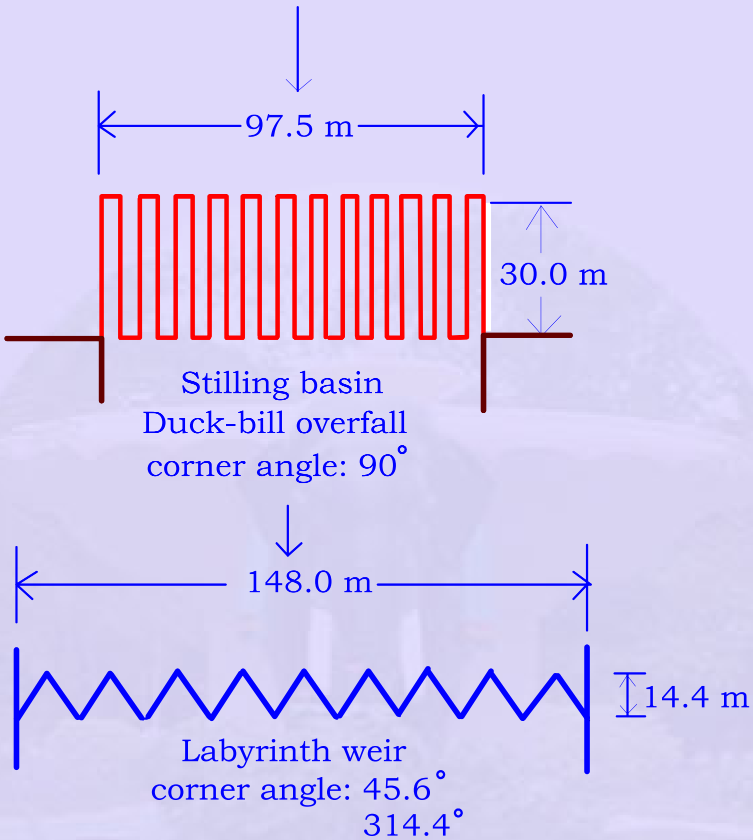
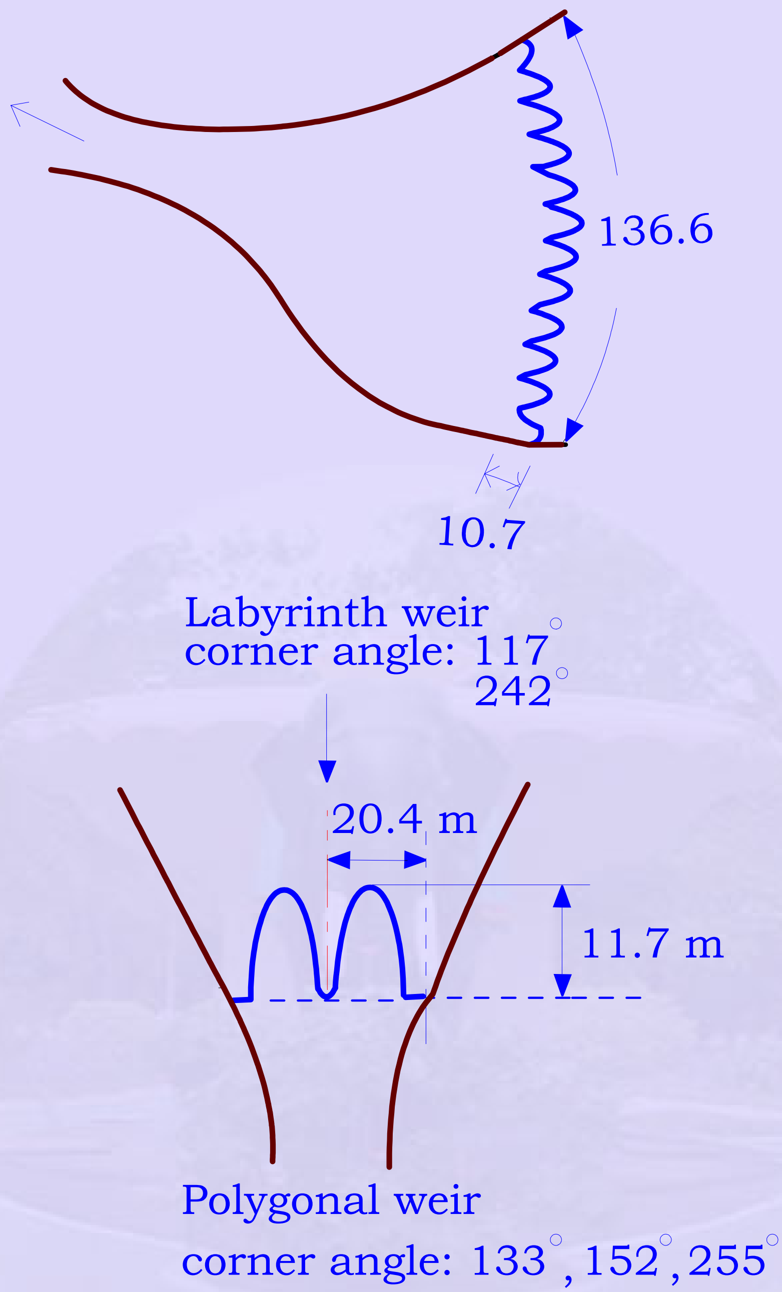
