Technical Report Documentation Page

1. REPORT No.

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

The Corrosion of Corrugated Metal Culverts in California

5. REPORT DATE

January 1959

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

State of California
Department of Public Works
Division of Highways

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

13. TYPE OF REPORT & PERIOD COVERED

12. SPONSORING AGENCY NAME AND ADDRESS

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

A paper to be presented at the Annual Meeting of the Highway Research Board January 5-9, 1959.

16. ABSTRACT

The history of corrugated metal pipe design in California has been punctuated with predictions of service life varying from 10 years to 100 years. These predictions of the anticipated service life of such pipe as employed in highway drainage structures were not estimated without some foundation of "field experience". However, the results of inspecting approximately 7,000 metal culverts in a portion of northern California indicated that the previously estimated service life of 10 or 100 years would depend on (1) the fundamental factors of abrasion and corrosion and (2) the geographic location in which the "experience" was accumulated.

This survey of 7,000 culverts indicated that there were specific types of rust which accompanied accelerated or significant corrosion. However, the thickness or the type of rust formed on the culvert metal could not be used always as a criterion of the degree of corrosion because the corrosion products for a similar degree vary in relation to the geographic location. In specific locations, the type and thickness of the rust can be employed to indicate a general magnitude of metal corrosion, but such cannot constitute a general criterion.

In practice, rapid field inspection can be accomplished by striking the culvert with a geologist's pick and then estimating the remaining metal thickness from the penetration or rebound of the pick.

In coastal, and later other geographic locations, it was observed that accelerated corrosion was linked to the apparent presence of anaerobic bacteria in the watershed. The presence of the sulfate reducing type of anaerobic bacteria was indicated by the perception of hydrogen sulfide gas and the anaerobic, or moisture saturated condition of the soil.

17. KEYWORDS

18. No. OF PAGES:

60

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1959-1960/59-21.pdf

20. FILE NAME

59-21.pdf

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

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By

J. L. Beaton

and

R. F. Stratfull

59-21

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THE CORROSION OF CORRUGATED METAL CULVERTS IN CALIFORNIA

By

J. L. Beaton *

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SYNOPSIS

The history of corrugated metal pipe design in California has been punctuated with predictions of service life varying from 10 years to 100 years. These predictions of the anticipated service life of such pipe as employed in highway drainage structures were not estimated without some foundation of "field experience". However, the results of inspecting approximately 7,000 metal culverts in a portion of northern California indicated that the previously estimated service life of 10 or 100 years would depend on (1) the fundamental factors of abrasion and corrosion and (2) the geographic location in which the "experience" was accumulated.

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To be presented at the 38th Annual Meeting of the Highway Research Board, Washington, D. C. January 5 - 9, 1959.

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In coastal, and later other geographic locations, it was observed that accelerated corrosion was linked to the apparent presence of anaerobic bacteria in the watershed. The presence of the sulfate reducing type of anaerobic bacteria was indicated by the perception of hydrogen sulfide gas and the anaerobic, or moisture saturated condition of the soil.

A research program covering the causes of corrosion of metal culverts is continuing as it is economically prudent to develop laboratory and field tests to predict whether or not a specific location is favorable to an acceptable life service for metal culvert installations.

INTRODUCTION

In the northwest district of the California State Highway System (District I) there are more than 7,000 corrugated metal culverts utilized as highway drainage structures. Some of these culverts were placed more than 40 years ago. A large percentage of these have been in use in excess of 20 years. As a result of this lengthy installation period, a reasonable percentage of culverts is showing signs of distress due to corrosion of the metal.

By 1950 the number of metal culverts reported to be in critical condition appeared to be increasing beyond that considered to be normal. This was resulting in unanticipated expenditures. For instance, when one section of highway was selected to be widened, it was found necessary to spend an additional $30,000 to replace a failed metal culvert under the old section before the pipe could be extended under the new. As a result, an investigation of the condition of the metal culverts in this one highway district was undertaken in 1953 and completed in 1954 so as to prepare a systematic replacement program and also to locate those areas where accelerated corrosion was likely to occur.

Generally, where corrosion was evident, it was found that the culverts were attacked primarily in the invert. It also was apparent that the chemicals or soils in the watershed over which the runoff water flows are a predominant factor affecting the corrosion rate of the metal pipes. Because of the apparent influence of the watershed soils on the corrosion of the metal culverts, the work of Starkey and Wight (Reference 1) and Kulman (Reference 2) on the

corrosive effect of anaerobic bacteria was of special significance in this investigation.

While the scope of this investigation was limited to physical and visual tests, there is no doubt that the apparent presence of the sulfate reducing anaerobic bacteria, as indicated by the presence of hydrogen sulfide gas, is an important factor in the rate of culvert corrosion in this area.

In searching through the literature on the corrosion of metals (References 1 through 8) and the corrosion of metal culverts (References 9 through 13), it was apparent that the corrosion of metal culverts is a relatively unexplored field.

Because of the great variety of environments and the types and locations of attack which exist in the culverts in California, the inspection methods used by other investigators (References 9 through 13) were not sufficiently flexible to provide an objective set of data. For this reason a destructive type of test was devised to judge the amount of culvert metal lost by corrosion.

SURVEY METHODS EMPLOYED IN THIS STUDY OF CULVERT PIPES

In order to expedite this survey, which required work in the cramped and poorly accessible spaces peculiar to culvert studies, it was necessary to devise a quick, even though approximate, method of evaluating metal loss.

