allows for a small increase in screen length compared to a planar screen structure having the same total vertical drop and streamwise width. Finally, the concave panel increases the pressure on the screen face which increases the orifice component of flow.

Figure 19 shows the effect of changing the screen curvature (arc radius). The base screen design is similar to the planar screen described earlier. The accelerator drop is 0.1 m, the screen incline at the top edge is 60° from horizontal, and the screen length is 1 m in all cases. The screen panel is the

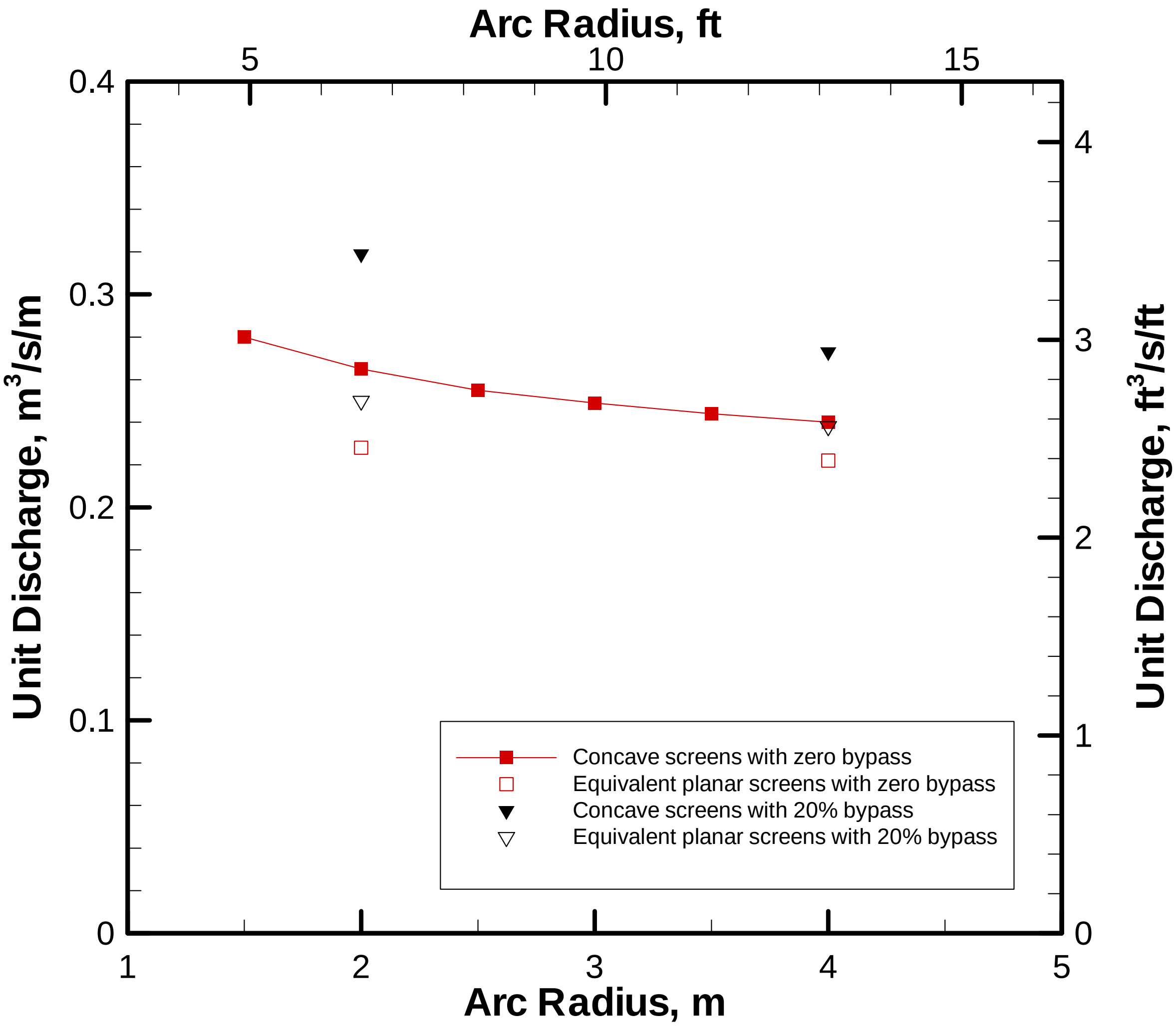


Figure 19. Effect of screen curvature on unit discharge through screen.

same as that used previously, 1 mm slots, 5° wire tilt, and 0.060” wires. As the arc radius is changed, the discharge angle at the bottom of the screen changes, and the total head drop required for the structure changes. The figure shows that increasing the curvature (reducing the arc radius) does increase capacity, even though it is reducing the total head across the structure. For comparison, the capacities of equivalent planar screens (screens having a 1 m length and a slope that produces the same drop height as the curved screen) were analyzed for two cases. The increases in discharge for the concave screens were 16.2% for the 2-m radius screen and 8.1% for the 4-m radius screen. Similarly, concave and equivalent planar screens were examined at a 20 percent bypass flow condition, and the capacity increases for the concave screens over the planar screens were 14.7% and 27.6%, respectively. This is consistent with the fact that flow depths over the screen face are greater when some bypass flow is occurring, and the pressure increase caused by streamline curvature is proportional to the flow depth.

### Effect of Screen Properties

The screen properties of slot width, wire width, and wire tilt angle can significantly affect screen capacity. Slot width and wire width both affect screen porosity, which affects the amount of orifice-type flow through the screen surface. Wire tilt angle affects the shearing of flow through the screen.

Figure 20 shows the effect of slot width, at three different screen incline angles. Capacity becomes more sensitive to slot width as the screen incline angle becomes flatter. For the 35° incline, the performance at a 20% bypass condition is also shown, and the effect of the bypass flow is to further increase the sensitivity of the capacity to the slot width. These observations are all consistent with the fact that the slot width affects orifice-type flow. If the lines on figure 20 were projected to the left axis (i.e., to a slot width of zero), the unit discharge at that point would be the amount associated with shearing by the tilted wires.

Figure 21 shows the effect of the wire width, which is essentially the inverse of the effect of the slot width. Discharge through the screen decreases with increasing wire width, and is more sensitive to the wire width at flatter screen incline angles. Again, when operating with some bypass flow, the capacity is more sensitive to the wire width. If the lines on figure 21 were projected to the right (i.e., to a large wire width), the unit discharge that they approach would be the amount associated with shearing by the tilted wires.

