REPORT **MR 87-1**

STUDY OF USE, DURABILITY, AND COST OF CORRUGATED STEEL PIPE ON THE MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENTS HIGHWAY SYSTEM

MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENT

ABSTRACT

This study reviewed the Missouri Highway and Transportation Department's policy of culvert type selection, durability of culvert pipe, and costs of replacement or rehabilitation of corrugated metal pipe. A literature search, survey of adjoining States, and results of Department investigations and field trials are included.

Zinc-coated corrugated steel pipe (CSP) was found to be much less durable than reinforced concrete pipe (RCP). Current field reports indicate CSP is being replaced as early as 20 years of age due to rusting out of the lower portion of the flowline (invert).

It is recognized that CSP has a lower initial installed cost than RCP. However, CSP is expected to be replaced one to four times during the anticipated life of an RCP.

At this time, it is concluded that in order for CSP to be an equal alternate to RCP for culverts under roadways carrying high volumes of traffic, the pipe should have an expected life of at least 100 years.

Costs for culvert replacement were found to be increasing annually and becoming a major item in the Department's budget. In 1986, the Department's own personnel placed 37,583 linear feet of CSP at a cost of $968,890 and CSP were replaced or lined by contract on 94.653 miles of roadway at a cost of $450,094.

Various coatings for CSP were considered that extend the service life of CSP. However, no coating was found that extended the life and durability of CSP to the extent that it is comparable to RCP.

The Department is reviewing its policy on materials used for crossroad pipe culverts.

STUDY OF USE, DURABILITY, AND COST OF CORRUGATED STEEL PIPE ON THE MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENT'S HIGHWAY SYSTEM

STUDY NUMBER MR 87-1

Prepared By

MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENT

DIVISION OF MATERIALS AND RESEARCH

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INTRODUCTION

The Department's current policy for selection of type of culvert pipe to be used has been in effect for many years and is contained in Chapter IX, Section 9-10 of the Surveys and Plans Design Manual. A copy of that policy is shown in Appendix A. Briefly, the policy allows corrugated metal pipe for all entrances but restricts the use of corrugated metal pipe for crossroad installation to roadways with less than 400 ADT regardless of surface and roadways with more than 400 ADT that do not have a concrete or asphaltic concrete surface.

Corrugated metal pipe has only been permitted for culvert installations in those areas that when the need for replacement occurs, it is not detrimental to or does not seriously impede the flow of traffic. Examples are entrances, approaches and crossroad culverts on those facilities with lower traffic volumes and which do not have a high type pavement surface. On the remainder of the highway system, only those culvert materials which will give the greatest known life expectancy are permitted. For culverts and storm water conveyance, that material is concrete.

There were several reasons for the development of the current design policy. The first being to maintain the integrity of the facility. It was thought that if a culvert pipe had to be replaced under a high traffic volume roadway there would be an unacceptable disruption of traffic. Second, in many cases, the initial lanes of construction may ultimately serve as part of a multi-lane facility and the culvert pipe needs to have as long a life as possible. Third, when an existing highway facility is no longer needed by the Department it is normally relinquished to local governmental agencies such as counties or cities where it continues to serve for many years.

Due to the necessity for replacement of corrugated steel pipe by contract and due to the increasing quantity of corrugated steel pipe being purchased and installed by the Department's own forces this study was initiated to review the use, durability, and cost of zinc-coated corrugated steel pipe.

CONCLUSIONS AND RECOMMENDATIONS

It is apparent from the quantity of zinc-coated corrugated steel pipe (CSP) being replaced by the Department's own forces and the quantity being replaced by contract, that a major problem exists with the durability of CSP. In 1986, the Department's personnel placed 37,583 linear feet of CSP at a cost of $968,890. Also, the CSP were replaced or lined by contract on 94.653 miles of roadway at a cost of $450,094.

The Department's culvert type selection policy allows as much or more use of CSP as the adjoining States surveyed, except Kansas.

In Missouri, roadbeds and highway corridors are selected and designed with no foreseeable intent to relocate. At the present time, approximately 25 percent of the Department's roadbeds are already 50 years or older and 74 percent are over 25 years of age. Current field reports show that CSP is being replaced as early as 20 years of age due to rusting out of the lower portion of the flowline (invert).

Zinc-coated corrugated steel pipe is less durable than RCP with Missouri soils and drainage. The mode of failure is different for the two types of pipe. Failure of CSP is nearly always due to a material failure, rusting out of the invert. Failure of RCP is normally due to disjointed pipe sections, a mechanical failure.

It is recognized that CSP has a lower initial installed cost than RCP. However, CSP is expected to be replaced one to four times during the anticipated life of an RCP.

At this time, it is concluded that in order for CSP to be an equal alternate to RCP for culverts under roadways carrying high volumes of traffic, the pipe should have an expected life of at least 100 years.

Current coatings for corrugated steel pipe are all susceptible to degradation under certain conditions, particularly abrasion. Several types of coatings have been proposed for use and have been tested by the Department. The only coatings for steel pipe accepted, to date, are zinc and aluminized Type 2.

It is recommended that age and condition of replaced or rehabilitated CSP continue to be recorded, that cost data continue to be collected and analyzed and a State-wide culvert condition survey be performed.

It is further recommended the data collected be tabulated and reported for a Department review of policy concerning culvert materials used on the Highway System.

SCOPE

The proposed method of study was to review the Department's current design policy, determine the age of the roadbed of the Department's existing highway system, review the economics of concrete and corrugated steel pipe placed by contract, review some recent contracts that required lining or replacing the corrugated steel pipe, review the quantity and cost of corrugated steel pipe being purchased and placed by the Department's own forces, conduct a telephone survey of six adjoining states, and conduct a literature search of research pertaining to concrete and corrugated steel pipe.

Field data of corrugated steel pipe was obtained by District personnel and the Materials and Research Division's Field Office.

Quantities and cost were obtained from various Divisions within the Department.

DISCUSSION

Current Design Policy - The Department's current policy for selection of type of culvert pipe to be used has been in effect for many years. The policy allows corrugated metal pipe (CMP) under all entrances, under roadways with less than 400 average daily traffic (ADT) regardless of surface type, and under roadways with more than 400 ADT that do not have a portland cement concrete or asphaltic concrete surface. A copy of the Department's current design policy is contained in the Surveys and Plans Design Manual, Chapter IX, Section 9-10 and is shown in Appendix A.

The Department's design policy also requires that when Group I or II pipe is specified, the hydraulic design is to be based on CMP. Due to CMP having a higher roughness coefficient and lower full flow capacity than reinforced concrete pipe (RCP), basing the hydraulic design on CMP results in a larger diameter pipe than if the hydraulic design were based on RCP. The size, shape, and direction of corrugations, i.e., annular or helical, will also affect the coefficient of roughness. Coatings such as bituminous or polymer materials cannot be used to lower the coefficient of roughness for CMP because the coating will be lost first leaving the hydraulic condition controlled by the uncoated CMP.

Corrugated metal pipe in this report means zinc-coated corrugated steel pipe (CSP), aluminized Type 2 - coated corrugated steel pipe, or corrugated aluminum alloy pipe. Pipe is specified as Group I when corrugated metallic-coated steel pipe, RCP, or vitrified clay pipe is allowed. Pipe is specified as Group II when corrugated metallic-coated steel pipe, RCP, or aluminum alloy pipe is allowed. Zinc-coated corrugated steel pipe is almost always furnished when CMP is specified or when Group I or II pipe is allowed. Data in this report pertains to CSP and CMP will only be used when referring to policy or specifications.

Corrugated metal pipe is permitted only for culvert installations in those areas that when the need for replacement occurs, it is not considered to be detrimental to or does not seriously impede the flow of traffic. Examples are all entrances, approaches, and crossroad culverts on those facilities with lower traffic volumes and which do not have a high type pavement surface (portland cement concrete or asphaltic concrete). On the remainder of the highway system, only those culvert materials with the longest known life are permitted. For culverts and storm water conveyance, that material is portland cement concrete, at this time.

There were several reasons for current design policy. The first being to maintain the integrity of the facility. It was thought that if a culvert pipe had to be replaced under a high type pavement surface there would be an unacceptable disruption of traffic. Second, in many cases, the initial lanes of construction may eventually serve as part of a multi-lane facility and the culvert pipe needs to be made of a material with as long a known life as possible. Third, when an existing highway facility is no longer needed by the Department it is normally relinquished to local governmental agencies such as counties or cities where it continues to serve for many years. Fourth, in the case of abandonment, there may be need for the culvert to function indefinitely to prevent flooding of adjacent property.

Roadbed Life - The design life of a roadbed cannot be defined as a specific number of years and the roadbed life for a low traffic volume road is not necessarily less than that of an Interstate. Corridors for highways are selected with no foreseeable intention to relocate. There may be addition of lanes, straightening of curves and resurfacing but the roadbed and corridor remain essentially the same. Approximately 25 percent of the roadbeds in the Department's highway system are already 50 years or older and 74 percent are over 25 years in age.

Table I shows the age - mileage distribution of the roadbeds in the Department's current highway system as obtained from the 1986 Service Ratings. Figures 1 and 2 graphically display the same data. Information was not available on roadbeds turned over to cities or counties for their continued use.

Reinforced Concrete Culvert Pipe - This study was

TABLE I

ROADBEDS CONSTRUCTED YEAR SHOWN
OR EARLIER AND STILL IN SERVICE

	INTERSTATE		PRIMARY		SUPPLEMENTARY		TOTAL	
YEAR	MILES	PERCENT	MILES	PERCENT	MILES	PERCENT	MILES	PERCENT
1921			25.9	.3	86.2	.4	112.1	.3
1926			551.7	7.2	334.9	1.4	886.5	2.6
1931			1741.9	22.7	942.6	3.8	2684.5	7.8
1936	7.0	.3	3491.5	45.5	4967.1	20.2	8465.6	24.5
1941	7.6	.3	3977.3	51.9	7099.1	28.9	11084.0	32.1
1946	9.4	.4	4215.2	55.0	7517.1	30.6	11741.6	34.0
1951	46.8	2.0	4489.4	58.6	9944.7	40.5	14480.9	41.9
1956	285.7	12.3	4762.4	62.1	13972.0	56.8	19020.1	55.0
1961	652.1	28.2	5314.7	69.3	19432.1	79.1	25399.0	73.5
1966	1317.6	56.9	5913.7	77.1	22846.2	92.9	30077.5	87.0
1971	1703.1	73.6	6489.2	84.6	23822.3	96.9	32014.5	92.6
1976	2132.5	92.2	7121.8	92.9	24226.0	98.6	33480.3	96.9
1981	2215.3	95.7	7404.3	96.6	24418.2	99.3	34037.8	98.5
1986	2313.8	100.0	7667.3	100.0	24579.5	100.0	34560.5	100.0

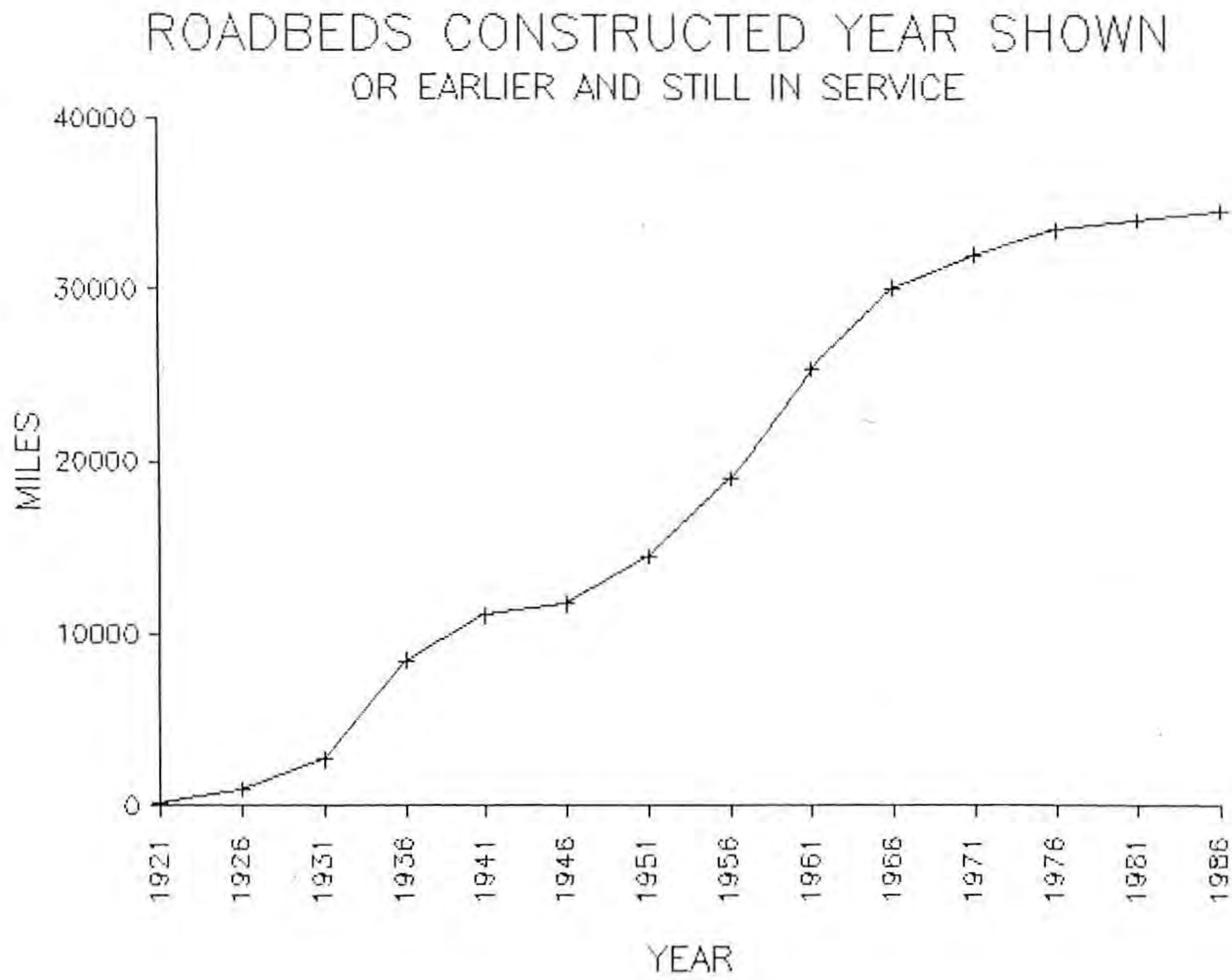
ROADBEDS CONSTRUCTED YEAR SHOWN
OR EARLIER AND STILL IN SERVICE
MILES
40000
30000
20000
10000
0
1921
1926
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
YEAR

FIGURE 1

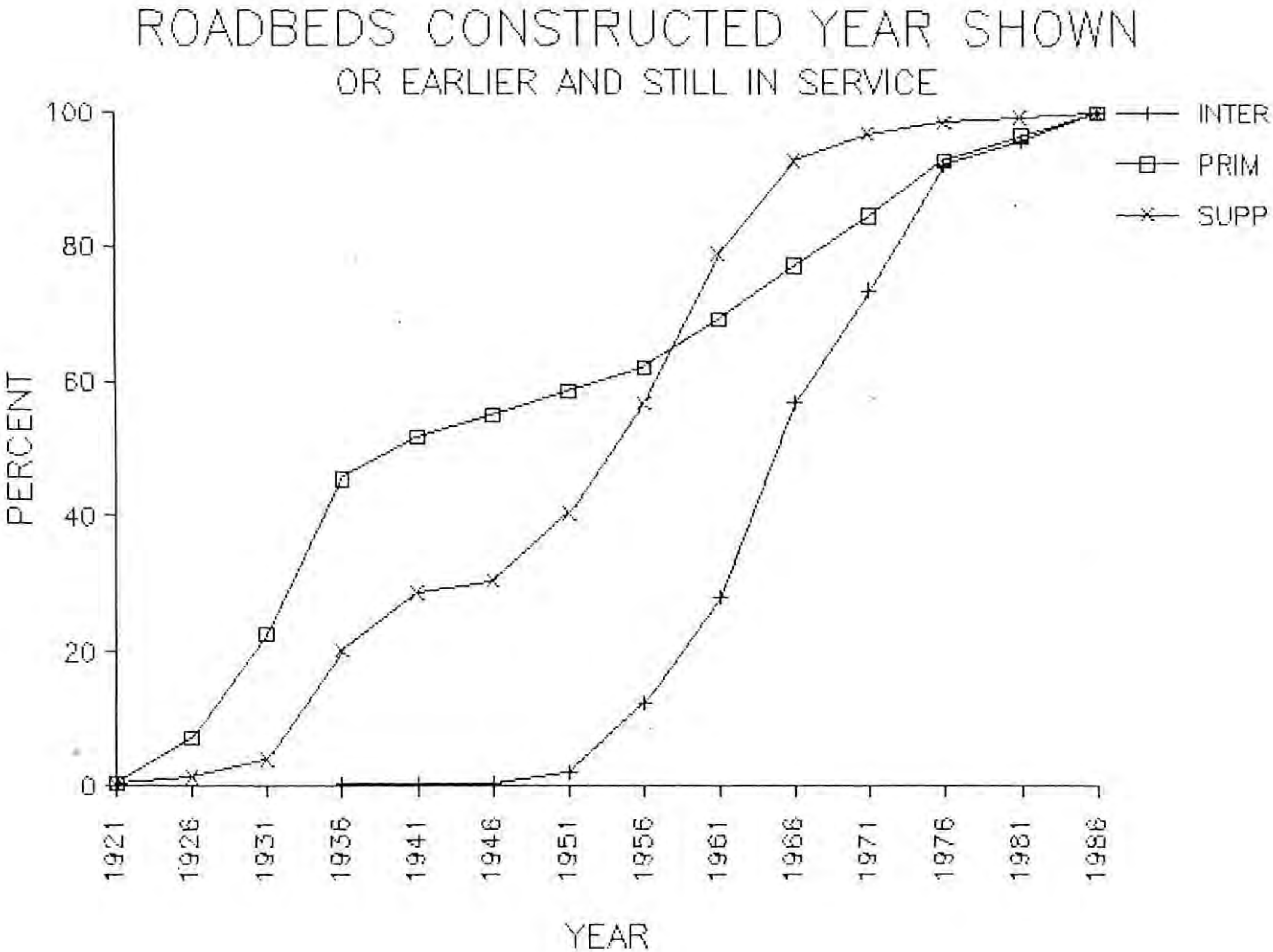
ROADBEDS CONSTRUCTED YEAR SHOWN
OR EARLIER AND STILL IN SERVICE
PERCENT
100
80
60
40
20
0
1921
1926
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
YEAR
INTER
PRIM
SUPP

FIGURE 2

initiated to review the use and cost of zinc-coated corrugated steel pipe. However, the economics and years of satisfactory service expected from culverts by the Department must necessarily include some reference to RCP as it is the standard against which all other culverts are currently measured.

Although they had been used since the mid 19th century as sanitary sewers, irrigation pipes, and storm sewers, RCP began to be used extensively as highway culverts with the great expansion of the nation's highway system, about 1915.

Specific chemical and physical factors which can be detrimental to concrete pipe are 1) acids, 2) sulfates, 3) chlorides, 4) freeze-thaw weathering, 5) abrasion, and 6) structural failure. Locations in Missouri where these conditions are severe enough to result in durability problems for RCP used as highway culverts are rare.

Missouri does have acidic flow (low pH) in some areas that over a long period of time does erode RCP. The degree of loss of service life is not yet known.

Sulfates, chlorides, and freeze-thaw weathering have not been detrimental to RCP culverts on the Department's highway system. Freeze-thaw action may be detrimental to the culvert as mentioned later in this section, however, it is not considered detrimental to the concrete material.

The abrasive action of aggregate particles over any material causes erosion. However, in RCP abrasive wear is minimal and is not a cause for concern on the Department's highway system.

Reinforced concrete pipe used as highway culverts in Missouri have not exhibited failure of the concrete material. Any RCP installation rated as failed has been due to disjointed pipe sections sometimes accompanied by faulting and infiltration or exfiltration. This may be caused by freeze-thaw action, high velocities at the outlet causing undercutting of the pipe, or differential fill settlement.

Proper compaction, modern day longer lengths of RCP sections, and end protection for the culvert have minimized failures. Installations on steep slopes or unstable soils may, in special cases, necessitate the pipe sections being mechanically tied together.

