ARIZONA DEPARTMENT OF TRANSPORTATION

INTERMODEL TRANSPORTATION DIVISION

PIPE SELECTION GUIDELINES AND PROCEDURES

FEBRUARY 1, 1996
WITH MARCH 21, 1996 REVISIONS

ROADWAY ENGINEERING GROUP
DESIGN SECTION

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

ARIZONA DEPARTMENT OF TRANSPORTATION

INTERMODEL TRANSPORTATION DIVISION

PIPE SELECTION GUIDELINES AND PROCEDURES

FEBRUARY 1, 1996
WITH MARCH 21, 1996 REVISIONS

ROADWAY ENGINEERING GROUP
DESIGN SECTION

31-086
$3.00
pg.80

ARIZONA DEPARTMENT OF TRANSPORTATION
ROADWAY ENGINEERING GROUP
OFFICE MEMO

February 6, 1996

TO: ALL DESIGN PERSONNEL
Roadway Engineering Group
Bridge Drainage Section
Statewide Project Management Group
Valley Transportation Group
Local Government Section
Roadside Development Section

FROM: TERRY H. OTTERNESS THO
Design Program Manager
Roadway Design Section

RE: PIPE SELECTION GUIDELINES AND PROCEDURES
February 1, 1996

The subject document has been developed to provide design engineers with guidelines and procedures to determine pipe materials to be included in the construction plans as a bid condition. This procedure applies to all projects designed on the State Highway System.

This document supercedes all previous design memoranda issued from the Roadway Design Group and Highway Plans. The procedure is issued for immediate implementation and should be applied to design projects that are currently underway as determined by the project manager. It is desirable not to cause unnecessary rework on design projects that have progressed to near completion; on the other hand, changed conditions in the field cause extra work and additional costs. Please consult with Roadway Design if you need assistance in the decision whether to apply the procedure. Our goal is to include the appropriate pipe alternates as a bid condition.

Local Government agencies performing design work on their roadway systems will need to make a determination of whether they wish to follow the ADOT guidelines or to establish their own pipe selection alternates.

Please contact Roadway Design regarding any questions or guidance you may require. It is planned to hold some training and information sessions regarding the enclosed guidelines.

Please insure that the personnel in your offices receive a copy of the document as appropriate. Additional copies may be obtained from Engineering Records. Thank you for your support.

c: District Engineers
FHWA
Construction Group
Transportation Support Group
Materials Group
Traffic Group
Maintenance Group
Engineering Consultants Section
Contracts and Specifications Section
John Louis
Wayne Collins
Rick Genteman
August Hardt
Tom Schmitt

FORWARD

This document was developed to provide design engineers with guidelines and procedures to determine pipe materials to be included in the plans as a bid condition. The methodology for achieving minimum service life requirements for currently approved pipe materials is provided.

This document was developed by Roadway Design Section in joint cooperation with Bridge Drainage Section, Materials Group, Construction Group, and District Construction and has been approved for implementation through the ADOT Pipe Committee.

PIPE SELECTION GUIDELINES AND PROCEDURES

TABLE OF CONTENTS

I. FORWARD

II. TABLE OF CONTENTS

III. PIPE SELECTION GUIDELINES - Guidelines For Designers In Determination of Service Life For Various Types Of Pipe Materials 1

IV. PIPE SELECTION PROCEDURES 3

APPENDIX

A. PIPE SELECTION EXAMPLES 8

GENERAL PROCEDURE 8

Culvert and Storm Drain Applications 8
Data Collection 8
Determine Specifications For Pipe Types 8

EXAMPLES - Procedural Discussion 9

Steel Pipe - Galvanized & Aluminized 9
Aluminum Pipe 10
Concrete Pipe 10
Plastic Pipe 11
Exceptions 11
Maintaining Accurate Records 11

EXAMPLE PROBLEMS 12

Steel Pipe - Galvanized 12
Steel Pipe - Aluminized 14
Aluminum Pipe 15
Concrete Pipe 15
Plastic Pipe 16

PIPE SELECTION WORKSHEETS - Completed Forms For Examples

Galvanized Steel Pipe	Figure A-1 & 2
Aluminized Steel Pipe	Figure A-3 & 4
Aluminum Pipe	Figure A-5 & 6
Concrete Pipe	Figure A-7 & 8
Plastic Pipe	Figure A-9 & 10

B. PIPE SELECTION PROCEDURE FLOWCHARTS

Steel Pipe - Galvanized and Aluminized	Figure B-1
Aluminum Pipe	Figure B-2
Concrete Pipe	Figure B-3
Plastic Pipe - Corrugated High Density Polyethylene Plastic Pipe	Figure B-4

C. AISI AVERAGE SERVICE LIFE CHARTS FOR STEEL PIPE
Examples

Galvanized Steel Pipe	Figure C-1
Aluminized Steel Pipe	Figure C-2

D. ALLOWABLE TYPES OF CULVERT PIPE FOR VARIOUS pH AND RESISTIVITY RANGES

pH And Resistivity Limits Chart	Figure D-1

E. PIPE SUMMARY SHEET — Figure E-1

F. FILL HEIGHT TABLES

G. BLANK FORMS

Pipe Selection Worksheets

Galvanized Steel Pipe Selection
Aluminized Steel Pipe Selection
Aluminum Pipe Selection
Concrete Pipe Selection
Plastic Pipe Selection

AISI Average Service Life Charts For Steel Pipe

Galvanized Steel Pipe
Aluminized Steel Pipe

PIPE SELECTION GUIDELINES

GUIDELINES FOR DESIGNERS IN DETERMINATION OF SERVICE LIFE FOR VARIOUS TYPES OF PIPE MATERIALS

When selecting the type of pipe to use for a particular application and location the designer must achieve a predetermined pipe service life. Service life requirements for various pipe alternatives are described in the "Pipe Selection Procedures" beginning on page 3. The pipe selection options available for achieving service life include pipe composition, thickness, and coating. The soils elements that affect pipe service life are soil resistivity, pH, moisture content, and sulfate levels. Materials Section will investigate and document the soil elements at all culvert locations.

All steel pipe service lives will be based on the American Iron and Steel Institute (AISI) chart (see Appendix C). This chart determines expected service life based on specific soil pH and resistivity values. It allows increasing expected pipe service life by increasing pipe gage. **Increasing the gage of the pipe is the preferred method of achieving minimum service life rather than using bituminous coated pipe.** If a pipe is required to be bituminous coated to achieve the design service life, this coating will give the pipe an additional 20 years of service life. (See individual pipe type descriptions below for ranges in which bituminous coating is allowed.) Bituminous coating should mainly only be used if the pipe under consideration is not available in the gage needed to obtain Required Service Life. When pipe thickness without the need of bituminous coating is the preferred alternate to achieve Required Service Life the designer shall note in the contract documents that bituminous coating will NOT be considered as a construction Value Engineering Proposal (VEP).

If water will be persistently present inside the steel pipe, and/or moist soil will persistently be in contact with the outside of the pipe, the service life values in the AISI chart shall be halved. The Materials Lab Memorandum will indicate any moisture concerns at proposed pipe locations. The designer should observe field conditions to anticipate moisture concerns.

GALVANIZED STEEL PIPE

Service life for Corrugated Galvanized Steel Pipe (CGSP), Spiral Rib Galvanized Steel Pipe (SRGSP), Corrugated Galvanized Steel Structural Plate Pipe (CGSSPP), and Concrete-Lined Corrugated Galvanized Steel Pipe (C/LCGSP) shall be based on the AISI chart. Total expected pipe service life is dependent upon pipe gage and the bituminous coating's service life. For galvanized steel pipe to be a viable alternate the coordinate point for soil pH and resistivity must fall within the overall AISI chart limits. Only then can pipe gage be increased or the twenty years of bituminous service life be added to achieve the required service life. For a pH range 6 to 9 and a soil resistivity of 2000 ohm-cm or greater (as shown in the ADOT pH and Resistivity Table in Appendix D) bituminous coating is not normally required for corrosion protection.

ALUMINIZED STEEL PIPE

Service life for Corrugated Aluminized Steel Pipe (CASP) and Spiral Rib Aluminized Steel Pipe (SRASP) shall be based on the respective AISI chart. Total expected pipe service life is dependent on pipe gage and the bituminous coating's service life. For aluminized steel pipe to be a viable alternate the coordinate point for pH and resistivity MUST fall within the defined AISI chart limits for aluminized steel. These limits are defined as resistivity greater than 1500 ohm-cm and pH between 5 and 9 as well as resistivity between 1000 and 1500 ohm-cm and pH between 7.2 and 9.0. Only then can more service life be achieved by increasing pipe gage or providing a bituminous coating which will add twenty years of service life. At present there is no design procedure for CASP or SRASP outside these pH and/or resistivity ranges. Outside these limits use other pipe alternates.

ALUMINUM PIPE

Corrugated Aluminum Pipe (CAP) and Corrugated Aluminum Structural Plate Pipe (CASPP) with a soil pH of 5 to 9 and a resistivity of 500 ohm-cm or greater, shall be given a service life of 50 years for 16 gage aluminum, 62.5 years for 14 gage aluminum, and 87.5 years for 12 gage aluminum. The bituminous coating shall be given an additive service life of 20 years. At present there is no design procedure for CAP outside these pH and/or resistivity ranges. Other pipe alternates will be utilized.

CONCRETE PIPE

Precast Reinforced Concrete Pipe (RCP), Precast Non-Reinforced Concrete Pipe (NRCP), and Non-Reinforced Cast-In-Place Concrete Pipe (NRCIPCP) with a soil pH of 5 or greater shall be given a service life of 100 years. When the pH is less than 5 investigate the use of concrete admixtures to overcome the acidic soils or use other pipe types. For high sulfate levels Materials Section will notify the designer when Type V rather than Type II cement shall be required.

PLASTIC PIPE

Corrugated High Density Polyethylene Plastic Pipe (CHDPEPP), with a soil pH of 1.25 to 14 and all ranges of resistivity, shall be given a service life of 75 years.

PIPE SELECTION PROCEDURES

The designer should refer to the document entitled, "PIPE SELECTION GUIDELINES", subtitled "Guidelines For Designers In Determination Of Service Life For Various Types Of Pipe Materials" on page 1, while applying this procedure.

The goal of this procedure is to identify the pipe alternates and their requirements to include in the plans package. The designer will indicate on the plans Pipe Summary Sheet(s) (see Appendix E) all viable pipe alternates determined in accordance with these guidelines and procedures.

AVAILABLE PIPE TYPES

The following pipe types are available for use on ADOT highway design projects. Use of pipe types, other than those listed below, must be approved by the Assistant State Engineer-Roadway Engineering Group.

STEEL(Galvanized)

1. CGSP-Corrugated Galvanized Steel Pipe
2. SRGSP-Spiral Rib Galvanized Steel Pipe
3. CGSSPP-Corrugated Galvanized Steel Structural Plate Pipe
4. C/LCGSP-Concrete-Lined Corrugated Galvanized Steel Pipe

STEEL(Aluminized)

1. CASP-Corrugated Aluminized Steel Pipe
2. SRASP-Spiral Rib Aluminized Steel Pipe

ALUMINUM

1. CAP-Corrugated Aluminum Pipe
2. CASPP-Corrugated Aluminum Structural Plate Pipe

CONCRETE

1. RCP-Precast Reinforced Concrete Pipe
2. NRCP-Precast Non-Reinforced Concrete Pipe
3. NRCIPCP-Non-Reinforced Cast-In-Place Concrete Pipe

POLYETHYLENE

1. CHDPEPP-Corrugated High Density Polyethylene Plastic Pipe
   Class C - corrugated interior / Class S - smooth interior

PIPE SELECTION PROCESS

The pipe selection process begins when the designer determines the location of the new pipe. This station location must be supplied to Materials Section and be given within ±15' of the final pipe location. Pipes relocated outside this range may require soil retesting at the new locations.

The maximum height of fill over a given pipe section must also be known to determine the minimum pipe wall thickness or class of pipe required by dead and live loading. In metal pipes, this minimum wall thickness requirement frequently supplies more than enough thickness to meet all other service life criteria. Therefore, the designer should begin pipe selection by determining the pipe wall thickness required due to fill height. (See ADOT Fill Height Tables in Appendix F).

Materials Section will document the soil elements of resistivity, pH, high moisture, and sulfate levels at all culvert locations supplied by the designer. When designing a closed storm drain system, as soon as practical, once the approximate location of the storm drain is determined, the designer will contact District to confirm the suitability of a storm drain system at this location and contact Geotechnical Section to review the suitability of soils for trench conditions. A meeting will then be held with the designer, District and Geotechnical Section to reach a decision on whether to include NRCIPCP as an alternate. When NRCIPCP is included as an alternate, the plans will include separate pipe profile sheets if required for hydraulic considerations.

SPECIAL REQUIREMENTS

Minimum pipe size shall be 24" inside diameter. Pipes may be 18" in diameter when connecting inlets to an adjacent trunk line and where conflicts with other highway appurtenance features preclude the use of a 24" diameter pipe. However, District maintenance should concur with any proposed use of 18" pipe. C/LCGSP and NRCIPCP shall be 30" minimum inside diameter to provide sufficient space for inspection and repair of cracks. NRCIPCP shall not exceed 120" inside diameter. The designer must specify on the plans or special provisions when water tight joints are required. Siphons, irrigation systems, and storm drain systems require water tight joints. Refer to the current Approved Products List, maintained by ATRC, for approved CHDPEPP sizes. Only pipe sizes with approved joints will appear on the Approved Products List.

NRCIPCP will not normally be used under lengths of 200 feet. It is used for smooth interior applications only. It will not normally be used to construct open ended pipe culverts, due to extreme temperature differentials at pipe ends. If, however, NRCIPCP outlets to an open system through a structural headwall then a suitable doweling or reinforcing connection shall be considered to connect the pipe to the headwall.

Special Provisions may be necessary for some of these pipe types to describe additional requirements for special coatings, liners, joint requirements, or materials at specific sites. Special Provisions may be required to define installation or inspection requirements in addition to those shown in the applicable Standard Specifications.

In selecting pipe alternates and sizes, the designer shall consider such factors as durability, comparative costs, constructability, environmental considerations, service life, maintenance of traffic during pipe installations, soil conditions, fill heights, remote site factors, closed storm drain systems, potential for corrosive spillages, abrasive flows (bed load), need for water tight joints, slopes of inverts and hydraulic characteristics of pipe material inside surfaces.

Bituminous coating, invert liners, special reinforcing, or other treatment may be required before some of these types can be used at certain locations. In environmentally sensitive areas, bituminous coating may not be allowed. For any pipe types involving coatings or linings, extreme care in handling and installation is necessary to insure the durability that is expected by the designer. The possibility of chemical reaction must also be considered when connecting, coating, or lining metal pipes. The designer should verify the existing pipe materials as part of the alternative evaluation. No pipe type mixing will be allowed on a single run of pipe. For example, existing galvanized steel pipe would not be extended with new aluminized steel pipe. Reconstruction projects will require verification of the existing pipe material as part of the alternative evaluation.

In urban work particularly, and all projects in general, consideration is to be given to traffic maintenance and construction scheduling. Some techniques which may facilitate traffic handling and the appropriate use of NRCIPCP are:

1. Where traffic must be maintained through major intersections and open trench time is severely limited, precast pipe should be specified for this location.

2. When the open trench length, width and depth will permit bridging, such as with steel plates, the designer may give consideration to NRCIPCP as a viable alternative.

3. When several utility conflicts occur within a trench section, which would require multiple removals and setups of NRCIPCP forms, the designer should consider substituting precast pipe as the preferred alternate specified.

OPEN ENDED PIPE CULVERTS

1. Open ended pipe culverts will generally be designed based on corrugated type interiors unless hydraulic conditions warrant smooth interior. The Manning's "n" factor for design of corrugated metal and plastic pipe shall be 0.024.

2. They shall meet 50 year service life criteria on all State routes unless the designer can justify a shorter service life on selected, low volume secondary or local roads. In any case, a 25 year service life is the minimum on state routes.

CLOSED STORM DRAIN SYSTEMS

The most economical storm drain design will allow for all viable pipe types. This becomes a formidable task, however, when the designer starts to consider the endless number of pipe type combinations that are possible. Mixing and matching the best type pipe to use for trunk lines in combination with laterals can lead to complex and confusing design calculations. To simplify this procedure the designer should analyze only two closed storm drain systems: one using an n factor of 0.012 and the other using an n factor of 0.014. All smooth interior pipe types are represented by one of these n factors.

Use the same pipe type to analyze the entire closed system. Then show the viable pipe alternatives on the Pipe Summary Sheet. The contractor can then pick and choose the most economical pipe alternatives to use on the project. Any pipe type analyzed must meet minimum pipe type selection criteria before accepting it as a viable alternate. Furthermore, only those pipe types which meet the following conditions may be considered as alternates for storm drain use:

1. Closed system pipe types will be designed and constructed using smooth interior pipe.

2. A 75 year "maintenance free" service life is required for the interstate and freeway systems. A 75 year service life will be considered and may be required by the designer on other State routes where potential storm drain repair or removal would cause a major impact on the traveling public. All other circumstances require a 50 year service life for storm drains.

3. Bituminous coating shall not be used for closed storm drain systems.

4. The n factor for design shall be 0.012 for RCP, NRCP, C/LCGSP, SRGSP and smooth lined CHDPEPP. Use 0.014 for NRCIPCP.

5. If a separate profile is required, it will be indicated in the plans with separate profile sheets.

6. **C/LCGSP** and **SRGSP** shall not be utilized in closed storm drain systems under the following conditions:

   A. C/LCGSP and SRGSP shall not be used under interstate or freeway systems or any high volume urban sections.

   B. The pipe has a longitudinal run exceeding 1000 feet under paved roadway, paved shoulders and/or adjacent curb, gutter, or sidewalk of a state primary roadway.

   C. De-icing chemicals, agricultural or other corrosive agents may be "flushed" into the pipe periodically.

   D. The pipe is part of a closed conduit system connecting to either a pump station, siphon, or pressurized line. This includes lines which provide operational or detention storage.

7. **NRCIPCP** - The evaluation relative to NRCIPCP for consideration of its use in closed storm drain systems should include the following:

   A. New construction will usually provide opportunity for proper curing prior to backfilling and construction loads.

   B. Reconstruction will require a more detailed evaluation, particularly in urban areas. Consideration shall be given to the following:

      i. Maintenance of traffic on cross-streets, into and from businesses and residences.

      ii. Median cross over opportunities.

      iii. Any required restrictions in the length of time a trench would remain open. This would include trench containing cast pipe in the curing stage.

   C. Soil conditions - In that the trench is excavated to shape and provides for more than the lower half of the exterior form for the pipe conduit, soils must be stable. Conditions to be avoided include: sandy cohesionless soils, expansive soils, marshy or peaty areas, and areas subject to subsidence. Materials Section will determine the suitability of the soils.

ABRASION

When the velocity of flow through a metal pipe is greater than 7 ft/sec abrasive bed loads may become a factor. Concrete invert paving, increasing metal gage thickness, or using concrete or polyethylene pipe will be considered to address the potential abrasion problem.