Figure 22 shows the effect of the screen porosity, $p=s/(s+w)$, where $s$ is the slot width and $w$ is the wire width. Trends similar to those in figures 20 and 21 are evident, except that the relationship between capacity and porosity appears to be almost perfectly linear. At a porosity of about 0.25, the capacity is independent of the screen slope, a fact we also noted earlier while discussing the effect of the screen slope. Again, if the lines are projected to the left axis and a porosity of zero, the remaining capacity would be that associated with shearing by the tilted wires.

Figure 23 shows the effect of changing the wire tilt angle. Increasing the tilt angle causes an almost linear increase in discharge through the screen, and this effect is most pronounced for the steeper screens. The total capacity of the flatter screens is higher than that of the steeper screens because the orifice component of flow is greater. Projecting the lines to the left axis (no wire tilt) indicates the orifice component of the flow. Wire tilts greater than about 7° are reported to have poor performance due to separation of the flow from the wires (loss of the Coanda effect).

### Effect of Bypass Flow

The effects of bypass flow have already become somewhat apparent through the analysis of the reference screens and the effects of the other parameters. The presence of bypass flow means that flow depths across the screen are greater, and this tends to increase the amount of orifice-type flow through the screen and increase the sensitivity of the screen performance to other variables that affect orifice-type flow (e.g., porosity). Figure 24 shows the effect of bypass flow at different screen incline angles, and reaffirms this observation. The effect of bypass flow is most pronounced for the flatter angles, where orifice-type flow is dominant over shearing flow.

## EXAMPLE SCREEN EVALUATION

To demonstrate the application of the design tools provided in this report we will step through the selection of a screen for a hypothetical application. An earthen

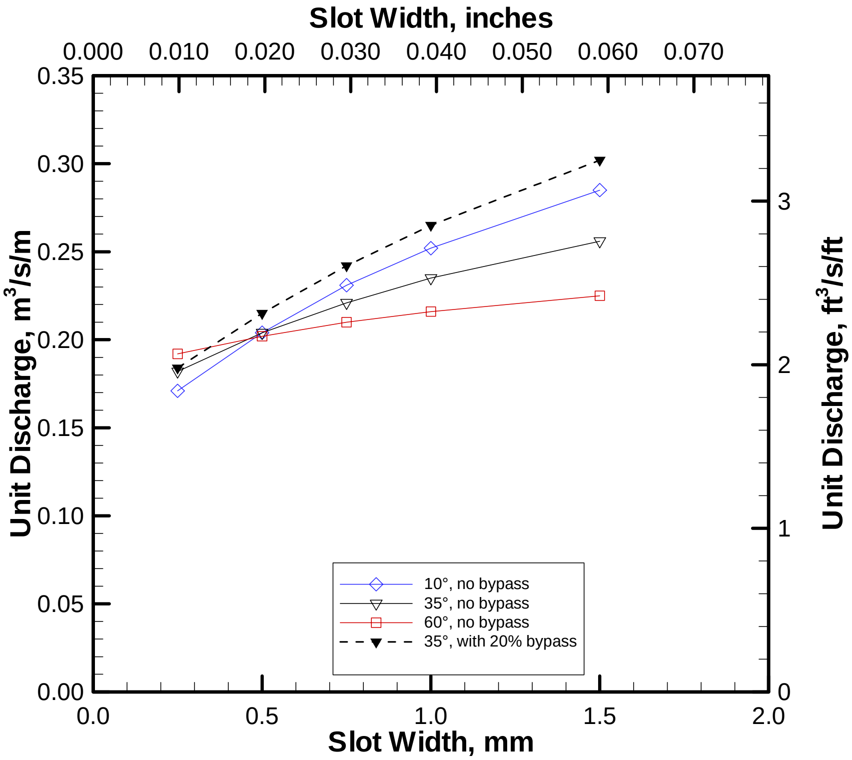


Figure 20. Effect of slot width on unit discharge through screen.

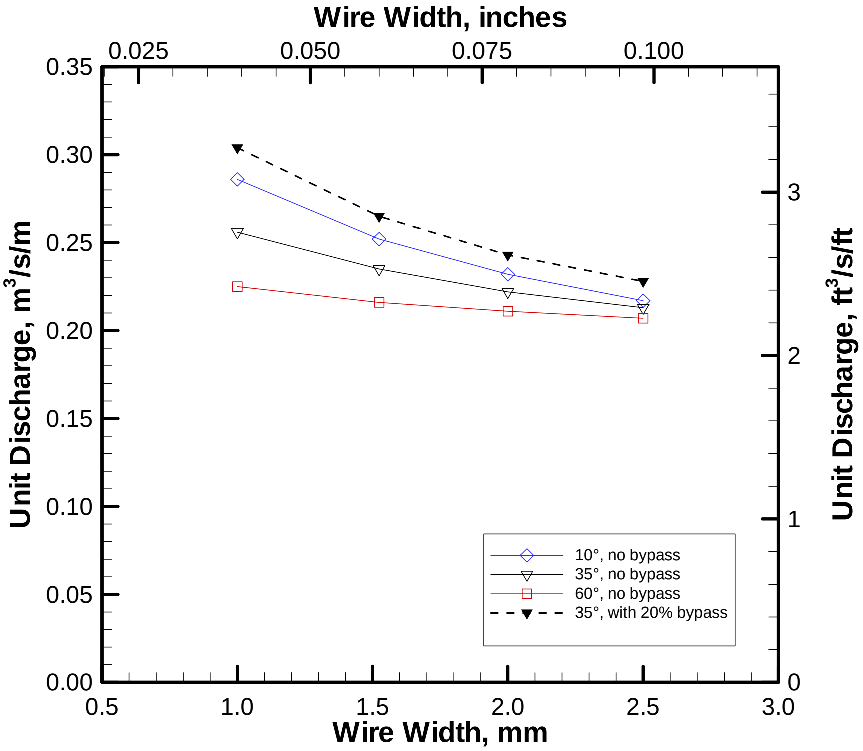


Figure 21. Effect of wire width on unit discharge through screen.