Research reports by some other State highway agencies indicate that RCP can be expected to have a service life in excess of 100 years. The Department's experience indicates a service life of 100+ years. Life predictions are typically based on material condition and age of the pipe at the time of inspection. Reinforced concrete pipe has been extensively used as a highway culvert for approximately 75 years and since there is generally very little material deterioration, the true life expectancy cannot yet be accurately predicted. However, there is every reason to believe that the useful life of RCP is much in excess of 100 years.

The Ohio Department of Transportation in its Culvert Durability Study, Report No. ODOT/L&D/82-1 dated January 1982, developed service life prediction curves for RCP based on pH of the flow and slope of the pipe. From Figure 30 of that report, an RCP on a one percent slope with a pH of 3.0 would have a service life of 80+ years. With a pH of 7.0 and slope of one percent, the service life would be expected to be almost indefinite (multiple hundreds of years).

In addition to having a long service life, RCP can generally be reclaimed and reused if location or size of an installation needs to be changed.

Mode of Failure of RCP and CSP - These two types of highway culvert are of totally dissimilar materials without a common characteristic except they are both designed to carry water from one point to another. It should be noted that the two types of culverts deteriorate and fail in different manners.

As already stated, RCP is affected by certain chemicals, freeze-thaw action, and physical or structural disjointing. In Missouri, under the Department's current design practices, RCP failures have been minimized. The service life of RCP may be shortened by the low pH of drainage in parts of the State but low pH is virtually the only environmental agent that affects RCP as a material.

Steel, as a material, and the coatings used for culvert pipe are attacked by water and a variety of other environmental agents. Corrugated steel pipe fails primarily by rusting through the lower flow line section of the pipe (invert). The protective coating over the steel is removed by water, abrasion, delamination, low or high pH drainage, or a variety of other reasons, allowing the base steel to be exposed. The steel then rusts and eventually is penetrated, nearly always in the invert. The causes and mechanics of steel corrosion are not addressed in this study.

Review of Economics - Unit bid prices for Group I, Group II, CMP and Class III RCP pipe installed by contract for each of the past five years, 1982 through 1986, were reviewed and a weighted average of the five years inclusive, was calculated for each size.

The five year weighted costs per linear foot for Class III RCP through 36 inch diameter are shown in Table II. The corresponding values for CSP are shown in Table III. Over 91 percent of all the Class III RCP and CSP installed by contract in the five year period were 36 inch diameter or less.

Costs of pipe over 36 inch diameter were not included in the tables because of the limited usage of those sizes. With small quantities, consideration of the actual installation conditions would greatly affect bid prices and those conditions were not available for this study.

TABLE II

5 YEAR WEIGHTED COST PER LINEAR FOOT FOR

CLASS III REINFORCED CONCRETE PIPE

Diameter (inches)	Linear Feet	Total Weighted Cost	Weighted Average Cost/Foot
12	91,648	$1,680,368.11	$18.34
15	81,648	$1,625,313.91	$19.91
18	105,759	$2,385,410.41	$22.56
21	12,353	$355,136.77	$28.75
24	58,054	$1,673,746.63	$28.83
27	2,928	$101,633.86	$34.71
30	33,815	$1,226,652.48	$36.28
33	16	$560.00	$35.00
36	31,772	$1,588,704.74	$50.00
Grand Total	417,993	$10,637,526.91	$25.45

NOTE: All original data obtained from 1982 through 1986 Unit Bid Prices issued by Missouri Highway and Transportation Department. Average low bid prices and annual quantity in linear feet were base figures.

TABLE III

5 YEAR WEIGHTED COST PER LINEAR FOOT FOR

CORRUGATED STEEL PIPE (GRP I, GRP II & C.M.P.)

Diameter (inches)	Linear Feet	Total Weighted Cost	Weighted Average Cost/Foot
12	21,632	$325,635.18	$15.05
15	56,283	$848,670.25	$15.08
18	61,041	$1,034,100.02	$16.94
21	2,970	$56,108.25	$18.89
24	24,065	$494,948.37	$20.57
27	0	0	0
30	9,468	$222,772.75	$23.53
33	0	0	0
36	8,703	$260,111.52	$29.89
Grand Total	184,162	$3,242,346.34	$17.61

NOTE: All original data obtained from 1982 through 1986 Unit Bid Prices issued by Missouri Highway and Transportation Department. Average low bid prices and annual quantity in linear feet were base figures.

The costs of the pipe are discussed here on a size basis even though they are not hydraulically equivalent.

As expected, the initial installed cost of CSP was less than Class III RCP in all sizes. In the sizes 12 through 36 inch diameter, the initial installed cost of CSP was 60 to 82 percent of the RCP with an average of 69 percent. A similar calculation of all Class III RCP and CSP placed by contract in 1986 showed a weighted average initial installed cost of CSP to be 78 percent of RCP.

Standard economic formulas may be used to attempt to equate the present worth of RCP and CSP. However, these formulas require bidding of both types of pipes for the same installation, hydraulically sizing each type of pipe, assuming a service life for each type of culvert for that location, and assuming an inflation factor and rate of return on money for the analysis period. This type of economic analysis could not be performed on the Department's culverts because 1) the life of CSP is too variable and would require a different analysis period for each installation, 2) where pipe are bid as alternates, the Department sizes the pipe on the basis of CSP which generally oversizes the RCP, and 3) selecting an inflation factor or interest rate is beyond the scope of this study.

Another problem with any economic prediction attempting to equate the two types of pipe is, it has to be assumed the Department would have the money and manpower to replace the culverts at time of failure. The Department neither loans nor borrows money, therefore, all expenditures are on a "pay as you go" basis. The current financial and manpower problems with replacement of CSP discussed elsewhere in this report highlight this problem.

Regardless of the manipulation of data or economic projections, the data previously collected by the Department and the data collected to date in 1987, shows clearly that CSP can be expected to be replaced from one to four times during the anticipated service life of RCP, which is at least 100 years.

The cost of repeated replacements cannot yet be estimated with any degree of accuracy. The cost of replacement of any pipe will be greater than the initial installed cost because replacement requires cutting the pavement surface, excavating the existing fill, and generally more traffic control. The height of existing fill above the culvert pipe and type of material in the fill directly impact the replacement costs.

The project discussed later in this report which was let only for the purpose of replacing CSP had a weighted cost per linear foot approximately three times that of CSP on projects where grading, paving, etc., are included. Those costs do not reflect the cost and inconvenience to the traveling public, the impaired roadway surface, and the increased safety hazards involved in culvert failure.

Replacement Or Rehabilitation By Contract - Many of the CSP and pipe arch (PA) installations are being replaced or lined with a polyethylene pipe as a part of a contract project. In 1986, five contracts for rehabilitation or replacement of CSP and PA were let. Four of these contracts totaling 75.613 miles of roadway were primarily to resurface the roadway. However, they included 14,253 linear feet of CSP and PA to be replaced or rehabilitated at an added cost of $365,897.80.

The fifth contract was let solely for the purpose of replacing 1,384 linear feet of CSP on 19.04 miles of roadway at a cost of $84,196.50.

No attempt has been made to identify or quantify contracts which only included replacement of a portion of the CSP or PA and contracts let prior to 1986 are not treated in this report.

There are currently at least 30 miles of roadway scheduled for contract letting including replacement or rehabilitation of CSP or PA.

Following is a brief description of the five contracts let in 1986 which typify the type of work that can be expected to increase in the future. The data is summarized in Table IV.

> Project 9-S-68-270, Route 68, Dent County was let to contract in January 1986. It was primarily a widening and resurfacing project. The original CSP were

TABLE IV

REPLACEMENT OR REHABILITATION BY CONTRACT

Route and County	Age of CSP or PA Lined or Replaced (yrs.)	Linear Feet of CSP or PA Lined or Replaced	Cost of Lining or Replacing CSP or PA ($)	Weighted Cost/Ft. of Lining or Replacing CSP or PA ($)	Total Cost of Lining or Replacing CSP or PA and End Sections ($)	Total Cost of Project ($)	Total CSP and PA Cost as Percent of Total Project (%)
68 Dent	52-54	2824	$ 53,549.50	$18.96	$ 63,371.50	$ 730,744.61	9
8 Crawford	49	1786	$ 32,490.00	$18.19	$ 49,140.00	$1,111,559.21	4
19 Gasconade	49-56	4809	$122,427.00	$25.46	$ 99,099.00	$2,102,088.46	5
142 Oregon	35-36	4834	$ 90,942.50	$18.81	$113,419.30	$ 925,133.63	12
T St. Charles	37-51	1384	$ 84,196.50	$60.84	$ 84,196.50	$ 84,196.50	100

badly deteriorated with a high percentage of the pipe having the invert totally rusted out. The original pipe could not be extended due to its condition and needed replacement. The CSP were originally installed on this project in 1932-34. Two crossroad CSP had been replaced prior to this project by the Department's Maintenance personnel.

This project was 9.633 miles long and required 2,824 linear feet of pipe. The 2,824 linear feet of CSP was placed at a cost of $53,549.50 or a weighted average cost of $18.96 per linear foot. Total cost of the pipe installation, including end sections, was $63,371.50.

In addition to the cost of total replacement by age 54 years, replacing the pipe created another problem. It is very difficult to recompact a cut trench without getting some settlement at a later date. Most of these installations have now settled and there is a depression in the roadway surface which is noticeable to the traveling public.

Project F-8-1(9) Secs A and B, Route 8, Crawford County was let to contract in June 1986. It was primarily a resurfacing project. The project was 16.596 miles long. The CSP were originally installed on this project in 1937. No record of maintenance replacement prior to 1986 was available.

This project required lining of 580 linear feet of CSP and replacement of 1,206 feet of CSP. Lining was performed by inserting a smooth wall polyethylene pipe into the deteriorated CSP. Lining of the 580 linear feet was completed at a cost of $10,282.00 or a weighted average cost of $17.73 per foot. The 1,206 linear feet of CSP was replaced at a cost of $22,208.00 or a weighted average cost of $18.41 per linear foot. Total cost of the pipe lining and pipe installation, including end sections, was $49,140.00

Lining of the crossroad pipe provided an alternative to closing the road to through traffic where high fill or other conditions made replacement difficult. However, the plastic lining reduces the opening in the pipe and can only be used where its hydraulic capacity is adequate.

Projects F-19-3(5) Secs A and B, F-19-2(9) Secs A and B, and RS-681(5), Route 19, Gasconade County were let to contract in November 1986. They were primarily resurfacing projects. These projects were 37.891 miles long. The CSP on these projects were originally installed between 1930-37. No record of replacement prior to 1986 by Maintenance was available.

These projects required lining of 1,675 linear feet of CSP at a cost of $40,868.00 or a weighted average cost of $24.40 per linear foot. It is interesting to note the bid prices for these projects, which is the second time polyethylene lining was specified, increased from $16.00 to $23.00 per foot for 14 inch diameter liner and from $22.00 to $34.00 per foot for 20 inch diameter liners. Bid prices from more projects would be required to establish the level of cost of polyethylene lining.

There was 3,134 linear feet of CSP replaced with CSP on these projects at a cost of $81,559.00 or a weighted average cost of $26.02 per linear foot. Total cost of the pipe installation, including end sections, was $99,099.00.

Project RS-BHS-1098(2) Secs A and B, Route 142, Oregon County was let to contract in November 1986. The project was primarily a resurfacing project. The project was 11.493 miles long.

The project required replacement of all the CSP and PA within the project limits. The CSP and PA were originally installed in 1950 and 1951.

There was 4,834 linear feet of CSP and PA replaced at a cost of $90,942.50 or a weighted average cost of $18.81 per linear foot. Total cost of the pipe installation, including end sections, was $113,419.30.

Project 6-S-T-787, Route T, St. Charles-Warren Counties was let to contract in July 1986. This project was let solely for the purpose of replacing

CSP. The project was 19.04 miles long.

The project required 1,384 linear feet of pipe at a cost of $29,544.00 for the CSP and placement. However, the total cost of the project including mobilization, repair of the pavement, etc., have to be included in the CSP cost since the project was solely for replacement of CSP. The total cost of the project was $84,196.50 or a weighted average cost per linear foot for the CSP of $60.84.

Replacement Or Rehabilitation By Maintenance Personnel- Maintenance of CSP is increasing in frequency and cost. The CSP deteriorates at variable rates, however, the large quantity of CSP placed between 1930 and 1965 have deteriorated to the point where they are now requiring replacement by Maintenance personnel or by contract.

Table V shows the linear feet of CSP actually replaced by Maintenance personnel in 1984, 1985, and 1986 along with the total cost and cost per linear foot. This table shows a dramatic increase in maintenance replacement of CSP at an increasing unit cost. The annual cost of CSP replaced by the Department's own forces has increased from approximately $400,000 in 1984 to approximately $1,000,000 in 1986.

Actual usage figures were only available for the past three years, however, quantities purchased by the Department were available for the past five years and are shown in Figure 3. This figure also shows an increasing quantity of

TABLE V

CORRUGATED STEEL PIPE USED BY MAINTENANCE

Year	Linear Feet of CSP Used	Price Per Linear Foot	Total Cost
1984	16,902	$23.33	$394,324
1985	21,889	$23.74	$519,645
1986	37,583	$25.78	$968,890

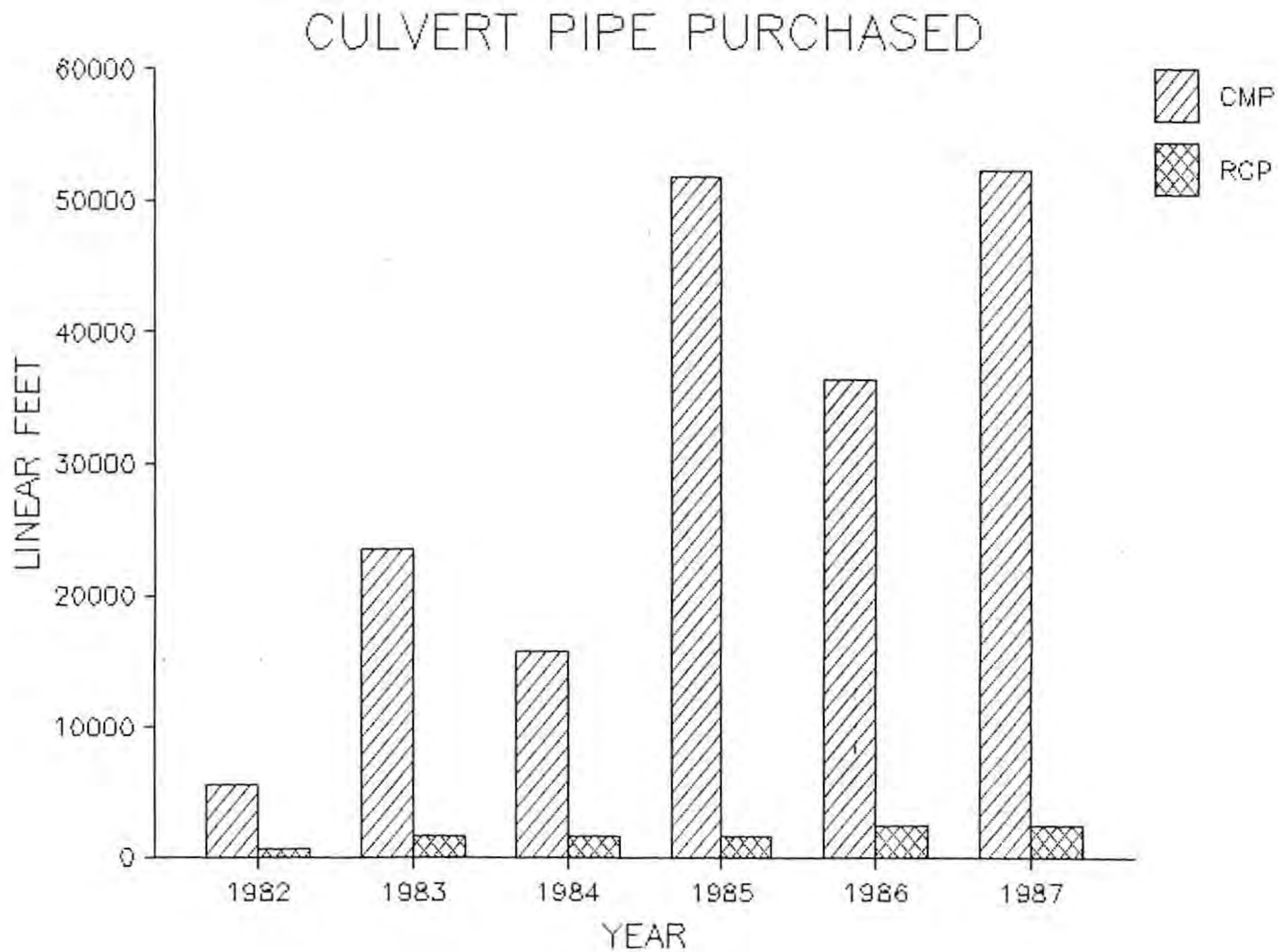
CULVERT PIPE PURCHASED
LINEAR FEET
60000
50000
40000
30000
20000
10000
0
1982
1983
1984
1985
1986
1987
YEAR
CMP
RCP

FIGURE 3

CSP being purchased. A small, fairly constant quantity of RCP is purchased each year.

The Department purchases and places approximately 1,500 linear feet of RCP per year. Most of the RCP is being used in District 7 to replace CSP that has failed due to acidic drainage conditions.

In addition to the replacement of CSP, it is common practice in some maintenance areas to rehabilitate CSP by placing concrete in the invert where the metal has rusted out. No cost data or number of pipe rehabilitated in this manner are available at this time.

Culvert Replacement Survey - In January of 1987, the Division of Materials and Research, as a result of rising concerns about culvert age and condition at the time of replacement, requested that the Districts gather and provide certain information on crossroad pipe being replaced either by Maintenance or by contract. The purpose of the survey is to establish the condition and age of the culverts replaced. The location, route, county, size and year of installation are recorded and the information received from January 1, 1987 through May 12, 1987, is attached as Appendix E.

An analysis of the information reveals that during this period, based on 515 reports from Districts 1, 3, 4, 5, 6, 8, 9 and 10, the newest CSP replaced was 20 years of age and the oldest was 59 years with an average age of 46.6 years. The data also indicates the CSP being replaced have partial or totally missing inverts. It does not reveal at what age the inverts rusted out. This survey is an ongoing project and information is still being compiled.

This survey also does not reveal the pipe with missing inverts that are not immediately scheduled for replacement due to availability of money and manpower. One District reports it has a large percentage of CSP that have the inverts missing but are not being replaced until the workload and financial condition allow.

Research - As a portion of this report, a literature search was performed. A list of the publications reviewed is attached as Appendix F. Some quotes from selected publications are attached as Appendix G. To briefly summarize the results of these reports as one author states in a 1984 report, "...it can be anticipated that with proper care the primary and Interstate roadways could well be in service 100 years from now." Durability problems exist with all protective coatings now commonly used on CSP and no nationally acceptable relationship between culvert service life and corrosion parameters has been developed.

Most researchers give a life expectancy of 100+ years to reinforced concrete pipe. The Department's experiences indicate a life expectancy of 100+ years for RCP. Loosening and faulting of end joints was the primary type of failure.

Zinc-coated corrugated steel pipe has been around a long time and has been the subject of many studies to determine why it fails and to try to predict life expectancy in different environments. Zinc-coated steel is affected by water, low pH, low electrical resistivity of soils, anaerobic bacteria, abrasive material, chlorides, sulfates, and many other factors. Predictions of life expectancy are generally based on only part of the environmental factors and therefore the predictive procedures should be considered local in nature. For instance, California uses pH and electrical resistivity to predict life expectancy. This method of trying to predict expected life has been the subject of several States' research and at least in the reports reviewed, the States have not been able to make the California method correlate with actual experience. The pH and electrical resistivity are important factors in setting the stage for corrosion but are not the only factors and in some cases are not considered significant. Wisconsin found bacteria to be a contributing factor in corrosion in 31 percent of the study sites. Maine and Ohio found little, if any, correlation between electric resistivity and actual condition. Utah found that approximately 14 pH tests were necessary in the field to obtain the true pH value within ± 1/2 unit. They also found the Department of Agriculture iso maps to not be accurate enough to use. They recommended pH be a lab test, not a field test. Neither California or Wisconsin gave weight to abrasion which is considered a major factor by New York.

