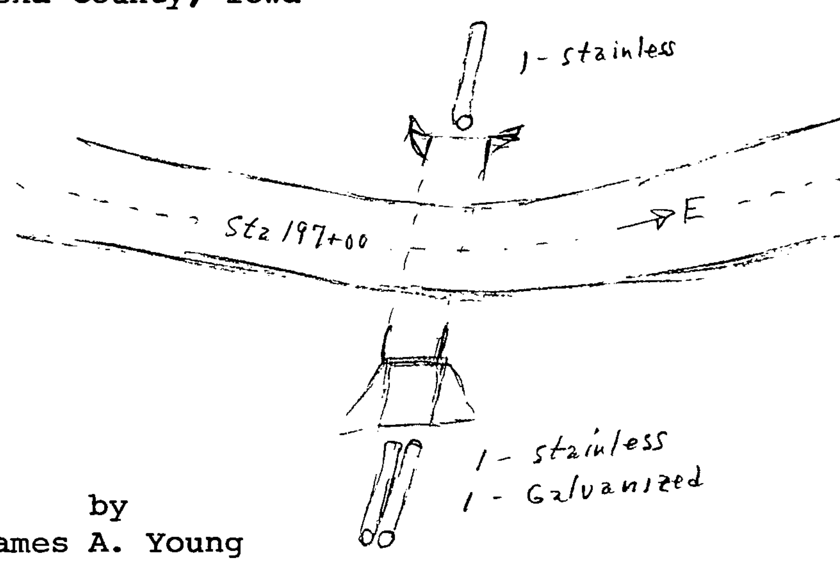
HR-2001

IOWA STATE HIGHWAY COMMISSION
Research Department

Preliminary Report on the Installation of Stainless Steel Culvert Pipe in Mahaska County, Iowa



by
James A. Young
and
William A. Ellingson

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1.0 Introduction

At the request of Mr. Arnold E. Levine, of the Levine Company, Centerville, Iowa, the Iowa State Highway Commission was asked to observe the partial fabrication of two stainless steel culvert pipes and later the Commission was asked if they would like to study their durability. These pipes were fabricated April 12, 1967 in Des Moines. Personnel of the Design and Materials Department were at the fabrication, but no Research people were present. The idea for the installation was conceived and a site selected after which the project was turned over to the Research Engineer.

The stainless steel pipes presumably contained the new Allegheny Metal, MF-1, whose composition is shown in Appendix A.

The primary aim of the stainless steel pipe is to reduce long term costs that are incurred through replacement and upkeep. The MF-1 has a theoretical life of infinity.

2.0 Purpose

The general purpose of this report is to describe the selection of and the general conditions at the installation site. An attempt will also be made, to show whether the use of stainless steel pipes in Iowa is justified from an economic as well as a practical standpoint.

3.0 Site Selection

According to Mr. Levine and the Allegheny - Ludlum Steel Corporation, MF-1 is highly resistant to the corrosive action of soils and various effluents which have pH ranges of 2-10. These credentials prompted the selection of a test site, by the Design Department, on Iowa Primary Road 92 in Mahaska County. In particular, Section 15 of Garfield Township (T75W-R16W) at station 197+00 42.5' right and left. A 3'x4' reinforced concrete box culvert is already in place at this location. The drawing in figure 1 shows details of placement.

This site was selected due to the high corrosive action of "mine water"[a] which is present in the area. The mine water does provide a very corrosive solution when it is in contact with the surface of the culvert, however the flow that will occur in the pipes is going to be less than 50 acre-ft per year (See Art. 4.0)

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[a]"mine water" is water which has run across the open mining areas of the region. There is quite a large amount of open mining in this area and the water which runs from these mining areas is denoted as "mine water".

4.0 Condition at the installation site

In 1954 or 1955, a 3'x4'x87' reinforced concrete box culvert was constructed and the wearing surface was coated with a bituminous material. In the ensuing 12 or 13 years the bituminous material has scaled and flaked off. Figure 2a and 2b show the condition of culvert.

2 A

Figure 2a

2 B

The deterioration of the bituminous coating was evident in the bottom of the culvert, however along the edges it was still in tact. This fact has lead observers to believe that the flaking and wearing of the material was due to the turbulant action of the water and not the corrosiveness of the water. The pH test that was performed showed that the pH of the water, was between 5 and 6. The pH of a near by stream was 6.

At the time of installation, water was flowing in the ditch because during the previous weekend a 1½" rain storm had fallen on the area. Water normally does not flow in the culvert, only during periods of run off.