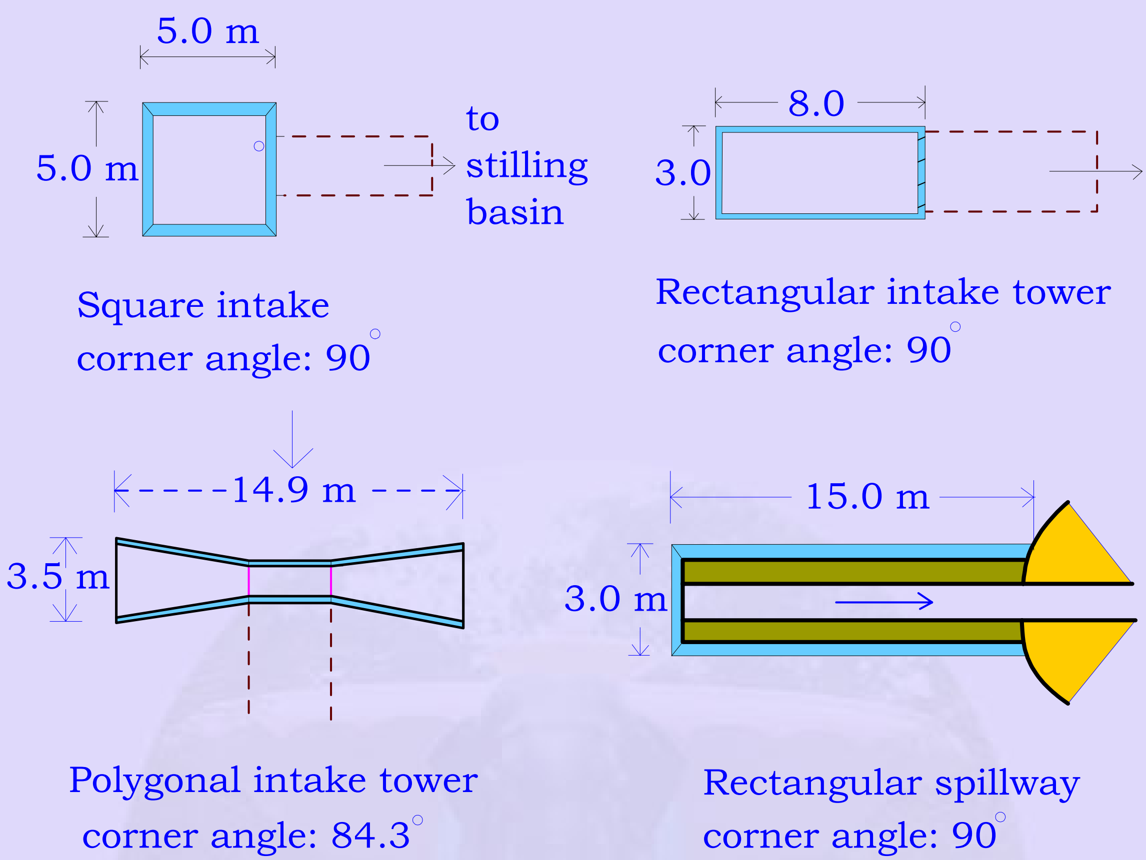
14.5 Polygonal weirs-Introduction