When the velocity of flow through a concrete pipe is greater than 40 ft/sec, increasing the compressive strength of the concrete along with increasing the specific hardness of the aggregate used will be considered to address the potential abrasion problem. Only increasing the compressive strength of the concrete may be economical, since increasing specific hardness may require an uneconomically located aggregate source (pit).

ARIZONA DEPARTMENT OF TRANSPORTATION

INTERMODEL TRANSPORTATION DIVISION

PIPE SELECTION GUIDELINES AND PROCEDURES

APPENDIX

APPENDIX

A

PIPE SELECTION EXAMPLES

PIPE SELECTION EXAMPLES

GENERAL PROCEDURE

Pipe selection design can be organized into a very systematic procedure. Flowcharts for each pipe type have been developed to lead the designer through the selection process (see Appendix B). Refer to the appropriate flowchart for the specific pipe type you are checking to gain an overall picture of how the selection procedure unfolds. Each chart leads progressively through the simplest and most direct path.

CULVERT AND STORM DRAIN APPLICATIONS

Pipe alternates are initially selected knowing the type of drainage system to be used. The designer applies either culvert or storm drain criteria. For example, cross culverts are typically designed using corrugated pipe; smooth pipe interiors are only utilized for culvert applications when required by hydraulic design. On the other hand, storm drains make use of the hydraulically more efficient smooth lined pipes. Here, smooth interior plastic pipe and all acceptable concrete alternates will survive the cut. Here, corrugated pipe alternates are not the preferred choice. The designer should use Pipe Selection Worksheets appropriate to the type drainage system being designed. This will reduce the pipe selection work required.

DATA COLLECTION

Pipe selection begins with the collection of certain design data. It is important that the designer organize design data from the beginning to simplify future reference. For this reason pipe selection worksheets are available for each pipe type. Take a look at the Galvanized Steel Pipe Selection worksheet as an example in Figure A-1. Each column represents the design of one pipe type at a specific plan sheet location (station). By the time the designer is ready to select specific pipe types the following data has already been determined:

1. Service Life Required
2. Flow Velocity
3. Pipe Size
4. Station Location
5. Fill Height
6. Trench Condition

The Materials Lab Memorandum will supply:

1. Soil pH
2. Soil Resistivity
3. High soil moisture locations
4. High soil sulfate level locations

Check to see that values are given for stations within fifteen feet either side of the final pipe location. If pipe location shifts outside this range then contact Materials Testing Section to see if values closer to the final pipe location should be obtained.

Insert this data into the appropriate blanks on the worksheet.

DETERMINE SPECIFICATIONS FOR PIPE TYPES

Apply the above information to determine specifications for each pipe type. The next design tool to use is the Fill Height Tables (see Appendix F). Follow the three step procedure below to obtain Corrugation Size and Wall Thickness, in the case of metal pipe, and Class, or Wall Thickness for concrete pipe.

1. Enter the pipe Fill Height Tables using the applicable fill height range for the type and size of pipe being designed.
2. Note whether this will be for a Trench or Non-Trench condition.
3. Using the specific pipe size (diameter for round pipe) and pipe type determine the corresponding Corrugation Size, Wall Thickness, or Class.
4. Note this information on the worksheet.

From this point forward the pipe selection design for each pipe type is unique.

STEEL PIPE

Using the Steel Pipe Selection worksheet find the Wall Thickness, determined using the Fill Height Tables, and circle it. Circle the AISI Thickness Factor given with this pipe thickness. The AISI Factor is one of two variables used in calculating the Expected Service Life, SLe. If a wall thickness greater than any listed is required write it in below the others listed.

Steel Pipe is available in Galvanized and Aluminized coatings. Each has its own limits in the AISI chart. Be sure you are using the correct chart for the pipe type you are analyzing. (See Appendix A).

The Service Life Expected, SLe, for Steel Pipe varies more pronouncedly than for any other pipe type. To determine SLe enter the appropriate AISI chart (for Galvanized or Aluminized Steel) and using the pH and Resistivity values determine the number of years for the Service Life Base, SLb (referred to as Average Life on the chart). Keep in mind that if high soil moisture is present the SLb must be reduced by half. Multiply the AISI Factor times SLb. (Make calculations at the bottom of the worksheet in the space provided.) This yields the Service Life Expected, SLe. If SLe > SLr (Service Life Required) then this pipe type and size is an acceptable alternate. If not, the designer has three options to make it so.

1. Increase the pipe wall thickness (pipe gage), which changes the AISI Factor and increases the SLb. Circle the preferred final values. Cross out the old.
2. Consider justifying a lower service life requirement if SLe is close to SLr.
3. Add bituminous coating. This adds twenty years to SLb. This option has limited application. It is not the preferred method for increasing service life.

If increasing the pipe thickness is selected, then recalculate SLe based on the new AISI Factor and compare it to the SLr. Circle the preferred final values. Cross out the old. The designer also has the option to combine any or all of these three options. For example, the designer may increase pipe thickness and add bituminous coating to achieve SLr.

Finally, if the exit flow velocity exceeds 7 ft/sec then abrasion due to rock flow must be investigated. The designer must consider the type of material carried by the flow (dirt, sand, rounded river rock, broken/jagged rock), and the magnitude of the flow. Types of treatment to address abrasion include increasing pipe wall thickness, bituminous or concrete invert paving, or using concrete pipe or high density polyethylene plastic pipe.

CHECK PIPE SIZE AVAILABILITY

When increasing the pipe wall thickness to achieve desired service life be sure to recheck that the size of pipe being designed is manufactured in the wall thickness being used. Also, check if corrugation size changes due to increased pipe wall thickness. This is mainly a concern for smaller diameter pipes which require very large wall thicknesses.

ALUMINUM PIPE

Aluminum Pipe selection differs slightly from Steel Pipe due to more restrictions in its use. Check the pH and Resistivity limits first. If pH is outside the range of 5 to 9, or Resistivity is less than 500 ohm-cm then Aluminum Pipe cannot be used at that location. Now determine the Pipe Wall Thickness, using the same Fill Height Table procedure as for Steel Pipe. This leads to a corresponding Expected Service Life as given in the Worksheet block. Circle both values. Check to see if SLe > SLr. If not, then use the same first two alternatives that were available for increasing Expected Service Life for Steel Pipe, namely:

1. Increase the pipe thickness.
2. Consider justifying a lower service life requirement.
3. Add bituminous coating.

Check the Velocity of Flow for abrasion. Use the same criteria as for Steel Pipe. Also, check Pipe Size Availability as for Steel Pipe.

CONCRETE PIPE

Concrete is the most durable pipe material. It is allowed a 100 year Expected Service Life. For most applications the designer will not require a higher service life. Therefore, Concrete Pipe, of any type, will almost always satisfy the Service Life Requirements.

As with the metal pipe types above the designer enters the Fill Height Tables to obtain essential pipe parameters unique to the type of concrete pipe under consideration. If analyzing Reinforced Concrete Pipe or Non-Reinforced Concrete Pipe determine the Class of Pipe for the Pipe Size, appropriate Fill Height, and type of Trench Condition. Similarly, obtain Wall Thickness for Non-Reinforced Cast-In-Place Concrete Pipe. Place this information on the Pipe Summary Sheet.

Three other design issues for concrete pipe must be addressed by the designer:

1. Is the soil pH < 5?
2. Is there high sulfate levels in the soil?
3. Is the Flow Velocity > 40 ft/sec?

LOW pH. If the pH is less than 5 then additional protection is needed for RCP and NRCP. The designer must request that these pipe be bituminous coated. The designer is not permitted to use NRCIPCP under these conditions.

HIGH SULFATE. Materials Group will indicate in the Materials Lab Memorandum if high sulfate levels occur at a given pipe location. If high concentrations exist the Memo will also indicate whether Type V cement should be used to make the concrete pipe.

HIGH FLOW VELOCITY. Finally, concrete pipe must be checked for abrasion potential. Concrete is generally very abrasion resistant. Only when flows exceed 40 ft/sec does it become a concern. If abrasion is likely a problem consider increasing the compressive strength of the concrete. Increasing the specific hardness of the aggregate used is also effective, but finding an economical source is often difficult. The designer could also consider using High Density Polyethylene Pipe. It has a record of having a high resistance to abrasion problems.

Each of these three unique problems for Concrete Pipe will require special notes on the Pipe Summary Sheet, its applicable plans detail sheet, or in the special provisions.

PLASTIC PIPE

This is the light, durable pipe with the long name. It is officially titled Corrugated High Density Polyethylene Plastic Pipe or CHDPEPP. It is the easiest pipe to design, but it also has the greatest restrictions. Rarely, if ever, will the designer face a problem for Plastic Pipe meeting the pH and Resistivity limits. It is good for pH values between 1.25 and 14, virtually the full range. For Resistivity it is good for ALL values. It also is given an Expected Service Life of 75 years, enough to meet most applications.

The three parameters which limit its use are:

1. A Pipe Size between 12 and 36 inches.
2. Approved water resistant and water tight joints (refer to ATRC's current Approved Products List for available pipe sizes).
2. A Fill Height ≤ 10 feet.

Plastic Pipe can be used as an acceptable alternate if ALL these conditions are met.

EXCEPTIONS

There may be times when the designer must look again at previously eliminated pipe types which were not considered because of the type of drainage system being used. For example, the designer may discover that all metal and plastic pipe in the culvert application are not acceptable because pH, resistivity, or fill height requirements are exceeded. What is a designer to do? Return to the concrete alternatives and see if they fulfill pipe selection requirements. Then select the alternate(s) most suitable to the application. This would be an unusual situtation, but at least the designer has an option.

A similar condition could happen with a storm drain application where plastic and concrete pipe alternates fail required fill height criteria. In this case the designer must obtain a special reinforced concrete pipe design that is strengthened to carry the required load.

MAINTAINING ACCURATE RECORDS

The designer now has a complete record of his pipe selection design. Information summarized on the worksheet is then transferred directly onto the Pipe Summary Sheet. If conditions change later in project development the designer need only revise the affected pipe location for each pipe type and revise the entry in the Pipe Summary Sheet.

EXAMPLE PROBLEMS

STEEL PIPE

The following examples show how to proceed through steel pipe selection design.
Each example assumes the designer has already gathered all the preliminary data needed to determine the appropriate pipe selections.

STEEL PIPE - GALVANIZED

The following eight examples will determine if galvanized steel pipe is an acceptable alternative for the given conditions. They will also determine all the criteria needed to define the pipe to be placed at these locations.

Example 1.

Minimum pipe wall thickness for the 1-3 foot fill height range in a trench condition is determined to be 0.064". This corresponds to an AISI Factor of 1.3. Using a pH of 7.2 and resistivity of 1500 ohm-cm yields a Sevice Life Base SLb = 50 years off the AISI chart. Multiplying the AISI Factor times SLb (1.3X50) gives a Service Life Expected SLe = 65 years which is less than the 75 years Service Life Required, SLr. To increase SLe try increasing the pipe wall thickness to 0.079". The new AISI Factor = 1.6 and SLe = 1.6 X 50 = 80 years, which is greater than SLr.

Another alternative is to add a bituminous coating to the lesser thick pipe. This yields SLe = 65 + 20 = 85 years. Also acceptable. Use the thicker pipe since it is preferrable to adding bituminous coating. But keep in mind that if on the overall project you use more coated pipes you may want to use coating here, too.

Example 2.

This example is similar to example 1. SLr has lowered to 50 years and pH and resistivity have changed to 8.8 and 2500 ohm-cm respectively. But the design is still straightforward. Wall thickness required by the non-trench condition and 3'-5' fill height remains at 0.064" meaning the AISI Factor is still 1.3. From the AISI chart the SLb has increased to 74 years. (Use the top line of the chart when pH is between 7.3 and 9.0.) Applying the AISI Factor of 1.3 yields 96 years. This is much greater than the 50 years required. In this example the minimum pipe wall thickness required by fill height conditions governed the design of the pipe thickness. No other criteria warranted further increases in thickness. This is a common condition and helps simplify steel pipe design.

Example 3.

Here SLr = 50 years, minimum wall thickness = 0.064" due to a non-trench condition in 5'-8' of fill, AISI Factor = 1.3, pH =6.5, resistivity = 6000 ohm-cm. SLb from the AISI chart is 45 years, but high moisture is present in the soil. Therefore, reduce SLb by half to 22.5 years. Calculating SLe = AISI Factor X SLb = 1.3 X 22.5 = 29 years. Obviously this is short of the 50 year minimum service life. The designer has three options to consider. First, the next size pipe wall thickness is 0.079" and has an AISI Factor of 1.6. This gives SLe = 1.6 X 22.5 = 36 years. Still short. Try the next thickness, 0.109" with AISI Factor = 2.2. SLe = 2.2 X 22.5 = 49.5 years (rounded up this becomes 50 years). This is close to the SLr. The designer has the option to consider justifying a lower value for SLr since the charts for figuring service life are empirical in nature and only approximate service life. Another alternative is to add bituminous coating (though not preferred) to the 0.064" thick pipe. This results in SLe = 29 + 20 = 49 years, which will work. Finally, for the thicker wall alternative check to see if the 24" diameter pipe is manufactured in a 0.109" wall thickness and, if so, will it require a larger corrugation size.

Example 4.

SLr = 50 years pH = 7.1 Resistivity = 600 ohm-cm
Fill Height = 3'-5' Thickness = 0.064" AISI Factor = 1.3 Trench Condition
The AISI chart yields SLb = 33 years. SLe = 1.3 X 33 = 43 years < 50 years.
Adding bituminous coating, SLe = 43 + 20 = 63 years, is OK, but increasing wall thickness one gage is more desireable and meets the requirement. It yields SLe = 1.6 X 33 = 53 years.

Example 5.

SLr = 50 years pH = 5.7 Resistivity = 3000 ohm-cm
Fill Height = 1'-3' Thickness = 0.064" AISI Factor = 1.3 Non-Trench Conditon
The AISI chart yields SLb = 29 years. SLe = 1.3 X 29 = 38 years < 50 years.
Adding bituminous coating yields SLe = 38 + 20 = 58 years. This would work. We can also try increasing thickness to 0.079" which has an AISI Factor of 1.6. SLe = (1.6 X 29) = 46 years. Still quite shy of the 50 year minimum. Increasing thickness to 0.109" yields SLe = (2.2 X 29) = 64 years. This will work and is preferrable to bituminous coating. On small diameter pipe, though, be sure to check that the pipe is made in the thicker gage being recommended. Also, check whether this thicker pipe needs a larger corrugation size.

Example 6.

pH = 9.3 Resistivity = 1500 ohm-cm Trench Condition
Since pH > 9.0 galvanized steel is not acceptable as a pipe alternate at this location.
In this example no metal or plastic pipe is an acceptable alternate. The designer must now look at concrete pipe alternates for a solution. As you will see, in Concrete Pipe Example 6 below, RCP will fit the need.

Example 7.

SLr = 50 years pH = 4.0 Resistivity = 2000 ohm-cm
Fill Height = 70'-90' Thickness = 0.138" AISI Factor = 2.8 Non-Trench Condition
The AISI chart yields SLb = 15 years. SLe = 2.8 X 15 = 42 years. It will take another gage increase to meet SLr. Thus SLe = 3.4 X 15 = 51 years. OK. Use this as the preferred alternate. Adding bituminous coating to the lowest gage pipe would also work. SLe = 42 + 20 = 62 years.

Example 8.

SLr = 50 years pH = 7.0 Resistivity = 1400 ohm-cm
Fill Height = 3'-5' Thickness = 0.064" AISI Factor = 1.3 Non-Trench Condition
High soil moisture at this location requires reducing the SLb by half. The AISI chart gives SLb = 39. This means that SLe = 1/2 X 39 X 1.3 = 25 years < 50 years. Increase pipe thickness to achieve the required Service Life. Use 0.079" with AISI Factor = 1.6. SLe = 1/2 X 39 X 1.6 = 31 years. Adding a bituminous coating will achieve SLr (SLe=31+20=51 years). Alternatively, increasing the pipe gage two more thicknesses (0.138") also gives acceptable results (SLe = 1/2 X 39 X 2.8 = 55 years) and is the preferred solution. Be sure, however, that the 30" pipe can be made in a gage this thick. Also ask, will this thick pipe need a larger size of corrugation?

STEEL PIPE - ALUMINIZED

The following example problems illustrate pipe selection procedures for Aluminized Steel Pipe.

Example 1.

SLr = 75 years pH = 7.2 Resistivity = 1500 ohm-cm
Fill Height = 1'-3' Thickness = 0.064" AISI Factor = 1.3 Trench Condition
The AISI chart gives a SLb = 50 years. Thus, SLe = 1.3 X 50 = 65 years < 75 years. Increase gage and try again. SLe = 1.6 X 50 = 80 years. OK. Bituminous coating on the lesser gage also works. SLe = 65 + 20 = 85 years. Use the extra gage choice. You will note that the procedure for Aluminized Steel Pipe in this case is identical to that for Galvanized Steel Pipe. This will always be the case as long as the pH and Resistivity values are within the AISI Chart limits for Aluminized Steel.

Example 2.

Slr = 50 years pH = 8.8 Resistivity = 2500 ohm-cm
Fill Height = 3'-5' Thickness = 0.064" AISI Factor = 1.3 Non-Trench Condition
The AISI chart Gives a SLb = 74 years. Thus, SLe = 1.3 X 74 = 96 years > 50 years. OK.
Again, this is the same result as was obtained for the galvanized steel pipe.

Example 3.

Slr = 50 years pH = 6.5 Resistivity = 6000 ohm-cm
Fill Height = 5'-8' Thickness = 0.064" AISI Factor = 1.3 Non-Trench Condition
The AISI chart gives a SLb = 45 years. Reduce this by half for soil moisture. Thus, SLe = 1/2 X 45 X 1.3 = 29 years. Once again, as you can see, this procedure is leading to the same results as was derived for galvanized steel pipe in Example #3. As long as the pH and resistivity data fall within the acceptable limits of the AISI chart for aluminized steel pipe the results will be identical.

Example 4.

SLr = 50 years pH = 7.1 Resistivity = 600 ohm-cm
Fill Height = 3'-5' Thickness = 0.064" AISI Factor = 1.3 Trench Condition
In this case the resistivity is outside the range of the AISI chart for aluminized steel pipe. Thus, aluminized steel pipe is not an acceptable alternative at this location.

Example 5.

SLr = 50 years pH = 5.7 Resistivity = 3000 ohm-cm
Fill Height = 1'-3' Thickness = 0.064" AISI Factor = 1.3 Non-Trench Condition
Since pH and Resistivity are within the AISI Chart limits for Aluminized Steel Pipe the result will be the same as for Galvanized Steel Pipe (see Galvanized Example #5 above).

Examples 6-8.

The Resistivity and /or pH at these locations are all outside the AISI chart limits. Example 6, pH = 9.3 > 9: Example 7, pH = 4.0 < 5; Example 8, Resistivity = 1400 ohm-cm < 1500 ohm-cm. Thus, Aluminized Steel Pipe is not an acceptable pipe alternative at these locations.

ALUMINUM PIPE

Example 1.