Coatings - The Department has checked various types of coatings over the years in an attempt to find a coating that would increase the life expectancy of a corrugated steel pipe to a point where it would approach that of RCP. To obtain faster results, pipes with various coatings have been placed in an area in District 7 known to have an acidic runoff and in areas in Districts 8 and 9 with abrasive type runoff.

The following discussion of various pipe coatings is a general summary of Department observation and research performed by others. In general, all the coatings have a durability problem when exposed to abrasion.

Epoxy Coated Corrugated Steel Pipe: Epoxy coatings are affected by direct sunlight. The Department tested epoxy coated CSP in an area with severe exposure (pH 3.0 ± 0.3). The acidic test section was abandoned as a failure after five years of exposure. The invert was approximately one-half gone and the top inside coating was brittle and blistered with the deterioration beginning at the cut edges of the individual sheets and at areas where exposed to direct sunlight.

Bituminous Coated and Bituminous Coated and Paved CSP: Bituminous coated pipe is reported as subject to poor adhesion, abrasion, and salts. Life expectancy of the coating ranges from 0 to 7 years. Bituminous coated and paved is subject to the same problems as bituminous coated but if the paving extends far enough around the pipe more life is gained - eight years according to Maine, at 30 years according to New York 100 percent would have failed, and Ohio gave a median life of 10+ years for paving that was overtopped by flow. Kansas DOT has reported only 12 percent of inside bituminous coatings were good in three and seven year old pipe.

The Department's investigation in 1965 concluded that plain bituminous coating added two years of life and coating and paving added about five years. The use of bituminous coating or paving was discontinued by the Department.

Asbestos Bonded Bituminous Coated and Paved Pipe: This pipe was reported by Ohio DOT to be performing satisfactorily after 12 years. This coating appears to be the best of the coatings reported on CSP. It is susceptible to abrasion and high salt concentrations. No prediction of service life was made in these reports.

Missouri has a test installation of this type pipe placed in 1974 in an acidic drainage area. The latest inspection in December of 1986 shows the exterior coating is deteriorating to the extent that small pieces are loose enough to be pulled up from the asbestos. The asbestos is now starting to debond from the pipe. Within four years after installation, the bituminous coating was severely cracked, both inside and out, with the cracks varying in width from minute to 1/8 inch or more. The invert itself is apparently starting to rust at the edges where a slight amount of debonding has occurred. The small amount of debonding is apparently the result of abrasion or mechanical damage. Asbestos bonded coating is no longer available due to environmental controls.

Polymer Coated Corrugated Metal Pipe: New York DOT reported polymer coatings as particularly susceptible to abrasive flow. Polymer coatings are immune to acidic flow and when the coating is not broken or penetrated it offers protection to the CSP. It is reported that problems due to delamination during fabrication still exist. No estimates of service life were made.

The Department has one polymer test installation in a non-abrasive, acidic drainage. It is a riveted pipe and at age six months all rivets were gone from the invert and approximately 1/8 inch of the exposed inlet edge of the metal sheet was gone. Delamination started at that point. After 15 years the deterioration has advanced and metal loss and delamination increases with each annual inspection. Current fabricating practice would probably be a lock seam pipe to protect against exposed rivets and cut edges.

Aluminum Coated Corrugated Steel Pipe: In 1952, several aluminum coated culverts were installed, evaluated and reported in 1981 with results as follows:

"Overall performance of pipe culverts is based on small sample size and test data having wide variability which may have contributed to inconsistent findings. However, statistical analyses of measured and subjected data as obtained from 28 year old pipe indicated overall performance of aluminum coated corrugated steel pipe culverts was equal to or better than zinc-coated corrugated steel pipe culverts."

The Department has accepted this pipe as equal to zinc-coated steel.

Aluminum-Zinc Alloy Coated Pipe: Bethlehem Steel reports based on laboratory tests and limited field installations, state this coating is equal to or better than zinc galvanizing. The coating is a mixture of approximately 55 percent aluminum and 45 percent zinc and appears to have the same problems as zinc-coated pipe. No prediction of service life was reported.

Missouri has not yet had this coating proposed for test or use.

Survey Of Most Adjoining States - A telephone survey of six of the adjoining States was made to ascertain what policy for culvert type selection, culvert design life, and roadbed design life is being used by those States. The survey form as completed by the telephone solicitor for each of the States is shown in Appendix H. A summary of the responses of each of the states, Arkansas, Illinois, Iowa, Kansas, Nebraska and Oklahoma, is as follows:

Arkansas requires concrete for all crossroad drainage structures under all interstate and primary routes and allows an alternate of concrete and steel under secondary routes, side roads, and entrances. They do not have a set number of years as design life expectancy for either the roadbed or drainage structures. They have trial installations of polymer coated steel and corrugated polyethylene pipe. The FHWA in Arkansas has told them polymer coated steel pipe is not an equal alternate to concrete.

Illinois requires concrete for all crossroad drainage structures under high type pavement. They allow an alternate of concrete or corrugated metal under entrances, minor side roads and low type pavements. They consider a roadbed design life to be at least 50 years.

Iowa requires concrete for all crossroad drainage structures under interstate and primary routes. Secondary roads are a county responsibility and the counties generally follow Iowa DOT specifications and procedures. Iowa allows an alternate of concrete or corrugated steel under all entrances and secondary side roads. They do not have a set number of years as design life expectancy for either the roadbed or culverts.

Kansas allows concrete and corrugated metal as equal alternates for all drainage except only concrete is specified for six counties in Southeast Kansas, locations where water stands in the culvert, or where continuous flow is expected. They do not have a set number of years for design life expectancy for either the roadbed or drainage structures. Kansas found bituminous coated pipe to have no significant benefit.

Nebraska requires concrete for all crossroad drainage structures under interstate routes, all concrete pavements, and all asphaltic concrete pavements with a 20 year projected traffic of 800 ADT or greater. Asphaltic concrete pavements in the "sand hills" may have either concrete or steel pipe regardless of traffic. Alternate materials are allowed on entrances. They do not have a set number of years as design life expectancy for either the roadbed or culverts.

Oklahoma requires concrete for all crossroad drainage structures. They allow either concrete or corrugated metal for entrances. Oklahoma does not have a set number of years as design life expectancy for either the roadbed or culverts. In special environments, they may allow bituminous coated or polymer coated steel pipe for entrances but not as crossroad.

Only one of the adjoining States, Illinois, has a design life for the roadbed which one could assume would also apply to drainage structures. Kansas allows corrugated metal to be used as crossroad drainage in more situations than the other States. As stated by Nebraska in relation to their "sand hills," corrosion of steel is not a problem in granular well drained soils where corrosive drainage is not present.

APPENDIX A

DESIGN POLICY

SECTION 9-10 NON-HYDRAULIC ASPECTS OF DRAINAGE DESIGN

9-10.1 GENERAL. Drainage structures are located and designed to adequately handle runoff across improvements and to handle runoff from the improvement. The location of culverts is covered in Chapter IV of this Manual. The hydraulic design of culverts and other drainage facilities is discussed in preceding sections. In this section criteria pertaining to the selection of culvert and storm sewer material and appurtenances are presented.

9-10.2 TYPES. Permissible culvert types are concrete box, reinforced concrete pipe, vitrified clay pipe, corrugated metal pipe, corrugated aluminum alloy pipe, and corrugated metal pipe-arch. In general, there are two methods of specifying the permissible culvert types dependent upon the design traffic and the surface type. The first method is to specify one particular culvert type and the second method is to specify a group of culvert types as described in succeeding sections. The final selection of the structure type is based on requirements in the Standard Specifications, on good engineering judgment, and economy with consideration of service and maintenance costs.

(1) ROADWAYS WITH LESS THAN 400 ADT AND ENTRANCES. Permissible types of culverts acceptable for use under all roadways with less than 400 ADT and all entrances regardless of traffic or pavement surface type are concrete box, reinforced concrete pipe, corrugated metal pipe, corrugated aluminum alloy pipe, and corrugated metal pipe-arch. Concrete box structures are considered for structures larger than 60 inches in diameter. The most economical structure type may be used. Corrugated metal pipe arch structures in sizes B-5 and larger are used where necessary because of limited allowable structure height. The Type B-1 through B-4 corrugated metal pipe arch is not acceptable. A battery of round pipe or single elliptical reinforced concrete pipe may be considered in lieu of B-1 through B-4 corrugated metal pipe arch. Twelve- and fifteen-inch pipes are not used for crossroad culverts, except where the use of an 18-inch pipe will create an unsightly or impracticable drainage condition. Beveled ends are specified for corrugated metal pipes larger than 48-inch diameter. Corrugated metal pipe-arches are not beveled. In general, the bevel should not be flatter than 2:1 nor should the skew exceed 15 degrees. If these controls are exceeded, special consideration is given to the use of headwalls, riprap, or slope pavement to stiffen the structure against uneven loading from the embankment and the dynamic forces of the water. Proposed designs for these conditions are submitted to the Main Office for approval.

In general, full circle pipes are specified on the plans by "Groups". These groups give the contractor the permissive option of furnishing any one or a combination of the pipe types within the specified group. One group of pipe (Group II) is provided for crossroad culverts for roads with design ADT of less than 400 and for side drainage such as under entrances regardless of the traffic. Concrete pipe is used for locations where high acidity or alkalinity of soils or waters or other corrosive elements are present. The permissive pipe types in Group II are (1) reinforced concrete, (2) corrugated metal, (3) corrugated aluminum alloy. When Group II pipe is specified hydraulic design computations should be based on corrugated metal pipe. In special cases as described in a subsequent section where one pipe type has a peculiar advantage over other pipe types, the particular pipe type may be specified in lieu of specifying groups.

(2) ROADWAYS WITH 400 OR MORE ADT WITH SURFACE TYPE OTHER THAN ASPHALTIC CONCRETE OR PORTLAND CEMENT CONCRETE. Permissible types of culverts acceptable for use under roadways with 400 ADT or more with surface type other than asphaltic concrete or portland cement concrete are concrete box, reinforced concrete pipe, corrugated metal pipe, and vitrified clay pipe (extra strength). Box culverts are specified only when it is more economical to build the box than it is to provide an equivalent pipe culvert.

In general, full circle pipes are specified on the plans by "Group". The group designation gives the contractor the permissive option of furnishing any one or a combination of the pipe types within the specified group. One group of pipes (Group I) is provided. The permissive pipe types in Group I are (1) reinforced concrete, (2) corrugated metal, (3) vitrified clay (extra strength). When Group I pipe is specified hydraulic design computations should be based on corrugated metal pipe. In special cases as described in a subsequent section where one pipe type has a peculiar advantage over other pipe types, the particular type may be specified in lieu of specifying the group. 12" and 15" pipes are not used except as outlets from drop inlets. Elliptical reinforced concrete pipe may be used in special cases, usually for storm sewers, where necessary because of limited allowable structure height.

(3) ROADWAYS WITH SURFACE TYPE OF ASPHALTIC CONCRETE OR PORTLAND CEMENT CONCRETE. Permissible types of culverts acceptable for use under roadways with surface type of asphaltic concrete or portland cement concrete are concrete box, and reinforced concrete or vitrified clay pipe (extra strength).

The type of pipe to be used is specified on the plans. The plans usually specify reinforced concrete pipe for all pipe structures except entrance pipe. Vitrified clay pipe is used only for sewers. Box culverts are specified only when it is more economical to build the box than it is to provide an equivalent pipe culvert.

12" and 15" pipes are not used except as outlets from drop inlets and in storm sewer systems. The requirements for using reinforced concrete pipe or vitrified clay pipe for structures may be waived if conditions warrant, such as poor structure foundation conditions, high fills, simplification of handling traffic, etc. Corrugated metal pipe is specified for the portion of median outlet pipes outside the edge of pavement where such pipes are located on high fills requiring a break in flowline grade. Details for such installations are illustrated on Figure 9-10.1. Corrugated metal pipe may also be specified to drain drop inlets into crossroad drainage structures when such installation necessitates a steep flowline grade and when the pipe will not extend under the pavement.

(4) ENTRANCE PIPE. Permissible types of pipe used for entrances are described in Section 9-10.2(1) and are usually specified by respective group. Flared end sections are not required.

(5) SIDE ROAD APPROACH STRUCTURES. Permissible types of structures acceptable for use under side road approaches are dependent on traffic volume or pavement surface type as described in Sec. 9-10.2(1) thru Sec. 9-10.2(3). Flared end sections are required where the side road design traffic exceeds 750 vpd.

(6) OUTER ROADWAY DRAINAGE STRUCTURES. Permissible types of culvert pipe acceptable for use under outer roadways are dependent on traffic volume or pavement surface type as described in Sec. 9-10.2(1) thru Sec. 9-10.2(3) except that continuous drainage structures extending under outer roadways are designed to the same standard as required for the portion of the structure under the main roadway. Since a continuous drainage structure usually increases the standard for the portion under the outer roadway, it is usually more economical to use independent structures. Where continuous structures are used, the runoff between the outer roadway and the main roadway is usually carried into the crossroad structure by drop inlets and pipe. Where the crossroad structure is a relatively small pipe, the drop inlet is constructed in the crossroad structure.

Flared end sections are specified at both ends of pipe structures 66" or less in diameter regardless of the pipe type. In special cases where low clearance exists and the structure is essentially at right angles on roads with less than 400 ADT, pipe arches with flared end sections may be specified.

(7) MULTIPLE OPENING INSTALLATIONS. Multiple opening structures, either boxes or pipes, are used only as required where the allowable structure height is restricted. Where multiple pipes are constructed, the pipes are separated by a distance of 1/2 their outside diameter, or a minimum of one foot, whichever is greater. Multiple box structures require special designs by the Division of Bridges. Where such designs are required, the Division of Bridges is furnished with the culvert section, grade across the structure, typical section, and any other necessary information. For drainage areas 1,000 acres and under which require a structure designed by the Bridge Division (multiple box, etc.), the District shall also make the necessary analysis and provide to the Bridge Division the drainage area, the magnitude of the discharge, frequency, and design highwater for placement on the plans for each structure.

(8) INSTALLATIONS FOR SPECIAL SITUATIONS. For installations on a project which normally would require Group I, or II, pipe options (See Sections 9-10.2(1) and 9.10.2(2), special conditions may exist which would justify the specifying of a single pipe type. Justification for the selection of a single pipe type includes, but is not limited to, unstable foundation, high embankments, high erosive forces, or other pertinent reasons. When any one or a combination of these factors exist, the culvert pipe type best suited to resist such destructive forces is selected and specified. When a single pipe type is specified, in lieu of a group, the reasons for such selection are included in the letter of transmittal of the plans.

(9) STORM SEWERS. Permissible storm sewer types are concrete box, reinforced concrete pipe and vitrified clay pipe (extra strength). Storm sewers are considered to be special installations and the particular type of structure necessary for the particular location is selected and specified on the plans.

9-10.3 BOX CULVERTS

(1) BOX CULVERT STANDARD PLANS. Box culvert standard plans for all roadways are tabulated in the "Table of General Design Data" in Chapter IV.

(2) BOX CULVERT SHAPE. The most economical box culvert shape is approximately square, or a span slightly less than the height. Hydraulic factors will control the required shape of the box culvert. Box culvert sizes are indicated on the plans as span x height.

(3) SMALL BOX CULVERTS. Small box culverts based on Drawing 703.30 of the Standard Plans are used only as required to meet unusual conditions since pipe structures are usually more economical.

9-10.4 PIPE HEADWALLS Type S pipe headwalls may be used in lieu of drop inlets for median pipes for medians 60 feet wide or wider. Details for Type S pipe headwalls are shown on Drawing 604.05, of the Standard Plans

9-10.5 FLARED END SECTIONS. Flared end sections are required for crossroad pipe structures where the design traffic exceeds 750 vpd as tabulated in Section 4-04, "Basic Design Data" Drawing 732.00 of the Standard Plans shows details for flared end sections. Where flared end sections are used on skewed pipe, the section is placed on the same line as the pipe, and the fill slope is warped to fit.

9-10.6 FLOODGATES Floodgates are specified for the outlet ends of pipes where required to prevent floodwater from backing through the pipe. Type 1 floodgates for mounting on concrete structures will require a special Item Number and special provision Type 2 flood gates shall be installed on corrugated metal pipe. The hydraulic head is to be specified on the plans If the hydraulic head is not specified on the plans, the height of fill above the pipe will be considered the hydraulic head. The number of floodgates is listed on the plans in accordance with pipe sizes

9-10.7 REINFORCED CONCRETE PIPES.

(1) CLASSES OF STRENGTH. Reinforced concrete pipe is available and is specified on the plans as any one of five classes designated as Class I, II, III, IV, or V. Class V pipe is the strongest design

(2) USE OF VARIOUS CLASSES. Class I and Class II reinforced concrete pipe is used only for sewers in trenches outside roadbed and street limits. Class I pipe is provided in 60" to 108" diameters, inclusive, and is used in trenches ten feet or less in depth Class II pipe is provided in sizes from 12" to 108" diameters, inclusive, and is used in trenches 15 feet or less in depth Deeper trenches require Class III, IV, or V pipe Class III, IV, or V pipe is used for all other drainage structures and are provided in sizes from 12" to 108" diameters, inclusive

(3) SELECTION OF PIPE CLASS AND BEDDING The selection of a proper class and bedding for reinforced concrete pipe at a specific location involves a detailed study and analysis of the conditions at the culvert location, and a comparative cost analysis of the various combinations which will satisfy the requirements for the particular installation. Usually more than one combination will meet the requirements When the culvert pipe is specified on the plans by Group I, or II, the contractor selects the class of pipe and class of bedding commensurate with the installation conditions When reinforced concrete culvert pipe is specified on the plans, the most economical combination of class of pipe and class of bedding is selected, with consideration given to service and minimizing the number of bid items The order of preference for using the five classes of reinforced concrete pipe is (1) Class I, (2) Class II, (3) Class III, (4) Class IV, and (5) Class V The order of preference for using the four classes of bedding is (1) Class C, (2) Class B, (3) Class B1, and (4) Class A The proper procedure is to use the lowest class of pipe in combination with the lowest possible class of bedding consistent with the requirements of the particular installation

(4) SPECIFYING PIPE CLASS AND BEDDING ON PLANS When reinforced concrete pipe is permitted as an option by Specifying Group I, or II, culvert pipe on the plans, neither the class of reinforced concrete pipe nor the class of bedding is specified When reinforced concrete pipe is specified on the plans, the class of reinforced concrete pipe is specified and the class of bedding is specified if a bedding other than Class C is used

(5) PAYMENT FOR BEDDING When reinforced concrete pipe is permitted as an option by specifying Group I, or II, culvert pipe on the plans, payment for special bedding is not included and the Class 3 Excavation includes only that quantity necessary for a minimum installation Where overfill heights are 34 feet or more, neither the excavation required for imperfect trench and concrete cradle nor the concrete for the cradle will be allowed for payment When reinforced concrete pipe is specified on the plans, the Class 3 Excavation is computed to include the excavation for the specified bedding Payment for all classes of bedding is included in the bid price for Class 3 Excavation, except Class A bedding where separate payment is made for the concrete

9-10.8 FILL SETTLEMENTS Fill settlements can seriously affect concrete box structures by opening joints and cracks sufficiently to allow the fill around the culvert to infiltrate into the culvert, thereby creating voids which can cause the roadbed to fail In areas subject to large settlements, other structure types are considered or the box culvert is designed to withstand the settlement. This requires special box culvert designs and where box culverts are to be so designed, the Division of Bridges is furnished with full information, including culvert sections, grades, and anticipated settlement. Box culverts with special collars around joints have been successfully designed and used in areas subject to large fill settlements Since such structures are expensive, it is sometimes more economical to use other structure types such as flexible pipe

9-10.9 CAMBER IN CULVERTS Camber as used in culvert design is defined as the distance the central portion of crossroad structures is constructed above final flow-line grade to compensate for anticipated settlement. Typical details for cambering culverts are shown on Drawing 726.30 of the Standard Plans. A structure designed with proper camber will settle to near flowline grade and elevation when it reaches final settlement. All culverts, except those on non-yielding foundations, are cambered at a minimum rate of 0.01 foot per foot of overfill. Cambers of 0.1 foot or less are not shown on plans. Where the fill settlement is known, culverts are designed with a camber equal to the anticipated settlement. The camber is shown on the culvert section at the roadbed shoulders by amount and flow-line elevation as illustrated in Chapter IV.

