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Hydraulic Design Criteria of Culvert

Construction engineering of the University of Technology in partial fulfillment of Requirement for the degree of B.Sc.
In Building and Construction Engineering

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Dedication

TO

MY .....

Precious Family, Father, Mother,

And Brothers, sister

Asst. prof. Dr. Jaafar S. Maatooq

MY .....

Precious supervisor

Dr. Ali Sadiq Al - Saadi

Dr. shukri saleh

Sajid mehdi omran

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B	Width of culvert
cfs	Cubic feet per second
CMP	Corrugated Metal Pipe
Coefficient Ke	Inlet coefficient
D	Drainage
DOT	Department of Transportation
FHWA	Federal Highway Administration
ft	Feet
HDPE	High Density Polyethylene
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HW	Head Water
In.	Inch
L	Culvert Length
n	Manning
NCHRP	National Cooperative Highway Research Program
PVC	Polyvinyl Chloride
Q	Discharge
Qp100	100 year frequency event
RCP	Reinforced Concrete Pipe
S	Culvert Slop
TL	Test Level
TW	Tail Water depth
USDOT	United States Department of Transportation
V	Velocity

Summary

The hydraulics structures are considered as very important structures which are used in controlling and distribution of water for different uses.

In this research, the box culvert are studied as the most important hydraulic structures, they are considered irrigation structure for roads, also they are used at the intersection natural cannels and irrigation cannels .

This research included studying and designing the different kinds of box culverts and the design consideration factors.

Three solved examples are included as a cases studying to explain the design procedure depending on design the culvert by knowing only the discharge and the water level.

A computer programming was used to compute the diameter of the box culverts .as result, the pipe culverts can be used on the discharge of the water less than 2.5 m3/sec and a box culverts can be used in the other cases.

Chapter one

INTRODUCTION

Chapter One

An Introduction to Culvert Design

1.1 Introduction

Culverts have been utilized for thousands of years as a means to transmit water under walkways or roads .A culvert conveys surface water through a roadway embankment or away from the highway right-of-way. In addition to this hydraulic function, it must also carry construction and highway traffic and earth loads; therefore, culvert design involves both hydraulic and structural design. The hydraulic and structural designs must be such that minimal risks to traffic, property damage, and failure from floods prove the results of good engineering practice and economics. Also considered minor structures, but they are of great importance to adequate drainage and the integrity of the facility.

It is a hydraulically short conduit which conveys stream flow through a roadway embankment or past some other type of flow obstruction .They come in many shapes and sizes, including round, elliptical, flat-bottomed, pear-shaped, and box. They vary from the small drainage culverts found on highways and driveways to large diameter structures on significant waterways or supporting large water control works.(1)

1.2 Materials of culvert

There are three primary materials that culverts are made out of: steel, precast concrete and polymer (plastic) show in figure (1.1).

When boxes or pipes are placed side-by-side to create a width of greater than twenty feet, the culvert is defined as a bridge in the United States. This is a requirement of the federal bridge inspection standards and ensures that the culvert is inspected on a regular basis.

Figure (1.1) Precast concert box culvert

Culverts are constructed from a variety of materials and are available in many different shapes and configurations. There selection factors include roadway profiles, channel characteristics, flood damage evaluations, construction and maintenance costs and estimates of service life.A culvert is any structure under the roadway, usually for drainage, with a clear opening of 20 ft. (6 m) or less measured along the center of the roadway between inside of end walls. Culverts, as distinguished from bridges, are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed or concrete riprap channel serving as the bottom of the culvert. For economy and hydraulic efficiency, engineers should design culverts to operate with the inlet submerged during flood flows, if conditions permit. Bridges, on the other hand, are not covered with embankment or designed to take advantage of submergence to increase hydraulic capacity, even though some are designed to be inundated under flood conditions. The selection of material for a culvert depends on several factors that can vary considerably according to location. Consider the following groups of variables:

1. Structure strength, considering fill height, loading condition, and foundation condition

2. Hydraulic efficiency, considering Manning's roughness, cross section area, and shape

3. Installation, local construction practices, availability of pipe embedment material, and joint tightness requirements

4. Durability, considering water and soil environment (pH and resistivity), corrosion (metallic coating selection), and abrasion

5. Cost, considering availability of materials.

The most economical culvert has the lowest total annual cost over the design life of the project. Do not base culvert material selection solely on the initial cost. Replacement costs and traffic delay are usually the primary factors in selecting a material that has a long service life. If two or more culvert materials are equally acceptable for use at a site, including hydraulic performance and annual costs for a given life expectancy, consider bidding the materials as alternates, allowing the contractor to make the most economical material selection.

1.3 Criteria used in culvert selecting:

The most commonly criteria used in culvert selection are:

1. Construction and maintenance costs

2. Risk of failure

3. Risk of property damage

4. Traffic safety

5. Environmental and aesthetic considerations

6. Construction expedience.

Although the cost of individual culverts is usually relatively small, the total cost of culvert construction constitutes a substantial share of the total cost of highway construction. Similarly, culvert maintenance may account for a large share of the total cost of maintaining highway hydraulic features. You can achieve improved traffic service and reduced cost by judicious choice of design criteria and careful attention to the hydraulic design of each culvert.

Before starting culvert design, consider site and roadway data, design parameters (including shape, material, and orientation), hydrology (flood magnitude versus frequency relation), and channel analysis (stage versus discharge relation).

1.4 Classification by Shape:

The common shapes of culverts used are, show in figure (1.2):

1. Circular
2. Pipe Arch or Elliptical
3. Arches
4. Box Sections
5. Multiple Barrels

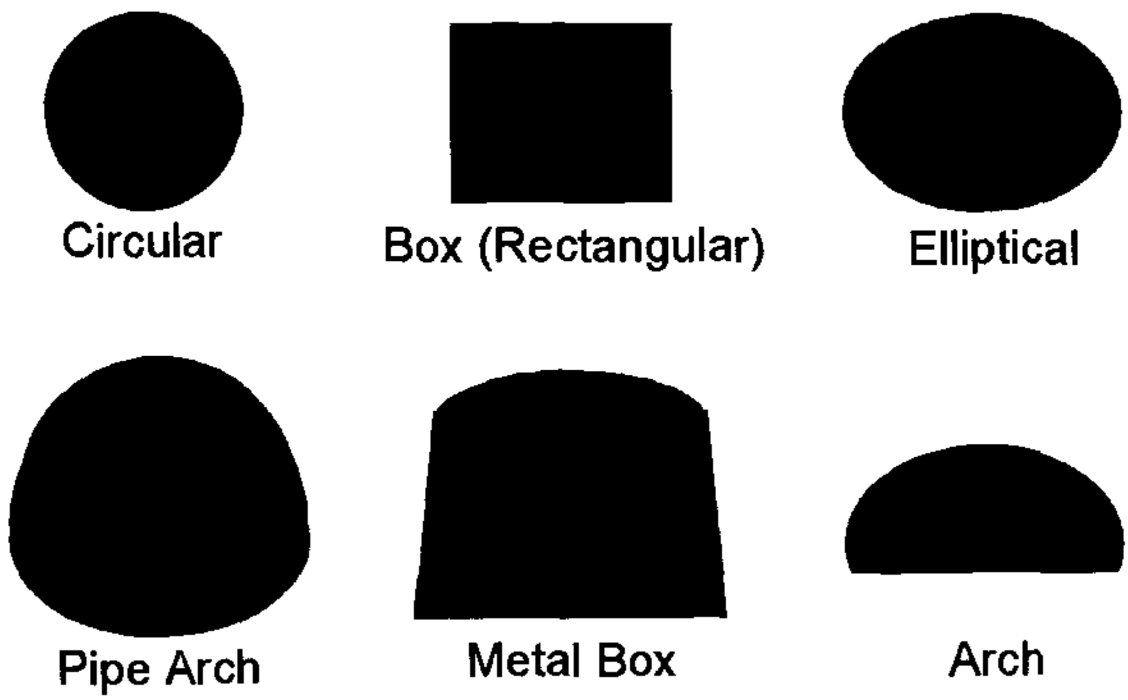


Figure **(1.2) commonly used culvert shapes.**

Numerous cross-sectional shapes are available. The most commonly used shapes are circular, pipe-arch and elliptical, box (rectangular), modified box, and arch. Base shape selection on the cost of construction, limitation on upstream water surface elevation, roadway embankment height, and hydraulic performance. Commonly used culvert materials include concrete (reinforced and non-reinforced), steel (smooth and corrugated), aluminum (smooth and corrugated), and plastic (smooth and corrugated).