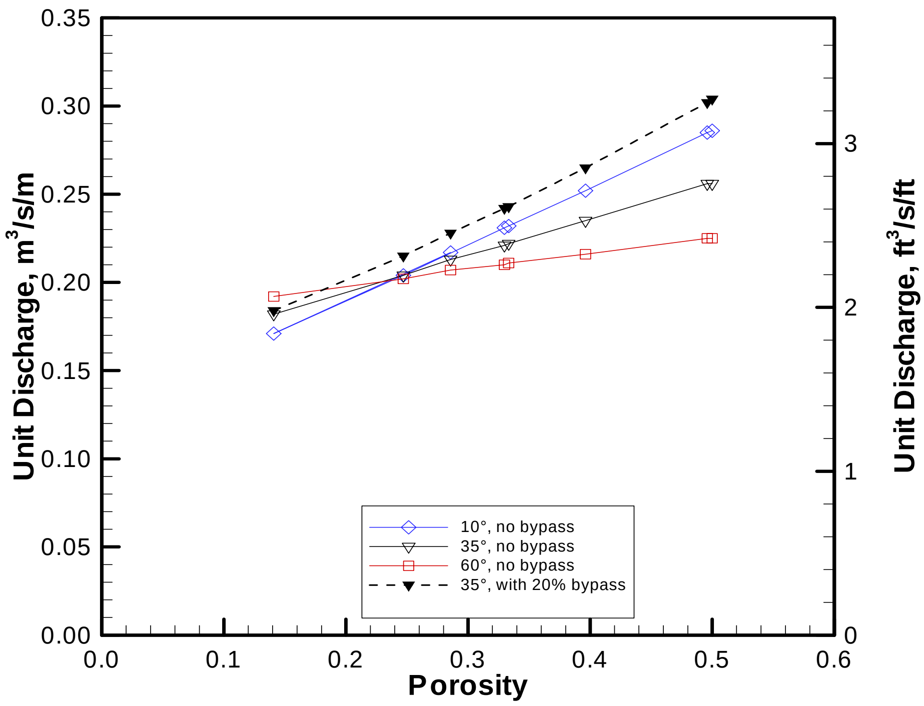


Figure 22. Effect of porosity on unit discharge through screen.

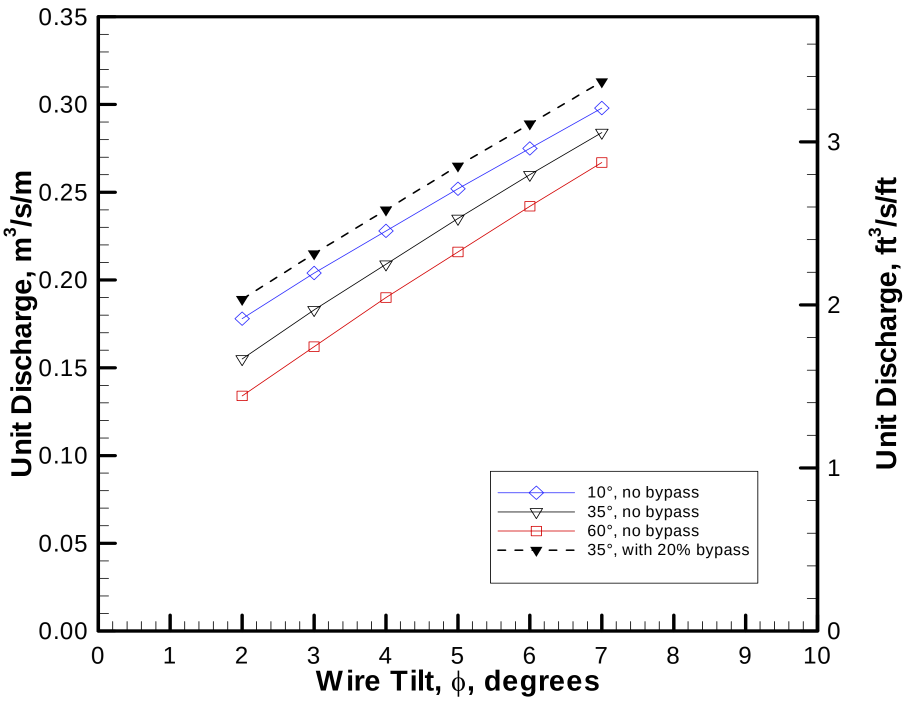


Figure 23. Effect of wire tilt angle on unit discharge through screen.