SLr = 75 years pH = 7.2 Resistivity = 1500 ohm-cm
Fill Height = 1'-3' Trench Condition
pH = 7.2 is between 5 and 9 and Resistivity is greater than 500 ohm-cm. Therefore, Pipe Wall Thickness will dictate the SLe. The minimal thickness of 0.060" only provides 50 years of service life. Increasing the thickness to 0.105" gives 87.5 years which is more than enough. Adding bituminous coating to a 0.075" thick pipe would yield 82.5 years. Also OK, but the thicker pipe would be preferrable.

Example 2 through 5 and 8.

In each of these cases the pH and Resistivity values are within the accepted range. It is simply a matter of picking the minimum wall thickness required to meet SLr = 50 years. The 0.060" wall thickness is sufficient which agrees with the minimum required by fill height tables.

Example	pH	Resistivity (ohm-cm)	Fill Height	Thickness
2	8.8	2500	3'-5'	0.060"
3	6.5	6000	5'-8'	0.060"
4	7.1	600	3'-5'	0.060"
5	5.7	3000	1'-3'	0.060"
8	7.0	1400	3'-5'	0.060"

Example 6 and 7.

In both cases the pH is outside the 5 to 9 range limit. Example 6, pH = 9.3 > 9; Example 7, pH = 4.0 < 5. The designer need look no further since this disqualifies each from being acceptable alternatives. The same would be true if the Resistivity was below 500 ohm-cm.

CONCRETE PIPE

Concrete Pipe is easy to select. Since it has a SLe = 100 years it will meet most project SLr's. The main concern is to find out from the Fill Height Table whether the type of Concrete Pipe is acceptable for the load. If it is the designer will find an applicable Class or Wall Thickness. Record this information in the Concrete Pipe Selection Worksheet. Three other conditions need to be checked, but it only takes one failed condition to eliminate a pipe type as an acceptable alternative. For example, if pH is less than 5 then NRCIPCP is not acceptable. Both RCP and NRCP can be used but must be checked to see if there are acceptable concrete admixtures to satisfy the low pH condition.

Example 1 - 8.

Fill Height Table requirements eliminated NRCP from Examples 4 & 6, NRCIPCP from Examples 3 & 5, and all three Pipe types in Ex. 7.

Example	Fill Height	RCP Class	NRCP Class	NRCIPCP Wall Thickness
1	1'-3'	II	2	3 1/2"
2	3'-5'	II	1	N/A
3	5'-8'	II	2	Not in Chart
4	3'-5'	II	Not in Chart	4"
5	1'-3'	III	3	Not in Chart
6	5'-8'	II	Not in Chart	5"
7	70'-90'	Not in Chart	Not in Chart	Not in Chart
8	3'-5'	II	1	N/A

Other restrictions to consider include: in examples 3 & 5 NRCIPCP is not acceptable since pipe size is less than 30"; in examples 2 & 8 NRCIPCP has wall thicknesses given, but a footnote indicates that this is not an acceptable alternate for a non-trench condition; likewise, examples 3, 5 & 7 are not acceptable due to non-trench conditions.

You will notice that in Example 7 no concrete pipe alternate is acceptable. Nor is the plastic pipe alternate, as will be seen in the next section. With no pipe type acceptable for this location what should the designer do? Here is a case where a special reinforced concrete pipe design is required. The design will need to be detailed in the project plans.

PLASTIC PIPE

Plastic Pipe is as easy to select as Concrete Pipe. With a SLe = 75 years CHDPEPP will suit most service life requirement needs. Only two other requirements need to be checked. Pipe size must be between 12" and 36" in diameter (24" minimum for most installations). And Fill Height must not exceed 10 feet.

The Fill Height Tables have been set up to assist the designer in selecting Plastic Pipe. If the designer cannot find the pipe criteria in the tables then Plastic Pipe is not acceptable as a pipe alternate.

Example 1 - 3, 5, and 8.

These five pipe meet minimum requirements in the Fill Height Tables. A check in the New Products List shows that 36" pipe, at this time, does not have acceptable joints. So, using plastic pipe in Example 1 is not acceptable. Plastic pipe in Examples 2, 3, 5, and 8 are acceptable pipe alternatives.

Example 4, 6, and 7.

These pipe are more than 36" in diameter. Example 4, Diameter = 42"; Example 6, Diameter = 48"; Example 7, Diameter = 60". Also, in Example 7 the fill height of 86' exceeds the 10' maximum. Therefore, Plastic Pipe is not an acceptable alternative at these locations.

ARIZONA DEPARTMENT OF TRANSPORTATION

GALVANIZED STEEL PIPE SELECTION

Sheet 1 of 10

Plan Reference Number	1	2	3	4
Location (Station)	511 + 16	513 + 20	518 + 45	520 + 02
Service Life Required SLr (Years) circle one	50 / (75)	(50) / 75	(50) / 75	(50) / 75
Pipe Size (inches or inch x inch)	36	30	24	42
Fill Height Range (ft-ft)	1-3	3-5	5-8	3-5
Corrugation (inch x inch) circle one	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	~~0.064"=1.3~~ (0.079"=1.6) 0.109"=2.2 0.138"=2.8 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	~~0.064"=1.3~~ ~~0.079"=1.6~~ (0.109"=2.2) 0.138"=2.8 0.168"=3.4	~~0.064"=1.3~~ (0.079"=1.6) 0.109"=2.2 0.138"=2.8 0.168"=3.4
pH	7.2	8.8	6.5	7.1
Resistivity (ohm-cm)	1500	2500	6000	600
High Soil Moisture? circle one	yes / (no)	yes / (no)	(yes) / no	yes / (no)
	Reduce the Average Life (years) in the AISI Chart by half. Use as SL_b			
Service Life Base, SLb (years)	50	74	$\frac{1}{2}$x45 = 22.5	33
Expected Service Life (years) **SLe=SLb*AISI Factor**	80	96	50	53
Velocity of Flow>7ft/sec? circle one	yes / (no)	yes / (no)	yes / (no)	yes / (no)
	Designer must check for possible abrasion problems due to bedloads.			

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
2. Consider justifying a lower service life requirement if **SLe** is close to **SLr**.
3. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 1	Plan Reference No. 2	Plan Reference No. 3	Plan Reference No. 4
SLe = 1.3 x 50 = 65 yrs	SLe = 1.3 x 74 = (96 yrs)	SLe = 1.3 x 22.5 = 29 yrs	SLe = 1.3 x 33 = 43 yrs
No good.	OK	No good.	No good
Increase wall thickness		Increase wall thickness	Increase wall thickness
to 0.079" OK		to ~~0.079"~~ 0.109"	to 0.079"
		Thickness O.K.	Thickness OK
SLe = 1.6 x 50 = (80 yrs)		SLe = ~~1.6~~ x 22.5 = ~~36 yrs~~	SLe = 1.6 x 33 = (53 yrs)
OK		2.2 (50)	OK
		check availability of thickness & corrugation OK	
Also, could add		Also, could add	Also, could add
bituminous coating		bituminous coating	bituminous coating
SLe = 65 + 20 = 85 yrs		SLe = 29 + 20 = 49 yrs	SLe = 43 + 20 = 63 yrs
OK		close enough - OK	OK
but not preferred		but not preferred	but not preferred

JAN 25, 1996

FIGURE A-1

ARIZONA DEPARTMENT OF TRANSPORTATION

GALVANIZED STEEL PIPE SELECTION

Plan Reference Number	5	6	7	8
Location (Station)	522+17	525+68	526+87	528+17
Service Life Required SLr (Years) circle one	(50) 75	(50) 75	(50) 75	(50) 75
Pipe Size (inches or inch x inch)	24	48	60	30
Fill Height Range (ft-ft)	1-3	5-8	70-90	3-5
Corrugation (inch x inch) circle one	(2 2/3x1/2) 3x1 5x1 6x2	(2 2/3x1/2) 3x1 5x1 6x2	2 2/3x1/2 (3x1) 5x1 6x2	(2 2/3x1/2) 3x1 5x1 6x2
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	~~0.064"=1.3~~ ~~0.079"=1.6~~ (0.109"=2.2) 0.138"=2.8 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	0.064"=1.3 0.079"=1.6 0.109"=2.2 ~~0.138"=2.8~~ (0.168"=3.4)	~~0.064"=1.3~~ ~~0.079"=1.6~~ ~~0.109"=2.2~~ (0.138"=2.8) 0.168"=3.4
pH	5.7	(9.3)	4.0	7.0
Resistivity (ohm-cm)	3000	1500	2000	1400
High Soil Moisture? circle one	yes (no)	yes (no)	yes (no)	(yes) no
	Reduce the Average Life (years) in the AISI Chart by half. Use as SLb.			
Service Life Base, SLb (years)	29	—	15	½ x 39 = 19.5
Expected Service Life (years) **SLe=SLb*AISI Factor**	64	Not Applicable	51	55
Velocity of Flow>7ft/sec? circle one	(yes) no	yes (no)	yes (no)	yes (no)
	Designer must check for possible abrasion problems due to bedloads.			

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
2. Consider justifying a lower service life requirement if **SLe** is close to **SLr**.
3. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 5	Plan Reference No. 6	Plan Reference No. 7	Plan Reference No. 8
SLe = 1.3 x 29 = 38 yrs	Outside pH range.	SLe = 2.8 x 15 = 42 yrs	SLe = 1.3 x 19.5 = 25 yrs
No good.	No good	No good	No good
Increase wall thickness		Increase wall thickness	Increase wall thickness
to ~~0.079"~~ 0.109"		to 0.168" OK	to ~~0.079"~~ ~~0.109"~~ 0.138"
~~No good~~ OK			~~No good.~~ OK
SLe = ~~1.6~~ 2.2 x 29 = (64) 46 yrs		SLe = 3.4 x 15 = (51 yrs)	SLe = ~~1.6~~ ~~2.2~~ 2.8 x 19.5 = 31 yrs = 42 = (55)
check availability of thickness & corrugation ~~No good~~ OK		OK	check availability of thickness and corrugation OK
CHECK FOR ABRASION			
Also, could add		Also, could add	Also, could add
bituminous coating		bituminous coating	bituminous coating
SLe = 38 + 20 = 58 yrs		SLe = 42 + 20 = 62 yrs	SLe = 31 + 20 = 51 yrs
OK		OK	OK
but not preferred.		but not preferred.	but not preferred.

JAN 25, 1996

FIGURE A-2

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINIZED STEEL PIPE SELECTION

Sheet 3 of 10

Plan Reference Number	1	2	3	4
Location (Station)	511+16	513+20	518+45	520+02
Service Life Required SLr (Years) circle one	50 / (75)	(50) / 75	(50) / 75	(50) / 75
Pipe Size (inches or inch x inch)	36	30	24	42
Fill Height Range (ft-ft)	1-3	3-5	5-8	3-5
Corrugation (inch x inch) circle one	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	~~0.064"=1.3~~ (0.079"=1.6) 0.109"=2.2 0.138"=2.8 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	~~0.064"=1.3~~ ~~0.079"=1.6~~ (0.109"=2.2) 0.138"=2.8 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4
pH	7.2	8.8	6.5	7.1
Resistivity (ohm-cm)	1500	2500	6000	(600)
High Soil Moisture? circle one	yes / (no)	yes / (no)	(yes) / no	yes / (no)
	Reduce the average life (years) in the AISI Chart by half. Use SLb.			
Service Life Base, SLb (years)	50	74	$\frac{1}{2}$ x 45 = 22.5	—
Expected Service Life (years) **SLe=SLb*AISI Factor**	80	96	50	Not Applicable
Velocity of Flow>7ft/sec? circle one	yes / (no)	yes / (no)	yes / (no)	yes / (no)
	Designer must check for possible abrasion problems due to bedloads.			

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
3. Consider jusifying a lower service life requirement if **SLe** is close to **SLr**.
2. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 1	Plan Reference No. 2	Plan Reference No. 3	Plan Reference No. 4
SLe = 1.3 x 50 = 65 yrs	SLe = 1.3 x 74 = (96 yrs)	SLe = 1.3 x 22.5 = 29 yrs	Resistivity is outside
No good.	OK	No good	acceptable range.
Increase wall thickness		Increase wall thickness	No good.
to 0.079"		to ~~0.079"~~ 0.109" OK	
		No good	
SLe = 1.6 x 50 = (80 yrs)		SLe = ~~1.6~~ 2.2 x 22.5 = ~~36~~ (50) yrs	
OK		~~No good~~ OK	
		check availability of thickness & corrugation	
Also, could add		Also, could add	
bituminous coating.		bituminous coating.	
SLe = 65 + 20 = 85 yrs		SLe = 29 + 20 = 49 yrs	
OK			
		Close enough. OK	
but not preferred.		but not preferred.	

JAN 25, 1996

FIGURE A-3

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINIZED STEEL PIPE SELECTION

Sheet 4 of 10

Plan Reference Number	5	6	7	8
Location (Station)	522+17	525+68	526+87	528+17
Service Life Required SLr (Years) circle one	(50) 75	(50) 75	(50) 75	(50) 75
Pipe Size (inches or inch x inch)	24	48	60	30
Fill Height Range (ft-ft)	1-3	5-8	70-90	3-5
Corrugation (inch x inch) circle one	($2^2/_3$x$^1/_2$) 3x1 5x1 6x2	(2$^2/_3$x$^1/_2$) 3x1 5x1 6x2	2$^2/_3$x$^1/_2$ (3x1) 5x1 6x2	(2$^2/_3$x$^1/_2$) 3x1 5x1 6x2
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	~~0.064"=1.3~~ ~~0.079"=1.6~~ (0.109"=2.2) 0.138"=2.8 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	0.064"=1.3 0.079"=1.6 0.109"=2.2 (0.138"=2.8) 0.168"=3.4	(0.064"=1.3) 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4
pH	5.7	(9.3)	(4.0)	7.0
Resistivity (ohm-cm)	3000	1500	2000	(1400)
High Soil Moisture? circle one	yes (no)	yes (no)	yes (no)	(yes) no
	Reduce the average life (years) in the AISI Chart by half. Use SLb.			
Service Life Base, SLb (years)	29	—	—	—
Expected Service Life (years) **SLe=SLb*AISI Factor**	64	Not Applicable	Not Applicable	Not Applicable
Velocity of Flow>7ft/sec? circle one	(yes) no	yes (no)	yes (no)	yes (no)
	Designer must check for possible abrasion problems due to bedloads.			

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
3. Consider jusifying a lower service life requirement if **SLe** is close to **SLr**.
2. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 5	Plan Reference No. 6	Plan Reference No. 7	Plan Reference No. 8
SLe = 1.3 x 29 = 38 yrs	pH is outside	pH is outside	Resistivity is outside
No good.	acceptable range.	acceptable range.	acceptable range.
Increase pipe thickness	No good.	No good.	No good.
to ~~0.079"~~ 0.109" OK			
~~No good~~ 2.2 OK (64)			
SLe = ~~1.6~~ x 29 = ~~46 yrs~~			
check availability of thickness and ~~No good~~ corrugation			
CHECK FOR ABRASION ←			
Also, could add			
bituminous coating.			
SLe = 38 + 20 = 58 yrs			
OK			
but not preferred.			

JAN 25, 1996

FIGURE A-4

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINUM PIPE SELECTION

Sheet 5 of 10

Plan Reference Number	1		2		3		4	
Location (Station)	511+16		513+20		518+45		520+02	
Service Life Required SLr (Years) circle one	50	(75)	(50)	75	(50)	75	(50)	75
5 ≤ pH ≤ 9? circle one	(yes)	no	(yes)	no	(yes)	no	(yes)	no
Resistivity ≥ 500? (ohm-cm) circle one	(yes)	no	(yes)	no	(yes)	no	(yes)	no
	Aluminum Pipe is not an acceptable alternate							
Pipe Size (inches or inch x inch)	36		30		24		42	
Fill Height Range (ft-ft)	1-3		3-5		5-8		3-5	
Corrugation (inch x inch) circle one	$2^2/_3$x$^1/_2$ (3x1) 9x$2^1/_2$		$2^2/_3$x$^1/_2$ (3x1) 9x$2^1/_2$		($2^2/_3$x$^1/_2$) 3x1 9x$2^1/_2$		$2^2/_3$x$^1/_2$ (3x1) 9x$2^1/_2$	
Pipe Wall Thickness(inches) **= Service Life Expected** (years) **SLe** circle or add appropriate thickness	~~0.060"=50.0 yrs~~ ~~0.075"=62.5 yrs~~ (0.105"=87.5 yrs)		(0.060"=50.0 yrs) 0.075"=62.5 yrs 0.105"=87.5 yrs		(0.060"=50.0 yrs) 0.075"=62.5 yrs 0.105"=87.5 yrs		(0.060"=50.0 yrs) 0.075"=62.5 yrs 0.105"=87.5 yrs	
Velocity of Flow>7ft/sec? circle one	yes	(no)	yes	(no)	yes	(no)	yes	(no)
	Designer must check for possible abrasion problems due to bedloads.							

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
2. Consider justifying a lower service life requirement if **SLe** is close to **SLr**.
3. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 1	Plan Reference No. 2	Plan Reference No. 3	Plan Reference No. 4
Increase wall thickness to 0.105"	Minimum wall thickness is O.K. SLe = (50 yrs)	Minimum wall thickness is O.K. SLe = (50 yrs)	Minimum wall thickness is O.K. (SLe = 50 yrs)
SLe = (87.5 yrs) OK			
Could also add bituminous coating.			
SLe = 62.5 + 20 = 82.5 yrs OK			
but not preferred.			

JAN 25, 1996

FIGURE A-5

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINUM PIPE SELECTION

Sheet 6 of 10

Plan Reference Number	5		6		7		8	
Location (Station)	522+17		525+68		526+87		528+17	
Service Life Required SLr (Years) circle one	(50)	75	(50)	75	(50)	75	(50)	75
5 ≤ pH ≤ 9? circle one	(yes)	no	yes	(no)	yes	(no)	(yes)	no
Resistivity ≥ 500? (ohm-cm) circle one	(yes)	no	(yes)	no	(yes)	no	(yes)	no
	Aluminum Pipe is not an acceptable alternate.							
Pipe Size (inches or inch x inch)	24		48		60		30	
Fill Height Range (ft-ft)	1-3		5-8		70-90		3-5	
Corrugation (inch x inch) circle one	(2 2/3x1/2)		2 2/3x1/2		2 2/3x1/2		2 2/3x1/2	
	3x1		3x1		3x1		(3x1)	
	9x2 1/2		9x2 1/2		9x2 1/2		9x2 1/2	
Pipe Wall Thickness(inches) = **Service Life Expected** (years) **SLe** circle or add appropriate thickness	(0.060"=50.0 yrs)		~~0.060"=50.0 yrs~~		~~0.060"=50.0 yrs~~		(0.060"=50.0 yrs)	
	0.075"=62.5 yrs		~~0.075"=62.5 yrs~~		~~0.075"=62.5 yrs~~		0.075"=62.5 yrs	
	0.105"=87.5 yrs		~~0.105"=87.5 yrs~~		~~0.105"=87.5 yrs~~		0.105"=87.5 yrs	
Velocity of Flow>7ft/sec? circle one	(yes)	no	yes	no	yes	no	yes	(no)
	Designer must check for possible abrasion problems due to bedloads.							