Weirs and spillways with a polygonal discontinuous center line can be designed in various manner. Figure 1 shows some of the examples such as square intake towers, labyrinth weirs, duck-bill overfalls.




136.6
10.7
Labyrinth weir
corner angle: 117°
242°
20.4 m
11.7 m
Polygonal weir
corner angle: 133°, 152°, 255°



Layouts of Overfall structures with Polygonal Center Line of Weir Crest

These weirs consist mainly of straight parts with corners in-between. The points of discontinuity are created by the intersection of two straight center lines. Closed polygons are possible.

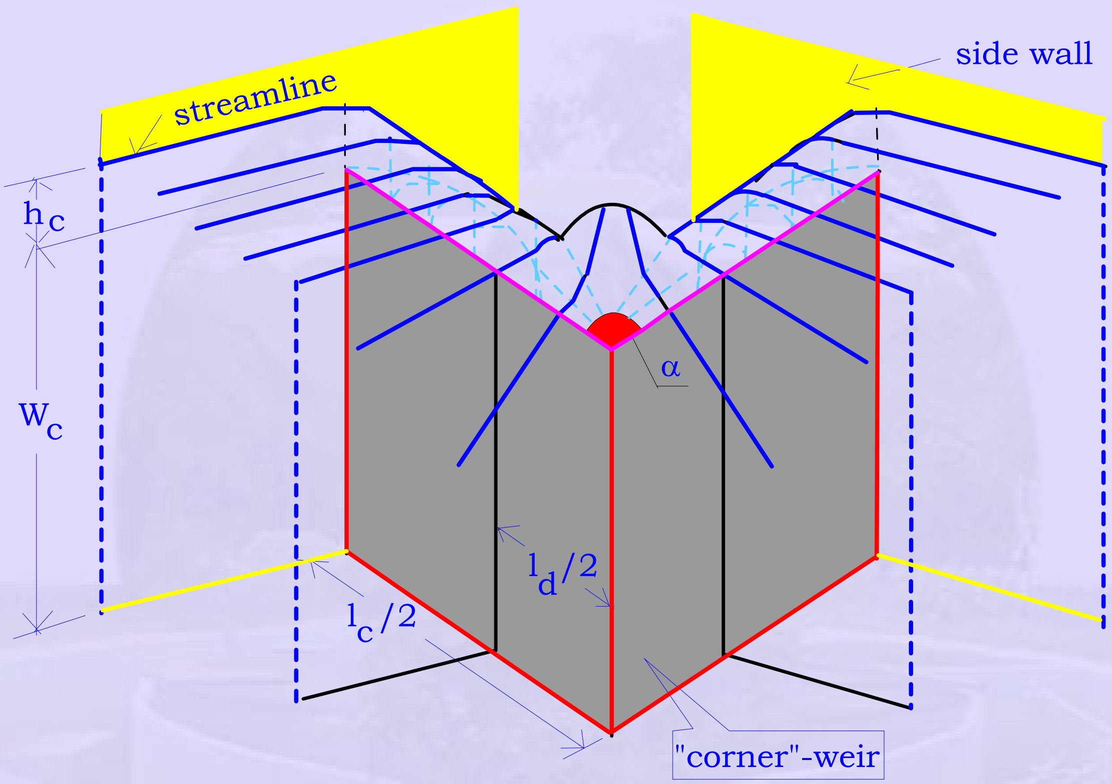
The length of an overfall structure can be considerably increased in case the width is limited. In case of small overfall heads, the discharge capacity may increase compared to straight overfalls situated orthogonally to the main flow direction. Intake towers in reservoirs with small water depth $[\leq 30.0 \text{ m}]$ and small floods $[\leq 100 \text{ m}^3/\text{s}]$ can be designed as square shaft spillways instead of the continuous straight or circular crests in plan, which are used very often.

The polygon is easier to construct than the circle. However, the hydraulic computation of the discharge capacity for the polygon is more complicated than for the continuous straight or circular crests in plan.