Total rainfall in the area is about 33 inches per year.[5] Assuming a velocity of 2.8 f.p.s. in the culvert and that the culvert will run 1.5 inches deep, an estimate of the time, t_e, to drain the area can be determined from the following equation,

$$t_e = \frac{LVwDo}{vV_B D_F} \quad .$$

This equation, with the proper substitutions, will yield a total flow time of 4.74 days per year. This means that only 1.30% of the time water is actually flowing in the ditch. (See Appendix B for calculation)

The data was all based on the assumption of no infiltration. If a coefficient of 0.5 had been used, this would reduce the flow to approximately 2.37 day/year.

Two problem areas were noticed during the installation process. The first, which could cause a considerable amount of trouble, is the weld which was used to bind the 14 ft. section to the 14^{o} elbow. This weld caused a general darkening and scalding of the area around the weld.

At the time of placement the stainless steel pipes had a slight amount of rusting on the interior at inlets and outlets. This oxidized condition was quite noticable and possibly will be a source of trouble in the future evaluation.

5.0 Soil Condition in Iowa

The state of Iowa 90% of its land area covered by 5 of the 36 great soil groups.[3] The Brunizens[b] make up the largest

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[b]The term "Brunizen" is proposed by Simonson, Rieken, and Smith[3] as a substitute for "Prarie Soil" which is used throughout the United States.

Figure 3
The welded
condition of the pipe

Fig 4A

Fig 4B

largest segment followed by the Grey-Brown Podzolic soils, the Planosols, the Wiesenbodens (also referred to as Humic-Grey Soils) and the Alluvial soils. The Lithosols and Bogsoils make up the other 10%.

The Brunizens are characterized by a pH range of 3.4 - 8.1. The Wiesenbodens have a pH range of 5.3 - 8.0, while the Grey-Brown Podzolic have a pH range of 3.8 - 6.4. Finally the Planosols have a range of 3.9 - 6.0.

The Grey-Brown Podzolic and Planosols are the soils which show tendencies to be highly corrosive. The existance of the different soil types is shown in Figure 5. Figure 6 shows the areas that are marked by high corrosive action of the soils. The area along the Mississippi extends northward into Minnesota and is comparable to Area II[2] of that state.

6.0 Economic Factors

In discussing the selection of different types of materials to be used by the ISHC in culvert construction, the life of the structure must be used in any type of economic study. The life of the culvert depends a great deal on the location of pipe within the state, Figure 6 shows the area of the state that has existing soil conditions that will yield a culvert "in service" for better than 50 years. Some of the worst conditions exist in the southeastern regions of the state, where highly corrosive "mine water" has caused some pipes to corrode in a much shorter period of time than 50 years. Figure 6 shows the area that has the greatest problem with corrosion. In this area corregated metal pipe has only a life expectancy of 20-25 years. This figure was arrived at by using the soil maps of Iowa (Figure 5) and Minnesota[2]. The correlation of the Podzolic and Planosol regions is quite acceptable . According to the Minnesota study[2] the life of a culvert in this region is between 45-75 years. In this report, in regard to life expectancy, a life of 25 years was used to take care of any natural discrepancies between southern Minnesota on southeastern Iowa.

A 25 year design life expectancy is predicted for corregated metal pipe in this region. The life of a concrete pipe is expected to be longer due to the availability of protective costings. The design life of concrete culverts will be assumed to be 50 years.[4]