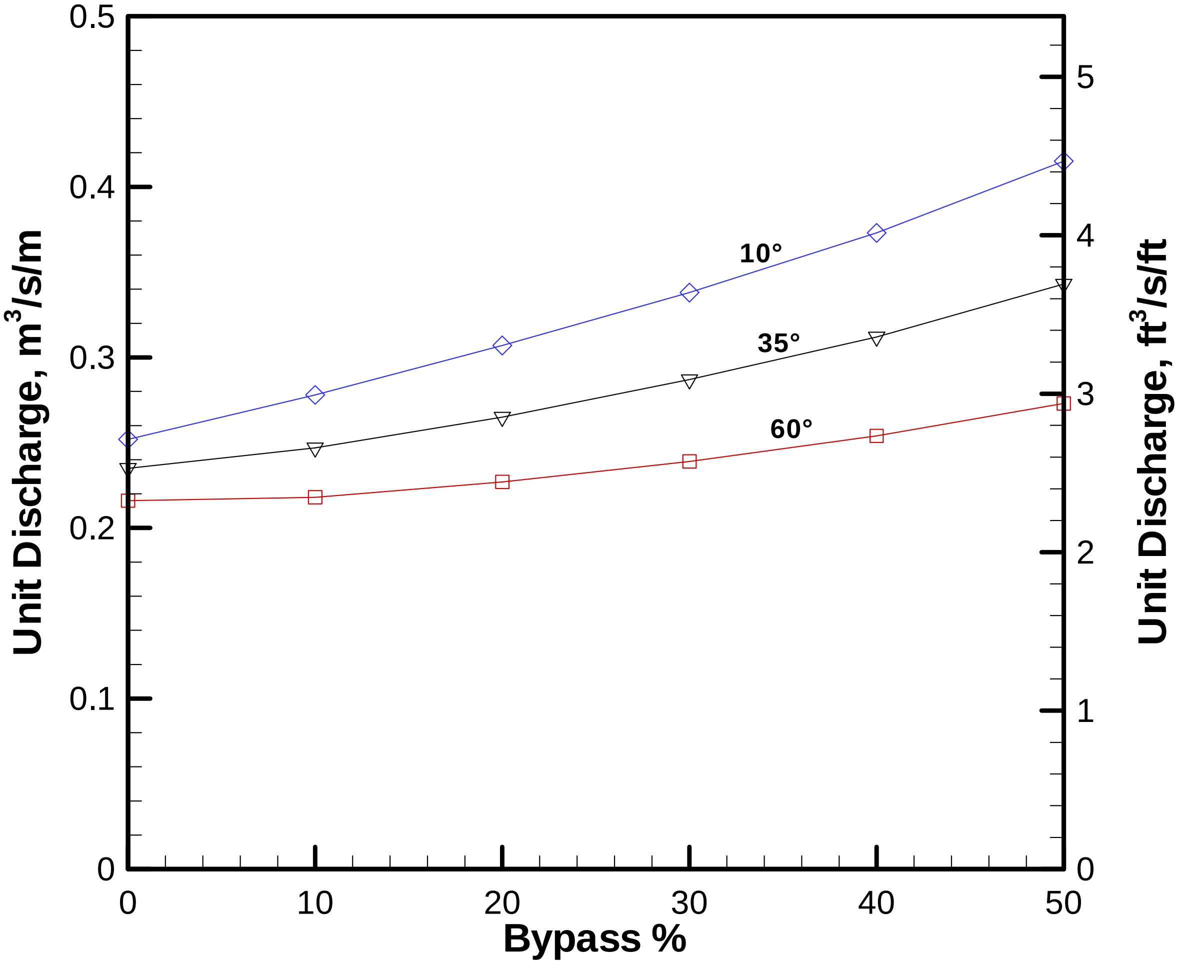


Figure 24. Effect of bypass flow on unit discharge through screen.

channel carries 4 ft$^3$/s and we wish to divert and screen 3 ft$^3$/s with a structure creating a total head drop of 1 ft or less in the main channel. Space restrictions at the site prevent the construction of a structure wider than 4 ft. The screen should utilize 0.75 mm slots, 0.060-inch (1.524-mm) wire, and a 5° wire tilt angle.

Solution: Start with the assumption that the structure will be 4 ft wide. The unit discharge approaching the structure is thus 1 ft$^3$/s/ft. The desired screened flow is 0.75 ft$^3$/s/ft and the bypass flow is 0.25 ft$^3$/s/ft (25% of the total flow). To keep the total head drop small, we will start with a screen incline angle of 15°. The screen porosity is 0.75/(0.75+1.524)=0.33.

Referring to figure 5, for a design discharge of 1 ft$^3$/s/ft, an ogee crest shape would reach the desired 15° angle with a drop height of only 0.015 ft. To increase the velocity at the top edge of the screen and promote better self-cleaning, we will provide a 0.25-ft drop across the accelerator plate and use a simple straight accelerator plate (accelerator plate will be approximately 1-ft long on a 15°

slope). We will assume that the discharge coefficient of the crest is approximately 3.1 $ft^{0.5}/s$. The hydraulic head on the crest can be estimated using the weir equation, $Q=CLH^{1.5}$. The result for the design discharge of 4 $ft^3/s$ is $H$=0.47 ft. This leaves approximately 0.25 ft of drop for the actual screen surface, assuming that the tailwater level will be at the elevation of the toe of the screen. The screen panel can thus be about 1 ft long. To determine whether this 4-ft wide by 1-ft long screen can divert the desired flow, we refer to the rating curve for one of the similar reference screens, fig. 10. This screen differs from our design in three respects: screen slope (10° rather than 15°); screen length (1.5 ft rather than 1 ft); and, slot width (0.5 mm rather than 0.75 mm). The porosity of this reference screen is about 0.25.

Figure 18 shows that as a first approximation, we can assume that screened discharge varies in proportion to $L^{1.24}$, where $L$ is the screen length, so the proportionality constant for making adjustments is $(1.5/1.0)^{1.24}=1.65$. Figure 17 shows that discharge reduces as the screen angle increases, but the effect is small when the porosity is low, so we can probably ignore the effect of screen angle for now. Figure 22 shows that an increase in porosity from 0.25 to 0.33 causes an increase in discharge of about 25 percent for a screen with a 15° slope.

To use the rating curve (fig. 10), we apply the proportionality constant to adjust our inflow discharge from 1 $ft^3/s/ft$ to 1.65 $ft^3/s/ft$, making it applicable to the additional length of the 1.5-ft long reference screen. The rating curve indicates that we will have a discharge of 1.07 $ft^3/s/ft$, which is 0.65 $ft^3/s/ft$ when we adjust it back to the actual 1-ft screen length (dividing by 1.65). Due to the porosity difference between the reference screen and the actual screen, we then increase the discharge by 25 percent, obtaining 0.81 $ft^3/s/ft$, or 3.24 $ft^3/s$ for the full 4-ft wide screen. This is greater than the required diversion of 3 $ft^3/s$, suggesting that we could reduce either the screen length of the screen width. However, before doing that, it would be worthwhile to verify the capacity using the *Coanda* computer program described later in this report, since we have made several approximations in the course of this analysis. Entering all of the actual data for this design, we find that the screened discharge is actually 2.86 $ft^3/s$ when the inflow is 4 $ft^3/s$. Thus, we need to increase the screen length by about 5 percent.

The *Coanda* computer program makes it relatively easy to develop screen designs having specific capacity characteristics, and one may find it unnecessary to use the design figures in many cases. However, the design figures do provide a starting point for developing designs, especially when the designer still has limited familiarity with the performance of Coanda-effect screens.

## RECOMMENDATIONS FOR DESIGNERS

The information provided in this report can be used by designers to quickly estimate screen capacities. Three items of information are needed as a starting point, the available head, the total flow required, and the available length for the screen structure (i.e., crest length). The first choices the designer must make are the slope of the screen and whether to use a planar screen or a concave panel.

To minimize the need for cleaning, steeper screens with a significant accelerator drop are always desirable if the site conditions will permit their use. Steeper screens are also good candidates for the use of a concave panel, since it will reduce the discharge angle at the toe and increase the flow through the screen. The concave reference screens have zero-bypass capacities of about 0.35 $m^3$/s/m or 4 $ft^3$/s/ft. If higher capacity than this is required, it would probably be best to consider a flatter slope, which will allow increasing the screen length.

When there is less than about 1 m (3 ft) of head available, low angle screens will probably be needed unless the flow needed is very small. Curved screen panels are probably not justified in this case because they only further flatten the slope at the toe of the screen, which may lead to debris accumulation problems, and the small increase in capacity probably will not offset the increased cost.

The accelerator plate is an important part of the screen. It ensures sufficient velocity at the head of the screen to make the screen self-cleaning, and conditions and aligns the flow as it approaches the screen. Accelerator plates can be constructed to a standard ogee crest profile, or they may consist of a circular arc or other smooth transition. The accelerator plate transition should be gradual enough that the flow does not separate from the crest. The *Coanda* computer program can determine the ogee profile shape for a given inflow design discharge, and for a given drop height it can compute the corresponding screen incline angle at the end of the ogee shape; alternately, the drop height for a given screen incline angle can be determined, or the design discharge can be determined for an ogee shape that produces a given drop height and screen incline angle.