1.5 Objective of this study:

The aims of this project is to study the all type of culvert and making a computer programming use to design the culvert by using a Visual Basic language. As a case study, and three examples had been solved .

Chapter Two

Review Literature

2.1 Historical Overview:

Culverts are commonly made from a variety of materials including reinforced concrete, corrugated metal, and stone. Precast reinforced concrete (RC) box culverts are very common and usually constructed as single or multi cell culverts. Precast RC box culverts offer advantages such as enhanced quality control, use of higher strength concrete, lower cost due mass production, and shorter installation time. In the 1970s there was a significant boom in culvert bridge construction in many countries. Most of these bridges, made of corrugated metal or reinforced concrete ,are now approaching 30 years of age and are deterioration at a high rate .Culvert bridge are subjected to aggressive environments(e.g., exposure to high moisture, temperature, and chlorides accelerate the corrosion of the metal pipes or the internal steel reinforcement leading eventually to loss of serviceability . Reinforcement bars made of fiber reinforced polymers (FRP) are corrosion resistant and therefore are suitable for internal reinforcement of RC box culverts.

1 _ Bob Barnard [(2)]: More than 50 stream simulation culverts have been constructed in Washington State since 1995. Bob summarizes monitoring conducted on 19 of these culverts in various settings. The monitoring goal was to compare the physical characteristics of the adjoining upstream channel with those of the culvert bed. The premise of stream simulation design is that similar physical characteristics imply similar passage compare the physical characteristics of the adjoining upstream channel with those of the culvert bed. The premise of stream simulation design is that similar physical characteristics imply similar passage conditions. Field parameters included channel geometry (channel width, slope and cross section, pool spacing, and residual pool depth) and sediment size distribution. Mathematical modeling using field data compared culvert and channel hydraulic performance including inlet contraction and depth distribution (quantification of shallow water habitat). Standard statistical tests were used to evaluate individual parameters; unfortunately the sample size was too small to perform multivariate analysis. Results show that when designed and constructed according to stream simulation design criteria (Culvert bed width = 1.2(Channel width) +2 feet, and slope of culvert < 1.25(Channel slope)), stream simulation culverts are reliable and create similar passage conditions compared to the adjoining channel.

This study attempted to compare culvert characteristics with a reference reach in the natural upstream channel. The implication is that if the channel inside the culvert is similar to the upstream reference then it accomplishes the goal of stream simulation. The measurements and analysis were selected to capture chief channel characteristics, not to determine whether a given culvert was "passable" to fish. In general, if width ratio is greater than 1.3 and slope ratio less than about 1.3, The stream simulation culvert design Method appears to successfully reproduce natural channel conditions inside the culvert for the channel types studied (moderately entrenched, coarsened streams). In particular:

1. Sediment distribution Slope ratios greater than about 1.1 tend to coarsen the bed material.

2. Hydraulic modeling Average velocity is negatively correlated with width ratio. Culvert width ratios less than 1.4 act as a constriction during storm events.

3. Depth distribution The area of shallow depth at the January 10% accidence flow equaled or exceeded that of natural channels when the width ratio is greater

Than 1.3. This type of habitat was limited or excluded when width ratios were less than 1.2.

2 _ Neal Smith [(3)]**:** In accordance with BD12/01 (Highways Agency DMRB 2.2.6), end treatments to corrugated steel culverts have to be designed to support the face edges of the steel where:

1. The skew angle of the structure exceeds 15°
2. The bevel of the square end exceeds 2:1
3. The cut end supports highway loading.

One suitable form of end treatment is a reinforced concrete collar beam. This should provide adequate support to the corrugated steel structure at its weakest location – the cut ends, where it is unable to act in ring compression. The design of Small ways North Bridge revealed that no specific guidance exists for the design of such collar beams, neither in standards nor in literature

published by suppliers, of corrugated steel culverts. The purpose of this paper is therefore to outline one potential means of designing such elements.
A simple design procedure for reinforced concrete collar beams has been proposed. Where a reinforced concrete collar beam is required in accordance with BD 12/011, it been proposed. Where a reinforced concrete collar beam is required in accordance with BD 12/011, it may be designed as follows:

(1) Produce line beam model representing centerline of collar beam.
(2) Use vertical spring supports to underside of collar beam and horizontal spring supports in the longitudinal direction of the culvert at those locations where the collar beam is below ground.
(3) Provide sufficient steel to resist the load effects of bending, shear and Torsion, obtained from the model
(4) Carry out SLS checks for crack widths and early thermal cracking

2.4 Bojan Pelivanoski [(4)]: Frequent roads and highways flooding can be referred mainly to design gaps and insufficient maintenance. In addition, damage to culverts usually results in a full or partial washout or misalignment of the culvert. These Damages may be due to insufficient design capacity or end treatments, inadequate slope protection, inadequate erosion protection, or inadequate Protection from stone and woody debris. Careful determination of the cause for the damage is necessary, as different causes require different mitigation or repair measures. Bojan deals with case study on culverts at regional road P-605 near Strumica in Macedonia. The seasonal storm events recently caused flooding at the section of constructed box culvert to pass the water flowing from a gully. Thus, first step in identifying the causes was to check the design and to do site visit. Hydraulic analysis of the section along the gully upstream and downstream of the road and the culvert was missing. This paper will present some results out of these analyses.

4 _ S. A. Serrag [5]: Libya is planning to construct a railway system along the coastline to serve the cities and towns as part of the infrastructure for the country. Since no direct runoff measurement records for the wades located in the study area are available, statistical and probability methods using the available precipitation data were employed in combination with empirical equations to determine maximum probable discharges through wades based on 100-year return period. Available daily precipitation data for a record of 41 years by three meteorological stations along the coastline covering the railway segment under consideration was collected and used. Due to the unavailability of hourly precipitation data from the three meteorological Stations, hourly rainfall records from Tripoli meteorological station were used.

A model is developed to establish a relationship between the daily and hourly precipitation for Tripoli station and was utilized to generate similar relationships for the other three stations.

In the hydraulic design of culverts, interest exits in extreme events such as the maximum values of rainfall of a storm, where in semi-arid areas occasional violent downpours might result in flash floods (torrential flows).

Due to the unavailability of hourly records of precipitations data for the Meteorological stations in the study area, a model was developed to establish a relationship between the daily and hourly precipitation for Tripoli station "has similar hydrological characteristics" and was utilized to generate hourly precipitation data for the other concerned three stations. There are no direct runoff measurement records in the study area. Statistical and probability methods have been employed in combination with the empirical equations to determine the maximum design discharges through wadis.

5 _ Bartlomiej Kunecki [6]: Corrugated steel culverts are increasingly being used in road and railway projects as the solutions alternative to small-span concrete and steel bridges. Their construction period is short, and the structures have both technical and economical advantages. Bartlomiej describes full-scale static test of an instrumented corrugated steel culvert with 2.99 m span and 2.40 m height. The corrugation is 159 × 50 mm, and the steel thickness is 3.75 mm. The Standardized railway loads configuration UIC 71 for Europe was applied at 0.80 m soil cover. The present test was carried out in the Bridge and Road Research Institute in Żmigród, Poland, in 1998. Several full-scale
field tests have been performed to validate the long-term performance and great load bearing capacity of these structures, but not very many structures have been tested in controlled conditions in a test facility, such as that described here.
The test results were compared with the results obtained from numerical analysis. Two Finite Element Method (FEM) models of tested structure were built within the Cosmos/M software. Various static systems with different boundary conditions were used for each FEM model.