When **SLe<SLr** consider three options to increase **SLe**:

1. Increase the pipe wall thickness (gage). This will increase the **SLe**.
2. Consider justifying a lower service life requirement if **SLe** is close to **SLr**.
3. Add bituminous coating. This adds 20 years to **SLe**. This is not normally a preferred option.

Plan Reference No. 5	Plan Reference No. 6	Plan Reference No. 7	Plan Reference No. 8
Minimum Wall Thickness is O.K. SLe = (50 yrs)	pH is outside acceptable range. No good.	pH is outside acceptable range No good.	Minimum wall thickness is O.K. SLe = (50 yrs)

JAN 25, 1996

FIGURE A-6

ARIZONA DEPARTMENT OF TRANSPORTATION

CONCRETE PIPE SELECTION

Sheet 7 of 10

Plan Reference Number	1		2		3		4	
Location (Station)	511+16		513+20		518+45		520+02	
Service Life Required SLr (Years) **>100 Years?** circle one	yes	(no)	yes	(no)	yes	(no)	yes	(no)
	Concrete Pipe is not an acceptable alternate.							
Pipe Size (inches or inch x inch)	36		30		24		42	
Fill Height Range (ft-ft)	1-3		3-5		5-8		3-5	
Trench And Non-Trench Conditions circle observed field condition	(Trench)	Non-Trench	Trench	(Non-Trench)	Trench	(Non-Trench)	(Trench)	Non-Trench
RCP Class choose one number in each column or write in D-Load	I (II) III IV V	I (II) III IV V	I (II) III IV V	I (II) III IV V	I (II) III IV V	I (II) III IV V	I (II) III IV V	I (II) III IV V
NRCP Class	2		1		2		X	
NRCIPCP Wall Thickness (inches)	3½		X		X		4	
pH	7.2		8.8		6.5		7.1	
pH<5? choose one	yes	(no)	yes	(no)	yes	(no)	yes	(no)
	For RCP & NRCP consider using concrete admixtures. NRCIPCP is not an acceptable alternate.							
High Sulfate Levels? circle one	(yes)	no	yes	(no)	yes	(no)	yes	(no)
	Pipe may require Type V cement.							
Velocity of Flow>40ft/sec? circle one	yes	(no)	yes	(no)	yes	(no)	yes	(no)
	Designer must check for possible abrasion problems due to bedloads.							

Plan Reference No. 1	Plan Reference No. 2	Plan Reference No. 3	Plan Reference No. 4
All concrete pipe types are acceptable, but check for need of Type V Cement. ←	NRCIPCP not acceptable for non-trench condition. RCP & NRCP are acceptable	NRCIPCP not acceptable. Pipe size of 24" < 30" required. Also, NRCIPCP not acceptable for non-trench condition. RCP & NRCP are acceptable.	NRCP is not an acceptable alternate. Not found in fill height tables. RCP & NRCIPCP are acceptable.

MAR 21, 1996

FIGURE A-7

ARIZONA DEPARTMENT OF TRANSPORTATION

CONCRETE PIPE SELECTION

Plan Reference Number	5		6		7		8	
Location (Station)	522+17		525+68		526+87		528+17	
Service Life Required SL_r (Years) >100 Years? circle one	yes	no	yes	no	yes	no	yes	no
	Concrete Pipe is not an acceptable alternate.							
Pipe Size (inches or inch x inch)	24		48		60		30	
Fill Height Range (ft-ft)	1-3		5-8		70-90		3-5	
Trench And Non-Trench Conditions circle observed field condition	Trench	Non-Trench	Trench	Non-Trench	Trench	Non-Trench	Trench	Non-Trench
RCP Class choose one number in each column or write in D-Load	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V
NRCP Class	3						1	
NRCIPCP Wall Thickness (inches)			5					
pH	5.7		9.3		4.0		7.0	
pH<5? choose one	yes	no	yes	no	yes	no	yes	no
	For RCP & NRCP consider using concrete admixtures. NRCIPCP is not an acceptable alternate.							
High Sulfate Levels? circle one	yes	no	yes	no	yes	no	yes	no
	Pipe may require Type V cement.							
Velocity of Flow>40ft/sec? circle one	yes	no	yes	no	yes	no	yes	no
	Designer must check for possible abrasion problems due to bedloads.							

Plan Reference No. 5	Plan Reference No. 6	Plan Reference No. 7	Plan Reference No. 8
NRCIPCP is not acceptable - pipe size 24" < 30" required. Also, NRCIPCP not acceptable for non-trench condition. RCP & NRCP are acceptable.	NRCP is not an acceptable alternate. Not found in fill height tables. RCP & NRCIPCP are acceptable.	No concrete pipe alternate is acceptable. Not found in fill height tables. Also, NRCIPCP is not acceptable for non-trench condition. Need special RCP design. ←	NRCIPCP not acceptable for non-trench condition. RCP & NRCP are acceptable.

MAR 21, 1996

FIGURE A-8

ARIZONA DEPARTMENT OF TRANSPORTATION

PLASTIC PIPE SELECTION

Sheet 9 of 10

Plan Reference Number	1	2	3	4
Location (Station)	511+16	513+20	518+45	520+02
Service Life Required SLr (Years) **>75 Years?** circle one	yes (no)	yes (no)	yes (no)	yes (no)
	Plastic Pipe is not an acceptable alternate.			
Pipe Size (inches)	36	30	24	(42)
12"≤Pipe Size≤36"? circle one	(yes) no	(yes) no	(yes) no	yes (no)
Pipe Size With Approved Joints? Check New Products List	yes (no)	(yes) no	(yes) no	yes (no)
	Plastic Pipe is not an acceptable alternate.			
Fill Height (ft)	1.6	4.2	7.1	4.7
Fill Height > 10'? circle one	yes (no)	yes (no)	yes (no)	yes (no)
	Plastic Pipe is not an acceptable alternate.			

Plan Reference No. 1	Plan Reference No. 2	Plan Reference No. 3	Plan Reference No. 4
36" pipe does not have acceptable joints. No good.	Acceptable.	Acceptable.	Pipe size > 36". No good.

JAN 25, 1996

FIGURE A-9

ARIZONA DEPARTMENT OF TRANSPORTATION

PLASTIC PIPE SELECTION

Plan Reference Number	5	6	7	8
Location (Station)	522+17	525+68	526+87	528+17
Service Life Required SLr (Years) **>75 Years?** circle one	yes (no)	yes (no)	yes (no)	yes (no)
	Plastic Pipe is not an acceptable alternate.			
Pipe Size (inches)	24	~~48~~	~~60~~	30
12"≤Pipe Size≤36"? circle one	(yes) no	yes (no)	yes (no)	(yes) no
Pipe Size With Approved Joints? Check New Products List	(yes) no	yes (no)	yes (no)	(yes) no
	Plastic Pipe is not an acceptable alternate.			
Fill Height (ft)	2.3	6.6	86	3.7
Fill Height > 10'? circle one	yes (no)	yes (no)	(yes) no	yes (no)
	Plastic Pipe is not an acceptable alternate.			

Plan Reference No. 5	Plan Reference No. 6	Plan Reference No. 7	Plan Reference No. 8
Acceptable.	Pipe size > 36". No good.	Pipe size > 36". Also, fill height exceeds 10'. No good.	Acceptable.

JAN 25, 1996

FIGURE A-10

APPENDIX

B

PIPE SELECTION PROCEDURE FLOWCHARTS

STEEL PIPE

CGSP, SRGSP, CGSSPP, C/LCGSP, CASP, SRASP

See Standard Specifications 501-3.02 and -3.04 for Bedding and Backfill Requirements

JANUARY 10, 1996

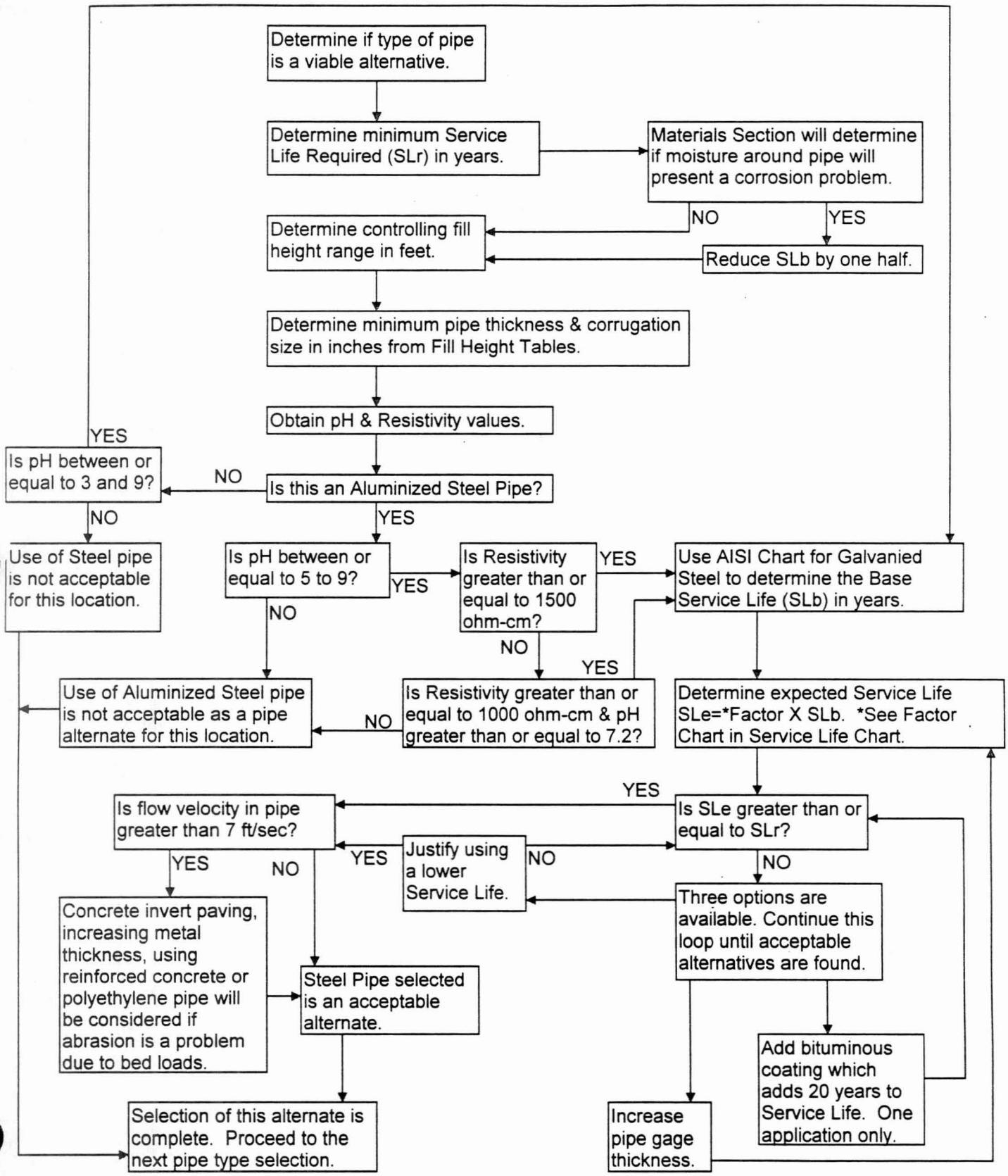


FIGURE B-1

ALUMINUM PIPE

CAP, CASPP

JANUARY 10, 1996

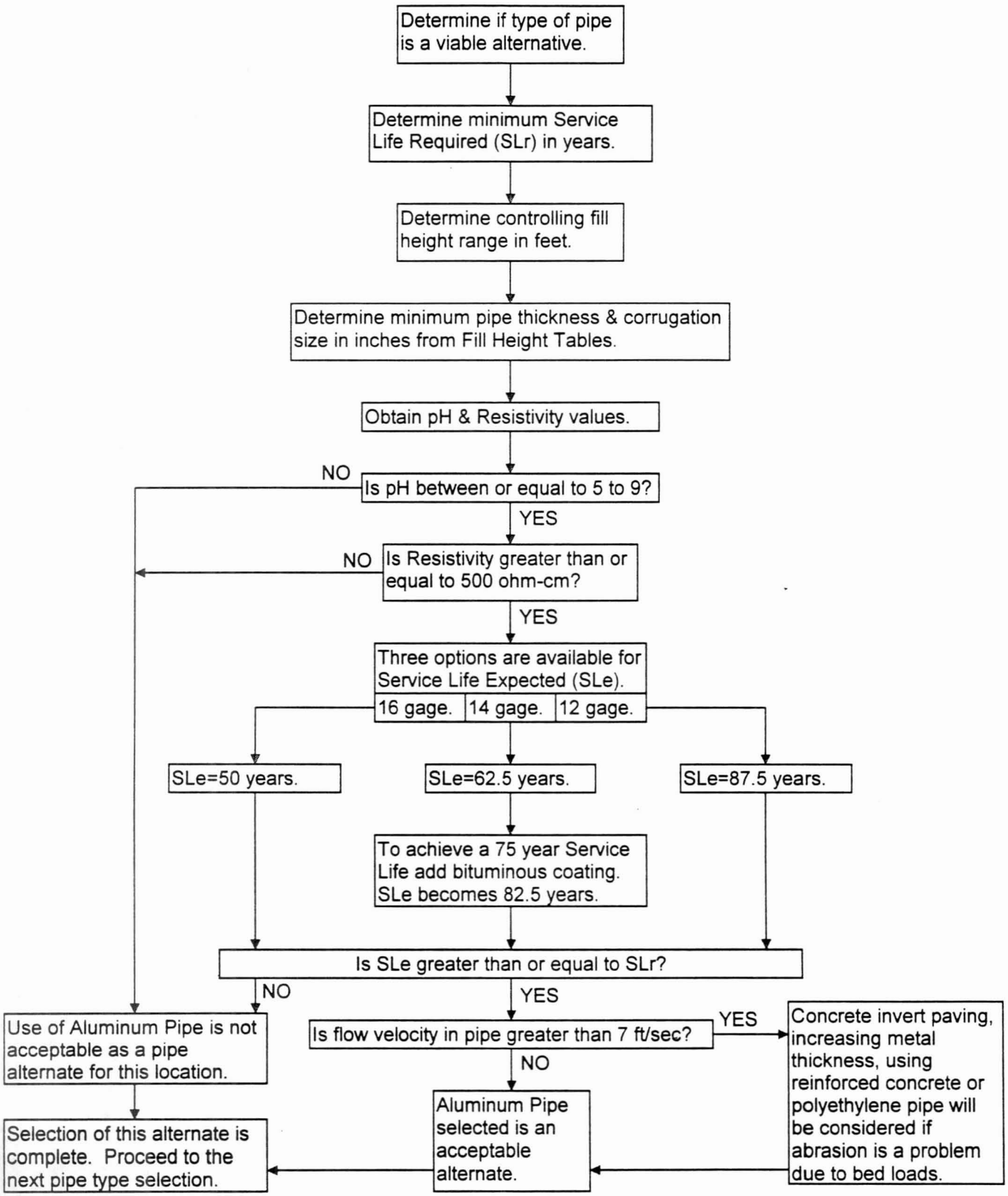


FIGURE B-2

CONCRETE PIPE

RCP, NRCP, NRCIPCP

JANUARY 10, 1996

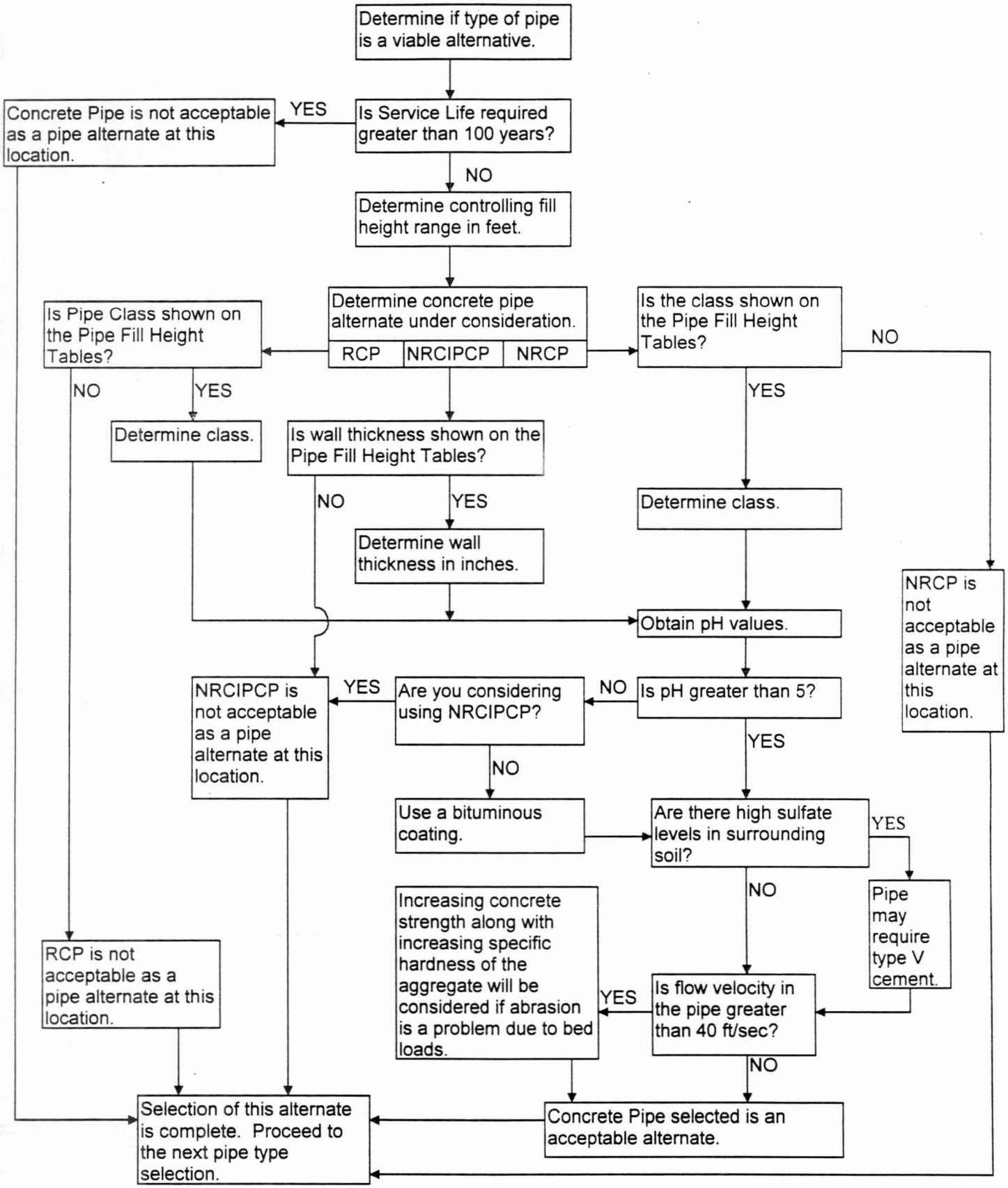


FIGURE B-3

CORRUGATED HIGH DENSITY POLYETHYLENE PLASTIC PIPE

CHDPEPP (Cell Class 324420c)

