Planning and Community Development Department
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Colorado Springs, Colorado 80910
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DEVIATION REQUEST AND DECISION FORM

Updated: 6/26/2019

PROJECT INFORMATION

Project Name :	**Sterling Ranch East Filing No. 6**
Schedule No.(s) :	52342-00-001, 52000-00-586
Legal Description :	See attached

APPLICANT INFORMATION

Company :	Classic SRJ Land, LLC
Name :	Loren Moreland
	☒ Owner ☐ Consultant ☐ Contractor
Mailing Address :	2138 Flying Horse Club Drive
	Colorado Springs, CO 80921
Phone Number :	719-592-9333
FAX Number :	N/A
Email Address :	Lmoreland@classichomes.com

ENGINEER INFORMATION

Company :	Classic Consulting		
Name :	Marc A. Whorton, P.E.	Colorado P.E. Number :	37155
Mailing Address :	619 North Cascade Ave.		
	Colorado Springs, CO 80903		
Phone Number :	719-785-2802		
FAX Number :	N/A		
Email Address :	Mwhorton@classicconsulting.net		

OWNER, APPLICANT, AND ENGINEER DECLARATION

To the best of my knowledge, the information on this application and all additional or supplemental documentation is true, factual and complete. I am fully aware that any misrepresentation of any information on this application may be grounds for denial. I have familiarized myself with the rules, regulations and procedures with respect to preparing and filing this application. I also understand that an incorrect submittal will be cause to have the project removed from the agenda of the Planning Commission, Board of County Commissioners and/or Board of Adjustment or delay review until corrections are made, and that any approval of this application is based on the representations made in the application and may be revoked on any breach of representation or condition(s) of approval.

V.P. 10/26/2024

Signature of owner (or authorized representative) Date

Engineer's Seal, Signature And Date of Signature

COLORADO REGISTERED MARC ALAN WHORTON 37155 PROFESSIONAL ENGINEER

10/27/2026

PCD File No. _____

DEVIATION REQUEST (Attach diagrams, figures, and other documentation to clarify request)

A deviation from the standards of or in Section **6.3.3** of the Drainage Criteria Manual (DCM) is requested.

Identify the specific DCM standard which a deviation is requested:

Section 6.3.3 in the DCM – For storm drain velocities in excess of 18 ft/sec the engineer must demonstrate that the higher velocities will be acceptable by the pipe manufacturers to meet an equivalent design life of 50 years.

State the reason for the requested deviation:

This subdivision has areas of fairly steep terrain which causes the need for streets and utilities to also follow this steep terrain. As such, the storm design in some areas produce velocities in the storm pipe that exceed 18 ft/sec.

Explain the proposed alternative and compare to the ECM standards (May provide applicable regional or national standards used as basis):

The proposed storm design in specified areas that exceed velocities of 18 ft/sec call for installation of Class IV RCP. Also see attached correspondence from a local pipe manufacturer that supports min. 50-yr. service life even at proposed velocities.

PCD File No. _____

LIMITS OF CONSIDERATION
(At least one of the conditions listed below must be met for this deviation request to be considered.)

☐ The ECM standard is inapplicable to the particular situation.
☒ Topography, right-of-way, or other geographical conditions or impediments impose an undue hardship and an equivalent alternative that can accomplish the same design objective is available and does not compromise public safety or accessibility.
☐ A change to a standard is required to address a specific design or construction problem, and if not modified, the standard will impose an undue hardship on the applicant with little or no material benefit to the public.

Provide justification:

This subdivision has areas of fairly steep terrain which causes the need for streets and utilities to also follow this steep terrain. As such, the storm design in some areas produce velocities in the storm pipe that exceed 18 ft/sec.

CRITERIA FOR APPROVAL

Per ECM section 5.8.7 the request for a deviation may be considered if the request is **not based exclusively on financial considerations**. The deviation must not be detrimental to public safety or surrounding property. The applicant must include supporting information demonstrating compliance with **all of the following criteria**:

The deviation will achieve the intended result with a comparable or superior design and quality of improvement.

The proposed storm design using Class IV RCP meets all other design criteria and continues to provide the required safe HGL design.

The deviation will not adversely affect safety or operations.

The proposed pipe design remains in a standard location within an esmt. or public right-of-way and thus has no affect on safety or operations.

PCD File No. _____

The deviation will not adversely affect maintenance and its associated cost.

The proposed storm design has no significant bearing or adverse affects on maintenance/cost as the storm pipe sizing is the same and the pipe locations are the same. Thus, the maintenance and associated cost on this system is not adversely affected.

The deviation will not adversely affect aesthetic appearance.

The nature of this deviation relates to a buried storm pipe and thus has no affect on aesthetic appearance.

The deviation meets the design intent and purpose of the ECM standards.

The proposed deviation indeed meets the design intent and purpose of the ECM standards by providing a safe HGL design for the proposed storm system along with providing the min. 50-yr. pipe service life.

The deviation meets the control measure requirements of Part I.E.3 and Part I.E.4 of the County's MS4 permit, as applicable.

This deviation continues to provide a safe storm system design and thus meets the County's MS4 permit. The proposed design is a buried pipe system change and does not impact surface drainage or ponds. Thus, all El Paso County MS4 requirements on the surface (i.e. ponds, swales and other BMPs) are still being provided.

PCD File No. _____

REVIEW AND RECOMMENDATION:

Approved by the ECM Administrator
This request has been determined to have met the criteria for approval. A deviation from Section **6.3.3** of the ECM is hereby granted based on the justification provided.

Denied by the ECM Administrator
This request has been determined not to have met criteria for approval. A deviation from Section _____ of the ECM is hereby denied.

ECM ADMINISTRATOR COMMENTS/CONDITIONS:

PCD File No. _____

1.1. PURPOSE

The purpose of this resource is to provide a form for documenting the findings and decision by the ECM Administrator concerning a deviation request. The form is used to document the review and decision concerning a requested deviation. The request and decision concerning each deviation from a specific section of the ECM shall be recorded on a separate form.