In estimating the relative metal loss of the culverts, the penetration or rebound of a geologist's pick striking the culvert was "transposed" in terms of percentage of original metal lost. The penetration or rebound from the blow of the pick was compared and "standardized" by comparing it to culvert metal of known thickness. After a short training period it was found that the survey personnel could obtain remarkable accuracy in determining the thickness of remaining culvert metal.

The ease and flexibility of this inspection method is clearly indicated by the time required for inspection and metal loss determinations of approximately 7,000 culverts. This survey was completed by a crew which averaged 3 men in 7 months of inspection time. It was not unusual to inspect 10 culverts per hour, even in mountainous terrain.

The inspection of culverts by striking the invert with a geologist's pick proved invaluable in determining the condition of culverts. For instance, culverts were observed with the invert rusted but with no visual perforations to indicate that the pipe was in other than relatively good condition. Yet, when the invert was struck with the geologist's pick, it was found that the invert of the pipe consisted of rust alone.

In some cases, especially in the same geographic locality, the appearance of a certain type or thickness of rust would indicate to some measure the condition of the pipe. However, the judgment of the condition of a culvert by the singular observation of rust or the lack of perforation would be misleading unless the inspector was an expert in correlating metal loss to the numerous types and thickness of rust.

It might also be mentioned that in the arid desert areas culverts were observed in which the spelter coating was apparently intact on the inside of the pipe, and the pipe would be judged to be in practically new condition. However, after testing the pipe with the geologist's pick, it would be found that the culvert had experienced considerable corrosion from the soil side of the pipe.

Other factors tabulated in the survey included: height of fill over the culvert, asphalt coating conditions, rust type, location and extent of metal deterioration, presence and origin of water, etc. A detailed explanation of the physical factors observed and a sample culvert inspection record sheet are included as Exhibits 1 through 6.

WATERSHED SOILS AND ACCELERATED CORROSION

In California there are areas where corrugated metal pipes have an economically long service life, and there are adjacent locations where the service life is short. An example of this variable service life of metal culverts is shown by Exhibit 7. This exhibit compares the service life of culverts installed in two distant sections of road, each approximately twelve miles in length. The corrosion rate of culverts in one of these areas is relatively rapid and variable, whereas the other is slow and consistent.

In judging the physical differences encountered in coastal areas where the culverts corrode at a relatively rapid rate and the inland areas where the culverts corrode at a slow rate, it was found that approximately 58% of the culverts in the coastal area carried year-round water flow as compared with only 2% in the inland location. This statistic within itself indicates that the presence of ground or surface water flow is a direct factor contributing to the accelerated corrosion of the culvert invert.

Although there were many cases where the presence of a continuous flow did not accompany an excessive corrosion rate, its presence does indicate a potentially corrosive location where additional protection of the galvanized culvert metal should be considered in the economic design of the structure.

The investigation of Starkey and Wight indicated that a soil which is non-aerated and which contains organic matter would support anaerobic bacteria. Also, their studies confirmed the fact that the corrosion rate of metal would be accelerated by anaerobic bacteria. An extreme example of this soil type would be a swamp

land. When this soil is disturbed, an odor of hydrogen sulfide may be perceived. The anaerobic bacteria form hydrogen sulfide. The hydrogen sulfide may be oxidized to form sulfurous and sulfuric acids, which are highly corrosive.

Since such bacteria are associated with organic reducing soils, a criterion was established in this survey that any soil which released perceptible quantities of hydrogen sulfide gas, when physically disturbed, was an organic reducing soil. The criteria used in this study to classify the watershed soils are described in Exhibit 3.

After observing 7,000 culverts, it was apparent that rainfall, abrasion, and invert silting would influence the rate of corrosion. However, it was also apparent that if a sufficient number of culverts were analyzed in a relatively large geographic area, the effect of the environment would evolve into a statistical mean and the influence of the watershed soils could then be determined.

Therefore, the service life of each culvert was plotted on a linear profile of the highway, and the geographic areas were defined by the corrosion rate of the culverts. A typical example of the type of plot used to define the geographic service life areas is shown in Exhibit 7.

After the service life of the culverts in each geographic area was determined, the distribution of watershed soil types was tabulated to ascertain the influence of soils to culvert corrosion.

When the soil types were classified and tabulated, it was found that 35% of the watersheds in the more corrosive geographic

areas contained organic reducing soils, whereas only 1% of the watersheds in the least corrosive areas involved soils of this type.

The predominate soil type found in the least corrosive geographic area was "inorganic oxidizing". Such inorganic oxidizing soils are defined as a soil containing less than 50% vegetation cover with the vegetation disintegrated by oxidation or by the process of drying.

Although the greatest number of organic reducing type soils were found in the coastal areas, it should be brought out that like soils have been observed throughout California. Observations indicated that any watershed soil, varying from clays to sands, could become an organic reducing type if the soil was continually saturated and sufficient vegetation or other organic matter was available to result in reducing conditions. Moisture saturation of the soil may occur when water is in a ponded condition or when the aeration of a heavy soil such as a clay is prevented by heavy vegetation or by the prolonged presence of moisture in the form of fog, rain, or seepage.