JANUARY 10, 1996

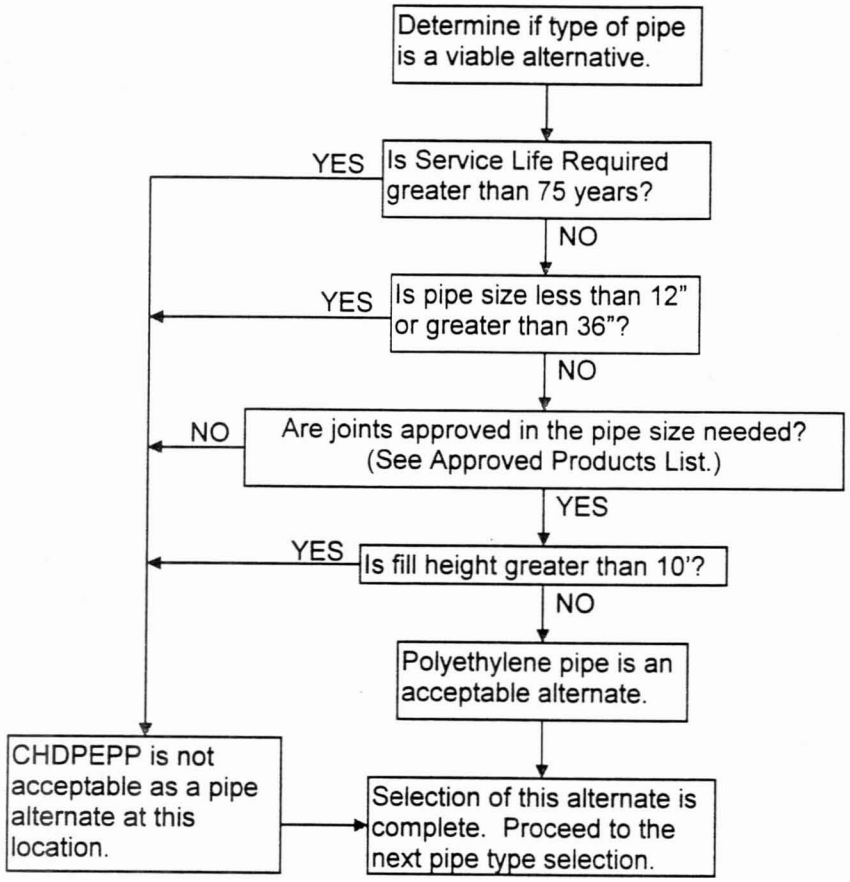


FIGURE B-4

APPENDIX

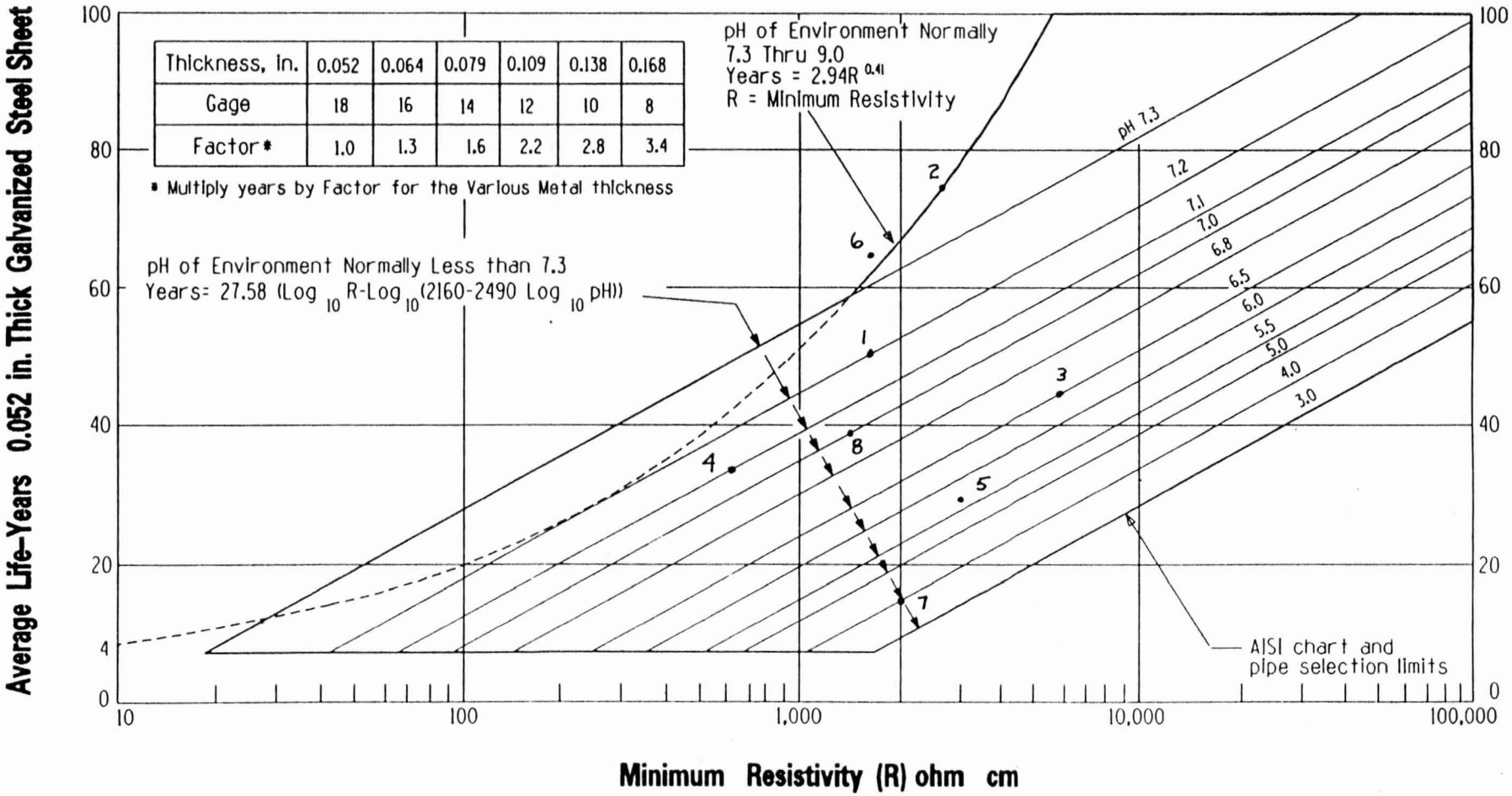
C

AISI AVERAGE SERVICE LIFE CHARTS

FOR STEEL PIPE

CHART FOR ESTIMATING AVERAGE SERVICE LIFE OF CORRUGATED GALVANIZED STEEL PIPE (CGSP), SPIRAL RIB GALVANIZED STEEL PIPE (SRGSP), AND CORRUGATED GALVANIZED STEEL STRUCTURAL PLATE PIPE (CGSSPP).

(COPIED FROM AISI CHART) - (FOR DRY SOIL CONDITIONS)



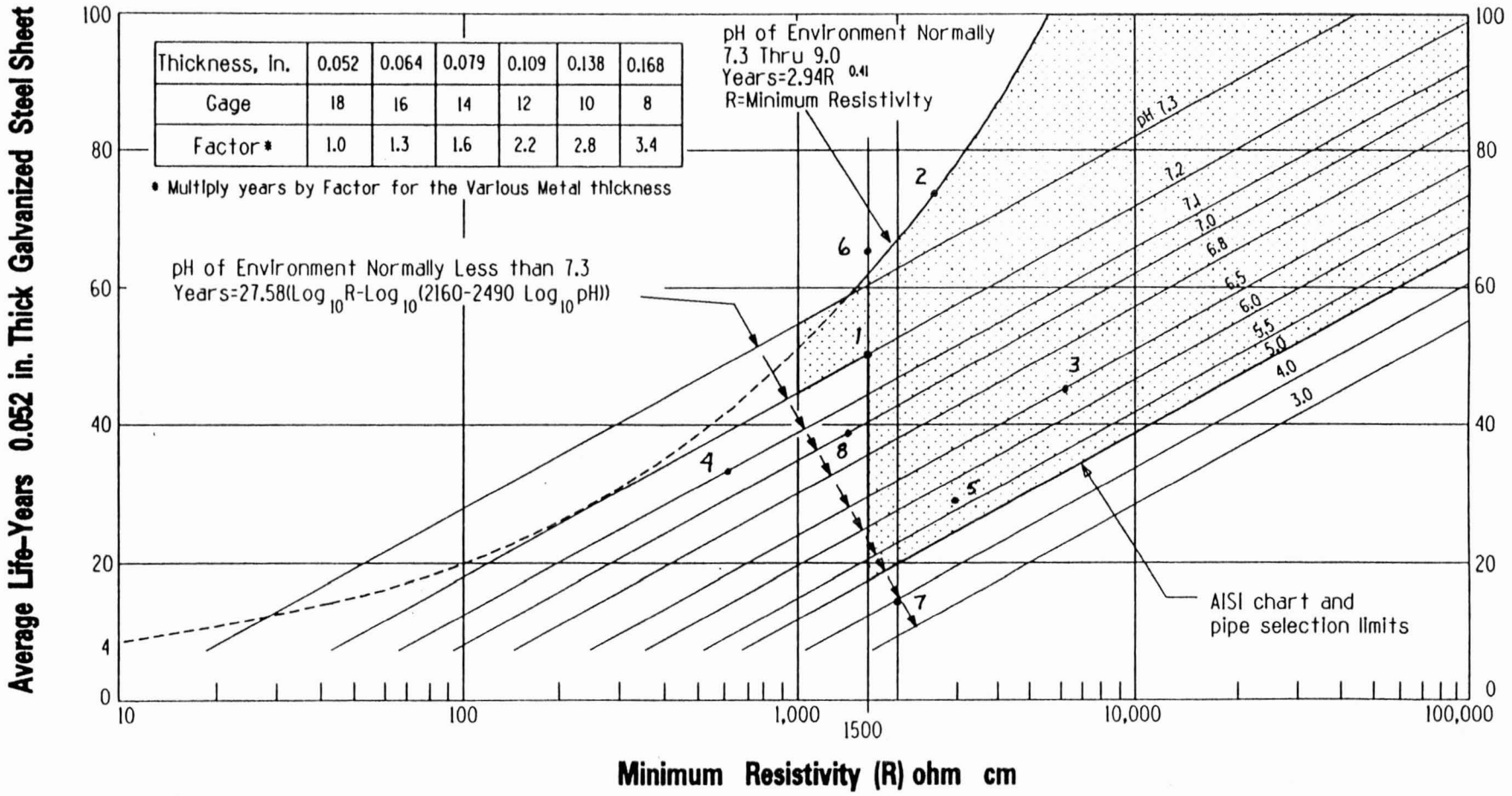
Thickness, in.	0.052	0.064	0.079	0.109	0.138	0.168
Gage	18	16	14	12	10	8
Factor*	1.0	1.3	1.6	2.2	2.8	3.4

* Multiply years by Factor for the Various Metal thickness

FIGURE C-1

CHART FOR ESTIMATING AVERAGE SERVICE LIFE OF CORRUGATED ALUMINIZED STEEL PIPE (CASP), AND SPIRAL RIB ALUMINIZED STEEL PIPE (SRASP).

(COPIED FROM AISI CHART) - (FOR DRY SOIL CONDITIONS)



Thickness, in.	0.052	0.064	0.079	0.109	0.138	0.168
Gage	18	16	14	12	10	8
Factor*	1.0	1.3	1.6	2.2	2.8	3.4

* Multiply years by Factor for the Various Metal thickness

FIGURE C-2

APPENDIX

D

ALLOWABLE TYPES OF CULVERT PIPE

FOR VARIOUS pH AND RESISTIVITY RANGES

ALLOWABLE TYPES OF CULVERT PIPE FOR VARIOUS pH & RESISTIVITY RANGES

RESISTIVITY (ohm-cm)	≥ 2000	1500-1999	1000-1499	500-999	< 500
ALLOWABLE PIPE OR COATING	A-B-C-D-E	A-B-C-D-E	A-B[1]-C-D-E	A-C-D-E	A-D-E

Notes:
1) Not allowed when pH is less than 7.2.

TYPES OF CULVERT PIPE OR COATING

A	Corrugated Galvanized Steel Pipe (CGSP), Spiral Rib Galvanized Steel Pipe (SRGSP), and Concrete Lined Corrugated Galvanized Steel Pipe (C/LCGSP), AASHTO M 36/M 36M, and Corrugated Galvanized Steel Structural Plate Pipe (CGSSPP), AASHTO M 167/M 167M and **Use pH and Resistivity Ranges in the AISI Chart.**
B	Corrugated Aluminized Steel Pipe (CASP) and Spiral Rib Aluminized Steel Pipe (SRASP) , AASHTO M 36/M 36M. **The pH Range is 5 to 9 (except for resistivity range 1000-1499 - see footnote 1).**
C	Corrugated Aluminum Pipe (CAP) , AASHTO M 196/M 196M and Corrugated Aluminum Structural Plate Pipe (CASPP) , AASHTO M 219/M 219M. **The pH Range is 5 to 9.**
D	Corrugated High Density Polyethylene Plastic Pipe (CHDPEPP) , AASHTO M 294. **The pH Range is 1.25 to 14 and all Ranges of Resistivity.**
E	Use Bituminous Coating on A, B or C when needed, AASHTO M 190 and AASHTO M 243.

November 6, 1995

FIGURE D-1

APPENDIX

E

PIPE SUMMARY SHEET

NOTE:
FOR PIPE CULVERT PLACEMENT
SEE STANDARD DRAWING C-13.15

NOTE:
PIPE OPTIONS SELECTED ARE THOSE REQUIRED TO MEET THE MININUM SERVICE LIFE.
SHADED PIPE OPTION FIELDS ARE NOT ALLOWABLE ALTERNATES.

DESCRIPTION							CSP								CAP					RCP	NRCP	NRCIPCP	CHDPEPP
										Coating													
Station	Plan Ref No. ⬡	● Controlling Fill Height Range (No.)	Size, (in.) Corrugated	Size, (in.) Smooth	Length (Ft.)	Skew (Degree)	◪ Corrugation	Wall Thickness (in.)	Zinc	Bit. Coated Zinc	Aluminum	Bit. Coated Aluminum	◪ Corrugation	Wall Thickness (in.)	Uncoated	Bit. Coated	Class - Non Trench	Class - Trench	Class	Min Wall Thickness (in.)	AASHTO M-294 Type C	AASHTO M-294 Type S
CULVERT APPLICATION																							
511+16	1	1	36		100		A	.079	X		X		B	.105	X								
513+20	2	2	30		110		A	.064	X		X		B	.060	X							X	
518+45	3	3	24		120		A	.109	X		X		A	.060	X							X	
520+02	4	2	42		110		A	.079	X				B	.060	X								
522+17	5	1	24		100		A	.109	X		X		A	.060	X							X	
525+68	6	3		48	120												II	II					
526+87	7	12	60		200		B	.168	X														
528+17	8	2	30		110		A	.138	X				B	.060	X							X	
STORM DRAIN APPLICATION																							
511+16	1	1		36	100												II	II	2	3½			
513+20	2	2		30	110												II	II	1				X
518+45	3	3		24	120												II	II	2				X
520+02	4	2		42	110												II	II		4			
522+17	5	1		24	100												III	III	3				X
525+68	6	3		48	120												II	II		5			
526+87	7	12		60	200												▲	▲					
528+17	8	2		30	110												II	II	1				X
Sheet Total																							

FILL HEIGHT RANGE TABLE (Ft.)												
RANGE NO.		1	2	3	4	5	6	7	8	9	10	11	12
FILL HEIGHT (Ft.)	>	1	3	5	8	11	15	20	25	30	40	55	70
	≤	3	5	8	11	15	20	25	30	40	55	70	90

● SHOULD FIELD CONDITIONS VARY FROM THE RANGE INDICATED, CONTACT DESIGN FOR RE-EVALUATION OF PIPE DESIGN REQUIREMENTS.

◪ PIPE CORRUGATION			
A	2⅔ x½	D	6x2
B	3x1	E	3x1 or 5x1
C	9x2½		

▲ See Detail for special design.

SHEET NO.	FINISHED PLANS	REVISIONS	LOCATION	DATE

/usr5/hp3/osmlpsl.dgn
20-MAR-1996 09:40
VIEW NAME:

FIGURE E-1

APPENDIX

F

FILL HEIGHT TABLES

ADOT

ROADWAY DESIGN

FILL HEIGHT TABLES

TRENCH AND NON-TRENCH CONDITIONS

CIRCULAR CULVERT

STORM SEWER AND IRRIGATION PIPES

CORRUGATED PIPE ARCHES

Revised January 19, 1996

RCP - LOAD Vs CLASS OF PIPE

Class I RCP - 800 D-load to produce 0.01" crack
(Do not use Class I for pipe less than 60" dia.)
Class II RCP - 1000 D-load to produce 0.01" crack
Class III RCP - 1350 D-load to produce 0.01" crack
Class IV RCP - 2000 D-load to produce 0.01" crack
Class V RCP - 3000 D-load to produce 0.01" crack

CSP IN THE TABLES INCLUDES:

Corrugated Galvanized Steel Pipe (CGSP)
Sprial Rib Galvanized Steel Pipe (SRGSP)
Corrugated Galvanized Steel Structural Plate Pipe (CGSSPP)
Corrugated Aluminized Steel Pipe (CASP)
Spiral Rib Aluminized Steel Pipe (SRASP)
Concrete - Lined Corrugated Galvinized Steel Pipe (C/LCGSP)

CAP IN THE TABLES INCLUDES:

Corrugated Aluminum Pipe (CAP)
Corrugated Aluminum Structural Plate Pipe (CASPP)

HDPEPP IN THE TABLES INCLUDES:

Corrugated High Density Polyethylene Plastic Pipe (CHDPEPP), cell class 324420c.

Notes:

1. For metal pipe design criteria see "Corrugated Metal Pipe Structural Design Criteria and Recommended Installation Practice," FHWA, 1970.
2. 5" X 1" Corrugated Steel Pipe (CSP) shall be equivalent to 3" X 1" CSP. For fill heights exceeding 29 feet contact ADOT Roadway Design for equivalent 5" X 1" wall thickness.
3. Ten foot maximum fill height (12 to 36 inch diameter) for CHDPEPP, cell class 324420c, based on 1992 AASHTO bridge specifications.
4. Fill heights shown in the tables are from top of subgrade to top of pipe.
5. Shaded areas in tables indicate pipe sizes outside the normal range of selection for culvert and storm drain design.