1.2. BACKGROUND

A deviation is a critical aspect of the review process and needs to be documented to ensure that the deviations granted are applied to a specific development application in conformance with the criteria for approval and that the action is documented as such requests can point to potential needed revisions to the ECM.

1.3. APPLICABLE STATUTES AND REGULATIONS

Section 5.8 of the ECM establishes a mechanism whereby an engineering design standard can be modified when if strictly adhered to, would cause unnecessary hardship or unsafe design because of topographical or other conditions particular to the site, and that a departure may be made without destroying the intent of such provision.

1.4. APPLICABILITY

All provisions of the ECM are subject to deviation by the ECM Administrator provided that one of the following conditions is met:

- The ECM standard is inapplicable to a particular situation.
- Topography, right-of-way, or other geographical conditions or impediments impose an undue hardship on the applicant, and an equivalent alternative that can accomplish the same design objective is available and does not compromise public safety or accessibility.
- A change to a standard is required to address a specific design or construction problem, and if not modified, the standard will impose an undue hardship on the applicant with little or no material benefit to the public.

1.5. TECHNICAL GUIDANCE

The review shall ensure all criteria for approval are adequately considered and that justification for the deviation is properly documented.

1.6. LIMITS OF APPROVAL

Whether a request for deviation is approved as proposed or with conditions, the approval is for project-specific use and shall not constitute a precedent or general deviation from these Standards.

1.7. REVIEW FEES

A Deviation Review Fee shall be paid in full at the time of submission of a request for deviation. The fee for Deviation Review shall be as determined by resolution of the BoCC.

CLASSIC CONSULTING SM
619 N. Cascade Avenue, Suite 200
Colorado Springs, Colorado 80903
(719) 785-0790

LEGAL DESCRIPTION

A PARCEL OF LAND LOCATED IN THE SOUTHWEST QUARTER OF SECTION 27 AND THE NORTHWEST QUARTER OF SECTION 34, TOWNSHIP 12 SOUTH, RANGE 65 WEST OF THE SIXTH PRINCIPAL MERIDIAN, COUNTY OF EL PASO, STATE OF COLORADO MORE PARTICULARLY DESCRIBED AS FOLLOWS WITH **BEARINGS REFERENCED** TO THE EASTERLY RIGHT-OF-WAY LINE OF STERLING RANCH ROAD AS DEDICATED IN HOMESTEAD NORTH AT STERLING RANCH FILING NO. 1 RECORDED MAY 19, 2023 IN THE OFFICE OF THE EL PASO COUNTY CLERK AND RECORDER UNDER RECEPTION NUMBER 223715150 BEING MONUMENTED AT EACH END BY A NO. 5 REBAR AND 1-1/2" ALUMINUM CAP STAMPED "PLS JR ENG LS 38252" FOUND FLUSH WITH GRADE; DETERMINED FROM GPS OBSERVATIONS TO BEAR SOUTH 13°28'29" WEST A DISTANCE OF 1168.84 FEET.

COMMENCING AT THE NORTHERLY END OF SAID EASTERLY RIGHT-OF-WAY LINE OF STERLING RANCH ROAD, SAID LINE ALSO BEING THE EXTERIOR OF VILLAGES AT STERLING RANCH RECORDED JULY 23, 2025 UNDER RECEPTION NUMBER 225715552 OF SAID EL PASO COUNTY RECORDS;

THENCE ON SAID COMMON LINE THE FOLLOWING TWO COURSES:

1. THENCE NORTH 58°28'29" EAST A DISTANCE OF 49.50 FEET;

2. THENCE SOUTH 76°31'31" EAST A DISTANCE OF 9.99 FEET TO THE **POINT OF BEGINNING**;

THENCE ON SAID EASTERLY RIGHT-OF-WAY LINE OF STERLING RANCH ROAD AS DEDICATED IN HOMESTEAD AT STERLING RANCH FILING NO. 1 THE FOLLOWING FOUR COURSES:

3. THENCE NORTH 13°28'38" EAST A DISTANCE OF 130.00 FEET;

4. THENCE NORTH 76°31'31" WEST A DISTANCE OF 10.01 FEET;

5. THENCE NORTH 31°31'31" WEST A DISTANCE OF 49.48 FEET;

6. THENCE NORTH 13°28'29" EAST, ON SAID EASTERLY RIGHT-OF-WAY LINE AND ITS NORTHERLY EXTENSION, SAID EXTENSION ALSO BEING THE EASTERLY RIGHT-OF-WAY LINE OF STERLING RANCH ROAD AS DEDICATED IN STERLING RANCH EAST FILING NO. 8 RECORDED _____ ___, 202__ UNDER RECEPTION NUMBER _____ OF SAID EL PASO COUNTY RECORDS A DISTANCE OF 846.01 FEET;

THENCE NORTH 76°31'31" WEST, ON THE NORTHERLY LINE OF SAID STERLING RANCH EAST FILING NO. 8 A DISTANCE OF 80.00 FEET;

THENCE NORTH 13°28'29" EAST A DISTANCE OF 121.71 FEET TO A TANGENT CURVE, HAVING A RADIUS OF 850.00 FEET, WHOSE CENTER BEARS SOUTHEASTERLY;

THENCE NORTHEASTERLY, ON SAID CURVE, THROUGH A CENTRAL ANGLE OF 63°41'16", AN ARC DISTANCE OF 944.83 FEET;

THENCE NORTH 77°09'45" EAST A DISTANCE OF 229.23 FEET TO A TANGENT CURVE, HAVING A RADIUS OF 1,160.00 FEET, WHOSE CENTER BEARS NORTHWESTERLY;

THENCE EASTERLY, ON SAID CURVE, THROUGH A CENTRAL ANGLE OF 13°55'23", AN ARC DISTANCE OF 281.88 FEET;

THENCE ON A LINE NON-TANGENT TO SAID CURVE, SOUTH 26°45'38" EAST, A DISTANCE OF 80.00 FEET;

THENCE SOUTH 20°20'04" WEST A DISTANCE OF 57.73 FEET;

THENCE SOUTH 23°31'28" EAST A DISTANCE OF 68.18 FEET TO A TANGENT CURVE, HAVING A RADIUS OF 570.00 FEET, WHOSE CENTER BEARS NORTHEASTERLY;