TABLE I

Percent of Total Culverts in each Soil Classification
Area Tabulated in Accordance to Service Life

Watershed Soil Type	Geographic Area Service Life		
	20 years or less	20 to 30 years	30 years or greater
Organic Reducing	33%	5%	1%
Organic Oxidizing	62%	54%	11%
Inorganic Oxidizing	5%	41%	88%
Number of Culverts	1820	2590	2590

As will be noted in Table I, the organic reducing and the organic oxidizing soils predominate in the more corrosive areas while the inorganic oxidizing soils predominate in the least corrosive area. Therefore, as indicated by this study, the presence of an organic reducing watershed would indicate a potentially corrosive location and an inorganic oxidizing watershed would indicate a non-corrosive site.

It may be that the organic reducing soils are more significant than indicated as there appears to be a definite probability that some of the soils classified as organic oxidizing may revert to organic reducing condition when the environmental conditions are favorable. For instance, during the winter rainfall in a certain

watershed reducing conditions may prevail, while in the relatively dry summer, oxidizing conditions may predominate in the same watershed. Such variable conditions are possible as evidenced by the work of Starkey and Wight. All soils were classified during the summer months of the year as high flow during the winter made inspections impossible.

An organic reducing soil as such may or may not indicate whether the watershed contains sulfate-reducing bacteria. These bacteria are generally recognized as Sporovibrio desulfuricans. In order to actually determine the presence of these bacteria, pathological studies are required. However, this was beyond the scope of this investigation.

DISCUSSION

As previously discussed, corrosion of metal culverts on the coastal sections of highway was rapid when compared to the inland sections of highway. As the corrosion rate of metal culverts in the coastal sections of highway is more marked than in the inland sections, the normal reaction of an investigator might be to judge the corrosion rate to be due to the effect of salt air. Unfortunately, this investigation did not formally evaluate the effect of salt air on the corrosion of metal culverts. However, chloride tests were performed on a few random water samples taken within a mile of the coast. The analysis indicated a range of 20 to 100 P.P.M. chlorides which corrosion-wise is not considered significant. Also, many observations confirmed the lack of corrosion on the projecting ends of coastal culverts, which were exposed for 20 years to a direct sea exposure. The lack of corrosion on the projecting ends of the culvert indicates that the salt air in itself plays a minor role in the corrosion of highway culverts. Evidence of invert corrosion indicates that the corrosion of a culvert in this coastal location is related primarily to the presence of moisture in the form of rain, fog, and ground water flow, and their resultant promotion of corrosive organic reducing watersheds.

Comparable rates of corrosion and similar corrosion products have been observed in culverts draining organic reducing watersheds in inland and coastal areas, which again indicates that salt air per se plays a minor role in the corrosion rate of culverts.

As will be noted in Exhibit 7, the corrosion rate of a number of culverts can be plotted for a highway section or a geo-

[illegible]

graphic area. A plot of this type can be utilized to designate the average or the economic service life of metal culverts to govern the selection of coatings or pipe materials for future installations in a designated area.

In the highway district in which this survey was performed, a corrosion area map was constructed which broadly defined the geographical areas in which a significant percentage of culverts failed in the following intervals of time: less than 20 years, 20 to 30 years, and greater than 30 years. This corrosion area map is in constant use by the Design and Maintenance departments and is used for the economic selection of coatings or pipe materials.

Since the causes of corrosion of metals were considered to be a complex phenomenon, a study was made of the literature of the factors which could affect the corrosion rate of culverts. Following this discussion is a resumé of the theory of corrosion and some of the pertinent factors which may influence the corrosion rate of culverts.

As there are factors other than flow and anaerobic bacteria which influence the corrosion rate of metal culverts, laboratory and field studies are in progress to develop a testing method to identify and predict a corrosive area.

A. Mechanism of Corrosion

There are many factors that affect the rate of corrosion of iron or steel in water. The corrosion of ferrous metal in substantially pure water and air can be chemically expressed as: $Fe+2H^{+} \gtrless Fe^{++}+2H$. It is common knowledge that two different metals can set up a galvanic corrosion cell. For example, when zinc and copper are immersed in an electrolyte

and electrically connected they will become anode and cathode respectively. When these two metals are electrically connected through a galvanometer, a current will be measured, and the zinc will disintegrate. In other words, a battery is formed. It is also true that differences in the electrolyte, such as chemical concentration or differential aeration, will cause anodic and cathodic areas to be set up on a single piece of metal.

By partly immersing specimens of plain carbon steel and also iron in water, and using three independent methods of measurements, Evans and Hoar (Reference 7) measured the quantity of electric current flowing between anodic and cathodic areas, and obtained a direct correlation between the current flowing and the weight of metal dissolved. Others, Brown and Mears (Reference 5), also Evans and Thornhill (Reference 8) obtained the same correlation between current quantity and weight of metal dissolved.

Similarly, the formation of anodic and cathodic areas on the same piece of metal are caused by non-uniformities which exist in all metals, or by non-homogeneous electrolytes.

As summarized by Speller (Reference 4), "It may now be regarded as established in substantially all cases of corrosion in the presence of water that the driving force of the corrosion reaction between metal and environment is electrochemical. The magnitude of this electrochemical potential, which varies with the environment and the metal, determines the tendency of the reaction to proceed, whereas the rate of

corrosion is determined mainly by the resistance to the continued progress of the reaction set up by certain of the corrosion by-products."

B. Pertinent Factors Influencing the Rate of Corrosion.

During the course of the culvert investigation a number of observations were made concerning factors affecting the rate of corrosion. Those factors considered to be of special significance were recorded. They were: evidence of extreme water hardness, which was indicated by a calcareous deposit in the culvert invert; rust formation, which was recorded as to its particular type, i.e., tubercle, flake, powder, etc.; and the evidence of hydrogen sulfide in the watershed soil.