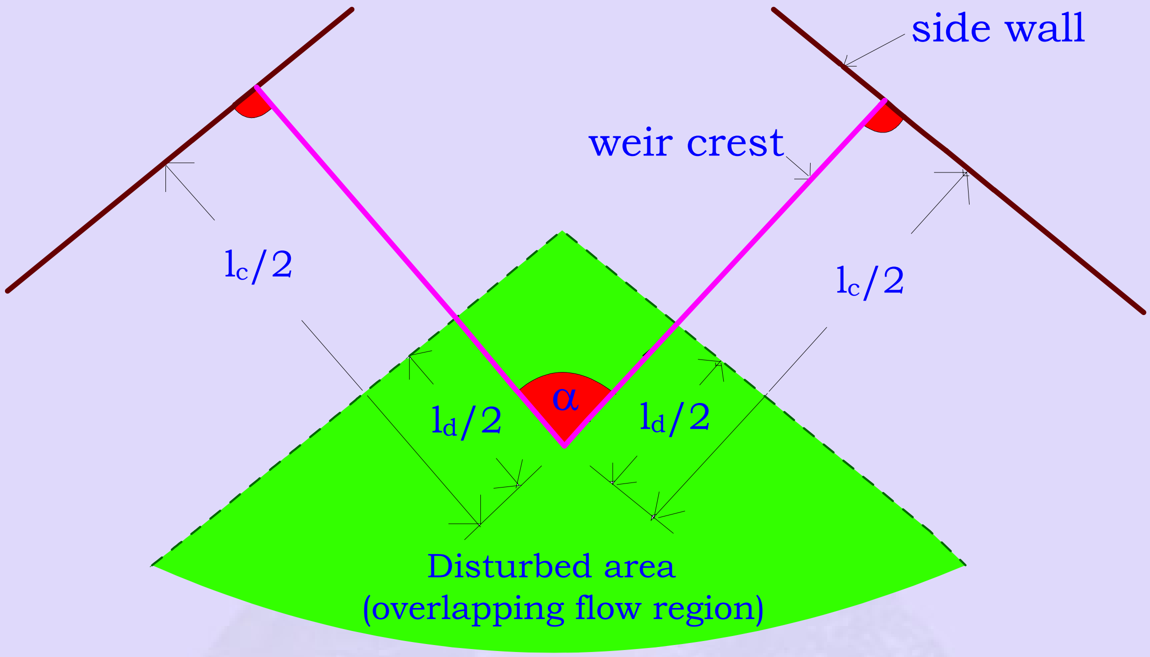
It is possible, for any combination or shape of a polygonal weir or overfall, to do the hydraulic computation with very accurate results with the help of the analysis given by Indlekofer and Rouve (1975).

14.5.1 DISCHARGE OF "CORNER WEIR”

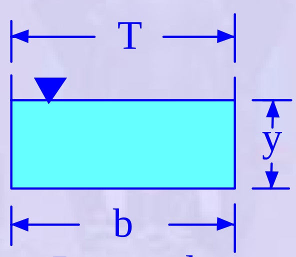
They investigated the "corner" weir, which is symmetrical and has orthogonal boundary conditions. The corner angle, α , is formed by both the straight sides of the weir and is measured in the downstream.



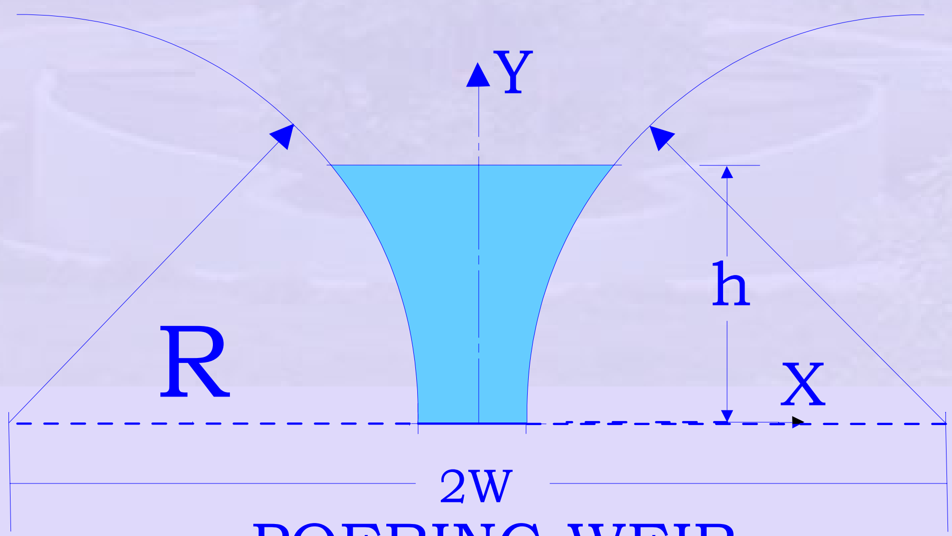
Isometric view of corner-weir looking downstream