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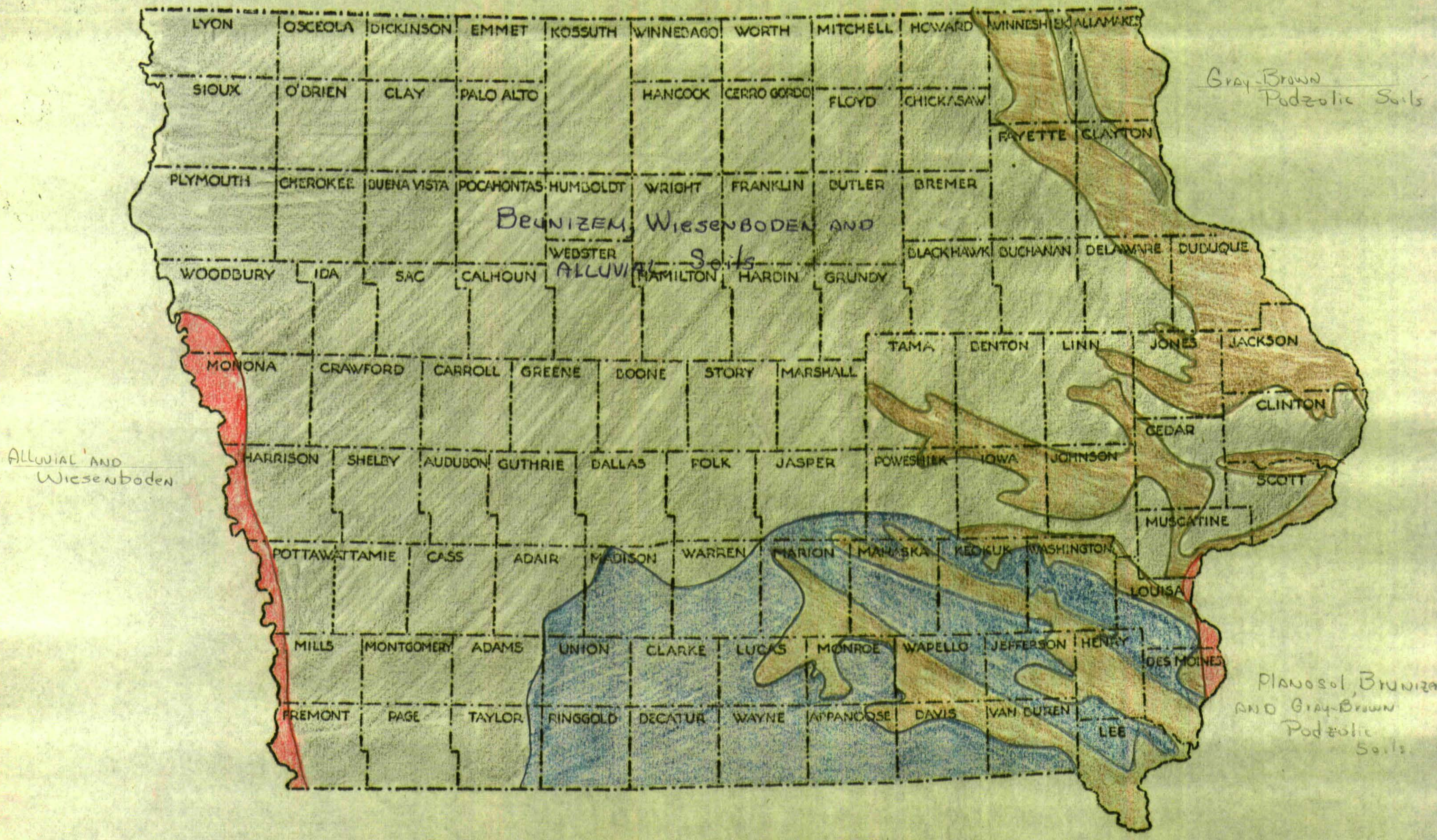

Figure 5 Iowa Soils

Why isn't 10% here as stated in text?