The apparent influence of these significant factors on the accelerated corrosion of metal culverts is discussed in the following paragraphs:

1. Influence of Water Hardness.

> Water not saturated with calcium carbonate is likely to corrode a metal pipe, and water saturated with calcium carbonate is, in general, relatively harmless. (Reference 6).
>
> The water issuing from a chalk or limestone formation will usually, although not invariably, be in equilibrium with calcium carbonate, i.e., will be non-aggressive. However, with very soft water, particularly rain water and some mineral spring water, the attack on a metal pipe is likely to continue indefinitely.

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In areas of heavy rainfall, with a quick runoff over saturated ground containing calcium the likelihood of the water becoming saturated with calcium is small. However, if the rate of runoff is slow enough, the water will become saturated with calcium and tend to deposit a calcareous layer in the culvert. Conversely, if the runoff is rapid, any removal of a calcareous deposit in the culvert will depend on the relative frequency of water not saturated with calcium.

The majority of waters used for public supply purposes normally contain a considerable amount of calcium carbonate, which is kept in solution as calcium bi-carbonate through the presence of carbon dioxide. If the excess of carbon dioxide present is just sufficient to keep the calcium carbonate in solution, any incipient corrosion will produce a rise in the pH value at the cathodic regions and will consequently lead to the precipitation of calcium carbonate. This will divert the cathodic reaction elsewhere, so that after a time the whole interior surface of the pipe will have become covered with a layer of calcium carbonate.

In the presence of sufficient oxygen, this layer of calcium carbonate will interact with iron salts, forming under the calcium carbonate surface a clinging form of ferric oxide rust. For many

waters, this layer will be more protective when oxygen is present in large quantities, because the rust will then be formed very close to the metal.

2. Influence of Rust.

In natural waters the precipitated rust usually carries down some compounds containing lime, magnesia, and silica, together with other insoluble materials from the water. These substances have considerable influence on the structure and density of the rust coating on the metal surface. A loose, non-adherent coating under ordinary conditions, may accelerate the rate of corrosion; a uniformly dense and adherent coating may form an effective corrosion barrier and reduce the rate considerably.

3. Influence of Hydrogen Sulfide.

"Hydrogen sulfide when present in water makes the water acid and causes rapid corrosion, even in the absence of oxygen. It is mostly found in soils that contain anaerobic bacteria, in water contaminated with sewerage, or in mineral water. In the presence of oxygen, sulfuric acid may be formed as a reaction product." (Reference 1 and 4)).

SUMMARY

This study is based on a survey of the condition of 7,000 corrugated metal plate culverts located in one of the highway districts of the California Division of Highways and supplemented by spot checks throughout the state.

During this study, a geologist's pick was utilized as a form of a "hardness tester" to estimate the amount of culvert metal lost to corrosion. It has been found to be a rapid and practical tool for the inspection of metal culverts. This type of test was found to be more reliable than an observed evaluation of the condition of a culvert. It was not unusual to inspect 10 culverts per hour using a combination of observation and "geologist's pick testing".

The reason for a lack of correlation between observation and destructive testing of the culverts was that the presence of rust was found to be an unreliable indicator of degree of corrosion. Generally, in various geographic locations the only conditions under which a tested and an initially observed estimate of culvert deterioration closely agreed was when the culvert was entirely corroded, perforated or new.

The over-all results of this study indicate that the service life of individual culverts is highly variable, depending upon the environment; and that the presence of continuous (or nearly so) water flow indicates a potentially corrosive area.

Also, it was found that the service life of culverts decreased as the percentage of soils classified as organic reducing

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The over-all results of this study indicate that the service life of individual culverts is highly variable, depending upon the environment; and that the presence of continuous (or nearly so) water flow indicates a potentially corrosive area.

Also, it was found that the service life of culverts decreased as the percentage of soils classified as organic reducing and organic oxidizing increased. Conversely, when the number of watershed soils classified as inorganic oxidizing increased, the service life of the culverts increased.

A soil was not classified as an organic reducing type unless an odor of hydrogen sulfide could be perceived. Anaerobic bacteria (Sporovibrio desulfuricans) form hydrogen sulfide. Although laboratory tests were not performed to isolate and identify these organisms, it is felt that the environments identified as organic reducing could support anaerobic bacteria. Also, the physical characteristics of the watersheds identified as organic reducing in this study agreed with the physical characteristics of soils described by Starkey and Wight as those supporting anaerobic bacteria.

Since the purpose of this study was primarily to determine the condition of each culvert as fast as possible, no attempt was made to determine the exact material specification under which the coating, galvanizing, or base metal of the particular pipe was furnished. It is therefore evident that the value in studying corrosive factors of the metals involved lies in gross statistical evidence rather than specific findings.

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ACKNOWLEDGEMENTS

This investigation of the corrosion of metal culverts was conducted as one of the activities of the Materials and Research Department of the California Division of Highways.

The authors wish to express their sincere appreciation to F. N. Hveem, Materials and Research Engineer of the Materials and Research Department, for his invaluable advice and direction during this study. Also, to the personnel of the California Division of Highways and those of the Materials and Research Department who extended their aid and cooperation during this study and especially to members of the Maintenance Department of the Division's District I who gave unstintingly of their time in determining the ages of the unidentified culverts.