6 _ Kent E. Cordes and Rolliri H. Hotchkiss [7]: The objective of this study was to update the design manual and procedures currently used by the Nebraska Department of R.oads (NDOR) Roadway Design Division and to provide consistent design procedures for the Roadway Design and Bridge Divisions to follow. To accomplish these objectives, four tasks were set forth.

First, review the current design procedures in the Roadway Design Division and the Bridge Division to gain an in-depth understanding of the procedures each division uses. Next, review the American Association of State Highway Transportation Officials (AASHTO) drainage manuals, drainage manuals, which provide guidelines for an agency to follow in developing a design manual. Third, update regional regression equations for the State of Nebraska. Finally, prepare the results of this study, as well as the results of two previous studies, for incorporation into the new design manual. The biggest concern with the current design procedures used at NDOR is the difference in methods used by the Roadway Design Division (culverts) and the Bridge

Division (bridges). The distinction between a bridge and a culvert is purely a structural one: a span of 20 feet or less defines a culvert, and a span of more than 20 feet defines a bridge. It is conceivable that one division might determine that a bridge was required in a location that the other division found appropriate for a culvert. For this reason, a consistent design procedure is needed for both divisions. The United States Geological Survey (IJSGS) regression equations for Nebraska

Chapter Three

hydraulic Design Criteria of Culvert

Design criteria of culvert

3.1 Design Standard and Considerations [8]

The design of a culvert should take into account many different engineering and technical aspects at the culvert site and adjacent areas. The list below presents the key considerations for the design of culverts.

1. Culverts can serve double duty as flow retarding structures in grass channel design. Care should be taken to design them as storage control structures if flow depths exceed several feet, and to ensure public safety.
2. Improved inlet designs can absorb considerable energy for steeper sloped and skewed inlet condition designs, thus helping to protect channels.

All culverts designs and installed shall conform to the design standards listed in the following sections.

3.2 Limitation of design criteria of culvert

1. Frequency Flood.
2. Velocity Limitations.
3. Buoyancy Protection.
4. Lengths and Slope.
5. Debris and Control.
6. Head water limitations.
7. Tail Water Consideration.
8. Storage.

9. Culvert Inlet.
10. Inlets With Headwall.
11. Wingwalls.
12. Improved Inlets.
13. Material Selection.
14. Culvert Skews.
15. Culvert Sizes.
16. Weep Holes.
17. Outlet protection.
18. Environmental Considerations.

The 25-year frequency storm shall be routed through all culverts and the 100-year storm shall be used as a check, to verify structures (e.g.,houses, commercial buildings) are not flooded or increased damage does not occur to the highway or adjacent property for this design event.

The hydraulic conditions downstream of the culvert site must be evaluated to determine a tail water depth for a range of discharge. At times, there may be a need for calculating backwater curves to establish the tail water conditions. The following conditions must be considered when establishing tail water conditions.

1. If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line should be determined.
2. For culverts that discharge to an open channel, the stage-discharge curve for the channel must be determined.
3. If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert may establish the design tail water depth for the upstream culvert.

4. If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body can be used to establish the culvert tail water.

3.3Design Procedures

3.3.1Types of Flow Control [9]

There are two types of flow conditions for culverts that are based upon the location of the control section and the critical flow depth. These flow conditions are presented in Figure 3-1 and described briefly below.

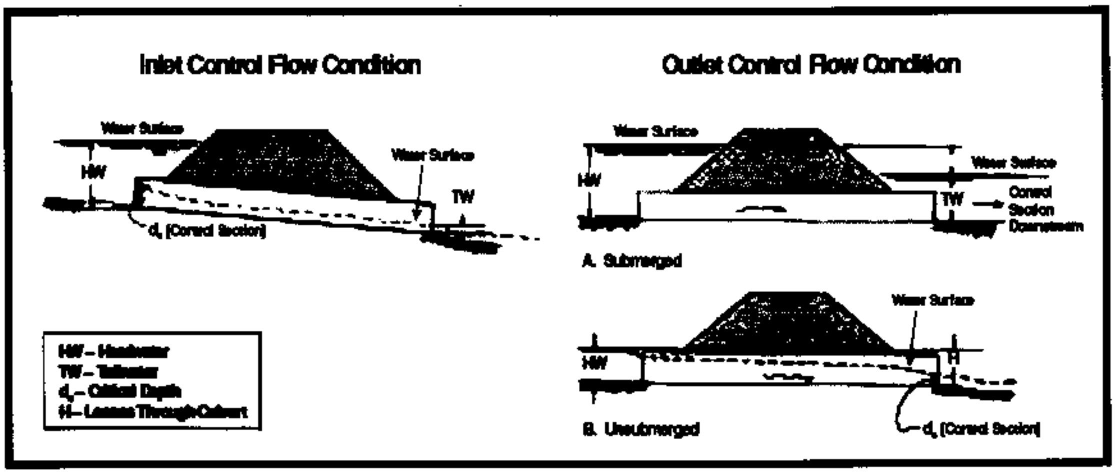


Figure 3-1. Culvert Flow Conditions

(Adapted from: USDOT, 1985)

A- **<u>Inlet Control</u>:** Inlet control occurs when the culvert barrel is capable of conveying more flow than the inlet will accept. This typically happens when a culvert is operating on a steep slope. The control section of a culvert is located just inside the entrance. Critical depth occurs at or near this location, and the flow regime immediately downstream is supercritical.

B- <u>Outlet Control</u>: Outlet control flow occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept. The control section for outlet control flow in a culvert is located at the barrel exit or further downstream. Either subcritical or pressure flow exists in the culvert barrel under these conditions. Proper culvert design and analysis requires checking for both inlet and outlet control to determine which will govern particular culvert designs. For more information on inlet and outlet control.

3.3.2the Procedures of design culvert

There are two procedures for designing culverts: manual use of inlet and outlet control nomographs; and the use computer programs such as HY8 or Heastad Methods programs such as Culvert Master or Flow Master. It is recommended that a computer model be used for culvert design. The computer software packages available use the theoretical basis from the nomographs to size culverts. In addition, these software packages can evaluate improved inlets, route hydrographs, consider road overtopping, and evaluate outlet streambed scour. By using water surface profiles, this procedure is more accurate in predicting backwater effects and outlet scour.

3.3.3Nomographs

The use of culvert design nomographs requires a trial and error solution. Nomographs solutions provide reliable designs for many applications. It should be remembered that velocity, hydrograph routing, roadway overtopping, and outlet scour require additional, separate computations beyond what can be obtained from the nomographs. Figures 3-2 and 3-3 show examples of an inlet control and outlet control nomographs for the design of concrete pipe culverts. For other culvert designs, refer to the complete set of nomographs in Appendix A.

3.3.4 Design Procedure

The following design procedure requires the use of inlet and outlet nomograhs.

(Step 1)

List design data:

Q = discharge (cfs)

S = culvert slope(ft/ft)

V = velocity for trial diameter(ft/s)

HW= allowable headwater depth for the design storm (ft)

L = culvert length (ft)

TW = tail water depth (ft)

Ke= inlet loss coefficient

D = pipe diameter (in)

(Step 2)

Determine trail culvert size by assuming a trial velocity 5 to 8 ft/s and computing the culvert area, A=Q/V. Determine the culvert diameter.

(Step 3)

Find the actual HW for the trial size culvert for both inlet and outlet control.

1. For inlet control, enter inlet control nomograph with D and Q find HW/D for the proper entrance type.
2. Compute HW and, if too large or too small, try another culvert size before computing HW for outlet control.
3. For outlet control enter the outlet control nomograph with the culvert length, entrance loss coefficient, and trail culvert diameter.
4. To compute HW, connect the length scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. Compute the headwater elevation HW from Equation 3-1.