THENCE SOUTHEASTERLY, ON SAID CURVE, THROUGH A CENTRAL ANGLE OF 36°28'32", AN ARC DISTANCE OF 362.87 FEET;

THENCE SOUTH 60°00'00" EAST A DISTANCE OF 295.92 FEET;

THENCE SOUTH 30°00'00" WEST A DISTANCE OF 146.68 FEET;

THENCE SOUTH 13°28'29" WEST A DISTANCE OF 1,264.46 FEET;

THENCE NORTH 76°31'31" WEST A DISTANCE OF 50.00 FEET;

THENCE SOUTH 13°28'29" WEST A DISTANCE OF 285.00 FEET TO THE NORTHERLY LINE OF AFORESAID VILLAGES AT STERLING RANCH;

THENCE NORTH 76°31'31" WEST, ON SAID NORTHERLY LINE, A DISTANCE OF 1,359.70 FEET TO THE **POINT OF BEGINNING**.

THE ABOVE DESCRIPTION PRODUCES AN AREA OF 2,722,474 SQUARE FEET (62.49940 ACRES).

ROBERT L. MEADOWS JR., PLS 34977
PREPARED FOR AND ON BEHALF OF
CLASSIC CONSULTING ENGINEERS AND SURVEYORS

Marc Whorton

From: Ryan Kempton <rek@kemptonconst.com>
Sent: Wednesday, July 23, 2025 9:46 AM
To: Marc Whorton
Cc: Austin Lenz; Loren Moreland
Subject: FW: [EXTERNAL] FW: RCP Pipe Spec. help
Attachments: Screenshot 2025-07-21 111251.pdf; CPInfo-Durability.pdf; velocity abrasion - RCP.pdf

Marc, see Rinker's response below. It also sounds like you can contact Brian directly if you need any thing else.

From: Brian Schram <Brian.Schram@Rinkerpipe.com>
Sent: Tuesday, July 22, 2025 4:25 PM
To: Ryan Kempton <rek@kemptonconst.com>
Cc: Jacob Kaul <Jacob.Kaul@RinkerPipe.com>
Subject: FW: [EXTERNAL] FW: RCP Pipe Spec. help

Ryan-
I've attached a couple of references from the American Concrete Pipe Association, but in both cases they suggest that velocities under 40 fps aren't normally a concern. If however, the engineers feels like there still is a concern (i.e. because of aggressive bed load in the storm water coupled with a high frequency of high velocity situations), we could look at providing higher strength concrete since that tends to add additional durability.

I hope this is helpful. I'm also available to speak with the engineer too if they'd like to give me a call.

Brian Schram, P.E.
Region Sales Manager
C 303-918-1628
9455 Boston Court
Henderson, CO 80640
RinkerPipe.com

Rinker MATERIALS® A QUIKRETE® COMPANY

From: Ryan Kempton <rek@kemptonconst.com>
Sent: Monday, July 21, 2025 12:15 PM
To: Jacob Kaul <jacob.kaul@rinkerpipe.com>
Subject: [EXTERNAL] FW: RCP Pipe Spec. help

CAUTION: This email originated from outside of the organization. Exercise caution when opening attachments or clicking links, especially from *UNKNOWN* senders.

cpinfo
American Concrete Pipe Association
Concrete Pipe Information

Precast Concrete Pipe Durability

Design methods for buried pipe are fairly well established, but durability, historically, has not been given proper consideration. Determining a project design life and the durability, or service life, of a pipe are considerations as significant as its hydraulic and structural functions. The definition of a durable pipe contains three variables that must be evaluated; required performance, pipe properties, and service conditions.

This C.P. Information reviews the significance of various physical and chemical factors which may be aggressive to concrete pipe; reviews the significance of pertinent service factors and concrete pipe properties, and durability design and performance of concrete pipe.

Introduction

Durability, or service life, of a pipe material is as equally important as its ability to perform intended structural and hydraulic functions. The capability of the pipe to continue to perform satisfactorily for an economically acceptable period is a fundamental engineering consideration. Unfortunately, predictions of durability cannot be made with the same degree of precision as can structural and hydraulic performance, consequently, durability is not accorded adequate consideration. Durability is concerned with life expectancy, or the endurance characteristics of a material or structure. Much research has been directed to the durability of some pipe materials, but the varying nature of climate, soils and geology, fluid impurities, construction materials, and the construction process itself have prevented the development of a systematic and practical theory for predicting performance.

The problem has been compounded by the assumed requirement that pipe must last almost indefinitely. The U.S. Bureau of Reclamation[1] defines a durable pipe as one that will withstand, to a satisfactory degree, the effects of service conditions to which it will be subjected. This definition contains three variables that must be evaluated; the pipe, the satisfactory degree of performance, and service conditions.

At the present time, there is no known material completely inert to chemical action and immune to physical deterioration. Concrete, under what might be considered normal exposure conditions, has a very long life.

Concrete pipelines have a history of excellent durability, and it is unlikely this record will change. Pipelines are beneath the ground where temperatures have very little variation, where atmospheric exposure is either not present or is greatly reduced, and where the materials in close proximity to the pipe may be non-aggressive. Laboratory test results, and damage records for cast-in-place concrete pavements and structures that have been exposed to atmospheric conditions, should not be related to buried precast concrete pipe unless it is determined that comparable conditions exist. Improper application of data could lead to over-design and excessive cost.

Aggressive Factors And Significance

The specific physical and chemical factors which can be aggressive to concrete pipe and which collectively account for practically all perceived durability concerns that could be encountered in traditional applications of the product include freeze-thaw and weathering, abrasion, acids, sulfates and chlorides. Conditions severe enough to result in actual durability problems for concrete pipe are, however, quite rare.

Freeze-Thaw/Weathering

Freeze-thaw damage is caused by water penetrating into the concrete and freezing, which generates expansion stresses and disrupts the concrete if it does not have sufficient strength to resist the expansion stresses. Severity of exposure is usually described by the frequency of freeze-thaw cycles. Atmospheric exposure usually accompanies freeze-thaw action, which complicates the situation. Thus, instead of a pure freeze-thaw situation, thermal stresses and evaporative surfaces with concentration effects and crystallization of ·various soluble salts in the pore structure could combine to provide an accelerated weathering effect.