Plan of Corner-weir



Rectanglar

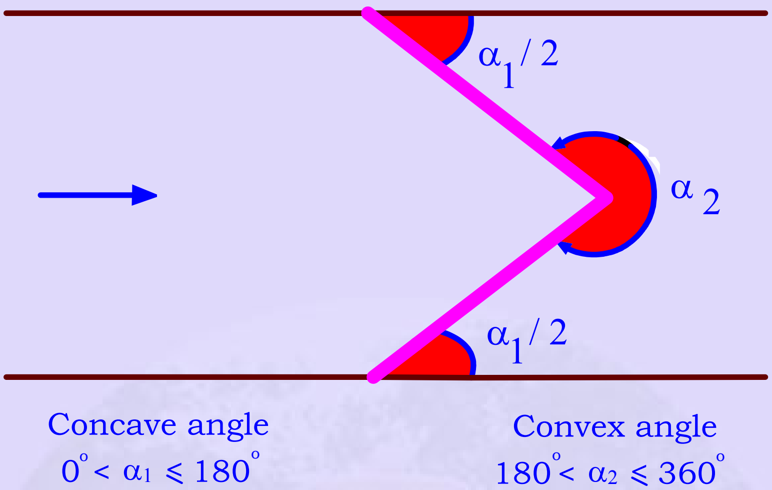


POEBING WEIR

Angle 'α' varies within the limits, Convex angle $0^\circ < \alpha \leq 180^\circ$

Concave angle $180^\circ < \alpha \leq 360^\circ$

In the physical system ("corner weir ") in the range of 180° to 360° does not perform satisfactorily. Therefore $\alpha_1 + \alpha_2 = 360^\circ$ in physical system.



Layout of Corner Weir

The flow over the corner weir can be apportioned as (1) disturbed area near the corner are shown in green color and

(2) With two-dimensional flow.

The length of the area of disturbed flow = $l_d / 2 + l_d / 2$

The length of the corner weir is l_c. Hence, $0 \le l_d \le l_c$

The local disturbance factor 'DF' with a distance, l, from the corner is defined as

$$DF(l) = \frac{C(l)}{C_n}$$

in which $C(l)$ and C_n are the coefficient of discharges for the corner weir of length 'l' and for the normal flow condition.

The discharge over the weir is written as $C_m = \frac{3Q_c}{2C_n l_c \sqrt{2g}\; h_{c,n}^{*\,3/2}}$

in which Q is the discharge, in m^3s^{-1}; b is the width of the weir, in meter; 'g' is the acceleration due to gravity 9.81 ms^{-2}; and 'h' is the head over the weir. The disturbance factor cannot be greater than 1.

Because of the continuity of flow between the corner and the side walls, it may be noted that the continuity of DF (L). At the point of transition, the following condition is required to be satisfied.

$$\mathrm{DF}\left(\frac{l_d}{2}\right)=1$$

For values $l \geq l_d / 2,\ \mathrm{DF}=l$. Accordingly, the mean distribution coefficient, C_m , of the overlapping flow zone can be written as

$$c_m = \frac{2}{l_d}\int_0^{l_d/2} \mathrm{DF}(l)\,dl$$

The discharge, Q_c, of the “corner " weir is

$$Q_c = \frac{2}{3} C_n \sqrt{2g}\ h_{c,n}^{3/2}\left[l_c - \left(1-C_m\right) l_d\right]$$