$HW=H+h_0-LS$ ....Equation 3-1

Where: H=head loss, ft

h_0=1/2(critical depth + D) or trail water depth, whichever is greater (maximum =D)

L = culvert length

S = culvert slope

(Step 4)

Compare the computed headwaters and use the higher HW nomograph to determine if the culvert is under inlet or outlet control

1. If **inlet control** governs, then the design is complete and no further analysis is required .
2. If **outlet control** governs and the HW is unacceptable, select a larger trial size and find another HW with the outlet control nomographs. Since the smaller size of culvert had been selected for allowable HW by the inlet control nomograph, the inlet control for the larger pipe need not be checked.

(Step 5)

Calculate exit velocity and if erosion problems may be expected, appropriate energy dissipation designs should be checked.

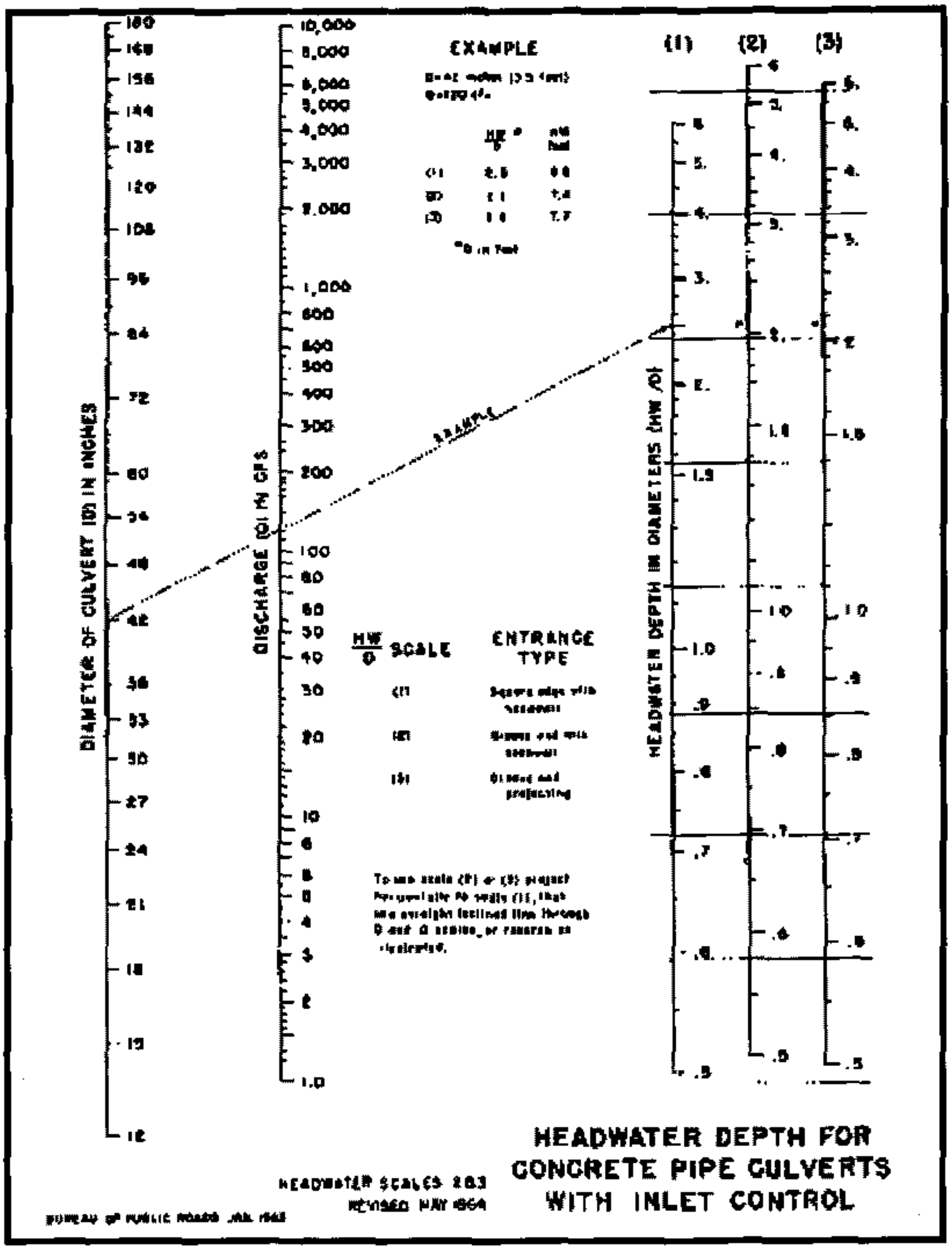


Figure 3-2, Head and Concrete Pipe Culverts Flowing Full
(Source: USDOT, 1985)

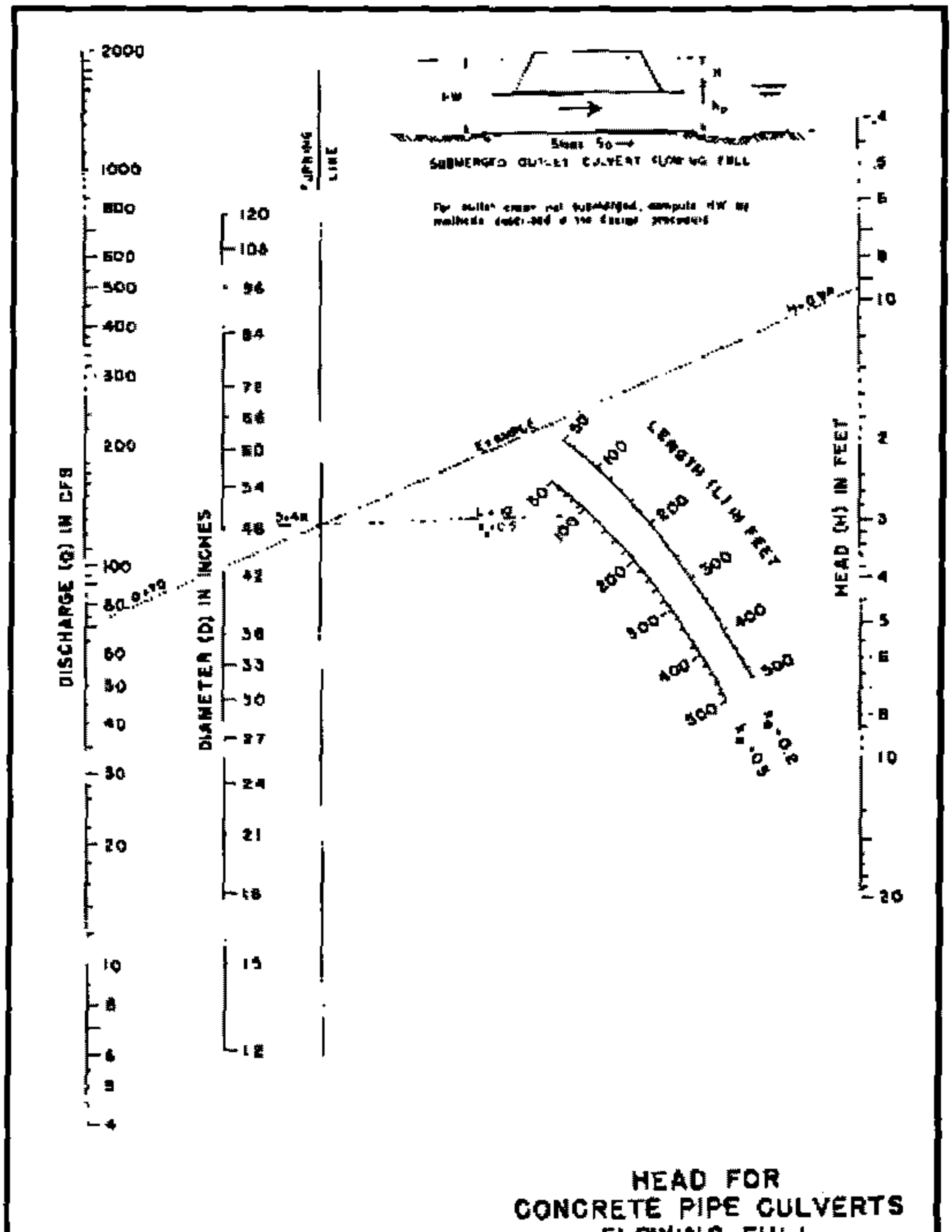


Figure 3-3 Headwater Depth for Concrete Pipe Culvert with Inlet Control

(Source: USDOT, 1985)

Chapter Four

Culvert Design Problem

Culvert Design problem

The following example problem illustrates the procedures to be used in designing culverts using the nomographs.