Normally, concrete pipe is not exposed to this combined set of conditions. When it has been, however, its performance has been excellent, primarily due to the high density and quality of the concrete. If the pipe is not buried, weathering could be

serious enough in some areas to warrant sealing the surface with a barrier coating.

The high strength, low water-cement ratio concrete of precast concrete pipe inherently has excellent resistance to freeze-thaw forces.

Abrasion

Effluent velocity, by itself, does not create problems for concrete pipe within the ranges normally encountered. Below velocities of 40 feet per second, the severity of velocity-abrasion effects depends upon the characteristics of the bed load and the frequency of flows capable of moving the bed load through the pipe at abrasive velocities. Above velocities of 40 feet per second, cavitation effects can occur unless the wetted surface is smooth. Bed loads are usually more of an engineering flow problem than a question of pipe abrasion, particularly in a sanitary or storm sewer system, and can be controlled by proper design. Increasing the compressive strength of the concrete, and the specific hardness of the aggregates, increases abrasion resistance.

Acids

Acids will attack most materials. Acid attack of concrete is a surface attack, in which the acid is neutralized by the concrete alkalinity, so that without acid replenishment, the reaction stops. Continuous replenishment of acid with a pH below 5.0 is considered aggressive and below 4.0 is highly aggressive to buried concrete pipe.

Exterior acid attack, although chemically the same as an interior attack, involves a completely different environment. When an acidic soil or groundwater is encountered, its effect on concrete is governed by pH, total acidity, groundwater conditions, and backfill material. Total acidity is the amount of acid available to attack the pipe. As an example, a total acidity of 25 milligrams per gram of soil equivalent with a pH of five would indicate a potentially aggressive situation, and a comprehensive analysis of the site and countermeasures should be required. Such aggressive situations occur very rarely naturally, and are generally man-made, such as sanitary landfills and industrial waste disposal areas.



In an installation with no movement or slow movement of groundwater, the acid in contact with the concrete pipe will be neutralized and form a neutral zone which stops further corrosion. For installations with significant groundwater flow, limestone backfill has been successfully used as a neutralizing barrier to prevent corrosion of the concrete pipe; and, also, an impermeable backfill material, such as clay, has proven to be an economical and successful barrier which prevents flow from reaching the concrete pipe.

In the pipe interior, acid attack can occur from two sources. The first source is the hydrogen sulfide mechanism, which may occur in sanitary sewers. Under the right conditions, sewage can generate hydrogen sulfide gas which may be converted to sulfuric acid on the unsubmerged crown of the pipe. Several scientific breakthroughs now enable the generation of hydrogen sulfide to be controlled in existing sewers and predicted in new sewers; and, in new sewers, if the problem cannot be alleviated by proper system design, then the concrete pipe can be designed to be sufficiently resistant to acid attack so as to meet the required project service life.[2,3] Acid attack resulting from sulfuric acid generated by hydrogen sulfide gas in sewers is limited to the unsubmerged interior of the pipe, and is affected by a number of factors, including effluent properties and velocity, and total alkalinity of the pipe.[2,3]

Note: Confusion prevails regarding sulfates, sulfides and sulfuric acid. Potentially aggressive sulfates are the soil alkalies found in dry western areas. Sulfates must penetrate the concrete and be concentrated by evaporation to cause disruption. The use of Type II or Type V cement is recommended to make cast-in-place concrete more sulfate resistant. Sulfides in sewage do not attack concrete. Hydrogen

sulfide gas does not attack concrete, but it does attack iron, steel and other metals, and is toxic and flammable. Under favorable conditions, hydrogen sulfide gas is converted to sulfuric acid on the crown of the sewer pipe. Sulfuric acid attacks the surface of concrete, iron, steel and other materials. Type II and Type V cements do not make concrete more resistant to acid attack, although they are erroneously specified as such by some agencies and engineers.

The second source of interior acids is the effluent. Occasionally, an effluent can contain some acid. In culverts, mine acid drainage could be a problem; in sewers, acids can be dumped in from a variety of sources. An acidic effluent will attack most pipe materials, and the area of attack is limited to the pipe invert, or the submerged portion. In any case, in the United States, it is illegal to dump acid in a sewer or stream. Pretreatment is required and has successfully alleviated corrosion problems. Acid attack by acidic effluents is limited to the wetted perimeter, and is affected by pH, total acidity, effluent velocity, and total alkalinity of the pipe.

If acids are encountered, and cannot be alleviated by other countermeasures, for either interior or exterior acids, a precast concrete pipe can be produced with a higher total alkalinity, increased concrete cover, a barrier coating or lining, or any combination of these. Additionally, for exterior exposure only, the backfill material can be either of low permeability, so as to inhibit acid replenishment, or calcareous aggregate, so as to neutralize the acid. Table I summarizes evaluation procedures and possible countermeasures for interior and exterior acids. Neither Type II nor Type V cement will increase the resistance of concrete to acids.

Table 1: Acid Exposure Evaluation and Countermeasures

Exposure Condition	Evaluation Procedures	Countermeasures
Interior	• For potential biochemical problems in sanitary sewers, determine rate of acid development, if any • For acidic effluents, determine pH, including cyclic variations, as well as continuous or intermittent flow characteristics • Accurately determine pH and total acidity	• Increase total alkalinity by use of calcareous aggregates • Increase concrete cover as sacrificial concrete • Use barrier lining
Exterior	• Evaluate installation condition from the standpoint of the potential acid replenishment	• Increase total alkalinity by use of calcareous aggregates • Increase concrete cover as sacrificial concrete • Use low permeability clay backfill • Use calcareous backfill • Use barrier coating

Sulfates

Sulfate problems have been almost exclusively limited to exposed cast-in-place concrete structures located in arid areas of North America with alkali soils. The U.S. Bureau of Reclamation has wide experience in these areas, and has developed general criteria for evaluating sulfate environments. The Bureau states, however, it has not found any sulfate problems in buried precast concrete pipe.[1] The resistance of precast concrete pipe to sulfate attack is easily understood in view of the Bureau's guidelines for preventing sulfate attack in exposed cast-in-place concrete, and the mechanism of sulfate attack. Besides use of Type II or Type V cement, and fly ash, the Bureau indicates sulfate resistance is increased by accelerated curing, high cement content, and low absorption exactly the characteristics of precast concrete pipe.