Changes in screen material do not have dramatic effects on capacity, except for the wire tilt angle, but this is typically standardized at 5°. Changing the wire width or slot width will have some effect on capacity, but not in direct proportion to the change in porosity (i.e., a 0.5-mm slot screen has nearly the same capacity as a 1-mm slot screen, especially if the screen incline is steep). Screen wire selections should be made on the basis of ensuring durability of the screen under the expected debris loads. Slot sizes should be chosen primarily on the basis of the size of debris to be screened.

## USING THE *COANDA* COMPUTER PROGRAM

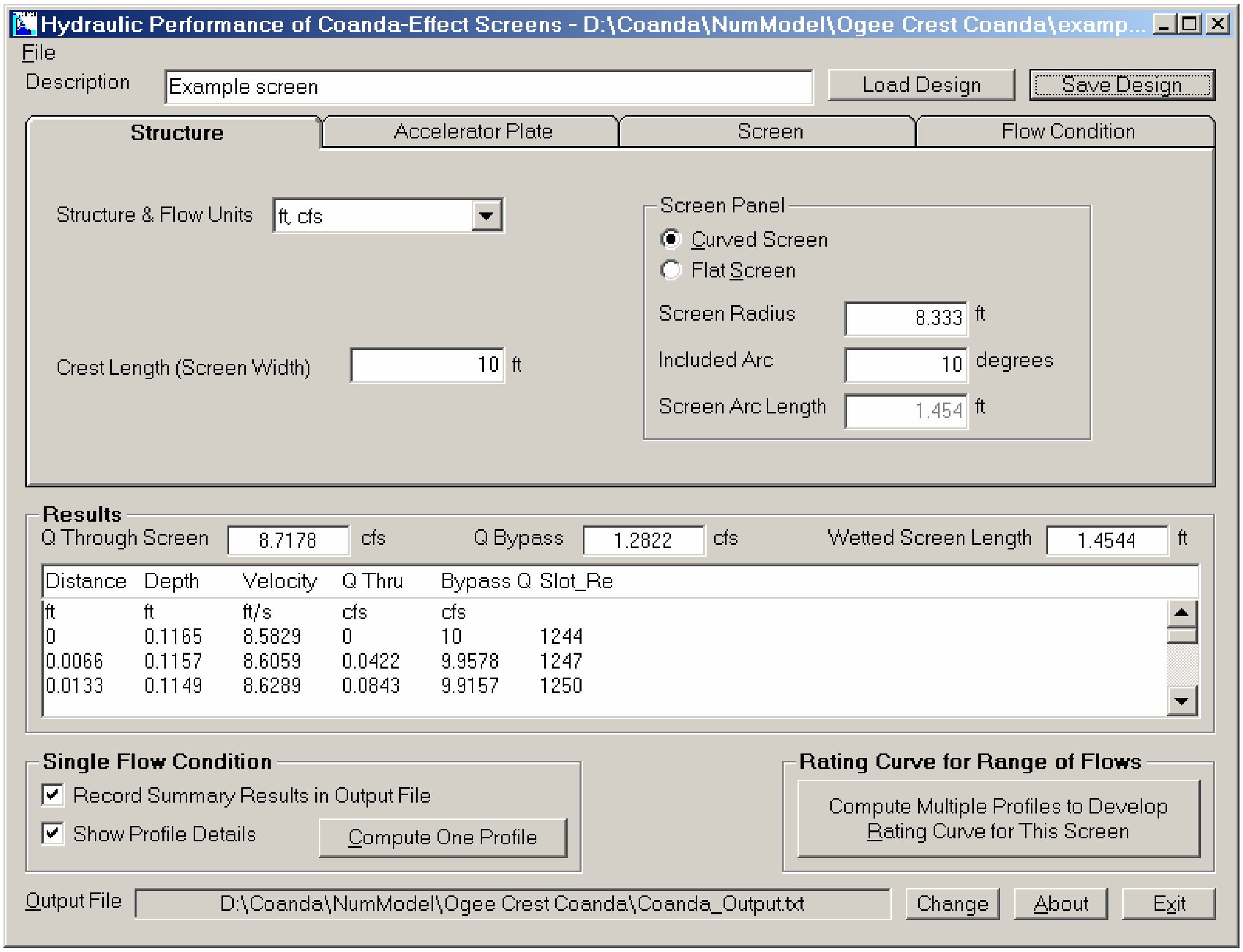
The numerical model used to develop the reference screen rating curves and evaluate the influence of changing design parameters is available to the public as a computer program for Windows computers. The setup kit for the software can be downloaded from <http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/>. The program is written in Visual Basic 4.0 and compiled for use on all 32-bit versions of Microsoft Windows (95, 98, Me, NT 4.0, 2000, XP).

Figures 25 and 26 show the program's input interface. Data are provided on four separate tabs:

- Structure information
- Accelerator plate properties
- Screen properties
- Flow condition to be evaluated

On the structure tab, the user may select either a curved screen or a flat screen and specify its basic dimensions; structure dimensions can be provided in units of feet or meters. For curved screens, the screen radius may be positive (the usual concave screen), zero (same as selecting a flat screen), or negative (a convex screen).

The accelerator plate can be either an ogee crest or a generic crest of no specific shape (e.g., a circular arc). For ogee crest shapes,



Description: Example screen

Structure & Flow Units: ft, cfs

Screen Panel
● Curved Screen
○ Flat Screen
Screen Radius 8.333 ft
Included Arc 10 degrees
Screen Arc Length 1.454 ft

Crest Length (Screen Width) 10 ft

**Results**
Q Through Screen 8.7178 cfs
Q Bypass 1.2822 cfs
Wetted Screen Length 1.4544 ft

```
Distance  Depth   Velocity  Q Thru  Bypass Q  Slot_Re
ft        ft      ft/s      cfs     cfs
0         0.1165  8.5829    0       10        1244
0.0066    0.1157  8.6059    0.0422  9.9578    1247
0.0133    0.1149  8.6289    0.0843  9.9157    1250
```