Size a concrete pipe culvert given the following example data, which were determined by physical limitations at the culvert site and hydraulic procedures described else where in this manual.

4.1 Deign of culvert using the nomagraph [10]

Input Data

Discharge for 2-yr flood= 35cfs

Discharge for 25-yr flood= 70cfs

Allowable headwater (HW) for 25-yr discharge = 5.25ft

Length of culvert = 100ft

Natural channel invert elevations-inlet = 15.50ft, outlet = 14.30ft

Culvert slope = 0.012 ft/ft

Tail water depth for 25-yr discharge = 3.5ft

Tail water depth is the normal depth in downstream channel

Entrance type = Groove end with headwall

Computations

(Step1)

Assume a culvert velocityof5ft/s.

Required flow area = 70cfs/(5ft/s)= 14 ft^2 (for the 25-yr recurrence flood).

(Step2)

The corresponding culvert diameter is about 48 in (4 ft). This can be calculated by using the formula for area of a circle: Area=$(3.14D^2)/4$ or D = $(\text{Area times } 4/3.14)^{0.5}$.

Therefore,

$D = [(14)(4)/3.14]^{0.5}$ [12in/1ft]

D = 50.7 in

(Step3)

A grooved end culvert with a headwall is selected for the design. Using the inlet control nomograph [Figure3-2], with a pipe diameter of 48 inches and a discharge of 70cfs; read a HW/D value of 0.93.

(Step4)

The depth of head water (HW) is (0.93)x(4)= 3.72 ft ,which is less than the allowable headwater of5.25ft. Since 3.72 ft is considerably less than 5.25, try a smaller culvert.

(Step5)

Using the same procedures outlined in Steps3 and4 the following results were obtained.

42-inch culvert – HW = 4.13 ft

36-inch culvert – HW = 4.98 ft

Select a 36-inch culvert to check for outlet control.

(Step6)

The culvert is checked for outlet control by using Figure 3-3.

With an entrance loss coefficient K_e of 0.20, a culvert length of 100ft, and a pipe diameter of 36 in., an H value of 2.8ft is determined. The headwater for outlet control is computed by **The Equation: HW = H + ho -LS**

Compute h_o

h_o = TW or $^{1/2}$ (critical depth in culvert + D), whichever is greater.

h_o = 3.5ft or ho = 0.5(2.7+3.0)= 2.85ft

Note: critical depth is obtained from Chart 4, located in index A.

Therefore: ho = 3.5ft the headwater depth for outlet control is:

HW = H + ho -LS = 2.8 + 3.5-(100) (0.012) = 5.10ft

(Step7)

Since HW for outlet (5.10ft) is greater than the HW for inlet control (4.98 ft) ,outlet control governs the culvert design. Thus, the maximum headwater expected for a 25-year recurrence floodis5.10ft, which isles than the allowable headwater of5.25ft.

(Step8)

Estimate outlet exit velocity. Since this culvert is on outlet control and discharges into an open channel down stream with tail water above culvert, the culvert will be flowing full at the flow depth in the channel. Using the design peak discharge of 70cfs and the area of a 36-inch or 3.0-foot diameter culvert the exit velocity will be:

Q = VA

Therefore:

$V = 70/ [(3.14)\ (3.0)^2 /4] = 9.9$ ft/s

With this high velocity, consideration should be given to provide an energy dissipater at the culvert outlet.

(Step9)

Check for minimum velocity using the 2-year flow of 35cfs.

Therefore:

$V = 35/ [(3.14)\ (3.0)^2/4) = 5.0$ft/s> minimum of 2.5 therefore, OK

(Step10)

Determine if any flooding to culvert the 100-year flow should be routed through the problems will be associated with this event.

4.2 Design Procedures for Beveled-Edged Inlets

Improved inlets include inlet geometry refinements beyond those normally used in conventional culvert design practice. Several degrees of improvements are possible, including bevel-edged, side-tapered, and slope-tapered inlets. Those designers interested in using side-and slope-tapered inlets should consult the detailed design criteria .

4.2.1 Design Figures [11]

Four inlet control figures for culverts with beveled edges are included in below figure (4-1) and figure (4-2 to 4-4).

3 circular pipe culverts with beveled rings

9 wing walls with flare angles of 18 to 45 degrees

10 90^{o} headwalls (same for 90^{o} wing walls)

11 skewed headwalls

The following symbols are used in Figure 4-1:

B -width of culvert barrel or diameter of pipe culvert;

D -height of box culvert or diameter of pipe culvert;

H -depth of pool or head, above the face section of invert;

N -number of barrels; and,

Q -design discharge.