Sodium, magnesium, and calcium sulfates in soil, groundwater, or effluent may be aggressive to concrete, if absorbed and concentrated by an evaporative surface in sufficient quantities within the concrete. The reaction of sulfates with certain concrete constituents results in expansive products which may disrupt the concrete. With respect to buried precast concrete pipe, sulfate problems are inhibited by a lack of the proper mechanism to concentrate· sulfates in the concrete, and further inhibited by the high strength, low absorption properties of precast concrete. Table 2 lists the relative severity of various sulfate soil and water conditions. Table 3 summarizes the exposure conditions which must be present for a sulfate problem to exist and some recommended countermeasures.

Chlorides

The most significant aggressive action of chlorides is corrosion of steel in reinforced concrete. Such problems are highly visible as damage to bridge decks resulting from use of de-icing chemicals. Maintenance problems have also been encountered with reinforced concrete seawater structures, such as pilings and piers, because of chloride-in-

Table 2: Degree of Sulfate Attack		
Relative Degree of Sulfate Attack	**Percent Water-Soluble Sulfate in Soil Samples**	**PPM Sulfate in Water Samples**
Negligible	0.00 to 0.10	0 to 150
Positive[1]	0.10 to 0.20	150 to 1,500
Severe[2]	0.20 to 2.00	1,500 to 10,000
Very Severe[3]	2.00 or more	10,000 or more

[1]Use Type II cement.
[2]Use Type V cement, or approved portland-pozzolan cement providing comparable sulfate resistance when used in concrete.
[3]Use Type V cement plus approved pozzolan which has been determined by tests to improve sulfate resistance when used in concrete with Type V cement.

duced corrosion of the reinforcement in tidal zones. Portland cement concrete protects embedded steel against corrosion under conditions that would be highly corrosive to bare steel.

Chloride ions disrupt the passivating action of concrete, which may allow corrosion of the reinforcement steel if oxygen is present. Research has established there is a critical chloride concentration at the concrete-steel interface required for corrosion to occur, and that oxygen must also be present to support corrosion. The factors needed to induce corrosion will more readily occur under the following conditions; low quality concrete of high permeability and porosity, cracks, and the inclusion of calcium chloride in the concrete mix.

A number of conditions can reduce the severity of chloride attack. Increased concrete cover will normally extend service life but will not prevent eventual corrosion under severe exposure conditions. High quality concrete with low permeability, and the absence of cracks and voids, will also extend the life of reinforced concrete under severe exposure conditions but will not prevent eventual corrosion if the mechanism of chloride build-up continues. Under extreme exposure conditions, the use of barrier type coatings is probably the most effective alternative.

Seawater has approximately 20,000 parts per million of chloride. Many concrete pipe installations are completely immersed in seawater and are performing satisfactorily after many years. This is primarily due to low oxygen solubility in high chloride waters plus the extremely low diffusion rate of oxygen through the saturated concrete cover.

As with sulfates, to cause corrosion, chlorides must be in solution, permeate the concrete, be concentrated, and, also, have a ready supply of oxygen. There are no reports nor evidence of any chloride induced corrosion problems with buried precast concrete pipe.

Again, this absence of problems is attributed to a lack of the proper mechanism to concentrate chlorides in concrete, a lack of oxygen, and the high strength, low absorption properties of precast concrete pipe.

Service Factors And Significance

There are a number of purely physical characteristics of the installation which directly and significantly influence the severity of exposure to potentially aggressive factors.

Table 3: Sulfate Exposure Conditions & Countermeasures

Exposure Conditions
- Sulfates must be in solution
- Hydrostatic gradient exists
- Evaporative surface to produce concentration effect exists

Countermeasures
- Reduce C3A content of cement
- Use accelerated curing
- Increase cement content
- Use pozzolans
- Decrease absorption

Hydrokinetics

With water at equal pressure on both sides of a pipe wall, the concrete eventually becomes saturated, stability is reached, and there is no water movement through the pipe wall. With a differential pressure, the hydraulic gradient causes movement of water through the wall, but direction of flow is highly significant. If the aggressive water were on the side of low pressure, the movement of non-aggressive water through the wall would tend to mitigate any aggressive attack. In any case, with no exposure to the atmosphere, there is no concentration effect. With an evaporative surface condition, water movement is due to either hydraulic gradient or capillary action, and there would be a concentration at or near the evaporative surface of whatever chemicals are in solution. These considerations are not relevant to acid environments, since acid attack is confined to the exposed surface. They are significant, however, in evaluating severity of sulfate or chloride exposures.

Full Atmospheric Exposure - Full atmospheric exposure of an installation can be a severe service condition for concrete pipe. Depending upon climate and location, the exterior of the pipe could be subjected to freeze-thaw cycles and thermal stresses, and chlorides in coastal tidewater areas.

Partial Burial - Partial burial can be a severe exposure condition. Only a partially evaporative surface is provided, but the concentration effect is more complex since the source of salts or sulfates may be either the effluent or moisture from the ground entering the pipe wall through capillary action and moving toward the evaporative surface.

Full Burial - Buried pipe usually is not exposed to freeze-thaw or thermal stresses, and concentration

effects are negligible. When installed above the water table, the hydraulic gradient within the pipe wall of a partially filled pipe is toward the outside, and directly opposite when below the water table. The former condition is more critical for high sulfate or chloride-containing effluents, while the latter is more critical for aggressive groundwater. If the pipe is located between the minimum and maximum groundwater elevations, the hydraulic gradients would reverse on a cyclical basis.