**Single Flow Condition**
☑ Record Summary Results in Output File
☑ Show Profile Details

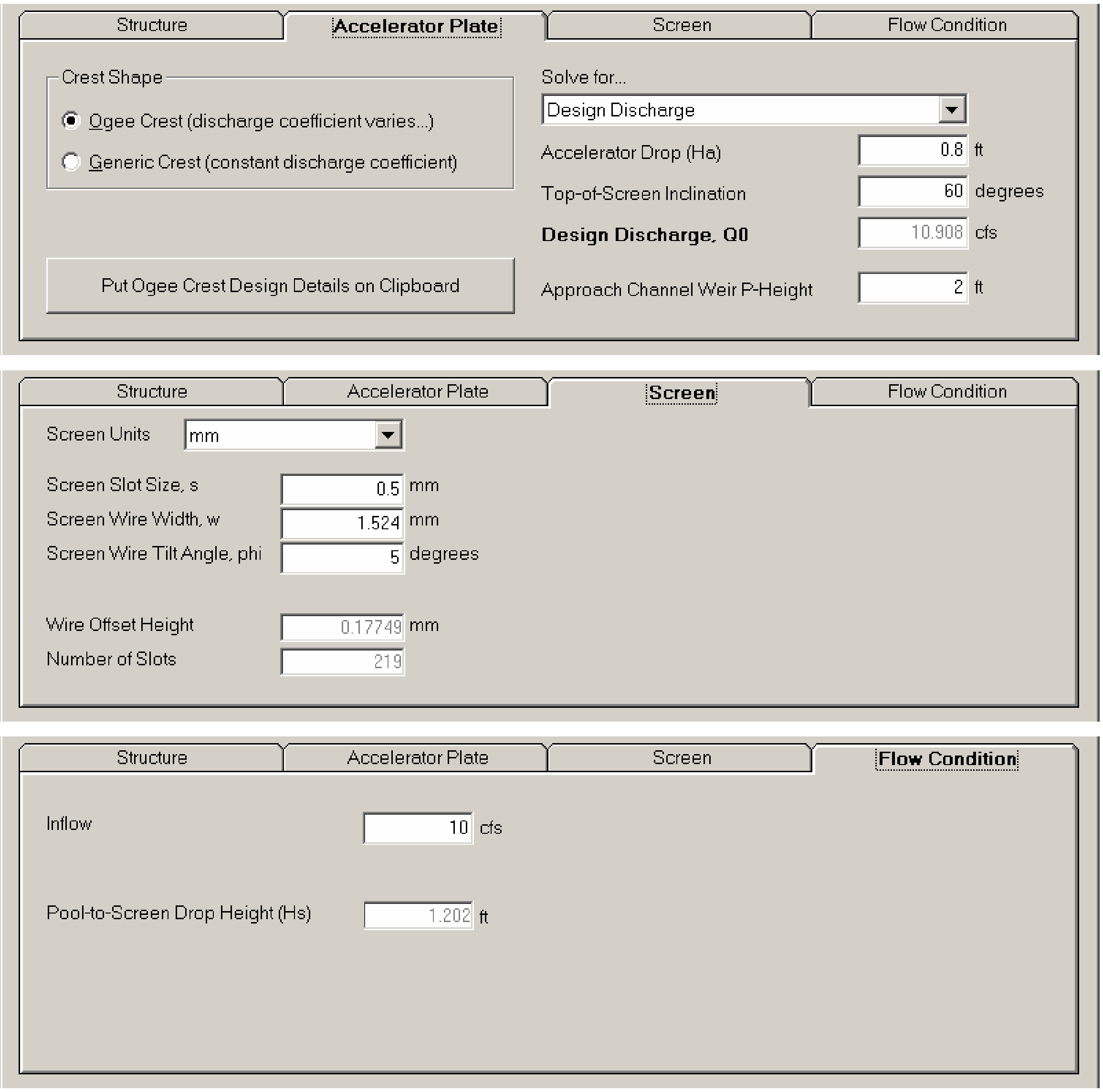
**Rating Curve for Range of Flows**

Output File: D:\Coanda\NumModel\Ogee Crest Coanda\Coanda_Output.txt

Figure 25. Computer program for estimating hydraulic capacity of Coanda-effect screens.

the discharge coefficient of the crest will be estimated separately for each flow rate, using information from *Design of Small Dams* (Reclamation 1987), while non-ogee crests will be assumed to have a constant discharge coefficient provided by the user. The user provides 2 of 3 pieces of design information about the accelerator plate: the vertical drop from the crest to the start of the screen, the incline angle at the downstream end of the accelerator plate, and the design discharge. The program computes the third quantity given the other two. The program can also generate a detailed ogee crest profile report when the user clicks the button labeled “Put Ogee Crest Design Details on Clipboard”. It should be emphasized that the “Design Discharge” shown on the “Accelerator Plate” tab is only the design discharge for the crest itself, not the screen. The actual flow rate to be used in computing the flow profile down and through the screen is provided in the “Inflow” text box on the “Flow Condition” tab.

Screen panel slot widths and wire sizes can be specified in inches or millimeters. The program computes the number of slots and the shearing offset height for a given combination of wire width, slot width, and wire tilt angle. Finally, on the flow condition tab, the user provides the inflow discharge over the crest, and the program computes the corresponding total drop height from the upstream pool to the top of the screen. This calculation uses the



Crest Shape

● Ogee Crest (discharge coefficient varies...)

○ Generic Crest (constant discharge coefficient)

Solve for... Design Discharge

Accelerator Drop (Ha) 0.8 ft

Top-of-Screen Inclination 60 degrees

**Design Discharge, Q0** 10.908 cfs

Approach Channel Weir P-Height 2 ft

Screen Units mm

Screen Slot Size, s 0.5 mm

Screen Wire Width, w 1.524 mm

Screen Wire Tilt Angle, phi 5 degrees

Wire Offset Height 0.17749 mm

Number of Slots 219

Inflow 10 cfs

Pool-to-Screen Drop Height (Hs) 1.202 ft

Figure 26. Additional input screens used to define accelerator plate and screen properties and the flow condition to be analyzed.

discharge coefficient of the ogee crest (or that provided by the user for generic crest shapes) and the standard weir equation, $Q=CLH^{1.5}$, where $Q$ is the inflow discharge, $C$ is the discharge coefficient, $L$ is the crest length, and $H$ is the head above the weir crest.

In addition to supplying input data, the user should specify an output file in the box at the bottom of the form. Clicking on the box or the "Change" button will allow the user to browse to locate an existing file, or enter a new file name. The output of the program will be an ASCII text format table.

Once input data have been provided, two options are available for executing the analysis. A single flow profile for the given inflow discharge can be computed using the "Compute One Profile" button. If the user also checks the "Show Profile Details" box, the detailed depth, velocity, and discharge profile down the length of the screen will be shown in the “Results” area of the form. This profile shows, at the leading edge of each screen wire,

- The distance traveled by the flow down the screen (Distance),
- The flow depth (Depth),
- The flow velocity (Velocity),
- The cumulative discharge that has passed through the screen (Q Thru), and
- The remaining discharge above the screen (Bypass Q).