The overall head, $h_{c,n}$, belonging to the discharge coefficient, C_n, under normal flow conditions (two-dimensional flow) can be estimated from

$$h_{c,n} = h_c + \frac{v_c^2 - v_{c,n}^2}{2g}$$

in which h_c = overfall head, assuming three dimensional flow, in meter, at the " corner " weir ; v_c = flow velocity, assuming three-dimensional flow, in meter per second, at the " corner " weir ; and $v_{c,n}$ = flow velocity under normal flow conditions (two-dimensional flow) at the " corner " weir. For the hydraulic calculation the length, l_d, of the disturbed area and the value of C_m must be known.

14.5.2 LENGTH l_d OF OVERLAPPING ZONE

With increasing overfall heads $h_{c,n}$ the length of the overlapping zone, l_d, grows symmetrically to the corner, as far as $l_d = l_c$.

In this case the mean disturbance coefficient is $C_m = \dfrac{3Q_c}{2C_n l_c \sqrt{2g}\ h_{c,n}^{*\,3/2}}$

If the corresponding limiting value for $h_{c,n} = h_{c,n}^*$.

Using the length, l_d, of the overlapping zone of flow, depending on the strength of disturbance, from Eq. 7 one may obtain

$$l_d = \left(l_c - \frac{3Q_c}{2C_n\sqrt{2g}\ h_{c,n}^{3/2}}\right)\frac{1}{1-C_m}$$

$$\bar{l}_d = l_c - \frac{3Q_c}{2C_n\sqrt{2g}\ h_{c,n}^{3/2}}$$

Thus $l_d = \bar{l}_d \dfrac{1}{1-C_m}$

in which $\bar{l}_d$ represents the length of disturbance. The independent variables

$l_c, Q_c, C_n,$ and $h_{c,n}$, are determined from experiments.

Indlekofer and Rouve have conducted investigations for sharp-crested “corner “weirs with corner angles $\alpha = 46.81^\circ$, 62.08°, 89.64°, and 123.45°. The crest thickness was 2mm. The discharge was determined by the Rehbock formula

$$Q = \frac{2}{3}\left(0.6035 + 0.0813\frac{h + \ 0.0011}{\mathrm{P}}\right) b\sqrt{2g}\left(h + 0.0011\right)^{3/2}$$

in which h is the overfall head, in meters; P is the weir height, in meters; and b is the width, in meters and C_n is the coefficient of discharge.

Length of Overlapping Zone Area $\bar{l}_d$

The length of overlapping zone area, $\bar{l}_d$, can be calculated using Eq. 12.

The length of disturbance, $\bar{l}_d$, is related to the overall head, $h_{c,n}$, by a simple linear function, $\bar{l}_d = A + \bar{B}h_{c,n}$

in which A is a constant, in meter; and $\bar{B}$ slope for $\bar{l}_d$. It must be mentioned that the constant, A is very small, and either positive or negative.

14.5.3 Length l_d of Overlapping Zone

Based on the laws of similitude, one can assume a linear relation between the length, l_d , of the zone of disturbance and the overfall head. The length, l_d , will be