TRENCH AND NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 1

FILL HEIGHT: GREATER THAN OR EQUAL TO 1' BUT NOT EXCEEDING 3'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP ③	CHDPEPP ④	
In.	Size ①	In.	Size ①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	IV	3	②	Ok	
15	2⅔X½	0.064	2⅔X½	0.060	IV	3	②	Ok	
18	2⅔X½	0.064	2⅔X½	0.060	IV	②	②	Ok	
21	②		②		IV	②	②	②	
24	2⅔X½	0.064	2⅔X½	0.060	III	3	②	Ok	
30	2⅔X½	0.064	3 X 1	0.060	III	2	3	Ok	
36	2⅔X½	0.064	3 X 1	0.060	II	2	3 ½	Ok	
42	2⅔X½	0.064	3 X 1	0.060	II	②	4		
48	2⅔X½	0.064	3 X 1	0.060	II	②	5		
54	3 X 1 ⑤	0.064	3 X 1	0.060	II	②	5 ½		
60	3 X 1 ⑤	0.064	3 X 1	0.075	II	②	6		
66	3 X 1 ⑤	0.064	3 X 1	0.075	II	②	6 ½		
72	3 X 1 ⑤	0.064	3 X 1	0.075	II	②	7		
78	3 X 1 ⑤	0.064	3 X 1	0.075	II	②	7 ½		
84	3 X 1 ⑤	0.064	3 X 1	0.105	II	②	8		
90	3 X 1 ⑤	0.064	3 X 1	0.105	II	②	8		
96	3 X 1 ⑤	0.079	3 X 1	0.105	II	②	8 ½		
102	3 X 1 ⑤	0.079	3 X 1	0.135	II	②	9		
108	3 X 1 ⑤	0.109	3 X 1	0.135	II	②	9 ½		
114	3 X 1 ⑤	0.109	9X2½	0.100	900 ⑥	②	10		
120	3 X 1 ⑤	0.109	9X2½	0.100	900 ⑥	②	10 ½		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION, USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS, OR NON-TRENCH CONDITION.

④ CELL CLASS NO. 324420C.

⑤ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

⑥ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA.) TO PRODUCE A .01" CRACK.

TRENCH AND NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 2

FILL HEIGHT: GREATER THAN 3' BUT NOT EXCEEDING 5'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③	CHDPEPP④	
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	II	1	②	OK	
15	2⅔X½	0.064	2⅔X½	0.060	II	1	②	OK	
18	2⅔X½	0.064	2⅔X½	0.060	II	1	②	OK	
21	②		②		II	1	②	②	
24	2⅔X½	0.064	2⅔X½	0.060	II	1	②	OK	
30	2⅔X½	0.064	3 X 1	0.060	II	1	3	OK	
36	2⅔X½	0.064	3 X 1	0.060	II	1	3 ½	OK	
42	2⅔X½	0.064	3 X 1	0.060	II	②	4		
48	2⅔X½	0.064	3 X 1	0.060	II	②	5		
54	3 X 1⑤	0.064	3 X 1	0.060	II	②	5 ½		
60	3 X 1⑤	0.064	3 X 1	0.075	II	②	6		
66	3 X 1⑤	0.064	3 X 1	0.075	II	②	6 ½		
72	3 X 1⑤	0.064	3 X 1	0.075	II	②	7		
78	3 X 1⑤	0.064	3 X 1	0.075	II	②	7 ½		
84	3 X 1⑤	0.064	3 X 1	0.105	II	②	8		
90	3 X 1⑤	0.064	3 X 1	0.105	II	②	8		
96	3 X 1⑤	0.079	3 X 1	0.105	II	②	8 ½		
102	3 X 1⑤	0.079	3 X 1	0.135	II	②	9		
108	3 X 1⑤	0.109	3 X 1	0.135	II	②	9 ½		
114	3 X 1⑤	0.109	9X2½	0.100	900⑥	②	10		
120	3 X 1⑤	0.109	9X2½	0.100	900⑥	②	10 ½		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS, OR NON-TRENCH CONDITION.

④ CELL CLASS NO. 324420C

⑤ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

⑥ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH AND NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 3

FILL HEIGHT: GREATER THAN 5' BUT NOT EXCEEDING 8'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③	CHDPEPP④	
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	III	I	②	OK	
15	2⅔X½	0.064	2⅔X½	0.060	II	I	②	OK	
18	2⅔X½	0.064	2⅔X½	0.060	II	I	②	OK	
21	②		②		II	2	②	②	
24	2⅔X½	0.064	2⅔X½	0.060	II	2	②	OK	
30	2⅔X½	0.064	3 X 1	0.060	II	2	3	OK	
36	2⅔X½	0.064	3 X 1	0.060	II	2	3 ½	OK	
42	2⅔X½	0.064	3 X 1	0.060	II	②	4		
48	2⅔X½	0.064	3 X 1	0.060	II	②	5		
54	3 X 1⑤	0.064	3 X 1	0.060	II	②	5 ½		
60	3 X 1⑤	0.064	3 X 1	0.075	II	②	6		
66	3 X 1⑤	0.064	3 X 1	0.075	II	②	6 ½		
72	3 X 1⑤	0.064	3 X 1	0.075	II	②	7		
78	3 X 1⑤	0.064	3 X 1	0.075	II	②	7 ½		
84	3 X 1⑤	0.064	3 X 1	0.105	II	②	8		
90	3 X 1⑤	0.064	3 X 1	0.105	II	②	8		
96	3 X 1⑤	0.079	3 X 1	0.105	II	②	8 ½		
102	3 X 1⑤	0.079	3 X 1	0.135	II	②	9		
108	3 X 1⑤	0.109	3 X 1	0.135	II	②	9 ½		
114	3 X 1⑤	0.109	9X2½	0.100	900⑥	②	10		
120	3 X 1⑤	0.109	9X2½	0.100	900⑥	②	10 ½		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS, OR NON-TRENCH CONDITION.

④ CELL CLASS NO. 324420C

⑤ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

⑥ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH CONDITION AND NON-TRENCH

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 4

FILL HEIGHT: GREATER THAN 8' BUT NOT EXCEEDING 11'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③	CHDPEPP④	
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	IV	2	②	OK⑤	
15	2⅔X½	0.064	2⅔X½	0.060	IV	2	②	OK⑤	
18	2⅔X½	0.064	2⅔X½	0.060	III	2	②	OK⑤	
21	②		②		III	2	②	②	
24	2⅔X½	0.064	2⅔X½	0.060	III	②	②	OK⑤	
30	2⅔X½	0.064	3 X 1	0.060	III	②	3	OK⑤	
36	2⅔X½	0.064	3 X 1	0.060	III	②	3 ½	OK⑤	
42	2⅔X½	0.064	3 X 1	0.060	III	②	4		
48	2⅔X½	0.064	3 X 1	0.060	III	②	5		
54	3 X 1⑥	0.064	3 X 1	0.060	III	②	5 ½		
60	3 X 1⑥	0.064	3 X 1	0.075	III	②	6		
66	3 X 1⑥	0.064	3 X 1	0.075	III	②	6 ½		
72	3 X 1⑥	0.064	3 X 1	0.075	III	②	7		
78	3 X 1⑥	0.064	3 X 1	0.075	III	②	7 ½		
84	3 X 1⑥	0.064	3 X 1	0.105	III	②	8		
90	3 X 1⑥	0.064	3 X 1	0.105	III	②	8		
96	3 X 1⑥	0.079	3 X 1	0.105	III	②	8 ½		
102	3 X 1⑥	0.079	3 X 1	0.135	II	②	9		
108	3 X 1⑥	0.109	3 X 1	0.135	II	②	9 ½		
114	3 X 1⑥	0.109	9X2½	0.100	945⑦	②	10		
120	3 X 1⑥	0.109	9X2½	0.100	940⑦	②	10 ½		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS, OR NON-TRENCH CONDITION.

④ CELL CLASS NO. 324420C.

⑤ MAX FILL HEIGHT 10'

⑥ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

⑦ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH CONDITION AND NON-TRENCH

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 5

FILL HEIGHT: GREATER THAN 11' BUT NOT EXCEEDING 15'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
21	②		②		IV	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
30	2⅔X½	0.064	3 X 1	0.060	IV	②	3		
36	2⅔X½	0.064	3 X 1	0.060	IV	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.060	IV	②	4		
48	2⅔X½	0.064	3 X 1	0.060	IV	②	5		
54	3 X 1④	0.064	3 X 1	0.060	IV	②	5 ½		
60	3 X 1④	0.064	3 X 1	0.075	IV	②	6		
66	3 X 1④	0.064	3 X 1	0.075	IV	②	6 ½		
72	3 X 1④	0.064	3 X 1	0.075	IV	②	7		
78	3 X 1④	0.064	3 X 1	0.075	IV	②	7 ½		
84	3 X 1④	0.064	3 X 1	0.105	IV	②	8		
90	3 X 1④	0.064	3 X 1	0.105	III	②	8		
96	3 X 1④	0.079	3 X 1	0.105	III	②	8 ½		
102	3 X 1④	0.079	3 X 1	0.135	III	②	9		
108	3 X 1④	0.109	3 X 1	0.135	III	②	9 ½		
114	3 X 1④	0.109	9X2½	0.100	1260⑤	②	10		
120	3 X 1④	0.109	9X2½	0.100	1245⑤	②	10 ½		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS, OR NON-TRENCH CONDITION.

④ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

⑤ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 6

FILL HEIGHT: GREATER THAN 15' BUT NOT EXCEEDING 20'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
21	②		②		IV	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	IV	②	②		
30	2⅔X½	0.064	3 X 1	0.060	IV	②	3		
36	2⅔X½	0.064	3 X 1	0.060	IV	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.060	IV	②	4		
48	2⅔X½	0.064	3 X 1	0.060	IV	②	5		
54	3 X 1⑥	0.064	3 X 1	0.060	IV	②	5 ½		
60	3 X 1⑥	0.064	3 X 1	0.075	IV	②	6		
66	3 X 1⑥	0.064	3 X 1	0.075	IV	②	6 ½		
72	3 X 1⑥	0.064	3 X 1	0.075	IV	②	7		
78	3 X 1⑥	0.064	3 X 1	0.075	IV	②	7 ½		
84	3 X 1⑥	0.064	3 X 1	0.105	IV	②	8		
90	3 X 1⑥	0.064	3 X 1	0.105	1700⑦	②	8		
96	3 X 1⑥	0.079	3 X 1	0.105	1685⑦	②	8 ½ ④		
102	3 X 1⑥	0.079	3 X 1	0.135	1670⑦	②	9 ④		
108	3 X 1⑥	0.109	3 X 1	0.135	1660⑦	②	9 ½ ④		
114	3 X 1⑥	0.109	9X2½	0.125	1610⑦	②	10 ⑤		
120	3 X 1⑥	0.109	9X2½	0.125	1605⑦	②	10 ½ ⑤		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.
② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.
③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.
④ MAXIMUM FILL HEIGHT 19'
⑤ MAXIMUM FILL HEIGHT 18'
⑥ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".
⑦ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 6

FILL HEIGHT: GREATER THAN 15' BUT NOT EXCEEDING 20'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔x½	0.064	2⅔x½	0.060	V	②			
15	2⅔x½	0.064	2⅔x½	0.060	V	②			
18	2⅔x½	0.064	2⅔x½	0.060	V	②			
21	②		②		IV	②			
24	2⅔x½	0.064	2⅔x½	0.060	IV	②			
30	2⅔x½	0.064	3 X 1	0.060	IV	②			
36	2⅔x½	0.064	3 X 1	0.060	IV	②			
42	2⅔x½	0.064	3 X 1	0.060	IV	②			
48	2⅔x½	0.064	3 X 1	0.060	IV	②			
54	3 X 1③	0.064	3 X 1	0.060	IV	②			
60	3 X 1③	0.064	3 X 1	0.075	IV	②			
66	3 X 1③	0.064	3 X 1	0.075	IV	②			
72	3 X 1③	0.064	3 X 1	0.075	IV	②			
78	3 X 1③	0.064	3 X 1	0.075	IV	②			
84	3 X 1③	0.064	3 X 1	0.105	IV	②			
90	3 X 1③	0.064	3 X 1	0.105	1785④	②			
96	3 X 1③	0.079	3 X 1	0.105	1795④	②			
102	3 X 1③	0.079	3 X 1	0.135	1790④	②			
108	3 X 1③	0.109	3 X 1	0.135	1770④	②			
114	3 X 1③	0.109	9X2½	0.125	1750④	②			
120	3 X 1③	0.109	9X2½	0.125	1755④	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

④ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 7

FILL HEIGHT: GREATER THAN 20' BUT NOT EXCEEDING 25'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
21	②		②		V	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
30	2⅔X½	0.064	3 X 1	0.060	V	②	3		
36	2⅔X½	0.064	3 X 1	0.060	IV	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.060	IV	②	4		
48	2⅔X½	0.064	3 X 1	0.060	V	②	5		
54	3 X 1⑥	0.064	3 X 1	0.060	V	②	5 ½		
60	3 X 1⑥	0.064	3 X 1	0.075	V	②	6 ④		
66	3 X 1⑥	0.064	3 X 1	0.075	V	②	6 ½ ⑤		
72	3 X 1⑥	0.064	3 X 1	0.075	V	②	7 ⑤		
78	3 X 1⑥	0.064	3 X 1	0.075	2075⑦	②	②		
84	3 X 1⑥	0.064	3 X 1	0.105	2055⑦	②	②		
90	3 X 1⑥	0.064	3 X 1	0.105	2035⑦	②	②		
96	3 X 1⑥	0.079	3 X 1	0.105	2020⑦	②	②		
102	3 X 1⑥	0.079	3 X 1	0.135	2010⑦	②	②		
108	3 X 1⑥	0.109	3 X 1	0.135	1995⑦	②	②		
114	3 X 1⑥	0.109	9X2½	0.150	1940⑦	②	②		
120	3 X 1⑥	0.109	9X2½	0.150	1935⑦	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½. 3"X1" = 3X1. ETC.
② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.
③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.
④ MAXIMUM FILL HEIGHT 24'
⑤ MAXIMUM FILL HEIGHT 21'
⑥ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".
⑦ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 7

FILL HEIGHT: GREATER THAN 20' BUT NOT EXCEEDING 25'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔x½	0.064	2⅔x½	0.060	V	②			
15	2⅔x½	0.064	2⅔x½	0.060	V	②			
18	2⅔x½	0.064	2⅔x½	0.060	V	②			
21	②		②		V	②			
24	2⅔x½	0.064	2⅔x½	0.060	V	②			
30	2⅔x½	0.064	3 X 1	0.060	V	②			
36	2⅔x½	0.064	3 X 1	0.060	V	②			
42	2⅔x½	0.064	3 X 1	0.060	V	②			
48	2⅔x½	0.064	3 X 1	0.060	V	②			
54	3 X 1③	0.064	3 X 1	0.060	V	②			
60	3 X 1③	0.064	3 X 1	0.075	V	②			
66	3 X 1③	0.064	3 X 1	0.075	V	②			
72	3 X 1③	0.064	3 X 1	0.075	V	②			
78	3 X 1③	0.064	3 X 1	0.075	2275④	②			
84	3 X 1③	0.064	3 X 1	0.105	2240④	②			
90	3 X 1③	0.064	3 X 1	0.105	2250④	②			
96	3 X 1③	0.079	3 X 1	0.105	2245④	②			
102	3 X 1③	0.079	3 X 1	0.135	2210④	②			
108	3 X 1③	0.109	3 X 1	0.135	2235④	②			
114	3 X 1③	0.109	9X2½	0.150	2180④	②			
120	3 X 1③	0.109	9X2½	0.150	2185④	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1".

④ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 8

FILL HEIGHT: GREATER THAN 25' BUT NOT EXCEEDING 30'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	V	②			
15	2⅔X½	0.064	2⅔X½	0.060	V	②			
18	2⅔X½	0.064	2⅔X½	0.060	V	②			
21	②		②		V	②			
24	2⅔X½	0.064	2⅔X½	0.060	V	②			
30	2⅔X½	0.064	3 X 1	0.060	V	②	3		
36	2⅔X½	0.064	3 X 1	0.060	V	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.060	V	②	4		
48	2⅔X½	0.064	3 X 1	0.060	V	②	5		
54	3 X 1⑤	0.064	3 X 1	0.060	V	②	5 ½ ④		
60	3 X 1⑤	0.064	3 X 1	0.075	V	②	②		
66	3 X 1⑤	0.064	3 X 1	0.075	V	②	②		
72	3 X 1⑤	0.064	3 X 1	0.075	V	②	②		
78	3 X 1⑤	0.064	3 X 1	0.075	2380⑥	②	②		
84	3 X 1⑤	0.064	3 X 1	0.105	2360⑥	②	②		
90	3 X 1⑤	0.064	3 X 1	0.105	2345⑥	②	②		
96	3 X 1⑤	0.079	3 X 1	0.105	2330⑥	②	②		
102	3 X 1⑤	0.079	3 X 1	0.135	2320⑥	②	②		
108	3 X 1⑤	0.109	3 X 1	0.135	2310⑥	②	②		
114	3 X 1⑤	0.109	9X2½	0.150	2245⑥	②	②		
120	3 X 1⑤	0.109	9X2½	0.150	2240⑥	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.

④ MAXIMUM FILL HEIGHT 26'

⑤ 5" X 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1" FOR FILL HEIGHTS NOT EXCEEDING 29 FEET, FOR FILL HEIGHTS EXCEEDING 29 FEET CONTACT ADOT ROADWAY DESIGN FOR EQUIVALENT 5" X 1" WALL THICKNESS.

⑥ SPECIAL DESIGN MUST MEET INDIC
A .01" CRACK.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 8

FILL HEIGHT: GREATER THAN 25' BUT NOT EXCEEDING 30'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔X½	0.064	2⅔X½	0.060	②	②			
15	2⅔X½	0.064	2⅔X½	0.060	②	②			
18	2⅔X½	0.064	2⅔X½	0.060	②	②			
21	②		②		V	②			
24	2⅔X½	0.064	2⅔X½	0.060	V	②			
30	2⅔X½	0.064	3 X 1	0.060	V	②			
36	2⅔X½	0.064	3 X 1	0.060	V	②			
42	2⅔X½	0.064	3 X 1	0.060	V	②			
48	2⅔X½	0.064	3 X 1	0.060	V	②			
54	3 X 1③	0.064	3 X 1	0.060	V	②			
60	3 X 1③	0.064	3 X 1	0.075	V	②			
66	3 X 1③	0.064	3 X 1	0.075	V	②			
72	3 X 1③	0.064	3 X 1	0.075	V	②			
78	3 X 1③	0.064	3 X 1	0.075		②			
84	3 X 1③	0.064	3 X 1	0.105		②			
90	3 X 1③	0.064	3 X 1	0.105		②			
96	3 X 1③	0.079	3 X 1	0.105		②			
102	3 X 1③	0.079	3 X 1	0.135		②			
108	3 X 1③	0.109	3 X 1	0.135		②			
114	3 X 1③	0.109	9X2½③	0.150		②			
120	3 X 1③	0.109	9X2½③	0.150		②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ 5" x 1" CORRUGATION SHALL BE EQUIVALENT TO 3" X 1" FOR FILL HEIGHTS NOT EXCEEDING 29 FEET, FOR FILL HEIGHTS EXCEEDING 29 FEET CONTACT ADOT ROADWAY DESIGN FOR EQUIVALENT 5" X 1" WALL THICKNESS.