9-10.10 CULVERT EXTENSIONS. All culvert extensions, both boxes and pipes, are extended with structures meeting current design requirements and standards, regardless of the type of standard of the existing structure. Pipe collars as detailed on Drawing 604.40 of the Standard Plans are used to connect different types of pipe, and concrete pipe to concrete pipe. Box culverts are extended in accordance with details shown on Drawing 703.35 of the Standard Plans and Figure 9-10.2. Additional fills on existing box culverts may require a structural analysis of the existing structure by the Division of Bridges. If so, the Division of Bridges is furnished a print of the completed culvert section and the standard to which the existing structure was designed, if known, for their use in making the analysis.

9-10.11 OVERFILL HEIGHTS

(1) MINIMUM FILL HEIGHTS. The minimum allowable fill or cover for all structures is one foot at the shoulder line, with the following exceptions: The minimum fill for structural-plate pipe structures is tabulated in Figure 9-10.7. In addition, the minimum clearance from the top of structures to the bottom of bases is six inches. Exceptions are special box culverts designed to carry traffic on the top slab. Where low type surfaces are used, the minimum fill at the shoulder on the inside of super-elevated curves is 18 inches. Minimum fill heights for vitrified clay pipe (extra strength) are 4 feet for the 8" through 21" diameters and 3 feet for the 24" through 36" diameters. Overfill heights which are less than those indicated as allowable for any one pipe type are not considered as justification for the elimination of specifying pipe types by "Groups" provided other criteria are satisfactory.

(2) DESIGN FILL HEIGHTS. If any question developes regarding the fill heights to be used, and where the fill height is between values tabulated for design, the design fill height is taken to the next increment requiring the higher design. Pipe culverts are designed throughout their length for the maximum design condition except in the case of structural plate pipe. Box culvert extensions and box culverts in sections are designed for the height of fill over individual sections in accordance with details shown on Figure 9-10.2. Box culverts are designed for all fill heights. Design fill heights for all pipe culverts specified by "Groups" are shown on the "B" sheets. The allowable overfill heights for corrugated metal pipe-arches and structural plate pipes are tabulated in Figures 9-10.6 and 9-10.7, respectively. These overfill heights indicate both a minimum and a maximum, neither of which should be exceeded. The column headed "Standard" under gage for pipe-arches in Figure 9-10.6 refers to the gage required for the particular structure by the Standard Specifications. If overfill heights exceed the range shown, a different gage may be necessary and a special design is requested from the Main Office. A special design is also requested for pipe-arches of a size not listed in Figure 9-10.6. If a different gage is necessary, the plans specify the gage required. Where overfill heights are greater than shown in the figure, consideration should be given to round pipe. The gage for structural plate pipe is specified on the plans and may be changed throughout the length of the structure, where economically feasible, dependent on the fill heights in accordance with Figure 9-10.7.

(3) MAXIMUM FILL HEIGHTS

(a) BOX CULVERTS. If the fill height exceeds the values tabulated on the Standard Plans, special designs are required. In such cases, the District furnishes the Division of Bridges with one copy of Form SP-8 and one print showing the completed culvert section. A form is submitted for each section of the culvert requiring special design. The Division of Bridges adds the design data to the form and returns it to the District for their use in computing quantities. An example of a completed Form SP-8 is shown on Figure 9-10.3 (see also Chapter IV).

(b) PIPES. Design overfill heights which are in excess of those indicated as allowable for any one pipe type are not considered as justification for the elimination of specifying pipe types by "Groups" provided other criteria are satisfactory.

9-10.12 CULVERT GRADES. Crossroad drainage structures are usually placed on a grade equal to the natural ditch grade or the ditch grade in which the culvert is being placed. Controlling grades for storm and sanitary sewers are given in preceding sections. Erosion may be a problem at the outlet end of culverts on steep grades, which sometimes can be reduced by breaking the grade through the culvert. Grade breaks can be used to reduce structure excavation. Drop structures can be used at the inlet end of culverts to reduce the grade through the culvert. Drop structures are used with discretion because of the ponding upstream, and because of the unstable condition that may be created by the ponding. The grade for pipes for median drop inlets is broken in accordance with the requirements and details illustrated on Figure 9-10.1.

9-10.13 CULVERT LENGTHS

(1) GENERAL. Culvert lengths are determined graphically by scaling from the culvert sections. The lengths are obtained by intersection of the structure with slope lines as shown on the culvert Standard Plans, and as described in the following sections. Precise lengths are not computed. In questionable cases a longer length is used. Skewed slopes used for culvert sections are shown on Figure 9-10.4. Intermediate values are interpolated.

(2) BOX CULVERTS. The length of box culverts is the distance between headwalls, and is scaled to the next higher foot. Headwalls are designed sloped along the flow-line grade. Box culverts over 75 feet long, and extensions, are built in sections, and the sections are designed to meet the requirements shown on Figure 9-10.2. The minimum length for box culverts is two feet greater than the roadbed width measured normal to the centerline of the roadbed.

(3) PIPES. The length of pipe culverts with headwalls is two feet longer than the distance between headwalls. Pipe headwalls are designed on a flat grade, regardless of the grade of the pipe. The length of pipe culverts not beveled and without headwalls is the distance between the slope lines at the flow line. Metal pipe lengths are scaled to the next higher even foot. Other pipe lengths are scaled to the next higher foot. The length of metal pipes with beveled ends is two feet longer than the distance between the intersection of the slope lines and the centerline of the pipe scaled to the next higher even foot. Pipe bends and special connections are not listed as a pay item on the plans. The plans do include notes to the effect that such items are required and that their costs are included in other items. The plans include, usually on the culvert sections, sufficient dimensions and detail to fabricate pipe with bends or special connections.

9-10.14 CLASS 3 EXCAVATION. Class 3 Excavation is measured and computed in accordance with details shown in Figure 9-10.5, supplemented by Figure 9-10.1 and applicable Standard Plans. Since the Standard Specifications provide for the payment of plan quantities of Class 3 Excavation, care is exercised in computing the quantities. Each structure is checked carefully on the field checks, and appropriate notes are made to insure that the quantities are as accurate as possible. A common error is to compute only the quantities below the ditch flow line where the structure approaches or exceeds the width of the natural ditch. Class 3 Excavation is computed to include the removal of only that part of an existing structure within the normal limits of Class 3 Excavation. The plans include a removal item for the removal of the portion or portions of existing structures outside the normal limits of Class 3 Excavation. Care is exercised to avoid duplicate payment for the same excavation, such as computing Class 3 Excavation where channel change quantities or roadway excavation has been computed.

9-10.15 CONNECTIONS. The plans provide for connecting new structures to existing structures, and connecting different types of new structures. The plans do not include an item for the connection of pipes to existing manholes, box culverts, drop inlets, or sewer pipes. The plans do include the pipe collar item for connecting different types of pipe or different sizes of pipes. Details for pipe collars are shown on Drawing 604.40, of the Standard Plans.

APPENDIX B

ROADBED LIFE

age

TAB OF ROADBED ~~WIDTH~~ BY YEAR,SYSTEM

16.09 APR 14, 1987

HP803FAD

AGE IS ROADBED HAS BEEN IN PLACE ATLEAST THIS LONG

SYSTEM	LENGTH	COMMENT
INTS	6.997	CONST 1936 AND PRIOR
INTS	7.573	CONST 1941 AND PRIOR
INTS	9.400	CONST 1946 AND PRIOR
INTS	46.811	CONST 1951 AND PRIOR
INTS	285.664	CONST 1956 AND PRIOR
INTS	652.141	CONST 1961 AND PRIOR
INTS	1,317.640	CONST 1966 AND PRIOR
INTS	1,703.108	CONST 1971 AND PRIOR
INTS	2,132.532	CONST 1976 AND PRIOR
INTS	2,215.325	CONST 1981 AND PRIOR
INTS	2,313.762	CONST 1986 AND PRIOR
PRI	25.866	CONST 1921 AND PRIOR
PRI	551.664	CONST 1926 AND PRIOR
PRI	1,741.892	CONST 1931 AND PRIOR
PRI	3,491.478	CONST 1936 AND PRIOR
PRI	3,977.260	CONST 1941 AND PRIOR
PRI	4,215.154	CONST 1946 AND PRIOR
PRI	4,489.381	CONST 1951 AND PRIOR
PRI	4,762.440	CONST 1956 AND PRIOR
PRI	5,314.693	CONST 1961 AND PRIOR
PRI	5,913.674	CONST 1966 AND PRIOR
PRI	6,489.185	CONST 1971 AND PRIOR
PRI	7,121.795	CONST 1976 AND PRIOR
PRI	7,404.269	CONST 1981 AND PRIOR
PRI	7,667.286	CONST 1986 AND PRIOR
SUPP	86.221	CONST 1921 AND PRIOR
SUPP	334.879	CONST 1926 AND PRIOR
SUPP	942.573	CONST 1931 AND PRIOR
SUPP	4,967.128	CONST 1936 AND PRIOR
SUPP	7,099.124	CONST 1941 AND PRIOR
SUPP	7,517.072	CONST 1946 AND PRIOR
SUPP	9,944.729	CONST 1951 AND PRIOR
SUPP	13,971.995	CONST 1956 AND PRIOR
SUPP	19,432.145	CONST 1961 AND PRIOR
SUPP	22,846.204	CONST 1966 AND PRIOR
SUPP	23,822.254	CONST 1971 AND PRIOR
SUPP	24,226.020	CONST 1976 AND PRIOR
SUPP	24,418.204	CONST 1981 AND PRIOR
SUPP	24,579.452	CONST 1986 AND PRIOR

APPENDIX C

PIPE QUANTITIES USED BY MAINTENANCE

ACRS2830 DATE 4/13/83

YEAR	DIST	517*	518*	
84	01	2,649.0	3.0	
84	02	148.0	4.0	
84	03	2,997.0	74.0	
84	04	2,139.0		
84	05	664.0		
84	06	1,093.0		
84	07	486.0	1,011.0	
84	08	1,645.0	240.0	
84	09	1,912.0		
84	10	3,211.0		
84		16,902.0	1,332.0	18,234
85	01	1,618.0		
85	02	772.0		
85	03	3,452.0	15.0	
85	04	3,737.0		
85	05	2,168.0		
85	06	1,657.0		
85	07	1,017.0	1,658.0	
85	08	2,092.0	50.0	
85	09	1,237.0		
85	10	4,139.0		
85		21,889.0	1,723.0	23,612

YEAR	DIST	517*	518*	
86	01	1,905.0	32.0	
86	02	3,060.0		
86	03	5,137.0	24.0	
86	04	4,651.0		
86	05	3,718.0		
86	06	2,980.0	20.0	
ACRG2839		DATE 4/17/87		
YEAR	DIST	517*	518*	
86	07	1,322.0	1,305.0	
86	08	4,847.0	125.0	
86	09	2,915.0	31.0	
86	10	7,948.0		
86		37,583.0	1,538.0	39,121
				80,967

Pipe quantities used by Maintenance in the years 1984, 1985 and 1986.

*Object Code 517 is CMP. Object Code 518 is RCP.

APPENDIX D

PIPES REPLACED OR REHABILITATED BY CONTRACT

ITEMIZED PROPOSAL

9-S-68-270
RTE 68
CO DENT

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS	AMOUNT DOLLARS	CTS
1	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	1,092	18	250	19929	00
2	725-01.24	24 IN. PIPE CULVERT GROUP I PER LIN FT	510	23	580	12025	80
3	725-01.30	30 IN. PIPE CULVERT GROUP I PER LIN FT	156	29	100	4539	60
4	725-01.36	36 IN. PIPE CULVERT GROUP I PER LIN FT	40	37	890	1515	60
5	725-02.15	15 IN. PIPE CULVERT GROUP II PER LIN FT	980	15	000	14700	00
6	725-02.18	18 IN. PIPE CULVERT GROUP II PER LIN FT	46	18	250	839	50
7	732-00.18	18 IN. FLARED END SECTION PER EACH	60	90	000	5400	00
8	732-00.24	24 IN. FLARED END SECTION PER EACH	26	97	000	2522	00
9	732-00.30	30 IN. FLARED END SECTION PER EACH	8	175	000	1400	00

ITEMIZED PROPOSAL

9-S-68-270
RTE 68
CO DENT

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	732-00.36	36 IN. FLARED END SECTION PER EACH	2	250	000	500	00
2	802-30.00	TYPE 3 MULCH PER ACRE	21	675	000	14175	00
3	805-10.00	SEEDING PER ACRE	21	675	000	14175	00
4		TOTAL FOR PROJECT				730744	61

SP-304 (REV 3-84)

ITEMIZED PROPOSAL

F-8-L(9)SEC A
RTE 8
CO CRAWFORD

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS CTS	AMOUNT DOLLARS CTS
1	616-10.47	TYPE III OBJECT MARKER PER EACH	60	11.250	675.00
2	619-10.00	MOBILIZATION PER LUMP SUM	1	10000.000	10000.00
3	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	9.3	125.000	1162.50
4	700-99.14	ALTERNATE A. 14 IN. INSERTION LINER PER LIN. FT.	193	16.000	3088.00
5	700-99.98	ALTERNATE B. LINING FOR 18 IN. CULVERT PIPE PER LIN. FT.	193	.000	
6	725-01.13	18 IN. PIPE CULVERT GROUP I PER LIN FT	348	18.000	6264.00
7	725-02.18	18 IN. PIPE CULVERT GROUP II PER LIN FT	42	22.000	924.00
8	732-00.18	18 IN. FLARED END SECTION PER EACH	14	375.000	5250.00
9	802-50.00	TYPE 2 OR TYPE 3 MULCH PER ACRE	15.8	675.000	10665.00

SP-304
(REV 5-84)

ITEMIZED PROPOSAL

F-8-1(9)SEC 8
RTE 8
CO CRAWFORD

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS	AMOUNT DOLLARS	CTS
1	408-10.10	PRIME-LIQUID ASPHALT RC 70 OR MC 30 — PER GALLON	390	1	200	468	00
2	601-10.00	FIELD LABORATORIES — PER LUMP SUM	1	3333	600	3333	60
3	606-10.10	GUARD RAIL TYPE A — PER LIN FT	900	13	500	12150	00
4	606-30.00	TERMINAL SECTION — PER EACH	2	600	000	1200	00
5	609-70.00	ROCK LINING — PER CU YD	60	18	000	1080	00
6	616-10.05	CONSTRUCTION SIGNS — PER SQ FT	818	3	500	2863	00
7	616-10.47	TYPE III OBJECT MARKER — PER EACH	60	11	250	675	00
8	622-10.00	TEMPORARY PAVEMENT MARKING — PER MILE	7.3	125	000	912	50
9	700-99.14	ALTERNATE A . 14 INCH INSERTION LINER — PER LIN. FT.	220	16	000	3520	00

CP-004
(REV 5-84)

ITEMIZED PROPOSAL

F-8-1(9)SEC 8
RTE 8
CO CRAWFORD

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS	AMOUNT DOLLARS	CTS
1	700-99.20	ALTERNATE A , 20 INCH INSERTION LINER PER LIN. FT.	167	22	.000	3674	.00
2	700-99.98	ALTERNATE B, LINING FOR 18 INCH CULVERT PIPE PER LIN. FT.	220		.000		
3	700-99.99	ALTERNATE B, LINING FOR 24 INCH CULVERT PIPE PER LIN. FT.	167		.000		
4	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	700	18	.000	12600	.00
5	725-01.24	24 IN. PIPE CULVERT GROUP I PER LIN FT	50	22	.000	1100	.00
6	725-02.18	18 IN. PIPE CULVERT GROUP II PER LIN FT	66	20	.000	1320	.00
7	732-00.18	18 IN. FLARED END SECTION PER EACH	28	375	.000	10500	.00
8	732-00.24	24 IN. FLARED END SECTION PER EACH	2	450	.000	900	.00
9	302-50.00	TYPE 2 OR TYPE 3 MULCH PER ACRE	12.7	575	.000	3707	.50

SP-304 (REV. 5-84)

ITEMIZED PROPOSAL

F-19-3(5)SEC A
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	618-10.00	MOBILIZATION PER LUMP SUM	1	20000	.000	20000	.00
2	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	9.2	60	.000	552	.00
3	700-99.14	ALTERNATE A: 14IN. INSERTION LINER PER LIN FT	1,158	23	.000	26634	.00
4	700-99.20	ALTERNATE A: 20IN. INSERTION LINER PER LIN FT	62	34	.000	2108	.00
5	700-99.98	ALTERNATE B: LINING FOR 18IN. CULVERT PIPE PER LIN FT	1,158		.000		
6	700-99.99	ALTERNATE B: LINING FOR 24IN. CULVERT PIPE PER LIN FT	62		.000		
7	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	1,222	26	.000	31772	.00
8	725-10.12	12 IN. CORRUGATED METAL PIPE PER LIN FT	28	15	.000	420	.00
9	732-00.18	18 IN. FLARED END SECTION PER EACH	51	120	.000	6120	.00

SP-304
(REV. 5-84)

ITEMIZED PROPOSAL

F-19-3(5)SEC 3
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS	AMOUNT DOLLARS	CTS
1	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	9.6	60	.000	576	.00
2	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	125	26	.000	3250	.00
3	725-10.12	12 IN. CORRUGATED METAL PIPE PER LIN FT	55	15	.000	825	.00
4	732-00.18	18 IN. FLARED END SECTION PER EACH	6	120	.000	720	.00
5		TOTAL FOR PROJECT				360034	.05

SP-304 (REV 5-44)

ITEMIZED PROPOSAL

F-19-2(9)SEC A&B
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	617-50.10	RELOCATING TEMPORARY TRAFFIC BARRIER PER LIN FT	1,314	7	.500	9855	.00
2	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	11	60	.000	660	.00
3	700-99.14	ALTERNATE A: 14 IN. INSERTION LINER PER LIN FT	247	23	.000	5681	.00
4	700-99.20	ALTERNATE A: 20 IN. INSERTION LINER PER LIN FT	76	34	.000	2584	.00
5	700-99.98	ALTERNATE B: LINING FOR 18IN. CULVERT PIPE PER LIN FT	247		.000		
6	700-99.99	ALTERNATE B: LINING FOR 24IN. CULVERT PIPE PER LIN FT	76		.000		
7	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	608	26	.000	15808	.00
8	725-01.24	24 IN. PIPE CULVERT GROUP I PER LIN FT	44	29	.000	1276	.00
9	725-10.15	15 IN. CORRUGATED METAL PIPE PER LIN FT	10	16	.000	160	.00

ITEMIZED PROPOSAL

F-19-2(9)SEC A&B
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	732-00.18	18 IN. FLARED END SECTION	PER EACH	28	120	000	3360	00
2	732-00.24	24 IN. FLARED END SECTION	PER EACH	2	145	000	290	00
3	803-10.00	SODDING	PER SQ YD	200	6	000	1200	00
4	805-10.00	SEEDING	PER ACRE	11.7	900	000	10530	00
5		SUBTOTAL ROADWAY					542793	16
6		BRIDGE NO. J-538R AT STATION 132+88						
7	202-10.50	SPECIAL WORK (BRIDGES)	PER LUMP SUM	1	7500	000	7500	00
8	202-30.00	ASPHALT REMOVAL (BRIDGES)	PER LUMP SUM	1	1000	000	1000	00
9	403-10.31	ASPHALT CEMENT (ASPHALTIC CONCRETE) 60-70 OR AC-20 (TYPE A MIX)	PER TON	.7	100	000	70	00

ITEMIZED PROPOSAL

RS-681 (5)
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	8	60	.000	480	.00
2	700-99.14	ALTERNATE A: 14 IN. INSERTION LINER PER LIN FT	57	23	.000	1311	.00
3	700-99.20	ALTERNATE A: 20 IN. INSERTION LINER PER LIN FT	75	34	.000	2550	.00
4	700-99.98	ALTERNATE B: LINING FOR 18IN. CULVERT PIPE PER LIN FT	57		.000		
5	700-99.99	ALTERNATE B: LINING FOR 24 IN. CULVERT PIPE PER LIN FT	75		.000		
6	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	863	26	.000	22438	.00
7	725-01.24	24 IN. PIPE CULVERT GROUP I PER LIN FT	94	29	.000	2726	.00
8	725-01.30	30 IN. PIPE CULVERT GROUP I PER LIN FT	44	32	.000	1408	.00
9	725-01.36	36 IN. PIPE CULVERT GROUP I PER LIN FT	41	36	.000	1476	.00