Just above the detailed results area, the form shows the total discharge through the screen, the bypass flow discharged from the toe of the screen, and wetted screen length. If the user checks the “Record Summary Results in Output File” box, these data will be recorded into the chosen output file.

The second method for performing the analysis is to click the “Compute Multiple Profiles…” button in the “Rating Curve for Range of Flows” area of the form. This causes the program to repeatedly compute profiles beginning with a small inflow discharge and then increasing the inflow until a 50% bypass flow condition is reached. This produces output data similar to that used to create the reference screen rating curves given in this report.

After the input data for a specific screen design have been entered, these data can be saved in a .COA file for later use. These are internally documented text-format files. Saved designs can be recalled for later analysis or modification. Data files can also be created and/or modified with a text editor. Input variables are listed one per line, and the order of the variables must be preserved.

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# Appendix

## APPLICATION EXPERIENCE

Table 1 provides a list of notable applications of Coanda-effect screens on water resources projects during the past 20 years. Applications have included small hydropower, irrigation and environmental diversions. Owners and operators of many of these projects were contacted and interviewed to determine their experiences with the screens. Details of each interview are provided in this appendix. Many of these structures utilized the commercially available Aqua Shear screen marketed by Aquadyne, Inc., of Healdsburg, California. Aquadyne was operated for many years by the late Mr. James Strong, who passed away in 2002. That company is expected to continue operations in the future after a period of reorganization, and other manufacturers also offer similar screen structures. The Aqua Shear screens were available in two standard configurations. Both utilized a concave screen panel and had the screen inclined at $60^o$ from horizontal at the top edge. One design had a total drop height of 40 inches, while the other had a total drop height of 47 inches. The screens were reported by the manufacturer to accept 1.0 and 1.5 ft$^3$/s/ft of crest length, respectively, but actually accepted much more at most sites.

Table A-1. Notable Coanda-effect screen installations

| Project Name | Location | Date Installed | Flow (ft$^3$/s) | Owner | Engineer |
|---|---|---|---|---|---|
| Prather Ranch | California | Oct-82 | 4 | TKO Power | Ott Water Engineers, Inc. |
| Bear Creek | California | Sep-84 | 70 | TKO Power | Ott Water Engineers, Inc. |
| Montgomery Creek | California | Sep-85 | 120 | Sithe-Energies USA, Inc. | Tudor Engineering Co. |
| Blueford Creek | California | Oct-86 | 30 | Mother's Energy, Inc. | *…owner* |
| Baker Creek | California | Aug-87 | 30 | Western Energy Assoc. | Tudor Engineering Co. |
| Crow Creek | California | Apr-88 | 120 | BIA | *…owner* |
| Kanaka Creek | California | Nov-88 | 35 | STS Hydropower Ltd. | *…owner* |
| Kekawaka Creek | California | Sep-89 | 70 | STS Hydropower Ltd. | *…owner* |
| Lost Creek | California | Oct-89 | 60 | Mega Renewables | Ensign & Buckley |
| Nyklemoe Wildlife Refuge | Minnesota | Oct-89 | 55.8 | Minnesota Dept. of Natural Resources | *…owner* |
| Wahianoa Intake | New Zealand | May-91 | 50 | Electricity Corp. of New Zealand | *…owner* |
| Forks of Butte | California | Sep-91 | 210 | Synergics (Energy Growth Partnership I) | RTA Associates, Inc. |
| Beaver City | Utah | Oct-91 | 26 | City of Beaver Creek, UT | Joens & DeMille Engr. |
| Falls Creek | Oregon | Sep-93 | 15 | Frontier Technology, Inc. | CH2M Hill |
| City Creek Intake | Utah | May-95 | 30 | Salt Lake City, UT | CH2M Hill |
| Center for Alternative Technology | Wales | Sep-95 | 3 | Private | Dulas, Ltd. |
| Stand-Alone Hydro Intake | Scotland | Oct-95 | 3 | Private | Dulas, Ltd. |
| Swiss Govt. Research | Switzerland | Oct-95 | 3 | Swiss Govt. | ENTEC |
| East Fork Hood River Sand Trap | Oregon | Sep-96 | 90 | East Fork Irrigation District | SJO Consulting Engineers |
| Oak Springs Hatchery | Oregon | Sep-98 | 7 | Oregon Dept. of Fish & Wildlife | Harza |
| Three Forks | California | | | Ross Burgess | |
| Rocky Mountain Arsenal | Colorado | Apr-00 | 25 | USFWS | Foster-Wheeler Environmental Corp. |
| Empire Water Treatment | Colorado | | | City of Empire | |
| Small Ag. Diversions | Colorado | | | Various | John Cerise |

## Montgomery Creek – California

This site is located about 40 miles northeast of Redding, California, just below the confluence of two creeks. The design flow is about 120 $ft^3/s$, with the flow provided to a small hydropower plant. The screen structure utilizes 24 Aqua Shear panels, for a total crest width of about 36 m (120 ft).

Figure A-1. Montgomery Creek intake.

The project operators are reportedly pleased with the performance of the structure, although they have modified the original design to make it more durable. These modifications included increasing the thickness of the accelerator plate and strengthening its attachment to the weir. Bolts used to attach the screens to the frame were modified and screens were welded to the accelerator plate. The width of the screen section is more than double the theoretically required width. However, several factors reduce the theoretical capacity of the screens, including:

- One third of the screens are original and 15 to 16 years old. Wear has occurred on the screens, especially due to an increase in bed load sediment passing over the screen following a large forest fire several years ago.
- The water is relatively warm and algae grows very easily on the wedge wires. During the summer months the operator has to clean the screens daily.
- The accelerator plate is too steep, causing the flow to arc over the top section of the screen during high flows.
- The transition between the accelerator plate and the screens is not smooth enough, causing water to skip over about the top 10% of the screen area.
- Some of the screens that were changed out due to wear have been replaced with planar panels rather than the original concave panels, which reduces their capacity somewhat.

The operators report that some sediment gets clogged between the wires, requiring an annual cleaning with a vibratory cleaner.

## Forks of Butte – California

The Forks of Butte diversion is located at Paradise, about 85 miles southeast of Redding, California. At this site a dam diverts water into a side channel and the screen structure is parallel to the river. The structure is about 47 m (150 ft) long, with a design capacity of about 210 $ft^3/s$, again serving a small powerhouse. Sediment has filled most of the pool upstream from the structure, causing an increase in approach velocity as the flow reaches the structure.

Figure A-2. Forks of Butte intake.