ACKNOWLEDGEMENTS

[illegible] investigation of the corrosion of metal culverts [illegible] of the activities of the Materials and [illegible] Department of the California Division of Highways.

The authors wish to express their sincere appreciation [illegible] Materials and Research Engineer for the Materials [illegible] for his invaluable advice and direction [illegible]. Also, to the personnel of the California [illegible] and those of the Materials and Research De[illegible] who extended their aid and cooperation during this study [illegible] to members of the Maintenance Department of the [illegible] District I who gave distinctly of their time in [illegible] the condemned culverts.

APPENDIX

Exhibit 1. Culvert Inspection Instructions

Exhibit 2. Culvert Inspection Instructions

Exhibit 3. Culvert Inspection Instructions

Exhibit 4. Culvert Inspection Terminology

Exhibit 5. Sample Culvert Inspection Record

Exhibit 6. Sample Culvert Inspection Record

Exhibit 7. Comparison of Culvert Corrosion Rates

CULVERT INSPECTION INSTRUCTIONS

The physical condition of a culvert is determined from the reaction or penetration of a prospector's pick to the metal surface and is described in % of original metal thickness lost.

The inspection report is to be filled out in such a manner that an engineer in the office can visualize the physical condition of a culvert in the field.

The following terminology is to be used on the inspection report to describe the varying culvert conditions:

INLET SECTION

Column	Abbreviation	Definition and Procedure
Type	Gal.	Galvanized C.M.P.
	A.D.	Asphalt dip C.M.P.
	A.B.	Asbestos bonded C.M.P.
	A.P.I.	Asphalt paved invert
	C.P.I.	Concrete paved invert
	R.C.P.	Reinforced concrete pipe
	P.C.P.	Plain concrete pipe
	R.C.B.	Reinforced concrete box
	P.C.B.	Plain concrete box
Installed 19___		The year the culvert was installed shall be inserted in this column.
	M.	Date of culvert installation not checked on plans. Installation date obtained from Maintenance foreman or other verbal source. Example: 25M - culvert installed in 1925, date obtained from maintenance forces.
Cond. Length		Designates the length in feet of culvert inspected visually or by test.
	A	Air
	W	Water
	V	Visual
		Example: A3 - the inlet or outlet section of the culvert projects 3' beyond the fill. The outside bottom section normally in contact with soil is in contact with air.
Silt Depth		Depth of silt designated in inches above the culvert invert.
Upstream ridge		The upstream face of a corrugation.

Column	Abbreviation	Definition and Procedure
	G	General
	P	Pit
	0 thru 10(x)	Describes metal loss in terms of % of original metal thickness. 1 = 10%, 2 = 20%, X = 100%
	0 thru 10(x)	Describes total area in %. 1 = 10%, 2 = 20%, X = 100%
		Example: 6P9 - 60% of the corrosion area has pits to a depth of 90% of the original metal thickness.
Splash	See upstream ridge	Area inside culvert where normal flow of water fluctuates or splashes most often.
Air		Designates corrosion area not in contact with soil or flowing water.
	O	Outside
	I	Inside
	0 thru 10(x)	1 = 10%, 2 = 20%, X = 100%
		Example: 01 designates that the outside section of culvert (section most likely to get direct sunlight) has lost 10% of its original metal thickness.
Soil		Designates the culvert section in contact with earth backfill.
Abrasion	0 thru 10(x)	1 = 10%, 5 = 50%, X = 100% A numeral in this column is the inspector's opinion of how much of the culvert metal loss is caused by abrasion.
Rust Type	Flake	Hard, adherent stratified rust flakes. Usually a black or a dark colored layer of rust adjacent to the metal surface.
	Fine powder	Relatively smooth to the touch, about the consistency of cement. Usually found with soil contact. Generally light in color.
	Coarse powder	Granular, relatively adherent. Usually found in atmospheric corrosion. Color varies from light to dark reddish brown.
	Tubercle	Generally are hard nodules of rust. Usually has a dark or black colored rust layer adjacent to metal surface. Usually found in areas subject to runoff water or sea water attack. Sometimes gelatinous in appearance. Indicates pitting of metal.

Column	Abbreviation	Definition or example
	W	Water
	H	Splash
	S	Soil
	A	Air
	O	Outside
	I	Inside
Asphalt Coating		Location of condition of asphalt coating is the same as rust type location.
Fill Shoulder		Height in feet from the crown of the culvert to the highway shoulder.
Metal Gage		This is the standard sheet metal thickness of the culvert steel.
Waterway		The adequacy of the waterway is determined by visual observation and/or statements by maintenance forces. If the roadway floods because the culvert is inadequate, designate the reason.
	W	Waterway
	S	Silt
	D	Debris
	P	Profile of road

EARTH TYPE

Organic	Watershed has more than 50% of land area covered by vegetation.
Inorganic	Watershed has less than 50% of land area covered by vegetation.
Reducing	Generally the soil is dark or mottled gray and black in color. Very often an odor similar to decomposing sewerage (H_2S) is perceived when moist soil is exposed a few inches below the surface.
Oxidizing	Land is well drained in an agricultural sense. Generally a light colored soil.