ITEMIZED PROPOSAL

RS-681 (5)
RTE 19
CO GASCONADE

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS.	AMOUNT DOLLARS	CTS.
1	732-00.18	18 IN. FLARED END SECTION PER EACH	42	120	.000	5040	.00
2	732-00.24	24 IN. FLARED END SECTION PER EACH	6	145	.000	870	.00
3	732-00.30	30 IN. FLARED END SECTION PER EACH	2	230	.000	460	.00
4	732-00.36	36 IN. FLARED END SECTION PER EACH	2	340	.000	680	.00
5		SUBTOTAL ROADWAY				420454	.66
6		BRIDGE NO. K-636R AT STATION 59+52.75					
7	202-10.50	SPECIAL WORK (BRIDGES) PER LUMP SUM	1	8000	.000	8000	.00
8	202-30.09	ASPHALT REMOVAL (BRIDGES) PER LUMP SUM	1	1000	.000	1000	.00
9	403-10.31	ASPHALT CEMENT (ASPHALTIC CONCRETE) 60-70 OR AC-20 (TYPE A MIX) PER TON	.8	100	.000	80	.00

ITEMIZED PROPOSAL

RS-BHS-1098(2) A & B
RTE 142
CO OREGON

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS.	AMOUNT DOLLARS	CTS.
1	616-10.47	TYPE III OBJECT MARKER PER EACH	10	15	000	150	00
2	616-10.52	WARNING LIGHT, TYPE B PER EACH	14	400	000	5600	00
3	617-50.00	TEMPORARY TRAFFIC BARRIER PER LIN FT	181	24	000	4344	00
4	617-50.10	RELOCATING TEMPORARY TRAFFIC BARRIER PER LIN FT	543	11	500	6244	50
5	618-10.00	MOBILIZATION PER LUMP SUM	1	13000	000	13000	00
6	621-05.11	TEMPORARY PAVEMENT STRIPING, 4 IN., SOLID WHITE (TAPE) PER 100 FT	2	100	000	200	00
7	621-10.05	PAVEMENT STRIPE REMOVAL (TAPE) PER 100 FT	2	150	000	300	00
8	622-10.00	TEMPORARY PAVEMENT MARKING PER MILE	11.5	180	000	2070	00
9	725-01.18	18 IN. PIPE CULVERT GROUP I PER LIN FT	2,398	15	900	38128	20

ITEMIZED PROPOSAL

RS-BHS-1098(2) A & B
RTE 142
CO OREGON

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	725-01.24	24 IN. PIPE CULVERT GROUP I PER LIN FT	378	21	400	8089	20
2	725-01.30	30 IN. PIPE CULVERT GROUP I PER LIN FT	126	26	500	3339	00
3	725-01.42	42 IN. PIPE CULVERT GROUP I PER LIN FT	42	36	750	1543	50
4	725-02.15	15 IN. PIPE CULVERT GROUP II PER LIN FT	1,092	14	700	16052	40
5	725-02.18	18 IN. PIPE CULVERT GROUP II PER LIN FT	232	16	400	3804	80
6	725-10.18	18 IN. CORRUGATED METAL PIPE PER LIN FT	32	25	300	809	60
7	725-10.36	36 IN. CORRUGATED METAL PIPE PER LIN FT	12	25	300	303	60
8	725-20.05	CORRUGATED METAL PIPE-ARCH TYPE 9-5 PER LIN FT	350	27	180	9513	00
9	725-20.08	CORRUGATED METAL PIPE-ARCH TYPE 9-8 OR 9-8A PER LIN FT	92	58	600	5391	20

ITEMIZED PROPOSAL

RS-BHS-1098(2) A & B
RTE 142
CO OREGON

LINE	ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS.	AMOUNT DOLLARS	AMOUNT CTS.
1	725-20.10	CORRUGATED METAL PIPE-ARCH TYPE B-10 OR B-10A	PER LIN FT	80	49	600	3968	00
2	732-00.18	18 IN. FLARED END SECTION	PER EACH	108	80	000	8640	00
3	732-00.24	24 IN. FLARED END SECTION	PER EACH	16	136	000	2176	00
4	732-00.30	30 IN. FLARED END SECTION	PER EACH	4	257	600	1030	40
5	732-00.36	36 IN. FLARED END SECTION	PER EACH	2	384	000	768	00
6	732-00.42	42 IN. FLARED END SECTION	PER EACH	2	720	000	1440	00
7	732-10.05	B5 FLARED END SECTION	PER EACH	16	208	000	3328	00
8	732-10.08	B8 FLARED END SECTION	PER EACH	4	545	600	2182	40
9	732-10.10	B10 FLARED END SECTION	PER EACH	4	728	000	2912	00

ITEMIZED PROPOSAL

6-S-T-787
RTE T
CO ST. CHARLES
AND WARREN

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	CTS.	AMOUNT DOLLARS	CTS
1	202-20.10	REMOVAL OF IMPROVEMENTS PER LUMP SUM	1	3000	.000	3000	.00
2	206-30.00	CLASS 3 EXCAVATION PER CU YD	1,046	17	.000	17782	.00
3	304-00.73	TYPE 1 OR TYPE 2 AGGREGATE FOR BASE (7 IN. THICK) PER SQ YD	533	3	.000	1599	.00
4	401-10.21	ASPHALT CEMENT (BITUMINOUS PAVEMENT) 85-100 OR AC-10 PER TON	4.3	55	.000	236	.50
5	401-20.10	MINERAL AGGREGATE (BITUMINOUS PAVEMENT) GRADE C PER TON	75	55	.000	4125	.00
6	408-10.10	PRIME-LIQUID ASPHALT RC 70 OR MC 30 PER GALLON	170	3	.000	510	.00
7	616-10.05	CONSTRUCTION SIGNS PER SQ FT	176	25	.000	4400	.00
8	618-10.00	MOBILIZATION PER LUMP SUM	1	23000	.000	23000	.00
9	725-02.12	12 IN. PIPE CULVERT GROUP II PER LIN FT	252	17	.000	4284	.00

SP-304
(REV. 5-64)

ITEMIZED PROPOSAL

6-S-T-787
RTE T
CO ST. CHARLES
AND WARREN

LINE	ITEM	DESCRIPTION / UNIT	QUANTITY	UNIT PRICE DOLLARS	UNIT PRICE CTS	AMOUNT DOLLARS	AMOUNT CTS
1	725-02.15	15 IN. PIPE CULVERT GROUP II PER LIN FT	90	18	000	1620	00
2	725-02.18	18 IN. PIPE CULVERT GROUP II PER LIN FT	410	19	000	7790	00
3	725-02.21	21 IN. PIPE CULVERT GROUP II PER LIN FT	30	20	000	600	00
4	725-02.24	24 IN. PIPE CULVERT GROUP II PER LIN FT	310	21	000	6510	00
5	725-02.30	30 IN. PIPE CULVERT GROUP II PER LIN FT	34	24	000	816	00
6	725-02.36	36 IN. PIPE CULVERT GROUP II PER LIN FT	76	28	000	2128	00
7	725-02.42	42 IN. PIPE CULVERT GROUP II PER LIN FT	70	30	000	2100	00
8	725-02.48	48 IN. PIPE CULVERT GROUP II PER LIN FT	112	33	000	3696	00
9		TOTAL FOR PROJECT				94135	50

PAGE

APPENDIX E

CULVERT SURVEY OF CROSSROAD

REPLACEMENTS OR REHABILITATION

CULVERT SURVEY OF CROSSROAD REPLACEMENTS OR REHABILITATION May 12, 1987

DISTRICT	COUNTY	ROUTE	LOCATION	Dia. IN.	LENGTH Feet	Gage	YEAR INSTALLED	YEAR REPLACED	AGE (YEARS)
1	Dekalb	W	0.5 Mi. E of Rt A	36	42	12	1957	1987	30
1	Dekalb	C	2 Mi. N of Rt 36	30	38	14	1956	1987	31
3	Knox	156	3.01 Mi. E of Rt 15	36	32	10	1935	1987	52
3	Knox	156	2.03 Mi. E of Rt 15	30	32	10	1935	1987	52
4	Benton	T	0,1 Mi. S of Rt C	70x46	48	unknown	1950	1986	36
4	Cass	B	6 Mi. E of Rt 71	18	45	unknown	1936	1986	50
4	Cass	B	4.1 Mi. E of Rt 71	36	40	unknown	1936	1986	50
4	Cass	7	2.0 Mi. W of Rt B	19.5		unknown	1937	1986	49
4	Henry	H	2 Mi. W of Jct K & H	63.5x42	46	unknown	1950	1987	37
4	Henry	M	2.051 Mi. W of Rt 13	36		12	1934	1987	53**
4	Henry	M	2.53 Mi. W of Rt 13	24		14	1934	1987	53**
4	Henry	M	0.15 Mi. W of Rt 13	24		unknown	1934	1987	53**
4	Henry	M	0.962 Mi W of Rt 13	36		12	1934	1987	53**
4	Henry	M	2.275 Mi. W of Rt 13	24		14	1934	1987	53**
4	Henry	M	2.275 Mi. W of Rt 13	24		14	1934	1987	53**
4	Henry	M	2.688 Mi. W of Rt 13	18		unknown	1934	1987	53**
4	Henry	M	2.984 Mi. W of Rt 13	18		unknown	1934	1987	53**
4	Henry	N	6.545 Mi. E of Cass Co Line	24		14	1934	1987	53**
4	Henry	N	6.45 Mi. E of Cass Co Line	18		16	1934	1987	53**
4	Henry	N	0.322 Mi. E of Cass Co Line	24		14	1966	1987	21**
4	Henry	N	0.923 Mi. E of Cass Co Line	48		12	1966	1987	21**
4	Henry	N	2.785 Mi. E of Cass Co Line	30		14	1966	1987	21**
4	Henry	N	3.09 Mi. E of Cass Co Line	30		14	1955	1987	32**
4	Henry	N	4.481 Mi. E of Cass Co Line	30		14	1955	1987	32**
4	Henry	N	4.535 Mi. E of Cass Co Line	36		12	1966	1987	21**
4	Henry	N	5.023 Mi. E of Cass Co Line	36		12	1955	1987	32**
4	Henry	N	5.204 Mi E of Cass Co Line	51x31		12	1955	1987	32**
4	Henry	N	7.957 Mi. E of Cass Co Line	18		16	1934	1987	53**
4	Henry	N	6.61 Mi. E of Cass Co Line	18		16	1934	1987	53**
4	Henry	N	6.83 Mi. E of Cass Co Line	[illegible]		16	1934	1987	53**
4	Henry	N	6.693 Mi. E of Cass Co Line	[illegible]		16	1934	1987	53**
4	Henry	N	7.41 Mi E of Cass Co Line	36		12	1934	1987	53**
4	Henry	N	7.842 Mi E of Cass Co Line	36		12	1934	1987	53**
4	Henry	N	9.118 Mi. E of Cass Co Line	24		14	1934	1987	53**
4	Henry	N	9.276 Mi. E of Cass Co Line	30		14	1934	1987	53**
4	Henry	N	10.051 Mi. E of Cass Co Line	18		16	1934	1987	53**
4	Henry	N	10.794 Mi. E of Cass Co Line	48		12	1934	1987	53**
4	Henry	N	11.435 Mi. E of Cass Co Line	18		16	1934	1987	53**
4	Henry	N	12.219 Mi. E of Cass Co Line	30		14	1934	1987	53**
4	Henry	N	12.514 Mi E of Cass Co Line	36		12	1934	1987	53**
4	Henry	N	13.719 Mi. E of Cass Co Line	24		14	1934	1987	53**
4	Henry	N	13.246 Mi E of Cass Co Line	24		unknown	1934	1987	53**
4	Henry	N	14.040 Mi. E of Cass Co Line	36		12	1934	1987	53**
4	Henry	N	20.818 Mi E of Cass Co Line	30		14	1964	1987	23**

4	Henry	N	21.135 Mi E of Cass Co Line	24		14	1966	1987	21**
4	Henry	N	21.370 Mi E of Cass Co Line	30		14	1966	1987	21**
4	Henry	N	21.930 Mi. E of Cass Co Line	36		12	1966	1987	21**
4	Henry	Z	0.25 Mi. E of Jct Z & JJ	32x63	42	12	1956	1987	31**
4	Henry	Z	0.25 Mi. E of Jct Z & JJ	56x38	40	12	1956	1987	31
4	Henry	Z	0.6 Mi. E Jct Z & JJ	32x63	38	12	1956	1987	31**
4	Henry	Z	0.6 Mi. E Jct Z & JJ	56x38	40	unknown	1956	1987	31
4	Henry	Z	0.55 Mi. E of Rt Z & NN	20x38	40	14	1956	1987	31**
4	Henry	Z	0.55 Mi. E Jct Rt Z & NN	35.5x23.5	40	unknown	1956	1987	31
4	Johnson	D	1.1 Mi. No of Rt D & EE	30	50	unknown	1947	1986	39
4	Johnson	BB	1.5 Mi. W of Rt 13	24	40	unknown	1957	1986	29
4	Johnson	OO	1.6 Mi. E of Rt M	28x20	40	unknown	1961	1986	25
4	Lafayette	D	1.3 Mi. N of Rt I-70	30	40	unknown	1935	1987	52**
4	Lafayette	D	0.9 Mi. S of Jct FF	18	40	unknown	1935	1986	51
4	Lafayette	D	2.3 Mi. S of Rt 24	24	40	unknown	1935	1986	51
4	Lafayette	D	0.85 Mi. S of Rt 24	24	40	unknown	1935	1986	51
4	Lafayette	D	0.1 Mi. N of Rt I-70	36	38	12	1935	1987	52**
4	Lafayette	D	2.3 Mi S of Rt 24	24	40	unknown	1935	1986	51
4	Lafayette	D	3.1 Mi. N of Rt I-70	18		unknown	1935	1987	52**
4	Lafayette	E	Jct Rt E & FF	54		12	1948	1987	39**
4	Lafayette	F	2.0 Mi. N of Rt 20	36	40	unknown	1936	1986	50
4	Lafayette	F	4.3 Mi. No of Rt 20	24	58	unknown	1936	1987	51**
4	Lafayette	P	0.5 Mi. N of Rt 24	24	36.5	unknown	1966	1986	20
4	Lafayette	U	3.2 Mi. E of Rt M	24	40	unknown	1960	1987	27**
4	Lafayette	U	0.35 Mi. S Jct U & M	24		unknown	1960	1987	27**
4	Lafayette	23	1.8 Mi. S of Rt PP	24	40	unknown	1934	1986	52
4	Lafayette	23	1.9 Mi. S of Rt PP	24	40	unknown	1934	1986	52
4	Lafayette	23	0.5 Mi. S of Rt PP	30	40	unknown	1934	1986	52
4	Lafayette	131	0.85 Mi. S of Rt U	18	40	unknown	1931	1986	55
4	Lafayette	131	0.75 Mi. S of Rt U	18	40	unknown	1931	1986	55
4	Lafayette	131	0.35 Mi. S of Rt OO	24		14	1931	1987	56**
4	Lafayette	FF	1.1 Mi. E of Johnson Co Line	24	44	unknown	1949	1987	38**
4	Pettis	D	1.9 Mi. E of Rt 127	24	34	14	1934	1987	53**
4	Pettis	D	1.7 Mi. E of Rt 127	18	40	16	1934	1987	53**
4	Pettis	D	1.5 Mi. W of Rt 127	30	45	14	1934	1987	53**
4	Pettis	D	0.4 Mi. E of Rt 7	29x42	40	unknown	1934	1986	52
4	Pettis	D	3.6 Mi E of Rt T	36		12	1934	1987	53**
4	Pettis	D	2.3 Mi. E of Rt T	24		14	1934	1987	53**
4	Pettis	D	2.3 Mi. E of Rt FF	30		14	1934	1987	53**
4	Pettis	D	1.7 Mi. of Rt FF	24		unknown	1934	1987	53**
4	Pettis	D	4 Mi. E of Rt FF	36		12	1934	1987	53**
4	Pettis	D	2 Mi. E of Rt FF	36		12	1934	1987	53**
4	Pettis	J	8.4 Mi. E of Rt 65	24	60	unknown	1932	1986	54
4	Pettis	J	9.3 Mi. E of Rt 65	18	44	16	1939	1986	47
4	Pettis	J	0.2 Mi. E of Rt 65	30		14	1933	1987	54**
4	Pettis	J&N	At Jct Rtes J & N	36	73	14	1932	1986	54
4	Pettis	M	.3 Mi. E of Rt V	15	46	unknown	1950	1986	36
4	Pettis	M	0.3 Mi. W of Rt V	15	46	unknown	1940	1986	46
4	Pettis	V	Jct Rt U & V (West)	36x21		14	1950	1987	37**
4	Pettis	V	Jct Rt V & U (East)	15		16	1950	1987	37**
4	Pettis	V	1.7 Mi. E of Rt U	30		unknown	1950	1987	37**

4	Pettis	V	0.5 Mi. E of Rt 65	30		14	1950	1987	37**
4	Pettis	Y	1 Mi. E of Rt 127	48	34	12	1953	1987	34**
4	Pettis	Y	1.0 Mi. E of Johnson Co Line	54		unknown	1955	1987	32**
4	Pettis	AA	0.6 Mi. W of Rt 127	30		unknown	1952	1987	35**
4	Pettis	AA	0.9 Mi. W of Rt 127	24	40	16	1952	1987	35**
4	Pettis	AA	1.4 Mi. W of Rt 127	24	40	16	1952	1986	34
4	Pettis	AA	1.5 Mi. W of Rt 127	30	45	14	1952	1987	35
4	Pettis	CC	2.2 Mi. E of Rt K	48	60	unknown	1956	1986	30
4	Pettis	CC	0.65 Mi E of Rt k	24	40	unknown	1956	1986	30
4	Pettis	127	3 Mi. S of Rt 50	25x34	40	14	1930	1986	56
4	Pettis	127	3.4 Mi. S of Rt 50	24	40	16	1930	1986	56
4	Pettis	127	3.5 Mi. S of Rt 50	25x34	40	14	1930	1986	56
4	Pettis	127	0.1 Mi. N of Rt D	24	40	unknown	1934	1986	52
4	Pettis	127	1.0 Mi S of Rt Y	24		14	1930	1987	57**
4	Saline	C	1.1 Mi. N of Rt 240	30	40	16	1933	1986	53
4	Saline	C	10.7 Mi. NW of Rt 240	30		16	1933	1986	53
4	Saline	C	9.3 Mi. NW of Rt 240	18	30	16	1933	1986	53
4	Saline	C	2.6 Mi. NW of Rt 240	36	40	16	1933	1986	53
4	Saline	C	2.55 Mi. MW of Rt 240	48	40	16	1933	1986	53
4	Saline	C	1.3 Mi NW of Rt 240	18	34	16	1933	1986	53
4	Saline	P	8.2 Mi. E of Jct Rt D & P	15	40	16	1960	1986	26
4	Saline	P	3.9 Mi. E of Jct Rt D & P	15	30	16	1947	1986	39
4	Saline	P	0.6 Mi. E of Jct E & P	18	30	16	1947	1986	39
4	Saline	127	2.8 Mi. S of Rt 65	36	42	12	1934	1987	53**
4	Saline	127	4.0 Mi. S of Rt 65	24		unknown	1934	1987	53**
4	Saline	127	3.8 Mi. S of Rt 65	36	54	12	1934	1987	53**
4	Saline	127	2.9 Mi. S of Rt 65	28	36	14	1934	1987	53**