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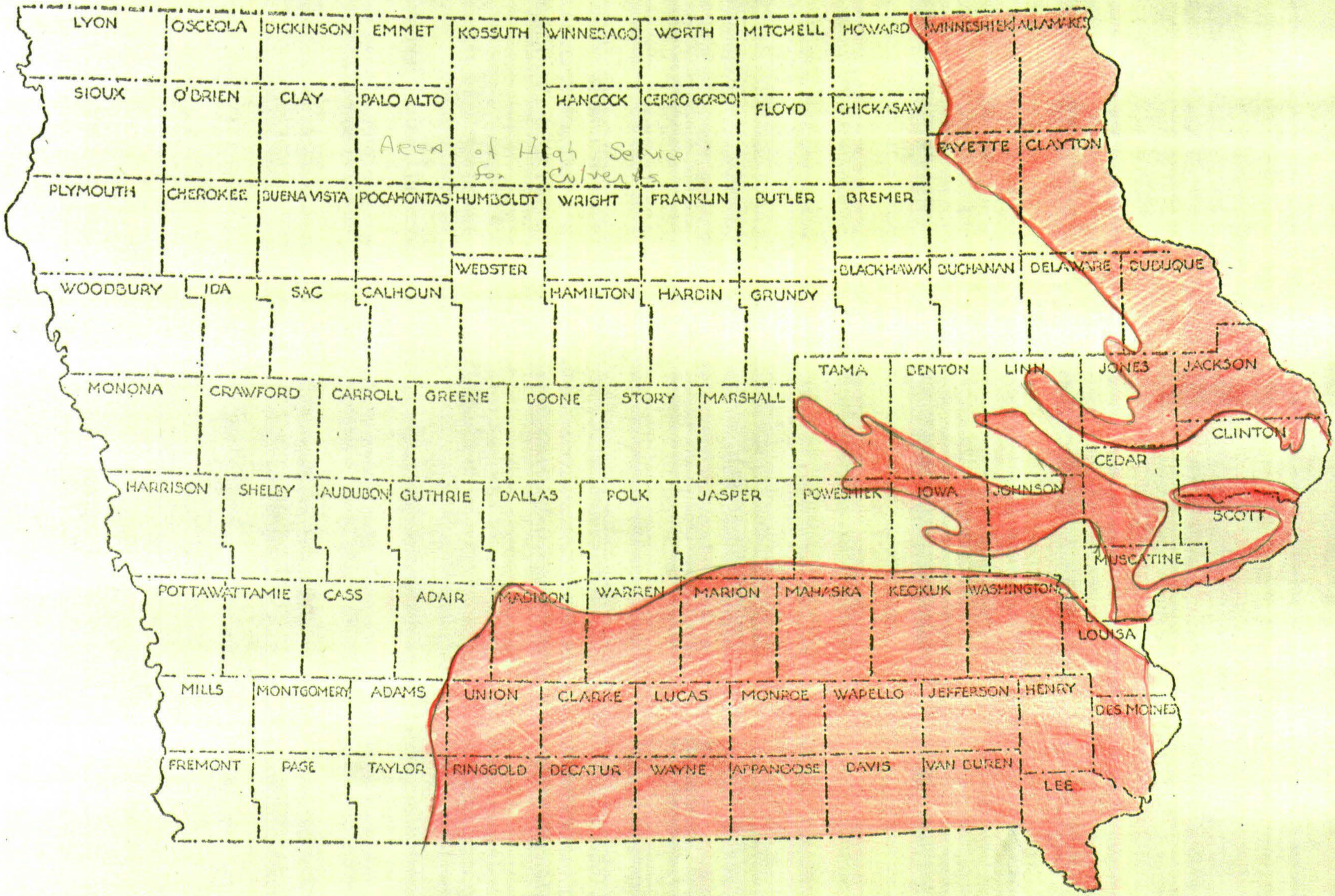

Figure 6. Shaded Area Represents area of High corrosive Action in the soil.

6.1 Annual Cost Analysis

Some assumption that must be made before beginning: (1) the interest rate for investment of 4% will not change over the next 50 years; (2) construction costs will not change; (3) assume 178' pipe under a 5' fill on a typical interstate project.

Corregated Metal Pipe

Length x construction cost (1967) = Total initial cost
178' x $5.83/lineal ft. = $1037.74
Principal x (crf-4%-50 yrs.) = Annual cost
(crf-4%-50 yrs.) = 0.04655020
1037.74 (0.04655020) = $48.31

Replacement Costs

(1) Remove & Replace pavement
30 Syds. x $20/Sy = $600

(2) Excavation and Removal of existing pipe
178' x $2.50/lineal foot = $445

(3) Detour in Median (including temporary surfacing) 2500 Cy x $50/Cy = $1250

(4) New Pipe
178' x $5.83 = 1037.74
Total 3332.74

Annual cost of $3332.74 invested 25 years from now = principal x present worth factor x capital recovery factor

(pwf' -4%-25) = 0.26223370
(crf-4%-50) = 0.04655020

Annual Cost = 332.74 (0.26223370) (0.046555020)
= $40.68

Total Annual Cost
= $48.31 + $40.68
= $88.99

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[c] based on average cost 1st 9 mo. 1967

Concrete Culvert Pipe

178' x 7.03 (1967 average) = $1251.34

Annual cost = 1251.34 (crf. 4%-50 years)
= 1251.34 (0.04655020)
= $58.25

Stainless Steel Pipe

178' x 14.37[d]

= 2557.86

Annual Cost = 2557.86 (crf.-4%-50 years)
= 2557.86 (0.04655020)
= $119.07

These costs reflect the high annual costs associated with the stainless steel pipe, they amount to, 50¢/lineal foot for corregated metal pipe, 33¢/lineal foot for concrete pipe and 67¢/lineal foot for stainless steel pipe.

7.0 Concluding Remarks

In conclusion, there are a few comments that should be made in regard to some statements contained in this report.