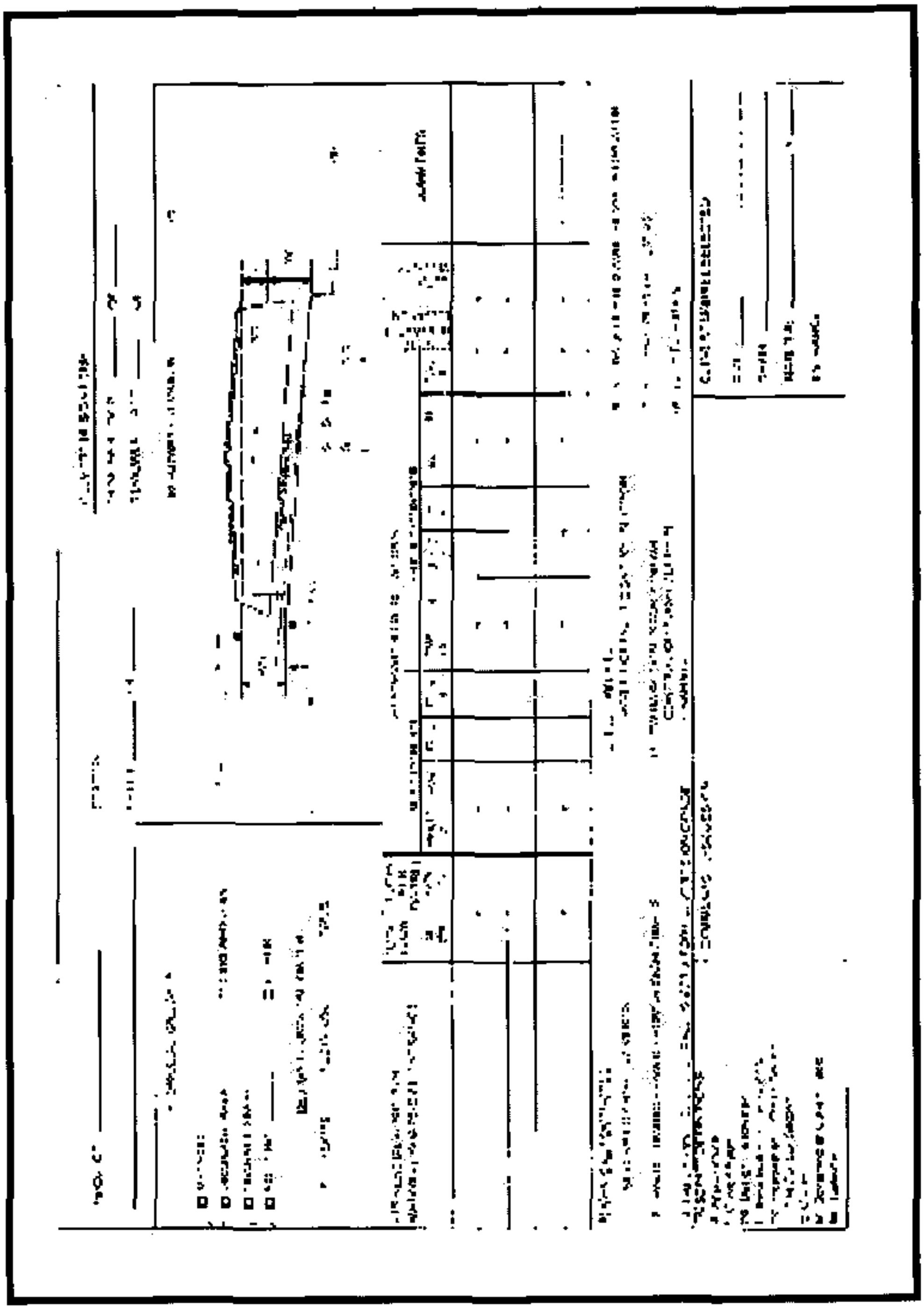


Figure 4-1. Culvert Design Calculation Form
(Source: USDOT, 1985)

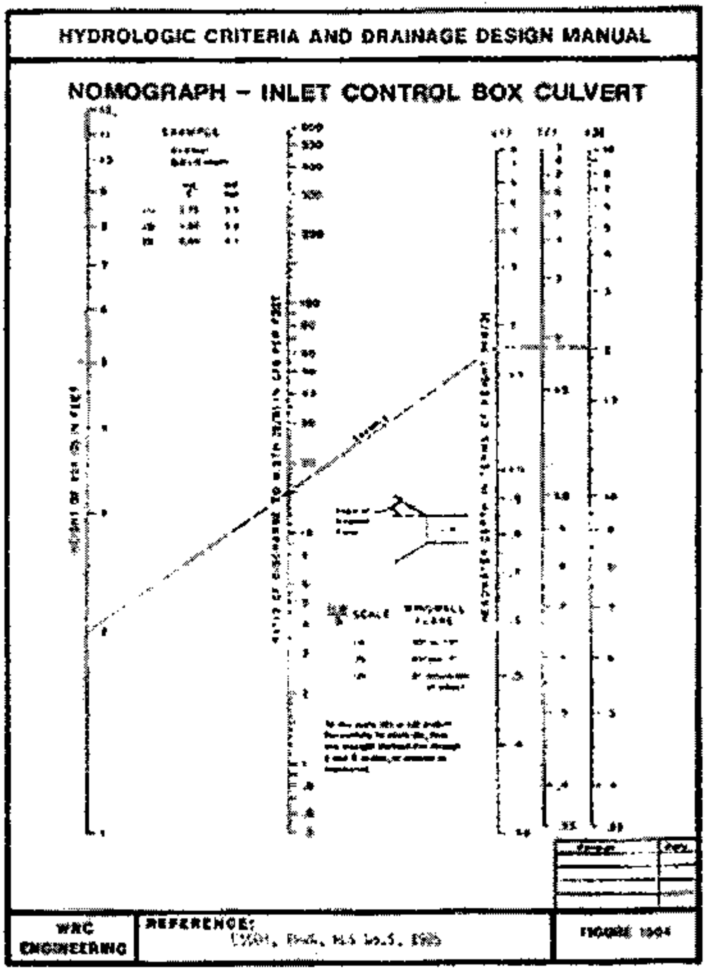


Figure 4-2 Inlet control box culvert
(Source: USDOT, 1985)

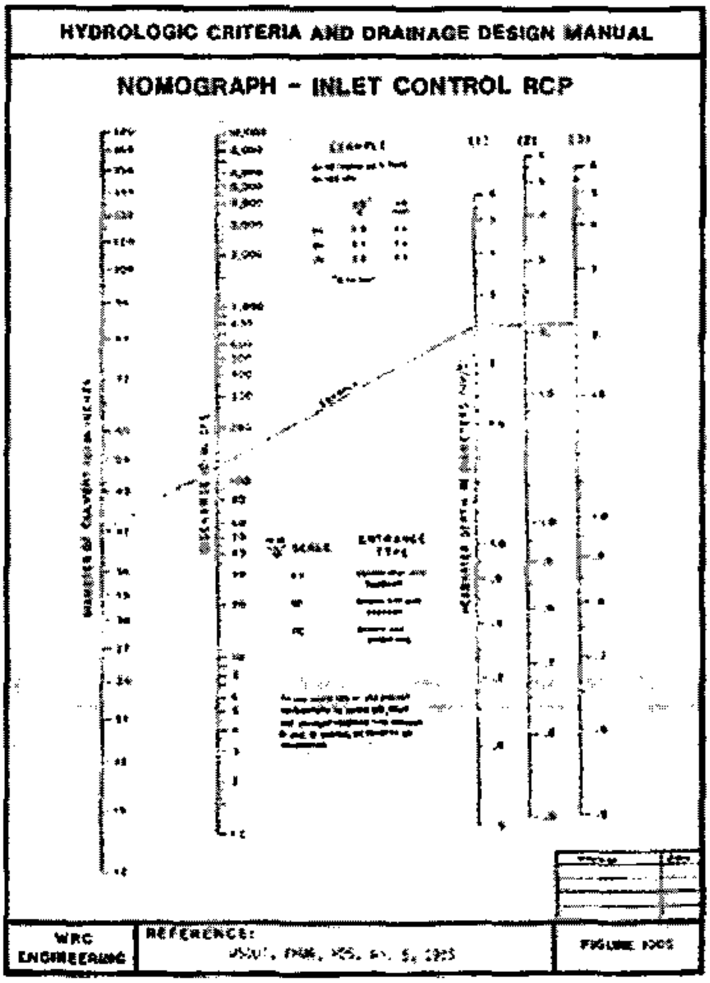


Figure 4-3 Inlet control RCP
(Source: USDOT, 1985)

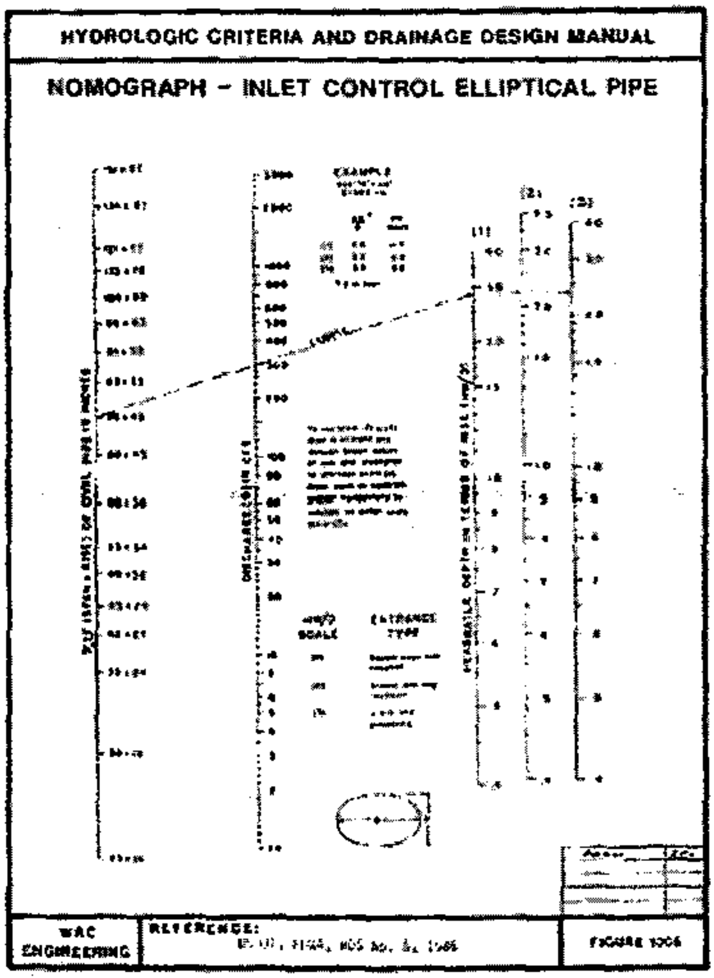


Figure 4-4 Inlet control elliptical pipe
(Source: USDOT, 1985)