**PIPE TO BE REPLACED DURING 1987 SUMMER

5	Boone	Z	2.18 Mi. S of Rt I-70	24	34	unknown	1933	1987	54
5	Boone	Z	3.37 Mi. S of Rt I-70	18	34	unknown	1933	1987	54
5	Boone	Z	4.99 Mi. S of Rt I-70	18	32	16	1933	1987	54
5	Boone	Z	4.99 Mi. S of Rt I-70	21	32	16	1933	1987	54
5	Boone	Z	5.64 Mi. S of Rt I-70	21	32	unknown	1933	1987	54
5	Boone	Z	5.64 Mi. S of Rt I-70	24	32	unknown	1933	1987	54
5	Boone	Z	7.39 Mi. S of Rt I-70	21	34	unknown	1933	1987	54
5	Boone	Z	9.72 Mi. S of Rt I-70	18	34	unknown	1933	1987	54
5	Boone	Z	10.00 Mi. S of Rt I-70	15	34	unknown	1933	1987	54
5	Boone	Z	11.23 Mi. S of Rt I-70	18	32	unknown	1947	1987	40
5	Boone	Z	11.71 Mi. S of Rt I-70	24	35	unknown	1947	1987	40
5	Boone	Z	12.49 Mi. S of Rt I-70	24	34	unknown	1947	1987	40
5	Boone	Z	12.91 Mi. S of Rt I-70	24	36	unknown	1947	1987	40
5	Boone	Z	13.09 Mi. S of Rt I-70	24	38	14	1950	1987	37
5	Boone	Z	17.16 Mi. S of Rt I-70(S Culv)	18	36	16	1936	1987	51
5	Boone	Z	17.16 Mi. S of Rt I-70(N Culv)	18	36	16	1936	1987	51
5	Boone	Z	17.39 Mi. S of Rt I-70(S Culv)	24	36	unknown	1936	1987	51
5	Boone	Z	17.39 Mi. S of Rt I-70(N Culv)	24	36	unknown	1936	1987	51
5	Boone	Z	17.45 Mi. S of Rt I-70	24	36	14	1936	1987	51
5	Boone	Z	17.62 Mi. S of Rt I-70	18	36	unknown	1936	1987	51
5	Boone	Z	18.05 Mi. S of Rt I-70	18	34	unknown	1936	1987	51
5	Boone	Z	18.23 Mi. S of Rt I-70	18	34	unknown	1936	1987	51

5	Boone	Z	19.09 Mi. S of Rt I-70	18	34	16	1936	1987	51
5	Callaway	D	5.040 Mi. S of Rt I-70	15	42	unknown	1932	1987	55
5	Callaway	D	5.786 Mi. S of Rt I-70	15	40	unknown	1932	1987	55
5	Callaway	D	7.061 Mi. S of Rt I-70	15	40	unknown	1932	1987	55
5	Callaway	D	9.307 Mi. S of Rt I-70	15	37	unknown	1932	1987	55
5	Callaway	D	0.804 Mi. S of Rt I-70	30	38	unknown	1962	1987	25
5	Callaway	D	1.268 Mi. S of Rt I-70	24	42	unknown	1962	1987	25
5	Montgomery	A	7.30 Mi. E of Rt 19	18	38	unknown	1936	1987	51
5	Montgomery	A	7.81 Mi. E of Rt 19	18		unknown	1936	1987	51
6	Franklin	H	0.74 Mi. S of Rt 50	15	28	16	1933	1987	54*
6	Franklin	185	1.04 Mi. N of Rt 50	18	36	16	1938	1987	49*
6	Franklin	185	3.8 Mi. N of Rt 50	18	36	16	1938	1987	49*
6	Franklin	185	4.01 Mi. N of Rt 50	18	36	16	1938	1987	49*
6	Gasconade	A	11.69 Mi. S of Rt. 50	18	36	16	1932	1987	55*
6	Gasconade	A	7.13 Mi. S of Rt. 50	36	36	12	1952	1987	35*
6	Gasconade	A	7.41 Mi. S of Rt. 50	18	30	16	1952	1987	35*
6	Gasconade	E	0.53 Mi. E of Rt. 19	36	40	10	1931	1987	56*
6	Gasconade	E	0.98 Mi. E of Rt 19	18	26	16	1931	1987	56*
6	Gasconade	E	1.16 Mi. E of Rt 19	18	48	16	1931	1987	56*
6	Gasconade	E	1.43 Mi. E of Rt 19	18	33	16	1931	1987	56*
6	Gasconade	E	3.69 Mi. E of Rt. 19	18	36	16	1931	1987	56*
6	Gasconade	E	4.52 Mi. E of Rt. 19	18	44	16	1931	1987	56*
6	Gasconade	E	5.26 Mi. E of Rt 19	18	34	16	1931	1987	56*
6	Gasconade	E	5.50 Mi. E of Rt. 19	18	36	16	1931	1987	56*
6	Gasconade	P	0.83 Mi. No of Rt. 28	18	44	16	1955	1987	32*
6	Gasconade	P	0.84 Mi. N of Rt. 28	24	42	16	1955	1987	32*
6	Gasconade	P	2.55 Mi. N of Rt. 28	18	36	16	1955	1987	32*
6	Gasconade	P	2.86 Mi. N of Rt. 28	18	40	16	1955	1987	32*
6	Gasconade	P	4.15 Mi. N of Rt 28	12	38	16	1955	1987	32*
6	Gasconade	V	0.4 Mi. E of Rt 19	30	42	14	1962	1987	25*
6	Gasconade	V	1.04 Mi. E of Rt 19	18	34	16	1962	1987	25*
6	Gasconade	V	3.86 Mi. E of Rt 19	18	46	16	1962	1987	25*
6	Gasconade	V	4.65 Mi. E of Rt 19	18	38	16	1961	1987	26*
6	Gasconade	Y	7.09 Mi. W of Rt 28	18	38	16	1957	1987	30*
6	Gasconade	Y	7.23 Mi. W of Rt 28	15	34	16	1957	1987	30*
6	Gasconade	Y	8.73 Mi. W of Rt 28	18	36	16	1957	1987	30*
6	Gasconade	Y	8.86 Mi. W of Rt 28	18	38	16	1957	1987	30*
6	Gasconade	Y	7.8 Mi. W of Rt. 28	36	50	12	1957	1987	30*
6	Gasconade	Y	8.92 Mi. W of Rt 28	15	34	16	1957	1987	30*
6	Jefferson	Y	0.75 Mi. S of Rt 30	18	34	16	1940	1987	47*
6	Gasconade	EE	2.85 Mi. N of Crawford Co Line	18	34	16	1963	1987	24*
6	Gasconade	EE	5.57 Mi. N of Crawford Co Line	18	38	16	1963	1987	24*
6	Gasconade	EE	9.2 Mi. N of Crawford Co Line	30	40	14	1963	1987	24*
6	Gasconade	100	3.97 Mi. W of Rt 19	18	30	16	1934	1987	53*
6	Gasconade	100	3.89 Mi. W. of Rt 19	30	36	14	1934	1987	53*
6	Gasconade	100	11.30 Mi. W of Rt. 19	18	60	16	1935	1987	52*
6	St Charles	D	0.86 Mi. E of Rt T	18	34	16	1936	1987	51*
6	Warren	U	1.60 Mi. S of Rt MM	24	34	14	1955	1987	32*
6	Warren	47	1.17 Mi. S of Rt. N	24	48	unknown	1932	1987	55 *

*TO BE REPLACED DURING THE SUMMER OF 1987

NOTE: The following list is pipe replaced in District 6 under Contract in 1986
Project 6-S-T-787. Data taken from 2B sheets.

6	St Charles	T	Sta. 110+76	30	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 117+64	18	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 165+19	24	68	Unknown	1935	1986	51
6	St Charles	T	Sta. 165+78	24	76	Unknown	1935	1986	51
6	St Charles	T	Sta. 226+97	24	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 251+88	24	40	Unknown	1935	1986	51
6	St Charles	T	Sta. 262+30	18	40	Unknown	1935	1986	51
6	St Charles	T	Sta. 270+31	48	36	Unknown	1935	1986	51
6	St Charles	T	Sta. 332+50	18	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 344+47	18	46	Unknown	1935	1986	51
6	St Charles	T	Sta. 390+59	24	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 438+53	18	34	Unknown	1935	1986	51
6	St Charles	T	Sta. 441+18	36	42	Unknown	1935	1986	51
6	St Charles	T	Sta. 514+00	18	32	Unknown	1935	1986	51
6	St Charles	T	Sta. 540+88	12	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 556+70	24	34	Unknown	1949	1986	37
6	St Charles	T	Sta.572+63	21	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 602+66	12	28	Unknown	1949	1986	37
6	St Charles	T	Sta. 620+33	12	28	Unknown	1949	1986	37
6	St Charles	T	Sta. 632+70	15	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 639+06	18	32	Unknown	1949	1986	37
6	St Charles	T	Sta. 650+82	18	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 661+14.8	12	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 670+82.5	12	36	Unknown	1949	1986	37
6	St Charles	T	Sta. 687+00	12	34	Unknown	1949	1986	37
6	St Charles	T	Sta. 741+54.5	36	34	Unknown	1949	1986	37
6	St Charles	T	Sta. 749+53.8	42	38	Unknown	1949	1986	37
6	St Charles	T	Sta. 756+19	48	76	Unknown	1949	1986	37
6	St Charles	T	Sta. 761+80	42	32	Unknown	1949	1986	37
6	St Charles	T	Sta. 793+95	18	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 807+57.9	12	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 895+00	18	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 852+57	24	24	Unknown	1949	1986	37
6	St Charles	T	Sta. 865+65	18	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 882+22	15	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 886+64	15	30	Unknown	1949	1986	37
6	St Charles	T	Sta. 945+00	12	36	Unknown	1949	1986	37
6	St Charles	T	Sta. 979+00	18	38	Unknown	1949	1986	37

NOTE: The following list is pipe replaced under contract in 1987,
Project F-19-3(5) Sec B

6	Gasconade	19	Sta. 538+40	18	40	Unknown	1930	1987	57
6	Gasconade	19	Sta. 538+75	18	41	Unknown	1930	1987	57
6	Gasconade	19	Sta. 547+50	18	44	Unknown	1930	1987	57

NOTE: The following list is pipe replaced or relined under contract in 1987,
Project RS-681(5)

6	Gasconade	19	Sta. 12+00	18	41	16	1936	1987	51

6	Gasconade	19	Sta. 27+98	18	46	16	1936	1987	51
6	Gasconade	19	Sta. 38+00	18	45	16	1936	1987	51
6	Gasconade	19	Sta. 87+65	18	52	16	1936	1987	51
6	Gasconade	19	Sta. 99+00	18	48	16	1936	1987	51
6	Gasconade	19	Sta. 101+85	24	75	16	1936	1987	51
6	Gasconade	19	Sta. 108+00	18	46	16	1936	1987	51
6	Gasconade	19	Sta. 148+39	18	42	16	1936	1987	51
6	Gasconade	19	Sta. 157+00	18	39	16	1936	1987	51
6	Gasconade	19	Sta. 167+66	18	41	16	1936	1987	51
6	Gasconade	19	Sta. 172+00	18	41	16	1936	1987	51
6	Gasconade	19	Sta. 178+00	18	42	16	1936	1987	51
6	Gasconade	19	Sta. 189+00	18	50	16	1936	1987	51
6	Gasconade	19	Sta. 199+36	18	41	16	1936	1987	51
6	Gasconade	19	Sta. 208+35	18	52	16	1936	1987	51
6	Gasconade	19	Sta. 228+00	18	41	16	1936	1987	51
6	Gasconade	19	Sta. 232+85	24	57	14	1936	1987	51
6	Gasconade	19	Sta. 243+13	18	41	16	1936	1987	51
6	Gasconade	19	Sta. 269+70	18	40	16	1936	1987	51
6	Gasconade	19	Sta. 296+35	30	44	14	1936	1987	51
6	Gasconade	19	Sta. 308+19	24	44	14	1937	1987	50
6	Gasconade	19	Sta. 318+45	18	41	16	1937	1987	50
6	Gasconade	19	Sta. 329+55	24	50	14	1937	1987	50
6	Gasconade	19	Sta. 335+10	18	35	16	1937	1987	50
6	Gasconade	19	Sta. 338+43	18	39	Unknown	1937	1987	50
6	Gasconade	19	Sta. 379+20	36	41	12	1937	1987	50

NOTE: The following list is pipe replaced or relined under contract in 1987,
Project F-19-2(9), Sec A & B

6	Gasconade	19	Sta. 108+67	18	46	Unknown	1932	1987	55
6	Gasconade	19	Sta. 113+61	18	45	Unknown	1932	1987	55
6	Gasconade	19	Sta. 139+72	18	60	Unknown	1932	1987	55
6	Gasconade	19	Sta. 144+55	18	42	Unknown	1932	1987	55
6	Gasconade	19	Sta. 153+98	18	57	Unknown	1932	1987	55
6	Gasconade	19	Sta. 187+68	18	47	Unknown	1932	1987	55
6	Gasconade	19	Sta. 203+00	18	48	Unknown	1932	1987	55
6	Gasconade	19	Sta. 210+00	18	44	Unknown	1932	1987	55
6	Gasconade	19	Sta. 227+50	18	44	Unknown	1932	1987	55
6	Gasconade	19	Sta. 304+56	18	41	Unknown	1932	1987	55
6	Gasconade	19	Sta. 353+30	18	50	Unknown	1932	1987	55
6	Gasconade	19	Sta. 367+54	18	57	Unknown	1932	1987	55
6	Gasconade	19	Sta. 372+70	18	53	Unknown	1932	1987	55
6	Gasconade	19	Sta. 386+00	18	47	Unknown	1932	1987	55
6	Gasconade	19	Sta. 412+68	18	47	Unknown	1932	1987	55
6	Gasconade	19	Sta. 425+00	24	44	Unknown	1932	1987	55
6	Gasconade	19	Sta. 428+47	18	50	Unknown	1932	1987	55
6	Gasconade	19	Sta. 503+64	18	77	Unknown	1932	1987	55
6	Gasconade	19	Sta. 510+25	24	76	Unknown	1932	1987	55

NOTE: The following list is pipe replaced or relined under contract in 1987,
Project F-19-3(5), Sec A

6	Gasconade	19	Sta. 75+00	18	50	16	1931	1987	56

6	Gasconade	19	Sta. 91+50	15	55	16	1931	1987	56
6	Gasconade	19	Sta. 105+80	18	65	Unknown	1931	1987	56
6	Gasconade	19	Sta. 112+30	18	51	Unknown	1931	1987	56
6	Gasconade	19	Sta. 127+30	18	52	Unknown	1931	1987	56
6	Gasconade	19	Sta. 136+25	18	68	Unknown	1931	1987	56
6	Gasconade	19	Sta. 139+75	18	51	Unknown	1931	1987	56
6	Gasconade	19	Sta. 147+20	18	76	Unknown	1931	1987	56
6	Gasconade	19	Sta. 149+50	15	55	16	1931	1987	56
6	Gasconade	19	Sta. 157+15	18	48	Unknown	1931	1987	56
6	Gasconade	19	Sta. 169+60	18	60	Unknown	1931	1987	56
6	Gasconade	19	Sta. 177+50	18	52	Unknown	1931	1987	56
6	Gasconade	19	Sta. 180+05	18	45	Unknown	1931	1987	56
6	Gasconade	19	Sta. 185+00	18	68	Unknown	1931	1987	56
6	Gasconade	19	Sta. 196+75	18	48	Unknown	1931	1987	56
6	Gasconade	19	Sta. 199+90	18	71	Unknown	1931	1987	56
6	Gasconade	19	Sta. 207+50	18	43	Unknown	1930	1987	57
6	Gasconade	19	Sta. 216+67	18	58	Unknown	1930	1987	57
6	Gasconade	19	Sta. 224+00	18	44	Unknown	1930	1987	57
6	Gasconade	19	Sta. 226+50	18	50	Unknown	1930	1987	57
6	Gasconade	19	Sta. 234+50	18	45	Unknown	1930	1987	57
6	Gasconade	19	Sta. 238+50	18	54	Unknown	1930	1987	57
6	Gasconade	19	Sta. 245+60	24	51	Unknown	1930	1987	57
6	Gasconade	19	Sta. 252+23	12	50	Unknown	1930	1987	57
6	Gasconade	19	Sta. 262+96	15	45	Unknown	1930	1987	57
6	Gasconade	19	Sta. 265+10	18	54	Unknown	1930	1987	57
6	Gasconade	19	Sta. 275+60	24	62	Unknown	1930	1987	57
6	Gasconade	19	Sta. 282+90	18	49	Unknown	1930	1987	57
6	Gasconade	19	Sta. 289+50	18	85	Unknown	1930	1987	57
6	Gasconade	19	Sta. 297+63	15	61	Unknown	1930	1987	57
6	Gasconade	19	Sta. 300+30	18	48	Unknown	1930	1987	57
6	Gasconade	19	Sta. 303+50	18	43	Unknown	1930	1987	57
6	Gasconade	19	Sta. 309+20	18	58	Unknown	1930	1987	57
6	Gasconade	19	Sta. 321+85	18	67	Unknown	1930	1987	57
6	Gasconade	19	Sta. 334+55	18	49	Unknown	1930	1987	57
6	Gasconade	19	Sta. 338+20	18	63	Unknown	1930	1987	57
6	Gasconade	19	Sta. 340+25	18	61	Unknown	1930	1987	57
6	Gasconade	19	Sta. 355+10	18	52	Unknown	1930	1987	57
6	Gasconade	19	Sta. 364+45	18	64	Unknown	1930	1987	57
6	Gasconade	19	Sta. 374+65	18	43	Unknown	1930	1987	57
6	Gasconade	19	Sta. 392+20	18	53	Unknown	1930	1987	57
6	Gasconade	19	Sta. 406+90	18	55	Unknown	1930	1987	57
6	Gasconade	19	Sta. 430+70	18	65	Unknown	1930	1987	57
6	Gasconade	19	Sta. 464+00	18	44	Unknown	1930	1987	57
6	Gasconade	19	Sta. 478+20	18	52	Unknown	1930	1987	57
6	Gasconade	19	Sta. 479+60	18	54	Unknown	1930	1987	57
6	Gasconade	19	Sta. 494+75	18	45	Unknown	1930	1987	57
6	Gasconade	19	Sta. 502+70	18	52	Unknown	1930	1987	57
8	Laclede	J	1.6 Mi W of Jct 5 & J	24	40	unknown	1948	1987	39
8	Laclede	J	2.7 Mi. W of Jct 5 & J	24	40	unknown	1948	1987	39

8	Laclede	J	2.9 Mi. W of Jct 5 & J	18	36	unknown	1948	1987	39
8	Laclede	J	1.4 Mi. W of Jct 5 & J	30	40	unknown	1948	1987	39
8	Phelps	72	4.3 Mi. S of Jct 72 & P	18	24	unknown	1934	1987	53
8	Stone	13	.2 Mi. S of Jct 13 & 248	15	30	unknown	1934	1987	53

Note: The following list is pipe replaced under contract in Dist. 9 (Job No. 9-S-68-270)
Data taken from 2B sheets

9	Dent	68	Sta. 3+18	18	46	unknown	1933	1986	53
9	Dent	68	Sta. 15+95	24	56	unknown	1933	1986	53
9	Dent	68	Sta. 39+35	24	56	unknown	1933	1986	53
9	Dent	68	Sta. 45+15	18	40	unknown	1933	1986	53
9	Dent	68	Sta. 46+30	18	40	unknown	1933	1986	53
9	Dent	68	Sta. 52+60	18	36	unknown	1933	1986	53
9	Dent	68	Sta. 59+94	24	38	unknown	1933	1986	53
9	Dent	68	Sta. 71+34	18	32	unknown	1933	1986	53
9	Dent	68	Sta. 89+40	18	38	unknown	1933	1986	53
9	Dent	68	Sta. 93+70	18	38	unknown	1933	1986	53
9	Dent	68	Sta. 115+00	18	36	unknown	1933	1986	53
9	Dent	68	Sta. 136+00	18	36	unknown	1932	1986	54
9	Dent	68	Sta. 148+75	18	32	unknown	1932	1986	54
9	Dent	68	Sta. 190+22	24	34	unknown	1932	1986	54
9	Dent	68	Sta. 197+31	18	32	unknown	1932	1986	54
9	Dent	68	Sta. 200+30	18	46	unknown	1932	1986	54
9	Dent	68	Sta. 210+95	18	32	unknown	1932	1986	54
9	Dent	68	Sta. 213+12	24	40	unknown	1932	1986	54
9	Dent	68	Sta. 215+95	24	36	unknown	1932	1986	54
9	Dent	68	Sta. 234+90	18	34	unknown	1932	1986	54
9	Dent	68	Sta. 244+50	24	40	unknown	1932	1986	54
9	Dent	68	Sta. 246+50	24	32	unknown	1932	1986	54
9	Dent	68	Sta. 250+25	18	40	unknown	1934	1986	52
9	Dent	68	Sta. 269+45	18	32	unknown	1934	1986	52
9	Dent	68	Sta. 271+40	18	38	unknown	1934	1986	52
9	Dent	68	Sta. 285+00	30	40	unknown	1934	1986	52
9	Dent	68	Sta. 291+35	30	32	unknown	1934	1986	52
9	Dent	68	Sta. 302+95	24	40	unknown	1934	1986	52
9	Dent	68	Sta. 305+60	18	38	unknown	1934	1986	52
9	Dent	68	Sta. 307+40	18	44	unknown	1934	1986	52
9	Dent	68	Sta. 313+00	18	42	unknown	1934	1986	52
9	Dent	68	Sta. 331+50	24	32	unknown	1934	1986	52
9	Dent	68	Sta. 335+85	18	34	unknown	1934	1986	52
9	Dent	68	Sta. 341+58	24	34	unknown	1934	1986	52
9	Dent	68	Sta. 345+00	24	40	unknown	1934	1986	52
9	Dent	68	Sta. 359+62	30	33	unknown	1934	1986	52
9	Dent	68	Sta. 386+25	18	38	unknown	1934	1986	52
9	Dent	68	Sta. 389+15	18	38	unknown	1934	1986	52
9	Dent	68	Sta. 397+30	18	36	unknown	1934	1986	52
9	Dent	68	Sta. 412+50	30	46	unknown	1934	1986	52
9	Dent	68	Sta. 422+85	18	32	unknown	1934	1986	52
9	Dent	68	Sta. 447+70	18	32	unknown	1934	1986	52
9	Dent	68	Sta. 450+06	18	34	unknown	1934	1986	52
9	Dent	68	Sta. 468+28	24	32	unknown	1934	1986	52

9	Dent	68	Sta. 475+86	18	32	unknown	1934	1986	52
9	Dent	68	Sta. 476+92	18	32	unknown	1934	1986	52
9	Dent	68	Sta. 481+80	18	32	unknown	1934	1986	52

NOTE: The following list of installations were placed under contract in 1985 (Job No. 9-S-95-254, Sec A
Data taken from 28 sheets.