Examples:

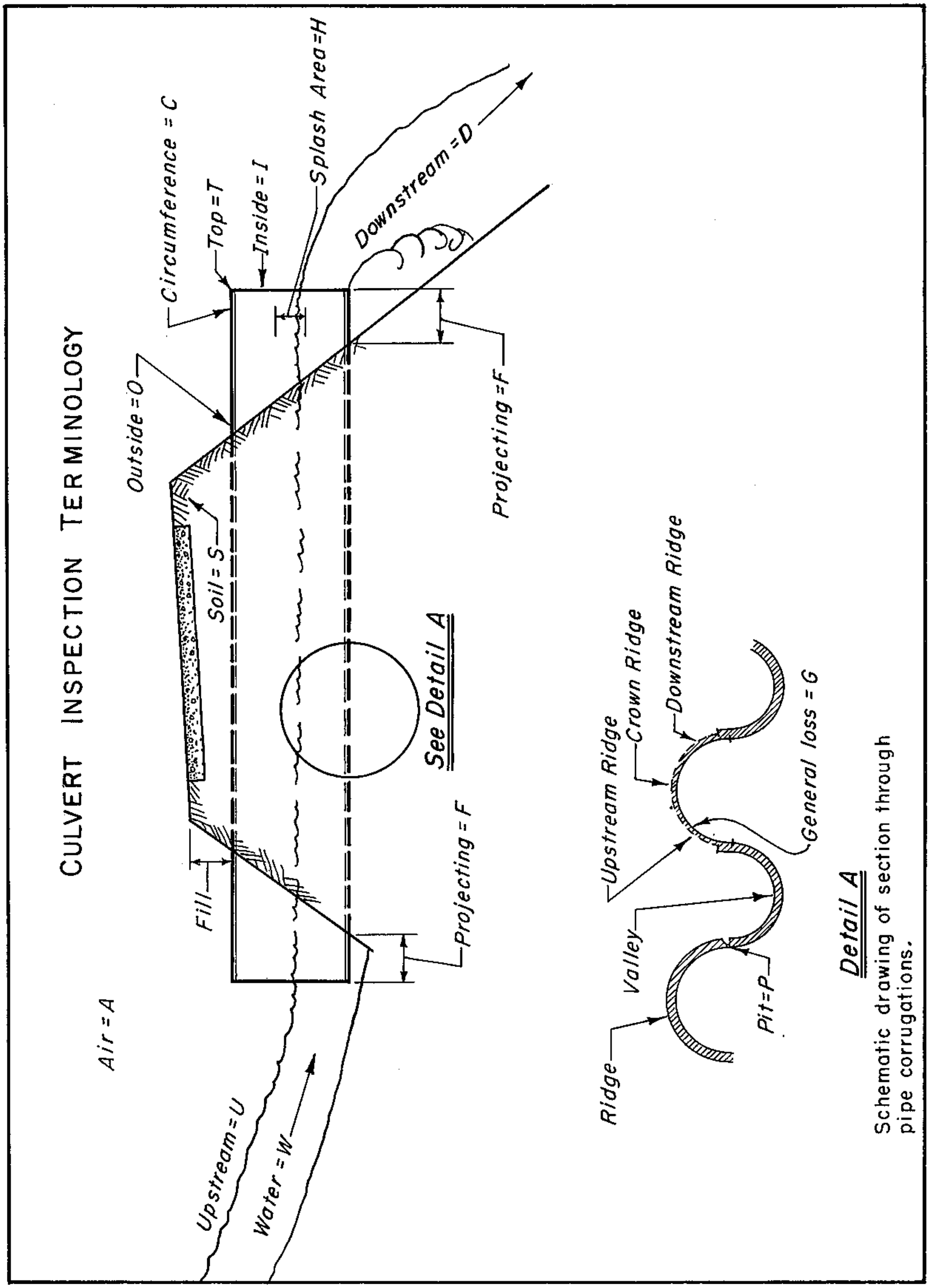
1. Inorganic Oxidizing: May be sand dunes or rocky watersheds with little topsoil or vegetation.