Replenishment

Certain installation characteristics have particular significance in relation to acidic groundwater exposure. The high alkalinity of concrete pipe will immediately neutralize acid that comes in contact with it, and the reaction will result in some loss of concrete surface. For this reaction to continue, there must be replenishment of the acid at the concrete surface. The rate of this replenishment at the external surface of the pipe depends upon the relative permeability of the backfill and bedding material in the pipe zone, the location of the pipe with respect to the water table, and to the fluctuation of the water table. These latter characteristics are categorized as essentially quiescent, moderately fluctuating, and grossly cyclic.

A tightly compacted clay around the pipe will create a relatively impermeable zone, minimizing the potential rate of replenishment. Conversely, a permeable zone around the pipe will not impede the free movement of groundwater and tends to maximize the replenishment potential. The least potential problem with either type of zone exists when the pipe is above the water table. The situation most conducive to replenishment is a permeable zone between the high and low water table, with grossly cyclic groundwater fluctuations, where both horizontal and vertical movement of groundwater can take place. A calcareous backfill, such as limestone, can provide a highly alkaline barrier around the pipe and neutralize the acid before it can contact the pipe wall.

Significance Of Concrete Pipe Properties

The properties of concrete pipe that may influence its durability are compressive strength, density, absorption, water-cementitious material ratio, cement content and type, aggregates, and total alkalinity. Reinforcement cover and admixtures, also, may influence the durability of concrete pipe.

Concrete Compressive Strength

Concrete compressive strengths are a function of available aggregates and cementitious material, mix design, inherent characteristics of the manufacturing process, and curing procedures. Higher strength usually means overall higher quality, i.e., greater abrasion resistance, lower permeability, and greater resistance to weathering and chemical attack. Minimum concrete compressive strengths of 4,000, 5,000, and 6,000 pounds per square inch are required by ASTM standards for precast concrete pipe. The strengths relate to structural, not durability, considerations and are required at time of delivery, usually a short period of time. The 28-day compressive strengths are much higher, often exceeding 8,000 pounds per square inch.

Density (unit weight)

Concrete density of pipe ranges from 135 to 165 pounds per cubic foot. The higher densities are achieved by greater consolidation of the concrete, higher specific gravity aggregates, or by a combination of the two. Higher densities attained exclusively through the use of aggregates with higher specific gravity are not necessarily indicative of an improved level of concrete durability.

Absorption

Absorption is an indicator of the concrete pore structure. The original application of the absorption test was in the early 1900's and for agricultural concrete drain tile, which was experiencing leaching action through the thin wall of this small diameter product. The absorption test proved to be an effective method for ensuring quality tile. Over the years, the absorption test has come to be erroneously considered by some engineers as a durability measure for impervious, thick wall concrete pipe.

Absorption by the cured concrete is influenced significantly by the absorption characteristics of the aggregates and the inherent characteristics of the manufacturing process. Hydration of the cement, which continues under the normally favorable installed pipe environment, further reduces the initial low absorption values for precast concrete pipe.

Water-Cementitious Material Ratio

Precast concrete pipe is produced with low water-cementitious material ratio concrete. The water-cementitious material ratio is so low for machine-made pipe that the concrete is said to have a negative slump, which means that water would have to be added before reaching a zero slump. Cast-in-place concrete mixes are designed with much higher water-cementitious material ratios, and placed with slumps ranging from two inches up to the maximum limited by size of the aggregate, resulting in relatively low strength concrete with excessive voids.

Cementitious Material

A high cementitious material content is normally used by precast concrete pipe manufacturers for a variety of reasons, but mainly because of manufacturing requirements. Other things being equal, increased cementitious material content leads to lower absorption,

higher compressive strength and increased resistance to weathering, freeze-thaw, and certain chemical environments. Higher cementitious material contents may also increase the probability of shrinkage cracking.

Cementitious Material Types

Both cement and fly ash are considered cementitious materials. Combinations of cementitious materials used in the manufacture of concrete pipe may be portland cement only, portland pozzolan cement only, or a combination of portland cement and fly ash wherein the proportion of fly ash is between 5 and 25 percent by weight of total cementitious material.



As specified in ASTM C150, Types I, II and V cements differ primarily in the allowable levels of tricalcium aluminate, C3A, content. C3A is the ingredient in cement which is principally involved in the disruptive expansion caused by sulfate reactions. Concrete made with lower C3A contents provides greater resistance to sulfate attack. Since cements are made from locally available materials, some Type I cements have less C3A than allowed by ASTM C 150 for Type V. Unless high sulfate resistance is required by the project specifications, or unless the type of cement is otherwise specified, concrete pipe is usually manufactured with Type I cement. Type II and Type V cements, and low C3A contents, do not increase resistance of concrete to acid attack. Type II and Type V cements may not be readily available in all areas.

Portland blast-furnace slag cement or portland-pozzolan cement used in the manufacture of concrete pipe must meet the requirements of ASTM C595. If Type IP portland-pozzolan cement is used, the pozzolan constituent must be flyash, which cannot exceed 25 percent by weight of the total portland-pozzolan content.

Fly ash used in the manufacture of concrete pipe must conform to ASTM C618, Class C or Class F.

Aggregates

Aggregates used in concrete pipe must meet the requirements of ASTM C 33, except for gradation. Gradation is established by the pipe manufacturer to provide compatibility with a particular manufacturing process, to achieve optimum concrete strength, and to control permeability. Other things being equal, harder and denser aggregates produce concrete with greater abrasion resistance. Aggregates that react with cement are rarely, if ever, a problem with precast concrete pipe. Aggregate sources are carefully tested and selected by the individual pipe manufacturer, and any problems would be clearly evident in pipe stockpiles.

Alkalinity

Total alkalinity of concrete has a greater influence on the ability of concrete to resist acid environments than any other property. All portland cement concrete is alkaline and will react with acid. Total alkalinity is a measure of the total reactivity of any given mass of concrete. Concrete with a total alkalinity of 40 percent will react with and neutralize twice the volume of any specific acid as would the same mass of concrete with a total alkalinity of 20 percent. Concrete pipe made with an aggregate which is nonreactive with acid, such as granite, will have a total alkalinity of 16 to 24 percent, depending upon cement content. Using calcareous aggregate, such as dolomite or limestone, can increase the total alkalinity to as much as 100 percent. Suitable sources of calcareous aggregates are not readily available in all geographical areas, and requiring their use could increase the cost of the pipe. All means of increasing durability for a specific aggressive environment should be evaluated by cost/benefit analyses.