9	Wright	95	Sta. 112+90	18	44	unknown	1933	1985	52
9	Wright	95	Sta. 116+60	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 121+25	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 174+40	18	42	unknown	1933	1985	52
9	Wright	95	Sta. 179+50	24	42	unknown	1933	1985	52
9	Wright	95	Sta. 236+00	18	72	unknown	1933	1985	52
9	Wright	95	Sta. 241+45	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 260+00	18	48	unknown	1933	1985	52
9	Wright	95	Sta. 298+75	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 305+60	18	46	unknown	1933	1985	52
9	Wright	95	Sta. 309+80	24	46	unknown	1933	1985	52

NOTE: The following list of installations were placed under contract in 1985 (Job No. 9-S-95-254, Sec B)
Data taken from 28 sheets.

9	Wright	95	Sta. 317+10	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 330+00	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 333+30	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 341+50	18	48	unknown	1933	1985	52
9	Wright	95	Sta. 376+15	24	48	unknown	1933	1985	52
9	Wright	95	Sta. 382+85	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 387+92	24	46	unknown	1933	1985	52
9	Wright	95	Sta. 406+00	18	38	unknown	1933	1985	52
9	Wright	95	Sta. 419+00	24	40	unknown	1933	1985	52
9	Wright	95	Sta. 434+50	18	46	unknown	1933	1985	52
9	Wright	95	Sta. 482+00	18	42	unknown	1933	1985	52
9	Wright	95	Sta. 503+50	24	40	unknown	1933	1985	52
9	Wright	95	Sta. 507+35	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 516+00	18	44	unknown	1933	1985	52
9	Wright	95	Sta. 519+50	18	42	unknown	1933	1985	52
9	Wright	95	Sta. 525+50	30	46	unknown	1933	1985	52
9	Wright	95	Sta. 529+00	18	48	unknown	1933	1985	52
9	Wright	95	Sta. 537+75	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 542+00	18	44	unknown	1933	1985	52
9	Wright	95	Sta. 546+15	18	50	unknown	1933	1985	52
9	Wright	95	Sta. 568+40	24	38	unknown	1933	1985	52
9	Wright	95	Sta. 578+40	18	42	unknown	1933	1985	52
9	Wright	95	Sta. 583+00	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 609+52	30	46	unknown	1933	1985	52
9	Wright	95	Sta. 614+80	18	42	unknown	1933	1985	52
9	Wright	95	Sta. 622+50	24	42	unknown	1933	1985	52
9	Wright	95	Sta. 645+80	18	44	unknown	1933	1985	52
9	Wright	95	Sta. 649+70	30	50	unknown	1933	1985	52
9	Wright	95	Sta. 662+00	24	42	unknown	1933	1985	52

9	Wright	95	Sta. 669+50	18	40	unknown	1933	1985	52
9	Wright	95	Sta. 680+65	18	46	unknown	1933	1985	52
9	Wright	95	Sta. 687+00	18	46	unknown	1933	1985	52
9	Wright	95	Sta. 690+00	18	50	unknown	1933	1985	52

NOTE: The following list of installations were placed under contract in 1987 (Job No. 9-S-142-253, Rt. 142, Oregon Co.)
Data taken from 2B sheets.

9	Oregon	142	Sta. 177+25	24	44	unknown	1950	1987	37
9	Oregon	142	Sta. 185+23	18	54	unknown	1950	1987	37
9	Oregon	142	Sta. 195+25	18	52	unknown	1950	1987	37
9	Oregon	142	Sta. 200+50	18	42	unknown	1950	1987	37
9	Oregon	142	Sta. 206+50	18	42	unknown	1950	1987	37
9	Oregon	142	Sta. 212+45	18	46	unknown	1950	1987	37
9	Oregon	142	Sta. 217+00	18	46	unknown	1950	1987	37
9	Oregon	142	Sta. 230+30	18	46	unknown	1950	1987	37
9	Oregon	142	Sta. 238+10	18	46	unknown	1950	1987	37
9	Oregon	142	Sta. 243+80	18	48	unknown	1950	1987	37
9	Oregon	142	Sta. 254+68	18	54	unknown	1950	1987	37
9	Oregon	142	Sta. 262+80	30	46	unknown	1950	1987	37
9	Oregon	142	Sta. 278+75	18	40	unknown	1950	1987	37
9	Oregon	142	Sta. 283+90	18	44	unknown	1950	1987	37
9	Oregon	142	Sta. 299+25	18	46	unknown	1950	1987	37
9	Oregon	142	Sta. 302+20	18	44	unknown	1950	1987	37
9	Oregon	142	Sta. 306+47	24	44	unknown	1950	1987	37
9	Oregon	142	Sta. 310+65	B-10 Arch	80	unknown	1950	1987	37
9	Oregon	142	Sta. 316+00	18	56	unknown	1950	1987	37
9	Oregon	142	Sta. 330+00	B-8 Arch	92	unknown	1950	1987	37
9	Oregon	142	Sta. 336+53	18	48	unknown	1950	1987	37
9	Oregon	142	Sta. 346+80	18	54	unknown	1950	1987	37
9	Oregon	142	Sta. 358+50	30	80	unknown	1950	1987	37
9	Oregon	142	Sta. 368+95	18	40	unknown	1950	1987	37
9	Oregon	142	Sta. 380+13	B-5 Arch	192	unknown	1950	1987	37
9	Oregon	142	Sta.401+50	18	40	unknown	1950	1987	37
9	Oregon	142	Sta. 406+20	B-5 Arch	40	unknown	1950	1987	37
9	Oregon	142	Sta. 409+63	B-5 Arch	38	unknown	1950	1987	37
9	Oregon	142	Sta. 411+00	B-5 Arch	38	unknown	1950	1987	37
9	Oregon	142	Sta. 425+35	18	40	unknown	1950	1987	37
9	Oregon	142	Sta. 436+50	24	42	unknown	1950	1987	37
9	Oregon	142	Sta. 438+35	24	42	unknown	1950	1987	37
9	Oregon	142	Sta. 448+15	24	40	unknown	1950	1987	37
9	Oregon	142	Sta. 462+70	B-5 Arch	42	unknown	1950	1987	37
9	Oregon	142	Sta. 468+20	18	42	unknown	1950	1987	37
9	Oregon	142	Sta. 482+00	42	42	unknown	1951	1987	36
9	Oregon	142	Sta. 487+40	18	40	unknown	1951	1987	36
9	Oregon	142	Sta. 494+80	18	40	unknown	1951	1987	36
9	Oregon	142	Sta. 503+50	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 506+90	18	50	unknown	1951	1987	36
9	Oregon	142	Sta. 515+55	18	52	unknown	1951	1987	36
9	Oregon	142	Sta. 527+00	18	56	unknown	1951	1987	36
9	Oregon	142	Sta. 536+00	18	40	unknown	1951	1987	36

9	Oregon	142	Sta. 539+50	18	46	unknown	1951	1987	36
9	Oregon	142	Sta. 556+50	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 577+50	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 581+70	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 589+00	18	8	unknown	1951	1987	36
9	Oregon	142	Sta. 593+90	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 598+50	18	42	unknown	1951	1987	36
9	Oregon	142	Sta. 602+50	18	42	unknown	1951	1987	36
9	Oregon	142	Sta. 613+50	18	42	unknown	1951	1987	36
9	Oregon	142	Sta. 624+50	18	46	unknown	1951	1987	36
9	Oregon	142	Sta. 631+70	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 638+00	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 642+00	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 652+00	18	50	unknown	1951	1987	36
9	Oregon	142	Sta. 657+75	18	40	unknown	1951	1987	36
9	Oregon	142	Sta. 659+75	36	12	unknown	1951	1987	36
9	Oregon	142	Sta. 669+16	18	58	unknown	1951	1987	36
9	Oregon	142	Sta. 672+60	24	68	unknown	1951	1987	36
9	Oregon	142	Sta. 675+90	18	54	unknown	1951	1987	36
9	Oregon	142	Sta. 681+50	18	50	unknown	1951	1987	36
9	Oregon	142	Sta. 688+00	18	52	unknown	1951	1987	36
9	Oregon	142	Sta. 697+75	18	48	unknown	1951	1987	36
9	Oregon	142	Sta. 703+35	18	46	unknown	1951	1987	36
9	Oregon	142	Sta. 706+30	18	44	unknown	1951	1987	36
9	Oregon	142	Sta. 715+00	18	24	unknown	1951	1987	36
9	Oregon	142	Sta. 750+00	24	52	unknown	1951	1987	36
9	Oregon	142	Sta. 758+18	18	46	unknown	1951	1987	36
9	Oregon	142	Sta. 761+08	24	46	unknown	1951	1987	36
9	Oregon	142	Sta. 772+25	18	48	unknown	1951	1987	36
9	Oregon	142	Sta. 3+00	18	44	unknown	1951	1987	36
10	Bollinger	N	0.6 Mi. E of Jct N & 51	30	42	14	1932	1986	54
10	Bollinger	N	Jct Rt N & Rt N(spur)	18	36	16	1932	1986	54
10	Bollinger	N	4 Mi. E of Rt 51	15	32	14	1932	1987	55
10	Bollinger	N	1.1 Mi. E of Rt 51	15	44	16	1932	1987	55
10	Bollinger	T	0.6 Mi. E of Rt 91	48	50	12	1952	1987	35
10	Bollinger	34	0.2 Mi. W of Rt DD	15	32	14	1927	1986	59
10	Madison	H	0.8 Mi. E of Rt K	B-8	104	12	1956	1985	29
10	MississiCCi	AA	1.5 Mi. N of Rt 77	24	38	14	1936	1987	51
10	Mississippi	102	0.2 Mi. N of Rt A.	24	36	14	1937	1987	50
10	Pemiscot	Z	0.7 Mi. S of Rt J	24	36	14	1932	1987	55
10	Wayne	Z	4.9 Mi. NE Jct Rt 2 & D	15	36	16	1958	1987	29

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APPENDIX F

CULVERT PIPE REFERENCES

CULVERT PIPE REFERENCES

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APPENDIX G

EXTRACTS FROM SELECTED REFERENCES

Materials and Research Review of: Transportation Research Record 1001, Symposium on Durability of Culverts and Storm Drains, 1984

Culvert Durability: Where Are We? George W. Ring - FHWA

This paper is a general discussion of durability of culvert pipe. He states "...it can be anticipated that with proper care the primary and Interstate roadways could well be in service 100 years from now."

He recognizes that prediction of the probable service life of all types of culverts is difficult because of continuing changes in materials, the use of various coatings, and the large number of variables that affect corrosion and erosion. No nationally acceptable relationship between culvert service life and corrosion parameters has been developed.

Ring listed some conclusions from an FHWA sponsored study on coatings:

1. Durability problems are encountered with all protective coatings now commonly used.

2. Alternate methods are available to protect culverts, other than organic coatings, and could have been used to advantage at many of the locations inspected in the field study.

3. Organic coatings are, by themselves, not satisfactory under abrasive stream flow conditions.

4. The durability of polymer coatings depends on the amount of salts in the soil or water, the continuity of the coating, the pH, and the abrasiveness of the bedload. Improvements are needed in production techniques to prevent damage that adversely affects performance. Polymer coatings are satisfactory where abrasive flows and high salt conditions are not encountered.

5. Asphalt adhesion to aluminum is poor. This coating would not be satisfactory in abrasive or corrosive environments.

6. Epoxy coatings and vitrified clay liners are effective when used on concrete in acidic streams. They might also be useful on corrugated metal under certain severe conditions.

7. Adhesion between asphalt and galvanized steel can be improved through the use of surface treatments and primers. The benefits of improved adhesion should be evaluated.

8. Asbestos-bonded asphalt coating is more durable than plain asphalt coating, but it is also subject to deterioration in abrasive or high salt environments.

9. The durability of asphalt coatings is influenced by application procedures, adhesion to the substrate, seasonal temperature changes, water absorption, turbulence in the stream flow, and abrasiveness of the bedload. Asphalt is satisfactory where abrasive flows and high salt conditions are not encountered.

10. Asphalt mastic is not a durable coating.

11. Asphalt composition varies widely depending on the source of crude oil. Performance variations of culvert asphalt are attributable to the water absorption and abrasion properties of asphalt and current methods of application.

12. There are several alternative coatings that should be evaluated for use on culverts. These coatings, while more expensive than current culvert coatings, could be cost effective for selected applications, such as on inverts.

13. Many state and AASHTO specifications should be made more specific.

Durability of Polymer-Coated Corrugated Steel Pipe, Carl M. Hirsch - National Corrugated Steel Pipe Association.

This paper discusses various polymer coatings. It also states the reason for coating the galvanized CMP is to increase its service life and to provide durability in severe environments.

Hirsch describes field tests of Coal-Tar-Based Resins (Nexon), Ethylene-Acrylic Acid, and PVC Plastisol (Bethlehem's PC). The field tests are all rated good to excellent and the effects of abrasion are minimized.

This author differs considerably from the New York DOT paper which reviews the same test sections at Genessee, New York. The New York DOT rated this coating as very poor.

No service life predictions are made. All the discussions are based on 9 years or less exposure.

Durability of Drainage Structures, Kenneth M. Jacobs - Maine DOT

The objective of this study was to evaluate the durability of several culvert materials. Erosion or abrasion are not considered problems in Maine due to flat slopes.

Galvanized CMP was estimated to be 28 years in 16 gage.

Bituminous coating and paving was found to add approximately 7 to 8 years to the life of galvanized CMP.

Reinforced Concrete Pipe was estimated to have a service life of 65 to 70 years. Two problems were found, mechanical failure of the outside 4 foot lengths of pipe due to frost heave and deterioration in pH less than 5.3.

Clad-Aluminum Alloy Pipe was estimated to have a service life of 100+ years in 16 gage. There were some problems with excessive deflection, also, the pH was normal (7±) and electrical resistivity was high (10,000 ohms/cm or over). This pipe was found to be the best of the metal pipe.

Aluminum-Coated CMP was found to have the coating overstressed in the rerolled ends. No service life estimated.

Aluminum-Zinc Coated CMP has performed better than zinc-coatings at sites where both coating systems were installed. No service life estimated.

Polymeric coatings at 5 and 10 years were found to have no delamination from the underlying zinc and the water side was found to be in near original shape. No service life estimate.

Epoxy Coated CMP at 2 years old were found to be in nearly original condition. No service life estimate.

Overview of Polymer Coatings for Corrugated Steel Pipe in New York, Robert M. Pyskadlo and Wallace W. Renfrew - New York DOT

Reports on the field performance of polymer coated pipe installed since 1977.

Within a few months of installation, Nexon coated pipe failed due to abrasion and caused New York to cease use of polymer coatings.

After six years the Beth-Cu-Loy PC coating were performing better than Nexon.

After 6 years at the most abrasive test site, 11 of 57 pipe were given a "5" rating (the worse rating possible in this study) meaning coating had peeled off in sheets with coating removed at crests of corrugations. Eight more were rated 3 or 4 which indicated fair to moderate abrasion damage.

In this report reference was made to 14 and 16 gage bituminous coated and paved pipe being prohibited in Southern New York.

Durability of Asphalt Coating and Paving on Corrugated Steel Culverts in New York, Wallace W. Renfrew - New York DOT

New York concluded that bituminous paving adds approximately 30 years life to round pipe and approximately 20 years on pipe-arches. The end point was considered to be when 50 percent of the bituminous paving was gone.

The data presented in the report does not substantiate an expected 30 year service. Of 127 pipe, 69 had failed at 15 years and they started failing at 5 years.

This report refers to a Kansas DOT study by Worley that revealed inside bituminous coatings were good on only 12 percent of 3 and 4 year old pipe. That report concluded bituminous coatings were of little value. A 1978 survey of the other 49 states indicated that few states use coated pipe and those that do assign only 7 to 9 years life to it.

Field Performance of Protective Linings for Concrete and Corrugated Steel Pipe Culverts. John Owen Hurd - Ohio DOT

Report deals with a variety of coatings for concrete and corrugated metal pipe. No life expectancy was projected for any of the coatings.

Found concrete pipe with an epoxy coating performed well at low pH sites and with none to moderate abrasion. The epoxy coating also deteriorates in sunlight at the ends of the pipe.

Found abrasion to be the major factor with polymer coated pipe with poor ratings achieved in as little as one year. Delamination along the lock seam has been noted on 24 of 48 pipe occurring from time of installation to 13 years.

Found asbestos-bonded bituminous coated and paved CMP to be performing satisfactorily after 12 years. Slow erosion of paving due to abrasion. Loss of coating occurs when paving is overtopped by flow. Satisfactory protection in none to moderate abrasion.

Fourteen concrete pipe with vitrified clay liners were found to be in very good condition at ages 3 to 12 years, in extremely acidic flow.

Field Performance of Concrete and Corrugated Steel Pipe Culverts and Bituminous Protection of Corrugated Steel Pipe Culverts.
John Owen Hurd - Ohio DOT

This study found bituminous coatings to have an average life of 3 years and a median life of 1.5 years.

Bituminous paving was found to have an average life of 12+ years and a median life of 10+ years.

Galvanized CMP was rated by metal loss. Graphs would indicate a 16 gage (0.064 inch thick) CMP would be eroded through in about 42 years in an abrasive condition and a pH of 7. It was noted that water pH and abrasion were the only environmental parameters affecting CMP.

Concrete pipe was projected to have a life expectancy of 100+ years except when pH was lower than 4. In less acidic flow, life expectancy is projected to be much longer.

Comprehensive Evaluation of Aluminized Steel Type 2 Pipe Field Performance. G. E. Morris and L. Bednar - Armco Steel Corp.

Report shows aluminum coating to perform better than zinc coatings after 30 year field tests.

Even though the overall results show superiority of the aluminum coating over zinc, it was pointed out that both coatings are susceptible to abrasion.

Armco discusses performance in severely corrosive environments but the water pH was between 6.2 and 8.1 at all but two culverts and they were 4.6 and 5.5. The resistivity of the water was generally in the "safe" range except at 3 culverts and at those 3 the pH was 7.01, 7.30, and 7.90.

MHTD evaluation of test sites in Missouri also would rate the aluminum coating equal or better than zinc.

Metal Loss Rates of Uncoated Steel and Aluminum Culverts in New York. Peter J. Bellair and James P. Ewing - New York DOT.

This was a study to establish a procedure for estimating life expectancy based on metal loss. This was done in two zones, Northern and Southern.

The metal loss for corrugated steel pipe was estimated to be 2 mils per year in the Northern zone and 4 mils per year in the Southern zone. Aluminum alloy was found to have a loss rate of 0.5 mils per year for both zones.