2. Organic Reducing: May be marshland or watersheds similar to those found on the coast. Odor of H_2S perceived.

A-85

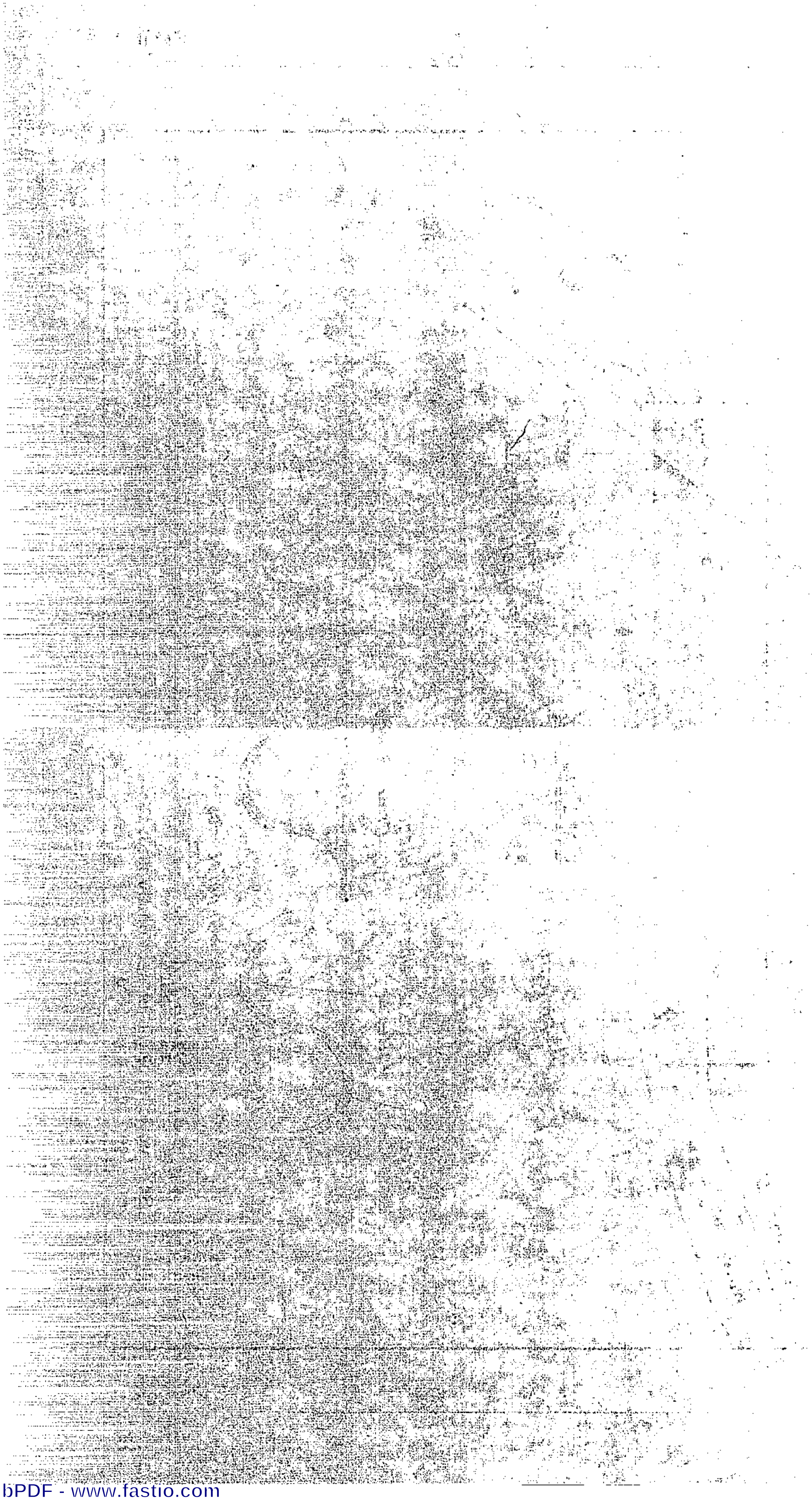
MCI - 1954

CULVERT INSPECTION TERMINOLOGY



Detail A

Schematic drawing of section through pipe corrugations.



STATE OF CALIFORNIA

MATERIALS AND RESEARCH DEPARTMENT
CULVERT INSPECTION RECORD

DIVISION OF HIGHWAYS

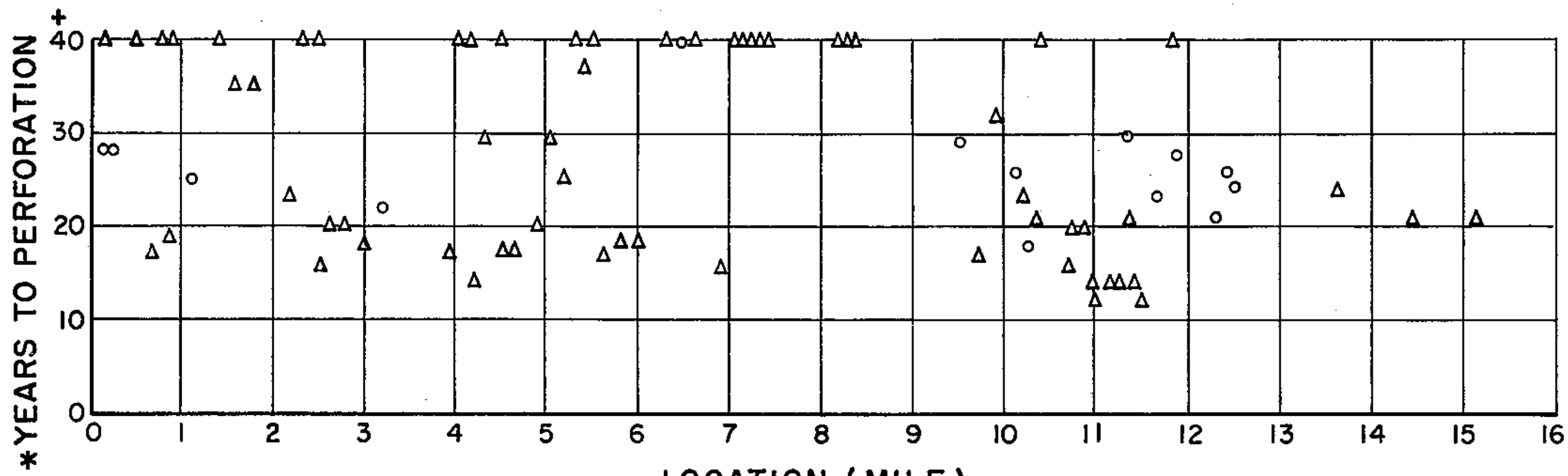
DIST. I CO. Hum RTE. 1 SEC. N INSPECTOR Smith DATE 5-5-54