④

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 9

FILL HEIGHT: GREATER THAN 30' BUT NOT EXCEEDING 40'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
21	②		②		V	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
30	2⅔X½	0.064	3 X 1	0.060	V	②	3		
36	2⅔X½	0.064	3 X 1	0.060	V	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.060	V	②	4 ④		
48	2⅔X½	0.064	3 X 1	0.060	②	②	②		
54	3 X 1	0.064	3 X 1	0.075	V	②	②		
60	3 X 1	0.064	3 X 1	0.075	V	②	②		
66	3 X 1	0.064	3 X 1	0.075	V	②	②		
72	3 X 1	0.064	3 X 1	0.105	V	②	②		
78	3 X 1	0.079	3 X 1	0.105	2900⑤	②	②		
84	3 X 1	0.079	3 X 1	0.105	2890⑤	②	②		
90	3 X 1	0.079	3 X 1	0.105	2880⑤	②	②		
96	3 X 1	0.109	3 X 1	0.135	2875⑤	②	②		
102	3 X 1	0.109	3 X 1	0.135	2870⑤	②	②		
108	3 X 1	0.109	3 X 1	0.135	2865⑤	②	②		
114	3 X 1	0.109	9X2½	0.200	2785⑤	②	②		
120	3 X 1	0.109	9X2½	0.200	2790⑤	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS

④ MAXIMUM FILL HEIGHT 38'

⑤ SPECIAL DESIGN MUST MEET INDICATED D-LOAD (LB/LFT/FT-DIA) TO PRODUCE A .01" CRACK.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 9

FILL HEIGHT: GREATER THAN 30' BUT NOT EXCEEDING 40'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔X½	0.064	2⅔X½	0.060	②	②			
15	2⅔X½	0.064	2⅔X½	0.060	②	②			
18	2⅔X½	0.064	2⅔X½	0.060	②	②			
21	②		②		②	②			
24	2⅔X½	0.064	2⅔X½	0.060	②	②			
30	2⅔X½	0.064	3 X 1	0.060	②	②			
36	2⅔X½	0.064	3 X 1	0.060	②	②			
42	2⅔X½	0.064	3 X 1	0.060	②	②			
48	2⅔X½	0.064	3 X 1	0.060	②	②			
54	3 X 1	0.064	3 X 1	0.075	②	②			
60	3 X 1	0.064	3 X 1	0.075	②	②			
66	3 X 1	0.064	3 X 1	0.075	②	②			
72	3 X 1	0.064	3 X 1	0.105	②	②			
78	3 X 1	0.079	3 X 1	0.105	②	②			
84	3 X 1	0.079	3 X 1	0.105	②	②			
90	3 X 1	0.079	3 X 1	0.105	②	②			
96	3 X 1	0.109	3 X 1	0.135	②	②			
102	3 X 1	0.109	3 X 1	0.135	②	②			
108	3 X 1	0.109	3 X 1	0.135	②	②			
114	3 X 1	0.109	9X2½	0.200	②	②			
120	3 X 1	0.109	9X2½	0.200	②	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 10

FILL HEIGHT: GREATER THAN 40' BUT NOT EXCEEDING 55'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	②	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
21	②		②		V	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
30	2⅔X½	0.064	3 X 1	0.060	V	②	3		
36	2⅔X½	0.064	3 X 1	0.060	V	②	3 ½		
42	2⅔X½	0.064	3 X 1	0.075	V	②	②		
48	3 X 1	0.064	3 X 1	0.075	②	②	②		
54	3 X 1	0.079	3 X 1	0.105	②	②	②		
60	3 X 1	0.079	3 X 1	0.105	②	②	②		
66	3 X 1	0.079	3 X 1	0.105	②	②	②		
72	3 X 1	0.109	3 X 1	0.135	②	②	②		
78	3 X 1	0.109	3 X 1	0.135	②	②	②		
84	3 X 1	0.109	3 X 1	0.135	②	②	②		
90	3 X 1	0.109	3 X 1	0.135	②	②	②		
96	3 X 1	0.138	9X2½	0.225	②	②	②		
102	3 X 1	0.138	9X2½	0.250	②	②	②		
108	3 X 1	0.138	9X2½	0.250	②	②	②		
114	3 X 1	0.138	②		②	②	②		
120	3 X 1	0.138	②		②	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 10

FILL HEIGHT: GREATER THAN 40' BUT NOT EXCEEDING 55'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔x½	0.064	2⅔x½	0.060	②	②			
15	2⅔x½	0.064	2⅔x½	0.060	②	②			
18	2⅔x½	0.064	2⅔x½	0.060	②	②			
21	②		②		②	②			
24	2⅔x½	0.064	2⅔x½	0.060	②	②			
30	2⅔x½	0.064	3 X 1	0.060	②	②			
36	2⅔x½	0.064	3 X 1	0.060	②	②			
42	2⅔x½	0.064	3 X 1	0.075	②	②			
48	3 X 1	0.064	3 X 1	0.075	②	②			
54	3 X 1	0.079	3 X 1	0.105	②	②			
60	3 X 1	0.079	3 X 1	0.105	②	②			
66	3 X 1	0.079	3 X 1	0.105	②	②			
72	3 X 1	0.109	3 X 1	0.135	②	②			
78	3 X 1	0.109	3 X 1	0.135	②	②			
84	3 X 1	0.109	3 X 1	0.135	②	②			
90	3 X 1	0.109	3 X 1	0.135	②	②			
96	3 X 1	0.138	9x2½	0.225	②	②			
102	3 X 1	0.138	9x2½	0.250	②	②			
108	3 X 1	0.138	9x2½	0.250	②	②			
114	3 X 1	0.138	②		②	②			
120	3 X 1	0.138	②		②	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 11

FILL HEIGHT: GREATER THAN 55' BUT NOT EXCEEDING 70'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	②	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
21	②		②		V	②	②		
24	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
30	2⅔X½	0.064	3 X 1	0.060	V	②	3		
36	2⅔X½	0.064	3 X 1	0.075	V	②	3 ½		
42	3 X 1	0.079	3 X 1	0.105	②	②	②		
48	3 X 1	0.079	3 X 1	0.105	②	②	②		
54	3 X 1	0.109	3 X 1	0.135	②	②	②		
60	3 X 1	0.109	3 X 1	0.135	②	②	②		
66	3 X 1	0.109	3 X 1	0.135	②	②	②		
72	3 X 1	0.109	9X2½	0.225	②	②	②		
78	3 X 1	0.138	9X2½	0.225	②	②	②		
84	3 X 1	0.138	9X2½	0.250	②	②	②		
90	3 X 1	0.138	②		②	②	②		
96	3 X 1	0.168	②		②	②	②		
102	3 X 1	0.168	②		②	②	②		
108	3 X 1	0.168	②		②	②	②		
114	3 X 1	0.168	②		②	②	②		
120	6 X 2	0.249	②		②	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 11

FILL HEIGHT: GREATER THAN 55' BUT NOT EXCEEDING 70'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔X½	0.064	2⅔X½	0.060	②	②			
15	2⅔X½	0.064	2⅔X½	0.060	②	②			
18	2⅔X½	0.064	2⅔X½	0.060	②	②			
21	②		②		②	②			
24	2⅔X½	0.064	2⅔X½	0.060	②	②			
30	2⅔X½	0.064	3 X 1	0.060	②	②			
36	2⅔X½	0.064	3 X 1	0.075	②	②			
42	3 X 1	0.079	3 X 1	0.105	②	②			
48	3 X 1	0.079	3 X 1	0.105	②	②			
54	3 X 1	0.109	3 X 1	0.135	②	②			
60	3 X 1	0.109	3 X 1	0.135	②	②			
66	3 X 1	0.109	3 X 1	0.135	②	②			
72	3 X 1	0.109	9X2½	0.225	②	②			
78	3 X 1	0.138	9X2½	0.225	②	②			
84	3 X 1	0.138	9X2½	0.250	②	②			
90	3 X 1	0.138	②		②	②			
96	3 X 1	0.168	②		②	②			
102	3 X 1	0.168	②		②	②			
108	3 X 1	0.168	②		②	②			
114	3 X 1	0.168	②		②	②			
120	6 X 2	0.249	②		②	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 12

FILL HEIGHT: GREATER THAN 70' BUT NOT EXCEEDING 90'

Dia	CSP		CAP		RCP	NRCP	NRCIPCP③		
In.	Size①	In.	Size①	In.	Class	Class	WALL THICKNESS In.		
12	2⅔X½	0.064	2⅔X½	0.060	②	②	②		
15	2⅔X½	0.064	2⅔X½	0.060	②	②	②		
18	2⅔X½	0.064	2⅔X½	0.060	V	②	②		
21	②		②		V	②	②		
24	2⅔X½	0.064	2⅔X½	0.075	②	②	②		
30	2⅔X½	0.079	2⅔X½	0.105	②	②	3		
36	3 X 1	0.079	2⅔X½	0.105	②	②	3 ½		
42	3 X 1	0.109	3 X 1	0.135	②	②	②		
48	3 X 1	0.109	3 X 1	0.135	②	②	②		
54	3 X 1	0.109	3 X 1	0.135	②	②	②		
60	3 X 1	0.138	9X2½	0.225	②	②	②		
66	3 X 1	0.138	9X2½	0.250	②	②	②		
72	3 X 1	0.138	②		②	②	②		
78	3 X 1	0.168	②		②	②	②		
84	3 X 1	0.168	②		②	②	②		
90	3 X 1	0.168	②		②	②	②		
96	6 X 2	0.249	②		②	②	②		
102	6 X 2④	0.280	②		②	②	②		
108	6 X 2④	0.280	②		②	②	②		
114	6 X 2④	0.280	②		②	②	②		
120	6 X 2④	0.280	②		②	②	②		

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.
② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.
③ NRCIPCP SHALL NOT BE USED FOR CULVERT PIPE INSTALLATIONS.
④ SIX BOLTS PER FOOT.

NON-TRENCH CONDITION

CIRCULAR CULVERT, STORM SEWER AND IRRIGATION PIPES

RANGE 12

FILL HEIGHT: GREATER THAN 70' BUT NOT EXCEEDING 90'

Dia	CSP		CAP		RCP	NRCP			
In.	Size①	In.	Size①	In.	Class	Class			
12	2⅔x½	0.064	2⅔x½	0.060	②	②			
15	2⅔x½	0.064	2⅔x½	0.060	②	②			
18	2⅔x½	0.064	2⅔x½	0.060	②	②			
21	②		②		②	②			
24	2⅔x½	0.064	2⅔x½	0.075	②	②			
30	2⅔x½	0.079	2⅔x½	0.105	②	②			
36	3 X 1	0.079	2⅔x½	0.105	②	②			
42	3 X 1	0.109	3 X 1	0.135	②	②			
48	3 X 1	0.109	3 X 1	0.135	②	②			
54	3 X 1	0.109	3 X 1	0.135	②	②			
60	3 X 1	0.138	9X2½	0.225	②	②			
66	3 X 1	0.138	9X2½	0.250	②	②			
72	3 X 1	0.138	②		②	②			
78	3 X 1	0.168	②		②	②			
84	3 X 1	0.168	②		②	②			
90	3 X 1	0.168	②		②	②			
96	6 X 2	0.249	②		②	②			
102	6 X 2	0.280	②		②	②			
108	6 X 2③	0.280	②		②	②			
114	6 X 2③	0.280	②		②	②			
120	6 X 2③	0.280	②		②	②			

① CORRUGATION SIZE IN INCHES: 2⅔"X½" = 2⅔X½, 3"X1" = 3X1, ETC.

② NOT APPLICABLE FOR THIS INSTALLATION USE OTHER EQUAL ALTERNATIVES.

③ SIX BOLTS PER FOOT.

TABLE 1A

CORRUGATED, STEEL PIPE ARCH 2 2/3" X 1/2" CORRUGATIONS RIVETED, WELDED OR LOCK SEAM FABRICATION

H-20 LOADING

SIZE - INCHES SPAN X RISE	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAXIMUM CORNER PRESSURE - 4000 LBS / SQ. FT.									
			16 Ga. - .064"		14 Ga. - .079"		12 Ga. - .109"		10 Ga. - .138"		8 Ga. - .168"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
17" X 13"	1.1	3½	1	13	1	13	1	13	1	13	1	13
21" X 15"	1.6	4⅛	1	12	1	12	1	12	1	12	1	12
24" X 18"	2.2	4⅞	1	13	1	13	1	13	1	13	1	13
28" X 20"	2.9	5½	1	13	1	13	1	13	1	13	1	13
35" X 24"	4.5	6⅞	1	12	1	12	1	12	1	12	1	12
42" X 29"	6.5	8¼	1	12	1	12	1	12	1	12	1	12
49" X 33"	8.9	9⅝			1	12	1	12	1	12	1	12
57" X 38"	11.6	11					1	12	1	12	1	12
64" X 43"	14.7	12⅜					1	12	1	12	1	12
71" X 47"	18.1	13¾							1	12	1	12
77" X 52"	21.9	15⅛									1	12
83" X 57"	26.0	16½									1	12

TABLE 1B

CORRUGATED, STEEL PIPE ARCH 3" X 1" CORRUGATIONS RIVETED, WELDED OR LOCK SEAM FABRICATION

H-20 LOADING

SIZE -INCHES SPAN & RISE	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAX. CORNER PRESSURE-4000 LBS/SQ. FT.							
			14 Ga. - .079"		12 Ga. - .109"		10 Ga. - .138"		8 Ga. - .168"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
60" X 46"	15.6	18¾			1	21	1	21	1	21
66" X 51"	19.3	20¾			1	21	1	21	1	21
73" X 55"	23.2	22⅞			1	20	1	20	1	20
81" X 59"	27.4	20⅞	1	17	1	17	1	17	1	17
87" X 63"	32.1	22⅝	1	17	1	17	1	17	1	17
95" X 67"	37.0	24⅜	1	17	1	17	1	17	1	17
103" X 71"	42.4	26⅛			1½	17	1½	17	1½	17
112" X 75"	48.0	27¾			1½	16	1½	16	1½	16
117" X 79"	54.2	29½			1½	16	1½	16	1½	16
128" X 83"	60.5	31¼					2	16	2	16
137" X 87"	67.4	33					2	16	2	16
142" X 91"	74.5	34¾							2	16

TABLE 2A

STRUCTURAL PLATE, STEEL PIPE ARCH 6" X 2" CORRUGATIONS BOLTED FABRICATION

H-20 LOADING

SIZE - INCHES SPAN X RISE FEET-INCHES	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAXIMUM CORNER PRESSURE - 4000 LBS / SQ. FT.							
			12 Ga. - .111"		10 Ga. - .140"		8 Ga. - .170"		7 Ga. - .188"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
6'-1" X 4'-7"	22	18	1	16	1	16	1	16	1	16
7'-0" X 5'-1"	28	18	1	14	1	14	1	14	1	14
7'-11" X 5'-7"	35	18	1	12	1	12	1	12	1	12
8'-10" X 6'-1"	43	18	1½	11	1½	11	1½	11	1½	11
9'-9" X 6'-7"	52	18	1½	10	1½	10	1½	10	1½	10
10'-11" X 7'-1"	61	18	1½	9	1½	9	1½	9	1½	9
11'-10 X 7'-7	71	18	1½	8	1½	8	1½	8	1½	8
12'-10 X 8'-4"	85	18	2	6	2	6	2	6	2	6
14'-1" X 8'-9"	97	18	2	5	2	5	2	5	2	5
13'-3" X 9'-4"	97	31	2½	12	2½	12	2½	12	2½	12
14'-2" X 9'-10"	109	31	2½	12	2½	12	2½	12	2½	12
15'-4" X 10'-4"	123	31	2½	11	2½	11	2½	11	2½	11
16'-3" X 10'-10"	137	31	2½	10	2½	10	2½	10	2½	10
17'-2" X 11'-4"	151	31	2½	10	2½	10	2½	10	2½	10
18'-1 X 11'-10"	167	31	2½	9	2½	9	2½	9	2½	9
19'-3" X 12'-4"	182	31			2½	8	2½	8	2½	8
19'-11" X 12'-10"	200	31			2½	8	2½	8	2½	8
20'-7" X 13'-2"	211	31			2½	7	2½	7	2½	7

TABLE 3A

CORRUGATED, ALUMINUM PIPE ARCH 2 2/3 " X 1/2" CORRUGATIONS RIVETED, WELDED OR LOCK SEAM FABRICATION

H-20 LOADING

SIZE - INCHES SPAN - RISE	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAXIMUM CORNER PRESSURE - 4000 LBS / SQ. FT.									
			16 Ga - .060"		14 Ga - .075"		12 Ga - .105"		10 Ga - .135"		8 Ga - .164"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
17" X 13"	1.1	3½	1	13	1	13	1	13	1	13	1	13
21" X 15"	1.6	4⅛	1	12	1	12	1	12	1	12	1	12
24" X 18"	2.2	4⅞	1	13	1	13	1	13	1	13	1	13
28" X 20"	2.9	5½			1	13	1	13	1	13	1	13
35" X 24"	4.5	6⅞			1	12	1	12	1	12	1	12
42" X 29"	6.5	8¼					1¼	12	1¼	12	1¼	12
49" X 33"	8.9	9⅝					1¼	12	1¼	12	1¼	12
57" X 38"	11.6	11							1¼	12	1¼	12
64" X 43"	14.7	12⅜							1½	12	1½	12

TABLE 3B

CORRUGATED, ALUMINUM PIPE ARCH 3 " X 1" CORRUGATIONS RIVETED, WELDED OR LOCK SEAM FABRICATION

H-20 LOADING

SIZE - INCHES SPAN - RISE	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAXIMUM CORNER PRESSURE - 4000 LBS / SQ. FT.							
			16 Ga - .060"		14 Ga - .075"		12 Ga - .105"		10 Ga - .135"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
60" X 46"	15.6	18¾	1¼	21	1¼	21	-	-	-	-
66" X 51"	19.3	20¾	1½	21	1½	21	-	-	-	-
73" X 55"	23.2	22⅞			1½	20	-	-	-	-
81" X 59"	27.4	20⅞					1¾	17	1¾	17
87" X 63"	32.1	20⅞					1¾	17	1¾	17
95" X 67"	37.0	24⅜					2	17	2	17
103" X 71"	42.4	26⅛							2	17