$$l_d = \frac{\bar{B}}{1-C_m} h_{c,n}$$

or using the slope B, for the length, l_d , of the overlapping zone

$$l_d = Bh_{c,n}$$

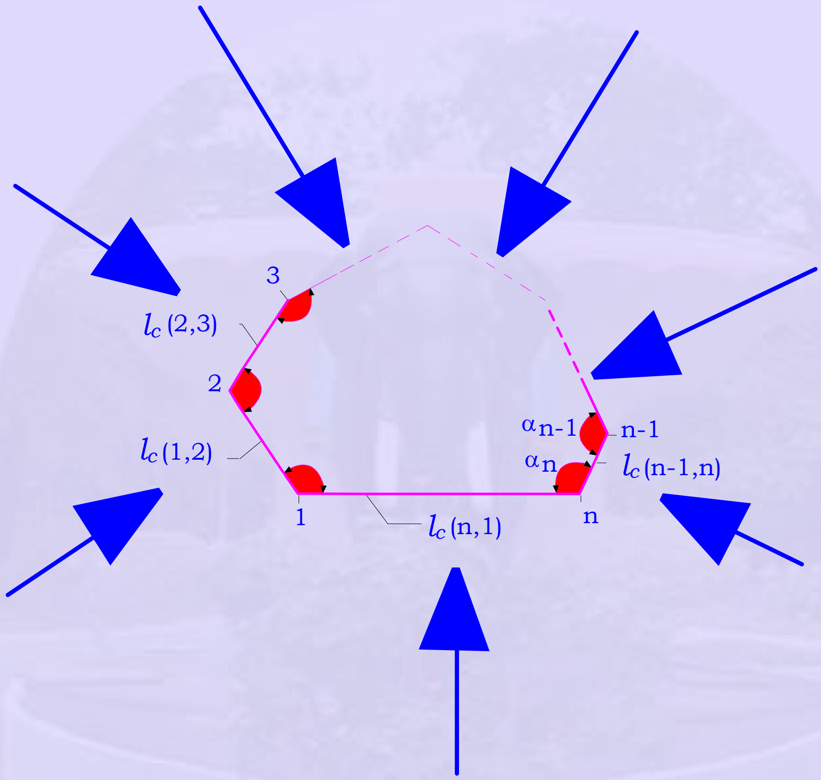
Because of the linearity $\mathrm{B} = \dfrac{l_c}{h_{c,n}^*}$

Mean Disturbance Coefficient C_m in overlapping zone - The mean disturbance coefficient, C_m, which considers the influence of the disturbance with a length, l_d, compared with the flow normal to a straight weir, can be calculated by,

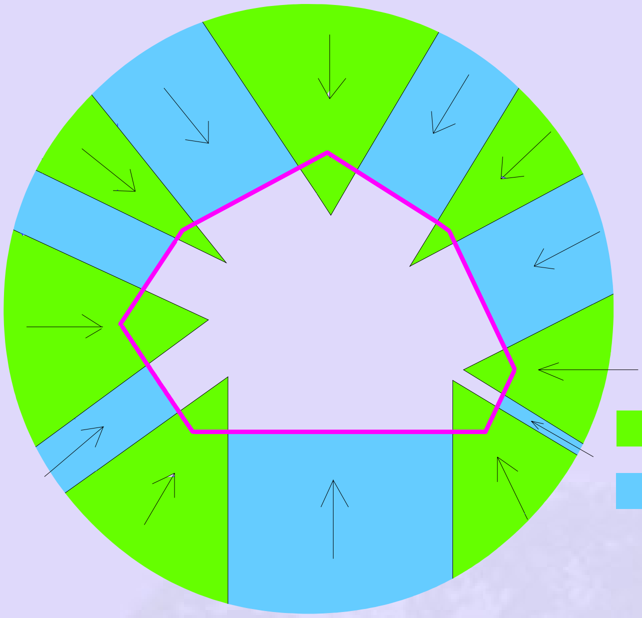
$$C_m = 1 - \frac{\overline{B}}{B}$$

using the slope $\overline{B}$ and B.

Figures show the typical Polygonal Plan with angles $0^\circ < \alpha < 180^\circ$.



Plan of the typical polygonal corner weir , Corner Angles 0° < α < 180° ;



Length of Overlapping zone for Constant Overfall Head

$$Q_c = \frac{2}{3} C_n \sqrt{2g}\ \mathrm{h}_{\mathrm{c,\,n}}^{3/2} \left[l_{c(n)} - \sum_{i=1}^{n} \bar{l}_{d,i} \right]$$

Example:

Discharge of Sharp-Crested Shaft Spillways with Equilateral Polygonal Plan

In case of shaft spillways, with equilateral polygonal in plan above Equation can be simplified as

$$Q_c = \frac{2}{3} C_n \sqrt{2g}\ n\ l_c\ h_{c,n}^{3/2} \left(1 - \frac{\bar{l}_d}{l_c} \right)$$

in which l_c is the length of the crest between two corner points and n is the number of corners.

Reference:

Indlekofer, Horst, and Rouve, Gerhard, "Discharge over Polygonal Weirs," Journal of the Hydraulics Division, ASCE, Volume 101, Number HY#, Proceeding paper 11178, March 1975, pp. 385 - 401.