			Existing Culvert – Inlet Section				Metal Loss – Water					Center Section				Metal Loss – Water					Outlet Section				Metal Loss – Water				
Mile	Station	Size & Length	Type	Installed 19__	Cond. Length	Silt Depth	UpStrm Ridge	Crown Ridge	DnStrm Ridge	Valley	Splash	Type	Installed 19__	Cond. Length	Silt Depth	UpStrm Ridge	Crown Ridge	DnStrm Ridge	Valley	Splash	Type	Installed 19__	Cond. Length	Silt Depth	UpStrm Ridge	Crown Ridge	DnStrm Ridge	Valley	Splash
	799+22	15" x 70'	Gal	25	8	0	G9	GX	G9	G9	-	Gal	25	V48	0	G9	GX	G9	G9	-	18" ADXT	35	14	0	G5	G5	G5	G5	-
	802+93	18" x 60'	Gal	25	6	0	G8	G7	G6	G6	-	Gal	25	V43	0	G8	G7	G6	G6	-	ADXT	35	1	4"	G5	G5	G5	G5	-
							3Px	3Px	6P7	4P9	-					3Px	3Px	6P9	4P9	-									
	803+00	12" x 40'	Gal	25	8	0	G6	G6	G7	G6	-	Gal	25	V25	0	G6	G6	G7	G6	-	Gal	25	2	6"	G4	G4	G4	G4	G7
							3Px	3Px	6P8	4P9	-					3Px	3Px	6P8	4P9	-					3Px	3Px	6P8	4P9	-
	921+85	18" x 70'	Gal	25	A3	0	G7	G7	G7	G7	-																		
							SP9	5P9	5P9	5P9	-																		
			Gal	25	3-6	0	G5	G5	G4	G4	-	Gal	25	V61	0	G5	G5	G4	G4	-	Gal	25	W3	0	G8	G8	G7	G9	-
							6Px	5P8	3P8	4P7	-					6Px	5P8	3P8	4P7	-					6Px	5Px	3Px	4Px	-
	922+50	24" x 60'	ADAPI	35	4	0	G0	G0	G0	G0	-	ADAPI	35	V52	0	G0	G0	G0	G0	-	ADAPI	35	4	0	G0	G0	G0	G0	-
	922+75	30" x 50'	Gal(CP)	25	10	0	GX	GX	GX	GX	GX	RCB	15	30	0						ADAPI	35	10	0	G0	G0	G0	G0	-

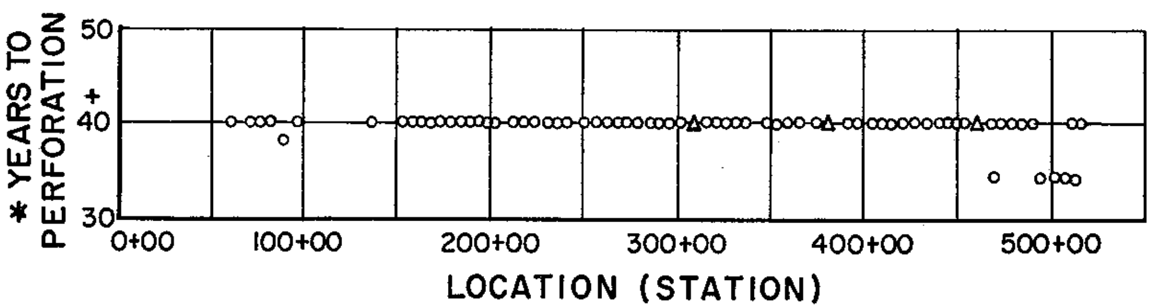
	Existing Culvert																							Previous Culvert		
	Metal Loss		Abrasion		Ground Water		Rust Type Location				Asphalt Coating				Fill Shldr			Earth Type				Water Way				
Mile Station	Air	Soil	Yes	No	Yes	No	Flake	Fine Pwdr	Coarse Pwdr	Tubercle	Excellent	Cracking	Chipping	Deteriorated	Inlet	Outlet	Metal Gauge	Organic	Inorganic	Oxidizing	Reducing	Adequate	Inadequate	Installed 19__	Type	REMARKS (Predominant cause of metal loss, etc)
799+32	9/10	2	2			✓	W	S	OA						8	12	16	✓		✓		✓				Air/Soil rated for galv.
799+32	GO	1	2				W	S			TA		OA	SW			16									" / " " " AD-XT
802+93	9/10	2	2			✓	W	S	OA	W					6	15	16	✓		✓		✓				" / " " " galv.
802+93	GO	1	2				W	S		W		TA	OA	SW			16									
803+00	9/10	2		✓		✓	WH	S	OA	W					1	3	16	✓		✓			D			
921+85	9/10	2		✓		✓	WS	S	OA	W					10	11	16	✓		✓		✓				
922+50	GO	1		✓	✓						W	TA	OA	S	15	17	14	✓		✓		✓				
922+75	9/10	2	5		✓		H	S	OA						20	30	12	✓		✓			W			Air/Soil rated for CPTXT
922+75	GO	1						S			W	TA	OA	S			12									" / " " " APT-XT

CULVERT CORROSION RATES

A Typical Comparison of Culvert Corrosion Rates Used for Corrosion Area Designation



HIGHWAY SECTION LOCATED IN AREA OF ORGANIC REDUCING WATERSHEDS



HIGHWAY SECTION LOCATED IN AREA OF INORGANIC OXIDIZING WATERSHEDS

NOTE:
No culvert with less than 10 years service plotted.

o = Galvanized C.M.P.

Δ = Asphalt Dip C.M.P.

* = Calculated from estimated metal loss at time of inspection.

+ = Culverts with calculated life in excess of 40 yrs. plotted on 40 year ordinate.