TABLE 4A

STRUCTURAL PLATE, ALUMINUM PIPE ARCH 9" X 2½" CORRUGATIONS BOLTED FABRICATION

H-20 LOADING

SIZE - INCHES SPAN X RISE	OPENING AREA SQ. FT.	CORNER RADIUS INCHES	FILL HEIGHTS TO TOP OF SUBGRADE - FT. MAXIMUM CORNER PRESSURE - 4000 LBS / SQ. FT.													
			THICKNESS .100"		THICKNESS .125"		THICKNESS .150"		THICKNESS .175"		THICKNESS .200"		THICKNESS .225"		THICKNESS .250"	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
6'-7" X 5'-8"	29.6	31.8	1½	23	1½	23	1½	23	1½	23	1½	23	1½	23	1½	23
6'-11" X 5'-9"	31.9	31.8	1½	22	1½	22	1½	22	1½	22	1½	22	1½	22	1½	22
7'-3" X 5'-11"	34.3	31.8	1½	21	1½	21	1½	21	1½	21	1½	21	1½	21	1½	21
7'-9" X 6'-0"	36.8	31.8	1½	20	1½	20	1½	20	1½	20	1½	20	1½	20	1½	20
8'-1" X 6'-1"	39.3	31.8	1¾	19	1¾	19	1¾	19	1¾	19	1¾	19	1¾	19	1¾	19
8'-5" X 6'-3"	41.9	31.8	1¾	18	1¾	18	1¾	18	1¾	18	1¾	18	1¾	18	1¾	18
8'-10" X 6'-4"	44.5	31.8	1¾	17	1¾	17	1¾	17	1¾	17	1¾	17	1¾	17	1¾	17
9'-3" X 6'-5"	47.1	31.8	2	16	2	16	2	16	2	16	2	16	2	16	2	16
9'-7" X 6'-6"	49.9	31.8	2	16	2	16	2	16	2	16	2	16	2	16	2	16
9'-11" X 6'-8"	52.7	31.8	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15
10'-3" X 6'-9"	55.5	31.8	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15	2¼	15
10'-9" X 6'-10"	58.4	31.8	2¼	14	2¼	14	2¼	14	2¼	14	2¼	14	2¼	14	2¼	14
11'-1" X 7'-0"	61.4	31.8	2½	14	2½	14	2½	14	2½	14	2½	14	2½	14	2½	14
11'-5" X 7'-1"	64.4	31.8	2½	13	2½	13	2½	13	2½	13	2½	13	2½	13	2½	13
11'-9" X 7'-2"	67.5	31.8	2½	13	2½	13	2½	13	2½	13	2½	13	2½	13	2½	13
12'-3" X 7'-3"	70.5	31.8	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12
12'-7" X 7'-5"	73.7	31.8	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12	2¾	12
12'-11" X 7'-6"	77.0	31.8	3	12	3	12	3	12	3	12	3	12	3	12	3	12
13'-1" X 8'-2"	83.0	31.8	3	11	3	11	3	11	3	11	3	11	3	11	3	11
13'-1" X 8'-4"	86.8	31.8	3	11	3	11	3	11	3	11	3	11	3	11	3	11
13'-11" X 8'-5"	90.3	31.8	3	11	3	11	3	11	3	11	3	11	3	11	3	11
14'-0" X 8'-7"	94.2	31.8	3	11	3	11	3	11	3	11	3	11	3	11	3	11
13'-11" X 9'-5"	101.5	31.8	3	11	3	11	3	11	3	11	3	11	3	11	3	11
14'-3" X 9'-7"	105.7	31.8	3	10	3	10	3	10	3	10	3	10	3	10	3	10
14'-8" X 9'-8"	109.9	31.8			3	12	3	12	3	12	3	12	3	12	3	12
14'-11" X 9'-10"	114.2	31.8			3	11	3	11	3	11	3	11	3	11	3	11
15'-4" X 10'-0"	118.6	31.8			3	11	3	11	3	11	3	11	3	11	3	11
15'-7" X 10'-2"	123.1	31.8			3	11	3	11	3	11	3	11	3	11	3	11
16'-1" X 10'-4"	127.6	31.8			3	10	3	10	3	10	3	10	3	10	3	10
16'-4" X 10'-6"	132.3	31.8			3	10	3	10	3	10	3	10	3	10	3	10

APPENDIX

G

BLANK FORMS

PIPE SELECTION WORKSHEETS
AISI AVERAGE SERVICE LIFE CHARTS FOR STEEL PIPE

ARIZONA DEPARTMENT OF TRANSPORTATION

GALVANIZED STEEL PIPE SELECTION

Sheet ____ of ____

Plan Reference Number								
Location (Station)								
Service Life Required SL_r (Years) circle one	50	75	50	75	50	75	50	75
Pipe Size (inches or inch x inch)								
Fill Height Range (ft-ft)								
Corrugation (inch x inch) circle one	$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2	
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	
pH								
Resistivity (ohm-cm)								
High Soil Moisture? circle one	yes	no	yes	no	yes	no	yes	no
	Reduce the Average Life (years) in the AISI Chart by half. Use as SL_b							
Service Life Base, SL_b (years)								
Expected Service Life (years) **SL_e=SL_b*AISI Factor**								
Velocity of Flow>7ft/sec? circle one	yes	no	yes	no	yes	no	yes	no
	Designer must check for possible abrasion problems due to bedloads.							

When **SL_e<SL_r** consider three options to increase **SL_e**:

1. Increase the pipe wall thickness (gage). This will increase the **SL_e**.
2. Consider justifying a lower service life requirement if **SL_e** is close to **SL_r**.
3. Add bituminous coating. This adds 20 years to **SL_e**. This is not normally a preferred option.

Plan Reference No.	Plan Reference No.	Plan Reference No.	Plan Reference No.

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINIZED STEEL PIPE SELECTION

Sheet ____ of ____

Plan Reference Number								
Location (Station)								
Service Life Required SL_r (Years) circle one	50	75	50	75	50	75	50	75
Pipe Size (inches or inch x inch)								
Fill Height Range (ft-ft)								
Corrugation (inch x inch) circle one	$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2		$2^2/_3$x$^1/_2$ 3x1 5x1 6x2	
Pipe Wall Thickness(inches)=**AISI Factor** circle or add appropriate thickness	0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4		0.064"=1.3 0.079"=1.6 0.109"=2.2 0.138"=2.8 0.168"=3.4	
pH								
Resistivity (ohm-cm)								
High Soil Moisture? circle one	yes	no	yes	no	yes	no	yes	no
	Reduce the average life (years) in the AISI Chart by half. Use SL_b.							
Service Life Base, SL_b (years)								
Expected Service Life (years) **SL_e=SL_b*AISI Factor**								
Velocity of Flow>7ft/sec? circle one	yes	no	yes	no	yes	no	yes	no
	Designer must check for possible abrasion problems due to bedloads.							

When SL_e<SL_r consider three options to increase SL_e:

1. Increase the pipe wall thickness (gage). This will increase the SL_e.
3. Consider jusifying a lower service life requirement if SL_e is close to SL_r.
2. Add bituminous coating. This adds 20 years to SL_e. This is not normally a preferred option.

Plan Reference No.	Plan Reference No.	Plan Reference No.	Plan Reference No.

JAN 25, 1996

ARIZONA DEPARTMENT OF TRANSPORTATION

ALUMINUM PIPE SELECTION

Sheet ____ of ____

Plan Reference Number								
Location (Station)								
Service Life Required SL_r (Years) circle one	50	75	50	75	50	75	50	75
$5 \leq pH \leq 9$? circle one	yes	no	yes	no	yes	no	yes	no
Resistivity ≥ 500? (ohm-cm) circle one	yes	no	yes	no	yes	no	yes	no
	Aluminum Pipe is not an acceptable alternate							
Pipe Size (inches or inch x inch)								
Fill Height Range (ft-ft)								
Corrugation (inch x inch) circle one	$2^2/_3$x$^1/_2$ 3x1 9x$2^1/_2$		$2^2/_3$x$^1/_2$ 3x1 9x$2^1/_2$		$2^2/_3$x$^1/_2$ 3x1 9x$2^1/_2$		$2^2/_3$x$^1/_2$ 3x1 9x$2^1/_2$	
Pipe Wall Thickness(inches) **= Service Life Expected** (years) **SLe** circle or add appropriate thickness	0.060"=50.0 yrs 0.075"=62.5 yrs 0.105"=87.5 yrs		0.060"=50.0 yrs 0.075"=62.5 yrs 0.105"=87.5 yrs		0.060"=50.0 yrs 0.075"=62.5 yrs 0.105"=87.5 yrs		0.060"=50.0 yrs 0.075"=62.5 yrs 0.105"=87.5 yrs	
Velocity of Flow>7ft/sec? circle one	yes	no	yes	no	yes	no	yes	no
	Designer must check for possible abrasion problems due to bedloads							

When $SL_e < SL_r$ consider three options to increase SL_e:

1. Increase the pipe wall thickness (gage). This will increase the SL_e.
2. Consider justifying a lower service life requirement if SL_e is close to SL_r.
3. Add bituminous coating. This adds 20 years to SL_e. This is not normally a preferred option.

Plan Reference No.	Plan Reference No.	Plan Reference No.	Plan Reference No.

ARIZONA DEPARTMENT OF TRANSPORTATION

CONCRETE PIPE SELECTION

Sheet_____ of_____

Plan Reference Number								
Location (Station)								
Service Life Required SLr (Years) **>100 Years?** circle one	yes	no	yes	no	yes	no	yes	no
	Concrete Pipe is not an acceptable alternate.							
Pipe Size (inches or inch x inch)								
Fill Height Range (ft-ft)								
Trench And Non-Trench Conditions circle observed field condition	Trench	Non-Trench	Trench	Non-Trench	Trench	Non-Trench	Trench	Non-Trench
RCP Class choose one class in each column or write in D-Load	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V	I II III IV V
NRCP Class								
NRCIPCP Wall Thickness (inches)								
pH								
pH<5? choose one	yes	no	yes	no	yes	no	yes	no
	For RCP & NRCP consider using concrete admixtures. NRCIPCP is not an acceptable alternate.							
High Sulfate Levels? circle one	yes	no	yes	no	yes	no	yes	no
	Pipe may require Type V cement.							
Velocity of Flow>40ft/sec? circle one	yes	no	yes	no	yes	no	yes	no
	Designer must check for possible abrasion problems due to bedloads.							

Plan Reference No.	Plan Reference No.	Plan Reference No.	Plan Reference No.

MAR 21, 1996

ARIZONA DEPARTMENT OF TRANSPORTATION

PLASTIC PIPE SELECTION

Sheet ____ of ____

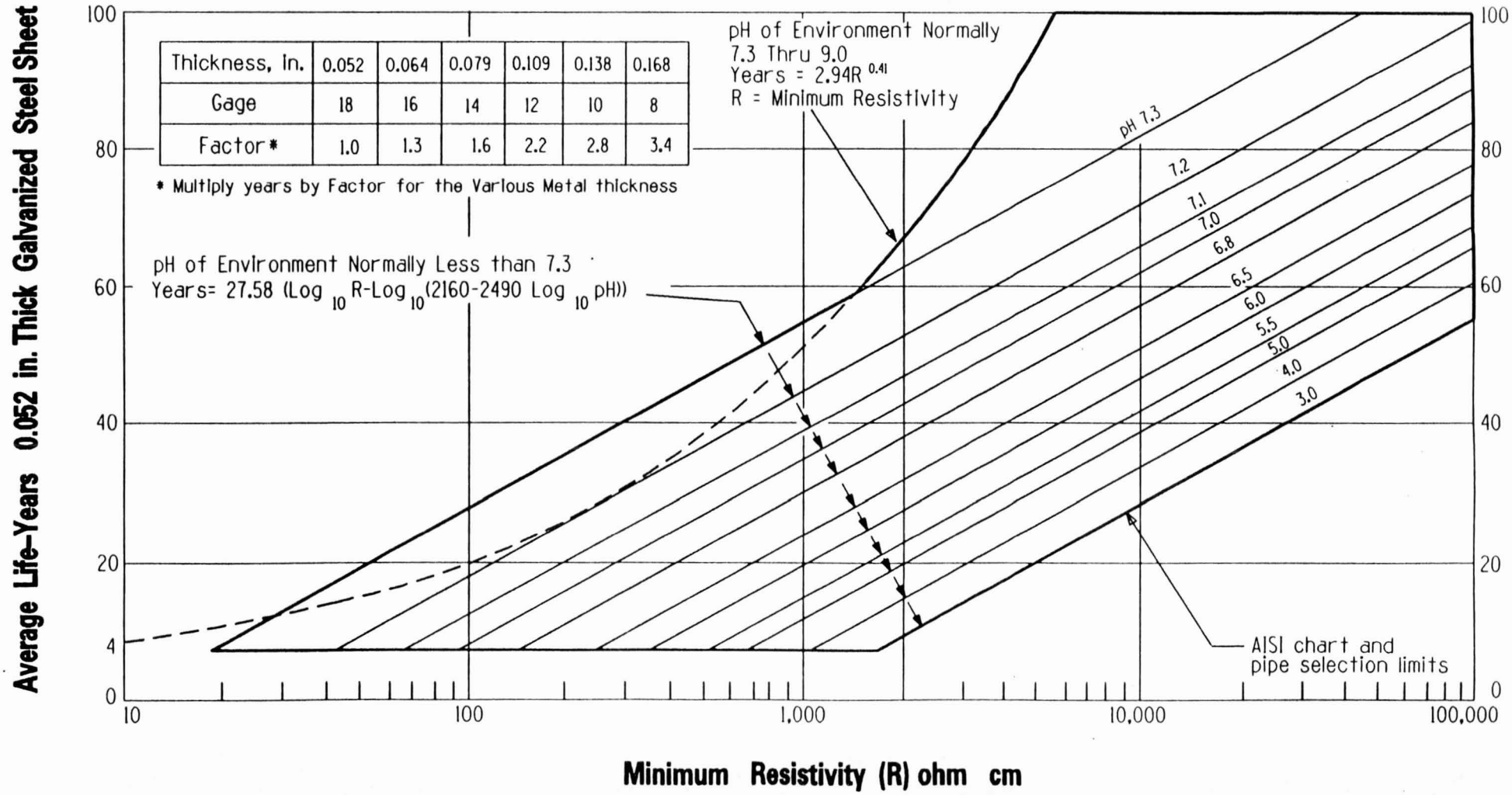
Plan Reference Number								
Location (Station)								
Service Life Required SLr (Years) **>75 Years?** circle one	yes	no	yes	no	yes	no	yes	no
	Plastic Pipe is not an acceptable alternate.							
Pipe Size (inches)								
12"≤Pipe Size≤36"? circle one	yes	no	yes	no	yes	no	yes	no
Pipe Size With Approved Joints? Check New Products List	yes	no	yes	no	yes	no	yes	no
	Plastic Pipe is not an acceptable alternate.							
Fill Height (ft)								
Fill Height > 10'? circle one	yes	no	yes	no	yes	no	yes	no
	Plastic Pipe is not an acceptable alternate.							

Plan Reference No.	Plan Reference No.	Plan Reference No.	Plan Reference No.

JAN 25, 1996

CHART FOR ESTIMATING AVERAGE SERVICE LIFE OF CORRUGATED GALVANIZED STEEL PIPE (CGSP), SPIRAL RIB GALVANIZED STEEL PIPE (SRGSP), AND CORRUGATED GALVANIZED STEEL STRUCTURAL PLATE PIPE (CGSSPP).

(COPIED FROM AISI CHART) - (FOR DRY SOIL CONDITIONS)

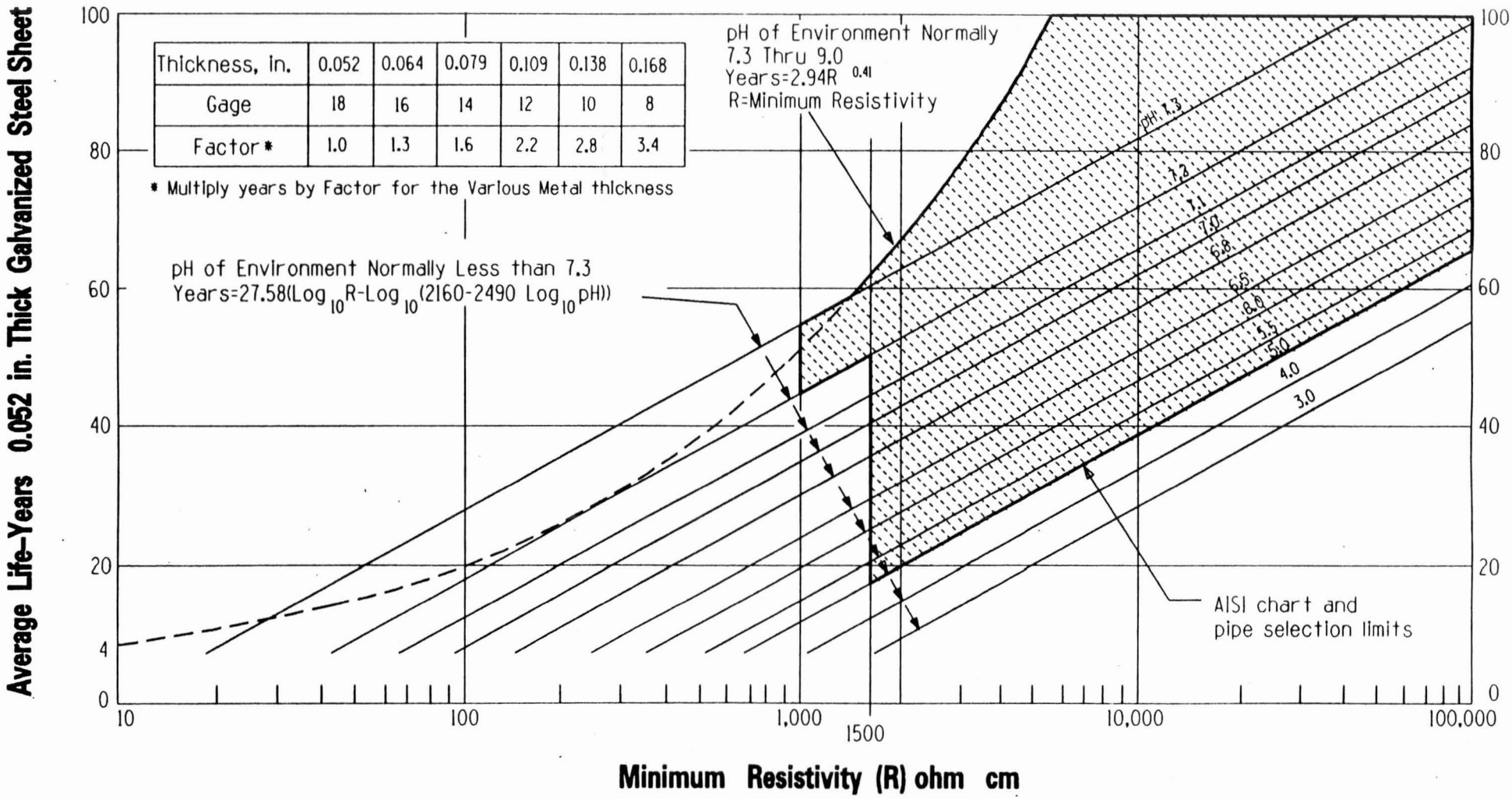


Thickness, in.	0.052	0.064	0.079	0.109	0.138	0.168
Gage	18	16	14	12	10	8
Factor*	1.0	1.3	1.6	2.2	2.8	3.4

* Multiply years by Factor for the Various Metal thickness

CHART FOR ESTIMATING AVERAGE SERVICE LIFE OF CORRUGATED ALUMINIZED STEEL PIPE (CASP), AND SPIRAL RIB ALUMINIZED STEEL PIPE (SRASP).

(COPIED FROM AISI CHART) - (FOR DRY SOIL CONDITIONS)



Thickness, in.	0.052	0.064	0.079	0.109	0.138	0.168
Gage	18	16	14	12	10	8
Factor*	1.0	1.3	1.6	2.2	2.8	3.4

* Multiply years by Factor for the Various Metal thickness