If New York used a 50 year design life for corrugated steel culverts, it would rule out 14 and 16 gage steel in the Northern zone and rule out all corrugated steel in the Southern zone.

Bacterial Corrosion of Steel Culvert Pipe in Wisconsin.
Robert Patenaude - Wisconsin DOT

Wisconsin tried to use the California procedure to predict expected culvert life, that is to use pH and soil resistivities. They were not successful. They then began a search for other contributing factors for corrosion and came up with anaerobic sulfate-reducing bacteria.

They found the bacteria did not affect concrete pipe or aluminum alloy pipe.

The study showed that corrosion at most culvert sites can be related singly or in combination to bacterial activity, low pH, and low electrical resistivity of soil or water or both at the site.

Galvalume Corrugated Steel Pipe: A Performance Summary.
A. J. Stavros - Bethlehem Steel Corporation.

Laboratory and field tests were used to evaluate the performance of Galvalume coating. Galvalume is 55 percent aluminum and 45 percent zinc.

Results of these evaluations show Al-Zn coatings superior to zinc.

Corrosion Resistance of Aluminum Drainage Products: The First 25 Years. T. J. Summerson - Kaiser Aluminum and Chemical Corporation.

Aluminum Clad Aluminum Alloy pipe has been in service approximately 25 years. Maine found the corrosion rate to be 0.2 mils per year and New York found the corrosion rate to be 0.5 mils per year. At this rate, estimated life would be 300+ years and 120+ years respectively.

The report concludes that Al-Clad Aluminum Alloy pipe should be used where the pH is between 4 and 9 and the resistivity greater than 500 ohm/cm.

Precast Concrete Pipe Durability: State of the Art. Mike Bealey - American Concrete Pipe Association.

Review of the use of concrete pipe. Presents Ohio DOT's graph showing 100+ years of expected life.

In response to discussion, the author's closure stated that a literature search in 1983 showed that 33 states and numerous other researchers had published 131 reports of culvert surveys and material evaluations. Of those reports, 63 percent are concerned with the deterioration and short service life of corrugated metal pipe, 28 percent cover multiple pipe materials, and only 5 percent deal only with concrete.

For Want of Air, A Drainage System Was Nearly Lost. Carl F. Crumpton, Glen M. Koontz, and Barbara J. Smith - Kansas DOT

This report, through example of one failure of a precast concrete flared end section, shows the need for air entrainment.

Innovated Repair of a Large Failing Structural Steel Plate Pipe Arch Culvert. Charles R. Duncan - FHWA

This report is about the repair of a large structural plate arch pipe originally installed in 1969. The 12 gage material had an estimated life of less than 10 years. Repair was effected by inserting a smaller arch pipe and grouting the void between the 2 pipe.

Invert Replacement of Corrugated Metal Structural Plate Pipe. Stephen R. Ikerd - FHWA

Report of the replacement of an invert in an 84-inch diameter bituminous coated pipe. This pipe was installed in 1952, the bituminous coating failed soon due to abrasion. A 4-inch thick bituminous invert was placed but it also abraded quickly. In 1973, a steel plate invert was placed with a mortar bed between the new plate invert and the old pipe invert.

Evaluation of Highway Culvert Coating Performance; Report No. FHWA/BD-80/059, June 1980, Final Report.

CONCLUSIONS

1. Durability problems are encountered with all protective coatings now commonly used.

2. Alternate methods are available to protect culverts other than organic coatings and could have been used to advantage at many of the locations inspected in the field study.

3. Organic coatings are, by themselves, not satisfactory under abrasive stream flow conditions.

4. The durability of polymer coatings depends on the amount of salts in the soil or water, the continuity of the coating, the pH and the abrasiveness of the bedload. Improvements are needed in production techniques to prevent damage which adversely affects performance. Polymer coatings are satisfactory where abrasive flows and high salt conditions are not encountered.

5. Asphalt adhesion to aluminum is poor. This coating would not be satisfactory in abrasive or corrosive environments.

6. Epoxy coatings and vitrified clay liners are effective when used on concrete in acidic streams. They might also be useful on corrugated metal under certain severe conditions.

7. Adhesion between asphalt and galvanized steel can be improved through the use of surface treatments and primers. The benefits of improved adhesion should be evaluated.

8. Asbestos bonded asphalt coating is somewhat more durable than plain asphalt coating but is also subject to deterioration in abrasive or high salt environments.

9. The durability of asphalt coatings is influenced by application procedure, adhesion to the substrate, seasonal temperature changes, water asorption, turbulence in the stream flow and abrasiveness of the bedload. Asphalt is satisfactory where abrasive flows and high salt conditions are not encountered.

10. Asphalt mastic is not a durable coating.

11. Asphalt composition varies widely depending on the source of crude oil. Performance variations of culvert

asphalt are attributable to the water absorption and abrasion properties of asphalt and current methods of application.

12. There are several alternative coatings which should be evaluated for use on culverts. These coatings, while more expensive than current culvert coatings, could be cost effective for selected application such as on inverts.

13. Many state and AASHTO specifications should be made more specific.

Durability of Corrugated Metal Culverts; New York State Department of Transportation, 1965 Survey; Highway Research Record No. 242, pgs 41-55.

CONCLUSIONS

Results of the statewide survey of corrugated steel culverts in service 2 to 35 yr indicate the following:

1. Uncoated culverts have performed satisfactorily from the standpoint of durability. Approximately 70 percent of those in service 25 yr or longer have lost less than one-half of their original thickness. The large majority of existing uncoated culverts can therefore be expected to provide total service of at least 40 yr.
2. Protective bituminous coatings have reduced metal loss significantly, coating/paving being appreciably more effective than coating alone.
3. Metal loss does not correlate with pH, electrical resistivity, chemical concentration, or other soil and water properties, within the limits usually encountered in New York.
4. Metal loss is primarily associated with normal corrosion, abrasion playing but a small part.
5. Culverts should be designed to satisfy durability requirements, in view of the thinner gages permitted by current structural design practices. A suggested design procedure for uncoated, coated, and coated/paved culverts is outlined in this report.

Results of the comparison survey of corrugated aluminum and steel culverts under essentially similar exposures from 1 to 4 yr warrant the following tentative conclusions:

1. Uncoated aluminum culverts exhibited no measurable metal loss. This indicates that protective bituminous coatings are not required, except where severe chemical or abrasive conditions exist.
2. Uncoated and bituminous-coated steel culverts in the comparison survey essentially duplicated the performance of steel culverts in the statewide survey.

Durability of Drainage Pipe; National Cooperative Highway Research Program Synthesis No. 50; 1978.

Bituminous Coatings, Page 15 and 16. Florida estimates bituminous coatings add about 10 years life to galvanized steel pipe; Oklahoma uses to assure 50 years life of culvert; Tennessee found it cost too much to properly apply and discontinued bit coatings; Kentucky found 3 to 6 years in highly acid sites; Maine found "good" life span in soils with resistivity higher than 2400 ohm-cm; Maryland and Kansas found 3 to 4 years and discontinued use. "The most common estimates of the increase in service life through use of reliable interior asphalt coating range from 10 to 15 years." Problems are adhesion, abrasion, solubility in petroleum waste, and bacterial attack.

Bituminous - Paved Inverts, Page 16. Generally reported as adding up to 25 years extra life. Problems are same as bituminous coated.

Precoated Galvanized Steel, Page 16 and 17. The main mode of failure is abrasion. West Virginia - advantages of precoated over bit coated are lower damage susceptibility in shipping and fewer effects from temperature change and aging.

Galvanizing, Page 17. Montana reports that zinc galvanizing is not an effective protection for steel in soils whose pH is outside the range of 6.0 to 9.0.

RESEARCH AND RECOMMENDATIONS

- The apparent poor correlation among corrosion indicators indicates that the collection of additional data on existing culverts and coatings and the continuation of research in this area are desirable.
- Transportation agencies with similar environmental conditions should work together to develop improved pipe material selection criteria.
- Coatings and treatments have been developed for pro- -ction of culvert pipes. Research is needed to determine : effectiveness of these coatings and treatments, the specific applicability of each, and their economic value.
- A culvert located under a deep fill or under a highway with high traffic volumes can not be easily replaced. Research into methods and materials that can be used to salvage in-place culverts would be highly desirable.
- There should be a continuing search to identify culvert materials that are resistant to corrosion and abrasion under a wide range of conditions and that possess the strength needed to meet structural requirements.
- A few state transportation agencies have corrosion engineers or specialists on their staffs. Others could benefit from the addition of such specialists, not only to analyze potential or actual corrosion of culverts, but also to assess corrosion of other facilities, such as bridge decks and lighting systems. Development of in-house expertise through training programs is a secondary means of enhancing capability.
- At present, only a few transportation agencies are engaged in any major research on pipe durability. There are some who believe that a more intensive research effort is desirable; however, there is some question as to how to organize the research. One approach might be a major study with nationwide support by all transportation agencies. A second approach would combine the efforts and funding of transportation agencies having common problems. Individual agencies should continue to document conditions at new pipe installations and to perform in-depth examinations when existing pipes are removed or replaced.

Evaluation of Drainage Pipe by Field Experimentation and Supplemental Laboratory Experimentation; Interim Report No. 3; Louisiana DOT; Nov. 1981.

CONCLUSIONS

Six years of field exposure have provided much information concerning the performance of various types of test culverts. The following conclusions have been reached at this time:

1. The type of culvert providing the best resistance to corrosion after six years of field exposure is the asbestos-bonded, asphalt-coated, galvanized steel pipe. It stands out in its ability to resist corrosion in the low-electrical-resistivity environments.

2. A number of the test culverts have corroded significantly after six years of field exposure in harsh environments. Eight of the individual test culverts have experienced perforation. These eight are as follows: a galvanized steel culvert, an uncoated aluminum culvert, an aluminum plate arch, an asphalt-coated galvanized steel culvert, a U.S. Steel Nexon 12-mil-coated galvanized steel culvert, a U.S. Steel Nexon 20-mil-coated galvanized steel culvert, an Inland Steel 10-mil coated galvanized steel culvert, and an Inland Steel 12-mil coated galvanized culvert.

3. The coated and uncoated pipes are experiencing the greatest amounts of corrosion at sites 6, 7, 9 and 10. The electrical resistivity of the effluent at these four sites is less than 350 ohm-cm.

4. Within six years, aluminum alloy culverts have developed significant pitting in environments with pH less than 5.0 as well as in environments with resistivity less than 1000. Service life of these culverts may be greatly reduced when either pH or resistivity falls into one of these categories.

5. Bituminous coating is susceptible to removal during transport and installation (especially in hot weather) and to cracking as it ages. Polymeric coatings cannot be relied on to seal moisture and air from metal culverts. Factors such as delaminations at the culvert edge and blistering undermine their ability to seal adequately in the environments where they are most needed.

Corrosion of Corrugated Metal Pipe; Kansas State Highway Commission; 1971.

Page 12. "A life of 40 to 50 years or more may be anticipated for normal galvanized steel pipe in Kansas at most locations other than near active coal mines."

From HRIS Abstracts, Accelerated Abrasion Tests of Polymeric Protective Coatings For Corrugated Metal Pipe; California DOT, Jan 77.

"It is concluded that polymeric coatings complying with M 246 do not necessarily possess abrasion resistance equal to that of hot-dipped asphalt coatings complying with M 190."

A Study of the Durability of Corrugated Steel Culverts in Oklahoma; Oklahoma Department of Highways; 1971.

Page 10, Recommendations. "In areas III and IV, all culverts should be coated inside and outside with bituminous material at least five hundredeths (0.05 in) in. in thickness in order to insure 50 years of culvert performance."

NOTE - Areas III & IV are about 9% of the state and are corrosive to steel culverts and will require special consideration.

Handbook of Steel Drainage and Highway Construction Products; 1971, Published by American Iron & Steel Institute; Page 214

"It is recommended that coatings (without invert paving) only be used for: (a) Protection of pipe interiors. Add 25 years (b) Pipe interiors in non-abrasive flows, free of ice action. Add 6 to 10 years."

Culvert Durability Study; Ohio DOT; January 1982.

Page 83. "Therefore, bituminous coating without invert paving, appears to be of little value."

Page 83 & 84. "From these relationships the average useful life of bituminous coating and paving was determined to be 19 years for all cases,..."

Page 88, Asbestos Bonded Bituminous Coating and Paving. "However, it would appear that the average life of the coating and paving would exceed 25 years..."

Page 88. Thermoplastic Coatings. Forming of lock seams appears to have detrimental effect on the bond between coating and metal. Rivets are unprotected to low pH flow. Thermoplastic itself is susceptible to abrasion.

Culvert Life Study, Technical Paper 74-1, January 1974, Department of Transportation - Bureau of Highways, Maine.

CONCLUSIONS

The results of the study based on statewide data, show (1) reinforced concrete pipe to have a life expectancy of approximately 100 years, (2) bituminous coated corrugated metal pipe with bituminous paved invert, 14 gage, to have a life expectancy of approximately 48 years, and (3) corrugated metal pipe, 14 gage, to have a life expectancy 38 years. Thus, ten years longer life may be attributed to the bituminous coating and paved invert, although this drops to 6 plus years where there is continuous stream flow.

Although aluminum corrugated metal pipe has been in use only 10 years, the data suggest the aluminum pipes are performing quite well in both what would be considered relatively normal environmental conditions for inland sites and sites which are exposed to saltwater.

Asbesto cement pipe for highway construction in Maine has been in use approximately 10 years and those sampled were rated as being in excellant condition.

Resistivity and pH are factors in the deterioration of culverts as are other factors, which are difficult to measure such as, stream flow, velocity, land runoff and the periods of time which portions of the invert remains submerged.

Durability of Corrugated Metal Culverts; New York State Department of Transportation, 1977 Survey; The Quarterly R&D Digest, No. 7, (NYDOT Publication).

> Field studies after the 1965 survey indicated, "...it appeared that metal loss rates far exceeded those estimated in the 1965 survey." In 1975, a change was made in design policy to provide greater protection of inverts by providing a minimum of 8 gage plates on inverts and coating and paving all 14 and 16 gage cross drains. "These changes provided sufficient metal for an annual corrosion rate of 0.004 inches, assuming a 40-year design life and that coating and paving protect a pipe for 25 years."

Having selected the measurement technique and sampling plan, 190 pipes were selected to provide broad coverage throughout the state, among the five corrosiveness zones previously established. Magnitudes of metal loss were similar to those estimated and measured in earlier work, but the distribution of losses did not correspond to the five zones.

Figure 1 shows two probability curves corresponding to two new zones shown in Figure 2. These results indicate that steel culverts corrode at markedly different rates in northern and southern portions of the state. For example, an annual corrosion rate of 2 mils (0.002 in.) is exceeded in about 10 percent of the culverts in Zone 1. About 70 percent of those in Zone 2 exceed that rate. The reasons are unclear. Several factors have been examined -- e.g., pH, soil and water resistivity, culvert gradient, culvert age -- but no relationships have been established. Recommendations thus have been made simply on a probability basis.

Based on the 1977 study, a simplified durability design procedure has been developed. In Zone 1, an annual metal loss rate of 2 mils has been assumed, and in Zone 2 an annual rate of 4 mils. These rates will be exceeded only about 10 percent of the time in either zone.

APPENDIX H

SURVEY OF SURROUNDING STATES' USAGE OF CORRUGATED METAL PIPE

Arkansas Department of Transportation
Mr. Paul Bedusk, Roadway Design Engineer
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   All Primary System X-Road drainage structures are required to be concrete.

   Arkansas allows CSP and RCP as alternates on Secondary System.

   On side roads and entrances they allow alternate of RCP, CSP and Corrugated Aluminum Pipe.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   They are planning a study on pipe durability.

   See Number 1.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed - No set policy. Considered indefinite. yrs.
   b. Pipe Culverts No yrs.
   c. Concrete Box Culverts-Structural Plate Pipe No yrs.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   They have some trial installations of plastic and polymer coated pipes.

   Mr. Bedusk said the FHWA informed them Polymer Coated was not equal alternate to concrete.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP -- $18.99/lin. ft., 1986 Average Installed Price

   b. 24" RCP -- $29.13/lin. ft., 1986 Average Installed Price

Illinois Department of Transportation
Mr. Jim Gehler, Chief of Materials and Research
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   Illinois specifies concrete for all X-Road drainage structures under high type pavements.

   Policy basically the same as Missouri. They allow alternate of concrete and CMP on entrances, minor side roads and low type pavements.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   See Number 1.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed 50 yrs.

   b. Pipe Culverts No yrs.

   c. Concrete Box Culverts-Structural Plate Pipe No yrs.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   No.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP

   b. 24" RCP

Iowa Department of Transportation
Mr. Bob Stoker, Assistant Road Engineer, and
Mr. Roger Bierbaum, Methods Engineer
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   All X-Road drainage structures on their Interstate and Primary systems are required to be concrete. The secondary or county system is designed, constructed, etc., by the counties who generally follow Iowa Department of Transportation specifications and procedures.

   Iowa Department of Transportation allows CSP and RCP as alternate on entrance and secondary side road X-Road drainage.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   Based on past observed good performance of concrete. Do not do any special testing. Also, see Number 1.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed - They do not have a set policy. Considered indefinite. yrs.

   b. Pipe Culverts No yrs.

   c. Concrete Box Culverts-Structural Plate Pipe No yrs.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   Bituminous Coated, Polymer Coated and Aluminum CMP are allowed as alternates on entrance, secondary side roads when special conditions exist but are seldomly used.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP

   b. 24" RCP

Kansas Department of Transportation
Mr. Don Jarboe, Chief, Materials and Research, and
Mr. Cliff Heckathorn
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   Kansas allows CMP and RCP as equal alternates for all drainage except for six counties in Southeast Kansas where concrete only is specified--CMP, Steel and Aluminum.

   CMP is typically required to be of larger diameter than concrete based on flow characteristics.

   At locations where water will stand in the culvert or have continuous flow concrete is required. Alternates allowed for intermittent drainage.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   Kansas policy is based on field studies of pipe durability. They feel that CMP will serve for 50 years under their environmental conditions.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed - No set figure. yrs.

   b. Pipe Culverts No yrs.

   c. Concrete Box Culverts-Structural Plate Pipe No yrs.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   They found bituminous coating to be of no significant benefit.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP

   b. 24" RCP

Nebraska Department of Transportation
Mr. Monty Fredrikson, Roadway Design
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   Policy adopted June, 1982.

   Concrete Pipe specified for all X-Road drainage under Interstate and PCCP and all asphaltic pavements with design ADT of 800 or more (20 year traffic projection), except asphalt pavements constructed in the "sand hills" may use CSP or RCP regardless of traffic. They allow alternates for field entrances, etc. Side road connections generally specified to be the same as mainline. Unusual soil conditions may dictate a specific type of pipe.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   Experience. See Number 1.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed - Considered indefinite. No yrs.

   b. Pipe Culverts No yrs.

   c. Concrete Box Culverts-Structural Plate Pipe No yrs.

   Interstate 32 to 35 years pavement design life.
   Other roads 20 year pavement design life.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   No. Soils in Nebraska do not represent a problem. They are not having problems with CSP corrosion.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP

   b. 24" RCP

Oklahoma Department of Transportation
Mr. Jack Telford, Materials Engineer
April 17, 1987

CULVERT PIPE USAGE SURVEY

1. Does your State specify Corrugated Metal Pipe (CMP) or Reinforced Concrete Pipe (RCP) or do you allow the contractor the option of using either type of material for culverts on new construction?

   Oklahoma specifies concrete for all X-Road drainage structures. They allow alternate CMP, RCP, etc., for entrances, etc.

2. What is the policy used to determine which type of culvert pipe is used at various locations?

   Sample soil for pH at the time of soil survey to determine suitability of CMP for entrances, etc.

   See Number 1.

3. Do you have a specified design life for the following? If so, how long?

   a. Roadbed - No set figure. Considered indefinite yrs.
   b. Pipe Culverts yrs.
   c. Concrete Box Culverts-Structural Plate Pipe yrs.

4. Do you use Coated Corrugated Metal Pipe? If so, what coatings are used and for what conditions?

   For special conditions allow Bituminous Coated, Polymer Coated, RCP for entrances, etc., but not for mainline X-Road drainage.

5. What is the average cost per linear foot for the following pipe, including installation:

   a. 24" CMP

   b. 24" RCP