The values of the pH of the water flowing in the stream bed was determined with litmous paper which is color based and the pH depends entirely on the color comparisons. The pH of the water does not seem to have any effect on the soil in the area. There were no pH tests performed on the soils in the area, therefore no data is available on this aspect. There are many variables that are connected to corrosion in pipes that were never studied or correlated in this study,[7] these include besides the hydrogen iron concentration, electric potential, saturation with calcium carbonate, velocity of flow, also factors such as grade of inlet, and grade of culvert. Some type of a study should have preceded this installation that would have indicated the condition of culverts in the same general area. Without this data proper analysis of the stainless steel pipes is next to impossible. All that can actually be done is by visual observation.

[d] Price per foot figured on the basis of $.29/lb quoted by Mr. Thorpe at the fabrication on 12 April 1967 plus the installation cost of galvanized pipe. (See Appendix C for calculations.)

In the economic analysis, the design life of the pipes is a many varied thing. The life of the concrete and galvanized pipes was predicted from the data available. The only available data on stainless steel pipe says that they have atheoretical life of infinity. At present, the policy on culvert pipes in Iowa is to use concrete culverts under roadways, and it is left to the contractors own judgment as to the type of pipe he wants to use for entrance pipes. Therefore, at present stainless steel pipes could be placed at entrance locations, only. Even though the life of the stainless steel pipe is infinite, the life of these entrances is not infinite. It is rather hard to believe that the entrances and possibly the roadway would not be re-worked if not even reconstructe in 50 years. This is how the 50 year life for the stainless steel pipe is obtained.

When one looks at the data pertaining to flow in Section 40, it is possible to ascertain that no real large amount of water goes through the test pipes in an average year. With a more judicious study, it is conceivable that a much better location could have been selected, and therefore more meaningful data extracted.

The continuing plan of study of these pipes consists of observations with short written reports by the observer. The velocity of the water will be checked, along with the pH of the water and soil at various times. These observations will continue for an undetermined period of time.

Appendix A

Typical Chemical Composition, Percentages

Alloy	C	Mn	Si	Cr	Ni	Ti	Fe
MF-1	0.04	0.50	0.40	11.00	0.20	0.50	Balance

Appendix B

$$t_E = \frac{LV_uDo}{vV_BD_F}$$

where: t_E = time to drain the area, days

L = Length of the barrel, ft.

V_w = Total volume of water, cu. ft.

D_o = Depth of barrel, ft.

v = Velocity of flow, ft/day

V_B = Volume of barrel, cu. ft.

D_F = Depth of flow in barrel, ft.

$$V_w = \frac{33 \text{ in./year}}{12 \text{ in./ft}} \times 36 \text{ acres} \times 43560 \frac{\text{ft.}^2}{\text{acre}}$$

$$= 431{,}244 \frac{\text{cu. ft.}}{\text{feet}}$$

$$V_B = 3 \times 4 \times 87 = 1044 \text{ cu. ft.}$$

$$t_e = \frac{87}{2.8} \times \frac{431{,}244}{1044} \times \frac{4}{1.5/12} \times \frac{1}{3600} \times \frac{1}{29}$$

$= 4.74$ days

$$\% \text{ of time water flowing} = \frac{4.74}{365} \times 100 = 1.30\%$$

Appendix C

Assume a pipe of one ft. length, 24 inch diameter, and 12 gage size.

24 inch, 12 gage weighs 39.6 lbs./ft.[6]
at \$.29/lb.
cost = 39.6 (\$0.29) = \$11.48

weight of 24 inch, 12 gage CMP
= 29.4 lbs./ft.'
cost = 29.4 lbs./ft. (\$0.10/lb.)[e] = 2.94

construction costs (1967) for CMP
= \$5.83/ft.

∴ installation = 5.83 - 2.94
= \$2.89/ft.

construction cost for stainless steel will be
= \$11.48 + \$2.89
=\$<u>14.37</u>/ft.

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[e] \$.10/lb was quoted by Mr. Thorpe for CMP same time as the price of \$0.29 for the Stainless Steel.

8.0 References

1. American Association of State Highway Officials, AASHO 1964

2. Durability Design Method for Galvanized Steel Pipe in Minnesota, Minnesota Members of National Cooregated Pipe Association, Spring 1967

3. "Understanding Iowa Soils", Simonson, Riecken, Smith 1952

4. Report on Limited Condition Survey of Galvanized Corregated Metal and Concrete Pipe Drainage Structure, unpublished-internal report, R-164, DeYoung, Stewart, Boring.

5. "Magnitude and Frequency of Iowa Floods", Schwob, Bulletin Number 28, Iowa Highway Research Board.

6. "Why Stainless Steel Culverts?" Allegheny Ludlum Steel Corporation.

7. Durability of Corregated Metal Culverts, State of New York Department of Transportation, Research Report 66-5, November 1967.