Concrete Cover

Minimum concrete covers over the reinforcing steel are specified in ASTM standards. These minimum covers represent a balance between structural efficiency and durability. Assuming both structural adequacy and proper crack control, greater durability is provided against a variety of aggressive conditions by a thicker concrete cover. A modification of cover to increase durability, however, requires re-evaluation of the structural design of the pipe, and possible use of non-standard forms which could lead to increases in pipe costs.

Admixtures

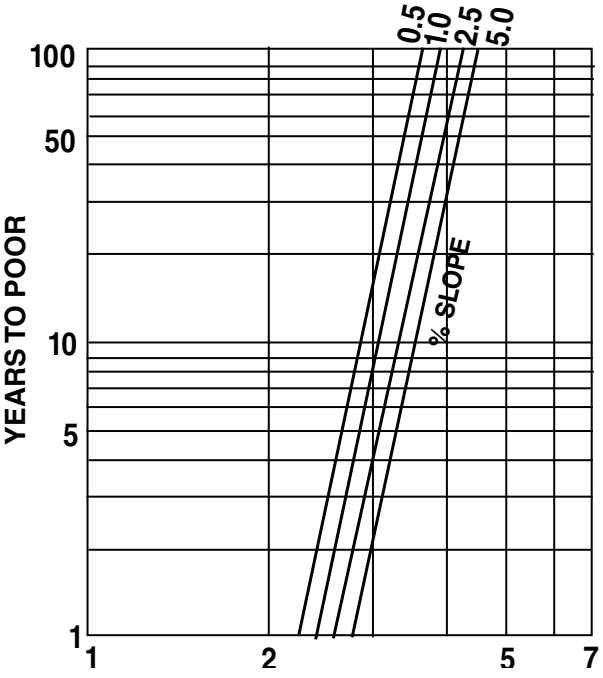
Admixtures sometimes used by concrete pipe manufacturers include calcium chloride, air entraining agents and water reducing agents. Air entrainment agents, which are normally used only in wet-cast pipe, increase freeze-thaw and weathering resistance. Water reducing agents are used to provide adequate workability with drier mixes. With the same cement content, water reducing agents can reduce absorption and increase compressive strength. Calcium chloride, while accelerating setting time, tends to reduce resistance to sulfate attack. Chlorides are also related to potential reinforcement corrosion. The use of admixtures should

be evaluated as to possible effects on durability performance.

Durability Design

Most aspects of buried pipeline design, from flow determination to loads to structural analysis, are very well established. The aspect of durability, however, is not as well understood by designers, and therefore, generally not given proper consideration. When bids are requested on alternate materials, a least cost analysis should be performed.[4] Any consideration of durability, and least cost analyses, must begin with definitions of the required project service life and the proven performance of pipe materials.

Figure 1: Concrete Pipe Culvert life



NCHRP Synthesis No. 50, "Durability of Drainage Pipe," defines service life by the number of years of relatively maintenance free performance, and states that a high level of maintenance may justify replacement before actual failure occurs.[5] As service life and project life guidelines, the synthesis states designers generally are looking for relatively maintenance-free culvert performance for at least 25 years in secondary road facilities; for 40 years or more in primary highway, urban transit, or rail facilities; and longer service life requirements for hard-to-place culverts in key urban locations or under high fills. The synthesis also states that a durability safety factor of at least two should be used to assure that the structure will definitely serve its required life span. Sewers are key facilities and constructed in urban areas where any installation replacement is costly in terms of both dollars and public inconvenience, and should be designed for a service life at least the same as required for pipe under high type road facilities.

The project design life is the length of time a specific roadway facility is expected to be in service. The project design life is normally set by the owner or authority responsible for the project. In cases where a roadway or facility cannot be disrupted for replacement of the pipe, a project design life of 100 years or greater should be considered. This is very typical of heavily traveled urban roadways, interstate highways, stormwater systems, sanitary sewers and installations under high fills or in remote areas with poor access. The selection of an appropriate project design life should reflect the transportation and commercial importance of the roadway, its effect on traffic, and the difficulty of replacement with inherent construction hazards to the traveling public.

Selection of a project design life must be made with care. Although the roadway may only serve for 50 years, the embankment usually remains in place and the movement of water through the embankment must be maintained indefinitely. The Missouri Department of Transportation acknowledged this in a durability report,[6] stating "Road beds and highway corridors are selected and designed with no foreseeable intent to relocate."

The present decaying infrastructure is indicative of the lack of consideration being given to project design life, material service life and maintenance costs, all key factors in least cost analyses of life cycle costs. Engineers have a duty to resist the false economies of selecting low project design lives, of using first cost analysis and of neglecting maintenance costs. Problems usually arise in rather short times because projects are designed so that initial costs are kept within the owner's construction budget, which generally produces very high post-construction maintenance costs. In this case, the client may hope to have sufficient capital later to pay higher operating and maintenance costs, he may hope to sell the project to someone or he may hope to turn the facilities over to someone else to maintain.

Concrete Pipe Performance

For all normal, everyday installations, the service life of concrete pipe is virtually unlimited. For example, some of the Roman Aqueducts are still in use after more than 2,000 years, and there is a buried concrete pipeline in Israel that was tentatively dated at 3,000 years old.[7] The first known concrete pipe sewer in North America was located, and five sections removed in September, 1982 for inspection and historical purposes.[8] Installed in Mohawk, New York in 1842, the six-inch precast concrete pipe was in excellent condition after 140 years of service.

A search for precast concrete pipe durability problems indicates very few problems exist, and consequently very few investigations have been conducted and published, other than on sulfides in sanitary sewers.[5,9]

By 1983, 28 states and numerous researchers had performed culvert surveys and investigated the durability of pipeline material since 1925, resulting in 131 reports. Since the durability of concrete pipe is so evident, and research money is normally spent only on problems, 63 percent of the reports are concerned primarily with the deterioration and short service life of corrugated metal pipe; 28 percent of the reports cover multiple pipe materials; and five percent of the reports deal with only concrete. An updated bibliography of these reports is presented in Buried Fact No.9, Bibliography - Pipe Material Durability.