The operating experience here has been similar to that at Montgomery Creek. To strengthen the structure against vibration, the screen was welded completely to the support structure. Knee braces were also added beneath each panel. When screen panels were replaced due to wear, the wire thickness was increased from the original 1/16 in. to 3/32 in.

Unlike Montgomery Creek there is no algae growth, due to the fact that the intake is in a deep canyon where little direct sunlight can hit the screens. The screens do not clog and no cleaning maintenance is necessary.

## City Creek Intake – Salt Lake City, Utah

The City Creek Intake collects the full flow of City Creek for municipal use. It was one of the first water supplies developed for the City of Salt Lake. The diversion ranges from 3 to 15 million gallons/day (4.6 to 23.2 $ft^3/s$). Prior to 1995 the structure was a bottom intake with a coarse trashrack and no screening of fine debris. A large amount of cleaning maintenance was required. In May 1995 the diversion was reconfigured to withdraw surface water and pass it over and through a Coanda-effect screen, approximately 12 ft long with a drop of about 5 ft. The screen structure was provided by Aquadyne, Inc. and utilizes stainless steel screen panels.

The screen does an excellent job of excluding coarse and fine debris, leaves and moss. The screen is cleaned about 2 to 3 times per year, with the diversion shut down. Cleaning is needed to remove leaves that accumulate near the toe of the screen and moss and calcium deposits (presumably calcium carbonate) on the surface of the screen. The water in City Creek is reportedly quite hard. This cleaning consists of blasting the top surface of the screen with a fire hose, then applying an acid to break up the calcium deposits. After the acid has had time to work, the screen is scraped by hand. The total time needed for cleaning is about 2 hours. The operators of the intake structure are extremely pleased with the screen's performance, although they would like to find a way to reduce calcium buildup on the screen.

### Kanaka Creek and Kekawaka Creek – California

These two diversions in northern California provide water for small, high-head hydropower plants operated by STS Hydropower, Ltd., a subsidiary of Northbrook Energy. The screens were installed during initial construction of the powerplants in 1988 and 1989 for the purpose of excluding fish (rainbow trout) and debris. Kanaka Creek is a 25-ft long, 35 $ft^3/s$ diversion, while Kekawaka Creek is a 50-ft long, 70 $ft^3/s$ diversion. The project operators have been very pleased with the screens, although they have made several improvements to them. Most notably, they modified the profile of the accelerator plate to make it a more gradual curve. Prior to this modification, flow separation from the accelerator plate was occurring at high flow rates, making the upstream portion of the screen panel ineffective. They also modified the attachment method for the screen panels, which were initially fastened to the structure by metal tabs. They found that vibration and hydraulic forces were causing the screen panels to “pop out”, so they removed the metal tabs and spot-welded the screens to the structure.

The streams supplying water to both of these screens carry heavy bed loads and organic debris consisting of leaves and alder buds. The screens are truly self-cleaning and require no manual cleaning. The bed load traveling over the screen gradually wears down the leading edge of the wires, reducing the flow capacity of the screen. The operators regularly replace screen panels because of this and estimate the average lifespan of a panel to be about 3 years.

### Crow Creek and K-Canal – Montana

The Crow Creek screen was constructed in 1988 to prevent the diversion of fish (primarily bull trout) at a 120 $ft^3/s$ irrigation diversion. The diversion includes a fish ladder on the opposite stream bank. The screen originally used 12 stainless steel Aqua Shear screen panels (60 ft of weir length), but was later reduced to 6 screen panels, as the screens accepted much more water than expected. At low discharges, stoplogs can be installed to concentrate the flow over just a few panels. The screen has operated well since its installation. The waters in the area are very productive, and the primary debris buildup on the screens has been algae growth. The screen is cleaned using a high-pressure washer. The screened was cleaned three times during the 2002 operating season, which is typical.

The K-Canal screen was constructed in 1998, using 12 new Aqua Shear screens and 6 screens salvaged from the modification of the Crow Creek screen. The maximum diversion is 240 $ft^3/s$. Operating experience and maintenance on this screen have been very similar to the Crow Creek screen. The screen was cleaned one time during the 2002 operating season.

### Rocky Mountain Arsenal – Denver, Colorado

The Rocky Mountain Arsenal is a former military facility near Denver, Colorado that is being converted to a wildlife refuge. A Coanda-effect screen was installed in the Spring of 2000 for the U.S. Fish & Wildlife Service to exclude undesirable fish, fish eggs, and larvae from water being supplied from the Farmer’s Highline Canal to several wetland ponds and lakes on the refuge. The screen replaced previous wire mesh screen panels that had required cleaning several times per day. The new screen has been cleaned only intermittently, when personnel visit the site for other reasons. The structure is 20 ft long, utilizing four standard Aqua Shear panels. The design flow for the site was 20 $ft^3/s$, and the screen has proven capable of accepting much greater flows. The receiving channel beneath the screen

Figure A-3. Rocky Mountain Arsenal screen.

proved to be undersized and cannot quite accept the full 20 $ft^3/s$. The screen performed well during the summer of 2001. A small amount of flow bypasses the screen due to blinding beneath the screen panels near the edges of the structure. Drought conditions in 2002 prevented any use of the screen.

### Oak Springs Hatchery – Oregon

A small Coanda-effect screen panel (presumably a 5-ft wide standard Aqua Shear module provided by Aquadyne) was installed on a new water intake for this hatchery in September 1998. The project is owned and operated by the Oregon Department of Fish and Wildlife. The screen is intended to remove leaves, twigs, and other debris from the incoming water, which is obtained from a nearby spring. The screen has worked very well since installation. Debris is manually swept off the screen a few times per year, and the screen is pressure-washed once per year to remove moss that grows on the screen surface. The screen is designed to accept 7 $ft^3/s$ without any bypass flow, since the spring-supplied source water does not contain fish.

### Small Ag Diversions - Colorado

Numerous small Coanda-effect screen structures have been installed in the past 2 to 3 years in western Colorado, primarily on projects converting from flood irrigation to sprinkler systems. The screens provide low-maintenance removal of fine debris that would potentially plug sprinkler nozzles. The screens are installed in modular turnout boxes that are installed into existing irrigation ditches. Because head is limited, screens are often installed on slopes of about 10º to 15º. Typical sizes are about 2 to 3 ft wide and about 3 ft long, with design diversion capacities less than 10 $ft^3/s$. Screens typically have a 0.5 mm slot width. These screens have worked very well and new installations continue to be made.

Figure A-4. A small Coanda-effect screen provides water to a sprinkler irrigation system near Carbondale, Colorado.