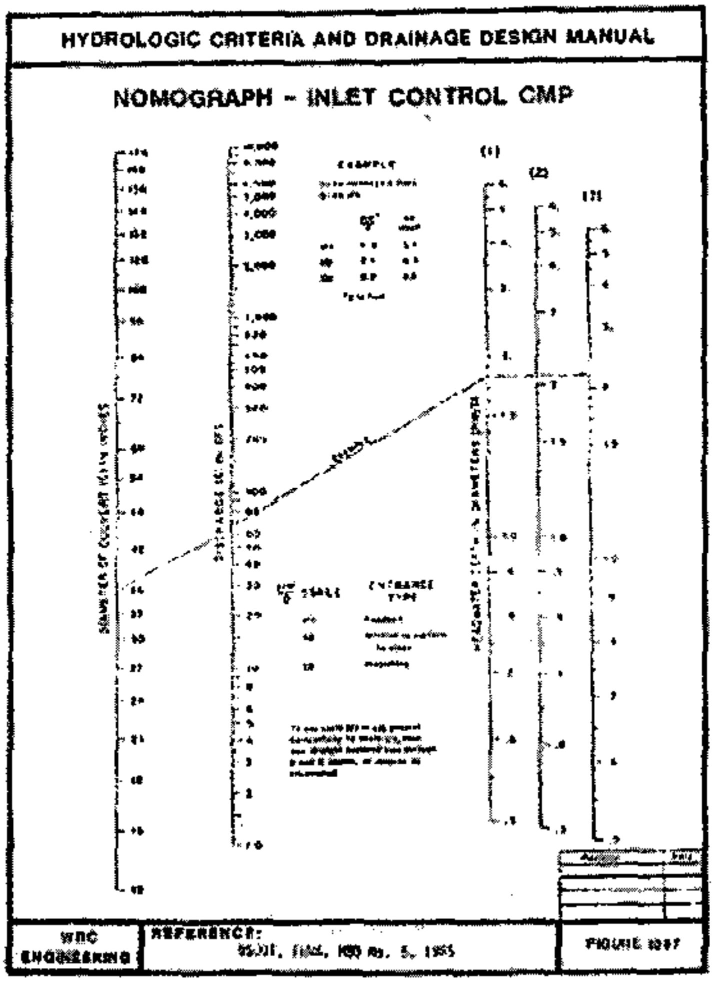


Figure 4-5 Inlet control CMP
(Source: USDOT, 1985)

4.3 solution example by using computer program

Example 1: The size of culvert spillway required discharging 100 second-feet at reservoir elevation 110 is to be determined. The normal still level of the spillway entrance is at elevation 100. The culvert is to flow partly full for all heads. If a circular conduit is selected, the design procedure is as follows:

The head-discharge-diameter relationship for a circular conduit with entrance placed flush with a vertical headwall can be obtained from equation (1) is used for the conduit is to flow partly full.(free board =0.6)

Solution:

Since an H of 10 feet is available, Q=100 second-feet

Put in equation (1) "that it is found from program"

$$\left(\frac{Q}{D^{5/2}}\right)=3.496+0.762\left(\frac{H}{D}\right)-5.344e^{\left(-\frac{H}{D}\right)} \text{ \{Equation (1)\}}$$

$$\left(\frac{100}{D^{5/2}}\right)=3.496+0.762\left(\frac{10}{D}\right)-5.344e^{\left(-\frac{10}{D}\right)}$$

Then

D=3

If a box culvert is selected, the procedure is as follows:

C_d is found from equation (2) "that it is found from program"

$$\frac{H}{D}=1424.033-\frac{2937.497}{C_d}+\frac{2284.933}{C_d^{\,2}}-\frac{791.837}{C_d^{\,3}}+\frac{71.392}{C_d^{\,4}} \text{ \{Equation (2)\}}$$

$$\frac{10}{D}=1424.033-\frac{2937.497}{C_d}+\frac{2284.933}{C_d^{\,2}}-\frac{791.837}{C_d^{\,3}}+\frac{71.392}{C_d^{\,4}} \quad , \; D=3$$

Then

C_d=0.6

$$Q=C_d wD\sqrt{2gH} \text{ \{Equation (3)\}}$$

$$wD=\frac{Q}{C_d\sqrt{2gH}}$$

Then

$2.5w = \frac{100}{0.6 * 8.02 * \sqrt{10}} = 6.6$ And w=2.19 feet.

Example 2: Find the discharge through the conduit in the previous example if the entrances are shaped to provide full conduit flow. The conduit length is 200 feet and the invert grade at the outlet is elevation 80.0. The conduit discharges freely at the outlet end.

Solution:

The procedure is as follows:

Equation (4) may be written:

$$\left(\frac{Q}{D^{5/2}}\right)^2 = \frac{1}{0.0252}\left[\frac{\frac{H}{D}+\frac{L}{D}\sin\theta-\frac{1}{2}}{1+K_e+f\frac{L}{D}}\right]$$

For a 3-foot circular conduit with K_e of 0.10 and f=0.0252, appendix for value n=0.014),

$$\left(\frac{Q}{15.6}\right)^2 = \frac{1}{0.0252}\left[\frac{\frac{10}{3}+\frac{200}{3}*\frac{20}{200}-\frac{1}{2}}{1+0.10+\frac{0.0252*200}{3.0}}\right]=136,$$ and $\frac{Q}{15.6}=11.67$. Then

Q=182 second-feet. This flow will provide a velocity of 25.7 feet per second in the conduit.

Equation (5) may be written as:

$$h_{SA} = \frac{v^2}{2g}(K_r + K_e + K_r) - (H - D).$$

The sub atmospheric pressure in the conduit, based on a pressure reduction coefficient, K_r, of 0.1 and a value of K_e 0f 0.1 for a rounded entrance is equal to:

$$\frac{(25.7)^2}{64.4}(1.0+0.1+0.1)-(10.0-3.0) = 5.3 \text{ Feet.}$$

4.3.1 Program conclusions

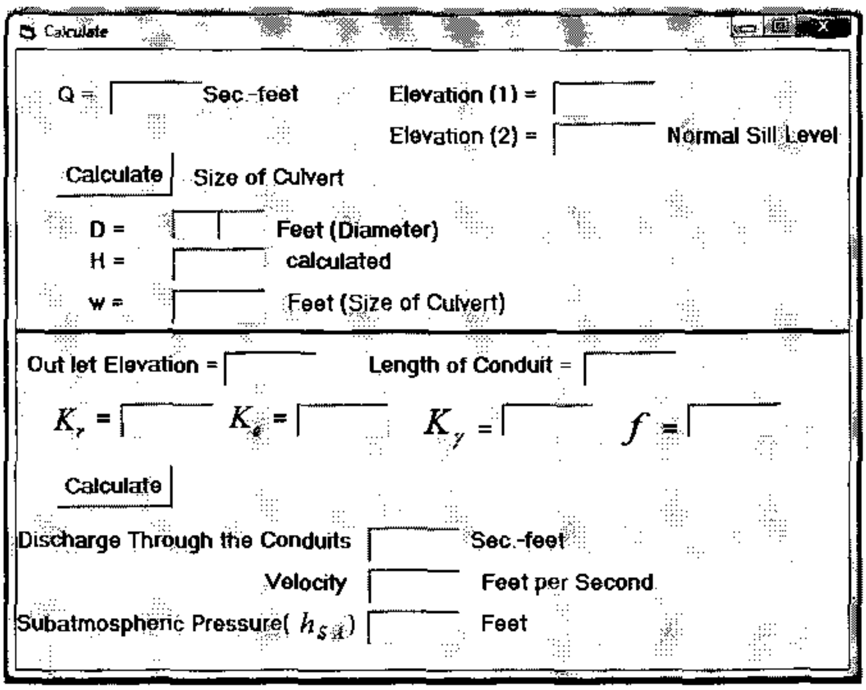
Data Fit Program

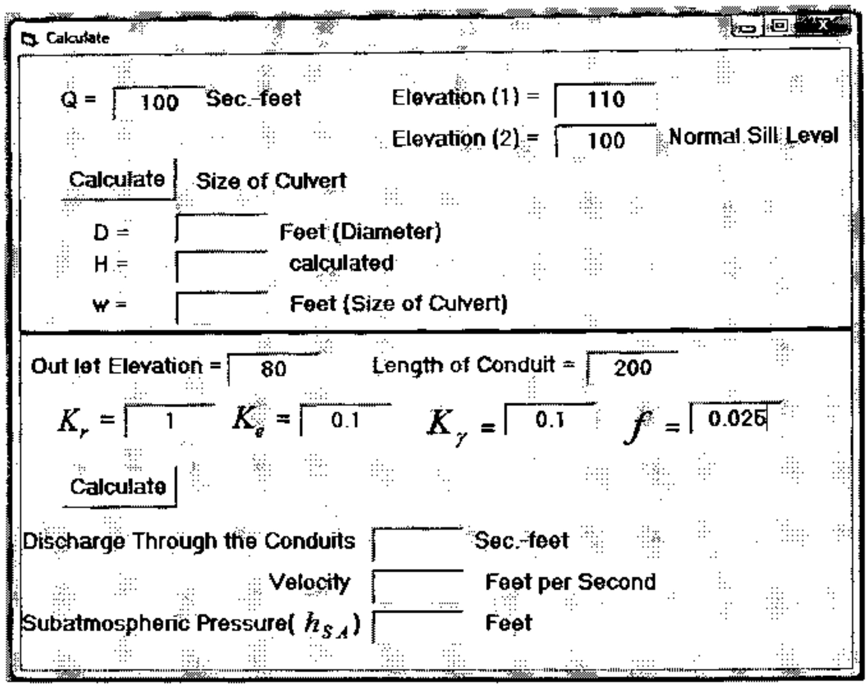
Data fit version 8.2.79

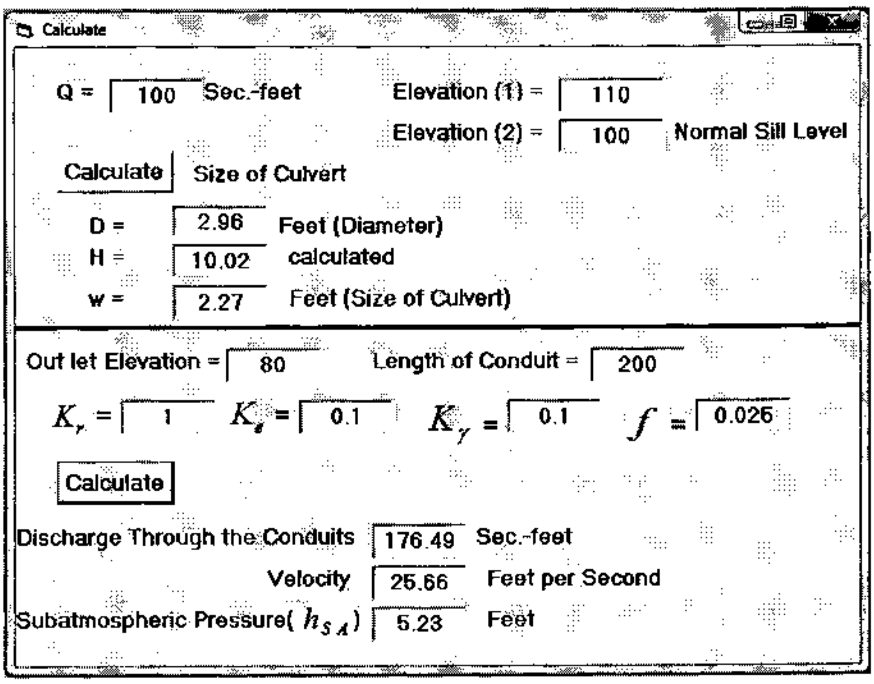
We use the data fit program software with version 8.2.79 by "Oakdale Engineering".

This software has done the Data Fit and makes mathematical models for any data with multi models and created the equation for each model with all statistical information about this equation.

We choose the suitable formula for our data with the suitable items for provided equation with this correlation factor, and this factor is less than another model with more items in its equation and we ignore because of difficulty for application its.




Calculate
Q = 100 Sec.-feet
Elevation (1) = 110
Elevation (2) = 100 Normal Sill Level
Calculate
Size of Culvert
D = Feet (Diameter)
H = calculated
w = Feet (Size of Culvert)
Out let Elevation = 80
Length of Conduit = 200
K_r = 1 K_e = 0.1 K_γ = 0.1 f = 0.025
Calculate
Discharge Through the Conduits Sec.-feet
Velocity Feet per Second
Subatmospheric Pressure(h_{SA}) Feet


Calculate
Q = 100 Sec.-feet
Elevation (1) = 110
Elevation (2) = 100 Normal Sill Level
Calculate
Size of Culvert
D = 2.96 Feet (Diameter)
H = 10.02 calculated
w = 2.27 Feet (Size of Culvert)
Out let Elevation = 80
Length of Conduit = 200
K_r = 1 K_e = 0.1 K_γ = 0.1 f = 0.025
Calculate
Discharge Through the Conduits 176.49 Sec.-feet
Velocity 25.66 Feet per Second
Subatmospheric Pressure(h_{SA}) 5.23 Feet

Chapter FIVE

CONCLUSIONS

Conclusions

In this research we conclude some important points as results from studying the application examples by using the computer programming which is written in a VISUAL BASIC language. Then the next points showed these important points:-

1) By knowing the discharger (Q) , the head level (H) and some design factors we can calculate the size and the diameter of the culverts.

2) By knowing the internal losses (Ke), design losses (k) and the velocity losses, we can obtained the resulting sub atmosphere pressure head (Ksa)

2) We can also obtain the discharge (Q) by knowing the diameter, the water level, internal losses (Ke) and the friction losses (f).

الخلاصة

تعتبر المنشأت الهيدروليكية من أهم المنشأت الحيوية التي تستخدم في السيطرة على المياه وتنظيم توزيعها على الأستخدامات المختلفة .

في هذا البحث تم دراسة البرابخ وهي احد المنشأت الهيدروليكية المهمة وكذلك هي منشأت بزل عرضية للطرق والسكك الحديدية .

وتستخدم البرابخ أيضاً عند تقاطع القنوات الطبيعية مع قنوات الري حيث يستخدم عندما يراد أمرار مياه القنوات الطبيعية أسفل قنوات الري .

يتضمن هذا المشروع دراسة وتحليل وتصميم البرابخ وأنواعها والأعتبارات التصميمية التي تعتمد عليها ، كما تم أختيار ثلاثة أمثلة لتوضيح الخطوات التصميمية التي يمكن أعتمادها في التصميم الهيدروليكي للبرابخ ، وكذلك تم أستخدام برنامج حاسوبي لتصممم وتحليل البرابخ بمعلومية التصريف والمنسوب ،وتم الحصول على قطر ومقياس البربخ .

وتم التوصل الى أن البرابخ الأنبوبية تستخدم عندما يكون تصريف المياه أقل من 2.5 م^3 / ثا ما عدا ذلك فأن البرابخ الصندوقية هي الملائمة للأستخدام بصورة عامة .

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