In 1982, the Ohio Department of Transportation published a major report on the results of a ten-year study of more than 1,600 culverts in all areas of the state, which included 545 precast concrete pipe installations.[10] The environmental conditions in Ohio are relatively neutral, as are most areas of North America, and the soils and water do not posses any characteristics which would contribute to premature deterioration of pipe, except for a few areas with mine acid drainage problems. A look at the overall study indicates the excellent performance of concrete pipe. Of the 519 concrete culverts studied, only nine were rated in poor condition, 33 in fair condition and 477 in good to excellent condition. Of the nine in poor condition, one has been repaired, and repairs are contemplated for the other eight. An equation for predicting service life was developed for precast concrete pipe, which relates pH and pipe slope to the number of years for the pipe to reach a poor condition. With the equation plotted graphically, Figure 1, it is readily apparent that a concrete pipe placed on an average slope of 1-1/2 percent, and installed in an environment with a pH of 7, will take about 1,000 years to reach a poor condition; and, in an aggressive environment with a pH of 4, the concrete pipe will last 100 years, which is generally longer than required currently for sewers and high type road facilities. As a comparative example, the Ohio report predicts that 16 gage corrugated steel pipe in an environment with a pH of 7 will last 20 years, and, in an aggressive environment with a pH of 4, 16 gage corrugated steel pipe is predicted to have a service life of only 3.5 years.

Summary

Precast concrete pipe has served in an impressive fashion for well over 100 years, and has experienced very few problems. These problems have been identified, related to very specific environments, and adequate countermeasures developed to alleviate the problems.

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CONCRETE PIPE HANDBOOK

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A number of conditions can reduce the severity of chloride attack. Increased concrete cover will normally extend service life but will not prevent eventual corrosion under severe exposure conditions. High quality concrete with low permeability, and the absence of cracks and voids, will also extend the life of the pipe under severe exposure conditions but will not prevent eventual corrosion if the mechanism of chloride build-up continues. Under extreme exposure conditions, the use of barrier type protective coatings is probably the most effective alternative.

A very small precentage of concrete pipe is installed under conditions for which serious chloride build-up is probable. The American Concrete Pipe Association has not received any reports or evidence of chloride induced corrosion damage to reinforced concrete pipe.

FREEZE-THAW AND WEATHERING

Freeze-thaw damage is caused by water penetrating into concrete interstices and freezing, which generates stresses and disrupts the concrete if it does not have sufficient strength to resist these stresses. Severity of exposure is usually described by the frequency of freeze-thaw cycles. Atmospheric exposure usually accompanies freeze-thaw action, which complicates the situation. Thus, instead of a pure freeze-thaw situation, thermal stresses and evaporative surfaces with concentration effects and crystallization of various soluble salts in the pore structure could combine to provide an accelerated weathering effect.

Normally, concrete pipe is not exposed to this combined set of conditions. When it has been, however, its performance has been excellent, primarily due to the high quality of the concrete. In some circumstances, weathering exposure could be serious enough to require sealing the surface with a protective coating. Such circumstances are not common, but can occur.

VELOCITY-ABRASION

Although velocity-abrasion is a subject that has been discussed extensively, very few generally accepted conclusions have been reached. There have been very few field observations and these have provided only limited data. Invert erosion has been observed in some culverts, but it has often been a composite phenomena in which velocity-abrasion was augmented by corrosion from aggressive waters.

Velocity, by itself, does not create problems for concrete pipe within the ranges normally encountered. At velocities of 40 feet per second, or greater, cavitation effects can be serious unless the surface is smooth and internal offsets at joints are closely controlled. Within the range of velocities up to 40 feet per second, the severity of velocity-abrasion effects depends upon the characteristics of the bed load. A **bed load** is the quantity of solids being moved through the pipe by the flow velocity. Bed loads may be intermittent or continuous and vary in particle size, hardness and specific gravity. They are usually more of an engineering flow problem than a

question of pipe abrasion, particularly in a sanitary or storm sewer system, and can normally be controlled by proper design.

Particle size and density are usually smallest in sanitary sewers, larger in combined and storm sewers, and largest in culverts. Specific hardness of the particles is subject to wide variation and is quite significant, because if the particles are not as hard as the concrete, the particles will be abraded rather than the pipe. Increasing the compressive strength of the concrete along with an increase in the specific hardness of the aggregate used, increases abrasion resistance.

SIGNIFICANCE OF CRACKING

The principles of reinforced concrete design are based upon the accepted concept that cracking of the concrete is necessary to permit development of the full tensile strength of the reinforcing steel. With precast reinforced concrete pipe, it became possible to utilize this cracking characteristic as a criteria for nondestructive quality control testing. This led to the development of the three-edge bearing test and the adoption by ASTM in the early 1930's of the 0.01-inch crack test as a measurable and reproducible method for determining pipe strength. This particular crack width was arbitrarily proposed by Professor W. J. Schlick of Iowa State University because a leaf gage of that dimension was readily available.

There is no structural significance to a 0.01-inch crack. It is simply the test criterion assigned by ASTM standards for reinforced concrete pipe, and the 0.01-inch crack has no meaning as a criterion of structural performance in the field.

Certainly, however, the magnitude of permissible cracks is important from the standpoint of potential exposure to aggressive factors. The 0.01-inch crack came to be widely regarded as a conservative value for the maximum width that should be accepted as nondeleterious in exposed structures. That the criterion is conservative is demonstrated by more than 50 years of experience in the United States and Canada during which there have been no reports of deleterious corrosion of reinforcement in a concrete pipe due to the existence of cracks of 0.01 inch magnitude.

EVALUATION OF CRACKS

A complete evaluation of the significance of crack widths must consider the aggressiveness of the pipe environment, the depth of crack penetration, and the thickness of concrete cover over the reinforcement.

Sources of aggressive chemical attack on concrete pipe are surface related phenomena in every case except that of chlorides. Furthermore, in order for destructive reactions to continue, there must be replenishment of the aggressive solution. The geometry of cracks which do not